15/-

PHYSICAL

GEOLOGY AND GEOGRAPHY

OF

GREAT BRITAIN


GEOLOGICAL MAP OF
GREAT BRITAIN
Index of Colours
18 Alluvium Drift &c.
17 Crag & Eocene
16 Cretaceous
15 Wealden & Purbeck
14 Oolitic Strata
13 Liassic Strata
12 Keuper Marl &c.
11 Bunter Sandstone
Trias
10 Magnⁿ Limestone
9 Rothliegende
Permian
8 Coal Measures
7 Millstone Grit
6 Carbˢ Limestone
Carboniferous Rocks
5 Old Red Sandstone & Devonian
4 Upper
3 Lower
Silurian
2 Cambrian
1 Laurentian
Felspathic Trap. Greenstone, Basalt &c.
Granite
0 50 100 Miles
ORKNEY ISLES
HEBRIDES
LEWIS
SKYE
MULL
ISLAY
CANTYRE
ARRAN I.
SUTHERLAND
Cape Wrath
Fig. 9.
Murray Frith
Spey
Findhorn
Dee & Don
Grampian Mts
L. Linnhe
Tay
Forth
Tweed
Firth of Clyde
Carrick Moorfoot & Lammermoor Hills
Solway
Eden
Fig. 10.
Tyne
Wear
Tees
Fig. 37
Fig. 18.
Pennine Hills
I. OF MAN
Flamborough Hᵈ
HOLDERNESS
Fig. 19.
Humber
Fig. 17.
Mersey
Dee
Clwyd
Fig. 11.
ANGLESEY
Carnarvon B.
LLEYN
Fig. 16.
Trent
Witham
The Wash
Cromer
Welland
Nen
Ouse
Cardigan Bay
Fig. 31.
Dinas Hᵈ
St. David's Hᵈ
St. Brides Bay
Milford Haven
Teify
Towy
Usk
Wye
Avon
Severn
Cotswolds
Chiltern Hills
LONDON
Thames
Nᵗʰ Foreland
North Downs
WEALD
South Downs
Beachy Hᵈ
Bristol Channel
Taw
Exe
Tamar
Lyme Regis
Portland Bill
PURBECK
Frome
Avon
I. OF WIGHT
Selsey Bill
Ouse
Fig. 24.
Figs. 21, 22
Start Point
Land's End
Stanford's Geograph. Estab. London

THE PHYSICAL GEOLOGY AND GEOGRAPHY OF GREAT BRITAIN:

A MANUAL OF BRITISH GEOLOGY.

BY

A. C. RAMSAY, LL.D. F.R.S. &c.

DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEYS OF THE UNITED KINGDOM.

WITH A GEOLOGICAL MAP, PRINTED IN COLOURS.

FIFTH EDITION.

LONDON:
EDWARD STANFORD, 55 CHARING CROSS.
1878.

There rolls the deep where grew the tree.
  O earth, what changes hast thou seen!
  There where the long street roars, hath been
The stillness of the central sea.

The hills are shadows, and they flow
  From form to form, and nothing stands;
  They melt like mist, the solid lands,
Like clouds they shape themselves and go.

TENNYSON.

TO THE MEMORY

OF

SIR HENRY THOMAS DE LA BECHE,

C.B., F.R.S.

TO WHOSE EARLY TEACHINGS IN PHYSICAL GEOLOGY

I AM SO MUCH INDEBTED,

THIS BOOK IS AFFECTIONATELY DEDICATED

PREFACE.

In this, the fifth edition, many improvements and additions have been made. Of these, the most important consists of an account of the British Formations, showing the topographical range of each in succession, their lithological characters and the general nature of their fossils. This part of the work begins with Chapter V., and ends with Chapter XVII., and it constitutes a condensed Manual of British Stratigraphical Geology from the Laurentian to the latest Pliocene strata. The substance of these 227 pages was originally written by me for Blackie's Cyclopædia, and by the kind permission of these gentlemen, I have, with some rearrangement and many additions, made much use of the matter printed in the article.

A leading feature in this part of the book is, that I have endeavoured to give *a sketch of the Physical Geography of each successive Geological Epoch*, so as to induce a scenic interest in the matter, beyond what can be gathered from mere lithological descriptions and lists of fossils, which, in the bald shape that they are sometimes presented to the reader, form merely the dry bones of geology.

By attentively reading and remembering these successive revolutions of ancient geographies, the reader will more or less realise the geological history of our country, and perceive those processes of physical evolution that, in the long lapse of time, gradually impressed on Britain its present geographical phase, which to most men seems so stable, but is, in reality, no more lasting than those which went before. As keen-eyed Chaucer well expounded five hundred years ago :—

> 'Well may men knowen, but it be a fool,
> That every part deriveth from his hool;
> Of no partie ne cantle of a thing,
> But of a thing that parfit is and stable,
> Descending so, till it is corumpable.
> And therefore of his wisé purveyance
> He hath so well beset his ordinance,
> That speces of things and progressions
> Shullen enduren by successions,
> And not eterne, withouten any lie:
> This maiest thou understand and seen at eye.'

Among many other matters, the subject of the Miocene strata of Britain has been more largely treated of, with special reference to the absence of recognised Miocene mammalia in our country, and the subject of glacial geology has, also, been treated more fully than in previous editions, while a condensed account of all the explored English bone-caves and their contents has been added, with special reference to the question of the antiquity of man.

I have to express my acknowledgment of the debt I owe to Mr. Etheridge and Mr. Sharman; to the first for much valuable information concerning the organic relics of each formation, and also for the plan of each of the sets of figures engraved as illustrative of the formations, every one of which may be considered as more or less typical of the strata or groups of strata referred to in the text, in which, however, all of the fossils figured are not always named. Mr. Sharman executed the drawings of these fossils with his accustomed skill and accuracy.

I have also added some landscapes. One of these, the Pass of Llanberis, fig. 86, is reduced from a coloured crayon drawing by Mr. Gillespie Prout, and fig. 87 is taken from a photograph. The original of fig. 88 was drawn by the late Sir Henry De la Beche, and fig. 89, with the dwindling ice entering the lake, is the representation of an episode in the history of the glacier, supposed and drawn by myself. The *blocs perchés* of fig. 90 was drawn by the late Professor Edward Forbes. All of these were originally published in my paper on 'The Old Glaciers of Switzerland and North Wales.' The Gorge of the Avon is from a photograph. All the other landscapes, excepting one from my 'Geology of Arran,' have been engraved directly from drawings, as they were roughly done in sepia and pencil in my geological note books, and, together with the sections and other illustrations, many of them new, they are intended to bring before the eye the meaning of various theories propounded in this work, by help of which, anyone, by a moderate exertion of thought, may realise the geological origin and meaning of the physical geography and scenery of our country, and thus, as he travels to and fro, add a new pleasure to those possessed before. The colours on geological maps will then no longer seem mysterious, but become easy to comprehend when associated with the geographical contours of our island.

ANDREW C. RAMSAY.

KENSINGTON: *May* 16, 1878.

CONTENTS.

CHAPTER XXVIII.

CHAPTER XXIX.

CHAPTER XXX.

CHAPTER XXXI.

CHAPTER XXXII.

CHAPTER XXXIII.

CHAPTER XXXIV.

CHAPTER XXXV.

CHAPTER I.

MODES OF FORMATION AND GENERAL CLASSIFICATION OF ROCKS, AQUEOUS AND IGNEOUS.

In old days, those who thought upon the subject at all were content to accept the world as it is, believing that from the beginning to the present day it had always been much as we now find it, and that, till the end of all things shall arrive, it will, with but slight modifications, remain the same.

But, by and by, when Geology began to arrive at the dignity of a science, it was found that the world had passed through many changes; that the time was when the present continents and islands were not, for the strata and volcanic products of which both are formed were themselves sediments derived from the waste of yet older lands now partly lost to our knowledge, or of newer accretions of volcanic matter erupted from below. Thus it happens that what is now land has often been sea, and where the sea now rolls has often been land; and that there was a time before existing continents and islands had their places on the earth, before our present rivers began to flow, and before all the lakes of the world, as we now know them, had begun to be.

Geology may therefore be defined as the science which investigates the history of the earth, or the successive changes which have taken place in the inorganic and organic kingdoms of nature, together with the causes of these changes, as far as they can be traced by observations on the structure and mode of occurrence of the mineral and organic bodies that form or are found in and upon the crust of the earth.

To place the events of this complicated history in clear chronological succession is the chief business of the geologist; and in doing so he unites the present with past geological epochs, and discovers that the physical world, as it now exists, is the result of all the past changes that have taken place in it. If, therefore, our knowledge were sufficient to admit of the construction of a complete system of physical geography, it would be but a full description of a geological epoch—namely, that of to-day; and a complete account of any old geological epoch, would be a perfect description of the physical geography of the world at that time.

To us, the chief dwellers on the Earth, the whole subject is of the greatest interest, and it is therefore my intention to endeavour to show in a simple manner—taking our own island as an example—whence the materials that form the present surface of the earth have been derived, why one part of a country consists of rugged mountains, and another part of high table-lands or of low plains; why the rivers run in their present channels; how the lakes that diversify the surface first came into being. In the course of this inquiry I shall have occasion to show that Britain has been joined to and severed again and again from the continent, and how some of the animals that inhabited, or still inhabit it, including its human races, came to occupy the areas where they live.

Assuming that I am partly addressing those who have not previously studied geological subjects in detail, it is needful that I should first enter on some rudimentary points, so as to make the remainder intelligible to all. Therefore I begin with an account of the nature of rocks; because it is impossible to understand the causes that produced the various kinds of scenery of our country, and to account for the classification of its mountains and plains, without first explaining the nature of the rocks which compose them.

To this will be added a concise account of the British strata in serial order, that the reader may understand something of the nature and history of the various stratified formations which, together with igneous rocks, form our island.

In doing this I will endeavour to get and to give some idea of the scenery of our region during the successive geological epochs, so as to give the reader some glimpses of those older stages of physical geography, each of which in its time, had man been there to see it, would have seemed as enduring as that passing phase of the Earth's history in the midst of which we live.

All rocks, in the broadest sense, are divided into two great classes—AQUEOUS and IGNEOUS; and there is a sub-class, which mostly consists of aqueous, but sometimes of igneous rocks that have been altered, and which in their characters often approach and even by insensible gradations pass into some of those rocks that are termed igneous, though in many respects very different from ordinary volcanic products such as lavas. In this chapter I shall, however, confine myself to a general description of the two great classes of rocks, those of *aqueous* or watery origin, and to those easily recognised as of *igneous* origin, which are products of subterranean heat.

By far the larger proportion of the surface rocks of the world have been formed by the agency of water, chiefly as a fluid, but partly as ice. Such rocks are made of *sediments*, and these sediments have been, and still are, chiefly the result of the action of atmospheric agencies, aided by chemical solutions, and of gravitation, aided by moving water. But by what special processes were they formed?

Air and water, but especially the latter, act both chemically and mechanically on the crust of the earth. Many minerals in rocks, such as felspars, hornblendic minerals, mica, &c., are composed of silicates of alumina and soda, potash, lime and magnesia. These are often associated with free silica. This is especially the case with some igneous rocks; and many of the stratified rocks consist in great part of substances of the same nature variously intermixed. Others consist of carbonate and sulphate of lime, &c., more or less pure. Of these, the carbonate of lime rocks, or common limestones, by far predominate; and they are sometimes nearly pure, forming immense areas of country, and sometimes mechanically intermingling, in every percentage, with other substances. All rain as it falls absorbs part of the carbonic acid in the air; and the water percolating through the rocks unites with and carries away in solution portions of the soda, potash, lime, or magnesia that enter into the composition of the minerals in rocks, and this promotes their disintegration. They crumble, and are in a condition to be borne to lower levels, and finally to the sea, by the mechanical agency of running water, or partly in solution.

Frost is also a powerful disintegrator. Water percolates into hollows, joints, and cracks; it freezes and expands, and thus helps to rend and break up the rocky and earthy masses. Some of its most obviously powerful effects are seen in the regions of glaciers and drift ice. In warm latitudes glaciers are found only at those great elevations on mountain ranges that rise above the limits of perpetual snow. On the Himalaya, the loftiest peaks of which are about 31,000 feet high, the greater glaciers descend to the level of about 14,000 feet; in the Alps, in the lower glacier of Grindelwald, to about 3,300; and in the Glacier du Bois to 3,350 feet above the sea. In the north of Norway, Greenland, and the southern part of South America, and in the Antarctic continent of Victoria Land, the large glaciers descend to the sea-level. In the two last-named regions, towards the poles, surfaces of vast extent are covered by ice in the form of universally diffused glaciers.

A glacier in temperate regions is chiefly supplied by the *drainage* of the snow that falls on those parts of the mountains which rise above the limits of perpetual snow; and its size is commensurate to the height of the mountains and the extent of area drained. Pressure of the yearly accumulating snow, and in less degree the summer's heat and the winter's cold, or, indeed, the summer day's thaw and the nightly frost, gradually change snow into ice, which experience proves, acts as a whole, like a plastic body, and glaciers progress down valleys at slow rates, proportionate to the steepness of their inclination, the volume of ice, and the season of the year—moving faster in summer and autumn, and slower in winter. The effect of this motion in these icy masses is to grind, polish, scratch, and groove the rocky valleys over which the glaciers pass, removing asperities, and giving portions of the rocky floor rounded and mammillated forms, termed *roches moutonnées*. A necessary result of this action is the production of much fine floury sediment. Ice-filled valleys are thus deepened and widened, and much sediment is formed, and brought within reach of the transporting power of rivers. Great blocks of stone and finer débris that fall from the hills on the surfaces of glaciers, are carried steadily onward in long lines till they reach the ends of these ice-rivers, where they form terminal moraines, and often, as fast as the mounds accumulate, these are proportionally wasted by the streams that flow from the ends of the glaciers.

In cold climates, where special glaciers descend to the sea, bergs break off often laden with blocks and finer sediments, and floating seaward they deposit their freights where they chance to melt. The breaking up of the ice-foot on sea-coasts, and of river ice, also transports large quantities of matter and scatters it abroad.

The quantity of material *degraded* and spread in the sea by these united means is immense, and consists of mud, sand, gravel, and rounded, subangular, and angular blocks, often polished, grooved, and scratched; and from the irregular mode of its accumulation, and the frequent grounding and scraping of icebergs along the sea-bottom, the whole of this matter, if exposed, would present one of the rudest forms of stratification.

But the chief agent in the transportation of sediments from higher to lower levels is running water. Great thunderstorms, water-spouts, and sudden thaws in snow-covered lands, frequently produce startling effects, stripping large areas bare of soil, and hurrying to lower levels vast masses of earth, shingle, and boulders.

Every one who has looked at large rivers knows that they are rarely pure and clear. The cause of this is obvious. All rain, especially if long continued, exercises a powerful mechanical effect on the surface of the earth, carrying much sediment into water-courses, which unite to form brooks, rivulets, and finally, if the country be large, great rivers. Soft surface soil is thus easily carried away even in low countries, and in hilly and mountainous regions sands, coarse rounded gravels, and boulders, won from the adjoining rocks, are hurried onward; and thus it happens, that great valleys and ravines have often been formed in all parts of the world by running water, and by the long-continued attrition of stones driven onward by torrents over rocky surfaces. As the accumulated waters of rivers reach low lands, their power of transporting coarse sediment decreases, and finally, in great rivers, like the Rhine, the Nile, the Amazons, the Mississippi, and the mighty rivers of China, India, and Northern Asia, all but the finest sediment is deposited long before they reach the sea.

On a smaller scale the same kind of phenomena are obvious in such English rivers as the Thames, the Severn, the Ouse that flows through York, and the Clyde and the Tay, in Scotland. Every river, in fact, carries sediment and impurities of various kinds in suspension or held in solution, and this matter, having been derived from the waste of the lands through which rivers flow, is carried to lower levels. Thus it happens that when rivers empty themselves into lakes—or, what is far more frequently the case, into the sea—the sediments which they hold in suspension are deposited at the bottom, and, constantly increasing, they gradually form accumulations of more or less thickness, generally arranged in beds, or, as geologists usually term them, in strata. Suppose a river flowing into the sea. It carries sediment in suspension, and a layer will fall over a part of the sea-bottom, the coarser and heavier particles near the shore, while the finer and lighter matter will often be carried out by the current and deposited further off. Then another layer of sediment may be deposited on the top, and another, and another, until, in the course of time, a vast accumulation of strata may be produced.

In this manner deltas are formed, and wide bays and arms of the sea have been thus filled up. As they fill, the marshes spread further and further, and, by overflows of the river bearing sediment, the alluvial flats rise higher and higher, till, as in cases like those of the Ganges and the Nile, kingdoms have been founded on mere loose detritus. A little reflection, too, will show that all lakes, be they ever so large, may, with sufficient time, get filled by this process with débris and become plains. Some of the old rocks of Britain are formed of sediments originally deposited in estuaries by rivers as large as the Mississippi or the Ganges, others were formed in lakes fresh or salt, bearing witness to ancient extinct physical geographies; and many a modern flat surface in Britain and in Switzerland, often covered by peat and traversed by a brook or a river, is only a lake-hollow filled with river-borne gravel, sand, and mud, overgrown by a marshy or peaty vegetation.

Again, if we examine sea-cliffs that rise direct from the shore, we find that the disintegrating effect of the weather produces frequent *débâcles* great or small on the faces of the cliffs, thus supplying material for the formation of shingle, which in gales the strong breakers driving against the cliff forms a 'powerful artillery with which the ocean assails the bulwarks of the land,' and aids in the work of destruction. On the east and south of England, where the strata largely consist of boulder-clay, Eocene clays, chalk, and oolitic sands, clays, and limestones, the waste of the softer strata has been in many places calculated at about two yards a year. Where the strata are harder, as on the west coast in Devon, Cornwall, and Wales, the waste is often so slow as to be generally ignored by ordinary observers. But the form of the coast proves it. Hard rocks resisting waste because of their hardness are apt to form headlands, while softer or more friable strata, wasting more rapidly, often occupy the recesses of coves and bays. The removal of the fallen detritus by the restless waters makes room for further slips of débris from above, and thus it happens that all sea-cliffs are in a state of constant recession, comparatively quick when made of clay or other soft strata, and when the rocks are harder, perhaps very slowly, but still sensibly to the observant eye, so that in time, be they ever so hard, they get worn more and more backwards. The material derived from this waste when sea-cliffs are truly rocky, generally forms, in the first instance, shingle at their bases, as, for example, with the pebbles of flint formed by waste of the chalk which contains them. These, being attacked by the waves, are rolled incessantly backwards and forwards, as everyone who has walked much by the sea must have noticed; for, when a large wave breaks upon the shore, it carries the shingle forward, rolling the fragments one over the other, and in the same way they recede with the retreating wave with a rattling sound. As in the running water of torrents, so this long-continued marine action has the effect of grinding angular fragments into rounded pebbles; and, in the course of time, large quantities of loose gravel have thus been formed. Such material when consolidated becomes a conglomerate.

If, also, we examine with a lens the sand of the sea-shore, we shall find that it is formed of innumerable grains of quartz, and these grains are generally not angular, but more or less rounded: their edges having been worn off by the action of waves and tides moving them backwards and forwards upon each other, till they became grains, like water-worn pebbles in shape, only much smaller. Such material when consolidated forms sandstone.

Finer-grained and more muddy deposits, in like manner, are generally formed of the minutest grains of sand, mixed with aluminous substances originally derived from the waste perhaps of felspathic rocks. Such material, when soft, forms clay; when consolidated, marl shale and slate.

In this manner very large amounts of mechanical sediments are forming and have been formed. The daily sifting action of breakers, intensified during long-continued heavy gales, the forcible ejection of muddy waters, sometimes hundreds of miles out to sea, from the mouths of great rivers like the Amazons, the power of tidal and great ocean currents such as the Gulf Stream, all contribute to scatter sediments abroad, and by their rapid or more gradual subsidence, the bottoms of vast submarine areas are being covered by *mechanical sediments*, which must of necessity often be of great thickness, and in which various kinds of strata may alternate with each other.

With sufficient time all land would, by these processes of waste, be eventually degraded beneath the sea (as was suggested by the naturalist Ray), were it not that the loss is compensated by disturbance and elevation of land, always slowly taking place over portions of the continents and islands of the world. Large areas are also slowly depressed beneath the sea; but to maintain the average balance of sea and continent, the amount of land elevated must exceed that depressed, or be equal to the amount of that depressed by gradual submergence, added to that destroyed by degradation.

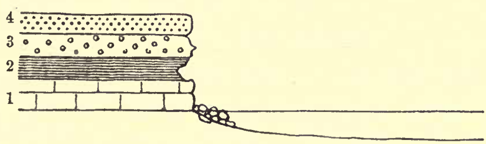
The evidences of past elevation and depression are simple. 1st. A large proportion of the rocks in many mountain ranges, however high above the sea, contain marine fossils, generally of extinct species. Such strata are in great part highly disturbed, broken, contorted, often pierced by igneous intrusions, and largely denuded. 2nd. On all continents and on many large islands raised beaches occur, and also superficial accumulations of loose strata, lying on the older rocks, and yielding shells, in great part, or altogether identical with those that now inhabit neighbouring seas; and these organic remains occur in such a manner, that it is plain they lived and died on the spots where they lie, ere those parts of the sea-bottom were elevated. In Britain, such beds are found more than 1,000 feet above the sea; and in South America, 1,300 feet on the western side of the Andes. 3rd. Experience shows that certain volcanic regions subject to earthquakes are often areas of elevation. The earthquake of 1835 in Chili is an instance when a large tract of the coast of South America was suddenly raised from four to twelve feet, and part of the sea-bottom converted into land; and it is probable that similar causes have conduced to raise by degrees the shelly strata above alluded to, to the height of 1,300 feet above the level of the sea. The chain of the Andes is volcanic, and the elevating forces and earthquakes of South-Western America are connected with this circumstance. The Mediterranean volcanic region (though marked by many oscillatory movements) is also as a whole one of elevation. The same is true of the volcanic islands of the Pacific, and also of Java, which contains many active volcanoes, and around the shores of which there are old coral reefs 140 feet above the level of the sea. Under other circumstances a great number of coral reefs of the kind called atolls and barrier reefs, yield, according to Darwin, perfect evidence of depression of land. In the Pacific an area more than 4,000 miles in length is now undergoing this kind of submergence. The same takes place in the Laccadive and Maldive archipelagos in the Indian Ocean. All these islands are non-volcanic. Where volcanoes occur the land is generally rising.

During such depressions strata may accumulate to an immense thickness under favourable conditions of supply, and time being also allowed for consolidation, when these are again unheaved they will, both as regards quantity and structure, be more apt to resist destruction than smaller masses of (probably) softer strata that were formed during periods of minor oscillations of sea and land.

Strata are consolidated (petrified) chiefly by pressure and chemical decomposition and recomposition. Some formations are many thousands of feet in thickness. In a set of strata 10,000 feet thick, the superincumbent weight on the lowest bed would be about 12,333 lbs. per square inch; but beside this, more intense pressures have taken place throughout all but the very latest geological epochs. This kind of pressure has been brought about by contraction of the crust of the earth due to radiation of the proper heat of our globe into space, the result being, that over broad areas rocky masses have been much contorted and compressed, and thus mountain ranges have been upheaved. In some rocks the particles are partly cemented by oxides of iron, in others by carbonate of lime. Minor beds of limestone are often formed on land from calcareous springs. Marine strata, formed of limestone, in the Adriatic, were found by Marsilli to be consolidated a foot beneath the surface. A great many rocks contain more or less carbonate of lime, and .along with this, or alone, many others contain silicates of soda or potash. These are soluble in carbonic acid, and entering into new combinations the whole becomes petrified. During these processes shells, echini, corals, bones, teeth, and scales of fish and of marine mammals, &c., are imbedded and cased in stone, and in a less degree terrestrial plants and animals are floated into lakes and estuaries, and occasionally out to sea, where those parts that escape decay and predaceous fish may become fossilised.

If we examine the stratified rocks that form the land, we very soon discover that a large proportion of them are arranged in thin layers or thicker bands or beds of *shale*, *sandstone*, *conglomerate*, and *limestone*, more or less pure; for shales are sometimes sandy, sandstones sometimes shaly, and most conglomerates have a sandy and sometimes a shaly or marly base in which the

FIG. 1.



pebbles are embedded, while limestones occur of every degree of impurity. These must have been formed in a manner analogous to that which I have just described, proving that such beds have been deposited as sediments from water. Take, for instance, a possible cliff by the sea-shore, and we shall perhaps find that it is made of strata, which may be horizontal, as in fig. 1,

FIG. 2.

or inclined, as in fig. 2, or even bent and contorted into every conceivable variety of form, as in fig. 3. If, as in the diagram, fig. 1, we take a particular bed, No. 1, we may find that it consists of strata of lime-

FIG. 3.

stone lying one upon the top of another. Bed No. 2 may be of shale, arranged in thin layers, more regularly than in No. 1. No. 3 may consist of pebbly materials, arranged in ruder layers, for, the material being coarse, the bedding may be irregular, or even quite indistinct. Then in No. 4, the next and highest deposit, we may have a mass of sandstone, arranged in definite beds. The whole of these various strata in the aggregate form one cliff. Rocks, more or less of these kinds, compose the bulk of the strata of the British Islands; and it must be remembered that these were originally loose stratified sediments, piled on each other often to enormous thicknesses, and subsequently consolidated by pressure and chemical action. In some cases after consolidation, they have been so much altered by heat and other agents of metamorphism, as to have lost almost all signs of their original stratification, while sometimes they are almost undisturbed, except by mere upheaval above the sea: in other cases the beds have been violently contorted, in the manner shown in diagram No. 3.

Next comes the question: Under what special conditions were given areas of these rocks formed?

Some formations, such as great part of the Silurian rocks of Wales and its neighbourhood, consist essentially of deposits that were originally marine mud and sand, accumulated bed upon bed, intercalated here and there with strata of limestone, the whole being many thousands of feet in thickness. These have since been hardened into rock. Others, like the Old Red Sandstone, were originally spread out in alternating beds of mud, sand, and stony banks, all coloured red by precipitation of peroxide of iron. Others, like the Liassic and Oolitic deposits, were formed of alternating strata of clay, sand, and limestone; while others, like the greater masses of the Carboniferous Limestone and the Chalk, were formed almost wholly of carbonate of lime.

When we examine such rocks in detail, we often find that they contain fossils of various kinds—shells, corals, sea-urchins, crustaceans, such as crabs and trilobites, the bones, teeth, and scales of fishes, &c., land plants, and more rarely the bones of terrestrial animals. For instance, in the bed of sandstone, No. 4 (fig. 1), we might find that there are remains of sea-shells; occasionally—but more rarely—similar bodies might occur in the conglomerate, No. 3; frequently they might lie between the thin layers of shale in

No. 2; and it is equally common to find large quantities of shells, corals, sea-urchins, encrinites, and various other forms of life in such limestones as No. 1, which, in many cases, are almost wholly composed of entire or broken shells and other marine organic remains.

Marine and lake sediments form soils on and in which the creatures live that inhabit the bottom of the waters, and it is easy to understand how numerous shells and other organic bodies happen thus to have been buried in muddy, sandy, or conglomeratic mechanical sediments, the component grains of which, large or small, have been borne from the land into water, there by force of gravitation to arrange themselves as strata. By the life and death of shells in these fossilised sediments, it is also easy to understand why they are so often more or less *calcareous*. The question, however, arises, *how it happens that strata of pure or nearly pure carbonate of lime or limestone have been formed*.

Though the materials of shale (once mud), sandstone (once loose sand), and conglomerate (once loose pebbles), have been carried from the land into the sea, and there arranged as strata, and though limestones have, in great part, been also mechanically arranged, yet it comparatively rarely happens that quantities of fine unmixed calcareous sediment have been carried in a tangible form by rivers to the sea, though it has sometimes been directly derived from the waste of sea-cliffs, and mixed with other marine sediments. When, therefore, it so happens that we get a mass of limestone consisting entirely of shells, corals, and other remains, which are the skeletons of creatures that lived in the sea, in estuaries, or in lakes, the conclusion is forced upon us that, be the limestone ever so thick, it has been formed entirely by the life and death of animals that lived in water. In many a formation—for instance, in some of the masses great and small of the *Carboniferous Limestone*—the eye tells us that they are formed perhaps entirely of rings of encrinites or stone-lilies, or of shells and corals, of various kinds, or of all these mixed together; and in many other cases where the limestone is homogeneous, the microscope reveals that it is made of foraminifera, or of exceedingly small particles of other organic remains. Even when these fragments are indistinguishable to the naked eye, reflection tells us that such marine limestone deposits must have been built up from the débris of life, for there is no reason to believe that vast formations of limestone, extending over hundreds of square miles, are now, or ever have been precipitated in the open ocean by inorganic chemical processes acting on mere chemical solutions. It sometimes happens, indeed, that gradual accumulations of such beds of limestone have attained thousands of feet of vertical thickness in what belongs to *recent* times in a geological sense, as for example in the great coral reefs of the Pacific Ocean, and, in less known degree, in the calcareous and foraminiferous mud of that ocean and of the Atlantic.

But where does the carbonate of lime come from by which these animals make their skeletons? If we analyse the waters of springs and rivers, we discover that many of them consist of water that is more or less hard—that is to say, not pure, like rain-water, but containing various salts in a state of chemical solution, the most important of which is generally bicarbonate of lime; for the rain-water that falls upon the land percolates the rocks, and, rising again in springs, carries with it salts of soda, potash, &c., and, if the rocks be calcareous, large percentages of bicarbonate of lime in solution. The reason of this is, that all rain in descending through the air takes up a certain amount of carbonic acid—one of the constituents, accidental or otherwise, of the air; and this carbonic acid has the power of dissolving the carbonate of lime which enters into the composition of a large proportion of stratified rocks, which sometimes as pure limestone, form great tracts of country. In this way it happens that springs are often charged with lime, in the form of a soluble bicarbonate, which is carried by rivers into lakes and estuaries, and, finding its way to the sea, affords material to shell-fish and other marine animals, through their nutriment, to make their shells and bones. Thus it happens that, by little and little, lime is abstracted from sea-water to form parts of animals, which, dying in deep clear water, frequently produce by their skeletons and shells immense masses of strata of nearly pure limestone, which is consolidated into rock almost as fast as it is formed.

What is going on now has been going on throughout all known geological time, from that of the deposition of the Laurentian rocks down to the present day.

Igneous rocks form a much smaller proportion of the surface rocks of most parts of the world, though in given areas, such as Iceland and the Faroe Islands, they largely predominate. To take Britain as an example: in North Wales, a considerable proportion, perhaps a twentieth part, of the rocks of Lower Silurian age are formed of igneous masses. The whole of the rest of Wales, till we come to Pembrokeshire, contains almost none whatever. In Cumberland a very large part of the Lower Silurian rocks are igneous, while a comparatively small proportion of igneous rocks is found among the Silurian rocks of the mainland of Scotland. Even the large masses of granite there, occupy but small areas when compared with the great extent of ordinary stratified and metamorphic rocks amid which they lie. It is chiefly in the Inner Hebrides that great masses of tertiary basalts occur. Igneous rocks exist even in much smaller proportions in Derbyshire, Northumberland, Devon, and Cornwall, excepting the occasional occurrence of large bosses of granite in the two last-named counties, as for example on Dartmoor, and at Land's End. If, however, we examine all the midland, southern, and eastern parts of England, we shall find hardly any igneous rocks whatever.

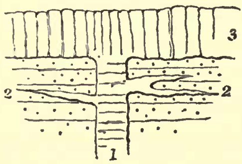
I have now briefly to indicate how we are able to distinguish igneous from aqueous rocks, in countries where there are neither active nor obvious craters of extinct volcanoes, such as those of Auvergne and the Eifel. To do this in detail would occupy a volume.

In a general way we can distinguish them from strata formed by aqueous deposition because many of them are *unstratified*, and have other external and internal structures different from those of aqueous deposits. To take examples: If we examine the lavas that flowed from any existing volcano, and have afterwards consolidated, we find that they are frequently vesicular. This vesicular structure is largely due to watery vapour, and partly to gases ejected along with the melted matter, which, expanding in their efforts to escape from the melted lava, form a number of vesicles, just as yeast does in bread, or as we see in some of the slags of iron furnaces, which, indeed, are simply artificial lavas. This peculiar vesicular structure is never found in the case of unaltered stratified rocks. Here, then, experience tells that modern rocks with this structure were formed by igneous agency, and this in ancient cases is not the less certain though the vesicles have since been filled by the infiltration and deposition of mineral matters in solution, such as carbonate of lime, zeolites and silica. Such igneous rocks are called amygdaloids, and it has not infrequently happened that on the surfaces of old masses of rock, the amygdaloidal kernels, say of carbonate of lime, have been dissolved out by the influence of rain-water bearing carbonic acid, and the surface has regained its original vesicular appearance.

Experience also tells us that some modern lavas are crystalline—that is to say, in cooling, their constituents, according to their chemical affinities, have crystallised in distinct minerals such as augite, various felspars, &c. When we meet with similar, even though not identical crystalline rocks, such as felspar—porphyries, trachytes, diorites and dolorites, associated with old strata, we are therefore entitled to consider them as having had an igneous origin.

In modern volcanic regions, such as Iceland, and in tertiary regions dotted with extinct volcanoes of Miocene or later age, where the forms of the craters still remain, the lavas are often columnar; and when we meet with columnar and crystalline rock-masses of Silurian, Carboniferous, or of any other geological age, we may fairly assume that such rocks are of igneous origin. Modern lavas have often a vitreous structure (glassy) such as obsidian, which its ancient analogue pitchstone closely resembles. Others possess a slaggy structure, and are sometimes formed of wavy ribboned layers that indicate a state of viscous flowing, similar to the contorted ribbon-like structure common in iron and other slags. Iron slag in fact is nothing but artificial lava, formed of the silica and alumina of the iron ore and its flux of lime, melted together and still retaining a percentage of iron. Ancient lavas, such as those of Snowdon, of Lower Silurian age, often still possess a slaggy and ribboned structure. Further, igneous rocks are apt to alter any strata through which they are ejected or over which they flow. Accordingly, in rocks of all ages, and of various composition, felspathic, doloritic (hornblende and felspar), dioritic

FIG. 4.



(augite and felspar), and various others, as in fig. 4, we frequently find veins (2) that have been injected among the strata, from dykes, as they are termed (1), rising vertically or nearly vertically through the beds from the end of which sometimes an overflow of lava (3) proceeded, that may or may not be columnar. In such cases the stratified rocks are apt to be altered for a few inches or even for several feet at their junction with the igneous rocks. If shales, they may be hardened or baked into a kind of porcellanic substance; if sandstones, turned into quartz-rock, something like the sandstone floor of an iron-furnace that has long been exposed to intense heat. Occasionally the strata have been actually softened by heat, and a semi-crystalline structure has been developed.

From these and many other circumstances, a skilled geologist finds no difficulty in deciding that such and such rocks are of igneous origin, or have been melted by heat. The crystalline structure identical with or similar to some modern lavas, the occasional columnar structure, the amorphous earthy look, also common in certain lavas, the slaggy, ribboned, and vesicular structures, the penetration of strata by dykes and veins, and the alteration of the stratified rocks at the lines of contact, all prove the point.

Modern volcanic ashes are simply fragments, small and large, of lava ground often to powder in the crater by the rise and fall of the steam-driven rocky material. This is finally ejected by the expansive force of steam, and with the liberated vapour, volcanic dust, lapilli and blocks of stone, are sometimes shot thousands of feet into the air mingled with watery vapour, which condensing in the higher atmosphere, falls with the ashes on the sides of the volcanic cone in heavy showers of rain. By the study of modern volcanic ashes, it is, after practice, not difficult to distinguish those of ancient date, even though they have become consolidated into hard stratified rocks. Their occasional tufaceous character, the broken crystals, the imbedded slaggy-looking fragment of rocks and bombs, and sometimes the occurrence of coarse volcanic conglomerates, every fragment of which consists of broken lava, all help in the decision. In fact, tracing back, from modern to ancient volcanoes, step by step through the various formations, the origin of ancient volcanic rocks is clear; and further, it leads to similar conclusions with respect to the igneous origin of bosses of crystalline rocks, such as some granites, syenites, and dioritic masses which, having been melted and cooled deep in the earth, were not ejected, and never saw the light till they were *exposed by denudation.*

CHAPTER II.

THE DIFFERENT AGES OF STRATIFIED FORMATIONS. THEIR SUCCESSIVE DEPOSITIONS.

The next point to be considered is—Are stratified rocks of different ages? They are, and the diagram, fig. 1, p. 13, will help to make this clear. There the bed No. 1 must be the oldest, because it was deposited in the sea (or other water) before bed No. 2 was laid above it as layers of mud, and so on to 3 and 4 —taking the strata in order of succession. But that is not enough to know. We are anxious to understand what is the actual history of the different stages which such minor beds represent. Now, if we had never found any fossil remains imbedded in the rocks, we should lose half the interest of this investigation, and our discovery, that rocks are of different ages, would have only a minor value. Turn again to the diagram. We find at the base, beds of limestone, No. 1, perhaps composed of corals and shells. The organic remains in the upper part of these beds lie above those in the lower part, and therefore the latter were dead and buried, before the once living shells which lie in the upper part inhabited the area. Above the limestone lie beds of shale, No. 2, succeeded by No. 3, a conglomerate, and then comes the bed of sandstone, No. 4; therefore the shells (if any) in the bed of shale, No. 2, are of younger date than those in the bed of limestone, No. 1; the organic forms, plants or animals as the case may be, in the conglomerate, No. 3, were buried among the pebbles at a later date than the shells in the shale, and the remains of life in the sandstone, No. 4, were latest of all; and in each bed, each particular form found there, lived and died before the sediment began to be deposited that forms the bed above. All these beds, therefore, contain relics of ancient life of different dates, each bed being younger or older than the others, according as we read the record from above or from below. It is evident that the same kind of reasoning is equally applicable to the inclined strata of fig. 2, or to the contorted beds of fig. 3.

But if we leave a petty quarry or sea cliff, and examine strata on a larger scale, what do we find? On many a coast, where the cliffs consist of stratified rocks, a lesson may easily be learnt on the method of understanding the order, or comparative dates of deposition of geological formations. The Liassic, Oolitic, and Cretaceous cliffs of Yorkshire, from the Tees to Flamborough Head, form excellent examples; or the coast of Devonshire and Dorsetshire, from Torquay to Portland Bill. I take part of the latter as an example, from Lyme Regis to the eastern end of the Chesil Bank.

If we eliminate those accidents called faults, we there find a *succession of formations* arranged somewhat in the manner shown in diagram No. 5.

The horizontal line at the base represents the shore line. On the west (1) represents red marly strata, known as the New red or Keuper marls. These pass under thin beds of white fossiliferous limestone (2), known as the Rhætic beds. These in their turn pass or *dip* under beds of blue limestone and clay, called Lower Lias (3), which are seen to dip under the Marlstone or Middle Lias (4), overlaid by the Upper Lias (5), on which rests the Inferior Oolite sand and limestone (6), followed by the Fuller's Earth clay (7). Next comes a series of strata (8), which for present purposes I have massed together, and which are known when they are all present as Great Oolite, Forest Marble, and Cornbrash. These dip under the Oxford Clay (9), which dips under a limestone called the Coral Rag (10), and still going eastward this dips beneath the Kimeridge Clay (11), which, in its turn, passes under the Cretaceous Series of this district, consisting of Gault (12), Upper Greensand (13), and Chalk (14) which in a bold escarpment overlooks the plain of Kimeridge Clay.[1]

FIG. 5.

Here, then, we *see* a marked succession of strata of different *kinds*, or having different *lithological characters*, formed, that is to say, of marls, clays, sands, and limestones, succeeding and alternating with each other. They are all sediments originally deposited in the sea, (if we except the New Red Marl, which was deposited in a Salt lake), for the forms of old life found in them prove this. Some are only forty or fifty feet thick, some are more than five or six hundred feet in thickness.

If we leave the coast cliffs and turn to the middle of

[1] The Portland beds being only occasionally present, are in this diagram purposely omitted, and this does not affect the general

England—from the borders of South Staffordshire and Warwickshire to the neighbourhood of London—we discover that the whole series is made of strata, arranged in successive stages more or less in the manner which I have already described, and they consist of similar materials. Thus, through Warwickshire and South Staffordshire, we have rocks formed of New Red Sandstone. The red sandstone dips to the east, and is overlaid by New Red Marl; the red marl dips also to the east, under beds of blue clay, limestone, and brown marl, forming the various divisions of the Rhætic beds and Lias; these pass under a great succession of formations of limestones, clays, and sands, &c., known as the Oolites; these, in their turn, are overlaid by beds of sand, clay, and chalk, named the Cretaceous series; which again, in their turn, pass under the Tertiary clays and sands of the London Basin. All these pass fairly under each other in the order thus enumerated. Experience has proved this, for though there are occasional interruptions in the completeness of the series, some of the formations being absent in places, yet *the order of succession is never inverted*, except where, by what may be called geological accidents, in some parts of the world, such as the Alps, great disturbances have locally produced forcible inversions of some of the strata. The Oolites, for example, in England, never lie *under* the Lias, nor the Cretaceous rocks under the Oolites.

Observation of the surface in cliffs, railway cuttings, and quarries, therefore proves this general succession of formations, and so does experience in sinking deep wells and mine shafts. If, for example, in parts of the midland counties we sink through the Lower Lias, we pass

question. Some minor formations known further inland are added to make the series more complete.

into the New Red Marl; if we pierce the red marl, we reach the water-bearing strata of the New Red Sandstone. If in certain districts we penetrate the Cretaceous strata, we are sure to reach the Upper Oolites, and under London many deep wells have been sunk through the Eocene beds, in the certainty of reaching the chalk and finding water.

It is, therefore, not that the mere surface of the land is formed of various rocks, but the several formations that form the land dip or pass under each other in regular succession, being, in fact, vast beds placed much in the same way as a set of sheets of variously-coloured pasteboard, placed flat on each other, and then slightly tilted up at one end, may slope in one direction, one edge of each sheet being exposed at the surface.

Vertical sinkings, therefore, in horizontal or slightly inclined strata, often prove practically what we know theoretically, viz. the underground continuity in certain areas of strata one beneath the other. Accurate but more difficult observation and reasoning has done the same for more disturbed strata, so that our island and other countries have been proved to be formed of a series of beds of rock, some many hundreds and some many thousands of feet in thickness, arranged in succession, the lowest *stratified* formation being of older and the uppermost of younger age.

Most of these strata are *fossiliferous*, that is to say *they contain shells, bones, and other relics of the creatures that lived and died in the waters or water-laid sediments of each special period*; or as sometimes happens, *the remains of land plants and terrestrial animals* that have been washed into the sea or into lakes. What is the more special evidence on this subject afforded by the rocks? As we proceed, we shall suppose, from west to east across the Secondary and Tertiary strata, and examine the fossils found in successive formations, we discover that *they are not the same in all*, and that most of them contain *marine* organic remains, which are in each formation of *species* and sometimes of *genera* more or less distinct from those in the formations immediately above or below.[1]

Thus turning again to fig. 5, p. 25, the Red Marly series No. 1, is rarely fossiliferous, and such fossils as these beds may contain are chiefly land plants, footprints of Amphibia, and small bivalve crustaceans. The Rhætic beds 2, contain sea-shells of a few genera and species, the latter somewhat distinct from those found in the Lower Lias No. 3, the fossils of which are again partly, but not altogether, of different species from those buried in the Marlstone No. 4, which again partly differ from the forms in the Upper Lias clay No. 5, and so on, stage by stage, through the remaining strata of the Oolitic rocks, up to the Kimeridge Clay No. 11. Throughout the whole series from the Rhætic beds (2), upwards to the Kimeridge Clay (11), there is an intimate relation, for in all the Liassic and Oolitic formations the general facies, that is to say, the grouping of *genera* (Ammonites, Belemnites, Terebratulæ, Pholadomyas, Oysters, &c.) is the same, and some species generally pass from each formation into the next above it; and not only so, but sometimes through several formations. There is, however, generally enough of difference in the species found in the different formations to enable anyone with sufficient knowledge to tell by fossils alone, if he found enough of them. what formation he may chance to be examining. When,

[1] There are also a few freshwater deposits, but the discussion of these is not essential to the present argument.

still ascending in the series, we come to the Cretaceous formations represented by 12, 13, and 14, a wonderful change takes place. None of the Oolitic species pass into these formations, and some of the genera, especially of chambered shells (Cephalopoda) are new. *There are no marine passage beds in England sufficiently developed clearly to unite the two series.* They were, in fact, separated in their deposition by a long period of time during which our territory generally formed land, and which is therefore *unrepresented in the British area by marked marine stratified deposits* of dates between Oolitic and Cretaceous times.

I have selected the above instances, as affording a good type of the kind of phenomena that occur again and again throughout the whole series of our geological formations. After a minute examination, therefore, of the stratigraphical structure of our island, the result is, that geologists are able to recognise and place all the rocks in serial order, so as to show which were formed first and which were formed latest; and the following is the result of this tabulation, omitting minor details.

It is a necessary part of the plan of this work to give some account of the range, structure, and fossils of the formations enumerated in the following table, and I shall therefore in succeeding chapters give a brief account of each formation or set of formations, beginning with the oldest, so as in some degree to show their general relations to each other, and, as far as I can, to give a description of the physical geography of each prominent geological epoch.

TABLE OF THE BRITISH FORMATIONS.

		Recent		Alluvia, peat, and estuarine beds now forming, &c.
		Post-tertiary		River and estuarine alluvia, and some peats, with human remains and works of art; whales, seals, &c., bones of Mammoth, and other land mammalia; flint implements, raised beaches, and bone caves, &c., in part. Latest traces of British glaciers. Great glacier moraines, and boulder clays with marine and freshwater interstratifications. Forest bed of Norfolk, Chillesford beds, and
Tertiary, or Cainzoic, and Post-tertiary.	UPPER	Newer Pliocene		Norwich Crag, with land mammalia, &c.
		Older Pliocene	Red Crag. Coralline Crag.	
	MIDDLE	Miocene		Bovey Tracey and Mull beds, with igneous rocks.
	LOWER	Upper Eocene	Hempstead beds Bembridge beds Osborne beds Headon beds	Freshwater river beds, with marine interstratification.
		Middle Eocene	Bracklesham and Bagshot beds	Marine.
		Lower Eocene		London Clay. Marine. Woolwich and Reading beds and Thanet sand. Freshwater, estuarine, and marine.
Secondary, or Mesozoic.	CRETACEOUS	Chalk Upper Greensand Gault Lower Greensand Atherfield Clay		Marine.
	WEALDEN SERIES	Weald clay and Hastings sands Purbeck beds		Freshwater river beds, estuarine and lagoon beds, with marine interstratifications.
	OOLITIC SERIES and	Portland Oolite and sand Kimeridge Clay	Upper	Marine in middle and south of England. Between the Inferior Oolite and Great Oolite, partly freshwater and terrestrial, in Northamptonshire, Lincolnshire, and Yorkshire.
		Coral Rag Oxford Clay	Middle	
		Cornbrash Forest Marble Bath or Great Oolite Stonesfield Slate Inferior Oolite and Sand	Lower	
	LIAS	Upper Lias Clay Marlstone (Middle Lias) Lower Lias Clay and Limestone Rhætic beds. Passage beds		
	TRIASSIC	Upper. New Red Marl (Keuper). Salt Lake. Lower. New Red Sandstone (Bunter). Lake deposits, probably salt, but perhaps partly fresh or brackish.		
Primary, Palæozoic.	PERMIAN	Permian	Magnesian limestone Rothliegende	Salt lakes.
	CARBONIFEROUS			Coal-measures and Millstone grit. Partly terrestrial, freshwater, and marine. Carboniferous limestone and shales. Chiefly marine, and in north of England, and Scotland, partly terrestrial and freshwater.
	OLD RED SANDSTONE, & DEVONIAN	Upper Lower		Freshwater lakes. Devonian marine.
	SILURIAN	Upper Silurian Lower Silurian		Marine.
		and Cambrian.		Probably marine and freshwater beds interstratified.
	LAURENTIAN			Marine.

CHAPTER III.

DENUDATION, SYNCLINAL AND ANTICLINAL CURVES, UNCONFORMABLE STRATIFICATION, AND WASTE PRODUCED BY CHEMICAL ACTION.

I MUST now more precisely explain the meaning of a few terms which I have already employed, and shall have occasion to use very frequently.

Denudation, in the geological sense of the word, means the stripping away of rocks from the surface, so as to expose other rocks that lay concealed beneath them.

Running water wears away the ground over which it passes, and carries away detrital matter, such as pebbles, sand, and mud; and if this goes on long enough over large areas, there is no reason why any amount of matter should not in time be removed. For instance, we have a notable case in North America of a considerable result from denudation, now being effected by the river Niagara, where, below the Falls, the river has cut a deep channel through the rocks, about seven miles in length. The proofs are perfect that the Falls originally began at the great escarpment at the lower end of what is now this gorge; that the river, falling over this ancient cliff, by degrees wore for itself a channel backwards, from two hundred to a hundred and sixty feet deep, through strata that on either side of the gorge once formed a continuous plateau.

I merely give this instance to show what I mean by denudation produced by running water. At one time the channel did not exist. The river has cut it out, and in doing so, strata—some of them formerly one hundred and sixty feet beneath the surface—*have been exposed by denudation.* Possible, but very uncertain calculations, show that to form this gorge a period at the least of something like thirty-five thousand years has been required. This is an important instance, and it is similar to many other cases constantly before our eyes, on a smaller scale, which rarely strike the ordinary observer.

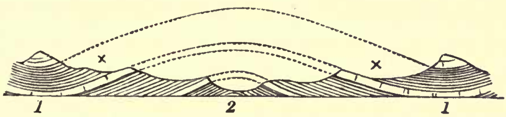
Refer to fig. 6, and suppose that we have different strata, 1, 2, 3, and 4, lying horizontally one above the other, together forming a mass several hundreds of feet in thickness. The running water of a brook

FIG. 6.

or river by degrees wore away the rocks more in one place than another, so that the strata 3, 2, and 1, were *successively cut into* and exposed at the surface, and a valley in time is formed. This is the result of denudation.

Or to take a much larger instance. The strata that form the outer part of the crust of the Earth have, in many places, by the contraction of that crust due to cooling of the mass, been thrown into *anticlinal* and *synclinal* curves. A synclinal curve means that the curved strata are bent downwards as in 1, Fig. 7, an anticlinal curve that they bend upwards as in 2. The whole were originally deposited horizontally, consolidated into rock, and afterwards bent and contorted. The strata marked × may perfectly correspond in all respects in their structure and fossils, and in hundreds

FIG. 7.



1. Synclinal curves. 2. Anticlinal curve,

of similar cases it is certain that they were once joined as horizontal strata, and afterwards thrown into anticlinal and synclinal curves. The strata indicated by dotted lines (and all above) *have been removed by denudation*, and the present surface is the result.

Chemical action is another agent that promotes waste or denudation. Thus rain water, always charged with carbonic acid, falling on limestone rocks such as the Carboniferous Limestone, or the Chalk, not only wears away part of these rocks by mechanical action, but also dissolves the carbonate of lime and carries it off in solution as a bicarbonate. This fact is often proved by numbers of unworn flints sometimes several feet in thickness scattered on the surface of the table-land of chalk in Wilts and Dorsetshire. The flints now lying loose on the surface once formed interrupted beds often separated by many feet of chalk. The chalk has been dissolved and carried away in solution chiefly by moving water, and the insoluble flints remain.

Degradation of the rocks of many regions is also powerfully affected by occasional landslips. The waste thus produced is seen on a large scale in many of the Yorkshire valleys, where Carboniferous sandstones and shales are interstratified, and vast shattered ruins of sandstones cumber the sides of the hills and the bottoms of the valleys in wild confusion (fig. 66, p. 329). In Switzerland the relics of old landslips are often seen on a magnificent scale; and some of these, such as those of the Rossberg, and St. Nicholas in the valley of Zermatt, have taken place in the memory of living men.

The constant atmospheric disintegration of cliffs, and the beating of the waves on the shore, often aided by landslips, is another mode by which watery action denudes and cuts back rocks. This has been already mentioned. Caverns, bays, and other indentations of the coast, needle-shaped rocks standing out in the sea from the main mass of a cliff, are all caused or aided by the long-continued wasting power of the sea, which first helps to destroy the land and then spreads the ruins in new strata over its bottom.

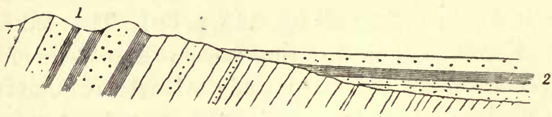
It requires a long process of geological education to enable anyone thoroughly to realise the conception of the vast amount of old denudations; but when we consider that, *over and over again*, strata thousands of square miles in extent, and thousands of feet in thickness, *have been formed by the waste of older* rocks, equal in extent and bulk to the strata formed by their waste, we begin to get an idea of the greatness of this power. The mind is then more likely to realise the vast amount of matter that has been swept away from the surface of any country, in times comparatively quite recent, before it has assumed its present form. Without much forestalling the subject of a subsequent chapter, I may now state that a notable example on a grand scale may be seen in the coal-fields of South Wales, of Bristol, and of the Forest of Dean. These three coal-fields were once united, but those of South Wales and Dean Forest are now about twenty-five miles apart, while the Bristol and Somersetshire coal-field is separated from both by the estuary of the Severn. These separations have been brought about by the agency of long-continued denudations, which have swept away thousands of feet of strata bent into anticlinal and synclinal curves in the manner shown at × in fig. 7, p. 33, and fig. 115, p. 601. The coal-field of the Forest of Dean has thus become an *outlier* of the great South Wales coal-field; and the Bristol or Somersetshire coal-field forms another outlier of a great area, of which even the South Wales coal-field is a mere fragment. Such denudations have been common over large areas in Wales and the adjacent counties, and in many another county besides.

Observation and argument alike tell us that we need have no hesitation in applying this reasoning to all hilly regions, whether formed of stratified rocks alone or intercalated with igneous rocks, and thus we come to the conclusion that the greater portion of the rocky masses of our island have been arranged and re-arranged under slow processes of the denudation of old, and the reconstruction of newer strata, extending *over periods* that seem to our finite minds almost to stretch into infinity.

Unconformable stratification, when its significance has been realised by the student, cannot fail at once to impress on the mind a sense of the degradation of strata in some old epoch similar to that which is now going on, and I know of few objects that speak more eloquently of *geological time.*

In the following diagram No. 1 represents an old land surface, in which perhaps beds of sandstone and slate or shale have been upheaved at a high angle. Let us then suppose that, by the wasting power of weather and the sea, the strata No. 2 have been won from that old land and deposited on the upturned and denuded edges of the strata No. 1. This constitutes a case of *unconformable stratification*, and this alone marks the lapse

FIG. 8.



1. Old disturbed strata.
2. Later beds lying unconformably upon them.

of immense periods of *geological time*, first by the deposition, consolidation, and upheaval of the strata No. 1, and secondly in the deposition of the strata No. 2, which were made from the waste of No. 1.

There are many cases of this kind of unconformity extending through all geological time from the Laurentian epochs onwards. If, in addition to this, we consider the meaning of the progressive changes of genera and species of animals and plants, as we proceed from the older to the newer formations (as expressed in Chapter II.), it soon becomes obvious, that as yet we have no means of even attempting to form any clear idea of the time that has elapsed since life first appeared on the surface of the world, whether we adopt the original view of a distinct creative act for each individual species, or prefer the later one of evolution and progressive development.

To explain in some detail the anatomical structure or existing Physical Geography of our island, as dependent on the nature of its strata and the alterations and denudations they have undergone is the main object of this book. In making this attempt I shall first describe in some detail and in chronological order all the rocky formations that constitute Great Britain, with reference, where it can be done, to the Physical Geology and Geography of each large special epoch, for only in this way may we hope to get an idea of how our island at length got into that phase of its history in which we happen to live. If the reader has been able to follow me in what I have already written, I think he will understand what I shall have to say in the remaining chapters.

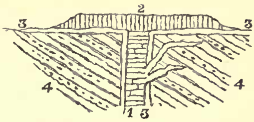
CHAPTER IV.

IGNEOUS ROCKS, METAMORPHISM, SHRINKAGE AND DISTURBANCE OF THE EARTH'S CRUST.

I HAVE already explained that all rocks are divided into two great classes, those of aqueous and those of igneous origin; and I have shown how aqueous rocks may generally be known by their stratification and by the circumstance that a great many of them contain relics of marine and freshwater life, in the shape of fossil shells, fish-bones, and other kinds of organic remains. The materials also of which these beds are composed generally show signs of having been in water, being rounded by the action of the waves of the sea, or by the running waters of rivers.

The other kinds of rocks, termed igneous, occasionally are associated in different localities with the formations named in the foregoing table. For instance, there are no volcanic rocks in Wales associated with the Carboniferous and Old Red Sandstone strata, while there are in Scotland, and true contemporaneous volcanic rocks are intercalated with the Lower Silurian rocks of Wales and Cumberland, while there are none associated with the equivalent strata in Scotland. Some of these contemporaneous igneous rocks consist of beds of volcanic ashes, others of old lavas, others of masses of matter which were intruded among the strata from below. Rocks that have been melted are known to be igneous by their crystalline, slaggy, scoriaceous, vesicular, or columnar structures, and also by the effects they have produced on the strata with which they are associated. Shales, sandstones, &c., are often hardened, bleached, and even vitrified at the points of junction with greenstone, basaltic, and felspathic dykes, or old lava beds (fig. 9), and the same kind of alteration takes place on a greater scale when large masses of igneous rocks have been intruded among the strata.

Fig. 9.

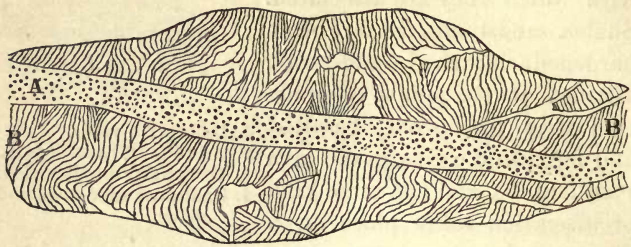


1. Dyke with veins.
2. Overflow of basaltic lava.
3. Altered strata at junction.
4. Unaltered sandstone and shale.

Then by comparing volcanic rocks of old date with those of modern origin, we are able to decide with perfect truth, that rocks which were melted long before the human race appeared upon the world are yet of truly igneous origin.

Changes of a more general character are especially marked in cases where granite, syenite, felspar and other porphyries and their allies, are associated with stratified deposits. Their igneous affinities are known by their crystalline structure, their modes of occurrence, and the effects they produce on the strata. Granite is composed of crystals of quartz, felspar, and mica; and syenite, according to old nomenclatures, of quartz, felspar, and hornblende. They often send veins or dykes into stratified rocks with which they are in contact, as in figs. 10 and 11, and frequently all along the line of junction, and often at great distances from it, alterations of the strata of an extreme character (metamorphism) are common. One marked distinction between granitic and volcanic and ordinary trap rocks is, that though injected veins of granite are common, granitic rocks never rose to the surface in a melted state, and overflowed like lava streams. This and their frequently

FIG. 10.



A, vein of granite; B, gneissic contorted mica-schist. The ramifying white spaces are white quartz. Milldam Goatfell, Brodick, Arran.

largely crystalline structure, together with peculiarities of crystallisation showing the presence of moisture, and

FIG. 11.

1. Granitic mass with injected veins among gneissic rocks.
2. Gneiss, metamorphosed strata.

also the transformations effected on the adjoining strata, prove the granitic rocks to have cooled and consolidated deep beneath the surface.

A third division, or *sub-class*, is known as *metamorphic rocks*. All strata as they assume a solid form become to a certain extent altered; for originally they were loose sediments of mud, sand, gravel, carbonate of lime, or mixtures of these. When these were accumulated, bed upon bed, till thousands of feet were piled one upon the other, then, by intense and long-continued pressure, heat, and chemical changes that took place in consequence of infiltrations among the strata themselves, by degrees they became changed into hard masses, consisting of shale, sandstone, conglomerate, or limestone, as the case may be. But these have not always remained in the condition in which they were originally consolidated, for it has often happened that disturbances of a powerful kind took place, and strata originally flat have been bent into every possible curve.

For long it was the fashion to attribute most of the disturbances that the outer part of the earth has undergone to the intrusion of igneous rocks. The inclined positions of beds, the contortions of stratified formations in mountain chains, and even the existence of important faults—in fact, disturbance of strata generally—were apt to be referred to direct igneous action operating from below. Granite and its allies, from the time of Hutton, were always, without exception, included in the ordinary list of igneous rocks, and some writers of deserved reputation still do so. In connection with this subject, gneiss, and other kinds of metamorphic rocks were, and by some are still, supposed to be exclusively the effect of the direct intrusion of granite among previously unaltered strata.

As a general rule highly metamorphosed rocks occur in regions where the strata have been greatly disturbed. Such rocks, when the metamorphism is extreme, consist of gneiss, which may be micaceous, hornblendic, or chloritic; and of mica-schist, chlorite-slate, talc-slate, hornblende-rock, crystalline limestone, quartz-rock, and a number of others, which it is not necessary for my present purpose to name. In Scotland, Ireland, Norway, Canada, &c., limestones, calcareous sandstones, and sandstones, as they approach granites, lose their (sometimes fossiliferous) characters, and become changed into crystalline limestones, serpentine, &c., and quartz rock. In other cases gradual changes of a different kind are observed in slaty and schistose rocks as they approach granites. Clay-slates are simply clays consolidated by pressure, often affected by cleavage, and sometimes chemically altered. Approaching granites ordinary slates often assume a foliated structure by the development of distinct mineral layers of quartz, felspar, and mica. This is gneiss. Analyse some kinds of mica-slate, gneiss, and common sandy clay, and their average composition will not differ more than three clays, three pieces of gneiss, and three bits of granite often do from each other.

Granite is sometimes merely gneiss still further metamorphosed by heat in the presence of moisture; and, though this is not the popular notion, I have long held it, and some other geologists share this opinion. When slate is changed to gneiss, there is no development of materials which were previously absent, but simply a re-arrangement of its constituents, according to their chemical affinities, in rudely crystalline layers, which seem in gneiss to have found facilities for their development in pre-existing planes, whether of bedding or of cleavage; or, in other words, if the rocks be uncleaved when metamorphism occurs, the foliated planes show a tendency to coincide with those of bedding; but if intense cleavage has preceded, the foliation will generally tend to follow the planes of cleavage. Furthermore, in gneissic rocks, garnets, schorl, staurolite and staurotide, hornblende, and other minerals are frequent in some localities, especially near and in contact with granite. All the chief materials of these are such as occur in the unaltered rock, and the chemical action (brought into activity by heat and moisture) which induced their development, may perhaps in some cases have been assisted by sublimations proceeding from melted matter below. The intensity in many countries of these metamorphisms, extending over many thousands of square miles (as in Scotland, Norway and Sweden, and Canada), and through rocks thousands of feet in thickness, proves that it was the result of a long-continued process, taking place probably in all cases at considerable depths. The whole has then been upheaved and disturbed, often many times, and *after denudation* the gneissic and the more thoroughly metamorphosed and sometimes intrusive granitic rocks were at length exposed at the surface.

Some of the metamorphic rocks, which I have to explain, have been highly disturbed, and in the north occupy about one-half of Scotland. Most of this area includes, and lies north-west of, the Grampian mountains; and I must endeavour to explain by what processes metamorphism of rocks has taken place, not in detail, but simply in such a manner as to give a general idea of the subject.

I have already said that typical gneiss consists of irregular laminæ of *mica*, *quartz*, and *felspar*, and it frequently happens that they are bent, or rather minutely folded, in a great number of convolutions, so small, that in a few yards of gneiss they may sometimes be counted by the hundred. All these metamorphic rocks and granite, were by the old geologists called Primary or *Primitive* strata, and were considered to have been formed in the earliest stages of the world's history, because in those countries that were first geologically described, they were supposed to lie always at the base of all the ordinary strata. From the peculiarity of the minute contortions in the gneissic rocks, a theory now known to be erroneous was developed, which was this:

It is frequently found that granite and granitic rocks are intimately associated with gneiss. Thus we often find masses and veins of granite, with gneiss upon their flanks bent in a number of small wavy folds or contortions. Granite is a crystalline rock, composed of felspar, quartz, and mica, and the old theory (so far true) was that the world at one time was in a state of perfect igneous fusion; but by and by, when it began to cool, the materials arranged themselves as distinct minerals, according to their different chemical affinities, and consolidated as granite. The great globe was thus composed entirely of granite at the surface; and by and by, as cooling still progressed, and water, by condensation, attempted to settle on the surface which still remained intensely heated, the water could not lie upon it, for it was constantly being evaporated into the atmosphere; but when the cooling became more decided, and consolidation had fairly been established, then water was able to settle on the surface of the heated granite. But as yet it could not settle quietly like the present sea: for by reason of strong radiating heat, all the sea was supposed to be kept in a boiling state, playing upon the granite hills that rose above its surface. The detritus thus worn from the granite by the waves of this primitive sea was spread over its bottom; and because the sea was boiling, the sediment did not settle down in the form of regular layers, but became twisted and contorted in the manner common in gneiss. All gneiss, therefore, was conceived to be the original primitive stratified rock of the world.

Subsequent research has shown that this theory will not hold; for this, among other reasons, that we now know gneissic rocks of almost all ages in the geological scale. Thus in Scotland the gneissic rocks are of Laurentian and Silurian age; in Devon and Cornwall we have gneiss both of so-called Devonian and Carboniferous ages. In the Andes there are gneissic rocks of the age of the Chalk, and in the Alps of the New Red, Liassic, Oolitic, and Cretaceous series; and in 1862 I saw in the Alps an imperfect gneiss of Eocene date pierced by granite veins, these strata being of the age of some of the soft and often almost horizontal strata of the London and Hampshire basins. It is therefore now perfectly well known to geologists that the term Primitive, as applied to gneiss, is no longer tenable; and the old theory has been abandoned.

I have stated that regions occupied by metamorphic rocks are apt to be much contorted. There seems, in fact, to be an intimate connection between excessive disturbance of strata and metamorphism. But by what means were masses of strata many thousands of feet thick bent and contorted, and often raised high into the air, so as to produce existing scenic results by affording matter for air and water to work upon? Not by igneous pressure from below raising the rocks, *for that would stretch instead of crumpling strata*, in the manner in which we find them in the Alps, Norway and the Highlands, or in less degree in Wales and Cumberland; but rather because of the radiation from the earth of heat into space, gradually producing a shrinkage of the earth's *crust*, which, here and there giving way, became crumpled along lines more or less irregular, producing partial upheavals, even though the absolute bulk of the globe was diminishing by cooling (figs. 3, 12, and 57). This, according to the theory long ago proposed by Elie de Beaumont, and adopted by De la Beche in his 'Researches in Theoretical Geology,' is the origin of mountain chains. After water took its place on the earth, by such processes land was again and again raised within the influence of atmospheric disintegration, and rain, rivers, and the sea, acting on it, were enabled to distribute the materials of sedimentary strata. Such disturbances of strata have been going on through all known geological time, and I firmly believe are still in progress.

Such shrinkage and crumpling, where it has been most intense and on the greatest scale, is often (where I know it) accompanied by the appearance of gneissic or other metamorphic rocks, and often of granite or its allies.

The oldest rock in the British Islands is gneiss, but that originally was doubtless a common stratified formation of some kind or other. In fact, as far as the history told by the rocks themselves informs us, we cannot get at their beginning, for all strata have been made from the waste of rocks that existed before; and therefore the oldest stratified rocks, whether metamorphosed or not, have a derivative origin.

I must now briefly endeavour to give an idea of the theory of metamorphism. The simplest kind is of that nature mentioned in Chapter I. namely, when melted matter has been forced through or overflows a stratified rock, and remaining for a time in a melted state, an alteration of the stratified rock in immediate contact with it takes place. Thus sandstone may, by that process, become converted into quartz-rock, which is no longer hewable, like ordinary sandstone, but breaks with a hard and splintery fracture. Here then rocks have been changed in character for a short distance from the agent that has been employed in effecting that minor kind of metamorphism (figs. 4 and 9).

On a much larger scale, the phenomena we meet with in a truly metamorphic region are as follows. In the midst of a tract of mica-schist, gneiss, or other altered rocks, a boss of granite (or one of its allies) rises, like those for instance of Dartmoor and Cornwall or of the north end of the Island of Arran. At a distance from the granite the beds may consist, perhaps, of unaltered shale, or of slate, sandstone, and limestone. As we approach the granite, the limestones become crystalline, and often lose all traces of their fossils; the sandstones harden and pass into quartz-rocks, and the shales or slates, or sandy beds and shales, lose their ordinary bedded texture, and pass by degrees into mica-schist, or perhaps gneiss, in which we find rudely alternating laminæ of quartz, felspar, and mica, often arranged in gnarled or wavy lines (foliation, figs. 10 and 11). As we approach the granite still more closely, we find possibly that, in addition to the layers of mica, quartz, and felspar, distinct crystals, such as garnets, staurolites, schorl, &c., are developed near the points of contact, both in the gneissic rock and in the granite itself.

It is not necessary for my argument that I should describe these minerals. It is sufficient at present to state the fact that such minerals are developed under these circumstances, and this is due to the influence of metamorphism.

Furthermore in some cases, as in the Laurentian rocks of Canada, great thicknesses of *interstratified* gneiss are so crystalline that, when a hand specimen or even a small part of the country is examined, they might seem to be truly granitic; but when the detailed geology of the country has been worked out, they are found to follow all the great anticlinal and synclinal folds of metamorphosed strata that have also in a minor way been intensely contorted. The same is the case in parts of the Alps.

I have already stated that if we chemically analyse a series of specimens of clays, shales, and slates, often more or less sandy, together with various gneissic rocks and granites, it is remarkable how closely the quantities of their ultimate constituents, in many cases, approach to each other. They are never identical, while yet the resemblance is close, as close indeed as it may be in two specimens of the same kind of sandy shale or slate. In all of them silica would form by far the largest proportion, say from 60 to 70 per cent.; alumina would come next, and then other substances, such as lime, soda, potash, iron, &c., would be found in smaller varying proportions; and what I now wish to express is, that the distinct minerals developed in the gneiss, such as felspar, mica, garnets, &c., *were not new substances* introduced into the rock, by contact with granite, or by any other process, but *were all developed under the influence of metamorphism from materials that previously existed in the strata before their metamorphism began*, aided by hydrothermal action due to the presence of heated alkaline waters deep beneath the surface of the earth. Through some process, in which heat played a large part, the rock having been softened, and water—present in most rocks underground—having been diffused throughout the mass and heated, chemical action was set up, and the substances that composed the shale or slate, often mingled with silicious sandy material, were enabled more or less to re-arrange themselves according to their chemical affinities, and distinct mineral materials were developed in layers from elements that were in the original rock.

I have stated that to produce this kind of metamorphism, heat aided by water is necessary, so as to allow of internal movements in the rocks by the softening of their materials, without which I do not see how complete re-arrangement of matter accompanied by crystallisation could take place; and though it has always been easy to form theories on the subject, yet so little is known with precision about the interior of the earth beyond a few thousand feet in depth, that how to obtain the required heat is a difficulty.

From astronomical considerations it is believed by many persons that the earth has been condensed from a nebulous fluid, and passing into an intensely heated melted condition, by radiation into space at length cooled so far, that consolidation commenced at the surface, and by degrees that surface has gradually been thickening and overlies a melted nucleus within.

As the earth cooled and consequently gradually shrunk in size, the hardened crust, in its efforts to accommodate itself to the diminishing bulk of the cooling mass within, became in places crumpled again and again. Hence the upheaval of mountain chains and disturbances of different dates, which have affected strata of almost all geological ages.[1]

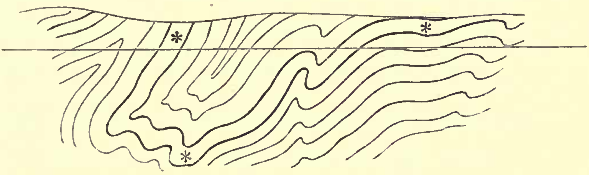
Reasoning on these disturbances, we know that strata which were originally deposited horizontally have often

[1] This theory is not universally received, and has been variously developed by different authors, but it would be quite beyond my present purpose to discuss the subject in detail, and, as far as I know, the hypothesis proposed by Elie de Beaumont seems best to explain the phenomena exhibited by the outside of the earth.

descended thousands of feet towards the centre of the earth, by gradual sinking of the sea-bottom, and the simultaneous piling up of newer strata upon them. The layer that is formed to-day beneath the water forms the actual sea-bottom; but neither the land nor the sea-bottom are steady. The land is in places slowly descending beneath the sea, and sea-bottoms are themselves descending also. It has frequently happened, therefore, that for a long period a steady descent over a given area has taken place, and simultaneously with this many thousands of feet of strata have by degrees accumulated bed upon bed, as for example in the Pacific Ocean in the region of modern atolls and barrier coral reefs.

As we descend into the earth the temperature rises, whence, in the main, the theory of central heat has been derived. In our latitude heat increases about 1° for every sixty feet, and the temperature therefore, at so great a depth as 30,000 feet, to which it could be shown some strata have sunk, may at present be about 500°. Furthermore, strata that were deposited horizontally have been frequently disturbed and thrown into rapid contortions, or into great sweeping curves; and by this means especially, strata which once were at the surface have often been thrown twenty, thirty, or forty thousand feet downwards, and therefore more within the influence of internal heat, as, for instance, in the bed marked * fig. 12, which may be supposed to represent a large tract of country. I do not wish it to be understood that the globe is entirely filled with melted matter—that is a question still in doubt; but were this book specially devoted to general questions of theoretical geology, I think I could prove, that the heat in the interior of the globe in places sometimes apparently capriciously eats its way towards the surface by the hydrothermal fusion or alteration of parts of the earth's crust, in a manner not immediately connected with the more superficial phenomena of volcanic action

FIG. 12.



—and for this, among other reasons, it may happen that strata which are contorted, have in places been brought within the direct and powerful influence of great internal heat. Under some such circumstances, we can easily understand how stratified rocks may have been so highly heated that they were actually softened; and most rocks being moist (because water that falls upon the surface often percolates to unknown depths), chemical actions were set going, resulting in a re-arrangement of the substances which composed the sedimentary rock. Thus certain strata, essentially composed of silica and silicates of alumina, and alkalies such as soda and potash, may have become changed into crystalline gneiss.

This theory of re-arrangement leads me to another question—connected with, but not quite essential to my argument, as far as relates to physical geography—viz., What is the origin of granite, which in most manuals is only classed as an igneous rock? For my part, with some other geologists, I believe that in one sense it is an igneous rock—that is to say, much of it has often been completely fused. But in another sense it is often a metamorphic rock, because it is sometimes impossible to draw any definite line between gneiss and granite, for they pass into each other by insensible gradations. About half-way up the Matterhorn in the Alps, among the largely-contorted beds, a thick stratum occurs, one end of which is true gneiss, on the western side of the mountain, which striking towards the eastern cliff, gradually gets more and more crystalline till at length it passes into true granite. On the largest scale, both in Canada and in the Alps, I have frequently seen varieties of gneissic rocks regularly interbedded with less altered strata, the gneiss being so crystalline, that in a hand specimen it is impossible to distinguish it from some granitic rocks, and even on a large scale the uneducated eye will constantly mistake them for granites. Another very important circumstance is that *granite* and its allies *frequently occupy the spaces that ought to be filled with gneiss* or other rocks, were it not that they have been entirely fused and changed into granite. I therefore believe that many of the granite rocks I have seen, are simply the result of the extreme of metamorphism brought about by great heat with presence of water.

One reason why it has been inferred that granite is not a common igneous rock is that, *enveloping* the crystals of felspar and mica, there is generally a quantity of *free* silica, not always crystallised in definite forms like the two other materials. Silica being far less easily fusible than felspar, it seems clear that had all the substances that form granite been merely fused like common lavas, the silica ought on partial cooling to have crystallised first, whereas the felspar and mica have crystallised first, and the silica *not used in the formation of these minerals* wraps them round often in an amorphous form. Therefore it is said that it was probably held in partial solution in hot water, even after crystallisation by segregation of the other minerals had begun. This theory, now held by several distinguished physical and chemical geologists, seems to me to be sound, especially as it agrees exceedingly well with the metamorphic theory as applied to gneiss—granite being sometimes simply the result of the extreme of metamorphism. In other words, when the metamorphism has been so great that all traces of the semi-crystalline laminated structure has disappeared, a more perfect crystallisation has taken place, and the result is a granitic mass without any minor lamination in it. Even then, however, certain planes often remain, strongly suggestive of original stratification, and even of planes of oblique stratification or false-bedding.

These general results are not founded on mere conjectures. In a memoir by Mr. H. C. Sorby, 'On the Microscopical Structure of Crystals, indicating the Origin of Minerals and Rocks,' among other important points, he describes numerous small cavities in the quartz of granites, which are partly filled with water 'holding in solution the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, sometimes one and sometimes the other salt predominating.' These 'fluid cavities' sometimes make up about five per cent. of the volume of the quartz, and he concludes that 'the fluid was not an *accidental* ingredient due to the percolation of water to a fused mass naturally containing none, but a *genuine* constituent of the rock when melted.' Reasoning on the underground temperatures necessary to expand the liquid so as to fill the cavities, by an elaborate process of argument he arrives at the approximate result, that 'the pressures under which granites were most probably formed' indicate depths from the surface varying from 15,100 to 65,500 feet. From certain passages it is evident that Mr. Sorby considers that gneiss and granite were formed approximately under similar circumstances. I quote this thoroughly philosophical memoir, that the reader may be less startled with the statement, that gneiss and some granites were formed by the metamorphosis of strata at depths counted by many thousands of feet, and also to give strength to the assertion, that under such circumstances water was present.[1]

If the above views be correct, though many granites having been completely fused have been injected among strata, and are thus to be classed as intrusive rocks, yet in the main, so far from the intrusion of granite having produced many mountains by mere upheaval, both gneiss and granite would rather seem to be often the results of the forces that formed certain mountain chains. Possibly this result was connected with the contraction of the earth's crust and the heat produced by the intense lateral pressure that, with much movement of parts, produced the contortion of vast masses of strata, parts of which, now exposed by denudation, were then deep underground, and already acted on by the internal heat of the earth in a degree proportionate to their depth.[2]

[1] See 'Journal of the Geological Society,' vol. xiv., 1858. Sorby.

[2] See Report, Brit. Assoc. 1866, p. 47: 'Address to the Geological Section,' Ramsay. Also an elaborate memoir by Mr. Robert Mallet, 'On Volcanic Energy, &c.,' Trans. Royal Soc., vol. clxiii. p. 147.

CHAPTER V.

LAURENTIAN, CAMBRIAN, AND LOWER SILURIAN ROCKS.

THE LAURENTIAN ROCKS are the oldest formations at present known in the world. They are metamorphic and mostly gneissic in character, and were for long classed as granitic and igneous rocks till their true nature was shown by the late Sir William Logan. They occupy vast tracts of country in Labrador and Canada, and are well seen on the north of the river Ottawa. They consist of two divisions, *Lower and Upper Laurentian*, the upper, according to Logan, lying quite unconformably on the lower strata. The gneiss of the lower division is chiefly orthoclase gneiss of great thickness, and it is interstratified with several thick bands of crystalline limestone, sometimes serpentinous, in one of which a remarkable foraminifer called *Eozoon Canadense* was found. This is the oldest known fossil. The upper Laurentian rocks, which also contain beds of limestone, are to a great extent formed of Labrador felspar, and in these no fossils are known.

In the Outer Hebrides and on the west coast of the Highlands between Cape Wrath and Tiree, Laurentian rocks occur of highly metamorphic gneiss, interpenetrated by numerous veins of granite. These strata much more closely resemble the Lower than the Upper Laurentian rocks of Canada, and though, at so great a distance from America, it is impossible to prove that they are equivalent formations, the presumption that they are of Laurentian age is very strong, and not the less so that strata, having all the characters of Cambrian rocks, lie quite unconformably upon them, fig. 54, p. 285. The district was first described by Sir Roderick Murchison. I can answer for the accuracy of his descriptions, having inspected the ground with him, and personally mapped a portion of the country at and about Durness. I know of no other part of the British Islands in which Laurentian strata certainly occur.[1] No fossils have yet been observed in these British rocks.

The CAMBRIAN and SILURIAN ROCKS of the British series come next in succession. If these strata were to be classified for the first time in England, with my present knowledge, I would divide them into three, as the most convenient method. The first series would include the purple and green grits and slates of the Longmynd and Wales, and range upward as high as the top of the Tremadoc slates; the second would range from the base of the Arenig slates to the top of the Bala or Caradoc beds, and the third from the base of the Upper Llandovery beds to the top of the Ludlow rocks. In Wales and its neighbourhood, where the most typical series is found, each of these great boundary lines is marked by unconformity, and analogous unconformities are more or less found elsewhere in the British Islands.

[1] After their discovery by Murchison, the Laurentian rocks and other details in the Highlands were mapped by Professor Geikie, F.R.S. See his Geological Map of Scotland, 1876.

It is probable, however, that only a few persons would as yet agree with me in this classification, and indeed, since the first publication, by Mr. Murchison, of 'The Silurian System,' dedicated to Professor Sedgwick in 1839, there has been, after a temporary lull, but little unanimity among British geologists on a subject about which European and American geologists care but little, and which is to a great extent a matter of local opinion.

In 1841 and 1842 Sir Henry de la Beche and those who worked with him, adopted the term Cambrian for all the purple grits and slates of St. David's and the Longmynd, then supposed to be unfossiliferous; while the name Silurian, nearly in the same sense as used by Murchison, was employed for all the strata between the uppermost beds of these rocks and the top of the Ludlow series. When the Government Geological Survey reached North Wales this classification continued for a time unchallenged. Professor Sedgwick had previously called the equivalents of part of these strata in the north of England the CUMBRIAN series, and at that time he called the blue and grey slaty series of Wales the CAMBRIAN series, on the assumption, then unquestioned, that they were all older than the recognised Llandeilo flags of Murchison. But in the progress of investigation by Sedgwick and many others, it appeared that his original Cambrian, and Murchison's original Lower Silurian strata, were in great part equivalent, and the great Professor of Cambridge naturally reclaimed all that part of his kingdom, the boundaries of which had, for all Wales, not been clearly defined when he first tried to subdue it. He therefore, maintained, that the true Cambrian series included all the strata from the base of the purple slates and grits to the top of the Bala beds or Caradoc sandstone of Murchison.

By way of healing differences and striking a just middle boundary, Professor Phillips and Sir Charles Lyell proposed that the term Cambrian should be used as including all the strata from the known base of the Longmynd, St. David's, and North Wales purple grits and slates, through the Lingula flags up to the top of the Tremadoc slates, a proposition which satisfied neither of the claimants.

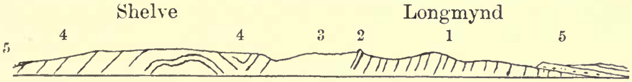
This is not a book in which to enter into the details of a controversy which has comparatively little interest beyond the confines of the British Islands, and will by-and-by be forgotten along with other minor debates, that in their day were of equal or more importance; but I have thought it worth while to sketch out the questions involved, that in the conflict of lecturers and writers of memoirs and manuals, ordinary readers may know something of the origin of the varieties of opinion implied in the different nomenclatures. In the meanwhile I shall use the old-fashioned nomenclature adopted by the Geological Survey, as most convenient for me, seeing that if any one in reading this book should find it needful to look at the maps and sections of that Survey, and at most other maps as well, he will find the word Cambrian restricted to those strata, that at St. David's, and in Merionethshire lie below the base of the Menevian beds. In this sense, then:—

The Cambrian rocks of Wales consist of the purple grits and slates, that form the greater part of the group of hills that lie east of Cardigan Bay between the estuaries of the Mawddach and most of the country S.S.W. of Ffestiniog. In that region their stratigraphical relation to the overlying Lower Silurian rocks will be seen by referring to fig. 62, p. 322. They form there the lowest central strata of a broad anticlinal curve. They are also well seen in the Passes of Llanberis and Nant Ffrancon in Carnarvonshire, where the celebrated slate quarries of Penrhyn and Llanberis lie in these strata. The slates are purple, purplish-blue, and green; and associated with them are beds of greenish and grey grits and conglomerates. It is important to observe that at Llanberis the latter contain numerous water-worn pebbles of felspathic traps, jasper, greenstone, black and purple slate, &c., so that these, forming part of the oldest rocks of Wales, have been partly derived from pre-existing rocky lands, similar to those that now form the neighbouring Silurian country, but no visible trace remains of this more ancient physical geography, except the pebbles in the conglomerate. In Anglesea the equivalent rocks are metamorphic chlorite and mica-schist and gneiss.

Cambrian strata also occur in the hills of the Longmynd of Shropshire, where the strata stand nearly on end. They consist of green, grey, and purple slaty rocks, grits, and conglomerates. The only traces of fossils yet discovered in these consist of worm-burrows, and a trilobite, *Palæopyge Ramsayi.*

FIG. 13.

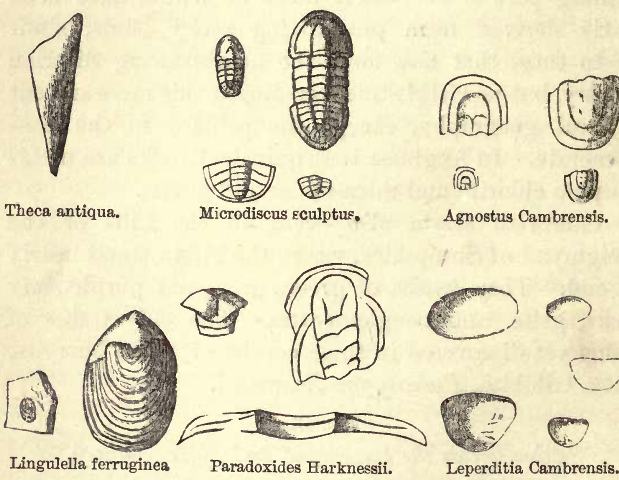
Section across the Longmynd and Shelve country.



1. Cambrian grits and slates. 2. Lingula flags of the Stiper stones. 3. Tremadoc beds. 4. Llandeilo and Caradoc rocks with igneous interstratifications. 5. Upper Llandovery and Wenlock rocks.

At St. David's, in North Pembrokeshire, in equivalent strata, Mr. Hicks found the following fossils in purple shales among the lowest beds of the series:—A small bivalve crustacean *Leperditia Solvensis* and *L. Cambrensis*, two small Brachiopods, *Lingulella ferruginea* and *L. primæva.* In a higher part of the series, consisting chiefly of yellowish sandstones and gray shales, he also found two sponges (*Protospongia*) and various trilobites, *Microdiscus sculptus*, *Conocoryphe Lyellii* and *C. Solvensis*, *Paradoxides Harknessii*, *Plutonia Sedgwickii*, *Agnostus Cambrensis*, and a Pteropod *Theca antiqua.* These rocks had previously been con-

FIG. 14.



Group of Cambrian Fossils.

sidered unfossiliferous, and the discovery is important as showing that in sediments so old there existed a considerable development of life of the same general type as that found in overlying Silurian strata.

In Sutherlandshire, as already stated, red Cambrian conglomerates lie on the Laurentian strata unconformably, and fossils discovered in the north of Scotland by Mr. Peach prove that Lower Silurian rocks (somewhat metamorphic) rest unconformably on both.

Till within the last few years it was customary to consider that all formations which had not yielded fossilised fresh-water shells were of marine origin. Mr. Godwin-Austen first broke through this fallacy, and often insisted that the Old Red Sandstone, as distinct from the Devonian rocks, was deposited in fresh-water lakes.

In 1871, I published two memoirs in the Journal of the Geological Society, in which I attempted to prove that in a broad sense, the red formations of Britain were deposited in lakes, salt or fresh, or in inland areas in which salt and fresh water alternated. In one of these,[1] I ventured to state 'that the absence of marine mollusca in the Cambrian rocks' of North Wales and the Longmynd, as yet observed, may be due to the same cause that produced their absence in the Old Red Sandstone (see p. 106), and that 'the presence of sun-cracks and rain-pittings in the Longmynd beds favours this suggestion.' The occurrence of marine fossils, chiefly in the grey slates and 'olive-green grits and shales' of St. David's, as described by Mr. Hicks, 'may,' I state, 'possibly mark occasional influxes of the sea into inland waters, due to oscillations of level,' producing the same kind of alternations of marine and fresh-water strata that occur in the Carboniferous series, and in the Miocene beds of Switzerland and the Rhine.

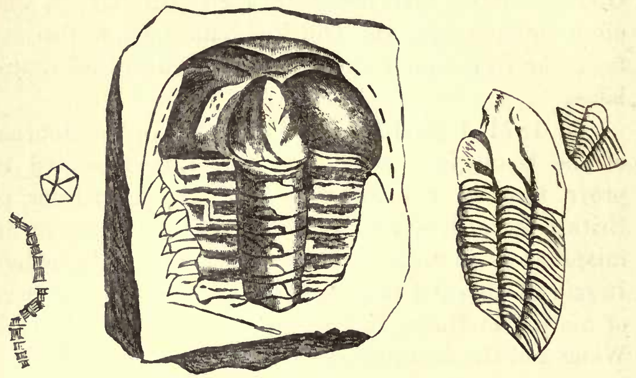
It is but right to state, however, that, as regards the Cambrian rocks, mine is not the usual opinion.

The Lower Silurian rocks which conformably

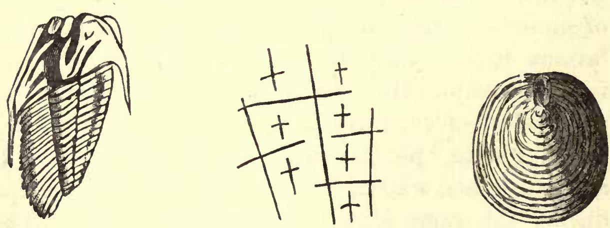
[1] On the Red Rocks of England of older date than the Trias. March 1871, 'Journal of the Geological Society,' vol. xxviii.

overlie the Cambrian strata, have been classed under various subdivisions, from the presence in each of certain Trilobites and other fossils, sometimes peculiar to, and sometimes more or less prevalent in, each sub-formation. To the oldest of these the name Menevian

Fig. 15.



Protocystites Menevensis. Paradoxides aurora. Arionellus longicephalus.



Conocoryphe coronata. Protospongia fenestrata. Discina pileolus.

Group of Menevian Fossils.

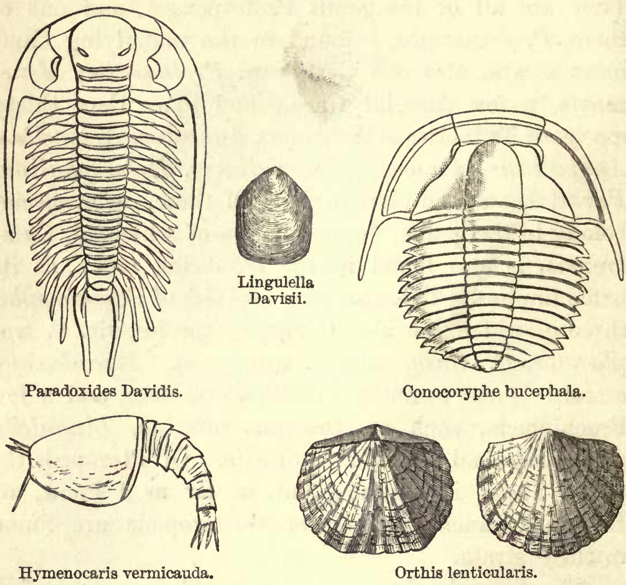
beds has been given, so called from Menapia, the old Roman name of St. David's. They are of inconsiderable thickness, and are found both in that district and in North Wales, circling round the Cambrian rocks of Merionethshire from Barmouth to Harlech, and in both areas there is a lithological passage and conformity between the Cambrian and Menevian strata, fig. 62, p. 322.

Four species of sponges are at present known in the Menevian beds of St. David's, named by Mr. Hicks. They are all of his genus Protospongia, and one of them, *P. fenestrata*, is found in the underlying Cambrian strata, also one Cystidean, *Protocystites Menevensis*, a few Annelid tracks, and more than thirty species of Trilobites of the genera *Agnostus*, *Arionellus*, *Anopolenus*, *Conocoryphe*, *Erinnys*, *Holocephalina*, *Paradoxides*, and *Carrausia*. Of these, seven species belong to the genus *Agnostus*, one of which, *A. Cambrensis*, is also found in the Cambrian rocks, as its name implies. There are seven species of *Conocoryphe*, three of which are also Cambrian species, viz. *C. applanata*, *C. Bufo*, and *C. humerosa*. *Paradoxides aurora* is also common to both formations, and a few Brachiopoda, such as *Discina pileolus*, *Lingulella ferruginea* and *Obolella sagittalis*. Of Pteropods the genus *Theca* is common, but, as far as I know, no Lammellibranch molluscs or Gasteropoda are found in these strata.

The *Lingula flags* rest conformably on, and in fact pass by lithological gradations into the Menevian beds (fig. 62, p. 322). They are best developed in Merionethshire, Carnarvonshire, and at St. David's, and consist of black and gray slaty rocks with beds of grit.

In these a marked and distinctive suite of fossils occurs, the chief of which are *Lingulella Davisii*, and many genera of Crustacea—*Conocoryphe bucephala* and two others, *Agnostus* (4), *Paradoxides* (2), *Holocephalina* (1), *Anapolenus* (2), *Erinnys*, and *Conocephalus*— all Trilobites; also a phyllopod crustacean, *Hymenocaris vermicauda*, and the bivalve crustacean *Leperditia bupestris*. Various annelids are found, *Cruziana*, &c., and in the higher part of the strata Polyzoa, of the genus *Fenestella*, together with a few

FIG. 16.



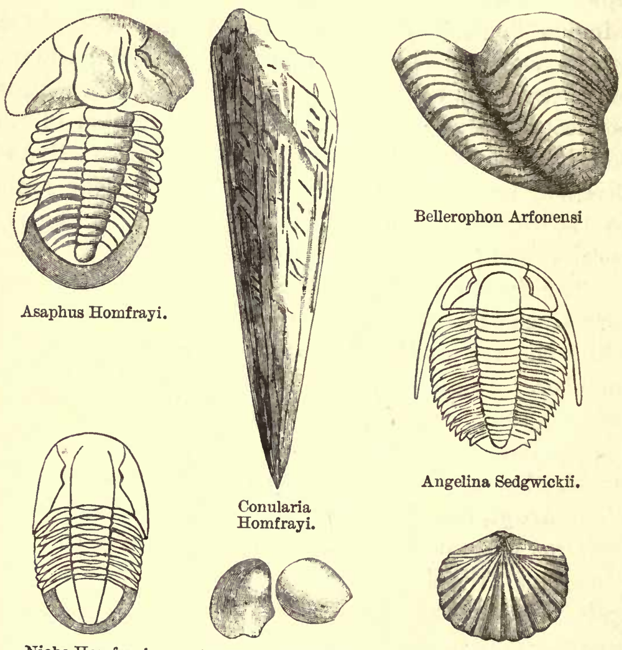
Group of Lingula Flag Fossils.

brachiopoda of the genus *Orthis*, *O. lenticularis* and others, *Obolella sagittalis* and *maculata*, and Discina labiosa, three species of Theca (pteropods), &c.

Of the fossils of this formation *Protospongia fenestrata* is common in the strata from the Cambrian to the Lower Lingula flags, *Agnostus Davidis* and *A. scutalis*, *Anopolenus Henrici*, *A. Salteri* are also found in the Menevian beds, together with *Conocoryphe applanata*, and *C. humerosa*, both of which begin in the Cambrian strata, while *C. variolaris* is common to the Lingula and Menevian strata. *Paradoxides Harknessii*, *P. Hicksii*, and *P. aurora* are common to all three formations, and *P. Davidis* to the two higher divisions. The same kind of passage of species upward from the Cambrian slates and grits to the Lingula flags, may be observed in some of the few genera and species of Brachiopoda, Lamellibranchiata, and Pteropoda, and I have specially insisted on this, in connection with the fact, that at the junction of the so-called three *formations*, there is no marked line of division, but a lithological gradation from the lower to the higher strata, accompanied by the passage of species from lower to higher geological horizons.

The *Tremadoc slates* succeed the Lingula flags, and may be considered as an upper member of that series, while the red and grey Cambrian rocks form a lower member. There is no clear lithological boundary-line between them, and the whole lie conformably. Fourteen genera of Trilobites are known in Wales from these strata, the most characteristic of which are *Asaphus Homphrayi*, &c., *Angelina Sedgwicki*, *Psilocephalus inflatus*, &c., and *Niobe Homphrayi*. Several of the genera of Trilobites are common to the Lingula flags and the Cambrian beds below. Of these, *Agnostus princeps* is found in the Menevian beds, and *Conocoryphe depressa*, *C. invita*, and *Olenus alatus* in the Lingula flags. *Orthis Carausii* is a characteristic brachiopod, and *Lingulella Davisii* and *L. lepis* are common to these strata and to the Lingula flags, together with *Obolella plicata* and *O. Salteri*, while *O. sagittalis* ranges from the Cambrian up to the Tremadoc slates. In Ramsey Island near St. David's many Lamellibranchiate molluscs have been found by Mr. Hicks, of the genera *Palæarca, Glyptarca, Davidia, Modiolopsis,* and others, also *Theca operculata* and other Pteropoda, and several species of *Bellerophon* occur (*B. Arfonensis,* &c.), together with Cephalopoda, viz., *Orthoceras seri-*

FIG. 17.



Group of Tremadoc Slate Fossils.

ceum, and *Cyrtoceras præcox*; also Encrinites, and a starfish, *Palasterina Ramseyensis.* Altogether, as now known, the life of the time was richer than that of the Cambrian and Lingula flag strata, but all of these faunas are probably very imperfect and fragmentary in the British area.

Leaving these details of stratification, I will now endeavour to catch a glimpse of the physical geography of our area during the time that the Cambrian, Lingula, and Tremadoc rocks were being deposited. I have already stated that the purple strata of the Cambrian series seem to me to have been deposited in inland fresh waters, subject to influxes of the sea, probably owing to occasional subsidence of the land; in the same manner, for example, that in Tertiary times the Miocene strata of Switzerland and the Rhine were deposited in great fresh-water lakes, in areas that underwent local temporary submergence. The thick strata of sandstones in the Cambrian rocks of Merionethshire, indicate the neighbourhood of land, and in Caernarvonshire the numerous beds of sandstone and coarse conglomerate interstratified with mud deposits—now slates, point not only to the proximity of land, but even give a clear idea of the kinds of rock of which that land was made. 'In the 8,000 feet of these rocks in Merionethshire there is very little slate, and even the 700 or 1,000 feet of interstratified slaty beds in Caernarvonshire are quite subordinate to the grits and conglomerates. * * *' 'The structure of this land may be partly inferred from the nature of the pebbles in the conglomerate, which are water-worn, and consist of purple and black slates, quartz-rock, felspathic traps, quartz-porphyries, and jaspers.'

The country from which these pebbles were derived must, indeed, have physically resembled North Wales of the present day, 'but except these pebbles no trace of that land remains in or near North Wales.'[1] Fragments of this old continent, however, probably still exist in the Laurentian rocks of the Outer He-

[1] 'The Geology of North Wales,' p. 160. A. C. Ramsay.

brides, on the coast of the West Highlands, where exceedingly red Cambrian sandstones and conglomerates lie quite unconformably on the Laurentian strata.

While the Menevian and Lingula beds were being deposited I think it more than probable that the pre-Cambrian continent still existed, for in the gritty strata that form a large part of the Lingula flags, and in the frequent presence of current marks (often called ripple-marks), there are many signs that these strata were deposited in shallow water, and thus it would happen, that during the time when these and the Tremadoc beds were being formed, the whole area was undergoing a process of slow sinking, into which sediments were being constantly carried, just in proportion as the gradual depression went on, so that, in the long run, what with the effects of sub-aërial degradation, and what with the results of progressing submersion, the old pre-Cambrian land of this neighbourhood finally was buried and disappeared.

CHAPTER VI.

ARENIG, LLANDEILO, AND BALA BEDS.

The Arenig Beds succeed the Tremadoc slates at St. David's in South Wales, and in North Wales they also overlie the Tremadoc slates between Towyn and the neighbourhoods of Dolgelli, Ffestiniog, Tremadoc, and Criccieth in Caernarvonshire, north of which they also occur in part of the country between Caernarvon and Bangor. They were first distinguished by Professor Sedgwick, and named Arenig slates, and afterwards termed *lower* Llandeilo beds by Sir Roderick Murchison, who had previously included them as part of the Llandeilo flags in his descriptions and sections of the Lower Silurian rocks that lie west of the Stiper Stones near Shelve, in Shropshire.

In the large district of Merionethshire the Arenig slates appear at the base of the great volcanic series of felspathic lavas and ashes, of which the mountains of Cader Idris, Aran Mowddwy, Arenig, and the Moelwyns form distinguished features in the landscape. They are in these districts never more than about 800 feet in thickness, and the Arenig beds of Merionethshire, at their base invariably consist of beds of grit, sometimes conglomeratic. The higher strata of this sub-formation are generally slaty. For reasons that will afterwards appear, I believe that the Arenig strata, on a large scale, rest unconformably on the underlying rocks of North Wales.

In Cumberland the Arenig slates form the mountains of Skiddaw and Saddleback, and from the borders of the Old Red Sandstone, a few miles further east, they stretch right across the country westward to Egremont and northward to Sunderland, south of which town, near Cockermouth, they are directly overlaid by the Carboniferous Limestone. In that country they have usually been called the Skiddaw slates. In Scotland the Durness strata belong to the same rocks.

In Britain the fossils that belong to this part of the Silurian series are not very numerous, taken as a whole, though some groups are remarkably abundant. As far as observation has gone, Hydrozoa of the sub-class Graptolitidæ first appear in these strata, including some 20 genera and 48 species. The greatest number of species belong to the genus *Didymograptus*, of which 20 species have been named, after which come *Tetragraptus*, *Diplograptus*, *Dichograptus*, and *Dendrograptus*.

Eighteen genera and 47 species of Trilobites occur in the same rocks, including *Agnostus* (*A. hirundo*, &c.); *Asaphus* (*A. Homfrayi*, &c.); *Ogygia* (*O. Selwynii*, &c.); *Trinucleus* (*T. Ramsayi*, &c.); *Calymene* (*C. parvifrons*, &c.), and many others. Of Brachiopoda there are 7 genera and 18 species including three Lingulas, *Lingulella Davisii* and *L. lepis*, 7 species of *Orthis*, including *O. calligramma* and *O. lenticularis*; 2 species of *Obolella*; 2 of *Discina*, and others. Of Lamellibranchiata there are only 5 genera and 8 species known, including *Modiolopsis trapeziæformis*, *Palæarca socialis*, and *P. amygdalus*, *Ctenodonta elongata*, &c., and *Redonia Anglica*. Pteropoda of the genera *Theca* and *Conularia* are found, and 6 species of *Bellerophon*, and of Cephalopoda there are 5 species of *Orthoceras*. Of univalve shells we have only 3 species—*Pleurotomaria Llanvernensis*, *Ophileta*, and *Raphistoma*, and several other fossils needless to enumerate.

In all, 184 species are known at present in the Arenig beds, mostly characteristic of these strata, for only about 8 per cent. pass upward into this horizon from the Tremadoc beds, a proportion of which go down into the Lingula flags, and about 7 per cent. pass upward into the Llandeilo flags.

Though in Wales the *base* of the Arenig beds is clear, it seems as yet impossible to draw any definite physical boundary between the Arenig beds and the overlying Llandeilo slates, for there is nothing like unconformity, and no marked lithological difference in the passage from one to the other. We have already seen that there is a very limited passage of species from the Arenig slates into those of the so-called Llandeilo series.[1]

Just about this time an important episode took place in the history of the Llandeilo and Bala beds over large tracts of Wales and Cumberland, for a series of volcanic eruptions occurred on a great scale while the strata were being deposited (fig. 62, p. 322). To this subject I shall by-and-by return.

In North Wales the Llandeilo and Bala or Caradoc beds combined, attain a thickness of from 4,000 to 6,000 feet, consisting chiefly of slaty rocks, sometimes interstratified with grits and occasional bands of limestone, of which the *Bala Limestone* is the most conspicuous. The whole series ranges right round the mountains of

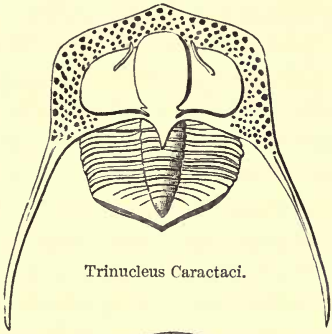
[1] The Llandeilo flags of North Wales are very unlike those of Llandeilo, which are generally called Upper Llandeilo beds.

Cader Idris, Aran Mowddwy, Arenig, and the Moelwyns, resting on the lava beds and ashes, and overlaid on the east by Upper Silurian strata, fig. 57, p. 304. They also form, with igneous rocks, the larger part of the Berwyn mountains, and with the Arenig slates the whole of the ground between the Stiper Stones and the Upper Silurian rocks of Chirbury and Montgomery, fig. 13, p. 59. The typical Caradoc Sandstone, crossing the strike, ranges between Church Stretton and Caer Caradoc, from whence it stretches in a broad band northward towards the Wrekin, and southward to Corston. The greater part of South Wales is formed of slates and grits of Llandeilo and Caradoc age, lying west and north of the Upper Silurian and Old Red Sandstone strata, and the same formations, associated with volcanic rocks, rise like an island surrounded by Upper Silurian strata, in the country between Builth and Llandegley in Radnorshire.

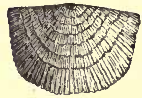
In South Wales, where they were first described by Murchison, the Llandeilo beds consist of sandy calcareous flags, black slaty rocks, and beds of grit and sandstone. A few beds of limestone occur in them in Carmarthenshire, at Llandeilo, and in Pembrokeshire near Narberth; and the Bala limestone is found higher in the series in the Caradoc or Bala beds of Merionethshire. They are often highly fossiliferous. There is a much larger development of fossils in the Llandeilo flags than in the pre-existing Silurian strata. The Trilobites of the Llandeilo beds are mostly peculiar to it, and the genera *Æglina*, *Barrandia*, and *Ogygia* are very common, *Ogygia Buchii* being especially characteristic. Viewed as a whole, however, the Llandeilo beds, as already stated, pass insensibly into, and have many genera and species in common with the Caradoc

FIG. 18.

Orthis calligramma.

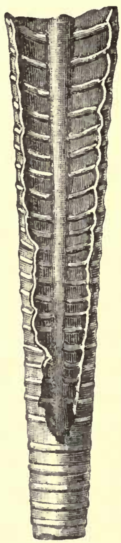


Trinucleus Caractaci.

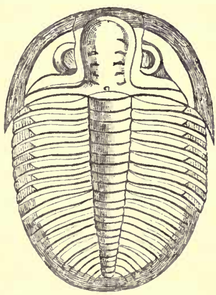


Strophomena rhomboidalis.

Murchisonia simplex.

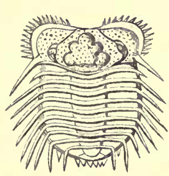


Orthoceras mendax.



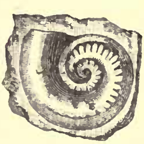
Ogygia Buchii.

Murchisonia subrotundata.

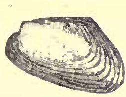


Acidaspis Jamesii.

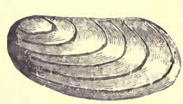
Lituites cornu-arietes.



Euomphalus corndensis.



Modiolopsis expansus.



Palæarca amygdalus.

Group of Llandeilo flag and Caradoc or Bala Fossils.

Sandstone or Bala beds. 19 genera and 34 species of corals have been described in these lower Silurian strata, among which *Heliolites* and *Petraia* are perhaps the most common.

Fragments of Echinodermata are common, including Cystideans, common in the Bala Limestone, and one star-fish, *Palæaster Caractaci*. In all, more than 40 genera and 200 species of Trilobites have been described from the whole series of Lower Silurian British rocks, among the chief of which are species of *Olenus*, *Agnostus*, *Ampyx*, *Lichas*, *Ogygia*, *Acidaspis*, *Asaphus*, *Harpes*, *Illænus*, *Phacops*, and *Trinucleus* (*T. Caractaci*). In the Caradoc beds alone, 23 genera and 111 species are known. Of bivalve shells there are 22 genera and 171 species of Brachiopoda, the most common of which belong to the genera *Strophomena*, *Leptæna*, *Lingula*, *Orthis*, and *Rhynchonella*.

Of the Lamellibranchiate molluscs there are 17 genera and 87 species known at present, prominent among which are *Ctenodonta*, *Modiolopsis*, *Pterinæa*, *Palæarca*, and *Ambonychia*. Of Pteropoda there are known 6 genera and 31 species, of which *Theca* is most abundant; 16 genera and 66 species of Gasteropoda, the most characteristic of which in point of numbers are *Euomphalus* (10), *Murchisonia* (15), *Pleurotomaria*, *Cyclonema*, and *Holopæa*. Of Nucleobranchiata, *Bellerophon* (14). Of the Cephalopoda there are 10 genera and 62 species—*Cyrtoceras* (5), *Lituites* (6), *Orthoceras* (42), *Phragmoceras* (1), and others. No fishes nor any other vertebrate animals have yet been found in the Lower Silurian rocks of Wales or elsewhere.

In Cumberland the Coniston Limestone is believed to be the equivalent of the Bala Limestone of North

Wales, and the assemblage of fossils in each is very nearly the same.

I have already mentioned the occurrence of an important episode characterised by volcanic eruptions, during the accumulation of the Lower Silurian strata in Wales. The proof of this is that in Carnarvonshire and Merionethshire extensive interstratified sheets of felspathic lavas and ashes are associated with the Silurian rocks on two horizons, the lower that of the Llandeilo beds, and the higher in the Caradoc series. I do not, however, wish to imply that between them there was a complete cessation of volcanic activity, but simply that in what is now the region of North Wales, there was for a time an interval of comparative repose.

If any one will examine the Geological Survey maps of North Wales, he will observe that opposite Barmouth, beginning with the hills on the south side of the estuary of the Mawddach, a great series of igneous rocks sweep round the country in a crescent form, including the mountains of Cader Idris, Aran Mowddwy, the Arenigs, and lastly the Moelwyns, the high southern escarpments of which overlook from the north the beautiful vale of Ffestiniog. These consist of felspathic lavas, and interstratified ashes or tufas, the whole being also associated with bands of Silurian slate, which are sometimes found to be fossiliferous, especially when bedding and cleavage coincide. Among these volcanic rocks, but especially in the Arenig, Tremadoc, and Lingula beds below them, there are numerous lines and bosses of greenstones (diorites, &c.), and also of more purely felspathic traps, which are not interbedded but distinctly intrusive. These I have elsewhere shown give evidence of the underground working of the melted matter, the eruption of which to the surface through volcanic rents, produced the lava-flows and ashes already mentioned. The ashy beds are sometimes coarse and tufaceous, but were also often formed of fine volcanic dust, which being now consolidated into hard felspathic rocks, are at first sight somewhat difficult to distinguish from the associated lavas. Practice, however, renders it comparatively easy, and in distinguishing the difference, the observer is aided by the circumstance, that *underneath* each lava current the slates, once beds of mud, are apt to be baked and porcellanised at the point of junction with the originally hot lavas, which having in the meanwhile cooled, the slaty beds that *rest on them* are in that respect unaltered.

The second series of eruptions may be traced as follows. Near Bala, not far below the limestone, there are a few thin bands of volcanic ashes. These, as we go northward to the rivers Machno, Lledr, and Conwy, gradually thicken, and by-and-by get mingled in that slaty area with numerous thin and thick bands of felspathic lavas, the importance of which as large masses, culminates in Snowdon and the surrounding area, going northward by Glyder-fawr, Glyder-fach, Carnedd Dafydd, and Carnedd Llewelyn, and so on to Conway. South of Snowdon the same kinds of lavas and ashes are seen in force on the sides of Moel Hebog, and the great mass of Llwyd-mawr near Dolbenmaen.

Other large bosses of *intrusive* rocks, mostly felspathic, occur on Y-Foel-frâs, between Snowdon and Conway, another between Llanllyfni and Bethesda, a third near the eastern shore of Menai Straits, and many more including the beautiful mountains of Yr Eifl, or The Rivals, in the north horn of Cardigan Bay, known as the district of Lleyn. These, ere exposure by denudation, probably were the *roots* of the volcanos, or in other words the deep-seated centres from whence the explosive force of steam drove out the lavas and showers of ashes, which, during successive eruptions, with minor periods of repose, got interstratified with the mud and sand beds that were deposited in the sea of the Llandeilo and Bala or Caradoc period.

On a smaller scale similar volcanic rocks are interstratified with the Llandeilo and Bala beds of the Berwyn Hills, also of the Breidden Hills, and the hills west of the Longmynd and Stiper Stones towards Chirbury and Church Stoke, of the country between Builth and Llandegley in Radnorshire, and in North Pembrokeshire from the ground round St. David's, extending for many miles to the east, by Mathry, Fishguard, St. Dogmells and Mynydd Preselley.

The next question that occurs to me is, what was the nature of the physical geography of this area during the deposition of the Arenig slates, and also at a later epoch when the Llandeilo and Caradoc or Bala beds were being deposited.

With regard to the Arenig slates in Pembrokeshire and Merionethshire, I know of no signs of unconformity, that is to say, of a lapse of time unrepresented by the deposition of marine strata either in Pembrokeshire or in Merionethshire, unless there be some symptoms of it in the latter county. But when we go further north into Carnarvonshire, the case is different. There, at the widening of the Passes of Llanberis and Nant Ffrancon, the Lingula flags are not more than 2,000 feet thick, whereas further south, between Ffestiniog and Portmadoc, they are at least 4,000 feet in thickness. Furthermore, in those valleys in Caernarvonshire there is, as yet, no certainty of the existence of the Tremadoc slates, and these ought to be found overlying the Lingula flags if the whole of the Silurian series were present. Still further, as we approach Caernarvon and Bangor, even the Lingula flags are absent, and the Arenig slates are found *lying directly on the purple slates and conglomerates of the Cambrian series* all the way from Bangor to Caernarvon. This clearly shows that the base of the Arenig slates has overlapped the whole of the Tremadoc slates and Lingula flags, in the area between the Ffestiniog and Portmadoc country and the neighbourhood of the Menai Straits, and an overlap so great means *unconformity* between the strata; or, in other words, in this area the strata of older date than the Arenig slates had been raised above the sea, and subjected to sub-aerial agencies of denudation, while the deposition of the Arenig slates was going on elsewhere. In this manner, therefore, it happens that the Arenig slates are now found resting directly on the Cambrian strata, without the intervention of the missing members of the series, viz., the Tremadoc slates and Lingula flags; and still further north, in Anglesea, these strata are also wanting.

The effect of this episode in the physical geography of the area seems to have been, that at this period a tract of land lay in the north-west of what is now Wales, and probably far beyond that district during the deposition of the Arenig strata on its borders, but what the features of that land were I cannot say, except that it may have extended to Ireland, where there is a similar unconformity, the Lingula flags and Tremadoc slates being also wanting in Wicklow. Probably the whole region was low and unimposing.

The next question that arises is, what was the nature of the physical geography during the time of the volcanic eruptions already mentioned? To me it seems to have been somewhat of this sort.

On the margin of the ancient land, or at some distance therefrom, volcanic eruptions took place in the sea-bottom somewhat of the nature of that which in 1831 took place in the Mediterranean between the islands of Pantellaria and the south-west coast of Sicily. This eruption was preceded by an earthquake on June 28, and on July 10 John Corrao from his ship saw a column of water 60 feet high and 800 yards in circumference spout into the air, succeeded by dense steam, which rose to a height of 1,800 feet. On the 18th the same mariner found an island twelve feet high, from the crater of which immense columns of steam and volcanic ashes were being ejected, 'the sea around being covered with floating cinders and dead fish.'[1] The eruption continued into August, when, by the ejection of what is often called volcanic ashes, viz., pumice, scoriæ, and lapilli, on the 4th of that month the island was said to have been more than 200 feet in height and 3 miles in circumference. From that time it gradually decreased in size, owing to the action of the waves, and towards the close of the year the island had been destroyed and disappeared, leaving only a reef beneath the sea with a black rock in the centre, from 9 to 11 feet under water, and which probably marked the position of the funnel of the short-lived volcano. Before the eruption took place it so happened that Captain (afterwards Admiral) W. H. Smyth sounded on the spot in more than 100 fathoms, and this, added to 200 feet that the island rose above the sea, gives 800 feet as the height of the cone from the

[1] Lyell's 'Principles of Geology,' vol. ii. p. 60, 12th edition.

bottom of the sea to its summit. In a case such as this, it is easy to see that the ordinary marine sediments of the area would get intermingled with volcanic ashes, and possibly with submarine streams of lava.

Explosions of steam accompanied by floating cinders are mentioned by Darwin as occurring at intervals in the South Atlantic; and anyone who will tax his memory a little will recollect that a large proportion of the volcanoes of the world are islands, or in islands, in the Atlantic, the Indian Ocean, the Indian Archipelago, and the Pacific Ocean, south and north. It has been often remarked that almost all volcanoes are in the neighbourhood of the sea.

I think, then, at the time of the deposition of the Llandeilo and Bala beds of our area, our terrestrial scenery consisted of groups of volcanic islands scattered over the area of what is now North Wales and South Wales, and extending westward into the region of the Irish strata of the same age, and northward as far as the sea that then rolled where Cumberland now stands; for there also volcanic rocks occur in great force, all of the same general character as those found in Wales. There is however, this difference between the two areas, that, whereas in Wales ordinary sediments are plentifully interstratified with lavas and ashes, and sometimes even lithologically intermingled with volcanic ashes, in the Cumbrian area it is only for a few feet at the very base of the volcanic series that interstratifications take place, the whole of the rest of these Silurian volcanic rocks of Westmoreland and Cumberland being quite destitute of any intermixture of marine sediments. Exclusive of intrusive rocks, the whole consists of purely terrestrial lavas, volcanic conglomerates and ashes, the latter often well stratified, for where showers of ashes fall there layers of stratification will be formed, whether they fall in the sea or on land. It has been suggested by Mr. Ward that some of this fine volcanic dust fell into lakes that filled old craters or areas of subsidence during periods of partial repose, and this seems highly probable, for the finely divided matter is so beautifully stratified, that these beds were, and still are by some, mistaken for marine strata.

When we consider the vast amount of these products of ancient volcanoes, there can be no doubt that, rising from the sea, some of them must have rivalled Etna in height, and others of the great active volcanoes of the present day, and, as most volcanoes have a conical form, we can easily fancy the magnificent cones of those of Lower Silurian age. But that is all we know respecting them, and whether or not they were clothed, like Etna, with terrestrial vegetation, no man can tell. It is hard to believe that they were utterly barren, but as yet no trace of a flora has been found in Lower Silurian strata.

There is another point bearing on the physical geography of the time that has sometimes crossed my mind in connection with these island volcanoes, which is, that we may, with some show of probability, surmise, that then, as now, the prevalent winds of this region blew from the west and southwest, for the following reason. In Merionethshire and Caernarvonshire the various volcanic products gradually thin out and disappear to the west, between the ground south of the estuary of the Mawddach, and the neighbourhood of Tremadoc on the north. As we pass round the large crescent-shaped masses of lavas and ashes it becomes evident as a rule that the ashy series of beds show a tendency to thicken more and more in an easterly direction for a space, and finally to decrease in thickness in the same direction, till, in the Bala country and further north, they are represented only by a few insignificant beds of ashy strata, a character of which the Bala limestone itself sometimes feebly partakes. The idea is, that the prevalent westerly winds had a tendency during eruptions to blow the volcanic dust and lapilli eastward, and that these materials fell thickest near the vents and at middle distances, and gradually decreased in quantity the further east they were carried.

To those unaccustomed to technical geological arguments a word of warning remains. Let no reader suppose that in Wales he will now find clear traces of these old volcanic cones and craters in their pristine form, such, for example, as the extinct craters of Auvergne and the Eifel. Semi-circular hollows surrounded by igneous rocks like those of Cwm Idwal and Cwm Llafar he will find plentiful enough, and these, in old guide-books and other popular literary productions, have sometimes been described as craters. So far from that being the case, such *cirques* or corries are ancient valleys of erosion, the rocks of which have been exposed to the weather perhaps ever since Upper Silurian times, and have been subsequently modified by glaciers, during the last Glacial Epoch, in days, comparatively speaking, not far removed from our own. The truth about these ancient volcanoes is, that long after they became extinct the whole Lower Silurian area was disturbed and thrown into anticlinal and synclinal curves, which suffered denudations before the beginning of the deposition of the Upper Silurian rocks, and the positions in which the lavas and ashes now stand will approximately be best understood, if we suppose Etna by similar disturbances to be half turned on its side, and afterwards that the exposed portion should be irregularly cut away and destroyed by processes of long-continued waste and decay, partly sub-aërial and partly marine.

The remaining areas in Great Britain occupied by Lower Silurian rocks lie in Scotland. The southern district extends from St. Abbs Head on the east to Portpatrick on the west coast, forming the uplands of the Lammermuir, Moorfoot, and Carrick Hills, fig. 55, p. 287. They chiefly consist of thick banded strata of grits and slaty beds, much contorted, and in the western part of the area, where bosses of granite and other igneous rocks occur, they are often metamorphosed. The fossils which they contain prove them to belong to the Llandeilo, and Bala or Caradoc series.

In Wigtonshire great blocks of gneiss, granite, &c. are imbedded in the dark slaty strata near Corswall, and similar large blocks occur in Carrick in Ayrshire. Where they came from I cannot say, for all the nearest granite bosses in Kirkcudbrightshire and Arran are of later date than the strata amid which these erratic blocks are found. I therefore incline to the opinion that they must have been derived from some Laurentian region, of which parts of the mainland and of the Outer Hebrides then formed portions, and when I first saw them I could, and still can conceive of no agent capable of transporting such large blocks, and dropping them into the graptolite-bearing mud, save that of icebergs. One of the blocks measured by me near Corswall, in 1865, is 9 feet in length, and they are of all sizes, from an inch or two up to several feet in diameter. Many persons have considered, and will still consider, this hypothesis of their origin to be overbold, but I do not shrink from repeating it, and I may mention that the same view with regard to these ancient boulder beds is held by Professor Geikie and Mr. James Geikie, who mapped the country.[1]

The Lower Silurian rocks of the south, pass underneath the Old Red Sandstone and Carboniferous rocks of the midland parts of Scotland, and rise again on the north in the Grampian Mountains. A great fault,

[1] I shall by-and-by have to notice the recurrence of glacial episodes at various epochs in geological history, a subject with which ever since 1855 I have had a good deal to do. (On Permian Breccias, &c. 'Journal of the Geol. Soc.' vol. ii. p. 185). It is difficult to make out the ground on which all the old, and many of the middle aged geologists, have cast aside the various evidences that have been adduced in support of the recurrence of glacial epochs or episodes, especially as I remember no argument that has been brought forward, excepting that in old times, the radiation of internal heat through the crust of a cooling globe, produced warm and uniform climates all over the surface, and that the further you go back in time the hotter they were. The Lias was accumulated in warm seas, and if so those of the Carboniferous times were warmer, and those of Silurian times warmer still, and I have heard a distinguished geologist declare in a public lecture, that the tropical vegetation of the Coal-measures, was due to the heat that radiated outwards from the earth's crust, aided by that produced by the flaring volcanoes of that epoch! Undoubtedly there must have been a *geologically prehistoric* time, when internal heat may have acted on the surface, and perhaps the sun may have been hotter than now, and that also had its effect. I, however, can see no signs of these internal and external interferences *since the times in which the authentic records of geological history have been preserved*, and these extend backward earlier than the Lower Silurian epoch. I recollect the time when what passed for strong arguments were urged to prove that the former great extension of the Alpine glaciers advocated by Agassiz, and the existence of glaciers in the Highlands, Cumberland, and Wales, proved by him and Buckland, were mere myths. Now, however, there is such a persistent run upon the subject, that more memoirs have been, and still are being, written about it, than perhaps on any other geological question. Coincident with this a beginning of the acceptance of the theory of the recurrence of glacial episodes, is slowly making its way both in England and the Continent.

proved by Professor Geikie, runs at the base of that so-called chain right across Scotland, from the neighbourhood of Stonehaven on the east coast, to Loch Lomond on the west. Its effect is to throw down the Old Red Sandstone on the south-east, partly against the Silurian rocks, and partly against volcanic tufas and other strata belonging to the Old Red Sandstone itself. From that region, nearly the whole of the Highlands, from the Grampians to the north coast of Scotland consists of Lower Silurian rocks often intensely contorted, and formed of quartz-rocks and flagstones, gneissic and micaceous schists, clay slate, and chlorite slate. Associated with these, there are certain limestones, sometimes crystalline, but where less altered, sometimes fossiliferous, fig. 55, p. 287. One of these, near the base of the Silurian series, runs in a long band from Loch Erriboll, on the north coast, southward to Loch Broom, where for a space of about fifteen miles it is lost, to reappear between the east side of Sleugach and Loch Carron. The same limestone is well seen in the Island of Lismore in Loch Linnhe, and here and there on the sides of Strathmore or the Great Glen (a line of fault), through which the Caledonian Canal was constructed. Elsewhere in the Highlands, further east, streaks of limestone occur. Immense masses of granite here and there rise in the midst of the strata, one of the smaller of which forms great part of Ben Nevis, the highest mountain in Britain, 4,406 feet in height, and another the splendid peaks of the Island of Arran. No interbedded igneous rocks have yet been found among the Silurian rocks of Scotland.

The strata of the Highlands, not of Lower Silurian age, are the Laurentian gneiss and Cambrian conglomerates and sandstones already mentioned, intersected by so many noble Fiords between Sleat and Cape Wrath, while on the east there are large tracts of Old Red Sandstone, more or less extending from Thurso in Caithness to the Great Glen, Moray Firth, the river Spey, and yet further east. Fig. 55, p. 287.

In times within the memory of the writer, all these metamorphic rocks of the Highlands were classed in Wernerian style as Primitive strata, thrown down in hot seas before the creation of life in the world. The progress of research showed that gneiss and other rocks now called metamorphic, are of many geological ages; and the fortunate discovery of fossils in these strata, at Durness, by Mr. C. Peach, in 1854, showed them to be of Arenig age, a discovery the importance of which was at once seen by Sir Roderick Murchison, who by this means, revolutionised the geology of the greater part of the northern half of Scotland. Feeling anxious to have a second opinion respecting the justness of his new views, he asked me to accompany him on a long tour through the northern Highlands in 1859, when I mapped part of the country at Durness and Loch Eriboll, and the whole matter seemed to me so plain, that the wonder is, that any man with eyes ever dreamed of disputing it. In these days no one now thinks of denying the Lower Silurian age of the chief part of the gneissic rocks of Scotland, the features of which have been mapped by Professor Geikie, first in concert with Sir Roderick Murchison, and afterwards personally in more detail.[1]

With regard to the physical geography of the time, little is certain but this, that almost the whole of the area now called Scotland was under the sea, during the time

[1] See 'Geological Map of Scotland,' last edition, by Archibald Geikie, LL.D., F.R.S., 1876.

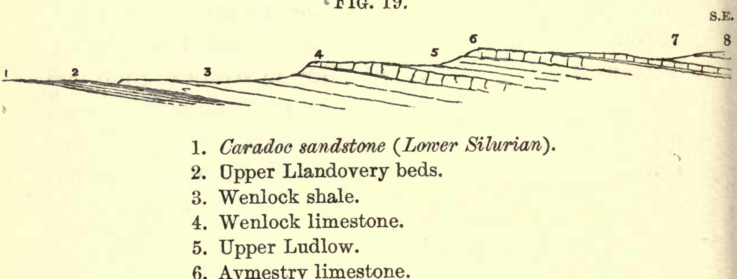
that these Lower Silurian strata were being deposited. The only sign of pre-existing land, is found on the west coast between Cape Wrath and Loch Torridon, where the Llandeilo beds lie alike unconformably on the Cambrian and Laurentian strata. This proves, that when the lowest Llandeilo beds began to be deposited, the underlying rocks formed the eastern margin of a territory, of which probably our Outer Hebrides was only a part, but how far it may have stretched westward it is impossible to say. However that may have been, it seems certain that long before the uppermost strata of the Lower Silurian rocks of Scotland were deposited, these fragments of an older land, which are still preserved on the west, had been long submerged and buried under the accumulating piles of the Silurian strata. That even then an extensive land lay not far off is certain, for the extent and great thickness of the Lower Silurian rocks affords a measure of the amount of waste of a pre-existing territory, the partial and gradual destruction of which, by all the agencies of denudation, provided mechanical sediments wherewith to form thousands of feet of Silurian strata of mud and sand, first consolidated, and long after metamorphosed into quartzite, gneiss, and mica-schist. This land may have occupied an area now covered by the Atlantic ocean.

CHAPTER VII.

UPPER SILURIAN SERIES.

The stratigraphical order of the Upper Silurian Series is shown in the table p. 30. They were deposited under the following circumstances:—The Lower Silurian rocks in large areas in the British Islands and in some other areas, were upheaved, more or less contorted, and in many places suffered a great amount of denudation before the deposition of the Upper Silurian strata began, which, therefore, in various districts lie quite *unconformably* upon them. In the

Fig. 19.



1. *Caradoc sandstone (Lower Silurian).*
2. Upper Llandovery beds.
3. Wenlock shale.
4. Wenlock limestone.
5. Upper Ludlow.
6. Aymestry limestone.
7. Upper Ludlow.
8. *Old Red Sandstone.*

typical district of Wenlock and Ludlow the arrangement of the various subdivisions of these Upper Silurian strata is as shown in figs. 19 and 22, the bands of limestone generally forming bold terraces, that look north-westward to the mountains of the Longmynd beyond Le Botwood and the beautiful valley of Church Stretton.

Notwithstanding the unconformity mentioned above, there are in Wales, and partly in Shropshire, rocks containing suites of fossils, many of them peculiar to the horizon in which they occur, and a few common to Upper and Lower Silurian. Part of these strata, such as the Lower Llandovery beds, have been formed during minor oscillatory movements of sea and land. In South Wales, *Stricklandinia* (*Pentamerus*) *lens* occurs plentifully in these *Lower Llandovery rocks*, and sparingly in the *Upper Llandovery rocks*; while *P. oblongus* occurs sparingly in the Lower Llandovery rocks, and in great numbers in the Upper Llandovery beds, on which rests the Tarannon shale. By far the larger part of the fossils of the Lower Llandovery rocks are, however, essentially of Lower Silurian type, and, besides, they are quite conformable with, and pass by easy lithological gradation into the underlying strata.

With the Upper Llandovery or Pentamerus beds,[1] as they were formerly called, the case is very different, for in Shropshire they rest *unconformably* on the Cambrian and Lower Silurian rocks indiscriminately, and possess a beach-like character, being in places formed of pebbles derived from the rocks on which they rest, as in fig. 20, and in Radnorshire near Builth, the Upper Silurian rocks including these Pentamerus-bearing strata, lie with extreme unconformity, alike on the lowest and the highest Llandeilo and Caradoc beds of that old volcanic area, as shown in figs. 20, 21, 22.

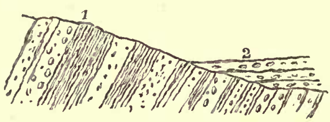
My belief, therefore, is that these Upper Llandovery beds, which form the true base of our Upper Silurian

[1] See fig. 23, p. 94, *Pentamerus oblongus* is so common in these strata that they were originally called *Pentamerus beds.*

strata wherever they occur, were often beaches of the period; and this is further proved by the fact that they are often conglomeratic, containing rounded pebbles derived from the rocks on which they rest, while, as at May Hill and Woolhope, they are coarsely sandy.

From these facts we arrive at the conclusion that during the beginning of Upper Silurian times, part of

FIG. 20.



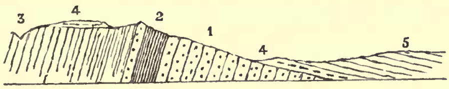
1. Cambrian rocks.
2. Pentamerus limestone and conglomerate.

the area now called Wales consisted of islands formed of Lower Silurian strata and volcanic rocks, round which the occasional consolidated beaches are still visible.

Going further into the physical geology of this epoch, we find that in South Wales the Upper Llandovery beds lie unconformably on a large scale on the Llandeilo and Caradoc series, a fact proved by the conflicting dips and strikes of the two sets of strata; while in North Wales, similar conflicting strikes, and the steady overlapping of the Upper on the Lower Silurian beds, proves the same fact, for east of Bala the base of the Upper Silurian beds lies about 2,000 feet above the Bala Limestone, while in the neighbourhood of Conway they almost touch that horizon.

Another important point connected with the physical geography of the period is that, after a time, the Lower Silurian islands and other areas began to undergo a process of slow depression beneath the sea. If we turn to the Shropshire area between Church Stretton and Chirbury, including the Cambrian rocks of the Longmynd, this is what we find. On the vertical and highly inclined strata of the Cambrian and Lower Silurian rocks, the conglomerates and limestones of the Upper Llandovery beds form in the lower country a kind of narrow fringe, surrounding great part of the area, and lying from 500 to 900 feet lower than the broad, flat-topped, and gently undulating hills of the Longmynd and Shelve. Almost on the highest level of one of these flats, at the well known Bog-mine, there is a small outlying patch of Upper Llandovery beds, formed of hard quartzose sandstone, at a height of 1,150 feet above the sea, as roughly indicated in the following diagram.

FIG. 21.



1. Cambrian grits, &c.
2. Lingula flags.
3. Tremadoc and Llandeilo beds.
4. Pentamerus beds.
5. Wenlock shale.

The inference is obvious, that these Pentamerus-bearing strata began to be deposited at the bases of the hills, and that by degrees, during a process of slow submersion, the sea crept on and on inland, accompanied by the deposition of marginal Upper Llandovery beds, till at length, like an island in the coral seas of the Pacific (but without the corals), this old Silurian Isle was entirely swallowed up and buried, deep beneath the succeeding great accumulations of Upper Silurian strata, which in the adjoining area of Wenlock and

Ludlow are more than 3,000 feet in thickness. The original extent of this long-buried island, may have been about 24 miles in length by 14 in breadth, about the size of the Isle of Man.

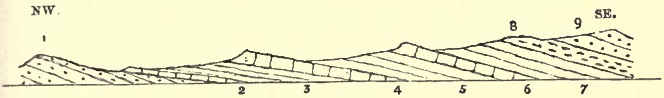
The same fate was undergone by the Llandeilo and Caradoc rocks, that with lavas, ashes, and intrusive greenstones, now lie between Builth and Llandegley in Radnorshire. This island was, however, lower and smaller, its length having been about 20 miles, by 10 at its greatest breadth.

That these two tracts of land stood as islands in an early Upper Silurian sea, I have no doubt; and on grounds less definite, I am of opinion, that at the very beginning of the Upper Silurian epoch, the greater part of Wales, both south and north, formed land, some of it higher than now, for since that time the Lower Silurian rocks of that region have undergone great and repeated denudations. As, however, the deposition of the Upper Silurian formations progressed, a steady submersion took place of the neighbouring land, from the waste of which, sediments were derived; but whether or not its highest mountains were swallowed up and buried before the close of the Upper Silurian epoch I am quite unable to say. That this entire burying of the Lower Silurian rocks of Cumberland took place, seems most probable; and while the Lower Silurian rocks of the Highlands of Scotland, and the West of Ireland, certainly formed high land during the beginning of Upper Silurian times, I have no precise data by which to determine what was their subsequent fate.

A section of the Silurian strata, as seen near Caer Caradoc and Wenlock, is shown in fig. 22.

The same kind of development passes southward beyond Ludlow, forming beautiful scarped woody terraces, but beyond that into South Wales the limestones disappear, or are occasionally only very feebly represented, and the whole consists chiefly of shales, sometimes sandy, in which no definite lines of subdivision for the subformations can be drawn.

FIG. 22.

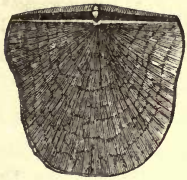


1. *Caradoc sandstone (Lower Silurian).*
2. Upper Llandovery limestone and sandstone lying unconformably on No. 1. } Upper Silurian.
3. Wenlock shale. } Upper Silurian.
4. Wenlock limestone. } Upper Silurian.
5. Lower Ludlow shales, concretionary. } Upper Silurian.
6. Aymestry limestone. } Upper Silurian.
7. Upper Ludlow sandy flags and shales. } Upper Silurian.
8. Passage beds, and } Upper Silurian.
9. *Old Red Sandstone.*

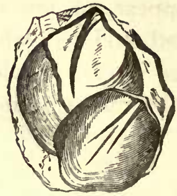
Far east of this, at Usk, Woolhope, May Hill, the Malvern and Abberley Hills, and at Dudley and Walsall, the limestone formations (so-called) are well developed, while in North Wales the Upper Silurian rocks chiefly consist of shales and interstratified grits without any bands of limestone. Near Llangollen, where the shaly strata are much affected by cleavage, they become true slate. In Scotland, the Upper Silurian rocks occur between the Solway Firth and the Cheviot Hills, and are said to lie unconformably on the Lower Silurian strata. Further north they only occupy small areas near Lesmahago, and at the north-west base of the Pentland Hills.

All of these formations are in general terms fossiliferous. The Wenlock limestone is in great part

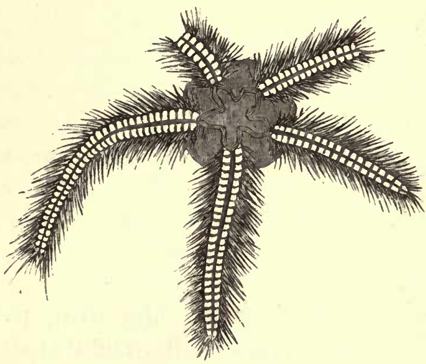
FIG. 23.



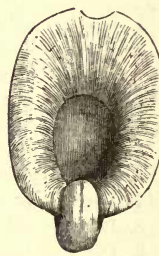
Strophomena euglypha.



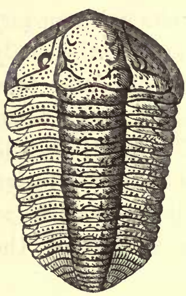
Pentamerus oblongus.



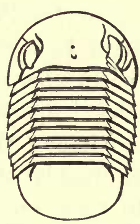
Protaster Miltoni.



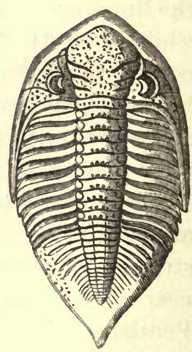
Bellerophon dilatatus.



Calymene Blumenbachii.



Illænus Barriensis.



Phacops caudatus.

Group of Upper Silurian Fossils.

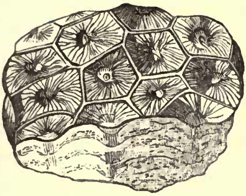
formed of Corals, Encrinites, Mollusca, and Trilobites, Corals often predominating. The most characteristic shell of the Aymestry limestone is *Pentamerus Knightii.*

The grouping of fossils in the Upper Silurian rocks is in general terms much the same as in the Lower series, although new genera appear, but a very large proportion of more than 700 Llandeilo and Caradoc species were extinct in our area, only about 16½ per cent. being common to the Lower and Upper series. The Corals, which are in general not very numerous in British Lower Silurian rocks, have increased to 82 species of 27 genera, of which 15 genera and about 65 species are new. The Echinodermata (stone lilies) increase to 55 species, only 1 species of which, an *Actinocrinus*, is common to Lower and Upper Silurian rocks. Several new starfish appear, especially in the Upper Ludlow rocks. There is one true Echinus (sea-urchin), *Palæchinus.* In Britain the Trilobites decrease to 30 genera and about 130 species. Among the Hydrozoa the Graptolites decrease to 3 species in Britain; and there are about 20 known species of Polyzoa. There are 21 genera and 126 species of Brachiopoda. Among these, of the genus *Atrypa* there are 8 species. *Athyris* and *Obolus* appear for the first time in lists of fossils. *Leptæna* from 10, decreases to 6 species; *Orthis* from 58 to 21; while *Rhynchonella* increases from 12 to 16, and *Strophomena* decreases from 27 to 15. Of the genus *Spirifera* there are 3 species in the Lower Silurian rocks, and 8 in the Upper. In all, 21 genera and about 126 species of Brachiopoda are known in the British Upper Silurian strata, and 22 genera and 171 species in the Lower. The Lamellibranchiate mollusca increase from 17 to 18 genera, and from 71 to 87 species, most of the latter being new. There are 7 species of Pteropoda of 3 genera. It is remarkable that the described Gasteropoda only amount to 15 genera and 52 species, while in Bohemia, in equivalent rocks, 200 species, some years since, are mentioned by Barrande, and as many of the Brachiopoda and Lamellibranchiate molluscs. Of the Nucleobranchiata 10 *Bellerophons* are known, and 7 genera and 53 species of Cephalopoda, among which the genus *Orthoceras* decreases from 42 to 35 species.

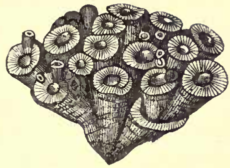
Near the top of the Upper Ludlow strata there are several thin bone beds, containing teeth and scales of small Placoid fish of the genera *Onchus* (?) *Sphagodus*, and *Thelodus*. At present these are the oldest known fishes. They are found in strata which contain several species of the remarkable crustaceans *Pterygotus* and *Eurypterus*, some of which are small in size, while the largest *Pterygotus*, discovered by Dr. Slimmon near Lesmahagow, in the uppermost Silurian rocks, attained about 9 feet in length. The very uppermost Silurian beds in England sometimes, as, for example, near May Hill, contain the remains of land-plants, consisting of small pieces of undetermined twigs, and the sporecases of one of the Lycopodiaceæ *Pachytheca spherica*.

In these last-named facts there is much significance, bearing on the physical geography of the next so-called geological epoch, which will be explained in the subsequent chapter. In the meanwhile I may remark, that I use the words *so-called geological epoch*, in the same sense that the words epoch or period are employed in dealing with civil or political events. Taking the geological world, and the civil world, which deals with the history of man as parallel, there is no break in time

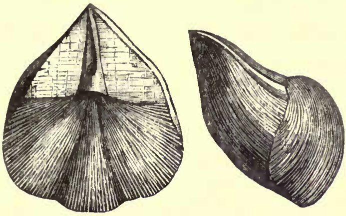
FIG. 24.



Arachnophyllum typus.

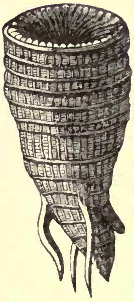


Cyathophyllum truncatum.



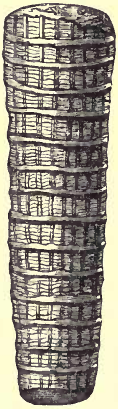
Cyrtia exporrecta.

Rhynchonella navicula.



Omphyma turbinata.

Petraia bina.



Orthoceras annulatum.

Group of Upper Silurian fossils.

in either case. In the latter, certain remarkable events induce us to break it into periods, characterised by special events, which were always led up to gradually by broad changes of power or of opinion. In the former, there are often great breaks in the chain of geological history, which, locally, are not filled up by stratigraphical deposits, and which under these circumstances form definite geological epochs, while in other cases (as in Civil history), the change of conditions was so great in given areas, that the new series of events may be locally classed as constituting new geological epochs. This is eminently the case when we attempt to realise the history of the Old Red Sandstone, as locally and physically distinct from that of the Contemporaneous Devonian strata.

CHAPTER VIII.

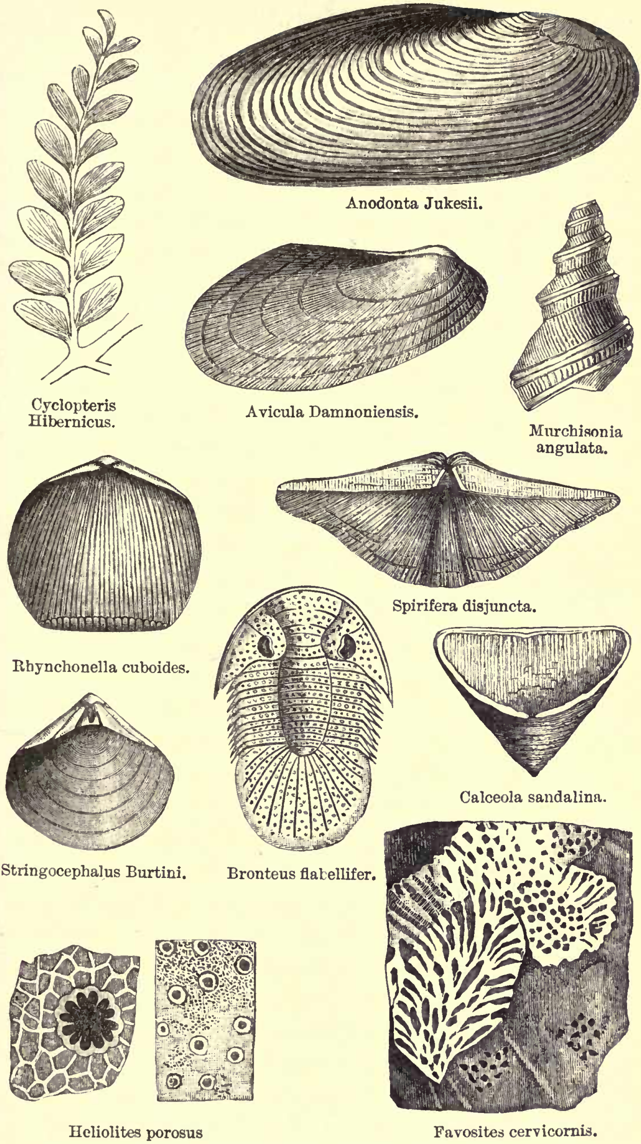
DEVONIAN AND OLD RED SANDSTONE ROCKS.

In 1836 Sedgwick and Murchison described the existence in Devonshire of a series of rocks bearing fossils intermediate in character between those of the Upper Silurian series and those of the Carboniferous Limestone. This was done with the assistance of Mr. Lonsdale in all the palæontological part of the question, in which the argument chiefly lay. On these and certain stratigraphical grounds, it was considered that they are the equivalents of the Old Red Sandstone of the centre of England and of Scotland, and the name Devonian being applied to them, the terms Devonian and Old Red Sandstone are generally considered as equivalents in point of geological time.

According to the late Professor Jukes, the lowest strata of the Barnstaple Bay district in North Devon consist of red sandstones and conglomerates, similar to those of part of the Old Red Sandstone of Ireland, and not unlike that of the Mendip Hills. This, taken in connection with the resemblance of the overlying strata to the lower Carboniferous rocks of the south of Ireland, led him to consider the chief part of the Devonian rocks of Devonshire to be of Carboniferous age. To this conclusion he was led partly by palæontological considerations into which I cannot here enter. The opposite opinion, that the Devonian strata are in the main *the marine equivalents* of the Old Red Sandstone, continues to be generally held. Till a new survey of Devonshire helps to settle the question I give the usual reading of the history of the *Devonian strata*, though I think it probable that Jukes will turn out to be correct in questioning the right of the Devonian strata to the conventional name of an independent series.

In Devonshire the strata have been divided into Lower, Middle, and Upper Devonian. The Lower chiefly consists of slaty beds and green and purple sandstones, with many Brachiopoda of the genera *Chonetes*, *Orthis*, *Spirifera*, &c. The Middle group, which includes the Plymouth limestone, contains numerous corals, the most common genera of which are *Acervularia*, *Alveolites*, *Cyathophyllum*, *Favosites*, *Petraia*, *Strephodes*, and the sponge *Stromatopora*. With these are found *Encrinites*, *Spirifers*, *Atrypæ*, *Leptænæ*, *Productæ*, *Rhynchonellæ*, *Stringocephali*, and *Calceola* (*C. sandalina*)—the last a genus peculiar to the Devonian rocks. Many Lamellibranchiate molluscs also occur, together with Gasteropoda of the genera *Euomphalus*, *Loxonema*, *Machrocheilus*, *Murchisonia*, *Pleurotomaria*, *Turbo*, &c. Also many Cephalopoda of the genera *Clymenia*, *Cyrtoceras*, *Orthoceras*, *Goniatites* and *Nautilus*. The last two are unknown in the British Silurian series, though Nautilus occurs in the Upper Silurian rocks of North America. The Goniatite may be roughly said to be intermediate in structure between the Nautilus and Ammonite. The latter does not occur in Palæozoic strata. A few Trilobites are found in the British Devonian rocks, and various Crinoids. The Upper Devonian group contains land plants and many shells, some of which are

Fig 25.



Group of Devonian fossils (marine); and two from Old Red Sandstone, the Cyclopteris and Anodonta (land and fresh-water), see p. 115.

identical with those found in the Lower Carboniferous Limestone shales.

There is in England a considerable diminution in the number of Devonian fossils when compared with those of the Silurian rocks. Thus about 1,500 species of Silurian fossils are named, while of *marine* Devonian we have under 400 species, and adding those of all kinds in the *freshwater strata* of the Old Red Sandstone, 535 species. Of corals, 11 of the genera only are also Silurian. Of Echinodermata, there are 10 genera and 21 species, only 3 of the genera being also Silurian; Crustacea, 13 genera, 35 species, 5 of the genera being also Silurian, including those found both in the Devonian rocks and the Old Red Sandstone. In the latter no Trilobites occur, but only Crustacea of the genera *Eurypterus* (6), *Pterygotus* (4) (fig. 26), *Stylonurus* (7), while in the Devonian formations of Devonshire we find 5 genera of Trilobites:—*Bronteus* (*B. flabellifer*) *Cheirurus* 2, *Phacops* 6, *Homalonotus* 2, and *Harpes* 1, all being genera common in the Silurian strata, though the species are distinct. Twelve of the Devonian genera of Brachiopoda occur in Silurian rocks, but of 96 Devonian *species* few pass downwards, and these are doubtful. The most prevalent genera of Brachiopoda are *Athyris*, *Atrypa*, *Cyrtina*, *Orthis*, *Rhynchonella*, *Spirifera*, *Streptorhynchus*, and *Terebratula*. Species of the genera *Leptæna* and *Pentamerus* decline in numbers, while *Orthis*, *Rhynchonella*, and *Spirifera* are much increased. Of 21 genera and 60 species of Lamellibranchiate molluscs, the species are all, or almost all, distinct from those of Siluria, while only 6 of the genera are the same. The most prevalent forms are *Aviculopecten* (10), *Pterinea* (9), *Cucullæa* (7), and *Ctenodonta* (7).

Megalodon is characteristic. Of the 13 genera of Gasteropoda, 9 are Silurian, but of 47 species, all are distinct. The most prevalent forms belong to the genera *Euomphalus* (6), *Loxonema* (8), *Macrocheilus* (7), *Murchisonia* (5) (there are 22 in the Silurian rocks), and Pleurotomaria 8. There are 5 species of *Bellerophon*, and 52 species of Cephalopoda, all distinct from Silurian species. Of 6 Devonian genera, only *Orthoceras*, *Poterioceras*, and *Cyrtoceras* are Silurian. The most prevalent species belong to the genera *Clymenia* (11), *Cyrtoceras* (13), *Goniatites* (10), this being their first appearance in the British strata, and *Orthoceras* (15), (there being 67 known species of this genus in the Silurian rocks).

It is stated that only about 10 per cent. of Upper Silurian fossils pass into the marine Lower Devonian strata. These two formations in England are, however, *not found in contact*, though they occur commonly enough in the regular order of succession on the Continent and in North America. About 10 per cent. of Lower Devonian fossils pass into the Middle Devonian, and about the same percentage from the Middle into the Upper. If this be true there may possibly be undiscovered unconformities between the subdivisions.

The Old Red Sandstone, *as distinct from the Devonian rocks*, is undoubtedly intermediate in age to the uppermost Silurian and the lowest Carboniferous strata. It is sometimes difficult to determine its precise limits either at its base or its top. It first received its name in contradistinction to the *New Red Sandstone*, the former occurring below, and the latter above the Carboniferous strata.

A vast triangular tract of Old Red Sandstone lies between the west coast of South Pembrokeshire, Bristol

Channel, the south and south-eastern borders of the Silurian rocks of Caermarthenshire, Breconshire, Radnorshire, and Shropshire, and the long line of Carboniferous, Silurian, and New Red Marl strata that runs from Colebrook Dale to the Severn, east of Dean Forest. Fancy in your 'mind's eye' the Carboniferous rocks of the great South Wales Coalfield, and of Dean Forest, to be stripped away, and the whole of the region mentioned, of 120 by 90 miles in length and breadth, would consist entirely of Old Red Sandstone. The lower part is chiefly composed of beds of red marl and sandstone, with cornstones; and the upper part contains strata of sandstone and conglomerate, forming the Beacons of Brecon, 2,860 feet high, these being the loftiest mountains in South Wales.

Cornstones are impure concretionary limestones, often imbedded in marl. In these, at the base of the series, near Ludlow, are species of *Pterygotus* and *Pterichthys*, and higher up, of *Onchus* and *Cephalaspis*, thus correlating them by fossils to the Old Red Sandstone of Scotland (fig. 26). Along the border of this formation, where the uppermost Silurian strata join the Old Red Sandstone, there is a gradual passage both palæontologically and in the colour and texture of the strata. The *Eurypteri* and *Pterygoti* chiefly belong to these passage-beds, and in the same strata at the very base of the Old Red strata, in which there are no mollusca, are species of fish of the genera *Auchenaspis*, *Onchus* (?), *Pteraspis*, *Cephalaspis*, and *Plectrodus*. The Silurian marine mollusca, in fact, quickly disappear where the beds begin to get red in colour, notwithstanding the perfect conformity of the two sets of strata in England and the borders of Wales, as, for example, in the neighbourhood of Ludlow. At Kington and south of Builth, where true passage-beds occur, the ordinary shells of the Upper Ludlow rocks become far less numerous, and are almost all of small size, including species of *Modiolopsis* and *Modiola*, *Lingula cornea*, *Platychisma helicites*, a small *Discina*, a small *Theca*, a few small Crustacea, of the genera *Leperditia*, *Cytherellina*, &c. The water was freshening and getting unfitted for marine life.

The remains of *Cephalaspis Lyellii* (fig. 26) are occasionally found all through the Old Red Sandstone of this large area. The absence of marine shells and the nature of the fossil fishes of the Old Red Sandstone long ago led Mr. Godwin-Austen to infer that the formation was deposited, not in the sea, as had always been asserted, but in a great fresh-water lake, or in a series of lakes. In this opinion I thoroughly agree, for the nearest living analogues of many of the fish are the Polypterus of the African rivers, the Ceratodus of Australia, and in less degree the Lepidosteus of North America. The red colour of the rocks also helps to the same conclusion. Each grain of sand and marl is red, because it is encrusted with a thin pellicle of peroxide of iron, which could not have been deposited from mere solution, as a crust enveloping *each grain of sand* at the bottom of a great open ocean; but if carbonate of iron were carried in solution into lakes, it might have been precipitated as a peroxide through the oxidising action of the air and the escape of the carbonic acid.[1]

[1] There is no analogy between the coarse red sandstones and finer marls of the Old Red Sandstone, and the very fine red ooze dredged from the deeps of the South Atlantic. The latter is a residue produced by the decomposition of Foraminifera, and in no way resembles the coarse mechanical strata of Old Red Sandstone.

The presence of land plants in the very uppermost Silurian strata, as, for instance, near Ludlow and May Hill, indicates the neighbourhood of land. The physical geography of the area was rapidly changing, marking the beginning of an evident *Continental epoch.* The subject is of so much importance, and when first propounded was considered to be such a dangerous innovation on established views, that I shall give the reasons in some detail, making use for that purpose of passages from my memoir 'On the Red Rocks of England, of older date than the Trias,' published in the 'Quarterly Journal of the Geological Society,' in 1871.

The circumstances which marked the passage of the uppermost Silurian rocks into Old Red Sandstone seem to me to have been:—First, a shallowing of the Silurian sea by accumulation of sediment, aided by slow upheaval, which gradually produced a great change in the physical geography of the district, so that the old marine area became changed into a series of mingled fresh and brackish lagoons, which finally, by continued terrestrial changes, were converted into lakes; and the occurrence of a very few genera or even species of fish and Crustacea, common both to the fresh and brackish or even salt waters, does not prove that the Old Red Sandstone is truly marine. At the present day, animals that are commonly supposed to be essentially marine, are occasionally found inhabiting fresh water. In the inland fresh lakes of Newfoundland, seals are common. They breed there freely, and never visit the sea. The same is the case in Lake Baikal in Central Asia, and it is on record that the inhabitants of the shores of the Sea of Aral, now brackish, were in old times clad in sealskins got from the seals that inhabited those waters; and though these facts bear but slightly on my present subject, seals being air-breathing Mammalia, yet in some of the lakes of Sweden ordinary marine Crustacea are found. This may be accounted for in the way that I now attempt to account for similar peculiarities in the Old Red Sandstone strata. These Swedish lake-areas were submerged after the close of the Glacial epoch; and being deep basins (scooped out in a manner which I shall explain in a later chapter), while the land was emerging by upheaval, and after its final emergence, the salt water of the lakes freshened so slowly, by influx of rivers, that some of the creatures inhabiting it had time by degrees to adjust themselves to new and abnormal conditions.[1]

Again, we may suppose a set of circumstances such as the following:—If, by changes of physical geography of a continental kind, a portion of the Silurian sea got separated from the main ocean, more or less like the Caspian and the Black Sea, then the ordinary marine conditions of the 'passage beds,' accompanied by some of the life of the period, might be maintained for what, in common language, seems to us a long time. The Black Sea was once united to the Caspian, and the Caspian to the Aral, forming one great inland sea, which under varying physical conditions, has more than once changed its form and extent. At all events, since its separation from the Black Sea the Caspian has been simply a great brackish lake. The Black Sea is now steadily freshening; and it is easy to conceive that by a geographical change, such as the upheaval of the Bos-

[1] For much valuable information on this subject, see 'Annals and Mag. of Nat. Hist.' third series, vol. i. 1858, p. 50, 'On the Occurrence of Marine Animal Forms in Fresh Water,' by Dr. E. von Martens: translated by Mr. W. S. Dallas.

phorus, it might be converted into a fresh lake, if the supply of river water were sufficient to overbalance evaporation and secure an overflow. At present a great body of salt water is constantly being poured out through the Bosphorus, and its place taken by the fresh water of rivers. Owing, however, to the uncongenial quality of the freshening water, some of the Black Sea shells are strangely distorted, as shown by Edward Forbes.

Or if we take the Caspian alone as an example, we have an inland brackish sheet of water, with a present area of 178,866 square miles, the surface of which is 83 feet below the level of the Black Sea. This, according to accepted zoological and physical views, was once united by a narrow strait with the North Sea. Changes in physical geography have taken place of such a kind that the Caspian is now disunited from the ocean, while its waters are still inhabited by a poor and dwarfed marine molluscan fauna, and by seals. If by increase of rainfall the Caspian became freshened, the loss of water by evaporation not being equal to supply, it would by-and-by, after reaching the point of overflow, be converted into a great fresh-water lake, larger in extent than the whole area now occupied by the British Islands and the Irish Sea. It is even conceivable that the great area of inland drainage of Central Asia, now holding many salt lakes, might in the same manner be so changed that all its lakes would become fresh and widened in extent, thus occupying areas larger than all the Old Red Sandstone of Europe. Under these circumstances, in the Caspian area we should have a passage more or less gradual from imperfect marine to perfectly fresh-water conditions, such as I conceive to have marked the advent of the Old Red Sandstone. When the whole area was fairly separated from the sea, the sediments might by degrees get into a condition to get coloured red in the manner previously mentioned. We have a case in point in an old inland sheet of water, as shown by the Red Marls of the extinct Miocene lakes of Auvergne in Central France.

The uniformity of action here sketched may present a difficulty to some geologists, seeing that on the borders of South Wales the Upper Old Red Sandstone, over a large space, overlaps the lower strata till they lie directly on Silurian rocks, and the same is the case in parts of Scotland. But on consideration these circumstances do not present any real difficulty. If the great hollow in which the Dead Sea lies, were gradually to get filled with fresh water, and the whole by degrees became silted up, 1,300 feet of strata would be added above the level of the present surface, and the upper strata all round would overlap the lower, apparently much as the Old Red Sandstone strata do in Wales and the adjoining counties. If the Caspian and other parts of the Asiatic area of inland drainage got filled with fresh water, the same general results would ensue.

Like the recurrent circumstances that have attended the rise and falls of empires through all historical time, so geological history has often more or less repeated itself, somewhere or other on the surface of the earth; and in this modern phase of Asiatic physical geography, it seems to me that we may have, so far as it has gone, a repetition of events, which, with minor variations, have happened again and again, in old-world geological epochs, the history of which I shall by-and-by have to record. The farther off geological records recede, like inscriptions in an unknown tongue, the more difficult are they to decipher; the nearer they come to our own day, they are often more easy to read.

In North Wales narrow streaks of Old Red Sandstone here and there crop out between the Upper Silurian rocks, and the Carboniferous Limestone of Flintshire and Denbighshire, and the same with bands of cornstone forms the fine escarpment of Traeth Dulas in Anglesey, where the sandstone lies directly on Lower Silurian rocks.

In the northern counties also, at Kirkby Lonsdale, Sedbergh, and Kendal, and all along the base of the Carboniferous Limestone between Orton in Westmoreland, and Greystock Park in Cumberland, patches and a long line of Old Red Sandstones, marls, and conglomerates occur.

A broad belt of Old Red Sandstone crosses Scotland in a north-east direction between the Firth of Clyde and the Firths of Forth and Tay, and Stonehaven in Kincardineshire, and Montrose. Patches lie in Arran, Bute, &c. The whole lies unconformably on Lower Silurian clay slates, and dips to the south-east under the *Carboniferous rocks* that occupy the great central depression through which the Forth and Clyde chiefly run. On the south-east side of this broad undulating hollow the Old Red Sandstone again rises from beneath the *Coal-measures* with a general north-west dip, and skirting the Lammermuir Hills, strikes south-west into the sea south of Ayr. On the south side of the Lammermuir Hills, it again appears on the hills between St. Abb's Head and Hawick, dipping under the Carboniferous rocks that, without a break, stretch from Berwick to the neighbourhood of Derby.

North of Stonehaven detached patches of Old Red Sandstone occur on the mainland as far as Pentland Firth, beyond which it forms the greater part of the Orkneys, and small portions of the Shetland Islands.

The first patch lies between Fyvie and Penman Bay in Aberdeenshire; the second forms both shores of Moray Firth and Dornoch Firth, and stretches a long way up the Great Valley of the Caledonian Canal, through which at one time I have no doubt it passed all the way to the Firth of Lorn, between Oban and the island of Mull; and the third forms the greater part of Caithness. On the west coast a large tract of hilly ground between the neighbourhood of Loch Awe, Oban, and Kerera is chiefly formed of Old Red conglomerate.

For the first compendious account of the Old Red Sandstone of Scotland the world is indebted to Hugh Miller, whose wonderful faculty of graphic description enabled him, unassisted, to describe the rocks and the remarkable forms of fish they contain, which till his time were almost altogether unknown. Something, however, still remains to be done, before the precise relations to each other of some of the parts of the Old Red Sandstone of Scotland are clearly established. The researches of Professor Geikie and other officers of the Geological Survey, have shown that, south of the Grampian Mountains, there is an upper set of strata, lying in basins unconformably on the lower Old Red Sandstone.

Conglomerate often lies at the base of any part of the series that rests directly on the ancient slates and gneissic rocks, and occasionally thick conglomerates are intercalated among the sandy strata on various horizons, as, for example, on Moray and Cromarty Firths. These beds are sometimes thin, and sometimes of enormous thickness. Some of these conglomerates are clearly volcanic breccias and ashy beds; as, for example, on part of the Ochil Hills, south of the Firth of Tay, and from thence stretching westward at intervals to the Forth, near Bridge of Allan. The ordinary sedimentary conglomerates are frequently very coarse, containing both water-worn and subangular fragments of the underlying rocks from the waste (denudation) of which it has been formed. Some of the fragments I have observed of a yard in diameter, in the great band of conglomerate that lies at the foot of the Grampian Mountains, and others, true boulders, of equal size, on the north coast of Scotland, east of Strathie in Caithness. The Silurian gneiss of the Grampian Hills and of the Highlands in general, is much older than the Old Red Sandstone, and the same may be said of the strata of the Lammermuirs, both of which were disturbed and denuded before the deposition of the Upper Silurian rocks. Later denudations of the same rocks formed the vast conglomerate of Old Red rocks south of Dunbar.

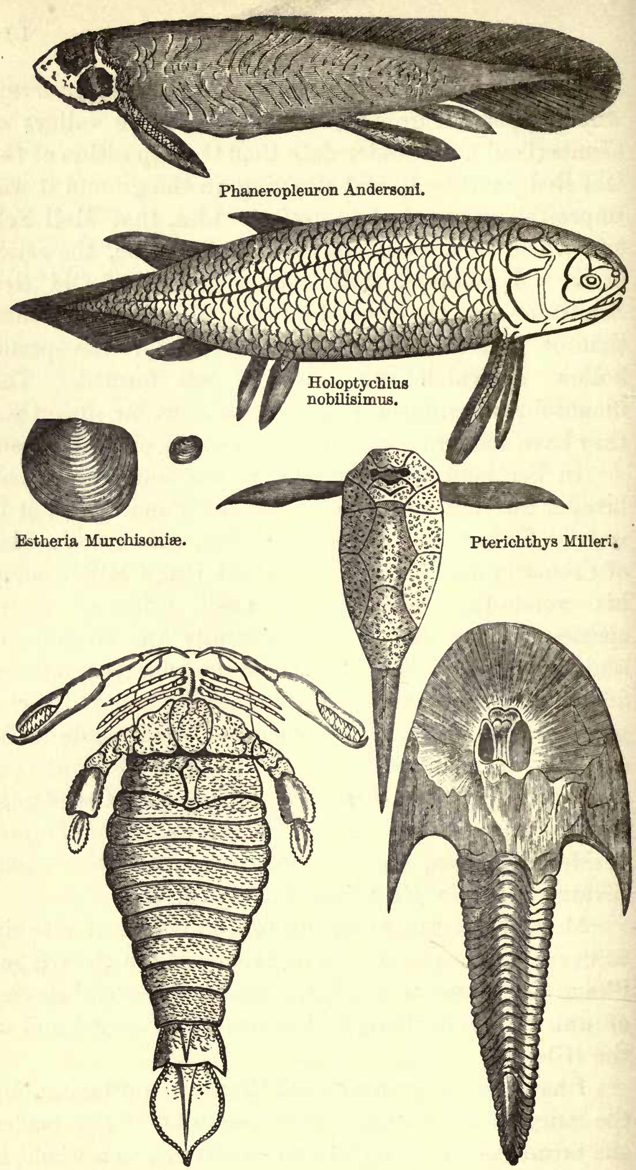
Some of these conglomerates possess a character which unmistakably marks them as glacial boulder clays. The stones are of all sizes, and not mere pebbles, and they are generally sub-angular, just like those of many of the boulder clays of the last Glacial Epoch. Like some of these boulder clays also, the stones are imbedded in a red marly paste, once unconsolidated clay, and in similar conglomerates in the Cumbrian region, scratched stones have been found in some cases unmistakably resembling those which are allowed by all to have had their markings produced by the agency of glacier ice. A bold man might even go further, for opposite the mouth of the valley of Ullswater, at the outlet of the lake, there are great heaps of angular boulder-conglomerate, culminating in the big mound-like hills of Mell Fell and the neighbourhood, the stones cemented in a marly base. It is an obvious fact to skilled geologists, well known to those of the Geological Survey, who mapped the ground, that some of the valleys of Cumberland are of older date than the deposition of the Old Red Sandstone, and standing on the ground it was impossible for me not to *feel* the idea, that Mell Fell and Little Mell Fell look like, and may be, the relics of an old moraine, shed from a glacier of Old Red Sandstone age, that flowed down a valley far older than that of modern Ullswater, and long before the special hollow in which the lake lies was formed. The mountains were much higher than now, for since then they have undergone an immense amount of denudation.

In Scotland fishes are more or less found in all the broader districts occupied by Old Red Sandstone, but it was chiefly in the north, in Caithness, and on both sides of Cromarty and Moray Firths, that Hugh Miller made his wonderful discoveries of fossil fishes of many species. They are found generally in bituminous schists and flags with occasional nodular concretions, and lie in various minor horizons among red and variegated sandstones and conglomerates, which contain the remains of many fish of the genera *Diplopterus*, *Coccosteus*, *Pterichthys*, *Diplacanthus*, *Osteolepis*, *Glyptolæmus*, *Dipterus*, *Holoptychius*, *Cephalaspis*, besides crustacea, such as *Pterygotus*, and the small bivalve *Estheria Murchisoniæ*. (Fig. 26.)

Most of the genera belong to a sub-order of Ganoid fish called *Crossopterygidæ* by Huxley, from the fringe-like arrangement of the fins, a sub-order several species of which are still living in the rivers of Senegal and in the Nile.

I have specially mentioned these circumstances, for the purpose of keeping before the mind of the reader the broad fact that the Old Red Sandstone, as a whole, is

FIG. 26.



Group of Old Red Sandstone fossils.

distinct in space, if not in time, from the marine Devonian strata, for in most books both are generally included under the term Devonian, and the ordinary reader makes no distinction between them. There is, however, this marked distinction, that one is of marine and the other of fresh-water origin, and therefore that the latter belongs to a broad Continental area, outside the shores of which our British Devonian beds were deposited, while in other areas, such as part of Russia, the intermingling of fresh-water and marine interstratifications seems to imply a set of estuarine conditions. That our Old Red Sandstone, to the very top, was of fresh-water origin is evident, not only by the presence of special genera of fish, but also in the rocks of Dura Den, of a fresh-water shell, *Anodonta Jukesii*, and of ferns, *Adiantites Hibernicus* and *Cyclopteris*, also *Lepidodendron*, &c. The shell proves fresh water, and the plants the vicinity of land. See Fig. 25, p. 101.

When all the foregoing statements are fairly considered, it seems to me that we obtain sufficient material from which to form a conception of the physical geography of our area during the deposition of the Old Red Sandstone; as follows:—

In a mountainous region of which the Scandinavian chain formed part, the lakes of the Old Red Sandstone epoch lay; for patches of these strata opposite Scotland, and bordering the sea, lie on the Norwegian coast. What was the extent of the Great Lake in which the central Scottish strata were deposited I am unable to say, for they strike out to sea in the Firth of Clyde on the west and to the North Sea on the east coast, forming a stretch of country 100 miles in length by about 60 in breadth. Whether or not, the Old Red Sandstone of this area was originally united to that which borders the Firths of Moray and Dornoch, and from thence on to the sandstones of Caithness and the Orkneys, I cannot tell, though it has been usually stated that the eastern side of the Lower Silurian rocks and the Grampian heights were continuously fringed by Old Red Sandstone. It seems to me, however, to be not unlikely, that as the great Grampian range south of the Dee even now attains to heights of about 2,000 feet in Kincardineshire, in older times, having suffered much less from denudation, they were higher than now, stretched further east, and possibly formed an effectual barrier between two lake-areas in which Old Red Sandstone was deposited. But even if the red sandstones of the whole of Scotland were once united to those of the coast of Norway, *in one continuous stretch of inland water*, it is not without parallel in the living world, for the brackish Caspian lake occupies a larger area, and it has been said that even in historical times the Caspian was larger than now. The great fresh-water lakes also of North America, from Lake Superior to Lake Erie, exclusive of Ontario, occupy an area far larger than the whole of Scotland with all its islands. Three of these lakes, Superior, Michigan, and Huron, practically form one sheet of water, united by straits somewhat analogous to those of the Bosphorus and Hellespont; and the lowest of these, Lake Huron, is only 37 feet below the level of Lake Superior, while Erie is 36 feet lower than Lake Huron, with a distance of more than 70 miles between them, part of which is occupied by Lake St. Clair.

When we try to realise the kind of scenery of this old period, we are led to something of this kind. The lake or lakes, was or were, more or less encircled by high mountains, and on the banks, and perhaps as occasional islands, volcanic cones disgorged streams of lava and discharged showers of ashes and stones, to be interstratified with the ordinary sediments, in a manner analogous to that which accompanied the deposition of the Miocene strata in Auvergne and other areas in what is now central France. At the same time, from the lofty mountains that now form the Highlands, but higher then, glaciers descended into the water, and fleets of icebergs floated hither and thither, and, melting, dropped their moraine matter to intermingle with other sediments, while further south, in Cumbria, similar glaciers descended from the ancient mountains, higher and different in form from those of modern date in the same area.

In a region still further south, we come to the lake in which the Old Red Sandstone of South Wales and the adjoining counties was deposited. These strata certainly spread further north and west than the edge of the main mass does now, a fact shown by the large outliers by Presteign, Clun, and Bettws Crwyn in Montgomeryshire. Making an allowance for this extension, the lake must have been not less than about 100 miles in length, by a breadth varying from 70 to 100 miles, for traces of Old Red Sandstone have been proved in deep borings through the coal-measures at the south end of the South Staffordshire coal-field. Away in the distant west, rose the lofty mountains formed in part of the far more ancient Lower Silurian rocks of North Wales, but no contemporaneous volcanic rocks are anywhere found among the Old Red Sandstone strata that were deposited in the adjacent lake, the eastern shores of which were, I think, low and unimposing.

Respecting the vegetation of the country there is little to say, for the ferns and lepidodendrons afford but feeble and fragmentary evidence. It may have been that the whole region stood at a comparatively high and bleak level, or it may be that the plant-bearing localities remain to be discovered. This, however, we know, that in North America, in equivalent strata, there lie buried the remains of a large and luxuriant flora, which generically has close affinities with that of the succeeding Carboniferous Epoch. Such plants as we have lie, some at the base, and others near the top of the British Old Red Sandstone, which, indeed, in some areas gradually merges into the Carboniferous strata, that, under varying marine and wide-spread terrestrial conditions, form the next stage of one long Continental Epoch.

CHAPTER IX.

CARBONIFEROUS SERIES.

Carboniferous Rocks.—In the south and middle of England, the Carboniferous rocks consist chiefly of Limestone at the base and Coal-measures above. Including the South Wales, the Forest of Dean, the Somersetshire and other areas, a typical section of the beds is as follows:—

	Feet.		Feet.
Coal-measures	1,000	to	12,000
Millstone grit	500	„	1,000
Yoredale rocks	100	„	1,000
Carboniferous or Mountain Limestone .	500	„	2,500
Carboniferous Limestone shale . . .	100	„	500
Yellow Sandstone with plants, Ireland, &c.	100	„	200

Generally resting on Old Red Sandstone.

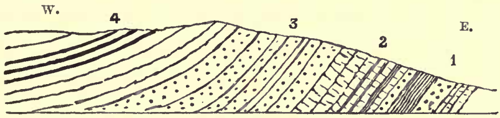
The *Yellow Sandstone* beds often form a passage from the Old Red Sandstone to the Carboniferous rocks, and the plants have carboniferous affinities. The accompanying *shales* in Pembrokeshire and elsewhere, contain numerous fish-teeth, *Spirifers*, *Productas*, and a few *Lingulas*; and the Carboniferous *Limestone*, which is more than 2,000 feet thick in South Wales, and in Somersetshire, is so highly fossiliferous that it may be stated that the whole of the limestone once formed parts of animals. The lowest 500 feet consists chiefly of fragments of *Encrinites*. The Yoredale rocks of Yorkshire have no precise lithological parallel in

South Wales and Somerset. They consist chiefly of shales and sandstones, with marine shells and occasional land-plants. The *Millstone grit* of South Wales is comparatively unfossiliferous, but sometimes contains the remains of plants, and more rarely Orthoceras and other marine shells.

The *Coal-measures* and *Millstone grit* of Monmouthshire, Glamorganshire, and Pembrokeshire, lie in a great oval basin, encircled by a rim of Carboniferous Limestone, beneath which lies the Old Red Sandstone. The Coal-measure beds alone were estimated by Sir William Logan at from 10,000 to 12,000 feet thick. They consist of alternations of sandstone, shale, fireclay or underclay, coal, and ironstone. There are about 100 beds of coal in the field, many of which are workable, chiefly in the lower part of the series, where the principal ironstones also occur. In the shales and sandstones large stems of plants are sometimes found standing vertically, in the positions in which they grew. Underneath each bed of coal is a bed of underclay with Stigmaria, forming the soil in which the plants were rooted, by the decay of which, passing through the stage of peat, material was supplied for the subsequent production of coal. Stigmaria, once supposed to be a special plant, was first proved by Mr. Binney to be the root of Sigillaria, and about the same time Logan showed that the *underclay* was a soil that lay invariably underneath beds of coal, and indeed that these roots and rootlets are in every underclay. The plants (the decay of which formed beds of coal) consisted largely of gigantic club-mosses, such as *Lepidodendron* and *Calamites* (Equisitaceæ) of various species, and many other ferns, with a few Coniferæ, &c.

Passing from east to west in this coal-field, the coals (sometimes the very same beds) gradually change from so-called bituminous to anthracitic varieties. It is remarkable that anthracite usually occurs in coal-fields the strata of which have been much disturbed and contorted, as, for instance, in the mountains of Pennsylvania. Anthracite is simply a metamorphic variety of coal; and in Pembrokeshire, where the coals are most anthracitic, the strata have been violently contorted. There is a connection between the heat that produced metamorphism and the lateral pressure that produced contortion, for pressure with movement is convertible into heat. A line of disturbance passes from the banks of the Wye south of Builth, through the north part of the coal-field south of Llandeilo, and from thence westward into Pembrokeshire, where masses of igneous rocks appear in contact with the coal-field. In connection with this, it may be that the rocks of the coal-field remained a long time highly heated, and so, by a species of distillation, deep under ground, the bituminous were converted into anthracite coals.

FIG. 27.



1. Old Red Sandstone.
2. Carboniferous Limestone. } Carboniferous series.
3. Millstone Grit. }
4. Coal measures with beds of coal. }

Dean Forest may be looked on as an outlier of the South Wales coal-field. Fig. 27 may be supposed to represent the arrangement of the strata on the east side of this very perfect basin. The limestone is about 700 feet thick, and the Coal-measures, according to De la Beche, 2,765 feet. The limestone contains brown hæmatite iron ore in cavernous holes. There are in the field 23 chief beds of coal.

The Bristol and Somersetshire coal-field was also originally joined to the South Wales Carboniferous rocks, till separated by denudation. The Carboniferous Limestone series near Bristol, and on the Mendip Hills, is about 2,500 feet thick, containing the usual marine fossils in great variety. The Coal-measures and Millstone grit of the Bristol and Somersetshire coal-field lie in a basin, the base of which is formed of this limestone. The Coal-measures are altogether about 7,000 feet thick, and consist of an upper and a lower series, separated by thick beds of grit, called the Pennant rock, about 2,000 feet in thickness, and which itself holds beds of coal, some of them of value. Altogether they contain about 46 beds of coal, with a total thickness of about 98 feet. A large part of this Carboniferous basin is unconformably covered by New Red marl and Liassic and Oolitic strata, and here and there portions of the coal-field are exposed by denudation of the New Red marl between Bristol and the Mendip Hills, where the beds rise rapidly, and a narrow strip of Coal-measures skirts the Mendip limestones, the whole dipping north at high angles. Similar Coal-measures probably underlie the marshes, and part of the secondary strata south of the Mendip Hills.

These three coal-basins, South Wales, Dean Forest, and Bristol, once united, have only been separated by denudation similar to that shown at p. 33. In the case of these coal-fields the intervening spaces are anticlinal, and the basins synclinal curves, and therefore it is not only possible, but probable, that other coal-basins may lie far to the east beneath the Oolitic, Cretaceous, and Eocene strata of the London basin.

The Culm-measures of Devonshire, though of true Carboniferous age, and probably representing much of the series, are nearly unproductive of coal. Near their base there are intermittent thin streaks of limestone, which may feebly represent part of the great masses of Somerset and South Wales, just as the thin worthless coals represent the numerous seams of these coal-fields. But the conditions of deposition in the areas were apparently very different. In the Devonshire area the purely terrestrial intervals, marked by the growth of land plants *in situ*, seem to have been infrequent and transitory, and from bottom to top common aqueous strata prevail.

Further north, in the neighbourhood of Newent, narrow bands of poor Coal-measures are barely traceable between the Old Red and the New Red Sandstones, and still further north, round Bewdley, there lies the coal-field of the Forest of Wyre, consisting of strata by no means very productive of coal-beds. They lie directly on the Old Red Sandstone, the Carboniferous Limestone being absent. The Coalbrookdale coal-field joins that of the Forest of Wyre, and lies partly on a thin development of Carboniferous Limestone, and partly unconformably on Upper Silurian rocks. On the north-west, the lower part of the *New Red Sandstone* is faulted against it, and on the east it is overlaid by *Permian* strata. It contains several bands of good nodular ironstones, which often yield *Producta*, *Conularia*, *Orbicula*, *Limulus*, and other marine remains, and in some of the strata fossil beetles, dragonflies, and spiders have been found. There are in places 22 beds of coal in this field, about 10 of which are workable, some of them from 3 to 6 feet thick, with beds of underclay, the whole being interstratified with shales and sandstones. The total thickness of these Coal-measures is about 1,000 feet. The adjoining coal-fields of Le Botwood and Shrewsbury are comparatively of minor importance. The North Wales coal-field in all essential geological points resembles that of South Wales, and lies on the Carboniferous Limestone, which is from 800 to 1,000 feet thick. South of Wrexham the whole dips east under the Permian rocks, and further north under the New Red Sandstone. The Denbighshire part contains at least 17 beds of coal, most of which are worked, and the Flintshire part at least 12 beds. A small fragment of the same strata occurs in the central part of Anglesey. It is underlaid by the Carboniferous Limestone, and on the south-east is faulted against the Cambrian rocks. Permian strata overlie it, but the smaller faults and a greenstone dyke which affect the coal do not pass through the Permian beds, which lie unconformably over all.

In the centre of England the basement beds of the South Staffordshire coal-field rest directly on the Wenlock Limestone of the Upper Silurian series. This field, in the northern part, contains 14 beds of coal. Getting closer to each other by degrees in the south, several of these coalesce to form the thick coal, in places 40 feet in thickness, with two thin partings. The rocks are pierced by basalts and a white felspathic-looking trap, which has charred the coals at the points of junction, and is undoubtedly connected with the great basaltic mass, called the Rowley Rag, that overlies the Coal-measures.

The New Red Sandstone on the east is faulted against the Warwickshire coal-field, and generally overlaid by the Permian rocks on the west. It contains six beds of workable coal, besides ironstone, and on the south, where the strata pass under the Lower Keuper Sandstones, several of these, as in South Staffordshire, coalesce to form two beds of coal. The lower part of the Coal-measures is traversed by several lines of intrusive dioritic greenstones running in the line of strike.

The Ashby-de-la-Zouch coal-field is overlaid by the New Red Sandstone, and partly underlaid by the Carboniferous Limestone, and partly, probably, by a continuation of the Cambrian rocks of Charnwood Forest. It is divided into two districts or minor basins—the eastern, containing 15 beds of coal, 11 of which are workable ; and the western 11 beds. Nine are of superior quality. The Coalbrookdale, South Staffordshire, and Warwickshire coal-fields present so many points of resemblance, that undoubtedly they were all originally formed as one coal-field, and even now in great part may be continuous in the districts that lie between, concealed by Permian and New Red strata.

North of this coal-field the Carboniferous rocks are somewhat modified in details. Between Derbyshire and Berwick they stretch north and south without a break for 200 miles, by about 60 miles in width. At the southern end, near Derby, the New Red Sandstone overlies them. West of Cheadle, along the edge of the North Staffordshire coal-field, they are generally faulted against the Permian rocks, north of which lie the coal-fields of Cheshire and Lancashire. The Carboniferous Limestone and Millstone grit rise between these coal-fields, forming the hills of Derbyshire ; and the Coal-measures are thrown off on either side of the anticlinal axis, forming, in the east, the Derbyshire and Yorkshire coal-field, and on the west those of North Staffordshire, Cheshire, and Lancashire. Three or four beds of igneous rock, called toadstone, lie in the limestone. The Millstone grit of these areas is much mingled with shale, and between it and the Carboniferous Limestone there are often thick beds of shale and sandstone, called the Upper Limestone Shale, or Yoredale rocks. North of the Ribble the Carboniferous Limestone itself is divided by numerous interstratifications of sandstone and shale, with occasional beds of thin coal, and this increasing in the northern parts of Northumberland, the equivalents of the southern mass of Carboniferous Limestone die away into a few subordinate beds of limestone, and fairly pass by degrees into a lower coal-field, with several poor beds of coal.

The Lancashire, Cheshire and North Staffordshire coal-fields, exclusive of the Millstone grit, vary from about 3,500 to 7,500 feet in thickness, counting from the beds on which the unconformable Permian strata happen to rest. They include about 30 coal-beds in North Staffordshire, in Lancashire 14 good seams about St. Helens, 15 at Wigan, 16 between Manchester and Bolton, and 13 at Burnley. Many of these, which in different districts go by different names, are equivalent beds. Fish remains and many marine and estuarine or fresh water shells occur among the interstratified shales and sandstones. There are also many beds of ironstone. The Nottingham, Derbyshire, and Yorkshire coal-fields united give about 15 beds of workable coal. All these are ironstone areas, and North Staffordshire is the great pottery district of England. The finer clay is imported, only the coarser qualities for tiles, &c., being native.

The Newcastle coal-field is about 1,600 feet thick, and contains about 16 beds of coal throughout the district. The *lower coal-field* of Northumberland, as already stated, is of the age of the Carboniferous Limestone series of Wales, and the Berwickshire coals of Scotland are of the same general age. There is another much smaller coal-field near Ingleton in North Lancashire which contains 8 beds of coal, and in Cumberland the Whitehaven Coal-measures, which lie on the Carboniferous Limestone, have 14 beds.

The great Scottish coal-fields lie in a broad synclinal curve, in which are the valleys of the Clyde and Forth. Beneath the Calciferous Sandstone and Carboniferous Limestone series, Old Red Sandstone, underlaid by Silurian rocks, rises on the south-east between St. Abb's Head on the east and Girvan on the west; while on the north-west the Old Red Sandstone resting on the Lower Silurian rocks of the Highlands, rises from beneath the same Carboniferous strata between the Frith of Tay and the Clyde, near Dumbarton. The whole tract is about 100 miles in length, by 40 to 50 in breadth.

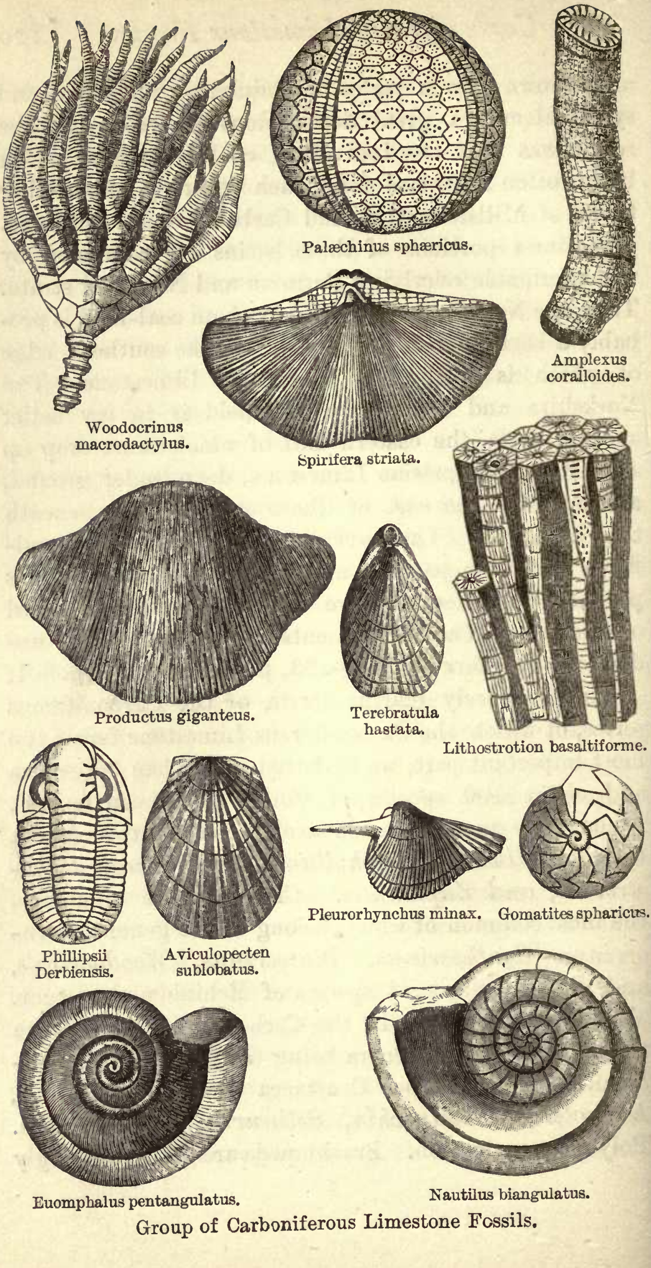
The lower Carboniferous strata are much intermingled with igneous rock, sometimes felspathic, sometimes augitic. Some of these are intrusive, but large masses consist of truly interbedded lavas, associated with strongly marked and thick strata of volcanic ashes and conglomerates, well seen, for example, on the cliffs between Dunbar and Belhaven. The Carboniferous Limestones, which in occasional bands overlie the Calciferous Sandstone, do not lie in a mass at the base of the Coal-measures, but, as in the North of England, the limestone occurs in several beds, chiefly in the lower part of the series, interstratified with beds of sandstone, shale, and occasionally of coal. In Linlithgowshire and the Campsie Hills limestones are interbedded with trap. Marine, fresh or brackish water, and terrestrial alternations are of constant occurrence. In some cases in East Lothian, beds of fireclay, with Stigmaria, and thin layers of coal lying on old terrestrial soils, immediately underlie marine limestones with Productas. In the Dalkeith coal-field valuable beds of coal with shales, &c. are interstratified with a thick series of beds of Carboniferous Limestone. The Burdiehouse brackish water limestone in East Lothian is the lowest of the limestones, and yields many small bivalve Crustacea of the genus Estheria, besides fish of the genera Megalicthys and Holoptychius.

In the East and Mid Lothian coal-fields about 20 beds of workable coal occur, besides many smaller layers. Eleven workable beds of coal are known above the Millstone grit or Moor rock, and 17 associated with the Carboniferous Limestone beds below the Millstone grit. The Carboniferous strata of the Lothians cross the Firth of Forth beneath the sea, and form great part of Kinross and Fife, where there are 29 workable beds, one of which is 21 feet, and others from 5 to 9 feet in thickness. The western part of the basin in Lanarkshire and Ayrshire yields 8 or 10 workable coal seams. It is in these districts that the well-known *black-band ironstones* occur.

I have already said that the South Wales, Dean Forest, Bristol and Devonshire Carboniferous areas originally formed one, and have been separated by disturbance of the strata and subsequent denudation. The same kind of original continuity may be inferred concerning all the coal-fields of the middle of England, North Wales, and northward to Cumberland and Northumberland, and the latter was even probably joined to the great coal-field of central Scotland. After the close of the Carboniferous epoch, this large area was also thrown into a series of undulating anticlinal and synclinal curves, great denudations occurred, and the result was that the individual coal-fields now lie in basins often separated from each other by intervening tracts of Millstone Grit and Carboniferous Limestone. Sometimes portions of these basins are concealed by unconformable overlying Permian and New Red strata. Thus, the Northumberland and Durham coal-field is probably a basin, partly out at sea, and the southern edge of which is overlaid by Magnesian Limestone. The Yorkshire and Derbyshire coal-field is in my belief another basin, the eastern half of which must crop up against the Magnesian Limestone, deep under ground, and miles to the east of where it first dips beneath that limestone. The Lancashire and North Wales coal-fields also form parts of another great basin, in places probably 6,000 feet or more beneath the New Red Marl of Cheshire. These statements will be more easily understood by referring to figs. 63, p. 325, and 115, p. 601.

In the purely marine strata of the Carboniferous series, of which the Carboniferous Limestone forms the most important part, we find that more than 30 genera and about 100 species of Corals have been named. Among the most common are species of the genera *Cyathophyllum*, *Clisiophyllum*, *Syringopora*, *Lithostrotion*, *and Zaphrentis*. Crinoidea are numerous, the most common of which belong to the genera *Actinocrinus*, *Cyathocrinus*, *Platycrinus*, *Woodocrinus*, and *Poteriocrinus*; 3 species of Echinidæ also occur. Trilobites are scarce in the Carboniferous rocks, the most characteristic genera being *Griffithides* and *Phillipsia*. Among other Crustacea there are *Estheria*, *Eurypterus*, *Prestwichia*, *Belinurus*, and *Limulus*. Polyzoa are common. Brachiopoda are also exceedingly

FIG. 28.

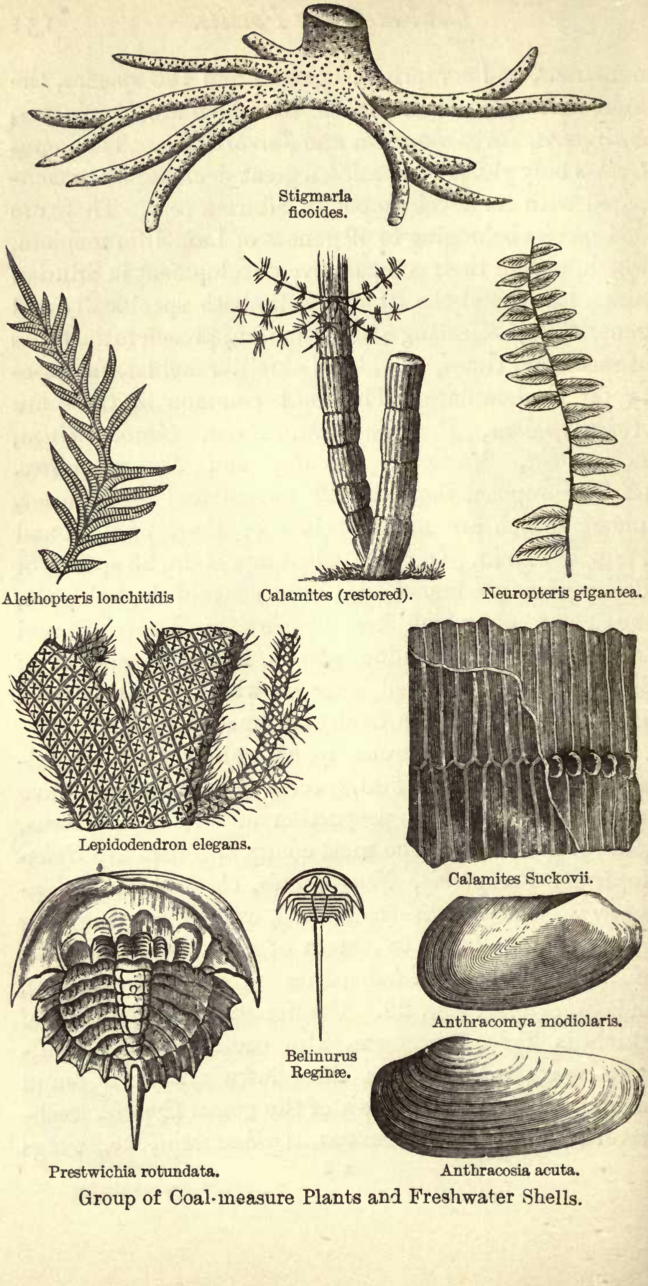


Group of Carboniferous Limestone Fossils.

numerous, and comprise 18 genera and 160 species, the most strikingly characteristic of which are *Productus*, *Spirifera*, *Rhynchonella*, and *Terebratula*. The genus *Orthis* only yields 12 species, a great decrease when compared with its development in Silurian seas. There are 334 species belonging to 49 genera of Lamellibranchiata, which, unlike their comparative development in Silurian rocks, far exceed the Brachiopoda, both specifically and generically, indicating a remarkable approach to the types of Secondary times, in which Lamellibranchiate molluscs by far predominate. The most common of these are *Aviculopecten*, *Posidonomya*, *Arca*, *Conocardium*, *Edmondia*, *Modiola*, *Nucula*, and *Sanguinolites*. Of Gasteropoda, there are 29 genera and 206 species, among which are many species of *Euomphalus* and *Pleurotomaria*. Of the Nucleobranchiata, 23 species of *Bellerophon* are known, and 148 species of Cephalopoda, the chief of which are *Goniatites*, *Nautilus*, and *Orthoceras*. Ninety-nine genera and 221 species of fish have been described, some of which probably lived alike in the sea and in fresh and brackish water.

In the Carboniferous rocks, chiefly in the Coal-measures, more than 500 species of fossil plants have been named, a large proportion of which are ferns, some of great size. The most common genera are *Sphenopteris*, *Pecopteris*, *Neuropteris*, *Cyclopteris*, *Odontopteris*, *Caulopteris* (tree-fern), &c. The remaining plants belong chiefly to genera of *Calamites* (Equisitæ of large size), *Lepidodendron* (tree Lycopodiums), and *Sigillaria*, Fig. 29. Coniferous trees, the fruit of which is *Trigonocarpum*, also occur. In the Coal-measure strata of Britain there have also been found many fresh-water Crustacea of the genus *Cypris*, fresh-water bivalves, *Anthracomya*, *Anthracosia*, &c., wings

FIG. 29.



Group of Coal-measure Plants and Freshwater Shells.

and wing-cases of beetles and other insects, spiders, &c. Rain pittings on the shales are not infrequent, together with sun-cracks and footprints of Labyrinthodont Amphibia, *Dendrerpeton*, *Anthracosaurus*, and other genera. The rain pittings in this special case, tell of showers falling on surfaces of moist mud, exposed by the temporary retirement of fresh water, and the sun-cracks of the drying and shrinkage of that mud; and these joined with the footprints of Amphibia tell of daily events which by happy accidents got perpetuated, first, by baking in the sun's rays. Next, when the area was again overflowed, new layers of mud settled on these impressions, and afterwards becoming consolidated into shale; and thus we have, in a measure, fossilised sunshine, showers, and footsteps of old Amphibians, imprinted, during their occasional visits to the moist land, on the margin of the water in which they chiefly lived.

Before closing the subject I must endeavour to explain under what broad conditions of Physical Geography the Carboniferous series was formed.

It is impossible to have an intimate knowledge of the Carboniferous rocks, even within the limited area of the British Islands, without coming to the conclusion, first, that the various strata were formed in seas, some comparatively open and deep, some shallow, estuarine, and restricted in area, and some in fresh water; and second, that beds of coal were due to terrestrial vegetable growths that flourished and died on the land, and were buried with the soils on which they grew. To examine all of these points in full detail would require the writing of a special treatise, and I can here only glance at the proofs.

In the southernmost parts of South Pembrokeshire, the limestone is about 2,500 feet thick. Going north to Haverfordwest it rapidly thins out, and finally disappears by overlap in a distance of twelve miles. A rapid thinning of the same strata also takes place between the shore of Bristol channel in Glamorganshire and the north side of the South Wales coal-field. In the Mendip Hills the limestone has also a thickness of about 2,500 feet. Traces of it are still seen south of Bideford Bay, at Cannington Park, a few miles north-west of Bridgewater, while on the northern borders of the Culm-measures of North Devon, it may be said to have almost entirely disappeared as a special formation. Among the limestone hills of Derbyshire it is of enormous thickness, and its base is unknown; but so indistinct is the bedding in part of the centre of that region, that it is often as hard to make out the details of stratification as it is in a large consolidated modern coral reef. North of Clitheroe the bosses of limestone are in places remarkably massive, and thin away in various directions so rapidly, that the incautious geologist is at first tempted to imagine faults where none exist. Further north, near Settle, Kendal, and round the sides of the Vale of Eden, it is well developed and distinctly bedded; but passing east and north, into Durham and Northumberland, it rapidly splits up into a few comparatively insignificant bands, separated by thick interstratifications of shale, sandstone, and minor beds of coal. The lower coal-fields in Scotland lie in equivalent strata.

In Ireland the phenomena are still more remarkable, for in the south and south-west, as described by Jukes, the same masses of limestone in a few miles sometimes thin away from some 2,000 to 200 or 300 feet in thickness.

The prevalence of corals in the thick masses of Carboniferous Limestone, and sometimes the rapid thinning out of these masses in opposite directions, point to the conclusion that they were true coral reefs, of the nature of the Barrier Reefs of Australia and the Pacific Ocean, and that they thinned away on one side to a feather edge in the direction of the land, and on the other more steeply towards the deep sea. These lenticular masses were probably formed round outlying islands, large and small, undergoing a process of slow depression, or otherwise on the shores of some old continent, the details of the original shape of which are now lost to our knowledge. One part of this land, however, consisted of that area now known as the mountainous parts of Wales, and the adjacent Silurian and Cambrian territory that underlies the *Coal-measures* of South Staffordshire, Warwickshire, and Leicestershire, Derbyshire, Cumbria, and the South of Scotland, while far north the Grampian mountains and the whole of the North Highlands stood higher above the level of the sea than they do now, for ever since they have suffered from denudation.

But while in the south, coral reefs of the nature of Barrier Reefs or Atolls were being formed, in the north the case was different; for there, as in parts of the modern Pacific, volcanic action was rife, and this is witnessed by the lavas and ashes, intermingled and interstratified with the whole of the Carboniferous series in Scotland. This area, together with the north of what is now England, was therefore more or less an area of elevation, accompanied by oscillations of partial depression. Thus it happens that in these regions, the bands of Carboniferous Limestone are quite insignificant when compared with the thick interstratifications of shale and sandstone with occasional beds of coal that lie between them, and which, excepting the beds of coal, were of ordinary aqueous sediments.

This naturally leads to the question under what circumstances were the purely mechanical sediments and the beds of coal formed? The answer is, that after the close of the Carboniferous Limestone epoch in the south, the area got filled up by the sands of the Millstone Grit and the more muddy strata (now shales and sandstones) that overlie them, and this shallowing of the seas may have been aided by partial upheaval of the area, till part of it was nearly at, and at length a little above, the level of the sea. Through this flat continental land, great rivers ran, bordered by wide marshy flats, on which the vegetation grew that by its decay and death became transformed into peat. Then by gradual depression these areas were again covered with water, in the first instance salt or fresh, as the case might be, but in all cases resulting in the deposition of layers of sediment. The area was thus converted by degrees into low land, covered by vegetation, a new growth and decay took place, and it was again depressed beneath the water to receive newer sediments, and so on through a vast period of time, till, for example, all the 10,000 feet of the South Wales coal-field were accumulated, interstratified with the hundred beds of coal, great and small, that lie among the shales and sandstones; and in equal or less degree the same was the case with all the other coal-fields of England and Wales, as far north as those of Lancashire and Yorkshire.

But when we come to other Carboniferous areas, further north, the case is somewhat different. There we find, in Durham, Northumberland, and Scotland, no thick masses of limestone, but only thin bands, interstratified with thick deposits of shale and sandstone, similar in most respects to those of the Coal-measures of Wales, and, like these, interstratified with beds of coal. The inference is obvious, that in these areas the conditions that prevailed were such, that a given area during oscillations of level was at one time sea, as proved by the sea shells in the strata, at another fresh water, as witnessed by the shells *Anthracosia*, *Anthracomya*, &c., and at another time land, as shown by the beds of coal, each underlaid by its terrestrial soil of underclay with Stigmaria, the roots of Sigillaria.

If this be true, we get a hint of a new phase of the physical geography of an epoch immediately succeeding that of the Old Red Sandstone. I have often thought that if we might imagine the vast flat territory of Northern Asia, with all its mighty rivers, to face south, so that they might run into a sub-tropical sea, we would have something like a picture of our Carboniferous epoch, succeeding one, the chief character of which, was the presence of numbers of large continental lakes. This at all events seems certain, that beds of coal are not the result of woody matter drifted into, and waterlogged in, lake hollows, by rivers, as was once imagined; but rather, considering the magnitude of the areas which the beds of coal cover, that they bear witness to the existence of a vast continent, or, if we take the whole world into account, of vast continents, through which wandering rivers traversed flat areas, comparable to those of the largest river areas of the living world. Deltas of the present day offer many analogies. The mouth of the Whang-ho or Yellow river is now 250 miles north from where it entered the sea about twenty years ago. The modern delta of the

Mississippi has an area of more than 12,000 square miles, consisting chiefly of sands and clays, with much vegetable matter, and that of the Nile an area of about 21,000. The delta of the Ganges and Brahmapootra is more than 48,000 square miles in extent, has peaty beds interstratified with clays and sands, containing freshwater shells and freshwater tortoises, often much below the level of the neighbouring sea. The area of all England and Wales is 57,812 square miles, and the areas of all the coal-fields of Great Britain extended to their original size did not equal that of this great delta.

It is not to be supposed that, in each coal-field, each bed of coal extends over the whole area. On the contrary they thicken and thin out, and have their edges like many a modern peat moss, and the vegetation of the Carboniferous epoch flourished and decayed rapidly, on moist ground and in a moist atmosphere, not of excessive warmth, as has often been stated, but, in the opinion of Sir Joseph Hooker, 'in a moist and equable climate,' that could scarcely have been sub-tropical.

CHAPTER X.

PERMIAN STRATA.

In England there are certain red strata, known as Permian, which occupy a sort of debatable ground, lying between the Carboniferous and New Red or Triassic series. Sometimes they have been classed with the former, sometimes with the latter, by those who like to insist on hard and fast lines of division between each formation. These strata, lying not quite conformably either with the underlying or the overlying formation, I prefer to consider as in some sense transition beds, making one of the steps in that change of the physical geography of our area which put an end to the development of Coal-measures, and made it possible under new conditions for the Permian strata to be deposited.

They are usually divided (as in Germany) into two subformations, viz.:—

Magnesian Limestone and Marl Slate,
Rothe-todteliegende.

The higher English beds in certain areas consist chiefly of Magnesian Limestone or Dolomite, interstratified with certain marls, and the lower of red marls, sandstones, and conglomerates. But if we take England as a whole this division does not hold good, for in the eastern part of England the Magnesian Limestone often lies directly on the Coal-measures, and in Lancashire and the Vale of Eden, in the north, only a few thin beds of Magnesian Limestone lie in the middle of red sandstones and marls. Hard and fast lines of division by no means hold good in this case.

The Permian strata were for long considered as forming a lower part of the New Red Sandstone, till separated from it by Professor Sedgwick, in his celebrated Memoir on the Magnesian Limestone. They were afterwards called *Permian* by Sir Roderick Murchison, from the ancient Government of Perm in European Russia, where they are extensively developed.

Between the neighbourhood of Nottingham and Tynemouth in Northumberland, they have been subdivided by Professor King, into—

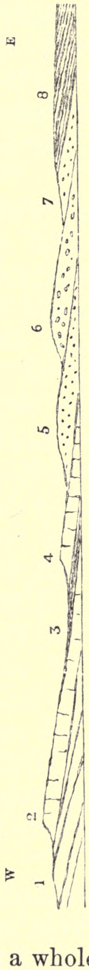
Crystalline and other limestones.
Brecciated limestone.
Fossiliferous limestone.
Compact limestone.
Marl slate.

The Marl slate lies at the base, but these subdivisions are by no means constant, and the lines between them are not always definite. In many places the rock consists of round masses of all sizes, often as large as good-sized cannon balls, all cemented together. The section is finely exposed on the sea-cliffs between Hartlepool and South Shields, with great outlying masses of rock rising out of the sands like ruined castles, pierced by caverns with lofty ragged pillars and arches, worn out by the restless sea, and through which the daily tide flows. In their range from Nottingham to this district the Magnesian Limestone is interstratified with three minor beds of red marl.

In Nottinghamshire the position of these Permian strata to the underlying Coal-measures, and the overlying Trias, or New Red series, is shown in the following diagram :—

Fig. 30.

Section across Coal-measures, Permian, and New Red strata, Nottinghamshire.



8. New Red Marl . . . . } Keuper } Trias, or New Red Series.
7. White and Red Sandstones and Marls . . } Keuper
6. Conglomerate . . . . } Bunter
5. Red Sandstone . . . . } Bunter
4. Magnesian Limestone . . . . . . } Permian.
3. Red Marl . . . . } Permian.
2. Magnesian Limestone . . . . . . } Permian.
1. . . . . Coal-measures.

Looked on as a whole, the Magnesian Limestone of this district lies quite unconformably on the Carboniferous series, for while between Nottingham and the neighbourhood of Leeds they lie upon Coal-measures, between Leeds and the vicinity of Darlington they overlap the north edge of the Yorkshire coal-field, and rest directly on the Millstone Grit and associated shales as far as the south end of the Durham coal-field, north of which they again lie on Coal-measures.

The limestone and marl slate are often fossiliferous.

In Lancashire, Cheshire, and North Staffordshire, the Permian strata chiefly consist of red marls and sandstones, interstratified near Manchester with a few thin bands of Magnesian Limestone, where both limestones and marls are fossiliferous, containing bivalve shells of the genera *Pleurophorus*, *Bakevillia*, and *Schizodus*, *Turbo*, *Natica*, &c. Similar marls and sandstones, bordered by New Red Sandstone, stretch at intervals from the border of the North Staffordshire coal-field to that of Shrewsbury, and skirt the Denbighshire coal-field on the east. In the more central parts of England the same kinds of rock border the Coalbrookdale, Forest of Wyre, South Staffordshire, and Warwickshire coal-fields. In the Permian strata of Warwickshire there are beds of conglomerate, the waterworn pebbles of which largely consist of fragments of Carboniferous Limestone. A few stems of trees have been found in them, together with *Calamites*, and two or three casts of shells of the genus *Strophalosia* (fig. 31), together with a Labyrinthodont Amphibian, *Dasyceps Bucklandi*.

A large extent of Permian red sandstones and marls occupy the beautiful Vale of Eden in Westmoreland and Cumberland (see fig. 104, p. 521), from whence Permian strata extend into the valleys of the Nith and the Annan in Scotland, brecciated like those of the Clent and Abberly Hills.

In the South Staffordshire district, and in the Clent and Bromsgrove Lickey Hills, the Permian marls and sandstones are capped by a remarkable brecciated conglomerate, consisting of pebbles and large blocks of stone, generally angular, imbedded in a marly paste, once soft clay. These conglomerate beds are about 400 feet thick. South of Colebrookdale, near Enville, and between that country and the Abberly and Malvern Hills, the same rocks occur, largely associated with coarse brecciated conglomerates, similar to those of the Clent Hills. The fragments have mostly travelled from a distance, apparently from the borders of Wales, and some of them are three feet in diameter. In some cases the smooth surfaces of the stones still retain striations, identical in character with those found in ordinary boulder-clay, or made by modern glaciers. Many of the stones are of greenstone and felstone, apparently derived from the Silurian traps of Montgomeryshire and North Wales, and at the south end of the South Staffordshire coal-field, near Northfield, I found in these strata large slabs of Pentamerus limestone, such as are only known in the Longmynd country, on the borders of the Cambrian rocks in Shropshire. So completely, indeed, does the whole deposit resemble the Post-pliocene boulder-clay, that I have no doubt that there was a glacial episode during part of the Permian epoch. In Thuringia the conglomerates of the Rothliegende have the same lithological character as the brecciated conglomerates of the Abberly Hills and Clent Hills, and they may be considered equivalents both in position and origin.

The chief part of the Permian fossils have been found in the Magnesian Limestone, and they are, generically and specifically, few in number, but, as a whole, their affinities and grouping are decidedly Palæozoic. Some of the genera of plants have a Coal-measure aspect, including *Calamites*, *Lepidodendron*, *Neuropteris*, *Sphenopteris*, and *Alethopteris*, besides *Walchia*, *Ullmannia*, *Cardicocarpon*, and fragments of silicified coniferous wood. Only 9 genera and 21 species of Brachiopoda are found in these strata, viz. *Camarophoria* 3, *Crania* 2, *Discina* 1, *Lingula* 2, *Producta* 2, *Spirifera* 3, *Spiriferina* 2, *Strophalosia* 4, and *Terebratula* 2. These partly belong to genera which also occur in the Carboniferous rocks. The same strata contain 16 genera and 31 species of Lamellibranchiate molluscs, the most common of which are of the genera *Schizodus*, *Gervillia*, *Solemya*, &c.; 26 species of Gasteropoda, 2 *Nautili*, and many ganoid fishes, the most common belonging to the very characteristic genus *Palæoniscus*, of which there are 6 species (fig. 31, p. 148). All the Permian fish have heterocercal tails, like the majority of the Palæozoic genera, in which the vertebral column is prolonged into the upper lobe of the tail, whereas in most of the modern fishes the vertebral column is not prolonged into either lobe. The reptilian remains, both of the red rocks and of the Magnesian Limestone, are partly Amphibian, as shown by the Labyrinthodont *Dasyceps Bucklandi* of Kenilworth, the footprints in the red Permian sandstones of the Vale of Eden, and Corncockle Moor, in Dumfriesshire, and *Lepidotosaurus Duffii* of the lower part of the Magnesian Limestone; while others from the marl slate, *Proterosaurus Speneri* and *P. Huxleyi*, were true land Lacertilian reptiles.

Excepting the Magnesian Limestone, all the Permian rocks are red. As with the thin pellicle of peroxide of iron that incrusts the grains of sand and mud of the Old Red Sandstone, so the colour of the red Permian sandstones and marls is due to a thin incrusting pellicle of peroxide of iron, such as I have elsewhere attempted to show is often characteristic of deposits in inland waters.

I now come to the main point:—What were the peculiarities of the Physical Geography of the British area in Permian times? To explain this I shall partly use the matter published in 1871, in the 'Journal of the Geological Society,' in my paper 'On the Red Rocks of England of older date than the Trias.'

First, the plants found in our Permian strata are chiefly of genera, but not of species, common to the Coal-measures, viz., *Calamites*, *Lepidodendron*, *Walchia*, *Chondrites*, *Ullmannia*, *Cardiocarpon*, *Alethopteris*, *Sphenopteris*, *Neuropteris*, and many fragments of coniferous wood of undetermined genera. Inland waters would be likely to receive land plants borne into them by rivers, but this yields no certainly conclusive evidence, since land plants are not very uncommon in marine strata of the Lias and Oolites.

The evidence derived from the remains of Labyrinthodont Amphibia and of land reptiles, clearly points to the close proximity of land. First, there is the Labyrinthodont *Dasyceps Bucklandi* from the red Permian strata near Kenilworth, and next, *Lepidotosaurus Duffii*, found near the base of the Magnesian Limestone, where it gradually passes into the underlying marl slate, and from the marl slate itself were obtained *Proterosaurus Speneri* and *P. Huxleyi*, both, according to Huxley, true land Lacertilian reptiles. Further north, in the red sandstones of the Vale of Eden, Professor Harkness found footprints, apparently of Labyrinthodonts, at Brownrigg, in Plumpton, and near Penrith; and many years ago numerous footprints were described by the late Sir William Jardine, which were found on the surfaces of beds of sandstone in Corncockle Moor and in other parts of Dumfriesshire. All of these footprints clearly indicate that the animals were occasionally accustomed to walk on bare damp surfaces, which were afterwards dried by the heat of the sun, before the flooded waters overspread them with new layers of sediment in a manner such as now takes place during variations of the seasons in many modern salt lakes. Pseudomorphs of crystals of salt in the Permian beds of the Vale of Eden, and deposits of gypsum and peroxide of iron, help to this conclusion, together with the occurrence of sun-cracks or rain-pittings impressed on the beds. The Pseudomorphous crystals of salt tell of the evaporation of pools by solar heat, for neither crystals of chloride of sodium (salt), nor deposits of sulphate of lime (gypsum), could have been formed amid common mechanical sediments at the bottom of an open ocean. Only concentration of salts, by solar evaporation of inland waters, could have produced this result.

Eight genera and 21 species of fishes have been found, chiefly in the marl slate. They are *Acrolepis* 1, *Cœlacanthus* 2, *Dorypterus* 1, *Gyracanthus* 1, *Gyropristis* 1, *Palœoniscus* 11, *Platysomus* 2, and *Pygopterus* 2. Generically they have strong affinities with those of the Carboniferous age, some of which were undoubtedly truly marine, while others certainly penetrated shallow lagoons bordered by peaty flats. There is nothing extraordinary in the occurrence of seafish in an inland salt lake.

If we now turn to the assemblage of shells we shall find it to be very poor in number. In the red marls and bands of Magnesian Limestone at and near Manchester, the very few species found in the marls and thin limestones are poor and dwarfed in aspect, and in this respect, and the small number of genera they somewhat resemble the living molluscan fauna of the Caspian Sea.

In the true Magnesian Limestone district of Nottinghamshire, Yorkshire, and Durham, the case is somewhat different. There we find a more numerous molluscan fauna, but wonderfully restricted when compared with that of Carboniferous Limestone times. I give it in some detail, that the reader may judge for himself, as the facts have an important bearing on my argument. The numbers are taken from Mr. Etheridge's forthcoming work.

Brachiopoda.—*Camarophoria* 3, *Crania* 2, *Discina* 1, *Lingula* 2, *Producta* 2, *Spirifera* 3, *Spiriferina* 2, *Strophalosia* 4, *Terebratula* 2: in all, 9 genera and 21 species.

Lamellibranchiata.—*Aucella* 1, *Mytilus* 2, *Avicula* 2, *Gervillia* 5, *Arca* 2, *Cardiomorpha* 1, *Ctenodonta* 1, *Leda* 1, *Myalina* 1, *Myochoncha* 1, *Pleurophorus* 1, *Edmondia* 1, *Astarte* 2, *Schizodus* 5, *Solemya* 4, *Tellina* 1: in all, 16 genera and 31 species.

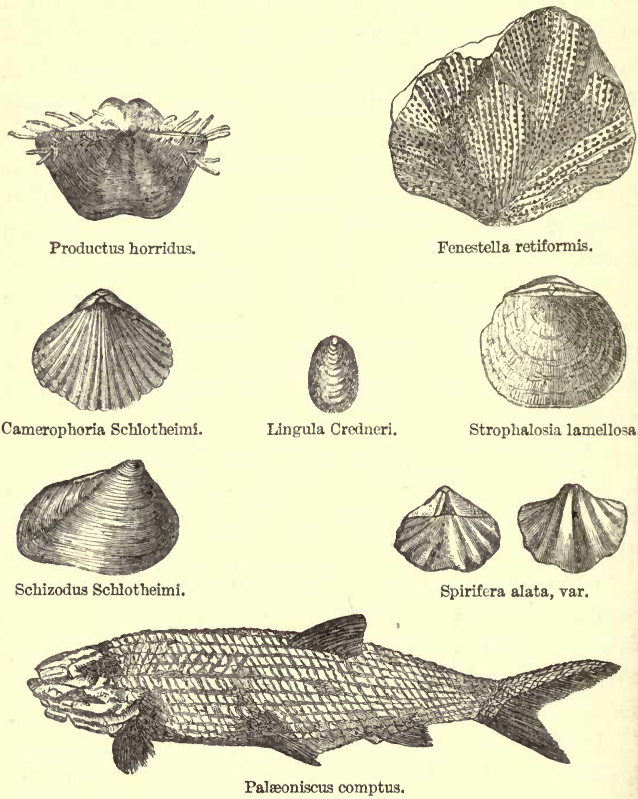
Univalves.—*Calyptræa* 1, *Chemnitzia* 1, *Chiton* 3, *Chitonellus* 4, *Dentalium* 1, *Natica* 2, *Pleurotomaria* 3, *Rissoa* 1, *Straparolus* 1, *Turbo* 5, *Turbonilla* 4: in all, 11 genera and 26 species.

Pteropoda.—*Theca* 1.

Cephalopoda.—*Nautilus* 1.

The whole comprises only 38 genera and 80 species, a very poor representative of the teeming life in the Carboniferous Limestone sea, from which more than 1,500 species have been named. It is to be remarked also,

FIG. 31.



Group of Permian Fossils.

that all of the Permian shells are dwarfed in aspect, when compared with their Carboniferous congeners.

In this poverty in number, and dwarfing of the forms, these Permian fossils may be compared with the still less numerous fauna of the Caspian Sea, as far as that fauna is known, which sea, or brackish lake, was, it is believed, once connected with the northern ocean, as the fauna seems to testify. My belief is, that these Permian waters were also of an inland, unhealthy nature, and, like those of the Caspian, had previously been connected with the open ocean.

Besides the poverty in number and small size of the mollusca, the chemical composition and lithological structure of the Magnesian Limestone, seem to me to afford strong hints that it was originally deposited in a large inland salt lake, and not that it was entirely derived from calcareous organisms, and subsequently altered into dolomite by chemical changes. I am well aware that there are such masses, occasionally, for example, in the Carboniferous Limestone which was formed in an open sea. Some modern atolls are known to become dolomitised, as described by Dana, but in the Magnesian Limestone corals are chiefly conspicuous by their absence. I repeat that the Permian Magnesian Limestone was not, as used to be supposed, formed in the sea, but in an inland salt lake, under such circumstances that carbonates of lime and magnesia were deposited simultaneously, probably, by concentration of solutions due to evaporation. In an open sea, lime and magnesia only exist in solution in very small quantities, and limestone rocks there are formed, as in coral reefs, by organic agency.

In some of the lower strata of the Magnesian Limestone, when weathered, it is observable that they consist of many curious thin layers, bent into a number of very small convolutions, approximately fitting into each other, like sheets of paper crumpled together. These dolomitic layers convey the impression that they are somewhat tufaceous in character, as if the layers, which are unfossiliferous, had been deposited from solutions.

In other parts of the district, along the coast of Durham, large tracts of the limestone consist of vast numbers of ball-shaped agglutinated masses, large and small, and I have observed in limestone caverns, in pools of water surcharged with bicarbonate of lime, that sometimes precipitation takes place on a small scale producing similar nodular bodies. It is notable also that when broken in two, many of the balls are seen to have a radiated acicular structure, that is to say, from the centre rudely crystalline-looking bodies all united, radiate to the circumference. In other places we find numerous bodies radiating in a series of rays that gradually widen from the centre, and are unconnected at their outer ends, which remind the spectator of radiating corals. There is, however, nothing organic about them, and I do not doubt that they owe their growth to some kind of crystalline action going on at the time that the limestone was being formed.

The occurrence of gypsum in the marly strata of the Permian series, helps to the conclusion that they were all deposited in inland waters, for it is impossible to conceive of pure sulphate of lime having been thrown down from solution in the ocean.

In these views I do not stand alone, for similar conclusions are held by Dr. Sterry Hunt, as shown in Sir William Logan's 'Geology of Canada,' and Professor Dana in his 'Manual of Geology.'

The chemical argument is not, however, what first led me to suspect that the Permian Magnesian Limestone was deposited chiefly from solution, in an inland salt sea, but rather the poverty and dwarfed character of the fauna alone, while I soon saw that the chemical deposition of the limestone may account for the total absence of fossils in the larger part of the formation. Whether or not the water was too salt for the healthy production of numerous shells and corals, is a question I have not yet attempted to solve, being in the meanwhile content to prove (as I think) that the waters formed inland lakes, that lay in a large continent which began in Old Red Sandstone times, but had undergone many modifications in its physical geography before the Permian lake-basins came into existence.

CHAPTER XI.

NEW RED SANDSTONE AND MARL, AND RHÆTIC BEDS.

The New Red Sandstone Series, or Trias, succeeds the Permian strata. It has received the name of *Trias* from the fact that when fully developed, as in Germany, it consists of the three great divisions of *Keuper* marls, *Muschelkalk*, and *Bunter Sandstein*. Comparatively few genera and no species of bivalve shells pass thus far upwards. The majority of the old genera of Brachiopoda disappear, and the whole grouping of the fossils now ceases to be Palæozoic, and assumes a character common to the Mesozoic or Secondary strata. The British section, with the exception of the Muschelkalk, is as follows:—

Keuper	Red marl and thin bands of white sandstone, with Rock-salt.
	White sandstone and red marl.
	(Muschelkalk absent in Britain).
Bunter	Soft red sandstone.
	Quartz conglomerate.
	Soft red sandstone.

These beds, with variations, occupy the undulating lands from Devonshire along the banks of the Severn, round the eastern borders of the Palæozoic rocks of Herefordshire and North Wales. From thence they stretch eastward to the Permian and Carboniferous rocks of Lancashire, North Staffordshire, and Derbyshire. They surround all the midland coal-fields and Permian beds between Shrewsbury, Coventry, and Derby, and from thence, everywhere unconformably overlying the Permian rocks, they stretch north in a long band from Nottingham to the river Tees.[1] The general arrangement of these strata will be easily understood by help of the diagram, p. 154.

No fossils are known in the New Red or Bunter Sandstones of England, but a few marine shells are found in equivalent strata on the Continent.

In England, above the Upper soft red sandstone are beds of red, white, and brown (Keuper) sandstone, with interstratifications of red marl, often ripple-marked, and containing bones and footprints, chiefly of Labyrinthodont reptiles, together with a few plants and a peculiar fish, *Dipteronotus cyphus*, found near Bromsgrove, in Worcestershire. The larger impressions of footprints are 8 to 10 inches in length, and in front of each there often is a smaller one made by the forefoot, fig. 33.

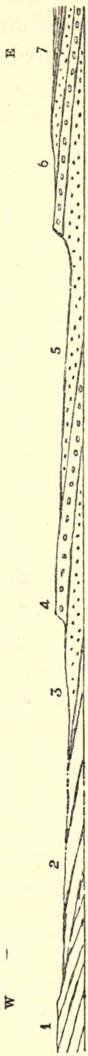
In beds of Magnesian conglomerate at the base of, and associated with the New Red Marl at the edge of the Mendip Hills, Dr. Riley and Mr. Stutchbury discovered

[1] The Muschelkalk (absent in Britain) may be well seen, among other places, near Gotha, and at Eisenach, in Thuringia. It is a grey shelly limestone, rich in *Terebratulæ*, *Trigoniæ*, *Myæ*, *Plagiostomas*, *Aviculæ*, *Oysters*, and *Pectens*. The genus *Ceratites*, closely allied to, if not a true *Ammonite*, occurs here. Lamellibranchiate molluscs, some of new genera, abound as individuals, while Brachiopoda (excepting *Terebratulæ*) sink in the scale.

At Guttenstein and Werfen, in the Austrian Alps, there are strata at the base of the New Red Sandstone which are not Permian, and which contain a rich and peculiar fauna—*Ammonites*, *Belemnites*, and other secondary forms, being mixed with *Orthoceratites*, *Goniatites*, and other genera usually considered characteristic of Palæozoic times.

FIG. 32.

Typical section across the New Red series, Shropshire, showing their relation to the Permian and Coal-measure formations.



7. New Red Marl . . . . . . } Keuper.
6. White and red sandstones and conglomerate . }
5. Red Sandstone } Bunter.
4. Conglomerate . . . . . . }
3. Red Sandstone }
2. Red Sandstones and Marls . . . . . Permian.
1. . . . . Coal-measures.

the bones of land lizards, *Thecodontosaurus antiquus*, *Palæosaurus Cylindrodon*, and *P. Platyodon.*

The rock salt of England lies above these beds in the great marly plains of Lancashire, Cheshire, and Worcestershire. It is found at varying depths, in interrupted lenticular beds, ranging from a few feet to about 120 feet in thickness. No fossils occur in the salt. The mass is usually of a reddish colour, due to the presence of ferruginous impurities.

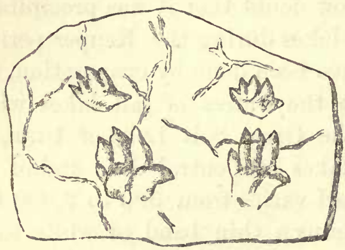
For long there was a total absence of any rational account of the manner of deposition of rock-salt, but I think few geologists now doubt that it was precipitated in supersaturated salt lakes during the Keuper period; and this could only have been done by evaporation, due to solar heat acting on the waters of salt lakes which had no outflow, like the Great Salt Lake of Utah, for example, or the salt lakes of Central Asia and of the Sahara.[1] The red marl varies from 500 to 2,000 feet in thickness, and contains a thin band of white sandstone, often with pseudomorphs of crystals of rock-salt, and also bearing a small bivalve crustacean, *Estheria minuta*, a lamellibranchiate small bivalve shell, *Pullastra arenicola*, a fish, *Hybodus Keuperi*, footprints of *Labyrinthodon giganteus*, and others, also bones of reptiles, and traces of land plants, fig. 33. Teeth also of a small Marsupial mammal, *Microlestes antiquus*, occur in the red marls near Watchett in Somersetshire. This is the oldest known mammalian relic. In Scotland, at Lossiemouth, Keuper sandstones contain scutes and bones of a crocodile, *Stagenolepis Robertsoni*, Hyperodapedon, and a land lizard, *Telerpeton Elginense.*[2]

[1] See memoir 'On the Physical Relations of the New Red Marl Rhætic Beds, and Lower Lias:' Geological Journal, 1871: Ramsay.

[2] On the Continent, near Strasburg, about thirty species of plants

On the whole, the same kind of arguments already applied to the Permian strata, may, with increased force, be used in relation to the New Red Sandstone and marl, especially the occurrence of rock-salt, gypsum, the red colour of the rocks, and the prevalence of the foot-prints and bones of Labyrinthodont Amphibia, and the remains of crocodiles, land lizards, Deinosauria, and plants. To me there remains no trace of a doubt that the New Red Sandstone was deposited in an inland lake, or lakes, possibly fresh, but probably brackish, and that

FIG. 33.



Labyrinthodon giganteus.

Estheria minuta.

Triassic Fossils.

the overlying Keuper or New Red Marl beds were formed in a great salt lake, or lakes, if we take all Europe into account.

But inferences still more striking may be drawn respecting the Physical Geography of the time.

By referring to the descriptions of the Old Red

are known in the Bunter beds, chiefly Ferns, Calamites, Cycads, and Coniferæ, and with them fish and Labyrinthodont amphibia, and marine mollusca of the genera *Trigonia*, *Mya*, *Mytilus*, and *Posidonia*, so few in number, that in connection with the Labyrinthodonts, &c., they suggest the idea not of an open ocean, but of a salt lake. Teeth of a Marsupial mammal (*Microlestes antiquus*) occur in a bed between the Keuper and Liassic strata in Würtemburg.

Sandstone, Carboniferous, Permian, and New Red formations, it will be seen that, by the writer, they are all considered to afford evidence of continental as opposed to purely marine conditions; for the Old Red Sandstone was deposited in fresh water, the Coal-measures, whether below, interstratified with, or above the Carboniferous Limestone, on the edges of, and to a great extent *on*, a continent with large rivers, marshes, and beds of peat, and the Permian and New Red series both in salt lakes; in other words, *a great continental epoch in Northern Europe (and in other regions), lasted from the close of the Upper Silurian epoch down to the end of the deposition of the New Red Marl, one main feature of which was the abundance of reptilian life, partly Amphibian.* Those parts of it in which the Permian and New Red strata were deposited can be best compared physically to the great area of inland drainage of Central Asia, so dry and arid where not artificially irrigated by rivers, and in which, from the Caspian Sea for 3,000 miles to the east, and far south towards the Himalayah, in a comparatively rainless district, all the lakes are salt, excepting those which have an outlet into some lower lake.

I specially draw attention to these remarkable inferences, for surely they give something like a broad view of an old phase of a long-enduring physical geography, so long, indeed, in my opinion, '*that the great continental era, which began with the Old Red Sandstone and closed with the New Red Marl, is comparable, in point of geological time, to that occupied in the deposition of the whole of the Mesozoic or Secondary series (later than the New Red Marl) and to the whole of the Cainozoic or Tertiary formations, and, indeed, to all the time that has elapsed since the begin-*

ning of the deposition of the Lias down to the present day.[1]

When portions of geological history can be reduced to some such form as this, it seems to possess a kind of human interest in its resemblance more or less to the physical geography of to-day.[2]

THE RHÆTIC BEDS occupy only a small space in England, estimated by superficial area ; for in general they run in a mere narrow strip between the New Red Marl and the Lower Lias, and in fact form true beds of passage from the Marl to the Liassic strata. To make this statement clear it is necessary to allude to a part of the geology of the Alps and of Italy.

Professor Stoppani has described a series of strata on the river Esino, in Italy, which he considers to be equivalent in geological time to the Red Keuper Marls north of the Alps. These strata, which he calls the *Infra-Lias*, contain about 200 species of fossils, chiefly mollusca, with a few Echinodermata and sponges, and at the top lie the well-known beds called the *Avicula contorta zone*, by Oppel, a name adopted in England for these strata by Dr. Wright, when he separated them from the ordinary beds of the Lias limestone and clay, and correlated them with their continental equivalents.

On the north side of the Tyrolese Alps, the Lower

[1] 'Proceedings of the Royal Society,' No. 152, 1874: Ramsay, 'On the Comparative Value of certain Geological Ages; or, Groups of Formation considered as Items of Geological Time.'

[2] Though I had often lectured on some of the questions respecting these old lakes and other points connected with the terrestrial conditions of the times, it was not till 1871 that I published anything on the subject in the papers alluded to in notes, and later, in 1874, in the 'Proceedings of the Royal Society.' Little or nothing is to be found in any Manual of Geology on the subject, except in the third edition of 'The Student's Manual of Geology,' by Professor Jukes, edited by Archibald Geikie, published in 1872.

St. Cassian and Hallstatt beds are believed by Hauer and Suess to represent the same strata; that is to say, they are *the ocean representatives* of the red marls of England and other parts of Europe, which I described as having been deposited *in large inland salt lakes.* The *Rhœtic beds* of England, which merely represent the very topmost part of the Italian series, seem to have been deposited in shallow seas and estuaries, or in lagoons or occasional salt lakes of small size, now and then separated from the sea by minor accidental changes in physical geography.

On the north shore of the estuary of the Severn, at Penarth, near Cardiff,[1] and elsewhere in England, there is a perfect physical gradation between the New Red Marl and the Rhætic Beds, shown by interstratifications of red, green, and grey marls, which, varying in different areas, pass upward by degrees into limestones, sandstones, and black shales. It is, therefore, impossible always to determine in this series precisely where the New Red Marl ends and the Rhætic Beds begin; and, indeed, all through the Red Marl, from bottom to top, there is a tendency to a recurrence of interstratified deposits that, lithologically, closely resemble the lower parts of the Rhætic beds, as, for example, at Penarth, near Cardiff. The 'White Lias' of Lyme Regis is now classed with this subformation.

All over England, wherever the base of the Lower Lias is well seen, the Rhætic beds, rarely more than 50 or 100 feet thick, are found to lie between the Lias and the New Red Marl. As a general rule they are seen to pass conformably and by easy gradations into each other, and they were, indeed, always classed with the Lias, till separated from these strata by Oppel.

[1] The Rhætic strata are sometimes called the Penarth Beds.

The succession of events that, through the Rhætic beds, marked the transition from the New Red Marl to the Lower Lias seems to have been as follows:—

In the latter part of the Triassic epoch, as already stated, our Keuper, or New Red Marl, beds were deposited in an area that now forms part of England, and this area was in those days a great salt lake.

This lake gradually got partly filled with sediments, and by-and-by, through change in amount of rainfall, or through increase of heat, it ceased to have an outflow, evaporation being equal to, or greater than, the influx of water. Concentration and precipitation of salts ensued as already explained.

Subsequently, during deposition of the marly sediments, by increase of rainfall, or climatic change of temperature, the water became somewhat less salt, but still sufficiently saline, by evaporation of the moisture on wet surfaces, to produce crystals of salt (now pseudomorphs) in sandy layers interstratified with the marls, together with layers and nodular masses of gypsum, which state of affairs continued up to, and even during, the deposition of recognised Rhætic strata. That Rhætic areas got dried by temporary exposure is certain, for besides the pseudomorphs, sun-cracks are common in the strata.

In our area, sinking of the district took place at or about the time when the lake or lakes got nearly filled with sediment, and a partial influx of the sea over shallow bottoms was the result. The deposits that ensued, accompanied by a small migration of marine forms of life, constitute the Rhætic beds of England.

Many years ago, the late Professor Edward Forbes stated to me that the fauna of the White Limestone of Lyme Regis, then called White Lias, reminded him, in its assemblage of forms, of the molluscan fauna of the Caspian Sea, which is few in genera and species, and of an abnormal kind, in consequence of the brackish quality of the water. In the Black Sea also, there are misshapen forms, stated by Edward Forbes to be due to the gradual freshening of the water, because of the constant influx of rivers into it, and the current that runs through the Bosphorus into the Mediterranean Sea. Both of these cases relating to continental seas of a lake-like character, bear on the subject in question; especially seeing that these British *beds of passage* are also comparatively poor in genera and species, and that some of the species, to which special names have been given, are variable or even distorted in form. Others are hard to distinguish from shells common in the Lias, while some also occur in the great Marine Rhætic series of the Continent, and some pass upwards into the ordinary Lias. It is, indeed, difficult not to believe, that some of these forms are in reality abnormal and due to the locally unhealthy quality of the water in which they lived.

Though this volume has little to do with general palæontology, the following account of the fauna bears on these questions, and I therefore give it in some detail. It also helps to show that our Rhætic beds represent a set of local conditions that marked the passage of the Keuper marls into the undoubted Lower Lias, and, indeed, in places it is hard to separate them lithologically.

In these Rhætic beds there are now known two Crustacea, viz. *Tropifer lævis,* from one of the Bone beds, and *Estheria minuta*, first known in the Keuper sandstones, and one Brachiopod, *Discina Townshendi*, the only one known in our Rhætic strata. Of the

Lamellibranchiate molluscs, *Lima præcursor* very much resembles *Lima punctata* of the Lias; *Monotis decussata* occurs at the top in thin limestone bands, which some have considered to form part of the Lower Lias. *Ostrea fimbriata* may possibly be *O. irregularis* of the Lias, but oysters are so variable in form that they are of small value in such an inquiry. *Pecten Valoniensis*, also a Rhætic shell, is a very variable form. *Plicatula intusstriata* passes into the Lower Lias. *Anoplophora musculoides*, another Rhætic shell, occurs with *Monotis decussata* in the thin bands of limestone at the top, which some geologists call Lias. *Modiola minima* is found both in the Rhætic and Lower Lias strata. Figures of some other well known fossils are shown in fig. 34.

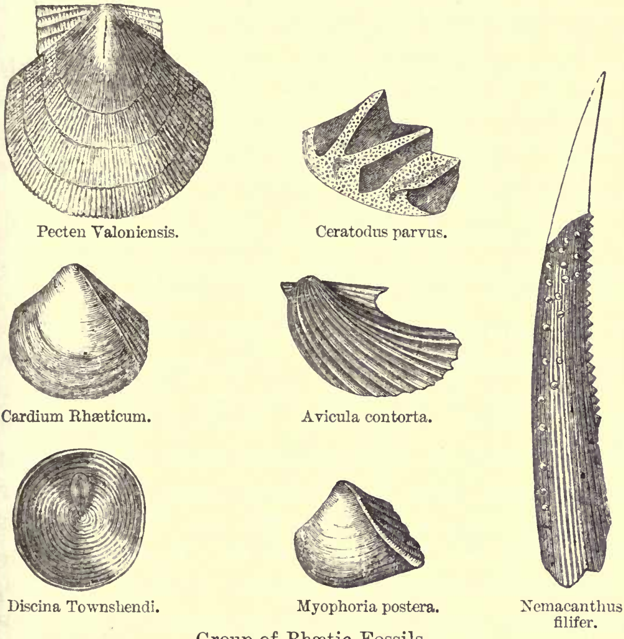
All the Gasteropoda of the Rhætic beds are said to be peculiar to that formation, and the same is the case with the fish; for, many years ago, Sir Philip Egerton declared 'that the beds in question, hitherto considered as belonging to the Lias, must be removed from that formation, inasmuch as they present a series of fishes not only specifically distinct from those of the Lias, but possess, in the Ganoid genera, the heterocerque tail, an organism confined to the fishes which existed anterior to the Lias.' [1] Of the Reptilia, *Plesiosaurus costatus*, *P. Hawkinsii*, *P. trigonus*, and, according to the late Mr. William Sanders, *Ichthyosaurus platyodon*, are common to these Rhætic beds, and to the basement beds of the Lower Lias. The discovery by Professor Boyd Dawkins of the small Marsupial mammal *Microlestes antiquus*, in the grey marls at Watchett, in Somersetshire, is not without significance, for it speaks

[1] 'A Notice on the Occurrence of Triassic Fishes in British Strata;' 'Proceedings of the Geological Society,' 1841, vol. iii., p. 409.

of the neighbourhood of land that bordered the old Triassic lake, and the succeeding shallow Rhætic sea, part of which was the Mendip Hills, 'the home of the Microlestes.'[1]

In the beds of passage, from 10 to 50 feet above

Fig. 34.



Group of Rhætic Fossils.

the Bone bed, there are certain thin bands in Gloucestershire, named by the Rev. P. B. Brodie, who

[1] For notices of this old land, see De la Beche 'On the Formation of the Rocks of South Wales and South-West of England'; and Ramsay, 'Denudation of South Wales and the Adjacent Counties of England,' Mem. Geol. Surv. vol. i. 1846; and 'Abnormal Conditions of Secondary Deposits,' &c., by Charles Moore, 'Quarterly Journal Geol. Soc.' vol. xxiii., 1867.

first described them, the 'insect limestones.' The fossilised contents of these bands throw some light on the physical geography of the lands that bordered the waters of the time, for in them have been found numerous elytra and other remains of Beetles, Grasshoppers, Cicadas, Dragon-flies, and other neuropterous insects, associated with a fresh-water shell of the genus *Cyclas*, the shells of *Cypris*, and with ferns, Cycads, and leaves of Monocotyledonous plants. These beds, therefore, indicate either fresh-water strata, or else the immediate proximity of land, from whence streams washed into the sea insects, fresh-water Crustacea, shells, and land plants.

Sir Charles Lyell remarks that 'the size of the species (of insects) is usually small, and such as taken alone, would imply a temperate climate; but many of the associated remains of other classes must lead to a different conclusion.'[1] This, however, seems to be explained by a remark long ago made to me by Edward Forbes, who, while working with Captain Graves, during the hydrographical survey of the Ægean Sea, observed that, during heavy rains, vast numbers of insects were washed into the sea, not such as inhabited the low hot shores of the Ægean, but those that lived in the high cool regions of the neighbouring mountains, which, caught in the floods of rain, were washed into rivers and borne onwards to yield food for fishes in the ocean.

In conclusion, if, as I believe, the New Red Marl was deposited in a salt lake, if it be the equivalent in time of the marine *Infra-Lias* beds of Stoppani in Italy, and of the Lower St. Cassian and Hallstatt beds of Hauer and Suess, then the *Avicula contorta* beds,

[1] 'Student's Elements of Geology,' p. 351, 1874.

being the natural marine successors of these strata on the Continent of Europe, are in like manner *the natural marine successors of the lake-formed sediments of the red Keuper marls*, and in reality are true passage beds from those red marls into the Lower Lias; and a candid consideration of the fossil fish, reptiles, shells, insects, and plants of the British Rhætic strata strengthens this view. When the waters of the old lakes were invaded by the sea, a migration of a few marine forms took possession of the old lacustrine area, and this depression gradually proceeding, culminated in the development of the great Liassic fauna, at a time when the old continent was submerged, and the mountain tracts were converted into groups of islands, the shores of which were washed by a broadening Liassic sea.

CHAPTER XII.

LIASSIC AND OOLITIC, OR JURASSIC STRATA.

In the previous chapter, I stated that the continental area in which lay the lakes of the epoch of the New Red Marl, underwent partial submersion, during which our passage beds, called the Rhætic or *Avicula contorta* strata, were deposited. This sinking of the land going on by degrees, resulted in the formation of groups of islands, round which, first the Lias, and afterwards the Oolitic series were deposited, the whole, on the Continent of Europe, and now often in Britain, being grouped under the name of *Jurassic* formations.

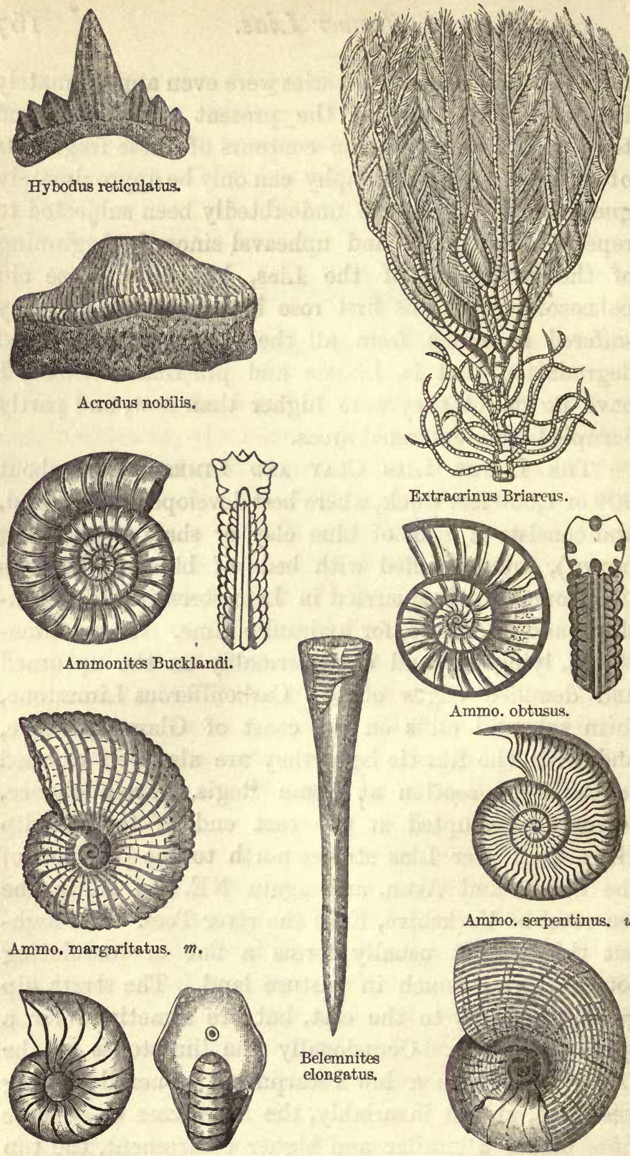
The general stratigraphical relations of the larger masses of the Liassic and Oolitic series, in the southern half of England, will be easily understood by reference to fig. 5, p. 25.

The high ground now called Wales and Herefordshire, undoubtedly formed part of one of these islands; Dartmoor and other palæozoic elevations in Devon and Cornwall formed others; probably the hilly regions of Derbyshire another; and, certainly, the Cumbrian mountains a fourth; while there can be no doubt that parts of the south of Scotland, and the greater heights of the Highlands, also stood as islands washed by the Liassic sea.

It is not, however, to be supposed that the actual forms of these island territories were even approximately identical with those of the present mountains, and the limits and orographic contours of these fragments of an old physical geography can only be approximately guessed at. They have undoubtedly been subjected to repeated disturbance and upheaval since the beginning of the deposition of the Lias, but after these old palæozoic mountains first rose high into the air, they suffered so much from all the agents of waste and degradation, that in Liassic and pre-Liassic times, I have no doubt they were higher than now, and partly occupied more extended areas.

The Lower Lias Clay and Limestone is about 900 or 1,000 feet thick, where best developed in England, and consists of beds of blue clay or shale (weathering brown), interstratified with beds of blue argillaceous limestone, largely quarried in Leicestershire, Warwickshire, and elsewhere, for hydraulic lime. These limestones, lying flat and unconformably on the upturned and denuded edges of the Carboniferous Limestone, form splendid cliffs on the coast of Glamorganshire, and, with the Rhætic beds, they are also well exposed in the coast section at Lyme Regis. From thence, scarcely interrupted at the east end of the Mendip Hills, the Lower Lias strikes north to the junction of the Severn and Avon, and again NE. and N. to the sea-coast of Yorkshire, E. of the river Tees. Throughout this area it usually forms a flat or undulating country, lying much in pasture land. The strata dip generally gently to the east, but are sometimes for a space quite flat. Occasionally the limestones of the Lower Lias form a low escarpment, generally facing west, and, almost invariably, the *Marlstone* or *Middle Lias* makes a similar and higher escarpment, the top

FIG. 35.



Group of Lias Fossils.

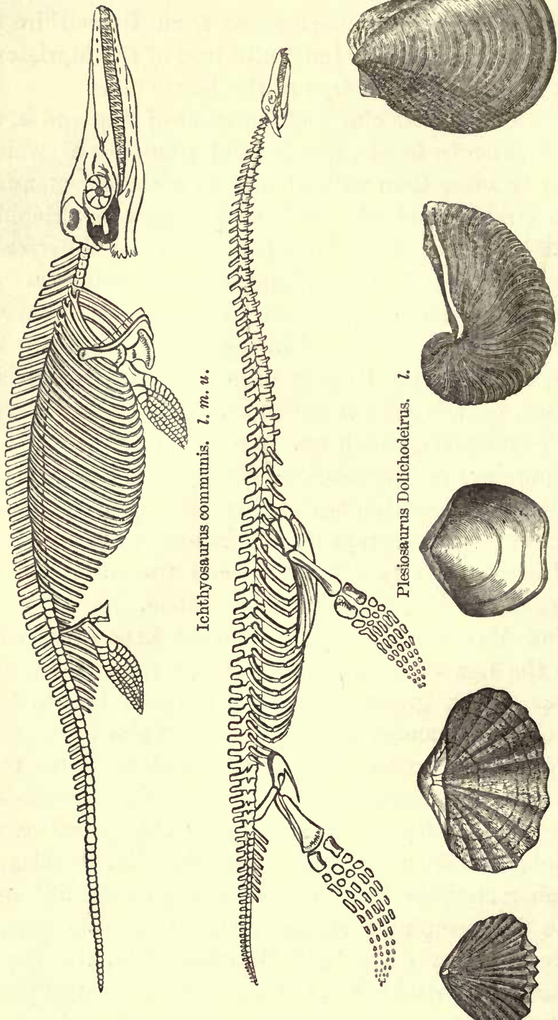
m. Middle Lias or Marlstone. *u.* Upper Lias ; all the rest Lower Lias.

of which is formed of a tough brown fossiliferous limestone, generally of only a few feet in thickness, but nearly constant in its occurrence from Dorsetshire to Yorkshire, and the very indefinite base of the Marlstone forms the eastern boundary of the Lower Lias.

The Lower Lias clay and limestone of England is, as a whole, rich in fossils, the general grouping of which cannot be more than noticed here in a cursory manner. These strata yield *Extracrinus* among the Crinoids, (fig. 35); of Brachiopoda, a few species of *Spiriferæ*, *Terebratulæ*, and *Rhynchonellæ*, and numbers of Lamellibranchiate molluscs, such as *Gryphæa incurva*, *Oysters*, *Pectens*, *Limas*, *Pinnas*, *Aviculas*, *Pholadomyas*, and others. Having been deposited mostly in deep sea, univalve shells are much less common, but of the Cephalopoda, which are free swimmers, there are vast numbers of *Ammonites*, *Belemnites*, and *Nautili* (see fig. 35), together with many fishes, and the great marine Enalosaurian reptiles, *Ichthyosaurus* (fish-lizard) and *Plesiosaurus* (see fig. 36), and the insectivorous flying reptile, *Pterodactylus brevirostris*.

The Marlstone series, or Middle Lias, which succeeds the Lower Lias clay, is generally somewhat argillaceous below, graduating upward into a brown, ferruginous, soft, sandy rock, with hard nodular bands, and a very marked brown ferruginous limestone at the top. It is ricn in many forms of *Ammonite*, *Belemnite*, *Plagiostoma*, *Lima*, *Pinna*, *Pholadomya*, *Pecten*, *Modiola*, *Terebratula*, and *Rhynchonella*, besides a very characteristic *Spirifer* (*S. Walcotti*, fig. 36), one of the few remaining shells of that Palæozoic genus. Where the Lower Lias and Marlstone join, the strata *graduate into each other*, but through the central parts of England these passage-beds are rarely clearly ex-

Fig. 36.



Ichthyosaurus communis. *l. m. u.*

Plesiosaurus Dolichodeirus. *l.*

Rhynchonella tetrahedra. *m.* Spirifera Walcotti. *l. m.* Terebratula numismalis. *l.* Grypha incurva. *l.* Lima gigantea. *l.*

Group of Lias Fossils.

l. Lower. *m.* Middle. *u.* Upper.

posed. In Yorkshire, however, on the sea-cliffs near Staithes, the stratigraphical relations of the strata are perfectly clear, and it is evident that there is no line of demarcation between them, and through about 15 feet of strata, including some of the well-known beds of ironstone, fossils common to both occur, one of the most conspicuous of which is *Pecten æquivalvis.*

The Upper Lias Clay plays a comparatively unimportant part in the physical geology of England. In Gloucestershire it first begins to appear near Bath, but so thin, that it is impossible to represent it on maps of the 1-inch to a mile scale. About Wotton-under-Edge it begins to get more definite, and from thence, in a narrow strip between the Marlstone rock, and the sands beneath the Inferior Oolite, it runs northward by Dursley, Stroud, Painswick, and Chipping Camden, and following all the contours of the Oolitic escarpment, looks out upon the great plain of Lias, in the broad valley of the Severn, or winds about among the intricate system of minor valleys that lie between Minchin-Hampton and Chipping Camden, and between Burford and Banbury. In this progress, gradually increasing in thickness, it forms great tracts of the clay lands in Northamptonshire, between Great Brington and Arthington, and in the neighbourhood of Uppingham and Oakham in Rutland, while further north, the clay runs in a long narrow strip, still overlying the Marlstone, into Yorkshire, where it is finely exposed in the sea-cliffs near Whitby, and where in old times great excavations were made for the extraction of shale, and the manufacture of alum.

Taken as a whole, the Upper Lias is a stiff dark blue clay, with occasional layers of limestone often nodular, containing many *Belemnites*, *Ammonites*, and

Nautili, and bivalve shells, similar, in general grouping of genera, to those of the Marlstone and Lias clay, with both of which, but especially with the Marlstone, it has species in common. In Yorkshire, the well-known jet of Whitby is excavated from the shales on the cliffs, and is formed of the fossilised stems of coniferous trees that grew on the hilly islands, on the west and north.

The remarkable assemblage of large Reptilia that inhabited the Liassic seas, the number of great and small Cephalopoda, including many species of Ammonites, Nautili, and Belemnites, the swarms of Terebratulæ and Rhynchonellæ, the plentiful genera and species of Lamellibranchiate molluscs and of univalve shells, all speak of warm seas, surrounding islands, on which grew Cycads, Zamias, and other plants, that seem to tell of a tropical or subtropical climate. Nor was this phase of the physical geography of the time specially peculiar to the Lower Lias, for it belongs alike to each of the divisions, and, as we shall by-and-by see, was continued into much later times.

Nothing is more clear to me than this, that there was no break in time between the successive conventional divisions of the Lower, Middle, and Upper Lias. Each in ascending succession lies quite conformably on the other; between the Lower and Middle divisions there is a clear lithological passage, accompanied by passage of species, and though there is generally a very sudden break in lithological character between the Marlstone and the Upper Lias clay or shale (due, perhaps, to rapid depression of the area), yet contrary to a not unprevalent belief, there is a greater number of species common to these divisions than is generally imagined.

Out of 668 known species in the Lower Lias, 94, or about 14 per cent. pass into the Middle Lias; and of 500 species in the latter, 57, or about $11\frac{1}{2}$ per cent. pass into the Upper Lias; while of 312 Upper Lias species, 39, or about $12\frac{1}{2}$ per cent. pass into the Inferior Oolite which succeeds it.

Few biologists and geologists now believe in the sudden extinction of entire old marine faunas, or even of the greater part of them, and their equally sudden replacement by new creations; for it begins to be generally understood that life is variable and progressive, the change of species in given areas being due chiefly, *in comparatively short epochs*, to migrations out of and into these areas, in consequence of changes of local conditions, such as depth of water, and nature of sediments, while in long periods of geological time, it is best accounted for by that process of evolution so clearly expounded by Darwin. Neither is it a fair test of the community of species in two so-called formations, to take the entire fauna of the lower one, and calculate the percentage of forms that pass into the overlying deposit, for, between the lower and upper parts of many thick formations, there is often the same kind of difference in assemblage of species that there is between the adjoining parts of two so-called distinct formations. In judging then of passage of species, if we had all the data, the fairest method would generally be to estimate the passage of forms by those in common between the upper part of the lower formation and the lower part of the upper one, in which case it would often be found, when there is a natural conformity between the strata, that the percentage of species that pass onward is much increased.

We now come to the Oolitic series of strata.

On the flank of the Cotswold escarpment, south of

Wotton-under-Edge, in Gloucestershire, the Upper Lias clay is very poorly developed, and between it and the ordinary limestone of the Inferior Oolite, there are thick beds of soft brown sand, with intermittent hard, sandy, calcareous bands, containing Ammonites, Belemnites, Pentacrinites, and bivalve shells. Above these there are bands of impure sandy limestone, called in 1856, by Dr. Wright of Cheltenham, the Cephalopoda bed, because of the prevalence in it of Ammonites, Belemnites, and Nautili, some of which, with other forms, are also common in the Upper Lias clay. This fact induced him to consider these sands and impure limestone to be so intimately related to the Upper Lias, that he named them in his Memoir 'the Upper Lias Sands '[1] instead of 'the Mitford Sands (of the Inferior Oolite,') a name long before given to them by William Smith.

According to existing lists, 17 species of Conchifera pass from the sands into the overlying Oolite strata, and, indeed, about 39 or 40 species of all kinds are common to the Upper Lias and the overlying Oolitic formations,[2] thus linking the Lias to the Oolites in a continuous chain of specific life.

Throughout the southern half of England, from the English Channel to the borders of Northamptonshire, the various members of the Oolitic series maintain a tolerably uniform character.

The Inferior Oolite Limestone forms the lowest member of this series. It first appears between the west end of the Chesil Bank and Bridport Harbour in Dorsetshire, from whence, underlaid by the before-mentioned sands, broken and interrupted by many faults, it ranges

[1] 'Journal of the Geol. Soc.' 1856, p. 292.

[2] As catalogued by Mr. Etheridge.

northward by Beaminster and Sherborne to the east end of the Mendip Hills and the neighbourhood of Bath, where it forms the flat tops of the scarped hills intersected by so many winding valleys. From thence, in a long narrow strip, it runs on by Wotton-under-edge, Dursley, and Painswick, in Gloucestershire, near which, on the flat-topped Cotswold Hills east of Cheltenham, it broadens, and more or less forms great part of the wide plateau that extends from Burford to the neighbourhood of Chipping Camden. Beyond this region it narrows, and finally thins away, and as a limestone disappears in Oxfordshire, a few miles north-east of Chipping Norton, where I shall leave it for a time.

It chiefly consists of yellow limestone, and along with other limestones of the series is called Oolitic, for in many cases they consist of concretionary bodies about the size of a pin's head, compacted like the eggs that form the roe of a fish (egg-stone) cemented in a calcareous matrix. One of the most typical sections occurs near Cheltenham, on the summit of the bold escarpment that overlooks that town. There, at the base, the Oolitic grains are often as large as peas, and the rock is locally called pea-grit.

The whole is apt to be fossiliferous, abounding in Lamellibranchiate molluscs, *Limas*, *Pectens*, *Oysters*, *Cardiums*, *Pholadomyas*, *Trigonias*, and others needless here to name ; and of Brachiopoda, *Terebratulas* and *Rhynchonellas* are exceedingly numerous. Gasteropoda also occur in profusion, including species of the genera *Pleurotomaria*, *Natica*, *Littorina*, *Patella*, &c. *Belemnites*, *Ammonites*, and *Nautili* are found in profusion, together with genera and species of sea-urchins, such as *Cidaris*, *Pseudo-diadema*, *Pygaster*, &c.

Plants are rare in the purely marine strata of Gloucestershire and the south of England, but fragments of coniferous trees are sometimes found, the most remarkable of which is a large cone of *Araucarites hemisphœricus*. This, in addition to the nature and multiplicity of genera and species of the marine fauna, plainly tells of land not far off, a fact that will become still more clear as we get further on with the history of the Oolites, and its bearing on the old physical geography of the land of the Oolitic epoch.

THE FULLER'S EARTH accompanies and overlies the Inferior Oolite through the whole length of this area, excepting where locally interrupted by faults. It consists chiefly of tenacious bluish clay, with frequent thin shelly bands of limestone, often largely charged with a small oyster, *Ostrea acuminata*, and with Terebratulæ. In the neighbourhood and south of Bath a strong band of limestone lies in the middle of the clay, known as the Fuller's Earth Rock.

Near Upper Slaughter in Oxfordshire, this subformation entirely thins away, and is known no more. Its greatest thickness, near Bath, is about 200 feet. The name was originally given to it by William Smith, because in places it contains beds of Fuller's Earth, long ago much used in the famous woollen factories of Gloucestershire. I call it a subformation, because very many of its fossils are also common in the Inferior Oolite, though a few are peculiar.

THE GREAT OR BATH OOLITE of this southern half of England succeeds the Fuller's Earth, and consists, when fully developed, of

Forest Marble.
Great Oolite.
Stonesfield Slate.

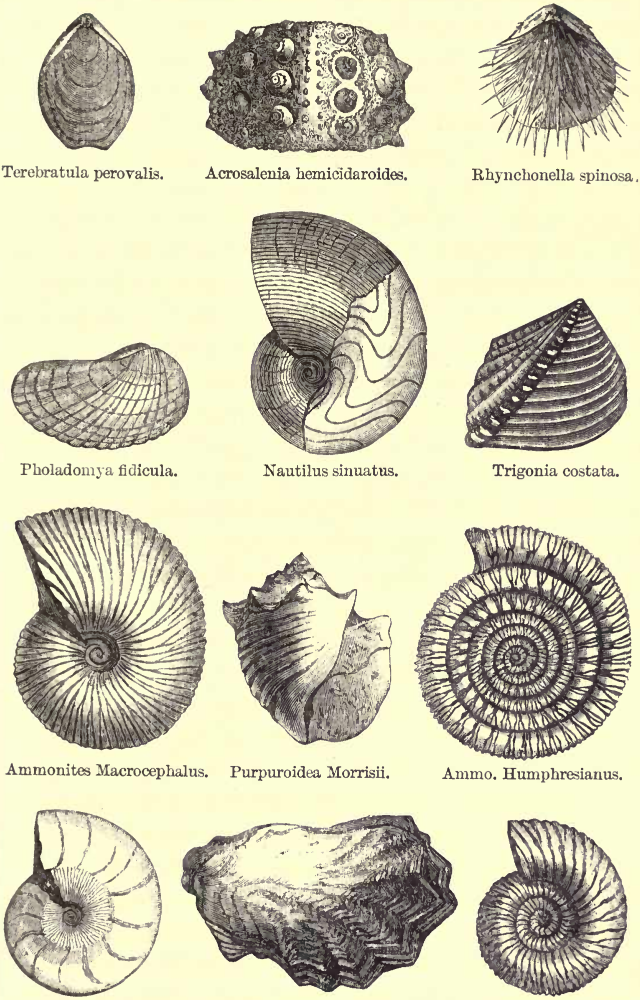
The local development called the *Stonesfield Slate* consists of beds of laminated shelly and oolitic limestone and sandy flags, with much false bedding, and containing ferns, *Cyclopteris*, *Glossopteris*, *Pecopteris*, &c.; Cycads, *Bucklandia squamosa*, Zamias, *Palæozamia* of various species, and Coniferæ. Elytra of beetles and wings of insects (*Libellula Westwoodii*, &c.); bones of *Plesiosaurus*, *Crocodile*, &c.; also *Ostrea*, *Terebratula*, *Rhynchonella*, *Lima*, *Pecten*, *Trigonia*, *Patella*, *Nerinæa*, *Belemnites*, *Ammonites*, &c., are all found in these thin shallow water deposits. The reptiles include *Ichthyosaurus advena*, *Plesiosaurus erraticus*, and crocodiles of the genus *Teleosaurus*, allied to the Gavial of the Ganges (*T. brevidens* and *T. subulidens*), together with a great carnivorous lizard, *Megalosaurus Bucklandi*, that walked on the neighbouring land, and was probably about 30 feet in length. A flying reptile, *Ramphorhynchus Bucklandi*, allied to the Pterodactyle, is found in this subformation, which has long been especially celebrated as containing the remains of mammals, viz. the lower jawbones of species of small insectivorous marsupials, *Amphitherium Broderipii*, *A. Prevostii*, *Phascolotherium Bucklandi*, and *Stereognathus Ooliticus*.

I call the Stonesfield Slate a local development because it is by no means of universal occurrence at the base of the Great Oolite, and is chiefly known in those parts of Gloucestershire that lie eastward of Cheltenham on the broad Oolitic plateau, and in Oxfordshire at and near the town of Stonesfield, where it perhaps attains its greatest thickness. There it is largely manufactured into what are called slates, but in reality are small slabs, the coarse fissile character of which has no relation to what is known as slaty cleavage. From these areas going south along the Oolites, the Stonesfield Slate rapidly thins away, or changes its lithological character, for it is quite unknown at the base of the Great Oolite towards Wotton-under-Edge and Bath. In the opposite direction going northward, the Stonesfield Slate passes into the Northampton Sand, where we will leave it for the present.

The Great Oolite was originally so called by William Smith in 1812, and the Upper Oolite in 1815, to distinguish it from the Lower or Inferior Oolite, which lies below the Fuller's Earth, whereas the former lies above it. It is often named the Bath Oolite, and the greatest development of that excellent building-stone is near the city, which is almost entirely built of 'Bath stone.' It first makes its appearance on the south near Norton St. Philip, about six miles south of Bath, from whence, overlaid by Forest Marble, it ranges northerly, forming the flat-topped scarped hills on either side of the Avon near Bath, and so on by Wotton-under-edge to Minchin-Hampton. Beyond this it forms a large part of the table land, intersected by valleys, that lie between Minchin-Hampton in Gloucestershire and Towcester in Northamptonshire. In Northamptonshire its lowest sandy beds are the equivalents of the Stonesfield Slate. To this part of the subject I shall return in describing important physical changes that take place further north.

The best beds of the Great Oolite are of cream-coloured limestone, so soft when first extracted from the quarry, that it can be easily sawed into blocks, but hardening on exposure. Some of its fossils are also found in the Fuller's Earth and the Inferior Oolite, and a few are first known in the Lias, and, indeed, throughout the whole there is a general agreement in the

FIG. 37.



Group of Fossils of the Lower Oolitic Formations.

genera of shells. Corals occur in the Great Oolite, including more than twenty species, chiefly belonging to the genera *Stylina*, *Isastrea*, *Thamnastrea*, &c., and Brachiopoda of the usual genera *Rhynchonella* (*Rh. concinna*, &c.), and *Terebratula* (*T. digona, T. obovata*, &c.), besides great numbers of Lamellibranchiata, the most numerous of which belong to the genera *Ostrea* (*O. Sowerbii*, &c.), *Pecten* (*P. vagans*, &c.), *Gervillia* (*G. monotis*, &c.), *Lima* (*L. cardiiformis*, &c.), *Mytilus* (*M. imbricatus*, &c.), *Trigonia* (*impressa*, &c.), *Cardium*, *Astarte*, *Ceromya concentrica*, &c. *Pholadomya socialis*, &c., *Cyprina*, *Pecten*, *Lima*, and many others. Near Minchin-Hampton it is rich in Gasteropoda, among the most common of which are many of the genera *Patella*, *Pleurotomaria*, *Trochotoma*, *Purpuroidea* (*P. Morrisii*), *Natica*, *Chemnitzia*, *Nerinea*, *Alaria*, *Ceritella*, *Cylindrites*, *Turbo*, and many others. Ammonites and Belemnites are rare at Minchin-Hampton, but further south Gasteropoda decline, and Cephalopoda are more numerous. Echinodermata of the genera *Acrosalenia*, *Clypeus*, *Echinobrissus*, and others are not uncommon, and Pentacrinite joints occur rarely. Fishes' teeth, *Hybodus*, *Pycnodus*, and *Strophodus*, and scales of *Lepidosteus* are sometimes found, and reptiles of the genera *Teleosaurus* and *Megalosaurus*, together with the gigantic *Ceteosaurus* (or whale-lizard), probably about 50 feet in length, and most likely amphibious.

The *Forest Marble* forms the topmost beds of the strata that usually are called Great Oolite. They are formed of shelly limestone, with much false bedding, very similar in structure to the Stonesfield Slate, and as a marble the rock has sometimes been used for ornamental purposes. Its beds are full of *Oysters*, stems of

Pentacrinites, fragments of *Echinodermata, Pectens, Aviculæ, Terebratulæ*, &c. In it occurs the *Bradford clay*, in which is found the beautiful Crinoid, *Apiocrinites rotundus*, and also *Terebratula digona*, and many fragments of Coniferous wood.

On the south coast the Forest Marble borders the sea for a considerable distance between Bridport Harbour and Portland Isle, from whence it ranges north by Wincanton to Frome in Somersetshire. A few miles further north, the Great Oolite proper crops from underneath it near Norton St. Philip, and beyond this town and Bath it everywhere overlies the Great Oolite, and forms the surface of vast tracts of country between the Avon, Cirencester, and Burford, in Gloucestershire, beyond which, towards Witney, on the river Windrush, it gets broken into outliers, and also becoming thinner, it either dies out, or is gently overlapped by the Cornbrash about three miles north of Bicester in Oxfordshire.

The Cornbrash forms the uppermost member of those formations that are usually classed as Lower Oolite. It is generally of inconsiderable thickness (15 to 100 feet), and beginning in Dorsetshire between Bridport and Weymouth, it ranges at the surface all across that county, excepting where overlapped by the Cretaceous strata between Abbotsbury and the neighbourhood of Evershot. It is remarkably constant, striking with the underlying and overlying strata all through Wiltshire, Gloucestershire, Oxfordshire, and Northamptonshire, and onward into Lincolnshire; but north of the Humber it disappears for a space, being again overlapped by unconformable Cretaceous strata.

Throughout all this long range it retains in a remarkable manner the same lithological character, showing evidence of deposition in shallow water. It is partly formed of pale marly limestones and clays, passing in places into shelly, and occasionally oolitic, building-stones. When partly decomposed near the surface, it assumes a rubbly character, and forms a fertile soil, whence its agricultural name of Cornbrash, the word *brash* being an old word expressive of this loose rubbly character.

The Cornbrash is generally very fossiliferous, the general assemblage of genera of Echinoderms, corals, Cephalopoda, Brachiopoda, Lamellibranchiata, &c. being much the same as in the Great and Inferior Oolites. So much, indeed, is this the case, that of the forms found in the Great Oolite, 100 species pass into the Cornbrash, while of those in the Inferior Oolite, 89 species pass up into the same formation.

This community of forms is very important, showing as it does, that if some of the Inferior Oolite species are absent in the Fuller's Earth and Great Oolite, they must, nevertheless, during the deposition of these strata, have lived elsewhere, and returned in a later time, that of the Cornbrash, to inhabit the same area when a congenial set of marine conditions ensued, thus establishing a strong and direct succession of life through the whole of these formations which together, in the language of the day, form the *Lower Oolite.* In fact, this division of these strata into *formations*, is in great part lithological, and the difference of faunas in them was dependent on changes of conditions of depth &c. in a sea, where limestone, sands, or clays were being deposited. The four so-called Oolitic formations already described, may in truth be spoken of as one, there being not much more difference between their fossils, than there is between those of what are called different zones in other recognised single formations.

Facts of this broad kind are of more importance to the general reader than trying to remember names of fossils, and what I now endeavour to do, is to disabuse the mind of the idea, too often implied in manuals, that the marked characteristic of strata is, that they consist of perfectly distinct zones, each having its own species, which have little connection with each other. What applies to the Lias and Lower Oolites, equally applies to the connection of the latter with the Middle, and of the Middle with the Upper Oolites, and I shall therefore treat the remainder of this subject as briefly as possible.

The next group of strata, as generally received, is formed of the Middle Oolites, which consist of the following divisions, the oldest being placed at the bottom :—

Coral Rag and Calcareous Grit.

Oxford Clay { Clay.
Kelloway Rock.
Clay ; a thin band.

In the south of England, much faulted, the Oxford Clay occupies considerable strips of country between Weymouth Bay and the river Bredy, about a mile east of Burton Bradstock. Beyond that faulted region, and the overlapping of the Cretaceous strata of Dorsetshire, the *Oxford Clay*, about 650 feet in thickness, comes on in great force at Melbury Samplord and Melbury Osmund, where it is underlaid by about 50 feet of Cornbrash. From thence it runs somewhat north-easterly, covering a broad tract of country, by Melksham in Wiltshire, and so on by Chippenham, Cricklade, Fairford, Bampton, Oxford, Bicester, Buckingham, Fenny Stratford and Bedford, north of which it covers an immense tract of country, twenty miles in width, in the neighbourhood of Huntingdon. Still further north it underlies the great alluvial flats of Cambridgeshire, and the waters of the Wash, and beyond this, in Lincolnshire, in consequence of the gradual overlap of the Cretaceous strata, the area occupied by the Oxford Clay narrows by degrees. North of the Humber it is entirely overlapped for a space, to reappear in Yorkshire, where it is well exposed on the sea-cliffs in Filey Bay, accompanied by the Kelloway Rock.

Not the least remarkable circumstance connected with the Oxford Clay is the very frequent occurrence in it of this Kelloway Rock, which some persons would willingly raise to the rank of an independent formation, because of its palæontological peculiarities. The thin clay that occasionally lies beneath it contains a goodly proportion of species also found in the Cornbrash, but a greater number found in higher parts of the Oxford Clay. When analysed it appears that the Calcareous sandstone, called the Kelloway Rock by Smith,[1] contains not less than about 150 species, of which very nearly one-half are also found in older formations, thus forming a close bond of union between them. An equal number passes upward from the Kelloway Rock into the overlying Oxford Clay, or, if absent there, are found in formations still higher in the series.

The *Kelloway Rock* contains many *Gryphœas* and *Ammonites,* one of which, *A. Calloviensis,* is especially characteristic of this stratum. Several other Ammonites, and *Ancyloceras Calloviense,* besides Nautili (*N. hexagonus*), &c., are found in it. Bra-

[1] I believe originally 'Kelloway's Rock,' named from Kelloway, who quarried it.

chiopoda and Lamellibranchiata, of genera and some species common to all the Oolites, are common. The *Oxford Clay* also contains many Belemnites, Ammonites, and other shells, among which, *Ammonites Jason*, *Ostrea flabelloides*, and *Gryphæa dilatata* are characteristic of this formation. *Trigonia costata*, an inferior Oolite species, passes upwards thus far. The general assemblage of fossils in the Oxford Clay and Kelloway Rock generically, and largely in species, strongly resembles that of the Lower Oolite formations, but the life is not so numerous. Fishes, *Hybodus*, *Lepidotus*, and *Pycnodus* are found, and Reptilia of the genera *Dakosaurus*, *Ichthyosaurus* (*I. dilatatus* and *thyreospondylus*), *Megalosaurus Bucklandi*, *Pleiosaurus gamma* and *P. grandis*, 4 species of *Plesiosaurus*, *P. Oxoniensis*, &c., *Rhamphorhynchus Bucklandi*, *Steneosaurus*, and *Streptospondylus Cuvieri*.

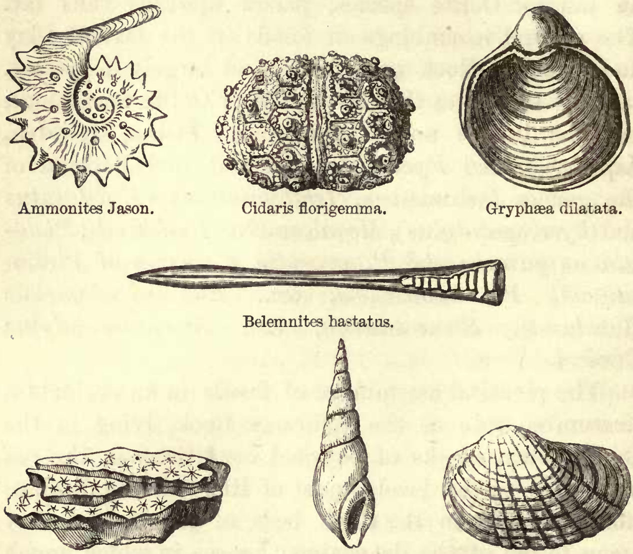
The plentiful assemblage of fossils in an accidental stratum so thin as the Kelloway Rock, lying in the Oxford Clay, speaks of physical conditions in the sea favourable to the development of life, and the diminution of species in the thick beds of the Oxford Clay seems to tell of the deepening of a sea in which much muddy sediment was being deposited.

The Coral Rag is a rubbly limestone, trending, with occasional interruptions, from Somersetshire to Yorkshire, the details of which it is unnecessary to give. It is associated in places with sandy strata known as the *Calcareous grits*, and is often almost entirely composed of broken shells and Echini, *Cidaris Smithii*, *Hemicidaris intermedia*, *Pygaster umbrella*, *Pygurus costatus*, &c., and numerous corals (whence its name) of the genera *Isastrea*, *Thecosmilia*, *Protoseris*, &c.,

Ammonites, a few Gasteropoda, and various genera of bivalves, common in the Oolitic formations.

This formation is rarely more than about 300 feet thick, and about one-third of its fossils are well known in older Oolitic strata, while less than a tenth pass

FIG. 38.



Ammonites Jason. Cidaris florigemma. Gryphæa dilatata.

Belemnites hastatus.

Isastræa explanata. Chemnitzia Heddingtonensis. Pholadomya æqualis.

Group of Fossils in the Middle Oolites.

upward into the overlying Kimeridge Clay and Portland rocks.

For reasons connected with the physical geography of this epoch, which will be mentioned further on, I confine the Upper Oolite to two formations, viz.:

Portland Limestone and Sand,
Kimeridge Clay.

The stratigraphical arrangement of these strata and of the overlying Purbeck Limestone is well seen in the Isle of Portland, where all the strata dip gently from north to south, as shown in the annexed diagram.

The Kimeridge Clay takes its name from Kimeridge Bay in Dorsetshire, on the cliffs of which it is well exposed, with bands of cement stones and many fossils, such as Ammonites, Belemnites, Reptilian bones, and many ordinary molluscous shells. Certain hard, shaley bands at Little Kimeridge have been at intervals used for the manufacture of naphtha and mineral oils, but, I think, never with great success. West of this area the clay is well known in the northern half of Portland Isle, in Portland Road, and in the country near the chalk hills, between Ringstead Bay and Abbotsbury. North of this it is overlapped by the Cretaceous rocks between Abbotsbury and Buckland Newton near Cerne Abbas, from whence, beginning in a narrow band, it gradually widens, trending north along the borders of the Cretaceous escarpment between Shaftesbury and Mere. West of Mere it occurs in interrupted patches at the foot of

Fig. 39.

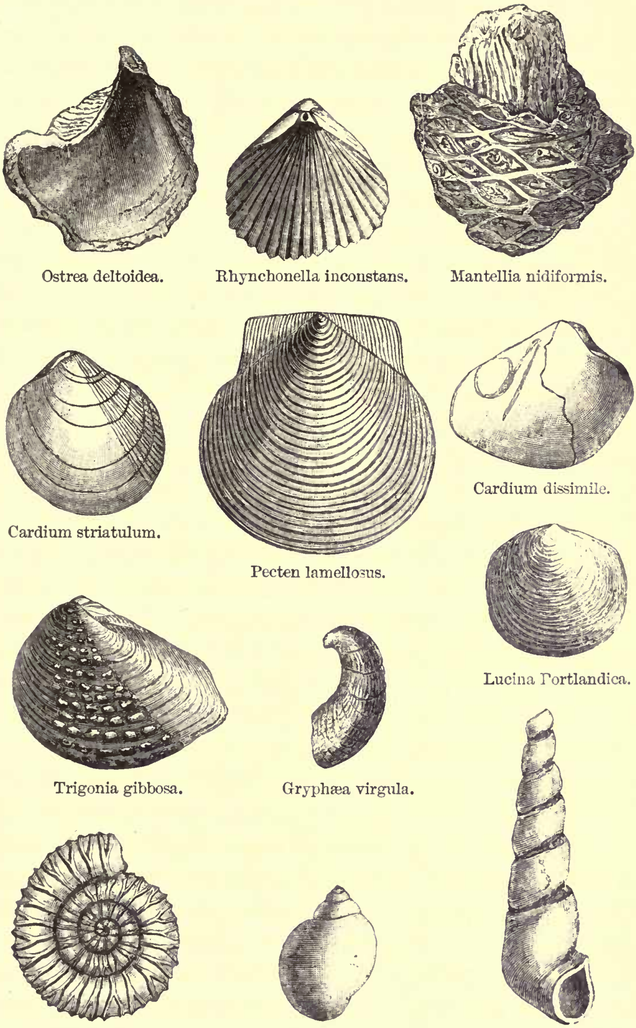
Section of the Oolitic and Purbeck strata, Isle of Portland.

1. Kimeridge Clay. 2. Portland Sand. 3. Portland Limestone. 4. Purbeck Beds.

this great escarpment as far north as Rowde, near Devizes, where it is again overlapped by the unconformable Cretaceous strata, to reappear at Calne, from whence, on the north-east, it comes on in great force, covering a broad tract of country by Swindon and Longcott. A little east of Longcott, a great tongue of Lower Greensand, running out to Farringdon, overlaps the Kimeridge Clay. Escaping from this overlap, the clay runs eastward by Abingdon, Netley, Quainton, and the south end of Stewkley, between which and Leighton Buzzard it is again overlapped by broad-spreading strata of Gault and Lower Greensand. Between this area and the fens of Lincolnshire it doubtless lies deep underground, well to the east of the Chalk escarpment, for it is well known to underlie much of the marshes on either side of the Wash, from whence it trends north in a strip at the base of the Lincolnshire Wolds as far as the Humber, where it is again unconformably overlapped by the Cretaceous strata of the Yorkshire Wolds, to reappear in great force in and around the Vale of Pickering, between Hambleton Hills and Filey Bay in Yorkshire.

The Kimeridge Clay is in places from 500 to 600 feet in thickness, but of late, in a great experimental boring in the Weald of Kent, after passing through the Purbeck and Portland Limestones and Sand, it was pierced to the depth of 921 feet, below which came clays supposed to be the Coral Rag and Oxford Clay, the base of which was not reached at 1,906 feet when for financial reasons the boring was abandoned. The meaning of this seems to be, that whereas these clays, in their range from Dorsetshire to Yorkshire, were deposited in comparatively shallow areas not very far from land, in the Kent area they were laid down in a much deeper sea.

FIG. 40.



Group of Kimeridge Clay and Portland Fossils. Upper Oolite.

A shell peculiarly characteristic of the Kimeridge Clay is a large oyster, *Ostrea deltoidea*, Fig. 40. Shells of the genera *Rhynchonella* (*Rh. inconstans*) and *Terebratula*, *Discina* (*D. Humphresiana*, &c.), *Lingula ovalis*, *Pinna*, *Astarte*, *Pecten*, *Trigonia* (*T. incurva*), and other bivalves, and *Ammonites* and *Belemnites*, are also common, the Belemnites sometimes almost paving the ledges of the seashore in Kimeridge Bay. Fishes of the Oolitic genera already named, with others, are found, and many remains of reptiles, among others Turtles, Crocodiles of the genera *Goniopholis*, *Teleosaurus* and *Steneosaurus*, 5 species of *Ichthyosaurus*, 8 of *Plesiosaurus*, and 5 of *Pleiosaurus*, some of the last of great size. *Cetiosaurus longus* and *Megalosaurus Bucklandi* also occur. Fragments of wood are not uncommon.

The Portland Limestone and Sand lie above the *Kimeridge Clay*. The best sections of these rocks occur in the Isle of Portland, as shown in fig. 39, p. 187. The sand which forms the base of the formation, is there 150 feet thick, and the limestone about 70. Of this, about 20 feet forms marketable stone in three horizons, from the best part of which the celebrated Portland stone is derived, used in many public buildings, of which St. Paul's may be cited as an example. The limestone, like those of most other Oolite formations, is cream-coloured, and generally fossiliferous. Among the most common forms found in it are *Trigonia gibbosa* and *T. incurva*, *Pecten lamellosus*, *Ostrea expansa*, *Cardium dissimile*, *Terebra Portlandica*, and various *Ammonites*, some of them of large size. The lowest beds are full of layers of flint and chert. The sand is fossiliferous, containing *Oysters*, *Cardiums*, &c. The Portland stone also occurs at the south end of the Isle of Purbeck, in the Vale of Tisbury in Wiltshire, at Swindon, and in the Vale of Aylesbury. The beds are very inconstant in their outcrop, only showing at those places which were probably near the original western margin of the sea of the period. At Swindon both limestone and sand are of trifling thickness. Outliers of it occur in Bedfordshire, and the whole has evidently been exposed to denudation before the deposition of the Cretaceous rocks.

Such is a brief outline of the marine Oolitic strata in the south and centre of England, and also of the Upper and Middle Oolites in their range into Yorkshire.

It will be observed that in this description I have specially insisted on the unconformable overlapping of the Cretaceous strata across the Portland, Kimeridge, and other formations, at intervals, all the way from Dorsetshire to Yorkshire, for by-and-by it will appear that this fact has an important bearing on the physical theory of the deposition of the Purbeck and Wealden strata, which come next in succession.

In the meanwhile, I must return to the Northamptonshire area, where we left the Lower Oolites, and follow them into Yorkshire, when it will be seen, that they were formed under physical conditions in some respects very different from those which obtained in the South, while the marine clays and limestones of the Lower Oolites of that area were being deposited.

It will be remembered that in Gloucestershire, a few miles west of Stow-on-the-Wold, the Fuller's Earth thins out, and the Inferior Oolite and Stonesfield Slate come together, the latter being formed in part of the sandy flags that make the base of the Great Oolite, and constitute the Stonesfield Slate. Going easterly into

Oxfordshire, these beds get still more sandy, the limestone of the Inferior Oolite disappears by degrees, sandy beds replace them, which are overlaid directly by the sands of the Great Oolite, the two forming together what are generally known as the Northampton Sands. By-and-by, in the district of Rockingham near Geddington, the Inferior Oolite Limestone begins to reappear, overlying the lower part of the Northampton Sands, and lying flat, and thickening by degrees, it forms the surface of a great tract of country towards Stamford and Thistleton, in Northamptonshire and Rutlandshire, also towards Grantham, and in Lincolnshire, being always underlaid by the Northamptonshire Sand. The Inferior Oolite of this district is well known as the Lincolnshire Oolite Limestone. The sands beneath it have been largely worked in Northamptonshire for ironstone, and their upper part is occasionally white, 'with remains of plants, sometimes vertical, also thin seams of lignite, and miniature *underclays*,' while 'thin seams containing *Cyrena* (a fresh-water bivalve shell) occur in this part of the series. These beds have been distinguished by Mr. Judd as the *Lower Estuarine Series*.[1]

Above the Lincolnshire Oolite Limestone there lie certain strata, named by Mr. Judd the *Upper Estuarine Series*, forming, in his opinion, the lowest part of the Great Oolite of this area. They are well seen in some of the cuttings of the Great Northern Railway, and on the top of the Inferior Oolite Limestone quarries at Ketton, Clipsham, and Casterton. As described by Mr. Judd, there are in these strata 'bands of sandy stone with vertical plant markings and layers of shells,

[1] 'Geology of Rutland,' &c. J. W. Judd, p. 92, 'Memoirs of the Geological Survey.'

sometimes marine, as *Pholadomya*, *Modiola*, *Ostrea*, *Neæra*, &c.; at other times fresh-water shells, as *Cyrena*, *Unio*,' &c., and he correctly states that 'all the characters presented by the beds of the *Upper Estuarine Series*, point to the conclusion that they were accumulated under an alternation of marine and fresh-water conditions, such as takes place in the estuaries of rivers.' These strata between Northampton and Grantham are rarely more than about 25 feet in thickness.

When we think of the meaning of these phenomena, it is evident that, while from Gloucestershire to the south coast, all the strata from the base of the Lower Lias to the top of the Oolitic series are marine, in the middle area of Northamptonshire, Rutland, and Lincolnshire, a set of conditions prevailed in the time of the deposition of the Lower Oolites that indicated filling up of the area, and temporary elevation of the old marine deposits, in places, quite above the level of the sea, so that swampy terrestrial surfaces were formed, through which wandered minor streams inhabited by fresh-water shells. Further north this fact becomes still more plain.

After crossing the Humber, and passing the unconformable overlap of the Cretaceous rocks of the Yorkshire Wolds, a series of Liassic and Oolitic strata appears in the North Riding, forming a great tract of beautiful hilly country, the sections of which are best seen on the coast cliffs that lie between the mouth of the Tees and Filey Bay. That part of the cliffs of which the strata are of Oolitic age, more or less includes *representatives in time* of all the so-called formations from the Inferior Oolite to the Kimeridge Clay inclusive. The lithological characters, and mode of formation, of all the strata that are presumed to lie between the horizon of the base of the inferior Oolite and the Cornbrash, are, however, of a very different nature from those of the equivalent strata in the south of England, and though I have examined these sections from end to end, I shall quote from the measured sections of Mr. Etheridge, and give the latest information.

Resting directly on the Alum shales of the Upper Lias, there are sands intermingled with bands of shale, the whole being about 50 feet thick. All the fossils, which are generally scarce, are of marine species, and the whole of the strata are known to palæontologists as the zone of *Ammonites Jurensis*, and it is generally considered to be the equivalent of the Midford Sands of the South of England, or the Sands of the Inferior Oolite, as named by William Smith.

Above these come strata, locally known as Dogger, consisting of about 30 feet of brown sands, which are sometimes ferruginous and red. They are interstratified with shaley sands, and the whole contains numbers of the marine fossils of the Inferior Oolite.

On these there lie about 200 feet of sandstone, destitute as far as known of the remains of any kind of life, except a few *land plants*. Then comes about 25 feet of sandy limestone, known as the Millepore Bed, full of fossils common in the Inferior Oolite of the south. This is succeeded by about 80 feet of shales interstratified with sandstones, as yet destitute of the remains of molluscs, but what is of especial interest, there are at least eight *distinct bands of coal*, interstratified chiefly with the shales, and several other lines of carbonaceous matter more interrupted and broken. What adds to the importance of this fact is, that the coal-beds have not been formed of drifted vegetation, for underneath each bed there occurs an *underclay* or old soil, charged with the roots of those plants, the decay of which on the spot formed the thin beds of coal, just in the manner that coal-beds were formed during the Coal-measure epoch, but, in the case of these Oolitic coal-beds, on a much smaller scale.

Above these fresh-water and terrestrial strata, there occur beds of 'grey limestone' and shales. It is often called the Scarborough Limestone, and is full of marine shells, &c., common in the ordinary Inferior Oolite. Finally, on the top of this, there are strata of sandstones and shales, often called the upper series, to distinguish them from the lower sandstones and shales that lie below the grey marine limestone. Like the lower series, they seem to contain no mollusca of any kind, and, indeed, the only fossils that have been found in them are the remains of plants scattered through the rocks, accompanied here and there by streaks of coaly matter. On the whole, such evidence as there is, tends to show that these also are fresh-water or at most estuarine strata.

Overlying these sands, there is a persistent band of impure limestone, generally from 3 to 6 feet thick, which is considered to represent the Cornbrash of more southern areas, where, it will be remembered, it lies directly on strata of the Great Oolite series. It is certain that in its fossils it is intimately related both to the Great and the Inferior Oolite, including the Fuller's Earth. If, therefore, we take the Lower Oolites as a whole, the most philosophical method of regarding them is to consider them as *one*. Owing to minor changes in the physical geography of the sea bottom, and of the neighbouring land, this formation was, during the progress of deposition, locally broken up into a series of subformations, now of limestone, now of clay, now of sand, and, according to locality, of marine, estuarine, fresh-water, and even terrestrial origin; marine in Dorset, Somerset, and Gloucestershire, partly passing into estuarine and fresh-water strata in Northamptonshire, at the very time, for example, that the marine sediments of the Stonesfield Slate, had washed in among them, from the neighbouring land, plants, insects, and marsupial mammals. Still further north, in Yorkshire, the equivalent of great part of the Inferior Oolite actually constitutes a coal-field, on a miniature scale, quite comparable, in its sandstones, shales, underclays, and beds of coal, to the broad and thick deposits of the Coal-measures, and showing the same kind of alternations of terrestrial and aquatic conditions, indicating, repeated filling by sediments of a certain area, its conversion into land, and its subsequent depression to receive new accessions of sands and shales.

These circumstances seem to me to agree, in a striking manner, with what may be surmised to have been the state of the geography of the neighbouring lands. In the south of what is now England the seas were broad and comparatively shallow, during all the time of the deposition of the Lower Oolites, and the islands round which these seas flowed (including Wales) were comparatively small. But further north we come to a fragment of a much larger land, formed of Palæozoic rocks, that in those days formed a mountainous country extending from the hills of Derbyshire far away to the northern extremity of Scotland, and how much further entire, or broken into islands, no man yet knows. In spite of disturbances of upheaval of later date than these Oolitic times, it may also very well have been that this old land was much higher than the highest Highland mountains of the present day, seeing the vast amount of waste and degradation that they have undergone since that ancient time, and we may be sure that it was surrounded by seas of this lower Mesozoic epoch, for fragments of the Oolitic strata still surround the island. This was the larger land, from which the rivers flowed that deposited the fresh-water sands described above. On the low banks of these rivers grew many a plant now represented merely by indistinct impressions—

> 'Their meaning lost,
> Save what remains on stone, or fragments vast'—

in which the relics of species of *Araucaria*, *Cycas*, *Zamia*, *Screw Pine*, and numerous other forms, together with gigantic *Equisetums* which grew in the still waters on their borders, while Marsupial mammals on the shores, and Trigoniæ and Terebratulæ in the seas, help us to realise that the physical characteristics of the time in some degree resembled that of Australia in our own day, a circumstance first noticed by Professor Owen.

This state of affairs was at length partly brought to an end by a gradual submergence, during which the Oxford and Kimeridge Clays were deposited in open seas, but the sinking of the area was not by any means so great as to swallow up the old islands round which the strata were formed, and which still remain, much changed, as the most lofty portions of Great Britain. Such fragments of the Jurassic strata as still remain on the coasts of Scotland throw some light on this question.

On the east of Scotland, at and near Brora, in Sutherland, the Liassic and Oolitic strata have been long known, and were first described in the Journal of the Geological Society in 1858 by Mr. (afterwards)

Sir R. Murchison. In 1859 I accompanied him during a tour in Scotland to that district, and mapped the strata with all its faults and dislocations, but never published the results. The region was afterwards investigated by Mr. Judd, and the results published in great detail in the 'Journal of the Geological Society,' for 1873. At the base lie Keuper sandstones, &c., with *Stagenolepis* (a crocodile) and *Telerpeton* (a land lizard), &c., above which are beds of sandstone and conglomerate, which may possibly represent the Rhætic beds. These are succeeded by about 400 feet of sandstone and shale, with plant remains and seams of coal (terrestrial), with pectens in the overlying strata. These are overlaid by limestones and beds of blue micaceous clay, both full of Lias fossils ; the whole is well seen on the shore near Dunrobin. Of later date, in the same district, the Lower Oolite consists partly of marine and partly of fresh-water strata, with *Oysters*, *Perna*, *Unio*, *Cyrena*, *Cypris*, &c., and land-plants and coal seams, one of which is 3½ feet thick, and has been worked. The Middle Oolites of the district are considered by Mr. Judd to represent the whole of the English strata from the base of the Oxford Clay to the Coral Rag inclusive. They are full of marine shells of the usual genera and species, and occasionally contain plants and bands of lignite. The whole series is perhaps nearly 1,000 feet thick, and consists to a great extent of sandstones, with occasional limestones, conglomerates, and shales. The Upper Oolite, which is supposed to represent the lower part of the Kimeridge Clay, and all the higher beds, are marine, with occasional remains of land plants.

As a whole, the Liassic and Oolitic series of Brora dip east and north-east along the shore between Dunrobin and Helmsdale, the older parts of the series being at Dunrobin, and the younger at and near Helmsdale A great fault, nearly 20 miles in length, runs along the shore, and throws the secondary strata down against the older Palæozoic rocks on the north-west. Interstratified with the black shales near Helmsdale, there are occasional beds of brecciated conglomerate. The shales contain thin layers of plants and many broken shells, and the breccias contain angular and subangular blocks, chiefly of Old Red Sandstone, with a mixture of the older rocks of the Highlands, sometimes 6 or 8 feet in diameter, in fact, boulder beds, which long ago suggested to me the action of floating ice. Mr. Judd suggests that they may be due to river ice, floated on streams flowing from the west, at a time when the larger part of the gneiss of the Highlands was covered by Old Red Sandstone, since denuded.

In the Inner Hebrides, the Lias, Inferior Oolite, Middle Oolite and Oxford Clay occur in the Island of Skye. The Lias, as described by Geikie, consists of beds of limestone, sandstone, conglomerate, and shale. It contains the usual fossils. The rocks are much disturbed, and the limestones have been metamorphosed into crystalline marble accompanied by the intrusion of syenite. The section at Loch Staffin, given by Edward Forbes, is as follows:—

Oxford Clay.	Inferior Oolite.
Estuary Shales.	Lias.
Middle Oolite.	

Between the Middle Oolite and estuary shales, a bed of columnar basalt is intercalated, and the whole is overlaid by amygdaloidal trap, which breaks through and overspreads the strata. These igneous rocks are intrusive and of Miocene age. The estuary shales contain *Oysters*, *Unios*, *Cyrenas*, *Paludinas*, &c., distinct from those of Brora and of the English Purbeck strata. In Mull, Lias and Oolites occur, ranging from the Lower Lias to the Upper Oolitic series, overlaid by Lower Cretaceous strata. They are traversed by many dykes and intrusive sheets of basalt, formerly considered as of Oolitic age, but now, as described by Professor Geikie, of Miocene date.

CHAPTER XIII.

PURBECK AND WEALDEN STRATA.

After the discovery by Dr. Mantell of the fresh-water nature of the Hastings Sands and Weald Clay, it became customary with some geologists, led by Edward Forbes, to consider the Purbeck Beds as forming the topmost subdivision of the Oolites, and the Wealden strata as belonging to the Cretaceous series; but as, in reality, the interval between the marked marine series of the Oolitic and Lower Cretaceous epochs is, in Britain, bridged over by the terrestrial and fluviatile episode of the Purbeck and Wealden beds, it is more convenient, and, in the chief part of the British area, more philosophical, to treat of these formations as marking one great local epoch.

For the stratigraphical arrangement of these strata in the Isle of Purbeck, see fig. 75, p. 347.

I here use the term Lower Cretaceous, in the sense in which it has been applied to the Atherfield Clay and Lower Greensand ever since the days of Dr. Fitton, at the same time being well aware, that all the Wealden strata above the Purbeck beds, and up to the top of the Lower Greensand, are the geological equivalents in time of the marine Neocomian strata of the Continent of Europe, though with us it happens, that the lower and middle subdivisions of these beds are represented by fresh-water strata in the south of England.

I have now to describe a series of deposits that were formed at the mouth of a river in a large delta, comparable in size to the largest deltas of the living world, and consisting of the following subdivisions, the oldest being placed at the bottom:

Purbeck and Wealden Series.	Weald Clay. Hastings Sands and Clays. Purbeck Limestone Marls and Clays.

The events that brought about the formation of these strata seem to have been as follows:

By the deposition of that series of beds of limestone and shales that constitute the Oolitic strata, a great marine area was more or less filled with sediments, the last of which is the Portland Limestone. Probably aided by partial upheaval of the flat-lying strata, a portion of this area was invaded by the waters of a large continental river, the rise of land having been sufficient to unite Britain with the Continent of what is now Europe, which, however, at that time presented very different contours from those of the present day. We must now conceive the old islands, which I described in the last chapter, as forming groups of hills and mountains, rising out of vast plains, the surface of which consisted of horizontal or nearly horizontal Upper Oolitic strata, through which, from some far-off unknown sources, a long and broad river ran. The earliest strata of the Purbeck Beds must have been formed in open, clear, fresh water, in the broad mouth of this river, for near Tisbury in Wiltshire, they pass gently into each other, the marine strata of the Portland and Purbeck Limestones being firmly united in the same quarries. The lowest beds of the Purbeck strata are of fresh-water origin, and on the whole the transition from the uppermost marine beds of the Portland, to the lowest fresh-water strata of the

Purbeck series, is sudden. These are about 8 feet thick, and contain fresh-water remains of the genera *Cyclas*, *Valvata*, *Limnæa*, *Physa* and *Cypris*.

Near the base of the Purbeck rocks, in the Isles of Portland and Purbeck (figs. 39 and 75), lie three beds, known as the 'dirt beds,' which, from their colour and earthy character, were clearly ancient soils. They are full of the silicified stems and stools of coniferous trees, the former procumbent and the latter with roots attached, standing in the soil in the position in which they grew. Plants (*Cycadites microphyllus*, &c.) allied to the modern Cycas and Zamia are also found in them. In the Isle of Purbeck the whole of the Purbeck strata are about 360 feet thick in their largest development. They consist chiefly of limestones and marls, principally of fresh-water origin, with interstratifications of marine, brackish-water, and terrestrial bands. According to the sections of the Government Geological Survey, by Bristow, there are indications of four terrestrial surfaces, eleven sets of fresh-water beds, four brackish water, and three marine bands, the last containing *Pectens*, *Modiolas*, *Aviculas*, and *Thracias*. One of these, the 'cinder-bed' of the quarrymen, is about 12 feet thick, and is composed almost exclusively of oysters (*Ostrea distorta*). Along with these, sparingly, was found a *Perna* and an Oolitic genus of *Hemicidaris*, *H. Purbeckensis*. The fresh-water shells of the various beds are chiefly species of *Paludina*, *Limnæa*, *Planorbis*, *Physa*, *Valvata*, and *Unio*, and *Cyclas*, and along with these are several species of small fresh-water bivalve crustacea of the genus *Cypris*. The celebrated Purbeck marble, so largely used in the palmy days of Gothic architecture for the decoration of churches, lies near the top of the Upper Purbeck Limestone. It is chiefly formed of remains of the delicate fresh-water univalve, *Paludina fluviorum.* Many fish have been found in the Purbeck strata; among these, *Lepidotus minor, Pholidophorus ornatus, Microdon radiatus, Ophiopsis breviceps, Hybodus,* and *Asteracanthus,* are the most characteristic.

Numerous wings, elytra, and other fragments of insects (Coleoptera, Orthoptera, Hemiptera, Neuroptera, and Diptera), occur in thin bands in the Purbeck Limestones. Some of these (dragon-flies, &c.) are

FIG. 41.

Physa Bristovi. Unio compressus. Ostrea distorta.

Cyrena media. Cypris Valdensis. Paludina fluviorum.

Group of Fossils from the Purbeck and Wealden beds.

such as would live on the marshy banks of rivers. Among the reptiles are Crocodilia—viz., *Goniopholis crassidens,* and *Macrorhynchus*; Lacertilia; fresh-water Tortoises, and Turtles—viz, *Pleurosternon concinnum, P. emarginatum, P. ovatum,* &c.

In 1854, portions of the jawbone of a small marsupial insectivorous mammal, *Spalacotherium tricuspidens,* were found by Mr. Brodie at the base of the middle Purbeck beds. At the close of 1856, Mr. Beckles commenced a further search in the same bed, which was rewarded by the discovery of about twenty species of mammals, belonging to the genera *Spalacotherium*, *Amblotherium*, *Peralistis*, *Achyrodon*, *Pterospalax*, *Peramus*, *Stylodon*, *Bolodon*, *Triconodon*, *Triacanthodon*, and *Plagiaulax*. They are altogether marsupial, and probably this Mesozoic mammalian life was 'low, insignificant in size and power, adapted for insect-food, for preying upon small lizards, or on the smaller and weaker members of their own low mammalian grade' (Owen). This mammalian fauna, as far as it goes, at once suggests comparison with the existing fauna of Australia, and the flora of the time has in part like analogies.

Overlying the Purbeck Limestone, in the Isle of Purbeck, there are thick accumulations of interstratified sand and clay, which belong to the geological horizon of the Hastings Sand and Weald Clay. They are well seen on the coast cliffs of Swanage Bay, and as far as I know have yielded no fossils excepting fragments of fossilised wood (fig. 75, p. 347).

In the Isle of Wight, strata of the same general age lie on the south-west coast, between Cowleaze Chine and the neighbourhood of Compton Bay. In these there occur *Cyrena* and *Cypris* and fragments of lignite, and similar strata with the same kind of fossil remains are found at the northern end of Sandown Bay.

But the largest area of these estuarine beds now exposed at the surface in England, is that of the Weald of Kent and Sussex, which, between the North and South Downs and the Lower Greensand, extends from the great shingle banks of Dungeness on the east, to the neighbourhood of Petersfield on the west, embracing an area of about 80 miles in length, by about 25 miles in breadth where its width is greatest. For the stratigraphical order of these strata, in this area, see diagrams, Nos. 71, 72, and 73, pp. 337–343.

In this area, near Battle, the lowest strata rise to the surface, being the fresh-water Purbeck Limestone, interstratified with beds of clay. For long in this area they were known as the Ashburnham Beds, but the fresh-water shells and other fossils found in them during the progress of the experimental boring already mentioned, clearly proved them to belong to the Purbeck Series. They are there about 180 feet thick, and overlie about 110 feet of shales, somewhat sandy, with chert, which may perhaps represent the Portland beds. In the Purbeck strata, at a depth of 130 feet, 35 feet of gypsum more or less pure were penetrated, a mineral much more sparingly developed in the lower strata of the Isle of Purbeck, and which I consider indicates, that these strata were not laid down in the sea, but probably in a lagoon temporarily separated from the main current of the river. Beneath the so-called Portland beds about 921 feet of Kimeridge Clay were pierced, followed by 985 feet of Coral Rag and Oxford Clay, when, for want of funds, this interesting experiment was stopped at a total depth of 1,906 feet from the surface.

The Hastings Sands and Weald Clay are almost exclusively fresh-water beds, and must be considered as a continuation of the deposits formed at the mouth of the great river, which commenced with the deposition of the Purbeck limestones and shales. The name *Wealden* applies to the whole group above the Purbeck rocks, and the term originated from the circumstance that these fluviatile beds are largely developed in the Weald of Kent and Sussex. Their true character was first discovered by Dr. Mantell. As a whole, the Hastings sands form the lower portion, though they are largely interstratified with beds of clay, and sometimes, by changes of character, the sands and clays of the series pass into each other. In the various beds are found Ferns of the genera *Alethopteris*, *Otopteris*, and *Sphenopteris*, the latter sometimes standing erect, as if in the position of growth. Coniferous wood and Cycadeous plants also occur. With rare exceptions, the shells are of fresh-water genera, viz. ten species of *Unio*, five species of *Cyrena*, besides *Cyclas*, *Melanopsis*, *Melania*, and *Paludina*, together with *Cypris*, *C. Valdensis*, and the strata containing these are sparingly interstratified with beds containing *Ostrea*, *Corbula*, and *Mytilus*. Several remarkable reptiles occur in the Weald, of the order Dinosauria, belonging to the genera *Hylæosaurus*, *Megalosaurus*, *Iguanodon*, *Plesiosaurus*, and *Pterodactylus*, together with nine species of Crocodilia, of seven genera. The *Iguanodon* was first described by Dr. Mantell as an herbivorous reptile of gigantic size. Its teeth were serrated like those of the modern Iguana, but unlike them it masticated its food. Various fish, of the Placoid and Ganoid orders, also occur in the Wealden. The strata composing the Hastings Sand series are about 700 feet thick.

The overlying beds of Weald Clay are of about equal thickness, and spread in a broad plain, or series of low undulations, all round the more hilly country of the sands. They lie between these sands and the overlying Atherfield Clay and Lower Greensand. It is in this clay that thin bands of the well-known Sussex marble occurs, so much used in old times for monumental purposes in churches, good examples of which may be seen in Westminster Abbey. It is formed chiefly of the agglomerated shells of *Paludina fluvi-*

orum. Interstratified with the Weald Clay there are a few thin bands sparingly charged with the remains of marine shells.

Enough has now been said to prove the fresh-water and estuarine character of the Purbeck and Wealden beds, and also, considering the broad spread of these formations in England, that they must have been deposited near and at the mouth of a large river. But to estimate the possible dimensions of this Delta we must go further afield.

It has been customary to estimate the area occupied by these deposits by measuring their length from west to east, between the Vale of Wardour and the Boulonnais in France, and from north-west to south-east, from Hampshire to Vassy, or in some cases taking a shorter diameter to Beauvais, and the respective diameters given of these lines are in the first case 320 miles and in the second 200 miles.[1] Even if these measurements were correct, which they are not, this method seems to me to be erroneous, for the measured diameters run too much in the same direction, whereas, as much as possible, they ought to be measured at right angles to each other. The real measurement from west to east, between the Vale of Wardour and the Boulonnais, is about 200 miles, and a line drawn nearly at right angles to this, between the south side of the Isle of Wight, where the Weald Clay occurs, and Quainton, in Buckinghamshire, where we find the most northerly outlier of the Purbeck beds, is about 100 miles in length. This would give an area for the Delta of about 20,000 square miles.

Rigidly to adhere to this measurement, as an accurate account of the size of the ancient Delta, would,

[1] See Lyell's 'Student's Elements of Geology,' p. 304, second edition.

however, be very erroneous. In the first place there is no reason to believe that the outliers in Buckinghamshire, near Aylesbury and Quainton, mark the original limits of the Purbeck strata, for the whole country has suffered so much by denudation, that we may be sure that these beds originally spread further. Again, on the south, the Wealden strata of the Isle of Wight are thick, and dip northerly between Cowleaze Chine and Compton Bay, and originally must have spread to some unknown distance beyond the coast cliffs, and, indeed, we may be sure that they now occupy part of the bottom of the sea beyond the coast line. Crossing the Straits of Dover to the Bas Boulonnais, we find the Weald Clay much attenuated, but passing under the Cretaceous strata for some unknown distance. Taking all these points into account it would probably not be too much to add one-half to the 20,000 square miles, as being nearer the original area of the Delta, or 30,000 square miles in all. The area of the Delta of the united great rivers of the Ganges and Brahmaputra, from the sea to the latitude of Rajmahal, is usually estimated at about 40,000 square miles, and therefore it would probably be under the mark to estimate the size of our old river as being quite as large as the largest of these great rivers of India. At the very least it must have been as extensive as the Delta of the Quorra in Africa, the area of which has been estimated at 25,000 square miles.

Facts such as these are sufficient to prove that this ancient stream was, in its day, a first class continental river. Away to the west of a great plain, through which it flowed, lay the granite hills of Devonshire, separated by a broad flat valley from what are now the mountains of Wales. The old Mendip Hills, which, as hills, were much older than the Oolitic series, then lay buried deep beneath the uppermost Oolitic strata, and all the ground between Wales and the high tracts of the North of England formed part of the vast plain that bordered the river; while far away, on the north, rose the majestic mountains which we now call the Highlands of Scotland, then much higher than now, for ever since that time they have been undergoing waste and degradation. We have probably no actual knowledge of the mountain vegetation of the period, but on the flats by the river there were *Equisetums* in the marshes, and ferns, coniferous trees, *Zamias*, and *Cycas* on the drier ground; crocodiles, turtles, and fish, swarmed in the waters; small marsupial mammals lived upon the flats, along with great reptiles, the *Iguanodon*, *Hylæosaurus*, and the gigantic *Megalosaurus*, while the winged *Pterodactyle* preyed on the insects that flitted through the air of a climate, probably as warm as that of the Delta of the Ganges.

How far to the west this old flat land spread no man can tell, but I have no doubt that Wales stood in the midst of it, for the Oolites passed out on the south through the area of what is now Bristol Channel, and on the north across the country now occupied by the estuaries of the Mersey and the Dee, and it is also very likely that at that period the whole of Ireland may have formed part of that old land. On the east our territory was undoubtedly joined to a great continent, which, after undergoing many revolutions, is now modern Europe, but it is hard to discover the details of its physical geography. Of this, however, we are sure, that the Scandinavian mountains were then loftier than at present, for they are certainly of older date than the deposition of the Old Red Sandstone, and probably older than the Upper

Silurian series, and have suffered degradation ever since; that the chain of the Ural was in existence, for it is of older date than the Permian strata; that the mountains of the Schwarzwald then rose high into the air, for they are older than the New Red Sandstone; but the Alps, the Pyrenees, and some other mountain chains, if they existed at all, were in the rudimentary stage of comparatively low lands, feebly indicated by the occasional occurrence of fresh-water beds amid the Oolitic and Purbeck strata, and by such phenomena as the occurrence of *Pterodactyles*, and the long-tailed *Archæopteryx macrura*,[1] in the Solenhofen state of Bavaria.

That a broad low-lying land existed at that time, amid which rose groups and ranges of mountains in what is now Europe, there is no reason to doubt, and how that phase of physical geography came to an end will form part of the subject of next chapter.

[1] A bird with a long vertebrated feathered tail.

CHAPTER XIV.

CRETACEOUS SERIES.

When the continent described in last chapter had endured for a long period of time, submergence of the area began to take place, accompanied by the deposition of the purely marine Cretaceous series, which in England is as follows, the oldest beds being placed at the bottom:

Upper	Chalk with flints. Chloritic marl, Chalk marl, and Chalk without flints. Upper Greensand. Gault.
Lower	Lower Greensand. Atherfield Clay.

I may here mention that in parts of the Continent of Europe, there are certain *marine* formations intermediate in position and date between the Oolitic and Cretaceous rocks, which are known as the Neocomian beds, so called from Neocomium, the ancient name of Neuchâtel, in Switzerland, where they are well developed. The assumption that the Hastings Sands and Weald Clay are the *fresh-water* equivalents in time of the lower and middle parts of these continental beds, is undoubtedly correct, the Lower Greensand of English geologists being the British representative of the Upper Neocomian strata.

Mr. Judd has shown that at the south end of Filey

Bay, in Yorkshire, we have the actual marine representatives of the continental Neocomian strata. These Yorkshire beds were formerly called Speeton Clay, and lie between the uppermost Oolitic strata of the district, called by Mr. Judd, Portlandian, and the Red Chalk or Hunstanton Limestone, which, according to that author, cannot be of later age than the Upper Greensand, and may be as early as the Gault.[1]

The area occupied by the Purbeck and Wealden strata underwent a long period of slow depression, during which these fresh-water strata with occasional marine interstratifications were deposited; and by sinking still further, the purely marine beds of the Atherfield Clay began to be formed. In fact, but for the presence in it of marine fossils, it is hard to draw any line between the Wealden and the Atherfield Clays, and no doubt the mud that formed the latter was at first carried seaward by the same great river, in the manner, for example, that muddy sediments are now deposited at and near the mouth of the Amazons on the east coast of South America.

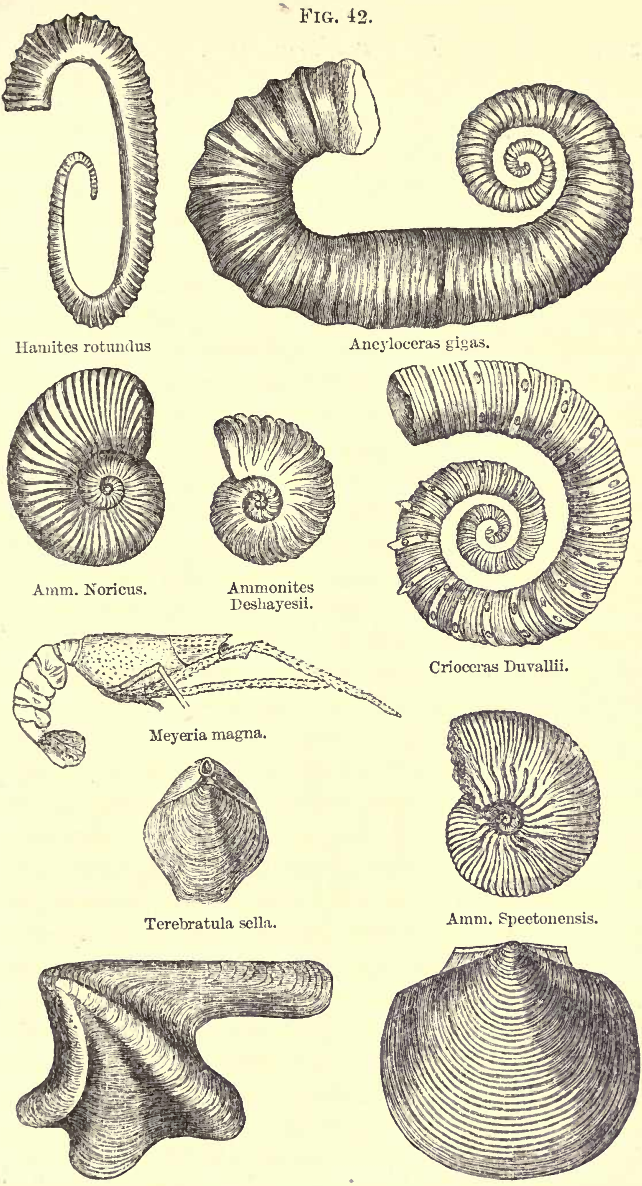
The *Atherfield Clay* takes its name from Atherfield, on the south-west coast of the Isle of Wight, where it is well seen overlying the Weald Clay, and is overlaid by the *Lower Greensand.* Its lowest beds form a kind of passage from the fresh-water strata of the Weald into the overlying marine beds of the Lower Greensand, both in the Isle of Wight and in the Wealden district, round which it circles at the edge of the Lower Greensand; for at Atherfield there seems to have been a depression of the fresh-water area and an influx of the sea, accompanied by the appearance of *Cerithium carbonarium*, accompanied by *Pinna* and *Panopæa* standing vertically in the position in which they lived. Many other shells

[1] 'Journal of the Geological Society,' 1868, vol. xxiv., p. 218.

are scattered through the clay, including the well-known *Perna Mulleti*, *Trigonia caudata*, *Gervillia aviculoides*, *Arcas*, *Pectens*, *Oysters*, *Rostellaria Parkinsoni*, and *Hemicardium Austeni*, &c. &c.

THE LOWER GREENSAND, of which the Atherfield Clay is a subdivision, comes next in succession, in the Isle of Wight, beginning with a bed of sandstone containing *Gryphæa sinuata* and many other shells, succeeded by 29 feet of clay, vulgarly called the 'lobster bed,' from the presence of *Meyeria magna*, formerly called *Astacus*, together with *Ammonites Deshayesii*, &c., overlaid by nodular bands with *Gervillia aviculoides*, &c., above which, clay is repeated, with the same *Meyeria*. Above this, sands and clays alternate to the top of the series, with many fossils, among which may be mentioned as characteristic, *Terebratula sella*, *T. Gibbsii*, *T. biplicata*, *Limas*, *Gryphæas*, *Gervillia solenoides*, *Ammonites*, *Nautili*, and other remarkable Cephalopoda of the genera *Crioceras*, *Ancyloceras*, and *Hamites*. The whole of these strata overlying the Wealden beds occur in magnificent sections along the southern cliffs of the Isle of Wight, dipping northerly under the Gault, Upper Greensand, and Chalk, which in a high ridge stretches across the island from Culver Cliff to Alum Bay. Overlaid by the Gault, and reposing on the Weald Clay, the Lower Greensand also sweeps round the whole Wealden area from Sandgate to Guildford and Haslemere, and from thence to the coast north of Beachy Head. Between Guildford and Haslemere it forms high scarped terraces. The sands are sometimes quite soft, with intercalated hard bands, and they are frequently ferruginous. A good building stone, very fossiliferous, being sometimes an impure limestone, called the Kentish rag, lies in the lower part

Fig. 42.



Group of Atherfield Clay and Lower Greensand Fossils.

of the formation, on the north side of the Weald at Maidstone. It rests on the Atherfield Clay. The general grouping of the fossils in all this area corresponds with that of the Isle of Wight. In Dorsetshire and part of Somersetshire, at the south end of the western escarpments of the Cretaceous rocks, the Lower Greensand is absent, and the Upper Greensand rests directly on the Lias and New Red series. Further north, the Lower Greensand reappears in Wiltshire, near Chapmanslade, about three miles east of Frome, and in a long narrow band follows the direction of the escarpment of Chalk, as far as the neighbourhood of Devizes, where it widens for a space, and runs north in a projecting tongue as far as Farringdon, where it is known as the Sponge gravel.

Beyond the Farringdon area, it is for a space of twelve miles overlapped unconformably by the Gault, to reappear a little south of Abingdon in a broad patch, that extends eastward about six miles to Chiselhampton, where it is again overlapped by the Gault, to reappear in a narrow strip between Great Hazeley and the neighbourhood of Thame. Several small outliers of Lower Greensand lie on the Purbeck strata, south, west, and north of Aylesbury. At Leighton Buzzard it appears in great force, covering all the country for miles round Woburn, from whence it trends away to the north-east, and disappears under the alluvium of the Fens of Cambridgeshire, and runs along the east side of the Wash, where, crossing under sea, it reappears in Lincolnshire, and following the line of the chalk escarpment runs in a NNW. line to the Humber. As a whole this formation may be described as consisting of yellow, grey, white, and green sands.

In the Weald country and on the north-west side of the great Chalk escarpment, between Devizes and the Wash, the Lower Greensand is often ferruginous, and has been worked for iron ore both in ancient and modern times. Fossil wood is of frequent occurrence, perhaps of Coniferous trees, and all the evidence tends to show that, in the English area, the strata were deposited in comparatively shallow seas not far from shore.

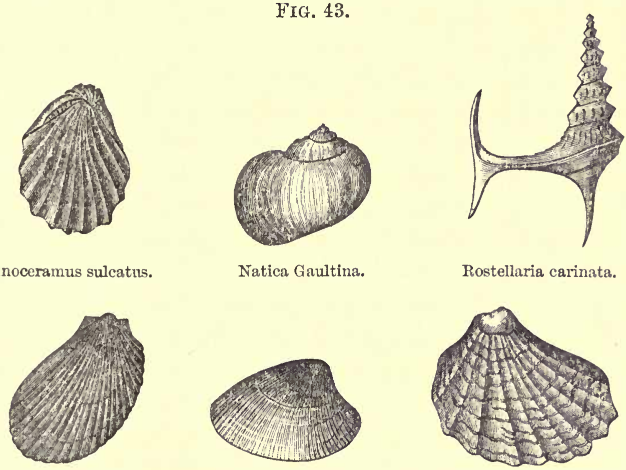
The general characters of the fossils of the series are as follows:—Echinoderms of the genera *Salenia*, *Cardiaster*, *Diadema*, *Discoidea*, *Echinobrissus*, together with *Pentacrinites*, are found in it. *Terebratulæ* and *Rhynchonellæ* are of frequent occurrence, with a few other Brachiopoda. Among the Lamellibranchiate molluscs are numerous *Limas*, *Gervillias*, *Perna*, *Oysters*, *Pectens*, and *Pinnas*, together with shells of the genera *Cardium*, *Venus*, *Trigonia*, *Myacites*, and *Nucula*. Gasteropoda are not generally numerous. Cephalopoda of remarkable forms are characteristic; for, in addition to several species of *Ammonites*, *Nautili*, and *Belemnites*, there are *Crioceras*, and *Ancyloceras*, like Ammonites half unrolled, *Crioceras Bowerbankii*, *Ancyloceras gigas*, *A. grande*, and *A. Hillsii*. Fishes are scarce, and only three reptiles have hitherto been described, one Chelonian, *Protemys serrata*, a *Plesiosaurus*, and a crocodilian saurian *Polyptychodon continuus*, said also to occur in the Lower Chalk.

Out of about 300 Lower Greensand species, 18 or 20 per cent. pass into the *Upper Cretaceous* series. Partly for palæontological considerations, and also because the Gault seems sometimes to lie, as it were, unconformably on the eroded surface of the sand, the dissimilarity in the grouping of fossils is so great, that it has been considered advisable to draw a marked line between the two groups; the Atherfield Clay and the Lower Greensand, when the term Neocomian is not applied to them, meaning *Lower Cretaceous*, and all above them to the topmost beds of the Chalk being considered as *Upper Cretaceous strata.*

The GAULT forms the base of the *Upper Cretaceous* series—or of the Cretaceous series, for those who choose to call the Lower Greensand Neocomian. It is a stiff blue clay, about 300 feet thick in its thickest development, but sometimes it is hard to separate it lithologically from the Upper Greensand. It appears in the Isle of Wight, overlying the Lower Greensand all across the Island; and ranges round the escarpment of the Weald in the same position, with occasional signs of a kind of unconformable erosion between them; and in the centre of England, from the neighbourhood of Devizes to the Wash in Norfolk, the Gault occasionally completely overlaps the Lower Greensand in an unconformable manner. In proof of this unconformity, occasional outlying patches of the Lower Greensand occur north of the Chalk escarpment, without any visible signs of it immediately at the base of the neighbouring Upper Cretaceous strata, which there ought to be, if these formations lay everywhere conformably on the Lower Greensand.

Many Foraminifera have been found in the Gault, and a few Corals, *Cyclocyathus Fittoni*, *Trochosmilia sulcata*, and *Caryophyllia Bowerbankii.* Its sea-urchins are of the genera *Cidaris* (*C. Gaultina*), *Hemiaster* (*H. Asterias*, *H. Baileyi*), and *Diadema tumida.* It contains many Crustaceans, such as *Astacus*, *Etyus Martini*, *Diaulax Carteriana*, *Palæocorystes Stokesii*, &c. Among the Brachiopoda and Lamellibranchiate molluscs the following are characteristic :—*Terebratula biplicata*, *Rhynchonella sulcata*, *Oysters*, *Pectens*, *Plicatula pectinoides*, *Pinna tetragona*, &c. ; *Gervillia solenoides*, *Inoceramus sulcatus*, &c. ; *Lima parallela*, *Cucullæa*, *Arca*, *Nucula pectinata*, &c. It also yields Gasteropoda of the genera *Dentalium*, *Solarium*, *Scalaria*, *Natica Gaultina*, *Pleurotomaria Gibbsii*, *Rostellaria carinata*, &c., and many Cephalopoda, such

FIG. 43.



Inoceramus sulcatus. Natica Gaultina. Rostellaria carinata.

Lima parallela. Nucula pectinata. Plicatula pectinoides.

Group of Gault Fossils.

as *Belemnites minimus*, &c. ; *Nautilus inequalis*, &c. ; *Ammonites splendens*, *A. dentatus*, *A. interruptus*, *A. lautus*, &c. &c. ; *Ancyloceras spinigerum*, *Hamites attenuatus* ; *H. rotundus*, &c. Traces of the Gault may probably be found along the lower outskirts of the Chalk all the way to Filey Bay in Yorkshire, where the Red Chalk has by some been considered to be its equivalent, or, at all events, to be of a geological date, not later than its successor the Upper Greensand.

It would be a great comfort to a proportion of the geological population, if the different formations were as clearly distinguishable on the ground, as they are on a map, by different colours, aided by numbers or letters for the use of the colour-blind. If to this, in the economy of Nature, it had so happened that no species had been permitted to stray from its own formation into the next in succession, the benefit would have been much enhanced, for to those with keen eyes for form, the finding of any single fossil would be sufficient to mark the place in the geological scale of any given formation. Then we should have a perfect and orderly symmetrical accuracy of detail, so that he who runs may read. But it so happens that this is not the case, for Nature loves variety, and performs her functions in various ways, and thus it happens that in certain cases the dividing lines between two formations, if we follow them far enough, are sometimes difficult to determine. Of these unruly formations in England the *Upper Greensand* forms one, in its occasional physical relations to its neighbours, the Gault below and the Chalk above.

The Upper Greensand in the West of England appears in great force, forming part of the strata that extend from the coast between Lyme Regis and Sidmouth, northward to the Black Down Hills, south of Taunton. West of the estuary of the Exe, it forms, in two outlying patches, the broad-topped hills of Great Hal-don and Little Hal-don, and south of the angle of the Teign, near Newton Bushell, there is another outlier on Milber Down. These lie so near the main mass, and approximately are so much on the same level, that they are obviously the work of ordinary denuding agencies on a broader area of Greensand. It is, however, at first sight somewhat surprising, to meet with a small outlier of Upper Greensand, only a few acres in extent, nearly fifty miles to the west of Black Down, at Orleigh Court, three miles south-east of Bideford Bay. This patch is mentioned by De la Beche, in his Report on the Geology of Cornwall, Devon, and West Somerset, and of late its existence as a solid outlier has been doubted. There is, however, so much angular chert on the spot, that sufficient material remains to show that the Greensand once spread westward so far, and in my opinion probably much farther.

Throughout these areas, the Upper Greensand may be briefly described as consisting of yellowish brown sand, partly compact, partly soft, with layers and detached pieces of chert, and towards the base it is partly green with specks of silicate of iron. The sands are often coarse, and contain layers of shells, frequently broken and fragmentary. The whole is little more than 200 feet in thickness.

East of Lyme Regis, this Greensand appears near Abbotsbury, on the southern and western flanks of the Chalk Downs at Whitehill. West of Chideock outlying patches lie on the marlstone of the Middle Lias, between Chideock and Bridport on the sand that underlies the Inferior Oolite, at Abbotsbury Castle on the Forest Marble, and from thence stretching north and west, at Shipton Beacon they lie on the Fuller's Earth. Beyond this the Cretaceous strata make a great curve east of Poorstock and Beaminster, lying generally on the Fuller's Earth. East of Cheddington, for some miles the Greensand lies on the Oxford Clay, then for a short space on the sand of the Calcareous

Grit, then from Buckland Newton, in Dorsetshire, to the neighbourhood of Shaftesbury, on Kimeridge Clay.

Near Shaftesbury the Gault comes on in force, and separates the Upper Greensand from the Oolitic rocks as far as the neighbourhood of East Knoyle, on the north side of the mouth of the Vale of Wardour. Between East Knoyle and Chapmanslade in Wiltshire, the Greensand lies chiefly on the Coral Rag, but partly on the underlying Oxford Clay, and the Gault, if present at all, is so thin that it cannot be mapped. It is probable that when the Gault was deposited elsewhere, this part of the Oolitic area was above the sea-level. From Chapmanslade, the Greensand, underlaid by Gault, runs along the lower part of the Chalk escarpment in an ENE. direction, by Westbury to Urchfont and Devizes, and from thence, lying nearly flat, the strata form the surface of a broad tract of country, eighteen miles in length from west to east, bounded on both sides by Chalk, the whole forming a low anticlinal north and south curve. Still further east, at Shalbourne and Sidmonton, near Kingsclere in Hampshire, two other tracts of Upper Greensand rise through the Chalk to the surface in anticlinal curves of an oval form.

Between Devizes, the Fens of Cambridgeshire, and the east coast of the Wash, the Upper Greensand runs to the north-east, in a long somewhat sinuous line, and nearly all along the strike it forms the lower part of the bold escarpment of the Chalk, which overlooks the great plain or table-land of Oolitic strata that runs across England from the coast of Dorsetshire to the Humber. North of the Humber, it is marked in ordinary maps as skirting the Chalk Wolds, first to the north and then to the east, as far as Filey Bay, but if such be the case, its sandy character is not always easily recognisable, which, indeed, is also the case much further south.

In the south-eastern part of Dorsetshire, the Upper Greensand crosses the Isle of Purbeck from west to east in a narrow line, overlying the well-known Punfield beds, and overlaid by the Chalk of the long and imposing ridge of Purbeck Hill, Knowl Hill, Nine Barrow Down, and Ballard Down. The Greensand itself makes no feature in the landscape. Fig. 75, p. 347.

Striking east under the sea, the Upper Greensand barely escapes forming part cf the great sea-cliff of chalk, that runs from Sun Corner near the Needles, to Compton Bay below Afton Down, from whence, overlying the Gault, it crosses the Island to the sea close under Bembridge Down. In this course, wherever the Chalk Downs are narrow, owing to the high angle of northern dip, there the line of Upper Greensand is also narrow, but where the angle of inclination is comparatively low, there both Chalk and Greensand spread over a broad space, between Mollestone Down and Carisbrook. A large outlier of Upper Greensand, capped by two outliers of Chalk, overlooks the sea on the south side of the Island between Chale Bay and Chine Head, the strata being nearly flat.

In the area of the Weald of Kent and Sussex (fig. 72), the Upper Greensand at the base of the escarpment of the Chalk, sweeps round the vast oval, from East Wear Bay, near Folkestone, to East Meon, near Petersfield, and from thence to the sea at Eastbourne, near Beechy Head, but not with absolute certainty all the way, for only here and there can the Greensand be faintly discovered, between the sea and Chevening, along a line of about fifty miles in length. Beyond this point it begins to get more distinct, and the malm-rock, fire-stone, and other lithological varieties, can be traced all along by Westerham, Merstham, Guildford, the Hog's Back, Farnham, and the extreme west of the area in the country round Binstead, Selbourne, and the ground about two miles west and south of Petersfield, where, as far as colour goes, it might often be taken for chalk.

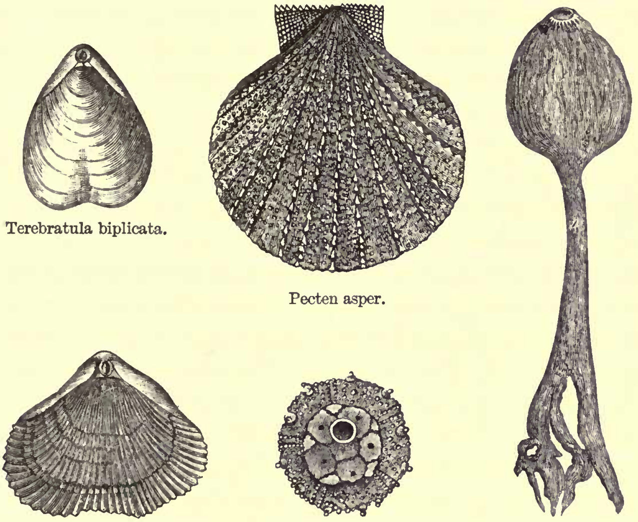
On the south side of the Wealden area, the Upper Greensand maintains the same general character by Cocking and Barlavington as far as Steyning, where its lithological character begins to change, and the beds pass into 'sandy marl and marly sand,' and near Eastbourne the strata are decidedly sandy.

Important deductions are to be drawn from the consideration of the lithological changes that take place in the character of the Upper Greensand, which will afterwards appear. A gradual change may be traced all the way from Devonshire to Cambridgeshire and the east end of the Wealden area, which throws some light on the physical geography of the time, especially when taken in connection with the circumstance, that out of more than 200 species of fossils in the Gault, about 46 per cent. pass onward into the Upper Greensand.[1] The Upper Greensand is often fossiliferous, containing *Cycads* and *Coniferous woods; Sponges*, *Siphonia pyriformis*, &c.; a few *Foraminifera; Corals, Trochosmilia tuberosa*, *Micrabacia coronula*; many Echinoidea, the chief of which belong to the genera *Cidaris*, *Cardiaster*, *Echinus*, *Pseudo-diadema*, *Salenia*, &c. Brachiopoda are common, *Terebratulæ* and *Rhynchonellæ* (*T. biplicata*, *Rh. latissima*,

[1] For much information on the Upper Greensand of the Wealden area see 'Memoirs of the Geological Survey, Geology of the Weald,' by W. Topley, 1875.

&c.). In Lamellibranchiate molluscs it is even richer than the Lower Greensand, abounding especially in species of the genera *Inoceramus*, *Gryphæa* (*lævigata*), *Lima*, *Pecten asper*, *Astarte*, *Trigonia*, *Cucullæa*, *Cyprina*, and *Cytherea*. It is also rich in Gasteropoda, such as *Turritella*, *Pleurotomaria*, *Natica* (*N. Gentii*), &c., and yields many species of *Ammonites*, *Nautili*,

FIG. 44.



Terebratula biplicata. Pecten asper. Rhynchonella latissima. Selenia personata. Siphonia pyriformis.

Group of Upper Greensand Fossils.

Hamites, *Baculites*, *Scaphites*, and *Belemnites*. Crustacea, *Hoploparia longimana*, *Necrocarcinus Bechii*, &c. Probably three species of Reptilia belong to this formation, *Plesiosaurus pachycomus*, a *Crocodile*, and a *Turtle*.

THE CHALK, from its familiar characters and general uniformity of structure, is the most easily recognisable of all the British formations. From west to east it stretches from the neighbourhood of Beaminster in Dorsetshire, to Beachy Head and the North Foreland, and passing beneath the Eocene formations of the Hampshire and London basins it spreads northward to Speeton, in Yorkshire.

The *Chloritic Marl* indicates a passage from the Upper Greensand into the Chalk. It consists of a chalky base specked with green grains, and varies from a few inches to a few feet in thickness. It is highly fossiliferous, abounding in *Ammonites*, *Nautili* (*N. lævigata*), and a small *Scaphite* (*S. æqualis*), besides *Oysters*, *Trigonias*, *Holaster*, &c., and many other Echinodermata.

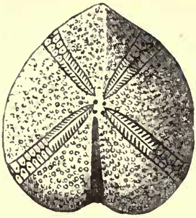
The *Chalk Marl*, which lies above the Chloritic Marl when both are present, is merely chalk with a slight admixture of argillaceous matter, and with its predecessor by no means deserves to be considered as a separate formation. The whole, therefore, may be massed as *The Chalk*. It consists of a soft white limestone, generally much jointed where exposed in quarries, and but for lines of flints, the bedding would often be scarcely distinguishable. On minute examination with the microscope, much of the Chalk is found to consist of the shells of Foraminifera, Diatomaceæ, spiculæ and other remains of Sponges, Polyzoa, and shells, highly comminuted. Somewhat similar deposits are now forming in the open Atlantic at great depths, chiefly of Foraminifera of the genus Globigerina, Polycystina and Diatomaceæ, and spiculæ of Sponges. In the Pacific, also, from Java to the Low Archipelago, over an area of about 4,000 miles in length, all the deep-sea deposits are of fine, white, calcareous mud, like unconsolidated chalk. In its thickest development in England the Chalk is about 1,200 feet thick in Dorsetshire, Hampshire, &c. The Lower Chalk usually contains no flints and, as already stated, is somewhat marly at the base, while the Upper Chalk is interstratified with many beds of interrupted flints. These are of irregular form, and lie in layers in the lines of bedding. A great proportion of them are stated by Dr. Bowerbank to be silicified Sponges, which often inclose other organic bodies, such as shells, fragments of Belemnites, &c.; others of large size, called Paramoudras, which are rare, stand vertically across the beds. These sometimes resemble, in general form, the large cup-shaped sponges of the Indian Ocean Alcyonium, or Neptune's cup.

As a whole, the Chalk dips gently from its western escarpment to the east and south, and round the Wealden area to the south and north, underlying the Tertiary strata of the Hampshire and London basins, and reappearing with precisely the same characters on the coast of France. Its area in Europe and Asia is immense. In the north of Ireland, between Belfast and the Giant's Causeway, there are patches of very hard Chalk on the coast, overlaid by columnar basalt of Miocene age. The great superincumbent pressure of these masses of igneous rocks has hardened the chalk, and therefore they have not, as is usually supposed, been altered by the heat of overflowing lavas, except possibly for an inch or two at the immediate point of junction, but this is somewhat foreign to our present subject. Traces of Chalk and Upper Greensand occur at Bogingarry, &c., in Aberdeenshire. These consist partly of chalk flints, partly of sandstone, possibly in place, and sufficient to show that Cretaceous rocks, which have been removed by denudation, probably once spread over that country. Cretaceous strata, discovered by Mr.

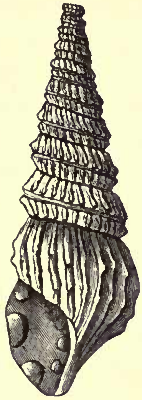
Judd, also occur in the Island of Mull beneath the Miocene basalts.

About half the genera, and a considerable number of Chalk species, are identical with those of the Gault and Upper Greensand, but it contains a far greater number, nearly 800, most of which are peculiar to itself. Plants are few, as might be expected in a wide deep-sea deposit. A great many Sponges have been described, chiefly from flints. Among the most numerous are species belonging to the genera *Ventriculites*, *Cephalites*, *Spongia*, and *Siphonia*. A large number of genera and species of Foraminifera are also described, among which *Globigerina bulloides*, *Dentalina gracilis*, and *Rotalina ornata*, are common. Of Corals about 15 species are known, several of which belong to the genus *Parasmilia* (*centralis*, &c.), *Caryophillia lævigata*, &c. Echinodermata are very numerous, among others including the genera *Ananchytes*, *Cardiaster*, *Cidaris*, *Cyphosoma*, *Diadema*, *Echinopsis*, *Galerites* and *Echinobrissus*, *Holaster*, *Micraster*, and *Solenia*, &c. Among its starfish are comprised the genera *Arthraster*, *Goniaster*, and *Oreaster*. Of these Goniaster is exceedingly characteristic. In addition it has yielded an *Ophiura* and several Crinoids, *Bourgueticrinus ellipticus*, *Marsupites Milleri*, &c. On shells, &c., found in the Chalk, are frequent Serpulæ. It also yields Cirripeds and a few Crustaceans, *Enoploclytia Sussexensis*, &c. Polyzoa are numerous, of many species. Like other members of the Cretaceous rocks, its Brachiopoda generically resemble those of the Oolites, including *Rhynconella*, *Terebratulina*, and *Terebratula*. The Lamellibranchiate molluscs of the Chalk are in some cases specifically identical with those of the Gault and Upper Greensand; and, generically, they bear the

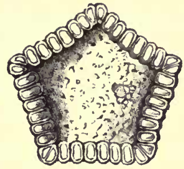
FIG. 45.



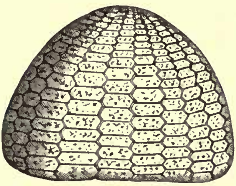
Micraster cor-anguinum.



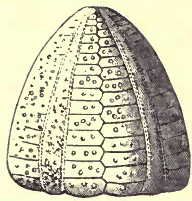
Turrilites costatus.



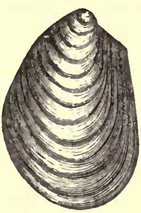
Goniaster Coombii



Ananchites ovatus.

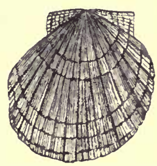


Echinoconus albo-galerus.

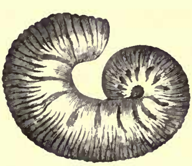


Inoceramus mytiloides.

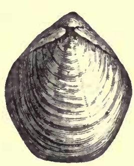
Nautilus pseudo-elegans.



Pecten Beaverii.



Scaphites æqualis.



Terebratula carnea.

Lima spinosa.

Globigerina bulloides.

Group of Fossils from the Chalk.

strongest resemblance, consisting, among others, of many species of *Inoceramus*, *Lima*, *Pecten*, *Oyster*, *Spondylus*, *Radiolites*, *Trigonia*, &c. Being a deep-sea deposit, it is poor in Gasteropoda, but rich in Cephalopoda, especially in *Nautili* (*N. elegans*, &c.), *Ammonites* (*A. Rothomagensis*, &c.), and *Turrilites* (*T. costatus*), besides *Baculites*, *Hamites simplex*, *Scaphites* (*S. æqualis*), and *Belemnites*.

Numerically as individually, though still very characteristic, Cephalopoda are less numerous in the Cretaceous than in the Oolitic and Liassic strata, though the latter contain fewer genera. In the Lias and Oolites there are nearly 300 species of Cephalopoda, most of which are Ammonites. In the Cretaceous rocks less than 200 species are known, about 70 of which are Ammonites. More than 80 species of fish are known in the Chalk, including all the four orders of Agassiz, Placoids, Ganoids, Cycloids, and Ctenoids. Many of the Placoids are Cestraciont fish, numerous species being of the genus Ptychodus. Ten genera of reptiles are known, two of which are allied to the Crocodilia, *Acanthophilis horridus*, and *Leiodon anceps*; the great *Mosasaurus*, 3 species; *Plesiosaurus*, 2 species, *Ichthyosaurus* and *Pterodactyle*, one of which is said to have measured eighteen feet across the expanded wings. Several Turtles occur in the Chalk, *Chelone Benstedi*, &c.

Having thus briefly described the Upper Cretaceous strata of England, I shall next endeavour to show what inferences may be drawn with regard to the physical geography of the British area, during the time occupied by their deposition.

We have already seen that, during the deposition of the Purbeck and Wealden strata, England formed part of a great continent, and that, during the formation of the Lower Greensand, this land suffered partial submergence, but by no means to such an extent that the Oolitic strata, which then extended far to the west, round Wales, were entirely sunk beneath the sea in which our Lower Greensand was deposited.

As a whole, the Lower Greensand, being a coarse and sandy formation, was deposited in shallow water, and great part of it was in the long run tranquilly heaved out of the sea, to undergo terrestrial waste and denudation before the deposition of the Gault began.

The deposition of the Gault in our area, first took place on a surface of country that was being gradually submerged, and part of the sediment was laid on the Lower Greensand, and part on various members of the Oolitic strata, from which the Lower Greensand had been removed by denudation. This Gault Clay is, however, so difficult to separate from the Upper Greensand in the eastern part of England, and the Upper Greensand is so difficult to separate by any clear line from the Chalk, that it now becomes necessary to consider the question of the mode of deposition of all three, if, indeed, except as local developments of different sedimentary character, they ought not to be considered, on a broad scale, as only one formation. Right or wrong, the origin of this idea was first declared by Mr. Godwin-Austen, whose large grasp of questions in physical geology, (to be found only in scattered memoirs, and unfortunately often only spoken in accidental remarks,) is by no means so well known as it would have been, had he printed all his stores of geological knowledge in consecutive form. All that I know of this subject with respect to these Cretaceous formations, is in the first instance derived from him, subsequently aided by personal observation on the ground.

The story revealed by these various strata is this: When, after the temporary upheaval of the Lower Greensand, the land gradually sank in part beneath the sea, it happened that the Upper Greensand was being deposited far in the west on a sea-bottom that now forms an eastern part of Devonshire. Not far from its margin, a fragment of the old greater land, in our day known in a modified form as the granite hills of Dartmoor, stood high above the level of the sea, and at the same time, on the opposite side of what is now the Bristol Channel, Wales also formed high land. The pebbly shore of the lower land near Dartmoor, has long ago been destroyed by denudation, but the sediments laid down not far from the shore still exist in the coarse sandy strata that form the Upper Greensand west and east of the river Exe. As we go eastward from that area towards Devizes, the Upper Greensand still continues to be comparatively coarse, and by degrees in Buckinghamshire, and Bedfordshire, and on into Cambridgeshire, it gets finer and finer, and at length becomes white, calcareous, and marly, and, as it were, seems to mingle with the Gault beneath and the Chalk above, and the Gault, indeed, in a lithological point of view, sometimes seems to disappear altogether.

In like manner, at the western end of the Wealden area, and along the base of the South and North Downs, the Upper Greensand for many miles consists of fine, white sand, and in the Malm-rock is somewhat chalk-like and calcareous, till going further east towards Folkestone, it gradually becomes untraceable as a special formation, and merges into the underlying Gault and the overlying Chalk.

The meaning of this is, that distinct coarse Upper Greensand strata were deposited not far from shore in the west, gradually getting finer towards the east, because the finer and lighter material was drifted further from shore. At the very same time, in the farther east of what is now England, the sediments were still finer, and depositions akin to Chalk, and even the Chalk itself, had begun to be formed in a deeper sea, far removed from land, so that according to this view, part of the lowest strata of the Chalk, in the eastern and south-eastern parts of England, were deposited contemporaneously with the coarse Upper Greensand of eastern Devonshire. On no other hypothesis that I know than this of Godwin-Austen's, can the phenomena connected with the Gault, Upper Greensand, and the lower strata of the Chalk, be rationally accounted for, and I believe that hypothesis to be true.

The upper strata of the Chalk consist of nearly pure chalk with lines of flint, and as it accumulated, the sinking of the western and northern fragments of the old continent steadily continued, till at length they almost, if not entirely, sank beneath a sea, broad and silent, except when roused by storms, like the Atlantic of our own time, for though the Echini and shells found in our chalk, show that the sea of those days was not so deep as the present Atlantic, yet the prevalence of prodigious numbers of Globigerina and other Foraminifera shows that the old and the new seas are akin in the nature of their organic sediments. If the whole of the older land was not submerged, (making an allowance for the lowering of the mountain lands by subsequent subaerial waste,) even then we can only suppose that a few insignificant islets rose above a waste of waters, that spread not only over Britain, but also over a very large part of the Europe of the present day, long before the Alps and the Pyrenees rose into mountain chains, and only a few islands formed of Palæozoic rocks stood above the waves. This surely was a striking phase of an older physical geography, which affected areas far wider than Europe alone, but which in the course of time came to an end in a manner which we shall presently see. To do so thoroughly we must consider the rocks of the continent for a little.

A vast lapse of time took place between the close of the deposition of the uppermost Cretaceous strata of England, and the commencement of the deposition of the succeeding Eocene formations, for in England we have no deposits of intermediate age. What, however, helps to prove this great hiatus is, that on the Meuse, at Maestricht, there is a calcareous formation about 100 feet thick, which lies unconformably on the Chalk, the line of unconformity being marked by a line of water-worn flint pebbles. Some of the fossils are of the same species with those found in the Chalk, and Cephalopoda of the genera *Baculites* and *Hamites*, not yet known in strata younger than the Cretaceous rocks of Europe, are found in the Maestricht beds. On the other hand, Volutes, and other genera of Tertiary type, are found in the strata, so that this marine fauna may be said to be of a type intermediate to those of the Cretaceous and Eocene epochs.

Extending for great distances round Paris, there are numerous small patches of pisolitic limestone, once united, but now separated by denudation. These contain some Cretaceous species, but many others are more Eocene than Cretaceous in their affinities.

At Faxoe also, in the Isle of Seeland, in Denmark, there is a yellow limestone so full of corals that it was probably a coral reef. It contains among other shells many univalves which are unknown or rare in the Chalk, such as *Cypræa*, *Oliva*, &c., and along with these *Baculites* and *Belemnitella*, both unknown in European Eocene strata, though the latest intelligence from Australia tells of a Belemnite in certain late Tertiary strata there. Overlying the common white Chalk, this Faxoe formation by its fauna also seems to be intermediate in date to the ordinary Cretaceous and Eocene strata.

But without such data as these it is evident to any reflective mind, that a great gap in time, unrepresented by any sedimentary formations in England, took place in our area between the deposition of the latest bed of English Chalk, and that of the earliest Eocene stratum, for, excepting a few Foraminifera, the species found in the Chalk seem all to have been remodelled before our Eocene epoch began, in so far that palæontologists recognise none of the species as identical, and before the days of Darwin they would generally have been spoken of as new creations.

CHAPTER XV.

EOCENE FORMATIONS.

THE EOCENE STRATA, to which we have now come in this epitome of British geological history, form the oldest members of the Tertiary or Cainozoic series. It ought, however, to be remembered, that the terms Palæozoic or Primary, Mesozoic or Secondary, and Cainozoic or Tertiary, are mere terms of local convenience, unfit even for minor territories such as Europe, as the notice of strata intermediate to the Chalk and Eocene beds shows at the end of last chapter. I cannot enter on the details of this subject here. Readers must work it out for themselves, and there is no lack of printed matter from which to do so.

The EOCENE ROCKS of England lie in two basins, those of London and Hampshire. Both are surrounded and underlaid by the Chalk. The London basin extends westward from the mouth of the estuary of the Thames to the neighbourhood of Marlborough, and northward till it is lost beneath the drift of Suffolk and Norfolk. The north boundary of the Hampshire basin runs from Beachy Head to the neighbourhood of Salisbury and Dorchester. The Chalk Downs near Newport, Isle of Wight, form its southern boundary. In both areas the Chalk and Tertiary strata are little disturbed, except in the Isle of Wight and at Purbeck, where for a space they have been heaved nearly on end. The Lower

Eocene rocks lie sometimes on upper beds of Chalk, and sometimes on beds lower in the series. They are, therefore, highly *unconformable* to each other, and this alone marks a great interval of time, unrepresented in England by the deposition of strata. The subject is evidently connected with the nearly total break in succession of *evident species* between the Cretaceous and Eocene formations; for, great continental areas of Chalk were heaved above the sea and remained as dry land for a period of time so long, that, when they were again submerged, the life of Cretaceous times had mostly been remodelled by slow evolution, and newer forms, in time became the legitimate successors of their long-buried ancestors.

When critically examined, it soon becomes evident that the strata of the basins mentioned above were not originally deposited in two distinct basin-shaped hollows, but that they were once united, and formed one great area of Eocene age. Long after, a disturbance of the Secondary and Lower Tertiary strata took place, which threw them into broad anticlinal and synclinal curves. One long and broad anticlinal curve passes along the Wealden area from east to west, and still further on through part of the Chalk. South of this we find the synclinal curve of the Hampshire basin, bounded on the south by the Cretaceous strata of the Isles of Wight and Purbeck, and on the north by the Chalk of the Salisbury, Winchester, and Brighton area, while north of the Weald, the Eocene rocks of the London basin bounded by Chalk lie in a similar synclinal curve, broad at its east or seaward end, and narrow at its western end towards Marlborough. When still more closely examined, it is found that many beds of our Eocene strata were deposited in fresh and in brackish water, and others in the sea, and the conclusion to be drawn from this is, that they largely consist of sediments that were thrown down at the mouth of a great river.

When we consider the original extension of these Eocene river beds, it is also remarkable that they lie within the same general limits as those of the older fluviatile deposits of the Purbeck and Wealden strata, as if, after a long interval, geological history were repeating itself in the same area. In our own day, occupying part of the same district, we have yet a third estuary, that of the Thames, small, but in some respects of more importance to the living world than many an estuary of fifty times its size.

The various subdivisions of the English Eocene strata are given in the Table of British Formations (p. 30), in which the classification of Professor Prestwich is used, which is also that adopted by Sir Charles Lyell in his Manuals. As far, however, as England is concerned, it is more philosophical, as it is certainly more convenient, to divide them into three groups, as follows:

Upper Fresh-water and Estuarine.	Hempstead beds.	
	Bembridge ,,	
	Osborne ,,	
	Headon ,,	
Marine.	Upper Bagshot Sand.	
	Middle Bagshot.	Barton Clay.
	Lower Bagshot.	Bracklesham beds.
	London Clay.	
Lower Fresh-water, Estuarine, and Marine.	Woolwich and Reading beds.	
	Thanet Sand.	

This classification has the merit of simplicity, being founded on circumstances relating to variations in the physical geography of the time in our area, while the other seems to be more arbitrary, being founded on considerations of a purely palæontological kind. It will at all events be most easy in this book to treat of the strata as consisting of a lower fresh-water and estuarine, a middle marine, and an upper fresh-water and estuarine series.

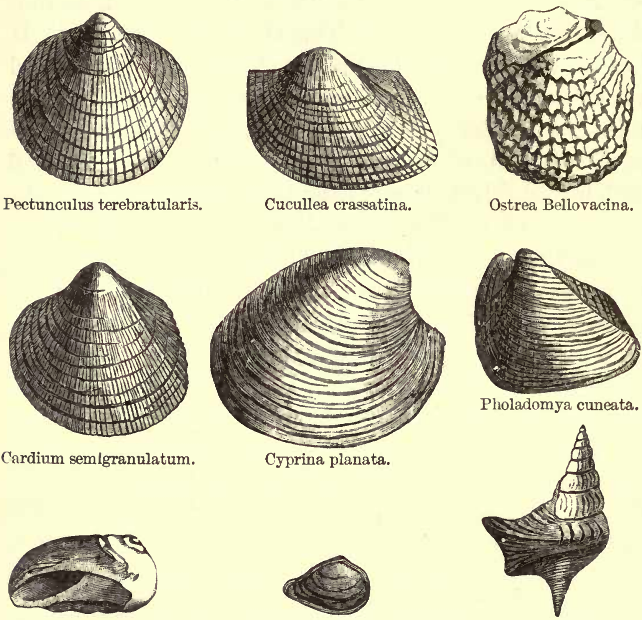
The *Thanet Sand*, absent in the Isle of Wight, is so named by Professor Prestwich because it is so well developed in the Isle of Thanet on the Thames. It lies at the base of the Eocene strata of England, and consists of fine, light-coloured, quartzose sands, partly mixed with clayey matter. It usually lies on a layer of Chalk flint, of an olive-green colour externally, and which probably represents the effect of the waste of the carbonate of lime of the chalk which was carried away in solution as bicarbonate, through the infiltration of rain-water after the deposition of the sands, the associated silica having been concentrated and deposited in this band. These sands range from the Isle of Thanet westward to the neighbourhood of London, varying from about 50 feet thick, in parts of Kent, to 4 feet, at East Horsley, where they disappear, being overlapped by the Woolwich and Reading beds. They are quite unknown in the Hampshire basin.

The fossils of this subformation are entirely marine, and embrace about 70 known species. Among these are a shark of the genus *Lamna*, *Pisodus*, and others; a *Nautilus*; Gasteropoda, such as *Fusus tuberosus*, *Scalaria Bowerbankii*, *Natica*, *Aporrhais*, &c.; a considerable number of Lamellibranchiata, such as *Nucula Thanetania*, &c.; *Pholadomya Koninckii* &c.; *Corbula*, *Cardium*, *Ostrea Bellovacina*, &c. &c.; Crustacea, *Hoploparia*, and *Palæocorystes*; spines of *Echini* (rare), a coral, a few Foraminifera, and *land-plants*. In the

Paris basin, so celebrated for its Eocene strata, the *Sables de Bracheux* are the equivalents of the Thanet Sand, in which the skull of a carnivorous quadruped (*Arctocyon primævus*) was found.

More than 20 species of shells found in the English Thanet Sand are also known in the Woolwich and

FIG. 46.



Pectunculus terebratularis. Cucullea crassatina. Ostrea Bellovacina.

Cardium semigranulatum. Cyprina planata. Pholadomya cuneata.

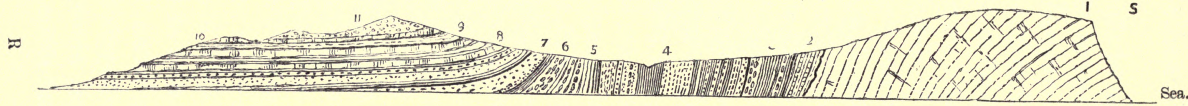
Natica depressa. Corbula Regulbiensis. Aporrhais Sowerbyi.

Group of Fossils from the Thanet Sand.

Reading beds, and in the London Clay, and Barton and Bracklesham beds. The Thanet Sands are, indeed, so like those of the Woolwich and Reading beds, that, but for their position, it is sometimes difficult to distinguish between them, and they were formerly

FIG. 47.

Section across the Isle of Wight from High Down to Headon Hill, showing the arrangement of the strata in Alum Bay. By H. W Bristow, F.R.S.



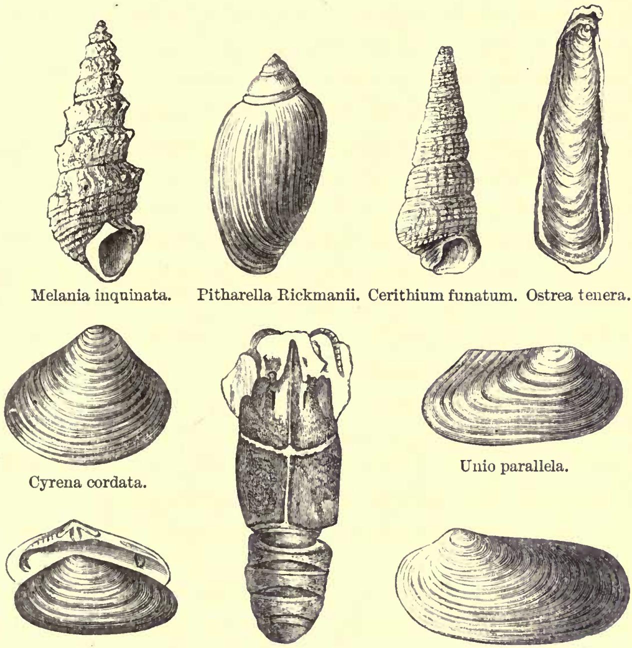
1. Chalk.
2. Woolwich and Reading beds.
3. London Clay.
4. Lower Bagshot Sand and Clay.
5. Bracklesham beds, Barton Clay.
6. Upper Bagshot Sands.
7. Lower Headon beds, Middle Headon beds.
8. Upper Headon beds.
9. Osborne beds.
10. Bembridge Limestone.
11. High level gravel (Post-pliocene).

looked upon as a portion of the Woolwich and Reading series, which partly consists of a few saltwater beds, interstratified with a preponderance of fresh-water deposits. Excepting that the Thanet Sand is altogether marine, it is possible that it might have continued still to be classed simply as one of the minor marine portions of the Woolwich and Reading series.

The *Woolwich and Reading beds*, formerly called the *Plastic Clay* (*Argile plastique* of the Paris basin), overlie the Thanet Sand, and rest directly on the Chalk, when, as in the greater part of the London basin, and in Hampshire and the Isle of Wight, the Thanet Sand is absent. They may be broadly described as consisting of many wedge-shaped interstratifications of mottled clays, light-grey sands, and pebble-beds, made of chalk flints, which are sometimes loose and gravelly, and sometimes hardened into conglomerates. From west to east the strata vary from 15 to 90 feet thick in the London basin. In the Hampshire basin they are still less developed (fig. 47), and the whole consists of mingled marine, estuarine, and often of purely fresh-water strata, marking the first obvious signs of the influx of a great river, formed by the drainage of a continent, the result of the upheaval above the sea of large areas of Chalk and other older rocks in what is now Britain and the nearest parts of France. There can be no doubt, however, that the Thanet Sands are the result of the same set of conditions, only they were deposited further from shore in a comparatively open sea.

More than 100 species of fossils are known in the Woolwich and Reading strata, including an herbivorous mammal of the genus Coryphodon, allied to the modern tapirs of South America, which live on the banks of the Amazons and other great rivers, also the bones of a bird, turtles, and the scutes of a crocodile; several fish of the genus *Lamna* (*L. contortidens*, &c.), *Lepidosteus*, *Lepidotus*, and *Myliobatis*; marine Gasteropoda, such as *Cerithium funatum*, &c.; *Fusus latus*, *Hydrobia Parkinsoni*, *Melanopsis brevis*, &c.; *Natica*, *Neritina*,

Fig. 48.



Melania inquinata. Pitharella Rickmanii. Cerithium funatum. Ostrea tenera.

Cyrena cordata. Unio parallela.

Cyrena telenella. Hoploparia gammaroides. Panopœa intermedia.

Group of Fossils from the Woolwich and Reading Beds.

and others. Lamellibranchiata, not very numerous as genera and species, but plentiful as individuals, occur both in the sands and clays, including species of *Arca*, *Cardium*, *Corbula*, *Cyprina Morrisii*, *Cyrena cordata*, &c., *Modiola elegans*, *Ostrea edulina* or *Bellovacina*, *O. elegans*, &c.; *Pectunculus*, *Psammobia*, &c.; Crustacea (*Hoploparia gammaroides*) and Foraminifera also occur.

A few land-plants have been found, as might be expected in estuarine strata, viz. *Dryandroides Prestwichi*, *figs*, *laurels* (*L. Hookeri*), *Grevillia Heeri*, and *Robinia Readingensis*; also great numbers of fresh-water shells in true fresh-water strata, such as *Paludina lenta*, &c.; *Planorbis lævigatus*, &c.; and several of the genera *Cyrena* (*C. cordata*, &c.) and *Unio*, together with the small bivalve Entomostraca, *Cypris* and *Cythere*.

Taken as a whole, the estuarine, and especially the fresh-water character of so many of the strata of this series, make the strongest impression on anyone engaged in mapping them.

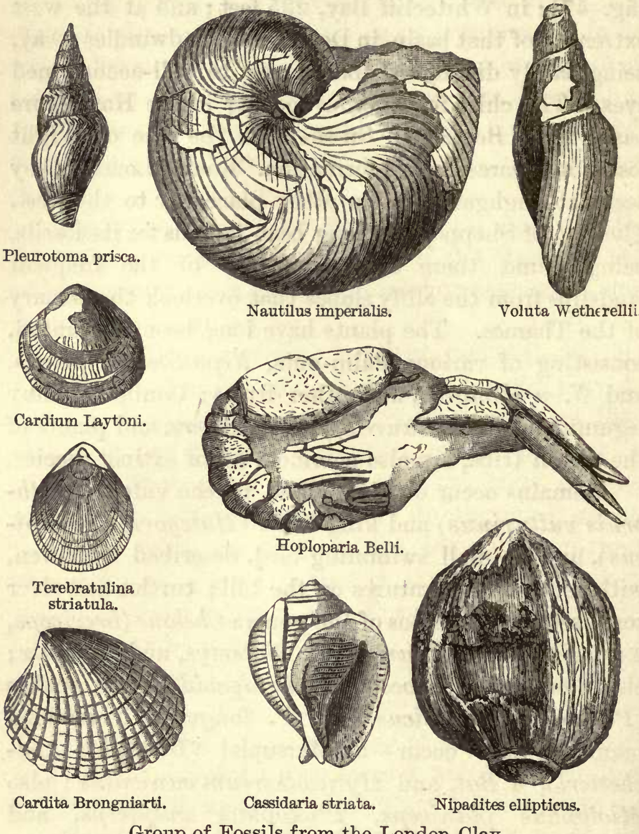
The *Oldhaven beds*, formerly included by Mr. Prestwich in the basement bed of the London Clay, lie between the above-named strata and the London Clay, and consist of fine sand containing water-worn pebbles of flint. They are of inconsiderable thickness, but very constant in their occurrence. With the rarest exceptions the fossils are marine; and they are numerous, consisting to a great extent of the same molluscous genera as those found in the Eocene strata below, with additions, and a proportion of the species are also found in the overlying London Clay. Their chief importance in this sketch is, that the sand with water-worn pebbles seems to indicate some oscillation of level, accompanied by stronger currents, in an estuary which carried flint-pebbles onward, toward the mouth of this old river.

The *London Clay* (fig. 47, p. 241), is a marine deposit, in the sense that the strata now forming in the broad estuary of the Amazons is marine. It usually consists of brown and bluish-grey clay, with occasional bands of calcareous concretions (septaria). In the London basin it varies in thickness from 50 feet in the extreme west, at Newbury, to 480 feet in Essex. In the Isle of Wight, at Alum Bay, it is only 200 feet thick (fig. 47); in Whitecliff Bay, 295 feet; and at the west extremity of that basin, in Dorsetshire, it dwindles away, being barely distinguishable except to well-accustomed eyes. The chief fossiliferous locality in the Hampshire basin is at Bognor in Sussex. In the Isle of Wight fossils are scarce in this formation. Round London they occur at Highgate, and in other places far to the west. The Isle of Sheppey has long been famous for its fossils, being found there chiefly because of the frequent landslips from the cliffy slopes that overlook the estuary of the Thames. The plants have long been celebrated, consisting of various Palm-nuts, *Nipadites ellipticus*, and *N. umbonatus*, and other fruits; Coniferæ, many leguminous plants, *laurels*, *figs*, *junipers*, and plants of the *citron* tribe, are also common, all of extinct species.

Remains occur of birds allied to the vulture (*Lithornis vulturinus*) and king-fisher (*Halcyornis toliapicus*), and a small swimming-bird, described by Owen, with tooth-like serratures on the bill; turtles and river tortoises are numerous of the genera *Chelone* (*breviceps*, &c.), *Emys* (*Conybeari*, &c.), *Platemys*, and *Trionyx*; also a crocodile (*Crocodilus champsoides*) and snakes (*Palæophis toliapicus* and *P. longus*). Terrestrial mammals also occur—a Marsupial (*Didelphis Colchesteri*), a *Bat*, and *Hyracotherium cuniculus*; also *Miolophus planiceps*, *Pliolophus vulpiceps*, and *Coryphodon eocænus*, which are tapir-like animals, in a distant way allied to the tapirs now found on the banks of South American rivers.

Plants, birds, reptiles, and mammals all tell of the immediate neighbourhood of land, and the marine fossils now to be mentioned seem in fact to have lived at the mouth of a great river.

FIG. 49.



Pleurotoma prisca. Nautilus imperialis. Voluta Wetherellii. Cardium Laytoni. Hoploparia Belli. Terebratulina striatula. Cardita Brongniarti. Cassidaria striata. Nipadites ellipticus.

Group of Fossils from the London Clay.

Nearly 60 *genera of fish* have been noted from the London Clay alone, including species of *Lamna* and many species of Rays (*Myliobatis*). Of the Cephalopoda, *Nautilus* (*N. Sowerbyi*, &c.) is common, together with Cephalopods, *Belemnosis plicata*, *Belosepia sepioidea*, and *Beloptera Levesquei*. Ammonites and Belemnites, genera common in the Cretaceous strata have disappeared. Gasteropoda occur in vast profusion, the most prominent genera being *Fusus* (*F. regularis*, *F. læviusculus*, &c.), *Murex* (*M. cristatus*, *M. coronatus*, &c.), *Pleurotoma* (*P. Helix*, *P. Keelii*, &c.), *Voluta* (*V. nodosa*, &c.), *Pyrula* (*P. Smithii*, &c.) *Cypræa* (*C. oviformis*), and *Rostellaria* (*R. ampla*, &c.). Lamellibranchiata, though common, are less numerous, including among others the genera *Pinna* (*affinis*, &c.), *Pholadomya* (*Dixoni*, &c.), *Arca*, *Avicula*, *Pecten*, *Cardium*, *Cyprina*, *Nucula*, &c. The Brachiopoda are only represented by *Lingula tenuis* and *Terebratulina striatula*, and there are a few Polyzoa. Crustacea are exceedingly numerous, especially crabs (Brachyura and Anomura), including the genera *Xanthopsis*, *Hoploparia*, &c.; and of Entomostraca, *Cythere* is common of many species. Among the Echinodermata we have *Hemiaster Bowerbankii*, &c.; *Goniaster*, *Cidaris*, *Astropecten Colei*, &c.; *Ophiura Wetherellii*, and *Pentacrinus*, and there are also a few Corals. Many of the fossils of the London Clay are found in other strata both above and below that formation, but a larger proportion is common to the overlying than to the lower formations.

Looked at in a comprehensive way, an accurate observer cannot fail to be struck with the fact that the assemblage of fossils found in the London Clay point in this direction, viz., that the whole of these strata were deposited in the estuary of a great continental river comparable to the Amazons and the Ganges. The Palm-nuts and the host of other plants help to prove it, and the remains of river tortoises, crocodiles, snakes, marsupial, and several tapir-like mammals, all point in the same direction. The estuarine conditions, begun during the deposition of the Woolwich and Reading beds, were still going on when the London Clay was thrown down, with this difference, that by sinking of the area, the estuary had become longer, wider, and deeper, but still remained connected with a vast continent, through which the Eocene river flowed.

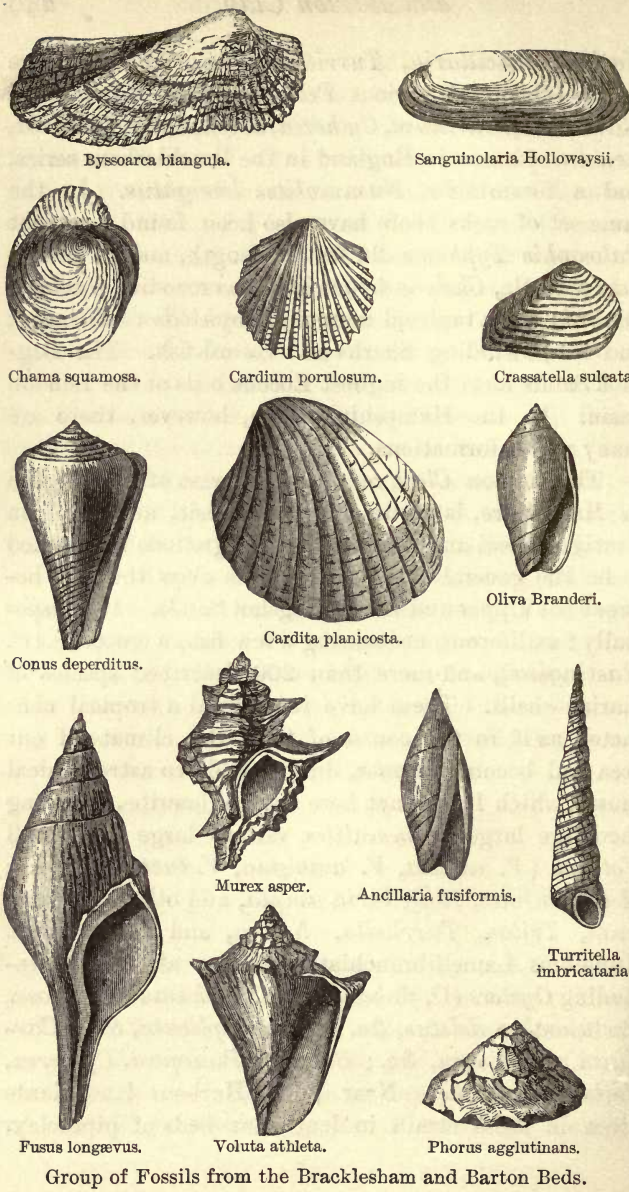
The *Bagshot* and *Bracklesham Sands* and *Clays*, fig. 47, succeed the London Clay. These are well shown on Bagshot Heath, and on the coast of Hampshire. On Bagshot Heath, they consist of light-brown and yellow sands, with beds of clay, which, in a rude way, form the middle part of the strata, thus dividing them into Lower and Upper Bagshot sands, the whole, where thickest, being about 300 feet thick. The sands are very sparingly fossiliferous, but the clay, in places, contains a few species. In the Hampshire basin, at Bracklesham and other places, the lithological character of these strata is very inconstant, but they consist of the following series of strata, which are partly quite local:—

Upper Bagshot Sands, &c.
Barton Clay (quite local).
Bracklesham shells, sands, and clays.
Lower Bagshot Sands and Clays, with occasional lenticular beds of pipe-clay containing leaves, &c.

These strata have yielded about 200 species of fossils, mostly distinct from those of the London Clay. Many of the Gasteropoda have a tropical aspect, such as *Cypræa Bowerbankii*, *Murex minax*, and *Conus diversiformis*. Gasteropoda, of these and other genera, are exceedingly numerous, viz., *Pleurotoma*, *Voluta*, *Natica, Ancillaria, Turritella,* &c., &c. A large *Oyster* (*O. picta*), various *Pectens,* a great *Cardita* (*C. planicosta*), *Cardium, Cytherea, Solen, Sanguinolaria,* &c., are common in England in the Bracklesham series, and a foraminifer, *Nummulites lævigatus.* In the same set of rocks there have also been found a serpent *Palæophis Typhæus*, 20 feet in length, and *P. porcatus*; a turtle, *Chelone trigoniceps*; a crocodile, *Gavialis Dixoni*; and a tapiroid mammal, *Lophiodon minimus*; and fish, including Sharks and Sword-fish. The Bagshot Sands form the highest Eocene beds of the London basin. In the Hampshire basin, however, there are many newer formations.

The *Barton Clay,* on the coast west of Lymington in Hampshire, is quite a local deposit, and both on stratigraphical and palæontological grounds is assumed to be the general equivalent of the clays that lie between the Upper and Lower Bagshot Sands. It is especially fossiliferous, containing a few fish, a crocodile (*C. Hastingsiæ*), and more than 200 described species of marine shells. These have in general a tropical character, as if in the course of time the climate of our area had become warmer, due possibly to astronomical causes, which I need not here stay to describe. Among them are large *Nummulites*, various large and small *Volutas* (*V. athleta, V. ambigua, V. luctatrix,* &c.); *Murex minax, Rostellaria ampla,* and others; *Buccinum, Triton, Turritella, Natica,* and many more. Numerous Lamellibranchiate molluscs also occur, including *Oysters* (*O. flabellula,* &c.); *Chama squamosa, Pectunculus deletus,* &c.; *Arca duplicata,* &c.; *Cardium porulosum,* &c.; *Cardita, Panopæa, Cytherea, Corbula,* &c , &c. Near Poole Harbour land-plants occur in these strata in lenticular beds of pipe-clay,

FIG. 50.



Group of Fossils from the Bracklesham and Barton Beds.

such as *Oaks*, *Yews*, *Cypress*, *Spindle-trees*, *Dryandra*, *Laurels*, *Limes*, *Figs*, *Sennas*, &c., &c., but all of extinct species. In this assemblage of plants we have ample evidence of the vicinity of land, and though modern crocodilia have no special objection to salt-water in the mouths of the Ganges, yet they are not in the habit of pursuing their game into the open ocean, and we may therefore more than suspect, that even this part of the Eocene series was deposited within the ocean mouth of a great river such as the Amazons.

The Bagshot series, including all the strata mentioned above, form the highest part of the Eocene strata, which exclusively contain marine mollusca.

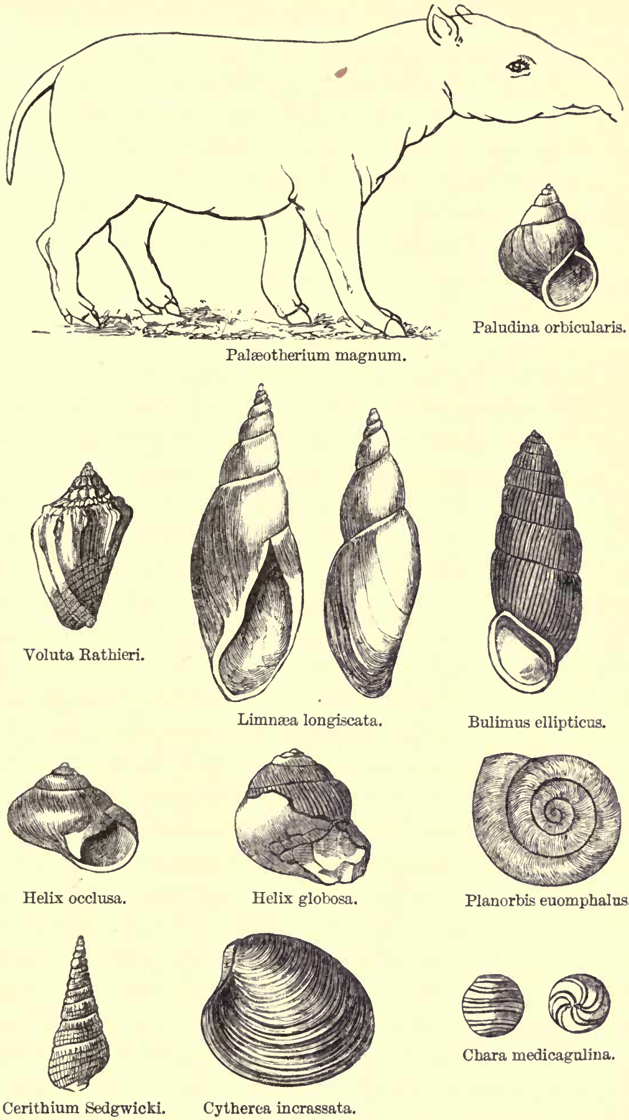
We now come to the undoubtedly Upper Fresh-water and Estuarine deposits.

The *Headon Hill Sands* (fig. 47), including the clays of *Hordwell Cliffs*, come next in succession. These form the lowest part of the great fluvio-marine deposits, which constitute the remainder of the Eocene rocks of Hampshire and the Isle of Wight, for none of these strata are found within the area of the London basin. Some of the marine shells of Hordwell are common to the Barton beds. Its marine strata contain sharks' teeth, *Murex*, *Buccinum*, *Ancillaria*, *Voluta*, *Marginella*, &c., *Oysters*, *Pectens*, *Corbula*, *Balanus*, &c., *Fusus porrectus*, *Oliva Branderi*, and *Nummulites lævigata*. The brackish-water strata have yielded *Cerithium mutabile*, *C. cinctum*, *Potamomya plana*, &c., and the fresh-water rocks contain *Paludina lenta*, *Planorbis euomphalus*, *Limnæa caudata*, *Cyclas*, several species of *Cyrena*, *Unio Solandri*, *Melania*, &c., besides land-shells of the genus *Helix*, and of vegetable remains, two species of *Carpolithes* (a conifer), and *Chara Wrightii*. In the Hordwell Cliffs and elsewhere, numerous reptiles have also been found, including two serpents *Palœryx depressus*, and *P. rhombifer*, *Turtles*, and seven species of *Trionyx*; *Crocodilus toliapicus*, and *Alligator Hantoniensis*. Among the mammals of the same beds have been found *Palæotherium annectens*, a three-toed animal somewhat like a tapir; *Anoplotherium commune*, having affinities both with pigs and ruminants; *Chœropotamus Cuvieri*, somewhat like the river-hog; *Dichodon cuspidatus* and *Microchœrus erinaceus*; also a bird, *Macrornis tanaupus*.

The *Osborne Beds* (fig. 47) succeed the Headon series, and are well seen on the coast near Osborne, and at Nettlestone in the Isle of Wight. Different sections vary in lithological character, but they may be generally described as consisting of sands and clays, from 60 to 80 feet thick, containing fresh-water shells, such as *Cyrena obovata*, *Achatina costellata*, *Limnæa longiscata*, *Melania costata* and *excavata*, *Melanopsis brevis*, *Paludina lenta* in great numbers, first known in the Woolwich and Reading series, and *P. globuloides*, *Planorbis euomphalus*, and five others, and a *Unio*. Entomostraca (Crustacea) also occur, viz., *Candona Forbesii*, *Cytheridea Mullerii*, and *Cythereis unisulcata*, with fresh-water plants *Chara Lyellii* and *C. medicagulina*. A land-shell, *Helix occlusa*, and a *Cerithium* are also found, the latter of which may have lived in brackish water, but the general assemblage is entirely fluviatile.

The *Bembridge Beds* (fig. 47) overlie the Osborne series in the Isle of Wight, and 'spread over the greater portion of the surface of the island which is occupied by Tertiary deposits.' They are fluvio-marine, and consist at the base of soft cream-coloured fresh-water limestone, sometimes 20 feet thick, overlaid by an Oys-

Fig. 51.



Group of Fossils from the Headon and Bembridge Beds.

ter band, which is succeeded by about 40 feet of marls. The limestone is a remarkable stratum, containing numerous nuclei of Chara, fresh water shells, viz. *Limnæa longiscata*, *Paludina globuloides*, *Planorbis*, *Melania*, and of land-shells, five species of *Helix*, *Bulimus ellipticus*, *Pupa perdentata*, and *Cyclotus cinctus.* Above this bed is a characteristic oyster-band with *Ostrea Vectensis*, and this is succeeded by marls in different bands highly charged with *Paludina lenta*, *Limnæa longiscata*, *Bulimus*, *Melania*, *Unio*, *Cyrena semistriata*, *C. obovata*, and other fresh and brackish water shells. In the Bembridge beds there has also been found the Anaplotheroid mammal *Dichobune cervinum*, and five species of *Palæotherium*, viz. *P. crassum*, *curtum*, *magnum* (fig. 51), *medium*, and *minus*; the nearest living analogues of which may be said to be the tapirs of the South American rivers.

The *Hempstead Beds* form the uppermost portion of the British Eocene strata. The Bembridge beds below pass gradually into them, and the fossils throughout the lower part of the Hempstead series are in great measure identical with those of the Bembridge marls, containing *Paludina lenta* in profusion, *Planorbis obtusus*, *Limnæa*, *Cyrena semistriata*, *Unio*, *Melania*, &c., and at the very top is a marine band containing *Corbula pisum*, and *Oysters*. The mammalia *Hyracotherium leporinum* and *Hyopotamus bovinus* and *H. Vectianus* (Suidæ) occur in these strata. These Hempstead beds were first clearly described by Edward Forbes, who considered them to be of Upper Eocene age. Sir Charles Lyell, however, following Mr. Pengelly, because of certain land plants, considered these uppermost strata to be Lower Miocene. Plants afford a more uncertain test of geological age than mollusca, and in the genera of plants alone, it would be as allowable to refer the Cretaceous flora of Aix-la-Chapelle to the Miocene age, as it is to refer the Hempstead beds to that epoch. The genera of mammalia, also of the Hempstead strata, are truly Eocene, for Hyopotamus is found in the Headon series, and Hyracotherium in the London Clay. The Hempstead beds, in fact, merge gradually into those below, and the uppermost stratum of all is marine, containing *Corbula pisum*, which is a well-known Eocene species, found in various subformations as low as, and including, the Barton Clay. The series may be said to be unfinished, and seems quite naturally to belong to the Eocene epoch. In old times, what kind of strata, if any, may have lain above the Corbula bed, no one knows.

In Hampshire, the same general series of fluvio-marine strata occurs, with variations in lithological character, but only as high as the Bembridge beds, the Hempstead strata having been removed by denudation.

If we now review the whole of the circumstances relating to the English Eocene strata, we find that in their lower and upper divisions they are decidedly of fresh-water and estuarine character, the fresh-water beds having been laid down in the broad mouth of a great river, so near the sea, that the area was liable by slight oscillations of level to intermittent influxes of the salt water, which produced minor marine interstratifications both in the Woolwich and Reading beds below, and in the upper strata, from the Headon to the Hempstead beds inclusive. But this is not all. Though, technically, the London Clay and the Bracklesham Barton and Bagshot beds are marine, as far as seashells are concerned, yet no one is likely to believe that these shell-fish lived and died in an open ocean. On the contrary, taken as a whole, all of the British Eocene formations may, in the widest sense, be spoken of as estuarine, for even the London Clay was evidently deposited in the broad mouth of a river like the Amazons or the Ganges; and nearly all the strata more or less contain evidence of the neighbourhood of land, in the bones of terrestrial and river mammalia, crocodiles, and gavials, serpents, birds, and numerous land plants. Pine cones, pods of acacia, fruits (*Nipadites ellipticus*), figs and laurels, lie thick in the London Clay of the Isle of Sheppey, and remind the beholder of the *Nipa fruticans*, a palm-nut that floats in the arms of the Delta of the Ganges.

The same kind of story is told in the Isle of Wight, in the beds of lignite found in the Bagshot and Bracklesham beds of Alum Bay. There, where the strata stand nearly vertically, it sometimes happens that each stratum can be accurately examined, and when last I did so, I observed under each bed of lignite a clay with rootlets in it, playing the same part to the Eocene lignites that the underclays do to the beds of coal of the Coal-measures, thus telling of marshes in the broad flats of the Eocene Delta, where vegetation growing and decaying formed beds of peat, that subsequently, buried under newer strata, became converted into lignite.

Strata in many ways similar to the Eocene rocks of England occur in France, in what is called the Paris basin, and in Belgium. It is not unlikely that with part of these estuarine strata, there may have been a direct connection with those of England, but whether or not, as yet I know of no data that tend to show from what direction this continental Eocene river flowed, or, in other words, what were the general shape and bearings of this vast Eocene continent. Of this, however, we may be sure, that somewhat altered in form and somewhat lowered by waste, the old Silurian lands of Wales, the north of England, and the Scottish mountains formed part of the Continent that gave birth to the Eocene river. The Eocene formations of the London basin all thin away as we pass from east to west, and it seems as if originally there had been a landward edge to the estuary in that direction, and possibly, but quite uncertainly, the river may have flowed through wide lands that stretched far to the west and north-west, or, on the other hand, it may have flowed through broad tracts of what is now part of the Continent of Europe. However that may be, I have no doubt that tributary streams poured into it from the west and north-west, for to my mind it is certain, that beyond the original edge of these Eocene formations, the Chalk spread far to the west, till it abutted on and probably rose high on the sides of the mountains of Wales, and passing westward on the south through the area of the present Bristol Channel, and on the north, across the space now occupied by the estuaries of the Dee and the Mersey, the Chalk of England formed a broad undulating plain, united to the Chalk of Antrim and the Cretaceous rocks of what is now the Western Isles of Scotland, which then formed part of the mainland, long before those volcanic eruptions took place that overspread the Chalk of Antrim with sheets of basalt, and gave rise to the present mountain scenery of the Inner Hebrides. If so, these upraised Cretaceous strata must have spread westward into areas now covered by the Atlantic, but of its actual extent nothing is certainly known.

Such is a general sketch of what I believe to have been the state of the Physical Geography of Britain during the Eocene epoch, when our land formed part of a continent differing in many great details from modern Europe, which, in its physical geography, underwent most important modifications, both before and during the deposition of the Miocene strata. Other great local changes afterwards brought the Miocene epoch to a close. I use such terms as these for want of better, for since the beginning of geological time, no epoch had either a definite beginning or a definite end, and, in a world-wide scale, the various epochs merged into each other like the colours in a rainbow, or the so-called epochs of the history of nations, which have only a local significance, when they are taken in connection with the history of the whole human race.

CHAPTER XVI.

MIOCENE EPOCH.

THE MIOCENE STRATA in England play a very unimportant part, in a physical point of view, excepting that the remains of many land plants which they contain give a high interest to these deposits from the light they throw on the climate of the time.

These strata lie not far from the mass of granite that forms the high ground of Dartmoor Forest, the highest point of which, called Yes Tor, is about 2,050 feet above the sea. At the foot of this mountain land there is a plain, of a kind of pear-shaped form, stretching, about seven and a half miles in length, between the neighbourhood of Bovey Tracey and Aller Mills, near Newton Abbot. It is about three miles in its greatest width from Blackpool to Knighton, two miles south-west of Chudleigh.[1]

[1] For these and some other details I am indebted to Mr. Horace B. Woodward, of the Geological Survey, who lately re-mapped the Bovey Tracey district, and also to the joint work of Mr. William Pengelly F.R.S. and the well known botanist, Professor Oswald Heer of Zurich, whose masterly description of the plants of the Bovey beds threw the first clear light on the geological age of the strata. See Woodward's 'Geology of England and Wales,' and 'On the Lignite Formation of Bovey Tracey,' by Messrs Pengelly and Heer, 'Philosophical Transactions,' 1862. The expense of the production and republication of this work was defrayed by the Baroness Burdett Coutts, who thereby conferred a boon on all students of Tertiary Geology.

The surface of the plain, according to Mr. Pengelly, consists of sandy clay, which contains a large number of angular and subangular stones lying unconformably on the Miocene strata, which consist of numerous beds of sand, clay, and, in the northern part, of lignite. According to Mr. Horace Woodward, the total thickness of these strata may be from 200 to 300 feet. The whole of these Miocene beds give the impression that they were originally deposited in a lake hollow, the sands and clays having been derived from the waste of the neighbouring Greensand and the granite of Dartmoor, while the vegetable matter that now forms the lignites consisted of stems and leaves of trees, fruits, ferns, &c., which were drifted by the streams of the time into the lake, where they got water-logged and sank, to be buried in the gradually accumulating strata.

In the northern part of the area, where the Bovey coal (lignite) occurs, near Bovey Tracey, the beds, according to Mr. Pengelly, dip at an angle of $12\frac{1}{2}°$, about 15° south of west, while according to Mr. Woodward, further south they dip much in the same direction about 5°. The lignite division of the strata is separated from the more southern clayey part of the area by a fault, probably of about 100 feet. In the opinion of Mr. Pengelly and Mr. Woodward, the strata south and east of the fault belong to an upper part of the series, which originally spread over that part of the strata in which the beds of lignite are found, having since been removed by denudation.

When we consider the effect of the fault, and also of the inclination of the strata, it is evident that the formation as originally deposited, must have spread beyond its present limits in the direction of the surrounding hills, and that the old lake probably washed the base of the granite hills of Dartmoor on one side, and the slopes of Greensand on the other. Of this there can be little doubt, that the fine clays, often light-coloured, which form so much of the series, were derived from the disintegration of the felspar of the granite of Dartmoor, and the sands, where pure, were probably partly made from the quartz of that granite, and partly from the waste of the neighbouring Upper Greensand hills, then no doubt more extensive and higher than now.

The climate of the period is unmistakably indicated by the plants, of which fifty species have been described by Heer, from these Lower Miocene beds. Some of these are ferns, including *Lastræa stiriaca,* and *L. Bunburii*, *Pecopteris lignitum* and *P. Hookeri*, and of the Order Coniferæ we have the branches, fruits, and seeds of the lofty *Sequoia Couttsiæ*, a genus that abounded in the Miocene epoch, and probably formed the most common tree in the woods that surrounded this lake. The nearest living analogue of this tree is the *Sequoia gigantea* of California, the Wellingtonia of our parks and gardens. Various grasses have been found, and fragments of a Palm-tree, *Palmacites Dæmonorops*, probably resembling the living Rotang-palm, and leaves of Oaks, *Quercus Lyellii*, of which, says Heer, 'similar species are still living in Mexico.' Three species of Figs and two of Grapes have been described, together with Laurels, Cinnamons, Birches, Willows, Waterlilies, &c., all of extinct species according to Heer, and eleven of which are common to the Miocene flora of Switzerland, both 'manifesting a sub-tropical climate.'

'If,' says Professor Heer, 'from the relics of the Bovey plants, we attempt to represent the vegetation of

Bovey as it existed in the Tertiary period, we shall have to sketch it somewhat in the following manner:—The woods which covered the slopes which surrounded the beds of lignite, consisted mainly of a huge coniferous tree (*Sequoia Couttsiæ*), whose figure resembled in all probability its highly admired cousin, the *Sequoia* (*Wellingtonia*) *gigantea* of California. It had just the same graceful slender form in its vernal shoots, thickly studded with leaflets; and the similarity continued in the older shoots and branches, which were clothed with scales. But it presented a distinct character in its shorter leaves, which were even more closely appressed to the shoots, and in its smaller cones. The leafy trees of most frequent occurrence were the cinnamons (*Cinnamomum lanceolatum* and *C. Scheutchzeri*) and an evergreen oak (*Quercus Lyelii*) like those which now are seen in Mexico. The species of evergreen figs were rarer, as were also those of *Anona* and *Gardenia*. The trees of the ancient forest were evidently festooned with vines, beside which the prickly Rotang-palm (*Palmacites Dæmonorops*) twined its snake-like form. In the shade of the forest throve numerous ferns, one species of which, *Pecopteris lignitum*, seems to have formed trees of imposing grandeur; besides which there were masses of underwood belonging to various species of the genus *Nyssa*, which is at present confined to North America. On the surface of the lake, in which were formed the deposits of clay and sand that lie between the lignite beds, were expanded the leaves of those water-lilies, the ornate seeds of which are preserved for our examination.'

A description so vivid needs no comment, and of this we may be sure, that this fragment of a flora only represents a small part of that of a vast continent, to which the British Islands were united, and which, embracing Iceland, spread far to the north and west into the area of what is now the Atlantic, and on the south was united to Africa, when as yet the Mediterranean had no existence.

In those days our British mountain lands formed of palæozoic rocks were mountainous then as they are now, but higher ; and elsewhere, especially after the close of the formation of the Eocene strata, the Alps, the Carpathians, and the Pyrenees, first rose into prominence as mountain chains, at the foot of which in Switzerland were great lakes, from the collective strata of which Professor Heer has numbered 900 species of plants and nearly as many insects, all such as must have lived in a subtropical climate, probably warmer than that of our Devonshire area, if we may judge by the fossilised remains of date-palms.

When, however, we travel northward from Bovey Tracey, the case is different, and to make this plain, I must lead you for a moment through the Western Isles of Scotland, and far beyond, among the islands of the Arctic Sea.

In Antrim, the island of Mull, and on the mainland opposite, and in Staffa, Rum, Eigg, Canna, and Skye, the Miocene rocks consist chiefly of the lava-flows and ashes of great terrestrial volcanoes. These, as they accumulated, overflowed and filled up the undulating valleys of chalk in Antrim, of Oolite and of Silurian gneiss in what is now the west of Scotland, and in the intervals of eruptions, lakes were sometimes formed, and terrestrial soils accumulated on the sides of volcanoes, some of which, according to Mr. Judd, grew by accretion of volcanic matter till they rivalled Etna in height, and seemed as if they might last for ever, but being diminished by central subsidence and long-continued sub-aerial waste, the mountain of Beinn More in Mull is now only 3,172 feet in height.

No shells of any kind have yet been found in the Bovey beds, nor have any been seen in the Hebrides, but in Mull, at the headland of Ardtun, the Duke of Argyll discovered in 1851 three thin leaf-bearing beds of shale, intercalated among beds of basaltic lava, and tufas or volcanic ashes. These vegetable remains consist of a conifer, *Sequoia Langsdorfii*, together with *Corylus Mac Quarrii*, a plane tree, *Platanus aceroides*, and a fern, *Filicites hebridica*, as yet only found in Mull. These, and I believe also the Flora of Antrim, are partly considered to belong to a more northern type of vegetation than the plants of Bovey Tracey, and two of the species, the *Coryllus* and *Platanus*, are also found in Iceland.

Associated with the volcanic rocks of Skye and the Faröe Islands, similar phenomena occur, with an analogous but still more northern flora, and the early volcanic eruptions of Iceland date back to the Miocene period. There, in beds of lignite called *Surturbrand*, are found the remains of Pines, Poplars, Elms, Plane-trees, Maples, Oaks, Tulip-trees, and Vines, in latitudes where nothing larger than dwarf-birches now grows. Only two of the Iceland species, as stated above, occur in Britain, and even the genera are distinct from those of Bovey, with the exception of *Sequoia* and an Oak. In Spitzbergen a similar flora of Miocene age occurs, and also in Greenland, far north of the Arctic Circle.

It may seem remarkable that, within the broad area of the British Islands, no mammalian remains have been found in the Miocene strata, for surely a land covered with a wealth of trees, grasses, and other plants could not have been destitute of animal life of many kinds, both in the waters and on the lands. But on reflection it is not to be wondered at that such remains are absent. In the first place there are no great river deposits of Miocene age remaining in Britain, in which such kinds of organic remains might lie buried, and the only lacustrine strata preserved lie in a small area of a few miles in length at Bovey Tracey. Neither is it likely that bones of mammalia should be found in the thin local soils, of a few inches in thickness, that were formed during the intervals of eruptions on the sides of lofty volcanoes. If, as I believe, a populous mammalian fauna lived and died and left their bones on the land of that old area, these bones decayed, unburied in sediments, and helped to nourish the luxuriant vegetation. But on the adjacent land, of what is now the Continent of Europe, there is no lack of mammalian and other bones to tell us what may have been the kinds of animals that inhabited our now insular area, for in the shallow near-shore deposits of the Faluns of Touraine, we find the *Dinotherium*, the elephantine *Mastodon*, *Rhinoceros*, *Hippopotamus*, *Dichobune*, and *Deer*, and in the fresh-water Miocene strata of the banks of the Rhine, between Bingen and Basle, a similar assemblage occurs.

In Switzerland, between the Alps and the Jura, besides fresh-water shells and spiders, and all the tribes of insects of familiar genera, we find *Salamanders*, *Frogs* and *Toads*, *Lizards*, *Crocodiles*, *Serpents*, *Tortoises*, and *Birds*. Of the mammalia in the Swiss strata, thirty-eight genera and fifty-nine species are named by Heer, which approach more closely to the Eocene fauna than to that of the present day. Of these, twenty-nine are extinct, and of the remainder only

Deer, *Wild boar*, and *Squirrels* still occur in Switzerland. Of the others, the *Lagomys*, a hare-like rodent, inhabits the temperate zone in Asia and North America, while five are denizens of warm and torrid zones, viz. the Gibbons in India, the Opossums in South America, the Rhinoceros and Musk-deer in India and Africa, and the Tapirs in India and South America. We may, therefore, believe that the climate was warm. Some of the details of this very interesting fauna are as follows:—

In the Miocene rocks of Switzerland there is found an Opossum, *Didelphys Blainvillei*, *Palæotherium Schinzii*, a Tapir *T. Helveticus*, and *Listriodon splendens*, closely allied to the Tapirs. Also two species of Mastodon, *M. tapiroides* and *M. turicensis*, nearly allied to Elephants, and *Dinotherium giganteum*, somewhat allied to the Mastodon. Five species of Rhinoceros are known besides *Anchitherium Aurelianense*, a mammal of equine affinities, and *Hipparion gracile*, which may be described as a three-toed horse, having on each side of the middle hoof two smaller toes which did not touch the ground. Six generas and eleven species of swine-like animals are known, two of which belong to the existing genus *Sus*, while the others are of extinct genera, but some of them closely allied to those still living. Of ruminant animals we find the *Chalicotherium antiquum*, allied to the Eocene Anoplotheria, and as large as the Indian Rhinoceros, together with two species of ruminants, smaller than a rabbit, *Microtherium Renggeri*, and *M. Cartieri*. Besides these there are found fossil, two species of Musk-deer, *Moschus Aurelianensis*, and *M. aquaticus*, and *Dorcatherium Naui*, somewhat allied, but differing in having seven molar teeth in the lower jaw, while the

Musk-deer has only six. Of true Deer there are seven species.

Of Rodentia, there are Squirrels, Hares, Chinchillas, and Beavers, and the hare-like rodents *Lagomys œningensis* and *L. Meyeri*. Six species of Carnivora have been found of the genera *Hyœnodon*, *Amphicyon*, *Potamotherium*, *Trochictis*, and *Galecynus*. The second of these is related to the Dog, the third to the Otter, the fourth to the Weasel and Badger, and the last unites some of the characters of the Dog and the Civet cat.

In the Swiss Miocene series the upper jaw of an Ape was found in the lignite of Elgg, and named *Hylobates antiquus*, by Lartet. It is most nearly related to the Indian Gibbon. Besides this, two other Apes are known in ground not far off, at Sausan and on the Swabian Alp. They have been named *Dryopithecus Fontani*, and *Semnopithecus pentalicus*, the former of which equalled the Orang and the Chimpanzee in stature, and appears to have come near the Gibbons, while the latter belonged to the group of long-tailed Indian monkeys.[1]

No one will suppose that the species described as occurring in the Miocene rocks of Switzerland, represent more than a fragment of a much larger fauna that inhabited that and other regions of the old continent, of which our own area then formed part, and it is impossible to believe that with a teeming fauna in the lands to the east and south, a portion of it, now changed into the British Islands,

[1] This epitome of the Miocene fauna is condensed from 'The Primæval World of Switzerland,' by Professor Heer, of the University of Zurich, edited by James Heywood, M.A., F.R.S., a most interesting book and worthily translated.

should have been destitute of all mammalian life, for it seems more than absurd to suppose, that none of these animals should have found their way into our area, while they swarmed in regions so near as Switzerland, France, and the Rhine, where, however, at that time no Rhine existed. On the contrary, I, for one, take it for granted that some of them must have inhabited the southern ground of our British area, where the old lake of Bovey Tracey lay in a latitude not two degrees further north than that old lake of the Valley of the Rhine, which in those days, between the mountains of the Black Forest and the Vosges, stretched all the way from Basle to Mayence and the neighbourhood of Bingen. The banks of that lake were inhabited by the same mammalia that inhabits the adjoining area of the great Miocene Swiss lakes, and we may readily believe that, in the physiography of the south British area, there was nothing inimical to the thriving of such species, for its climate was then warm, and its great plains, tablelands, valleys, and mountains, were doubtless clothed with a rich vegetation. This, however, we may assume, that, just as we pass northward, the vegetation of the day assumed a more northern type, so in the mountain land of that older Scotland, and on its western flanks, where lofty volcanoes were growing, the fauna would get mingled with northern forms, all of which seem to be lost to us even in a fossil state, the physical conditions of the British area having been of a kind, that no broad and thick sediments were deposited in which the bones of mammals could be preserved.

It is, however, possible, and indeed probable, that we get a glimpse of part of this mammalian life preserved in a curiously mingled fauna, the remains of which lie buried at the base of various members of the Crag. I have, therefore, gone into the subject of the Miocene fauna of the Continent in a way that at first sight may seem out of place in this book, but which in reality is not so, for it throws a reflected light on the assemblage of animals which there is good reason to believe partly inhabited our area during the same epoch.

CHAPTER XVII.

PLIOCENE STRATA.

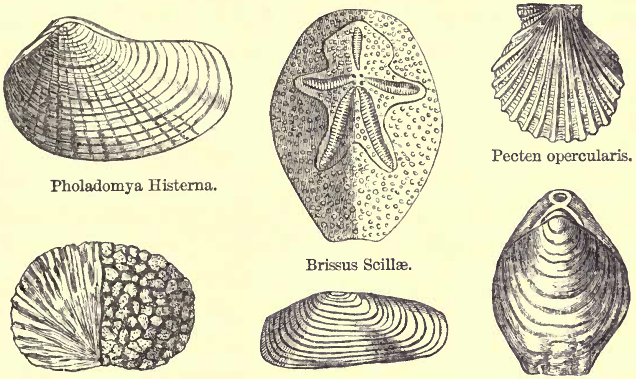
The Pliocene Strata, or Newer Tertiary beds, form the succeeding division of the Tertiary series, and in England are represented by the various subdivisions of the Crag of Suffolk and Norfolk. Resting, as these strata generally do, on an eroded surface of the London Clay, or more rarely, on the Chalk, their lower boundary is sufficiently clear; but the same is not the case with the upper limit of the Crag series, about which diversities of opinion exist, arising, no doubt, from the circumstance that it is absolutely indefinable, there being a kind of passage from the uppermost beds of Crag into overlying strata partly of drifts and glacial detritus. The whole series of Crags and disputed Crags is, indeed, probably not more than from 120 to 150 feet thick, and they make no decided mark on the physical geography of the country, though important in other points of view. After much consideration I incline, for the present, to restrict the term Crag to the following subdivisions:—

Norwich Crag: fluvio-marine.
Red Crag. } Suffolk.
Coralline Crag. }

The *Coralline* or *White Crag* lies on the London Clay in Suffolk, and consists of a few patches found in an area of about 20 miles in length, between the River Stour and Aldborough. It is generally not more than 60 feet in thickness. It consists in places almost entirely of Polyzoa (formerly called Corallines, whence the name, Coralline Crag), and elsewhere, in great part, of broken and entire shells, fragments of Echini, &c. Only four genera of Corals are known, all, according to the lists of Mr. Etheridge, of extinct species, and the same authority gives about 140 species of Polyzoa. The genera of Mollusca are almost entirely recent. The general character of the climate seems to have been milder than at present.

According to the researches of Mr. Searles Wood, modified by Mr. Gwyn Jeffreys and Prof. Prestwich, the

FIG. 52.



Pholadomya Histerna. Brissus Scillæ. Pecten opercularis. Fasciolaria aurantia. Glycimeris angusta. Terebratula grandis.

Group of Coralline Crag Fossils.

Coralline Crag contains 316 species of Mollusca, only 5 of which are Brachiopoda, *Argiope cistellula*, *Lingula Dumontieri*, *Orbicula lamellosa*, *Terebratula grandis*, and *Terebratulina caput-serpentis*. Of the Lamellibranchiata 151 species, of the Gasteropoda 160, and 1 Pteropod, *Cleodora infundibulum.* Of the 316 species only 52 are said to be extinct, or about 16 per cent. or, in other words, 84 per cent. are still living. Sixteen species of Echinodermata are known, 6 of which still live; and fish are found identical with living species of Cod, Pollack, and Whiting, together with large teeth of a shark, *Carcharodon megalodon*, *Otodus*, *Raia antiqua*, &c. It is quite possible that the Coralline Crag beds may be approximately of the same age with the marine shell beds of the Faluns of Touraine, in France, commonly called Miocene.

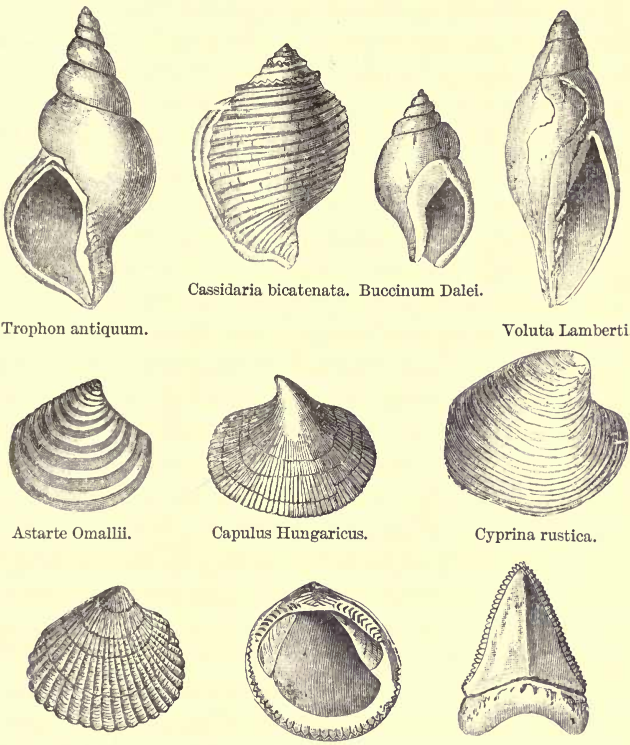
The *Red Crag* is chiefly a ferruginous sand, often crowded with shells entire and broken, very irregularly bedded, in a manner which shows that it was deposited partly in shallow seas, with strong tidal currents near shore, and, indeed, was partly accumulated between the high and low water lines.

At Felixstow the Red Crag is well seen on the sea-cliff, lying directly on the London Clay. It is crowded with shells, many of them broken, and was evidently deposited in shallow water. At Walton-on-the-Naze, where it also lies on London Clay, the sea was deeper, the shells being often unbroken, and in the state in which they died.

A hundred-and-forty species are common to the Red and Coralline Crag. In 234 species of shells, 150 now live in British seas, while '32 are now restricted to more southern and 23 to more northern seas' (Prestwich). In all about 92 per cent. of the Mollusca are said to be still living. In 25 species of corals, 14 still inhabit our coasts. Among its characteristic shells are *Trophon antiquum* (*Fusus contrarius*), and various species of *Murex*, *Voluta*, *Buccinum*, *Natica*, *Purpura*,

&c. Lamellibranchiate shells are still more common, such as *Mactra*, *Tellina*, *Cyprina*, *Astarte*, *Pectunculus*, *Pecten*, *Cardium*, &c. It is not unlikely that

Fig. 53.



Trophon antiquum. Cassidaria bicatenata. Buccinum Dalei. Voluta Lamberti.

Astarte Omallii. Capulus Hungaricus. Cyprina rustica.

Cardium Parkinsoni. Pectunculus glycimeris. Carcharodon megalodon.

Group of Red Crag Fossils.

some of the shells may have been derived from the waste of the Coralline Crag.

At the base of the Coralline Crag, in a pit by the Church near Felixstow, and in other places, there is frequently a stratum full of phosphatic remains, and known as the Coprolite bed. In it are found many sharks' teeth, vertebræ of fish, and many ear-bones and occasional vertebræ and other bones of whales. The sharks' teeth have often been derived from the London Clay, and the whales' bones are always very much water-worn, and have altogether a much more ancient appearance than that of the ordinary fossils of the Crag.

Among them are the bones and teeth of land mammalia of extinct species, *Castor veterior* (beaver), *Cervus dicranoceros* (deer), *Equus plicidens* (horse) and *Hipparion*, *Hyæna antiqua* and *Felis pardoides*, *Mastodon Arvernensis*, *M. tapiroides* and *Elephas Meridionalis*, *Rhinoceros Schleiermacheri* and *Sus antiquus*. Similar phosphatic remains, though fewer in number, have been found with bones of whales at the base of the Coralline Crag at Sutton. In both cases, many of the bones, &c., are worn and mineralised, and the question is, whether or not the greater part of these terrestrial mammalia belonged to the Crag epoch?

So plentiful are these, that to separate them from the Crag, for the manufacture of manure, forms a profitable branch of commerce.

There are many reasons for believing that during the later part of the Eocene and all through the Miocene epoch, the area now called Britain was joined to the Continent. The physical geography of the country was different, with, however, a general identity in so far that, as already shown, the Palæozoic mountainous regions now were mountainous then, while between them lay broad plains of secondary formations. In late Miocene times mammalian races must have inhabited our region, and their bones been scattered on the surface. A partial submergence of the country took place, so that Britain became for a time an island, and the marine Crag beds were deposited over part of our eastern area, the relics of which still remain in Norfolk and Suffolk. Some of the mammalia survived this partial submergence, and continued to inhabit the island during Pliocene times, and getting associated with varieties and new species, the bones of some of the extinct species may have been mingled with others then living, and all were washed into the basement beds of the above-named Crag formations during various oscillations of level.

The *Mammaliferous* or *Norwich Crag* consists of sand, gravel, and shells, generally only a few feet in thickness, and which, in Norfolk, lie upon the Chalk. From the nature of the fossils of the Norwich Crag, it is believed to have accumulated near the mouth of a river. It is never seen in contact with or overlying either the Coralline or Red Crag, and it is considered by Mr. Prestwich to be of the same age with the Red Crag, having been accumulated in an area partly estuarine, and separated from the purely marine area of the Red Crag by an emerged district consisting of the Coralline Crag.

In the Norwich Crag 139 species of marine Mollusca are known, of which 87, or 56 per cent. are common to the Coralline Crag, 137, or 88 per cent. to the Red Crag, and 93½ per cent. are still living. 'Comparing the three Crags the proportions of extinct species of marine Mollusca are, Coralline Crag 16 per cent. Red Crag, 7·7 per cent. and Norwich Crag 6·5 per cent.' (Prestwich). The latter contains about 20 species of land and fresh-water shells, such as *Helix*, *Planorbis*, *Paludina* (*P. lenta*, &c.), *Pupa*, *Limnæa*, *Cyclas*, *Cy-*

rena, &c., most of which are of living species. Besides these, there are found in it the bones of *Mastodon Arvernensis*, *Elephas meridionalis* (?), *E. antiquus*, and *Hippopotamus major* (?) together with the Horse, *Equus fossilis*, *Castor fiber* (beaver), the common *Otter*, *Deer*, &c.

The *Chillesford Clay* and *Sand* are generally considered to form part of the Norwich Crag series of strata. In the Chillesford district, which is inland, the Clay may lie to some extent unconformably on the Red Crag at Chillesford, and on the Coralline Crag near Sudbourne. In the Norwich district, it is a somewhat inconstant bed, or set of wedge-shaped beds, which, according to Mr. Horace Woodward, occur at different horizons in the Norwich Crag series. It is a very insignificant subformation, as regards thickness, and its marine fossils found in the sands are almost all of living species. The Bure valley beds, characterised by the presence of *Tellina Balthica*, may possibly form an upper part of the Norwich Crag series. They lie on the well-known Forest bed of Cromer, and together these may connect the uppermost Crag beds with the succeeding Glacial epoch.

It is frequently impossible to identify these minor subdivisions in areas even a small distance apart, for their identity is assumed to rest on the occurrence of certain assemblages of shells, and opinions on some points are so conflicting, that while some geologists consider the Forest bed to be older than all of the Norwich Crag deposits, others maintain that it is newer.

The last great Glacial epoch, Bone caves, River gravels, &c., will be treated of in succeeding chapters. These, less or more, belong to the age of human history, and are thus intimately related to the physical geography of the time in which we live.

Thus ends my brief sketch of the geographical range of the geological formations of Britain, in which, for obvious reasons, I have largely directed the attention of the reader to the subject of the Physical Geography of the British area during the epochs in which they were deposited.

It took a long time, by analyses of the order of deposition of stratified rocks and their contents, for geologists to establish the facts and reasonings now generally accepted, and the chief advances have been made in the last eighty years, beginning with the work of Hutton and William Smith. Notices occur in the pages of Herodotus, Aristotle, Strabo, and Pliny, which scarcely amount to geological ideas, but which show that they were cognisant of the occurrence of shells far inland, and high on the mountains; and they also reasoned on the mutability of the relative levels and positions of sea and land.

In the fifth century, Orosius, a Spanish divine, recognised the true nature of fossil shells, but referred them to the Deluge; and this opinion for long prevailed among such men as Lister (1683), Burnet (1690), Woodward (1695), and many more besides. Others in Italy (Olivi, 1584, Scilla, 1670, &c.), France, and England (Dr. Plot, 1677), held the absurd opinion that they were 'sports of nature,' the result of the fermentation of a '*materia pinguis*, or fatty matter'; or that 'petrified shells were stones in disguise, formed by the influence of the heavenly bodies.' A few remarkable men held more correct views on the subject. In 1580, 'a potter,' says Fontenelle, 'who knew neither Latin nor Greek, was the first who dared assert in Paris, and to the face of all the doctors, that fossil shells were true shells, deposited formerly in the sea in the places where they are found, . . . and he stoutly defied all the school of Aristotle to attack his proofs. This man was Bernard Palissy, Saintongeois, as great a *physician* as unassisted nature can produce.' In 1669, Steno published his remarkable treatise *De Solido intra Solidum naturaliter Contento*, in which he demonstrated that plants, shells, and teeth found in rocks are truly organic; and that they were buried in marine sediments, in the same manner that the remains of plants and marine animals are now entombed in modern sea bottoms. Hook, in his Discourse of Earthquakes (1688), maintains like opinions; and he inferred the extinction of species, and the introduction of varieties, consequent on changes in physical geography. Still further, he speaks of the 'records of antiquity which nature has left as monuments and hieroglyphic characters of preceding transactions; . . . and though it is very difficult to read them, and to raise a *chronology* out of them, . . . yet 'tis not impossible.' This is the earliest distinct hint of the principle of *succession of life in time.*

In 1760, Mitchell, in his Memoir on Earthquakes, in the 'Philosophical Transactions,' shows a clear perception of an order of superposition in strata, but he does not combine it with the fact of a parallel succession of life. About this time matters begin to become more definite, and a physician of Rudelstadt, George Christian Fuchsel, showed a remarkable knowledge both of *the succession of stratified formations and of the succession of life in time*, and his writings contain even more than the germ of many of the truths that, during the present century, have given so rapid an impulse to the science. In his system he distinguishes, resting on primitive schists, thirteen subformations, which in modern phrase, range between the *rothe todte*[1] and the *Muschelkalk*, each being characterised by a distinctive assemblage of fossils, or peculiarities of marine and fluviatile deposition, the carbonaceous strata being attributed to exotic plants of marshes and forests, the accumulation of which, by means of river floods, has produced coal.[2] As these formations contain remains of land plants and animals, the seas in which the strata were formed must have surrounded an ancient continent, which at an earlier date was also formed of strata after the manner of those he described, and this again by a continent older still, for he taught that the physical phenomena of the earth are constant and unchangeable.

Rather later, Werner, by his enthusiasm, eloquence, and skill as a mineralogist, also lent some aid to the cause; but his ignorant and bigoted adherence to the dogma that all rocks are aqueous, did much to retard the advance of truth. His far greater opponent, Hutton (1788), in his Theory of the Earth, expounded the true doctrine, which may be summed up as follows:—

1st. That, in the known geological history of the world, the course of events has never been disturbed by universal paroxysmal catastrophes, but that the course of change has been similar to that of the existing economy of nature.

[1] The passage is a little obscure: the words *rothe todte* would seem to imply that the strata are of Permian age, while the statement that the strata lie beneath the *formation houillère*, would bespeak strata perhaps equivalent to our Old Red Sandstone.

[2] 'Journal de Géologie,' 1830, p. 192.

2nd. That we know of no set of igneous rocks that can be proved to be of generally older origin than the earliest stratified deposits, but that *they may often be proved to be* of posterior origin.

3rd. That the stratified masses *were formed from the waste of pre-existing rocks, mingled with organic exuviæ.*

4th. That such strata afford a measure of the amount of pre-existing land destroyed to afford materials for their formation.

5th. That there may be a progressive formation of rocks in the bottom of the sea, contemporaneous with great and repeated alterations of lower strata, that approach the regions of internal heat (metamorphism).

6th. That all strata being derivative, and a machinery existing capable alike of erecting and destroying rocks, in the whole course of *visible* nature 'we find no vestige of a beginning—no trace of an end.'[1]

[1] In these modern days very few persons read Hutton, and those who trouble themselves about old geology are in general more familiar with Playfair's delightful 'Illustrations of the Huttonian Theory' than with Hutton's great original work, in which the philosophy of igneous, stratigraphical, and metamorphic geology was described in a manner that excited the admiring wonder of a few who in those days were able to appreciate his generalisations. One of these was the celebrated Dr. Black, Professor of Chemistry in the University of Glasgow, who thus wrote to the Princess Daschkow. 'In this system of Dr. Hutton there is a grandeur and sublimity by which it far surpasses any that has been offered. The boundless pre-existence of time and the operations of nature which he brings into our view, the depth and extent to which his imagination has explored the action of fire in the internal parts of the earth, strike us with astonishment. And when we consider the view he gives us of a great river, such as that of the Amazons, descending in a thousand streams from the country of the Andes, and forming those immense and level plains through which it flows in a great part of its course, the mind is expanded in contemplating

To the less precise generalisations of Fuchsel, William Smith added the complete proof of the *succession of life in time*, proving, as he did, in England, a clear succession of strata, each more or less characterised by its own suite of fossils ; and this gave, to a great extent, a perfect clue to the reading of that chronology on which Hook so vaguely speculated. To effect his object, Smith traced the English formations from end to end of the country with unwearied devotion, and at length, in 1815, produced his great geological map of England. He struggled long, almost unrecognised in his labours, but when they were well nigh at an end, men began by degrees to recognise that a master was among them, and in 1831, the first Wollaston medal was awarded to him by the council of the Geological Society, while in his annual address, Professor Sedgwick hailed William Smith as 'the father of English geology.' He died in 1839, and surely his name will last as that of a great original observer, even though it may be surmised that the time was ripe for that discovery, which, unknown to Smith, had been partly forestalled by Fuchsel.

The doctrines of Hutton and Smith combined gave the key to great part of the modern system of geology, and later works have carried out and improved upon their conclusions, in a series of masterly investigations

so great an idea, and the length of time which the change thus imagined (I may say demonstrated) must have required.' I am indebted to Professor Young of Glasgow for this extract from a manuscript volume of Dr. Black's letters preserved in the Hunterian Museum. Dr. Black was born in France in 1728. In 1756 he was appointed Professor of Chemistry in Glasgow, and in 1766 he was transferred to fill the Chair of Chemistry in the University of Edinburgh. He died, at the age of 71, in 1799. He was therefore the contemporary of Hutton, who died in 1796, and they were intimate friends.

that now entitles geology fairly to take its place among the exact sciences. Few persons now study the old prophets and fathers in geology, and therefore I have thought it well to give the foregoing imperfect sketch of the slow progress of the steps by which at length men have become able to analyse the order of deposition of formations, and of their fossilised contents, as abridged in the foregoing chapters.[1]

[1] The words formation, epoch, series, period, are in this book only used as convenient terms. When analysed they often imply that certain links, chapters, or whole books are missing in geological history, epochs in fact unrepresented in given areas by stratified formations. If I were to write a complete history of the British rocks, I would endeavour to explain the special meaning of each of these unrepresented gaps in time. A thorough-going physical geologist, working in concert with a thorough palæontologist, might even hope to form a fair notion of the nature of the missing life of the unrepresented epochs.

CHAPTER XVIII.

THE PHYSICAL STRUCTURE OF SCOTLAND—THE HIGHLANDS —THE GREAT VALLEYS OF THE FORTH AND CLYDE—THE LAMMERMUIR, MOORFOOT, AND CARRICK HILLS.

I NOW come to that part of the subject in which it will be my duty to explain the connection between the geological phenomena of Britain and the nature of its modern scenery. In this chapter I shall briefly describe the most mountainous part of Britain, and tell why great part of Scotland is so rugged. In another chapter I shall have to show that there is a strong contrast between the physical features of Scotland, and those of the middle and east of England, and to explain why the conformation of these two districts, and those of the east and west of England, are essentially so distinct.

In Scotland gneissic rocks and granites are extensively developed. The north-west coast of Sutherland, and the outer Hebrides, chiefly consist of the oldest known formation, called Laurentian, as already stated in Chapter V. Above them, in Sutherland, there are unaltered red or purple Cambrian sandstones and conglomerates, which lie unconformably on the Laurentian gneiss. In fact, the Laurentian strata were disturbed, metamorphosed, and much wasted by denudation, before the deposition of those Cambrian strata began, and fragments of the denuded gneiss help to make up the conglomerates. The Lower Silurian rocks come next in the series, and form about nine-tenths of the Highlands of Scotland north of the Grampians. They consist chiefly of gneiss and mica-schist, with numerous bosses of granite, and near their base are partly formed of thick masses of quartz-rock, interbedded with two bands of crystalline or semi-crystalline limestone, containing Lower Silurian fossils, by which their age has been ascertained.

Next, on the north-east coast, we have the Old Red Sandstone, the Upper Silurian rocks, which form such an important part of the English strata, being absent.[1]

Farther south, above the Old Red Sandstone, lie the Carboniferous rocks, consisting of Calciferous sandstone, limestone, and Coal-measures, the limestone forming in Scotland but a very small intercalated part of the series. These strata lie in the great valley between the Old Red Sandstone of the Ochil range on the north, and the Old Red and Silurian rocks of the Lammermuir, Moorfoot, and Carrick hills, on the south. Besides these formations, there are others in some of the Western Islands, such as Skye and Mull, and in the east and south of Scotland, and elsewhere. These consist of various members of the Lias, Oolitic, and Miocene strata in the Isles, and a little Permian in the south, which, however, form such a small part of Scotland, that only in the Isles and a small part of the mainland at Ardnamurchan, and on the hills that overlook the Sound of Mull, do the Miocene igneous rocks seriously affect its physical geography. Therefore I shall chiefly confine myself to the mainland of the north Highlands, for I wish specially to treat of the

[1] This order for the north of Scotland was first established by Sir R. Murchison. See 'Siluria.'

facts connected with the greater physical features of Scotland, omitting minor details.

In the extreme north of Scotland, in Sutherland and Caithness, the manner in which the strata generally lie is shown in the following diagram. (*See* Map, line 4.)

FIG. 54.

I have already mentioned that, in some of the Western Isles, from the Lewes to Bara, and in the north-west of the mainland of Scotland, from Cape Wrath to Gairloch, the country, to a great extent, consists of certain low tracts formed of Laurentian gneiss (No. 1), twisted and contorted in a remarkable manner. Upon this old gneiss the Cambrian rocks (2) lie, rising often into mountains, which face the west in bold escarpments, and slope more gently towards the east. These strata frequently lie at low angles very *unconformably* upon the old Laurentian gneissic rocks; the meaning of this being, that the latter were disturbed, contorted, and extremely denuded, before the deposition of what I believe to be the fresh-water, the Cambrian strata that lie upon them. The bottom beds of the latter consist of conglomerates of rounded pebbles, partly derived from the waste of the Laurentian gneiss, which, therefore, is so old, that it had been metamorphosed and was land before the deposition of the Cambrian beds. Upon these unaltered Cambrian rocks, and again quite unconformably, the fossiliferous Lower Silurian strata (3) lie, sometimes in the manner shown in the diagram; and conclusions, regarding upheaval and denudation, may be drawn from this second unconformity, similar to those that have been mentioned respecting the unconformity of the Cambrian on the Laurentian rocks. *In both a great interval of time is indicated unrepresented by stratified formations.* The bottom beds of the Lower Silurian strata consist of quartz-rock and two beds of limestone (3), the latter so altered that the fossils are sometimes with difficulty distinguishable, even by those most skilled in the determination of genera and species. Above the upper limestone we have a vast series of beds of mica-schist and gneissose rocks (4), mostly flaggy in the north-western region, but, in the eastern parts of Sutherland and Aberdeenshire, often so highly contorted and metamorphosed that they are, in some respects, similar to the more ancient Laurentian gneiss.

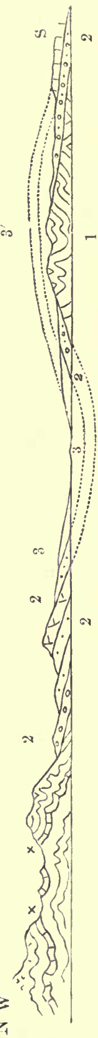
Now these metamorphosed Silurian rocks, here and there associated with bosses of granite and syenite (*g*), form by far the greater part of that rocky region known as the *Highlands* of Scotland, which stretches over brown heaths and barren mountain ranges, all the way from Loch Eribol on the north shore, far south across the Grampians, to the Firth of Clyde on the west, and Stonehaven on the east.

In Sutherland, as a whole, the Silurian strata dip eastward, and in Caithness we have the Old Red Sandstone (5) lying quite unconformably upon the Silurian gneiss, and dipping towards the sea. At its base the Old Red Sandstone consists of conglomerate, not formed merely of small pebbles, like those of an ordinary shingle-beach, but frequently of huge masses, suggestive of ice-borne boulder-beds, mingled with others of smaller size. All of them have evidently been derived from the partial destruction of those ancient Silurian gneissic rocks (4) that underlie the Old Red Sandstone.

Again, if we examine the map of Scotland, we find a broad band of Old Red Sandstone running from Stonehaven on the east coast to Dumbarton on the west, and there also masses of conglomerate lie at the base, as in No. 2, fig. 56. Overlooking this broad band, the Grampian mountains No. 1 rise high into the air, still reminding the beholder of the ancient line of coast *of a vast inland lake*, against which the waves of the Old Red Sandstone waters beat, and from its partial waste, aided by glaciers and the work of coast-ice, formed the boulder-beds that now make part of the conglomerates. We are thus justified in coming to the conclusion that the North Highlands generally formed land before the time of the Old Red Sandstone, the Grampian mountains, even then separated from the Scandinavian chain, as a special range forming a long line running from north-east to south-west, the bases of its hills being washed by the waters which deposited the Old Red Sandstone itself.

What amount of denudation the gneissic mountains of the Highlands underwent, before and during the deposition of the Old Red Sandstone, it is impossible to determine, but it

Fig. 55.



1. Lower Silurian rocks, with crystalline limestone. 2. Old Red Sandstone. 3. Carboniferous strata.

must have been very great. I consider it certain, that from these mountains glaciers descended through ancient valleys, now lost, and indeed that other subangular conglomerates of the Old Red Sandstone in various parts of Britain consist of stratified moraine matter. All the ordinary influences of terrestrial waste—rain, rivers, frosts, snow, ice, wind, and waves—were at work sculpturing the surface of that old land, and on the very same land they have been at work from that day to this. What was the precise form of the highlands that bordered this Old Red Sandstone lake, it is now impossible to know, except that it was mountainous; but this is certain, that after the early disturbances of the strata, the general result of all the wasting influences, acting down to the present day, has been to produce the present scenery. Thus it is certain that all the Cambrian and Laurentian rocks of the north-west of Scotland, were once buried deep beneath Lower Silurian gneiss thousands of feet thick; that on the west these Silurian strata have been, in places, almost utterly worn away, and the Cambrian rocks, as in Suilven, have thus been exposed and moulded into an outlier by subsequent waste. Some of these mountains in Sutherland now form the grandest and most abrupt peaks of the north-west Highlands, standing, steep-sided and high like Suilven, isolated, on a broad raised platform of Laurentian gneiss. And just as a railway navigator leaves pillars of earth in a railway cutting, to mark how much he has removed, so the great excavator, Time, has left these mountain landmarks to record the greatness of his operations.

It is at first hard to realise these facts, but observation and reflection combined lead to this inevitable result.

FIG. 56.

View of Suilven, Canisp, and the neighbourhood, Sutherland.

Suilven, 2,396 feet high, in the middle of the drawing.

If we again examine the Map, we find that a large tract of country, forming great part of the *Lowlands*, stretches across Scotland from north-east to south-west, including the Firths of Tay and Forth, and all the southern and eastern shores of the Firth of Clyde. This area is occupied by Old Red Sandstone and rocks of Carboniferous age (Nos. 2 and 3, fig. 55), mostly stratified, but partly igneous. To the south lie the heathy and pastoral uplands known as the Carrick, Moorfoot, Pentland, and Lammermuir Hills, marked 1′, which, like the Highlands, are also chiefly formed of Silurian rocks, but much less altered, and rarely possessing a gneissic character. These plunge beneath the Old Red Sandstone, and rise in the Grampian mountains on the north changed into quartz-rock, mica-schist, and gneiss. The unaltered Carboniferous and Old Red Sandstone rocks thus lie, as a whole, in a hollow, between the Grampian and the Lammermuir ranges, the coal-bearing strata chiefly consisting of alternations of shale, sandstone, limestone, and coal, mingled with volcanic products of the period.

I have already explained, in Chapters VIII. and IX. how these Old Red and Carboniferous rocks were formed, showing that the latter consist of strata partly of fresh-water and partly of marine origin, for not only are the limestones formed of corals, encrinites, and shells, but many of the shales also yield similar fossils, while some strata are charged with fresh-water shells. Beds of coal are numerous, and under each bed of coal there is a peculiar stratum, which often, but not always, is of the nature of fire-clay, and is sometimes called 'underclay,' this in England being a miner's term, on account of its position beneath each bed of coal. As already explained, the 'underclays' were the soils on which land plants grew, and from this it is plain that the conditions attending the deposition of the Carboniferous strata, were in great part terrestrial.

In the Scottish Coal-measures there are in Edinburghshire over 3,000 feet of coal-bearing strata, so that the lowest bed of coal may be nearly three thousand feet below the highest bed, in the centre of the basin, where the strata are thickest. Most of the beds rise, or 'crop,' as miners term it, to the surface somewhere or other, this 'outcrop' being the result of disturbance of the strata and subsequent denudation, and it is by means of this disturbance and denudation that we are enabled, by an easy method, to estimate the thickness of the whole mass of strata, and to prove that one bed lies several thousands of feet below another.

In the Scottish area, during the formation of part of the Old Red Sandstone and of the Coal-measures, many volcanoes were at work ; and thus we have dykes and bosses of felspathic trap and greenstone, and interstratifications of old lava streams, and beds of volcanic ashes mingled with common sedimentary strata. These, being often harder than the sandstones and shales with which they are interbedded, *have more strongly resisted denudation*, and now stand out in hilly ranges, like the Pentland, Ochil, and Campsie Hills, the Renfrewshire and Ayrshire Hills on the Clyde, or in craggy lines and bosses, like Salisbury Crags, the Lomonds of Fife, and the Garlton Hills in Haddingtonshire, which give great diversity to the scenery, without ever rising to the dignity of mountains.

Having thus briefly rehearsed the mode of formation of the more important Scottish formations, we may already begin to perceive what is the cause of the mountainous character of the *Highlands*, and of the softer features of the *Lowlands*. It is briefly this: that, in very ancient geological times, before the deposition of the Upper Silurian series and Old Red Sandstone, the Lower Silurian rocks, which form almost entirely the northern half of Scotland, had already been raised high into the air, metamorphosed, and greatly disturbed. Such metamorphic rocks, though, as a whole, difficult of destruction, *yet consist of intermingled masses of different degrees of hardness*, whence the great variety of their outlines is the result of the softer rocks having been most easily worn away. In the south of Scotland, from Galloway to the coast of Berwickshire, the same strata, forming the upland of the Carrick, Moorfoot, and Lammermuir hills, have been equally disturbed, though perhaps not originally raised to the same height, but being comparatively unmetamorphosed, they are generally somewhat less hard, and have therefore been more wasted by denudation, whence their average lower elevation. Though the mountains of these southern Highlands cannot compare in height with those of the north, they are sometimes both striking and picturesque in outline, especially where associated as gneiss and other metamorphic rocks with great bosses of granite and quartz-porphyries, in Wigtonshire, Kirkcudbrightshire, and Selkirkshire, in the south of Scotland. These gneissose lines run in the general strike of the strata, all the way from Lauderdale, to the cliffs of the Rhinns of Galloway that bound St. Patrick's Channel.

Nothing can be more impressive, in its way, than the noble amphitheatre of hills that surround the sombre moorland basins of Loch Doon, Loch Finlas, and the smaller lakes and tarns that lie further south and west of the Rhinns of Ketts, the highest granitic peak of which has an elevation of 2,668 feet above the sea. Magnitude is not always essential to grandeur, and as in human, so in nature's architecture, proportion of parts often strikes the mind with a sense of majesty which is wanting in larger bulks.

If we take the area of these southern Highlands, it amounts to about 6,000 square miles, in which the greater hills vary from 1,300 to 2,695 feet in height, in the east the highest being Seenes Law 1,683 feet, further west Black Hope Scaur, 2,136 feet, still further west Whitecombe Edge in Berwickshire 2,695 feet, and further west still, the Rhinns of Ketts 2,668 feet. In the whole district, more than half the area is under 1,000 feet in height, by far the larger part of the remainder between 1,000 and 2,000 feet; and all the remainder, above 2,000 and under 2,668 feet, occupies a small area of about 75 square miles.

If we turn to the true Scottish Highlands, there we find more than a dozen of mountains the heights of which exceed 3,000 feet, including Ben Klibreck 3,157 feet, Ben Hope 3,061 feet, and Ben More 3,281 feet in height, all in Sutherland. In Ross there are Ben Dearig 3,551 feet, Ben Wyvis 3,720 feet, and Sleugach, said to be 4,000 feet in height. In Inverness-shire, Ben Attowe, also 4,000 feet high; while south and south-east of the string of lakes in the Great Glen, of which Loch Ness is one, there are Ben Voirlich 3,180 feet, Ben Lomond 3,192 feet, Glas Mhiul 3,501 feet, Ben Dearg 3,918 feet, Ben Lawers 3,984 feet, Cairn Gorm 4,090 feet, Ben Mac Dhui 4,296 feet, and Ben Nevis 4,406 feet in height. If next we take the whole area of the Lower Silurian rocks of the Highlands, between the Great Glen and the south-eastern slope of the Grampian Mountains, it appears that not one-third of the country is more than 500 feet above the sea, of the remainder less than a quarter ranges between 500 and 1,000 feet in height, while of the rest a large part ranges between 1,000 and 2,000 feet; and after that, about as much remains between 2,000 and 4,406 feet in height, as would cover half the area of the Lower Silurian hills, of what I have called the south Highlands, between Berwickshire and Wigtonshire.

Beyond Glen More and the Caledonian Canal, as far as the north coast of Scotland, the Highlands have the same general character, though the amount of ground above 2,000 feet in height is comparatively less in the total area, and this amount gradually decreases in proportion the further north we go. Section No. 54, page 285, gives an idea of the general contours in north Sutherland. There, on the flanks of the mountains in Caithness, the Old Red Sandstone, lying in comparatively flat strata, forms an undulating plain consisting of conglomerates on the west, and chiefly of sandstones from thence to Sinclair Bay, where it slips under the sea, while further south, between Noss Head and Bervie Ness, high cliffs overlook the sea.

South of Strath Ullie or Helmsdale, the same Old Red Conglomerates and Sandstones skirt the Silurian rocks, crossing the Firths of Dornoch, Cromarty, and Inverness, and Beauly Basin, and stretching south to the noble mountain of Mealfourvounie, 3,060 feet in height, from whence, crossing Loch Ness, it skirts the country in a broad band beyond the mouth of the Spey. In all this area a large part of the strata consists of conglomerate, and where this rock occurs, because of its occasional hardness, and the very considerable disturbance of the rocks, some of the country ranges between 800 and nearly 1,500 feet in height. In no part of

Scotland that I know, are the conglomerates (made of the waste of the older Silurian mountains) more striking than in this region, and the glacial origin of some of them to my mind is unmistakable, especially on the shores of the Beauly Firth near Drynie. All the embedded stones have been derived from the old Silurian mountains, some of them are from four to five feet in diameter, and many of them are subangular in shape, just like the boulders in much of the glacial detritus of what is ordinarily called the Glacial epoch.

In time, the Old Red Sandstone period came to an end, and above that series—for it consists of two members, the upper member of which lies *unconformably* on the lower—the Carboniferous rocks were formed. The whole were then again disturbed together—a disturbance not confined to Scotland only, but embracing large European and other areas.

But before the deposition of the Old Red and Carboniferous series, there is reason to believe that a wide and deep valley already existed between the Grampian mountains and the Carrick, Lammermuir, and Moorfoot range; and in this hollow the Old Red Sandstone was deposited, partly derived from the waste of the Silurian hills on the north and south. But by-and-by, as deposition progressed, the land began to sink on the south, and the upper strata of Old Red Sandstone overlapped the lower beds, and began, as it were, to creep southwards across the Lammermuir Hills, which, sinking still further, were in turn invaded by the lower Coal-measures and Carboniferous Limestone series. It appears, therefore, from a consideration of all the circumstances connected with the physical relations of the strata, that the Coal-measures once spread right across the Lammermuir range, and were united to the Carboniferous strata that now occupy the north of England, thus, with part of the Old Red Sandstone, covering great part of the Silurian strata of the south of Scotland. This unconformable covering has, however, in the course of repeated denudations, been removed from the greater part of that high area, and now the Carboniferous strata are only found in force in the great central valley through which flow the rivers Forth and Clyde.

This will be easily understood by referring to the section, fig. 55, across the central valley of Scotland, from the Grampian mountains to the Lammermuir hills, in which the following relations of the various formations are shown.

The gneissic rocks of the Grampian mountains (No. 1), with bands of Limestone marked +, pass under the Old Red Sandstone (No. 2), and rise again, highly disturbed, but not much metamorphosed, in the Lammermuir hills (1′). On these the lower conglomerates of the Old Red Sandstone (No. 2) lie unconformably, adjoining and overlying which, there is a series of beds of red sandstones which generally dip SE. for a space about ten miles in breadth, as seen, for example, on either side of Strath Earn and the Tay above Perth. These are succeeded by an upper series of Old Red Sandstone rocks, which run from the neighbourhood of Stirling to the estuary of the Esk, near Montrose, on the east coast, and to Cupar and the mouth of the Firth of Tay, at Ferryport. The lower part of this upper series is often interstratified with volcanic lavas, ashy breccias, and conglomerates of a felspathic nature. These being hard and dipping south-easterly from the Forth to the mouth of the Tay, generally form a high escarpment, the steep-scarped front of which faces to the north-west, in accordance with a law that, on a great scale, rules the mode of formation of such slopes, the more gentle inclines being in the direction of the dip, and the steep scarp sloping at right angles to the average inclination of the strata. (See fig. 55, p. 287).

Let anyone who wishes to see this effect, walk to the summit of the Ochil Hills, and there, from the edge of the scarp, he will see in the main a gentle slope to the south-east, while below, on the north-west, the delighted eye ranges across the fertile plains and undulations of the Teith, Strath Allan, and Strath Earn, while, far beyond, this almost unrivalled view is bounded by the lofty chain of the Grampian Mountains. Let the reader also understand that the whole of the Lower Old Red Sandstone as far as the Grampians was once buried deep under this upper series, and he will then begin to realise the prodigious amount of denudation that the region has suffered before it assumed its present aspect.

Above and merging into the Old Red Sandstone come the Carboniferous rocks No. 3, fig. 55, lying in a wide faulted and denuded synclinal curve,[1] but with many a high boss of basalt standing out in bold relief in the midst. Such are the Lomonds of Fife, Dunker Law, and Bishop Hill, north of the Forth, while south of that estuary Arthur's Seat forms a well-known example, and the pastoral tract of the Pentland Hills, formed of Upper Old Red Sandstone, mingled with contemporaneous igneous rocks, stand in high relief above the fertile plains of Midlothian and Dalkeith.

I have already stated that the southern continuation of the Upper Old Red and Carboniferous strata once spread over the Lammermuir Hills in a kind of anticlinal curve, in the manner shown by the dotted lines No. 3′, on the diagram fig. 56.

[1] The diagram is, however, too small to show these breaks.

Now why is it that the Carboniferous and Old Red Sandstone rocks have been specially preserved in the great valley, and almost entirely removed from the upland region of the Lammermuir hills? The reason is this:—

When strata have been thrown into a series of anticlinal and synclinal curves, it has frequently happened that those parts of the disturbed strata that were thrown downwards, so as to form deep basin-shaped hollows, were by this means saved, for long periods of time, from the effects of denudation, while the upper parts of the neighbouring anticlinal curvatures, being exposed to all the wasting influences of the air, rain, rivers, and the sea, were denuded away.

In other words, some widely extended portions of the strata lay so deep that no wasting influence had access to them, and they have escaped denudation, and the basin—as geologists term it—remains. *This is the reason why so many coal-fields lie in basins.* It is not, as used to be supposed, that the Carboniferous beds were deposited in basins, but that by disturbance part of the strata were thrown into that form, and saved from the effects of denudation. *Such basins are, therefore, equally common to all kinds of formations*; though, because they rarely contain substances of economic value, they have not met with the same attention that Coal-basins have received.

In the case now under review it happens that the Old Red Sandstone and Carboniferous rocks lie in the hollow, and, though much worn away and fragmentary, they have been to a great extent preserved; while the continuation of part of the same formations that lay high in an anticlinal form, and originally spread over the Lammermuir hills (3′), has been almost all removed by denudation. The reason of this is, that *during frequent oscillations of land, relatively to the level of the sea, the higher ground was much more often above water than the lower part*, and therefore exposed to waste and destruction. To understand this thoroughly, let us suppose that the whole of the formations now forming this area were, in an ancient epoch, underneath the sea, and then let parts of it be raised, more or less above that level, well into the air. Part of the area now known as the Lammermuir Hills, *then covered by Old Red Sandstone and Coal-measures*, rose above the water, and was immediately subjected to the wear and tear of breakers on the shore, and of rain, rivers, frost, and other atmospheric influences; while, on the other hand, that portion that lay deep in the synclinal curve was beneath the level of the sea, and thus escaped denudation, because no wasting action takes place in such situations.

By geological *accidents* such as these, the greater features of Scottish scenery have been produced. The Highlands are mountainous because they are composed of rocks much disturbed, metamorphosed, and mostly crystalline, and intermingled with great and small bosses of hard granite. All of these rocks having been often and long above water, have been extremely denuded: such denudations having commenced so long ago, that they date from before the time of that extremely venerable formation, the Old Red Sandstone, probably indeed ever since what, for want of better words, we term the close of the Lower Silurian epoch, and the waste has been going on, more or less, down to the present day.

Being formed for the most part of materials of great but unequal hardness, and associated with masses of granite, the high land has been cut up into innumerable valleys by the repeated action of rain, rivers, and glaciers, whence their mountainous character; for the special outlines of mountains, as we now see them, are rugged, less by disturbances of strata, than by the scooping away of material from greatly elevated tracts of country. By *mere elevation and disturbance* of strata, the land might rise high enough; but as mountain regions now exist, it is by a combination of disturbance of strata with extreme denudation, going on both while and after slow disturbance and elevation was taking place, that peaks, rough ridges, ice-worn surfaces, and all the cliffs and valleys of the Highlands in their present form, have been called into existence. They are undergoing further modification now.

Let anyone go to the western part of Sutherland and climb Suilven, and he will get a clear idea of what is meant by a considerable amount of denudation. The mountain is based on a wide, low, undulating plateau of Laurentian gneiss, dotted with unnumbered lakes and tarns. From this plateau it rises abruptly into the air, like a little Matterhorn, 2,396 feet in height, and its sides are as steep as those of the noble Swiss mountain. They are formed of horizontal Cambrian purple conglomerate and grits, cut by nature into great terraced steps, on which by devious courses the climber reaches the summit. From thence let him turn to the east, and there, five miles distant, set on the same plain, he will descry the steep-sided Canisp, formed of the same Cambrian strata once united to those of Suilven, and Coulmore. Here is 'a monstrous cantle' cut out of these strata, and yet if the reader, for the whole, would multiply that by a hundred, he would probably not exaggerate the amount of denudation that these ancient rocks have suffered in the Highlands.[1] Fig. 56, p. 289.

Farther south the different nature, both of the Silurian and newer rocks, coupled with other geological accidents, have produced the great valleys of the Forth and Clyde, and the tamer but still hilly scenery of the Southern Highlands, as they are sometimes called These consist mainly of the Lammermuir, Moorfoot, and Carrick Hills, now often massed under the name of the Lammermuir range. But they are not a range. They consist in reality chiefly of a tableland, or old *plain of denudation*, older for the most part than the Old Red Sandstone and Carboniferous rocks; which plain, after being long buried, was subsequently again exposed by denudation of the overlying strata.

The present scenery of hill and valley in the southern part of Scotland is therefore, in great part, the result of the waste of this old tableland, and the scooping out of valleys and lake-basins, by rain, rivers, and old ice, which, as a great ice-sheet, at one time covered the whole of Scotland and much more besides. The effects of this were, in later times, modified by minor glaciers, during those oscillations of temperature that marked what we now call the Glacial epoch, and all the ordinary water produced by rain and rivers is modifying the scenery now.

[1] For cases in point see my memoirs on 'The Geology of North Wales,' and 'On the Denudation of South Wales and the Adjacent Counties,' 'Memoirs of the Geological Survey,' vol. i., 1846.

CHAPTER XIX.

RECAPITULATION OF THE GENERAL ARRANGEMENT OF THE STRATIFIED FORMATIONS OF ENGLAND.

THE geology of England and Wales is much more comprehensive than that of Scotland, in so far that it contains many more formations, and its features therefore are more various. England is the very Paradise of geologists, for it may be said to be in itself an epitome of the geology of almost the whole of Europe, and much of Asia and America. Very few European geological formations are altogether absent in England. On the Continent, however, some have a larger importance than in England, being more truly oceanic deposits in some cases, and more thoroughly developed lacustrine or terrestrial deposits in others. In some countries larger than England the whole surface is occupied by one or two formations, but in England nearly all the formations shown in the column (p. 30) are more or less developed. Those of Silurian age lie chiefly in England, in Cumberland and Westmoreland, and in the west, in Wales (fig. 57, p. 304). Above them lie the Old Red Sandstone and Devonian rocks, occupying large areas in Herefordshire, Worcestershire, South Wales, and in Devonshire and Cornwall. Above the Old Red Sandstone come the Carboniferous strata, which form large tracts of Devonshire, Somerset, and part of Gloucestershire, and in South Wales skirt the Bristol Channel, and stretch into the interior in Pembrokeshire, Glamorganshire, and Monmouthshire; while in the north they border North Wales, and form a broad backbone of country that reaches from the borders of Scotland down to North Staffordshire and Derbyshire. Other patches, here and there, rise from below the Secondary strata into the heart of England. (*See* Map.)

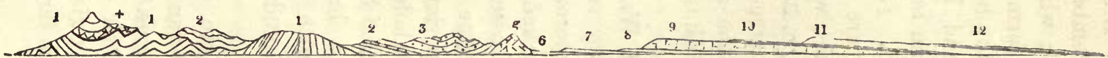
The general physical structure of England, from the coast of Wales to the Thames, will be easily understood by a reference to fig. 57, p. 304, and to the following descriptions; and this structure is eminently typical, explaining, as it does, the physical geology of the greater part of England south of the Staffordshire and Derbyshire hills.

The Lower Silurian rocks of Wales (No. 1) consist chiefly of slaty and solid gritty strata, accompanied by, and interbedded with, numerous felspathic lavas and beds of volcanic ashes, marked + ; and mingled with these there are numerous bosses and dykes of felstone, quartz-porphyry, greenstone (diorite), and the like. These last, by their superior hardness, give a mountainous character to the whole of North Wales, from Merionethshire to the Menai Straits. In part of north Pembrokeshire also, in a less degree, igneous rocks are largely intermingled with the Lower Silurian strata, and these, by help of denudation, now form a very hilly country.

Without again entering into details, it is here sufficient to state that the Cambrian and Lower Silurian epoch was ended in the British area by disturbance and contortion of the strata, and their upheaval into land. This disturbance necessarily gave rise to long-continued denudations of this early English land, both by ordinary

FIG. 57

Diagrammatic Section from the Menai Straits across Wales, the Malvern Hills, and the Escarpments of the Oolitic Rocks and the Chalk. *See Map, line* 6.



Nos. 1 to 3, 5, and *g* represent the disturbed Cambrian, Lower and Upper Silurian, and Old Red Sandstone mountainous country of North Wales, the adjacent countries on the east, and the Malvern Hills *g*.

6 to 8 the plains and slightly undulating grounds of the New Red Sandstone, Red Marl, and Lias.

9 and 10 the great Oolitic escarpment of the Cotswold Hills, forming the first tableland.

11 the great escarpment of the Chalk, forming a second tableland, above which lie the Eocene strata, 12.

The Upper Oolites, close below the Chalk escarpment 11, are in places of less height relatively to the sea than the edge of the Oolitic escarpment at 9.

atmospheric agencies, and also by the action of the waves of the sea of a younger Silurian period, the evidence of which is seen in the conglomerates of the Upper Llandovery beds, which, mingled with marine shells, lie unconformably on the denuded edges of the Cambrian and Lower Silurian strata of the Longmynd in Shropshire, like a consolidated sea beach. Slow submergence then took place beneath the Upper Silurian sea, in which the Upper Silurian rocks were gradually accumulated unconformably till, perhaps, they entirely buried the Lower Silurian strata (2, fig. 57), for in places they attained a thickness of from three to six thousand feet.

As shown in Chapter VIII. the uppermost Upper Silurian beds of Wales pass insensibly into a newer series, known as the Old Red Sandstone (3, fig. 57), formed, if we include the entire formation, of beds of red marl, sandstone, and conglomerate, which in all the British areas by the absence of marine shells, and the occasional presence of crocodilians, land reptiles, and of fish (whose nearest allies live in the rivers and lakes of America and Africa, or in the brackish pools of Australia), seem to have been deposited in lakes. In Wales these strata again pass upwards into the Carboniferous Limestone, which is overlaid in Wales, Derbyshire, and Lancashire, by the Millstone Grit and the Coal-measures.[1]

In Yorkshire, Durham, Northumberland, and Scotland, the Carboniferous Limestone has no pretension to be ranked as a special formation, for it is broken up into a number of bands interstratified with masses of

[1] This is not shown in fig. 57, but the Carboniferous Limestone No. 4 is shown in fig. 67, p. 330, lying, as it does in North Wales, unconformably on Silurian rocks.

shales and sandstones bearing coals. In fact, viewed as a whole, the Carboniferous series consists only of one great formation, possessing different lithological characters in different areas, these having been ruled by circumstances dependent on whether the strata were formed in deep, clear, open seas, or near land; or actually, as in the case of the vegetable matter that forms the coals, on the land itself.

The English Carboniferous rocks differ from the Scottish beds in this, that in general they have not been mixed with igneous matter, except in Northumberland and Derbyshire, where, in the last-named county, the Carboniferous Limestone is interbedded with ashes and lava, locally in Derbyshire called 'toadstones.' In South Staffordshire, Colebrook Dale, the Clee Hills, and Warwickshire, there is a little basalt and greenstone, which may possibly be of Permian age, intruded into, and perhaps also partly overflowing, the Carboniferous rocks in Permian times; but in Glamorganshire, Monmouthshire, North Staffordshire, Lancashire, and Yorkshire, where the Coal-measures are thickest, no igneous rock of any kind occurs. There and elsewhere in England the Coal-measures as usual consist of alternations of sandstone, shale, coal, and ironstone.

Next in the series come the Permian rocks (2, 3, 4, fig. 30, p. 141), which, however, rarely occupy so great a space in England, as materially to affect the larger features of the scenery of the country. They form a narrow and marked strip on the east of the Coal-measures from Northumberland to Nottinghamshire, where they chiefly consist of a long, low, flat-topped terrace of Magnesian limestone (*see* Map), interstratified with two or three thin beds of red marl sometimes containing gypsum. The scarped edge of this limestone, which is sparsely fossiliferous, faces west, and overlooks the lower undulations of the Coal-measure area.

There are other patches of Permian sandstones, marls, breccias, and conglomerates, in the South of Scotland, the Vale of Eden, and the West of Cumberland, and they are also here and there present on the borders of the Lancashire, North Wales, Shropshire, and all the Midland coal-fields, and on the Silurian rocks of the Abberley and Malvern Hills. Throughout all the districts enumerated above, these Permian strata chiefly consist of red sandstones, conglomerates, and marls, and part of them, in the districts of the Malvern and Abberley Hills, near Enville, and at Bromsgrove, consist of consolidated true Permian glacial boulder-clays.

The Permian beds form the uppermost members of the so-called Palæozoic or old-life period—a term somewhat unphilosophical, in so far that it partly conveys a false impression of a life essentially distinct from that of later times. But it is at present convenient, for all geologists know when the word palæozoic is used what formations are meant, embracing all the strata from those of Permian date down to the lower Laurentian. During the time they were forming, this and other parts of the world suffered many oscillations of level, accompanied by denudations, as shown in previous chapters.

Before the end of this Palæozoic epoch, the Permian beds were deposited in great inland salt lakes, analogous to the Caspian Sea and other salt lakes in Central Asia, at the present day. That area gives the best modern idea of the state of much of the world during Permian times.

In the same continental area, and partly on the Permian rocks, partly on older subjacent strata, the New Red Sandstone and Marl of our region were then deposited in lakes perhaps occasionally fresh, but as regards the marl certainly salt. These formations fill the Vale of Clwyd in North Wales, and in the centre of England range from the mouth of the Mersey round the borders of Wales to the estuary of the Severn, eastwards into Warwickshire, and thence northwards into Yorkshire, along the eastern border of the Magnesian limestone (*see* Map). They are absent in Scotland. In the centre of England the unequal hardness of its subdivisions sometimes gives rise to minor escarpments (Nos. 4 and 6, fig. 32, p. 154), most of them looking west over plains and undulating ground formed of soft red sandstone. Such escarpments are especially remarkable in the case of the Keuper sandstone, which lies at the base of the New Red Marl. These strata frequently form a good building stone, often white, and because of their hardness having better resisted denudation than the red sandstones below, they stand out as bold cliffy scarps facing west, with long gentle slopes to the east. Such are Hilsby Hill, that looks out upon the Mersey, near Frodsham; the beautiful terraced scarps of Delamere Forest, the grand castle-crowned cliff of Beeston by the North Western Railway, near Tarporley, and the beautiful heights, often well wooded, that stretch from thence to the south, and form the Peckforton Hills. There, among spots that haunt the memory, in the ancient park of Carden, scarped by nature and cut into terraced walks and caverns, among the red and white cliffs grow great rhododendrons, which sow themselves in every mossy cleft of the rocks; luxuriant brackens, male ferns, lady ferns, Lastræas, and others of smaller growth, while all forest trees attain a goodly growth, and low down in the flat, deer are grazing up to the gates of the old broad-fronted timbered Hall. It is indeed a splendid sight to stand on the edges of these scarped hills and look across the great rolling plains of New Red Sandstone below, bounded by Moel Famau and all the mountains of North Wales that surround the beautiful Vale of Clwyd; or twenty miles further south, from the abrupt cliff of Grinshill, to see the tall spires of Shrewsbury backed by the renowned Caer Caradoc, the Wrekin, the high line of the flat-topped Longmynd, and the craggy Stiper Stones.

The New Red Marl passes insensibly into the Rhætic beds, which again pass insensibly into the Lower Lias. In England there is therefore a gradation between the New Red Marl and the Lower Lias.

The Lias series, Nos. 3, 4, 5, fig. 5, consists of three belts of strata, running from Lyme Regis on the south-west, through the whole of England, to Yorkshire on the north-east: viz. the Lower Lias clay and Limestone, the Middle Lias or Marlstone strata, and the Upper Lias clay. The unequal hardness of the clays and limestones of the Liassic strata causes some of its members to stand out in distinct minor escarpments, often facing west and north-west. The Marlstone No. 4, forms the most prominent of these, and overlooks the broad meadow-land of Lower Lias clay that form much of the centre of England.

Conformable to and resting upon the Lias are the various members of the Oolitic series (6 to 11, fig. 5).[1] That portion termed the Inferior Oolite occupies the base, being succeeded by the Great or Bath Oolite,

[1] See also the 'Column of Formations,' p. 30.

Cornbrash, Oxford Clay, Coral Rag, Kimeridge Clay, and Portland beds. These, and the underlying formations, down to the base of the New Red Sandstone, constitute what geologists term the Older Mesozoic or Secondary formations, and all of them, from their approximate conformability one to the other, occupy a set of belts of variable breadth, extending from Devon and Dorsetshire northwards, through Somersetshire, Gloucestershire, and Leicestershire, to the north of Yorkshire, where they disappear beneath the German Ocean.

FIG. 58.

1. Portland Oolite.
2. Purbeck Limestones and Marls.
3. Wealden Sands and Clays.
4. Cretaceous strata.

When the Portland beds had been deposited (see figs. 39 and 58), the entire Oolitic series, in what is now the south and centre of England, and much more besides in other regions, was raised above the sea-level and became land. Because of this elevation, there is evidence in the Isles of Purbeck, Portland, and the Isle of Wight, and in the district known as the Weald, of a state of affairs which must have been common in all times of the world's history. We have there a series of beds, consisting of clays, loose sands, sandstones, and shelly limestone, indicating, by their fossils, that they were accumulated as a delta and in lagoons in an estuary, where fresh water and occasionally brackish water and marine conditions prevailed at the mouth of a great continental river. The position of these beds, with respect to the Cretaceous strata, will be seen in fig. 72, p. 339, marked *w*, *h*, proving that they are intermediate in date to the Oolites and Cretaceous rocks, for in the Isle of Purbeck, near Swanage, they are seen lying between the two (fig. 75, p. 348).

This episode at last came to an end, by the complete submergence of the Wealden area, and of the greater part of England besides; and upon these fresh-water strata, and the Oolitic and other formations that partly formed their margins, a set of marine sands and clays were deposited in the south of England, consisting of the Atherfield Clay and the Lower Greensand *s*, *d* (fig. 72, p. 339) is now often classed with the Upper Neocomian beds of the Continent, but in England they have till lately generally been known as the Lower Cretaceous strata. The distinction is not important to my present purpose. Then comes the clay of the Gault, above which lies the Upper Greensand. Resting upon the Upper Greensand comes the Chalk (No. 11, fig. 57, and *c*. fig. 72), the upper portion of which contains numerous bands of interstratified flints, which originally were partly marine sponges, since silicified. The Chalk, where thickest, is from one thousand to twelve hundred feet in thickness. The Liassic and Oolitic formations were sediments spread in warm seas surrounding an archipelago of which Dartmoor, Wales, Cumberland, and the Highlands of Scotland formed some of the islands. But the Chalk was a deep sea deposit, formed to a great extent of microscopic foraminiferæ, and while it was forming in the wide ocean, it seems probable that the old islands of the Oolitic seas subsided so completely, that it is doubtful whether or not even Wales and the other older mountains of Britain were almost entirely submerged.

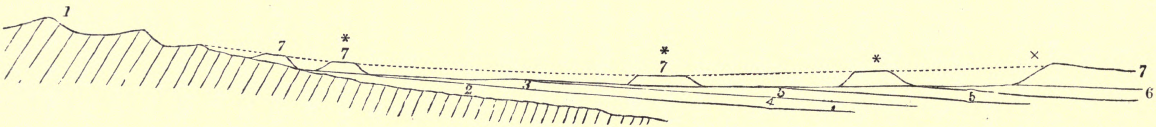
During the period that the Oolitic formations formed part of the land through which the river flowed that deposited the Wealden and Purbeck beds, they were undergoing constant waste, so that in the course of time, having been previously tilted upwards to the west with an eastern dip (fig. 59), they were worn into what I have elsewhere termed *a plain of marine denudation* (*see* p. 497). The submergence of the Wealden area was followed by the progressive sinking of the Oolitic and older strata further west, so that, as the successive members of the Cretaceous formations were deposited, it happened that by slow sinking of the land, the Upper Cretaceous strata gradually overlapped the edges of the outcropping Oolitic and Liassic formations, till at length they were intruded on the New Red series, and even on the Palæozoic strata of Devonshire itself, as shown in fig. 59.

The upheaval of the Chalk into land brought this epoch to an end, and those conditions that contributed to its formation ceased in our area. As the uppermost member of the Upper Secondary rocks, it closes the record of Mesozoic times in England.

This brings us to the last divisions of the British strata which I shall now name. These were deposited on the Chalk, and are termed Eocene formations (No. 12, fig. 57, p. 304). At the base they consist of marine and estuary deposits, known as the Thanet Sand, and Woolwich and Reading beds, and which are of comparatively small thickness, say from 50 to 150 feet. These lie below the London Clay and form the outer border of the London basin. The Woolwich and Reading beds are found in the Isle of Wight, and in part constitute the Hampshire and London basins. In these we have in places the same kind of alternations of fresh-

FIG. 52.

Overlap of the Oolitic and other Strata by Cretaceous Formations.



1. Represents the Palæozoic strata. 2. The New Red beds. 3. The Lias. 4, 5, 6. Various members of the Oolites, and 7. The upper Cretaceous strata. The dotted line represents the original continuation of the Chalk westward, the slope marked × the present escarpment of the Chalk, and the hills marked with asterisks (*) outlying patches of the same, the relics left by old denudations, and which help to prove the original far westward extension of the Upper Cretaceous strata.

water and marine shells that I mentioned as occurring in the Wealden and Purbeck strata; but with this difference, that though the shells belong mostly to the same genera, they are of different species—the old fresh-water life is replaced by new.

Upon the London Clay, which is a marine formation, varying from 200 to 500 feet thick, the Bracklesham and Bagshot beds were deposited. These consist of marine unconsolidated sands and clays, occurring as outliers—isolated patches left by denudation around Bagshot, and elsewhere on the London Clay, and overlying the same formation in the Isle of Wight, where they are well seen in Alum Bay. In both these places they are only sparingly fossiliferous, but at Bracklesham and Barton, on the Hampshire coast, they contain a rich marine molluscan fauna of a tropical or sub-tropical character. Upon these were formed various newer fresh-water strata, occasionally interbedded with thin marine bands, the whole evidently accumulated at the mouth of a river. For the names of these minor formations, I refer the reader to the column, p. 30.

I have in this chapter given a brief recapitulation of the geological and stratigraphical positions of the series of the larger and more solid geological formations that are concerned in producing the physical structure of England (*see* Map), and I will in the following chapters endeavour to show by the help of fig. 57, and other diagrams, the part that these formations play in producing the scenery of the country.

CHAPTER XX.

THE MOUNTAINS OF DEVON, WALES, AND THE WEST OF ENGLAND — THE VALLEY OF THE SEVERN, AND THE OOLITIC AND CHALK ESCARPMENTS—THE HILLY CARBONIFEROUS GROUND OF THE NORTH OF ENGLAND, AND ITS BORDERING PLAINS AND VALLEYS—THE PHYSICAL RELATION OF THESE TO THE MOUNTAINS OF WALES AND CUMBERLAND.

In the far west, in Devon and in Wales, also in the north-west, in Cumberland, and in the Pennine chain which joins the Scottish hills, and stretches from Northumberland to the Carboniferous Limestone hills of Derbyshire north of Ashbourne, we have what forms the mountainous and more hilly districts of England and Wales.

In Wales, especially in the north, the country is essentially of a mountainous character ; and the middle of England, such as parts of Staffordshire, Worcestershire, and Cheshire, may be described as flat and undulating ground, sometimes rather hilly. But, as a whole, these midland hills are insignificant, considered on a large scale, for when viewed from any of the more mountainous regions in the neighbourhood, the whole country below appears almost like a vast plain. To illustrate this. Let us imagine any one on the top of the gneissic range of the Malvern Hills (*g*, fig. 57, p. 304), which have, on a small scale, something of a mountainous character, and let him look to the west: then, as far as the eye can reach, he will see hill after hill stretching into Wales (1 to 3, fig. 57); and if he cast his eye to the north-east, he will there see what seem in the distance to be interminable low undulations, looking almost like perfect plains; while to the east and south-east there lies a broad low flat (6 to 8), through which the Severn flows, bounded by a flat-topped escarpment (9) facing west, and rising boldly above the plain. This escarpment is formed of the Oolitic formations, which constitute so large a part of Gloucestershire. These, as the Cotswold Hills, form a tableland, overlooking on the west a broad plain of Lias Clay and of New Red Marl, across which, on a clear day, from the scarped edge of North Gloucestershire, far to the west, we may descry the whole of the Malvern range, the well-known clump of firs on the top of May Hill near the Forest of Dean, and away to the north, the distant smoke of Colebrook Dale.

This remarkable Oolitic escarpment stretches, in a more or less perfect form, from the extreme south-west of England northward into Yorkshire (*see* Map). But it is clear that the Oolitic strata could not have been originally deposited in the scarped form they now possess, but once spread continuously over the plain far to the west, and only ended where the Oolitic seas washed the high land formed by the more ancient disturbed Palæozoic strata of Dartmoor, Wales, and the North of England. Occasional outliers of Lias and Oolite attest this fact, as, for example, in the large outlier of Lower Lias and Marlstone between Adderley and the neighbourhood of Whitchurch in Cheshire and Shropshire. This outlier occupies an area of about 50 square miles, and is at least 50 miles distant from the main mass of the nearest Lias, near Droitwich in Worcestershire. Indeed, I firmly believe that the Lias and Oolites entirely surrounded the old land of Wales, passing westwards through what is now the Bristol Channel on the south, and the broad tract of New Red formations, now partly occupied by the estuaries of the Dee and Mersey, that lie between Wales and the Carboniferous rocks of the Lancashire hills.

The strata that now form the wide Oolitic tableland, have a slight dip to the south-east and east, and great atmospheric denudations having in old times taken place, and which are still going on, a large part of the strata, miles upon miles in width, has been swept away, and thus it happens that a bold escarpment, once—for a time in Yorkshire and the Vale of Severn—an old line of coast cliff, overlooks the central plains and undulations of England, from which a vast extent and thickness of Lias and Oolite have been removed. That the sea was not, however, the chief agent in the production of this and similar escarpments will be shown further on.

An inexperienced person standing on the plain of the great valley of the Severn, near Cheltenham or Wotton-under-edge, would scarcely expect that when he ascended the Cotswold Hills, from 800 to 1,200 feet high, he would find himself on a second plain (9, fig. 57, p. 304); *that plain being a high tableland*, in which here and there deep valleys have been scooped, chiefly opening out westward into the plain at the foot of the escarpment. These valleys have been cut out entirely by frost, rain, and the power of brooks and minor rivers.[1]

If we go still farther to the east, and pass in

[1] Such valleys are necessarily omitted on so small a diagram, and the minor terraces on the plain, especially such as 7, are exaggerated.

succession all the outcrops of the different Oolitic formations (some of the limestones of which, overlying beds of clay, form minor scarps), we come to a second grand escarpment (11, fig. 57), formed of the Chalk, which in its day also spread far to the west, covering unconformably the half-denuded Oolites, till it also abutted upon the ancient land formed of the Palæozoic strata of Wales, and by-and-by, as that land sunk in the sea, buried it in places altogether. After consolidation and emergence, this Chalk formation also suffered great waste, and the result is this second bold escarpment also facing westerly, which stretches from Dorsetshire on the south coast of England into Yorkshire north of Flamborough Head. Occasional outlying patches of the Cretaceous formations attest its earlier western extension in the south-west of England, and the same overlap may be inferred with justice respecting the relations of the Oolitic, Triassic, and Upper Cretaceous strata throughout the length and breath of England. (*See* fig. 59, p. 313.)

The Eocene strata, which lie above the Chalk, in their day also extended much farther to the west, because here and there, near the extreme edge of the escarpment of Chalk, we find outlying Eocene fragments, and potholes more or less filled with the relics of Eocene strata. On the opposite page there is a drawing of such potholes filled with relics of the Plastic Clay of the Woolwich and Reading beds, which in and round Savernake Forest generally overlie the Chalk in a mere thin covering of red and mottled clay and yellow sand, often mixed with a few rounded flint pebbles. On the top of all there is frequently a layer of semi-angular high level gravel, and all of these have been more or less let down into the potholes, by the dissolving of the underlying chalk

Fig. 60.

Potholes in the Chalk of Savernake Forest, near Marlborough.

by the carbonic acid in rain-water, and thus pockets of Eocene strata have been preserved. The proof of this original extension westward is shown in the following diagram.

FIG. 61.

1. Chalk. 2. Part of the main mass of the Eocene beds. 2′. Outlying patch of the Eocene beds near the edge of the escarpment.

It is impossible that these outliers could have been originally deposited on this the edge of the Chalk, and not also on other strata that lie west of the present escarpment, and therefore it may be assumed that they originally extended further westward, and with the Chalk, have been denuded backwards till they occupy their present area. But the Eocene beds being formed of soft strata—chiefly clays and sands—though they make undulating ground, form no bold scenery. They rest in patches on the tableland, or in a large and somewhat depressed area in a manner shown at 12, fig. 57.[1] Such is the general manner in which the southern part of England has attained its present form.

Nearly the whole of the west of England, that is to say, of Devon and Cornwall, and of Wales, consists of Palæozoic strata, viz.: Devonian and Old Red Sandstone, Cambrian, and Silurian with all its igneous interstrati-

[1] Were I going into extreme details on this part of the subject, there are many distinctive features in the scenery of the Eocene formations dependent on synclinal curves in the strata, and other accidents, and the same remark may be extended to the scenery of many formations more important in a scenic point of view. The plan of this book purposely excludes such details, my object being merely to explain the connection of the greater geological features of the country with its physical geography.

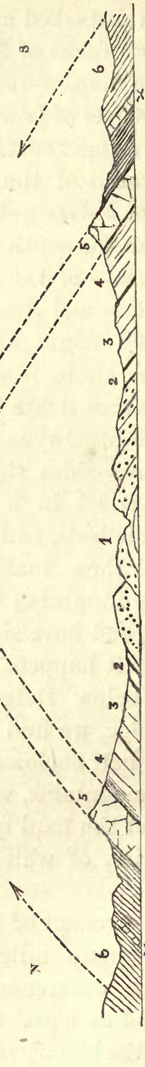
fications, and of the Carboniferous series, all of which have been much disturbed and extensively denuded.

The Cambrian rocks of Merionethshire, for example, marked 2 on the map, were once buried deep beneath more than 20,000 feet of Lower Silurian strata. Let anyone climb to the rugged centre of this Cambrian area, and stand on the summit of the great grit-formed cliffs of Rhinog-fawr or of Y-Graig-ddrwg (the bad cliff). From thence turning to the south and south-east, he will see the long ridgy peaks of the interstratified felstones and ashes of Cader Idris and Aran Mowddwy, further north-east the serrated edges of Moel Llyfnant and the Arenigs, and the circle is continued on the northern side of the Cambrian strata by the noble heights of the Manods and the Moelwyns near Ffestiniog and Portmadoc. On three sides the great anticlinal boss of Cambrian grits is set in a curved frame of Silurian slates and volcanic beds, and on the fourth it is bordered by the sea. All these rocks, and much more besides, once overlaid the Cambrian beds, in the form of a great anticlinal curve, and have since been removed by denudation; and thus it happens that between the estuary of the Mawddach below Dolgelli, and that of Traeth-bach at Portmadoc, we find this inner group of gritty hills, more than half enclosed by that somewhat distant ring of higher mountains, which are highest, as a rule, simply because of the hard quality of the great inclined beds of porphyries, of which they are so largely composed. (Fig. 62.)

In this brief account of a fragment of North Wales of about 1,200 square miles, lies the essence of the matter, for with differences of detail, the whole of the strata suffered an equal amount of disturbance and denudation, and the history simply comes to this. Much

FIG. 62

Section across the Cambrian and part of the Lower Silurian rocks of Merionethshire.



1. Cambrian grits. 2. Menevian. 3. Lingula flags. 4. Tremadoc and Arenig slates. 5. Igneous series. 6. Llandeilo and Bala. × Bala limestone.

of the Silurian rocks in North Wales are of a slaty character, interbedded with masses of hard igneous rocks, which attain in some instances a thickness of thousands of feet. It is, therefore, easy to understand how it happens that with disturbed and contorted beds of such various kinds, those great denudations, which commenced as early as the close of the Lower Silurian period, and have been continued intermittently ever since, through periods of time so immense that the mind refuses to grapple with them—it is, I repeat, easily seen how the outlines of the country have assumed such varied and rugged outlines, as those which North Wales, and in a less degree parts of North Pembrokeshire, Devon, and Cornwall, now present.

I have said that the Secondary and Lower Tertiary strata have not been anywhere disturbed nearly to the same extent as the Palæozoic formations in England. Though occasionally traversed by faults, yet with rare exceptions most of the strata have been elevated above the water without much bending or contortion on a large scale. What chiefly took place was a slight uptilting of the strata to the west, which, therefore, all through the centre of England, dip as a whole slightly but steadily to the east and south-east. This is evident from the circumstance that on the Cotswold Hills the lowest Oolitic formation (Inferior Oolite, No. 9, fig. 57) forms the western edge of the tableland, while, in spite of a few minor escarpments that rise on the surface of the upper plain, the uppermost Oolitic beds that dip below the Cretaceous strata, are sometimes at a lower level than the Inferior Oolite at the edge of the plateau.

The great result, then, of the disturbance and denudation of the Palæozoic strata, and of the lesser disturbance and denudation of the Secondary rocks, is, that the physical features of England and Wales present masses of Palæozoic rocks, forming groups of mountains in the west, then certain plains and undulating grounds composed of New Red Sandstone, Marl, and Lias, and then two great escarpments, the edges of tablelands, which rise in some places to a height of more than a thousand feet: the western one being formed of Oolitic, and the eastern of Cretaceous strata, which, in its turn, is overlaid by the Eocene series of the London and Hampshire basins. *See* fig. 57.

If we now turn to the north, what do we find there?

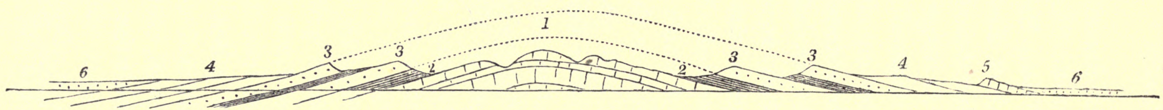
Through the centre of this part of England a great tract of Palæozoic country, more than 200 miles in length, stretches from the southern part of Derbyshire to the borders of Scotland, and joins with the hilly ground of Berwickshire. It consists of Carboniferous rocks, ranging from the Carboniferous Limestone up to those that pass beneath the base of the Permian strata. Further west, between Morecambe Bay and the Solway, lie the Silurian and Carboniferous rocks of the Cumbrian area, separated from the Carboniferous formations of Northumberland, Durham, and Yorkshire, by the Permian beds of the Vale of Eden.

As far as the north borders of the Lancashire and Yorkshire coal-fields, the Carboniferous rocks lie in the form of a broad *anticlinal curve.*

At the southern end of this area, a wide tract of Carboniferous Limestone hills ranging up to 1,200 feet in height, occupies the centre of the anticlinal curve, on each side of which, the Yoredale shales and thick strata of Millstone grit dip east and west as the case may be. The latter, being interstratified with comparatively soft beds of shale, run in long bold escarpments (fig. 63), that often trend north and south both on the west and east sides

Fig. 63.

Section across the Carboniferous Rocks of Derbyshire and Lancashire.



1. Carb. Limestone forming the hilly centre of the anticlinal curve. 2. Yoredale shales, soft, and forming valleys of denudation. 3. Terraced escarpments of hard sandstones, Millstone grit. 4. Coal-measures, consisting of softer rocks generally, forming a lower undulating country. 5. Escarpment of Magnesian Limestone (Permian) overlaid by 6, New Red Sandstone.

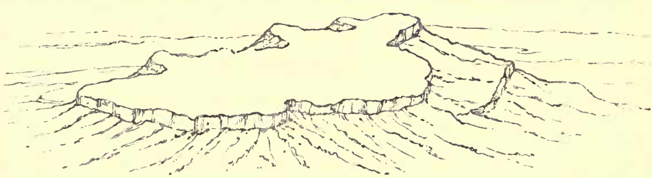
of the Carboniferous Limestone, fine examples of which may be seen in the country near Chatsworth on the east, and between Chapel-le-Frith, Buxton, and Hartington, and the neighbourhood of Leek, on the west. Let anyone get to the highest limestone hills in the midst of the area, and look west to Ax Edge beyond Buxton, and east towards Rowseley or Bakewell, and he will see these escarpments, the nearest on either side, being generally separated from the limestone hills by a deep valley excavated in the soft Yoredale shales. This special piece of geological anatomy is, indeed, characteristic of the whole of the region, the limestone hills being almost entirely surrounded by a valley, or valleys, the chief watershed of which is near Castleton on the north, beyond which, on the east, the Derwent flows, well wooded, and still often bordered by oaks,[1] while on the west the classic Dove runs down a similar valley, till it enters that gorge of tall limestone cliffs, which itself has cut some miles above Ashbourne. Narrow dry dales are common in the Carboniferous Limestone region, and probably some of these are the relics of old underground watercourses, the roofs of which have fallen in.

In the northern part of Derbyshire, near Hathersage and the High Peak, the Millstone grit lies in broad plateaux, often from 1,000 to 1,200 feet in height. Great part of the country, east towards Derwent Dale and north of the High Peak, is called the Woodlands. In places the steep hill-sides are still dotted with little woods and single trees of birch, ash, mountain ash, oak, and elder, the relics of the forest that once gave this high country its name.

[1] Derwyn is Welsh for an oak, whence probably the original name of the river.

If from the Snake Inn on the Glossop road you climb the High Peak, or, as it is often called, Kinder Scout, taking Fairbrook as your route, you first pass across shales with beds of Yoredale grit, over which the water falls in tiny cascades, and at length, high on the top, the view is barred by a great cliff of rock running in a sinuous line to right and left. It consists of coarse quartzose sandstone, covered in great part by about 12 feet of peat, which in all directions is intersected by devious steep-sided water-worn channels, among which, in trying to work out a straight course, you are apt to return to the point from whence you started. If you could from a balloon look down upon it, it would

FIG. 64.



look somewhat as in fig. 64, its whole length being about 6 miles by 2 in breadth. This is the character of the country. Kinder Scout is in the centre of a long, low, anticlinal curve, and the strata lie nearly flat, while to the right and left the equivalent strata form definite scarps, dipping in opposite directions.

Where bare of peat, the surface of this little tableland is marked by numerous monumental-looking pillars of stone, sometimes undercut, which helps to show how high flat areas of such rocks are worn away by ordinary atmospheric agents. Some of these have such forms as in the following diagram, fig. 65, and I give them to show that even on the top of the table-land, where of running water there is almost none, degradation and lowering of the surface does not absolutely

FIG. 65.

cease. This work is aided by the easy decomposition of the felspar, which forms an important ingredient in this coarse-grained sandstone, and during heavy gales that sweep across the high bare plateau, the sand is driven along the surface, and grating along the bases of the projecting masses of rock, these become undercut, and eventually must topple over. In this way, Brimham rocks, and rocking-stones, and other isolated rock-masses have been formed in other districts, as, for example, such a grand mass of granite as the Mainstone of Dartmoor, now unhappily blasted away and sold by its proprietor.

There is no area that shows better than this part of Derbyshire how valleys have been formed in a high tableland composed of Carboniferous sandstones and shales. There are landslips everywhere. Going up the valley from Hathersage a notable landslip is to be seen on the hill-side west of the Derwent and south of Yorkshire Bridge. Between that and the twenty-fifth milestone, on the road to Glossop, there are several on either side of the valley. On the north side of the valley of the Ashop, the shattered masses cumber the hill-side for at least three miles, and on the east side of Alport Dale, there is one vast landslip a mile in length. The whole hill-side has slipped bodily away, part lies in tumbled ruins all the way down to the river, and part still stands in tower-like peaks and solid flat-topped castlelike masses, called Alport towers and Alport castles.

This is the law of waste in such cases:—

FIG. 66.

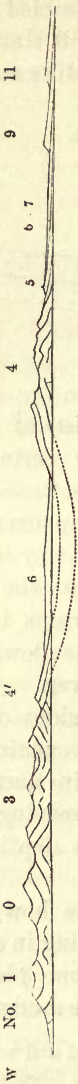
The upper strata of the tableland consists of thick beds of sandstone, much jointed, and easily permeated by rain-water; the shale beneath becomes softened and slippery, and great masses of sandstone slip over the brow, and, once there, by gravity find their way to the bottom of the valley. Just in proportion as the river attacks and carries away the crumbling ruins below, the upper part of the slip gradually creeps down the slope, till at length it reaches the river. Thus repeated slips take place on one or both sides of the valley, and though the river is always deepening its channel, the waste from the hill-sides, by slips and rain-waste, is proportionate to the average deepening, and thus the valley goes on increasing both in depth and width.[1]

It requires little imagination to divine how such valleys began to be formed by streams running in slight inequalities on the very top of the sandstone plateau, till at length, channels being cut through the sandstones,

[1] These and many other valleys are also deepened and widened by the process described at pp. 533-36 in regard to the Moselle, &c.

Fig. 67.

Section from Snowdon to the East of England.



landslips came in aid, and are still in progress. This general description, with local variations dependent on lithological variations, and the dips, strikes, and faults of the strata, may serve for much of the Carboniferous ground in the middle of the anticlinal curve, as far as the northern borders of the Yorkshire and Lancashire coal-fields.

If we now construct a section from the Menai Straits, across Snowdon and over the Derbyshire hills to the east of England, the arrangement of the strata may be typified in the following manner (fig. 67, and Map, line 17). In the west, rise the older disturbed Silurian strata, Nos. 1 to 3, which form the mountain region of Wales. On the east of these lies an upper portion of the Palæozoic rocks, 4, consisting of Carboniferous beds with an escarpment facing west. They are less disturbed than the underlying Silurian strata on which they lie unconformably. Then, in Cheshire, to the east of the Dee, lie the great undulating plains of the New Red series, 6, and these form plains because they consist of strata that have never been much disturbed and still lie nearly flat, and are soft and easily denuded, whence, in part, the soft rolling undulations of the scenery. Then more easterly, from under the strata of New Red Sandstone, the disturbed Coal-measures again rise, together with the

Millstone Grit and Carboniferous Limestone forming the Derbyshire hills, 4′. These strata dip first to the west, underneath the New Red Sandstone, and then roll over to the east, forming an anticlinal curve, the Limestone being in the centre, and the Millstone Grit on both sides dipping west and east; and above the Millstone Grit come the Coal-measures, also dipping west and east. Together they form the southern part of the Pennine chain. Upon the Coal-measures in Nottinghamshire, Derbyshire, and Yorkshire, dipping easterly at low angles, we have, first, a low escarpment of Magnesian Limestone 5, then the New Red Sandstone and Lias plains 6 and 7, which are covered to the east by the Oolite 9, forming a low escarpment, the latter being overlaid by that of the Chalk 11. In this district, except in North Yorkshire, the Oolitic strata, being thinner, do not form the same bold scarped tableland that they do in Gloucestershire and the more southern parts of England. As shown in the diagram the Cretaceous rocks also rise in a tolerably marked escarpment.

Further north the grand general features are as follows:—If a section were drawn across England from the Cumberland mountains south-easterly to Bridlington Bay, the following diagram, fig. 68, will explain the general arrangement of the strata, and the effect of this on the physical geography of the district.

On the west there are the Green Slates and porphyries, No. 1, consisting of lavas and volcanic ashes, hard but of unequal hardness, and some of them, therefore, by help of denudation giving specialities of form to some of the loftiest mountains of Cumberland. Then comes 2, the Coniston Limestone, overlaid by Upper Silurian rocks, 3, forming a hilly country, between which

FIG. 68.

Section from Cumberland towards Bridlington.

1. Igneous rocks or Green Slates and Porphyrys (lavas and volcanic ashes) of Lower Silurian age. 2. Coniston Limestone. 3. Upper Silurian grit, &c. 4. Carboniferous Limestone, between faults. 5. Yoredale rocks and Millstone grit. 6. Magnesian Limestone. 7. New Red strata. 8. Lias. 9. Chalk.

and the Carboniferous grits, 5, lies the Carboniferous Limestone between two faults in a broken country. Then comes a marked feature in the district, consisting of the long, gently sloping beds of Yoredale rocks and Millstone Grit, No. 5, dipping easterly till they slip out of sight beneath the Magnesian Limestone, No. 6, overlaid in succession by New Red beds and Lias plains, 7 and 8, which are overlooked by an escarpment of Chalk, 9. This Chalk is overlaid by Boulder-clay, the eastern edge of which forms a cliff overlooking the sea.

North of this region, till we come to the east side of the Vale of Eden, the country is much complicated by faults and other disturbances, and to describe it in detail would occupy much space, but east of the Vale of Eden the structure of the country is again exceedingly simple, the whole of the Carboniferous rocks dipping steadily east at low angles, all the way from the escarpment that overlooks the vale, to the German Ocean that borders the Northumberland coal-field, fig. 69, p. 334.

While travelling northward from London by the Great Northern Railway, many persons must be struck with the general flatness of the country after passing the Cretaceous escarpments north of Hitchin. Before reaching Peterborough the line enters on the great peaty and alluvial flats of Cambridgeshire, Lincolnshire, and the Wash, a vast plain, and once a great bay, formed by the denudation of the Kimeridge and Oxford Clays. It has been for long the recipient of the mud of several rivers—the Ouse, the Nen, the Welland, the Witham, and the Glen. Nature and art have combined, by silting and by dykes, to turn the flat into a miniature Holland, about 70 miles in length and 36 in width. Near Stamford, passing through the low, flat-topped undulations of the Oolitic and Lias, with

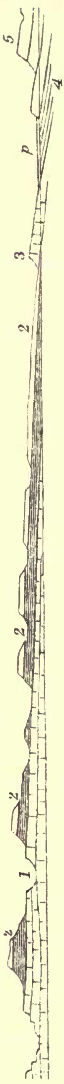


Fig. 69.

Ingleborough. Penyghent.

their minor escarpments facing west, the railway emerges, after crossing the Trent, on a second plain, through which, swelled by many tributaries—the Idle, the Don, the Calder, the Aire, the Wharfe, the Nidd, the Ure, the Swale, and the Derwent—the Trent and the Ouse flow to enter the famous estuary of the Humber.

Passing north by York the same plain forms the bottom of the low broad valley that lies between the westward rising dip-slopes of the Millstone Grit, &c., and the bold escarpment of the Yorkshire Oolites on the east, till at length it passes out to sea on either side of the estuary of the Tees. The adjoining diagram represents the general structure of the region on a line from Ingleborough on the west to the Oolitic moors.

On the west lie the outlying heights of the ancient camp of Ingleborough, and of Penyghent, capped with Millstone Grit and Yoredale rocks (2), which, intersected by valleys, gradually dip eastward, the average slope of the ground over long areas often corresponding with the dip of the strata in the manner shown in the diagram,[1] till they slip under the low escarpment of Magnesian Limestone (3).

Let the reader attentively consider this part of the diagram, and he may I hope convince himself how little ordinary valleys, large or small, are directly pro-

[1] This kind of slope is often called a dip-slope.

duced by fractures and 'convulsions of Nature,' for in this and many similar cases, what can be their origin but the tranquil scooping powers of disintegration and running water, aided by an unknown amount of time. East of the Magnesian Limestone lies the plain (*p*), almost as flat as a table, and covered to a great extent with an oozy loam, like the warps of the Wash and the Humber, and like these, perhaps, formed of old river sediments. The New Red and Lower Lias strata (4) lie beneath the warp, and for the most part, below the level of the sea, and high on the east, like a great rampart, the escarpment of the Oolites (5) rises in places to a height of more than 1,100 feet, with all its broad-topped moorlands and deep well-wooded valleys. Such is the anatomy of the fertile Vale of York and its neighbourhood.

CHAPTER XXI.

THE ORIGIN OF ESCARPMENTS, AND THE DENUDATION OF THE WEALD—GREY WETHERS AND THE DENUDATION OF THE EOCENE STRATA.

In the foregoing pages much has been said about *escarpments*. The origin of all escarpments, excepting modern sea cliffs, is generally the same, and they are nearly all marked by this peculiarity, that the strata dip at low angles in a direction opposite to the slope of the scarp, thus:—

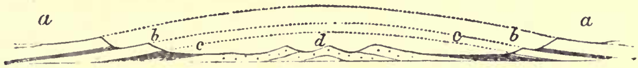
Fig. 70.

1. Strata with a low dip, *e* escarpment. 2. Detritus slipped from the escarpment down towards the plain *p*.

The Weald of Kent and Sussex and the surrounding Chalk hills form excellent examples of what I wish to explain, and I therefore return to the south-east of England. In the Wealden area we generally find a plain, bounded by hills of Lower Greensand and Chalk, on the north, south, and west, while the clayey plain itself surrounds a nucleus of undulating sandy hills in the centre. The whole of this Wealden area forms a great amphitheatre, on the outermost rim of which the

Chalk rises in bold escarpments, forming what are known as the North and South Downs. On the east it is bounded by the sea. There can be no doubt that the Chalk and the underlying formations of Upper Greensand, Gault, Lower Greensand, and Weald Clay originally extended across all the area of the Weald for a breadth of from twenty to forty miles from north to south, and nearly eighty from east to west (figs. 71 and 73). This vast mass, many hundreds of feet thick, has been swept away, according to an opinion formerly universal among geologists, by the wasting power of the sea, but, I believe, chiefly by atmospheric agencies; so much so, indeed, that I am convinced that all the present details, great and small, of the form of the ground, are due to the latter. The result is, that great oval escarpments of Lower Greensand, and outside of that of Chalk surrounding the Wealden area, rise steeply above the nearest plain, which is composed of the Weald Clay, from beneath which the Hastings Sands crop out, forming a central nucleus of hilly ground, in the manner shown in the following diagram, the height of which is purposely exaggerated so as to bring the features prominently before the eye.

N FIG. 71. S



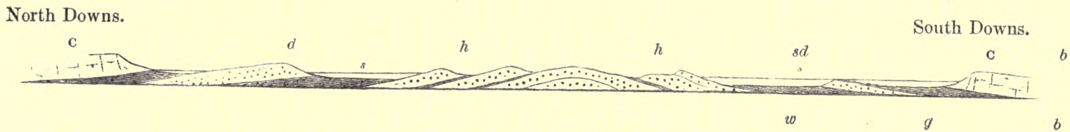
a a Upper Cretaceous strata, chiefly Chalk, forming the North and South Downs; *b b* escarpment of Lower Greensand with a valley between it and the Chalk; *c c* Weald Clay, forming plains; *d* hills formed of Hastings Sand and Clay. The Chalk, &c. once spread across the country, as shown in the dotted lines.

Let us endeavour to realise how such a result may have been brought about. The idea that the Wealden area once formed a vast oblong bay, of which the Chalk hills were the coast cliffs, is exceedingly tempting; for, standing on the edge of the North Downs near Folkestone, and looking west towards Ashford, and south-west across the Romney Marsh, it is impossible not to compare the great flat to a sea overlooked by all the bays and headlands, which the winding outlines of the Chalk escarpment, both of the North and South Downs, are sure to suggest. And in less degree the same impression suggests itself, wherever one may chance to stand on the edge of the Chalk Downs, all the way from Folkestone to Alton and Petersfield, and from Petersfield to Eastbourne. For years, with others, I held this view; but for years, with me, it has passed into the limbo of hypotheses no longer tenable.

If the Wealden area were lowered into the sea just enough to turn the Chalk escarpments into sea-cliffs (*see* Map and fig. 72), we should have the following general results. Let the line *a b* represent the present sea level, and the lines *s s s* the level of the sea after depression; then, so far from the area presenting a wide open sea, where heavy waves could play between the opposite North and South Downs, we should have an encircling cliffy coast of chalk *c; the base of which cliff, if we follow the escarpment all round from the neighbourhood of Folkestone to that of Eastbourne, unlike all common coasts, would in some cases be washed by the ordinary tides, while within a mile or two, the depth of the sea close to the cliff of chalk must have been from* 200 *to* 300 *feet.* In other words the *base of the Chalk* and Upper Greensand all round the Weald from Folkestone to Eastbourne could not have formed a continuous shore line in recent times, for some

Fig. 72.

Diagram showing the general effect of a partial submergence of the Weald. Map, line 10.



c c Chalk and Upper Greensand forming North and South Downs.
g Gault generally forming a plain.
s d Escarpments of Lower Greensand.
w Weald clay generally forming a plain.
h h Central hills of Hastings Sand.

parts of it are at the sea level now; while other parts, along gently undulating lines at the bases of the North and South Downs, rise to more than 250 feet above the sea.

On the supposition that the Wealden area was once an oblong bay, this land would also have been formed of two narrow strips of country, one on the south at least 60, and the other on the north not less than 100, miles long, both of which project eastward from the Chalk of Hampshire, to form what we now call the North and South Downs. These hills generally rise high above the Eocene strata that skirt them on the north and south, and these Eocene beds, under the supposed circumstances, would be covered by sea, while the scarped cliffs of Chalk, as shown on the diagram, would overlook a sea-covered plain of Gault *g*; outside of which, near the shore, would be a series of ridgy islands of Lower Greensand *s d*, which, at present, in some parts of the country, rise into escarpments higher than the Downs themselves. Beyond these there would be a sea where the flats of Weald Clay *w* now lie; inside of which would rise an island, or rather group of islands, formed of the Hastings Sand series *h h*. This form of ground would certainly be peculiar, and ill adapted in form to receive the beating of a powerful surf, so as to produce *on the inner side only*, the cliffy escarpment that forms the steep edge of the oval of Chalk. Further, if the area had been filled by the sea, we might possibly expect to find traces of superficial marine strata of late date, as in some other parts of England, scattered across the surface between the opposite Downs. But none of these traces exist. On the contrary, the underlying strata of the Cretaceous and of the Wealden series everywhere crop up and form the surface of the ground, except where here and there, near the Chalk escarpments, they are strewn with flints, the relics of the subaërial waste of the Chalk, or where *they are covered by fresh-water sands, gravels, and loams of the ancient rivers of the country.*

I believe, therefore, that the form of the ground in the Wealden area, which was once attributed to marine action, has been mainly brought about by atmospheric causes, and the operation of rain and running waters. One great effect of the action of the sea, combined with atmospheric waste, when prolonged over great periods of time, is to produce extensive *plains of marine denudation* like the line *b b*, fig. 97, p. 497; for this combined result is to *plane off*, as it were, the asperities of the land, and reduce it to an average tidal level.

Suppose the curvature of the various formations across the Wealden area to be restored by dotted lines, as in figure, No. 73, which is very nearly on a true scale. Let the upper part of the curve be planed across, as shown in fig. 73, and let the newly-planed surface, slightly inclined from the interior, be represented by the line *p p*. Against this line, the various masses of the Hastings Sand *h h*, Weald Clay *w*, the Lower Greensand *s*, the Gault *g*, and the Chalk and Upper Greensand *c*, would crop up. Then I believe that, by aid of rain and running water, large parts of these strata would be cut away by degrees, so as to produce in time the present configuration of the ground. *If it were not so, we might expect that the rivers of the Wealden area should all flow out at its eastern end, through long east and west hollows, previously scooped out by the assumed wasting power of the sea, where the ground is now low, and looks out upon the sea,* *and towards which, the long plains of Gault and Weald Clay directly lead.* But this, except with certain rivulets, is so far from being the case, that some streams, like the Beult, rise close to the sea coast and flow westward. If, on the other hand, such a plain as *p p* once existed, it is easy to understand, *how the rivers in old times flowed from a low central watershed to the north and south across the top of the Chalk, at elevations at least as high as, and probably even higher than the present summit-levels of the Downs.*

Then, as by the action of running water, the general level of the *inner* country was being unequally reduced, so as to form tributary streams each cutting out its own valley, the greater rivers, augmented in volume by these tributaries, were all the while busy cutting and deepening those north and south channels through the Chalk Downs now known as the valleys of the Stour, the Medway, the Dart, the Mole, the Wey, which run athwart the North Downs, and the Arun, the Adur, the Ouse, and the Cuckmare, which, through gaps in the South Downs, flow south.[1] On any other supposition, it is not easy to understand how these channels were formed, unless they were produced by fractures or by marine denudation, of neither of which is there any proof. Through most of these gaps *no known faults run of any kind*, and the whole line of the Chalk is singularly destitute of fractures.

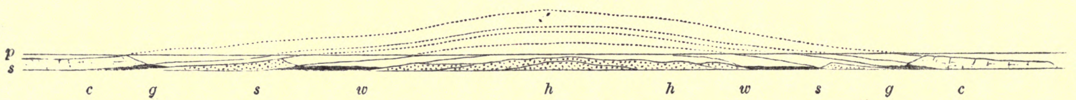
We get a strong hint of the probability of the truth of this hypothesis of the denudation of the Weald in

[1] This kind of argument was applied by Mr. Jukes to explain the *behaviour* of some of the rivers of Ireland, and he supposed that it might possibly apply to the Weald.—'Geological Journal,' 1862, vol. xviii. p. 378.

FIG 73.

Diagrammatic section across the Weald, with the anticlinal curve restored as high as the Chalk.

Map, line 11.



s s The level of the present sea.

p p The level of the old *plain of marine denudation*, after the dotted parts had been *planed* or denuded off.

c c Chalk and Upper Greensand, *g g* Gault, *s s* Lower Greensand, *w w* Weald Clay, *h h* Hastings sand. Part at least of the Eocene beds probably lay above the curved strata of Chalk marked in the dotted line.

the present form of the ground. Thus after the formation of the marine plain *p p*, the Chalk being comparatively hard, has been partly denuded, and now stands out as the bold escarpments of the North and South Downs. The soft clay of the Gault has been more easily worn away, and forms a hollow or plain between the Chalk and the Lower Greensand. The Lower Greensand, full of hard calcareous bands and ironstone, more strongly resisting denudation, forms a second range of scarped hills, overlooking the more easily wasted Weald Clay, which makes a second and broader plain, from under which rise the subdivisions of the Hastings Sands, forming the undulations of the hills of Ashdown Forest, and other places, in the broad centre of the low anticlinal curve. The absence of flints over nearly the whole of the Wealden area, excepting near the Downs, is easily explained by this hypothesis, *for the original marine denudation had removed all the Chalk, except near the margin* (see fig. 73), *long before the rivers had begun simultaneously to scoop out the valleys of the interior, and to cut the transverse valleys across the North and South Downs.*[1]

Given sufficient time, I see no difficulty in this result. But the question arises, how much time, in a geological sense, can be given?

It is believed that, excepting for a few feet close upon the coast, this southern part of England was not depressed beneath the sea during any part of the Glacial period. It has, therefore, been above water for a very long time. On the edge of the North Downs there are

[1] The original sketch of these views was published in 1863, and enlarged and much improved in 1864, in a second edition of this work. For greater detail on the same subject, see Foster and Topley, 'Journal of the Geological Society,' 1865, vol. xxi. p. 443.

certain fragmentary outliers described by Professor Prestwich. These by some persons have been supposed to be outliers of the Lower Eocene strata, called the Woolwich and Reading beds, but Professor Prestwich considers them to belong to part of the Crag. The physical evidence seems to me to be in favour of the former.

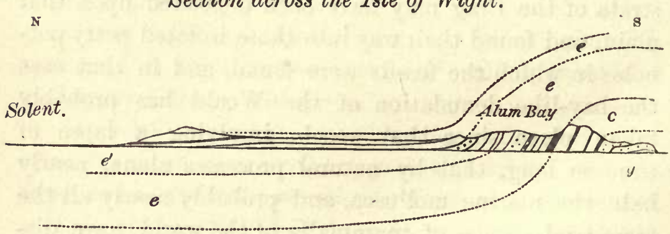
If they belong to any part of the Eocene series, then, as they lie as it were accidentally conformably on the Chalk, they were evidently affected by the disturbance that raised the Wealden into an anticlinal curve, and depressed the Chalk and overlying Eocene beds into the now divided synclinal curves of the London and Hampshire basins, and therefore, the beginning of the chief denudation of the Weald, by which it gradually assumed its present form, *was post-Eocene.* Under these circumstances it is probable that the Eocene beds themselves were cut across during the gradual formation of the plain of marine denudation. On the other hand, if the outliers on the Chalk escarpment west of Folkestone be parts of the Crag beds, then it is possible that strata of the Crag may have been deposited upon that plain, and found their way into those isolated petty pot-holes in which the fossils were found, and in that case the bay-like denudation of the Weald has probably taken place since that epoch, implying a lapse of time so long, that by natural processes alone, nearly half the marine mollusca, and probably nearly all the terrestrial species of mammalia of the world, have disappeared and been slowly replaced by others. This may mean little to those who still believe in the sudden extinction of whole races of life; but to me it signifies a period analogous to the distance of a half-resolved nebula, the elements as yet being wanting by means of which we may attempt to calculate its remoteness.

I have gone so far into details on this subject, because the 'Denudation of the Weald' has given rise to much theorising by distinguished authors, and I wish to show the reasons why I think that the amphitheatre-like form of the area, and the escarpment of the Chalk, are not due to marine denudation or the beating of sea waves. On the contrary, the outer crust of Chalk that once cased the whole as the strata of the anticlinal curve having been *planed off*, and by subsequent elevation a tableland having been formed, the softer rocks below that cropped up to the surface of this plane were then attacked by running water, and worn away so as to form by degrees the hills and valleys of the district, including the great escarpment of the North and South Downs.

Though the Secondary and older Tertiary strata of England generally lie flat or dip at low angles, yet in

FIG. 74.

Section across the Isle of Wight.



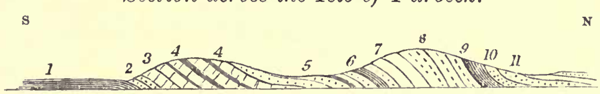
g, Lower Greensand; *c*, Chalk; *e*, Woolwich and Reading beds, London Clay and Bracklesham and Bagshot Sands, and the overlying Freshwater strata *é*.

one instance they have been very considerably disturbed; for on a line which runs through the Isle of Wight and the Isle of Purbeck they stand nearly on end. Those who are familiar with the Isle of Wight will remember that from east to west, or from White Cliff Bay to Alum Bay, there is overlying the Lower Greensand *g*, a long range of Chalk hills, *c*, the strata of which dip towards the north, and are overlaid by the older Tertiary strata *e*, that is to say, the Woolwich and Reading beds, the London Clay, the Lower Bagshot Sands and Clays, the Bracklesham Beds, the Upper Bagshot Sands, and all the higher freshwater and estuarine divisions *é*, as enumerated in the column p. 30, and in the diagram, p. 241.

The whole pass under the Solent, as shown in the lower dotted lines *e é*, fig. 74, and rise again on the mainland in Hampshire, a considerable portion of which is composed of various subdivisions of the Eocene rocks. The same general relations of the Secondary and Eocene strata are seen on the mainland in the Isle of Purbeck, at and west of Swanage, as shown in the following section north of Kimeridge Bay (fig. 75).

FIG. 75.

Section across the Isle of Purbeck.



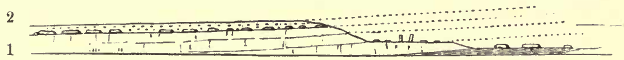
1. Kimeridge Clay. 2. Portland Oolite sand. 3. Portland Oolite limestone. 4. Purbeck limestone and marls, chiefly freshwater beds. 5. Weald sands and clay, freshwater. 6. Neocomian and Greensand. 7. Chalk without flints. 8. Chalk with flints. 9. Woolwich and Reading beds. 10. London Clay. 11. Bracklesham and Bagshot beds.

Now these disturbed strata of the Isle of Wight were deposited horizontally, and after disturbance, the Chalk, *c*, spread over an extensive area of Lower Greensand, *g*, to the south, and the Eocene rocks *e* once spread over the Cretaceous rocks in a curve, at a great height, as shown in the dotted lines *e e* (fig. 74). Taking the whole of the south-eastern part of England, from Suffolk to Beachy Head, and westward to Salisbury and Dorchester, the sections shown in figs. 74 and 75 merely form part of the two great anticlinal and synclinal curves of which the Hampshire and London basins form parts. Here then in our Secondary and Tertiary rocks we get evidence, though in less degree, of the same kind of disturbance and denudation of which we have such striking proofs when we consider the structure of the countries in the western and north-western area, which are composed of Palæozoic rocks. In the central part of England the Secondary and Tertiary strata, not having been so much disturbed, have necessarily not been so much denuded in height, but chiefly backwards from west to east.

I have still a few words to add respecting the denudation of the Eocene strata. Some of these beds in the Woolwich and Reading and in the Bagshot series consist of sands, portions of which become exceedingly hard, especially when exposed to the air. I have already said that these formations, together with the Chalk, once spread much further to the west than they do now, because outlying patches of Eocene rocks occur here and there almost at the very edge of the great Chalk escarpment, as shown in fig. 61, p. 320. Part of the original continuation of both in a westward direction is shown in the dotted lines in the same diagram.

It so happened that when the wasting processes took place that wore away both these formations from west to east, the softer clays and part of the sands of the Eocene strata were more easily removed than the harder rocky portions, and the result is that over large areas, such as Marlborough Downs, great tracts of Chalk are strewn with huge blocks of tabular quartz-grit, lying so close together that some years ago, over miles of country, I could almost leap from block to block, without touching the chalk on which they lie. They are, however, in such great request for building and paving purposes, that in the long run they will probably be all broken up and carried away.

FIG. 76.



In the above figure, No. 1 represents the Chalk, and 2 the overlying Eocene clays and sands; and the isolated blocks, lying directly on the topmost beds of the Chalk, represent the thickly scattered masses of stone left on the ground *after the removal by denudation of other and softer parts of the Eocene strata*, No. 2. Frequently these masses are found scattered even on the terraces of the Lower Chalk, a remarkable example of which occurs at the Prehistoric town of Avebury, near which, the lower terrace of Chalk (as in the diagram) is strewn with 'grey wethers,' as they are termed, and immense masses of these, set on end by a vanished people, stand in the ancient enclosure. Sometimes even on the plains of Gault or Kimeridge Clay, well out to the north or west of the escarpment, as for instance at Swindon, and also in the Wealden area, blocks angular or half-rounded lie in the meadows, marking the immense waste to which the whole territory has been subjected long after the close of Eocene times. They plainly tell, that the Chalk and overlying Eocene beds once spread far across the plains which the abrupt Chalk escarpments now overlook. These have been and are still being wasted back, for they are comparatively easily destroyed, but the strong 'grey wethers' remain, and as the rocks on which they once lay were slowly wasted away and disappeared, these masses of tough and intractable silicious stone gradually subsided to their present places.

Besides the name of 'grey wethers,' they are also known as Sarsen stones, and Druid stones, and all the standing masses of Avebury and Stonehenge, popularly supposed to be Druidical temples, have been left, by denudation, not far from the spots where they have since been erected into such grand old monuments by an ancient race.[1]

I might add many details respecting the origin of the scenery of other portions of England, such as the relation of the secondary rocks to the older rocks of Devon, the structure of the Malvern Hills, a true miniature mountain range, and of the Mendip Hills, or of the beautiful Vale of Clwyd, in North Wales, consisting of a bay of soft New Red Sandstone, bounded by Silurian mountains and old limestone cliffs, and of the still larger Vale of Eden, in the North, where the mountains of Cumberland look down on an undulating ground formed of Permian and partly of New Red strata (fig. 104, p. 521). But some of these regions will be dealt with when I discuss the subject of the British rivers, and in the meanwhile it would not

[1] The smaller stones at Stonehenge have been brought from a distance. They are mostly of igneous origin, and are believed by Mr. Fergusson to have been votive offerings. See 'Memoirs of the Geological Survey of Great Britain; the Geology of parts of Wiltshire and Gloucestershire.' sheet 34, 1858, pp. 41-44. Also a memoir by Professor Maskelyne.

add much to the general knowledge which I have already endeavoured to express, viz., that England is mountainous and very hilly in the west and north, in Devon, Wales, Cumberland, and from Derbyshire continuously all through to Scotland, because of disturbances and great denudations; and that it consists of undulating plains and of tablelands in the central and eastern parts, because the strata there are generally much flatter and softer, and because they have been denuded in such a manner, that immense tracts of Chalk and Lower Greensand, in the Weald and in the middle and west of England, have been cut away by a slow process of gradual recession due to atmospheric influences, and thus it happens that their edges now form long escarpments, which are still receding in the direction of the dip of the strata, and therefore at right angles to the slope of the scarp.

CHAPTER XXII.

THE MIOCENE AND PLIOCENE FORMATIONS.

The Eocene strata of England taken as a whole may be looked upon as estuarine beds. At the base, the Woolwich and Reading beds, and also the upper parts of the series in the Isle of Wight and Hampshire, consist of strata deposited in brackish, salt, and fresh water, at or near the mouth of a great river, and the abundance of plants and terrestrial remains in the London Clay, and other marine divisions of the series, proves that they also were deposited near the mouths of such rivers, say, as the Mississippi and Amazon. Both in their lower and upper divisions, these strata in France and England contain a large terrestrial mammalian fauna, the genera of which are so antique that they have no very close relation with those now living. Nevertheless, they are remotely related to living genera, and some may even be the direct ancestors of living species through Miocene and Pliocene intermediate forms. To give an idea of the antiquity of this old fauna, it is safe to say that when they lived the Alps had scarcely any place as a principal mountain range.

This book has little to do with palæontology, but I have already stated in a previous chapter, that in Germany there are formations containing terrestrial (as distinguished from marine fossils), with mixed Eocene and Miocene generic forms, and I lay a little stress on these points, because, after we get through these doubtful and fragmentary stratigraphical and zoological gradations, we at length emerge on a time generally recognised as Miocene or Middle Tertiary, the larger part of the flora and fauna of which has the closest analogy to those that now inhabit the earth, the flora, possibly, even in part, specifically, and part of the fauna, certainly generically. Most of the modern types are represented in one part of the world or another: Elephant, Rhinoceros, Hippopotamus, Horses, Deer, Oxen, Camels, Giraffes, Monkeys, and various carnivora. Nor are fresh-water reptilia wanting, though they are less distinctive, some of the modern representatives of these animals having held their place through longer epochs of time.

I recapitulate these facts, because the circumstances, bearing as they do on the present physical geography of our part of the world, are very distinct, and I shall soon have something more to say about the later unions of England with the Continent, and migrations of life consequent thereon.

The Hempstead beds of the Isle of Wight partly connect the Eocene and Miocene epochs, in so far that the plants of these strata (always an imperfect guide) are related to Miocene species. But stratigraphically, the Hempstead beds are inseparable from the Eocene beds below, and their fossils, those that lived in water, are almost without exception the same.

True Miocene strata are very poorly represented in *England*, as shown in Chapter XVI., in the description of Bovey Tracey, and they play no important part in its physical geography. The slopes which surrounded the old lake of Bovey Tracey were clothed with splendid pines of the genus Sequoia (Wellingtonia), oaks, cinnamons, figs, dryandra, prickly vines, nyssa, and other plants, and on the lake water-lilies expanded their leaves and flowers.

The present Europe, partly then a continent, was, in Miocene times, the theatre of wide-spread volcanic eruptions in Central France, Germany, and that part of the British Islands now known as the Inner Hebrides, and also in the north-east of Ireland. In that region they play a much more important part in connection with the physical geography of our country than they do at Bovey Tracey. In the land of Antrim, from thence through the Isles of Mull, Rum, Eigg, Cana, Muck, and Skye, a vast broken belt of Miocene volcanic rocks forms great part of the Inner Hebrides; and far beyond Britain, in the Faroe Islands, Iceland, Spitzbergen, and Franz Joseph Land, the same volcanic series is found, fragments perhaps of one large continuous territory, or, if not, at all events of a series of large islands, of which the Faroes make one of the fragments.

In Scotland these volcanic rocks consist chiefly of Basalts, Dolerites, Felstones, and Amygdaloids, interbedded with agglomerates of lapilli, large blocks, and volcanic bombs, such as are piled on the sides of almost all volcanoes, and which often go by the name of volcanic ashes. These occur, associated with beds of clay or soil, and streaks of lignite. Some of the clays contain leaves of plants. The late Professor Edward Forbes determined their age, and later observations made by Professor Heer confirm his accuracy.[1]

[1] For an elaborate memoir on these volcanic rocks, see Mr. Judd 'On the Ancient Volcanoes of the Highlands, &c.,' 'Journal of the Geological Society,' 1874, vol. xxx., p. 220. The whole subject of the growth and decay of these volcanoes is there treated of in a manner never before attempted.

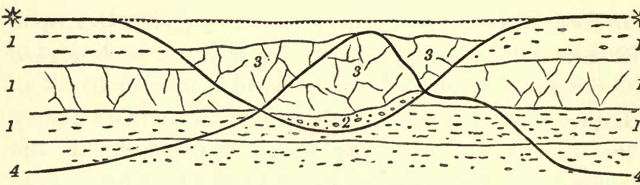
It is clear that the beds of lignite in the Western Isles, and the shales with leaves, indicate long pauses here and there in the activity of many craters. Vegetation on a large scale had time to flourish. After an unknown lapse of time, the vast inclined plateaux of lava, above which the lofty craters rose, are still, in Antrim, from 600 to 900 feet thick, and more than 3,000 feet in Mull. The denuded edges of the several lava-streams now form a wonderful series of terraces, rising tier upon tier, like Titanic steps, high on the hills on both sides of the Sound of Mull, and the splendid columnar basalt of Fingal's Cave, in Staffa, is known to all tourists among the Inner Hebrides. The same terraced forms are prominent in Skye, and in many of the smaller islands. But where are the craters from which these vast volcanic piles of lavas and ashes were ejected? They are all gone and utterly wasted away, and only their deep-seated roots remain to mark the sites, above which mountains grew by accretion, as high as Etna, which is growing even now. It is a remarkable circumstance, and worthy to be noted, that these deep-seated centres of crystalline rocks are now apt to form some of the highest portions of the islands. They have been bared by denudation, and their hardness helps to preserve them.

Long before these extreme denudations took place, when the islands formed part of a wide-spreading territory, old river-beds intersected it, running through an ancient land, formed of Laurentian, Cambrian, and Silurian rocks, that spread far to the west, north, and east.

These rivers scooped out valleys in the Miocene lavas and tufas, which were again partly filled by torrents of basalt and obsidian. In the case of the

Scuir of Eigg, the lava (obsidian 3, fig. 77) flowed over the valley gravel (2) and buried it. Since then the waste has been so great, that the destruction of the older hills that bounded the valley has literally exalted the valley and laid the hills low, for the obsidian was harder than the walls of the valley, and has longer resisted destruc-

Fig. 77.



1. Old lavas, &c. 2. River valley scooped out by denudation. 3. Obsidian filling valley. 4. Present outline of the country produced by later denudations.

tion, and thus it happened that the Scuir of Eigg became one of the most striking peaks in the Western Islands.

Thus it also happens that in the old volcanic plateaux valleys a thousand feet deep have been excavated, and the whole region has by denudation been changed into a line of fragmentary islands, the high sea cliffs of which attest the greatness of the waste they have in time undergone.[1]

During this time the greater contours of England remained the same, that is to say, the old mountain lands of Devon, Wales, and Cumbria, though suffering from denudation, remained mountainous still, and, together with the lower country, the whole was merely upheaved so far that England was joined to the Con-

[1] See A. Geikie, 'Jour. Geol. Society,' xxvii., 'On Tertiary Volcanic Rocks.'

tinent, and over the land, mammalian races in late Miocene times migrated into our region, their bones being now found buried at the bases both of the Coralline and Red Crag, but chiefly in the latter. Probably they lived here in the earliest Pliocene times, as the relics of an older Miocene fauna, and got intermixed with varieties and new species. These include Beaver, Deer, Horse and Hipparion, Hyæna, and a Felis; Bears, Pig, Tapir, Rhinoceros, Mastodon, and perhaps a true Elephant,[1] all belonging to genera with which we are quite familiar in the present world, if we except the Hipparion and Mastodon, and these have close relations, the first with the horse and the second with the elephant.

The Crag formations of England in descending order consist of three divisions, Norwich Crag, Red Crag, and Coralline Crag. The Red and Coralline Crags are rich in marine fossils, and the Norwich Crag also contains a marine fauna, together with twenty-four species of land and fresh-water shells. According to Mr. Prestwich, the above-named formations contain from 84 to 93 per cent. of living species. But though very important in a stratigraphical point of view, when viewed in connection with marine life, the Crag plays a very unimportant part in the physical structure of England, occurring as they do only in a few small shelly patches of insignificant thickness in Norfolk and

[1] Castor veterior, Cervus dicranoceros, Equus plicidens (?), Felis pardoides, Hipparion, Hyæna antiqua, Mastodon arvernensis, Mastodon tapiroides (?), Elephas meridionalis (?) Rhinoceros Schleirmacheri, Sus antiquus (?), Tapirus priscus, Ursus arvernensis, Megaceros Hibernicus (?). See Prestwich, 'Journal Geol. Society,' 1871, vol. xxvii., p. 348. Mr. Prestwich considers this fauna as probably of Pliocene age, that is to say, contemporaneous with the deposition of the crag.

Suffolk. They are, in fact, often so far buried under superficial strata that they require to be looked for, and the whole country being flat they do not at all affect the scenery, excepting in a minor way in the coast cliffs. Physically they chiefly indicate a certain amount of submergence and subsequent emergence in late times, before the epoch of the *Forest bed*, and that is all, for, as already frequently insisted on, we are not to consider Great Britain as having always been an island during and between the periods that I have already described. It is an accident that it is now an island; and it has been islands many times, and an island more than once before, and in many shapes. When I describe other periods, still later than the Crag, we shall be able to understand a little more definitely the precise kind of changes that our land in latter days has undergone.

Younger than the Crag there are certain other minor deposits, portions of which are scattered here and there throughout England. One of the most remarkable, the 'Forest bed,' lies underneath the glacial deposits on the shore, at Cromer, in Norfolk. This minor formation has been traced for some distance between high and low water mark. It consists of dark sandy clay, with plants, above which there is a band of coarse gravel, containing the remains of elephants, &c., then bands of clay and gravel, with marine and fresh-water shells and fragments of wood. The plants noticed in the Forest bed are: *Pinus sylvestris* (Scotch fir), *Abies excelsa* (a Pine), *Taxus baccata* (Yew), *Prunus spinosa* (Sloe), *Menyanthes trifoliata* (Buckbean), *Quercus* (Oak), *Alnus* (Alder), *Nymphæa alba* (Water-lily), *Nuphar lutea* (Yellow Water-lily), *Ceratophyllum demersum* (Horn-wort), and *Potamo-*

geton (Pondweed), together with fronds and rhizomes of ferns.

In the Forest bed and the overlying gravel the following land mammalia have been found: *Elephas antiquus* (the ancestor of the African Elephant), *E. meridionalis*, *Rhinoceros megarrhinus*, *R. Etruscus*, *Hippopotamus major*, *Equus caballus* (the common horse), *Machairodus* (a tiger?), *Bison priscus* (?), *Bos primigenius* (Aurochs), *Sus Arvernensis;* four species of bears, *Ursus Arvernensis*, *U. Spelæus* (Cave bear?), *U. Etruscus*, *U. arctos* (White bear); six species of deer, *Cervus megaceros* (often miscalled the Irish elk), *C. elaphus* (Red deer), *C. Sedgwickii*, *C. Poligniacus*, *C. capreolus* (Roedeer), *Mygale moschata* (Musk shrew), *Sorex fodiens* and *S. remifer* (Shrews), *Arvicola amphibia* (Field-mouse), *Castor Europæus* (common beaver), *Trogontherium Cuvieri* (a great Beaver), two species of whales, and fish.[1] The whole speaks of a past physical geography, at least during part of which, with a mild climate, our country seems to have been joined to the Continent. It must, however, be confessed that this assemblage of mammalia is not quite devoid of the appearance of being a little too miscellaneous, and several authors have declared that some of the bones, having been picked up on the shore between high and low water mark, may have been washed up from the neighbouring sea-bottom, and thus got mixed with others of later geological date which really belong to the Forest bed. However this may be I have given the list as it originally stood, with some slight corrections by Professor Boyd Dawkins, and whichever theory be

[1] The above list is taken from Mr. Prestwich 'On the Crag Beds of Suffolk and Norfolk;' 'Quarterly Journal of the Geological Society,' vol. xxvii., p. 466.

true, it cannot fail to impress the reader as throwing light on some one of the ever-shifting physical and biological phases that our country has undergone, each of which in its day seemed as constant as that in the midst of which we live. The special episode of the Forest bed points to this, that it exhibits a fragment of the vegetation and fauna of the last pre-glacial epoch, at a time when England was united to the Continent, and when a flora and fauna, in part new, migrated across the intervening plain into our area.

CHAPTER XXIII.

THE GLACIAL EPOCH.—EXISTING GLACIER REGIONS.

I HAVE now to describe a remarkable episode in Post-Tertiary times, known as the *Glacial epoch*, which is certainly later than the latest beds of the Crag, and is generally considered to be of later date than the 'Forest bed' of Cromer, on sound stratigraphical evidence. The effect of local mountain glaciers, and of far broader sheets of glacier ice that descended from the mountains and overspread great plains, have left unmistakable traces over large parts of the northern and southern hemispheres; and without going into all the minutiæ of the subject I shall be able to describe the history of that period, as it affects the scenery of Britain, with something like detail. Before doing so, however, I must lead the reader into Switzerland, and show what kind of effect is being produced there by the ice of the present day, and afterwards into Greenland and Victoria Land, and show what takes place there, and then by the knowledge thus gained I shall be able to return to our own country and explain what took place here in that icy episode, which, measured by ordinary standards, is far distant in time, but which, by comparison with the more ancient periods, almost approaches our own day.

The first thing to be done is to explain what a glacier is. In any large and good map of Switzerland we see certain white patches here and there on the higher mountain ranges of the Alps. These are more or less covered by snow and glaciers. The highest mountain in the Alps, Mont Blanc, rises more than 15,000 feet above the sea, and there are many other mountains in this great chain which approach that height, ranging from 10,000 to 15,000 feet high. The mean limit of perpetual snow upon the Alps, is about 8,500 feet above the level of the sea. Above that line, speaking generally, the country is to a great extent covered with snow, excepting where the tall cliffs are too steep to hold it, or on those sides of even high valleys that face the southern sun. In the higher regions it gathers on the mountain slopes, and in the large *cirques* or recesses, which like vast amphitheatres, are characteristic of all true mountain groups or ranges that I have seen. By force of gravity, and the alternate melting and regelation of the molecules of ice, especially in summer, the gathered snow presses downwards into the main valleys; where, chiefly in consequence of the immense pressure exerted by the vertical weight and onward pressure of the accumulated mass, the snow year after year is converted into moving ice. Without entering on details, it is enough if I now state that this is proved by well-considered observations made by the best observers of the icy phenomena of the Alps.[1]

Still accumulating, year upon year, by degrees this ice slides down the valley, and is often protruded in great tongues far below the limits of perpetual snow; for some Swiss glaciers descend as low as from *three* to *four* thousand feet or thereabouts above the level of

[1] See Dr. James Croll's work on 'Climate and Time.'

the sea, whereas the limit of perpetual snow is 8,500 feet. Ever melting on its surface, in its mass, and at the end, each glacier is yet ever renewed by yearly falls of snow, and by direct gravity on the slopes, and by pressure of accumulating snow and ice behind, and by melting and regelation, it is urged down the valley and maintains its average size. I will not enter into all the details of the structure of the ice of glaciers, because that will not help us in the special geological investigation now in view; but I will describe what are the effects produced by a glacier in the country over which it slides, and various other glacier-phenomena affecting the scenery of the Alps, and therefore affecting the scenery of our own country in past times when glaciers existed here, and still affecting it in the relics they have left.

A glacier slides more or less rapidly according to the mass of ice that fills the valley, and to the greater or less inclination of the slope, for in these respects it behaves very like a river. If we have a vast river like the Mississippi flowing down a broad valley, although the slope of the valley may be gentle, still the river flows with rapidity, in consequence of the greatness of the body of water; so if we have a mass of ice, which represents the snow-drainage of a large tract of country, *covered with perpetual snow*, then the *glacier flows with a rapidity proportionate to the mass of ice*, and that rate of progress is modified, increased, or diminished, in accordance with the fall and width of the valley, so that when it is steep, the glacier flows comparatively fast, and when the angle at which the valley slopes is small, it flows with comparative slowness. Like a river also when the valley expands in width, so does the glacier broaden to meet the mountain sides on either hand, and should an extra steep descent occur in its channel, as in the glacier of the Rhone, the ice becomes troubled and shattered, like a silent frozen cataract, to re-unite below in a more tranquil sheet. So also in the valley of Hinter Rhine, above the source of the river, a tall cliff bounds the eastern side of the Rhine glacier, above which another large ice-sheet presses to the edge of the precipice, from whence in summer, constant avalanches, now here, now there, fall with a sheer descent and a recurrent roar like that of a great waterfall.

All glaciers are traversed by cracks termed *crevasses*. Now the mountain peaks that rise above the surface of a glacier are in places so steep that the snow refuses to lie upon them, even when they may happen to be above the limits of the average line of perpetual snow, so that masses of rock being severed by atmospheric disintegration, constantly fall from the slopes and find a temporary resting-place on the surface of the ice at the margin of the moving glacier, and, as it were, float upon its surface in long continuous lines; for the motion of a glacier is so slow, that the stones that fall upon its surface are sufficiently numerous to keep up a continuous line of blocks, earth, and gravel, often of great width. In like manner if an island-like boss of rock rises through the ice in the middle of a glacier, a line of stony débris travels on the surface of the glacier from the lower end of the island, which, often buried in the winter's snow, becomes again exposed during the heat of summer. These stones, when two glaciers combine to form one stream of ice, as in the lower glacier of the Aar, meet at the V-shaped angle of junction, and form one grand line running down the centre of the glacier (fig. 78). Such lines of débris, whether at the sides or in the middle of a glacier, are termed *moraines*, and at length all this material that has not fallen into crevasses floats on, and is finally slowly shot into the valley at the end of the ice-stream, frequently forming large mounds, known as *terminal moraines.*

All glacier ice, even in the depth of winter in Arctic regions, is said to be at a temperature of about 32° Fahr. that is to say, just about the melting point, excepting near the surface, as far as the cold atmospheric temperature can penetrate. This, it is said, is rarely more than eight or ten feet. Therefore, it is a common statement that, beneath every glacier, water is constantly flowing, caused by the melting of the ice below all the year round, and also by the summer heat on the surface of the glacier, and in some cases, to a less degree, by springs that rise in the rocks below the ice.[1] In parts of some glaciers where crevasses are not numerous, we frequently find large temporary brooks, which generally disappear with the frost at night; but in all the glaciers that I have seen, long before we reach their lower end, all the surface water has found its way to the bottom of the ice.

The water that runs from the end of a glacier very often emerges from an ice-cavern as a ready-made muddy river, charged with the *flour of rocks*, produced in great part by the grinding power of the glacier moving over its rocky floor, and this river carries away the moraine

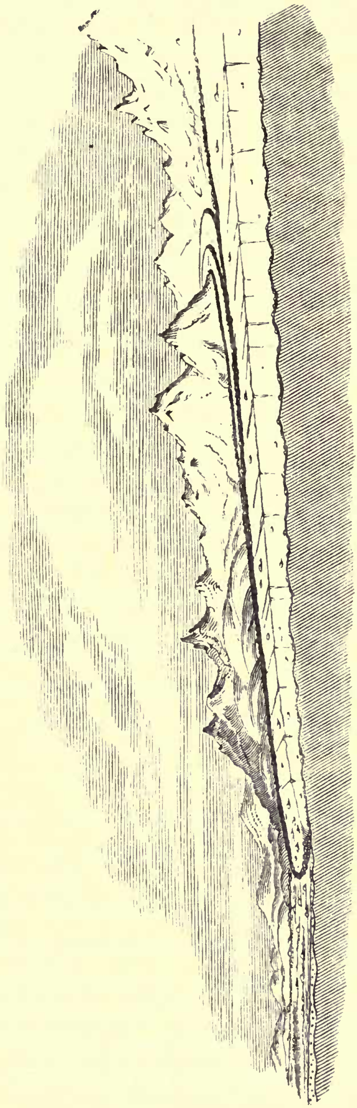
[1] I am, however, informed by Mr. James Eccles that in the mid-winter of 1875 when he was in the Valley of Chamouni no water flowed from the end of the well-known Glacier de Bossons, and that at the lower end of the large glacier of the Mer de Glace (Glacier des Bois) the stream which is large in summer had decreased to a tiny rivulet. The subject requires more systematic investigation both in the Alps and Greenland.

rubbish that the glacier deposits at its lower ends, in some cases almost as fast as it is formed, perhaps, I might rather say, as slowly as it is formed, because day after day we may see scarcely any difference in the details of certain moraines, though, when being worked upon by water, all stones of moderate size that have been shed from the ice are in the long run apt to be carried down the valley by the ever-changing streams that flow from the ends of glaciers along the length of many terminal moraines. In some cases, however, it happens that, from various circumstances, both terminal and lateral moraines have been so well preserved from destruction, that they form long enduring features in the scenery.

Something remains to be said about moraine-stones before I describe the glacial phenomena of our own island. When an immense weight of glacier ice, in some cases hundreds, or in Arctic and Antarctic regions even two or three thousand feet in thickness, passes over solid rocks, by the pressure of the moving mass, the rocks in the valley over which it slides become smooth and polished—not flatly, but in flowing lines, presenting a largely mammillated surface. Furthermore, the stones of the surface-moraines frequently fall into fractures called crevasses, and the small débris and finely powdered rocks that more or less cover the glacier are borne into these crevasses by the water that flows upon the surface, and much of this matter finds its way to the bottom of the ice, fig. 78. The bottom of a glacier, therefore, is not simple bare ice, but between the ice and the rock over which it flows there are blocks of stone imprisoned, and fine silicious and often felspathic débris (chiefly worn from the floor itself), which may be likened to emery powder. The

FIG. 78.

Imaginary Section of a Swiss Glacier.



Showing Moraines, Crevasses, and the undulating form of the ground underneath (small Roches Moutonnées).

result is that, let the rock be ever so hard, it is in places polished almost as smooth as a polished agate, and this surface is also finely striated and coarsely grooved by the débris that, imprisoned between the ice and the rocky floor, is pressed along in the direction of the flow of the ice. By degrees deep furrows are sometimes thus cut in the rocks.

But the stones that are imprisoned between the ice and the rocky floor not only groove that floor, but in turn they also get scratched by the harder asperities of the rocks over which they are forced; and thus it happens that many of the stones of moraines are covered with straight *scratches*, often crossing each other irregularly, so that we are able by this means to tell, independently of the forms of the heaps, whether such and such a mass is a moraine or not, and indeed, under any circumstances, whether certain stones have been acted on by glacier ice.

These indications of the rounding, smoothing, scratching, and grooving of rocks, in lines coincident with the direction of the flow of glaciers, together with moraine heaps, erratic blocks, and scratched stones, are so characteristic of glaciers, that we are able to establish the important fact that the Swiss glaciers were once of far larger dimensions than they are now, and have gradually retreated to their present limits. For example, all down the Valley of the Rhone, from the end of the Rhone glacier to the Lake of Geneva, mammillated rocks (*moutonnée*), moraine-mounds, and great erratic blocks, are of frequent occurrence, a notable case occurring on the slopes behind Monthey, some sixty miles below the source of the river, where the 'blocks of Monthey' have long been celebrated. Fifty miles beyond that, the same great glacier that filled the valley of the Rhone, spread across the area, now filled by the Lake of Geneva and all the lowlands of Switzerland, in a vast fan-like form, a hundred and twenty-five miles in width from below Geneva to the neighbourhood of Aarau, and deposited part of its terminal moraine on the slopes of the Jura behind Neuchâtel, 2,200 feet above the level of the lake. The famous Pierre à Bot, 50 feet long by 20 feet wide, and 40 feet in height, forms one of a belt of moraine blocks at a height of about 800 feet above the level of the lake of Neuchâtel. Every Alpine valley, whether in the heart of the mountains, or on the northern slopes opening into the lowlands of Switzerland, or on the wide plains of Italy that lie between the Alps and the Po, tells the same story; and the old glacier of the Dora Baltea, about a hundred miles in length, which from Mont Blanc to beyond Ivrea filled the whole valley of Aosta, has left on the plains of Italy a vast moraine 60 miles in circumference, more than 1,600 feet in height, and in places 6 or 7 miles in width. The signs of vanished gigantic glaciers constantly strike the practised eye, and are indeed frequently as fresh as if the glacier had scarcely left the rocks before the existing vegetation began to grow upon their surfaces.

Such being the case in the Alps and other regions where we are able to study the action of modern glaciers in detail, we have next to inquire—Is there anything further to learn in regions where glaciers are found on a far greater scale? Those who have read the descriptions of navigators will be aware that in Greenland the average snow-line, as a whole, descends lower and lower as we go northward, till at length the whole interior of the country becomes covered by one snow-field, which, pressing seaward from the interior, gives birth to a prodigious number of large glaciers, many of which protrude far into the Fiords, while very many others on a smaller scale descend directly into the sea from the mountains on either side. In other cases, as on straight parts of the coast of Melville Bay, the glacier-ice crowns the cliffs for miles, and breaking off in masses, falls in cataracts of small-shivered icebergs into the sea, grinding and smoothing the rock as they descend. But in the same region when broad valleys open out towards the sea, then it frequently happens that prodigious glaciers push their way out far beyond the shore. These are in some cases 12 or 20 miles across at their ends, and in the case of the great Humboldt glacier, 60 miles across, ending in a cliff of ice in places 300 feet in height. One of these vast glaciers has been estimated as being at the very least 3,000 feet in thickness. Great masses of ice breaking away from their ends form icebergs, which, sometimes laden with moraine rubbish, like that which partly covers the glaciers of Switzerland, float out into the Greenland seas, and are carried south by a current in Baffin's Bay. Not infrequently icebergs float far into the Atlantic, beyond the parallel of New York, and they have been seen even off the Azores.

Along the shores also, when the sea freezes, the ice becomes attached to the coast. By-and-by, as summer comes on, the ice partly breaks away, leaving what is called an *ice-foot* still joined to the land. Vast quantities of débris during part of the year fall from the cliffs, and are lodged upon the ice-foot, and when it breaks off and floats away and melts, the rubbish is strewn about, and accumulates on the bottom of Baffin's Bay. In like manner the icebergs melt chiefly in Baffin's Bay, but sometimes escaping from thence and melting in the seas of warmer climates, their stony freights, when they have any, get scattered abroad here and there over the bottom of the West Atlantic, which, therefore, must be dotted with erratic blocks and other débris borne from far northern regions.

The same kind of phenomena, on a still grander scale, are common in the Antarctic regions of Victoria Land. There, between south latitude, 71° and 79°, the land, as described by Sir James Ross, rises in places to 10,000, and even 15,000 feet in height, and the whole country may almost be said to be covered by a universal sheet of glacier ice, which, protruding far seaward, rises in cliffs from 150 to 250 feet above the level of the sea. Such a wall, east of Mount Erebus, extended in 1841 for a distance of about 600 miles, and from it and parts of the coast great tabular bergs break off, occasionally bearing blocks of volcanic rocks. Sir James estimated the average thickness of the glacier ice to be not more than 1,008 feet, but in many cases this is doubtless an under-estimate. This Antarctic continent is probably as large as or larger than Australia, and every yard of its surface must be ground and polished by the nearly universal glacier that radiates from its centre to the sea.

Having ascertained what are the signs by which a glacier may be known, and also the signs left by ice-bergs, I shall now show that a large part of the British Islands has been subjected to *glaciation*, or the action of glacier-ice.

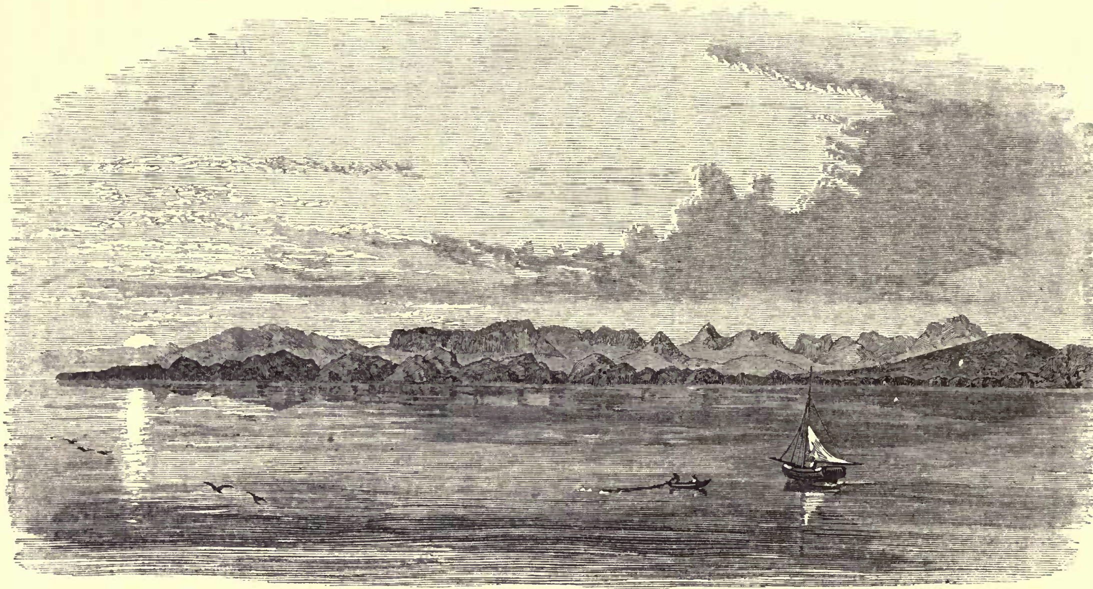
CHAPTER XXIV.

OLD BRITISH GLACIERS.

THOSE who have closely observed the Highlands of Scotland and of Cumberland, may remember that, though the weather has had a powerful influence, rendering the mountains in places rugged, jagged, and cliffy, yet, notwithstanding this, their general outlines are often remarkably rounded, flowing in great and small mammillated curves, a configuration of ground tolerably plain in the accompanying view (fig. 80), especially in the rocks of the island in the foreground. When we examine the valleys and plains in detail we also find that the same mammillated structure frequently prevails. These rounded forms are known in Switzerland as *roches moutonnées*, a name now in general use among those who study the action of glacier-ice. Similar ice-smoothed rocks strike the eye in many British valleys, marked by the same kind of grooving and striation, so characteristic of the rocks of Switzerland. Almost every valley in the Highlands of Scotland bears them, and the same is the case in Cumberland, Wales, and other districts in the British Islands, and not in the valleys alone, but also in the low countries as far as Liverpool and the middle of England.

Considering all these things, geologists, led many years ago by Agassiz, have by degrees come to the

FIG. 79.



Mountains of Ross-shire, with the Island of Rona in front.

conclusion that large parts of the northern hemisphere were, during the 'glacial period,' more or less covered, or nearly covered, with a coating of thick ice, in the same way that the greater parts of Greenland, Spitzbergen, and the whole of Victoria Land are covered at present. Britain formed part of this area, and, by the long-continued grinding power of great glaciers nearly universal over the northern half of our country and Wales, the whole surface became *moulded by ice.* The relics of this action still remain strongly impressed on this country to attest its former power, and I need scarcely say that the same kind of phenomena are equally striking in Ireland.

It might be unsafe to form this conclusion merely by an examination of such a small tract of country as the British Islands, but when we consider the great Scandinavian chain, and the northern half of Europe generally, we find that similar phenomena are common over the whole of that area, and in the North American Continent, as far south as latitude 38° or 40°; for when the soil, or the superficial covering of other débris is removed, we discover over large areas that the solid rock is smoothed and polished, and covered with grooves and striations, similar to those of which we have experience among the glaciers of the Alps. I do not speak merely by common report in this matter, for I know it from personal observation, both in the Old Continent and the New. We know of no power on earth, of a natural kind, which produces these indications except moving ice, and therefore geologists are justified in attributing them, even on this great continental scale, to ice-action.

This conclusion is fortified by many other circumstances. Thus, I have stated that in the Alps there is evidence that the present glaciers were once on an immensely larger scale than at present. The proof not only lies in the polished and grooved rocks far removed from the actual glaciers of the present day, but also in numerous moraines on a scale so immense that the largest now forming in the Alps are of pigmy size when compared with them. Such a moraine is the great one of the Dora Baltea, sometimes called the Moraine of Ivrea, which, on the plains outside the mouth of the Val d'Aosta, encloses a circuit of about sixty miles, and rises above the plain more than 1,600 feet in height, being altogether formed of mere accumulations of moraine rubbish. Its width in places averages about seven miles, as mapped by Gastaldi. Many others might be cited. The same kind of phenomena occur in the Altai Mountains, the Himalayah, the Caucasus, the Rocky Mountains, the Andes, the Sierra Nevada, and the Pyrenees of Spain, the Atlas of Morocco, the mountains of Sweden and Norway, the Black Forest and the Vosges, and in many other northern mountain chains or clusters, great or small, that have been critically examined. In the southern hemisphere, where mountain ranges are comparatively scarce, the same ancient extension of glaciers is prominent in New Zealand. Therefore there can be no doubt that at late periods of the world's history a climate or climates prevailed over large tracts of the earth's surface generally, but not always, of extreme arctic severity, for there were intermittent episodes of comparative warmth, when what is misnamed perpetual snow disappeared, or almost disappeared from mountain regions of moderate height. The cold of these minor cycles in time (for as shown by Dr. Croll, glacial cycles alternate in the northern and southern hemispheres) was produced by causes about which there have been many guesses, and which, perhaps, are only now beginning to be understood.

It is not very many years, since a great difference in the geographical distribution of land and sea was regarded as a possible or even a probable cause of the occurrence of important changes of climate during Geological Time. If, said Lyell, in his earlier writings, all the continental lands, were gathered in tropical regions, and the rest of the globe were mainly covered by sea, the climates of the world would be tropical and temperate according to their latitudes, and if all the land were mainly massed round the poles, even in the tropics there would be no tropical heat such as they now endure, while the greater portions of the northern and southern hemispheres would suffer from climates of extreme severity. In such a sketch as this it is needless to argue the question, at all events as regards this special glacial epoch, for the obvious reason that it is an established fact that during most of that epoch, the continents of the world, mountain chains and all, were distributed much as they are at present, with occasional minor variations in detail due to short local submergences.

Neither is it worth while to discuss the facile explanation of variation of climate, being due to the sun with all its planets travelling through alternate hot and cold regions of space. Such an idea crops out now and then in conversation, but I do not remember to have met any educated physicist who seriously entertained it.

I believe that the day may come, when both astronomers and geologists will be forced to allow that, in great cycles of geological time, changes have taken place in the position of the earth's axis of rotation, *in a slowly cumulative manner*, by gradual disturbances of what is called the crust of the earth, but by no means by sudden upheavals of vast mountain tracts at or near the poles, or anywhere else on the earth's surface; and, indeed, the phenomena of the vegetation of old geological epochs in formations as far north as land has been discovered, seems to me to point in that direction and in no other. At all events it is plain, that no such sweeping changes of physical geography have taken place in those comparatively short episodes of geological history, that have graduated into each other from the beginning of this latest glacial epoch down to the present day, and therefore it is needless to discuss the question here.

There is, however, an astronomical cause which seems to meet all the circumstances of any one glacial epoch, and is therefore deserving of the gravest attention. The question has been worked out with great skill by Dr. James Croll, first, in various memoirs, and latterly, in his celebrated work 'Climate and Time,' and I can only state in a very sketchy manner some of his main conclusions.

Alternations of cold and warm or temperate climates, in the same latitudes, are in the first instance due to the varying eccentricity of the orbit of the earth, by which 'a host of physical agencies are brought into operation, the combined effect of which is to lower to a very great extent the temperature of the hemisphere whose winters occur in aphelion, and to raise to nearly as great an extent the temperature of the opposite hemisphere, whose winters of course occur in perihelion.' It is perhaps possible that the orbit of the Earth may become circular, at periods of time prodigiously far removed from each other, but at present, when the earth in its elliptical orbit is furthest from the sun (aphelion), the distance is about 90 millions of miles, and its smallest distance (perihelion) is about 89,864,480 miles. The varying amount of ellipticity is owing to the ever-changing positions of the planets in our solar system within and without the orbit of rotation of the earth, and we can imagine a state of combination of the planets, the effect of the attraction of which must be to lengthen the ellipse in the extremest possible degree, so that the earth in aphelion would be 98½ millions of miles distant from the sun. This is not a mere guess, for it has been approximately calculated by Leverrier and other astronomers. The eccentricity of the earth's orbit is at present decreasing, and it will reach its minimum in about 24,000 years.

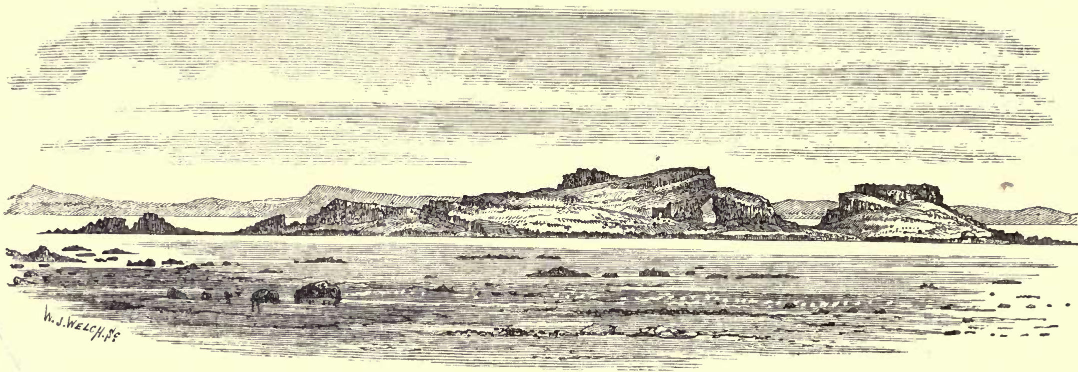
In connection with degrees of eccentricity, Dr. Croll argues that the distribution of ocean-currents is due to the system of winds, and in the modern world the existing system of winds is due to those astronomical causes that, by help of eccentricity have produced a minor glacial epoch in part of the southern hemisphere at the present day, and a remarkably mild one over Western Europe and great part of the north. This coincidence of winds and great ocean currents is shown by Dr. Croll in a map, the most familiar of which to us, being the westerly and south-westerly winds and currents of the Gulf Stream, the warm winds from which so largely raise the average temperature of the British Islands and the whole of the western part of Europe. There being nothing equivalent to this current running south towards the great Antartic Continent of Victoria Land, this circumstance, taken in connection with the fact that the southern winter occurs in aphelion, has produced in that region a minor glacial epoch, so that in south latitudes, between about 64° and 78°, the whole country is nearly entirely shrouded in glacier-ice, and is altogether uninhabitable by man, while in the northern hemisphere, in equivalent latitudes, there are no parts of North America and Europe totally uninhabited, and even the north of Norway in summer, when the sun does not set, is often inconveniently warm, and the traveller is troubled with clouds of mosquitoes.

The present winter of the southern hemisphere being when the earth is in aphelion, the result is this, that the winter of the Antipodes is seven or eight days longer than our own, for the further the earth is removed from the sun, the more slowly it moves in its orbit, and the nearer it is, it moves in proportion more rapidly, and this somewhat lengthened winter, coupled with the absence of heated water flowing south from equatorial regions, has enabled the snows to accumulate, and being but little affected even by the summer's sun, the country is continually buried in ice, while in Norway and on the shores of the Baltic, in equivalent latitudes, forests, grass, and crops abound. The winter of our northern hemisphere is of course seven or eight days shorter than that of the south, and the earth is at that season with us nearest to the sun, and our summer being a little longer though further from the sun, the effect of its heat corresponds to the difference, irrespective of the powerful effect of the heated water of the Gulf Stream.

If such marked results are produced with this comparatively small amount of eccentricity, it is reasonable to suppose that with the greatest possible eccentricity the effect must be much greater, and it has been calculated that when this by slow degrees takes place, the earth in aphelion is distant from the sun about $98\frac{1}{2}$ millions of miles, or nearly 7 millions of miles further from the sun than when eccentricity is at a minimum, or about $8\frac{1}{2}$ millions further than its greatest distance now. The earth, therefore, in aphelion would be more than 14 millions of miles farther from the sun than when in perihelion, and if, in accordance with the precession of the equinoxes, it so happened that winter in the northern hemisphere took place when the earth is furthest from the sun, then by calculation it has been shown that 'the direct heat of the sun in winter would be one-fifth less during that season than at present, and in summer one-fifth greater.' But this extra amount of heat in summer would even less have sufficed to remove the snow and ice then, than it suffices to remove it from Victoria Land at the present day; for just as that region is all summer apt to be involved in clouds and fogs by vapours, due to partial evaporation of melting snow, even so on a greater scale the same effect must have been produced in old epochs, when greater glacial epochs took place alternately in the northern and southern hemispheres.

It was during part, or in parts of one of these periods, that great part of what is now the British Islands, was last almost entirely covered with ice, for, as I have already shown, similar phenomena are periodical, and have occurred in several old geological epochs. I do not say that our area consisted of islands during the whole of the last Glacial epoch, and probably during part of it they were united with the Continent, and the average level of the land may then have been somewhat higher than at present, by elevation of the whole, and also because since the first appearance of British glaciers it has suffered much degradation; but whether this was so or not, the mountains and much of the lowlands were long covered with a universal coating of ice, pro-

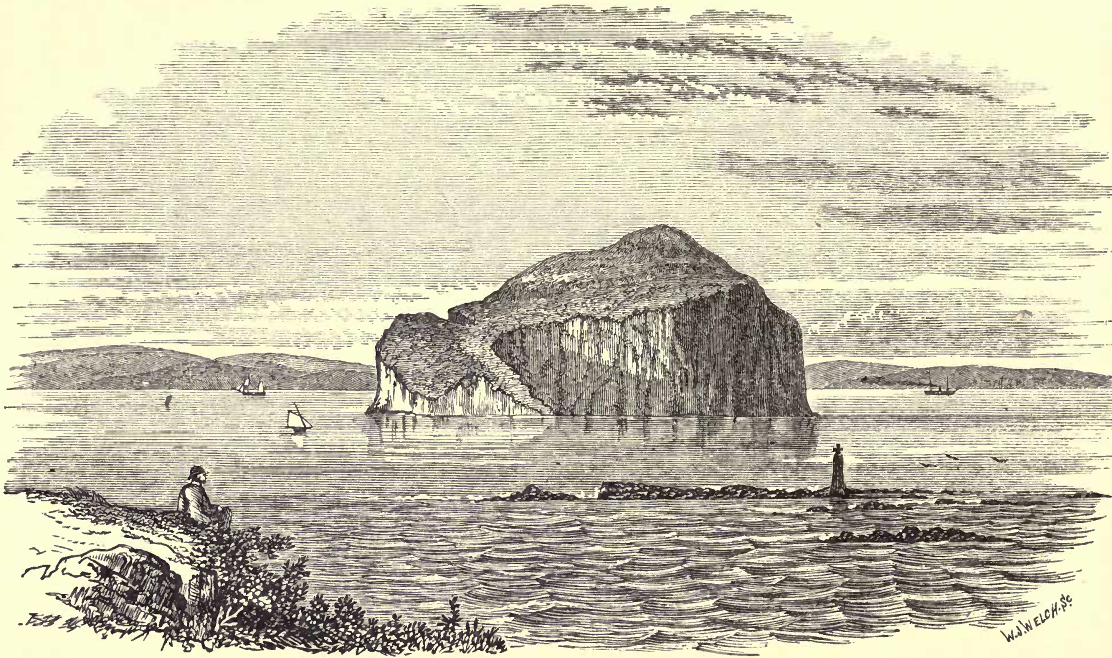
Fig. 80.



Fidra Island, North Berwick, Firth of Forth.

bably as thick as that in the north of Greenland in the present day. During this time all the Highland mountains were literally buried in ice, which, partly flowing eastward, joined a vast ice-sheet coming westerly and southerly from Scandinavia. In another direction a thick sheet of the same Highland ice pressed southward into the valley of the Tay, where a low stratum of the glacier passed eastward to the sea, while the remainder pressed up the slopes and across the summits of the Ochil Hills, and on to the valley of the Forth, where it found a vent for a further outflow to the east, at a time when the Bass Rock, Fidra Island, Inch Keith, Inch Colon, and all the other beautiful islands of the Firth of Forth, lay as mere *roches moutonnées*, buried so deep under glacier-ice that it overflowed the eastern part of the Lammermuirs and spread southward into Northumberland. Some of these islands still retain their ice-worn surfaces, while others, such as the Bass and Fidra, have become scarred and cliffy by the action of weather and the sea (figs. 80 and 81). Another part of the great glacier-ice passed west across the Hebrides, and southerly into the Firth of Clyde, where, passing over Bute, and smothering and smoothing those large mammillations the Cumbraes, it was reinforced by the snows of Arran, and buried that 'craggy ocean pyramid,' Ailsa Craig. All the southern Highlands, from Fast Castle on the east to Wigtonshire on the west coast, were also covered with glacier ice, together with Northumberland, Durham, and the beautiful dales of Yorkshire, scooped out of the Carboniferous series of rocks. Cumberland too was buried in ice, part of which crossed the vale of Eden and over the hills beyond, carrying detritus to the eastern shore of England. So great was this ice-sheet that, joining with the ice-

Fig. 81.



Bass Rock, Firth of Forth.

stream coming from what is now the basin of the Clyde, it stretched away south so far that it overflowed Anglesea, and, so to speak, overcame the force of the smaller tributary glaciers that descended from the mountains of North Wales; for the glacial striations of Anglesea point not to the Snowdonian range, but about 25° to 30° east of north, directly toward the mountains of Cumberland. South of Wales, in England, I know of no definite signs of the direct action of glaciers.

Much of the Lower Boulder-clay is known as 'Till' in Scotland; and it was only by slow degrees that geologists became reconciled to the idea that this Till is nothing but moraine rubbish on a vast scale, formed by those old glaciers that once covered the northern part of our country. In fact, Agassiz, who held these views, and Buckland who followed him, were something like twenty years before their time; and men sought to explain the phenomena of this universal glaciation by every method but the true one. Mr. Robert Chambers was, I think, the first after Agassiz who asserted that Scotland had been nearly covered by glacier ice, and now the subject is being worked out in all its details, thus coming back to the old generalised hypothesis of Agassiz, which is now accepted by many of the best geologists of Europe and America.

The general result has been that the whole of the regions of Britain mentioned[1] have literally been *moulded by ice*, that is to say, the country in many parts was so much ground by glacier-action, on a continental scale, that though in later times it has been more or less scarred by weather, enough remains of the effects to tell to the observant eye the greatness of the

[1] And equivalent regions in Ireland which in this book it is not my object to describe.

power of moving ice. Suddenly strip Greenland of its ice-sheet, and it will present a picture, something like the greater part of Britain immediately after the close of this Glacial period.

During the time that these results were being produced by glacial action, there were occasional important oscillations in temperature, so that the ice sometimes increased and sometimes diminished, and land animals that lived habitually outside the great glacier limits, at intervals advanced north or retreated south with the retreating or advancing ice.

Evidence of the same kind is not wanting in England, for erratic stones and large blocks of granite, gneiss, felspathic traps, Carboniferous Limestone, &c. are scattered over the west and east coasts and the central counties of England. Boulders of Shap granite of Cumberland are common in Staffordshire, and even in the valley of the Severn, about twelve miles north of Cheltenham, and they have also been borne across the central watershed of the north into the plains of Yorkshire, near Darlington, and further south on the banks of the Humber. This distribution of erratic stones, on the east of England, throws much light on the subject of the motion of large sheets of glacier-ice, and therefore it is worth while to give a few details, some of which are probably not generally known.[1]

At and a little south of Berwick-upon-Tweed, where the sea-cliffs are clear, or, when the Till has been re moved, the surfaces of quarries of Carboniferous Limestone are found to be ice-polished and grooved, the striations point from 10° to 12° south of east, in the

[1] The observations were made in 1863 during an examination of the glacial accumulations on the coast-cliffs by Professor J. Geikie, Mr. Aveline, and myself, and are extracted from my note-book.

direction, in fact, of the onward march of the vast glacier that flowed from the Highland mountains down the valley of the Forth, and overflowing the Lammermuir Hills, spread across the border into England. The stones in the Till are scratched, and consist of Carboniferous Limestone (very angular at the base of the Till) and of other materials derived from the northern hills. Some of the boulders are from one to two yards in diameter, and the beach-like sands and gravels that overlie the Till are charged with large blocks of limestone and porphyry at the base, and many broken sea-shells. In places these sands are strangely contorted, as if they had been disturbed and pushed on by moving ice. The large blocks in them are of the Carboniferous Limestone of the country, and the smaller ones consist of what seems to be Silurian Lammermuir grit, granite, probably from the same area, and felspathic and augitic porphyries, &c.

About ten miles further south, near Belford, the glacial striations trend about 15° south of east, and still point towards the upper part of the estuary of the Forth, and much of the low ground round Belford and Lucker is formed of those singular mounds, called Kames in Scotland, and Eskirs in Ireland, beautiful examples of which are known to many persons at Carstairs and Carnwath in Lanarkshire, near Stranraer in Wigtonshire, and in many other areas in Scotland.[1] So identical are the phenomena, that in my note-book I find that I compare the English examples with those of Carstairs and Carnwath, and like the existing lakes and pools in these, the Kames of Belford and Lucker in older times

[1] For details respecting Scottish Kames, see 'Great Ice Age,' J. Geikie, chapter xix.

held lakes and tarns in the hollows of the mounds, but now filled with peat.

On the coast near Alnmouth, in Northumberland, there is a large sand-bank overlooking the river with intercalations of fine loamy clay. The sand contains fragments of coal and other Carboniferous rocks, and in the middle of the sand there lies a lenticular patch of Boulder-clay, from six to ten feet thick, full of angular ice-scratched stones confusedly mingled with the clay. They consist of pieces of Carboniferous Limestone, porphyries, sandstone, &c. the largest being about a foot in diameter.

Some miles south of Blyth there is a cliff forming a promontory on the coast, made of boulder-clays, near Seaton. It consists of two divisions, rarely separated by thin lenticular bands of sand. The lower band of greyish-blue clay is charged with large boulders, while in the upper one, which is of a brown colour, the stones are much smaller. The lower boulder-clay seems to belong to the great glacier period that produced the Till, and the upper band to a later glacial episode, and except in the parting of sand, there are no signs of true stratification. The large blocks, which are very numerous, chiefly consist of Carboniferous sandstone and conglomerate, which are often from one to two yards in diameter. Blocks of Carboniferous Limestone are fewer in number, as might be expected, for the Boulder-clay lies on Coal-measures, while the Limestone occurs more than twenty miles to the north and northwest. Mingled with these are fragments of granite and greenstone.

On both banks of the Tyne, above Newcastle, there are great banks of sand, gravel, and tilly clay, all charged with ice-scratched stones of no great size. They consist of Coal-measure sandstones and conglomerate, Carboniferous Limestone, and more sparingly, Lammermuir grits and granite. In pits thirty feet in depth, beneath sands, the clay is very fine, containing a few scratched stones, and we were informed that this clay has been sunk through to a depth of fifty fathoms (300 feet), so that the bottom of this pre-glacial river-valley is much below the level of the sea.

Under Tynemouth, at the mouth of the river, there is a high cliff of stiff Boulder-clay, about 50 or 60 feet in height, facing North Shields. Stones and boulders large and small are scattered all through the clay from bottom to top approximately in the following proportions:—

Carboniferous Sandstone	34		
„ Limestone	27		
„ Coal	10	80 per cent.	
„ Ironstone	5		
„ Shale	4		
Lammermuir grit		19	„
Greenstone		1	„

There are several irregular thin bands of gravel and sand in the Till. It will be observed that excepting two insignificant outlying patches of Magnesian Limestone at Tynemouth, all the rocks up to and beyond the borders of Scotland belong to the Carboniferous series, and the result is, that of the ice-borne erratics, 80 per cent. belong to these formations, and only 19 per cent. to the more distant Silurian grits of the Lammermuir range.

At Sunderland, about a mile north of the harbour light, there is a section of boulder-clay lying on the Magnesian Limestone. The surface of this rock has been polished by glacier ice, and the striations trend very nearly from north-east to south-west. The overlying clay has the character of genuine Till, and the change in the direction of the striations from those previously noticed, may possibly be due to the pressure of the inferred Scandinavian ice-sheet, which is supposed to have united with that coming from Scotland, and may for a space have deflected the line of its onward march from the NNW. On the other hand, it may be a mere local accident connected with a later part of the Glacial epoch, when a distinct individual glacier flowed from the far western watershed, more than a thousand feet in height, about the sources of the Wear, which may have spread into a fan-shape as it reached what is now the shore. Such smaller glaciers existed, for in these long dales of Durham and Yorkshire there are distinct moraines, which mark the gradual decline of the glaciers, and through which, and through the Boulder-clay, the rivers have cut their modern channels.

Stones derived from the Magnesian Limestone first appear in the Till south of Tynemouth. In the neighbourhood of Sunderland, the percentage of various kinds of rocks seems to be nearly as follows :—

Carboniferous Sandstone	29	59 per cent.	
,, Limestone	21		
,, Coal	6		
,, Shale	2		
Magnesian Limestone		22	,,
Lammermuir grits, &c.		16	,,
Greenstones and Basalts		4	,,

The cliff is about 30 feet in height, and shows the section given in fig. 82.

The Till seems to have been worn on the surface before the deposition of 3 and 4.

It will be observed by consulting any geological map, that, as in the previous case, the large percentages of Carboniferous rocks have travelled from the wide-spread Carboniferous country to the north, that the smaller percentage of Magnesian Limestone fragments must have been derived from the small area immediately

FIG. 82.

1. Rotten nodular Magnesian Limestone.

2. Stiff brown Till with blocks and scratched stones. The largest are of Carboniferous Limestone and Magnesian Limestone, from 1 to 1½ yards in diameter, and 1 block 2½ feet of Lammermuir grit.

3. Sand and loamy beds with scratched stones, rare.

4. Finely laminated clay.

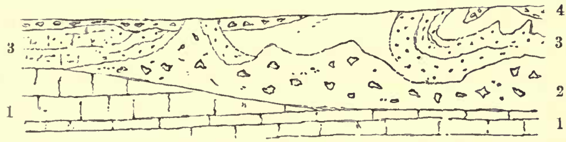
north of Sunderland, occupied by that formation for a distance of about 9 or 10 miles, and the decreased proportion of Lammermuir rocks have had to travel not less than 70 miles.

Somewhat further south we find 57 per cent. of Carboniferous rocks, 32 per cent. of Magnesian Limestone, and only 9 per cent. of Lammermuir grits.

About half way between Sunderland and Seaham, where on a sea-cliff stiff Boulder-clay or Till lies on the Magnesian Limestone, the latter is covered with glacial groovings which run from NNW. to SSE. and all along the sea-cliffs of this neighbourhood there is a lower Boulder-clay with a very irregular surface, on which there lies sand and gravel, often very much contorted, which in its turn is overlaid by patches of an upper Boulder-clay.

At Seaham ironworks and elsewhere, such sands and gravels in the middle of the Till frequently thin away in wedge-shaped ends.

FIG. 83.



1. Magnesian Limestone. 2. Lower Boulder-clay.
3. Sand and gravel. 4. Upper Boulder-clay.

It is unnecessary and would be wearisome to the reader, were I to describe all the details of the sections I have examined between Hartlepool near the mouth of the Tees, and Spurn Point at the mouth of the Humber. Suffice it to say that, in the Liassic and Oolitic region of Yorkshire, the valleys that open upon the sea are apt to be more or less filled with boulder-clays, sands, and gravels, and the same phenomena occur in many parts of the high sea-cliffs. Thus at Cromer Point, about $2\frac{1}{2}$ miles north of Scarborough, there are beds of sand and gravel in places about 120 feet thick, which lie on an undulating surface of shales, &c., of the Oolitic series. The embedded pebbles largely consist of sandstones (Oolitic in part), grits, porphyry, &c., and at the top, about 130 feet above the sea, there are beds of clayey gravel with small stones and *fragments of sea-shells.*

In Cayton Bay, about three miles south of Scarborough, lying upon Oxford Clay, there is Boulder-clay, with a great variety of boulders of Carboniferous Limestone, Lammermuir grit, basalts, greenstones, and other rocks that lie nearer the spot. Many of these are sub-angular and many are well rounded, and both kinds are often marked with glacial scratchings. Above this Boulder-clay there are beds of gravel with fragments of marine shells, and the embedded stones only show the ghosts of scratchings, as if they had been nearly obliterated by trituration. Above this gravel, Boulder-clay again occurs in a little hollow, in which there are deposits of fine clay and shell-marl, with Paludinas, &c. The relics of such old pools are common on the surfaces of irregular deposition of the boulder-clays all the way from Northumberland to the Humber, and doubtless far beyond.

On the coast, from one to two miles north of Bridlington, lying on chalk, there are beds of Till interstratified with beds of sand and gravel, parts of the Boulder-clay among the Till being much contorted. In one case they were seen to lie in an old valley of erosion in the Chalk, the lowest strata consisting of stratified brecciated chalk gravel, overlaid by sand, on which there rested chalky sand and gravel, which in its turn is overlaid by Till with irregular minor interstratifications of sand; and in another case, about three miles north of Bridlington, fragments of sea-shells occur in the gravel about 150 feet above the sea. Near Bramston, in Holderness, a few miles south of Bridlington, on the shore, there are large boulders of gneiss, basalt, diorite, &c.

Immediately north of Hornsea, about twelve miles south of Bridlington, the Till, which partly forms a sea-cliff fifty or sixty feet high, is very irregularly bedded, and contains numerous scratched stones of flint and chalk, Carboniferous Limestone (more scarce), Silurian grit, granite, gneiss, &c. The quantity of stones of chalk is quite a new and remarkable feature in the section, for north of Flamborough Head, in the Oolitic country, I found none. The Till, which forms the base of one end of the cliff, is overlaid by sand and gravel, which again is overlaid by lenticular patches of Till, covered by higher gravels, on which, in a hollow, there occur clays with Paludinas deposited in an old fresh-water pool. The same kinds of sections, with variations, are found all the way from Hornsea to Withernsea and Spurn Point, and here and there many large boulders of granite, Carboniferous and Lias Limestones, Sandstones with Stigmarias, &c., lie on the shore, bearing witness to the recession of the cliff, which is fast wearing away under the united influence of landslips, and the action of breakers and tides on the fallen masses of clay. Nor do the remains of sea-shells cease, for at Out Newton, by the shore, the base of the cliff, in which frequent landslips occur, consists of stiff blue Till with erratic blocks and many fragmentary shells, overlaid by clay with smaller stones, on which lies well-stratified warp clay, surmounted by beds of sea-sand and gravel, which again is overlaid by red Till with scratched stones. On the shore of the Humber, also, when excavations were in progress connected with the building of a fort, beds of sand, gravel, and warp were exposed, containing sea-shells intensely contorted, as if the strata had been subjected to strong lateral pressure.

Between the Humber and the Wash I have no personal knowledge of the coast sections, which are of the same general nature as those of Holderness. South and south-east of the Wash, as far as the neighbourhood of the Thames, much has been written about glacial detritus, with the details of which I will not now meddle. It is enough to state that by Mr. Searles Wood, junr. and Mr. F. W. Harmer, they have been divided into Lower and Upper Boulder-clays, between which there are beds of sand and gravel, often contorted, thus presenting points of resemblance to the sections on the coast which I have described between Berwick-on-Tweed and the mouth of the Humber. These sands and gravels which contain sea-shells have been named by these gentlemen 'Middle Glacial.'

The Upper Glacial Boulder-clay has been called by Mr. Wood and Mr. Skertchly the great Chalky Boulder-clay, from the circumstance that it chiefly consists of chalk, ground up by an advancing glacier travelling from north-east to south-west, the chalky and flinty débris being sparingly mingled with fragments of Oolite, quartz, basalt, granite, &c., sometimes smooth and striated. Though chiefly formed of chalky material, yet when found lying on Kimeridge Clay it is found to be mingled with the detritus of that formation, and when it reaches the Oxford Clay, all three are intermingled. The Boulder-clay lying on each formation that lay under the glacier ice-sheet, which was invading the country from north to south, always partakes of the nature of the underlying rock, and the total area occupied by this chalky Boulder-clay must, according to Mr. Skertchly, have been more than 3,000 square miles in the south-east of England. If, however, this supposed glacier extended as far south as Romford, where there is Boulder-clay with scratched chalk-flints and masses of Oxford and Kimeridge Clay, then the area covered by the great Chalky Boulder-clay and its southern continuation instead of 3,000 square miles must have covered 9,000 or 10,000 square miles of ground.

It must now be evident to the reader, that on the east coast of England, and on the adjoining ground in the interior, there is no want of evidence of a cold episode or of episodes when snow and glacier-ice largely prevailed in these regions under some form or other. A minority of persons who excel in the art of doubting will of course dissent for a time, but the proof is too strong to be withstood by commonplace minds. On the whole, also, it would appear that the complete glacial deposits of the east of England consist of Lower and Upper Boulder-clays, between which there lie stratified sands and gravels containing sea-shells, and that these strata were deposited in the sea during a temporary intermission of the cold of a Glacial Epoch. Shells, sometimes fragmentary and sometimes entire, are also found plentifully enough in the Boulder-clays of Holderness and elsewhere.

In older times the origin of these Boulder-clays was attributed chiefly to icebergs that, laden with moraine matter, broke from glaciers that descended, during a period of partial submergence, to the sea, and which, floating south and melting, scattered boulders and stony débris mixed with fine mud across the bottom of the sea.

But of late there has been a tendency in some writers to attribute the origin of all, or almost all of the British Boulder-clays to the direct action of glaciers, and to look upon them as *ground-moraine* matter, the *moraine profonde* of Swiss and French authors, which is supposed to have a modern parallel in the vast quantity of débris, believed to underlie and be pushed forward by the mighty ice-sheet that passes seaward from the great basin of central Greenland, and finds its vents through unnumbered fiords into Baffin's Bay. On these grounds both the Boulder-clays of the east of England, are looked upon by Mr. Skertchly as having been formed by the direct action of glaciers, the upper Boulder-clay being the work of the larger and later ice-sheet, when it so happened that the cold of that region became most intense.

Assuming this theory to be true, the old glacier must have reached the plateau of Romford that overlooks the valley of the Thames, and the low country on the coast of Essex, near Southend. One serious difficulty to its acceptance occurs in the fact, that on the coast-cliff near Lowestoft there are beds of Boulder-clay which overlie thick strata of soft false-bedded sands with gravel, *and these sands lie apparently quite conformably and undisturbed beneath the Boulder-clay.* If the latter was the *ground-moraine* that underlay a heavy glacier pressing southward, it is hard to understand why the sands show no signs of pressure and glacial erosion. Neither is it necessary to suppose that glaciers are always needed for the production of ice-polished surfaces of rock and for the making of Boulder-clay, for, as shown by Professor H. Youle Hind, the formation of both on a large scale is now and has been for long in progress on the north-east coast of Labrador, through the agency of 'Pan ice,' which 'is derived from Bay ice, floes, and coast ice, varying from five to ten or twelve feet in thickness, all of which are broken up during spring storms.' This broken ice is pressed on the coast by winds, 'and being pushed by the unfailing Arctic current, which brings down a constant supply of floe-ice, the pans rise over all the low-lying parts of the islands, grinding and polishing exposed shores,' and removing 'with irresistible force every obstacle which opposes their force . . . and the masses pushed or torn from those surfaces . . . are urged into the sea and rounded into boulder forms by the rasping and polishing pans.' Here, too, goes on the process of manufacturing Boulder-clay, for the deep hollows and ravines, at present under the sea, the records of former glacial work, are being filled with clay, sand, unworn and worn rock fragments, producing a counterpart of some varieties of Boulder-clay.[1] I have quoted thus far from Professor Hind's admirable memoir, for it has sometimes been stated, that all the contorted Boulder-clays and interbedded sand, with shells entire and broken in England, were pushed bodily upon the land by a vast advancing sheet of glacier-ice, even to heights of a thousand and twelve hundred feet. As the British Islands during the Glacial epoch were more than once much in the same state as the north of Labrador, there can be little doubt that some of the British glacial phenomena were produced by the same causes.

[1] See 'Notes on some Geological Features of the North-Eastern Coast of Labrador,' by Henry Youle Hind, M.A., 'Canadian Naturalist,' vol. viii.

CHAPTER XXV.

OLD BRITISH GLACIERS CONTINUED.

I SHALL now briefly describe some of the broader features of the glacial phenomena of the western coasts of England, with here and there necessary allusions to and descriptions of the interior of the country.

It is a self-evident proposition, that when cold began to increase sufficiently to produce glaciers in Britain, these in their infancy must have been first formed in the high regions of the north, where precipitation of snow was greatest among the mountains of the Highlands. As the climate got more severe, such glaciers would spread from the upland glens in all directions, and by-and-by, as cold and precipation became more and more intense, and at last the whole mountain land, like the interior of Greenland, got smothered in ice, a prodigious onflow of glacier ice spread from the Highlands west into the Atlantic across the Outer Hebrides, and south into the North or Irish Channel along the ice-buried valleys of the Sound of Jura, Loch Fyne, and the whole of the Firth of Clyde, in the midst of which the island of Arran then formed, what it may seem presumptuous to call, only a great *roche moutonnée* ; or if any of its peaks then stood above the surface of this *mer de glace,* they yielded but a feeble contribution of ice to swell the general mass of the glacier. Escaped from the Highlands, the glacier split upon the island of

Rathlin off the coast of Antrim,[1] and being largely reinforced by tributary ice that descended from the Galloway mountains and all the high lands, the slopes of which, then filled with tributary ice, now send rivers into the Solway, the advancing mass invaded the area called the Irish Sea, where, it was still further swelled by the glaciers that descended from the mountains of Cumberland.

These facts are further confirmed by observations in the Isle of Man by the Rev. J. G. Cumming, who shows that the chief glacial striations in that island trend from NNE. to SSW. as if the ice that made them, travelled from the high ground of Kirkcudbrightshire and the northern borders of the Solway Firth.

If we now go into the interior of the country what do we find? First, it is obvious to anyone with an eye educated in glacial phenomena, that the whole of the mountains of Cumbria and Westmoreland have been buried in ice during the period of extremest cold. Though now somewhat ruined by time, their mammillated forms proclaim it, and in the time that the glacier-ice attained its maximum, that ice, pressed on by ice coming from the north, must have passed southward into and far beyond Morecambe Bay. East of this mountain-land, between the rivers Kent and Lune, almost all the striations run about SSW. while a very few trend near south-westerly, while on all the high Fells on both sides of the Ribble, the prevailing direction of the striæ is either south or a few degrees west of south, as shown by Mr. R. H. Tiddeman in his memoir 'On the Ice-Sheet in North Lancashire and adjacent parts of Yorkshire and Westmoreland.'[2] I am

[1] Vividly described by Mr. J. Geikie, 'Great Ice Age,' chap. xxiv.

[2] 'Journal of the Geological Society,' vol. xviii., 1872, p. 471.

well acquainted with the country, and can vouch for the accuracy of his observations, and what makes them of special value in this inquiry is, that such striations range from a few feet up to 40, 100, 200, 300, 550, 775, 1,100, and 1,375 feet above the sea, and at many intermediate elevations.

One great fact which they teach is this, that the broad and thick ice-sheet, urged onward from the north, buried the whole of the region described, and all the ground to the east as far as the sea, and further, that the glacier *moulding itself to the shape of the country* (after the manner of all glaciers), was pressed right onward with so much force, that the long northern slopes of the east and west valleys offered comparatively no more impediment to its onward march, than an occasional transverse bar of rock hinders the onward flow of a river. Occasionally there are striations that do not quite conform to the rule, but in some cases I feel convinced that these were due to *undercurrents* in the ice in some of the deeper valleys, and at a later date to minor glaciers that got specialised in the valleys during the decline and disappearance of the ice-sheet.

At Liverpool, and on the opposite side of the Mersey, Mr. Morton observed on the Keuper Sandstone certain ice-grooves, trending S. 35° E.[1], and it seems to me that this direction is connected with the circumstance that when the northern ice-sheet reached the rising ground of Denbighshire and Flintshire, it was deflected to the right and left, and while one part flowed south-easterly across the plains and undulations of Cheshire, another part flowed south-westerly, and, scraping the coast hills of North Wales, overwhelmed Anglesea and the low ground of Lleyn that forms the north horn of Cardigan

[1] 'Reports of British Association, Liverpool,' 1870.

Bay. This I shall presently prove, for having brought our ice so far south, it is now time to explain the part played by the mountains of Wales in this glacial history.

When glaciers first began to form among the mountains of the Highlands of Scotland, from 200 to 300 miles north of Wales, though the heights of the latter region may have been far more snowy than they ever are now, yet at first it is probable that the snow did not continue through the year, and therefore no glaciers were formed. But in time, as the great glaciers advanced, and the cold increased and snow in North Wales became perennial, then glaciers began to be formed, first in the high valleys in the upper recesses of the mountains; and as the climate and precipitation of snow grew more severe, these glaciers must have waxed in size, till at length they filled all the valleys, and intruded on the plains and low undulating grounds beyond. How far south they extended from the mountains of Merionethshire I do not know, but probably the ice-flow went far into South Wales. Neither is it possible to say how far these early glaciers of Snowdonia stretched across the broad undulations of Anglesea, for, if they did so, the marks that they made were afterwards entirely obliterated by the onward march of the great northern glacier which I have already described, and which I have no doubt extended southward into St. George's Channel. In aid of this statement I would quote the opinion of the Reverend M. Close, and the later observations of Professor Hull. The central plain of Ireland forms a great basin, surrounded by the broken mountains of the south from Kerry to Wicklow, and of the west and north-west from Galway to Donegal.

Like Greenland of the present day, but on a smaller scale, the whole of this basin of more than 120 miles in diameter was deeply buried in snow and ice, which, in glacier fashion, found vents through the broad gaps in the circling mountains, westward into the Atlantic, and eastward in the direction of what is now the Irish Sea, to join the ice-sheet that worked its way south from Scotland and the north of England.[1]

If all this be true, it is easy to see how any older ice-grooves in Anglesea must have been obliterated, and in aid of this argument I will now give a more particular account of the glaciation of Anglesea, seeing that it has an important bearing on the whole question of the great northern glacier.

The structure of the low ground of Caernarvonshire, within three or four miles of the Menai Straits, in almost all respects resembles that of Anglesea, both in its geology and physical geography. The Menai Straits

[1] With Messrs. Hicks, Homfray, and Etheridge, near St. David's, on the coast of Pembrokeshire, I have seen well marked glacial striations on the rocks on the coast at Trwyn-hwrddyn, Porth-clais, and Pen-dal-deryn. In the first two they point NW. and SE., and in the last NE. and SW. Boulder-clay with ice-scratched stones is common, and chalk flints mingled with stones native to the district, are not uncommon on the mainland and in Ramsey Island. Flints are also found in quantity, mingled with ice-scratched erratics, all along the low ground of Glamorganshire north of Bristol Channel between Cardiff and Bridgend, and Boulder-clay is indeed common here and there all over South Wales. When the Geological Survey was in that district glacial phenomena had just begun to be heard of, and the 'drift,' as it was termed, was chiefly looked upon as a troublesome superficial deposit that concealed the boundary lines of the solid rocks beneath. Till some qualified person surveys the whole of the glacial phenomena of South Wales and the adjacent counties in a connected manner, it would be premature to connect the striations in Pembrokeshire with the northern glacier described in this book.

divide the two regions; but Carboniferous rocks form the larger part of either shore, and the Straits may be considered simply as a long shallow valley, the bottom of which happens to lie beneath the level of the sea. The question thus arises—At what epoch and by what means was Anglesea separated from the mainland?

Looking north-west across the country from any of the minor heights a mile or two inland between Bangor and Caernarvon, no one would even suspect the existence of the Straits. The whole of Anglesea is low; and only one steep escarpment, a minor one, occurs in the island—that of the Old Red Sandstone overlooking Traeth Dulas, which rises abruptly above the tidal flat of the Traeth to the height of about 250 feet.

The entire island may, indeed, be looked on as a gently undulating plain, the higher parts of which attain an average elevation of from 200 to 300 feet above the level of the sea; while most of its principal brooks and small rivers run north-east and south-west, in depressions with gently sloping sides; and only one inland valley, with the same trend, is of any marked importance, namely that of Malldraeth Marsh, in which a small coalfield lies. There are, however, a few exceptions to the average levels mentioned above—the summit of Holyhead mountain being 709 feet, and Garn, near Llanfairynghornwy, 558 feet above the sea, while the greatest elevation crossed by the sections of the Geological Survey (sheet No. 40) is only about 400 feet high.

On the opposite side of the Straits, the same kind of low, undulating scenery prevails for several miles inland, with the same kind of minor north-east valleys, one marked instance of which occurs in a long, shallow, and narrow valley, in, or alongside of which, the Caernarvon and Bangor road runs for several miles.

The surface of the ground on both sides of the Straits is to a considerable extent composed of glacial detritus, with erratic boulders large and small (from the north), gravel, sometimes sand, and clay, from which any number of ice-scratched stones may be gathered from well-exposed sections, as, for example, in the Boulder-clay coast-cliff of the Mount at Beaumaris, or anywhere else in similar cliffs round the shores of Anglesea, or, inland, in occasional pits and fresh cuttings on both sides of the Straits. Through these glacial accumulations the rocks of the country frequently appear, sometimes in barren tracts of considerable extent, sometimes in small isolated bosses of gneiss or grit, often covered with heath or furze, while the more fertile grounds of the whole of Anglesea consist chiefly of glacial detritus, with here and there small alluvial meadows by the sides of the streams.

When freshly stripped of glacial débris, or even of a mere thin turfy soil, the underlying rocks are often found to be ice-smoothed and marked with glacial striæ, running generally from about 30° to 40° west of south. The larger valleys of Malldraeth Marsh and the Menai Straits (with others of minor note) run in hollows in the same general direction.

I have already shown that in mountain regions where glaciers exist, or have in past times existed, the disturbances of the earth's crust that produced the elevation of the mountains go back to periods long antecedent to the last great Glacial epoch. Thus the first great upheaval of the Alps is of pre-Miocene age, and the last, as far as the Alps is concerned, closed the Miocene epoch, while the mountains of Scotland and

Cumberland were mountains at least before Old Red Sandstone times, and the last great movement of the rocks of Wales is certainly older than the Permian epoch, and, probably, like the mountains of Cumberland, very much older.

There was therefore plenty of time, in what is now Wales, long before the beginning of the great Glacial episode, for the more ordinary agents of denudation to have formed deep valleys, down which, when that episode began, the growing glaciers might gravitate, deepening their channels as they pressed forward, and mammillating and striating the rocks over which they slid; for the great original valleys of the mountains were by no means entirely scooped out, but merely modified by the glaciers.

Thus, for example, it happens in Wales that all the striations in the valley of Dolgelly and the estuary of the Mawddach, in Merionethshire, follow the south-westerly trend of the valley, the glacier that filled it when at its greatest being fed by the snows of the slopes of Cader Idris and Aran Mowddwy, and those of the tributary valleys of Afon Eden and the Mawddach that joined it from the north; while from a central low watershed, near the sources of the Wnion, another branch pressed north-easterly, into and far beyond the region now occupied by Bala lake.

The striated rocks exposed among the sands at low tide in the estuary of the Mawddach, and the islet-like heathy bosses of rock that stand out amid the marshy moss opposite Barmouth, are merely *roches moutonnées*, once buried deep beneath the glacier that pressed forward to join the great northern glacier that then filled Cardigan Bay.

In like manner all the western valleys of the

Cambrian mountains of Merionethshire, such as those of Afon Atro, Ardudwy, and Afon Ysgethin, are marked by deep grooves and striations pointing more or less westward, according to the trend of the valleys.

In ascending the valley from Llanbedr on the coast south of Harlech to Llyn-cwm-bychan, the experienced eye is at once attracted by the long smooth sweeps of the ice-ground rocks of Mynydd Llanbedr, all trending towards the west, and from the summit of Graig-ddrwg, looking south towards Rhinog-fawr, the same effects of old glacier-ice are seen on a still grander scale. The deep craggy pass of Bwlch-drws-Ardudwy is itself strongly ice-grooved, while the western flanks of Graig-ddrwg are covered with deeply incised striations, up to the very summit of the mountain, all trending westward. The rock-bound hollows of Llyn-cwm-bychan, and other mountain turns, tell in like manner of the effects of thick masses of glacier-ice, as I shall afterwards explain.

The broad flat moors and roughly hilly, but not mountainous country of Cors-goch, Afon Eden, Trawsfynydd, and indeed all the lower ground bounded by the splendid amphitheatre of scarped mountains formed by the Arenigs, the Manods, the Moelwyns, and the Cambrian steeps of Diphwys, Graig-ddrwg, Rhinog-fawr, and Cefn-cam, were at the same time filled to the brim with deep accumulations of snow and ice, from which were discharged radiating currents of glaciers, one pressing southward to swell the ice-stream that filled the valley of what is now the estuary of the Mawddach, another through the Pass of Afon Treweryn between Arenig Mawr and Arenig Bach eastward towards Bala and the valley of the Dee, there to be aided in the work of erosion by the glaciers that descended from either flank of Aran Mowddwy. Further west, swelled by all the snows of the Manods and the Moelwyns, a great ice-stream flowed south-west, into what is now the broad flat of Traeth Bach, there to be joined by another tributary which, partly descending Cwm Llydaw and Cwm-llan from the high eastern slopes of Snowdon, filled Nant Gwynant, and debouched into the area now occupied by the marshy flat of Traeth Mawr. In all of these the directions of the striations necessarily conform to the trend of the valleys—easterly, southerly, or south-west, as the case may be. And this must have been the case even though it happened that the mountain valleys and broader amphitheatres were filled to the very brim, and overflowing with ice and snow in such a manner that, had there been human eyes to look on the scene, it would have been impossible to have specialised each individual glacier. In such a case, however, there were many deviations consequent on under and upper ice-currents, the upper parts of glaciers diverging from the direction of the under-flow, and passing across what are now low watersheds, like that of Llyn Cawlyd, which lies between the valley of the Llugwy, and that of the Conwy—a circumstance to which special attention has been called by the Rev. W. T. Kingsley.

On the north-west slopes of the Snowdonian range,[1] great glaciers poured their ice-streams down the valleys of Llyniau Nant-y-llef to the west, and of Llyn Cwellyn, Llanberis, and Nant-ffrancon, the last deriving additional power by aid of the tributary ice-flows of Cwm-llafar and Afon-gaseg, the chief gathering grounds

[1] I use the word *range* as a convenient term. There is no range of mountains in North Walés. Taken collectively they form a group.

of which, were the cliffy *cirques* on the western flanks of Carnedd Llewelyn and Carnedd Dafydd, which, with Y-Foel-frâs, formed one great nursery of the glaciers of Caernarvonshire, sending off ice-flows eastward to Capel Curig and the valley of the Conwy, and westward to where Bangor now stands and the Lavan sands.

None of these glaciers, at a certain epoch, quite reached the region now occupied by the Menai Straits, but escaping from the higher bounding-walls of their valleys, they spread out in the shape of broad fans on the north-western slopes of the minor hills that now overlook the Straits. This is partly proved by the northerly curve of the glacial striations at the mouth of the Pass of Llanberis, on the flatter area above the steep slopes of the slate-quarries by Llyn Peris and Llyn Padarn.

If, as I believe, these glacier masses did not cross the Straits into Anglesea, we must look for some other cause for the production of the north-east and south-west striations which mark the whole of that broad region.

These striations point directly towards the mountains of Cumberland, a country which, lying further north, was at one time buried so deeply under snow and ice, that almost all its mountains look simply like gigantic *roches moutonnées*. From Cumberland, as already stated, a vast mass of ice flowed southward; and reinforced by the ice-streams that came from the mountains of Carrick in the south of Scotland, and from the basin of the Clyde, it overspread the region now occupied by the shallow sea of Morecambe, Lancaster, and Liverpool bays, that lie between Cumberland and Anglesea, nowhere more than 30 fathoms deep.

In its onward course, this mighty glacier buried all the hills and rounded knolls of Great Ormes Head, Little Ormes Head, and Diganwy, which are still on a large scale so strikingly *moutonnée*, and pressing along the slopes of Llanfair-fechan, the lower end of Aber Valley, the seaward flank of Moel Wnion, and across the lower end of the valley of the Ogwen, it marked its track by long, slightly-inclined terraces, somewhat faintly marked, but still clear to the experienced eye when looked for from the shores of Beaumaris. Beyond this the glacier continued its course across Lleyn, and onward to the region now occupied by St. George's Channel.

Furthermore, in my opinion, so great was the size and power of this ice-flow, that it hindered the glaciers of Y-Foel-frâs, Llanberis, and Nant-ffrancon from encroaching on the territory of Anglesea, and they simply joined the larger glacier as minor tributary ice-streams. For this reason it happens that the glacial striations of Anglesea, as we might at first expect, *do not point towards the old glacier-valleys of Snowdonia that open on the Straits, but run at right angles to the courses of these comparatively minor glaciers.*

If we now turn to the rocks that form the banks of Menai Straits, we find that they chiefly consist of nearly flat-lying Carboniferous strata, and looking at the disposition of these beds from Traeth Melyn, opposite Caernarvon, to Llanfair-pwll-gwyngyll, in Anglesea, and on the opposite shore from Caernarvon to Bangor, there is no reason to doubt that from end to end they once filled the whole of the region now occupied by the Straits. The larger part of this region, as it now exists, is of Carboniferous Limestone age; but it by no means consists entirely of solid limestone. On the contrary, numerous bands of shale and friable sandstones and conglomerates are intermingled with the limestones, together with beds of soft red marl. On the coast opposite Caernarvon, the low cliffs are entirely formed of red marl overlying the limestone; and on the Caernarvonshire coast, for three miles north of the town, also overlying the limestone, there are soft shales of the Coal-measures, sometimes red and marly, and containing thin seams of coal.

In Anglesea, from three to four miles north-west of the Straits, lies the valley of Malldraeth Marsh, the rocks of which also consist of Carboniferous Limestone, Millstone grit, soft Coal-measure shales, with a little sandstone, beds of coal, and Permian strata; and this valley, nine miles in length, runs almost exactly parallel to the valley of the Menai Straits. Many years ago, at its north-eastern end, I saw deep glacial striations on the Millstone Grit, running straight down the shallow valley towards Caernarvon Bay.

Considering that the south-westerly trend of each of these valleys and of others of minor note, corresponds with the general direction of the glacial striations of Anglesea, and therefore with the onward course of the great glacier that produced them, I have been led to the conclusion that both of the shallow valleys were scooped out in comparatively soft rocks, by the grinding power of the vast glacier coming from the north-east, and that when in the course of time the climate ameliorated, and the glacier disappeared, the sea flowed in where part of the glacier had been, and thus it was that Anglesea got separated from the mainland and first became an island. The islets in the narrower and shallower part of the Straits at the Menai and tubular bridges are merely weathered *roches moutonnées*, once overridden by the moving glacier, and Menai Strait is merely a long and broad glacial groove, which was first laid bare by the partial removal of the boulder-beds, after the close of the Glacial epoch.

CHAPTER XXVI.

GLACIAL EPOCH CONTINUED. SUBMERGENCE AND RE-ELEVATION OF LAND, AND FINAL DISAPPEARANCE OF BRITISH GLACIERS.

In describing the glacial phenomena, my chief concern in this book is to show the effects produced by ice on the general scenery of the country, and it is therefore unnecessary that I should here attempt to go into all the details of glacial and interglacial episodes, and of minor upheavals and depressions of land, thus seemingly tracing out a chronological series of geological events as clear and precise as any six or eight stages in the succession of the Oolitic subformations. It is enough for me at present to deal with a broader view of the subject.

Whether or not, before and during the first growth of the glaciers, the British area, by upheaval, was united to the Continent, I do not know, but of this I am certain that, probably during, and certainly after the largest extension of glacier-ice, the land underwent a process of submersion, and while the great glacier was retiring, the diminishing ice, still descending to the sea, deposited moraine rubbish there. In Scotland, marine shells *in situ* are found at heights somewhat more than 500 feet above the level of the sea, and if the whole of Britain were then submerged only to that depth, it must have presented the spectacle of a group of islands. One of these would consist of the mountainous country north of the Caledonian canal, fringed by many small islands on the west. The next would extend from the canal to the valleys of the Tay and Forth, bordered by many islands on the west and south, and in both the ground was penetrated by many fiords, some of which were longer than our longest fiord-lochs of the present day. The third large island included most of the country between the Clyde and Forth, and the Solway and Tyne, while two deeply-indented islands lay south of that line and the Derbyshire hills north of Ashbourne. On the east of these would lie fourteen islands, formed of part of the North and East Ridings of Yorkshire, while nine-tenths of Wales would form one large island with many small ones lying to the east, south-east, and south, including the highlands of Devon and Cornwall.

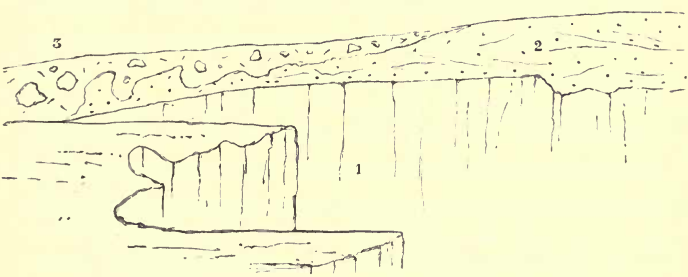
Such islands, as far as Wales and Cumberland were concerned, I am convinced still maintained their minor glaciers, which descended to the sea, where their ends broke off as icebergs, which, floating hither and thither, deposited their stony freights as they melted. We shall, however, presently see that in some districts there is evidence of the country having sunk much more than 500 feet.

In many parts of England shell beds associated with glacial material are by no means uncommon, and it is difficult to believe that in scores of places where they occur, on the coast cliffs between Berwick and the Humber, they had always been thrust up from the sea by glaciers. The most plentiful species there, as determined by Mr. Etheridge, are *Cardium edule, Cyprina Islandica, Dentalium entalis, Leda oblonga*, and *Saxicava rugosa,* together with undetermined species of *Venus* and *Tellina.* In Cheshire, near Macclesfield, lying between a lower and an upper Boulder-clay, Professor

Prestwich found marine shells in sand and gravel at a height of about 1,200 feet. I have visited the place, and saw the shells *in situ*; and at Congleton, 600 feet above the sea, I also found sea-shells.

Similar shell-bearing deposits at a low level are found near the Mersey at Blackpool, and on the coast north of the Ribble, and I have also observed them in Caernarvonshire in the district of Lleyn. In the same county similar deposits were found by the late Mr. Joshua Trimmer, about five miles SE. of Caernarvon, near the summit of Moel Tryfan, at a height of about 1,170 feet above the level of the sea. With that locality I have been long acquainted, and in 1876 I revisited it along with Mr. Etheridge. The section occurs at a slate quarry in the Cambrian rocks. This, after being long abandoned, has of late years been worked with vigour, and the result is, that good sections are exposed as the gravel and boulder-clay are gradually cleared away from the surface. In August 1876 the section was as follows:—

FIG. 84.



1. Cambrian slate. 2. Shell-bearing sands and gravels.
3. Glacier Boulder-clay.

The sands and gravels are all marked by oblique lamination (false bedding) and have a beach-like aspect, with sea-shells, broken and entire, of the following species:[1]

LAMELLIBRANCHIATA.

Cardium echinatum, *C. edule* * and its variety *rusticum*, *Astarte borealis*, * *A. compressa* (var. *globosa*), *A. sulcata*, *Cyprina Islandica*, *Tellina Balthica*, * *Mya?* *Saxicava rugosa*, * *mactra ovalis*, * and various fragments.

GASTEROPODA.

Trochus magus, *Lacuna vincta*, *Littorina littorea*, * *Turritella communis*, * *Pleurotoma pyramidalis*, *P. turricula*, *Buccinum undatum*, *Nassa reticulata*, *Purpura lapillus*, * *Murex erinaceus*, * *Trophon antiquum*, *T. clathratum*, *T. scalaroides*, *T.?* *Dentalium*, and various fragments.

The stones on the ground consist of species of diorite, felspar, porphyry, jasper, chalk-flints, Silurian slate, &c. The surface of the sands beneath the boulder-beds is very irregular, and has been much eroded, in my opinion probably by the pressure of a glacier during the deposition of the moraine matter that forms the overlying Boulder-clay. The latter contains large masses and smaller fragments of igneous rocks from the Lower Silurian mountains on the east, jasper, quartzite, purple and blue slate, &c., and looks like part of an old moraine. All the way up the slope, from the neighbourhood of Llandwrog, quantities of moraine mounds cumber the ground, and ice-scratched stones abound, and even small water-worn pebbles are marked by glacial striæ. Some of the blocks are very large. In the underlying gravels also stones sometimes occur, faintly marked by

[1] Those marked * were also found by Mr. Etheridge and the author.

glacial striations, as if the materials, during the progress of submersion, had been derived from older moraines, and, being water-worn by attrition on the margin of the sea, the original sharpness of the scratches had been well nigh obliterated.

At various levels on the low ground between Caernarvon and Criccieth, on the north coast of Cardigan Bay, there are extensive deposits of sand and gravel, well stratified, and much resembling those of Moel Tryfaen, but in them I have not yet found sea-shells. They are overlaid by boulder-beds, and the same is the case with similar half-consolidated strata on the sea-cliffs of Anglesea at Lleiniog, and beyond, between Beaumaris and Penmon near Puffin Island.

Putting all these facts together I see no reason to get rid of the hypotheses published by me in 1859,[1] that, as a slow submersion of the land took place, the diminishing glaciers, still descending to the level of the sea, deposited their moraine-rubbish there, which matter was often remodelled by the waves to form sand and gravel. Gradually sinking more and more, and sufficient cold still continuing, the minor glaciers, descending from groups of icy islands, entered the sea and broke off in icebergs, which, as they melted, deposited their stony freights on the sands and gravels that more or less covered the bottom of the sea.

To what depth this progressive submersion may have reached I cannot say, but I think it cannot have been less than from 1,200 to 1,500 feet. In corroboration of this it is worthy of note that the Rev. Maxwell Close has described sea-shells as occurring at the height of 1,300 feet on the Wicklow Hills. The features of the

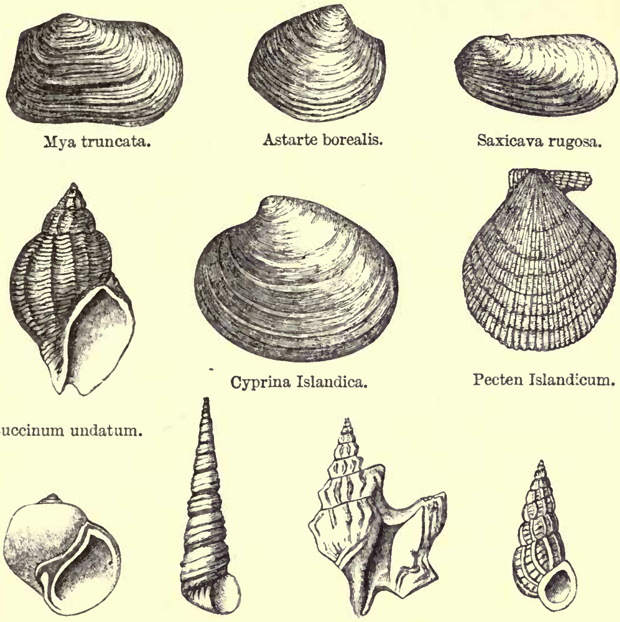
[1] 'Old Glaciers of North Wales, and Peaks, Passes, and Glaciers.'

ground where the circumstances can be best studied are as follows.

On the north-western flank of the Caernarvonshire mountains, which looks towards the Menai Straits, there are certain high moorland tracts, the surfaces of which, more or less strewn with boulders, have very gentle slopes, and when the sections are exposed, caused by the cutting action of brooks, the subsoil is found to be Boulder-clay, full of ice-scratched stones. The slopes of Moel Tryfan are surrounded by such material, which stretches from thence north-east towards the valley of Llyn Cwellyn or Cwm Seiont, and on the opposite side of that valley, beyond Bettws Garmon, comes on again in the higher ground. Its continuity is again interrupted by the valley of Llanberis at Llyn Padarn, on the north-east side of which, from 800 to 1,200 feet above the sea, the same inclined plains of drift are continued to Nant-ffrancon, north-west of the great Penrhyn Slate quarries, while on the north-east side of that valley the same plain stretches still further north. In one part of these glacial drift deposits, on the moor of Ffridd Bryn-mawr, I found sea-shells at a height of about 1,000 feet above the level of the sea, and I was informed by Mr. Trimmer that shells had also been found in corresponding clays, on corresponding heights, on the east side of the Ogwen, beyond Bethesda. The shells which I found were examined by Edward Forbes, but unfortunately they have since disappeared. Similar deposits in the same region seem to attain a height of at least 1,500 to 1,800 feet, but without insisting on this it is something to be assured that marine strata-bearing shells attain a height on these Welsh mountains of 1,000 feet and more.

Further proof of this is to be found in an upper detritus which covers much of the lower parts of Scotland and of England, composed of clay, mixed with stones and great boulders, many of which are scratched, grooved, and striated, in the manner of which we have experience in the glaciers of Switzerland and Norway. Sands and

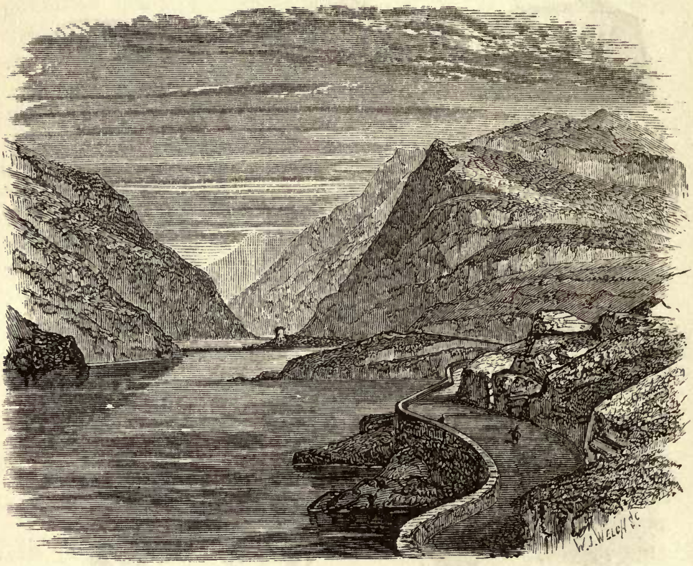
FIG. 85.



Group of Post-Pliocene Fossils, Clyde beds.

gravels, with perfect sea-shells, are interstratified with these boulder-beds, and sometimes the clays themselves contain unbroken shells, as, for example, in the low ground of Shropshire between Coalbrook Dale and Wellington. Here and there, even in the heart of the moraine-matter of the Till, there are patches of sand and clay interbedded. The main mass, indeed, is not stratified, because glaciers rarely stratify their moraines, but the waves playing upon them, as they were deposited in the sea, arranged portions in a stratified manner; and there occur at intervals in these patches in Scot-

Fig. 86.



Pass of Llanberis.

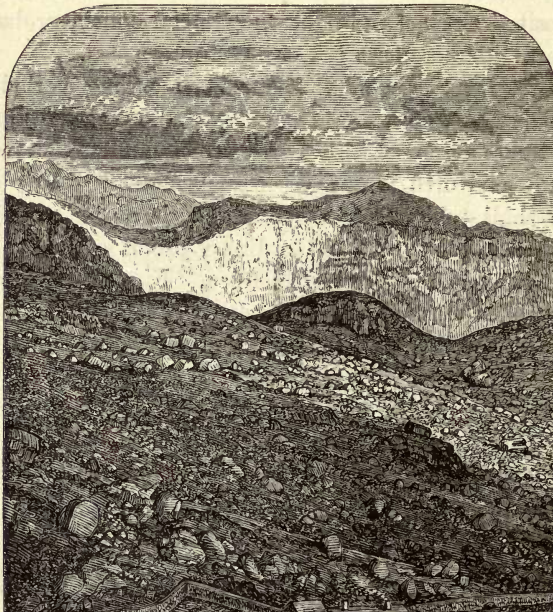
land the remains of sea-shells of species such as now live in the far north.

In the low grounds that border the estuaries and alluvial plains of the Clyde, the Forth, the Endrick, and elsewhere, up to 125 and 262 feet above the sea, there are well known brick-clays which sometimes contain erratic boulders and ice-scratched stones. Here and there many sea-shells are found in these strata, all of existing species, but the general assemblage of forms indicates an arctic climate comparable to that of Greenland of the present day, a circumstance many years ago pointed out by Mr. James Smith of Jordanhill. The evidence all tends to prove that these strata were deposited during a part of the Glacial epoch, probably towards its close (fig. 85, p. 417).

After what seems to have been a long period of partial submergence the country gradually rose again, and the evidence of this I will prove chiefly from what I know of North Wales.

I shall take the Pass of Llanberis as an example, for there we have all the ordinary proofs of the valley having been filled with glacier-ice. First, then, during and after the time of the great ice-sheet, the country to a great extent sunk below the water, and drift was deposited, and must more or less have filled many of the deep narrow valleys of Wales, and which still remains in part in some of the broader expanses of the country. When the land was rising again, the glaciers gradually increased in size, although they never reached the immense magnitude which they attained at the earlier portion of the icy epoch. Still they became so large, that such a valley as the Pass of Llanberis was a second time occupied by ice, which, without invading Anglesea, spread itself into the lowlands beyond, and the result was, that the glacier ploughed out the drift and loose rubbish that more or less cumbered the valley. Other cases, such as those of Nant-ffrancon and Aber, could easily be given. By degrees, however, as we approach nearer our own days, the climate slowly ameliorated, and the glaciers began to decline, till, becoming less and less, here and there as they died away, they left their terminal and lateral moraines, still in some cases as well defined as moraines in lands where glaciers now exist. Beautiful examples of such moraines are seen in the Pass of Llanberis, between the precipice south of

FIG. 87.



Moraines and *Roches Moutonnées* between Cwm-glas and Blaen-y-nant, Pass of Llanberis.

the road and the bridge called Pont-y-gromlech. Not far behind the house called Blaen-y-nant, there is a large moraine lying on the slope of the hill. It consists of heaps of boulders, clay, and angular gravel and blocks, identical in genera spect with many

Swiss moraines. Some of the loose stones are scratched, the lines crossing each other confusedly; and the mass of the moraine is formed of three or four concentric elliptical mounds, which merge together at their bases, and mark on a small scale the gradual decrease of the Cwm-glas glacier. These circle round the lower side of a large *roche moutonnée*, which forms a small hill, as shown in front of the cliff in the middle of fig. 87.

A little behind this hill, about half a mile south of Blaen-y-nant, a perfectly symmetrical terminal moraine, grass-grown, but strewn with travelled blocks, ranges across the valley between two brooks, almost as regular in form as an artificial earthwork. It is between 1,200 and 1,300 feet above the sea. Higher up, on the west side of Cwm-glas, the striæ on the rocks run NNE. below the space where the glacier, in a cataract of ice, once slid down the cliff that now appears so grim. Four white threads of water glance on its side, the sole representatives, in another form, of the jagged ice-fall, that on a smaller scale must have resembled the ice-cataract of the glacier of the Rhone. Beyond this cliff, in one of the innermost recesses of Snowdon, lies an upland valley bounded on three sides by tall cliffs, in the midst of which lie two small, deep, clear tarns about 2,200 feet above the sea, each in a perfect basin of rock. Between these pools and the cliff below, a large quantity of moraine-débris, derived from Crib-goch, cumbers the ground. The rocks on which it lies are often perfectly smoothed, rounded, and deeply grooved; and the striæ that, lower down the valley, strike straight towards the Pass, here branch to the south-west and south-east, following the courses of two minor valleys on either side of a peaked ridge that descends from Crig-goch to the ground between the pools. Tiny moraine mounds scattered about, tell of the last remnants of ice ere the shrunken glaciers finally melted away in the upper recesses of the mountain.

From the summit of Snowdon three of the old glacier valleys may be seen that radiate from the mountain. On the east, the magnificent amphitheatre of Cwm-glas and Llyn Llydaw, with all its striated *roches moutonnées*, moraine mounds, and numerous perched blocks; on the south, the deep glen of Cwm-y-llan, with its ice-worn surfaces of rock on the sides of the hills, in which, just below the peak of Snowdon, there is a symmetrical moraine about half a mile in length, formed in the latter days of the glacier, that once flowed down to join the larger ice-stream that descended through Nant Gwynant and the valley of Llyn-y-ddinas, and so onward to Traeth-mawr below Beddgelert. Just below the peak lies the broad precipitous *cirque* of Cwm-y-clogwyn, in which may be faintly seen the terminal moraine of a minor glacier, partly circling the pool of Llyn-goch; and, descending by the path to Llanberis, a vast moraine heap lies immediately north and west of the deep-set tarn of Llyn-du'r Arddu.

It would be easy for me to give a similar description of the large glacier that filled the valley of Nant-ffrancon, and flowed onward to where Bangor now stands, where, as a terminal moraine, it deposited those beautiful wooded mounds that form the park of Penrhyn Castle. Further up the valley, beyond Ogwen Bank, the river is barred across by striated grits, dotted with erratic blocks, and high above is the craggy tributary valley of Cwm-graianog. Its whole length is not over half-a-mile, and at its mouth, above the steep descent to Nant-ffrancon, a small but beautifully symmetrical moraine crosses the valley in a crescent-shaped curve.

Another striking example of the moraines of a retreating glacier may be seen in Llyn Idwal, first

FIG. 88.

Glacier of the Pass of Llanberis.

described by Mr. Charles Darwin in 1842. Below an amphitheatre of steep hills and cliffs lie the waters of Llyn Idwal, which are dammed up by ice-worn rocks strewn with moraine. Below the moraine, down to the Ogwen, the rocks are strikingly *moutonnée*, the striations gradually curving round NW. to take the direction of the main valley. On either side of Llyn Idwal lie several moraines, four in number on the west. They run in long symmetrical mounds lengthwise in the valley, and were deposited at intervals at the side of the glacier when it ceased to fill the valley from side to side, and was gradually decreasing in size. There is also some appearance of an inner terminal moraine where the lake narrows towards its southern end.

When the ice of these later glaciers of Llanberis and Nant-ffrancon was thickest, in my opinion it could not have been less than 1,300 feet thick in the former, and from 1,000 to 1,200 feet in the latter.

In Switzerland there is an offshoot of the glacier of the Aletsch which, at the foot of the Aeggischhorn, projects from the great glacier a short way into the valley in which the little lake lies, well known as the Märjelen See. This lake is drained by a small brook, which tumbles down the rocky ground to pass under the glacier of the valley of Viesch. The right and left sides of the lake are bounded by mountains, but the side opposite the outflowing brook is overlooked by an ice-cliff of the Aletsch glacier, which was about 60 feet in height where highest when I first visited the spot. The water was then 97 feet deep where deepest, and this I proved by soundings from the edge of the ice-cliff. Occasionally masses of ice fall from this cliff and break up into numerous icebergs, some of them large enough to float boulders of moderate size. The bergs, floating hither and thither, melt by degrees, and boulders and smaller stones are thus scattered over the bottom of the lake. At intervals, it is said, of about eight years, a crack or crevasse opens in the ice, and all the water of the lake passes away under the glacier to swell the river that flows from under its lower end.

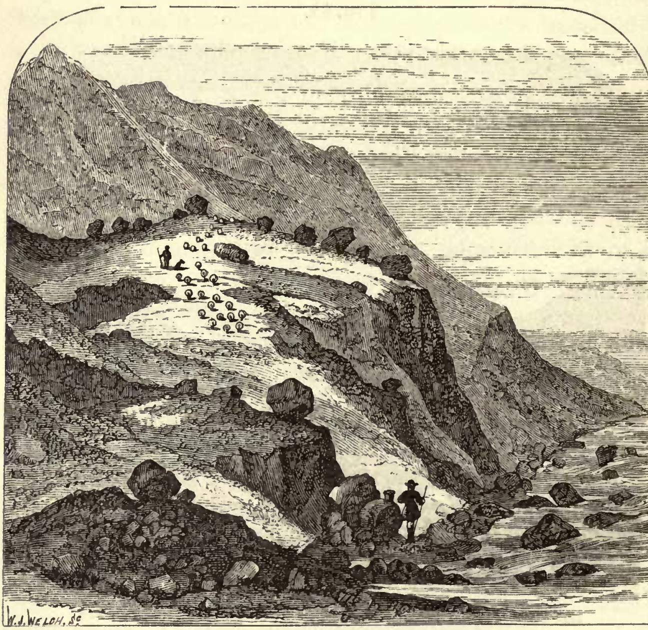
In the valley of Llanberis there are two well known lakes, Llyn Padarn and Llyn Peris, and on a clear day, when the water is still and pure, from a boat one can see boulders here and there lying on the bottom of the shallower parts of the lakes. In fig. 88 the Pass of Llanberis is represented as it may have been at some period when from end to end it was comparatively full of ice. In fig. 89 it is shown as it must have existed

FIG. 89.

An episode in the history of the Glacier of Llanberis.

for a time when the glacier, by amelioration of climate, had retired from all the lower part of the valley, and debouched into an upper part of what is now Llyn Peris. As it gradually receded, moraine stones, that fell from its end, got scattered over the bottom of the lake; for in those days the alluvial flat had no existence which, but for a short river, now divides into two an older lake of more than five miles in length. In the foreground, are the then unweathered block-strewn *roches moutonnées*, on which Dolbadarn castle now stands, which here and there are still marked by distinct glacial striations. This scattering of boulders on the

FIG. 90.



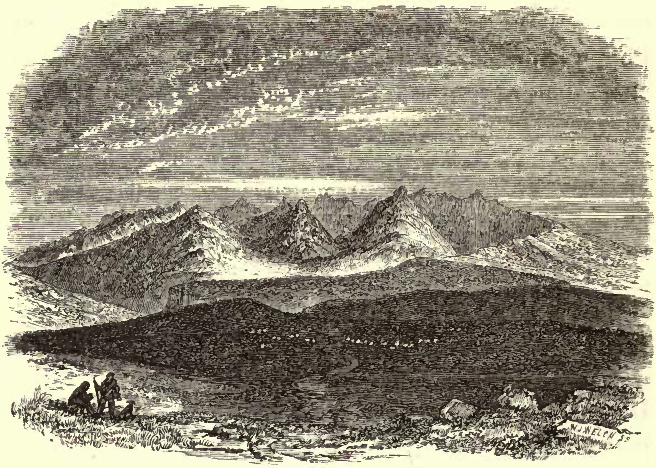
Roche Moutonnée, with *Blocs Perchès*, Pont-y-gromlech, Pass of Llanberis.

bottom of the lake is analogous to that which now takes place in the Märjelen See, or which on a great scale once took place, as the mighty glacier of the Rhone was, from where Geneva now stands, slowly retreating fifty miles eastward towards Bex. In the shallow water near Geneva, boulders shed from the huge glacier may still be seen with their tops above water, and in the midst of the Delta of the Rhone, between Bex and the mouth of the river, portions of an old terminal moraine peep through the wide alluvial flats and marshes which began to be deposited by its waters, at a time when the lake was several miles longer than at present.

The gradual retreat of the glacier of the Pass of Llanberis is further proved by numerous *perched blocks*, which, here and there, isolated or in groups, stand on the surfaces of *roches moutonnées*, as, for example, at Pont-y-gromlech, and in many other places, masses of stone that, so to speak, floated on the surface of the ice, were left perched upon the rounded rocks in a manner somewhat puzzling to those who are not geologists; for they lie in places to which they clearly cannot have rolled from the mountains above, because their resting places are separated from it by a hollow; and, besides, many of them stand in positions so precarious, that if they had rolled from the mountains, they must, on reaching the points where they lie, have taken a final bound and fallen into the valley below. But when experienced in the geology of glaciers, the eye detects the true cause of these phenomena, we have no hesitation in coming to the conclusion that, as the glaciers declined in size, the errant stones were let down upon the surface of the rocks so quietly and so softly, that there they will lie until an earthquake shakes them down, or until the wasting of the rock on which they rest precipitates them to a lower level. Finally, the climate still ameliorating, the glaciers shrunk farther and farther into the heart of the mountains, until, at length, here and there, in their very uppermost recesses, we find the remains of tiny moraines, marking the last relics of the ice before it disappeared from the country.

The same kind of evidence of a period of greatest glaciation, followed by partial submersion, re-elevation, and the gradual retreat of the later glaciers, is plain in almost every valley in Cumberland, and Mr. Ward confirms this old view of mine, as applied to Wales, in his late account of 'The Glaciation of the Northern Part

Fig. 91.



Old glacier *cirques* in Arran, from Lagan Hills.

of the Lake District,' in the 29th volume of the Journal of the Geological Society.

In Scotland also the land underwent partial submersion and re-elevation during the Glacial epoch, and the gradual retreat of the later glaciers is witnessed in many a valley in the Carrick and Lammermuir Hills, in the moraines of the cirques of Arran, and through the mainland of the Highlands, and in Skye in the valleys of the Cuchullin Hills. I could give special instances in some of those regions, but they would add little to the effect of what I have stated, and would needlessly lengthen this book.

Again, when the glaciers were retiring westward, up the dales of Yorkshire and Northumberland, the ice left, as it retreated, heaps of débris originally forming irregular mounds, often enclosing cup-shaped hollows; but these, which sometimes still remain in the more recent smaller moraines, have in the more ancient and larger ones often got filled up by help of rain washing the fine detritus into them; and the whole has become so smooth that the original *moundiness* has, by degrees, been nearly obliterated. In like manner the same has taken place in the wide valley that crosses England eastward from the bend of the river Lune, near Lancaster, by Settle to Skipton, including most of the country between Clitheroe in Lancashire and Skipton, and as far south as Pendle Hill and the other hills that border the Lancashire Coal-field on the north. And this is what we find:—The great glacier sheets that came down the valley of the Lune from the Cumbrian mountains and Howgill Fells, and from the high hills of which Ingleborough and Pennygent form prominent features, spread across the whole country to the south, and fairly overflowed the range of Pendle Hill into the region now known as the Lancashire Coal-field, and far beyond. The result was that the whole of the country between Clitheroe and Skipton, including the country south of Clapham and Settle, was rounded and smoothed into a series of great *roches moutonnées*, partly formed of Carboniferous Limestone; and as the final glaciers retired, through gradual change of climate, these became covered with mounds of moraine-matter, now not easy, at first sight, to distinguish from that *marine drift* which, at equal levels, covers so much of the country further south.

There is often great difficulty in distinguishing between these latter moraines and the great masses of moraine-matter that were formed during that earlier period when the northern ice-sheet covered the greater part of Britain, and which undoubtedly were not terminal, but actually lay under the ice—*moraines profondes*, as they have been termed by French and Swiss geologists. Neither is it always easy to distinguish between this 'Till' and the marine glacial drift when shells are absent, for the plains of the latter melt into gentle slopes of glacial débris that pass far up the valleys, and on the hill-sides over many high watersheds.

One reason for this difficulty is that, in certain stages of the history of the period, the larger sheet or sheets of glacier-ice covered the hills and filled the valleys so thickly and completely that, pushing out to sea, they even excluded it from parts of valleys that were at a lower level than the sea itself; and moraine-matter thus got sorted and mingled with other marine deposits. This partly accounts for the gradual merging of those marine gravelly mounds, called Kames or Eskers, into Boulder-clay and true moraine heaps full of ice-scratched stones. The Eskers themselves are often largely charged with water-worn stones originally well ice-scratched. These glacial scratchings have since been almost entirely worn away by friction, the stones having been rubbed against each other by moving water. The mere ghosts of the original sharp scratchings now remain.

The foregoing sketch of the Glacial epoch is of much importance in a geological point of view, more especially because of the pictures we get of phases of a physical geography in these regions, so different from that of to-day, and which judged by any geological standard is yet so recent. Besides, the events of this period of plentiful snow and ice gave distinctive characters both to our mountains and much of our lowlands, different, in many respects, from those of mountain ranges and lowlands where glaciers never were. No one with an eye educated in glacier work, can fail to recognise the *moulding by ice* of the outlines of the Highland and Cumbrian mountains. Their lines are often smooth and flowing curves, and, excepting here and there, cragginess is not their special characteristic. In North Wales the mountains are apt to be more craggy, partly because of the variable hardness of the rocks, and partly because, being further south, that region was not so completely smothered in ice as the more northern mountains.

CHAPTER XXVII.

GLACIAL EPOCH CONTINUED.—ORIGIN OF CERTAIN LAKES.

THERE is an important subject connected with the physical geography of our country, and that is, the multiplicity of lakes in the mountain regions, and the question thus arises—To what physical operations do they happen to be so numerous in some districts and so scarce or altogether absent in others?

When glaciers descended into valleys, and deposited their terminal moraines, it sometimes happened that when a glacier declined in size its moraine still remained tolerably perfect, with this result—that the drainage formerly represented by ice is now represented by running water, which is dammed in between the surrounding slopes of the solid mountain and the mound formed by the terminal moraine, thus making a lake. There are such minor lakes on the Italian side of the Alps below Ivrea, and there are several among the mountains of Wales, which at least are partly dammed in by moraines, and a few, perhaps, entirely so. They are always small, and may be classed as tarns, lying at the bases of cliffs in the upper recesses of the mountains. Whether there are any in Scotland, dammed by the terminal moraines of common valley glaciers, I do not know, although they may exist in parts that I have not visited. Furthermore, sometimes on the *outer* side of these moraines we find what seems to be stratified boulder-drift, in which cases it would appear that glaciers descended to the level of the sea, and deposited their moraines there, and, breaking up, floated about as icebergs bearing boulders. By-and-by, the glacier that was produced by the drainage of snow disappeared, and is now represented by water, forming a lake dammed by a moraine, outside of which lie long smooth slopes of stratified drift. In the majority of cases, however, as already stated, I believe that most of these small lakes are only partly blocked in by moraine matter, and that, like some of the large lakes of both sides of the Alps which have moraines at their outlets, even if these moraines were removed they would be found to be entirely enclosed by solid rock formations.

Such lakes in Wales are always on a small scale, but there are others on a larger scale, having a far more important bearing upon the physical geography of our country and of many other countries in the northern hemisphere, and I have no doubt also in the south. The theory which I propound is my own, and in its first conception is not now much more than seventeen years old. It gave rise at the time to a considerable amount of opposition, and also to some approval.[1]

There is no point in physical geography more difficult

[1] See 'The Old Glaciers of Switzerland and North Wales,' 1860. Soon after the special paper was published in the 'Journal of the Geological Society' in 1862, it was with satisfaction that I received a letter from Dr. Julius Haast, stating that the theory perfectly applied to many of the lakes in New Zealand, and that he had adopted it after the perusal of my paper. See also on the 'Erosion of Valleys and Lakes,' 'Philosophical Magazine,' 1864, and 'Sir Charles Lyell and the Glacial Theory of Lake Basins,' 'Philosophical Magazine,' 1865.

to account for than the origin of many lakes. When thought about at all it is easy to see that lakes are the result of the formation of hollows, a great proportion of which can be easily proved to be *rock-basins*—that is to say, hollows entirely surrounded by solid rocks, the waters not being retained by mere loose detritus. But the great difficulty is, how and why were such large numbers of these *rock-basins* made in special regions?

I have often been so much misunderstood and misrepresented in this matter, that those who had not read my early papers on the subject might easily have supposed that I attributed the origin of all lake-basins to glacial erosion, and that in spite of my having, in print, formally disclaimed any such idea. It is not likely that any man could have entertained it who had seen lakes in old volcanic craters, who was familiar with the fact of subsidences in old and new volcanic regions, and who, besides, expressly stated that there were doubtless other kinds of lakes, the origin of which he probably knew nothing about.

A great many lakes lie in valleys, and many persons in times past and present have been easily satisfied as to the causes that produced mountains, valleys, and lakes. To the uneducated, the first and obvious explanation is, that in all its grand features the world was originally made very much as it now stands. With the half educated, even in geology, the explanation is, that the irregularities of the surface have been caused purely by dislocations, or, going one step further, that deep openings 'were primarily due to *cracks* which took place during the various movements which each chain has undergone at various periods,' the meaning of which I conceive to be, that mountain valleys necessarily lie in lines of curvature, dislocation, and fracture, and that the mountains on each side of them are in their present forms mountains, far less because of denudation, than by reason of operations of fracture and dislocation. For clear demonstrations of such assertions none are given, and I now propose to give a *résumé* of the reasons as originally published by me and since confirmed by others, which show, how it happened that certain rock-bound hollows were scooped out by the agency of glacier-ice. In doing so, I shall briefly go into other subjects than those involved in questions of mere movements of the earth's crust.

In the first place, consider what is the effect of marine denudation. On the sea-shore, where waves are always breaking, the effect of this, and of the weathering of cliffs that rise above the waves, is to waste back the land. But the sea in this case *cannot make a deep hollow below its own average level.* What it might do, if there were hollows there, would be to fill them with detritus, for it cannot cut them out. The consequence is, that the chief power of the sea and the weather combined, working on the land and wasting it back, *is to act as a great planing machine, wearing down the larger irregularities that rise above its level* in the manner shown in the description of the first denudation of the Weald at page 343, and of South Wales at page 497, so as in the end to form *a plain of marine denudation.*

Again, what is the effect in any country of running water? *Rivers cannot make large basin-shaped hollows surrounded by rocks on all sides.* All that running water can do upon the surface is to scoop out trenches or channels of greater or less width, forming gorges or wider valleys, according to the nature of the rivers and the rocks, and the time employed in the work. If we have an inclined plane with a long slope, gentle or steep, water will run upon it because of the slope; and, aided by atmospheric disintegration, it will cut out a channel, *but it cannot make a large rock-bound lake-basin*, though it can scoop out a small one below a waterfall, or where two rapid streams meet, it may hollow out a pool or linn by reason of the turbulence of the water.

Again, it has been contended that the hollows were formed *by the disturbance of the rocks, so as to throw them into a basin-shaped form.* But when we take such lakes as those of Geneva, the lake of Thun, the lakes of Lucerne, Zurich, Constance, and the great lakes on the Italian side of the Alps, or many of the Welsh, Cumberland, or Highland lakes, and examine the strata critically, we find that they do not lie in the form of basin-shaped, synclinal hollows, but, on the contrary, the *strike* of the strata often runs right across the lake-basins instead of circling round them, or they may be bent and contorted in a hundred curves all along and under the length of the lake. Such synclinal depressions are the rarest things in nature: that is to say, hollows formed of strata bent upwards at the edges all round into the form of a *great dish*, the very uppermost bed or beds of which shall be continuous and unbroken underneath the water of the lake. Some such synclinal hollows are found in the upper valleys of the Jura, but without lakes, and in which the drainage runs into *potholes*, and finds its way to the level of the Val de Travers, where ready-made rivers issue from caverns in the Secondary rocks. But these synclinal hollows can be explained on principles quite different from those I have to propound. If such synclinal lake-basins exist at all, I never saw one, though specially looking out for them in many regions, and I believe that they have been only assumed by persons who have not realised the meaning of denudations on a large scale, and therefore are apt to consider hills and valleys as the result, mainly, of disturbance and dislocation. From repeated examination, I feel indeed assured, that the Swiss and other valleys generally, and the lake-valleys in particular, do not lie in gaping rents, fissures, or in synclinal curves; and, indeed, after half a life spent in mapping rocks, I believe that there is no *necessary* connection between fractures and the formation of valleys, excepting that in certain cases *a line of close fracture was also a line of weakness*, on which the watery agents that promote denudation were more easily able to work, especially, if on each side of the fault the rocks happen to be of different degrees of hardness.

It might, however, be said that these lakes lie in *areas of special depression*, made by the sinking of the land underneath each lake. So difficult indeed did it seem to Playfair, the great illustrator of Hutton, to account for the origin of the rock-basin in which the Lake of Geneva lies, that he was forced to propound the hypothesis that beds of salt had been dissolved underneath its bottom, which therefore sunk, and so formed a hollow for the reception of its waters. Lakes are, however, so numerous in the Alps, North Wales, Cumberland, and the Highlands of Scotland, where they occur by the hundred, and in part of North America by the thousand, that I feel sure the theory of a particular depression for each lake, will not hold in these or in any other northern or southern region that has been acted on by glacier-ice on a great scale. In that part of North America which lies well east of the Rocky Mountains, and north of latitude 40°, it is as if the whole country were sown broadcast with lakes, large and small; and great part of the country not being mountainous, but consisting of undulating flats, it becomes an absurdity to suppose that, so close together, a special area of depression was provided for each lake. The physical geology of America, Scotland, and Sweden, for example, entirely goes against such a supposition; and I believe that it is equally untenable for the Alps and the lowlands between the Alps and the Jura. Having come to these conclusions, it is plain that it is not a simple thing to account for the existence of hollows, composed of hard rocks, which completely enclose lakes.

If, then, we have disposed of these erroneous hypotheses, what is left? If the sea cannot form such hollows, nor weather, nor running water, and if the hollows were not formed by synclinal curves of the strata, and if they do not lie in gaping fissures, nor, for most lakes, in areas of special depression, *the only remaining agent* that I know *is the denuding power of ice.*[1]

In the region of the Alps it is a remarkable circum-

[1] I must again guard myself against misapprehension. Some lakes owe their existence merely to inequalities in 'the drift' or other glacial deposits, many to extinct volcanic craters, and others, especially in volcanic regions old and new, to special subsidences. An excellent paper on this subject 'On the Ancient Volcanoes of the District of Schemnitz Hungary,' has been published by Mr. J. W. Judd, F.R.S. in vol. xxxii. of the 'Journal of the Geological Society,' 1876; and I have no reason to doubt that the Great Salt Lake, the Yellowstone Lake, and others in the barely extinct region of the Rocky Mountains, have a similar origin. Neither would I think of attributing the origin of the great lakes of Africa to glacial influences, any more than I would the Black Sea, the Caspian, and the Sea of Aral. He would also be worse than a bold man, who would speak of the Salt Lakes of the Sahara as being of glacial origin, to say nothing of others too numerous to name.

stance that all the large lakes lie in the direct channels of the great old glaciers—*each lake in a true rock-basin.* This is important, for though it is clear that the drainage of the mountains must have found its way into these hollows, either in the form of water or of glacier-ice, yet if ice had nothing to do with their formation, *we might expect an equal number of lakes great and small in other regions where the rocks are equally disturbed or of like nature, but where there are no traces of glaciers.* I have never observed that this is the case, but rather the reverse.

I will take the Lake of Geneva as a special example (as I did in my original paper) before applying the theory to our own country. This lake, once more than 50, is now about 40 miles, long, its upper end between the neighbourhood of Bex and the mouth of the Rhone having been filled with moraine matter and alluvium. In its broadest part about 12 miles wide, it lies at the mouth of the upper valley of the Rhone and directly in the course of the great old glacier, which was more than a hundred miles in length from the present glacier of the Rhone to where at its end it abutted upon the Jura, by about 130 miles in width at Geneva, from south-west to north-east, at what was once considered to be its lower end. There, however, it is now known that its bulk was swelled by the tributary glaciers of the Arve descending from Mont Blanc, and of the valleys of the lakes of Annecy and De Bourget, flowing west and north-west from the high Alps further south, so that its most westerly edge lay at least 60 miles beyond Geneva, as far as Lyons on the Rhone.

In old maps, showing the extent of the great ancient glaciers of Switzerland, authors were somewhat too timid, and large blank spaces were here and there left among mountains of the second and third classes, as if they were not sufficiently lofty to have contributed their quota of ice to fill the minor valleys. But on the map that accompanies Professor Rütimeyer's memoir on the Pliocene and Glacial epoch, that distinguished author has boldly drawn a continuous line of moraine-matter, extending from Lyons along the south-east flank of the Jura, and from thence to Steyer, in Austria, about 20 miles from Linz on the Danube.

I do not doubt the general fidelity of this bold generalisation, and if it be true, it seems to me that, during the most intense part of the Glacial epoch, the whole of Switzerland between the Alps and the Jura must have been covered with glacier-ice. If so, to the eye (had human eyes been there to see it) it must have been impossible to specialise individual glaciers such as those of the Rhone, the Rhine, the Linth, the Reuss, and the Aar. Nevertheless when we consider the great antiquity of the post-Miocene disturbance of the Alps, I do not doubt that in some form those valleys existed, in which case the great glacier, maintaining an average uniformity of surface, must still have been thickest in the lines of the pre-existing valleys, and the erosive power of the moving ice must have been proportionally increased thereby. The effects produced on the country over which the under-current of the Rhone glacier flowed were commensurate to its great size and thickness.

The Lake of Geneva where deepest, towards its eastern end, is a little more than 1,000 feet in depth, and it gradually shallows to its outflow. By examining the sides of the mountains on either side of the valley of the Rhone, through which the glacier flowed, we are able to ascertain what was the thickness of the ice in that valley when the glacier attained its greatest size viz., at least 5,200 feet above the present bottom of the valley at Viesch, and more than 3,700 feet at Morcles, not far above the southern end of the delta of the Rhone, which once formed part of the lake. If we may suppose that this latter thickness continued approximately as far as the deepest part of the lake between Evian and Cully, the glacier may have been nearly 4,700 feet thick, if we add to the above thickness at Morcles the depth of the water.[1] By similar observations on the *Jura*, it is clear that where the ice abutted on that range, it still maintained a thickness of something like 2,200 feet where thickest, swelled as it was by the vast tributary masses of glacier-ice that progressed down the valley of the lakes of Thun and Brienz, and also by that of the Arve and of Chamouni, and by others of smaller size that flowed down the valleys south of the lake.

Consider the effect of this gigantic glacier flowing over the Miocene rocks, which in this part of Switzerland are comparatively soft, and yet of unequal hardness! That mass, working slowly and steadily for a period of untold duration, must have exerted a prodigious grinding effect on the rocks below. Where the glacier-ice was thickest, there the grinding power was greatest, especially on the softer Miocene strata, and the underlying rock was consequently to a corresponding extent worn away. No one can doubt that the ice-flow that pressed down the upper valley of the Rhone exercised a great amount of eroding power, representing as it did the snow-drainage of all the

[1] For details on this question, see 'Notice sur la conservation des Blocs Erratiques et sur les Anciens Glaciers du Revers Septentrionale des Alpes,' par M. Alphonse Favre, Archives des Sciences de la Bibliothèque Universelle, November 1876.

FIG. 92. *Lake of Geneva and Soundings.*

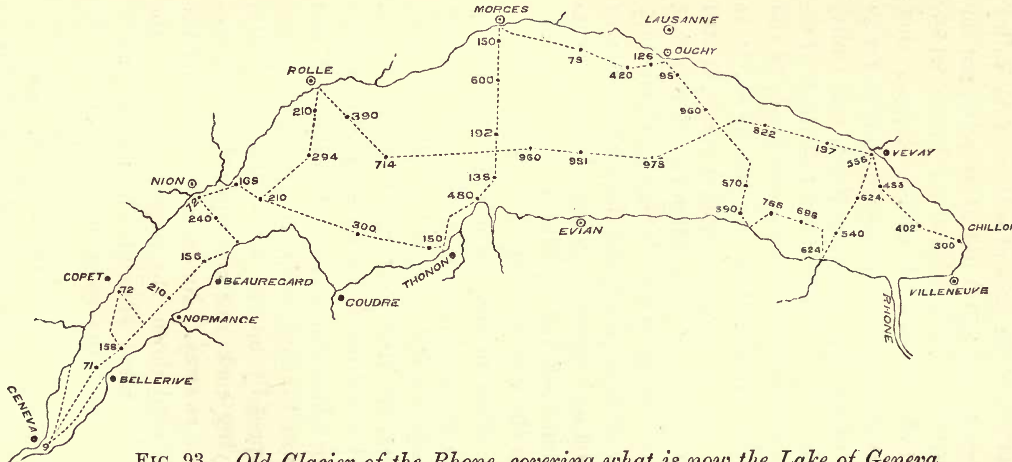
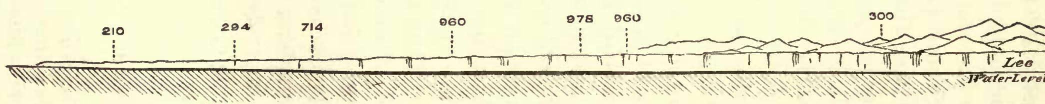


FIG. 93. *Old Glacier of the Rhone, covering what is now the Lake of Geneva.*



The shaded part represents the rock-basin beneath the lake. The dark line the lake, showing its depths on a true scale. Thelight part above represents the Old Glacier of the Rhone. Figures, depth of the lake in feet.

southern slopes of the Oberland, and the northern drainage of all the southern Alps, from Mont Blanc to the Matterhorn, which looks down on the modern puny glacier of the Rhone. But where at its western end, near Geneva, the ice was thinner, there the pressure and grinding power were less, and the waste of the underlying rock was proportionately diminished. The result was, that a great hollow was scooped out, *at least* 984 feet deep as sounded by De la Beche, or about 1,000 feet as given by later measurements in the deepest part, without allowing for the moraine matter that, in later times, must have been left in the depths of the lake by the retreating glacier, or for the modern sediment that covers the bottom. At first it may be difficult to realise this theory and to appreciate the mode of action of the ice, but when we compare the depth with the length of the lake and the height and weight of the ice above, and reduce all to a true scale, as shown in fig. 92, it becomes evident that the depth of the rock-basin is comparatively quite insignificant.

I have elsewhere shown that the rock-bound lakes of Brienz and Thun had the same kind of origin. These were originally one lake, but are now separated by broad alluvial meadows. In like manner the Lakes of Lucerne, Zug, the Wallen See, Zurich, and Constance, all lie in rock-basins of erosion by glacier ice. The same is the case with many other Swiss lakes of minor note, and should anyone wish to see actual basins, visibly bordered by glaciated rocks, let him critically inspect the lakes of Sarnen and Lungern on the route from Lucerne across the Brunig. The deep hollows in which the great Italian lakes lie on the south side of the Alps had a similar origin.[1]

[1] See Memoir by the Author, 'On the Glacial Origin of certain

It may seem strange that I should take the Lake of Geneva as a special example, when the lakes of Llanberis, Llyn-llydaw, and Bala in Wales, Windermere in the Cumbrian region, Loch Doon in Ayrshire, Loch Katrine, or Loch Lomond, and many other lakes in the Highlands, would on a smaller scale do as well. But though it was in Wales that the first idea of the theory struck me, while mapping its moraines and ice-grooves in 1854, yet it was only after a critical examination of many of the lakes in and around the Alps, that in 1861 I ventured to assert that nearly all their basins were scooped out by the great glaciers of the icy period. I then first clearly saw its bearing as a veritable discovery in physical geography, affecting not Switzerland and Britain alone, but a large part of the habitable world.

If we examine the maps of the northern hemisphere generally, beginning at the equator, and going north, it is remarkable that, excepting lagoons, crater-lakes, and a few formed by subsidence in volcanic areas, we find very few important lakes in its southern regions, and these chiefly in Central Africa, where no traveller has yet tried to account for them. As we proceed northwards in America, in latitudes 38° and 40°, the lakes on the eastern half of the continent begin to increase, and soon become tolerably numerous. North of New York, towards the St. Lawrence, they become so numerous, that they appear on large maps to be scattered over the country in every direction, and beyond this to the west and north of Lake Superior and the St. Lawrence, the whole country is, so to speak, sown

Lakes,' &c. 'Jour. Geol. Soc.' 1862, vol. xviii. For the germ of the whole subject see also 'The Old Glaciers of Switzerland and North Wales,' 'Peaks, Passes, and Glaciers,' republished as a separate book 1860.

broadcast with lakes large and small, and a vast number of the smaller ones are omitted partly for want of room, and partly because even now they are unknown to topographers. The whole of that area *has been completely covered by ice*, as the researches of geologists show.

Coming to this side of the Atlantic, and examining the Scandinavian chain on the east, where the slopes are less inclined than on the western flank, all round the Gulf of Finland, and the Swedish coast of the Baltic, the whole country is covered with lakes, many, if not all, of which lie in true rock-basins, a fact which I inferred in my memoir on lakes published in 1864, and which has since been proved by Mr. Amund Helland, of Christiania, in his late memoirs, a summary of which is given in his paper 'On the Ice-Fjords of North Greenland, and on the Formation of Fjords, Lakes, and Cirques in Norway and Greenland.'[1] In Finland, according to Professor Nordenskiold, the lakes lie in a glaciated country, being chiefly dammed in by heaps of detrital matter called Osar.[2] Go into North Wales where glaciers were once in every valley; there we have the lakes of Llanberis, once one, and 107 feet deep where deepest, of Cwellyn, Ogwen, Llyn-y-Ddinas, Llyn Gwynant, Llyn-llydaw (180 feet), Glaslyn, (114 feet), and all the lakes and tarns near Capel Curig, and in the upper Corries, each lying in a true rock-

[1] 'Journal of the Geological Society,' 1877, vol. xxiii. p. 142.

[2] The Eskers of Ireland and the Kames of Scotland. These are common in the valley of the Clyde, especially near Lanark and Carstairs, where they form elongated irregular mounds of gravel which sometimes merge into true glacial detritus. They enclose lakes and peat-mosses, once lakes. They have been mapped and described by Professor Geikie. They occur in the grounds of Castle Kennedy near Stranraer, enclosing two beautiful lakes, and also in Northumberland, Lancashire, and Yorkshire.

basin. All the lakes in Cumberland that I have examined (and of which I have seen soundings) lie in true rock-basins (unless, in some cases, a few of the smaller ones may be dammed up by mere moraines or other superficial detritus); and this has been confirmed by Mr. Ward in his various memoirs on the glaciation of Cumberland, published in the 'Journal of the Geological Society.' I was also informed by the late Professor Jukes, and personally know, that the glacial origin of many of the celebrated lakes in Ireland, and of others unknown to fame is equally clear. Professor Hull also has confirmed the view that great numbers of the lakes in Ireland lie in veritable rock-basins, often crowded together in districts some of which I have not yet seen. Few or no parts of Britain have been more intensely glaciated than Ireland, and, indeed, all of these regions have been extremely abraded by glacier-ice.

In Scotland, in the southern hills, and in Kirkcudbrightshire and Ayrshire, there are many truly rock-bound lake-basins scooped out of the Silurian rocks of the Carrick Hills. If anyone wants a convincing proof let him go to Loch Doon, where at the outflow of the lake he may see the rocks perfectly *moutonnée* and well grooved, slipping under the water in a manner that unmistakably marks an ice-worn rocky barrier, while elsewhere all round the lake is circled by mountains, the highest of which is more than 2,800 feet in height. In the Shetlands and the Orkneys, in the Lewes and all the Western Islands, in Sutherland, Inverness-shire, Perthshire, Dumbartonshire, and the Mull of Cantyre, the country is, as it were, sown with lakes—a number of which I can testify by personal observation lie in true rock-basins.

Let anyone climb to the summit of Suilven in

Sutherland, which rises sharp and steep-sided above a broad, bare, undulating plateau of gneiss (p. 289) and let him count the lakes, large and small, seen from the top. In 1859, on one side alone I counted forty-two, and turning round to count those on the other sides, I thought—their name is legion! and gave it up. I cannot assert that each one is a rock-basin, but everyone that I visited, not there alone, but in other Highland areas, is so, and it is simply absurd to suppose that each tarn or larger lake was provided with a special area of subsidence wherein its water might lie, especially when many of such hollows lie in one broad plateau. As for tilting up the outlets of valleys, or the depression of their upper reaches, it would indeed require a remarkable series of tiltings to have produced the myriad lakes of Scotland, Sweden, and North America, and it would be difficult to give a reason why such unnumbered special tiltings should have been confined to areas the surfaces of which had all been subject to glaciation.

Rock-bound basins are, however, not confined to the land, for they are almost universal in the bottoms of fiords, or, as they are called in Scotland, Salt-Water Lochs, which so largely intersect all coasts where glaciers are or have been.

All Scotchmen who know the west coast are familiar with these long, narrow, mountainous arms of the sea, which any person capable of a grain of thought at once recognises as seaward continuations of inland valleys, which, it is well known, were, in Scotland and Norway, filled with glaciers. As far as I know, Professor James D. Dana, of Newhaven, U.S., was the first who distinctly stated that 'fiord-latitudes and drift-latitudes are the same.'[1] In the term 'drift-latitudes' are in-

[1] 'Manual of Geology,' 1863, p. 543.

cluded all those glacial influences that polished and grooved rocks and scattered erratic boulders.

Ever since exact Admiralty charts were published, it has been well known that our fiords are generally shallower at their mouths than further up, and it is more than thirty years ago since Mr. Charles Darwin observed, that 'Tierra del Fuego may be described as a mountainous land, partly submerged in the sea, so that deep inlets and bays occupy the place where valleys should exist' ('Journal of a Naturalist'). He has also remarked that the fiords are generally shallower towards their mouths than in the interior, at that time attributing this fact to the gathering of sediments on those exposed parts of the coast that are more subject to the abrading action of the sea than they are in the stiller interior reaches. In my memoir on Lakes, published in 1862, I stated of Scotland and Norway that the fiords and lochs are the prolongation of valleys down which glaciers flowed, and each was itself filled with a glacier, and I attributed the origin of their deep interior basins to the grinding power of glacier-ice; and in 1865, in the 'Philosophical Magazine,' I compared their inner great depths to those of Loch Lomond, itself once a fiord and a true rock-bound basin; for, in among the group of beautiful islands, *mere striated roches moutonnées*, near the outflow of the Leven, the water is only from 8 to 17 fathoms deep, while opposite Ben Lomond it deepens to 89 fathoms, or 534 feet, and above Tarbet opposite Culness to 105 fathoms, or 630 feet. If the country were to sink 20 feet, the surface of Loch Lomond would be at the level of the sea, and a few feet of additional depression would again convert it into a fiord like Loch Long, Loch Fyne, or Loch Etive.

Though I have no doubt that many seaward extensions of land valleys, now fiords, were once dry land valleys themselves, and that the deeper hollows in them were sometimes excavated when the whole stood above the level of the sea, yet this is not essential, for as has been observed by Mr. Amund Helland in his masterly papers (already quoted) on the Glaciation of Greenland, Norway, and Sweden, if a great glacier be sufficiently powerful to push onward, and grind for many miles along the bottom of a long fiord, the scooping out of rock-bound basins will be much the same as if its whole length were above the level of the sea.

I am not aware of any such fiords on the coast of England, though it may very well be that in Wales the Estuary of the Mawddach may be an old lake or rock-bound fiord-basin now greatly silted up, for the frequent *roches moutonnées* opposite Barmouth, once islands, seems to indicate a rocky barrier there.

When, however, we go into Scotland, where the mountains are high and the valley ice-streams were thick, there is no lack of them there. From Loch Erriboll, with its ice-ground mountains and islets, fig. 94, to the Firth of Clyde there is not a fiord that is not deeper in its further recesses than at its mouth, a fact proved by the charts of the Admiralty.[1] It is needless here to enter into minute details, but I may mention that the small fiord of Loch Erriboll is 78 feet deep near its upper end, and much shallower at its mouth. Half way up, little Loch Broom has a depth of 342 feet, and at its mouth is nowhere deeper than from 60 to

[1] For a recent account of this subject see 'The Great Ice Age, by James Geikie, LL.D., F.R.S., in which, on very clear maps, he shows soundings both of inland fiords, and sea rock-basins near the British coasts.

Fig. 94.

Loch Erriboll, Sutherland.

156 feet. Loch Fyne, about eight miles below Inverary, is 414 feet deep, and is very much shallower 15 miles further down, while in Loch Etive, near Oban, the whole theory is brought prominently before the eye, as shown in the accompanying picture, fig. 95.

The mouth of this sea loch or fiord at Connel Ferry is so narrow, that it seems as if a stone might almost be thrown across, but further up it spreads into a noble sheet of water, and its length is about 20 miles, and its greatest depth 456 feet. When the tide is up, on a quiet day, all is still and unruffled from end to end; but as the tide falls the water gets troubled across the mouth of the fiord, two rocky islets begin to appear, and by-and-by, standing on the *roche moutonnée* in the foreground, it becomes plain that a rocky barrier traverses the fiord from side to side, over which the outflowing sea falls with a roar that may be heard for a mile or more.[1] If the region were raised for a few feet, Loch Etive, by influx of rivers, would by degrees become changed into a freshwater lake, like its neighbouring tributary rock-bound basin Loch Awe, which is 306 feet deep where deepest. Here then is what may be called a demonstration of the glacial origin of many rock-bound fiord basins, unless we can persuade ourselves to believe that all the great fiords of Scotland, Norway, Greenland, and North and South America, were by some special operation upheaved at their mouths, no matter how the inlets trend, so that some day when these countries may be further elevated, the fiords shall all be converted into inland rock-bound freshwater lakes![2]

[1] Coruisk in Skye is another case in point on a smaller scale.

[2] The Lakes of Maggiore and Como were once fiords. Long

Fig. 95.

Mouth of Loch Etive, Connel Ferry.

This point is clear, that most of our country, as in Greenland and Victoria Land now, was in the icy period ground by a heavy weight of slowly moving and long enduring glacier-ice, which I firmly believe was the scooping power that originated most of the lake scenery of our country. I go further, for in ice-worn rocky regions, both north and south of the equator, the farther north or the farther south we go the more do lakes increase in number, and I am convinced, that this fact is not a mere accidental coincidence, but is one of the strongest proofs of the former existence of that widespread coating of glacier-ice that in old times moulded the face of so much of both hemispheres. The day has been when Greenland was a mild and fertile country,[1] and should such an episode return, its land-surface will be varied by a prodigious number of lakes, and should its fiords emerge, its splendid highland valleys will show many a long stretch of fresh water dotted with islands, like some of the lakes of Sweden, of Loch Lomond, and others in Scotland, or like Lake Champlain in North America.

This full theory, brought out in March, and published in August 1862, of the origin of so many lakes in the northern hemisphere, wherever there have been either widespread continental or even isolated mountain glaciers, was on the whole received with disfavour, or 'faint praise,' in England and Switzerland when first produced, and it fared but little better in the north of Italy, where, however, it was then allowed that it 'deserved the gravest attention,' and its general principles have since been accepted by Gastaldi. Now

before this was discovered I had proved them to be rock-bound glacier lake-basins.

[1] In Miocene times.

it finds its way into geological manuals, and many monographs, reports, and memoirs; in some of which it has been stated that it must in the long run be accepted as the origin of those rock-basins of the northern hemisphere that are occupied by lakes.[1]

Finally, if I were to classify lakes directly and indirectly produced by glacial action, it would be as follows—the first named being most and the last least numerous: 1st. True rock-basins scooped by glacier-ice out of the solid rocks. 2nd. Lake hollows due to irregular accumulation of moraine-matter on broad flattish surfaces, among which in many districts may be

[1] See Professor Geikie, 'Phenomena of the Glacial Drift of Scotland;' Sir William Logan, 'Report on the Geology of Canada,' 1863, where he states that the great North American lake-basins 'are depressions, not of geological structure, but of denudation; and the grooves on the surfaces of the rocks which descend under their waters appear to point to glacial action as one of the causes which have produced these depressions.' Also Dr. Newberry, in the 'American Annual of Scientific Discovery,' for 1863, and in other publications. Following my view, he allows that glacier-ice excavated all the great lakes, from Ontario to Lake Superior, excepting Lake Superior, an exception for which I see no necessity. See also reports by Dr. Julius Haast on the Geology of New Zealand; and the writings of Dr. Hector and Captain Hutton on the same region; Professor Geikie, 'The Scenery of Scotland viewed in connection with its Physical Geology,' 1867, and 'The Student's Manual of Geology,' by the late Professor Jukes, third edition, edited by Professor Geikie. Mr. Jukes strongly advocated this theory in papers in the 'Reader,' in a long controversy with the late Dr. Falconer. See also 'The Great Ice Age,' by James Geikie, F.R.S., both for lakes and fiords, and last, not least, the letter of Signor Gastaldi in the 'Journal of the Geological Society' to Sir Charles Lyell, 1873, vol. xxix., in which he says, 'I have given you summarily the reasons which have converted me to Mr. Ramsay's theory.' I could quote other authors on the same side of the question, and I am more than content with the rapid progress it has made. Sir Charles Lyell gives a qualified assent in his 'Student's Elements of Geology,' 1871.

included those dammed in by Eskers or Kames, well known on a large scale in Finland, and good examples of which, on a smaller scale, may be seen at Carstairs, and in the beautiful grounds of Castle Kennedy near Stranraer. Many of these lakes since their formation have got filled with alluvial detritus, and are now peat mosses. There are also many small hollows formed in original irregular accumulations of the boulder-clays of Northumberland and Durham, now filled with laminated clays, sands, and bearing fresh-water shells and plant-remains, and some of these shallow lakes still exist as such. 3rd. Moraine-dammed lakes, which I think on the whole are scarce, for many that appear to be so are in reality more than half rock-basins, or only dammed up by moraine-matter for a part of their depth.

Of lakes in Britain, formed by sinking of the ground, I know of none, save a few pools of water formed by the infalling of New Red Marl above salt-mines and brine-pits.

CHAPTER XXVIII.

NEWER PLIOCENE EPOCH, CONTINUED—BONE-CAVES, AND TRACES OF MAN—MIGRATION OF TERRESTRIAL ANIMALS INTO BRITAIN ACROSS THE DRIFT PLAINS—SUBSEQUENT SEPARATION OF BRITAIN FROM THE CONTINENT—DENUDATION OF THE COASTS OF BRITAIN.

I HAVE already said, and will here briefly recapitulate, that, during the Tertiary and later epochs, England has been repeatedly joined to the mainland: a circumstance proved by the mammalia that migrated hither after each successive emergence. Our Eocene terrestrial fauna, of a very antique type, is the same as that of the Eocene strata of France; our Miocene fauna (if the mammalia found in the Crag migrated hither in late Miocene times) is of the same general type as the fauna of some later Miocene phases of the Continent and this type, with important modifications, still continued after the Crag was raised out of the sea, and England was again joined to the Continent during the time that the vegetation of the 'Forest Bed' flourished. In the main the mammalian Miocene fauna of the world was the obvious predecessor of the fauna of the present day. The species are mostly different, the types mostly are the same.

In this 'Forest-bed,' elephants, hippopotami, rhinoceroses, horses, deer, oxen, pigs, a tiger, and bears, beavers, and other mammals abound, most of them of extinct species. Such large mammalia, on any hypothesis, did not originate in a small detached island like England, but formed parts of large families that inhabited the north of Europe, America, and Asia, at various comparatively late periods of geological time, and they could only have passed into our area by the union of England with the Continent.

Again, in the south of England, at Selsey Bill, there are post-Pliocene strata on the sea-shore, described by Mr. Godwin-Austen, one of the beds containing species of living marine shells, not belonging to icy seas, and overlaid by icy Boulder-drift. In the former there were found the remains of a well-known species of elephant, *E. antiquus*, lying on clay, on which stumps of trees, the remains of an old wood, still stand.

These Boulder-clays were formed during a period of cold, accompanied by the great glaciers that covered so much of the north of Europe, as I have already explained. While, or after the glaciers were largest, the country slowly sank, and, severed from the mainland, became merely groups of islands. But it was again elevated, and there is evidence that it was then united to the Continent, for we find in later deposits the remains of a number of terrestrial animals, some of the species of which are unknown in the older formations. The Elephants which lived before this time must have been driven out of our area by that submergence, unless some of them, with other mammalia, managed to live on in the extreme south of what is now England, which apparently suffered a smaller change of level. Farther north, such large animals as the Elephant, Rhinoceros, and Hippopotamus could not have lived on mere groups of icy islands, on which vegetation must have been scanty. They required a large amount of vegetation to feed on, and therefore they must have died out or been banished from our area by that partial submergence, the rivers of which, under any climatic conditions, could not have been sufficiently large to support numerous Hippopotami. We find, however, that on the re-elevation of the country, it must have been reunited to the Continent, because the great hairy elephant, *Elephas primigenius*, again appears, associated with a number of other animals that, after the re-elevation of the land, migrated from the Continent of Europe to our area, the bones of which are found in the old alluvia of rivers, partly of older and partly of younger date than the Glacial period. If, as is often stated, *E. primigenius* occur in the Forest-bed, then, in the opinion of most of our geologists, it lived in the British area before the beginning of the Glacial epoch, and therefore I say that the Mammoth reappeared, and as that great elephant is found in Scotland in early inter-glacial strata, it seems by no means improbable that he obtained a footing in our area in pre-glacial times.

This, indeed, is only one of several migrations of mammalia, that took place both from and into our country during various episodes that occurred in the long-continued Glacial epoch. It was for some time the fashion to attribute the occurrence in such superficial deposits of what may be called *conflicting faunas*, to the annual changes of summer and winter temperatures. In this way it was attempted to account for the presence of Lions, Hyænas, Hippopotami, &c., in strata supposed to be precisely of the same age with those that contain the bones of Reindeer, Mammoths, Musk-sheep (*Ovibos moschatus*), and White Bears. When the glaciers and the cold declined in summer, and ice disappeared from the rivers, then the Hippopotami made a raid to the north accompanied by Lions and Hyænas, and when the winter cold returned they retreated further south, leaving such snowy land as there was in exclusive possession of White Bears, Musk-sheep, Reindeer, and perhaps hairy Mammoths with a warm coat of wool beneath the long hair. But with the advance of research interglacial episodes began to be established, when, in the language of Mr. James Geikie, there took place 'a great recession of the confluent glaciers consequent upon a change of climate.'[1]

In connection with this subject it is now necessary to say something of the bones found in limestone caves, especially as the subject is intimately connected, not only with a large and partially extinct mammalian fauna, but also with the presence of man as a hunting denizen of the British area, at the time in which these carnivorous and browsing mammalia roamed the country.

Bone-caves are often of very old date, and always occur in limestone strata, in which they have been formed in consequence of part of the carbonate of lime having been dissolved. Most solid limestone rocks are jointed: that is to say, they are parted by narrow fissures, often vertical, through which water that falls on the surface can easily find its way. Rain-water percolates through the joints, and the carbonic acid, picked up by the water as it falls through the air, by degrees dissolves part of the limestone, and carries it away in solution in the form of bicarbonate of lime. Running in underground channels, caves have thus been formed, often of great extent, and branching in many directions, through which streams sometimes still run.[2]

[1] 'The Great Ice Age,' p. 339, second edition.

[2] The great limestone caves of Kentucky form the most pro-

Close to Clapham, in Yorkshire, in the grounds of Ingleborough, such a cave runs from the side of a limestone gorge into the hill, 800 yards in length, and no doubt further if it were followed. From its top, 'like natural sculpture in cathedral cavern,' beautiful stalactitic pendants and pillars descend to the floor; delicate open arcades run along the ledges, large fretted accretions of stalagmite swell out in the angles of the cavern between the floor and sides, and great flat pendants of stalactite hang like petrified banners from the walls. Sometimes the cavern runs in a long low gallery, sometimes it rises into high chambers, scooped into ogee arches; and wherever a chamber occurs, there we find a joint in the rocks, through which water from above percolates, and continues the work of sculpture. The whole is the result of the dissolving of carbonate of lime by carbonic acid in the water; and modern drippings and a rivulet in the cavern still carry on the work through all its length. White rats live in the cave, and fresh-water shrimps, perhaps washed from above, have been seen in the brooklet; but I am not aware that any fossil bones have been found in it, though they are common in other caverns in the same county near Settle, in the Carboniferous Limestone of Derbyshire, North and South Wales, the Mendip Hills, and in the limestone caverns of many other parts of England.

It is impossible to fix with absolute accuracy the precise age of such caves, or the time when all the bones that are fouud in them were buried there; for the

minent examples. At Ottawa a large part of the river falls into a chasm in Silurian limestone and is seen no more. The *perte du Rhône*, below the Lake of Geneva, is a minor example. The Caldes of Yorkshire, where large brooks flow from limestone caves at the sides of the valleys of mountain limestone, are well known. I have already, p. 436, mentioned others in the Jura.

wearing out of the caves has been going on for unknown periods of time, and some of them may have been filled with sediments, perhaps charged with bones, again and again. There is often proof that, by underground changes of waterflow, old consolidated gravels that filled them to the roof have been, at various periods, forcibly cleared out by natural means. When, therefore, we find bones in these caverns, mixed with red loam, sand, gravels, and angular fragments of rock, it is very difficult, and perhaps sometimes impossible, to define to what precise *minor period* they belong; for, *viewed on a large scale, all periods from later Miocene times downwards are minor periods.*

In such caves the bones of extinct mammals, probably of pre-Glacial, and certainly sometimes of Glacial times, are found, together with the remains of species that still inhabit our country and the Continent of Europe; and as it is hard to separate them, I must devote these paragraphs to caves in general.

Sometimes the skeletons, or parts of them, seem to have found their way in through the mouths of the caverns; more frequently they were washed in through 'pot-holes' and openings in their roofs. On the verge of the mouths of large bell-shaped pot-holes, on the Carboniferous Limestone plateaux of Yorkshire, under which we hear the water rushing, I have often seen the carcases, or detached bones, of sheep waiting for a flood to be carried below.

Sometimes the detached bones of animals, or the animals themselves, have been dragged in by beasts of prey, such as Bears and Hyænas, that inhabited these caves. One evidence of this is, that the bones are frequently gnawed, and still bear the marks of the teeth of carnivora, as first shown by Dr. Buckland; and another, that the angles of the caverns themselves are occasionally smooth, having been polished by the animals rubbing against the rock, as they passed by corners and along other uneven surfaces on their way into and out of their dens.

I repeat that there is no doubt that many of these caves date from before the Glacial epoch, and therefore that the bones of animals must have found their way into some of them before that period, 'while yet our England was a wolfish den'; and since the glaciers died away many of the caves have been more or less tenanted down to the present day, or bones have been at intervals washed into them; and thus it happens, that organic remains of older date than the Glacial epoch may be found in the same cave with bones belonging to that period, and to minor epochs that come down to historical times, and even to our own day.

Mingled with the bones of extinct and modern species in England and Wales, flint implements, and other works of man, have been found; and though it has often been said that these are of later date than the remains of extinct species sometimes found in the glacial deposits, it has not only not been *proved* that this is the case, but in my opinion, and in that of many competent judges, the very opposite view has been reduced to a demonstration. Some of the Devonshire caves in which works of man were found, having apparently been above the sea during the whole of the Glacial epoch men frequented them. Others farther north, like that of Cefn in North Wales, were below the sea during part of the Glacial epoch, for the boulder-beds reach a higher level; and, with Dr. Falconer, I found fragments of marine shells of the drift in the cave overlying the detritus that held the bones of elephants and other mammalia. No human remains were found in that cavern. During part of the time some of the caves in the south of England seem to have been inhabited, while others farther north lay underneath the ice-sheet, so that part of the northern land was desolate, and for a time uninhabited by beast or man. This, however, is certain, that man, the Mammoth, and other extinct mammalia, were contemporaneous, and to make this general statement more definite, I shall give a condensed account of the proofs on which it rests, selecting for that purpose some of the caves that have been explored by competent observers.

First, however, I will observe that the bones of wild animals, together with implements made by man, have in all the caverns generally been preserved in much the same manner. As already stated, they were often washed into caverns from above through fissures, and sometimes they were carried in by beasts of prey through the mouths of dry caves. Often, in some of the lower strata of caverns, they lie in a red loamy earth mixed with stones. Over this there frequently lies a thick deposit of *stalagmite* or carbonate of lime, deposited from water dropping from the roofs of the caverns. Some caves are, or have been, filled or almost filled, with stalagmite, and in it bones, horns, and other relics are buried. In this way bones became sealed up in the caves safe from the effects of air and, to some extent, of moisture; and the result has been the natural burial and preservation of those old races of animals that formerly inhabited our land.

At least thirty-six British caves have been recorded as holding the remains of terrestrial mammalia, and doubtless the list will be largely increased. I will arrange those I have to notice geographically, beginning with the north of England, and I may mention that England is peculiarly fortunate in the possession of so many dens and caverns, most of which have been excavated by natural processes in Carboniferous Limestone, which forms such large tracts of country both in England and Wales. The remainder are chiefly in the Devonian Limestone of Devonshire, while a few are in Oolitic or other limestone strata. In connection with this subject, it is worthy of remark, that the poverty of Scotland in the fossilised bones of Elephants, Hippopotami, Rhinoceroses, Lions, and perhaps of man or his works, is, doubtless, chiefly due to the general absence in that country of large masses of Carboniferous Limestone, while Ireland, more than half the surface of which is made of Carboniferous Limestone, will probably yield a rich crop of such organic remains, when leisure permits people to search for them.

The Victoria Cave, near Settle in Yorkshire, is entered at the base of a Scar in the Carboniferous Limestone, at a height of about 1,450 feet above the sea. Since 1870, it has been carefully excavated under a trustworthy committee, and reports have been issued on the subject by Professor Boyd Dawkins, and since 1873 by Mr. R. H. Tiddeman of the Geological Survey. The mouth of the cave was at first much obscured by talus, fallen from the cliff or Scar, and when this was removed, a layer was found inside the cavern, partly composed of charcoal and burnt bones. It was on this layer that the original discoverer of the cavern, Mr. Jackson of Settle, found, in 1838, coins, iron spear-heads, brooches, and many other articles, all pointing to the fact that the cave had been tenanted during, or not long after, the Roman occupation of Britain. All this comes easily within the range of what may be called modern history.

Beneath this stratum there lies partly at the entrance of the cavern an accumulation of angular stones, about six feet thick, at the base of which, resting on grey clay, there occurred charcoal, a bone bead, flint flakes, and broken bones of the Brown Bear, Stag, Horse, and *Bos longifrons* (Celtic shorthorn). Professor Dawkins guardedly speculates on the date of this human occupation, as having been 'about 4,000 or 5,000 years ago,'[1] a moderate computation of a portion of backward time that few will grudge, and which to my mind seems short compared with the earlier history of man and other mammalia in relation to this cavern.

Beneath these shingly deposits at the entrance of the cave, and 'at the base of all the talus'[2] there was found a genuine glacial Boulder-clay, charged with ice-scratched stones and boulders, consisting of upper Carboniferous black limestone derived from the north, conglomerates from the base of the Carboniferous Limestone also from the north, while other boulders consisted of Carboniferous sandstones, and 'a very large proportion of Silurian rocks,' the nearest large areas of which are in Cumbria and the south of Scotland. The extent of these Boulder-clays has been proved over an area of 1,200 square feet, and this lies upon the edges of deposits of grey clay, and a lower reddish cave-earth, which is a kind of loam peculiar to many bone-caves. The local absence of Boulder-clay on the ground at the top of the cliff, shows that the material could not have fallen from above before the accumulation of the

[1] 'Cave Hunting,' p. 115.

[2] R. H. Tiddeman, Victoria Cave Exploration Committee, 1875.

shingly débris called 'screes,' and, in Mr. Tiddeman's opinion, this Boulder-clay forms part of the ground-moraine of a great glacier coming from the north, such as that described in Chapter XXIV.

'The bones in the caverns,' says Mr. Tiddeman, 'appear to group themselves chiefly along two horizons, which are separated from one another by a greater or less thickness of cave-earth, laminated clay, and stalagmite.' The organic remains found in these beds are arranged by him as follows:—

	Man.	Hyæna.	Fox.	Grizzly Bear.	Brown Bear.	Badger.	Elephas Antiquus.	Horse.	Rhinoceros leptorhinus.	Hippopotamus.	Pig.	Red-deer.	Reindeer.	Bos primigenius.	Goat or Sheep.
Upper Bed	×	—	×	×	—	×	—	×	—	—	×	×	×	?	×
Lower Bed	×	×	×	×	×	—	×		×	×		×	—	×	—

The general assemblage closely resembles that found in 1821 by Dr. Buckland in the famous Kirkdale Cave in the Vale of Pickering in Yorkshire, and such as is also known in the Dream Cave, and others near Wirksworth in Derbyshire. In the Victoria Cave all the bones in the lower bed are marked by the gnawing of the teeth of Hyænas. One bone from this bed is of special interest, a fragment which Mr. Busk identified as part of a human fibula. No one doubts the existence of man along with the modern fauna of the upper bed, which is later than the Boulder-clay. But a man co-existent with a Glacial, or probably a pre-Glacial fauna, is a very different matter, and, accordingly, some eminent osteologists have lately declared that though they cannot assert that the fragment is not part of the bone of a man, on the other hand they cannot deny that it may just as well be part of the fibula of a bear.

On a point such as this, though I have been in the cave, I have no claim to form an opinion, but subsequent paragraphs will show that though at present the question has not been decided by the evidence yielded by the Victoria Cave, there are yet grounds for the certain belief, that man in the British area lived in inter-Glacial and probably even in pre-Glacial times.

The next caves I shall mention are, like the Victoria Cave, of unusual importance, because of their contents and the careful manner in which they have been explored by the Rev. J. Magens Mello and Mr. Thomas Heath, assisted in the determination of species by Professor Boyd Dawkins. These caverns occur in the Magnesian Limestone (Permian) of Creswell Crags in Derbyshire, about ten miles ENE. of Chesterfield, and two miles SSE. of Whitwell. Three of the explored caves are known by the names of Robin Hood's Cave, the Pin Hole, and Church Hole.

In the first-named the layers consist in descending order of:

1. Stalagmite, 2 ft.
2. Breccia, with bones and flint implements, 1 ft. 6 in.
3. Cave-earth, with bones and implements, 1 ft. 9 in.
4. Mottled bed, with bones and implements, 2 ft.
5. Red sand, with bones and quartzite implements.

The upper soil in the cavern 'yielded traces of Romano-British occupation, such as enamelled bronze fibulæ, fragments of pottery,' &c. 'In the surface soil and in the *upper part* of the Breccia (No. 2), there occur some bones of the domestic hog, goat, sheep, and Celtic shorthorn, but no implements of a Neolithic type were found associated with these.' Beneath this upper part, the explorers found 'teeth and bones of the bear, the fox, the hare, the reindeer, the hyæna, and the woolly rhinoceros and horse. Together with these were found numerous flint implements, mostly chips and flakes, but some few of them were carefully wrought lanceolate weapons, trimmed on either side.'

'The cave-earth below the Breccia contained the relics of a similar fauna, with one or two additions, but a different type of implements was met with . . . none presenting the more elaborately-shaped forms of those of the Breccia.' One or two are of bone, and numerous implements of quartzite rudely fashioned from water-worn pebbles, and, as pointed out by Professor Dawkins, they are of an earlier type than those found in the overlying Breccia.

The red sand bed at the base of all also contained relics of most of the animals common in the overlying strata, but no traces of human bones or works have yet been found therein.

Exclusive of the uppermost part of the Breccia, No. 2, the following remains of Mammalia have been found: Man, Lion (var. *Felis spelæa*), *Hyæna spelæa*, the Fox, Wolf, Bears (*Ursus ferox* and *U. arctos*), *Cervus Megaceros* (great Irish deer), Reindeer, *Bison priscus*, Horse, *Rhinoceros tichorhinus*, *Elephas primigenius* (Mammoth), Pig and Hare.

One point seems to be certain, that between the Romano-British epoch and the sub-epochs recorded in the table of strata given above there is a great gulf. From the historical epoch we make a sudden leap 'in the dark backward and abysm of time,' into the elephantine era of Palæolithic man, for no instrument of Neolithic type has been found in any of the caverns. Further, the remains indicate two climatal stages, 'when man, the hunter and fisherman, endured all the vicissitudes of a climate, at one time mild enough for the Hippopotamus to be an occupant of the Yorkshire rivers, at another so severe that amid the snow and ice of an Arctic winter he would have to struggle for existence in company with the Reindeer, the Glutton, and the Arctic Fox.'

As these and many other caves of England are doubtless of pre-glacial origin as to their original scooping out, it may well be that some of the bones are as old as those found beneath the boulder-beds of the Victoria Cave, but of this there is no absolute proof.

The next caves I have to mention are those on the western side of the Vale of Clwyd, which lie in the escarpment of the Carboniferous Limestone that rises from under the New Red Sandstone which fills the lower part of the valley. One of these is the well-known bone-bearing cave of Cefn, described in 1833 by Mr. Stanley, afterwards Bishop of Norwich. This cave and part of its contents I have seen along with Mrs. Wynn of Cefn, and the late Dr. Falconer, whose researches on the extinct mammalia of India are so well known. Among the bones found in the cave are *Elephas antiquus* (the ancient representative of the modern African elephant), *Rhinoceros hemitœchus*, *Hippopotamus*, Cave-Bear, Spotted Hyæna, and Reindeer. In this cave a human skull and cut antlers of a stag were discovered 'in the lower entrance,' as described by Professor Boyd Dawkins, but no attempt has been made to separate the flint implements found in these caves into Palæolithic and Neolithic ;[1] nor has anyone determined that any of the bones belonged to distinct

[1] See pp. 540 and 545 for figures of Palæolithic and Neolithic flint implements.

pre-Glacial, inter-Glacial, or post-Glacial epochs. My own strong impression—for I may not call it conviction—is, that some or all of the bones found a way into the Cefn Cave before the partial submersion of Wales during the Glacial epoch, and were sealed therein before the shelly sands were deposited in the cavern, as recorded at page 462.

It is certain that the Vale of Clwyd at that time was occupied by the sea, for the Boulder-clay of the banks of the River Elwy is charged with well-preserved sea-shells, and if Moel Tryfan was submerged 1,175 feet, it is unlikely that the Vale of Clwyd did not suffer something like an equal submergence. *Elephas antiquus* and *Elephas primigenius* are alike known as animals that lived, the last in Glacial, and the former, in pre-Glacial time, and if, as I believe, the former be the ancestral precursor of the African, and the latter of the Indian elephant, it may be hard to determine which has the oldest ancestry as a distinct species, while it is by no means certain that both species may not have crossed into the British area before the advent of the Glacial epoch.

Going further south, the limestone cliffs of the promontory of Gower are penetrated by no fewer than ten caverns, all of which have been more or less explored—one, the Paviland Cave, by Dr. Buckland in 1823, and the others by Colonel Wood since 1848. They yielded a vast number of bones, according to Falconer of almost every species elsewhere known in British caves, including *E. primigenius* and *E. antiquus*, *Rhinoceros primigenius*, and *R. hemitœchus*, *Hippopotamus major*, Hyæna, Cave-Bear, Wolf, Fox, &c., and in one cave, called Bosco's Den, there were found a thousand shed antlers of the Reindeer, which were extracted by Colonel Wood. In one of the caves, called Long Hole, he made the important discovery of *Rhinoceros tichorhinus*, and *R. hemitœchus*, along with manufactured flint knives in the same undisturbed deposit.

In the Paviland Cave, which was unscientifically opened before it was visited by Dr. Buckland, there were found the remains of the Mammoth, Woolly Rhinoceros, Hyæna, Cave-Bear, and many other animals in red earth, under the usual crust of stalagmite which formed the upper floor. With these was found a human skeleton, stained red by infiltration of an oxide of iron, and called by the quarrymen, 'the red lady of Paviland.' According to Dr. Buckland, the contents of the cavern seemed to have been disturbed by old diggings, and it was therefore his opinion that the body had been buried there at some ancient time. This cave must probably have been inhabited, for charcoal and sea-shells of edible species were found in it, and near the skeleton some carved beads and ornaments of ivory, possibly made from the tusks of the Mammoth, which with the skull lay close by the body. It is also said that a small chipped flint was found in the same place.

I have no doubt that the antiquity of this famous skeleton must be very great, but who can tell how old, not in years, but according to standards of comparative geological antiquity? Even though the débris had been disturbed there is no valid reason why the man should not have been coeval with the Mammoth and his contemporary Mammalia, for the figure of that great hairy elephant, with its enormous curved tusks carved on its own ivory, has been found at La Madelaine in the Dordogne; and in Denmark there was found a skull of this species with a flint arrow-head sticking in the bone. How late they survived in Europe no written history tells, though the unwritten history of flint weapons in caverns shows that Palæolithic man hunted the great beast; while in Asia, as all readers know, his whole body has more than once in summer dropped out of the frozen mud cliffs of the great Siberian rivers, a region in which he, perhaps, survived very much later than in Europe. We may be permitted to regret that 'the red lady of Paviland' was exhumed 44 years ago, long before the art of 'Cave Hunting' ranked as a branch of palæontological science in which an early history of man is involved.

On the west side of Caermarthen Bay lies Caldy Island, about a mile from the Pembrokeshire shore, near Tenby. About forty years ago a cave was discovered there in the northern sea-cliff, which was quarried for limestone, and which I visited with Dr. Buckland in 1841, when the last relics of the cavern were disappearing under the operations of the quarrymen. Bones and teeth of Mammoths, Rhinoceroses, Hyænas, Lions, and other Mammalia common in such caves occurred in abundance, and I well remember the glee with which Dr. Buckland on his knees gathered the bony harvest into a large silk bandana, while surreptitiously I sketched him in the act. Other caves have since been explored in Caldy, and on the mainland of Pembrokeshire, with like results.

I specially mention the caves in Caldy, because they help to prove the long lapse of time that has taken place since so many great mammals lived on ground, part of which is now only an island one mile in length. It must indeed have taken a great number of years for atmospheric influences and sea waves to have worn a channel a mile in width so as to separate the island from the mainland, for the waste of sea cliffs as hard as the Carboniferous Limestone is so slow, that the lifetime of generations of men sees but little change in their outlines, and rude camps and earthworks of unknown age even now stand on many a hard rocky promontory, almost as fresh as the day when they were first constructed. These were my first reflections when I saw the traces of the old mammalian inhabitants of what now is Caldy, and the same train of thought is entertained by Professor Dawkins in his book on 'Cave Hunting.' They are sufficiently obvious to all who are not imbued with a sense of unprovable and needless cataclysmic forces.

On the eastern side of the upper part of Bristol Channel, the Mendip Hills, and other large bosses of Carboniferous Limestone, are seamed by numerous caverns charged with bones. Taken all in all, the assemblage is much the same as that found in the caves already mentioned, and like some of these, the bones, as remarked by Dr. Buckland, were carried into underground water-channels by streams falling into swallow-holes. This involves a very considerable change in the physical geography of the region since these streams ran. Unless the Carboniferous Limestone be more or less coated with impermeable strata, such as Red Marl, Lias clay, or Boulder-clay, the rain immediately sinks through innumerable joints open to the surface, and thus it happens that rivers, or even unimportant brooks, are rare in tracts formed exclusively of masses of limestone. From the evidence of outlying remnants, it seems probable that the Mendip Hills were once extensively covered by a thin casing of Lias clay, over which streams ran in the Pleistocene epoch, and carried the bones of dead animals into swallow-holes, just as at the present day, in the upper valleys of the Jura, good-sized streams are engulfed in swallow-holes of marly Miocene beds, to pass into the Jurassic limestones below, and again to reappear as ready-made rivers in deep transverse valleys, as, for example, in the Val de Travers below Combe Varin. The removal from the surface of the Mendip Hills of such strata by ordinary denuding agents, must have occupied a period of time long and of unknown duration.

There is, however, another view of the subject which cannot fail to strike a reflective mind with wonder, speaking as it does so strongly of time. In those caves which were not hyæna dens, thousands of bones of grazing animals and of carnivora, are found crowded together 'in most admired confusion.' Lions and hyænas did not specially prefer to devour their prey at the mouths of swallow-holes, nor was the surface of the ground strewn broadcast with bones of carnivora and other mammals, like gravel-stones on many a fresh ploughed field; and when we think of bones, horns, and teeth, 'by the thousand,' in so many large caverns, most of which must have been washed in by very slow degrees, the mind, for this reason alone, becomes powerfully impressed with the idea of the long endurance of so-called Pleistocene time.

On the south side of the Mendip Hills, about a mile and a half north-west of Wells, there is a hyæna den called Wookey Hole, which has been hollowed out in the dolomitic conglomerate, which in so many places fringes and lies unconformably on the Carboniferous Limestone.

This cave was discovered in 1852, and from 1859 to 1863 it was systematically explored by Professor Boyd Dawkins, the Rev. J. Williamson, and Messrs. Willett, Parker, and Ayshford Sanford. Professor Dawkins gives an admirable account of the work in his 'Cave Hunting,' to which I must refer my readers for a number of interesting and graphic details. When first opened in 1852 'the workmen found more than 300 Roman coins, among which were those of Allectus and Commodus.' As the work progressed year by year, and the contents of the cave were cleared out and examined, vast numbers of bones and teeth and horns were discovered, under conditions which proved that they were not introduced by water, but that the cavern had been a veritable hyæna den, which at intervals had also been occupied by savage men, as the occurrence of charcoal, calcined bones, and distinctly formed implements of flint and chert clearly testified. All of these implements are of Palæolithic type (see fig. 112, p. 540).

To give an idea of the quantity of bones, Mr. Dawkins states that 'the remains obtained in 1862–3, from 3,000 to 4,000 in number, afford a vivid picture of the animal life of the time in Somerset. They belong to the following animals, the implements representing the presence of Man :—

Man	35	Woolly Rhinoceros	233
Cave-Hyæna	467	Rhinoceros hemitæchus	2
Cave-Lion	15	Horse	401
Cave-Bear	27	The Great Urus	16
Grizzly Bear	11	Bison	30
Brown Bear	11	Cervus Megaceros	35
Wolf	7	Reindeer	30
Fox	8	Red Deer	2
Mammoth	30	Lemming	1

The remains of these animals were so intermingled, that they must have been living at the same time.' I cannot refrain from adding Mr. Dawkins' vivid description 'of the condition of things at the time the hyæna den was inhabited. The hyænas were the normal occupants of the cave, and thither they brought their prey. We can realise these animals pursuing elephants and rhinoceroses along the slopes of the Mendip till they scared them into the precipitous ravine, or watching until the strength of a disabled bear or lion ebbed away sufficiently to allow of its being overcome by their cowardly strength. Man appeared from time to time upon the scene—a miserable savage armed with bow and spear, unacquainted with metals, but defended from the cold by coats of skin. Sometimes he took possession of the den and drove out the hyænas—for it is impossible for both to have lived in the same cave at the same time. He kindled his fires at the entrance to cook his food and to keep away the wild animals; then he went away, and the hyænas came back to their old abode.'

Kent's Hole, near Torquay, in Devonshire, has long been one of the most famous caverns in England. Mr. Pengelly, F.R.S., has given an extensive account of the 'Literature of Kent's Cavern' in the 'Transactions of the Devonshire Association,' from which it appears that Mr. Thomas Northmore of Exeter first dug through the stalagmitic covering, and 'exclaiming with joy, "Here it is!" pulled out an old worn-down tusk of a Hyæna, and soon afterwards a metatarsal bone of the Cavern-Bear,' and among twenty or thirty other teeth and bones 'were two jaws, upper and lower, of either the Wolf or the Fox.' In 1827, Mr. (afterwards Sir) Henry De la Beche mentions the cavern as 'celebrated on account of the remains of elephants, rhinoceroses, hyænas, bears, deer, wolves, &c.,' and specially connects this discovery with the name of the Rev. John McEnery, who had previously made a valuable collection of such remains with the intention of publishing a descriptive account of his CAVERN RESEARCHES. The manuscript, which was in the possession of Mr. E. Vivian, who published portions of it, has wisely been printed entire by Mr. Pengelly with all its imperfections. When it was begun no one knows, but 'some portions of it are certainly not older than the year 1836 . . . and no portion can be assigned to a later date than 1840, as the author's decease took place on February 18, 1841.'

To analyse the whole of Mr. McEnery's mutilated fasciculus is needless in a work like this, and it is enough to state that under the upper and lower stalagmites he recognised the bones and teeth of the Mammoth (*E. primigenius*), Rhinoceros, Horse, Ox, (bison ?) Irish Elk (*Cervus megaceros*), Red Deer, Stag, Fallow Deer, Reindeer, Bears (*Ursus cultridens*, *U. Spelæus*, *U. Arctoideus*, *U. Priscus*), Hyæna, Wolf, and doubtless others unnamed.[1] He specially recognised that the bones had been gnawed, and also insists on the fact that flint implements occur in intimate association with the bones. In 1840 Mr. Godwin-Austen makes the remark that 'arrow-heads and knives of flint occur in all parts of the cave and throughout the entire thickness of the clay, and no distinction, founded on condition, distribution, or relative position, can be observed whereby the human can be separated from the other reliquiæ ;'[2] and further on he adds, 'there is no ground why we should separate man from that period and those accidents when and by which the cave was filled.' The breadth of these remarks (unacceptable at the time), by an experienced observer, who has on this and other sub-

[1] I print these from the imperfect Fasciculus G as they stand, with the exception of the Wolf, mentioned elsewhere.

[2] 'Trans. Geol. Soc.,' London, second series, vol. vi., t. 2, p. 444.

jects often been years before his time, left but little in the way of theory for subsequent observers, though there still remains plenty of work in detail.

All the flint instruments and flakes found in this cavern below the upper stalagmite, are of palæolithic types, a fact of much importance [1] in relation to the antiquity of man.

The last cave that I shall mention is that of Brixham, Devonshire, in the limestone that forms the south side of Tor Bay. It was discovered in 1858, and Mr. Pengelly at once saw the necessity of securing the right of exploration, so as to ensure the most accurate possible examination of its contents and the mode of their occurrence. Of this committee I happened to be one of the members, and to 'Mr. Pengelly the committee are indebted for the active and constant superintendence of the work and for the record of each day's proceedings.' [2] In the same summer I visited the cave with Dr. Falconer and Mr. Pengelly, and made a plan of it; and at a later date it was resurveyed by Mr. Bristow, whose plan is published in the 'Philosophical Transactions,' to accompany the report drawn up by Mr. Prestwich. At that time the stalagmitic floor of the cavern was mostly undisturbed, and a Reindeer's horn was firmly cemented in the stalagmite. In the first six weeks of the workings about 1,500 bones were exhumed, a large number of which belonged 'to skeletons of small animals, like the Rabbit and Fox, found near the surface.'

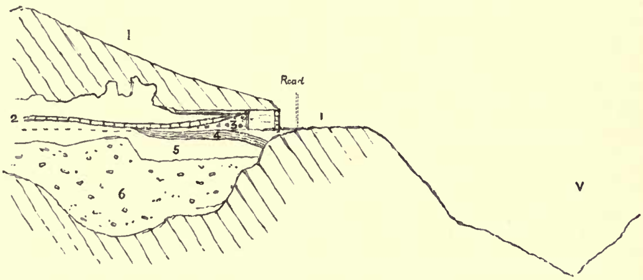
In part of the cave, which has many ramifications,

[1] See 'Ancient Stone Implements, &c.' by John Evans, F.R.S., F.S.A. &c. pp. 442–466.

[2] Report on the exploration of the Brigham Cave, 'Philosophical Transactions of the Royal Society,' 1873, vol. clxiii. p. 475.

the section was subsequently proved to be as follows, in descending order:

Fig. 96.



1. Devonian Limestone.
2. Stalagmite.
3. Breccia.
4. Black bed.
5. Cave-earth.
6. Shingle.
v. Valley.

The cave is about 66 feet above the bottom of the valley V.

The exploration, as far as it could conveniently be followed, was completed in the summer of 1859, the work having been carried on in galleries, which, with many ramifications, comprised a space measuring 135 feet from north to south and 100 from east to west, as reported by Mr. Pengelly.

In the abstract of the report by Professor Prestwich, published in the 'Proceedings of the Royal Society,' vol. xx. 1872, it is stated that 'mammalian remains were found sparingly in the stalagmite, No. 2, in abundance in the cave-earth, No. 5, and rarely in the shingle, No. 6.' They are of the following species: *Elephas primigenius* (Mammoth), *Rhinoceros tichorhinus* (Woolly Rhinoceros), *Equus caballus* (common Horse), *Bos primigenius*, *Bos taurus* (common Ox), *Cervus elaphus* (Red Deer), *C. tarandus* (Reindeer), *Capreolus capreolus* (Goat), *Felis leo* (var. *spelæa*, Lion), *Hyæna spelæa*, *Ursus spelæus*, *Ursus ferox* (Grizzly Bear), *Ursus arctos* (Brown Bear), *Canis vulpes* (Fox), *Lepus timidus* (Hare), *Lepus cuniculus* (Rabbit), *Lagomys spelæus* (Hare-rat of Siberia), *Arvicola amphibius* (Water-rat), and *Sorex vulgaris* (Shrew-mouse).

Of these the small mammalia of living species were found near the surface, and were no doubt of comparatively recent introduction. Of the remainder a few were discovered in the stalagmite, No. 2, but by far the greater number in the cave-earth, No. 5, while a small number also occurred in the shingle, No. 6. As in some other cases, previously mentioned, the cave was sometimes a Hyæna den, for the bones bear the marks of their teeth, and at a period a little later, 'the great number of very young, or even fœtal bones, afford the strongest possible evidence that the Bear actually inhabited the cavern.' With regard to the traces of man, 'not a single human bone has been found in Brixham Cave; but thirty-six rude flint implements and chips, referable to man's workmanship, were met with in different parts of the cave; of these sixteen were found in the shingle, No. 6 . . . In fourteen instances their infraposition to bones of the Mammoth, Rhinoceros, Hyæna, Tiger, (? Lion), Bear, Reindeer, Red Deer, Horse, and Ox, is perfectly well proved, as many as 120 of such bones having been discovered higher in the cave-earth' than the place where these flints were found. Woodcuts of some of the instruments given by Mr. Evans in his report on the implements discovered, leaves no doubt that they were fashioned by man, and all of them are of undoubted early palæolithic type, more or less similar to fig. 112, p. 540.

As far as caves are concerned, this concludes the evidence of the co-existence of savage man with a mammalian fauna, some of the species of which are extinct; but excepting the Victoria Cave, none of the others yield any direct evidence as to whether man lived in these regions before or, at least, during part of the Glacial epoch (see p. 466). Something else, however, remains to be said on this part of the subject when I come to treat of river-gravels and alluvia.[1]

The antiquity of man being thus clearly established, it becomes obvious that his advent into our area was either of pre-Glacial or of inter-Glacial date. I say inter-Glacial, because Mr. Skertchly has lately discovered palæolithic flint implements in certain brick-earths. Similar, and I believe identical brick-earths underlie the 'Chalky boulder-clay' in the neighbourhood, the boulder-clay having been removed by denudation from that portion of the brick-earth in which the implements were found at Botany Bay near Thetford in Suffolk. The announcement at once provoked strenuous opposition, and therefore on a tour of inspection of Mr.

[1] A list of cave mammalia is given by Professor Boyd Dawkins in a memoir in the Journ. Geol. Society, 1869, vol. xxv. p. 194. His entire list contains 46 or 47 species, as follows; Man, Rhinolophus ferum-equinum, Sorex vulgaris, Ursus arctos, U. spelæus, U. ferox, Gulo luscus, (the Glutton), Meles taxus, Mustela erminea, M. putorius, M. martes, Lutra vulgaris, Canis vulpes, C. lupus, Hyæna spelæa, Felis catus, F. pardus, F. leo, F. lynx, Machairodus latidens, Cervus megaceros, Alces malchis, Cervus Browni, C. tarandus, C. capreolus, C. elaphus, Bos primigenius, Bison priscus, Hippopotamus major, Sus scrofa, Equus caballus, Rhinoceros leptorhinus, R. tichorhinus, Elephas antiquus, E. primigenius, Lemmus, Lepus curriculus, L. timidus, Lagomys spelæus, Spermophilus erythrogenoides, S.——(?), Arvicola pratensis, A. agrestis, A amphibius, Castor fiber, Mus musculus. Mr. Pengelley has written many important papers on Bone-Caves and their connection with prehistoric man.

Skertchly's work with Mr. Bristow, we took care to examine into this point. The result was that I satisfied myself of the truth of Mr. Skertchly's observations that the implement-bearing brick-earth in places underlies a boulder-clay, which in his opinion is not of the earliest date, in which case the men who made these tools must have been of inter-Glacial age. If so, why may these men not have been the descendants of men who inhabited the country in pre-Glacial times, and who, when the cold increased, and sheets of glacier-ice advanced far south, retreated into the Devonshire area, as I have hinted in page 470. Perhaps we cannot prove it, but there is nothing improbable in the hypothesis, and I am not the only one who believes it. One thing is certain, that when rude man, along with other mammalia, some of them extinct, first migrated into the British area, he must have done so over land, and no one doubts that in all tertiary and post-tertiary time Britain has been again and again united to the Continent, both before and after the Glacial epoch. For example:

After the elevation of the country that succeeded its partial depression under the sea during part of the Glacial period, the probabilities are more than strong, that England was united to the Continent, not by a mass of solid rock above the sea level, but by a plain formed by the elevation of the Boulder-beds over part at least of the area now occupied by the German Ocean. Across this plain many animals migrated into our area, some of the species probably for the second time. It is the belief of many geologists, that at the same period Ireland was united to England and Scotland by a similar plain across the area now covered by the Irish Sea, and over this, into Ireland, the *Cervus megaceros*, formerly called the Irish Elk, the Mammoth, and other animals migrated into that region. The proof is equally clear that Ireland during part of the Glacial period, like England, was partly submerged, so as to form a group of islands; and, therefore, to allow of the country being re-inhabited by large mammals, there must have been ground over which these mammals travelled into the Irish area after the re-elevation of the country.

An excellent surmise was offered us on this subject by Professor Edward Forbes, who drew attention to some remarkable observations made by Mr. Thompson of Belfast with regard to the comparative number of reptiles that are found in Belgium, in England, and in Ireland. In Belgium there are in all 22 species of serpents, frogs, toads, lizards, and the like. In England the number of species is only 11, and in Ireland 5; and the inference that Professor Forbes drew was, that these reptiles migrated from east to west, across the old land that joined our island to the Continent, before the denudations took place that disunited them. Before the breaking up of that land, a certain number had got as far as England, and a smaller number as far as Ireland, and the continuity of the land being broken up, their further progress was stopped.

These denudations, of course, did not cease with the breaking up of the land that joined our territory to the Continent; and, in raised beaches and submerged forests, there are proofs of several oscillations of the relative levels of sea and land since that period. This waste of territory is, indeed, going on still, and will always go on while a fragment of Britain remains. Before proceeding further I would advance one or two proofs to show how steady the waste of our country is.

Along the east coast of England, between Flamborough Head and Kilnsea, the strata are composed of drift or boulder-clay, sometimes of more than a hundred feet in *known* thickness, and forming well-marked sea cliffs. This district is called Holderness, and many towns, long ago built upon the coast, have been forced by degrees to migrate landwards because of the encroachment of the sea. 'The materials,' says Professor Phillips, 'which fall from the wasting cliff' (a length of 36 miles) 'are sorted by the tide, the whole shore is in motion, every cliff is hastening to its fall, the parishes are contracted, the churches wasted away.' The whole area on which Ravenspur stood, once an important town in Yorkshire, where Bolingbroke, afterwards Henry IV., landed in 1399, is now fairly out at sea. The same may be said of many another town and farmstead, and the sea is ever muddy with the wasting of the unsolid land. In like manner, all the soft coast cliffs, from the Humber to the mouth of the Thames, are suffering similar destruction in places at an average rate of from two to four yards a year. The line of coast from Hunstanton to Cromer and Mausley, and much further south, is wasting away at a rate estimated by Mr. Reid of the Geological Survey, at probably not less than an average of about two yards a year east and west of Cromer. The strata consist of boulder-clay, laminated clays, fresh-water and marine, and soft sands and gravels. The cliffs are often lofty, and vast landslips are of frequent occurrence down to the shore, where the restless waves rapidly dispose of the material. High up on the edges of the cliff we see the relics of old brick-built walls, that once belonged to vanished farmhouses, and strongly-built tunnels, now in ruins, that descended to the sea, and were once used by fishermen, gape high on the cliffs, themselves a greater ruin. One notable example is found at Eccles-by-the-sea in Norfolk. The town at a comparatively late period extended beyond the church tower, which is partly buried in blown sea-sand, and the church itself has been destroyed.

On the south side of the estuary of the Thames stands the ruined church of the Reculvers, on a low hill of Thanet Sand, half surrounded on the land side by the relics of a Roman wall, that in old times encircled the little town, then probably at least a mile from the sea. The church has been abandoned, but is preserved as a landmark by the Admiralty, and groins have been run out across the beach to prevent the further waste of the cliff by the sea. As it is, all the seaward side of the Roman wall, has long been destroyed, the waves have invaded the land, and half the churchyard is gone, while from the cliff the bones of men protrude, and here and there lie upon the beach. A little nearer Herne Bay, the same marine denudation sparingly strews the beach with yet older remains of man, in the shape of palæolithic flint weapons of a most ancient type, washed from old river gravels that crown part of the cliff.

In the Isle of Sheppy, great slips are of frequent occurrence from the high cliff of London Clay that overlooks the sea. Two acres of wheat and potatoes in this manner slipped seaward in 1863. When I saw them the crops were still standing on the shattered ground below the edge of the cliff.

Again, in the Hampshire basin, on the south coast of England, if we walk along the footpaths that are used by coastguardsmen, we often find that the path on the edge of the cliff comes suddenly to an end, and has been re-made inland. This is due to the fact that the cliffs, chiefly composed of clay and sand, are so soft, that, as in Sheppy and Holderness, every year large masses of country slip out seaward and are rapidly washed away by the waves.

The waste of this southern part of England and of Holderness has been estimated at the rate of from two to three yards every year. In the course of time, therefore, a great area of country must have been destroyed. At Selsey Bill there is a farmhouse standing, twenty years ago about 200 yards from the shore, and since the farmer first settled there, as much land has been wasted away as that which lay between his house and the sea. The site of the ancient Saxon Cathedral Church that preceded that of Chichester is known to be far out at sea. But this waste is not confined to the softest kinds of strata, for further west, in Devonshire, we find the same kind of destruction going on, one remarkable case of which is the great landslip in the neighbourhood of Axmouth, which took place in the year 1839. The strata there consist on the surface of Chalk, underlaid by Upper Greensand, which is underlaid by the Lias Clay. The Chalk is easily penetrated by water, and so is the sand that underlies it. After heavy rains, the water having sunk through the porous beds, the clay beneath became exceedingly slippery, and thus it happened, that the strata dipping seaward at a low angle, a vast mass of Chalk nearly a mile in length slipped forward, forming a grand ruin, the features of which are still constantly changing by the further foundering of the Chalk and Greensand. The waves beating upon the foundering masses destroy them day by day, and in time they will entirely disappear, and make room for further landslips. If we walk along the southern coast of Dorsetshire and Devon, and criticise it with a geological eye, it is obvious that a great number of similar landslips have taken place in times past, of which we have no special record.

In the north country the same kind of history is plain all along the Liassic and Oolitic cliffs of Yorkshire, on a coast formed of almost the finest cliffs in England. Not very many years ago at Rosedale, on the north horn of Runswick Bay, an important set of iron works, offices and cottages, with a pier and harbour, were by a landslip at night utterly ruined and borne into the sea. The slight seaward dip of the strata, composed of clays and sands, ought to have warned the proprietors of the insecurity of the position of their works, had they possessed sufficient geological knowledge.

In parts of our country in the west, the Silurian rocks, Old Red Sandstone and Coal-measures on the coast, show equal evidence of waste, though much slower in its progress; as for instance at St. Bride's Bay, in Pembrokeshire (*see* Map), where the north and south headlands are formed in great part of hard igneous rocks that stand boldly out seaward; while between these points there are softer Coal-measure strata, which once filled what is now the bay—and spread far beyond. But because of their comparative softness they have been less able than the igneous rocks of the headlands to stand the wear and tear of the atmosphere and the sea waves, and thus having been worn back a large bay is the result. I know of no place in Britain where the effects of long-continued marine denudation can be better marked than in this part of Pembrokeshire. Let the observer cross to Ramsey Island, opposite St. David's, and ascend one of the rocky hills. Below he will see that a large part of the island forms a portion of an extensive tableland, which is continued far into the mainland of Pembrokeshire, broken only by minor hills formed of hard igneous rocks which have more effectually resisted denudation, while far to the south the islands of Skomer and Skokholm continue the outlines of the upland plain, such as in Chapter XXX. I have called an old plain of marine denudation.

All along the west coast, where solid rocks prevail, the hardest masses usually form promontories, while the bays have been scooped in softer material; and this fact, though the rate of waste may not be detected by the eye in many years, yet proves the nature of marine and atmospheric denudation when combined on coast cliffs. The very existence of sea cliffs proves marine denudation, for the strata that form these cliffs come abruptly to an end in precipitous escarpments. To see this in perfection let any one walk along the coast cliffs formed of Old Red Sandstone near Arbroath in Forfarshire. There the broad inland plain ends abruptly in vertical precipices, that rise from 150 to 250 feet above the waves at their base, and while the tide is retreating to its completest ebb, long reefs and skerries of hard edged strata tell of the progressive cutting back of a great modern *plain of marine denudation*, similar to that old one which stretches inland from the high edge of the existing cliff.

The Needle-rock near Fishguard, the Needles of the Isle of Wight, and many other rocky 'stacks' form excellent cases in point, standing a little aloof from the high cliffs of rock that form the shore-line; and the Orkney Islands themselves are only fragments of an older land separated by denudation from the mainland of Scotland. While being deposited, Nature never ends strata in a cliff-like form. They were hardened and raised into land. The weather and the waves attacked them, wore them back, and cliffs are the result. I re-mention these matters to show that such denudations on a great scale are going on now, and therefore, when I speak of former unions and separations of our island with and from the mainland by denudation and oscillation of level, the statement is founded on excellent data.

CHAPTER XXIX.

BRITISH CLIMATES AND THEIR CAUSES—RAINFALL IN DIFFERENT AREAS—AREAS OF RIVER DRAINAGE.

Before discussing the subject of rivers and river-gravels and alluvia, I now come to other phenomena connected with the physical structure of our island and its geography generally; and first, with regard to the rain that falls upon its surface. If we examine the best hydrographic maps of the Atlantic, we find on them numerous lines and arrows showing the direction of the flow of the ocean currents as first drawn by Captain Maury. One great current flows from the Gulf of Mexico, where the water in that land-locked area within the tropics is exceedingly heated; and flowing out of the gulf, it passes E. and NE. across the ocean, and so reaches the European area of the North Atlantic. So marked is the heat of this immense current that, in crossing from England to America, the temperature of the water suddenly falls some degrees. Twenty years ago, in crossing the Atlantic, I was in the habit early in the morning of taking the temperature of the water with one of the officers of the steamboat. We then found that at about five o'clock in the morning for several days, the temperature of the sea was always about four degrees above the temperature of the air, but quite suddenly, in passing out of the Gulf Stream, at the same hour of the morning, the temperature of the water was found to average about four degrees below that of the air.

Where in ocean current maps the arrows point southwards, there are cold streams of water coming from the icy seas of the north. One of these passes along the east coast of America, and coming from the North Sea, many an iceberg detached from the great glaciers of Greenland is floated from Baffin's Bay across the banks of Newfoundland into the Western Atlantic, as far south even as the parallel of New York. The western half of the North Atlantic is thus kept cool, and the water is often colder than the air.

The Gulf Stream occupies a very great width in the Atlantic, and approaches tolerably near to our own western coast, and the effect of this body of warm water flowing northward is to divert the isothermal lines (lines of equal temperature) far to the north, over a large part of the Atlantic area, and also of that of the western half of Europe. Thus a certain line runs across North America, about latitude 50°, representing an average temperature for the whole year of 32°. Across that continent it passes tolerably straight, but no sooner does it get well into the Atlantic than the Gulf Stream, flowing northwards, warms the air, and the result is, that the line bends away to the far north above Norway; thus in the west of Europe producing an average warmer climate, for the whole year, than exists in corresponding latitudes in North America, the middle of Europe, and the interior of Asia. Our British climate, and all the west of Europe, becomes, as it were, abnormally warm, owing to the influence of the Gulf Stream, and we at once recognise this fact from the circumstance that trees of goodly size grow much further north on the west coasts of Europe than on the east coasts of North America. Another effect that the Gulf Stream produces, is to cause a great amount of moisture in the west of Europe, and if we consult a rain map of the British Islands, we see represented by different shades the average amount of rainfall in different areas—the darker the shade the greater the quantity of rain. The prevalent winds in the west of Europe are from the SW. and therefore during a great part of the year, the south-west wind warm comes laden with moisture across the land from the sea where the Gulf Stream flows.

In the extreme south-west of England, in Cornwall, from 37 to 54 inches of rain falls every year; and the average for the county may be taken at about 43 or 45 inches. In Devonshire the rainfall varies from 31·75 and 32·6 at Sidmouth to 53·17 inches on Tavistock. In Somerset from 28·57 at Langport to 42 at East Harptree. In Dorset from 18·45 at Abbotsbury to 32·24 inches at Bridport. In Wiltshire from 28·59 at Swindon to 29·27 inches on Salisbury Plain. In Hampshire from 27 at Aldershot to 38 inches in Petersfield. In Sussex from 26·37 at Hastings to 29 inches at Chichester. In Kent and Surrey from 23·82 at Kew to 32·67 inches at Hythe. In Middlesex from 25·85 at Hampstead to 23·11 inches on Winchmore Hill. The rainfall in the western part of the south of England is therefore much greater than in the east.

In like manner in Pembrokeshire the annual rainfall varies from about 31 to 40 inches, and may be averaged at about 36 inches, and in Cardiganshire at Lampeter about 45·18 inches, in Glamorganshire at Cardiff about 42 inches, in Caermarthenshire and Breconshire at about 40 inches, and in Montgomeryshire and Merionethshire at about 54 inches. In Caernarvonshire the fall is about the same, but at Beddgelert in 1870 it amounted to 101·58 inches, and in the Pass of Llanberis to 76·67, while at Caernarvon close by the sea the rainfall was only 38·02 inches. In Anglesea the average fall is about 34½ inches.

In Staffordshire, further from the west coast and from the mountains, the average rainfall is about 23 inches, in Leicestershire about 19 inches, in Bedfordshire about 16 inches, and in Norfolk about 24 to 25 inches. In this southern half of England the rainfall therefore evidently decreases from west to east. Lancashire is a rainy county. At Manchester the rainfall varies from 32·59 to 36·77 inches, at Bolton 44·21 to 49, and at Coniston it is as high as 64 inches, but that is in the Cumbrian region of Lancashire. In Cumberland the annual rainfall varies from about 22 at Cockermouth, on the low ground near the coast, to 154 inches at Seathwaite, in the heart of the mountains, and in 1871 it is stated to have been still higher, and perhaps the average rainfall of the whole of that mountain region may amount to about 70 inches annually. As we pass eastward it decreases, but on the highest grounds of Yorkshire and Northumberland there are places where it rises from 51 to 56 inches, while in the lower ground at Holbeck, Leeds, it falls to about 22·85, at Newcastle to about 24, and at North Shields on the coast to about 26 inches.

In Scotland the same kind of observation holds good with regard to the rainy character of the west. In Argyleshire the lowest rainfall in 1870 was 42 inches at Inverary, and the highest 109·20 inches at Lochgoilhead. The average rainfall for the whole county, and in the islands, may perhaps be estimated at from 55 to 60 inches. At Portree in Skye, in 1871, it amounted to 104·26 inches. The mountainous character of the country produced that result, for in the Isle of Lewes in the same year the rainfall at Stornoway was only 31·79 inches, while at Cromarty on the east coast of Scotland about 26 inches of rain fell. In parts of Aberdeenshire the average fall is from 24 to 33·5 inches, and in Fife the fall is from about 20 to 30 inches, in Midlothian from 29 to 37, and in Haddingtonshire from 23 to 25. The same rule of decrease of rainfall therefore prevails in Scotland that prevails in England, and it is needless to multiply instances. The area, therefore, of Great Britain varies much in the fall of rain, and the average temperature of the western area is raised and rendered agreeable by the influence of the Gulf Stream. So much is this the case, that certain garden plants grow through the winter in Wales and the west of England, and even in the far north-west of Scotland, which the winter cold of Middlesex kills. I have seen bamboo canes growing in the open air in a garden in Anglesea all the year round, and common fuchsias on the shores of Loch Erribol in Sutherland.

Now the watery vapour in the air that rises from the heated water of the Gulf Stream, is carried to the British coast by the prevalent west and south-west winds, and is partly intercepted on its passage eastward by the mountains which rise in the west of Ireland and Great Britain. Everyone who has visited Cumberland and Wales knows how rainy these regions are compared with the centre and east of England. The reason is, that the air laden with moisture from the Atlantic rises with the winds against the western flanks of the mountains into the colder regions of the atmosphere, and the air also expanding at these heights, rain is precipitated there and upon adjacent lands. The same is the case in Scotland, where the Highland mountains on the west produce a like effect; and thus, partly because it is the first land that the wind laden with moisture reaches, and partly because of the mountains, it happens that a greater amount of rain is precipitated in the western than in the eastern parts of our Island.

If we examine our country with regard to special areas of drainage, we find, that they are exceedingly numerous. In Scotland the rivers that run into Moray Firth drain an area of about 2,500 square miles; the Spey, which runs into the German Ocean, nearly 1,200 square miles. The Tay drains an area formed by the Grampian mountains and part of the Old Red Sandstone of 2,250 square miles. The Forth, including its estuary, drains an area of about 2,000 square miles. The Clyde, not including the greater part of its estuary, drains an area of 1,580 square miles, the Tweed 1,870 square miles.

In England, the Tyne drains 1,100 square miles, the Tees, 774. If we take the Trent and the Ouse as draining one area, the immense extent, for such a country as ours, of about 9,550 square miles are drained into the Humber. The Witham, the Welland, the Nen, and the Great Ouse, flowing into the old bay of the Wash, drain 5,850 square miles. The Thames drains an area of about 6,160 square miles; and if we include all the estuary, about 10,000. The Severn drains an area of 8,580 square miles. The Avon that enters the sea at Christchurch drains 1,210 square miles; the Ex, 643; the Towey, in Caermarthenshire, 506; the Dee, 862; the Mersey, 1,748; the Ribble, 720; and the Eden, 995; and if we take all the rivers that run into the Solway Firth, including the Eden, the area drained amounts to nearly 3,000 square miles. This leads to the question of the origin of river valleys and their different geological dates.

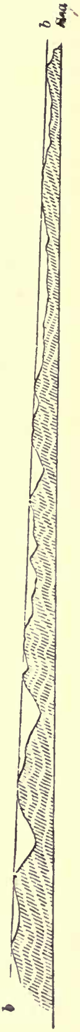
CHAPTER XXX.

ORIGIN OF RIVER VALLEYS—THEIR RELATION TO TABLE-LANDS—ESCARPMENTS CUT THROUGH BY RIVERS—GEOLOGICAL DATES OF DIFFERENT RIVER-VALLEYS—THE SEVERN, THE AVON, THE THAMES, THE FROME, AND THE SOLENT—TRIBUTARIES OF THE WASH AND THE HUMBER—THE EDEN AND THE WESTERN-FLOWING RIVERS—SCOTLAND.

It is difficult, or almost impossible, even approximately to settle precisely what are the geological dates of the valleys through which many rivers run ; or, in other words, when they first began to be scooped out, and through what various periods their excavation was intermittently or continuously carried on. No one has yet thoroughly analysed this subject, and only of late years have I begun clearly to see my way into it. Nevertheless a good deal has been done even now, and a great deal more will be accomplished when, with sufficient data, the whole subject may come to be investigated. In Wales, for example, there are vast numbers of rivers and brooks, small and large, and when we examine the relation of these streams to the present surface of the country, we often find it very remarkable. Fig. 97 is a diagram representing no particular section, but simply the general nature of the sectionsacross the Lower Silurian strata of Cardiganshire, as shown by myself in a paper given to the British

Association at Oxford in 1847. The dark-coloured part represents the form of the country given in the original sections on a scale of six inches to a mile horizontally and vertically. The strata of this area, and, indeed, of much of South Wales, are exceedingly contorted. The level of the sea is represented by the lower line; and if we take a straight-edge, and place it on the topmost part of the highest hill, and incline it gently seaward, it touches the top of each hill in succession, in the manner shown by the line *b b*. This line is as near as can be straight, and, on the average, has an inclination of from one to one and a half degrees; and it is a curious circumstance that in the original line of sections there were no peaks rising above that line—they barely touched it and no more. It occurred to me when I first observed this circumstance that, at a period of geological history of unknown date, perhaps older than the beginning of the deposition of the Permian and New Red Sandstones, *this inclined line that touches the hill-tops must have represented a great plain of marine denudation.*

Fig. 97.



Atmospheric degradation, aided by sea waves on the cliffs by the shore, are the only powers I know that can denude a country *so as to shave it across*, and make a plane surface either horizontal or slightly inclined. If a country be sinking very gradually, and the rate of waste by all causes be proportionate to the rate of sinking, this will greatly assist in the production of the phenomena we are now considering: and a little reflection will show, that the result would be an inclined plane like that of the straight line *b b* in the diagram. Let South Wales be such a country: then when that country was again raised out of the water, the streams made by its drainage immediately began to scoop out valleys; and though some inequalities of contour forming mere bays may have been begun by marine denudation during emergence, yet in the main I believe that the inequalities below the line *b b have been made by the influence of rain and running water.* Hence the number of deep valleys, many of them steep-sided, that diversify Wales, all the way from the Towey in Caermarthenshire to the slaty hills near the southern flanks of Cader Idris and the Arans.

On ascending to the upper heights, indeed, anywhere between the Vale of Towey and Cardigan Bay, it is impossible not to be struck with the average uniformity of elevation of the flat-topped hills that form a principal feature of the country. The country already described as seen from Ramsey Island is part of this plain,[1] and much further north let anyone ascend Aran Mowddy or Cader Idris in Merionethshire, and look south and south-east. From thence he will behold, as far as the eye can reach, a wide extent of flat-topped hills, which form the relics of a vast tableland, now intersected by numerous rivers, which, in the long lapse of untold ages, have scooped out unnumbered labyrinthine valleys eastward into Montgomeryshire, and far south into Cardiganshire. Between the rivers Towey and Teifi, and in other areas, these hills, in fact, form the relics of a great plain or tableland *in which the valleys have been scooped out*; and in the case of the country represented in fig. 97, 'the higher land, as it now exists, is

[1] See p. 487

only the relic of an average general gentle slope, represented by the straight line (*b b*) drawn from the inland heights towards the sea.'[1] Mr. Jukes applied and extended the scope of the same kind of reasoning to the south of Ireland, with great success. In various parts of Europe, notably in those regions that have been longest above the water—on the banks of the Moselle and of the Rhine, and in the great coalfield west of the Appalachian chain in North America—we find unnumbered valleys intersecting tablelands, of a form that leads us to believe that they also have been made by the long-continued action of atmospheric waste and running waters; and I believe that the valleys of South Wales have been formed in the same way, and in their origin are even often of latest palæozoic dates.

Nothing is more remarkable in the history of rivers than the circumstance that very frequently they run straight through bold escarpments, which at first sight we might suppose ought to have barred the course of the streams.[2] The Wye in South Wales, for example, runs through a bold escarpment of Old Red Sandstone hills; and the same is the case with the Usk.

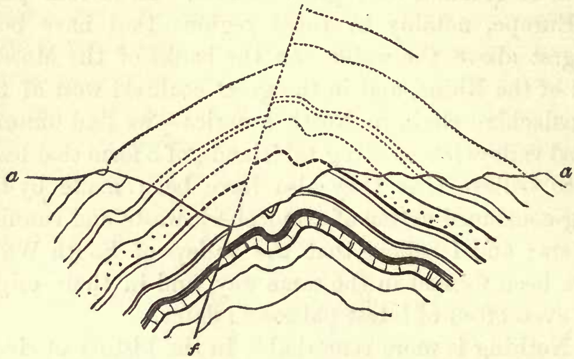
For long it was customary to attribute such breaches in escarpments, and indeed valleys in general, to disturbances and fractures of the strata, producing a wide separation, and actually making hills. But when we realise that thousands of feet of strata have often been removed by denudation since the great disturbances of the Welsh strata took place, it becomes clear that the present valleys are in no way immediately connected with them; for even if there be dislocations or faults

[1] Reports, British Association, p. 66, 1847.

[2] This has already been alluded to in the case of the rivers of the Wealden, pp. 108–119.

in some of the valleys, these faults when formed were, as far as regards the present surface, thousands of feet deep in the earth. All they could do might have been

Fig. 98.



a Present surface of the ground.

The dotted lines show the continuation of an anticlinal curve broken by a fault *f*.

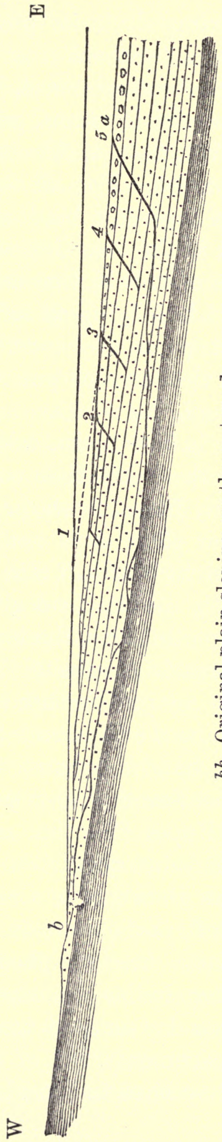
The dotted lines above the surface *a a* represent a certain amount of strata removed by denudation.

to establish lines of weakness along which subsequent denudation may have excavated valleys.

The real explanation of such cases as those of the Wye and the Usk is this. At some period, now uncertain, the beds of the Old Red Sandstone, well seen in the escarpment of the Beacons of Brecon, *a*, and the Caermarthen Fans, once spread much farther westward, forming a great plain, *b b* (fig. 99), the result of earlier denudations. This plain sloped gently eastward, and the dotted line shows the general state of old outcrops of the strata. The river then ran over ground perhaps even higher than the tops of the hills of the present escarpment, and by degrees it cut itself a

FIG. 99.

gram showing the mode of formation of the escarpment of the Beacons of Brecon and the Caermarthen Fans, South Wales.



bb, Original plain sloping gently eastward.
1, 2, 3, 4, 5, successive escarpments.

channel approximately in its present course, but varied and widened by subsequent river action; and, as it cut out that valley, the escarpment, by the influence of rain and other atmospheric causes, gradually receded to the points marked 1, 2, 3, 4, 5, and *a*, the last being the present escarpment. For all observation tells us that escarpments of a certain kind work back in this way, that is to say, in the direction of the dip of the strata.

One reason of this is, that escarpments often partly consist of hard beds lying on softer strata. The softer strata are first more easily worn away along the line of strike, and thus an escarpment begins to be formed. Once established, the weather acting on the joints and other fissures in the rocks, takes more effect on the steep slope of the scarp than on the gentle slope that is inclined away from the scarp. The loosened detritus on the steeper slope slips readily downward, and is easily removed by floods of rain; and thus the escarpment constantly recedes in a given direction, while on the opposite gentle slope, the loosened detritus, smaller in amount, travels so slowly that it rather tends to block the way against further waste. In this way we can explain how the Wye and the Usk break through the Old Red Sandstone and find their way to the estuary of the Severn; why the Severn itself breaks through the Upper Silurian escarpment of Wenlock Edge; why certain other rivers—such as the Dee in Wales, and the Derwent in Cumberland—cut through escarpments of Carboniferous Limestone; and how, indeed, the same kind of phenomena are everywhere prevalent under similar circumstances. Of this I shall say more when I come to treat of the Oolitic and Cretaceous escarpments.

But when we have to consider the origin of some of the larger river valleys, there is a great deal that is difficult to account for. One thing is certain, that before the Glacial epoch the greater contours of the country were much the same as they are now. The mountains of Scotland, Wales, and of Cumberland, and the great Pennine chain, existed then, somewhat different in outline, and yet the same essentially; the central plains of England were plains then, and the escarpments of the Chalk and Oolites existed before the Glacial period. All that the ice did was to modify the surface by degradation, to smooth its asperities by rounding and polishing them, to deepen valleys where glaciers flowed, and to scatter quantities of moraine-detritus, partly in the shape of boulder-clay and of marine boulder beds, and sands and gravels, over the plains that form the east of England, and the Lias and New Red Sandstone in the middle.

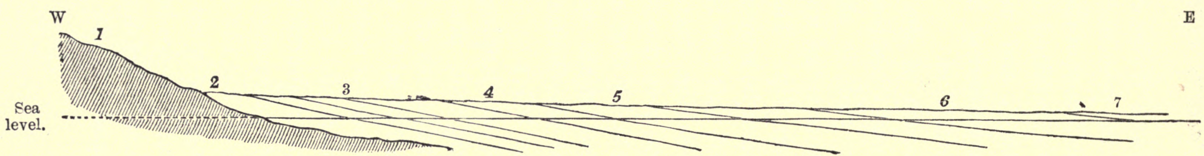
If we examine the valley of the Severn from Bristol northwards through Coalbrook Dale, we find that for a large part of its course the river runs down a broad valley, between the old Palæozoic hills and the escarpment formed by the tableland of the Cotswold Hills which are highest in the neighbourhood of Cheltenham. That valley certainly existed before the Glacial epoch, because we find boulders and boulder-drift far down towards Tewkesbury; and therefore, I believe that before the Glacial epoch this part of the Severn ran very much in the same course that it does at present. During part of the Glacial epoch the country sank beneath the sea, and Plinlimmon itself, where the river rises, was perhaps buried in part beneath the waters. When the country again emerged, the old system of river-drainage in that area was resumed; and the Severn, following in the main its old course, cut a channel for itself through the boulder-clay that partially blocked up the original valley in which it ran. *When* that original valley was formed through which the older Severn ran is the point that I shall now attempt to discover. This subject is intimately connected with the origin and geological dates of the channels of many of the other large rivers of England, most of which, unlike the Severn, flow eastward to the English Channel and the German Ocean.

I must begin the subject by a rapid summary of certain physical changes that affected the English Secondary and Eocene strata long before the Severn, after leaving the mountains of Wales, took its present southern and south-western course along the eastern side of the Palæozoic rocks that border that old land.

About the close of the Oolitic epoch the Oolitic formations were raised above the sea, and remained a long time out of water; and, during that period, those atmospheric influences that produced the sediment of the great Purbeck and Wealden delta were slowly wearing away and lowering the land, and reducing it to the state of a broad undulating plain. At this time the Oolitic strata still abutted on the mountain country now forming Wales and parts of the adjacent counties. They also completely covered the Mendip Hills, and passed westward as far as the mountains of Devon passing out between Wales and Devonshire through what is now the Bristol Channel. The whole of the middle of England was likewise covered by the same deposits, overlying the rocks that now form the plains of Shropshire, Cheshire, Lancashire, and the adjoining areas, so that the Lias and Oolites passed out to the area now occupied by the Irish Sea, over and beyond the present estuaries of the Dee and the Mersey,

FIG. 100.

General Arrangement of the Lower Secondary Formations before the Deposition of the Upper Secondary Strata.



1. Disturbed and hilly Silurian Old Red and Carboniferous strata. 2. New Red beds. 3. Lower Lias. 4. Marlstone and Upper Lias. 5. Lower Oolites. 6. Middle Oolites. 7. Upper Oolites and Purbeck beds.

which lie between North Wales and the hilly ground of Lancashire, formed of previously disturbed Carboniferous rocks. In brief, most of the present mountainous and hilly lands of the mainland of Britain were mountainous and hilly then, and must have been much higher than now, considering how much they have since suffered by denudation.

At this period, south of the Derbyshire hills, and through Shropshire and Cheshire, the Secondary rocks lay somewhat flatly; while in the more southern and eastern areas they were tilted up to the west, so as to give them a low eastern dip. The general arrangement of the strata would then be somewhat as in fig. 100.

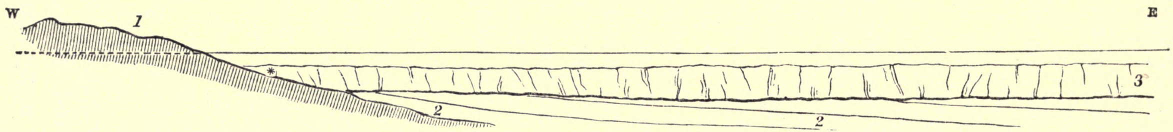
The submersion of this low lying area brought the deposition of the Wealden strata to a close, and the Cretaceous formations were deposited above the Wealden and Oolitic strata, so that a great unconformable overlap of Cretaceous strata took place across the successive outcrops of the Oolitic and older Secondary formations. (See fig. 101.)

The same kind of overlapping of the Cretaceous on the Oolitic formations, took place at the same time in the country north and south of the present estuary of the Humber, the proof of which is well seen in the unconformity of the Cretaceous rocks on part of the Oolites and Lias of Lincolnshire and Yorkshire.

At this time, the mountains of Wales, and other hilly regions made of Palæozoic rocks, must have been lower than they were during the Oolitic epochs; partly by the effect of long-continued waste due to atmospheric causes, but much more because of gradual and greatly increased submergence during the time that the Chalk was being deposited. It is even possible that

FIG. 101.

Early Overlap of the Cretaceous Strata on the Lower Secondary Formations.



1. Disturbed hilly land, as in fig. 34. 2. New Red Liassic and Oolitic strata, &c.
3. Cretaceous strata lying *unconformably* on and overlapping the denuded edges of No. 2, and at * abutting on the half-submerged mountains of Wales.

during the Upper Cretaceous period Wales sunk almost entirely beneath the sea.

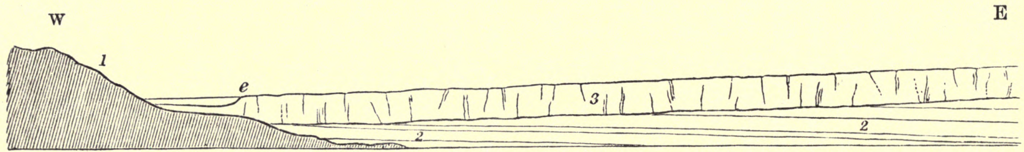
I omit any detailed mention of the phenomena connected with the depositions of the freshwater and marine Eocene strata because at present this subject is not essential to my argument.

The Miocene period of old Europe was essentially a continental one. Important disturbances of strata brought it to a close, at all events physically, in what is now the centre of Europe; and the formations partly formed in the great fresh-water lakes that lay at the bases of the older Alps were, after consolidation, heaved up to form new mountains along the flanks of the ancient range; and all the length of the Jura, and far beyond to the north-east, was elevated by disturbance of the Jurassic, Cretaceous, and Miocene strata. The broad valley of the lowlands of Switzerland began then to be established, long afterwards to be overspread by the huge glaciers that abutted on the Jura, deepened the valleys, and scooped out all the rock-bound lakes.

One marked effect of this extremely important elevation, after Miocene times, of so much of the centre of Europe was, that the flat, or nearly flat-lying Secondary formations that now form great part of France and England (then united), were so far affected by the renewed upheaval of the Alps and Jura that they were to a great extent tilted, at low angles, to the *north-west.* That circumstance gave *the initial north-westerly direction to the flow of so many of the existing rivers of France*, and led them to excavate the valleys in which they run, including the upper tributaries of the Loire and Seine, the Seine itself, the Marne, the Oise, and many more of smaller size; and

FIG. 102.

Post-Miocene Westerly Dip of the Cretaceous Strata of England.



1. Old Wales. 2. Oolitic strata, &c. 3. Chalk, &c. The surface of the Chalk slopes gently from east to west.

my surmise is, that this same westerly and north-westerly tilting of the Chalk of England *formed a gentle slope towards the mountains of Wales*, as shown in fig. 102, and the rivers of the period of the middle and south of England at that time flowed westerly. *This first induced the Severn to take a southern course between the hilly land of Wales and Herefordshire and the long slope of Chalk then rising to the east.* Aided by the tributary streams of Herefordshire, it began to cut a valley towards what afterwards became the Bristol Channel, *and established the beginning of the escarpment of the Chalk*, *e*, fig. 102, which has since gradually receded, chiefly by atmospheric waste, so far to the east. If this be so, then the origin of the valley of the Severn between *e* and 1 *is of immediate post-Miocene date, and is one of the oldest in the lowlands of England.*[1]

The course of the Avon, which is a tributary of the Severn, and joins it at Tewkesbury, is, I believe, of later date than the latter river. It now rises at the base of the escarpment of the Oolitic rocks east of Rugby, and gradually established and increased the length of its channel in the low grounds now formed of Lower Lias and New Red Marl as that escarpment retired eastward by virtue of that law of waste which causes all inland escarpments to retire away from the steep slope and in the direction of the dip of the strata.

If the general slope of the surface of the Chalk of this part of England had been easterly instead of westerly at the post-Miocene date alluded to, then the initial course of the Severn would also have been easterly, like

[1] Many of the valleys of Wales must be very much older.

that of the Thames and the rivers that flow into the Wash and the Humber.

One of the best known rivers that enters the estuary of the Severn is the other Avon, which flows through Bath and Bristol. Its physical history, on a small scale almost precisely resembles that of the Rhine between Basle and Bonn.[1]

West of Bristol there is a high plateau of Carboniferous Limestone, the flat top of which attains a height of nearly 400 feet above the level of the sea. Through a deep narrow gorge in this limestone (fig. 103) the river flows, between Clifton and Durdham Downs on the east and Leigh Wood on the west, north-west of which it enters the low grounds and finds its way to the estuary of the Severn at King's Road. Above Bristol, north and south of the river, the country consists of a number of isolated flat-topped hills, of which Dundry Hill and the Mendips form conspicuous members, while in the neighbourhood of Bath, Lansdown, Charmy Down, Odd Down all the minor Oolitic plateaux now form portions of what was once a continuous broad tableland with minor undulations. In these regions the Avon takes its rise, swelled by many north-flowing tributaries, one of which, the Chew, rises on the north flank of the Mendip Hills. North of Bath, several minor streams flow into the Avon through beautiful valleys which have been scooped out of the Oolitic plateau, while the Boyd, the Siston, and the Frome pass through the soft undulating grounds of Lias, New Red Marl, and Coal-measures that lie west of the bold Oolitic escarpment between Bath and Wotton-under-edge. Some of these streams rise at

[1] 'On the Physical History of the Rhine,' 'Journ. Geol. Society,' 1874, A. C. Ramsay.

heights approximately as high as the summit level of the limestone gorge through which the Avon flows below Bristol.

The vulgar notion respecting the Avon and its gorge is, that before that ravine was formed all the low ground through which the river and its tributaries flow was a large lake, that 'a convulsion of nature' suddenly

FIG. 103.

Gorge of the Avon at Clifton, Bristol, looking down the river.

rent the rocks asunder and formed the gorge through which the river afterwards flowed, and so drained the hypothetical lake. It is scarcely necessary to add, that had there been a large lake in that area, we might expect to find lacustrine deposits and organisms in some parts of these valleys, but none exist.

The true explanation is, that in some late tertiary period of geological history, the surface of the country on either side of the river above the gorge formed a great plain, somewhat higher than the summit level of the Carboniferous Limestone plateau. This plain being slightly inclined to the west at the time the Severn was scooping out its valley, as I have already explained at p. 508, the ancient Avon flowed over the top of the plateau of Clifton and Durdham Downs, through a minor inequality of the surface, and, as rivers do, it steadily worked at the deepening of its own channel. As it did this, so in like proportion the river and its tributaries in the upper part of their courses gradually wasted and lowered the hill-sides and valleys through which they flowed, being aided by rains and snows and all the ordinary agents of atmospheric denudation; and thus it happens, that what was once a high slightly-inclined tableland, has been converted partly into flat-topped fragments of a high plain, and partly into undulating hills and vales; while in the great Oolitic plateau, that stretches eastward as far as the Chalk escarpment, we have still remaining a large tract of the ancient plain, with this difference, that the average gentle slope of its surface is now east instead of west.

This naturally leads to the question, Why is it that the Thames, and some other rivers that flow through the Oolites and Chalk, run eastward? The answer seems to be, that after the original valley of the Severn was well established by its river, a new disturbance of the whole country took place, by which the Cretaceous and other strata were tilted eastward, not suddenly, but by degrees, and thus a second slope was given to the Chalk and Eocene strata, in a direction opposite to the dip, that originally led to the scooping out of the present valley of the Severn. This dip lay east of the comparatively newly-formed escarpment of the Chalk indicated by the dark line in fig. 102 marked *e*. The present Chalk escarpment, in its beginning, is thus of older date than the Oolitic escarpment (fig. 57, p. 304), but it would be hard to prove this, except on the hypothesis I have stated.

When this slope of the Chalk and the overlying Eocene strata was established, the water that fell on the long inclined plain east of the escarpment of the Chalk necessarily flowed eastward, and the Thames, in its beginning, flowed from end to end entirely over Chalk and Eocene strata.

The river was larger then than now, for I am inclined to believe, that in these early times of its history, the south of England was joined to France, the Straits of Dover had no existence, and the eastern part of the Thames as a river, not as a mere estuary, ran far across land now destroyed, perhaps directly to join an extension of the north flowing river which we now call the Rhine. At its upper end, west of its present sources, the Thames was longer by about as much probably as the distance between the well-known escarpment of the Cotswold Hills and the course of the Severn as it now runs, for the original escarpment of the Chalk must have directly overlooked the early valley of the Severn, which was then much narrower than now (*see* p. 509). But by processes of waste identical with those that formed the escarpment of the Wealden (figs. 71, 72, 73, pp. 337–343), the Chalk escarpment gradually receded eastward, and as it did this the valley of the Severn widened, and the area of the drainage of the Thames was contracted.

By-and-by the outcropping edges of the Oolitic strata becoming exposed, a second and later escarpment began to be formed, while the valley of the Severn gradually deepened; but the escarpment of the Chalk being more easily wasted than that of the Oolite, its recession eastward was more rapid, and this process having gone on from that day to this, the two escarpments in the region across which the Thames runs are far distant from each other.

All this time the Thames was cutting a valley for itself in the Chalk, and by-and-by, when the escarpment had receded to a certain point, its base became in part lower than the edge of the Oolitic escarpment that then, as now, overlooked the valley of the Severn, only at that time the valley was narrower. While this point was being gradually reached, the Thames by degrees was joined by the growing tributary waters that drained part of the surface of the eastward slope of the Oolitic strata, the western escarpment of which was still receding; and thus was brought about, what at first sight seems the unnatural breaking of the river through the high escarpment of Chalk between Wallingford and Reading.

From the foregoing remarks it will be understood why the sources of the Thames, the Seven Springs and others, rise so close to the great escarpment of the Inferior Oolite, east of Gloucester and Cheltenham. But just as in times long gone, the sources of the Thames once rose westward of the Seven Springs, so well known on the Cotswolds, so the sources of the river now, are not more stationary than those that preceded. The escarpments, both of Chalk and Oolite, are still slowly changing and receding eastward; and as that of the Oolite recedes *the area of drainage will diminish and the Thames decrease in volume.* This is a geological fact, however distant it may appear to persons unaccustomed to deal with geological time

A change in the story of an old river, even more striking than that of the Thames, has taken place in the history of what was once an important stream further south. Before the formation of the Straits of Dover, the solid land of England, formed of Cretaceous and Eocene strata, extended far south into what is now the English Channel. The Isle of Wight still exists as an outlying fragment of that land. At that time the Nine Barrow Chalk Downs, north of Weymouth Bay and Purbeck, were directly joined as a continuous ridge with the Downs that cross the Isle of Wight from the Needles to Culver Cliff. Old Harry and his Wife, off the end of Nine Barrow Downs, and the Needles, off the Isle of Wight, are small outlying relics, left by the denudation of the long range of Downs that once joined the Isle of Wight to the so-called Isle of Purbeck, and of the land that lay still farther south of Portland Bill the Isle of Wight and Beachy Head.

North of this old land, the Frome, which rises in the Cretaceous hills east of Beaminster, still runs, and, much diminished, discharges its waters into Poole Harbour. But in older times the Solent formed part of its valley, where, swollen by its affluents, the Stour, the Avon, the Test, and the Itchin, it must have formed a large river, which, by great subsequent denudations and changes in the level of the land, has resulted in the synclinal hollow through which the semi-estuarine waters of the Solent now flow.[1]

The same kind of argument that has been applied

[1] See Mr. T. Codrington 'On the Superficial Deposits of the South of Hampshire and the Isle of Wight.' Quart. Jour. Geol. Soc. 1870, vol. xxvi., p. 528, and Mr. John Evans, 'Stone Implements,' Chap. XXV.

to the Thames is equally applicable to the Ouse, the Nen, the Welland, the Glen, and the Witham, rivers flowing into the Wash, all of which rise either on or close to the escarpment of the Oolites, between the country near Buckingham and that east of Grantham, which rocks were once covered by the Chalk.

With minor differences, the same general theory equally applies to all the rivers that run into the Humber. I believe the early course of the Trent was established at a time when, to say the least, the Lias and Oolites overspread all the undulating plains of New Red Marl and Sandstone of the centre of England, spreading west to what is now the sea, beyond the estuaries of the Mersey and the Dee. A high-lying anticlinal line threw off these strata, with low dips, to the east and west; and, after much denudation, the large outlier of Lias between Market Drayton and Whitchurch in Shropshire, is one of the western results. Down the eastern slopes the Trent began to run across an inclined plain of Oolitic strata. Through long ages of waste and decay the Lias and Oolites have been washed away from these midland districts, and the long escarpments formed of these strata lie well to the east, overlooking the broad valley of New Red Marl through which the Trent flows.

The most important affluent of the Trent is the Derwent, a tributary of which is the Wye of Derbyshire. The geological history of the Wye is very instructive. It runs right across part of the central watershed of England, formed by the great boss of the Carboniferous Limestone of Derbyshire. This course, at first sight seems so unnatural, that the late Mr. Hopkins of Cambridge stated that it was caused by two fractures in the strata, running parallel to the winding course of the river.[1] There are no fractures there of any importance. The true explanation is as follows:

At an old period of the physical history of the country, the valley north and west of Buxton had no existence, and the land there actually stood higher than the tops of the limestone hills to the east. An inclined '*plain of marine denudation*,' stretched eastwards, and gave an initial direction to the drainage of the country. The river began to cut a channel through the limestone rocks; and as it deepened and formed a gorge, the soft Carboniferous shales in which the river rose, were also worn away by atmospheric action, and streams from the north and west began to run into the Wye. By the power of running water, those valleys were deepened simultaneously and proportionately to their distance from the sources of the river; and the farther the Wye flowed, the more was its volume increased by the aid of tributary streams and springs. Thus it happens that the Wye seems to the uninitiated unnaturally to break across a boss of hills, which, however, were once a mere slightly undulating unbroken plain of limestone. There is no breakage of the rocks, and nothing violent in the matter. It was and is, a simple case of the wearing action of running water cutting a channel for itself from higher to lower levels, till, where Rowsley now stands, it joined the Derwent, which flows in a long north and south valley scooped

[1] 'On the Stratification of the Limestone District of Derbyshire,' by W. Hopkins, M.A., &c. For private circulation. 1834. In p. 7 he says, 'When two longitudinal faults, ranging parallel, are not very distant from each other, they sometimes form a *longitudinal valley*, of which the valley of the Wye is a splendid instance. In such cases, however, it is curious that the faults do not generally coincide with the steep sides of the valley, but are distant from them by perhaps from 50 to 200 or 300 yards.'

by itself, chiefly in comparatively soft Yoredale shales between the high-terraced hard moorland scarps of Millstone Grit, and the still harder grassy slopes of the Carboniferous Limestone.

When we come to the other rivers that enter the Humber north and west of the Trent, the case is more puzzling. The Oolites in that region were extensively denuded before the deposition of the Chalk; so that between Market Weighton and Kirkby-under-dale in Yorkshire, the Chalk is seen to overlap unconformably the Oolitic strata, and to rest directly on the Lower Lias, which there, as far as it is exposed, is very thin. The Chalk, therefore, overspread all these strata to the west, and lay directly on the New Red beds of the Vale of York, till, overlapping these, it probably intruded on the Carboniferous strata of the Yorkshire hills farther west. At this time the Oolites of the northern moorlands of Yorkshire seem also to have spread westward till they also encroached on the Carboniferous slopes, the denuded remains of which now rise above the beautiful valleys of Yoredale and Swaledale, the whole, both Carboniferous and Secondary, strata having gentle eastern and south-eastern dips. These dips gave the rivers their initial tendency to flow south-east and east; and thus it was that the Wharfe, the Ouse, and the Swale, cutting their own channels, formed a way to what is now the estuary of the Humber, while the escarpments of the Chalk and Oolite were gradually receding eastward to their present temporary positions.

That the Oolitic strata spread northward beyond their present scarped edges is quite certain; but whether or not they extended far enough north to cover the whole of the Durham and Northumberland coalfield I am unable to say. Whether they did so or not does not materially affect the next question to be considered; for if they did spread over part of these Carboniferous strata, they must have thinned away to a feather edge in times long before the Oolitic escarpment began to be formed.

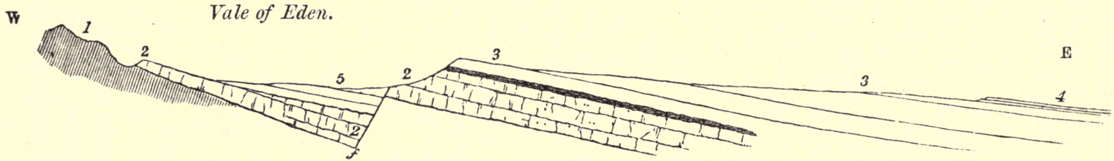
Taken as a whole, from the great escarpment of Carboniferous Limestone that overlooks the Vale of Eden on the east, all the Carboniferous strata from thence to the German Ocean have a gentle eastern dip; so gentle, indeed, that, on Mallerstang and other high hills overlooking the Vale of Eden, outlying patches of Millstone Grit, still remain to tell that once the whole of the Coal-measures spread across the country as far as the edge of the Vale, and even far beyond in pre-Permian times, for the Carboniferous Limestone on both sides of the Vale of Eden, now broken by a fault, was once continuous, and the Whitehaven coalfield was then united to that of Northumberland. These gentle eastern and south-eastern dips, caused by upheaval of the strata on the west and north-west, gave the initial tendency of all the rivers of the region to flow east and south-east. Thus it happens that the Tees, the Wear, the Derwent, the Tyne, the Blyth, the Coquet, and the Alne, have found their way to the German Ocean, cutting and deepening their valleys as they ran, the sides of which, widened by time and subaerial degradation, now often rise high above the rivers in the regions west of the Coal-measures, in a succession of terraces of limestone bands, tier above tier, as it were in Titanic steps, till on the tops of the hills we reach the Millstone Grit itself.

I now turn to the western-flowing rivers, about which there is far less to be said.

First, the Eden:—This river flows along the whole

FIG. 104.

Section from the Cumbrian Mountains across the Vale of Eden to the Northumberland Coalfield.



1. Silurian Rocks. 2. Carboniferous Limestone. 3. Yoredale rocks and Millstone Grit. 4. Coal-measures. 5. Permian Conglomerates, Sandstones, and Marls.

length of that beautiful valley, through various Permian rocks, for nearly forty miles. At the mouth of the valley, at and near Carlisle, a patch of New Red Marl lies on the Permian sandstones, and on the Marl rests the Lias. Whether the whole length of the Permian strata of the Vale of Eden was once covered by these rocks it is impossible to determine, but I believe that it must have been so to a great extent, and also that the Lias may have been covered by Oolitic strata. A great fault east of the Eden has thrown these formations down on the west, so that the faulted edge of the Permian beds now abuts on the high Carboniferous hills that form the eastern side of the valley. As these Permian and Secondary were denuded away by time, the present river Eden began to establish itself, and now runs through rocks in a faulted hollow, in the manner shown in fig. 104. What is the precise geological date of the origin of this great valley and its river course in their present form, I am unable to say; but I believe that it may approximately be of the same age as the valleys last described: that is to say, of later date than the Oolites, and probably it is later than the Cretaceous and Eocene, or even than the Miocene epoch. And so with the other rivers of the west of England—the Lune, the Ribble, the Mersey, and the Weaver.

In Wales, the Dyfi partly runs in a valley formed by denudation along an old line of fault; and the Teifi in Cardiganshire, and the Towey in Caermarthenshire, in parts of their courses along lines running in the direction of the strike of soft Llandeilo flags, sometimes slaty and easily worn down by water, their valleys being bounded on either side by hills to a great extent formed of harder Silurian grits.

To sum up the subject: It seems to me that all the rivers of Wales, whether flowing through Silurian, Old Red, or Carboniferous rocks, have been busy scooping out their valleys ever since the close of that great continental epoch that ended with the influx of the Rhætic and Liassic sea across the Triassic salt lakes, and though these valleys were modified by ice, and partially filled with detritus, during a short episode of submergence in glacial times, the rivers re-asserted their rights to their old channels when emergence took place. All the important rivers, therefore, that flow east and west and north and south through the Silurian rocks of Wales, are in their origin approximately of the same age, and from Cader Idris to Pembrokeshire they have all cut their way through a tableland with minor undulations, while here and there remains a higher hill, the rocks of which were unusually hard. This old upland was indeed of great extent, and its relics stretch far and wide into the northern part of Denbighshire, and into Montgomeryshire and South Wales. As already stated, standing on the summit of Cader Idris or of Aran Mowddwy, 2,960 feet high, and looking east and south, the eye, as far as it can reach, ranges across a vast extent of old tableland, the plane surface of which near the Arans is about 1,900 feet above the level of the sea, or more than 1,000 feet below the summits of the neighbouring mountains. All intersected by unnumbered valleys, to the ordinary observer it is merely a hilly country, while an eye versed in physical geology at once recognises that all the diversities of feature are due to fluviatile erosions that have scooped out the valleys.

For this reason it also happens that the Dee now cuts right across the Carboniferous escarpment west of Erbistock and the lower area of the Permian strata;

for when the Dee began to run, that escarpment had no existence, and the strata of these formations stretched further to the west, ending along some line now unknown in a sort of feather edge, and forming part of the great inclined plane over which the Dee ran at a level hundreds of feet above the bottom of its present valley. By-and-by, as the river channel deepened, the escarpment began to be formed, its face sloping in a direction at right angles to the general dip of the strata, after the habit of all such escarpments. The whole was strictly analogous to the manner in which the rivers of the Weald acted at a later date, and also for the same reason that the Thames now cuts across the escarpment of the Chalk. Escaped into the low country of the New Red series, the history of the Dee becomes simple, and requires no special illustration.

But this process of ordinary fluviatile erosion is not the only agent that has been at work in Wales, for in later geological times the Glacial epoch supervened, and the moving ice of thick glaciers exercised a strong abrading power. Then it was that in the mountain-region of the west, ice-smoothing, mammillations, and striations were so strongly impressed on the sides of so many valleys, and so many lake-basins were scooped out, and among others the rock-bound basin of Bala Lake; and though the face of the country is always being slowly changed, the time that has elapsed since the close of the Glacial epoch is comparatively so short, that the large essential rocky features of the regions traversed by the rivers have since that time undergone no important alteration.

In the 'Journal of the Geological Society' for 1876, I published the Physical History of the Dee. It is too long, and the necessary diagrams are too large for publication in such a book as this, but the leading features of the story are, that before entering the plains of Cheshire, the river, passing through Bala Lake, runs through the beautiful Vale of Llangollen, which as far as the behaviour of the river is concerned, may on a small scale be compared to that of the Moselle (see p. 534, Chap. XXXI.). At the mouth of its valley the river passes through a bold escarpment of Carboniferous Limestone and Millstone Grit, whence suddenly bending to the north it passes through flats of New Red Sandstone to its long shallow estuary beyond Chester.

The greater part of the Silurian region on either side of Bala Lake, and of the Dee, stood high above the level of the sea, from remote geological times, and formed a wide tableland, extending far to the south, and also to the east and north-east, and on its edges rose the more mountainous land, formed by the Lower Silurian volcanic rocks, splendid relics of which still remain in the peaks of Cadir Idris, the Arans, and Arenigs.

When, by the drainage of this old land, the Dee, induced by minor undulations of the ground, began to flow in its earliest channel, it is clear that its present source, Bala Lake, had no existence; for whereas the river at that time must have flowed on a surface of land not less high than that on either side of the present valley near Corwen and Llangollen (now, in places, from 1,600 to 1,800 feet high), the surface of Bala Lake is only 600 feet above the level of the sea, while the neighbouring watershed between the lake and Dolgelli is only 200 feet higher. As the river could not flow up hill, it is clear that in that early stage of its history, the valley of the Dee about Bala, must have been at least from 1,300 to 1,400 feet higher than it is now, and consisted of a mass of Silurian rocks, great part of which has since been removed by denudation.

In my opinion this region of North Wales has never been depressed beneath the sea since the beginning of the Permian epoch, excepting in part during a short episode in Glacial times (see p. 413). During that long lapse of geological ages, there was therefore ample time for the action of all the ordinary processes of subaerial denudation, the most powerful of which is the action of rain, rivers, and glaciers, and thus it happened that the Dee, a river of very ancient date, wandering hither and thither, by degrees deepened its channel in the same manner that the Rhine and the tortuous Moselle have cut out theirs, as described in my memoir 'On the Physical History of the Valley of the Rhine.' While this process was going on, minor tributary valleys were cut by rain and rivers in the tableland to right and left of the great main channel, and other smaller rivers in adjacent regions playing the same general part, this wide tableland of marine denudation was gradually turned by the scooping out of unnumbered valleys, into a region of hill and dale.

The Vale of Clwyd is of extreme antiquity, for it was a valley before the deposition of the New Red Sandstone, and it may be that the Clwyd has flowed ever since the end of the Triassic epoch, and the Conwy like the Dee is at least as old.

I cannot pretend to give a detailed account of the river systems of Scotland. My personal knowledge of the subject is less minute, and however minute it might be, the subject is difficult.[1] Something of the subject

[1] Professor Geikie, who fully realises the difficulty of the subject, nevertheless enters into it and explains it, as far as his present knowledge will allow, in his work, the 'Scenery and Geology of Scotland.'

I know myself, but for fuller details the reader must refer to Professor Geikie's work, from which part of what I have to say is drawn.

By referring to any good geological map of Scotland and the north of England, it will be seen that the country is intersected by two great valleys, running from north-east to south-west, viz., the valley of Loch Ness running from Moray Firth to Loch Linnhe, and also the valleys of the Forth and Clyde. If we go farther south another valley traverses England from Tynemouth to the Solway Firth. The general strike of all the older formations of Scotland is more or less from south-west to north-east, and starting from the watershed of the north-west of Scotland between Loch Linnhe and Cape Wrath, it will be seen that almost all the larger rivers flow to the east and south-east, transverse to the strike of the strata. In fact, like the Thames, they may be said to start from a great scarped watershed facing the Atlantic, and run from thence more or less in accordance with the general dip of the strata, or rather in conjunction with that, down a sloping plain of marine denudation, till they find their way into the sea or into the great valley of Loch Ness. Thus, in some degree, they follow the same general law that guided the east-flowing rivers of England, though traversing much more mountainous ground, they have cut their valleys in hard, greatly disturbed, and metamorphic Lower Silurian strata.

South of the Great Valley, the rivers follow a north-east course, in Strath Dearn and Strath Spey, approximately parallel to the trend of the Great Valley, running in valleys probably excavated in lines of strike occupied by strata, less hard than the general mass of the country. The Tay does the same in the upper part of its course. South of Strath Spey, the rivers find their way east and south-east to the German Ocean; the Tay and the Forth from a high watershed that crosses Scotland from the neighbourhood of Fraserburgh on the east to Crinan on the west coast. To a great extent it is formed of hard granitic rocks and associated gneiss, and on this account it is high because of its power to resist denudation.

Like so many other rivers, the Tay has cut its way in old times over, and now through, a high belt of ground, that of the Sidlaw Hills just above the estuary; and the Forth, the Teith, and the Allan have in like manner breached that long range of Trappean Hills, known as the Ochils and the hills of Campsie.

The whole of the estuary of the Forth and the greater part of the valley of the Clyde lie in an exceedingly ancient area of depression. That country is also covered more or less with Boulder-clay, and with later stratified detritus of sand and gravel which were formed in part by the remodelling of the Glacial drifts. These rivers ran in that area before the commencement of these deposits, and indeed for unknown ages before that period. But we have no distinct traces of those earlier epochs when we try to trace them as regards the history of the rivers of Scotland; and we know little besides this, that the Forth and the Clyde ran in their valleys long before the deposition of the Boulder-clay, and with other rivers resumed to some extent their old courses after the emergence of the country.

As of the rivers already mentioned, this may also be said of the Tweed, that we know nothing for certain of its history, except that its valley is of later age than the Old Red Sandstone and Carboniferous rocks.

My own opinion is, that all the valleys of the South of Scotland may be said to have been formed generally contemporaneously with the valleys of the adjoining region of the north of England already described.[1]

Of this we are certain, that some very ancient valleys in Scotland are older than the Old Red Sandstone, the deposition of which has more or less filled them with detritus, and they are now being re-excavated by running water. Taken as a whole, most of them may be said to be as old as the river-made valleys of Wales and Cumberland, for the disturbances which affected the Silurian and other palæozoic formations of Scotland were coeval with those that first raised the mountains of Cumberland, Wales, and Ireland high above the level of the sea.

[1] A model of the Thames Valley, by Mr. J. B. Jordan, coloured geologically, may be seen at the Geological Museum, Jermyn Street. It clearly explains the relation of the river to the Oolitic and Cretaceous escarpments, pp. 513–15.

CHAPTER XXXI.

RELATION OF RIVER VALLEYS AND GRAVELS TO THE GLACIAL DRIFTS—RIVER TERRACES—BONES OF EXTINCT MAMMALS AND HUMAN REMAINS FOUND IN THEM—RAISED BEACHES, ETC.

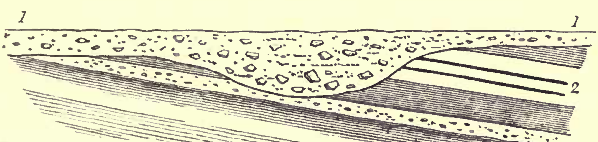
It is certain that by far the greater number of the river valleys of Britain, north of Bristol Channel and the Thames, *have been very much modified, and some of them deepened during the Glacial period*, a fact indeed sufficiently proved by the Glacial excavation of all the lakes that lie in rock-bound basins. Some valleys in England have been greatly modified since the Glacial period came to an end.

It may, however, be safely said that before the Glacial period the larger features of the river systems of Britain were much the same as now. When, before and during partial submergence, Boulder-clay overspread great part of the country, the river channels of the lower lands often got filled with that clay entirely, or in part. When the land emerged and surface drainage was restored, most of the rivers followed their old channels. In some cases they nearly scooped the Boulder-clay entirely out of them from end to end, but in others, as with the Tyne and the Wear, accidents partly turned the rivers aside, and having disposed of a thin covering of Boulder-clay, they proceeded to excavate deep and winding valleys in the Sandstone rocks below. This may be well seen at Durham on the Wear.

'The pre-Glacial valley,' says Mr. H. H. Howell, in a letter which I quote, 'runs nearly north and south from Durham to Newcastle. The river Wear, instead of following this old valley, meanders about, winding in and out of it, and at Durham cutting right across it, and passing into the sandstones of the Coal-measures, through which it has cut its way in a narrow gorge. At Chester-le-Street, half-way between Durham and Newcastle, the river Wear leaves the course of the old valley altogether, and, turning to the east, makes its way to the sea at Sunderland, passing principally through sandstones and shales of the Coal-measures, and cutting through the Magnesian Limestone, just before entering the sea.'[1]

It is for this reason that coal-miners in Northumberland and Durham, while mining a bed of coal, some-

Fig. 105.



1. Boulder-clay filling a valley. 2. Coal-measures with beds of coal.

times find it crop up deep underground against a mass of Boulder-clay that fills an ancient rocky valley, of which the plain above gives no indication.

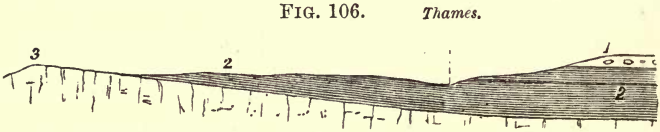
Again, if we examine the channels of other rivers in the south-east of England, we find that in places the

[1] See 'Transactions of the North of England Institute of Mining Engineers,' vol. xiii. pp. 69 to 85, especially the Map at p. 69 and the section p. 77.

Ouse, and its tributaries in Bedfordshire, and also many other streams flow through areas covered with this clay, and have cut themselves channels through it in such a way as to lead to the inference that parts of the valleys in which they run did not exist before the Boulder-bed period, but that they have excavated their courses through it and the underlying Oolitic strata, and thus formed a new system of valleys. These often only apply to parts of their channels.

Again, with regard to the Thames, I have said that it is remarkable that it rises in the Seven Springs, not far from the edge of the Oolitic escarpment of the Cotswold Hills that overlooks the Severn, which runs in the valley about 1,000 feet below. The infant Thames

FIG. 106.



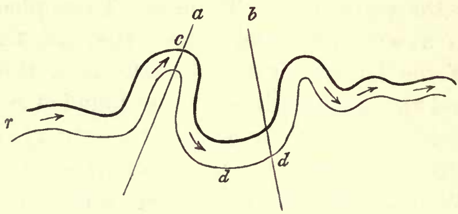
1. Boulder-clay. 2. London Clay. 3. Chalk.

thus flows at first across a broad tableland of Oolitic rocks, and by-and-by comes to a second tableland formed of the Chalk, and the wonder is that there its course was not turned aside by that high escarpment. Instead of that being the case, a valley cuts right across the escarpment of Chalk, through which the river flows, and this I have already explained in Chapter XXX. This escarpment dates from long before the deposition of the Boulder-beds, for we find far-transported boulders and Boulder-clay at its base, while in the same neighbourhood the drift has not always been deposited on its slopes, nor yet does it lie on the top. Yet north of the mouth of the estuary of the Thames in Essex we find Glacial deposits down to the level of the sea and passing into it; and near Romford, east of London, there are tablelands covered with Boulder-clay, which overlook the valley of the Thames. These phenomena, taken as a whole, certainly show that all the upper valley of the Thames is of older date than the Glacial epoch, and though Boulder-beds are found at Southend, on the north side of the mouth of the estuary, none occurs on its southern shores, nor in the plains and valleys of the Weald. Therefore, I now see no reason why the lower valley of the Thames west and east of London should not be entirely pre-Glacial, in which case it may be that some of its high-level gravel terraces belong to that date. The question is still in debate among geologists. I use the term high-level gravels to express the fact that thick deposits of gravel and loams having been formed in the valley, this alluvial detritus was subsequently cut into a succession of river-terraces in consequence of changes, slight but effective, in the physical geography of the area, and it is obvious that the highest terrace overlooking the river must be the oldest, and so on in succession till we reach the river-bank of to-day.

Before describing the relation of the river-gravels of the south of England to the Glacial epoch and palæolithic implements and mammalia, it is desirable to explain some of the details of the manner in which rivers have excavated their own valleys in solid rocks where no valleys existed before the drainage of the country took the general direction of its present flow. On the Continent, the Moselle and the Seine form excellent examples, and on a smaller scale many British rivers, including the Thames, have followed the same law.

Suppose a river flowing in a sinuous channel in the direction in which the arrows point in the following diagram:—

FIG. 107.



If the banks be high, they almost always have the shape shown in the section lines *a* and *b* across two of the greater curves of the river. The water rushing on

FIG. 108, *a*.

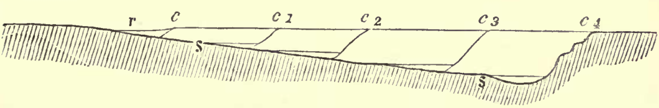
is projected with great force against the concave part of the curve, *c*, fig. 108, and in like manner it is again strongly projected against the concave cliff, *d*,

FIG. 109, *b*.

fig. 109. The result is, that the water wears back the cliffs, *c* and *d*; or, what tends to the same end, in conjunction with the wearing action of the water, the débris, loosened by atmospheric causes on the steep slopes, *c* and *d*, readily slips down to the level of the river, and is carried away by the force of the stream, thus making room for further slips.

When we think of the meaning of this, it at once explains the whole history of these constantly recurring forms, in all winding rivers that flow between rocky banks higher than broad alluvial plains and deltas. Take the history of the curve, fig. 107, as an example. On a high tableland the river, *r*, at an early period of its history, flowed where it is marked in fig. 110, the beginning of the curve, *c*, fig. 107, having already been established, but without any high cliffs. Then the stream, being driven with force against the concave curve, *c*, by degrees cut it back, we shall suppose, to c^1, at the same time deepening its channel. A

Fig. 110.



cliff was thus commenced at c^1, and, as the river was changing its bed by constant encroachment in the same direction, a gentle slope, *s*, began to be established, facing the cliff c^1, and so, on and on, through long ages, to c^2, c^3, and c^4, where the present cliff stands, itself as temporary as its smaller predecessors. This is the reason why in river curves, the concave side of the curve is so often opposed by a high rocky bank, while the convex side so generally presents a long gentle slope, *s s*, often more or less covered with alluvial detritus. In countries free of glacial débris, these effects are often best seen in their perfect simplicity; and in this way the Moselle, and the Seine near Rouen are, so to speak, model rivers. In many a British river it is clearly seen—on the Wye in South Wales, in many a river and minor stream in Derbyshire, Lancashire, and Yorkshire, and on the Thames, on the banks of its long sweeping curves where it passes through the Cretaceous escarpment between Appleford and Wallingford. In this way rivers must act and have always acted. It was during a residence on the banks of the Moselle in 1860 that I first learned this lesson.

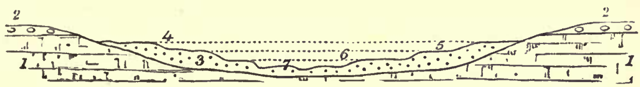
On the banks of the Thames below Maidenhead, and on those of many other rivers, there are frequent terraces, often cut out in more ancient gravels, which it had previously deposited. This is one of the effects of the past and present progressive action of rivers, close to or at various distances from any river as it now exists, according to its size and other circumstances. Sometimes these terraces have even been cut in solid rock, but more frequently in Boulder-clay, or in old gravels. Cases such as the following are frequent. The hills or tablelands on either side are, perhaps, made of solid rock, and the terraces lying between the higher slopes and the rivers consist of gravel of comparatively old date. The river at one time flowed over the top of the highest gravel terrace, and winding about from side to side of the valley, and cutting away detritus, it formed the terraces one after another, the terrace on the highest level being of oldest date, and that on the lowest level, that bounds the modern alluvium, the latest.

Thus, in the following figure, No. 1 represents the solid rocks of a country, covered on the top of the tableland with Boulder-clay, No. 2, these bounding a wide valley partly filled with ancient gravel, No. 3, which originally filled the valley from side to side as high as the uppermost dotted line, 4; but a river flowing through, by degrees bore part of the loose detritus to a lower level, thus cutting out the terraces in succession, marked Nos. 5, 6, and 7.

It often happens, that alluvial and gravelly deposits that sometimes even cap minor hills are left marking ancient levels of rivers; and in such gravels, sands, and loams, the bones of animals of extinct and living species have been often found, together with the palæolithic handiwork of ancient races of men.

Viewed as a whole, the remains of mammalia found in these river beds, have been generally believed to be of post-Glacial age, and in this opinion I coincide with regard to some of the rivers. One circumstance is, however,

FIG. 111.



worthy of special remark, that to a great extent they are identical in the river gravels of the southern half of England, with the species found in the British bone-caves, a list of which is given at page 481.[1] They consist of the White and Cave Bears, the Ermine, the Otter, Fox, Wolf, Hyæna (*spelæa*), Lion, the Red-deer, Reindeer, and *Cervus megaceros*, the Musk-sheep, Ox and Bison, Hippopotamus (*major*), Pig, Horse, two species of Rhinoceros (*R. leptorhinus* and *R. hemitœchus*), two species of Elephants (*E. primigenius* and *E. antiquus*), Hare-rat (*Lagomys spelæus*), *Spermophilus* (a

[1] The Cave Mammalia, also known in river deposits, are *Rhinolophus, ferum-equinum, Vespertilio noctula, Sorex vulgaris, Ursus Arctos, Gulo luscus, Meles taxus, Mustela putorius, M. martes, Felis catus, F. pardii, F. lynx, Machairodus latidens, Alces malchis, Cervus Browni, Rhinoceros leptorhinus* (?), *Lepus cuniculus, Lagomys spelæus, Spermophilus erythrogenoides, Arvicola pratensis, A. agrestis, A. amphibius,* and *Castor fiber.*—DAWKINS.

Squirrel), Rabbits, Mice, and some other small animals. With the extinct Mammals mentioned above, the works of man in the state of flint weapons, &c. have of late years become familiar to English geologists. For long they shrunk from the idea with excessive caution, and the full proof first came before them from France.

In the year 1847, a French *savant,* Mons. Boucher de Perthes, of Abbeville, published an account, in the first volume of his 'Antiquités celtiques,' of flint implements, the work of man, found in association with the teeth of the Mammoth (*Elephas primigenius*) in the old river gravels of the Somme. The strata consisted of surface soil, below which were nearly five feet of brown clay, then loam, then a little gravel containing land shells, and along with these shells the teeth of the Mammoth. Below that level there occurred white sand and fresh-water shells, and again the bones and teeth of the Mammoth and other extinct species; and along with these bones and teeth, a number of well-formed flint hatchets of what we now call the palæolithic type.

Geologists were for long asleep on this subject. M. de Perthes had printed it many years, but none of them paid much attention to him. At length, Mr. Prestwich having his attention drawn to the subject, began to examine the question. He visited M. de Perthes, who distinctly proved to him, and afterwards to other English geologists, that what he had stated was incontestably the fact. These implements are somewhat rude in form, but when I say 'rude,' I do not mean that there is any doubt of their having been formed artificially. They are not polished and finished, like those of later date in our own islands, or the modern ones brought from the South Sea Islands; but there can be no doubt whatever that they were formed by the hand of man; and I say this with authority, since, for more than thirty years, I have been daily in the habit of handling stones, and no man who knows how chalk flints are fractured by nature, would doubt the artificial character of these ancient tools or weapons.

The same kind of observations have been made in our own country. In the neighbourhood of Bedford, on the Ouse, there are beds of river gravel of this kind which rise about twenty-five feet above the level of the river, in broad terraces; and in one of these, far above the river, there have been found a considerable number of flint hatchets, associated with river shells, the bones of the Mammoth, old varieties of oxen, and various other mammalia. By the river Waveney also, on the borders of Norfolk and Suffolk, at Hoxne near Diss, the same phenomena have been observed in old gravel pits, made for the extraction of road materials; and it has been proved that near the mouth of the estuary of the Thames, between the Reculvers and Herne Bay, flint hatchets of Palæolithic type have fallen from the top of a cliff of Eocene sand, which is capped with high-level river-gravel of the ancient river. These were first found by Mr. T. Leech (see fig. 112). Later I found one on the beach partly water-worn by the waves, and at the same time, Prof. T. McKenny Hughes found another, fresh and unworn, and both are of palæolithic type. No bones have as yet been observed in that precise locality along with the implements, but in many places further up the Thames, the remains have been found of extinct mammalia. For example, at Acton, a few miles west of London, at a height of about twenty feet above high-river mark, Colonel Lane Fox found *Elephas primigenius*, *Rhinoceros hemitœchus*, *Hippopotamus major*, *Bos primi-*

genius, *Bison priscus*, *Cervus tarandus*, and other species in a middle terrace; and at a height of seventy

Fig. 112.

Palæolithic flint hatchet, Herne Bay. In the Museum of Practical Geology.

feet above high-water mark, near the same village, he found a palæolithic flint implement, besides flint flakes.

They lay in a bed of ochreous sandy clay, about one foot in thickness, which reposed immediately on the blue London Clay.

On the south side of the Thames, on the Cray, a tributary of the Darent, which enters the Thames at Dartford Marshes, palæolithic implements have been found near Green Street Green; and in other places, in the valley of the Medway near Maidstone, and elsewhere in Kent, worked flints have been found by Professor Hughes, Mr. Whitaker, and others.[1] It is therefore very clear that the bones of *Elephas primigenius* and other mammalia, some of them extinct, occur in many places associated with the works of pre-historic man. As yet, however, the bones of man have never been discovered along with extinct mammals in British river gravels, unless we get a hint on the subject from the discovery of human skulls, fifty-three feet beneath the surface, at the Caron tin stream-works, north of Falmouth, 'mingled with bones of deer and other animals, among wood, moss, leaves, and nuts,' and 'at Pentuan human skulls are stated to have been found under about forty feet of detrital accumulations, also mingled with the remains of deer, oxen, hogs, and whales.'[2]

There is, of course, plenty of evidence that some of the alluvial deposits of the Thames and many other southern rivers are altogether post-glacial, and the history of these alluvia can often be traced down to

[1] For many details see 'Ancient Stone Implements,' by John Evans, F.R.S., chap. xxiii.

[2] 'Geological Report on Cornwall, Devon, and West Somerset,' 1839, p. 407: 'The Geological Observer,' 1853, p. 449. Sir H. T. De la Beche. The accounts of these discoveries are scarcely sufficiently definite for an opinion to be formed with respect to their comparative antiquity.

historical times, as, for example, in the case of the alluvial meadows of the Ouse, once a commodious estuary, in which the Saxon fleets could ride as far up as Alport, a mile above Lewes. Further north the peats and broad marshy alluvia of the Wash lie on Boulder-clay, and the same is the case with what may be called the recent *warps* of the Humber and much of the loamy alluvial strata that cover the broad plain of York and pass northward to the Tees, between the Oolitic escarpment and the uprising of the western slopes of the Magnesian Limestone and Carboniferous rocks. The gravels and clayey alluvia of the Wear and the Tyne play the same part, beautiful examples of the latter being well seen on the banks of the Tyne below Newcastle, and above that town at the junction of the North Tyne with the larger river. In great part of the Severn valley the same kind of phenomena are apparent, and indeed in many of the river valleys of England the occurrence of old river detritus above the Boulder-clay is not to be doubted.

These gravels and other alluvia were therefore often made by rain and the wasting action of the rivers sometimes working on the Boulder-clays, and sometimes partly wearing out new valleys, and when flooded spreading sediments abroad on their banks. As in the older alluvia, so in these more recent deposits, it is natural that many bones of Mammalia should be found, a few of which may be of extinct species. It is, however, certain, that in the subject of river-gravel Mammalia, there has been a good deal of confusion arising from the habit of their having been assumed to be all of the same age.

I have already stated (p. 482) that after the deposition of the Glacial deposits, Britain, by a considerable elevation of the land and sea-bottom, was re-united to the Continent, chiefly by a broad plain of Boulder-clay. Through this plain I think that the Rhine must have wandered in pre-historic times to what is now a northern part of the North Sea, and all the eastern rivers of England—the Thames, the rivers of the Wash and the Humber, the Tyne—and possibly some of the rivers of Scotland, were its tributaries.

This Boulder-clay, from the manner in which it was formed had a very irregular surface, enclosing lakes and pools, some of which may still be seen on the plains of Holderness. I have said that *after* the deposition of the Boulder-clay, Britain was re-united to the Continent, but it is well known that various oscillations of the relative level of the land to the sea took place during the Glacial epoch, and under these circumstances it may, not improbably, have been partly joined to the mainland during inter-Glacial episodes, or again, when glacier ice covered broad tracts of country.

At such times the present mouths of many British rivers could have had no immediate relation to their ancient mouths, for the places of their present mouths then lay far inland. Under such circumstances it seems not unlikely that alluvial gravels, such as those of Bedford Level, may have been deposited in lakes dammed up by some old Boulder-clay that formed part of the plain through which the rivers flowed. The wide gravel plain within the circuit of the great moraine of the Dora Baltea in Piedmont forms a sort of case in point, for, according to Gastaldi, an old lake-hollow has there been entirely filled with gravel borne by the river from the Val d'Aosta.

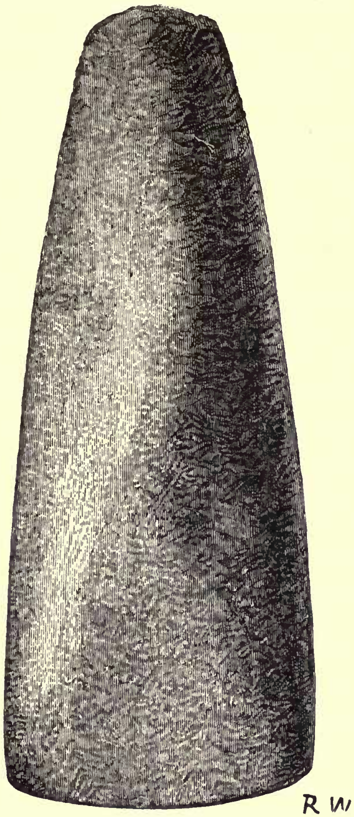
It is often difficult to account for the great thickness of these lowlying gravels on any other hypothesis, since in many cases they are not estuarine, for they contain no sea-shells, but only land and fresh-water species, mingled with occasional trunks of trees, and the bones of mammalia, some of which are of extinct species.

I have previously stated that bone-caves in Britain as caves, may have been of pre-Glacial date, and the occurrence of worked flints along with extinct mammals in the Victoria Cave, shows that there man is either of inter-Glacial or pre-Glacial age, for, at the mouth of the cavern, Boulder-clay lay *over* the sediments that contained these remains, as proved by Mr. Tiddeman (see p. 465). In like manner I am satisfied that Mr. Skertchly has nearly proved to demonstration the occurrence of flint implements in brick-earth beneath the Chalky Boulder-clay of the neighbourhood of Brandon, this brick-earth being probably of inter-Glacial age, for the Chalky Boulder-clay is, in his opinion, not one of the earliest glacial deposits. I have also shown, by the testimony of many accurate investigations, that in the bone-caves of Somersetshire and Devonshire the works of man occur with extinct mammals, and the same is the case in the ancient gravels of the Thames and other rivers.

Arguing on these points, Mr. James Geikie says: 'If palæolithic deposits have a very limited range, such is not the case with those of neolithic age (fig. 113). Implements belonging to this latter age occur everywhere throughout the British Islands. From Caithness to Cornwall, and from the east coast of England to the western borders of Ireland they are continually being picked up. Even in the bleak Orkney and Shetland Islands, and all over the inner and outer Hebrides, relics of neolithic times have been met with, so that the wide distribution of these implements is in striking contrast to the limited range of palæolithic remains.

We know that neolithic man was accompanied by a

Fig. 113.



Neolithic hatchet in the Museum of Practical Geology. Dredged from the bed of the Thames, Erith.

mammalian fauna that differed very much from that with which palæolithic man was associated. Dogs, horses, pigs, several breeds of oxen, the bison, the red deer, the Irish elk, and such like, were the characteristic forms of neolithic times. . . .

How then are all these facts to be accounted for? . . . The answer which I give to all these queries is simply this—the palæolithic deposits are of pre-Glacial and inter-Glacial age, and do not, in any part, belong to post-Glacial times. They are either entirely wanting, or very sparingly represented, in the midland and northern counties, in Wales, Scotland, and Ireland, because all those regions have again and again been subjected to the grinding action of land-ice, and the destructive influence of the sea. But in those districts which were not submerged during the last great depression of the land, and in such regions as were never overwhelmed by the confluent ice-masses, the valley gravels form a continuous series of records from pre-Glacial times to the present day. . . . To the last inter-Glacial period, then, we must refer the great bulk of the palæolithic river-gravels of the south-east of England.'[1]

I go further than this, for though it cannot be proved to a demonstration that man inhabited our area in pre-Glacial times, yet the concurrence of probabilities that he did so is so great, that I have a profound conviction that, at that epoch, here he must have been. I have already more than hinted at his presence in the south, in the caves of Devonshire, while the more northern areas were shrouded in ice (p. 462). If he inhabited the British area during inter-Glacial times, why should he have come at that precise period and not before. It seems to me much more probable that he did live here before the Glacial epoch began, and that he retired to

[1] 'Great Ice Age,' pp. 530 and 531.

the south before the advancing glacier ice-sheets. The changing climate might by degrees suit him well enough, for do not the Greenlanders of our own time live in comfort in their own way among and on the edges of the snows and glaciers of Greenland. Ethnologically, Professor Boyd Dawkins, in 'Cave Hunting,' has compared them to our own Palæolithic Man. If in Britain such men survived the Glacial epoch, their blood, much diluted, may even be among us still.

Before quitting this part of the subject I may repeat that on the Continent, in caves on the Meuse, Dr. Schmerling found bones of men mingled with those of the Cave Bear, Hyæna, Elephant, and Rhinoceros.

In a magnificent work, 'Reliquiæ Aquitanicæ,' by the late Messrs. Edouard Lartet and Henry Christy, ably edited by Professor T. Rupert Jones, an account is given of the caves of Dordogne in the south of France. These, in the valley of the river Vezère, have yielded bones of *Hyæna* and *Felis spelæa* (Lion), *Ursus spelæus*, Wolf and Fox, the Mammoth, Musk Sheep, Aurochs, Chamois, Ibex, Reindeer, Red Deer, *Megaceros Hibernicus*, Horse, and a few others, and among these were found numerous implements both of flint and bone. The caverns were inhabited by man, and numbers of the bones have been broken, partly for the extraction of the marrow. Among the bone implements are needles, harpoons, and daggers, while of stone there are numerous flint knives, spear-heads, &c., all made by chipping, and, unlike neolithic implements, quite unpolished. More interesting still, on the bones and horns themselves are carved prehistoric drawings, executed with considerable skill, of the Reindeer, Horse, Ibex, Bison, Birds, and most important of all, from the Cave of La Madelaine, in Dordogne, an unmistakable incised drawing of the Mammoth with shaggy mane, executed on part of a tusk of the gigantic beast. Should anyone still feel inclined to doubt the stratigraphical evidence that man was contemporary with the Mammoth, he will probably feel compelled to admit the evidence yielded by this tusk.[1]

Further, in the surface strata of the Meuse, called Loess near Maestricht, human skeletons with some abnormal peculiarities are said to have been found. I have seen these bones, which certainly have an antique look, but some doubt exists as to the precise circumstances under which they were discovered. In the same neighbourhood, however, it is certain that a human jaw was found in strata containing the remains of Mammoths, &c. Many other examples might be given, of the remains of old races of men in such like caverns or in river deposits; but enough has been said to show that there can be no doubt that man was contemporary with extinct Mammalia; and there can be little doubt that his origin in our island dates back to a time when the country was united to the mainland, and that, along with the great hairy Mammoth, the Rhinoceros, the Hippopotamus, Lion, Hyæna, and other mammalia partly extinct, he travelled hither at a time when the arts were so rude, that he had no means of coming *except on foot.*

One word more on a kindred subject. Round great part of our coast we find terraces from twenty to fifty feet above the level of the sea, and in some places the

[1] A fine specimen of this cave bone-breccia, with a needle and flint implement, may be seen in the Museum of Practical Geology, together with casts in plaster of some of the carved figures. The originals, including the figure of the *Elephas primigenius,* belong to the British Museum.

terrace runs with persistence for a number of miles. Round the Firth of Forth, for example, on both shores, there is an old sea cliff of solid rock, overlooking a raised beach or terrace, now often cultivated, and then we come to the present sea beach. This terrace usually consists of gravel and sea-shells, of the same species with those that lie upon the present beach, where the tide rises and falls. The same kind of terrace is found on the shores of the Firth of Clyde, and round the Isle of Arran, and in almost all the other estuaries of Scotland, and in places round the coast of the West Highlands. Old sea caverns are common in these elevated cliffs, made at a time when they were daily washed by the waves. Similar or analogous raised beaches occur on the borders of Wales, and in the south of England. In Devon and Cornwall there are the remains of old consolidated beaches clinging to the cliffs from twenty to thirty feet above the level of the sea. It is clear, therefore, that an elevation of the land has occurred in places to the extent of about forty feet, at a very recent period, long after all the living species of shell-fish inhabited our shores. In Scotland other old sea terraces occur at heights of a hundred feet and more.

Further, in the alluvial plains that border the Forth, and on the Clyde in the neighbourhood of Glasgow, at various times, in cutting trenches, canals, and other works, the bones of whales, seals, and porpoises, have been found, at a height of from twenty to thirty feet above the level of high-water mark. Now it is evident that whales did not crawl twenty or thirty feet above high-water mark to die, and therefore they must either have died upon the spot where their skeletons were found or been floated there after death. That part of the country, therefore, must have been covered with salt water, which is now occupied simply by common alluvial detritus. But the story does not stop there, for together with the bones of the whales in the upraised marine clays of the Forth, implements of bone and wood have been obtained, and in beds on the Clyde, canoes were found in a state of preservation so perfect that all their form and structure could be well made out. Some of them were simply scooped in the trunks of large trees, but others were built of planks nailed together—square-sterned boats indeed, built of well-dressed planks—and the inference has been drawn by my colleague, Professor Geikie, who has described them, that this last elevation took place at a time that is possibly historical.

There is one piece of evidence with respect to the possible recent elevation of these terraces which I think is deserving of attention, and it is this:—In the neighbourhood of Falkirk, on the south shore of the Firth of Forth, there is a small stream, and several miles up that stream, beyond the influence of the tide of the present day, there were, at the end of last century, remains of old Roman docks, near the end of the Roman Wall, usually called the Wall of Antoninus, that stretched across Scotland from the Firth of Clyde to the Firth of Forth. These docks are now no longer to be seen; but so perfect were they, that General Roy, when commencing the triangulation of Scotland for the Ordnance Survey, was able to describe them in detail, and actually to draw plans of them. When they were built they were of course close to the tide, and stood on the banks of a stream called the Carron, believed by Professor Geikie to have been tidal; but the sea does not come near to them now. He therefore naturally inferred that when they were constructed the relative height of the land to the sea must have been less than at present.

Again, the great Wall of Antoninus, erected as a barrier against invasions by the northern barbarians of the territory conquered by the Romans, must have been brought down close to the sea level at both ends. Its eastern termination is recognised by most antiquaries as having been placed near Carriden, where the great Falkirk flats disappear along the shore. Its western extremity, not having the favourable foundation of a steep rising ground, now stands a little way back from the sea-margin of the Clyde. When it was built it was probably carried to the point where the chain of the Kilpatrick Hills, descending abruptly into the water, saved any further need for fortification. But owing to a probable rise of the land, a level space of ground, twenty or twenty-five feet above the sea, now lies between high-water mark and the base of the hills, and runs westward from the termination of the wall for several miles as far as Dumbarton. Had this belt of land existed then, there appears little reason to doubt that the Romans would not have been slow to take advantage of it, so as completely to prevent the Caledonians from crossing the narrow parts of the river, and drive them into the opener reaches of the estuary below Dumbarton.

While the position of marine shells *in situ* proves the former presence of the sea at a height of 20 or 25 feet above its present level, along both sides of the island, it is possible that in the case both of the Clyde and Forth, the change of level within the human period may be partly due to silting up, though it must always be extremely difficult to draw a line between the results of the two operations.

CHAPTER XXXII.

QUALITIES OF RIVER-WATERS—DISSOLVING OF LIMESTONE ROCKS BY SOLUTION.

I HAVE already given a sketch of the chief river areas of Great Britain, but I did not enter upon one important point connected with them, namely, the qualities of their waters. If we examine the geological structure of our island with regard to its watersheds and river-courses, we find, as already stated, that the larger streams, with one or two exceptions, run into the German Ocean; the chief exception being the Severn and its tributaries, which drain a large proportion of Wales, and a considerable part of the interior of England. A much larger area of country is, however, drained towards the east than to the west.

When we examine the qualities of the waters of our rivers, we find that this necessarily depends on the nature of the rocks and soils over which they flow. Thus the waters of the rivers of Scotland are, for the most part, soft. All the Highland waters, as a rule, are soft; the mountains being composed of granitic rocks, gneiss, mica-schist, and the like, a very small proportion of limestone being intermingled therewith, and the other rocks being, for the most part, almost free from carbonate of lime. Only a small proportion of lime, soda, or potash, is taken up by the water that falls upon, flows over, or drains through these rocks, the soda or potash being chiefly derived from the felspathic ingredients of the various formations, and therefore the waters are soft. For this reason, at a vast expense, Glasgow has been supplied with water from Loch Katrine, which, lying amid the gneissic rocks, is, like almost all other waters from our oldest formations, soft, pure, and delightful. The same is the case with the waters that run from the Silurian rocks of the Lammermuir Hills; and the only fault that can be found with all of these waters, excepting by anglers in times of flood, is that they are apt to be a little flavoured and tinged by colouring matter derived from peat.

The water of the rivers drained from the Silurian Cumberland mountains is also soft, and so little of the waters of that country rises in the lower plateaux of Carboniferous Limestone that it scarcely affects their quality.

The water from the Welsh mountains is also in great part soft, the country being formed of Silurian rocks, here and there slightly calcareous, from the presence of fossils mixed with the hardened sandy or slaty sediment, that forms the larger part of that country. So sweet and pleasant are the waters of Bala Lake, compared with the impure mixtures we sometimes drink in London, that it has been more than once proposed to lead it all the way for the supply of water for the capital; and the same proposition has been made with regard to the waters of Plinlimmon [1] and the adjacent mountains of Cardiganshire. But when in Wales, and on its borders, we come to the Old Red Sandstone district, the marls are somewhat calcareous, and interstratified with impure concretionary limestones,

[1] Properly Plymlumon.

called cornstones, and the waters are harder. The waters are apt to be still harder in the Carboniferous Limestone tracts that sometimes rise into high escarpments round the borders of the great South Wales coalfield, and in Flintshire and Denbighshire.

Again, the waters that flow from the northern part of the Pennine chain, as far south as Clitheroe and Skipton, are apt to be somewhat hard, because they drain areas composed partly of Carboniferous Limestone. But, as a rule, wherever they rise in, and flow through strata formed of Yoredale shales and sandstones and Millstone Grit, the waters are soft; and this is one reason why so many reservoirs have been constructed in the Millstone Grit regions of Lancashire, Yorkshire, and Derbyshire, for the supply of large towns and cities such as Bradford, Preston, Manchester, and Liverpool. All the waters of the Carboniferous Limestone of Derbyshire, such as the Dove and the Wye, are hard. All the rivers that flow over the Permian rocks and New Red Sandstone and Marl, are, as a rule, somewhat hard, and the waters of the Lias, and the Oolitic and the Cretaceous rocks, are of necessity charged with those substances in solution that make water hard, because the Lias and Oolites are so largely formed of limestones, and the Chalk is almost entirely composed of carbonate of lime.

It thus happens that, as a general rule, most of the rivers that flow into the sea on the eastern and southern shores of England, as far west as the borders of Devonshire, are of hard water. The waters of the Severn are less so, but still they contain a considerable amount of bicarbonate of lime in solution. The waters of the Mersey, the Dee, and the Clwyd, are also somewhat hard, while those that flow westward in Wales are soft and pleasant, and would always be wholesome were it not that many are polluted, and the fish killed in them, by the refuse of the crushed ores of lead and copper mines.

Before proceeding to other subjects, I must try to give some idea of the quantity of some of the salts which are carried in solution to the sea by the agency of running water.

The first case I shall take is at Bath, where there is a striking example of what a mere spring can do. The Bath Old Well yields 126 gallons of water per minute, which is equal to 181,440 gallons per day. There are a number of constituents in this water, such as carbonate of lime, nearly nine grains to the gallon; sulphate of lime, more than eighty grains; sulphate of soda, more than seventeen grains; common salt, rather more than twelve and a half grains; chloride of magnesium, fourteen and a half grains to the gallon, &c. &c.—altogether, with our minor constituents, there are 144 grains of salts in solution in every gallon of this water, which is equal to 3,732 lbs. per day, or 608 tons a year. A cubic yard of limestone may be roughly estimated to weigh two tons. If, therefore, these salts were precipitated, compressed, and solidified into the same bulk, and having the same weight, as limestone, we should find the annual discharge of the Bath wells capable of forming a column 3 feet square in diameter, and about 912 feet high. Yet this large amount of solid mineral matter is carried away every year in invisible solution in water which, to the eye, appears perfectly limpid and pure. There are many other salt springs in England, such as those of Cheltenham, and numberless others nominally fresh, each of which brings to the surface its proportion of salts in solution. Indeed, it has been shown by the late Professor Rogers that all springs contain an appreciable proportion of common salt besides other ingredients in solution. This being the case, and rivers being fed by springs that rise in rocks, in addition to the water drained from the surface, it is obvious that all rivers must contain various proportions of substances soluble in the rocks, and, indeed, it is known that even small quantities of silica may be dissolved in pure distilled water.

The Thames is a good type of what may be done in this way by a moderate-sized river, draining a country which, to a great extent, is composed of calcareous rocks. It rises at the Seven Springs, near the western edge of, and therefore not far from the highest part of the Oolitic tableland of the Cotswold Hills, and flows eastward through all the Oolitic strata, composed mostly of thick formations of limestone, calcareous sand, and masses of clay, which often contain shelly bands and scattered fossil shells. Then, bending to the south-east, below Oxford, it crosses the Lower Greensand, the Gault, the Upper Greensand, all calcareous, and the Chalk, the last of which may be roughly stated as consisting of nearly pure limestone: then through the London Clay and other strata belonging to the great Eocene formations of the London basin, which are nearly all more or less calcareous. The Thames may therefore be expected to contain substances of various kinds in solution in large quantities; and to those derived from the rocks must be added, all the impurities from the drainage of the villages and towns that line its banks between the Seven Springs and London.

At Teddington, on a rough average for the year, 1,337 cubic feet of water (equal to 8,343 gallons) pass seaward per second: and, upon analysis, it was found that about twenty-two and a half grains of various matters, chiefly bicarbonate of lime, occur in solution in each gallon, thus giving 187,717 grains per second passing seaward. This is equal to nearly 96,540 lbs. per hour, 2,316,960 lbs. per day, or 377,540 tons a year: and this amount is chiefly dissolved *out of the bulk of the solid rocks and surface soils of the country*, aided by sewage matter derived from the drainage of towns, and mineral and animal manures used in agriculture, the whole passing out to sea in an invisible form, known only to the analytical chemist. What proportion of this is exclusively derived from substances contained in the rocks I am unable to say, but Professor Prestwich in his Presidential Address to the Geological Society in 1872 mentions that, according to different estimates, the average daily discharge of the Thames at Kingston has been variously estimated by Mr. Beardmore at 1,145 millions, and by Mr. Harrison at 1,353 millions of gallons.

'Taking,' says Professor Prestwich, 'the mean daily discharge at Kingston at 1,250 million gallons, and the salts in solution at 19 grains per gallon, the mean quantity of dissolved mineral matter there carried down by the Thames every twenty-four hours is equal to 3,364,286 lbs. or 1,502 tons, which is equal to 548,230 tons in a year. Of this daily quantity, about two-thirds, or say 1,000 tons, consist of carbonate of lime, and 238 tons of sulphate of lime; while limited proportions of carbonate of magnesia, sulphates of soda and potash, silica, and traces of iron, alumina, and phosphates constitute the rest. . . . Therefore' (with some minor eliminations) 'the quantity of carbonate of lime carried away from the area of the Thames basin above Kingston (2,072 square miles) is equal to 797 tons daily, or 290,905 tons annually. Adding the other ingredients not included in Professor Prestwich's calculation, such as chlorides of sodium and potassium, sulphates of soda and potash, carbonate of magnesia, silica, alumina, &c., the sum total of substances annually carried to the sea in solution, will closely approximate to my earlier calculation.

If we consider that this is only one of many rivers that flow over rocks which contain lime and other substances easily soluble, we then begin to comprehend what an enormous quantity of matter by this—to the eye—perfectly imperceptible process is being constantly carried into the sea. If we take all the other rivers of the east, and those of the south of England (exclusive of those of Devon and Cornwall), we find that they drain more than 18,000 square miles, to a great extent consisting of limestone and other calcareous rocks; and if we assume the amount of outflow from the sum of these rivers to be only three times that of the Thames (and I believe it must be more), we may have about 872,715 tons of bicarbonate of lime and other substances passing with these rivers annually to the sea in solution.

The rivers of the west coast of England and of the whole of Wales drain about 30,000 square miles; and the waters, as a rule, are much softer than those of the east of England. But it does not necessarily follow, in the course of a year, that these rivers, in proportion to rainfall and the areas which they drain, do not each carry off as much matter in solution as those of the east of England. Their softness is due to the circumstance, that the rock-formations of the west are much less calcareous than those of the eastern division of the kingdom. I have already shown that the greatest amount of rainfall for given areas is in the west of

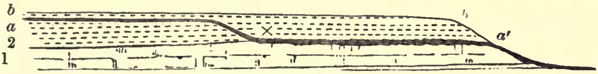
England and Wales, especially in the mountain regions, and this extra amount of rainfall must have the effect of producing an extra amount of solution of the alkaline and other constituents that so largely form the constituents of those palæozoic rocks that form the hilly regions. If so, then, for given areas, the quantity of matter carried to the sea by the western areas, may be approximately equivalent in a year to that which is found in the eastern-flowing rivers. This idea, new to me, was first impressed on my mind by reading the Presidental Address of Mr. T. Mellard Reade to the Liverpool Geological Society, 1877, in which, among other important matters, he states that 'a total of 68,450,936,960 tons of water run off the area of England and Wales annually, equal to 18·3 inches in depth, which leaves 13·7 inches for evaporation. The total solids in solution amount to 8,370,630 tons, about equal to 558,042 tons in a year, if reduced to a solid state. This would cover four square miles of ground with a stratum of limestone one foot thick, assuming that 13½ cubic feet go to a ton, and also, for the sake of argument, that all the matter in solution is in the state of bicarbonate of lime. We know this not to be the case, but this makes no difference in respect of the amount of the various salts dissolved out of the rocks. According to Mr. T. Mellard Reade's estimate of 15 feet to the ton, 'the amount of denudation, if distributed equally over England and Wales, reckoned at 58,300 square miles, would be ·0077 of a foot per century, that is, it would take 12,978 years to reduce it one foot.' There is no doubt, however, that the quantity carried away in solution varies much in different geological areas, for of all the rocky formations, limestones are most easily acted upon by carbonic acid in rain water.

If we could take all the rivers of the world into the calculation, how great the amount must be. The St. Lawrence alone drains an area of 297,600 square miles, three and a third times larger than the whole of Great Britain, and that of the Mississippi is 982,400 square miles, or more than three times as large as the area drained by the St. Lawrence. The Amazon drains an area of 1,512,000 square miles, but it is needless to multiply cases.

It is a necessary part of the economy of Nature that this dissolving of the constituents of rocks should always be going on over all the world, for it is from solutions of lime and other salts thus obtained by the sea, that plants and shell-fish derive part of their nourishment, plants for their tissues, and Mollusca and other creatures for their shells and bones. As it is now, so has it been through all proved geological time, and doubtless long before; for the oldest known strata, the Laurentian rocks, were themselves originally formed of ordinary sediments, and consist in part of thick strata of limestone that must have been formed by the life and death of organic creatures in the sea.

This waste of material by the *dissolving* of rocks is indeed evident to the practised eye over most of the solid limestone districts of England, and I shall therefore say a little more on the subject. On the flat tops of the Chalk Downs, for example, over large areas in Dorsetshire, Hampshire, and Wiltshire, quantities of angular unworn flints, many feet in thickness, completely cover the surface of the land, revealing to the thoughtful mind the fact, that all these accumulations of barren stones have not been transported from a distance, but represent the gradual destruction by rain and carbonic acid, of a vast thickness of chalk with layers of flint, that once existed above the present surface. The following diagram will explain this:—

FIG. 114.



1, Chalk without flints. 2, Chalk with flints. *a a*, the present surface of the ground marked by a dark line. *b b*, an old surface of ground, marked by a light line. Between *a a* the surface is covered by accumulated flints, the thickness of which is greatest where the line is thickest between *a′* and ×, above which surface a greater proportion of chalk has been dissolved and disappeared.

An irregular mixture of clay with flints, often several feet thick, is also frequent on the surface of the Chalk Downs on both sides of the valley of the Thames. The flints, though sometimes broken, are in other respects of the shape in which they were left by the dissolving away of the Chalk, and the clay itself is an insoluble residue, originally sparingly mingled with that limestone.

There is no doubt but that the plateaux of Carboniferous Limestone of the Mendip Hills, of Wales, of Derbyshire, and of the north of England, have suffered waste by solution, equal to that of the Chalk, only from the absence of flints in these strata we have no insoluble residue by which to estimate its amount. In Lancashire, north of Morecambe Bay, in Westmoreland, and in Yorkshire, east, north-east, and north-west of Settle, the high plateaux of limestone are often for miles half bare of vegetation. The surface of the rock is rough and rugged from the effects of rain-water and the carbonic acid it contains; looking, on a large scale, like surfaces of salt or sugar half dissolved. The joints of the rock have been widened by this chemical action, and it requires wary walking, with your eyes on the ground, to avoid, perhaps, a broken leg. The Oolites must have suffered in the same way, especially where not covered by Boulder-clay; for, it must be remembered, that such effects are chiefly the result of the exposure of limestones on the actual surface of the ground.

Let me, in concluding this chapter, once more recall to the mind of the half-instructed reader that the sea is the final recipient of all invisible solutions and of all visible sentiments.

> All mountain rivers lost, in the wide home
> Of thy capacious bosom ever flow.

Rain and rivers are the unwearied destroyers of all lands, aided by the restless beating of the waves on rock-bound coasts. These destroy but to reconstruct new strata, by the upheaval of which future lands shall rise. As the Ocean is now, so has it been throughout all authentic geological history, and

> Its voice mysterious, which whoso hears,
> *Must think of what will be, and what has been—*

is always present to the mind of the physical geologist, ever since the time when John Ray, in 1691, published his far-seeing work 'On the Wisdom of God manifested in the Works of Creation.'

CHAPTER XXXIII.

SOILS.

The soils of a country necessarily vary to a great extent, though not entirely, with the nature of the underlying geological formations. Thus, in the highlands of Scotland the gneissic and granitic mountains are generally heathy and barren, because they are so high and craggy, and their hard rocky materials sometimes come bare to the surface over considerable areas. Strips of fertile meadow land lie chiefly on narrow alluvial plains, which here and there border the rivers. Hence the Highlands mainly form a wild and pastoral country, sacred to grouse, black cattle, sheep, and red deer.

Further south, Silurian rocks, though the scenery is different, produce more or less the same kinds of soil, in the broad range of hills that lies between the great valleys of the Clyde and Forth, and the borders of England, including the Muirfoot and the Lammermuir Hills, and the high grounds that stretch southwards into Carrick and Galloway. There, the rocks, being chiefly composed of hard, untractable, gritty, and slaty material, form but little soil because they are difficult to decompose. Hence the higher ground is to a great extent untilled, though excellently adapted for pastoral purposes. Where, however, the slopes are covered more or less with old ice-drifts and moraine matter, the soil, even high on the slopes, is deep, and the ground is fertile, and many beautiful vales intersect the country. Through this classic ground run the Whitader and the Tweed, the Teviot and the Clyde; the White Esk, the Annan, the Nith, and the Dee, which run through the mountains of Galloway to the Solway Firth. Most of these rivers have often a bare, unwooded, and solitary pastoral character in the upper parts of their courses, gradually passing, as they descend and widen, into well cultivated fields and woodlands.

The great central valley of Scotland, between the metamorphic series of the Highland mountains and the less altered Silurian strata of the high-lying southern counties, is occupied by rocks of a more mixed character, consisting of Old Red Sandstone and Marl, and of the shales, sandstones, and limestones of the Carboniferous series, intermixed with considerable masses of igneous rocks. The effect of denudation upon these formations in old times, particularly of the denudation which took place during the Glacial period, and also of the rearrangement of the ice-borne débris by subsequent marine action, has been to cover large tracts of country with a happy mixture of materials—such as clay mixed with pebbles, sand, and lime. In this way one of the most fertile tracts anywhere to be found in our island has been formed, and its cultivation for nearly a century has been taken in hand by skilful farmers, who have brought the agriculture of that district up to the very highest pitch which it has attained in any part of Great Britain.

Through the inland parts of England, from Northumberland to Derbyshire, we have another long tract of hilly country, composed of Carboniferous rocks, forming in parts regions so high that, except in the dales, much of it is unfitted for ordinary agricultural operations.

The Derbyshire limestone tract, for the most part high and grassy, consists almost entirely of pasture lands, intersected by cultivated valleys. On the east and west that region is skirted by high heathy ridges of Millstone Grit. North of the limestone lies the moss-covered plateau of Millstone Grit, called Kinder Scout, nearly 2,000 feet in height; and beyond this, between the Lancashire and Yorkshire coalfields, there is a vast expanse of similar moorland, intersected by grassy valleys. Still further north, all the way to the borders of Scotland, east of the fertile Vale of Eden, the country may also be described as a great high plateau, sloping gently eastward, through which the rivers of Yorkshire and Northumberland have scooped unnumbered valleys.

The uplands are generally heathy, with occasional tracts of peat and small lakes; but when formed partly of limestone, grassy mountain pastures are apt to prevail, through which in places those 'blind roads' run northward into Scotland, so graphically described in chapters xxii. and xxiii. of Scott's 'Guy Mannering.' Here and there the deeper valleys are cultivated, dotted with villages, hamlets, the seats of squires, farms, and the small possessions of the original *Statesmen.* Of this kind of land the Yorkshire dales may be taken as a type. Nothing is more beautiful than these dales, so little known to the ordinary tourist. The occasional alluvial flats of the Calder, the Aire, Wharfdale, Niddesdale, Wensleydale, Swaledale, Teesdale, Weardale, the Derwent, and the valleys of the North and South Tyne, all alike tell their tale to the eye of the geologist, the artist, and the farmer. The accidental park-like arrangement of the trees, the soft grassy slopes leading the eye on to the upland terraces of limestone or sandstone, which, when we look up the valleys, are lost in a long perspective, the uppermost terrace of all sometimes standing out against the sky, like the relic of a great Cyclopean city of unknown date, as in the time-weathered grits of Brimham Rocks. These together present a series of scenes quite unique in the scenery of England.

The larger part of this northern territory is therefore, because of the moist climate of the hilly region, devoted to pasture land, as is also the case with large portions of Cumberland and the other north-western counties of England, excepting the Vale of Eden and the southern shores of the Solway, where the Permian rocks and the boulder-clays of that noble valley generally form excellent soils, well watered by the Eden and all its tributary streams that rise in the mountains of Westmoreland and Cumberland, and the high broad-topped hills of Northumberland and Durham. The high mountain tracts of Cumbria are known to all British tourists for their wild pastoral character, intersected by exquisite strips of retired green alluvial valleys, and the famous lakes, sometimes wild and bare of trees, but often so well-wooded and luxuriant. This is essentially the lake-country of Britain south of the border, for all the lakes in Wales would probably not suffice to fill Windermere with water.

The same general pastoral character that is characteristic of Cumberland and Westmoreland is also observable in Wales, where disturbance of the Palæozoic rocks has resulted in the elevation of a great range, or rather of a cluster of mountains—the highest south of the Tweed. In that old Principality, and also in the

Longmynd of Shropshire, there are tracts of land, amounting to thousands upon thousands of acres, where the country rises to a height of from 1,000 to 3,500 feet above the level of the sea. Much of it is mostly covered with heath, and is therefore fit for nothing but pasture land: but on the low grounds, and on the alluvium of the rivers, there is often excellent soil. The more important valleys also are much larger than those of Cumbria, and the width of the alluvial flats is proportionate to the size of their rivers.

The Vale of Clwyd, in Denbighshire—the substratum of which consists of New Red Sandstone, covered by Glacial débris, and bounded by high Silurian hills—is fertile, and wonderfully beautiful. The Conwy, the Mawddach, the Dovey, the Ystwyth, the Aeron, and the Teifi, are all bordered by broad, fertile, and well wooded margins, above which rise the wild hills of North and South Wales. The Towey of Caermarthenshire, the Cothi, and all the large rivers of Glamorganshire, the Usk and the Wye, are unsurpassed for quiet and fertile beauty. No inland river of equal volume in Britain surpasses the Towey in its course from Llandovery to Caermarthen. Rapid, and often wide, it flows along sometimes through broad alluvial plains, bounded by wood-covered hills, the plains themselves all park-like, but with many a park besides, and everywhere interspersed with pleasant towns, farms, seats, and ruined castles.

Taken as a whole, the eastern part of the country of South Wales, in Breconshire and Monmouthshire, and in the adjacent parts of England in Herefordshire, and parts of Worcestershire, occupied by the Old Red Sandstone, though hilly, and in South Wales occasionally even mountainous, is naturally of a fertile kind.

This is especially the case in the comparatively low-lying lands, from the circumstance that the rocks are generally soft, and therefore easily decomposed; and where the surface is covered with drift, the loose material is chiefly formed of the waste of the partly calcareous strata on which it rests, and this adds to its fertility, for the soil is thus deepened and more easily fitted for purposes of tillage. If anyone is desirous to realise the exquisite beauty of the scenery of the English Old Red Sandstone, let him go to the summit of the Malvern Hills, or of those above Stoke Edith, and cast his eye north and west, and there in far-stretching undulations of hill and dale, with towns and villages, farms and parks, he will survey a vast tract, unrivalled in varied beauty, dotted with noble woods and orchards, and fruit trees set in every hedge, while through the fertile scene wander the Teme, the Lug, and the stately Wye, in many a broad curvature, winding its way from the distant Plynlimmon to lose itself in the wide estuary of the Severn.

On the whole, however, the moist character of the climate of much of Wales and Cumberland, and of the north of England in its western parts, renders these regions much more fitted for the rearing of cattle than for the growth of cereals.

In the centre of England, in the Lickey Hills, near Birmingham, and in the wider boss of Charnwood Forest, where the old Palæozoic rocks crop out like islands amid the Secondary strata, it is curious to observe that a wild character suddenly prevails in the scenery, even though the land lies comparatively low, for the rocks are rough and untractable, and stand out in miniature mountains. Much of Charnwood Forest is, however, covered by drift, and is now being so rapidly enclosed, that, were it not for the modern monastery and the cowled monks who till the soil, it would almost cease to be suggestive of the England of mediæval times, when wastes and forests covered half the land.

If we now pass to the Secondary rocks that lie in the plains, we find a different state of things. In the centre of England, formed of New Red Sandstone and Marl, the soils are for the most part naturally more fertile than in the mountain regions of Cumberland and Wales, or in some of the Palæozoic areas in the extreme south-west of England. When the soft New Red Sandstone and especially the Marl are bare of drift, and form the actual surface, they often decompose easily, and form deep loams, save where the conglomerate beds of the New Red Sandstone come to the surface. These conglomerates consist to a great extent of gravels barely consolidated, formed of water-worn pebbles of various kinds, but chiefly of liver-coloured quartz-rock, like that of some of the conglomerates of the old Red Sandstone, derived from some unknown region, and of silicious sand, sometimes ferruginous. This mixture forms, to a great extent, a barren soil. Some of the old waste and forest lands of England, such as Sherwood Forest and Trentham Park, part of Beaudesert, and the ridges east of the Severn near Bridgnorth, lie almost entirely upon these intractable gravels, or on other sands of the New Red Sandstone, and have partly remained uncultivated to this day. As land however becomes in itself more valuable, the ancient forests are being cut down and the ground enclosed. But a good observer will often infer, from the straightness of the hedges, that such ground has only been lately taken into cultivation, and at a time since it has become profitable to reclaim that which at no very distant date was devoted to forest ground and to wild animals.[1]

In the centre of England there are broad tracts of land composed chiefly of New Red Marl and Lias clay. If we stand on the summit of the great escarpment, formed by the Oolitic tableland, we look over the wide flats and undulations formed by these strata. The marl consists of what was once a light kind of clay, mingled with a small percentage of lime; and when it moulders down on the surface, it naturally forms a fertile soil. A great extent of the arable land in the centre and west of England is formed of these red strata, but often covered with Glacial débris.

It is worthy of notice that the fruit tree district of Great Britain lie chiefly upon red rocks, sometimes of the Old and sometimes of the New Red Series. The counties of Devonshire, Herefordshire, and Gloucestershire, with their numerous orchards, celebrated for cider and perry, lie in great part on these formations, where all the fields and hedgerows are in spring white with the blossoms of innumerable fruit trees. Again, in Scotland, the plain called the Carse of Gowrie, lying between the Sidlaw Hills and the Firth of Tay, stretches over a tract of Old Red Sandstone, and is famous for its apples. What may be the reason of this relation I do not know; but such is the fact, that soils composed of the New and Old Red Marl and Sandstone, are generally better adapted for such fruit trees than any other in Britain.

The Lias clay in the centre of England, though often

[1] There are many other forest lands in England, too numerous to mention, some on Eocene strata, some on Boulder-clay, which, by help of deep draining, are gradually becoming cultivated regions.

laid down for cereals, forms a considerable proportion of our meadow land. It is blue when unweathered, and includes many beds of limestone, and bands of fossil shells are scattered throughout the clay itself. From its exceeding stiffness and persistent retention of moisture, it is especially adapted for grass land, for it is not easy to plough, and thus a large proportion of it in the centre of England is devoted to pastures, often intersected by numerous footpaths of ancient date, that lead by the pleasant hedge-rows to wooded villages and old timbered farmsteads. When we pass into the Middle Lias, which forms an escarpment overlooking the Lower Lias clay, we find a very fertile soil; for the Marlstone, as it is called, is much lighter in character than the more clayey Lower Lias, being formed of a mixture of clay and sand with a considerable proportion of lime, derived from the Marlstone Lime-rock itself, and from the intermixture of fossils that often pervade the other strata. The course of the low flat-topped Marlstone hills, well seen in Gloucestershire, and on Edgehill, and all round Banbury, striking along the country and overlooking the Lower Lias clay, is thus usually marked by a strip of peculiarly fertile soil, often dotted with villages and towns with antique churches and handsome towers, built of the brown limestone of the formation.

Ascending the geological scale into the next group, we find the Oolitic rocks formed, for the most part, of beds of limestone, with here and there interstratified clays, some of which, like the Oxford and Kimeridge Clays, are of great thickness, and spread over large tracts of country. The flat tops of these limestone Downs, when they rise to considerable height, as they do on the Cotswold Hills, were, until a comparatively recent date, left in a state of natural grass, and used chiefly as pasture land. They formed a feeding ground for vast numbers of sheep, whence the origin of the woollen factories of Gloucestershire, but are now to a great extent brought under the dominion of the plough, and on the very highest of them we find fields of turnips and grain. The broad flat belts of Oxford and Kimeridge Clay, that lie between the western part of the Oolite and the base of the Chalk escarpment, are in part in the state of grass land.

In the north of England the equivalents of the Lower Oolites form the broad heathy tracts of the Yorkshire moors, and the fertile Vale of Pickering is occupied by the Kimeridge Clay.

If we pass next into the Cretaceous series, which in the middle and south of England forms extensive tracts of country, we meet with many kinds of soil, some, as those on the Lower Greensand, being excessively silicious, and in places intermingled with veins and strings of silicious oxide of iron. Such a soil still remains in many places intractable and barren. Thus, on the borders of the Weald from Leith Hill to Petersfield, where there is very little lime in the rocks, there are many wide-spread unenclosed heaths, almost as wild and refreshing to the smoke-dried denizens of London, as the broad moors of Wales and the Highlands of Scotland. These, partly from their height, but chiefly from the poverty of the soil, have never been brought into a state of cultivation. Running, however, in the line of strike of the rocks, between the escarpments of the Lower Greensand and the Chalk, there are occasionally many beautiful and fertile valleys rich in fields, parks, and noble forest timber.

One of these, between the slopes of the Greensand and the escarpment of the Chalk, consists of a long strip of stiff clay-land formed of the Gault, which, unless covered by drift or alluvium, generally produces a wet soil along a band of country extending from the outlet of the Vale of Pewsey in Wiltshire north-eastward into Bedfordshire.

In Kent, Surrey, and Sussex, the Weald Clay occupies an area, between the escarpment of the Lower Greensand and the Hastings Sands, of from six to twenty miles wide, encircling the latter on the north, west, and south. It naturally forms a damp stiff soil when at the surface; but is now cultivated and improved by the help of deep drainage. In many places there are deep beds of superficial loam, on some of which the finest of the hop-gardens of that area lie. Loamy brick earths often occupy the low banks of the Thames and Medway, in Kent, also famous for hop-grounds and cherry orchards, and for those extensive brick manufactories so well known in the neighbourhood of Sittingbourne. Similar loams sometimes overlie the Kentish Rag (Lower Greensand), and the Lower Eocene strata on the south bank of the estuary of the Thames.

The Hastings Beds for the most part consist of very fine sand, interstratified with minor beds of clay, and they lie in the centre of the Wealden area, forming the undulating hills half-way between the North and South Downs, extending from Horsham to the sea between Hythe and Hastings. They form on the surface a fine dry sandy loam; so fine, indeed, that when dry it may sometimes be described as an almost impalpable silicious dust. Much of the country is well wooded, especially on the west, where there are still extensive remains of the old forests of Tilgate, Ashdown, and St. Leonards. Down to a comparatively late historical period, both clays and sands were left in their native state, partly forming those broad forests and furze-clad heaths that covered almost the whole of the Wealden area. Hence the name Weald or Wold (a woodland), a Saxon, or rather Old-English term, applied to this part of England, though the word does not now suggest its original meaning, unless to those who happen to know something of German derivatives.

In the memory of our fathers and grandfathers, these wild tracts were famous as resorts for highwaymen and bands of smugglers, who transported their goods to the interior from the seaport towns of Kent and Essex by means of relays of pack-horses.

The Chalk strata of the South Downs stretch far into the centre and west of England in Hampshire and Wiltshire. South of the valley of the Thames the same strata form the North Downs, and this Chalk stretches in a broad band, only broken by the Wash and the Humber, northward into Yorkshire, where it forms the well-known Yorkshire Wolds. Most Londoners are familiar with the Downs of Kent and Sussex. In their wildest native state, where the ground lies high, these districts were probably, from time immemorial, almost bare of woods, and 'the long backs of the bushless downs,' are still often only marked here and there by 'a faintly shadowed track' winding 'in loops and links among the dales,' and across the short turf of the upper hills. Yet here, also, cultivation is gradually encroaching.

On the steep scarped slopes overlooking the Weald, chalk often lies only an inch or two beneath the grass, and the same is the case on the western and north-western slopes of the long escarpment which stretches in sinuous lines from Dorsetshire to Yorkshire, where it ends in the lofty sea cliffs on the south side of Filey Bay, near Flamborough Head. Many quarries, often of great antiquity, have been opened in the escarpments that overlook the Lower Greensand, and some of great extent, now deserted and overgrown with yews and other trees, form beautiful features in the landscape. The steep scarped slopes, and even the inner dry valleys are likewise frequently sparingly dotted with yew-trees and numerous bushes of straight-growing juniper.

West and north of the London basin the Chalk generally lies in broad undulating plains, forming a tableland of which Salisbury Plain may be taken as a type. Within my own recollection, these plains were almost entirely devoted to sheep, but they are now being gradually invaded by the plough, and turned into arable land. Many of the slopes of the great Chalk escarpments on the North and South Downs in the West of England, on the Chiltern Hills and elsewhere, are however so steep, that the ground, covered with short turf, and in places dotted with yew and juniper, is likely to remain for long unscarred by the ploughshare.

In many places the surface of the Chalk, as already stated, is covered by thick accumulations of flints, and elsewhere over extensive areas by clay, a residue left by the dissolving of the carbonate of lime of the Chalk. This clay invariably forms a stiff cold soil, and is plentiful on parts of the plains of Wiltshire, Berkshire, and Hertfordshire, and also on the Chalk of Kent and Surrey. It has often been left uncultivated, and forms commons, or furze-clad and wooded patches. The loam which accompanies it is occasionally used for making bricks. In the east part of Hertfordshire, Essex, and

Suffolk, the Chalk is almost entirely buried under thick accumulations of glacial débris, which completely alters the agricultural character of the country.

Various formations of the Eocene beds occur on all sides of London. They are often covered by superficial sand and gravel. Through the influence of the great population centred here, originally owing to facilities for inland communication afforded by the river, this is now, in great part, a highly cultivated territory. Here and there, however, to the south-west, there are tracts forming the lower part of the higher Eocene strata, known as the Bagshot Sands, which produce a soil so barren that, although not far from the metropolis, it is only in scattered patches that they have been brought under cultivation. They are still for the most part bare heaths, and being sandy, dry and healthy, camps have been placed upon them, and they are used as exercise grounds for our soldiers.

Higher still in this Eocene series of Hampshire, lie the fresh-water beds on which the New Forest stands, commonly said to have been depopulated by William the Conqueror, and turned into a hunting ground. But to the eye of the geologist it easily appears that the wet and unkindly soil produced by the clays and gravels of the district form a sufficient reason why in old times, as now, it never could have been a cultivated and populous country, for the soil for the most part is poor, and probably chiefly consisted of native forest-land even in the Conqueror's day.

The wide-spreading Boulder-clay of Holderness north of the Humber, of Lincolnshire on the coast, and of Norfolk, Suffolk, Hertfordshire, and Essex, for the most part forms a stiff tenacious soil, somewhat lightened by the presence of stones, and often sufficiently fertile when well drained. In Suffolk and Essex the chalky Boulder-clay covers wide tracts of flat land, and was formerly much used as a dressing for other soils, and it forms an excellent soil in itself.

The great plain of the Wash consists partly of peat on the west and south, but chiefly of silt. These broad flats, about seventy miles in length from north to south, and forty in width, include an area of more than 1,700 square miles. The whole country is traversed by well-dyked rivers, canals, drains, and trenches. Standing on the margin of the flat, or walking on the long straight roads or dykes, cheerfulness is not the prevailing impression made on the mind. The ground looks as level as the sea in a calm, broken only by occasional dreary poplars and willows, and farm houses impressive in their loneliness. The soil of these fens ere the crops grow, is often as black as a raven, the ditches are sluggish and dismal, and the whole effect is suggestive of ague. Windmills of moderate size stand out from the level as conspicuous objects, and here and there the sky-line is pierced by the ruins of Crowland Abbey, Boston tower, and the massive piles of the Cathedrals of Ely and Peterborough on the margins of the flat. Yet it is not without charms of a kind; as, when at sunset, sluice, and windmill, and tufted willows, combined with light clouds dashed with purple and gold, compose a landscape such as elsewhere in Western Europe may be seen in the flats of Holland. The same impression, in less degree, is made on the banks of the Humber, where the broad warped meadows, won from the sea by nature and art, lie many feet below the tide at flood, for walking in the fields behind the dykes, when the tide is up, good-sized vessels may be seen sailing on the rivers above the level of the spectator's head. An old and entirely natural loamy silt, somewhat of the same character, follows the course of the Ouse, and, to a great extent, covering the fertile vale of York, passes out to sea in the plains that border the Tees.

On the west coast the wide plains of the Fylde in Lancashire, north and south of the estuary of the Ribble, in some respects resemble those of the Wash.

Such is a very imperfect sketch of the general nature of the soils of Great Britain, and of their relation to the underlying rocks. We have seen that throughout large areas, the character of the soil is directly and powerfully influenced by that of the rock-masses lying below. *It must be borne in mind, however, that the abrading agencies of the Glacial period have done a great deal towards commingling the detritus of the different geological formations, producing widespread drift soils of varied composition.* This detritus is far from being uniformly spread over the island. In some districts it is absent, while in others it forms a thick mantle, obscuring all the hard rocks, and giving rise to a soil sometimes nearly identical with that produced by the waste of the underlying formation, and sometimes of mixed clay and stones, as in Holderness. Thus the Boulder-clay, though often poor, sometimes forms soils of the most fertile description, as for instance in certain upper members of the formation in parts of the Lothians, and in the chalky Boulder-clay of Norfolk and Suffolk.

CHAPTER XXXIV.

RELATION OF THE DIFFERENT RACES OF MEN IN BRITAIN TO THE GEOLOGY OF THE COUNTRY.

I SHALL now give a brief account of the influence of the geology upon the human inhabitants of different parts of our Island.

Great Britain is inhabited by several peoples, more or less intermingled with one another. It requires but a cursory examination to see that the more mountainous and barren districts, as a whole, are inhabited by two Celtic populations, very distinct from each other, and yet akin. The lowland parts are chiefly occupied by the descendants of Teutonic and Scandinavian races, now intimately intermixed, in some degree with the earlier Celtic inhabitants, who themselves on their coming undoubtedly mingled with yet earlier tribes.

It will be remembered that both in England and on the Continent of Europe, remains of man (his bones and weapons) have been found in caves and river gravels, associated with bones of the Mammoth, Rhinoceros, Reindeer, and other mammalia, some of which are now extinct. That these early people, who at least date back to the Glacial epoch, were savage hunters, often living in caves, when they could find such ready-made accommodation, there can be but little doubt; but to what type of mankind they belonged, or whether they are represented by any unmixed modern type, no man knows. Possibly the cave men of Dordogne in France, who carved daggers out of Reindeer horns, and cut the figure of the Mammoth on his own tusk, may now be represented in Europe by the Laplanders (Mongolian), gradually driven north by the encroachment of later and more powerful nations. Or they may have been dark-complexioned, black-haired and black-eyed *Melanochroi*, of whom the Basques of Spain are the least obliterated representatives, and traces of whom, according to Professor Huxley, are still among us in the black-haired portion of our Celtic population, and in the swarthy sons of Italy and Spain.[1]

'Early Greek writers,' says Mr. William F. Skene in his 'History of Celtic Scotland' (1876), 'seem to have had a persuasion that the portion of the inhabitants of Britain who were more particularly connected with the working of tin, possessed peculiarities which distinguished them from the rest.' These people—the Silures —inhabited the Cassiterides, now called the Scilly Islands, and as quoted from Diodorus, were 'singularly fond of strangers, and, from their intercourse with foreign merchants, civilised in their habits.' This intercourse arose from traffic in tin. In 'Critiques and Addresses' (1873), Professor Huxley states that, 'Eighteen hundred years ago the population of Britain comprised people of two types of complexion—the one fair and the other dark. The dark people resembled the Aquitani and the Iberians, the fair people were like the Belgic Gauls,' and the Silures who had 'curly hair and dark complexions,' within historical times 'were predominant in certain parts of the west of the southern half of Britain, while the fair stock appears

[1] 'Journal of the Ethnological Society,' vol. ii. 1871, pp. 382, 404.

to have furnished the chief elements of the population elsewhere.'

Mr. Skene is of opinion that 'an examination of the ancient sepulchral remains in Britain gives us reason to suppose, that a people possessing certain physical characteristics (those of the Silures), had once spread over the whole of both the British Isles.' Quoting from Professor Dawkins' 'Cave Hunting,' that author states, on the authority of Dr. Thurnham, that in the 'long barrows and chambered-gallery graves of our island' the 'crania belong, with scarcely an exception,' to 'the Dolichocephali or long-skulls' of the neolithic age, as shown by 'the invariable absence of bronze and the frequent presence of polished stone implements.' 'In the round barrows, on the other hand, in which bronze articles are found, they belong mainly to the Brachycephali or broad-skulls.' These belonged to Celtic people.

On the evidence of skulls and flint implements, it has been reasonably surmised that an Iberian population once spread over the whole of Britain and Ireland. But from the dawn of definite European history, the dark populations of Iberian type have constantly been losing ground in the world. In Spain their language remains, but their blood is now far from pure, but in Britain if any trace of their ancient tongue is left, it has been so largely overlapped and worn away by succeeding waves of Celtic invasion, that probably its existence is scarcely recognisable, though the influence of their blood is perpetuated in the black hair and dark eyes of many of the inhabitants of Wales, both South and North.

At what time the first appearance of a Celtic people in Britain took place no one knows, but however this may be, it is certain that before the landing of Julius Cæsar, more than 1,900 years ago, both sides of the English Channel were inhabited by people speaking a Celtic tongue, mingled, in the south-east of England, with fair-haired and blue-eyed Belgæ, who in time had been absorbed among the Celtic population, and spoke their language. The modern descendants of these people are the Welsh (Cymry) and Cornish men; but I consider that at that period distinct tribes of Celts, the Gael, inhabited the greater part of what is now termed Scotland, the Isle of Man, and Ireland, and at least all the western, and part of the southern, coasts of Wales.

Analyses of modern Welsh and Gaelic prove that these Celtic branches, now so distinct, yet sprung from the same original stock. Nevertheless, I believe that the Gael, as a people, are more ancient in our islands than the Cymry; and I think there is strong presumptive evidence that the ancestors of the Pictish Gael (who, however, afterwards became so largely intermixed with Scandinavian blood) once spread, not only much further south than the borders of the Highlands, but that before the Roman invasion they occupied the Lowlands of Great Britain generally, excepting what are now the more southern countries, where the Cymry had obtained a firm footing, and were steadily pressing northward and westward.

From intimate personal knowledge of Wales, its topography and people, I for long held the opinion that the Gwyddel (Irish Gael) were the earliest Celtic inhabitants of Wales. This is not the popular view, and it was with much satisfaction that I lately found, that twelve years before the first edition of this book was published, the subject had been ably discussed by the

Rev. William Basil Jones (now Bishop of St. Davids) in his celebrated essay entitled 'Vestiges of the Gael in Gwynnedd.' As late as the sixth century we find great part of the western coast of Wales and all Anglesea inhabited by the Gwyddel. From Caernarvonshire to Pembrokeshire and Glamorganshire, the word Gwyddel forms a frequent part of compound names of places, such as Llan-y-Gwyddel (Holyhead), Trwyn-y-Gwyddel, the extreme promontory of Lleyn in the north horn of Cardigan Bay, Murian-'r-Gwyddel, ancient fortifications near Harlech, and many others. The special frequency of such names near the coast seems to point to the circumstance, that the fortified positions there formed the last refuges of the retiring Gael against the onward march of the encroaching Cymry. One of these, Cytiau-'r-Gwyddelod (the Irishmen's cots), is a skilfully fortified position on Holyhead mountain, where tradition tells of a battle, in which the Gwyddel were utterly defeated by Caswallawn Law Hir, late in the sixth century. Subsequent piratical invasions of Wales by the Irish are recorded, which even come down to Norman times, but without permanent results.[1]

There is a little feeble evidence that Christianity had obtained a slight footing in Britain early in the third century, and it is certain that early in the fourth century it began to be largely established, and although 'when the Roman left us, and their law relaxed its hold upon us,' in the year 409, England, overwhelmed by successive hosts 'of heathen swarming o'er the northern sea,' again became pagan, this forcible con-

[1] Mr. Skene in his 'Four Ancient Books of Wales,' and in 'Celtic Scotland,' has treated this subject with his usual skill and vigour. He dissents from the opinion of the Bishop of St. David's respecting the priority of the Gwyddel in Wales.

version did not extend to the inhabitants of the mountains of Wales, where the early Church still continued to flourish among the Gwyddel. This throws an interesting light on the circumstance that so many of the churches in the western part of the mainland of Wales and in Anglesea were dedicated to Gaelic saints, where the Gwyddel still ruled the land. The names, also, of many of the rivers in England and even in Wales have a Gaelic and not a Welsh origin, complete or in combination. Thus, all the rivers called Ouse, Usk, Esk (*Uisge*), the Don, and others, derive their names from the Gaelic.

Again, it is a characteristic of rivers often to retain the names given them by an early race long after that race has been expelled, and thus the Gaelic *Uisge* (water) has not in all cases been replaced by the archaic Welsh word *Gwy*. This old Welsh word we constantly find in a corrupt form, as in the Wye, the Medway, the Tawe, the Towey, and the Teifi, the Dyfi or Dovey, and the Dove; or the water of the rivers is expressed in another form by the later *dwfr* or *dwr*, as in Stour, Aberdour, &c. In both languages river (*Afon* or *Avon*) is the same.

In his chapter on the Ethnology of Scotland,[1] Mr. Skene remarks that 'Uisge in Gaelic, and Wysg in Welsh, furnish the Esks, Usks, and Ouses, which we find here and there;' but it seems to me that these names, common both in England and Scotland, have, as now pronounced, more of a Gaelic than a Welsh *twang*, and afford a hint of the early occupation of England and Wales by the Gael. In Anglesea, by the side of Afon Alaw, the river of the water-lilies, there is a farm called Tyddyn Wysgi—the farm by the water—

[1] 'Celtic Scotland,' vol. i. p. 215.

the final word being the precise equivalent in sound to the Gaelic *Uisge*, though it cannot be denied that it may come directly from the Welsh Wysg, which also is an old word for water.

Again, in Wales, on Cader Idris, there still remains the name of a lake, Llyn Cyri (pronounced Curry), a word unintelligible to the Welsh (as Arran is to the Gael), but easily explained by the Gaelic word *Coire*, a cauldron, or Corrie, a word applied to those great cliffy semi-circular hollows or *cirques* in the mountains, in which tarns so often lie. Other places called Cyri, of like form, are also found in Merionethshire.

If, then, the earlier inhabitants of Britain were Gaelic, they were driven westward into Wales, and northward into the mountains of Scotland, by the superior power of another and later Celtic population that found its way to our shores, and pushed onwards, occupying the more fertile districts of England and the south of Scotland, and possibly even creeping round the eastern coasts north of the Tay, and occupying the lowlands of Caithness. The Gael, including the Picts, would not willingly have confined themselves to the barren mountains if they could have retained a position on more fertile lands. One proof of this as regards Wales is, that as late as the early part of the sixth century all that part of the country west of a line roughly drawn from Conway to Swansea was inhabited by an Erse-speaking people, the Gwyddel[1] of the Welsh,[2] who were slowly retiring before the advancing Cymry, and their last unabsorbed relics expelled from the coast finally sought refuge with their kindred

[1] Gwyddel literally means dwellers in the Forest, Forestieri, Waldmen, Welsh.

[2] See 'The Four Ancient Books of Wales,' Skene, vol. i., p. 43.

people in Ireland. In the same century, according to Mr. Skene, 'from the Dee and the Humber to the Firths of Forth and Clyde, we find the country almost entirely possessed by a Cymric population,' and though it may be presumptuous to differ from an authority so distinguished, I do not stand alone in the opinion that the Cymry spread still further north, and pressed upon the Gael, at all events on the west of Scotland, as far as the verge of the mountains of the Highlands.

It is remarkable that a number of the names of places in the centre and south of Scotland are not Gaelic, but have been given by the later conquering race, and can be translated by anyone who has even a superficial knowledge of Welsh, and it is certain that, from the Lowlands of Scotland all through the midland and southern parts of Britain, the country was inhabited in later Celtic times by the same folk that now people Cornwall and Wales. The names of scores of places now unintelligible to the vulgar, prove it. Thus there are all the Coombs (*Cwm*) of Devon, Somersetshire, and even the south-east of England; Dover, so named from the river Douver (*dwfr*, *water*), still correctly pronounced by the French; and at Bath, by the Avon, we have 'Dolly (*dolau*) meadows'; near Birmingham, the 'Lickey hills' (*llechau*); near Macclesfield, the rocky ridge called 'the Cerridge' (*cerrig*); and in the hills of Derbyshire 'Bull gap,' the Welsh *bwlch*, translated, just as in another instance *dolau* is repeated in the English word meadows. Again, in Scotland we have the islands of the Clyde called the Cumbraes (*Cymry*), *Aran*, Welsh for a peaked hill, *Aberdour* (the mouth of the water), Lanark (*Llanerch*, an open place in a forest, or clearing), Blantyre (*Blaen-*

tir, a promontory or projecting land), Pennycuik (*Pen-y-gwig*, the head of the thicket), and many other corrupted Welsh names. The wide area over which this language was spoken is indeed proved by the ancient Welsh literature, for the old heroic poem of the Gododin was composed by Aneurin, a native of the ancient kingdom of Strath Clwyd, which stretched through the west country beyond Dumbarton over Cumberland as far south as Chester.[1] In Mr. Skene's opinion, it records a battle, fought on the shore of the Firth of Forth some time between A.D. 586 and 603,[2] while others, and I incline to this view, suppose the battle to have taken place at or near Catterick in Yorkshire.

However this may be, it is certain that the British Celts, when the Romans invaded our country, overspread the whole of Great Britain south of the Firths of Forth and Clyde. By-and-by they mixed with their conquerors, but the Romans, as far as blood is concerned, seem to have played an unimportant part in our country. They may have intermarried to some extent with the natives, but they occupied our country very much in the manner that we now occupy India. Coming as military colonists, they went away as soon as their time of service was up, and finally abandoned the country altogether.

Partly before, but chiefly after, the retirement of the Romans, invasions took place by the Teutonic

[1] See 'Freeman's History of the Norman Conquest,' vol. i. p. 35.

[2] In the learned work by Mr. Skene, the author with great force and probability shows good reason, not only for the actual existence of Arthur, but he even traces his march through the country and shows where his battles were fought, ending with the crowning victory at Badon or Bouden Hill, in Linlithgowshire.

people from the shores of the Baltic near the mouth of the Elbe (*Angles*), and Scandinavia; and, in the long run, they permanently occupied the greater part of the land. Then the native tribes, absorbed, slain, or dispossessed of their territories, and slowly driven westwards, retreated to join their countrymen into the distant and mountainous parts of the country, where the relics of this old Celtic people are still extant in Devon and in Cornwall, while among the mountains of Wales the same Celtic element yet forms a distinct and peculiar people. There, till after the Norman conquest, they still held out against the invader, and maintained their independence in a region barren in the high ground, but traversed by many a broad and pleasant valley. Living, as the relics of the old Britons are apt to do, so much in memories of the past, the slowly dying language, and even the antique cadences of their regretful music, speak of a people whose distinctive characters are gradually waning and merging into a newer phase of intellectual life.

It appears then that the oldest tribes now inhabiting our country, both in Scotland and in the south, are to be found among those most ancient of our geological formations, the Silurian rocks, which, by old palæozoic disturbance, form the less accessible mountain lands; while the lower and more fertile hills, the plains and tablelands, and Scotland south of the Grampians, are chiefly inhabited by the descendants of the heathen, who made good their places by the sword after the departure of the Romans.

On the east of Scotland, also, along the coasts of the Moray Firth, in Caithness, and in the Orkney and Shetland Islands, the people are of Scandinavian origin and speak Scotch, thus standing out in marked contrast with the Gaelic clans, who possess the wilder and higher grounds in the interior and western districts. There is here a curious relation of the human population to the geological character of the country. The Scandinavian element is strongly developed along the maritime tracts, which, being chiefly composed of Old Red Sandstone, stretch away in long and fertile lowlands; while the Celts are pretty closely restricted to the higher and bleaker regions where the barren gneissic and schistose rocks prevail.

CHAPTER XXXV.

INDUSTRIAL PRODUCTS OF THE GEOLOGICAL FORMATIONS—ORIGIN OF LODES—QUANTITIES OF AVAILABLE COAL IN THE COALFIELDS—ORIGIN OF THEIR BASIN-SHAPED FORMS—CONCEALED COAL-FIELDS BENEATH PERMIAN, NEW RED, AND OTHER STRATA—SUMMARY.

To enter into detail upon the peculiar effect of geology on the industry of the various races or the populations of different districts, would lead me far beyond the proposed scope of this work. I shall, therefore, only give a mere outline rather than attempt to exhaust the subject.

First, let us turn to the older rocks. In Wales, as I have already stated, these consist to a great extent of slaty material. The largest slate quarries in the world lie in the Cambrian rocks of Caernarvonshire. One single quarry, that of Penrhyn in Nant Ffrancon, is half a mile in length, and more than a quarter of a mile from side to side. Other quarries of equal importance collectively occur in the Pass of Llanberis, and there are large quarries in the same strata at Nant-y-llef, but none of these are of the same vast size. Important quarries also lie in the Lower Silurian rocks near Ffestiniog in Merionethshire, and there are large slate quarries in the Wenlock shale, near Llangollen, and others of minor note scattered about Wales, but always in Cambrian or Silurian rocks.

In these districts there is a large population which is chiefly supported by the quarrying and manufacture of slates. The Penrhyn slate quarry, near Bangor, presents a wonderful spectacle of industry. It is about half a mile in length, and a quarter of a mile wide, and forms a vast amphitheatre, which is worked all round, on one side in thirteen high and broad terraces, like the steps of a Titanic stair. The periodical blastings sound like the firing of parks of artillery. Vast mounds of rubbish, the waste of the quarry, cover the hills on either side. More than 3,000 men are there employed in the making of slates, which are exported to all parts of the world. The quarries at Llanberis employ nearly an equal number of men; and the rubbish there shot down the high slopes into Llyn Peris was lately rapidly destroying the beauty of one of the most romantic lakes in Wales, and unless the waste be disposed of on the hill-sides, it threatens in the long run to fill Llyn Peris from end to end. The same ruthless disposal of waste material has of late years been exercised on the south-western side of Llyn Padarn, in long banks of ugly shingle, that encroach on the water of the lake and spoil the natural curving symmetry of its shore. Areas occupied by water are often considered to be places specially designed for the accommodation of rubbish, and if the quarries on the Dolbarn side of the lake were successful and largely worked, in time it might be quite possible to fill the whole of that beautiful sheet of water with an unsightly débris of slate.

In Merionethshire, near Ffestiniog, some slate quarries are worked in caverns and some in open day. The number of men and boys employed in the Ffestiniog district in January 1872 was about 3,350.[1] There are also slate quarries in South Wales, but few of them have been worked to much advantage, and in Cumberland, where slates are or have been worked in the green slates of the volcanic rocks of the Lower Silurian series. The material composing these slates is simply very fine volcanic dust, hardened by intense pressure, and rendered fissile by slaty cleavage.

In Scotland, in the small island of Easdale, in the Firth of Lorn, there are slate quarries that have been worked for many years, which produce a good, coarse-grained slate, but they are of small importance compared with the immense quarries of North Wales. It is probably not an over-estimate to say that about 15,000 men are employed in the slate quarries of Britain, involving, perhaps, the direct support of about 50,000 people.

So steady is the profit sometimes derived from slate quarries, that every here and there in North Wales, where the rocks are more or less cleaved, speculators go to work, and opening part of a hill-side, find a quantity of rotten stuff, or of slate full of iron pyrites, or cut up by small joints, or imperfectly cleaved; and after a time, when money runs short, they sell the property to other speculators, who sometimes ruin themselves in turn.

In various districts of Great Britain the rocks abound in the ores of certain metals, which, generally occurring in hilly regions, the workers in these mines are rarely congregated in great crowds like the slate quarriers of North Wales, or the miners of coal and iron. I will first allude to the case in which the mineral wealth is derived from what are termed lodes, or

[1] This fact was supplied to me by the kindness of Mrs. Percival of Bodâwen.

fissures in the rocks, sometimes running for miles, and more or less filled with quartz, calc-spar, and ores of metals, which yield our chief supplies of copper, tin, zinc, and lead.

It is worthy of remark that these lodes are almost wholly confined to our oldest or Palæozoic rocks. The Devonian rocks are intersected by them in Devon and Cornwall, and the Lower Silurian formations in Wales, Cumberland, the Isle of Man, and the hills of the south of Scotland, and here and there throughout the Highlands. In the Carboniferous Limestone they are also largely worked in North Wales, Yorkshire, and Derbyshire.

The chief districts in England where copper and tin are found are in Devon and Cornwall; and in the Lower Silurian rocks of Wales, especially in Cardiganshire and Montgomeryshire, there are ores of copper, and many lodes highly productive in ores of lead, some of which are rich in silver. No tin mines occur in that district. Gold also has been long known in Merionethshire, between Dolgelli, Barmouth, and Ffestiniog, sometimes, as at Clogau, in profitable quantity, but generally only in sufficient amount to show reason for starting companies which occasionally lure unwary speculators to their loss. This Welsh gold is found in lodes generally in and near the base of the Lingula flags, which in that area are talcose, and pierced by eruptive bosses of igneous rocks and greenstone dykes.

In older times extensive gold mines were worked in Caermarthenshire at the Gogofau (*ogofau*, caves), near Pumpsant, between Llandovery and Lampeter. These excavations were first made open to the day in numerous irregular extensive quarryings and caverns, where the gold-bearing quartz-veins and strings were followed into the hill. So extensive are these old works, that a minor valley was in the course of ages scooped out in the hill-side, and in the wood close by there is a deep artificial excavation now called *Cwm-henog*, which in English means Old-cave-valley. Later, lofty well made galleries were driven, which cut the lodes deeper underneath. Gold was also found in washings of the superficial gravel, for more than a mile in length, on the banks of the river Cothy, and in the little upland valley that runs from the Gogofau towards the village of Cynfil Cayo. The well cut galleries are Roman, but it has been surmised that the ruder caverns date from more ancient British times. The washing of the gravels for gold may probably be both of the old British and Roman ages, and for aught that is known the mines may have been worked in both ways in later times. It is not many years since the quartz veins were again systematically worked by an enterprising and skilful miner, but though gold was got, the result was not sufficiently profitable to warrant the continuance of the work.

The huge excavations must have made ugly scars on the hills in the days when they were freshly worked, but time has healed them. The heaps of rubbish are now green knolls, and gnarled oaks and ivy mantle the old quarryings.

In the Carboniferous Limestone districts of North Wales, Derbyshire, Lancashire, and the Yorkshire dales, there are numerous lead mines; and, as I have already said, lead ore occurs in the underlying Silurian strata, as in South Wales, and also in the Lead Hills in the south of Scotland, where lead associated with silver, and even a little gold, has long been worked.

I must now endeavour to give an idea of what a lode is. A lode is simply a crack, more or less filled with various kinds of mineral matter, such as layers and nests of quartz, carbonate of lime, carbonate of copper, sulphide of copper, sulphide of lead, oxide of tin, or with other kinds of ores. Various theories have been formed to account for the presence of ores in these cracks. Formerly, the favourite hypothesis was, that they were formed by sublimation from below, somehow or other connected with the internal heat of the earth; and the ores were supposed to have been deposited in the cracks through which the heated vapours passed. A great deal also has been said on the effect of electric currents passing through the rocks, and aiding in depositing along the sides of fissures the minerals which were being carried up by sublimation, or were in solution in waters that found their way into the fissures. I dare not utter any positive statement on the question, but my opinion is that the ores of metals in lodes have generally been deposited from solutions.

We know that water, especially when warm, can take up silica in solution and deposit it, as in the case of the Geysers in Iceland; and we also know that metals may, in some states, be held in solution in water, both warm and cold. This is proved by the accurate results of chemists, who, it is said, have detected silver, gold, and copper in solution in sea water. We must remember that when the lodes or cracks were originally formed, those parts of them that we explore were not so near the surface as we now see them; but in a great many cases they lay deep underneath, covered by thousands of feet of rock that have since been removed by denudation. They were probably, in all cases, channels of subterranean filtration, both in their upper portions that have been removed by denudation, and in the parts originally deeper that now remain.

It is not unlikely, also, that these subterranean waters must often have been warm, seeing that they sometimes lay deep in the interior of the earth, and came within the influence of internal heat, whatever may be its origin. If so, it is all the more likely that the ores which we meet with in these cracks or lodes were formed by infiltration of solutions, followed by deposition; for strings of copper, lead, and tin, for example, occur in the mass, just in the same way that we find mixed with them strings of carbonate of lime or quartz. This being so, then, just as the lime and silica may have been derived from the percolation of water through the rocks that form the country on each side of the lode, so the metalliferous deposits seem to have been derived from metalliferous matter minutely disseminated through the neighbouring formations. We are, however, still in the dark as to many of the conditions under which the process was carried on.

Ores of iron are common in lodes, and in hollows or pockets, both in the limestones of the Devonian and Carboniferous periods. In North Lancashire, at and near Ulverstone, rich deposits of hæmatite lie among the joints and other fissures of the limestone, and often fill large ramifying caverns deep underground. A vast trade has sprung up in the district in consequence of these discoveries within the last twenty-five years.

In the Coal-measures, however, we have our greatest sources of mineral wealth, because they have been the means of developing other kinds of industry besides that which immediately arises from the discovery of the minerals which the Coal-measures contain. In the great coalfields of this formation occur all the beds of coal worth working in Britain. In the South Wales coalfield there are more than 100 beds of coal, about

70 of which are worked somewhere or other. The quantity of available coal in that coalfield has been estimated by Mr. Vivian and Mr. Clark at about 36,500 millions of tons. In the Forest of Dean at least 23 beds of coal occur; and the quantity untouched and still available has been stated by Mr. Dickinson to be 265 millions of tons. In the Bristol and Somersetshire coalfields, where there are about 87 beds of workable coal, according to Mr. Prestwich, the quantity of coal still available is said to be nearly 4,219 millions of tons. In South Staffordshire, in the south part of the field, there are seven well-known beds, one of them 40 feet thick, and a greater number in the north; and in Coalbrook Dale there are 18 beds, all partly worked. The unexpended portions of these, added to the available coals of the Forest of Wyre and Clee Hill coalfields, amounts to nearly 2,000 millions of tons still available, as estimated by Mr. Hartley. In Leicestershire there are about 30 beds of coal over one foot thick, and Mr. Woodhouse states that nearly 837 millions of tons are available; and in Warwickshire, where five chief beds are worked, about 458½ millions. In Nottinghamshire, Derbyshire, and Yorkshire, one large coalfield, about 19 beds are worked somewhere or other in the coalfield, and, according to Mr. Woodhouse, more than 18,000 millions of tons are still available. In North Staffordshire, there are about 28 workable beds of well-known coal, and others besides not yet worked, and it is stated by Mr. Elliot that 4,826 millions of tons still lie there at available depths. In Lancashire and Cheshire more than 40 beds of coal over one foot of thickness are known, many of them of great value, and about 5,636 millions of tons according to

Mr. Dickinson are still available. In North Wales there are probably about 41 beds of coal over one foot in thickness, and according to Mr. Dickinson more than 2,100 millions of tons may still be extracted. In the Northumberland and Durham coalfield at least 9 beds are worked, and the amount still available is about 10,000 millions of tons, according to Mr. Foster; and in Cumberland the same authority states that about 405 millions of tons still remain unworked and available.

In the foregoing estimates, taken from the Coal Commission Report (1871), all coals over one foot in thickness are included, and it has been assumed that all coals under 4,000 feet in depth may be available, though this may possibly be an over-estimate as to the depth at which coals may be worked, in consequence of increase of temperature as we sink to lower depths. The total amounts to more than 90,000 millions of tons.

The population employed in working coal-pits was said by the Inspectors of Coal-mines in 1870 to be 350,894 persons, and the quantity of coal raised in the same year is calculated by Mr. Hunt to have been about 110 millions of tons. In 1875, the coal-pit population was 535,845, and in 1876, 515,845. The quantity of coal raised in 1875 was 133,306,485 tons, extracted from 4,445 collieries, and in 1876, 134,125,166 tons, from 4,329 collieries. These figures are taken from the annual statistics compiled by the Inspectors of Mines, and a curious calculation is made by Mr. Thomas Bell, that *if all the coal raised in* 1876 *were averaged at* 12 *inches thick, it would require* 158 *square miles of coal to yield the amount given above.* A statement such as this brings the quantity more vividly before the mind than figures, or words, viz. one hundred and thirty-four millions, one hundred and twenty-five thousand, one hundred and sixty-six tons.

Besides coal and iron, the Coal-measures yield quantities of clays, which are of considerable value. The chief of these is fire-clay, which is used so largely in the manufacture of crucibles and fire bricks, and in furnaces.

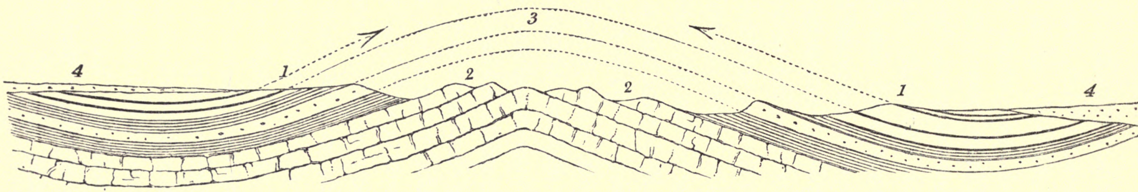
If we look at the geological map of England, we see that large patches are coloured black. These are the Coal-measure districts of Great Britain. Some of these coalfields, as for instance, the coalfields of South Wales and the Forest of Dean, lie obviously in basin-shaped forms, and the coal-beds and other strata crop to the surface all round the basin. But in other parts of England, the coal-formation does not occur in obvious basins, but seems merely to form a portion of the ordinary surface of the country. Nevertheless, the basin-shaped form of the Coal-measures is often continued under the overlying Permian and New Red formations, *one half or more of these basins being hidden from view, and buried under hundreds of feet of more recent strata that lie uncomformably upon them.* The reason of this is that the Carboniferous strata were disturbed and thrown into *anticlinal* and *synclinal* folds before the beginning of Permian and New Red Sandstone times, as shown in fig. 115, p. 601.

The coalfields marked No. 1 now show at the surface. Strata marked 2 separate them. These consist of Carboniferous Limestone lying *in an anticlinal curve*, as in Derbyshire, and part of the original coalfield shown by the dotted lines 3, in old times covered 2. The remaining parts of this original coalfield on the east and west are now partly covered by Permian and New Red Sandstone rocks 4, shrouding parts of the strata that lie in *synclinal curves.* The high rising strata of the upper part of the *anticlinal curve* were destroyed by denudation, and great part of the *synclinal curves* have been preserved because they were *bent down so low*, and partly covered by newer rocks, and have therefore been protected from the wasting effects of rain, rivers, and the sea in older times. This, I repeat, is the reason why *so many coalfields lie in basin-shaped forms.* And this form is quite independent of Permian and Secondary strata lying accidentally on the coal-beds. Thus the South Wales and Forest of Dean coalfields were never covered by these formations, and both are basin-shaped, and form with the Bristol and Mendip Coalfield parts of one original coalfield, now turned into three coal-basins by disturbance and denudation.

North of South Wales and Dean Forest all the other coalfields of England, and I think I may add of Scotland, probably once formed one coalfield; and these have been separated by disturbances which threw their strata into long anticlinal and synclinal curves. The Staffordshire, North Wales, and Lancashire coalfields were certainly one, and these were united to the Warwickshire, Leicestershire, and Nottingham and Derbyshire coalfields, which again joined that of Durham and Northumberland, which again was united to the coalfields of Cumberland, and probably of Scotland. They have since been disjoined by curvature of the strata combined with denudation, and the Northumberland and Yorkshire coalfields are now independent basins, partly buried under Permian and New Red Sandstone strata. And so, of the other visible coalfields, Warwick, Leicester,

Fig. 115.

Diagram showing the Origin of the Basin-shaped form of many Coalfields.



1. Coalfields showing at the surface in part. 2. Carboniferous Limestone. 3. Anticlinal curve between the two Coalfields, which were once joined. 4. Permian and New Red strata covering parts of the two basin-shaped Coalfields.

South Stafford, North Stafford, Cheshire, Lancashire, and the North Wales coalfields, are still probably one or almost one coalfield, only great parts of them are buried and concealed deep under Permian and New Red strata, in some places several thousand feet deep.

Thus it sometimes happens, by a combination of the curvature of strata and faults, that only by a series of geological accidents have the Coal-measures been brought to the surface and exposed to view. We may take the South Staffordshire coalfield as an example, where the New Red Sandstone and Permian rocks are thrown down against the coalfield on both sides. Originally, before these faults took place, the New Red Sandstone and other rocks spread entirely over the surface. The New Red Sandstone and Marl, where thickest, are more than 2,000 feet thick; above it lies the Lias, 900 to 1,500 feet thick; then comes the Oolites, and lastly, all the Cretaceous strata. This enormous mass of superincumbent strata, once lying above the South Staffordshire Coal-measures, was afterwards dislocated by faults, which brought the lower Permian and New Red portions of them down against the sides of the present coalfield. A vast denudation ensued, whereby many of the formations nearest the surface were removed, and the whole country was worn down to one comparatively general level. It is by such processes that some of our large and productive coalfields have been exposed at the surface. Hence we now find a great manufacturing population all centred in areas (like those of South Staffordshire, Warwickshire, and Ashby-de-la-Zouch) which might never have been known to contain coalfields, had it not been for the geological accidents of those faults and denudations which I have explained.

In my report as a member of the Coal Commission (1871), I have shown that under Permian and New Red strata, north of the Bristol coalfield, there may probably be about 55,000 millions of tons of coals available, at all events under 4,000 feet in depth, and to this Mr. Prestwich has added 400 millions of tons for the Severn Valley on the south side of the estuary.

The busy population that now covers the coalfields, and to which so many railways converge, may therefore some day spread over adjoining agricultural areas, and render them as wealthy, smoky, and repulsive to the outward eye as many visible coalfields now are. Between the mouth of the Firth of Clyde and the mouth of the Firth of Forth the whole country is one great coalfield, and this is the part of Scotland where the population is thickest. Bordering Wales and the mountains of Lancashire and Derbyshire, on the east and west, are three great coalfields, and these districts also contain dense populations. Further north lies the great Newcastle coalfield, where, again, the population is proportionately redundant. All the central part of England, which is dotted over with coalfields, teems in like manner with inhabitants. The South Wales coalfield, which is the largest of all, however, does not, except in places such as Swansea, Llanelly, Dowlais, Merthyr Tydvil, and other centres, show everywhere the same concentration of population. A great part of this area has till lately not been opened up by railways, and the coal has been heretofore not worked to the same extent as in the coalfields of the middle and northern parts of England, which have been extensively mined for a longer period.

Some years ago, after the publication of Mr. Hull's 'Coalfields of Great Britain,' Professor Jevons, in a work 'On the Coal Question,' showed that if the increase of our population goes on as it has been doing in years past, and if the productive industry of the country keep pace with the population, the whole of the coal now available in the country would be exhausted in 110 years. Mr. John Stuart Mill, taking alarm, in his place in Parliament urged upon the nation to act as worthy trustees for their descendants, to save money while there is yet time, and to pay off as much as possible of the national debt; and by-and-by, at the instance of Mr. Vivian, a Coal Commission was appointed to examine into this alarming state of affairs.

The result as regards the duration of coal was stated in the three following hypotheses:—the first is, that the population and manufactures of the country have nearly attained a maximum amount, or will merely oscillate without advancing. In this case our coal may last for about 1,273 years, an opinion to which Mr. Hunt of the 'Mining Record' Office still adheres. The second, according to Mr. Price Williams, is this:—The population of Great Britain in 1871 was 26,943,000. According to a given law of increase, in the year 2231, the population may be 1·31,700,000, in fact, near 132,000,000, or rather more than five times the present number. It is hard to realise this crowded population in our little country, but allowing the assumption to be correct, in a hundred years from 1871 the population of Britain would be very nearly 59,000,000, and the home consumption of coal 274,200,000 tons a year, in which case our coal will only last about 360 years. A third view is that adding 'a constant quantity equal to the annual increase (of consumption) of the last 14 years, which we may take at 3,000,000 of tons . . . . at the end of a hundred years the consumption would be 415,000,000 tons per annum, and the now estimated quantity of coal available for use would represent a consumption of 276 years.'[1] I offer no positive opinion on this subject, but I suspect the first view is likely to be nearer the truth than the last.

However this may be, it is certain that some day or other our coal must be practically exhausted, but so many things may happen ere that time that it is doubtful if even we, the trustees of the future, need to concern ourselves very much about the matter. Personal prudence, selfishness, or the love of money, will not be hindered by anxiety about people who are to live hundreds of years hence, and great part of England will still continue smoky as long as coal lasts in quantity, or at all events till the laws are enforced against the production of unnecessary smoke. All the centre of England is thick with it, floating from every coalfield, and from all the dependent manufacturing towns. The heaths and pastures of Derbyshire and Yorkshire between the two great coalfields are blackened by smoke, and even in the rainiest weather the sheep that ought to be white-wooled are dark and dingy. Every coalfield in England as it happens, is a centre of pollution to the air. But this does not affect the manufacturing population of these districts excepting in a sanitary, and therefore in a moral, point of view, and this state of affairs is too apt to be considered unavoidable in the present state of economics and unscientific practice, though it is not so of necessity.

What will be the state of Britain when all the coal is gone? The air at all events will be purified, and the

[1] 'Report of the Coal Commissioners,' pp. 16 and 17.

hideous heaps of slag, so suggestive of wealth, power, culture, and prosperity, that disfigure South and North Staffordshire, and all the other iron-making districts, will in time crumble into soil, and, covered by grass and trees, they will one day become beautiful features in the landscape; for man cannot permanently disfigure nature. Even when this thing takes place will there be any necessity for the country being reduced to absolute poverty? Our mountain lands, like the Schwarzwald, may be more woody than at present, and yield supplies of fuel, the plains and tablelands more richly cultivated, and who knows besides what motive powers may by that time be economised other than those that result from the direct application of artificial heat? Holland and the lowlands of Switzerland without coal are two of the happiest and most prosperous countries in Europe, and it appears as if Italy would follow in their steps, but on a larger scale. In the far future, Britain may still be prosperous, powerful, and happy, even though all its coal be exhausted.

Of late years a great deal of valuable iron ore has been obtained from the top of the Lower Lias and from the Marlstone of Yorkshire, and this tends still more rapidly to exhaust our coal. The result has been the rapid growth of the enterprising district and port of Middlesborough on the Tees. At night the whole country is aglow with iron furnaces, and the time may arrive when the beautiful Oolitic valleys of North Yorkshire will become a black country as smoky as the Lancashire and Staffordshire coalfields.

The Northampton Sands of the Oolites also yield large quantities of silicious ironstone. It must not, however, be supposed that ironstone is everywhere plentiful in that formation, nor yet in the Marlstone, and far less in the Lower Lias. I have seen prospectuses of mining companies in the middle of England, in which it was stated that all the ironstone bands of Middlesborough are present in ground where scarce an ounce of them exists.

In older times, in the Weald of the south of England, a considerable amount of iron ore used to be mined and smelted with wood or charcoal, before the Coal-measures were worked extensively, and when the Weald was covered to a great extent with forest. Then the chief part of our iron manufactures was carried on in the south-east of England. Indeed, late in the last century, there were still iron furnaces in the Weald of Kent and Sussex. The last furnace is said to have been at Ashburnham; and here and there we may even now see heaps of slags overgrown with grass, and the old dams that supplied the water which drove the water-wheels that worked the forges of Kent and Sussex. It is said that cannon used in the fight with the Spanish Armada came from this district; and the rails round St. Paul's and other churches of the time of Sir Christopher Wren were forged from the Wealden iron.

I have already remarked that a large part of the wealth which we owe to our Carboniferous minerals, arises, not so much from the commercial value of the coal and ironstone of the coalfields, as from the fact that they form the means of working many different branches of industry. To the vast power which steam has given us, very much of our extraordinary prosperity as a nation is due. Yet were it not for our coal-beds, the agency of steam would be almost wholly denied to us. And hence it is that our great manufacturing districts have sprung up either in, or in the vicinity of coalfields. There iron furnaces glare and blow day and night, there are carried on vast manufactures in all kinds of metal, and there our textile fabrics are chiefly made. In these busy scenes a large part of the population of our island finds employment, and thence we send to the farthest parts of the earth those endless commodities which, while they have supplied the wants of other countries, have given rise in large measure to the wealth and commerce of our own.[1]

There are some other geological formations which afford materials for manufactures other than coal and ores of metals. Thus, in the south-west of England, in the granitic districts of Devon and Cornwall, a great proportion of the finer kinds of clays occur, which are used in making stoneware and porcelain. In Devon and Cornwall the decomposition of granite affords the substance known by the name of Kaolin, from which all the finer porcelain clays are made. It is formed by the disintegration of the felspar of granite. This felspar consists of silicates of alumina, and soda or potash. The soda and potash are comparatively easily dissolved, chiefly through the influence of carbonic acid in the rain-water that falls upon the surface; and the result is that the granite decomposes to a considerable depth. In some cases I have seen granite, undisturbed by the hand of man, which for a depth of twenty feet or more might be easily dug out with a shovel. Owing to this decomposition, a portion of the felspar passes into kaolin, which is washed down by rain into the lower levels, where, more or less mixed with quartz

[1] At least it was so till lately, and there is no reason to suppose that the mining and manufacturing industry of Britain has declined except for a time.

and the other ingredients of granite, it forms natural beds of clay. This is dug out, and the clay is transported chiefly to the district of the Potteries in North Staffordshire. The same process is sometimes secured by art, when the decomposed granite being dug out, is washed by artificial processes, and the more aluminous matter is separated from the quartz with which it was originally associated. Then, in the Potteries, it is turned into all sorts of vessels—fine porcelain, stoneware, and common-ware in every variety of size, and form, and texture.

In the Eocene tertiary beds, in the neighbourhood of Poole, there are large lenticular beds of pipe-clay, interstratified with the Bagshot Sand. Great quantities of this clay are exported into the Pottery districts to be made into the coarser kind of earthenware, and they are also mixed with the finer materials from Devon and Cornwall, to make intermediate qualities of stone-ware and china.

But in addition to clay, the chalk is brought into requisition to furnish its quota of material for this manufacture. The flints that are found embedded in the chalk, chiefly in layers, are also transported to the Potteries, and ground up with the aluminous portions of the clay, since it is sometimes necessary to use a certain proportion of silica in the manufacture of porcelain.

Many other formations, such as the Old and New Red Marls, are also of use when clay is required for the manufacture of bricks. The Oolitic and Liassic strata are to a great extent composed of clay, such as Lias Clay, Fullers' Earth Clay, Oxford and Kimeridge Clay; there is also the Weald Clay, and the Gault lies in the middle of the Cretaceous strata. The Boulder-clay is also often used in manufactures, and the silts of the Wash and of many another river. An abundance of material is found in all of these formations for the manufacture of bricks, earthenware pipes, and so on; and it is interesting to observe how in this respect the architecture of the country is apt to vary according to the nature of the strata of given areas. In Scotland and the north of England, where hewable stone abounds, almost all the houses are built of sandstone, grey and sombre; in many of the Oolitic districts they are of limestone, and generally lighter and more graceful; while on the Red Marls, Lias, and in the Woodland area of the Weald we have still the relics of an elder England in those beautiful brick and timbered houses that speak of habits and manners gone by.

In the upper Lias clay in Yorkshire, beds of lignite and jet are found near Whitby, which locally forms a not unimportant branch of manufacture.

The glass-sand used in this country is chiefly derived from the Eocene beds of the Isle of Wight, and from the sand-dunes on the borders of the Bristol Channel. In the Isle of Wight, the sandy strata lie above the London Clay, and are the equivalent of part of the Bagshot sands. They are remarkably pure in quality, being formed of fine white silicious sand. These sands are largely dug and exported to be used in glass-houses in various parts of the country, as in Birmingham and elsewhere.

A large proportion of the cement-stones of our country comes from the Lias limestone. These limestones are not pure carbonate of lime, but are formed of an intermixture of carbonate of lime and aluminous matter. It is found by experience that the lime from this kind of limestone is peculiarly adapted for setting under water. Hence the Lias limestone has always been largely employed in the building of piers and other structures that require to be constructed under water. Cement stones are also found to some extent in the Eocene strata, and are obtained from nodules dredged from the sea-bottom at Harwich, and the south of England. These are transported hither and thither, to be used as occasion may require.

The chief building stones of our country, of a hewable kind, are the limestones of the Oolitic rocks, the Magnesian Limestone, the Carboniferous Limestone, the Carboniferous sandstones, and the sandstones of the Old and New Red series. The Caradoc Sandstone, also in Shropshire near Church Stretton, yields a good building stone. The chief Oolitic building stones are from the Isle of Portland and the Bath Oolite. St. Paul's and many other churches in London were built of Portland stone, and the immense quantities of rejected stones in the old quarries, show how careful Sir Christopher Wren was in the selection of material. The Bath stone also affords a beautiful yellow limestone, which comes out of the quarries in blocks of great size, and is easily sawn and hewn into shape. Nearly the whole of Bath has been built of this stone, and it has been largely used in Westminster Abbey and other buildings in London. Excellent building stones are also got from the Inferior Oolite limestone, especially in the neighbourhood of Cheltenham, from the Cotswold Hills.

In England the Magnesian Limestone is extensively quarried for building purposes. It is of very various qualities, sometimes exceedingly durable, resisting the effects of time and weather, and in other cases decomposing with considerable rapidity. The Houses of

Parliament were chiefly built of this stone. In districts where it occurs, in Nottinghamshire and Yorkshire, there are churches, and castles such as Conisbro', built of it, wherein the edges of the stones are as sharp as if fresh from the mason's hands. You can see the very chisel-marks of the men who built the castle, in days possibly before, but certainly not long after the landing of William the Conqueror.

The Carboniferous Limestone also is an exceedingly durable stone. The Menai bridges were built of it. In Caernarvon Castle the preservation of this limestone is well shown. The castle is built of layers of limestone and sandstone, the sandstone having been chiefly derived from the Millstone Grit, or from sandstones interstratified with the limestone, and the limestone from quarries in Anglesea, and on the shores of the Menai Straits. The limestone has best stood the weather. Sandstone, though durable, is rarely so good as certain limestones, which, being somewhat crystalline, and sometimes formed to a great extent of Encrinites, also essentially crystalline in structure, have withstood the effect of time.

The Carboniferous Sandstones in Lancashire, Derbyshire, Yorkshire, and in Wales and Scotland, afford large quantities of admirable building material, which has been used almost exclusively in the building of Leeds, Edinburgh, Glasgow, and many other towns. Some of it is exceedingly white, is easily cut by the chisel, and may be obtained in blocks of immense size. But in some of the beds there is so much diffused iron, not visible at first sight, that in the course of time this, as it oxidises, produces stains which discolour the exterior of the buildings.

Unlike limestones, basalts and other hard and tough rocks, such sandstones as the Millstone Grit and Gannister beds of the Coal-measures, are ill adapted for macadamising roads, for traffic rapidly grinds it into its original state of loose sand. Nevertheless, in some regions they have nothing else to use, and to obviate its defects the following process is used near Barnsley and in other parts of Yorkshire. The rocks in question were made from the débris of granites and gneiss, similar to those of the Scotch Highlands. The stone being quarried in small slabs and fragments, is built in a pile about 30 feet square, and 12 or 14 feet high, somewhat loosely; and while the building is in progress, brushwood is mingled with the stones, but not in any great quantity. Two thin layers of coal, about 3 inches thick, at equal distances, are, so to speak, interstratified with the sandstones, and a third layer is strewn over the top. At the bottom facing the prevalent wind, an opening about 2 feet high is left, something like the mouth of an oven. Into this brushwood and a little coal is put and lighted. The fire slowly spreads through the whole pile, and continues burning for about six weeks. After cooling the stack is pulled down, and the stones are found to be vitrified. Slabs originally flat have become bent and contorted like gneiss, and stones originally separate, get, so to speak, glued together in the process of vitrification, aided by the soda, potash, and iron, which form part of the constituents of felspar and mica and act as a flux.

In the year 1859 I visited a vitrified fort called Knockfarril, near Strathpeffer in Ross-shire, 'and came to the conclusion that the vitrification had been done of set purpose, and that the effect had been produced by burning wood.' In the first volume of Dr. John Hill Burton's 'History of Scotland,' 1866, he ex-presses a wish that science would explain the manner in which vitrification of forts was effected. Having formed the opinion that the Yorkshire method of vitrification most closely resembled that used by the old fort-builders, I wrote to Mr. Burton giving an account of it, and the letter with sundry blunders in geological names is printed in a paper by Mr. John Stuart, LL.D. in the 'Proceedings of the Society of Antiquaries of Scotland,' 1868–9. All the vitrified forts in Scotland are either in the Highlands, or in Berwickshire and Galloway, where rocks easily vitrified abound, and but that there are neither vitrified forts nor native celts in modern Yorkshire, one would almost be tempted to speculate on the art of vitrification having descended there, from an ancient Pictish people of the bronze age, such as are supposed by Dr. Julius Ernest Fodisch to have erected the scorified ramparts of the forts in Bohemia. The vitrification of rocks in Yorkshire I have thought worthy of being recorded, throwing as it does some light on the method employed in the construction of forts in times that seem to us to be prehistoric.

The New Red Sandstone also yields its share of building stones, but much of it is very soft and easily worn by the weather, a notable example of which was seen in the Cathedral at Chester before its restoration. The white Keuper Sandstone of Grinshill, north of Shrewsbury, the Peckforton Hills, and Delamere Forest, is an excellent stone. The Old Red Sandstone is also used as a building stone in its own area, and, as already stated, the Caradoc Sandstone of Shropshire, near Church Stretton, yields a beautiful white material.

The rock-salt of Worcestershire and Cheshire is a valuable commodity. It lies in the New Red Marl, low in the series, and, as already explained, was the result of the solar evaporation of an inland lake, like, for example, the great salt lake near Utah, in the Rocky Mountains, or of the salt lakes of central Asia. The waters that ran into it contained quantities of salt in solution; and as the lake had no outlet, and only got rid of its water by evaporation, concentration of the chloride of sodium ensued, till at length super-saturation being induced, precipitation of rock-salt took place. The same formation yields the greater part of the gypsum quarried in England, though some also occurs in the Red Marl of the Magnesian Limestone series.[1]

In Devonshire and Cornwall, on Shap Fell in Westmoreland, and in Scotland chiefly near Aberdeen, the granite quarries afford much occupation to a number of people. Now that it has become the fashion to polish granites, these rocks are becoming of still more importance. But as they are not so easily hewn as sandstone, they do not come into use as ordinary building stones, except in such districts as Aberdeen, where no other good kind of rock is to be had. Basalt, Greenstones, and Felspathic porphyries from North Wales, Scotland, Charnwood Forest, and other districts in England, are also largely employed for building and road-making, and the Serpentines of Cornwall and Anglesea, and the Marbles of the Carboniferous Limestone of Derbyshire, yield beautiful materials for ornamental purposes.

I have now attempted to give an idea of the general physical geography of our country, both in ancient and

[1] For a full account of the physical formation of these deposits, see 'Journ. Geol. Soc.' 1871, vol. xxvii. pp. 189 and 241.—Ramsay.

modern times, as dependent on its geology. I have described the classification of all the formations in serial order, and showed the distribution of these rocks over our country, and in doing this I have tried to give a sketch of the physical geography of our area, during the deposition of each successive group of formations. At various times they have all been affected by disturbances and denudations, and the grand result is, that where most disturbed, hardened, and denuded, there we have mountainous districts; for the greater prominence and ruggedness of surface of these regions, arises partly from the hardness of the igneous, metamorphic, and common stratified rocks, partly from the denudations which they have undergone. The Secondary and Tertiary rocks being younger and not so much disturbed, have in our country not been so much denuded, and therefore generally form plains and tablelands.

Moreover, we saw that over all these surfaces, in addition to the vast amount of erosion which must have been effected in Palæozoic, Secondary, and older Tertiary times, renewed denudations, accompanied by great cold, occurred at a very late epoch. The result of this abrasion has been to cover the surface more or less with loose superficial detritus, upon which part of the fertility of portions of the country and the peculiarity of some of its soils depend.

I then passed on to notice what I considered to be a very remarkable result of this last great denudation, brought about under the influence of ice, by which the chief part—I by no means say all—but by which the chief part of the lakes of our country have been formed; and not of our country alone, but of a large part of the northern, and I have no doubt also of the southern hemisphere. It is a remarkable thing, indeed, to consider, if true—and I firmly believe it to be true—that so many of those hollows in which lakes lie have been scooped out by the slow and long-continued passage of great sheets of glacier ice, quite comparable to those vast masses that cover the extreme northern and southern regions of the world at this day.

The water-drainage of the country is likewise seen to be dependent on geological structure. Our larger rivers chiefly drain to the east, and excepting the Severn, the Dee (Wales), the Mersey, the Solway, and the Clyde, the smaller ones to the west, partly because certain axes of disturbance happened to lie nearer our western than our eastern coasts. Again, the quality of water in these rivers depends, as we have seen, on the nature of the rocks over which they flow, and of the springs by which they are supplied.

Then, when we come to consider the nature of the population inhabiting our island, we find it also to be greatly influenced by this old geology. The earlier tribes were in old times driven into the mountain regions in the north and west, and so remain to this day—still speaking their own languages, but gradually mingling now, as they did before, with the masses of mixed races that came in with later waves of conquest from other parts of Europe. These later races settling down in the more fertile parts of the country, first destroyed and then again began to develop its agricultural resources. In later times they have applied themselves with wonderful energy to turn to use the vast stores of mineral wealth which lie in the central districts. Hence have arisen those densely-peopled towns and villages in and around the Coal-measure regions, where so many important manufactures are carried on. Yet in the west, too—in Devon and

Cornwall, and in Wales where some of the great Coal-measure, metalliferous, and slaty regions lie—there are busy centres of population, where the operations are often directed by, and the manual labour connected with the mineral products is well done by the original Celtic inhabitants.

It is interesting to go back a little and inquire what may have been the condition of our country when man first set foot upon its surface. We know that these islands of ours have been frequently united to the Continent, and as frequently disunited, partly by elevations and depressions of the land, and to a great extent, also, by denudations. When the earliest human population of which we have any traces came, Britain was doubtless united to the Continent. Such is the deliberate opinion of some of our best geologists, and also that these pre-historic men inhabited our country along with the great hairy Mammoth, the Rhinoceros, the Cave Bear, the Lion, the Hippopotamus, and many modern animals—and perhaps, in pre-Glacial times, they travelled westward into what is now Britain from the Continent, along with these extinct mammalia. The country was then most probably covered by great forests, swamps, and peaty flats, unless it may have been that the Chalk downs and the higher mountain-tops were bare.

But in times much later, denudations and alterations of level having taken place, our island again became disunited from the mainland: and now, with all its numerous firths and inlets, its great extent of coast, its admirable harbours, our country lies within the direct influence of that Gulf Stream which softens the whole climate of the West of Europe, and we, a people of mixed race, Celt, Scandinavian, Angles, and Norman, more or less intermingled in blood, are so happily placed that, in a measure, we have the command of a large portion of the commerce of the world, and send out fleets of merchandise from every port.

And we are happy, in my opinion, above all things in this, that by an old denudation we have been dissevered from the Continent of Europe, and our boundaries are clear. Thus it happens that, free from immediate contact with countries possibly hostile, and not too much biassed by the influence of peoples of foreign blood, during the long course of years in which our country has never seen the foot of an invader,[1] we have been enabled, with occasional disturbance of foreign wars and political factions, progressively so to develop our own ideas of religion, political freedom, and political morality, that we stand one of the freest and most prosperous countries on the face of the globe.

I have now completed the somewhat arduous task undertaken in preparing this much enlarged edition of an old book. It is, after all, but a sketch of a large subject, and no one can be more sensible than I am of its imperfections; but with all its faults and omissions, I think that this is the first work in which an attempt has been made to trace in detail the absolute connection of the Physical Geology and Physical Geography of old epochs in Britain with that of the present day. Right or wrong in some of the questions raised, it is the work of one who, through more than half a lifetime, has

> 'pry'd through Nature's store,
> Whate'er she in th' ethereal round contains,
> Whate'er she hides beneath her verdant floor,
> The vegetable and the mineral reigns;

[1] The small French descents of Pembrokeshire and Ireland do not deserve the name of invasions.

Or else he scans the globe—those small domains,
Where restless mortals such a turmoil keep,—
Its seas, its floods, its mountains, and its plains:

Let the reader learn from it what he can, and judge of the result.

INDEX.

LIST OF BOOKS

PUBLISHED BY

EDWARD STANFORD,

55, CHARING CROSS,

LONDON, S.W.

AGENT, BY APPOINTMENT, FOR THE SALE OF THE ORDNANCE AND GEOLOGICAL SURVEY PUBLICATIONS, THE ADMIRALTY CHARTS, INDIA OFFICE PUBLICATIONS, ETC.

BRITISH MANUFACTURING INDUSTRIES. Edited by G. Phillips Bevan, F.G.S., &c. A Series of Handy Volumes, each containing three or more subjects by Eminent Writers. Post 8vo, cloth, each 3*s.* 6*d.*

List of the Subjects of each Volume, with the Names of the Contributors:—

Iron and Steel	W. Mattieu Williams, F.C S., F.R.A.S.
Copper	J. A. Phillips, F.C.S., F.G.S. (Memb. Inst. C.E.).
Brass, Tin, and Zinc	Walter Graham.
Metallic Mining	Prof. W. Warrington Smyth, F.R.S., F.G.S.
Coal	A. Galletly (Edin. Mus. Science and Art.)
Collieries	Prof. W. Warrington Smyth.
Building Stones	Prof. Hull, F.R.S., F.G.S.
Explosive Compounds	W. Mattieu Williams, F.C.S., F.R.A.S.
THE BIRMINGHAM TRADES.	
Guns, Nails, Locks, Wood-screws, Railway Bolts and Spikes, Buttons, Pins, Needles, Saddlery, Electroplate	The late W. C. Aitken (Birmingham).
Pens and Papier-Mâché, Ammunition, Percussion Caps and Cartridges, Anchors and Chain Cables	G. Lindsey (Birmingham).
Acids and Alkalies	Prof. Church, M.A., F.C.S. (Royal Agricultural College, Cirencester).
Oils and Candles	W. Mattieu Williams, F.C.S., F.R.A.S.
Gas and Lighting	R. H. Patterson, F.S.S.
Wool	Prof. Archer, F.R.S.E. (Director of Edinburgh Museum of Science and Art).
Flax and Linen	W. T. Charley, M.P.
Cotton	Isaac Watts (Sec. Cotton Supply Association).
Silk	B. F. Cobb (Sec. Silk Supply Association).

Edward Stanford, 55, Charing Cross, London.

Hosiery and Lace	The late W. Felkin (Nottingham).
Carpets	Christopher Dresser, Ph.D.
Dyeing and Bleaching	T. Sims (Mayfield Print Works).
Pottery	L. Arnoux (Art Director of Minton's Manufactory).
Glass and Silicates	Prof. Barff, M.A., F.C.S.
Furniture and Woodwork	J. H. Pollen, M.A. (S. Kensington Museum).
Paper	Prof. Archer, F.R.S.E.
Printing	Joseph Hatton.
Bookbinding	H. T. Wood, B.A. (Society of Arts).
Engraving	The late Samuel Davenport.
Photography	P. Le Neve Foster (Society of Arts).
Toys	G. C. Bartley (South Kensington Museum).
Tobacco	John Dunning.
Hides and Leather, Gutta-percha, and Indiarubber	J. Collins, F.B.S. (Edinburgh).
Fibres and Cordage	P. L. Simmonds, F.R.C.I.
Ship-building	Capt. Bedford Pim, R.N., M.P.
Telegraphs	Robert Sabine, C.E.
Agricultural Machinery	Prof. Wrightson (Royal Agricultural College, Cirencester).
Railways and Tramways	D. K. Clark (Mem. Inst. C.E.).
Jewellery	G. Wallis (South Kensington Museum).
Gold Working	Rev. Charles Boutell, M.A.
Watches and Clocks	F. J. Britten (British Horological Institute).
Musical Instruments	The late E. F. Rimbault, LL.D.
Cutlery	F. Callis (Sheffield).
Salt, Preserved Provisions, Bread	J. J. Manley, M.A.
Sugar Refining	C. Haughton Gill.
Butter and Cheese	Morgan Evans (late Editor of 'Milk Journal').
Brewing and Distilling	T. Pooley, B.Sc., F.C.S.
The Industrial Classes and Industrial Statistics, 2 Vols.	G. Phillips Bevan, F.G.S.

Also, uniform in size and type, price 4s. 6*d. each,*

BRITISH INDUSTRIES.

Sea Fisheries	E. W. H. Holdsworth, F.L.S., F.Z.S., &c.
Salmon Fisheries	Archibald Young (Commissioner of Scotch Salmon Fisheries).
Horticulture	F. W. Burbidge.

ADDERLEY.—COLONIAL POLICY and HISTORY—REVIEW of "THE COLONIAL POLICY of LORD J. RUSSELL'S ADMINISTRATION, BY EARL GREY, 1853," and of SUBSEQUENT COLONIAL HISTORY. By the Right Hon. Sir C. B. ADDERLEY, K.C.M.G., M.P. Demy 8vo, cloth, 9*s.*

ALPS (The).—TOURISTS' GUIDE to the UPPER ENGADINE.—Translated from the German of M. CAVIEZEL. By A. M. H. With Coloured Map. Post 8vo, cloth, 5*s.*

AMERICA, NORTH.—NOTES on the GEOGRAPHY of NORTH AMERICA, PHYSICAL and POLITICAL. With Coloured Physical Map. Crown 8vo, cloth, 1*s.*

AMERICA, SOUTH.—NOTES on the GEOGRAPHY of SOUTH AMERICA, PHYSICAL and POLITICAL. With Coloured Physical Map. Crown 8vo, cloth, 1*s.*

ANDLAU'S GRAMMAR and KEY to the GERMAN LANGUAGE: Being an easy and complete System for acquiring this useful tongue, with Progressive Exercises, &c. By the Baron VON ANDLAU, late Director of the German, French, and Classical College, Clapham Rise. Fourth Edition. Demy 12mo, cloth, 3*s.* 6*d.*

—— GERMAN READING BOOKS: Containing Sentences, Descriptions, Tales, and Poetry, with the necessary Explanations in English, for the Use of Schools, Private, and Self Instruction. Demy 12mo, cloth. First Course, 3*s.* 6*d.*; Second Course, 4*s.* 6*d.*

ANSTIE.—The COAL FIELDS of GLOUCESTERSHIRE and SOMERSETSHIRE, and their RESOURCES. By JOHN ANSTIE, B.A., F.G.S., Assoc. Inst. Civil Engineers, &c. With Tables and Sections. Imperial 8vo, cloth, 6*s.*

BAINES.—The GOLD REGIONS of SOUTH-EASTERN AFRICA. By the late THOMAS BAINES, F.R.G.S. Accompanied by a Biographical Sketch of the Author. With Portrait, Map, Photographs, and Illustrations. Demy 8vo, cloth, 15*s.*

BARFF.—ELEMENTARY CHEMISTRY. By F. S. BARFF, M.A., Professor of Chemistry at the Royal Academy of Arts. Illustrated with Diagrams, and containing Questions for Calculation, and a Special Chapter on Apparatus. Fcap. 8vo, cloth, 1*s.* 6*d.*

BATES.—COMPENDIUM of GEOGRAPHY and TRAVEL in CENTRAL AMERICA, WEST INDIES, and SOUTH AMERICA. Based on Hellwald's 'Die Erde und Ihre Völker.' Edited and extended by H. W. BATES, F.R.G.S., Author of 'The Naturalist on the Amazon.' With Ethnological Appendix by A. H. KEANE, B.A. Large post 8vo, cloth, with Thirteen Maps and Seventy-three Illustrations, 21*s.*

BEAUVOISIN'S (Mariot de) FRENCH VERBS at a GLANCE. New Edition, Thirty-third Thousand, enlarged and entirely rewritten. Demy 8vo, price 1*s.*

BELLAMY.—TABLES for the USE of ENGINEERS and ARCHITECTS in Taking out QUANTITIES of MASONRY, IRONWORK, &c. By C. J. BELLAMY, C.E. Second Edition, with Additions. Royal 8vo, cloth, 15*s.*

BEVAN.—TOURISTS' GUIDE to the COUNTY of KENT: Containing full Information concerning all its favourite Places of Resort, both on the Coast and Inland. By G. PHILLIPS BEVAN, F.G.S. With Map, and Plans of Canterbury and Rochester Cathedrals. Fcap. 8vo, cloth, 2*s.*

—— TOURISTS' GUIDE to the NORTH and EAST RIDINGS of YORKSHIRE: Containing full Information concerning all the favourite Places of Resort, both on the Coast and Inland. By G. PHILLIPS BEVAN, F.G.S. With Map, and Plan of York Minster. Fcap. 8vo, cloth, 2*s.*

—— TOURISTS' GUIDE to the WEST RIDING of YORKSHIRE: Containing full Information concerning all its principal Places of Resort and Interest. By G. PHILLIPS BEVAN, F.G.S, Author of 'Handbook to the County of Kent.' With Map. Fcap. 8vo, cloth, 2*s.*

BIRCH.—EXAMPLES of LABOURERS' COTTAGES, with PLANS for IMPROVING the DWELLINGS of the POOR in LARGE TOWNS. By JOHN BIRCH, Architect, Author of 'Designs for Dwellings of the Labouring Classes,' awarded the Medal and Premium of the Society of Arts. Imperial 8vo, cloth, illustrated, 3*s.* 6*d.*

BOWRING.—The DECIMAL SYSTEM, in NUMBERS, COINS, and ACCOUNTS. By the late Sir JOHN BOWRING, LL.D. With 120 Engravings of Coins, Ancient and Modern. Post 8vo, cloth, 4*s.*

BRAZILIAN COLONIZATION, from an EUROPEAN POINT of VIEW. By JACARÉ ASSU. Demy 8vo, cloth, 2*s.* 6*d.*

BROWN.—CANOE and CAMP LIFE in BRITISH GUIANA. By C. BARRINGTON BROWN, Associate of the Royal School of Mines, late Government Surveyor in British Guiana. With Map and Ten Coloured Illustrations. Demy 8vo, cloth, 21*s.*

BROWN and LIDSTONE.—FIFTEEN THOUSAND MILES on the AMAZON and its TRIBUTARIES. By C. BARRINGTON BROWN, Ass. R.S.M., Author of 'Canoe and Camp Life in British Guiana;' and WILLIAM LIDSTONE, C.E. Demy 8vo, cloth, with Map and numerous Wood Engravings, 21*s.*

BROWNE.—The MERCHANTS' HANDBOOK. A Book of Reference for the use of those engaged in Domestic and Foreign Commerce. By W. A. BROWNE, LL.D. Second Edition. Demy 12mo, cloth, 5*s.*

—— MONEY, WEIGHTS, and MEASURES of the CHIEF COMMERCIAL NATIONS in the WORLD, with the British Equivalents. By W. A. BROWNE, LL.D. Fifth Edition. Demy 12mo, cloth, 1*s.* 6*d.*

BUCKLEY.—BOTANICAL TABLES for the USE of JUNIOR STUDENTS. Table of Common Terms used in Describing Plants, comprising those usually required in the Cambridge Local Examinations for Juniors. Also a Table of the Chief Natural Orders of British Plants, arranged according to Bentham and Oliver. By ARABELLA B. BUCKLEY. Folded in cloth cover, 1*s.* 6*d.*

BURBIDGE.—HORTICULTURE. By F. W. BURBIDGE, Author of 'Domestic Floriculture,' 'Cultivated Plants,' &c. Uniform in size and type with 'British Manufacturing Industries.' Edited by G. PHILLIPS BEVAN, F.G.S. With Illustrations. Post 8vo, cloth, 4*s.* 6*d.*

CANNES.—TAYLOR and RIDDETT'S GUIDE to CANNES and its NEIGHBOURHOOD. By F. M. S. With Map and Frontispiece. Post 8vo, cloth, 4*s.*

DREW.—The NORTHERN BARRIER of INDIA; A Popular Account of the Jummoo and Kashmir Territories. By FREDERIC DREW, F.R.G.S., F.G.S., Author of the 'Jummoo and Kashmir Territories: a Geographical Account.' With Map and Illustrations. Large post 8vo, cloth, 12*s.*

DUN.—BRITISH BANKING STATISTICS: with Remarks on the Bullion Reserve and Non-Legal-Tender Note Circulation of the United Kingdom. By JOHN DUN, General Manager of Parr's Banking Company, Limited. Demy 8vo, cloth, 5*s.*

EDWARDS.—The GERMANS in FRANCE. Notes on the Method and Conduct of the Invasion; the Relations between Invaders and Invaded; and the Modern Usages of War. By H. SUTHERLAND EDWARDS. Post 8vo, cloth, 10*s.* 6*d.*

EVILL.—A WINTER JOURNEY to ROME and BACK. With Glances at Strasburg, Milan, Florence, Naples. Pompeii, and Venice, and an Account of the Siege and Fall of Strasburg. By WILLIAM EVILL, Jun. Third Edition, with Map and Appendix. Crown 8vo, cloth, 4*s.* 6*d.*

FOSTER.—MANUAL of GEOGRAPHICAL PRONUNCIATION and ETYMOLOGY. By A. F. FOSTER, A.M., Author of 'A General Treatise on Geography.' Ninth Edition. Fcap. 12mo, limp cloth, 2*s.*

GAWLER.—SIKHIM: With Hints on Mountain and Jungle Warfare. By Colonel J. C. GAWLER, F.R.G.S., late Deputy Adjutant-General in India. With Map and Illustrations. Demy 8vo, paper, 3*s.*; cloth, 3*s.* 6*d.*

GILL.—CHEMISTRY for SCHOOLS: an Introduction to the Practical Study of Chemistry. By C. HAUGHTON GILL, late Assistant Examiner in Chemistry at the University of London, late Teacher of Chemistry and Experimental Physics in University College School. Third Edition. One Hundred Illustrations. Crown 8vo, cloth, 4*s.* 6*d.*

GREEN.—VESTIGES of the MOLTEN GLOBE, as Exhibited in the Figure of the Earth, Volcanic Action, and Physiography. By WILLIAM LOWTHER GREEN, Minister of Foreign Affairs to the King of the Sandwich Islands. Demy 8vo, cloth, 6*s.*

HALL.—The MINERALOGIST'S DIRECTORY; or, A GUIDE to the PRINCIPAL MINERAL LOCALITIES in the UNITED KINGDOM of GREAT BRITAIN and IRELAND. By TOWNSHEND M. HALL, F.G.S. Post 8vo, cloth, 6*s.*

HANDBOOK OF TRANSLATION from the LATIN, GREEK, FRENCH, and GERMAN LANGUAGES. Post 8vo, 2*s.* 6*d.*

HAY.—ASHANTI and the GOLD COAST, and WHAT WE KNOW OF IT. A Sketch. By Vice-Admiral Sir JOHN DALRYMPLE HAY, Bart., M.P., C.B., D.C.L., F.R.S., &c. With Coloured Map. Second Edition. Crown 8vo, cloth, 2*s.* 6*d.*

HOLDSWORTH.—DEEP-SEA FISHING and FISHING BOATS. An Account of the Practical Working of the various Fisheries carried on around the British Islands. With Illustrations and Descriptions of the Fishing Boats, Nets, and other gear in use; and Notices of the Principal Fishing Stations in the United Kingdom. By EDMUND W. H. HOLDSWORTH, F.L.S., F.Z.S., &c., late Secretary to the Royal Sea Fisheries Commission. Medium 8vo, cloth, 21*s.*

HOLDSWORTH.—SEA FISHERIES. By E. W. H. HOLDSWORTH, F.L.S., F.Z.S., &c., Author of 'Deep Sea Fishing and Fishing Boats.' SALMON FISHERIES. By ARCHIBALD YOUNG, Commissioner of the Scotch Salmon Fisheries. Uniform in size and type with 'British Manufacturing Industries.' With numerous Illustrations. Post 8vo, cloth, 4*s*. 6*d*.

HOPE.—The HEROES of YOUNG AMERICA. By ASCOTT R. HOPE, Author of 'A Book about Boys;' 'A Book about Dominies,' &c. With Map and Illustrations. Crown 8vo, cloth, 6*s*.

HOWLEY.—GEOGRAPHY of NEWFOUNDLAND: for the Use of Schools. By JAMES P. HOWLEY, Assistant Geological Surveyor. With Map, crown 8vo, cloth, 2*s*.

HULL.—COAL FIELDS of GREAT BRITAIN; their History, Structure, and Resources; with Notices of the Coal Fields of other parts of the World. By EDWARD HULL, M.A., F.R.S., Director of the Geological Survey of Ireland, Professor of Geology in the Royal College of Science, Dublin, &c. With Maps and Illustrations. Third Edition, revised and enlarged, embodying the Reports of the Royal Coal Commission. Demy 8vo, cloth, 16*s*.

—— The PHYSICAL GEOLOGY and GEOGRAPHY of IRELAND. By EDWARD HULL, M.A., F.R.S., Director of the Geological Survey of Ireland. Author of 'The Coal Fields of Great Britain.' With Maps and Illustrations. Post 8vo, cloth, 7*s*.

HUMPHRY.—ST. MARTIN-IN-THE-FIELDS IN THE OLDEN TIME. By W. G. HUMPHRY, B.D., Vicar. Second Edition, Enlarged. Crown 8vo, cloth, 1*s*. 6*d*.; paper cover, 1*s*.

HURLBURT.—BRITAIN and HER COLONIES. By J. B. HURLBURT, M.A., LL.D., Member of the Convocation of the University of Toronto. Demy 8vo, cloth, 10*s*.

HUTCHINSON.—The PARANA: With INCIDENTS of the PARAGUAYAN WAR and SOUTH AMERICAN RECOLLECTIONS, from 1861 to 1868. By THOMAS J. HUTCHINSON, F.R.G.S., F.R.S.L., F.E.S., &c., H.B.M. Consul for Callao (late for Rosario). With Map and Illustrations. Demy 8vo, cloth, 21*s*.

INSTRUCTIVE PICTURE BOOKS.—No. I. NATURAL HISTORY of ANIMALS.—A few Attractive Lessons from the Natural History of Animals. By ADAM WHITE, Assistant, Zoological Department, British Museum. With Fifty-four folio Coloured Plates. Tenth Edition, containing many new Illustrations by Mrs. BLACKBURN and others, price 7*s*. 6*d*.

—— No. II. VEGETABLE WORLD.—Lessons from the Vegetable World. By the Author of 'The Heir of Redclyffe,' 'The Herb of the Field,' &c. Fifth Edition, with many new Plates, price 7*s*. 6*d*.

—— No. III. GEOGRAPHICAL DISTRIBUTION of ANIMALS.—Lessons on the Geographical Distribution of Animals, or the Natural History of the Quadrupeds which characterise the Four Divisions of the Globe. In Sixty folio Coloured Plates. Third Edition, price 7*s*. 6*d*.

—— No. IV. SKETCHES from NATURE, or PICTURES of ANIMAL and VEGETABLE LIFE in ALL LANDS. Second Edition. In Forty-eight folio Coloured Plates, price 7*s*. 6*d*.

—— No. V. PICTORIAL LESSONS on FORM, COMPARISON and NUMBER, for Children under Seven Years of Age. With Explanations by NICHOLAS BOHNY. Seventh Edition. Thirty-six oblong folio Coloured Illustrations, price 7*s*. 6*d*.

JENKINSON.—PRACTICAL GUIDE to CARLISLE, GILSLAND, the ROMAN WALL, and NEIGHBOURHOOD. With Map and Frontispiece. Fcap. 8vo, cloth, 5*s*.

—— SMALLER PRACTICAL GUIDE to CARLISLE and NEIGHBOURHOOD. With Map. Fcap. 8vo, 2*s*.

—— PRACTICAL GUIDE to the ENGLISH LAKE DISTRICT. With Nine Maps and Three Panoramic Views. Contents:—Introduction—How to Spend a Flying Visit to the Lakes—a Fourteen Days' Pedestrian Tour—Charges for Conveyances, Ponies, and Guides—Heights of Mountains, Lakes, Tarns, and Passes—Local Names—Meteorology, Geology, and Botany. Fifth Edition. Fcap. 8vo, cloth, 6*s*.

*** The SECTIONS separately: KESWICK—WINDERMERE and LANGDALE—CONISTON, BUTTERMERE, and WASTWATER—GRASMERE and ULLSWATER. With Maps, price 1*s*. 6*d*. each.

—— EIGHTEEN-PENNY GUIDE to the ENGLISH LAKE DISTRICT: Containing Charges for Conveyances, Ponies, and Guides; Heights of Passes, Mountains, Lakes, and Tarns, with Information and Instructions respecting Walks, Drives, Boating, Ascents, Excursions, &c. Fcap. 8vo, with Map, 1*s*. 6*d*.

—— PRACTICAL GUIDE to the ISLE OF MAN. Contents: How to Spend a Flying Visit to the Isle of Man—Voyage round the Island—Hotel Tariffs—Coaches, &c.—a Walk round the Island—Index, &c. Also, Chapters on Local Names—Mineralogy—Civil History—Ecclesiastical History—Geology—Botany—Zoology—Agriculture—Commerce—and Sea Trout-fishing. With Map. Fcap. 8vo, cloth, 5*s*.

—— SMALLER PRACTICAL GUIDE to the ISLE OF MAN. Containing Distances—Heights of Mountains—Charges for Porters and Conveyances—How to spend a Flying Visit—Voyage round the Island, &c. With Map. Fcap. 8vo, 2*s*.

—— PRACTICAL GUIDE to the ISLE OF WIGHT. Containing full and Original Information for Tourists respecting Walks, Drives, and Excursions; Railway Trains, Steamers, Coaches, Boats, Hotels, Public Buildings, Places of Worship, &c.; also, Chapters on the Local Names, the History, Geology, Botany, Quadrupeds, Reptiles, Fresh-water Fishes, Birds, and Butterflies; the Fortifications; Agriculture, Commerce, and Fisheries of the Island. With View of Osborne House and Six Maps. Fcap. 8vo, cloth, 6*s*.

—— SMALLER PRACTICAL GUIDE to the ISLE OF WIGHT: Containing Information for Tourists concerning Walks and Excursions, Railway Trains, Steamers, Coaches, &c. With Two Maps. Fcap. 8vo, 2*s*.

—— PRACTICAL GUIDE to NORTH WALES. Contents: How to Spend a Flying Visit to North Wales—A Seventeen Days' Tour—Hotel Tariffs; and Charges for Conveyances, Ponies, and Guides—List of Mountains—List of Tarns and Lakes—Local Names—History—Geology—Botany—Mines and Minerals—Angling. With Two Maps. Fcap. 8vo, cloth, 6*s*. 6*d*.
*** The SECTIONS also separately: CHESTER—LLANDUDNO—BETTWS Y COED and SNOWDON—DOLGELLEY and BALA—ABERYSWYTH and LLANGOLLEN. With Map, price 1*s*. 6*d*. each.

—— SMALLER PRACTICAL GUIDE to NORTH WALES. Contents: How to Spend a Flying Visit—A Seventeen Days' Tour—Hotel Tariffs, &c. With Map. Fcap. 8vo, 2*s*. 6*d*.

JOHNSTON.—COMPENDIUM of GEOGRAPHY and TRAVEL in AFRICA, for General Reading. Based on Hellwald's 'Die Erde und Ihre Völker.' Edited and Extended by KEITH JOHNSTON, F.R.G.S. With Ethnological Appendix by A. H. KEANE, B.A. Large post 8vo, cloth gilt, with Sixteen Maps and Diagrams, and Sixty-eight Illustrations, 21*s*.

KINCAID.—CONIC SECTIONS—The METHOD of PROJECTIONS. By the Rev. SIDNEY BOLTON KINCAID, M.A., Trinity College, Cambridge; Master of the Modern Side of Ipswich School. Author of 'The Air Engine,' 'An Index of British Geology,' &c. Crown 8vo, cloth, 2*s*. 6*d*.

KING.—VIRGIL'S ÆNEID: Translated into English Verse by the Rev. J. M. KING, Vicar of Cutcombe, late Scholar of Ball. Coll., Oxon. Second Edition. Crown 8vo, cloth, 7*s*. 6*d*.

LEES.—A FEW DAYS in BELGIUM and HOLLAND: An Idle Book for an Idle Hour. By LADY LEES, Author of 'Dried Flowers,' 'Effie's Tales,' &c. Contents: Bruges, Ghent, Antwerp, Bruxelles, Rotterdam, the Hague, Delft, Leyden, Haarlem, Amsterdam, &c. Crown 8vo, cloth, 4*s*. 6*d*.

LEWIS.—The ENGLISH LANGUAGE: Its GRAMMAR and HISTORY; together with a TREATISE on ENGLISH COMPOSITION, and SETS of EXERCISES and EXAMINATION PAPERS for the ASSISTANCE of TEACHERS and STUDENTS. By the Rev. HENRY LEWIS, B.A., Principal of Culham Training College. Seventh Edition. Fcap. 8vo, cloth, 3*s*.

—— ENGLISH GRAMMAR for BEGINNERS, in a SERIES of EASY LESSONS. By the Rev. HENRY LEWIS, B.A., Principal of Culham Training College. Intended for the use of Junior Classes, and as an Introduction to the Author's larger English Grammar. Third Edition. Fcap. 8vo, price 2*d*.

LEWIS (J.).—DIGEST of the ENGLISH CENSUS of 1871, compiled from the Official Returns and Edited by JAMES LEWIS (of the Registrar-General's Department, Somerset House). Sanctioned by the Registrar-General, and dedicated by permission to the President, Vice-Presidents, and Council of the Statistical Society of London. Royal 8vo, cloth, 5*s*.

LOBLEY.—MOUNT VESUVIUS: A DESCRIPTIVE, HISTORICAL, and GEOLOGICAL ACCOUNT of the VOLCANO, with a NOTICE of the RECENT ERUPTION. By J. LOGAN, F.G.S. With View, Map (printed in Colours), and Section. Demy 8vo, cloth, 2*s*. 6*d*.

LONDON GUIDE. How to get from or to any Part of London, or its Suburbs, Public Building, Place of Worship, Exhibition, Institution, Place of Amusement, &c.; with Times, Fares, Prices of Admission, Speciality, &c. Fourth Edition. With Map. Crown 8vo, cloth, 3*s*. 6*d*.

LONDON, ROUND ABOUT.—TOURISTS' GUIDE to the COUNTRY within a circle of TWELVE MILES ROUND ABOUT LONDON. With Historical, Archæological, Architectural, and Picturesque Notes, suitable for the Tourist, Antiquarian, and Artist. To which is added a Series of Specimens of Walking Excursions, limited to six miles, and visits to Hatfield, Knole, St. Albans, and Windsor, with a copious Index. By a Fellow of the Society of Antiquaries. Fourth Edition. Fcap. 8vo, cloth, with Map, 2*s*.

LUCAS.—HORIZONTAL WELLS. A New Application of Geological Principles to effect the Solution of the Problem of Supplying London with Water. By J. Lucas, F.G.S., of the Geological Survey of England. With Maps. Crown 4to, cloth back, 10*s.* 6*d.*

MAIN.—MILTON'S LYCIDAS. Edited, with Interpretation and Notes, by Francis Main, M.A., of the Inner Temple, Barrister-at-Law, one of the Classical Masters at the Bristol College. Post 8vo, printed wrapper, 1*s.*

—— MILTON'S L'ALLEGRO. Edited with Interpretation, Notes, and Derivations: to which is appended, A Scheme of Analysis and Parsing, with Examples. By Francis Main, M.A., of the Inner Temple, Barrister-at-Law, one of the Classical Masters of Bristol College. Intended for the use of pupils Preparing for the Oxford Local Examinations in 1878, and for Schools. Post 8vo. Printed wrapper, 1*s.*

MANN.—DOMESTIC ECONOMY and HOUSEHOLD SCIENCE. Adapted for Home Education, and for Schoolmistresses and Pupil Teachers. By Robert James Mann, M.D., Late Superintendent of Education at Natal. Post 8vo, cloth, 4*s.* 6*d.*; or, cloth gilt, gilt edges, 5*s.*

MANLY.—PRINCIPLES of BOOK-KEEPING by DOUBLE ENTRY, in a Series of Easy and Progressive Exercises. By Henry Manly, for more than Thirty-three years Principal Writing Master and Teacher of Book-keeping in the City of London School. Revised and Enlarged by Henry William Manly, Actuary to the Mutual Life Assurance Society, and Fellow of the Institute of Actuaries. Fourth Edition. Demy 8vo, cloth, 4*s.* 6*d.*

MARTIN.—THEORIES of HORIZONTAL CURRENTS in the OCEAN and ATMOSPHERE, and of Eastation of Planetary and other Celestial Bodies, being new Theories of Natural Forces not before discovered, and accounting for many Natural Phenomena, hitherto unsolved problems. By John Martin. Seventeen Illustrations. Crown 8vo, 3*s.*

MEADEN.—A FIRST ALGEBRA for Use in Junior Classes. By the Rev. R. Alban Meaden, M.A., late Scholar of Emmanuel College, Cambridge; Senior Mathematical Master of the Bradford Grammar School. Fourth Edition, revised and enlarged. Fcap. 8vo, cloth, 1*s.* 6*d.*

MEDHURST.—The FOREIGNER in FAR CATHAY. By W. H. Medhurst, H.B.M. Consul, Shanghai. With Coloured Map. Crown 8vo, cloth, 6*s.*

MILLER.—NOTES on the MORNING and EVENING PRAYER and the LITANY, with a Chapter on the Christian Year. By Fredk. Miller, Malvern Link National School. Second Edition. Fcap. 8vo, cloth, 1*s.*

—— ELEMENTARY GEOGRAPHY for ELEMENTARY SCHOOLS. An Introduction to Physical and Political Geography. By Fredk. Miller, Master of the Malvern Link National School. Fcap. 8vo, limp cloth, 8*d.*

MILLETT.—An AUSTRALIAN PARSONAGE; or, the SETTLER and the SAVAGE in WESTERN AUSTRALIA. By Mrs. Edward Millett. With Frontispiece. Second Edition. Large post 8vo, cloth, 12*s.*

MIMPRISS.—CHRIST an EXAMPLE for the YOUNG, as EXHIBITED in the GOSPEL NARRATIVE of the FOUR EVANGELISTS. Harmonized and Chronologically Arranged. By Robert Mimpriss. Illustrated by Fifty-five Engravings, and a Map. Fifth Edition. Cloth, 6*s.*

MULHALL.—From EUROPE to PARAGUAY and MATTO GROSSO. By Mrs. M. G. MULHALL. With Illustrations. Demy 8vo, cloth, 5*s.*

MULHALL.—The ENGLISH in SOUTH AMERICA. By MICHAEL G. MULHALL. Demy 8vo, cloth, with Twenty-two Illustrations, 16*s.*

NEW ZEALAND HANDBOOK: Containing a New and Accurate Coloured Map, and giving a full description of the Provinces; with Tables of Statistics, Prices, and Wages; Land Regulations; Instructions for the Voyage, Outfit, and Arrival in the Colony; also Observations on New Zealand Pursuits and Investments. Twelfth Edition. Fcap. 8vo, 1*s.*

NOBLE.—DESCRIPTIVE HANDBOOK of the CAPE COLONY: its CONDITION and RESOURCES. By JOHN NOBLE, Clerk of the House of Assembly, Cape of Good Hope. With Map and Illustrations. Crown 8vo, cloth, 10*s.* 6*d.*

PALMER.—The ORDNANCE SURVEY of the KINGDOM: Its Objects, Mode of Execution, History, and Present Condition. By Captain H. S. PALMER, R.E. Five Coloured Index Maps. Demy 8vo, cloth, 2*s.* 6*d.*

PHILPOT.—GUIDE BOOK to the CANADIAN DOMINION: Containing full information for the Emigrant, the Tourist, the Sportsman, and the small Capitalist. By HARVEY J. PHILPOT, M.D. (Canada), M.R.C.S.L., &c. With a Preface by THOMAS HUGHES, Esq., M.P., and a COLOURED MAP. Super-royal 16mo, 4*s.*

POOR RELIEF IN DIFFERENT PARTS OF EUROPE: being a Selection of Essays, translated from the German Work, 'Das Armenwesen und die Armengesetzgebung in Europäischen Staaten herausgegeben,' Von. A. Emminghaus. Revised by E. B. EASTWICK, C.B., M.P. Crown 8vo, cloth, 7*s.*

POPE.—A CLASS BOOK of RUDIMENTARY CHEMISTRY. By the Rev. GEO. POPE, M.A., Fellow of Sidney Sussex College, Cambridge, and one of the Masters of the College, Hurstpierpoint. 18mo, stiff cover, 9*d.*

PURDY.—RETURN to PARLIAMENT of OWNERS of LAND, 1873. SUMMARY DIGEST—ENGLAND AND WALES. By FREDERICK PURDY, F.S.S., Principal of the Statistical Department, Local Government Board. Large 8vo, paper cover, 2*s.*

RAMSAY.—PHYSICAL GEOLOGY and GEOGRAPHY of GREAT BRITAIN. By A. C. RAMSAY, LL.D., F.R.S., &c., Director-General of the Geological Surveys of the United Kingdom. Fifth Edition, considerably enlarged, and Illustrated with NUMEROUS SECTIONS, FOSSILS, LANDSCAPES, and a GEOLOGICAL MAP of GREAT BRITAIN, printed in Colours. Post 8vo, cloth.

RICE.—NOTES on the GEOGRAPHY of EUROPE, PHYSICAL and POLITICAL. Intended to serve as a Text-Book for the use of Elementary Classes. By WILLIAM RICE, F.R.G.S. Crown 8vo, limp cloth, 9*d.*

ROBSON.—CONSTRUCTIVE LATIN EXERCISES, for Teaching the Elements of the Language on a System of Analysis and Synthesis, with Latin Reading Lessons and copious Vocabularies. By JOHN ROBSON, B.A. Lond. Eighth Edition. 12mo, cloth, 4*s.* 6*d.*

ROBSON.—FIRST GREEK BOOK. Containing Exercises and Reading Lessons on the Inflexions of Substantives and Adjectives, and of the Active Verb in the Indicative Mood. With copious Vocabularies. Being the First Part of the Constructive Greek Exercises. By JOHN ROBSON, B.A. Lond. Third Edition. 12mo, cloth, 3*s.* 6*d.*

ROWAN.—The EMIGRANT and SPORTSMAN in CANADA. Some Experiences of an Old-Country Settler. With Sketches of Canadian Life, Sporting Adventures, and Observations on the Forests and Fauna. By J. J. ROWAN. With Map. Large post 8vo, cloth, 10*s.* 6*d.*

RUSSELL.—BIARRITZ and the BASQUE COUNTRIES. By Count HENRY RUSSELL, Member of the Geographical and Geological Societies of France, of the Alpine Club, and Société Ramond, Author of 'Pau and the Pyrenees,' &c. Crown 8vo, with a Map, 6*s.*

SCHOOL-BOYS' LETTERS for COPYING and DICTATION: being a Series of Lithographed Letters on Subjects interesting to School-Boys, with Remarks on the Essentials of Good Writing, &c. Third Edition. Large post 8vo, cloth, 2*s.* 6*d.*

SCHOOL PUNISHMENT REGISTER.—THE LONDON SCHOOL REGISTER of PUNISHMENTS. Designed to meet the Requirements of School Boards, &c. Fcap. folio, stiff boards, cloth back, 2*s.* 6*d.*

SCHOOL REGISTERS.—THE DURHAM SCHOOL REGISTERS. By the Rev. CANON CROMWELL, M.A., Principal of St. Mark's College, Chelsea.

	s.	*d.*
1. Admission Register for 1000 Names	3	0
2. Class Register for Large Schools (50 Names)	0	8
3. Class Register for Small Schools (34 Names)	0	6
4. General Register or Summary, for Three Years	3	0

—— LONDON SCHOOL REGISTER of ADMISSION, PROGRESS, and WITHDRAWAL. Adapted to the Requirements of the Committee of Council on Education. By WILLIAM RICE, F.R.G.S., Author of the 'London Class Register,' the 'Class and Home Lesson Book of English History,' the 'Scholar's Wordbook and Spelling Guide,' the 'Orthographical Copy Books,' &c. Fcap. folio, stiff boards, leather back, 4*s.*

—— LONDON CLASS-REGISTER and SUMMARY of ATTENDANCES and PAYMENTS. Ruled and Printed for 52 Weeks. Adapted to the requirements of the "Special Minute of the Committee of Council on Education." By WILLIAM RICE, F.R.G.S., Author of the Class and Home-Lesson Book of English History,' &c. A New and Improved Edition. Fcap. folio, 1*s.*

—— VARTY'S CLASS REGISTER of INDIVIDUAL PROGRESS. To contain the Admission Numbers and Names of the Children, their Attendance and Absence, and Relative Position in the Class. Fcap. folio, 1*s.*

—— HALBRAKE REGISTER of ATTENDANCE and STUDIES. Designed for Private and Middle-Class Schools. Second Edition. Demy 8vo, coloured wrapper, 8*d.*

SCOTT.—The FAMILY GUIDE to BRUSSELS: Comprising Hints upon Hiring Houses, Furniture, Servants, Cost of Living, Education, and the General Information necessary for a Family purposing to reside in that city. By J. R. SCOTT, of Brussels. Crown 8vo, cloth, gilt, 4*s.*

SEYD.—THE BANKS OF ISSUE QUESTION. Memorial Addressed to the Governor and Court of Directors of the Bank of England, and submitted to the Select Committee of the House of Commons of 1875. By ERNEST SEYD, F.S.S., Author of 'Bullion and Foreign Exchanges,' 'The London Banking and Clearing House System,' &c. Royal 8vo, 3*s*.

SHARP.—RUDIMENTS of GEOLOGY. By SAMUEL SHARP, F.S.A., F.G.S. Part I. Introductory and Physical—Part II. Stratigraphical and Palæontological. Second Edition, revised and enlarged. Crown 8vo, cloth, 4*s*.

SIMMS.—THE FIRST SIX BOOKS of the ILIAD of HOMER, Translated into Fourteen-Syllable Verse, with Preface and Notes, and a Map of Greece in the Homeric Age. Designed as a Reading Book for Colleges and Schools. By the Rev. EDWARD SIMMS, M.A., Oxon., Vicar of Escot, Devon. Demy 8vo, cloth, 7*s*. 6*d*.

SIMPLE LESSONS.—Chiefly intended for Elementary Schools and for Home Use. By the most Eminent Writers. Contents:—Our Bodily Life—How and Why we Breathe—Food—Drink—Cookery—Plain Needlework—Clothing—Air and Ventilation—The Sicknesses that Spread—Weather—Astronomy—Birds—Flowers—Money. 18mo, cloth, 2*s*. 6*d*. The Simple Lessons are also published separately, 3*d*. each, or 16*s*. per 100 assorted. The set of 14, in card case, 3*s*.

SMITH.—The PEASANTS' HOME, 1760-1875. By EDWARD SMITH, F.S.S. Being the Howard Prize Essay, 1875. Crown 8vo, cloth, 3*s*. 6*d*.

STANFORD'S COMPENDIUM OF GEOGRAPHY AND TRAVEL for GENERAL READING. Based on Hellwald's "Die Erde und Ihre Völker." Translated by A. H. KEANE, B.A. A Series of Volumes descriptive of the Great Divisions of the Globe. Large post 8vo.

Europe.—Edited and extended by A. C. RAMSAY, LL.D., F.R.S., Director-General of the Geological Surveys of the United Kingdom; Author of 'Physical Geology and Geography of Great Britain.'

Asia.—Edited and extended by Col. YULE, F.R.G.S., Author of 'Travels of Marco Polo.'

Africa.—Edited and extended by KEITH JOHNSTON, F.R.G.S. With Sixteen Maps, Ethnological Appendix, and Sixty-eight Illustrations. Cloth, gilt, 21*s*.

North America.—Edited and extended by Professor F. V. HAYDEN, of the United States Geological Survey.

Central and South America.—Edited and extended by H. W. BATES, Assistant-Secretary of the Royal Geographical Society; Author of 'The Naturalist on the Amazon.' With Thirteen Maps, Ethnological Appendix, and Seventy-three Illustrations. Cloth gilt, 21*s*.

Australasia.—Edited and extended by A. R. WALLACE, F.R.G.S., Author of 'The Malay Archipelago.'

SULLIVAN.—THE PRINCES OF INDIA. An Historical Narrative of the principal events from the Invasion of Mahmoud of Ghizni to that of Nadir Shah. By Sir EDWARD SULLIVAN, Bart., Author of 'Letters on India,' 'Trip to the Trenches,' 'Rambles in North and South America,' &c. Second Edition. Crown 8vo, cloth, with Map, 8*s*. 6*d*.

SYMONS.—BRITISH RAINFALL, 1876. The Distribution of Rain over the British Isles during the Year 1876, as observed at about 1700 Stations in Great Britain and Ireland. With Maps and Illustrations. Compiled by G. J. SYMONS, F.M.S., F.R.B.S., Member of the Scottish Meteorological Society, &c. Demy 8vo, cloth, 5*s*. [*Published Annually.*

TAYLOR.—BOYS of OTHER COUNTRIES. By BAYARD TAYLOR. The Little Post-Boy—The Pasha's Son—Jon of Iceland—The Two Herd Boys—The Young Serf. With Illustrations. Crown 8vo, cloth, 4*s*. 6*d*.

TOOGOOD.—SIMPLE SKETCHES from CHURCH HISTORY, for YOUNG PERSONS. By Mrs. TOOGOOD. New Edition. 18mo, 1*s*. 6*d*.

TREGELLAS. — TOURISTS' GUIDE to CORNWALL and the SCILLY ISLES. Containing full Information concerning all the principal Places and Objects of Interest in the County. By WALTER H. TREGELLAS, Chief Draughtsman, War Office. With Map. Fcap. 8vo, cloth, 2*s*.

VERDAD.—From VINEYARD to DECANTER. A Book about Sherry. By DON PEDRO VERDAD. With a Map of the Jerez District. Sixth Thousand, revised and enlarged. Fcap. 8vo, cloth, 1*s*.

VICTORIA, The BRITISH "EL DORADO." Showing the advantages of that Colony as a field for Emigration. By a COLONIST of Twenty Years' Standing, and late Member of a Colonial Legislature. With Two Coloured Views and a Map. Super-royal 16mo, cloth, 5*s*. 6*d*.

WALLACE.—MINERAL DEPOSITS. The Laws which Regulate the Deposition of Lead Ore in Mineral Lodes. Illustrated by an Examination of the Geological Structure of the Mining Districts of Alston Moor. By W. WALLACE. With Map and numerous Coloured Plates. Large demy 8vo, cloth, 25*s*.

WEBBER.—The KAIETEUR FALLS, BRITISH GUIANA. The ESSEQUIBO and POTARO RIVERS. With an Account of a Visit to the Kaieteur Falls. By Lieut.-Colonel WEBBER, 2nd West India Regiment. With Map and Frontispiece, and Descriptive Notes on the Geology of Guiana. Crown 8vo, cloth, 4*s*. 6*d*.

WILKINS.—The GEOLOGY and ANTIQUITIES of the ISLE of WIGHT. By Dr. E. P. WILKINS, F.G.S., &c. With Relief Map of the Island, coloured geologically. Super-royal 8vo, cloth, 7*s*. 6*d*.

WILLIAMS.—Through NORWAY with a KNAPSACK. A New and Improved Edition. With Notes on Recent Changes, suggested by a Recent revisit. By W. MATTIEU WILLIAMS, F.R.A.S., F.C.S., &c., Author of 'The Fuel of the Sun,' &c. With Map. Crown 8vo, cloth, 6*s*.

—— Through NORWAY with LADIES. By W. MATTIEU WILLIAMS, F.R.A.S., F.C.S., Author of 'Through Norway with a Knapsack.' With Map and Illustrations. Crown 8vo, cloth, 12*s*.

WORTH.—TOURISTS' GUIDE to SOUTH DEVON: Rail, Road, River, Coast, and Moor. By R. N. WORTH, F.G.S. With Map, and Plan of Exeter Cathedral. Fcap. 8vo, cloth, 2*s*.

Library or Wall Maps.

EUROPE.—Scale, 50 miles to an inch; size, 65 inches by 58. Coloured and mounted on linen, in morocco case, *3l.* 13*s.* 6*d.*; on roller, varnished, *3l.*; spring roller, 6*l.*

ENGLAND and WALES.—Scale, 5 miles to an inch; size, 72 inches by 84. Coloured, 2*l.* 12*s.* 6*d.*; mounted on linen, in morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 4*l.* 4*s.*; spring roller, 6*l.* 6*s.*

LONDON and its SUBURBS.—On the scale of six inches to a mile: constructed on the basis of the Ordnance block plan. Price, in sheets, plain, 21*s.*; coloured, in a portfolio, 31*s.* 6*d.*; mounted on linen, in morocco case, or on roller, varnished, 2*l.* 15*s.*; on spring roller, 5*l.* 5*s.* Single sheets, plain, 1*s.*; coloured, 1*s.* 6*d.* A Key Map may be had on application, or per post for one stamp.

SCOTLAND.—Scale, five miles to an inch; size, 52 inches by 76. Coloured, 42*s.*; mounted on linen, in morocco case, 3*l.* 3*s.*; on roller, varnished, 3*l.* 13*s.* 6*d.*; spring roller, 5*l.* 5*s.*

IRELAND.—Scale, 5 miles to an inch; size, 43 inches by 58. Coloured, four sheets, 25*s.*; mounted, in case, 35*s.*; on roller, varnished, 2*l.* 2*s.*; on spring roller, 4*l.* 4*s.*

ASIA.—Scale, 110 miles to an inch; size, 65 inches by 58. Coloured and mounted on linen, in morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 3*l.*; spring roller, 6*l.*

AFRICA.—Scale, 94 miles to an inch; size, 58 inches by 65. Coloured and mounted on linen, in morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 3*l.*; spring roller, 6*l.*

NORTH AMERICA.—Scale, 83 miles to an inch; size, 58 inches by 65. Coloured and mounted on linen, in morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 3*l.*; spring roller, 6*l.*

CANADA.—LARGE MAP of CANADA, including New Brunswick, Nova Scotia, Newfoundland, and a large portion of the United States. By JOHN ARROWSMITH. Scale, 16 miles to an inch; size, 96 inches by 54. Eight Coloured Sheets, 2*l.* 12*s.* 6*d.*; mounted, in case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 4*l.* 4*s.*; spring roller, 8*l.*

UNITED STATES and CENTRAL AMERICA, with Canada, New Brunswick, Nova Scotia, Newfoundland, and the West Indies. Scale, 54½ miles to an inch; size, 72 inches by 56. Coloured and mounted on linen, in morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 3*l.*; spring roller, 6*l.*

SOUTH AMERICA.—Scale, 83 miles to an inch; size, 58 inches by 65. Coloured and mounted on linen, morocco case, 3*l.* 13*s.* 6*d*: on roller, varnished, 3*l.*; spring roller, 6*l.*

AUSTRALASIA.—Scale, 64 miles to an inch; size, 65 inches by 58. Coloured and mounted on linen, morocco case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 3*l.*; spring roller, 6*l.*

General Maps.

EUROPE.

EUROPE.—STANFORD'S PORTABLE MAP of EUROPE; showing the latest Political Boundaries, the Railways, the Submarine Telegraphs, &c. Scale, 150 miles to an inch; size, 36 inches by 33. Fully coloured and mounted on linen, in case, 10*s.*; on roller, varnished, 14*s.*

CENTRAL EUROPE.—DAVIES'S MAP of CENTRAL EUROPE; containing all the Railways, with their Stations. The principal roads, the rivers, and chief mountain ranges are clearly delineated. Scale, 24 miles to an inch; size, 47 inches by 38. Sheets, plain, 10*s.*; coloured, 12*s.*; mounted on linen, in case, 16*s.*

AUSTRIAN EMPIRE. By J. Arrowsmith. Scale, 28 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

DENMARK and ICELAND. By J. Arrowsmith. Scale, 13 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

FRANCE, in DEPARTMENTS. With a Supplementary Map, divided into Provinces, and a Map of the Island of Corsica. By J. Arrowsmith. Scale, 31 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

GERMANY. By J. Arrowsmith. Scale, 25 miles to an inch; in two sheets, size of each, 22 inches by 26. Price of each, coloured sheet, 3*s.*; mounted, in case, 5*s.*

ITALY, including Sicily and the Maltese Islands. By J. Arrowsmith. Scale, 20 miles to an inch; in two sheets, size of each, 22 inches by 26. Price of each, coloured, 3*s.*; mounted in case, 5*s.*

NETHERLANDS and BELGIUM, including Luxembourg and the Country to the East as far as the Rhine. By J. Arrowsmith. Scale, 13 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

RUSSIA and POLAND, including Finland. By J. Arrowsmith. Scale, 90 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

SPAIN and PORTUGAL. By J. Arrowsmith. Scale, 30 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

SWEDEN and NORWAY. By J. Arrowsmith. Scale, 35 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

SWITZERLAND. By J. Arrowsmith. Scale, 10½ miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

TURKEY in EUROPE, including the Archipelago, Greece, the Ionian Islands, and the South part of Dalmatia. By J. Arrowsmith. Scale, 40 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

BRITISH ISLES.

BRITISH ISLES.—NEW WALL MAP. Constructed on the basis of the Ordnance Survey, and distinguishing in a clear manner the Cities, County and Assize Towns, Municipal Boroughs, Parliamentary Representation Towns which are Counties of themselves, Episcopal Sees, Principal Villages, &c. The Railways are carefully laid down and coloured, and the Map from its size is well suited for Public Offices, Institutions, Reading-Rooms, Railway Stations, good School-Rooms, &c. Scale, 8 miles to an inch; size, 81 inches by 90. Price, coloured, mounted on mahogany roller, and varnished, 3*l.*

BRITISH ISLES.—DAVIES'S NEW RAILWAY MAP of the BRITISH ISLES, and part of France. Scale, 22 miles to an inch; size, 31 inches by 38. Price, coloured in sheet, 6*s.*; mounted on linen, in case, 9*s.*; or on roller, varnished, 15*s.*

ENGLAND and WALES.—LARGE SCALE RAILWAY and STATION MAP of ENGLAND and WALES. In 24 sheets (sold separately). Constructed on the basis of the trigonometrical survey. By J. Arrowsmith. Scale, 3 miles to an inch; size of each sheet, 20 inches by 28. Price, plain, 1*s.*; mounted in case, 2*s.* 6*d.*; coloured, 1*s.* 6*d.*; mounted in case, 3*s.* Size of the complete map, 114 inches by 128. Price, plain, in case or portfolio, 1*l.* 5*s.*; coloured, in case or portfolio, 1*l.* 8*s* ; mounted on cloth to fold, in case, coloured, 4*l.* 4*s.*; on canvas, roller, and varnished, 4*l.* 14*s.* 6*d.*: on spring roller, 9*l.* 9*s.*

ENGLAND and WALES.—STANFORD'S PORTABLE MAP of ENGLAND and WALES. With the Railways very clearly delineated; the Cities and Towns distinguished according to their Population, &c. Scale, 15 miles to an inch; size, 28 inches by 32. Coloured and mounted on linen, in case, 5*s.*; or on roller, varnished, 8*s.*

ENGLAND and WALES.—WALL MAP. Scale, 8 miles to an inch; size, 50 inches by 58. Price, mounted on mahogany roller, varnished, 21*s.*

WALES.—NORTH and SOUTH WALES. Re-issue of Walker's Maps, thoroughly revised and corrected to the present date. Scale, 3 miles to an inch. Each in sheet, 32 inches by 27, coloured, 3*s.*; mounted to fold in case for the pocket, 6*s.*

SCOTLAND.—NEW WALL MAP, showing the Divisions of the Counties, the Towns, Villages, Railways, &c. Scale, 8 miles to an inch; size, 34 inches by 42. Price, coloured, mounted on mahogany roller, and varnished, 12*s.* 6*d.*

SCOTLAND, in COUNTIES. With the Roads, Rivers, &c. By J. Arrowsmith. Scale, 12 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

IRELAND, in COUNTIES and BARONIES, on the basis of the Ordnance Survey and the Census. Scale, 8 miles to an inch; size, 31 inches by 38. On two sheets, coloured, 8*s.*; mounted on linen, in case, 10*s.* 6*d.*; on roller, varnished, 15*s.*

IRELAND.—NEW WALL MAP, showing the divisions of the Counties, all the Towns, Principal Villages, Railways, &c. Scale, 8 miles to an inch; size, 34 inches by 42. Price, coloured, mounted on roller, varnished, 12*s.* 6*d.*

IRELAND, in COUNTIES. With the Roads, Rivers, &c. By J. Arrowsmith. Scale, 12 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

Edward Stanford, 55, Charing Cross, London.

LONDON.

MODERN LONDON and its SUBURBS, extending from Hampstead to the Crystal Palace, and from Hammersmith Bridge to Greenwich; showing all the Railways and Stations, the Roads, Footpaths, &c. Scale, 6 inches to the mile; size, 5 feet by 6. On six large sheets, 25*s.*; mounted on linen, in case, or on roller, varnished, 42*s.*

COLLINS' STANDARD MAP of LONDON. Admirably adapted for visitors to the City. Scale, 4 inches to a mile; size, 34½ inches by 27. Price, plain, in case, 1*s.*; coloured, 1*s.* 6*d.*; mounted on linen, ditto, 3*s.* 6*d.*; on roller, varnished, 7*s.* 6*d.*

BRITISH METROPOLIS.—DAVIES'S NEW MAP of the BRITISH METROPOLIS. Scale, 3 inches to a mile; size, 36 inches by 25½. Price, plain sheet, 3*s.* 6*d.*; coloured, 5*s.*; mounted on linen, in case, 7*s.* 6*d.*; on roller, varnished, 10*s.* 6*d.* With continuation southward beyond the Crystal Palace, plain sheet, 5*s.*; coloured, 7*s.* 6*d.*; mounted on linen, in case, 11*s.*; on roller, varnished, 15*s.*

RAILWAY MAP of LONDON and ENVIRONS.—STANFORD'S SPECIAL MAP of the RAILWAYS, RAILWAY STATIONS, TRAMWAYS, POSTAL DISTRICTS, and SUB-DISTRICTS, in LONDON and its ENVIRONS. Scale, 1 inch to a mile; size, 24 inches by 26. Price, coloured and folded, 1*s.*; mounted on linen, in case, 3*s.*

RAILWAY MAP of LONDON.—The 'DISTRICT' RAILWAY MAP of LONDON, showing all the Stations on the 'Inner,' 'Middle,' and 'Outer' Circles of the Metropolitan Underground Railways, with the principal Streets, Parks, Public Buildings, Places of Amusement, &c. Size, 37 inches by 24. Coloured, and folded in cover, 6*d.*

PARISH MAP of LONDON.—STANFORD'S MAP of LONDON and its ENVIRONS, showing the boundary of the Jurisdiction of the Metropolitan Board of Works, the Parishes, Districts, Railways, &c. Scale, 2 inches to a mile; size, 40 inches by 27. Price, in sheet, 6*s.*; mounted on linen, in case, 9*s.*; on roller, varnished, 12*s.*

LONDON and its ENVIRONS.—DAVIES'S MAP of LONDON and its ENVIRONS. Scale, 2 inches to a mile; size, 36 inches by 28. The main roads out of London, the Minor Roads and Footpaths in the Environs, the Railways completed and in progress, are carefully defined, Price, sheet, 4*s.*; coloured, 5*s.* 6*d.*; mounted on linen, in case, 8*s.*; or on roller, varnished, 14*s.*

ENVIRONS of LONDON.—A MAP of the ENVIRONS of LONDON, including twenty-five miles from the Metropolis. Scale, ¾ of an inch to a mile; size, 36 inches by 35. This Map includes the whole of the County of Middlesex, with parts of the Counties of Surrey, Kent, Essex, Herts, Bucks, and Berks. Price, on one large sheet, coloured, 8*s.*; mounted, in case, 10*s.*; on roller, varnished, 14*s.*

ENVIRONS of LONDON.—DAVIES'S MAP of the ENVIRONS of LONDON. Scale, 1 inch to a mile; size, 43 inches by 32. Price, sheet, plain, 4*s.*; coloured 5*s.* 6*d.*; mounted on linen, in case, 8*s.*; or on roller, varnished, 14*s.*

ENVIRONS of LONDON.—STANFORD'S NEW MAP of the COUNTRY TWELVE MILES round LONDON. Scale, 1 inch to a mile; size, 25 inches by 25. Price, plain, folded in case, 2*s.* 6*d.*; coloured, ditto, 3*s.* 6*d.*; mounted on linen, ditto, 5*s.* 6*d.*

ASIA.

GENERAL MAP OF ASIA.—By J. ARROWSMITH. Scale, 300 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

NORTHERN ASIA, including Siberia, Kamtschatka, Japan, Mantchooria, Mongolia, Tchoongaria, Tibet, and the Himalaya Mountains. By J. ARROWSMITH. Scale, 170 miles to an inch; size, 26 inches by 26. Sheet, coloured, 4*s.*; mounted, in case, 7*s.*

CENTRAL ASIA.—STANFORD'S MAP of CENTRAL ASIA, including Teheran, Khiva, Bokhara, Kokan, Yarkand, Kabul, Herat, &c. Scale, 110 miles to an inch; size, 22 inches by 17. Coloured sheet, 2*s.* 6*d.*; mounted, in case, 5*s.*

ASIA MINOR, &c. (TURKEY in ASIA). With portions of Persia, the Caspian Sea, and the Caucasian Mountains. By J. ARROWSMITH. Scale, 55 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

INDIA.—STANFORD'S NEW PORTABLE MAP of INDIA. Exhibiting the Present Divisions of the Country according to the most Recent Surveys. Scale, 86 miles to an inch; size, 29 inches by 33. Coloured, 6*s.*; mounted on linen, in case, 8*s.*; on roller, varnished, 11*s.*

INDIA.—MAP of INDIA. By J. ARROWSMITH. Scale, 90 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

CEYLON.—MAP of CEYLON. Constructed from a Base of Triangulations and corresponding Astronomical Observations. By Major-General JOHN FRASER, late Deputy-Quartermaster-General. Reconstructed by JOHN ARROWSMITH. Scale, 4 miles to an inch; size, 52 inches by 78. Eight sheets, coloured, 2*l.* 5*s.*; mounted, in case, 3*l.* 13*s.* 6*d.*; on roller, varnished, 4*l.* 4*s.*; spring roller, 6*l.* 16*s.* 6*d.*

CEYLON.—COFFEE ESTATES of CEYLON. Map showing the Position of the Coffee Estates in the Central Province of Ceylon. By J. ARROWSMITH. Size, 15 inches by 20. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

BURMAH, &c.—A Map showing the various Routes proposed for connecting China with India and Europe through Burmah, and developing the Trade of Eastern Bengal, Burmah, and China. Prepared under the direction of JOHN OGILVY HAY, F.R.G.S. Scale, 33 miles to an inch; size, 27 inches by 32. Coloured, 3*s.*; mounted, in case, 5*s.*

BURMAH and ADJACENT COUNTRIES.—Compiled from various MSS., and other Documents. By J. ARROWSMITH. Scale, 24 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

CHINA.—MAP of CHINA. By J. ARROWSMITH. Scale, 90 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

CHINA and JAPAN.—STANFORD'S MAP of the EMPIRES of CHINA and JAPAN, with the Adjacent Parts of British India, Asiatic Russia, Burmah, &c. Scale, 110 miles to an inch; size, 38 inches by 24. One sheet, full coloured, 8*s.*; mounted on linen, in case, 10*s.* 6*d.*; on roller, varnished, 14*s.*

AFRICA.

GENERAL MAP of AFRICA.—By J. Arrowsmith. Scale, 260 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

EGYPT.—MAP of EGYPT. Compiled from the most authentic materials, and founded on the best Astronomical Observations. By Colonel W. M. Leake, R.A., LL.D., F.R.S. Scale, 10 miles to an inch; size, 34 inches by 52. Two sheets, coloured, 21*s.*; mounted, in case, 28*s.*; on roller, varnished, 36*s.*

EGYPT.—MAP of EGYPT: including the Peninsula of Mount Sinai. By J. Arrowsmith. New Edition. Scale, 26 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

AFRICA (NORTH-WEST).—MAP of NORTH-WEST AFRICA, including the Coast of Guinea, and the Isle of Fernando Po, on the South, and the Western parts of Egypt and Darfur, on the East. By J. Arrowsmith. Scale, 130 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

AFRICA (SOUTH).—MAP of SOUTH AFRICA to 16 deg. South Latitude. By Henry Hall, Draughtsman to the Royal Engineers, Cape Town. Scale, 50 miles to an inch; size, 34 inches by 28. Two sheets, coloured, 10*s.* 6*d.*; mounted on linen, in case, 13*s.* 6*d.*; on roller, varnished, 15*s.*

AFRICA (SOUTH-EASTERN). — MAP of SOUTH-EASTERN AFRICA. Compiled by Henry Hall. Scale, 25 miles to an inch; size, 26 inches by 22. Sheet, 4*s.*; mounted on linen, in case, 6*s.*

AFRICA (WEST COAST).—MAP of the WEST COAST of AFRICA. Comprising Guinea and the British Possessions at Sierra Leone, on the Gambia, and the Gold Coast, &c. By J. Arrowsmith. Scale, 50 miles to an inch. Two coloured sheets; size of each, 22 inches by 26, 6*s.* Mounted, in case, 10*s.*

CAPE of GOOD HOPE and SOUTH AFRICA.—MAP of SOUTH AFRICA, Cape Colony, Natal, &c. By Henry Hall. Scale, 50 miles to an inch; size, 29 inches by 17. Sheet, price 4*s.* 6*d.*; mounted, in case, 6*s.* 6*d.*

CAPE COLONY (EASTERN FRONTIER).—MAP of the EASTERN FRONTIER of the CAPE COLONY. Compiled by Henry Hall. Scale, 8 miles to an inch; size, 40 inches by 38. Sheets, 18*s.* 6*d.*; mounted on linen, in case, 25*s.*; on roller, varnished, 31*s.* 6*d.*

NATAL.—A MAP of the COLONY of NATAL. By Alexander Mair, Land Surveyor, Natal. Compiled from the Diagrams and General Plans in the Surveyor-General's Office, and from Data furnished by P. C. Sutherland, Esq., M.D., F.R.S., Surveyor-General. Scale, 4 miles to an inch; size, 54 inches by 80. Coloured, Four Sheets, 2*l.* 5*s.*; mounted, in case, or on rollers, varnished, 3*l.*

NATAL.—MAP of the COLONY of NATAL. Compiled in the Surveyor-General's Office. Size, 11½ inches by 14½. Sheet, coloured, 1*s.*; mounted, in case, 2*s.* 6*d.*

NUBIA and ABYSSINIA, including Darfur, Kordofan, and part of Arabia. By J. Arrowsmith. Scale 65 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

AMERICA.

BRITISH COLUMBIA.—NEW MAP of BRITISH COLUMBIA, to the 56th Parallel North Latitude, showing the New Gold Fields of Omineca, the most recent discoveries at Cariboo and other places, and the proposed routes for the Inter-Oceanic Railway. Scale, 25 miles to an inch; size, 39 inches by 27. Price, in sheet, coloured, 7*s.* 6*d.*; or mounted on linen, in case, 10*s.* 6*d.*

CANADA.—MAP of UPPER and LOWER CANADA, New Brunswick, Nova Scotia, Prince Edward's Island, Cape Breton Island, Newfoundland, and a large portion of the United States. By J. ARROWSMITH. Scale, 35 miles to an inch; size, 40 inches by 26. Two sheets, coloured, 6*s.*; mounted, in case, 10*s.*; on roller, varnished, 15*s.*

UNITED STATES and CANADA.—STANFORD'S NEW RAILWAY and COUNTY MAP of the UNITED STATES and TERRITORIES, together with Canada, New Brunswick, &c. Scale 54½ miles to an inch; size, 57 inches by 36. Two sheets, coloured, 21*s.*; case, 25*s.*; on rollers, varnished, 30*s.*

UNITED STATES.—STANFORD'S HANDY MAP of the UNITED STATES. Scale, 90 miles to an inch; size, 40 inches by 25. Coloured sheet, 7*s.* 6*d.*; mounted, in case, 10*s.* 6*d.*; on roller, varnished, 15*s.*

UNITED STATES.—STANFORD'S SMALLER RAILWAY MAP of the UNITED STATES. Scale, 120 miles to an inch; size, 29 inches by 17½. Two sheets, coloured, 4*s.* 6*d.*; mounted on linen, in case, 6*s.* 6*d.*

CENTRAL AMERICA.—BAILEY'S MAP of CENTRAL AMERICA, including the States of Guatemala, Salvador, Honduras, Nicaragua, and Costa Rica. Scale, 8 miles to an inch; size, 40 inches by 27. Sheet, 7*s.* 6*d.*; mounted on linen, in case, 10*s.* 6*d.*; on roller, varnished, 14*s.*

MEXICO.—A GENERAL MAP of the REPUBLIC of MEXICO. By the Brigadier-General PEDRO GARCIA CONDE. Engraved from the Original Survey made by order of the Mexican Government. Size, 50 inches by 37. Sheets, price, 10*s.* 6*d.*; mounted on linen, in case, 18*s.*

BERMUDAS.—MAP of the BERMUDAS. Published by direction of His Excellency Major-General J. H. LEFROY, C.B., R.A., Governor and Commander-in-Chief of the Bermudas. Scale, 2½ miles to an inch; size, 62 inches by 63. Mounted, in case, or on roller, varnished, 21*s.*

WEST INDIA ISLANDS and GUATEMALA.—Showing the Colonies in possession of the various European Powers. By J. ARROWSMITH. Scale, 90 miles to an inch; size, 26 inches by 22. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

JAMAICA.—A NEW MAP of the ISLAND OF JAMAICA. Prepared by THOMAS HARRISON, Government Surveyor, Kingston, Jamaica, under the direction of Major-General J. R. MANN, R.E., Director of Roads and Surveyor-General. Scale, 2½ miles to an inch; size, 64 inches by 27. Mounted, in case, or on roller, varnished, 21*s.*

BARBADOES.—Topographical Map, based upon Mayo's Original Survey in 1721, and corrected to the year 1846. By Sir ROBERT H. SCHOMBURGH, K.R.E. Scale, 2 miles to an inch; size, 40 inches by 50. Two sheets, coloured, 21*s.*; mounted, in case, 28*s.*; on roller, varnished, 37*s.*

AUSTRALASIA.

AUSTRALIA.—From Surveys made by order of the British Government, combined with those of D'Entre, Casteaux, Baudin, Freycinet, &c. By J. ARROWSMITH. Scale, 80 miles to an inch. On two sheets; size of each, 22 inches by 26. Sheets, coloured, 6*s.*; mounted, in case, 10*s.*

AUSTRALIA.—Constructed from Official and other original Documents, adjusted to the Maritime Survey of Flinders, King, Wickham, Stokes, Blackwood, Stanley, &c. By J. ARROWSMITH. Scale, 27 miles to an inch. In Nine Sheets. [*Preparing.*

WESTERN AUSTRALIA.—With Plans of Perth, Fremantle, and Guildford. From the Surveys of John Septimus Roe, Esq., Surveyor-General, and from other Official Documents in the Colonial Office and Admiralty. By J. ARROWSMITH. Scale, 16 miles to an inch; size, 40 inches by 22. Two sheets, coloured, 6*s.*; in case, 10*s.*

SOUTH AUSTRALIA.—Showing the Division into Counties of the settled portions of the Province. With Situation of Mines of Copper and Lead. From the Surveys of Capt. Frome, R.E., Surveyor-General of the Colony. By J. ARROWSMITH. Scale, 14 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; in case, 5*s.*

QUEENSLAND.—STANFORD'S NEW MAP of the PROVINCE of QUEENSLAND (North-Eastern Australia): Compiled from the most reliable Authorities. Scale, 64 miles to an inch; size, 18 inches by 23. In sheets, coloured, 2*s.* 6*d.*; mounted on linen, in case, 4*s.* 6*d.*

VICTORIA.—A NEW MAP of the PROVINCE of VICTORIA (Australia): Showing all the Roads, Rivers, Towns, Counties, Gold Diggings, Sheep and Cattle Stations, &c. Scale, 20 miles to an inch; size, 31 inches by 21. In sheet, 2*s.* 6*d.*; or mounted on linen, in case, 4*s.* 6*d.*

NEW ZEALAND.—STANFORD'S MAP of NEW ZEALAND: Compiled from the most recent Documents. Scale, 64 miles to an inch; size, 17 inches by 19. Full-coloured, in sheet, 2*s.*; mounted on linen, in case, 3*s.* 6*d.*

NEW ZEALAND.—From Official Documents. By J. ARROWSMITH. Scale, 38 miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted, in case, 5*s.*

NELSON and MARLBOROUGH.—A NEW MAP of the PROVINCES of NELSON and MARLBOROUGH, in New Zealand, with Cook's Strait, and the Southern Part of the Province of Wellington. Scale, 8 miles to an inch. Size, 40 inches by 27. In sheet, coloured, 7*s.* 6*d.*; mounted on linen, in case, 10*s.* 6*d.*

TASMANIA (Van Diemen's Land).—From MS. Surveys in the Colonial Office, and in the Van Diemen's Land Company's Office. By J. ARROWSMITH. Scale, 10½ miles to an inch; size, 22 inches by 26. Sheet, coloured, 3*s.*; mounted in case, 5*s.*

Geological Maps.

BRITISH ISLES.—GEOLOGICAL MAP of the BRITISH ISLES. By Professor A. C. Ramsay, LL.D., F.R.S., Director-General of the Geological Surveys of the United Kingdom. Scale, 11½ miles to an inch; size, 50 inches by 58. Mounted on rollers, varnished, 42*s.*

BRITISH ISLES.—STANFORD'S GEOLOGICAL MAP of the BRITISH ISLES. Compiled under the Superintendence of E. Best, H.M. Geological Survey. Scale, 25 miles to an inch; size, 23 inches by 29.

ENGLAND and WALES. By Andrew C. Ramsay, LL.D., F.R.S., and G.S., Director-General of the Geological Surveys of Great Britain and Ireland, and Professor of Geology at the Royal School of Mines. This Map shows all the Railways, Roads, &c., and when mounted in case, folds into a convenient pocket size, making an excellent Travelling Map. Scale, 12 miles to an inch; size, 36 inches by 42. Fourth Edition, with Corrections and Additions. Price, in sheet, 1*l.* 5*s.*; mounted on linen, in case, 1*l.* 10*s.*; or on roller, varnished, 1*l.* 12*s.*

ENGLAND and WALES. Showing the Inland Navigation, Railways, Roads, Minerals, &c. By J. Arrowsmith. Scale, 18 miles to an inch; size, 22 inches by 26. One sheet, 12*s.*; mounted in case, 15*s.*

SOUTH-EAST ENGLAND.—GEOLOGICAL MODEL of the SOUTH-EAST of ENGLAND and Part of France; including the Weald and the Bas Boulonnais. By William Topley, F.G.S., Geological Survey of England and Wales, and J. B. Jordan, Mining Record Office. Scale, 4 miles to an inch horizontal, and 2,400 feet to an inch vertical. Coloured and varnished in black frame, to hang up, 5*l.*; or packed in case for safe transit, 5*l.* 5*s.*

LONDON and its ENVIRONS. Scale, 1 inch to a mile; size, 24 inches by 26. Compiled from various authorities by J. B. Jordan, Esq., of the Mining Record Office. Price, folded in cover, 5*s.*; mounted on linen, in case, 7*s.* 6*d.*; or on roller, varnished, 9*s.*

IRELAND. By Joseph Beete Jukes, M.A., late Director of H.M. Geological Survey of Ireland. Scale, 8 miles to 1 inch; size, 31 inches by 38. On two sheets, 25*s.*; mounted on linen, in case, 30*s.*; or on roller, varnished, 32*s.*

SOUTH AFRICA.—GEOLOGICAL SKETCH MAP of SOUTH AFRICA. Compiled by E. J. Dunn from personal observations, combined with those of Messrs. A. G. and T. Bain, Wylie, Atherstone, Pinchin, Sutherland, and Button. Scale, 35 miles to an inch; size, 34 inches by 28. One sheet, 10*s.*; mounted in case, 13*s.* 6*d.*; on roller, varnished, 16*s.*

CANADA and the ADJACENT REGIONS, Including Parts of the other BRITISH PROVINCES and of the UNITED STATES. By Sir W. E. Logan, F.R.S., &c., Director of the Geological Survey of Canada. Scale, 25 miles to an inch; size, 102 inches by 45. On eight sheets, 3*l.* 10*s.*; mounted on linen, on roller, varnished, or in two parts to fold in morocco case, 5*l.* 5*s.*

NEWFOUNDLAND.—GEOLOGICAL MAP of NEWFOUNDLAND. By Alexander Murray, F.G.S., assisted by James P. Howley, and Drawn by Robert Barlow. Scale, 25 miles to an inch; size, 26 inches by 26. One Sheet, 10*s.*; mounted in case, 12*s.* 6*d.*

VARTY'S EDUCATIONAL SERIES of CHEAP WALL MAPS, for class teaching, constructed by ARROWSMITH, WALKER, &c. New and revised editions, coloured, mounted, and varnished.

The World in Hemispheres. Size, 51 inches by 26. Price 12*s.*
The World (Mercator). Size, 50 inches by 32. Price 10*s.*
The British Isles. Size, 51 inches by 41. Price 10*s.*

Also the following, each 6*s.*, size, 34 inches by 26:—

Europe.	Australia.	Journeyings of the Children of Israel.
Asia.	England.	S. Paul's Voyages and Travels.
Africa.	Scotland.	
America.	Ireland.	
New Zealand.	Roman Empire.	

VARTY'S LARGE OUTLINE MAPS. Price, in plain sheet, 2*s.*; coloured, 3*s.*; mounted on rollers, 7*s.*

The World (globular), 2 feet 3 inches by 4 feet 3 inches. Price, in plain sheet, 1*s.*; coloured, 1*s.* 6*d.*

The World (Mercator), 21 inches by 15 in.

And the following, plain sheet, 1*s.* 3*d.*; coloured, 1*s.* 6*d.*; mounted on rollers, 4*s.*; size, 2 feet 10 inches by 2 feet 2 inches.

Europe.	America.	Ireland.
Asia.	England.	Palestine (O. Test.).
Africa.	Scotland.	Palestine (N. Test.).

STANFORD'S OUTLINE MAPS. Size, 17 inches by 14, printed on drawing paper. A Series of Geographical Exercises, to be filled in from the Useful Knowledge Society's Maps and Atlases. Price 6*d.* each.

World in Hemispheres, West.	Germany, General.	India.
World in Hemispheres, East.	Italy, General.	China.
Europe.	Spain and Portugal.	Palestine.
British Isles.	Russia.	Africa.
England.	Denmark. Sweden. Norway. } one Map.	Egypt.
Scotland.	Turkish Empire.	America, North.
Ireland.	Asia.	Canada, and the United States.
France.	Asia Minor.	America, South.
Netherlands.	Greece.	West India Islands
Switzerland.		Australia.
		New Zealand.

STANFORD'S PROJECTION SERIES. Uniform in size, price, &c., with Stanford's Outlines.

The OXFORD SERIES of OUTLINE MAPS. Size, 16 inches by 14. Price 3*d.* each.

Edward Stanford, 55, Charing Cross, London.

Scripture and Animal Prints.

PRECEPTIVE ILLUSTRATIONS OF THE BIBLE. A Series of Fifty-two Prints to aid Scriptural Instruction, selected in part by the Author of 'Lessons on Objects.' The whole from Original Designs by S. Bendixen, Artist, expressly for this Work. They have been recently re-engraved, and are carefully coloured. Size, 17½ inches by 13.

Price of the Work.

The Set of 52 Prints, in Paper Wrapper	52*s.*
——— in One Volume, handsomely half-bound	60*s.*
——— in Varty's Oak Frame, with glass, lock and key	60*s.*

Single Prints, 1*s.* each; mounted on millboard, 1*s.* 4*d.* each.

VARTY'S SELECT SERIES of DOMESTIC and WILD ANIMALS, Drawn from Nature and from the Works of Eminent Artists. In 36 carefully-coloured Plates, exhibiting 130 Figures. Size, 12 inches by 9.

The selection of Animals has been limited to those which are most known and best adapted to elicit inquiry from the young, and afford scope for instruction and application.

		Bound in Cloth.	In Frame and Glass.
Set of 36 Prints, Coloured	18*s.*	24*s.*	24*s.*
——— Plain..	12*s.*	17*s.*	18*s.*

Single Prints, coloured, 6*d.*; mounted on millboard, 10*d.*

The ANIMAL KINGDOM at ONE VIEW, clearly exhibiting, on four beautifully-coloured Plates containing 184 Illustrations, the relative sizes of Animals to Man, and their comparative sizes with each other, as arranged in Divisions, Orders, &c., according to the method of Baron Cuvier.

Exhibited on four Imperial Sheets, each 30 inches by 22:—

	Cloth, Rollers, and Varnished.	On Sheets.
Complete Set,		
Animals and Landscape, *full coloured* ..	38*s.*	18*s.*
Animals only coloured	35*s.*	15*s.*
Single Plates, *full coloured*	10*s.*	5*s.*

VARTY'S GRAPHIC ILLUSTRATIONS of ANIMALS, showing their Utility to Man, in their Services during Life and Uses after Death. Beautifully coloured. Size, 15 inches by 12. Price, the set, 31*s.* 6*d.*; in frame, with glass, lock and key, 39*s.* 6*d.*; or half-bound in leather, and lettered, 1 vol. folio, 42*s.*

The 21 *separate Prints may also be had, price* 1*s.* 6*d. each.*
Or Mounted on Millboard, 1*s.* 10*d.*

For complete lists of Edward Stanford's Publications, see his General Catalogue of Maps and Atlases, List of Books, Educational Catalogue, &c., gratis on application, or by post for one penny stamp.

8 /