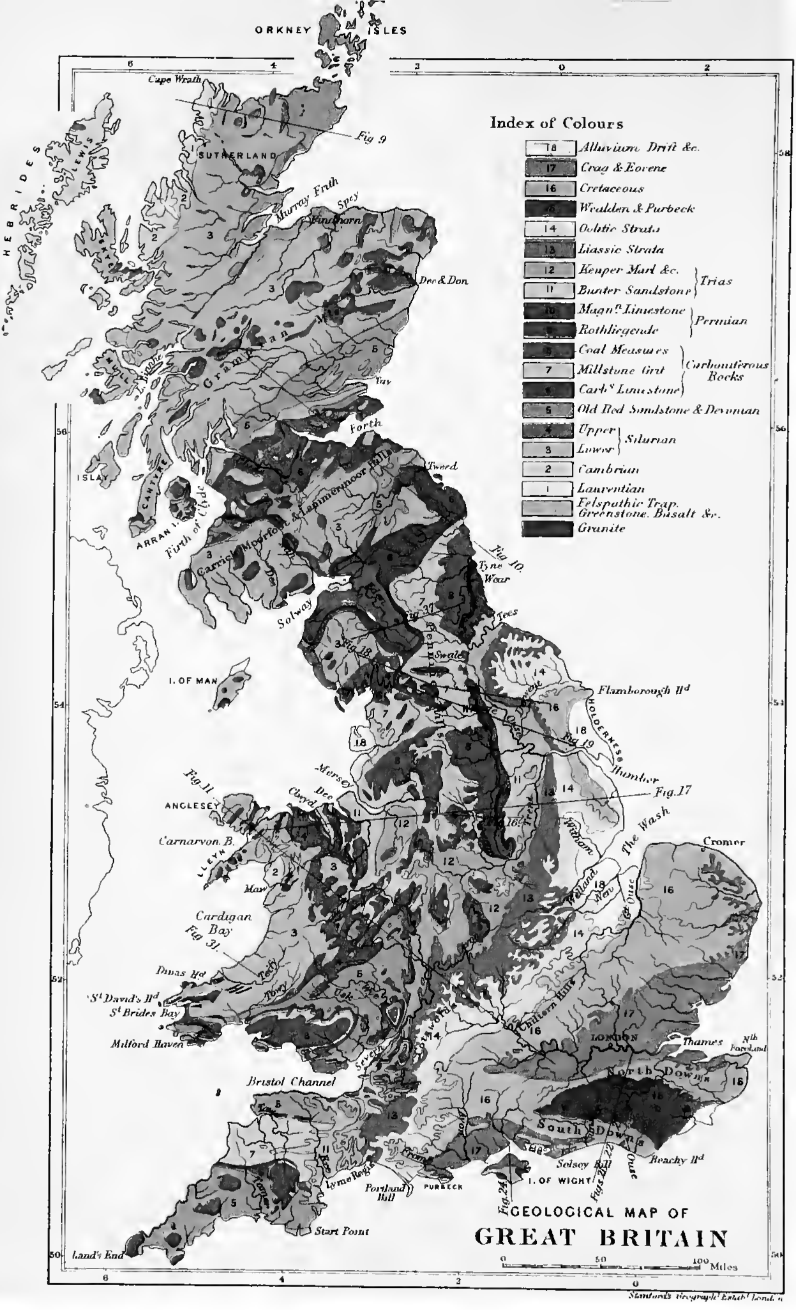
THE PHYSICAL GEOLOGY AND GEOGRAPHY OF GREAT BRITAIN.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THE PHYSICAL GEOLOGY AND GEOGRAPHY OF GREAT BRITAIN.

BY

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

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

WITH A GEOLOGICAL MAP, PRINTED IN COLOURS.

FOURTH EDITION.

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There rolls the deep where grew the tree.
O earth, what changes hast thon 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.

THE first edition of this book was printed as Lectures from a shorthand report, and published with my consent. At the request of the reporter I read and corrected the proof-sheets; but being much occupied at the time with other necessary work, many imperfections and mistakes, and a few positive errors, escaped my notice. In the second edition the whole was thoroughly revised, corrected, and in parts almost rewritten. A good deal of fresh matter was added, including a map, reduced for England from my own geological map, and for Scotland from the map by Sir Roderick Murchison and Mr. Geikie.

My object in delivering the original course, and in publishing the second edition was to show how simple the geological structure of Great Britain is in its larger features, and how easily that structure may be explained to, and understood by, persons who are not practised geologists.

This, the third edition, has also been partly re-written; it contains much new matter, the form of lectures has been abandoned, and the book is now divided into chapters. The preliminary sketch of the different formations, and of the phenomena connected with the metamorphism of rocks, have been much enlarged, and many long and important paragraphs have been added in the chapters on the physical structure of England and Scotland, partly on subjects connected with the Coal question, partly on the glacial epoch, partly on the union of Britain with the Continent at various epochs, and the migrations of animals hither, and on many other subjects. An entire new chapter has been added on the origin of the river courses of Britain, and large additions have been made to the earlier brief accounts of soils, and the economic products of the various geological formations. There are also many new illustrative sections, intended to bring before the eye the meaning of the various theories propounded in the work, and it is hoped also calculated when enlarged for instruction in the class room. The whole work is indeed one-third larger than the second edition, and many questions have been re-considered and improved too numerous to be mentioned in detail.

Any one with a very moderate exertion of thought may realise the geological meaning of the physical geography of our country, and, almost without effort, add a new pleasure to those possessed before as he travels to and fro. The colours on geological maps will then no longer appear mysterious, but become easy to comprehend when associated with the geography of our island; and this book may perhaps serve as a kind of condensed explanation of geological maps of Great Britain, and smooth the way for those who are just entering on the subject and feel alarm at its seeming difficulties.

ANDREW C. RAMSAY.

KENSINGTON: *July* 1872.

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CHAPTER I.

THE 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, always 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 ranges 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 what is now sea 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 when all the lakes of the world, as we now know them, had no place on the Earth. 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 how some of the animals that inhabited Britain 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.

The accidents or physical changes that have subsequently befallen these rocks will follow this introduction, for on such circumstances the skeleton of all scenery depends.

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 rocks that have been altered, and which in their characters often approach and even by insensible gradations pass into some of those rocks that have been termed Igneous, in a popular sense, though in many respects very different from ordinary volcanic products. 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 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 by 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?

Every one knows that the rain which falls upon the land, draining the surface, first forms brooks, and that these brooks, running into common channels and joining, by degrees often become rivers; and every one who has looked at large rivers knows that they are rarely pure and clear—as, for instance, in the cases of the Thames, the Severn, the Ouse that flows through York, the Clyde and the Tay, in our own country; or notably on a great scale, as shown in the muddy rivers of China, the Ganges, the Mississippi, the Nile, and the mighty rivers of northern Asia. 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. Thus, for instance, 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 formed.

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, rise higher and higher, till, as in cases like those of the Ganges and the Nile, kingdoms have been formed of mere loose detritus. A little reflection, too, will show that all lakes, be they ever so large, may, with sufficient time, by this process get filled with débris and become plains. Some of the old rocks of Britain are formed of sediments deposited by a river as large as the Mississippi or the Ganges, 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-born gravel, sand, and mud, overgrown by a marshy vegetation.

Again, if we examine sea-coasts where cliffs rise from the shore, we find that the disintegrating effect of the weather produces constant débâcles great or small on the faces of the cliffs, and that the waves, aided by the shingle beating upon the cliffs themselves, wear them away. 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 very slowly perhaps, but still sensibly to the observant eye, so that in time, be they ever so hard, they get worn more and more backwards. This is the reason why the harder rocky masses are apt to form headlands, while the softer or more friable strata, wasting more rapidly, form the recesses of bays. The material derived from this waste when the cliffs are truly rocky, in the first instance, generally forms shingle at their bases, as, for instance, with the pebbles of flint formed by the waste of chalk. These being attacked by the waves, are rolled incessantly backwards and forwards, as every one 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. This continued action has the effect of grinding angular fragments into rounded pebbles; and, in the course of time, large amounts of loose shingle are often thus formed. Such material when consolidated becomes a conglomerate.

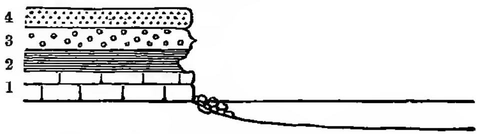
If, also, we examine with a lens the sand of the sea-shore, we shall find that it is formed of innumerable grains of quartz, and these grains are generally not angular, but more or less rounded; the edges having been worn off by the action of the waves moving them backwards and forwards upon each other. Thus the little particles rubbing for ages upon each other, their angularities are gradually worn off, and they become grains, more or less like rounded 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, 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 Amazon, the power of tidal and other marine currents, all contribute to scatter sediments abroad, and by their rapid or more gradual subsidence (the coarse generally near shore, the finer often far out at sea) 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.

If we examine the 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*, or *conglomerate*, which must have been formed in a manner analogous to that which I have just described, proving that these beds have been deposited as sediments from water. They are also often associated with bands of limestone, more or less pure. Take, for instance, a possible cliff by the sea-shore, and we shall perhaps find that

Fig. 1.



it is made of strata, which may be horizontal, as in fig. 1, or inclined, as fig. 2, or even bent and contorted

Fig. 2.

into every conceivable variety of form, as in fig. 3. If, as in the diagram, fig. 1, we take a particular

Fig. 3.

bed, No. 1, we may find that it consists of strata of limestone lying one upon the top of another. Bed

No. 2 may be of shale, also arranged in thin layers, more regularly than in No. 1. No. 3 may consist of pebbly materials, also arranged in rude 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 forms one cliff. Rocks, more or less of these kinds, compose the bulk of the strata of the British Islands; and remember 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 they have since been still further altered by heat, but sometimes they are almost undisturbed, except by mere upheaval above the sea; while in other cases the beds have been violently broken and contorted, in the manner shown in the diagrams.

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

Some formations, such as the Silurian rocks of Wales and its neighbourhood, consist essentially of deposits that were originally marine mud, 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 great stony banks 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 the soils on and in which the creatures live that inhabit the bottom of the waters, and it is easy to understand how many 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 upper 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 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.

Now, though the material 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 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 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 beds 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 exceedingly small particles of broken organic remains. Even when these fragments are indistinguishable, reason tells us that such marine limestone deposits must have been built up of 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 from mere chemical solutions. It sometimes happens, indeed, that gradual accumulations of such beds of limestone have attained two or three thousand feet of vertical thickness.

But where does the carbonate of lime come from by which these animals make their skeletons? If we analyse the waters of rivers, we discover that many of them consist of hard water—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 bicarbonate of lime; for the rain-water that falls upon the land percolates the rocks, and rising again in springs, carries with it, if the rocks be calcareous, 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, sometimes as pure limestone, forming great tracts of country. In this way it happens that springs are often charged with lime, in the form of what chemists call 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.

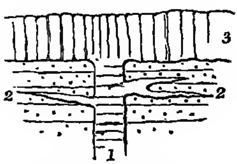
Igneous rocks form a much smaller proportion of the outer rocks of the world. Thus, to take Britain as an example: in North Wales, a considerable proportion, perhaps a twentieth part, of the rocks are formed of igneous masses. The whole of the rest of Wales, till we come to Pembrokeshire, contains almost none whatever. The same comparatively small proportion of igneous rocks is found in parts of Scotland and

Cumberland, and in even less proportion they also exist in Derbyshire, Northumberland, Devon, and Cornwall. But, if we examine all the midland, southern, and eastern parts of England, we shall find almost no igneous rocks whatever.

I have now to explain how we are able to distinguish igneous from aqueous rocks; and, in a general way, we can do so 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 chiefly due to gases and watery vapour, ejected along with the melted matter, which, expanding, in their efforts to escape from the melted lava, form a number of small 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 once formed part of a melted mass. 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. When we meet with similar, even though not identical crystalline rocks, 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 and slaggy structure, and are sometimes formed of ribboned layers, similar to the contorted ribbon-like structure common in iron and other slags. Ancient lavas, such as those of Snowdon, of Lower Silurian age, possess this 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 (augite and felspar),

Fig. 4.



and various others, as in fig. 4, we frequently find veins (2) that seem to have been injected among the strata, and dykes, as they are termed (1), rising vertically or nearly vertically through strata, and sometimes an overflow of lava (3) that proceeded from a dyke 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 semi-liquid rock. This is finally ejected by the expansive force of steam, and with the liberated vapour it is shot high into the air. 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 fragments of rock, and sometimes the 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, which, having been melted and cooled deep in the earth, were never 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. 8, will assist 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 deposited above it as layers of mud overlying the bed of limestone already formed, 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, 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. Those in the upper part of the 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 came into 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 had lived and died in succession 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.

But if we leave a petty quarry or 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.

Fig. 5.

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 Rhœtic 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 Kimmeridge 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 Kimmeridge Clay.*

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 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

* The Portland beds being only occasionally present, are in this diagram purposely omitted, and this does not affect the general question. Some minor formations known inland are also added to make the series more complete.

east, under beds of blue clay, limestone, and brown marl, forming the various divisions of the *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 countries we sink through the Lower Lias, we pass 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 variousy-coloured pasteboard, placed flat on each other, and the slightly tilted up at one end, may slope in one diretion, one edge of each sheet being exposed at the surfae.

Vertica sinkings, therefore, in horizontal or slightly inclined srata, often prove practically what we know theoreticaly, viz. the underground continuity of strata one beneat the other. Accurate but more difficult observationnd reasoning has done the same for more disturbed stata, so that our island and other countries have been poved to be formed of a series of beds of rock, some f many hundreds and some of many thousands of eet in thickness, arranged in succession, the lowest *strtified* formation being of oldest and the uppermost of yungest age.

Most of thes strata are *fossiliferous*, that is to say, *they contain shes and other relics of the creatures that lived and died i the waters or water-laid sediments of each special priod.* What is the 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.*

Thus turning again to fig. 5, p. 20, 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 Rhœtic 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 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 Kimmeridge Clay No. 11. Throughout the whole series from the Rhætic beds (2), upwards to the Kimmeridge 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, Terebratula,

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

Pholadomya, 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 knowledge to tell by fossils alone, if he found enough of them, what formation he may chance to be examining. When, 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 many of the genera, especially of chambered shells (Cephalopoda), are new. *There are no marine passage beds in England to unite the two series.* They were, in fact, separated in their deposition by a long period of time during which our territory 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 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.

TABLE OF THE BRITISH FORMATIONS.

		Recent		Alluvia and estuarine beds now forming, &c.
Tertiary, or Cainzoic, and Post-tertiary.	UPPER	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 clay, with marine and freshwater interstratifications.
				Forest bed of Norfolk, Chillesford beds, and
		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, Osborne beds, Bembridge beds, Headon beds	Freshwater river beds, with marine interstratification.
		Middle Eocene	Braklesham 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	Wealden, Purbeck Beds		Freshwater river beds, estuarine and lagoon beds, with marine interstratifications.
	OOLITIC SERIES	Portland Oolite, Kimmeridge 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	Lower	
	and LIAS	Upper Lias Clay and Sand, Marlstone (Middle Lias), Lower Lias Clay and Limestone, Rhœtic 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, or Palæozoic.	PERMIAN	Permian		Magnesian limestone. Inland salt lake.
				Rothliegende. Probably salt lake.
	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 probably. Devonian marine.
	SILURIAN	Upper Silurian, Lower Silurian and		Marine.
		Cambrian.		Probably marine and freshwater beds interstratified.
	LAURENTIAN			Marine.

The Laurentian rocks, which are the oldest known formations in the world, lie in Scotland, chiefly in the outer Western Isles, and the north-western parts of Sutherland, and consist of gneiss in a very advanced stage of *metamorphism.* They have yielded in Canada one fossil, Eozoon Canadense, discovered by Sir William Logan.

The Cambrian rocks, which succeed them, lie unconformably on the Laurentian rocks of Sutherland, and in Wales contain a few fossils. The area occupied by this series is not large, being chiefly confined to parts of Shropshire, North and South Wales and the north-western part of Scotland. I consider them to consist partly of freshwater beds, but this is not the usual opinion.* If we examine the Silurian rocks, which come next in succession, and which occupy much of Wales, Cumberland, the high lands of Scotland north of the border, and the greater part of the Highlands, we find in places the relics of vast numbers of forms of life altogether marine, except at the very top, where there are traces of land plants. In Wales the Lower Silurian rocks (Lingula flags) are conformable to and pass quite insensibly into the Cambrian rocks, and above this horizon there are two unconformities in the series, one between the Llandeilo beds, and the Tre-

* See 'On the Red Rocks of England of older date than the Trias.' Ramsay, 'Quart. Jour. Geol. Soc.' 1871, p. 241.

madoc and Lingula beds, and another between the Upper and Lower Silurian strata.*

The Devonian rocks are usually considered to be intermediate in date between the Upper Silurian and Carboniferous strata. The late Mr. Jukes, however, asserted with great ability, that the Devonian rocks of Devonshire are in reality of Lower Carboniferous age, and after much opposition some other geologists begin to accept his theory. But this is not the place to discuss the subject.

The Old Red Sandstone as a whole, is, however, certainly intermediate in age between the Silurian and Carboniferous series. I believe that it was formed in lakes. The remains of fish, some of which have their nearest analogues in the Polypterus of Africa and the Ceratodus of Australia, help to confirm this view. It contains few other fossils, excepting where it passes into the Upper Silurian rocks below, and the Carboniferous rocks above, where it sometimes holds land plants and freshwater shells.

The shells, encrinites, and fish of the Carboniferous Limestone and other members of the Carboniferous series prove their marine origin, while the ferns, Calamites, great Lycopodiums, and Coniferous trees of the Coal Measures, prove the terrestrial origin of those

* The details of all the subdivisions of the Silurian strata are not given in the column.

beds of coal that still lie on the very soils on which they grew. Other strata associated with these contain freshwater shells.

The Permian rocks, at least those of Britain, were, I consider, deposited in inland salt seas analogous to the Caspian, and the New Red series was also formed in lakes, extremely salt, at all events while the Keuper Marls were being deposited in which our beds of rock-salt lie. The Rhœtic strata mark the passage from this series into the Lias, and they contain in England a small Caspian-like fauna of marine shells.

The Lias and all the Oolites are marine formations, deposited in warm seas round scattered groups of islands, and the Purbeck and Wealden beds were chiefly deposited at the mouth of a great river.

The Lower Greensand (Neocomian) is a marine formation, together with all the Cretaceous strata, the upper part of which, the Chalk, was formed to a great extent in an open sea by the deposition of microscopic foraminifera, like those now making strata in the deep Atlantic.

The British Eocene beds were partly marine and partly freshwater, but even the marine deposits were laid down near the mouth of a great river.

The Miocene strata of Bovey Tracey and the Western Isles were partly freshwater and partly terrestrial deposits, while the Coralline and Red Crags are exclusively marine. The Norwich Crag was partly formed at the mouth of a stream. The remainder of the strata were partly marine and estuarine, and a large part of them give strong evidence of arctic terrestrial conditions when all the Boulder-clay and the more distinct moraines of the period were formed.

By a complete analysis of the order of deposition of the rocks and their contents, geologists—led by the researches of William Smith, are enabled to come to the important conclusion that each formation was marked by its own peculiar forms of life; that is to say, that each formation was in its time a sea-bottom or a series of sea-bottoms, in which peculiar kinds of life flourished, which life for some reason in part or altogether disappeared, before a new period commenced, in which new species inhabited the waters, which in their turn also died out; and so on in progressive stages, from the oldest known epochs, through the whole of the formations, until at last we come to the epoch in which we now live.* It is not, however, my business, in a

* 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 meaning 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.

book bearing specially on physical geography, to give a description of the various organic forms that have lived through these ages. That can only be done in a larger course of Geological and Palæontological study, involving a complete account of all the known formations.

It is necessary, however, to explain the general order of the formations, because I shall have frequent occasion to speak of the rocks by their names, and to show their physical relations to each other in a scenic point of view, these relations being connected with phenomena dependent on their ages and the nature of the rocks, and the disturbances they have undergone at intervals of time.

CHAPTER III.

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

I MUST now explain the meaning of certain terms which I 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 elapsed. This is an important instance for what is not a very large district of the modern world, and it is similar to many other cases of the same kind, constantly before our eyes, on a smaller scale, which rarely strike the ordinary observer.

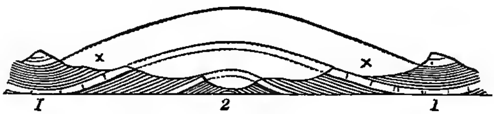
Refer to fig. 6, and suppose that we have different strata, 1, 2, 3, and 4, lying horizontally one above

Fig. 6.

the other, together forming a mass several hundreds of feet in thickness. Running water in the state of a brook or river by degrees wears away the rocks more in one place. than another, so that the strata 3, 2, and 1, *are 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, many places, by the contraction of that crust due to cooling of the mass of the earth, been thrown into *anticlinal* and *synclinal* curves. A synclinal curve means that the curved strata are bent downwards as in 1, an anticlinal curve that they bend upwards as in 2.

Fig. 7.



1. Synclinal curves. 2. Anticlinal curve.

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 of similar cases it is certain that they were once joined as horozontal strata, and afterwards thrown into anticlinal and synclinal curves. The part indicated by dotted lines and more besides *has 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, &c. 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.

The constant atmospheric disintegration of cliffs, and the beating of the waves on the shore, is also 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 any one 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 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 and of the Forest of Dean. These two coal-fields were once united, but are now about twenty-five miles apart, and this separation has been brought about by the agency of long-continued denudations, which have swept away thousands of feet of strata bent into an anticlinal curve. 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 formed of stratified and intercalated 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.

To explain in some detail the anatomical structure 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; and 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.

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 showed 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 great class of rocks, termed igneous, are frequently crystalline, and from the effects which they produce upon stratified rocks when they are in contact, the latter are often altered. Then by comparing igneous 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.

But there is a third division, a *sub-class*, known as *metamorphic rocks*, (that is to say, stratified and even some rocks commonly recognised as igneous,) which have undergone a much greater kind of alteration. All strata as they assume a solid form become to a certain extent altered; for originally they were loose sediments of mud, sand, gravel, or carbonate of lime. When these were accumulated, bed upon bed, till thousands of feet were piled one upon the other, then, by intense and long-continued pressure, (which alone is sometimes sufficient to harden strata,) by 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 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 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, micaceous, hornblendic, or chloritic: mica-schist, hornblende rock, crystalline limestone, quartz-rock, and a number of others, which it is not necessary for my present purpose to name. It will be enough if I select one of the most generally known kinds of metamorphic rock as a type, and endeavour to explain how it happened that such rocks assumed their peculiar crystalline characters.

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.

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 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 may find a mass of granite, with gneiss upon its flanks bent in a number of small wavy folds or contortions. Granite is a crystalline rock, composed of feldspar, 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 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 therefore 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 the elements to work upon? Not by igneous pressure from below raising the rocks, for that would stretch instead of crumpling strata in the manner 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.

This, according to the theory long ago proposed by Élie 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 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 an igneous is 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 metamorphism.

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, feldspar, and mica, often arranged in gnarled or wavy lines (foliation). As we approach the granite still more closely, we find possibly that, in addition to the layers of mica, quartz, and feldspar, 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 complex great anticlinal and synclinal folds of metamorphosed strata that have been intensely contorted. The same is the case in parts of the Alps.

Now, 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 feldspar, 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. 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 sandy material, were enabled more or less to re-arrange themselves according to their chemical affinities, and distinct materials were developed from elements that were in the original rock.

I have stated that to produce this kind of metamorphism, heat aided by water is necessary, 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 generally believed 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.

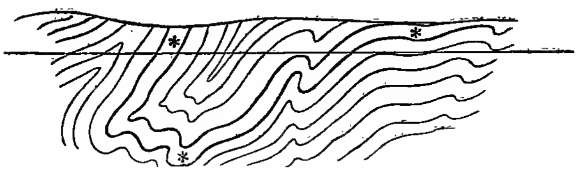
As the Earth cooled and consequently gradually shrunk in size, the hardened crust, in its efforts to accommodate itself to the diminishing bulk of the cooling mass within, became in places crumpled again and again. Hence those disturbances of different dates, which have affected strata of almost all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

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

* 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.

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 we descend into the earth the temperature increases, whence, in the main, the theory of central heat has been derived. 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. 8. 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—and for this, among other reasons, it may happen that strata which are contorted have in places been brought within the direct influence of internal heat. Under some such circumstances, we can easily understand how stratified rocks may have

Fig. 8.



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 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, that it has often been completely fused. But in another sense it is a metamorphic rock, partly because it is sometimes impossible to draw any definite line between gneiss and granite, for they pass into each other by insensible gradations. 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 all the granitic 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 minerals. 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, as already stated, 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.

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, I cannot clearly tell how, but possibly connected with the heat produced by the intense lateral pressure that produced the contortion of such 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 proportionate to their depth.*

* See Report, Brit. Assoc. 1866, p. 47: 'Address to the Geological Section,' Ramsay.

CHAPTER V.

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 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 features 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 west coast of Sutherland and the outer Hebrides chiefly consist of the oldest known formation, called Laurentian, named from a vast tract of gneissic rocks on the north shores of the St. Lawrence and the Ottawa, the geological age of which was first determined by Sir William Logan. Above them, in Sutherland, there are certain unaltered red or purple sandstones and conglomerates, which lie quite unconformably on the Laurentian gneiss. In fact, the Laurentian strata were exceedingly 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. As the latter lie beneath the Silurian beds, they are supposed to be equivalent to the strata called Cambrian in Wales. 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 occasional lines and 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.*

Farther south, above the Old Red Sandstone, lie the Carboniferous rocks, consisting of Calciferous sand-

* This order for the north of Scotland was first established by Sir R. Murchison. See 'Siluria,' and Map of Scotland by Sir R. Murchison and Mr. Geikie.

stone, 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 Ochill range on the north, and 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 do they seriously affect its larger physical geography; and therefore I shall chiefly confine myself to the mainland of the north Highlands, for I wish specially to treat of the 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. 9.

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 oldest 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 the Cambrian strata 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 strata. Upon these unaltered Cambrian beds, and again quite unconformably, the Lower Silurian strata (3) lie, sometimes in the manner shown in the diagram; and the same conclusions regarding upheaval and denudation, may be drawn from this second unconformity that have already 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.

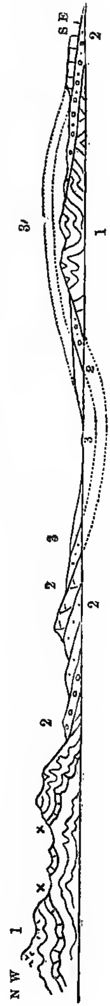
Now these metamorphosed Silurian rocks, here and there associated with bosses of granite and syenite (*g*), form by far the greater part of that rocky region known as the *Highlands* of Scotlands, stretching over brown heaths and barren mountain ranges, all the way from Loch Eribol on the north shore 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 (line 5), 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. 10. Overlooking this broad band, the gneissose mountains No. 1 rise high into the air; still reminding the beholder of that 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 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.

Fig. 10.



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 must have been very great. I consider it certain that from these mountains glaciers descended through ancient valleys, now lost, and indeed that other sub-angular conglomerates of the Old Red Sandstone in various parts of Britain consist of stratified moraine matter, the origin of which in later cases will afterwards be explained. 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 high lands 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 original disturbance 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 almost utterly worn away, and the Cambrian rocks have thus been exposed and moulded by subsequent waste. Some of these mountains in Sutherland now form almost the grandest and most abrupt peaks of the north-west Highlands, standing (like Suilven) alone 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 land-marks to record the greatness of his operations.

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

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. 10), 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 rocks plunge beneath the Old Red Sandstone comparatively unaltered, and rise in the Grampian mountains on the north changed into 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.

Now how were the Carboniferous rocks formed? They consist of strata partly of freshwater 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. Beds of coal are numerous (whence the name Coal-measures), and under each bed of coal there is a peculiar stratum, which often, but not always, is of the nature of fire-clay. Sometimes it is called 'under-clay,' this in England being a miner's term, on account of its position beneath each bed of coal. Coal itself consists of mineralised vegetable matter; and when we examine the shales and sandstones associated with it, we frequently find in them quantities of vegetable remains, Ferns, stems of reed-like plants (*Calamites*), great Lycopodiums (*Sigillarias*), and trunks and cones of coniferous trees, &c. When the under-clay is narrowly examined, we also generally find in it a number of portions of plants called *Stigmaria*, now known to be the root of a fossil tree called *Sigillaria*; and this led Sir William Logan, Mr. Binney, and other geologists, to infer that the under-clay was the original soil on which the plants grew, the decay and subsequent mineralisation of which formed beds of coal.

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 'out-crop' being the result of disturbance of the strata and subsequent denudation, and, by an easy method, it is by means of this disturbance and denudation that we are enabled to estimate the thickness of the whole mass of strata, and to prove that one bed lies several thousands of feet below another.

Since the 'under-clay' contains roots, and was the soil on which land-plants grew, it is clear that the lowest bed of coal was originally at the surface, and was formed by the growth and decay of plants. After a time it seems to have descended slowly, and other strata were deposited upon it, sometimes in the sea, or sometimes and more frequently at the mouths of great rivers and in adjoining marshes, where a certain area was being filled with sediment. By degrees a portion of the area, by filling up, again became fit for the growth of terrestrial plants, which plants decayed and formed another carbonaceous stratum, that in its turn again sunk, and other strata were deposited upon it. Vegetable growth again took place, and so by intermittent sinkings and accumulations a great number of strata were produced, terrestrial, marine, estuarine and freshwater, which by degrees became a vast pile thousands of feet thick. The beds of vegetable remains were, probably, after death, when first formed, somewhat in the state of peat, and by immense pressure and gradual chemical changes they in a long lapse of time became mineralised, while by much later disturbance and denudation they are now in places exposed to view. In this way the Coal-measures were formed, not in Scotland alone, but over large tracts of country now known as England and Wales, and the continents of Europe, Asia, and North America. In England some of the coal-fields, similar in structure to those of Scotland, are from 6,000 to 10,000 feet thick.

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, Ochill, 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 given a very brief account of 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 Old Red Sandstone, the 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 outline 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 uplands 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 less hard, and have therefore been more wasted by denudation, whence their lower elevation. Then on the flanks of the Highland mountains, and partly round the eastern magin of what is now Scotland, the softer strata of the Old Red Sandstone, in various subformations, were deposited in a great freshwater lake formed partly, as the conglomerates testify, from the waste of the older Silurian strata. In time, the Old Red Sandstone period came to an end, and above that series—for it consists of two members which lie *unconformably* on each other—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 lwoer 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. 10, 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 Highlands (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 Old Red Sandstone (No. 2) lies unconformably, above which come the Carboniferous rocks No. 3, lying in a wide broken and denuded synclinal curve. The diagram is, however, too small to show these breaks. The southern continuation of these strata once spread over the Lammermuir hills in a kind of anticlinal curve, in the manner shown by the dotted lines on the diagram below, No. 3′.

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 obtained 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 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 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, 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 necessarily mountainous because they are composed of rocks much disturbed, metamorphosed, and mostly crystalline, and intermingled with bosses and lines of hard granite. These 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 Lower Silurian times, 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 mountains, as we now know them, are rendered 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 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.

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 table-land, older for the most part than the Old Red Sandstone and Carboniferous rocks; which, after being long buried, was subsequently again exposed by denudation of the overlying strata.

The present scenery of hill and valley even in the Southern part of Scotland is in great part the result of the waste of this old table-land, and the scooping out of valleys by rain, rivers, and old ice, first as a great ice-sheet covering the whole of Scotland and much more besides, modified afterwards by minor glaciers during the oscillations of temperature that marked what we now call the Glacial Epoch.

CHAPTER VI.

GENERAL ARRANGEMENT OF THE STRATIFIED FORMATIONS OF ENGLAND—THEIR ORIGIN, STRATIGRAPHICAL AND GEOGRAPHICAL POSITIONS, AND UNCONFORMITIES.

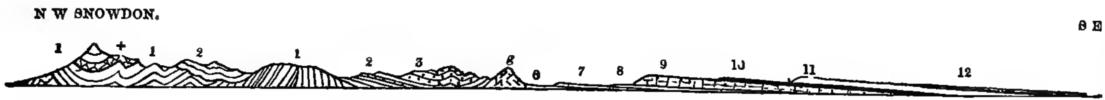
The geology of England and Wales is much more comprehensive than that of Scotland, in so far that it contains many more formations, and its features therefore are more various. England is the very Paradise of geologists, for it may be said to be in itself an epitome of the geology of almost the whole 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 we find all the formations shown in the column (page 26) more or less developed. Those of Silurian age lie chiefly (in the north of England), in Cumberland and Westmoreland, and (in the west) in Wales. 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 to 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. 11 and to the following descriptions; and this structure is eminently typical, explaining, as it does, the physical geology of the chief part of England south of the Staffordshire and Derbyshire hills, p. 74.

The Lower Silurian rocks of Wales (No. 1, fig. 11) consist chiefly of slaty and solid gritty strata, accompanied by, and interbedded with, felspathic lavas and volcanic ashes, marked + ; and mingled with these

Fig. 11.

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 and *g* represent the disturbed Palæozoic 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 table-land.

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

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

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 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 entering into details respecting the minor formations, known as the Lower and Upper Llandovery beds, it is 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 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 on and perhaps entirely buried the Lower

Silurian strata (2, fig. 6), till in places they attained a thickness of from three to six thousand feet.

The uppermost Upper Silurian beds of Wales pass insensibly into a newer series known as the Old Red Sandstone (3, fig. 11), 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 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 (with a possible unconformable break in the middle) again pass upwards into the Carboniferous Limestone, which is overlaid in Wales, Derbyshire, and Lancashire by the Millstone Grit and the Coal-measures.†

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 shales and sandstones bearing coals. In fact, viewed as a whole, the Carboniferous series consists only of one great formation possessing different lithological

* Ceratodus of Queensland, Polypterus of the Nile, and much more remotely the Lepidosteus of the St. Lawrence.

† This is not shown in fig. 11, but the carboniferous limestone No. 4 is shown in fig. 17, p. 102, lying, as it does in North Wales, unconformably on Silurian rocks.

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 Carboniferous Limestone is entirely formed of sea shells, encrinites, corals, and other organic remains, and attains a thickness of two thousand six hundred feet in South Wales and the southwest of England; and in Derbyshire, where no man has ever seen its base, because it rolls over in an anticlinal curve, it reaches a greater thickness. The Millstone Grit is in South Wales 1,000 feet thick, and the true Coal-measures, which are generally more or less of the same nature as those which I have described as occurring in Scotland, are in Monmouthshire and Glamorganshire not less than 10,000 feet thick.

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 'toad-stones.' In South Staffordshire, Coalbrook 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; the coal everywhere being the remains of the decayed plants that grew upon the soils of the period, in the same way that I described them as growing in their day on what is now the Scottish Coal-measure area.

Next in the series come the Permian rocks (5, fig. 16), which, however, rarely occupy so large 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 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.* The marls occasionally contain gypsum, and dolomitic limestones are sparingly associated with these strata in Cumberland and Lancashire. Molluscs are generally but not always scarce, consisting of a few saltwater, but not necessarily truly ocean species, in the limestones and marls of Lancashire and Cumberland. The conglomerates of Cumberland,† South Staffordshire, Enville, and the Abberley and Malvern hills, are generally rough, coarse and subangular, the stones and boulders being south of Cumberland embedded in a red marly paste. In my opinion these are simply old boulder-clays.

These conglomerates here and there on a small scale form somewhat prominent points in the landscape, such as Wars Hill on the Malvern and Abberley range, and Frankly Beeches in South Staffordshire.

Taken as a whole the Permian formations played a

* Often called the *Rothliegende*: a German name pretty generally adopted over Europe, for strata that were formerly called in England Lower New Red Sandstone. It was used to prevent confusion between these strata and the New Red Sandstone, sometimes called the Bunter beds.

† Locally known as Brockram.

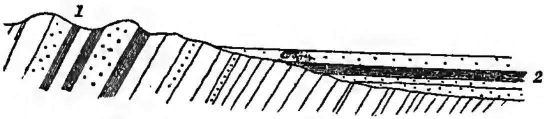
very important part in the ancient *continental physical geography of* what is now Britain and other countries.*

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 at present convenient, for all geologists know when the word palæozoic is used what formations are meant, embracing all the formations 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 oscilliations of level accompanied by denudations. Thus the Llandeilo and Bala beds lie unconformably on the Lingula flags and Cambrian rocks; the Upper Silurian rocks lie unconformably on the Lower Silurian strata, parts of the Old Red Sandstone often lie unconformably on both Lower and upper Silurian rocks, the Carboniferous strata lie here and there at random on any of the older formations down to the Cambrian, and the Permian beds lie in various districts on any formation from the Cambrian rocks up to the Coal-measures. Each special *unconformity* indicates that the older or lower lying strata were disturbed, raised into land, and denuded

* See 'The Red Rocks of Britain of Older Date than the Trias,' by A. C. Ramsay, Quart. Journ. Geol. Soc., 1871, p. 241.

before or while the overlying beds were being deposited above them, thus.—

Fig. 12.



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

At the close of the Permian period a further disturbance of strata,—in other words a considerable, and no doubt slow change in physical geography,—marks the so-called end of this Palæozoic epoch over much of what is now Europe and more besides. An old continent was remodelled, accompanied by the wasting action of the sea and of rivers, and all the common atmospheric agencies, and what is now Britain formed part of it. 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. As with the Permian strata this, the oldest of the Mesozoic or Secondary rocks, was formed of the material of Palæozoic rocks, that then stood above the surface of the water.

The New Red Sandstone series (No. 6, figs. 11 and 16) consists in its lower members of beds of red sandstone and conglomerate, sometimes 1,500 feet in thickness, often called the Bunter Sandstone, and above them are placed red and green marls, chiefly red, interstratified with a few sandstone beds often white and grey. These in Germany go by the name of the Keuper strata, and in England are called New Red Marl. The whole on the Continent, where the Muschelkalk is present, is called the Trias. 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, most of them looking west, over plains and undulating ground formed of softer strata. In the New Red Sandstone and Marl of Great Britain there are no relics of marine life, but traces of amphibious reptiles, bivalve crustacea, fish, and land plants are of occasional occurrence. Marine shells, &c., are plentiful in the Muschelkalk, which forms the middle part of the series in Germany, but is absent with us.

The New Red Marl passes insensibly into the Rhœtic beds which are only a few feet thick, and 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 fossils of the Rhœtic beds are marine, and some of the species pass into the Lias.

The Lias series, Nos. 7 and 8, fig. 11, 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 Lias is rich in the relics of marine life, and it is in these strata that those remarkable marine reptiles, the Ichthyosauri, Plesiosauri, and Pterodactyles occur so plentifully. In the Upper Lias the jet occurs, so well known in the shops of Scarborough and Whitby. 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. 8, fig. 11) 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).* That portion termed the Inferior Oolite occupies the base, being succeeded by the Great or Bath Oolite, Cornbrash, Oxford Clay, Coral Rag, Kimmeridge 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.

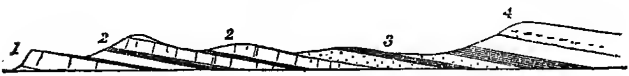
In the south of England all of these formations are marine, and from Northamptonshire to Yorkshire they partly consist of estuarine, freshwater, and land deposits with thin beds of coal.

When the Portland beds had been deposited (forming 1, fig. 13), 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

* See also the 'Column of Formations,' p. 26.

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 in an estuary where freshwater and occasionally brackish-water and marine conditions prevailed. The position of these beds with respect to the Cretaceous strata, will be seen in fig. 22, p. 112, marked *w*, *h*, and to prove that they are intermediate in date to the Oolites and Cretaceous rocks, I may mention that in the Isle of Purbeck, near Swanage, they are seen lying between the two.

Fig. 13.



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

The Wealden and Purbeck beds, indeed, represent the delta and lagoon beds of an immense river, which in size may have rivalled the Ganges or the Mississippi, and in the sediments of which were buried land-plants, small marsupial or pouched mammalia, and terrestrial reptiles, and mingled with them the remains of shells, fish, turtles, and crocodiles, and other forms native to its waters. I do not wish it to be understood that this immense river was formed simply by the drainage of the small territory we now call Great Britain. I do not indeed quite know where the mass of the continent lay through which it ran and which it drained, though I think it partly lay to the north and west; but I do know that England formed a part of it, and that in size that continent must have been larger than Europe and probably as large as Asia, or the great continents of North and South America.

I must, however, explain how we know that the Wealden series were accumulated chiefly under freshwater conditions. The proof lies partly in the nature of the strata, but chiefly in the nature of the organic remains contained in them. The fish give no positive proof, but the crocodilian reptiles yield more conclusive evidence, together with the shells, most of them being of freshwater origin, such as Unio, Paludina, Planorbis, Limnæa, Physa, and such like, which you may find living in many a river, pond, or canal of the present day. Some of these are so very like existing species that it requires all the skill of the palæontologist to tell that there is any difference between them. But now and then we find bands of marine remains, not confusedly mixed with the freshwater deposits, but interstratified with them; showing that at times the delta of the river had sunk a little, and that it had been invaded by the sea, so that oysters and other *salt-water* mollusca lived and died there.

Then by gradual changes it was again lifted up, and became an extensive freshwater area. It is important to mention these circumstances, because the present nature of some of these half consolidated strata exercises a considerable effect on the amount and nature of the later denudation of the rocks in the south-east of England, and consequently upon its scenery.

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 freshwater strata, and the Oolitic and other formations that partly formed their margins, a set of marine sands and clays were deposited, and upon these thick beds of pure white earthy limestone, the lowest part (Lower Greensand), belonging to what on the Continent is called the Neocomian and the upper part to the Cretaceous period. The lower part of these formations in the south of England, consisting of the Atherfield Clay and the Lower Greensand *s*, *d* (fig. 22, p. 112,) is now generally classed with the Upper Neocomian beds of the Continent, but in England they have generally been known as the Lower Cretaceous beds. 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. 11, and *c*. fig. 22), the upper portion of which contains numerous bands of interstratified flints which originally were mostly 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.

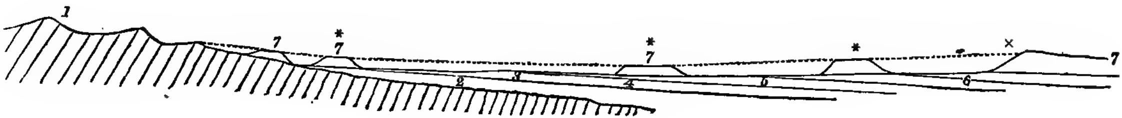
During the period that the Oolitic formations formed part of the land through which the river flowed that deposited the Wealden and Purbeck beds, they were undergoing constant waste, so that in the course of time, having been previously tilted upwards to the west with an eastern dip (fig. 34, p. 214), they were reduced into what I have elsewhere termed *a plain of marine denudation* (*see* p. 204). The submergence of the Wealden area was accompanied 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 strata, till at length they were intruded on the New Red series and even on the Palæozoic strata of Devonshire itself, as shown on the next page.

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 of which I shall now treat. These were deposited on the Chalk, and are termed Eocene formations (No. 12, fig. 11, p. 74). 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 thick. 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 basin. In the Woolwich and Reading beds we have in places the same kind of alternations of freshwater 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

Fig. 14.

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 of old denudations, and which help to prove the original far westward extension of the Upper Cretaceous strata.

different species—the old freshwater 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 later river. For the names of these minor formations, I refer the reader to the column, p. 26.

I may mention that the word Eocene was first used by Sir Charles Lyell to express the dawn or beginning of recent life, or of that kind of life that exists in the world at the present day; at a time when a small percentage of shells still living were believed to be common to these lower tertiary formations. At present not one Eocene shell is recognised as living at the present day.

I have now given an idea 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. 11, and other diagrams, the part that these formations play in producing the scenery of the country.

CHAPTER VII.

THE MOUNTAINS OF WALES AND THE WEST OF ENGLAND —THE VALLEY OF THE SEVERN, AND THE COTSWOLD, OOLITIC, AND CHALK ESCARPMENTS—THE HILLY CARBONIFEROUS GROUND OF THE NORTH OF ENGLAND, AND ITS BORDERING PLAINS AND VALLEYS—THE PHYSICAL RELATIONS 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 mountain regions in the neighbourhood, the whole country below appears almost like a vast plain. To illustrate this. Let us imagine anyone on the top of the gneissic range of the Malvern Hills (*g*, fig. 11, p. 74), which have 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. 11); and if he cast his eye to the north-east, he will there see what seem to be interminable low undulations, 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, formed of the Oolitic formations which constitute so large a part of Gloucestershire. These, as the Cotswold Hills, form a table-land, overlooking on the west a broad plain of Lias Clay and of New Red Marl.

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 in all probability 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. 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 that lie between Wales and the Lancashire hills, now partly occupied by the estuaries of the Dee and Mersey. The strata that now form the wide Oolitic table-land have a slight dip to the south-east and east, and great atmospheric denudations having in old times taken place (still going on), a large part of them, miles upon miles in width, has been swept away, and thus it happens that a bold escarpment, once—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. 11); *that plain being a table-land*, 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.*

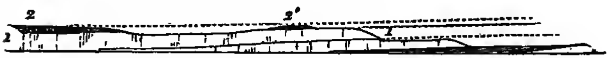
If we go still farther to the east, and pass in succession all the outcrops of the different Oolitic formations (some of the limestones of which form minor scarps), we come to a second grand escarpment (11, fig. 11), formed of the Chalk, which in its day also spread far to the west, covering unconformably the half-denuded Oolites, till in its early beginning 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 perhaps in places altogether. After consolidation and emergence this Chalk formation has 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 (*see* fig. 14, p. 90).

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

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

escarpment of Chalk we find outlying Eocene fragments. The proof of this original extension westward is shown in the following diagram.

E Fig, 15. W



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 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 table-land or in a large depressed area in a manner shown at 12, fig. 11.*

Such is the general manner in which the southern part of England has attained its present form. Nearly

* 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 cynclinal 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.

the whole of the west of England, that is to say, of Devon and Cornwall, and of Wales, consists of Palæozoic strata, viz.: Devonian, Old Red Sandstone, Cambrian, and Silurian with all its igneous interstratifications, and the Carboniferous series. All these have been much disturbed and extensively denuded. They are formed of beds of variable hardness—much of the Silurian rocks in Wales being 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 Wales, and in a less degree parts of 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. 11) forms the western edge of the table-land, 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 at a lower level than the Inferior Oolite at the edge of the plateau, as shown in fig. 11.

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 present masses of Palæozoic strata, forming a group of mountains in the west, then certain plains and undulating grounds composed of New Red Sandstone and Lias, and then two great escarpments, the edges of table-lands, 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. 11.

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 sonthern part of Derbyshire to the borders of Scotland. It consists of Carboniferous rocks, ranging from the Carboniferous Limestone up to those that pass beneath the base of the Permian strata. Further west near the mouth of the Solway, lie the Silurian and Carboniferous rocks of the Cambrian area, separated from the Carboniferous formations of Northumberland and Yorkshire by the Permian beds of the Vale of Eden.

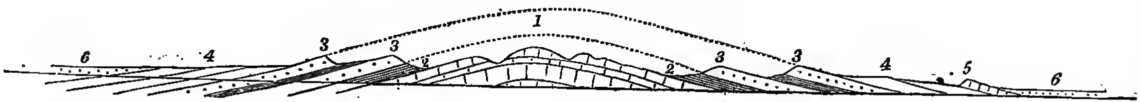
As far as the north borders of the Lancashire and Yorkshire coal-fields, the Carboniferous rocks lie in the form of a broad *anticlinal curve*, that is to say, they dip east and west in the manner shown in the opposite diagram.

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 too 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. 37, p. 230.

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. 17, and

Fig. 16.

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. Permian beds, overlaid by 6. New Red Sandstone.

Fig. 17.
Section from Snowdon to the East of England.

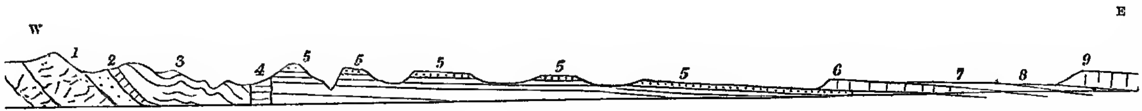
Map, line 17). In the west, rise the older disturbed Silurian strata, Nos. 1 to 3, which form the mountain region of Wales. On the east of these lies an upper portion of the Palæozoic rocks, 4, consisting of Carboniferous beds with an escarpment facing west. They are less disturbed than the underlying 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 which 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 table-land that they do in Gloucestershire and the more southern parts of England. As shown in the diagram (fig. 17), 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 Bridington Bay, the following diagram, fig. 18, 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 so-called 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 forming the loftiest mountains of Cumberland. Then comes 2, the Co-

Fig. 18.

Section from Cumberland towards Bridlington.



1. Igneous rocks, 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.

niston limestone, overlaid by Upper Silurian rocks, 3, forming a hilly country, between which 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, 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 low cliff overlooking the sea.

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 estuarine bay, formed by the denudation of the Kimmeridge and Oxford Clays. It has been and still is 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. 19.

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., on the west, 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 Ingleborough and 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,* till they slip under the low escarpment of Magnesian Limestone (3). East of this 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, 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 with all its broad-topped moorlands and deep well-wooded valleys. Such is the anatomy of the fertile Vale of York and its neighbourhood.

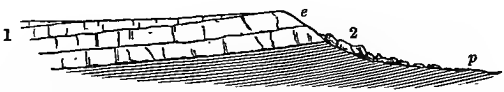
* This kind of slope is often called a dip-slope.

CHAPTER VIII.

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. 20.



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 Lower Greensand and Chalk hills 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 outside 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 (fig. 22, p. 112). 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 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. 21. S

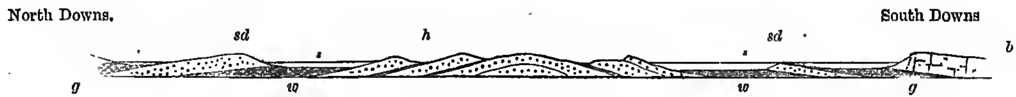
a a Upper Cretaceous strata, chiefly Chalk, forming the North and South Downs; *b b* minor escarpments of Lower Greensand; *c c* Weald clay, forming plains; *d* hills formed of Hastings sand and clay. The Chalk, &c. once spread across the country, as shown in the dotted lines.

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, for instance, of the North Downs near Folkestone, and looking south-west across the Romney Marshes, 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 on the east 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 I have long felt that it is no longer tenable.

If the Wealden area were lowered into the sea just enough to turn the Chalk escarpments into cliffs (*see* Map and fig. 22), 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, if we follow the escarpment all round from the neighbourhood of Folkestone to that of Eastbourne, unlike all common coasts, is at very unequal levels.* This land would also be 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 would project eastward from the Chalk of Hampshire, to form what we 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

Fig. 22.

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.

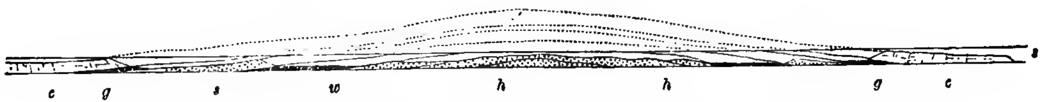
islands, formed of the Hastings Sand series *h h*. This form of ground would certainly be peculiar, and ill adapted in form to receive the beating of a powerful surf, so as to produce *on the inner or scarped side only* the cliffy escarpment that forms the steep edge of the oval of Chalk. Further, if 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 down *c c*. 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 freshwater 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 has been 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 on land 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. 31, p. 204; for, this combined result is to *plane off* as it were the

Fig. 23.

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, *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 *c'*.

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. 23, which is very nearly on a true scale.

Let the upper part of the curve be planed across (in the manner explained at p. 204, and let the newly-planed surface, slightly inclined from the interior, be represented by the line *p p* (fig. 23). 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 rise close to the sea coast and flow westward. If, on the other hand, such a plain as *pp* once existed, it is easy to understand how *the rivers might in old times have 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 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. 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 there is 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 the present form of the ground. Thus after the formation of the marine plain *pp*, the Chalk being com-

* 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.—*Geol. Journal*, 1862, vol. xviii. p. 378.

paratively hard has been partly denuded, and now stands out as a bold escarpment in the Downs. The soft clay of the Gault has been more easily worn away, and forms a hollow or plain. The lower Greensand, full of hard calcareous bands and ironstone, more strongly resisting denundation, 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 central hills of Ashdown Forest, and other places. 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. 22), *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.**

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

* 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.

period. It has, therefore, been above water for a very long time. On the edge of the North Downs there are certain fragmentary outliers described by Mr. Prestwich. These by some persons have been supposed to be outliers of the Lower Eocene strata called the Woolwich and Reading beds, but Mr. Prestwich considers them to belong to part of the Crag.

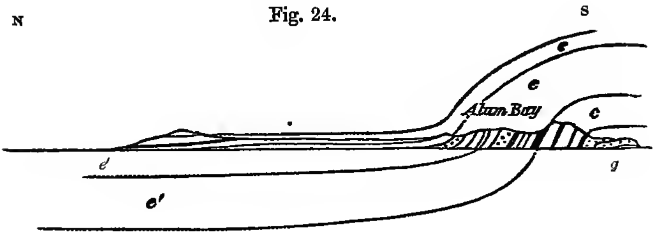
If they belong to any part of the Eocene series, then those denudations of the Weald that produced its present form may have been going on ever since the close of the Eocene period, that is to say, all through the Miocene and subsequent epochs. Those who are acquainted with Continental geology will realise the meaning of this when they consider that it implies a lapse of time perhaps longer than it has taken to form the labyrinthine network of valleys cut into the great table-land of the Rhine and Moselle, or more striking still, to form the whole range of the Jura, the present outlines of all the lowlands of Switzerland that lie between those mountains and the Alps, and to upheave and greatly to waste by denudation the sub-Alpine hills of which the Righi is one. On the other hand, if the outliers on the Chalk escarpment west of Folkestone be parts of the Crag beds, then 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 distance.

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 of the strata of the anticlinal curve having been *planed off*, and by subsequent elevation a table-land 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 escarpments 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 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

Fig. 24.



that from east to west, or from White Cliff Bay to Alum Bay, there is 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 and the London Clay, the Bracklesham and Bagshot Sands, and the higher freshwater beds of the Eocene series.

The whole pass under the Solent, as shown in the lower dotted lines *è è*, fig. 24, and rise again on the mainland in Hampshire, a considerable portion of which is composed of various sub-divisions 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 Kimmeridge Bay (fig. 25).

Now these disturbed strata were originally deposited horizontally, and after disturbance the Chalk, *c* (fig. 24), once spread over an extensive area of Lower Greensand, &c., *g*, to the south, and the Eocene rocks, *e*, once spread over the Cretaceous rocks in a curve, at a great height,

Fig. 25.

1. Kimmeridge Clay. 2. Portland Oolite sand. 3. Portland Oolite limestone. 4. Purbeck limestone and marls, chiefly freshwater beds. 5. Weald sands and clay, freshwater. 6. Necocomian and Greensand. 7. Chalk without flints. 8. Chalk with flints. 9. Woolwich and Reading beds. 10. London Clay. 11. Bracklesham and Bagshot beds.

as shown in the dotted lines *e e* (fig. 24). 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 country 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. 26. 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 portions of the sands, and the result is that over large areas, such as Marlborough Downs, great tracts of chalk are strewn with huge blocks of tabular sandstone lying so close together, that sometimes over miles of country you may almost leap from block to block without touching the chalk on which they lie.

Fig. 26.

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 they are found scattered even on the terraces of the Lower Chalk, a remarkable example of which occurs at the old British 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 Kimmeridge Clay well out to the north or west of the escarpment, as for instance at Swindon, and 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, in fact, that the Chalk and overlying Eocene beds once spread far across the plains which the Chalk escarpments 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 in which they once lay were slowly wasted away and disappeared, they gradually subsided to their present places. Besides the name of 'grey wethers,' they are known by the name of 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.*

I might add many details respecting other portions of England, such as the relation of the Secondary rocks to the older rocks of Devon, the structure of the Malvern 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. 37, p. 230). But it would not add much to the general knowledge which I have 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 the south of Scotland, because of disturbance and great denudations; and that it consists of undulating plains and of table-lands in the central and eastern parts because the strata there are generally flatter and softer, and because they have been denuded in such a manner that large parts of them in the Weald

* 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.

and in the middle and west of England have been partly cut away and thus their edges form long escarpments.

I have still something to say about the Middle Tertiary or Miocene rocks, and also of the softer coverings of later date, that more or less shroud the harder skeleton that chiefly forms the mainland of Britain.

CHAPTER IX.

THE MIOCENE AND PLIOCENE TERTIARY FORMATIONS.

The Eocene strata of England taken as a whole may be looked upon as estuarine beds. The lower or Woolwich and Reading beds and also 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, but perhaps on a somewhat smaller scale. 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 may state that in Germany there are formations containing terrestrial, as distinguished from marine fossils, containing 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, perhaps, even in great part, specifically: and, with great 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 mention these facts, because now we begin to approach our own time, and the circumstances bearing on the last physical changes on our part of the world begin to become more distinct, and I shall soon have something to say connected with this subject, about some of 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 chiefly the same.

True Miocene strata are very poorly represented in England, and they play no important part in its physical geography. They are only known on the south of Dartmoor in Devonshire, at Bovey Tracey, under a flat peaty area, ten miles long by two miles wide, where they chiefly consist of beds of clay and sand, interstratified with bands of lignite. These strata, the age of which was for long time a puzzle, were within the last few years first fully investigated through the liberality of the Baroness Burdett Coutts, who provided funds for that object. The result of much labour by Mr. Pengelly was, that after an examination of the fossil plants, by Professor Heer of Zurich, they proved to be of Miocene age. 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. 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 adjacent land of Antrim, 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, and in Iceland, the same volcanic series is found now, 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 dolerites and bassalts, interbedded with volcanic ashes. The latter, however, occur associated with beds of clay and of coal or lignite. Some of the clays contain leaves of plants, first noticed by the Duke of Argyll, and ever since well known as the Miocene leaf-bed of Mull. The late Professor Edward Forbes determined their age, and later observations made by Professor Heer confirm his accuracy. The plants are partly the same as those of Bovey

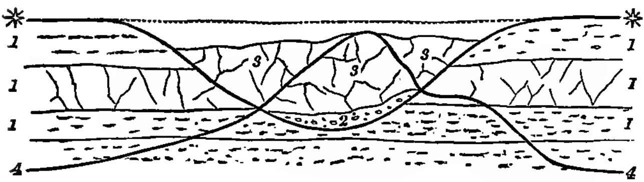
Tracey, which, however, are more nearly related to the Miocene floras of the Rhine, Switzerland, and Bohemia, than to the flora found farther north. The flora from Mull is in some points more allied to the Miocene floras of the Faroe Isles, Iceland and Greenland.

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 that were formed by this volcanic action (above which the peaks and craters rose) are still in Antrim, from 600 to 900 feet thick, and more than 3,000 feet in Mull. They formed part of wide-spreading lands of great antiquity, partly formed of many older formations. Old river beds intersected them, running through an ancient continent formed of Laurentian, Cambrian, and Silurian rocks far to the west and north-west. These rivers scooped out valleys in the Miocene lavas and tufas, which were again partly filled by lava-torrents of basalt and obsidian. In the case of the Scuir of Eigg, the lava (obsidian 3, fig. 27) flowed over the valley gravel 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 destruction, and thus it happened that the Scuir of Eigg became one of the most striking peaks in the Western Islands.

By waste such as this, every trace of the outlines of the old craters has been obliterated. The mountain craters have been planed off, and what remains are simply lava-flows and ashes such as we might find if the higher halves of Iceland or Etna were planed

Fig. 27.



1. Old lavas, &c. 2. River hollow scooped out by denudation. 3. Obsidian filling valley. 4. Present outline of the country produced by later denudations.

away, and you were left to guess thereafter where the later craters had been. Thus it 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.*

* See A. Geikie, 'Jour. Geol. Society,' vol. xxvii., 'On Tertiary Volcanic Rocks.'

During all this time, the greater contours of England remained the same, the country being merely upheaved so far that it was joined to the Continent, and over the land, mammalian races in late Miocene times migrated into our region, their bones being now found buried both in 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,* 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 freshwater shells. According to Mr. Prestwich, the

* Castor veterior, Cervus dicranoceros, Equus placidens (?), Felis paroides, 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.

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, they play 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 Suffolk. They are, in fact, generally so far buried under superficial strata that they require to be looked for, and thus do not at all affect the scenery. 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.

If England has undergone these changes in late times, far greater are the numbers and the kinds of changes that it must have undergone in periods that went before, of which the records are often entirely lost.

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 an island or islands many times 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 which is the Chillesford Clay. One of the most remarkable, the 'Forest Bed,' lies underneath the glacial drift 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 freshwater 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), *Merianthes trifoliata* (Buckbean), *Quercus* (Oak), *Alnus* (Alder), *Nymphœa alba* (Water-lily), *Nuphar lutea* (Yellow Water-lily), *Ceratophyllum demersum* (Horn-wort), and *Potamogetum* (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*, *E. priscus* (a variety of the last), *E. meridionalis*, *Rhinoceros megarhinus*, *R. Etruscus*, *Hippopotamus major*, *Equus caballus* (the common horse), *Machairodus* (a tiger?), *Bison priscus*, *Bos primigenius* (Auroch), *Sus savernensis*; four species of bears, *Ursus arvernensis*, *U. Spelœus* (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), and *C. ardeus*; *Mygale moschata* (Musk shrew), *Sorex fodiens* and *S. remifer* (Shrews), *Arvicola amphibia* (Field-mouse), *Castor europæus* (common beaver), *Trogonotherium Cuvieri* (a great Beaver), two species of whales, and fish.* The whole speaks of a past physical geography, at least during part of which, perhaps with a mild climate, our country seems to have been joined to the Continent.

Later still there are other small formations, very important in themselves and definite as regards some geological and palæontological questions, but like the Cromer beds, as they scarcely affect the features of the country, I shall here say nothing about the causes that brought about a patch here and a patch there of gravel or loam, in which we find relics of the Hippopotamus, Rhinoceros, Elephants, Musk, Sheep, Lions, and other mammalia.

* 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.

CHAPTER X.

THE GLACIAL EPOCH.

I MUST now describe a remarkable episode in Post-Tertiary times, known as the *Glacial epoch*, of later date than the Cromer 'Forest bed,' and certainly of earlier date than many of the patches just alluded to. This formation has left its traces over great part of the northern, and also over a large portion of the southern hemisphere; and I shall be able to describe the history of that period, as it affects the scenery of Britain, with something like accurate 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 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. The mean limit of perpetual snow upon the Alps, is 8,500 feet above the level of the sea. Above that line, speaking generally, the country is mostly covered with snow, and in the higher regions it gathers on the mountain slopes and in the large *cirques* or recesses, and by force of gravity it 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 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.

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 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, 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.

All glaciers are traversed by cracks which are 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 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 in the middle of a glacier, above the surface of the ice, 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. 28). 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 shot into the valley at the end of the ice-stream, frequently forming large mounds, known as *terminal remains*.

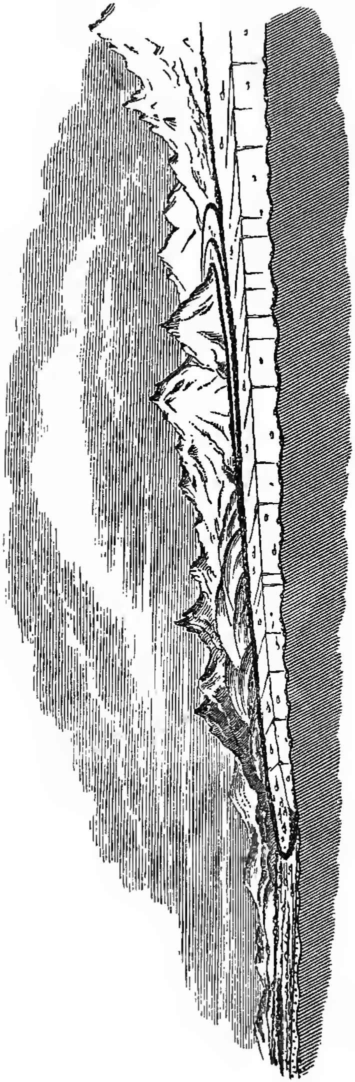
All glacier ice, even in the depth of winter in Arctic regions, is at a temperature of about 32° Fahr., that is to say, just about the melting point, excepting near the surface as far as the cold atmospheric temperature can penetrate. This it is said is rarely more than eight or ten feet. Therefore, 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. 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 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. In some cases, however, it happens that from various circumstances both terminal and lateral moraines are so long 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 ice, in some cases hundreds or even two or three thousand feet in thickness, forming a glacier, 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 (fig. 28, p. 142). 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

Fig. 28.

Imaginary Section of a Swiss Glacier,



Showing Moraines, Crevasses, and the undulating form of the ground underneath (small Roches Moutonnées).

bottom of the ice. The bottom of a glacier, therefore, is not simply bare ice, but between the ice and the rock over which it flows, there are blocks of stone imprisoned, and siliceous and often feldspathic débris (chiefly worn from the floor itself), which may be likened to emery powder. The 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 great 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. The signs of vanished gigantic glaciers 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 Switzerland, where we are able to study the action of modern glaciers in detail, we have next to enquire, 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 ice-line, as a whole, descends lower and lower as we go northward, till at length the whole country becomes covered by one universal glacier. The same universal covering of ice is also found in that southern land, known as Victoria Land, where the mountains rise, some of them ten, twelve, and fourteen thousand feet above the sea, and except here and there, where the cliffs are very steep, the whole country is covered with a coating of thick glacier-ice. In Greenland, where the coast happens to be high and steep, the glaciers break off at the top of the cliffs and fall in small shivered icebergs into the sea. But 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 twelve or twenty miles across at their ends, and, in the case of the great Humboldt glacier, sixty 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 three thousand feet in thickness. Great masses of ice breaking away from their ends form icebergs, which sometimes laden with moraine rubbish, like that which covers the glaciers of Switzerland, float out into the Greenland seas, and are carried South by a current in Baffin's Bay. Not unfrequently they 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, all 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, and sometimes escaping from thence and melting in the seas of warmer climates, their stony freights get scattered abroad, here and there over the bottom of the west Atlantic, which becomes strewn with erratic blocks and other débris borne from far northern regions. The same kind of phenomena, on a still grander scale, are common in Antarctic regions near Victoria Land.

Having ascertained what are the signs by which a glacier may be known, and also the signs left by icebergs, I shall now show that a large part of the British islands has been subjected to *glaciation*, or the action of ice.

Those who know the mountains of the Highlands of Scotland may remember that, though the weather has had a powerful influence upon them, rendering them in places rugged, jagged, and cliffy, yet, notwithstanding this, their general outlines are often remarkably rounded, flowing in great and small mammillated curves. 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 nearly as far as the middle of England.

Considering all these things, geologists, led many years ago by Agassiz, have by degrees almost universally come to the conclusion that a very large part of the northern hemisphere was, during the 'glacial period,' covered, or nearly covered, with a coating of thick ice, in the same way that the greater part of Greenland and the whole of Victoria Land are covered at present. Britain formed part of this great area, and, by the long-continued grinding power of a great glacier nearly universal over the northern half of our country and the high ground of Wales, the whole surface became *moulded by ice.* The relics of this action still remain strongly impressed on the country, to attest its former power.*

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°, when the soil, or the superficial covering of what is called drift, 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 World and the New. We know of no power on earth, of a natural kind, which produces these indications except moving ice, and therefore

* I need scarcely say that the same kind of phenomena are equally striking in Ireland.

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 mere 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, in New Zealand, the Sierra Nevada, and the Pyrenees of Spain, the mountains 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. Therefore there can be no doubt that at late periods of the world's history a climate 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. The cold of these minor cycles in time (for as shown by Mr. Croll the glacial cycles alternated 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. According to Adhemar, and Mr. Croll, the glacial episodes were due to occasional excessive eccentricity of the earth's orbit. It is enough for the present argument if we realise the fact.

It was during part or in parts of this period that great part of what is now the British islands was covered with ice. I do not say that they were islands at that time, and perhaps during part of it they were still united with the Continent, and the average level of the land may then have been higher than at present, by elevation of the whole, and a little because it had not suffered so much degradation: but whether this was so or not, the mountains and much of the lowlands were covered with a universal coating of ice, probably 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 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 also found a vent for a further outpouring to the east. Another part passed into the Firth of Clyde. All the southern Highlands from Fast Castle on the east to Wigtonshire on the west coast, were also covered with glacier ice; Northumberland, Durham, and all the great 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-stream coming from the north, it stretched away south so far that it overflowed Anglesey, and, so to speak, overcame the force of the smaller glaciers that descended from the mountains of North Wales; for the glacial striations of Anglesey point not to the Snowdonian range, but about 25° to 30° east of north, directly to the mountains of Cumberland. South of Wales, iu England there are few signs of direct glacier action.

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 most of the best geologists of Europe and America.

The general result has been that the whole of the regions of Britain mentioned* 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 power of moving ice. Suddenly strip Greenland of its ice-sheet, and it would present a picture something like Britain immediately after the close of this Glacial period.

During the time that these great results were being

* And equivalent regions in Ireland which in this book it is not my object to describe.

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 in more temperate regions, at intervals advanced north or retreated south with the retreating or advancing ice. At length, however, a slow submersion of the land took place; and as it sank the diminishing glaciers, still descending to the level of the sea, deposited their moraine rubbish there. Gradually the land sunk more and more, the cold still continuing, till this country, previously united to the continent of Europe, became a group of icy islands, still covered with snow and glaciers, which descended to the sea, and broke off in icebergs. These floating south deposited their stony freights as they melted. The 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 gravels, with sea-shells, are interstratified with these boulder beds, and sometimes the clays themselves contain shells. 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, sometimes arranged portions in a stratified manner; and there occur at intervals, in these patches in Scotland, the remains of sea-shells of species such as now occur in the far north. Here, therefore, we have another proof of that arctic climate which, in old times, came so far south.

In Wales we find similar evidence, long since described by myself,* of the sea having risen at least 2,000 feet upon the sides of the mountains, for Wales, like Scotland, also became a cluster of islands, round which the drift was deposited, and great blocks of stone were scattered abroad, floated on icebergs, that broke from an old system of glaciers, and melted in the neighbouring seas. In this stratified material sea-shells were long ago found in Caernarvonshire by Mr. Trimmer on Moel Tryfaen, and by myself near Snowdon, from 1,100 to 1,400 feet above the sea.

Erratic blocks of granite, gneiss, feldspathic traps, and of other rocks, some of which came from the Highlands of Scotland, some from the Cumberland mountains, some from the Welsh mountains, and some from the farther region of the great Scandinavian chain, were in the same manner spread over the central

* See 'The Old Glaciers of Switzerland and North Wales,' in 'Peaks, Passes, and Glaciers,' 1859. Republished in a separate volume 1860. Longmans.

counties, and the west and east of England, probably just like those boulder-beds that are now being formed at the bottom of the Atlantic by icebergs that float south from the shores of Greenland. Boulders of Shap granite from the Cumbrian regions are scattered about the middle of England, on the banks of the Humber, and even in the valley of the Severn about twelve miles north of Cheltenham; and ice-scratched chalk-flints and masses of Oolitic shales and loose Liassic shells occur as far south as a flat plateau above Romford, overlooking the broad estuary of the Thames.

Most of these marine boulder-drifts are rudely stratified when viewed on a large scale, and, as already stated, often interbedded with sand and rounded gravel; but it is remarkable that in most of the clays that form the larger part of the formation, the stones and boulders that stud the mass are scattered confusedly, and frequently stand on end, like the stones in the Moraine-Till of Scotland and the north of England. This is the case even when they are associated with sea-shells, which shells prove the marine nature of what often looks like a mass of heterogeneous rubbish. A great number of these shells occur in a broken state, and from Scotland to Suffolk, on the coast cliffs, they may be found plentifully enough when carefully looked for. Between Berwick and the Humber, I have seen them in scores of places; the most plentiful species, as determined by Mr. Etheridge, being *Cardium edule, Cyprina Islandica, Venus, Dentalium entalis, Tellina, Leda oblonga, Astarte borealis,* and *Saxicava rugosa.* On the west coast by the Mersey, and near Blackpool, and on the shores of the Menai Straits near Beaumaris, they are sometimes equally plentiful, and far inland near Wellington, Congleton, and Macclesfield, I observed the same kind of broken shells in places 600 feet above the sea, and Mr. Prestwich observed them near Macclesfield, at a height of fully 1,200 feet.

It is remarkable also that a prodigious number of ice-scratched stones occur in this drift, in Holderness, north of the Humber, and elsewhere, under such conditions, that the idea is suggested that they were marked not only by glaciers, but also by the agency of coast ice. As we travel south, we find that the numbers of different kinds of stones increase according to the number of formations passed. North of the Magnesian limestone district, the fragments to a great extent consist of Silurian, Old Red, and Carboniferous rocks, then these become mixed with pieces of Magnesian limestone, by and by Oolitic fragments are added, and in Holderness, in places almost half the number of stones are of Chalk generally well scratched, and often mingled with broken shells. But it is evident that the low chalk hills of Yorkshire are not of a kind to have given birth to glaciers, and therefore the scratching and distribution of the chalk-stones in this upper drift may have been produced by coast ice. The same may be said of other low parts of England, both on the coast and inland where the drift prevails, the currents which scattered the ice-borne material having on a great scale flowed approximately from north to south.*

South of the estuaries of the Severn and the Thames, England is for the most part destitute of boulder-drift, and it is only close on the sea near Selsea and Brighton that erratic boulders of granite, &c., have been found, apparently floated from the Channel Islands or from France.

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 the drift was deposited and more or less filled many of the valleys of

* It has been supposed by Mr. Croll that the boulder clays of Holderness, &c., with all their broken shells, were pushed forward and left on the land by the great northern glacier that, coming from Norway and North Britain, filled great part of the German Ocean. This is the alternative if submersion is not allowed.

Wales. 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 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 of the same kind could easily be given, while, on the other hand, in many valleys we find the drift still remaining. 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.

Frequently, masses of stone, that floated on the surface of the ice, were left perched upon the rounded *roches moutonnées*, in a manner somewhat puzzling to those who are not geologists; for they lie in such places that they clearly cannot have rolled into them 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 our country. The same kind of evidence of the gradual retreat of glaciers is plain in almost every valley in Cumberland, in Wensleydale and many another Yorkshire dale, in the Carrick and Lammermuir hills, in Arran, and through the Highlands of Scotland. I could give numerous special instances, but they would add little to the effect of what I have stated, and would needlessly lengthen this book.

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 Kaims 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.

Again, when the great ice-sheet was retiring westward from the German Ocean, up the dales of Yorkshire and

Northumberland, it 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. 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 glacier 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.

All these things give distinctive characters both to our mountains and much of our lowlands, very different, I believe, from those of mountain ranges and lowlands where glaciers never were. I confess, however, that *I have never seen mountains that have not been affected by old glaciers*, my travels having been confined to Europe north and partly south of the Alps, and to the temperate parts of North America.

CHAPTER XI.

GLACIAL EPOCH CONTINUED—GLACIAL ORIGIN OF CERTAIN LAKES.

There is an important subject that affects the physical geography of our country, and that is what I believe to be the glacial origin of many lakes.

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 lakes on the Italian side of the Alps below Ivrea, and there are several among the mountains of Wales. Whether there are any in Scotland dammed by the terminal moraines of common valley glaciers I do not know, although I have no doubt that they may exist in parts that I have not visited. Furthermore, sometimes on the *outer* side of these moraines we find stratified boulder-drift, showing that an old glacier descended to the level of the sea, and deposited its moraine 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.

Such lakes 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 thirteen years old. It gave rise at the time to a considerable amount of opposition, and also to some approval.*

There is no point in physical geography more difficult 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 are true *rock-basins*; that is to say, hollows entirely surrounded by solid rocks, the waters not being retained by mere loose detritus. But the great diffi-

* Soon after the special paper was published, 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.

culty is, how were these *rock-basins* made? 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 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 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 114, and of South Wales at page 204, 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.*

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 that 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.

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 the great geologist 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 great 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 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 the northern part of North America 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 yet in areas of special depression, *the only remaining agent* that I know *is the denuding power of ice.* In

* For details see 'Quarterly Journal of the Geological Society,' 1862, vol. xviii. p. 185. There are many lakes and inland seas which I do not doubt occupy areas of special depression, for I by no means wish to be understood that this theory accounts for the probable origin of all lakes. Many are dammed up by drift, and in other regions some may owe their origin to causes of which I know nothing.

the region of the Alps it is a remarkable circumstance 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 before applying the theory to our own country. This lake, once more than fifty, is now about forty miles long, and in its broadest part about twelve 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, from south-west to north-east at its lower end. The effects produced on the country over which it flowed were commensurate to its great size.

The Lake of Geneva, where deepest, towards its eastern end, is 984 feet in depth, and it gradually shallows to its outflow. By examining the sides of the mountains

Fig. 29. *Lake of Geneva and Soundings.*

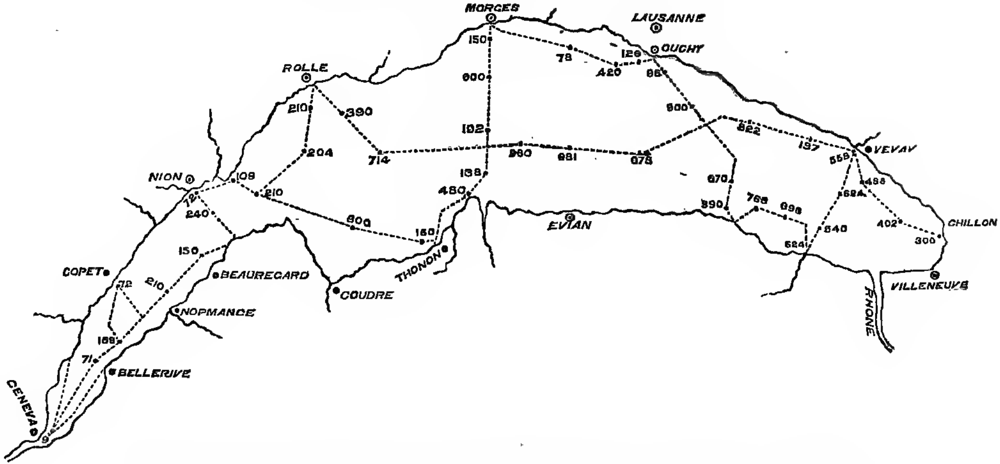
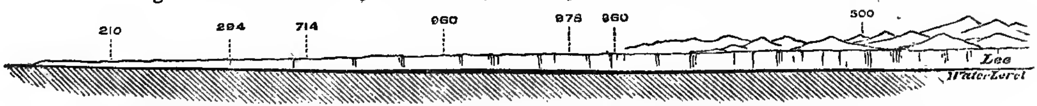


Fig. 30. *Old Glacier of the Rhone, covering what is now the Lake of Geneva.*



The shaded part represents the rock-basin beneath the lake. The dark line the lake, showing its depths on a true scale. The light part above represents the Old Glacier of the Rhone. Figures, depth of the lake in feet.

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 where the glacier attained its greatest size, viz. at least, 2,800 feet above the surface of the lake, or nearly 3,800 if we add the depth of the water.* 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 the glacier 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, and the underlying rock was consequently to a considerable extent worn away; but where at its western end near Geneva the ice was thinner by

* But probably more; this estimate is taken from the observations of several Swiss geologists. I believe it could be proved that the ice must have been considerably thicker, for the original bottom of the lake is now partly covered by deposits, first of moraine-matter left by the retreat of the Rhone glacier, afterwards covered by sediment poured into the lake by the river.

reason of the melting of the glacier, 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 in the deepest part, without allowing for the sediment that covers the bottom, and this hollow shelves up all round towards the present margin of the lake. 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. 30, it becomes evident that the depth of the rock-basin is comparatively quite insignificant.

It may seem strange that I should take the Lake of Geneva as an example, when the lakes of Llanberis in Wales, Windermere in the Cumbrian region, Loch Doon in Ayrshire, or many a loch 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 their basins were scooped out by the great glaciers of the icy period; some of which were as thick or thicker than that which descended the valley of the Rhone. I then first clearly saw its bearing as a discovery affecting the physical geography, not of Switzerland and Britain alone, but of 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 and crater-lakes, we find very few important lakes in its southern regions, and these chiefly in Central Africa, where no one has yet tried to account for them.* As we proceed northwards in America, in latitudes 38° and 40°, the lakes begin to increase, and soon become tolerably numerous. North of New York, towards the St. Lawrence, they become so numerous that they appear on a map to be scattered over the whole 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 broadcast with lakes large and small; and a vast number of the smaller ones are omitted partly for want of room, and partly because they are unknown to topographers. The whole of that country *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

* They are, probably, like the Caspian, relics of old seas, but now freshened.

the Gulf of Finland, and the Baltic, the whole country is covered with lakes, many of which lie in true rock-basins, while in Finland, according to Professor Nordenskiold, they are, in a glaciated country, chiefly dammed in by heaps of detrital matter called Ösar.* Go into North Wales where glaciers were in every valley: there we have the lakes of Llanberis, of Cwellyn, Ogwen, Llyn-y-Ddinas, Llyn-Gwynant, Llynllydaw, and all the lakes and tarns near Capel Curig, and in the upper Corries. 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 I was informed by the late Professor Jukes, and personally partly know, that the glacial origin of some of the celebrated lakes in Ireland and of others unknown to fame besides is equally clear. All these regions have been extremely abraded by glacier-ice.

In Scotland, in the Southern Highlands and in Kircudbrightshire and Ayrshire, there are also many truly rock-

* The Eskers of Ireland and the Kaims of Scotland. These are common in the great valley of the Clyde, especially near Lanark and Carstairs, where they form vast elongated irregular mounds of gravel above the true glacial detritus. They inclose lakes and peat-mosses, once lakes. They have been mapped and described by Mr. Geikie. They also occur in the grounds of Castle Kennedy near Stranraer, enclosing two beautiful lakes, and in Northumberland, Lancashire, and Yorkshire.

bound lake-basins scooped out of the Silurian rocks of the Carrick Hills. If any one 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 unmistakeably marks an ice-worn rocky barrier. 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. Some, however, lie in hollows, made by unequal accumulation of glacier drifts, or among the bending gravelly mounds of the 'Kaims.' This point is clear that all the country, like 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 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.

This full theory, brought out in March and published in August 1862, of the glacial origin of so many lakes in the northern hemisphere, or rather wherever there have been either widespread continental or 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 allowed that it 'deserved the gravest attention.' Nevertheless, it begins to find its way into geological manuals, 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 hemispere generally that are occupied by lakes.*

Finally, if I were to classify the lakes produced

* 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; Professor Geikie, 'The Scenery of Scotland viewed in connection with its Physical Geology,' 1865, 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. Sir Charles Lyell gives a qualified assent in his 'Student's Elements of Geology,' 1871.

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 the 'drift' on broad flattish surfaces, among which in many districts may be included those dammed in by Eskers or Kaims, well known on a large scale in Finland, and good examples of which, on a smaller scale, may be seen in the beautiful grounds of Castle Kennedy, near Stranraer; 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.

CHAPTER XII.

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 main land; a circumstance proved by the mammalia that must have 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 (if the mammalia found in the Crag migrated hither in Miocene times) are of the same type as the faunas of later phases of the continents of Europe, North America, and other regions; and this type, with 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 direct 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, and species of rhinoceros, horse, deer, oxen, pigs, a tiger, and bears, beavers, mice, 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 minor 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 over-laid 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-drifts were formed during a period of cold, accompanied by the great glaciers that covered so much of the north of Europe and America, as I have already explained. While the Boulder-drift was forming, the country slowly sank, and severed from the main land became merely groups of small 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 could not have lived on mere groups of icy islands, on which, if there was any vegetation, it was exceedingly 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 submergence. 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—unless, indeed, it also belongs to the epoch of the Forest-bed, which is somewhat doubtful. Whether or not this is the case, it is 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 at least of younger date than the Glacial period.

But before discussing these it is necessary to say something of the bones found in limestone caves.

These 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 being 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 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.*

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;

* The great limestone caves of Kentucky form the most prominent 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. 166, mentioned others in the Jura.

delicate open arcades run along the ledges, large fretted accretions of stalagmite swell out in the angles of the cavern between the floor and the 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 whenever 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 freshwater 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.

It is impossible to fix with accuracy the precise age of such caves, or the time when all the bones that are found in them were buried there; for the wearing out of the caves has been going on for unknown periods of time, and some of them 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, or 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 of pre-Glacial and 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 specially to caves.

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 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, in their way in and out of their dens.

There is no doubt that many of these caves date from before the Glacial epoch, and also that the bones of animals found their way into some of them before that period; and since it closed many of them have been more or less tenanted as caverns 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 is often said that these are of later date than the mammalian remains of extinct species sometimes found in the glacial deposits, it is by no means *proved* that this is the case. Some of the Devonshire caves in which works of man were found, being above the sea during Glacial times, 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. Some of those in the south of England seem to have been inhabited, while others farther north lay underneath the icy sea, or otherwise that part of the northern land was so greatly shrouded in the great ice-sheet that it was desolate and uninhabited by beast or man.

This, however, is certain, that man, the Mammoth, and other extinct mammalia, were contemporaneous, for his works and their bones have been found together in Kent's Hole, and in Brixham Cave in Devonshire, in the caverns of Gower in Glamorganshire and elsewhere in England. The skulls and other bones of men were long ago discovered by Dr. Schmerling in limestone caverns near Liège, associated with the bones of the Mammoth, Rhinoceros tichorhinus, Cave hyænas and lions, in a way that left no doubt of their having lived at the same period of time in that region so near our own.

These bones in caverns have frequently been preserved in this manner. As already stated, they have been 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 the lower parts of caverns, they lie buried in a red loamy earth mixed with stones. Over this there frequently lies a thick cake of *stalagmite*, or of 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, some of them extinct, that formerly inhabited our land.

Thirty-six British caves have been recorded as holding the remains of terrestrial mammalia. Most of these caves have been excavated by natural processes alone, in Carboniferous limestone, and the others are chiefly in the Devonian Limestone of Devonshire, while a few are in Oolitic or other limestone strata. Among the most celebrated caverns are Brixham Cave and Kent's Hole, near Torquay in Devonshire; Wookey Hole, in the Mendip Hills, Somerset, and Long Hole, Gower, Glamorganshire and others in the north of England, all of which contain remains of man or his works, such as flint implements and bone needles. Along with these in the Brixham Cave are three species of bears, *Ursus arctos* (the Brown Bear), *Ursus spelæus* (Cave Bear), and *U. ferox*; the Fox, the Wolf, and *Hyæna spelæa*; *Felis spelæa* (in reality *Felis leo*, the common lion); four species of deer, *Cervus megaceros* (often erroneously named the Great Irish Elk), *Cervus tarandus* (Reindeer), *C.*

capreolus (Roe-deer), *C. elaphus* (Red-deer); *Bos primigenius* (Auroch); the Horse; *Rhinoceros leptorhinus*; *Elephas primigenius* (the Great Hairy Elephant or Mammoth); Rabbits, Hares, and *Lagomys spelæus* (now living in Siberia, and sometimes called the Rat-hare). In Kent's Cavern, Toquay, the same species occurred, together with Common Shrews, *Meles taxus* (the Badger), Ermine, *Lutra vulgaris* (the Otter), *Machairodus latidens* (a large Tiger?), Pigs, *Rhinoceros tichorhinus*, *Arvicola pratensis*, *A. agrestis*, *A. amphibius* (the Bank Vole, the Field Vole, and the Water Vole), a Beaver *Castor fiber*, and the Common Mouse, *Mus musculus*. The same kind of assemblage of animal forms is found in Long Hole and in Wookey Hole, and as yet, without relics left by man, in the caves of Bleadon, Kirkdale, and in Spritsail Tor, Gower, Glamorganshire, and in many others.* On the whole the most

* These lists are taken from a paper by Mr. Boyd Dawkins, who has worked most successfully at this subject, 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 erythrogenoidos, 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.

prevalent forms are Bears, Otters, Foxes, Wolves, Hyænas, Panthers, Deer, Oxen, Pigs, Rhinoceros, Elephants, and Field Mice.

After the elevation of the country that succeeded its partial depression under the sea during the drift part of the Glacial period, the probabilities are that England was again 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-drift over part at least of the area now occupied by the German Ocean. Across this plain many animals migrated into our area, some of them 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 Drift period, like England, was partly submerged, so as to form a group of small islands; and, therefore, to allow of the country being reinhabited 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 the late Professor Edward Forbes, who drew attention to some remarkable observations made by the late 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 there are also 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 aud 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 distance 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. 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 now 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 at a considerable distance 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 church-yard 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 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 about 200 yards from the shore, and since the farmer first settled there as much land has been wasted away as that which now lies 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 Dorsetshire, where Oolites and Chalk form the cliffs, 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 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 out seaward, 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 that southern coast of Dorsetshire, 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 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. Indeed, all along the west coast, where solid rocks prevail, the hardest masses usually form the 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. 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 mention these things 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 the main land by denudation, and oscillation of level, the statement is founded on excellent data.

CHAPTER XIII.

BRITISH CLIMATES AND THEIR CAUSES — RAINFALL IN DIFFERENT AREAS—AREAS OF RIVER DRAINAGE.

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 drawn by Captain Maury. One great current begins in 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 first passes E. and then NE., across the Atlantic and so reaches the European area of the North Sea. 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. Fifteen 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 the map 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. 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 comes laden with moisture across the land, warm and moist from the sea where the Gulf Stream flows.

In the extreme south-west of England, in Cornwall, from 22 to 47 inches of rain fall every year; and the average for the county may be taken at about 36 inches. In Devonshire the rainfall varies from 16·64 and 19·87 at Sidmouth, to 52·33 inches on Dartmoor. In Somerset from 19·06 at Taunton, to 36·76 at West Harptree. In Dorset from 18·45 at Abbotsbury, to 29 inches at Blandford. In Wiltshire from 18·14 at Chippenham, to 25·25 inches at Salisbury. In Hampshire from 16·51 at Aldershot, to 26·90 inches in Woolmer Forest. In Sussex from 18·18 at Hastings, to 32·79 inches at Chichester. In Kent and Surrey from 16·38 at Margate, to 28·90 inches at Cranbrook. In Middlesex from 16·22 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 about 37½ inches, in Glamorganshire 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 38·02 inches. In Anglesey 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 21 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 is about 30 inches, at Bolton 40, 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 113 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 45 inches annually. As we pass eastward it decreases, but on the highest grounds of Yorkshire and Northumberland there are places where it rises from 40 to 50 inches, while in the low ground at Doncaster on the east it falls to about 21, at Newcastle to about 24, and at Shields on the coast to 22 or 23.

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. On the west coast of the same county, where the land is lower, and in the islands, the rainfall varied from about 19 to 59 inches. In Fife the fall is from about 18 to 25 inches, in Midlothian from 16 to 27, and in Haddingtonshire from 17 to 23. The same rule of decrease of rainfall therefore prevails in Scotland that prevails in England, and it is needless to multiply instances. The climate, therefore, of Great Britain varies in the fall of rain, and the average temperature of the western area is also 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 Anglesey 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.

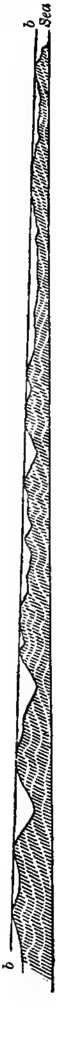
In England, the Tyne drains 1,100 square miles, the Tees 774. If we take the Trent and the Ouse as draining one area, the immense extent, for such a country as ours, of about 9,550 square miles are drained into the Humber. The Witham, the Welland, the Nen, and the Great Ouse, flowing into the old estuary 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 XIV.

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 rather impossible, even approximately to settle precisely what are the geological dates of the valleys through which the 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 analysed this subject, and for my part, I only begin to see my way into it. Nevertheless a little may be done even now, and a great deal 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

Fig. 31.



when we examine the relation of these streams to the present surface of the country, we often find it very remarkable. Fig. 31 (Map, line 14) is a diagram representing no particular section but simply the nature of the real sections across 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 straightedge, 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 (as indicated in fig. 28) 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 New Red Sandstone, *this inclined line that touches the hill-tops must have represented a great plain of marine denudation.*

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 plain 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 a great 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. 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. 28, 'the higher land, as it now exists, is only the relics of an average general gentle slope, represented by the straight line (*b b*) drawn from the inland heights towards the sea.' * 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 have been made by the long-continued action of atmospheric waste and running waters; and I believe that the South Wales valleys have been formed in the same way.

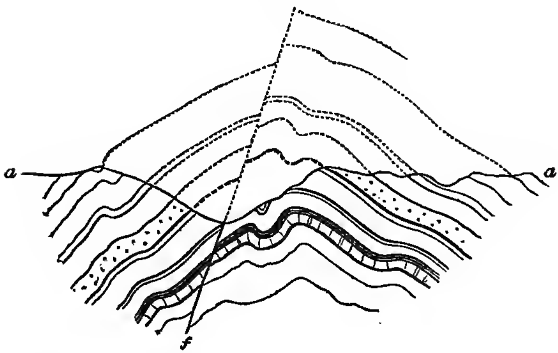
Nothing is more remarkable in the history of rivers than the circumstance that very frequently they run

* Reports, British Association, p. 66, 1847.

straight through bold escarpments, which at first sight we might suppose ought to have barred the course of the streams.* 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 dis-

Fig. 32.



a Present surface of the ground.

The dotted lines show the continuation of an anticlinal curve broken by a fault *f*.

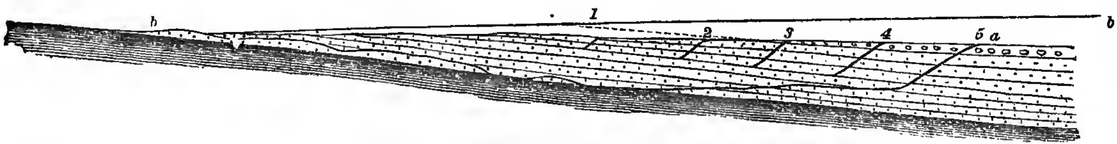
The dotted lines above the surface *a a* represent a certain amount of strata removed by denudation.

turbances 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

* This has already been alluded to in the case of the rivers of the Wealden, pp. 108–119.

Fig. 33.

Diagram 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.

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 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 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, now 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. 29), the result of earlier denudations there. This plain sloped gently eastward, and the dotted lines show 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 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, which I described in Chapter X., 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 as now; 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 great valley between the old Palæozoic hills, and the escarpment formed by the table-land of the Cotswold range, that rises so high 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.

Then 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

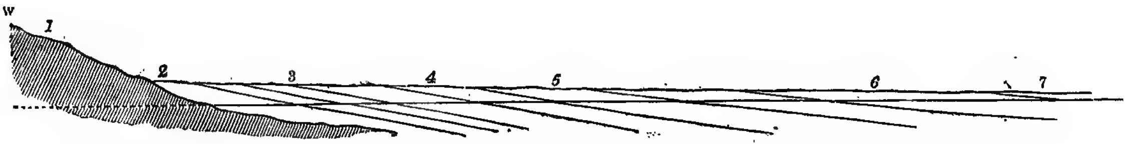
Oolitic strata still abutted on the mountain country now forming Wales and parts of the adjacent counties. They also completely covered the Mendip Hills, and passed westward as far as the hilly ground of Devonshire, running out between Wales and Devonshire through what is now the Bristol Channel. The 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, 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 the following figure 34.

The submersion of this low-lying area brought the

Fig. 34.

General Arrangement of the Lower Secondary Formations before the Deposition of the Secondary Strata.



1. Disturbed and hilly Silurian Old Red and Carboniferous strata. 2. New Red beds. 3. Lower Lias. 4. Marlstono and Upper Lias. 5. Lower Oolites. 6. Middle Oolites. 7. Upper Oolites and Purbeck beds.

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. 35, on next page.)

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.

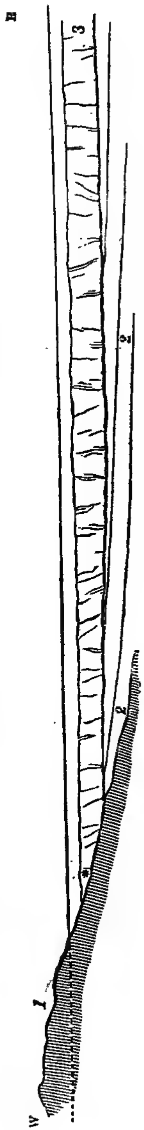
At this time the mountains of Wales, and other hilly regions made of Palæozoic rocks, must have been lower than they were during the Oolitic epochs; partly by the effect of long-continued waste due to atmospheric causes, but much more because of gradual and greatly increased submergence during the time that the Chalk was being deposited. It is even possible that during that period Wales sunk almost entirely beneath the sea.

I omit any detailed mention of the phenomena connected with the deposition 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

Fig. 35.

Early Overlap of the Cretaceous Strata on the Lower Secondary Formations.



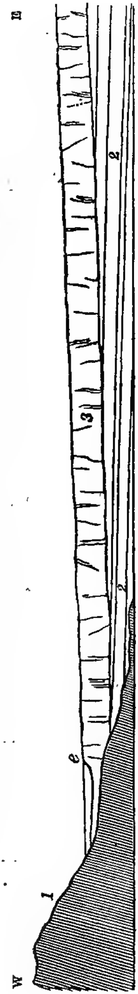
1. Disturbed hilly land, as in fig. 34. 2. New Red Liassic and Oolitic strata, &c. 3. Cretaceous strata lying *unconformably* on and overlapping the denuded edges of No. 2, and at * abutting on the half-submerged mountains of Wales.

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 freshwater 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 low lands of Switzerland began then to be established, long after 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 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,

Fig. 36.

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.

as shown in fig. 36, 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 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. 33, 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 low lands of England.**

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. (Fig. 20, p. 108.)

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

* Many of the valleys of Wales may be much older.

the initial course of the Severn would also have been easterly, like that of the Thames and the rivers that flow into the Wash and the Humber.

This 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 fairly 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 of course east of the comparatively newly formed escarpment of the Chalk indicated by the dark line in fig. 36 marked *e*. The present Chalk escarpment in its beginning is thus of older date than the Oolitic escarpment (fig. 11, p. 74), though 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 drained 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 the north flowing rivers of what we now call the Rhine and its tributaries. At its other 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. 218). But by processes of waste identical with those that formed the escarpment of the Wealden (figs. 21, 22, 23, pp. 110–114), the Chalk escarpment gradually receded eastward, and as it did this the valley of the Severn widened, and the area of the Thames drainage contracted.

By-and-by the outcropping edges of the Oolitic strata becoming exposed, a second 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 was 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 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 course, 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 denundations, 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.*

The same kind of argument that has been applied 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

* See Mr. T. Codrington 'On the Superficial Deposits of the South of Hampshire and the Isle of Wight.' Quart. Jour. Geol. Soc., 1870, vol. 26, p. 528, and Mr. John Evans, 'Stone Implements,' Chap. XXV.

plain of Oolitic strata. Through long ages of waste and decay the Lias and Oolites have been washed away form these midland districts, and the long escarpments fromed 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.* There are no fractures there of any importance. The true explanation is as follows:

At an older priod 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*

* '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 casee, 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.'

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of marine denudation,' stretched eastwards, giving 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, also got 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 the distance from the rise of the river; because the farther it 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 mere case of the wearing action of running water cutting a channel for itself from high to lower levels, till, where Rowsley now stands, it joined the Derwent, which flows in a long north and south valley scooped 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 completely to overlap uncomformably 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 Ooolite were gradually receding eastward to their present temporary positions.

That the Ooolitic 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 coal-field 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 before the Oolitic escarpment began to be formed.

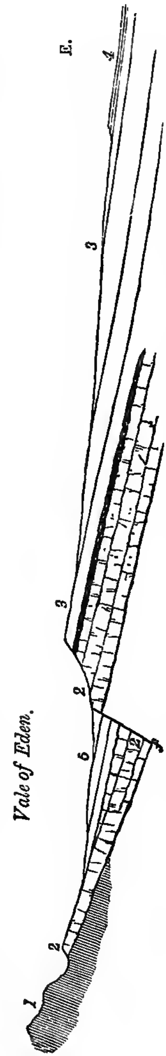
Taken as a whole, from the great escarpment of Carboniferous limestone that overlooks the Vale of Eden on the east, all the Carboniferous strata from thence to the German Ocean have a gentle eastern dip; so gentle, indeed, that, on Mallerstang and other high hills overlooking the Vale of Eden, outlying patches of the lower Coal-measures, or Gannister beds, 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 coal-field was then united to that of Northumberland. These gentle eastern and south-eastern dips (the latter from the borders of Scotand), 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 subaërial 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 great steps, till on the tops of the hills we reach the Millstone grit itself.

I now turn to the western rivers of England, about which there is far less to be said.

First, the Eden. This river flows along the whole length of the beautiful valley of that name, through 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 some extent, and also that the Lias was probably covered by Oolitic strata. As these 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. 35. 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

Fig. 37.

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.

rivers of the west of England—the Lune, the Ribble, the Mersey, and the Weaver; unless, indeed, some of these rivers, including the Dee and the Clwyd, had their western courses determined by that post-Miocene western tilting of the strata that, I believe, originally established the greater part of the channel of the Severn.

Of the Conwy, and the western flowing rivers of Wales, all that can be said is, that they may have begun far back during an unknown epoch, for the country has been above water to a great extent, *at least* ever since the Permian and New Red beds were deposited. 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.

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 much more difficult.* Something of the subject I know myself, but for fuller

* Professor Geikie, who fully realises the difficulty of the subject, nevertheless enters into it, and explains it as far as present knowledge will allow, in his work, the 'Scenery and Geology of Scotland.'

details the reader must refer to Professor Geikie's work, from which much 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 formations of Scotland is from south-west to north-east, and starting from the water-shed of the north-west of Scotland between Loch Linnhe and Cape Wrath, it will be seen that almost all the 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 water-shed 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, having 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 water-shed that crosses Scotland from the neighbourhood of Peterhead to Crinan. 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 great rivers ran in that area before the commencement of these deposits, and indeed for very long before that period. But we have no perfectly 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 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.*

* 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 Oölitic and Cretaceous escarpments, pp. 221–223.

CHAPTER XV.

RELATION OF RIVER VALLEYS AND GRAVELS TO THE GLACIAL DRIFTS—RIVER TERRACES—BONES OF EXTINCT MAMMALS AND HUMAN REMAINS FOUND IN THEM—RAISED BEACHES, &c.

It is certain that by far the larger part of the river valleys of Britain north of Bristol Channel and the Thames, *have been very much modified, and many 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, however, been partly scooped out since the Glacial period.

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 during partial submergence, the Boulder-clay overspread great part of England, 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.

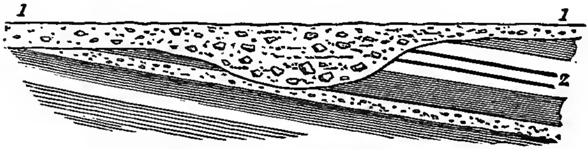
'The Pre-Glacial valley,' says Mr. H. H. Howell, in a letter which I quote, 'runs nearly north and south from Durham to Newcastle. The river Wear, instead of following this old valley, meanders about, winding in and out of it, and at Durham cutting right across it, and passing into the sandstones of 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.'*

It is for this reason that coal miners in Northumber-

* 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.

land and Durham, while mining a bed of coal, sometimes find it crop up deep underground, against a

Fig. 38.



ou lder-clay filling a valley. 2. Coal-measures with beds of coal.

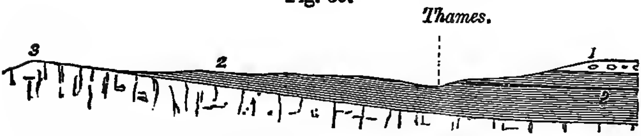
mass of Boulder-clay that fills an ancient rocky valley of which the plain above gives no indication.

Again, if we examine the channels of other rivers in the south-east of England, we find that in places the Ouse and its tributaries in Bedfordshire and 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 overlook the Severn, which runs in the valley about 1,000 feet below. The infant

Thames thus flows at first across a broad table-land of Oolitic rocks, and by-and-by comes to a second table-land 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. 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 table-lands which overlook the valley of the Thames covered with Boulder-clay. These deposits, stopping

Fig. 39.



1. Boulder-clay. 2. London clay. 3. Chalk.

suddenly on the edge of a slope, suggest that the lower part of the Thames valley may perhaps have been chiefly scooped out since the Glacial epoch.

The valley of the Thames at and above its estuary is partly filled with gravels, sands, and fine loam or brick-earths, some of them containing freshwater and land shells, and the bones of the Mammalia, deposited by the river in an older stage of its history before its channel was cut down to its present level; and if it be true that this part of the Thames valley has been scooped out since the deposition of the Boulder-clay, then these alluvial deposits are of later age than that formation. But this is doubtful. There are no recognised Boulder-beds in England anywhere in or south of the valley of the Thames, and it may be that part of the ancient alluvial deposits of the river are contemporaneous with the Glacial epoch, or even of somewhat older date.

There is, however, clearer evidence bearing upon the question of the comparative age of river deposits in many parts of England. The Bedford gravels widely spread on the banks of the Ouse are *seen* to overlie Boulder-clay, and all the alluvial strata of the Wash, of various minor ages, are known in places to rest upon it. The same is the case with the *warps* old and recent of the Humber, and of all the loamy alluvial strata that cover the broad plain of York, and pass northward to the mouth of the Tees, between the great Oolitic escarpment and the western slopes of the Magnesian Limestone and Carboniferous rocks. The gravels and the loamy 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, below certain undetermined levels, 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 entirely, and when flooded spreading sediments abroad on their banks. In these deposits a great many bones of Mammalia are found, many of which are of extinct species.

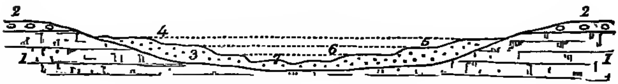
I have already stated (p. 157) that after the deposition of the Glacial deposits, Britain, by a considerable elevation of the land and sea-bottom, was reunited to the Continent by a broad plain of Boulder-clay. Through this plain I think that the Rhine must have wandered in pre-historic times to what 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 drift or Boulder-clay from the manner in which it was thrown down had a very irregular surface, enclosing lakes and pools, some of which may still be seen in what remains of it on the plains of Holderness. The present mouths of these British rivers had no immediate relation with their ancient mouths. The places of their present mouths then lay far inland, and in some cases it seems not unlikely that their existing alluvial gravels, such as those of Bedford Level, may have been deposited in lakes, dammed up by the Boulder-clay of the great plain through which the rivers flowed. It is often difficult to account for the thickness of these gravels on any other hypothesis, for in many cases they are not estuarine, that is to say, where the rivers entered the sea; but purely freshwater inland sedimentary deposits, containing no organic forms excepting those of land and freshwater shells, of land animals, and occasionally trunks of trees and other plants.

On the banks of the Thames, and many other rivers, there are frequent terraces. It is one of the effects of the past and present progressive action of rivers to form terraces upon their banks; close to or at various distances from any river as it now is, according to its size and other circumstances. Sometimes these terraces have been cut out in solid rock, more frequently in Boulder-clay, or in old gravels which the river itself had deposited. Cases such as the following are frequent. The hills 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 table-land with Boulder-clay, No. 2, and bounding a wide valley partly filled with ancient gravel, No. 3, which originally filled the valley from side to side as

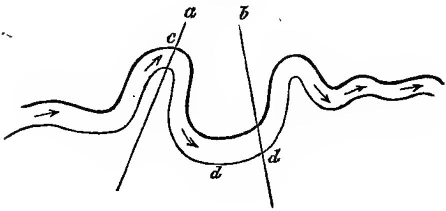
Fig. 40.



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. Or again, in other cases (as in the Moselle, the Seine, and also in many British rivers), where no more anciently excavated valley existed before the drainage took the general direction of its present flow, the river has excavated its own valley by the destruction of the solid rocks through which t flows.

Suppose a river flowing in a sinuous channel in the direction in which the arrows point in the following diagram :—

Fig. 41.



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

Fig. 42.

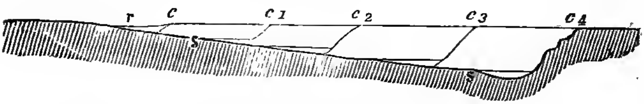
on is projected with great force against the concave part of the curve, *c*, figs. 41 and 42, and in like manner it is again strongly projected against the concave cliff,

Fig. 43.

d, figs. 41 and 43. 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*, figs. 42 and 43, 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 figs. 41 and 42, *c*, as an example.

Fig. 44.



On a high table-land the river, *r*, at an early period of its history, flowed where it is marked in fig. 44, the beginning of the curve, *c* (fig. 41), 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 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, and 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 drift, 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. This is the way in which such rivers act, and have always acted.* In many a British river it is clearly seen: on the Wye of South Wales, the Thames, and in many a river and minor stream in Derbyshire, Lancashire, Yorkshire, and elsewhere.

In the occasional terraces which accompany the formation of river valleys, and in outlying patches of old river gravels that sometimes even cap minor hills, it often happens that alluvial and gravelly deposits are left marking ancient levels of the rivers; and in such gravels, sands, and loams (fig. 40), the bones of animals of extinct and living species have been often found, together with the handiwork of ancient races of men.

Viewed as a whole, the animals found in these river beds are now generally believed to be mostly of post-Glacial age, and in this opinion I partly coincide. They are also, to a great extent, identical with those

* I first clearly understood this subject while studying the Moselle in 1860.

found in the British bone-caves. By reference to page 187 it will be seen that many of them are also found in the cave and river deposits; the remainder as yet being absent, though there seems to be no reason why most of them should not hereafter be found.* They consist of the White and Cave Bears, the Ermine, the Otter, Fox, Wolf, Hyæna (*Spelœa*), Lion, the Red-deer, Reindeer, and *C megaceros*, the Musk-sheep, Ox and Bison, Hippopotamus (*major*), Pig, Horse, two species of Rhinoceros, two species of Elephants (*E. primigenius* and *E. antiquus*), the Rabbit (*R. leptorhinus* and *R. hœmitœchus*), Hare Rat (*Lagomys spelœus*), Spermophilus a Squirrel, and Mouse.

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

* 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.

shells, and along with these shells the teeth of the Mammoth. Below that there occurred white sand and freshwater 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.

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 hatches 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 since 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—lying 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, 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 have fallen from the top of a cliff of Eocene sand capped with river gravel of the ancient Thames. These were first noticed by Mr. T. Leech, and I myself found one on the beach, partly water-worn by the waves. At the same time, Mr. T. McKenny Hughes found another, fresh and unworn. No bones have as yet been observed in that district along with the implements. But it is 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 men.

As yet, however, the bones of man have never in our country been discovered along with extinct mammals in the gravels, unless we get a hint on the subject from the discovery of human skulls fifty-three feet beneath the surface at the Carron tin stream-works, north of Falmouth, along with bones of Deer, &c.* As already stated, his works are, however, well known associated with such mammalia in Kent's Hole and Brixham Cave, near Torquay; in the caves of Gower, Glamorganshire, and in other British caverns. 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, as previously mentioned. Further, in the surface strata called the Loess of the same river near Maestricht, human skeletons are said to have been actually found. I have seen these bones, which certainly have an antique look, but some doubt exists as to their authenticity. 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 as far back as the time when the country was united to the main land, and that,

* 'Geological Report on Cornwall, Devon, and West Somerset,' 1839, p. 407. 'The Geological Observer,' 1853, p. 449. Sir H. T. De la Beche.

along with the great hairy Mammoth, the Irish Elk, the Rhinoceros, 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 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 occasionally 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.

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 in the very same beds in which the remains of these marine mammalia have been discovered 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 historical, and even since the Roman occupation of our island.

There is one piece of evidence with respect to the very 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; and therefore he 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 at Carriden, on the top of a considerable cliff, 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.*

* With regard to the lists of Mammalia, pp. 134, 187, 248, I have held for years that the Indian Elephant is a mere variety of the Mammoth (*E. primigenius*). Mr. Busk has lately declared that *Hippopotamus major* is identical with the living *H. amphibius*. Other cave and river mammals, as is the Lion (*F. spelæa*), may, in time, also be recognised as belonging to living species.

CHAPTER XVI.

QUALITIES OF RIVER-WATERS — DISSOLVING BY SOLUTION OF LIMESTONE ROCKS.

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 water-sheds 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, as a rule, 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 feldspathic 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 tinged with 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,* 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, 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 coal-field, 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 large reservoirs have been constructed in the Millstone grit regions of Lancashire, Yorkshire, and Derbyshire, for the supply of large towns and cities such

* Properly Plymlumon.

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 are of hard water that flow into the sea on the eastern and southern shores of England, as far west as Devonshire. 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 ore 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; etc. etc.—altogether, with other 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 square column of 3 feet 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.

Again, 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, and therefore not far from the highest part of the Oolitic table-land 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 8,332 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 187,477 grains per second passing seaward. This is equal to nearly 96,417 lbs. per hour, 2,314,004 lbs. per day, or 377,058 tons a year;* and this amount is almost entirely dissolved *out of the bulk of the solid rocks and surface soils of the country*, and is passing out to sea in an invisible form only known to the analytical chemist.

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 1,131,174 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 though the waters, as a rule, are much softer than those of the east of England, it would perhaps not be

* Mr. Prestwich, on slightly different and perhaps better data, makes the quantity 290,905 tons annually. 'Anniversary Address to the Geological Society,' 1872, p. 43.

much over the mark to estimate the average amount of salts in solution at about one-fifth of what is assumed to be in the eastern rivers, and we should therefore get about 377,000 tons; making for England in all, about 1,885,000 tons per annum. In a year this would give about a square mile of rock a foot thick, in 1,000 years about 1,000 square miles, and in 10,000 years—a small item in geological time—10,000 square miles, or 3,040 square miles one yard thick.

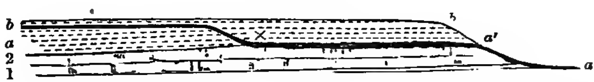
If we could take all the rivers of the world into the calculation, how great the amount must be. The St. Lawrence alone drains an area of 297,600 square miles, three and a third times larger than the whole of Great Britain, and that of the Mississippi is 982,400 square miles, or more than three times 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

Lawrentian 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.

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. 45.



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 x, 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 north and west 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 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, Derbyshire, and 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.

CHAPTER XVII.

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 frequently come bare to the surface over great areas. Strips of more 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 kind 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 ground being mostly high is to a great extent untilled, though excellently adapted for pastoral purposes. Where, however, the slopes descend, and are covered more or less with old ice-drifts and moraine-matter, the soil 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 a bare and unwooded pastoral character in the upper parts of their courses, gradually passing, as they descend and widen, into 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 part 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 coal-fields, 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, except when formed of limestone, and then mountain grassy pastures are apt to prevail. The deep 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.

The same general pastoral character is 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 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 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 and fertile margins, above which rise the wild hills of North and South Wales. The Towey of Caermarthenshire, the Cothi, and all the larger rivers of Glamorganshire, the Usk and the Wye, are unsurpassed for quiet and fertile beauty. No inland river 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 hill 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 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. The soil is thus deepened and more easily fitted for purposes of tillage; but on the whole the moist character of the climate of Wales and Cumberland, and of much 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 well water-worn rounded pebbles, of various kinds, but chiefly of liver-coloured quartz-rock, derived from some unknown region, and of siliceous 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 Bridgenorth, lie almost entirely upon these intractable gravels, or on other barren 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.*

In the centre of England there are broad tracts of land composed chiefly of New Red Marl and Lias clay. When we stand on the summit of the great escarpment, formed by the Oolitic table-land, 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 on the surface it moulders down, it

* 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.

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 drift.

It is worthy of notice that the fruit tree districts 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 better adapted for fruit trees than any other in Britain.

The Lias clay in the centre of England, though often 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 towers built of the brown limestone of the formation.

Ascending on 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 Kimmeridge Clays, are of great thickness, and spread over considerable 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 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 being 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 Kimmeridge Clay that lie between the western part of the Oolite and the base of the Chalk escarpment are in great 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 Kimmeridge 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 siliceous, and, in places, intermingled with veins and strings of siliceous 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 escarpment of the Lower Greensand and the Chalk, there are many beautiful and fertile valleys rich in fields, parks, and noble forest timber.

Between the slopes of the Greensand and the escarpment of the Chalk there is a long narrow 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 help and deep drainage. In many places it is covered by loamy brick earths, on which the finest of the hop gardens of that area lie. Similar brick earths often occupy the low banks of the Thames in Kent, also famous for hop-grounds, and for those extensive brick manufactories so well known in the neighbourhood of Sittingbourne.

The Hastings Sands for the most part consist of very fine siliceous sand, interstratified with minor beds of clay, and they lie in the centre of the Wealden area, forming the undulating hills that lie 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 sort of loam; so fine, indeed, that when dry it may sometimes almost be described as an impalpable siliceous 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.

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—'the bushless downs'—and they are still largely used for pasturage, yet here, also, cultivation is gradually encroaching. On the steep scarped slopes overlooking the Weald the chalk generally 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 these escarpments, and some of great extent, now deserted and overgrown with trees, form beautiful features in the landscape.

West and north of the London basin the Chalk generally lies in broad undulating plains, forming a table-land of which Salisbury Plain may be taken as a type. Within my own recollection, these plains were almost entirely devoted to sheep, but are 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 Wilts, Berkshire, and Herefordshire, and on the chalk both north and south of London. It has often been left uncultivated, and forms commons, or furze-clad and woody patches. Occasionally the clay is used for making bricks. In the east part of Hertfordshire and Suffolk the Chalk is entirely buried under thick accumulations of glacial drift, which completely alters the agricultural character of the country.

The clay 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 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, and the east of Essex, for the most part forms a stiff tenacious soil, somewhat lightened by the presence of stones and often sufficiently fertile when well drained. The great plain of the Wash consists partly of peat on the west and south, but chiefly of silt. These broad flats, about 70 miles in length from north to south, and 40 in width, include an area of about 1,000 square miles.

In wandering over the district one is constantly reminded of the flats of Holland. The whole country is traversed by well-dyked rivers, canals, drains and trenches, and walking in the fields behind the dykes, when the tide is up, good-sized vessels are seen sailing on the rivers much above the level of the spectator's head. The same impression 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. 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 many 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 drift 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.

CHAPTER XVIII.

RELATION OF THE DIFFERENT RACES OF MEN IN BRITAIN TO THE GEOLOGY OF THE COUNTRY.

I SHALL now say a few words on the influence of the geology upon the inhabitants of different parts of our island.

Great Britain is inhabited by several races, 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 other races now intermixed, and in less degree with the earlier Celtic inhabitants, who themselves on their coming probably 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 were savage hunters, 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.*

However this may be it is certain that about 2,000 years ago both sides of the English Channel were inhabited by people speaking a Celtic tongue (Cæsar), and who, in the south-east of England, were mingled with fair-haired and blue-eyed Belgæ, who in time had been absorbed among the Celtic population, and then spoke their language. The modern descendants of these people are the Welsh (Cymry) and Cornish men; but I consider that at that period a distinct tribe of

* 'Journal of the Ethnological Society,' vol. ii. 1871, pp. 382, 404.

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 it may be proved that the ancestors of the original Scottish Highlanders (who, however, are now largely intermixed with Scandinavian blood) once spread, not only much further south than the borders of the Highlands, but that they even occupied the Lowlands of Great Britain generally, for the names 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.

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 ancient 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 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 (*Avon*) is the same.

Again in Wales itself, 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.

If the earlier inhabitants were Gaelic, then 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 even creeping round the eastern coast north of the Tay, and occupying the lowlands of Caithness. The Gael would not willingly have confined themselves to the barren mountains, if they could have retained a position on more fertile lands. The proof of this as regards Wales is, that as late as A.D. 597, 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 * (Gael) of the

* Gwyddel literally means dwellers in the Forest, Forestieri, Waldmen, Welsh.

Welsh,* who were slowly retiring before the advancing Cymry, and the last relics of whom, expelled from the coast, finally sought refuge with their kindred people in Ireland. The names of many of the churches of Anglesea, and of the west of Wales generally, derived from old Saints, were given by the Gwyddel, before they were finally expelled.

Thus, I believe, it happens that the Highlands of Scotland, beyond the Great Valley, are chiefly inhabited by the Gael. 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 the 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; Cumberland (*Cymru*); and at Bath, by the Avon, we have 'Dolly (*dolau*) meadows'; near Birmingham

* See 'The Four Ancient Books of Wales,' Skene, vol. i., p. 43.

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*) Arran, 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, said to have been a native of the ancient kingdom of Strath Clwyd, which stretched through the west country from Dumbarton over Cumberland as far south as Chester.* In Mr. Skene's opinion, it records a battle, fought on the shore of the Firth of Forth sometime between A.D. 586 and 603.†

* See 'Freeman's History of the Norman Conquest,' vol. i., p. 35.

† 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.

However this may be, it is certain that the British Celts, when the Romans invaded our country, overspread the whole of the southern part of Great Britain. 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 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, slain or dispossessed of their territories and slowly driven westwards, retreated 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 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 mountain lands, while the lower and more fertile hills, the plains and table-lands, and Scotland south of the Grampians, are chiefly inhabited by the descendants of 'the heathen of the northern sea,' 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 XIX.

INDUSTRIAL PRODUCTS OF THE GEOLOGICAL FORMATIONS—ORIGIN OF LODES—QUANTITIES OF AVAILABLE COAL IN THE COAL-FIELDS—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 Carnarvonshire. 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 almost equal importance collectively, occur in the Pass of Llanberis, and there are 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 (Llandeilo beds) near Ffestiniog in Merionethshire. There are also 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. The periodical blastings, twice a day, 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, is rapidly destroying the beauty of one of the most romantic lakes in Wales, and threatens in the long run to fill it from end to end. There are many other smaller quarries in the neighbourhood, while in Merionethshire, near Ffestiniog, some are worked in caverns instead of open day. The number of men and boys employed in the Ffestiniog district in January 1872 was about 3,350.* There

* This fact was supplied to me by the kindness of Mrs. Percival of Bodâwen.

are also slate quarries in South Wales, Cumberland, and at Easdale in Scotland, but they are all comparatively unimportant 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 great 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, 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, and the hills of the south of Scotland, and here and there throughout the Highlands. In the Carboniferous Limestone they are also found 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 form pretexts for getting up companies which occasionally lure unwary speculators to their loss. This Welsh gold is found in lodes 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 shallow caverns, where the gold-bearing quartz-veins and strings were followed into the hill, and sometimes by actual extensive quarries. Later lofty well-made galleries were driven, which cut the lodes deeper underneath. The gold was also found in washings of the superficial gravel, of nearly a mile in length, on the banks of the river Cothy. The galleries and the washings are Roman, but it has been surmised by the proprietor, Mr. Johnes, that the ruder caverns partly date from more ancient British times. The huge excavations must have made ugly scars on the hills in the days when they were 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, sulphuret of copper, sulphuret of lead, oxide of tin, or with other kinds of ore. Various theories have been formed to account for the presence of ores in these cracks, and to this day the subject is not perfectly clear. 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 may 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. For my own part, I do not doubt that the ores which we meet with in these cracks or lodes were formed by infiltration; 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. If this be 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 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 coal-fields of this formation occur all the beds of coal worth working in Britain. In the South Wales coal-field there are more than 100 beds of coal, about 70 of which are worked somewhere or other. The quantity of available coal in that coal-field has been estimated by Mr. Vivian and Mr. Clark at about thirty-six and a half thousand 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 coal-fields, 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 coal-fields, 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 four hundred and fifty-eight and a half-millions. In Nottinghamshire, Derbyshire, and Yorkshire, one large coal-field, about 19 beds are worked somewhere or other in the coal-field, 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 coal-field 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 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.

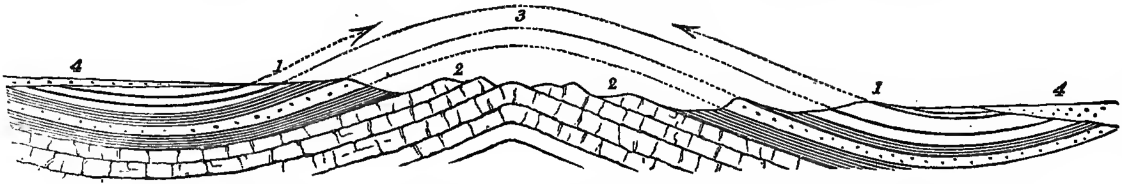
Besides coal and iron, the Coal-measures yield quantities of clays, which are of considerable value. The chief of these is fire-clay, which is used so largely in the manufacture of crucibles and fire-bricks, and in furnaces.

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 coal-fields, as for instance, the coal-fields 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 unconformably 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 in fig. 46, p. 302.

The coal-fields 1, 1, now show at the surface. Strata marked 2 separate them. These we may suppose to consist of Carboniferous limestone *in an anticlinal curve*, as in Derbyshire, and part of the original great coal-field shown by the dotted lines 3, in old times covered 2, and has been removed by denudation. The remaining parts of this original coal-field 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*

Fig. 46.

Diagram showing the Origin of the Basin-shaped form of many Coal-fields.



1. Coal-fields showing at the surface in part. 2. Carboniferous Limestone. 3. Anticlinal curve between the two Coal-fields, which were once joined. 4. Permian and New Red strata covering parts of the two basin-shaped Coal-fields.

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 is the reason why *so many of our coal-fields lie in basin-shaped forms.* And this form is quite independent of Permian and Secondary strata lying on the coal-beds. Thus the South Wales and Forest of Dean coal-fields were never covered by these formations, and both are basin-shaped, and form with the Bristol and Mendip Coal-field parts of one original coal-field, now turned into three coal-basins by disturbance and denudation.

All the existing coal-fields of England, and I think I may add of Scotland north of this, also once formed one coal-field; and these also have been separated by disturbances which threw their strata into long anticlinal and synclinal curves. The Staffordshire, North Wales, and Lancashire coal-fields were one, and these were united to the Warwickshire, Leicestershire, and Nottingham and Derbyshire coal-fields, which again joined that of Durham and Northumberland, which again was united to the coal-fields of Cumberland and probably of Scotland. They have been disjoined by curvature of the strata combined with denudation, and the Northumberland, and Yorkshire coal-fields, are now independent basins, partly buried under Permian and New Red Sandstone strata. And so, of the other visible coal-fields, Warwick, Leicester, South Stafford, North Stafford, Cheshire, Lancashire, and the North Wales coal-fields are still probably one coal-field, only great parts of them are buried and therefore 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 coal-field as an example, where the New Red Sandstone and Permian rocks are thrown down against the coal-field 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, or Permian and New Red, portions of them down against the sides of the present coal-field. 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 coal-fields 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 coal-fields, 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 coal-field 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 coal-fields, 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 the coal-fields themselves now are. Between the mouth of the Firth of Clyde and the mouth of the Firth of Forth the whole country is one great coal-field, 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 coal-fields, and these districts also contain dense populations. Further north lies the great Newcastle coal-field, where, again, the population is proportionately redundant. All the central part of England, which is dotted over with coal-fields, teems in like manner with inhabitants. The South Wales coal-field, 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 by no means worked to the same extent as in the coal-fields 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 'Coal-fields 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 131,700,000, 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.'* 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 manufacture of unnecessary smoke. All the centre of England is thick with it, floating from every coal-field and from all the dependent manufacturing towns. The heaths and pastures of Derbyshire and Yorkshire between the two great coal-fields are blackened by smoke, and even in the rainiest weather the sheep that ought to be white-wooled are dark and dingy. Every coal-field 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 sanatory, and therefore in a moral point of view, and this state of affairs is too apt to

* 'Report of the Coal Commissioners,' pp. 16 and 17.

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 hideous heaps of slag so suggestive of wealth 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 table-lands 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 will come when the beautiful Oolitic valleys of North Yorkshire may become a black country as smoky as the Lancashire and Staffordshire coal-fields.

The Northampton Sands of the Oolites also yield large quantities of siliceous 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 even here and there we may now see heaps of slags overgrown with grass, and the old dams which supplied the water that drove the water-wheels that worked the forges of Kent and Sussex. It is said that the cannon that were 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 also 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 coal-fields, 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 coal-fields. 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.

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, 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, stone-ware, 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 Kimmeridge 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 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 an important 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 siliceous 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 soon after the time 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, and the limestone from quarries in Anglesey, 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, and in the neighbourhood of Leeds and Edinburgh, afford a large quantity of admirable building material, which has been used almost exclusively in the building of these towns. Some of it is exceedingly white, it 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, forms dark stains which discolour the exterior of the buildings. 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 of 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 originally was the result of the solar evaporation of an inland salt lake, like, for example, the waters of 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 supersaturation 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.*

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

* For a full account of the physical formation of these deposits, see Journal Geol. Soc., 1871, vol. xxvii., pp. 189 and 241.—Ramsay.

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 Anglesey yield a beautiful material for ornamental purposes.

I have now attempted to give an idea of the general physical geography of our country, as dependent on its geology. I first described the classification of rocks. I divided them into two classes, and one sub-clas ; consisting of aqueous rocks formed by the action of water, igneous rocks by the action of heat, and of metamorphic rocks most of which were originally stratified, but have since been acted on by heat and other influences. I then showed the distribution of these rocks over our country. They have been affected by disturbances and denudations—so 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 not being so much disturbed, and being younger, have never been so much denuded, and therefore form plains and table-lands.

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 most of those great hollows in which our 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 large rivers chiefly drain to the east, and excepting the Severn 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. These axes of disturbance belong to very different periods. 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 original languages, but gradually mingling now, as they did before, with the great 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 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 enquire 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, by great plains of Boulder-drift. Such is the deliberate opinion of some of our best geologists, and also that these prehistoric 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 they travelled westwards into what is now Britain from the Continent of Europe, along with these extinct mammalia. The country was then most probably covered by great forests, swamps, and lakes, unless it may have been that the Chalk downs and the high mountain-tops were bare.

But in far later times, denudations and alterations of level having again taken place, our island became again 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 great 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 the immediate contact of 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,* we have been enabled, with but little disturbance, progressively so to develop our own ideas of religion, of political freedom, and of political morality, that we now stand one of the freest and most prosperous countries on the face of the globe. If we act as we ought to do, we may still improve. There is plenty of room.

* The miserable French descents in Pembrokeshire and Ireland do not deserve the name of invasions.

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[P. T. O.

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