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Explanatory Notes.

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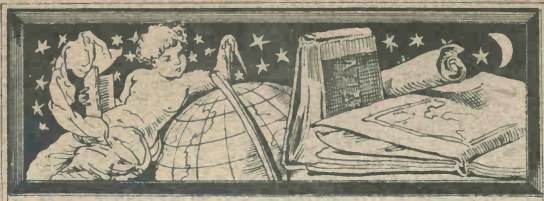

COMPANION MAP TO ENGLAND AND WALES

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A NEW
GEOLOGICAL MAP
OF
SCOTLAND

Reduced from the
Ordnance and Geological Surveys

UNDER THE DIRECTION OF

SIR ARCHIBALD GEIKIE, D.SC., LL.D., F.R.S.,

Director-General of the Geological Survey.

ACCOMPANIED BY DESCRIPTIVE MEMOIR.

Topography by JOHN BARTHOLOMEW, F.R.G.S.

Scale, 10 Miles to an Inch.

JOHN BARTHOLOMEW & CO.,

The Edinburgh Geographical Institute,

THE EDINBURGH GEOGRAPHICAL INSTITUTE

EXPLANATORY NOTES

TO ACCOMPANY A NEW

GEOLOGICAL MAP

OF

ENGLAND & WALES

BY

SIR ARCHIBALD GEIKIE, D.C.L., D.Sc., F.R.S.

Director General of the Geological Survey

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1897

EXPLANATORY NOTES

TO ACCOMPANY THE

Geological Map of England and Wales

SINCE the appearance in the year 1815 of the first general geological map of England and Wales, by William Smith, numerous maps of the whole and of parts of the country on various scales have been published. The earliest of these, by G. B. Greenough, was begun while that of William Smith was in preparation, and appeared four years later—in 1819. It passed into the hands of the Geological Society of London, has from time to time been improved, and is still on sale. Its topography, however, compiled and engraved in the early part of the century, was from the beginning imperfect, and its geology has been so repeatedly and extensively altered that its later forms bear only a general resemblance to the original. The Geological Survey, begun in 1835, has now completed the mapping of the whole country on the scale of one inch to a mile, and is issuing a reduction on the scale of four miles to one inch. All general maps now prepared are based on the sheets of this official survey. In 1859, the late Sir A. C. Ramsay, then Local Director of the Geological Survey of Great Britain, published a general map of England and Wales on the scale of twelve miles to an inch. It was a reduction from the Survey maps as far as these had at the time been published. In successive editions it has been improved, and up till now it has been the best available map, but its

topographical basis was too inaccurate for the production of a wholly satisfactory representation of the geology.

Five years ago, Mr. Bartholomew, who had with great labour constructed from the sheets of the Ordnance Survey a general topographical map of England and Wales on the scale of ten miles to an inch, expressed to me his willingness to employ the same plates for the production of a geological map of the country, if I would superintend the reduction from the published maps of the Geological Survey. His map is so good as a general topographical representation of the country, that it appeared to me likely to prove convenient and useful if the geology were inserted on it. Accordingly, his proposal was eventually carried into effect, and the map so prepared is now issued to the public. While the reduction has been made by Mr. Bartholomew's able assistant, Mr. Bosse, it has been repeatedly revised by some of my colleagues in the Geological Survey, as well as by myself. The late Mr. W. Topley, F.R.S., took a large share in the early stages of this labour, and since his death the task has been carried on by Mr. H. B. Woodward, F.R.S., Mr. W. Gibson, and Mr. W. W. Watts. I have drawn the Sections which are placed round the borders of the map to explain the geological structure of the country.

The following brief Notes are intended merely for the general reader or traveller who may have no special geological knowledge, but may be induced to take the map with him as a convenient guide in journeying across the country. The meaning of the various colours and the nature of the rocks they represent are here briefly explained.

A cursory glance at a geological map of England and Wales reveals some of the fundamental features in the geology of the country. In the first place, it shows that a line drawn in a nearly north and south direction from the coast of Durham, about the mouth of the Tees, to that of Devon, at the mouth of the Exe, divides the region into two parts. To the west of that line the colours are distributed in patches of widely different sizes, and apparently scattered at random. To the east, on the other hand, the several tints are disposed in bands which follow each other continuously across the island from the shores of the North Sea to those of the English Channel. In the western half of the country the rocks belong mostly to the Palæozoic formations. They have generally been greatly disturbed, many of them having been plicated, crumpled, and

squeezed. For the most part they consist of harder materials than those to the east of them. Hence, partly owing to their greater durability, and partly to the influence of their disturbances and upheavals, they rise into the highest tracts of ground. Beginning on the north, and tracing the series of older rocks from the Scottish Border to Devonshire, we pass successively over the hills of the Lake Country, the Pennine Chain, Wales, and Dartmoor, and we note that these eminences usually form detached groups, such as those of Cumberland, Westmoreland, and North Wales.

In the eastern half of the island, on the other hand, the rocks are arranged in successive bands which present their edges towards the west, and sink below each other towards the east. The harder members of the series, such as limestone and sandstone, rise into long ridges, while the softer clays, marls, and shales subside into valleys or spread out into plains. The hills are not only less lofty than those of the western side, but they are further distinguished by their prolongation into continuous ridges. The most familiar examples of this type of scenery are supplied by the chalk hills. Thus the North Downs, which run for many miles westward from the Dover cliffs, mark the trend of the chalk through that part of the country, while the corresponding range of the South Downs reveals the long unbroken outcrop of the same rock from Beachy Head to Salisbury Plain.

It is thus evident that the landscapes of the country depend for their character mainly upon the nature and distribution of the rocks underneath the surface. The traveller or tourist who journeys with a geological map in his hand can mark how each distinct change in topography arises from a corresponding alteration in the character of the geology. The variations of scenery consequently acquire for him a new meaning and interest. There is no part of Europe where the relation here described can be better seen than in England. Even from a rapid railway journey much may be learnt here regarding the dependence of topography upon geological structure.

In the second place, a little closer study of the map will show us that, on the whole, the oldest rocks lie along the western shores, and the youngest along the eastern. If we were to land in Anglesey and traverse the country to the coast of Suffolk, we should pass successively from some of the most ancient formations of Britain to some of the newest, as is illustrated by the section on the left side of the map. At Holy-

head we should find ourselves among quartzites and schists of higher antiquity than even the most ancient of the Palæozoic formations, which further south, in Anglesey, are found resting on the edges of these primeval rocks. Crossing into Caernarvonshire, we should come upon some of the oldest stratified deposits in the country, belonging to the Cambrian system, and from these, ranging into the great cone of Snowdon, and thence into Montgomeryshire, we should ascend in the geological scale through the vast thickness of the Silurian system, up to the base of the Old Red Sandstone. We should next enter upon the still younger Carboniferous system, and pass in succession into the Permian and Triassic formations, until, in Leicestershire, we should reach the edge of the Jurassic series. The various members of that series would stretch to northward and southward of our line of traverse, the successive limestones rising into long lines of escarpment and sinking gently eastward under younger strata, until, beyond the alluvial fen-country of Cambridgeshire and Huntingdon, the Chalk, with its long escarpment, would present itself, undulating eastward through Norfolk and Suffolk, and slipping gently under the much younger Crag deposits, which are laid bare by the waves along the East Coast.

In the third place, further examination of the map will disclose the important fact that by far the largest part of the framework of the country consists of sedimentary rocks, that is, of deposits of fragmentary or detrital materials which have been laid down under water, and mostly under the sea. The largest part of these materials is composed of mechanical detritus, like the gravels, sands, and muds of our present shores and sea-floor, and it now appears solidified into such rocks as sandstones, grits, conglomerates, or shales. A considerable proportion, however, consists of the remains of once living calcareous organisms, such as shells, crinoids, and corals, and is now found in the form of limestone. The forms of surface produced by the mechanical sediments are well exhibited by the grits, greywackes, and slates of Wales, which have been greatly plicated and cleaved, and by the horizontal Millstone Grit of the picturesque dales of Yorkshire. The scenery of the limestones is typically displayed by the Chalk downs, by the Mountain-limestone uplands of Derbyshire, and by the Jurassic ridges of the Cotteswold Hills and the moors of Eastern Yorkshire.

In the fourth place, the map clearly shows that while most

of the country is composed of sedimentary materials, it contains also many detached masses of igneous origin. These are mainly confined to the western side of the island. Some of them are portions of large bodies of eruptive material which probably never reached the surface, but was intruded from below into the crust of the earth and solidified there. The granite tracts of Devon and Cornwall may be taken as examples of this type. But a large proportion of the igneous rocks are of truly volcanic origin—that is, they prove that volcanic action was vigorous where they now occur. They include many varieties of lavas and ashes. As they are intercalated in successive stratified formations, they mark widely separated periods of volcanic activity. The oldest volcanoes of which the geological epoch can be fixed were those which have left their lavas and tuffs or ashes in the Cambrian system of North and South Wales. The most prolonged and extensive eruptions took place in the Silurian period, and produced the masses which now form the more conspicuous hills of the Lake district, as well as Snowdon, Glyder, the Arans, Arenig, Cader Idris, and many more heights in Wales. There are no known volcanic rocks in the Old Red Sandstone of England or Wales; but they occur on a diminished scale in the Devonian system of Devonshire, and in the Carboniferous series of the Isle of Man, Derbyshire, Somerset, and Devonshire. The latest English volcanoes appear to have been those which erupted certain dark basic lavas in the Permian period near Exeter and Crediton; but in Tertiary time some of the fissures which were then opened in Britain stretched across the North of England, and gave passage to the uprise of long dykes of dark lava. The most conspicuous of these dykes, that of Cleveland, may be seen on the map extending from near the Yorkshire coast to near Carlisle.

The accompanying Table represents the succession of the various geological formations of England and Wales, arranged in stratigraphical order, the youngest being placed at the top and the oldest at the bottom. With regard to the Igneous Rocks, the three great groups of Basic (Serpentine, Basalts, Dolerites, and Gabbro), Intermediate (Syenite, Diorite, Andesites), and Acid (Rhyolites, Felsites, Quartz-porphyry, Granite, and Granophyre), are distinguished on the Map.

Table of the Geological Formations of England and Wales in descending order.

POST-TERTIARY.	PLEISTOCENE OR GLACIAL.		Plateau gravels. Eskers. Coombe-rock. Erratics of Selsea. Moraines of the higher hills. Upper boulder-clays. Middle sands and gravels. Lower boulder-clay.
	RECENT.		Blown sand. Recent fluviatile alluvium and river-terraces. Peat, now forming in some places, the oldest portions possibly belonging to the Glacial Period. Cavern deposits. Submerged forests. Recent estuarine and marine deposits. Raised beaches.
TERTIARY or CAINOZOIC.	PLIOCENE.	NEWER.	Forest Bed group. Weybourne and Chillesford Crags. Red and Norwich Crag.
		OLDER.	St. Erth beds. Coralline or Suffolk Crag. Lenham Beds.
	OLIGOCENE.		Hamstead group. Bembridge group. Osborne group. Headon group.
	EOCENE.		Upper Bagshot and Barton group. Middle Bagshot and Bracklesham group. Lower Bagshot group. London Clay. Oldhaven beds, Woolwich and Reading group. Thanet Sand.
SECONDARY or MESOZOIC.	CRETACEOUS.	UPPER.	Upper Chalk with flints (Senonian). Middle Chalk without flints (Turonian). Lower Chalk (Cenomanian). Upper Greensand. Gault.
		LOWER.	Lower Greensand (Speeton clay, &c., Neocomian). Wealden (Speeton clay, &c., Neocomian).
	JURASSIC.		Purbeck group. Portland group. Kimeridge group. Corallian group. Oxford Clay and Kellaways rock. Great or Bath Oolite group. Fuller's Earth. Inferior Oolite. Lias—Upper, Middle, and Lower.
	TRIASSIC.		Rhætic group. Keuper series. Bunter series.

PRIMARY or PALÆOZOIC.	PERMIAN.		Magnesian Limestone. Red Marls, Sandstones, and Breccias.
	CARBONIFEROUS.		Coal-measures. Millstone Grit. Carboniferous Limestone series.
	OLD RED SANDSTONE AND DEVONIAN.		Upper. Middle. Lower.
	SILURIAN.	UPPER.	Ludlow group. Wenlock group. Llandovery group.
		LOWER.	Bala and Caradoc group. Llandeilo group. Arenig group.
	CAMBRIAN.		Upper or Olenus series (Tremadoc slates, Lingula flags). Middle or Paradoxides series (Menevian). Lower or Olenellus series (Harlech and Llanberis).
	PRE-CAMBRIAN.		Longmyndian rocks. Uriconian volcanic series (? Charnwood Forest). Schists, &c. (Dalradian ?), of Anglesey, Caernarvonshire, &c.

PRE-CAMBRIAN (x).[1]—In various parts of the country certain ancient rocks, which rise to the surface in the midst of much younger formations, may be classed together as pre-Cambrian, though they probably represent widely separated periods of geological time. Of these the largest display is to be found in Anglesey and the western borders of Caernarvonshire. They consist of various gneissic and schistose rocks, including green silky schists, like those of the Scottish Highlands, and large lenticular masses of white quartzite. The quartzite of Holyhead has yielded some worm-burrows, like those found in the west of Sutherland and Ross. It is difficult to fix the true stratigraphical position of these rocks; but as they are covered unconformably by unaltered Lower Cambrian strata, they must be older than the Cambrian period. They evidently consist in great part of extremely metamorphosed sedimentary materials. They include also various igneous intrusions, while some of the green schists suggest that they may perhaps have been

[1] The letters and figures placed after the names of the systems and formations refer to the symbols employed to distinguish them on the map.

originally basic volcanic tuffs. Some of the more massive parts of the igneous series to the east of Holyhead display in great perfection the proofs of intense mechanical deformation. Cores of the original rock may still be recognised amidst the crushed material around them which has been converted into green schist.

On the eastern Welsh border, south and east from Shrewsbury, a group of extremely ancient volcanic rocks has been named Uriconian by Dr. Callaway. It forms a ridge on which the Silurian and even the oldest Cambrian strata rest. Its rocks are thus shown to be probably pre-Cambrian. They consist of compact volcanic ashes and felsitic lavas, with rhyolitic structures, which point to some of the earliest eruptions in the geological history of England and Wales.

Other small masses of pre-Cambrian rocks rise to the surface in the Malvern Hills and at the Lizard Point, while a large but much-obscured tract lies in Charnwood Forest, where some striking volcanic agglomerates occur, probably of pre-Cambrian age. The occurrence of these detached areas of rocks that can claim so high an antiquity opens up some interesting and difficult questions in the geological evolution of the country. Where they appear from under the Cambrian strata they were probably deeply buried beneath that system; but there would appear to have been some great terrestrial movements during Palæozoic time, whereby certain portions of the pre-Cambrian platform were ridged up, and also enormous denudation, by which these tracts had the whole of their overlying pile of sediment stripped off them. The Uriconian ridge was exposed and buried again in Upper Silurian time. The rocks of Charnwood Forest survived as a picturesque group of peaks until they were entombed under the marls of the Triassic waters. It is evident that the local disturbances during the Palæozoic periods must have been on a great scale, and that while sedimentation went on with little interruption in certain districts, it was interrupted by upheaval in others not far off, and gave place to stupendous and prolonged denudation.

The thick mass of sedimentary strata forming the tract of country known as the Longmynd was regarded by the Geological Survey many years ago as of Cambrian age; but more recent investigation tends to place it below the Cambrian system, and above the Uriconian volcanic series.

CAMBRIAN (a).—This great system of rocks occupies a comparatively small space at the surface. It appears in

Anglesey, in Caernarvonshire and south-west Pembrokeshire, emerging from underneath the overlying conformable Silurian strata. It is seen also in a small tract at the Malvern Hills, in Shropshire, and in Warwickshire. Probably a large part of the Skiddaw Slates, which cover much of the northern part of the Lake District, and reappear in the Isle of Man, is to be referred to this ancient division of the geological record.

The Cambrian system consists mainly of mechanical sediments, which in the lower part are somewhat coarse in texture, forming grits and conglomerates, but which pass upward into finer sandstones and shales or slates. It is usually grouped in three divisions, each distinguished by a characteristic form of trilobite. The lowest or Olenellus series has been determined by Professor Lapworth to occur in the Shropshire area, where it consists of thin quartzite passing up into flags, grits, shales, and sandstones, and where it has yielded the characteristic *Olenellus*. In that region it is overlain with conglomerates and limestones containing *Paradoxides*, forming the Middle Cambrian group. The Upper group, composed of the Shineton shales, has afforded specimens of *Olenus*, *Dictyograptus*, &c. The total thickness of these three groups in the Shropshire region is estimated at about 3000 feet. In Wales, however, the system attains considerably greater dimensions, reaching perhaps to 12,000 feet or more. The Lower group in the Principality consists of massive sandstone, grits and conglomerates (Harlech, Llanberis), which lie upon and pass down into a volcanic platform, consisting of tuffs, diabases, and quartz-felsites (" Pebidian " of Dr. Hicks). The Middle or Menevian group is well developed in South Wales, where along the coast of Pembrokeshire its sandstones, shales, and slates, about 600 feet thick, have furnished a number of fossils, including the typical *Paradoxides*. The Upper group consists of two divisions. At the bottom, and passing down into the Menevian strata, lie the Lingula Flags—bluish and black slates and flags, which took their name from the abundance of a lingula (*Lingulella Davisii*) in them. They are believed to sometimes exceed 5000 feet in thickness. The Tremadoc slates, well developed in the district from which they take their name, and where they are about 1000 feet thick, contain a number of trilobites, among which the characteristic *Olenus* occurs. The top of the Cambrian system of Wales is now generally drawn at the summit of the Tremadoc group, but there is no abrupt

break at this horizon, the Cambrian sediments passing gradually upward into the Silurian series.

SILURIAN (b).—This system occupies a large part of Wales. Sinking underneath younger formations, it rises again to the surface farther east, and appears in a number of detached areas from the head of the estuary of the Severn northwards through Gloucestershire, Herefordshire, Worcestershire, and Staffordshire; but it no doubt extends under the Old Red Sandstone and Carboniferous rocks across the whole of the North of England, for it ascends once more to the surface in Westmoreland and Cumberland, where it forms the hilly ground of the Lake District. It reappears in the Isle of Man, and extends under the Irish Sea into Ireland on the west, and into Scotland on the north.

The Silurian rocks of England and Wales are divided into two portions, Lower and Upper, each of these being further grouped into separate formations, distinguished from each other partly by lithological characters, but chiefly by their typical organic remains. One distinguishing feature of these formations is the presence in them of abundant *Graptolites*, which vary both in genera and species from bottom to top of the system. Double graptolites are specially found in the Lower Silurian deposits, and single graptolites in the Upper. The whole system has been arranged in zones, each marked by the presence of some distinctive graptolite. Trilobites are likewise abundant, and may be made use of to distinguish the several formations.

I. The *Lower Silurian* formations are three in number—Arenig, Llandeilo, and Bala or Caradoc.

(1.) The Arenig formation (b^1) may reach a thickness of 4000 feet. It consists of dark shales, slates, flags, and sandstones, which are typically developed in and around Arenig Mountain. A prominent feature of this division of the system is the occurrence of abundant intercalated volcanic rocks, which prove that while the Arenig sediments were deposited there were active submarine volcanoes over the site of what is now the heart of Wales. The lavas and tuffs of these eruptions rise into conspicuous eminences, such as Arenig Mountain, the Arans, Cader Idris, and others.

(2.) The Llandeilo formation (b^2), sometimes perhaps 3000 feet thick, comprises dark argillaceous, sometimes calcareous flagstones, sandstones, and shales, and was first named by

Murchison, from its development about Llandeilo in Caermarthenshire. It extends into Pembrokeshire, and rises to the surface in the Lower Silurian inlier of Builth.

(3.) The Bala or Caradoc rocks (b^3) have been computed to reach a thickness of 6000 feet where fully developed. In North Wales they consist of grey and dark slates, grits, and sandstones, with two subordinate seams of limestone, and attain a great development around Bala, in Merionethshire, where they were first studied by Sedgwick. In that region they include a vast mass of contemporaneously erupted volcanic rocks which tower into some of the finest scenery of North Wales. Snowdon and the surrounding mountains consist largely of these volcanic materials.

In the district of Caer Caradoc, Shropshire, the corresponding strata consist of yellowish and grey sandstones. In the Lake District an enormous mass of volcanic material, estimated by some observers at 10,000 or 12,000 feet in thickness, occupies the place of the Bala and Llandeilo rocks below a limestone (Coniston), which from its fossils is regarded as the equivalent of the Bala limestone of Wales.

II. The *Upper Silurian* formations are likewise three in number—Llandovery, Wenlock, and Ludlow.

(1.) The Llandovery rocks (b^5) consist of a lower group of grey grits, from 600 to 1500 feet thick; a central group of yellow and brown ferruginous sandstones (May Hill sandstone), about 800 feet thick, resting unconformably on the older members of the system; and an upper group of fine smooth grey or blue shales (Tarannon shale), having an extreme thickness of 1000 to 1500 feet.

(2.) The central division of the Upper Silurian series or Wenlock group (b^6), in the typical Silurian district of Murchison, consists of three distinct groups of strata—a lower limestone and shale (Woolhope), well displayed in the valley of Woolhope, Herefordshire, where it is about 30 or 40 feet in thickness; a central mass of grey and black shales (Wenlock Shale), traceable for ninety miles from the Severn near Coalbrookdale to Caermarthen, and in the northern part of its course attaining a depth of more than 2000 feet; and an upper calcareous deposit, known as the Wenlock Limestone—a thick-bedded, flaggy, and concretionary rock, from 100 to 300 feet thick, and abounding in fossils, particularly in corals. In North Wales the soft shales and limestones of the Wenlock group give place to hard grits, flags, sandstones, mudstones, and

shales (Denbighshire Grits), which sometimes reach a united thickness of at least 3000 feet.

(3.) The Ludlow group (b^7), in the typical district of Siluria, is essentially composed of shales, with occasionally a central band of limestone (Aymestry), the whole having an aggregate thickness of about 1000 feet. The highest member of the group consists of a band of fine yellow, red, and grey micaceous sandstones (tilestones), which form a passage into the overlying Old Red Sandstone. These rocks are best seen in the Herefordshire region, where they were studied by Murchison.

The remarkable change into hard, cleaved, and plicated rocks which is observable when the Upper Silurian formations are followed, even into North Wales, continues to be observable northwards across the Lake District into the south of Scotland. Nevertheless the stratigraphical position of the northern Silurian formations is satisfactorily fixed by the occurrence of marked zones of graptolites. The Upper Silurian formations are developed in the eastern and northern tracts of Wales and in the southern part of the hills of the Lake District.

Old Red Sandstone and Devonian (c).—Along the eastern border of Wales the highest member of the Upper Silurian series passes upward conformably into the red strata which form the base of the Old Red Sandstone—a vast succession of red rocks which, stretching from Shropshire across South Wales, attains a thickness of probably not less than 10,000 feet. The lower parts of this system of red sediments consist of red and green shales and flagstones, with sandstones and thin cornstones. The central and main portion is made up of red and green sandy marls and clays, with red sandstones and cornstones, the higher members consisting of grey, red, brown, and yellow sandstones, and bands of conglomerate, pass upward conformably into the base of the Carboniferous system. In general the Old Red Sandstone of England and Wales is barren of organic remains. Its lower and central parts have yielded remains of fossil fishes (*Cephalaspis*, *Pteraspis*, &c.), while the higher portions have furnished other genera of fishes (*Pterichthys*, *Holoptychius*) and remains of land-plants.

In North Wales and the northern counties of England the narrow belts and patches of Old Red Sandstone which appear

between the Silurian and Carboniferous formations belong to the Upper division of the system. They pass upward into the Carboniferous strata above them, and lie with a violent unconformability on the Silurian rocks below. In these regions, therefore, a large part of the stratigraphical series is wanting, which is supplied in South Wales and Shropshire.

The Devonian system in England is confined to Devon and Cornwall. Though it presents a strong contrast to the Old Red Sandstone, both in its lithological and its palæontological characters, it is regarded as the geological equivalent of that system. The Old Red Sandstone appears to have accumulated in a series of lakes or inland seas. The Devonian formations, on the other hand, are shown by their included fossils to have been deposited in the sea. They are generally grouped in three sections, named Lower, Middle, and Upper.

The Lower Devonian group consists of slates, grits, and greywackes, seen at Cockington and elsewhere near Torquay, and at Foreland and Lynton in North Devon. The Middle group is best displayed in South Devon, where it consists largely of massive fossiliferous limestones (Torquay, Plymouth), which pass laterally into volcanic rocks (Ashprington). In North Devon this group is represented by the grey silvery slates of Ilfracombe, and the limestone grit and slate of Combe Martin. The Upper Devonian rocks consist of red and grey slates and grits sometimes with a fossiliferous limestone (Chudleigh). These strata pass upward into the so-called Culm-measures, which belong to the Carboniferous system. The chief horizons for Devonian fossils are to be found in the limestones of Torquay and Plymouth, which have furnished a large series of corals, together with trilobites and brachiopods.

CARBONIFEROUS ($d^{1\text{-}5}$).—This important geological system is extensively developed in England and Wales. It forms a broad tract of country, extending from the borders of Scotland southward through the Pennine Chain till it sinks below the plain of the Midlands at Derby. In a broken fringe it encircles Wales, from Anglesey to the mouth of the Dee, and thence southward into Monmouthshire, where it spreads out into the high tableland of the South Wales coal-field, and stretches to the western shores of Pembrokeshire. It rises in a number of detached tracts in the centre and south-west of England, and covers a wide space in Devon and Cornwall. It is divided into three main series of strata, each of which is distinguished

on the map—Carboniferous Limestone, Millstone Grit, and Coal-measures.

(1.) The Carboniferous Limestone (d^{1-3}, formerly known as the Mountain Limestone) forms conspicuous topographical features in some parts of the country where it is well developed. It surrounds the South Wales coal-field, where it passes down into the Old Red Sandstone. In the Pennine Chain it attains the great thickness of 4000 feet, yet its base is not there seen. Spreading out over the high grounds of Derbyshire, Yorkshire, and Lancashire, its gently inclined undulating strata form a striking type of scenery, projecting to the surface in sheets and knobs of bare pale stone, and winding in white escarpments along the green slopes of the valleys. Even where it does not spread so continuously over the ground, it sometimes reaches a great development, as in the ridge of the Mendip Hills, where it is 3000 feet thick. It consists of massive, well-bedded limestone, composed of the remains of calcareous organisms. Its fossils may often be seen projecting in enormous numbers from exposed surfaces of the rock, where they have been etched out by the weather. Traced northward, the limestone is found to be more and more split up with intercalations of shale and sandstone, which contain land-plants. We may infer that, while a tolerably deep sea extended over the south of England, a land clothed with vegetation lay somewhere to the north, probably where the Scottish Highlands now rise, and that from this terrestrial surface the sand, mud, and drifted plants were derived. Some remnants of submarine volcanoes occur in the Carboniferous Limestone of Derbyshire, where a series of basic lavas and tuffs (toadstone) is associated with necks of agglomerate. At the south end of the Isle of Man, near Weston-super-Mare, and in the Culm-measures of Devonshire, other volcanic intercalations have been found.

The Millstone Grit (d^4) comprises a persistent group of grits and sandstones, with shales and clays, which overlie and pass down into the limestone series below, and shade upward into the coal-bearing series above. These strata are from 400 to 1000 feet thick in South Wales, but in North Staffordshire they have been estimated to be 4000 and in Lancashire 5500 feet in thickness. In Yorkshire and Lancashire, where they are nearly flat, their successive beds wind along the sides of the dales as long regular lines of terrace.

The Coal-measures (d^5) are made up of frequent alterna-

tions of sandstones, shales, fireclays, coal-seams and ironstones, and are distinguished as the chief repositories of workable coal. In Lancashire they reach a thickness of 8000 feet; in South Wales they are 12,000 feet thick; but the true top of the system is probably nowhere now to be seen in England, having been removed by denudation, which appears to have begun before the Permian period. The detached areas into which, by movements of the terrestrial crust and by denudation, the Coal-measures have all separated, are known as coal-fields. It will be seen from the map that on either side of the Pennine Chain a series of coal-fields lies upon the Millstone Grit, which dips on either side from the crest of that anticlinal fold. These coal-fields are overspread by younger formations, beneath which they are prolonged, so that the coal-seams can be followed and worked far beyond the visible limits of the coal-fields at the surface. In South Wales, on the other hand, the margin of the coal-field is formed by the underlying Millstone Grit, so that no coal can be found beyond the actual visible margin of the field. In the centre of England some of the coal-fields rest directly on ancient rocks, without the intervention of any Millstone Grit, Carboniferous Limestone, or Old Red Sandstone. In Warwickshire the Coal-measures lie on Cambrian strata, and in Leicestershire on still older rocks. There would thus seem to have been an ancient ridge which ran through the centre of the country, and was not submerged until the Coal-measures were deposited. Recent boring operations have revealed the existence of Coal-measures underneath the Secondary formations of the south-east of Kent. It is possible that these Carboniferous rocks extend across the south of England and join the Bristol coal-field.

PERMIAN (e).—The highest member of the series of Palæozoic systems is known as the Permian. It is found flanking the Carboniferous rocks along both sides of the Pennine Chain, continuously on the east side, and in disconnected strips on the west side. It appears also overlying the Coal-measures along the Welsh border and in the central counties, and it extends in a belt across the peninsula of Devonshire.

Two distinct types of the system are observable in England. On the west side of the island, from the Solway Firth to the coast of Devonshire, it consists mainly of red and brown sandstones, with conglomerates and breccias (e), which in Cumber-

land reach a thickness of 3000 feet. In Devonshire these strata include the traces of some contemporaneous volcanoes in the form of thin sheets of lava. To the same period of eruption may possibly belong the various basic sills which in the Midlands and on the Welsh border have been intruded into the Coal-measures.

The eastern type is quite different, and resembles that of Germany. It displays a mass of Magnesian Limestone or dolomite ($e^{2\text{-}4}$), about 600 feet thick, underlain by some red and variegated sandstones, hard brown shale (Marl Slate), and thin limestones, and overlain by a thin group of sandstones, clays, and gypsum, or anhydrite. There is a general dearth of organic remains in the Permian rocks. The Magnesian Limestone is the chief fossiliferous repository. This formation is best seen along the coast-line south of Tynemouth, where it forms a range of picturesque cliffs.

TRIASSIC (f).—At the base of the great series of Secondary or Mesozoic formations lies the Trias, which, consisting, like the Permian, mainly of red strata, was formerly classed with that system as the New Red Sandstone. It occupies a tolerably continuous area, which, beginning near Gloucester, spreads over the great plain of the Midlands, and then divides into two arms, one of which stretches up the west side of the Pennine Chain to Morecambe Bay, while the other sweeps along the eastern base of that ridge to the sea at the mouth of the Tees. A detached area lies in the north-west of Cumberland, extending to the shores of the Solway Firth and crossing into Scotland. Another series of patches extends from the head of the Severn estuary across to the southern coast of Devonshire.

The Trias consists of three divisions—(1) Lower or Bunter; (2) Upper or Keuper; and (3) Rhætic.

(1.) The Bunter series ($f^{1\text{-}3}$) is made up of three groups of strata, having a united thickness of 1000 to 2000 feet. At the bottom lie soft bright-red and variegated sandstones, from 80 to 650 feet thick. In the centre a group of harder reddish-brown pebbly sandstones and conglomerates, from 60 to more than 1000 feet in thickness, is known as the Pebble beds. While at the top another series of bright-red and mottled sandstones reaches a depth of from 200 to 700 feet.

(2.) The Keuper series ($f^{5\text{-}6}$) is composed of a lower group of red, white, and brown sandstones and marls (water-stones),

from 150 to 250 feet thick (f^5), and of an upper group of red and grey shales and marls (f^6), which form the most important member of the Trias. They range in thickness from 800 to sometimes as much as 3000 feet, and are particularly distinguished by including beds of rock-salt and gypsum. The salt-works of Cheshire derive their supplies of brine from this group.

(3.) The Rhætic formation (fg, Penarth Beds) is made up of red, green, and grey marls, black shales, and pale limestone ("White Lias"), which are often only a few yards and rarely reach 150 feet in thickness. Yet in spite of its insignificant proportions this group of strata runs with singular persistence throughout England and Wales. One of its most interesting seams is the "bone-bed"—a ferruginous and micaceous sandstone containing remains of fishes and saurians.

JURASSIC (g).—Under this name are comprised the various strata which led William Smith, in the neighbourhood of Bath, to the discovery that the sedimentary rocks of England could be identified from one district to another by means of their enclosed organic remains. The sub-divisions made by him are still on the whole retained, together with the local provincial names which he attached to them. Four chief divisions are recognisable, each of these being separated into minor groups. They range across England from the coast-line of Yorkshire to that of Dorset, and form some of the most characteristic scenery of the country. In the north they rise to heights of more than 1400 feet above the sea, and form the broad moorlands south of Middlesborough. They mount also in the south into the range of the Cotteswold Hills. But throughout most of their course they form a succession of low ridges and intervening plains, the former marking the outcrop of the limestones and other harder members of the series, while the latter indicate the position of the softer shales and clays.

At the bottom of the whole series lies the (1.) Lias ($g^{1\text{-}4}$), which is composed of three tolerably well-marked groups of strata. The lowest of these, known as the Lower Lias (g^1), consists of numerous thin blue and brown limestones with partings of dark shale, having a total maximum thickness of 900 feet. In the centre comes the Marlstone (g^2), or Middle Lias (350 feet), composed of various limestones with underlying sands and clays, and sometimes, as in the Midlands and in Yorkshire, including valuable ironstones. The Upper Lias ($g^{3\text{-}4}$, 400 feet) is made up of shales and clays, with nodular

limestones passing up into sands. Numerous palæontological zones have been recognised in the Lias, each of which has received a name from the characteristic ammonite which it contains. Ten such zones have been separated in the Lower Lias.

(2.) The Lower Oolites. This series contains three chief sub-divisions. At the bottom the Inferior Oolite (g^5, 260 feet), in the south-western and central counties, consists mainly of shelly (marine) limestones with clays and sandstones, but as it is followed northward, increasing evidence of fresh-water and terrestrial conditions are traceable, until in Yorkshire the strata, swelling out to a thickness of 800 feet, are composed chiefly of sandstones, together with shales and seams of coal and ironstone. Next in order comes the argillaceous deposit known as the Fuller's Earth, which is only found in the southern and south-western counties, where it attains a thickness of nearly 150 feet. The uppermost group of the Lower Oolites is well developed around Bath, whence it has been called Bathonian ($g^{6\text{-}8}$). In Gloucestershire and Oxfordshire it displays three sub-groups of strata, of which the lowest consists of thin-bedded limestones and sands (Stonesfield slate), the middle of shelly limestones (Great Oolite), and the uppermost of clays (Bradford clay), shelly limestone (Forest marble), and earthy limestone (Cornbrash). Of these sub-groups, the most persistent is the Cornbrash (g^9), at the top of the whole. Varying from 5 to 40 feet in thickness, this rock extends continuously into Yorkshire.

(3.) The Middle or Oxford Oolites ($g^{10, 11}$) comprise two well-marked formations. The lower of these consists of a local calcareous sandstone (Kellaways Rock) and of a stiff blue and brown clay, well developed in Oxfordshire, whence it has received the name of Oxford Clay (g^{10}). It ranges from 300 to 600 feet in thickness. The Upper or Corallian group (g^{11}, 250 feet) consists of limestone and calcareous grits, with occasional clays, traceable with local modifications across the country from the coast of Dorset to that of Yorkshire. It received its name from the abundance of corals in its rubbly limestone (Coral Rag).

(4.) The Upper or Portland Oolites ($g^{12\text{-}14}$) are divisible into three groups. At the bottom comes the Kimeridge Clay (g^{12}, 600 feet), well developed on the Dorsetshire coast, whence it can be followed into Yorkshire. In the centre lie the Portland Beds (g^{13}), consisting of marls and sands towards the base and limestones above, one of which is the well-known

"Portland Stone," so largely used as a building material. The highest group (Purbeck Beds, g^{14}, 350 feet) is best seen in the Isle of Purbeck, where it consists chiefly of fresh-water limestones and clays, including layers of soil with the stumps of the trees which grew in them, but the central part of the group contains marine shells. These strata have long been celebrated for the mammalian remains which they have yielded.

CRETACEOUS ($h^{1\text{-}5}$).—This system of formations occupies a well-defined area in the south and east of England. Capping the hills of eastern Devonshire it stretches eastward to the coasts of Sussex and Kent. From this southern band it diverges at the broad tract of Salisbury Plain, and continues in another band north-eastwards to the shores of Norfolk. Beyond the Wash it reappears in Lincolnshire, crosses the Humber, and stretching northward into the Wolds of Yorkshire, is finally cut off in the sea-cliffs of Flamborough Head.

The Cretaceous system is divided into two main sections, the Lower or Neocomian and the Upper. The Lower Cretaceous rocks present two distinct types in England. In the southern counties they consist of a lower delta-formation known as the Wealden, surmounted by some marine sandy strata termed the Lower Greensand (h^2). The Wealden group has at its base the Hastings sands and clays (h), which pass down into the Purbeck group. Above these comes the thick deposit of Weald Clay (h^1, 1000 feet) which forms a conspicuous feature in the geological map of the south-east of England. It represents the delta of an ancient river, and, like modern delta-deposits, contains the remains of land plants and of terrestrial animals (in this case deinosaurian reptiles), together with fresh-water shells. In Yorkshire the "Speeton Clay" consists of marine clays and shales, which in their lower part are equivalents of the Kimeridge Clay of the south of England, but which in their higher parts contain true Neocomian or Lower Cretaceous fossils, while at the top they may even belong to the higher division of the Cretaceous system.

The Upper Cretaceous series is divisible into three well-marked groups of strata, distinguished from each other alike by lithological characters and fossil contents. The lowest group (h^3) is known as the Gault (100 to 300 feet), a stiff dark-blue clay, with thin seams of pyritous and phosphatic nodules and occasional seams of green sand. This deposit

passes upward into certain sandy strata, often greenish in colour, which have long been called Upper Greensand (h^4). Under this term, however, have been included strata now known to be equivalent to the Gault. The Upper group of the system is composed mainly of the soft pulverulent limestone called Chalk (h^5), and forms topographically by far the most conspicuous member of the whole system to which it gave its name. It is this formation which rises into the undulating area of Salisbury Plain, and stretches thence eastward into the bare, smooth, treeless ranges of the North and South Downs, and which reappears with the same kind of features in the Wolds of Yorkshire. The Chalk can be separated into three divisions—Lower (Cenomanian), consisting of the Glauconitic Marl, Chalk Marl, and Grey Chalk; Middle (Turonian), composed of white chalk without flints; and Upper (Senonian), also made of white chalk, but distinguished by the abundance of its black flints.

The Cretaceous system of England has undergone considerable disturbance in the southern counties, having been thrown into a series of undulations which greatly affect its distribution at the surface. Thus, as illustrated in the horizontal sections on the map, the North and South Downs form the two sides of a broad arch, from the crown of which the Chalk has been entirely removed so as to reveal the Lower Cretaceous series in the broad plain of the Weald. The denudation thus indicated is likewise conspicuous along the western outcrop. The fringe of detached patches of Chalk on that line are remnants of a once continuous sheet of Chalk that formerly stretched far to the west of the present limits of the formation.

The TERTIARY formations of England are almost entirely confined to the south-eastern counties, where they occupy two large districts. One of these, known as the London basin, covers a wedge-shaped area, which, beginning in Wiltshire, broadens out towards the east, keeping along the base of the North Downs to within a few miles from the North Foreland, and stretching north-eastward to the coast of Suffolk. The other and much less extensive district, called the Hampshire basin, is separated from that of London by a broad uprise of the Chalk. Originally the Tertiary deposits were probably continuous across the whole of the south-east of the country. They have participated in the plications which have folded the Cretaceous system and in the subsequent denudation. The

extent to which they have been wasted is impressively indicated by the numerous outliers scattered over the surface of the Chalk.

The English Tertiary formations have been divided into three groups—Eocene, Oligocene, and Pliocene.

The **EOCENE** group ($i^{1\text{-}7}$), as developed in the London basin, differs in some degree from the type which it assumes in Hampshire. At its base lies the Thanet Sand, not found in Hampshire, and best seen in the eastern part of the London basin. Next comes a variable series of plastic clay, loam, sand, and pebble-beds, called the Woolwich and Reading, and the Oldhaven Beds ($i^{1\text{-}2}$), succeeded by the chief member of the Eocene group—the London Clay (i^{3}), a stiff brown and bluish-grey clay, with septaria of earthy limestone, which in Essex attains a thickness of about 500 feet. This deposit is, in the London basin, surmounted by the Bagshot Sands, but in Hampshire and the Isle of Wight by a different and much thicker succession of deposits ($i^{4\text{-}7}$), the most interesting of which are the Bracklesham Beds of the Sussex coast, long noted for the abundance of their marine organisms. The highest Eocene strata in the London basin are the uppermost Bagshot Sands; but in Hampshire they consist of clay (Barton), which on the coast and in the Isle of Wight is 300 feet thick, and is remarkable for the great number and excellent preservation of its shells. The Barton Clay is overlain by from 140 to 200 feet of pure siliceous sand, used for glass-making, which passes upward into the base of the Oligocene series.

The **OLIGOCENE** strata ($i^{8\text{-}11}$) of England occur only in the Isle of Wight and part of the opposite county of Hampshire. Resting conformably on the Eocene series, they consist of thin seams of sand, clay, marl, and limestone, which may reach a maximum thickness of 800 feet. They are divided into four groups, each of which is named from the locality in the Isle of Wight where it is typically exhibited. The lowest, called the Headon group, consists of two series of fresh-water deposits, separated by a middle stage, containing brackish water and marine fossils. The Osborne Beds are likewise full of fresh-water shells. The Bembridge group consists of two stages, the lower composed of limestone, containing abundant land and fresh-water shells, the upper presenting a thicker succession of marls, of fresh-water, estuarine, and marine origin. The Hamstead Beds were chiefly deposited in fresh-water,

estuarine, or lagoon conditions, but their uppermost visible strata were accumulated in the sea. Denudation has, however, removed all the deposits which may originally have covered these strata, and nothing has been left anywhere in England to enable us to fill in the gap thus made in the geological record.

Next in order of age come the **PLIOCENE** formations, there being no representative in England of the Miocene series. The English Pliocene is separable into two divisions, called Older and Newer. The Older series (k^1) comprises the White, Suffolk, or Coralline Crag, which covers a considerable space in the east of Suffolk, where it consists of shelly sands, containing about 60 per cent. of still living shells. On the southern edge of the North Downs, near Lenham in Kent, patches of sand, which lie on the Chalk and descend into pipes in that rock, contain such an assemblage of shells as to prove them to be of Pliocene age. Fragmentary though they are, they possess much interest, inasmuch as they point to the submergence of the south-east of England during older Pliocene time to the extent of perhaps 860 feet below its present level.

The newer Pliocene groups (k^2) include the Red and Norwich Crag, specially developed in Norfolk and Suffolk, and consisting of red and brown shelly sands and gravels, in which the proportion of extinct shells is about sixteen, the Chillesford Beds and the Forest Bed group. The fossils preserved in these deposits indicate a gradual lowering of the climate of Britain during Newer Pliocene time. Arctic species of shells begin to make their appearance in the Red Crag, and Mediterranean forms rapidly diminish from the Coralline Crag upwards. The Forest Bed group contains a flora that indicates a mild and moist climate; but immediately above it lie layers of sand, loam, and gravel, with marine Arctic shells and a fresh-water deposit containing mosses, dwarf-willows, and birches, and pointing to a temperature as severe as that of the North Cape.

Above the Pliocene, and covering a far more extensive proportion of the surface of England and Wales, come the various kinds of Drift—boulder-clays, gravels, sands, moraines, and other detrital accumulations which record the passage of the Ice Age. These superficial deposits are not shown upon the map, because to insert them would in large measure obscure the underlying geology of the country. In some districts, as,

for instance, in large tracts of East Anglia, they entirely conceal the rocks underneath. They fill up the valleys, and even ascend to great heights among the hills.

Of the more recent deposits only two varieties are represented on the map—alluvium and blown sand. The alluvial tracts along the river-valleys are shown by a special tint, which serves to indicate some of the chief drainage lines of the country.

NOTES ON THE HORIZONTAL SECTIONS

I. *Section across England and Wales from Holyhead to Beachy Head.*—This Section is drawn across the general strike of the formations from north-west to south-east, and represents the stratigraphical succession from the pre-Cambrian rocks up to the top of the Mesozoic series. In Anglesey the most ancient schists and quartzites are succeeded by Carboniferous and Permian strata. Beyond the line of the Menai Strait the Cambrian strata (which in Anglesey lie unconformably on the schists) reappear with their underlying sheets of porphyry and tuff, and pass under the Lower Silurian series in the valley of Llanberis. There is on the whole an ascending section through the Arenig and Bala rocks to the top of Snowdon, and in the upper part of the series a great thickness of volcanic material is included, together with massive intrusive sills. By another vast fold of the terrestrial crust, the Arenig series is once more brought up to the surface with its volcanic intercalations in the ridge of Moel Wyn, while the Cambrian series is likewise exposed in a broad anticline. The Arenig rocks roll over to the south-east, and with their volcanic sheets form the picturesque ridge of Arenig Mountain, whence they plunge eastwards under the Llandeilo and Bala groups. By a series of plications, Lower and Upper Silurian rocks are made to succeed each other, and to spread over the wide tract of country to the valley of the Severn. East of Chirbury the Lower Silurian lavas and tuffs, with the Arenig strata on which they rest, rise to the surface and are accompanied by the great sill of Corndon. Eventually the Cambrian quartzites make their appearance in the ridge of the Stiper-stones, followed by the underlying pre-Cambrian rocks of the Longmynd ridge. Some of the enormous dislocations of this region are indicated on

the Section by the two faults which let down the wedge of Wenlock and Ludlow strata between the Longmynd and the Uriconian rocks of Hope Bowdler or Caer Caradoc.

From this part of the Section an ascending succession of strata can be followed through the Upper Silurian formations into the Old Red Sandstone, which is seen to undulate for many miles to the east. On Brown Clee and Titterstone Hills outliers of Coal-measures have been preserved under intrusive sheets of basalt, and a larger tract of the same formation, spreading out into the Forest of Wyre Coal-field, lies on the Old Red Sandstone and extends to the vale of the Severn near Worcester. Here the Section enters the Mesozoic series of strata. First come the Keuper and Bunter groups, followed by the thin band of the Rhætic deposits, which crops out to the east of Worcester and dips under the Lias. Their gentle inclinations enable the strata to spread out over wide areas. Outliers of the Lower Oolites are seen capping the Lias many miles in advance of the main outcrop of these groups. The members of the Jurassic series are successively traversed, until to the south-east of Oxford, the Cretaceous system sets in with its prominent escarpment of Chalk rising above the Gault and Upper Greensand. The London Tertiary basin is shown by the descent of the Chalk below the Tertiary deposits on the one side and its uprise from beneath them on the other. The angle of inclination, however, is so gentle that, if drawn on a true scale, the strata would seem to be nearly horizontal. On the south side of the basin the Chalk mounts into the ridge of the North Downs, and presents another bold escarpment to the great plain of the Weald, where the Wealden groups are exposed in a broad anticline. The ridge of the South Downs is formed by the outcrop of the Chalk on the south limb of the fold. There cannot be any doubt that the Chalk was once continuous across the Weald, and that its disappearance is entirely owing to prolonged denudation.

II. *Section across the centre of England from the borders of Wales at Denbigh over the Cheshire Plains, the Derbyshire Hills, and the plains of the Trent, to the coast of Lincolnshire at Saltfleet.*—At the west end of this Section the Denbighshire grits of the Upper Silurian series are seen to be unconformably covered by the Upper Old Red Sandstone and Carboniferous Limestone, against which the Trias of the vale of Clwyd is let down by faults on either side of the depression. On the east side the three members of the

Carboniferous system are seen to dip away from the Silurian ridge under the Triassic plains of Cheshire, which stretch eastwards to the base of the broad Pennine Chain. The great denudation of the Carboniferous rocks is shown by the outliers of Millstone Grit and Coal-measures left detached on the hill-tops. East of Buxton the Carboniferous Limestone appears, with its bands of volcanic toadstone, and after undulating for some miles finally slips below the Yorkshire coal-field. Still farther east the Permian series dips under the Triassic groups, which occupy the low plain of the Trent, until they pass under the Jurassic series. From the fine escarpment at Lincoln that series sinks gently eastward underneath the Cretaceous system, which extends to the coast.

III. *Section from the Solway across the Lake District and the Pennine Chain to the coast of Yorkshire at Flamborough Head.*—This Section explains the structure of the ground in the north of England. At the west end the Trias rises from under the Solway Firth, and is faulted against the Whitehaven coal-field, which in turn has been let down by a dislocation on the east side. From under the unconformable Carboniferous strata, the Lower Silurian volcanic rocks are seen to emerge, and to be followed by the great mass of Skiddaw slate, with its intrusive granite. After various folds and fractures the rocks roll over to the south-east, and the volcanic series again makes its appearance, and swelling out to its maximum thickness, occupies the high grounds of the Lake District, until it dips below the Coniston or Bala Limestone. Then come the Upper Silurian formations, which extend eastwards for many miles as the platform on which the Carboniferous system there reposes. The Section affords an illustration of the great denudation of that system, Ingleborough and Penygent remaining as colossal monuments of the amount of material removed. It will be seen that some of the valleys have been excavated completely through the thick Carboniferous series, and have laid bare the Silurian platform below. Towards Ripon, the Permian band sets in, and is soon overspread by the Trias of the plain of the Ouse, which in turn dips under the Jurassic system of the East Yorkshire hills. When the Section reaches the uplands of the Wolds it enters the district of the Chalk, which covers all the rest of the ground until it ends abruptly at the line of precipice that culminates at Flamborough Head.

IV. *Section across the Isle of Wight.*—This Section is drawn

in a north and south direction across the Isle of Wight, on a much larger scale than the others, with the view of showing the succession of the Tertiary and Cretaceous formations of the south of England. At the north end, the four groups of the Oligocene series are seen to occupy the low ground stretching from the Solent to the chalk downs in the middle of the island. At the top lie the Hamstead Beds, with their denuded upper surface; underneath them comes the Bembridge group of marls and limestone, which, as the dip is gently northwards, are succeeded by the Osborne Beds, emerging towards the northern shore. It will be observed, however, that these low angles of inclination rapidly change towards the south, until the strata become vertical, or even slightly overhang. Thus the lowest Oligocene group, that of the Headon Beds, is allowed to rise from under the sea. It is followed by the Eocene series—Barton Clay, Bracklesham Beds, Bagshot Sands, London Clay, and Woolwich and Reading Beds—all vertical or nearly so, along the coast cliffs of the western and eastern ends of the island. Next comes the Chalk, also in vertical beds, which strike from the Needles to Culver Cliff. The various members of the Cretaceous system appear successively in their proper order, but as the inclination rapidly lessens, they occupy progressively broader tracts of the surface, until the Lower Cretaceous formations cover a wide space of ground, revealing on the western coast a part of the Wealden series. It will be seen from the dotted line that this tract lies over a broad flat anticline, and that on the south side the higher members once more appear in a detached outlier at St. Catherine's Down. The blue Gault gives rise to extensive landslips of the Upper Greensand and Chalk above, and thus produces the picturesque scenery of the Undercliff. One of the most impressive lessons conveyed by this Section is the evidence it supplies that extensive terrestrial disturbances have affected the south of England since older Tertiary time. Another lesson is the proof furnished of the vast amount of denudation which has taken place during the same interval.

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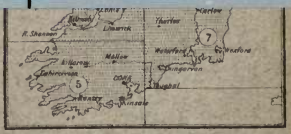

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