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THE WEALD

BY

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PREFACE.

In the year 1908, at the annual meeting of the South Eastern Union of Scientific Societies, the President, Sir Archibald Geikie, took as the subject of his Presidential Address, The Weald. This Address was published in the South Eastern Naturalist for that year. As the Haslemere district lies within the wide area discussed in the Address, it occurred to the Committee of the Haslemere Natural History Society that it would be an advantage to their members if the Address were made more accessible to them by being reprinted as one of the series of "Science Papers" which from time to time the Society issues. Application was accordingly made to the Council of the South Eastern Union for permission to reprint the Address. This permission has been most courteously given for which the Haslemere Society desire to express their cordial thanks.

The Address on the Weald here appears as No. 8 of the "Science Papers". Sir Archibald Geikie, who is now President of the Haslemere Natural History Society, has made one or two verbal corrections in the text which otherwise is reprinted verbatim as it originally appeared.

HASLEMERE EDUCATIONAL MUSEUM
January 1923

THE WEALD.

In thanking the Members of the South-Eastern Union of Scientific Societies for the honour they have done me in electing me their President for this year, I should like, first of all, to congratulate them on their singular good fortune in having their homes in a region which, among the varied landscapes of this country, is altogether unique in the combination of advantages which it offers for the prosecution of natural history studies. By its striking topography, most of its surface is comprised between the well-defined boundaries of the North and South Downs. Within these limits the commingling of plains, valleys and hills illustrates with admirable clearness the close dependence of the outer features of a country upon the nature and distribution of the rocks that lie below the surface, as well as the intimate relation between these rocks and the character of the soils which overlie them. The wide range in the nature of the ground from the low clayey flats up to the high sandy moors, the alternation of meadows and woodlands with tracts of forest and heath, and the mingling of modern cultivation with relics of the primitive wildness have nourished a varied flora and fauna to the infinite delight of the naturalist. Besides all these manifold inland attractions, there is the added and priceless advantage of a continuous coast-line with its endless variety of topographic form, its

picturesque and instructive exposures of the rocky framework of the district, and its ready access to the wealth of interest afforded by the sea.

Having made my home among the hills at the western end of this remarkable region, I have learnt to appreciate its fascination. Looking over the vast plain of the Weald which stretches eastward like a broad estuary from the uplands of South-western Surrey, I often find myself in reverie among the visions of the past which this landscape is so eminently fitted to conjure up before the mental eye. No part of England has presented its topographical problems in a more simple and attractive form. These problems must be more or less familiar to most of my audience. Some of you have doubtless devoted yourselves to their elucidation on the ground, and consequently have more practical acquaintance with their special local characteristics than I can pretend to possess. I have no new views regarding them to lay before you, and I am afraid that the outline of the subject which is all that I can attempt to offer this evening, may seem to be only a re-statement of what, to at least some, has long been familiar knowledge. And yet I venture to think that some of the problems still await a satisfactory solution, and still offer a wide field for more detailed observation. It has therefore appeared to me that if I select "The Weald" as the subject of my address on the present occasion, the choice may not be inappropriate, and may even be useful should it serve to indicate a few of the lines of investigation along which further enquiry appears to be desirable.

Research of this kind is more effectively carried on by those resident on the ground, and it is more especially suitable for such combined action as local societies and field-clubs are so well fitted to provide.

The leading facts in the geological history of the Weald have been so often described and are now so familiar, that for my present purpose I need offer no more than the briefest recapitulation of them, selecting for more detailed reference such of them as invite further investigation. Let me remark at the outset that in our attempts to re-construct the geography of former periods in the history of the earth's surface, there is a natural predisposition to be too much influenced by the present grouping of sea and land. It is not always easy to realise that in times by no means extremely remote, this grouping may have been entirely different from what it is now. The sea undoubtedly once covered tracts which for many centuries have been thickly peopled, while on the other hand the site of many a once fair landscape now lies beneath the waves. Still more difficult is it to appreciate the evidence which proves that this interchange or alternation of sea and land has taken place, not once only, but again and again over the same region, throughout the long ages since living creatures first appeared upon the surface of the earth. Nowhere could the proof of such successive revolutions be studied more convincingly than in the South-eastern counties of England.

The earliest scene of which traces have been recovered in the evolution of this part of the country has

been made known by the deep borings in Kent. Half a century ago, Godwin Austen, from a profound study of the geology of Northern France, Belgium, and the South-west of England, came to the conclusion that deep beneath the Chalk and the Wealden deposits of the South-eastern counties Coal-measures would be found. This brilliant generalisation, as is well known, has now been verified by the discovery of several seams of coal at Dover. It is thus shown that the ancient uplands of the Ardennes stretched across into England, with their plicated and ruptured rocks and their basins of coal. How far the seams met with at Dover extend, and whether other fields of coal exist under the Weald, can only be discovered by further underground search beneath the vast pile of Secondary formations which has been deposited in this region. From what has been brought to light by the borings, it may perhaps be inferred that the Palæozoic rocks do not form an even floor, but are grouped in lines of ridge and hollow, as in their continuation through Northern France and Belgium. They have been found to lie many feet deeper below the present surface of the ground in some places than in others not far distant. Thus in the sub-Wealden boring near Battle, which was started on the lowest visible portion of the Secondary formations, a thickness of no less than 1,905 feet was pierced without reaching the bottom of these formations, while near Dover the Coal-measures were struck at a depth of 1,157 feet. In a distance of some forty miles, there was consequently a difference of level in the surface of the old Palæozoic land amounting to more than

750 feet. At the one place the boring rods may have gone down upon a hill or ridge, while at the other, they sank into what after Carboniferous time had been a valley of which they did not reach the floor. Such inequalities must be expected in any future explorations for coal in the district lying westward from that in which this mineral has already been met with.

There does not seem to be any great probability that a single extensive coal-field will be discovered. Most likely the Coal-measures, if found, will be seen to have been plicated and ruptured so as to be broken up into detached basins or pockets, surrounded by still older rocks containing no coal. At some future date, when the coal-fields in this country shall be approaching exhaustion, it may be thought desirable to begin a systematic series of borings for coal in the Weald, but the undertaking will necessarily be costly, and there will always be the risk that, even when the Palæozoic floor is reached, the rocks there may be found to belong, not to the Coal-measures but to the Devonian or other more ancient and non-coal-bearing masses. Such an investigation, if ever carried out, might enable the geologist to trace some of the broader features of the earliest land-surface of which any vestige remains in the South-east of England. We may conjecture that the topography of that buried land will be found to resemble some parts of the region watered by the Sambre and the Meuse, between Maubeuge and Liège.

While the Kent borings have revealed the existence of an ancient land lying many hundreds of feet beneath the present surface of the ground, they have at the

same time shown that this land sank under the sea, in which, during a prolonged series of ages, the thick Jurassic sediments were accumulated. The deep boring near Battle shows that the amount of the submergence was not improbably a good deal more than 2,000 feet, for the bottom of the Secondary rocks was not there reached. We must picture to ourselves that while the land was slowly sinking, it was buried under a constantly thickening pile of wide sheets of sand and mud, together with the abundant debris of shells, corals and other calcareous organisms. As it went down, these various deposits rose higher along its slopes, filling up its valleys and at last entombing even its highest ridges.

Of this thick mass of mainly marine accumulations, the oldest portion which can now be seen at the surface, is to be found near Battle, where, as the result of the great Wealden plication of the strata, followed by prolonged denudation, the Purbeck beds have been brought up to daylight. These deposits of shale, limestone and gypsum, bear witness to a mingling of fresh and brackish waters, into which plants and the carcases of various animals were washed from neighbouring land. The vegetation of the time, judging from the remains of it which have been preserved among the strata, presented a great contrast to that of the deciduous woodlands around us at the present day, for its seems to have consisted largely of cycads and conifers. The fauna, too, with its huge deinosaurs, plesiosaurs, and crocodiles, its little marsupial mammals and its ganoid fishes was strangely unlike the animal groups with which we are now familiar here. An inter-

esting feature in the geography of that time is indicated by the seams of gypsum in the Purbeck series, which are here much thicker than they are westward in Dorset. They may represent the sites of lagoons in which sea-water was so far concentrated by evaporation as to throw down its dissolved sulphate of lime. Such bitter waters were unfavourable for life, and few fossils may be expected to be found in the gypsum, save such as were drifted from the land.

The next scene which the geological panorama spreads before our imagination is one wherein the Purbeck meres and lagoons were submerged and replaced by a wide estuary or lake, into which a large river was pouring a constant burden of sand and silt. The sediment thus transported consisted at first chiefly of sand and gravel with alternations of clay, afterwards almost wholly of fine mud. These accumulations continued to be piled over each other until they reached a total thickness of some 2,000 feet. It is to them that the name of the Wealden series has been given. By the removal of later formations which once covered them, they are now exposed at the surface and fill the broad expanse of the Weald between the North and South Downs. They have been likened to the deposits of a large river which, draining a wide region, formed an extensive delta in the estuary at its mouth. From the remains of the plants and animals which were swept down by this river, we glean some idea of what must have been the general aspect of the land at that time. The vegetation included various types of ferns, horse-tail reeds, conifers and cycads. The bones, teeth and

scutes found in these deposits show that the fauna comprised sundry types of deinosaurs, winged pterodactyls, crocodiles and turtles. But such organic relics are of comparatively rare occurrence. The scattered and fragmentary relics of the land-animals bear witness to the disintegration of the connecting ligaments, as the carcases decayed in their progress towards the sea.

Where, then, lay the land from which these remnants of terrestrial life were drifted? The answer to this question is not easily to be found. As the Wealden deposits thin out rapidly in a northerly direction, the land evidently did not lie on that side. For a similar reason we may infer that its site is not to be sought either to the east or west within the existing limits of England. The only quarter which seems to offer itself as possibly that in which some vestige of the Wealden land may still remain lies to the south. There, on the further side of the English Channel, the rugged ridges of Brittany, projecting their crystalline and Palæozoic rocks into the Atlantic, remain as the greatly denuded core of an ancient land. Some light might perhaps be thrown on this interesting problem in the geography of a former geological period by a study of the composition of the coarser sediments in the Wealden series of deposits. The resources of modern petrography have armed the geologist of our day with far ampler and more effective means of conducting such an enquiry than were possessed by his predecessors. A microscopic examination of the materials of the abundant sands and sandstones below the Weald Clay might supply some evidence, and more useful still would be a detailed

study of thin slices of the pebbles that are here and there gathered together as bands of conglomerate between the sandy deposits. Such layers of coarser material are to be found in the Ashdown Sand; others occur in the Wadhurst Clay, in the Tunbridge Wells Sand, and occasionally even in the Weald Clay. It would be well worth the while of some member of this Union of Scientific Societies to undertake the research which I here suggest. It would involve an examination of the rocks of Brittany for the purpose of comparison with the materials that have gone to the making of the Wealden sediments. Even if it should ultimately lead to no definite conclusion, it could not fail to be of interest to anyone who would enter upon it. On the one hand it would lead him into closer acquaintance with the landscapes of to-day, and on the other it would bring before him suggestive glimpses into those of the remote past.

We know as yet little or nothing as to the rate at which thick masses of sedimentary material were accumulated in bygone ages. On any supposition the time required for the deposition of such a group of deposits as the Wealden series must have been long when compared with our human standards. It was doubtless marked by many minor geographical changes, such, for instance, as may be indicated by the abrupt alternation or succession of different kinds of detritus. Nevertheless, there does not appear to be any evidence of a serious interruption of the slow elaboration of sedimentary material in the delta of the Wealden river. The area, however, was gradually undergoing a move-

ment of depression, either continuous or intermittent. Yet the volume of the fluviatile waters would seem to have remained ample enough to fill the broad estuary and to prevent the open sea from taking full possession of it. At least no thoroughly marine fossils have, so far as I am aware, been obtained from the Wealden formations. The organic remains found in these strata are all either relics of the flora and fauna of the land, or remains of fluviatile or estuarine life.

At last, however, the downward movement of the region was quickened, and the waters of the outer sea spread over the delta. This episode of geological history is revealed by the Atherfield Clay which, with its characteristic marine fossils, is in some places seen to lie immediately on the fresh-water or estuarine cyprid-shales of the Weald Clay. Such an abrupt transition not improbably points to tolerably rapid subsidence, unless it can be partly explained by considerable erosion of the upper part of the Weald Clay before the Atherfield Clay was laid down. If we may judge from the varying thickness of the marine accumulations which were now deposited, the sinking was greatest in a westerly direction over the area of the Isle of Wight and the borders of Hampshire and Surrey. At first only fine mud gathered upon the sea bottom, where it covered up and preserved the abundant assemblage of shells and corals for which the Atherfield Clay has long been famous. But as the downward movement lessened or ceased, the sea in this region grew gradually shallower. Vast banks of sand, some hundreds of feet in depth, were now formed on the sea-floor. It is out

of these deposits, known as the Lower Greensand, that the high grounds of Blackdown and Hindhead, with all their picturesque surroundings of hill and valley, have since been carved.

Again, the same question here suggests itself as is presented by the great thickness of the Wealden sediments. Whence came all this deep accumulation of detrital material that forms the Lower Greensand? At present we cannot tell. But the same mode of enquiry which I have recommended for the investigation of the Wealden series, might be usefully adopted in this case also. Various promising horizons might be searched for evidence of the character of the rocks of the land whence the detritus was derived. The pebble-bed in the Hythe group and its derivative fossils, the pebbles and coarse sands of the Sandgate group, and the conglomeratic bands of the Folkestone beds, deserve more minute study than, so far as I know, they have yet received. It will be remembered that the late Dr. Sorby fifty years ago drew attention to the inferences suggested by the false-bedding in the Folkestone group of sandy deposits. He believed that the evidence there presented by that characteristic structure indicates the transport of the sediment by a current from N.N.W., and the existence of open sea towards the north. It may not be possible ever to discover the actual site of this old Cretaceous land, but at least our acquaintance with the ancient geography of the region would be increased by a knowledge of the nature of the rocks of which that land consisted.

The next scene in the history of our district is

recorded in the wide-spread band of clay called the Gault. This persistent but variable band, with its crowded commingling of well-preserved shells, represents a renewal or more rapid increase of the subsidence of the sea-bottom. Into the deeper water which thus arose fine mud was diffused over a wide extent of the south and east of England. That the time occupied by this deposition was prolonged is indicated both by the thickness of the Gault, which sometimes exceeds 300 feet, and by the succession of biological zones which the deposit comprises. Eventually a change in geographical conditions took place similar to that which supervened upon the Atherfield Clay. The waters in which the Gault was accumulated were invaded by currents transporting quantities of sand which gathered into wide banks and shoals, more particularly along the western borders of our district, and thence westwards into Devonshire. But these accumulations, to which the name of Upper Greensand has been given, did not reach the magnitude attained by those which were heaped upon the Atherfield Clay.

If the succession of Cretaceous formations which we have now traced from the Purbeck beds to the top of the Upper Greensand, be compared with that of the rest of Western Europe, it will be found to present many special features indicating that the geological changes in progress here had on the whole a local character. The movements of the terrestrial crust seem to have varied considerably from one part of the region to another, both in direction and in rate. While in some places the land was sinking, in others it was

rising, and where subsidence was in progress it varied in amount to the extent of hundreds of feet within comparatively short distances. But in our retrospect we have now reached the records of a time when the local character of the changes gave way to one of a more general and wide-spread character. This alteration in the sequence of events is strikingly disclosed by the great calcareous formation known as the Chalk. This member of the Cretaceous series bears witness to the prolonged submergence of a large part of north-western Europe. The sea then stretched eastwards across northern France and Belgium to the confines of Germany and northward to the skirts of the Scandinavian mountains. How much of the British Islands rose out of the water it is difficult to ascertain, so great has been the extent of the subsequent denudation of the region. There seems, however, to be much probability in the view that not more than a few of the higher peaks and ridges may have stood above sea-level. Over this vast expanse of deep sea the Chalk was deposited in some places to a depth of as much as 1,500 feet. So great was the amount of subsidence that the margin of the mainland retreated eastward far away from its previous coast-line, and little or none even of the finer silt, borne by currents from the shore, reached the tract of sea-floor where England now stands. We must think of the Chalk as a kind of ooze, slowly gathering in clear water, from the continuous fall of minute foraminifera and the accumulation of molluscs, echinoderms, corals, and other calcareous organisms on the bottom. Now and then, at long intervals, a stray

boulder of granite has been found in this deposit, such as may have been imprisoned among the roots of a tree which drifted out to sea.

Within our own borders, save such exceptional examples as these transported boulders and occasional pieces of drift-wood, little or no evidence is available whence an idea can be formed as to the aspect of the land of this epoch in geological history. But far to the east, where the Chalk sea washed the northern flanks of the uplands of Western and Central Germany, abundant remains have been recovered of the vegetation by which the land was covered. These remains possess a peculiar interest, inasmuch as they include the earliest relics of deciduous trees resembling the familiar types of our own day. Among them are forms of alder, ash, elm, fig, laurel, maple, oak, poplar, tamarisk, and numerous ferns. With these are mingled fragments of sequoia and other conifers, together with several kinds of screw-pine.

It is rather by a study of the progress of plant and animal life, as recorded in the succession of stratified formations, than by a consideration of the mere thickness and extent of these formations, that we can best appreciate the value of geological time. If we apply this test to the series of strata from the base of the Wealden groups to the top of the Chalk, we cannot but be impressed with the magnitude of the interval between these two stratigraphical horizons, no matter what theory of organic evolution may be adopted. While genera and species were continually succeeding each other, the general type of life continued to be

distinctly Mesozoic. But above the Chalk lies one of the most notable breaks in the Geological Record of Western Europe. The strata which immediately succeed the Chalk bear emphatic testimony to the passage of a prolonged interval of time, which is not here represented by any contemporaneous formation. They reveal not only an entire transformation of the geography of Western Europe, but also an extraordinary change in the general aspect of the living things both in the sea and on land. The lycopods, ferns, cycads, and yew-like conifers, which had been the dominant types of vegetation during the Mesozoic ages, now gave place to the hardwood trees, and evergreens which, first appearing in later Cretaceous time, became thenceforward the prevalent flora of this region. The ammonoid types of molluscan life, so characteristic of the Secondary ages, now wholly disappeared. Not less completely did the reptilian forms vanish which had for so long been the most conspicious animals on land and sea—the huge deinosaurs, pterosaurs, ichthyosaurs, and plesiosaurs. So remarkable a revolution furnished to the convulsionist geologists of a former generation one of the most telling pieces of evidence in favour of their doctrine of sudden catastrophes and re-creations on the surface of the globe.

But the progress of research has led the geologists of our own day to disbelieve in such periodic destructions and renovations, and to come to the conclusion that the evidence, once thought to point so strongly in favour of cataclysmic action, is capable of a less sensational and more probable interpretation. There

is now a general conviction that the remarkable stratigraphical and palæontological break at the top of the English Chalk can be most satisfactorily accounted for by regarding it as proof of the lapse of an enormous period of time, of the passage of which no stratiform records have been left in this country. During this prolonged interval many geographical vicissitudes may have happened here, which may even have left memorials in the form of stratified deposits. But such chronicles, if they ever existed, had been entirely destroyed and removed before the deposition of the oldest portion of the Tertiary series, which now immediately overlies the Chalk. It is as if a series of important chapters had been torn out of a volume of human history.

It would, therefore, be vain to try to form a mental picture of what was happening in this district during so long a period of geologically unrepresented time. We must take up the interrupted thread of the narrative which is supplied by the lowest of the series of Tertiary formations in the South-Eastern Counties. We there learn that the ooze of the Cretaceous sea, ultimately consolidated into firm chalk, had been pushed upward above sea-level and had undergone extensive denudation. It is conceivable that there may have been repeated oscillations of level and frequent interruptions and repetitions of the degradation of the Chalk. It is at least certain that much of that formation had been worn away before the deposition of the Thanet Sand at the bottom of the Tertiary series. The well-rounded flints in the Woolwich and Reading Beds, and the flint-

shingle in the Blackheath Beds, must represent a prolonged waste of the Chalk.

This extensive denudation indicates how entirely the geographical conditions had altered from the time when the sea overspread most of Britain and allowed the Chalk ooze to be deposited. It appears that the sea-bottom was upraised unevenly, so that instead of being covered by one wide expanse of clear and fairly deep water, it came to be divided into more or less distinct, though often connected, basins, and here and there to be pushed up into dry land. The Woolwich and Reading Beds, for example, include the estuarine accumulations of a large river, which drained some vanished land lying probably towards the west. The London Clay bears witness to the sinking of the floor of the estuary and the transport of the river-mud by marine currents over the whole of the south-east of England eastwards into French Flanders and Belgium. So long did the submergence last that a depth of 400 or 500 feet of clay was laid down over the central parts of the area. This deposit has preserved a considerable assemblage of the marine organisms of the time, as well as many relics of the flora and fauna borne seaward from the land. From these fossils we learn what a striking change had taken place in the general character of the life of both land and sea during the long interval since the time of the Chalk. They indicate a somewhat tropical climate in Western Europe, for the plants include various types of fan-palms, liquidambar, laurel, almond, eucalyptus, and other genera; among the molluscs are species of *Murex*, *Cypraea*, *Pyrola*, *Voluta*,

Nautilus, and *Belosepia;* while remains of turtles, tortoises, crocodiles, sea-snakes, various tapir-like animals and opossums have likewise been obtained. Such a collection of organisms points to the prolonged transport and entombment of the spoils of the land on the bottom of a sea which no doubt covered the area of the Weald. The London Clay, however, has long since been wholly stripped off this district, and its history must be made out from the portions which survive to the south and north.

I do not propose to pursue further this brief outline of the history of our district during the ages represented by the older Tertiary deposits. We do not know to what extent these deposits ever spread over the Weald. Where they are best developed outside of our district, they contain a record of continued alternations of land and sea and the persistence of a tropical climate.

From out of the fragmentary chronicles of this shadowy time, there emerges into light the great crucial event to which the distinctive features in the structure and scenery of the Weald are primarily due. The repeated upward and downward movements of the crust of the earth which we have been tracing in the chronicles supplied by the Secondary and Tertiary formations were, even when most wide-spread, so gentle in their effects upon the rocks which they upraised or depressed, that violent displacements do not appear to have been frequent. The several stratified formations succeed each other without abrupt discordance, preserving their general parallelism for hundreds of square miles. Over-

laps and unconformabilities do occur among them, but evidence of disturbance and denudation can seldom be seen in any single section, and can for the most part be ascertained only by careful mapping of the ground. Where the Chalk can be observed to be covered by the base of the Tertiary series, th two formations usually appear to be perfectly conformable.

But at a particular epoch in early Tertiary time, this equable type of elevation and depression gave place to one of another kind. It was a period of great commotion in the solid frame work of the European continent. The centre of maximum disturbance lay along the great chain of the Alps. Vast masses of the rocks that form the foundations of these mountains were torn up from the depths, driven for miles over some of the youngest formations, and left high on the crests. So that now the astonishing sight is presented where thousands of feet of strata, not older than our soft London Clay, have been plicated, crumpled, crushed, and hardened, and have been buried under huge transplaced sheets of the very oldest rocks of the chain. Even if these gigantic displacements had been confined to Central Europe, we cannot suppose that they could occur without an accompaniment of earthquakes far more wide-spread and disastrous than any of which man has had experience within historic time. But the disturbances within the terrestrial crust reached to great distances beyond the Alps. Far to the north, during some part of this time of vigorous subterranean energy, the volcanoes broke forth which, from Antrim and the West of Scotland by

the Faroe Islands to Iceland, poured out floods of lava, of which such picturesque remnants have been left in the chain of the Inner Hebrides.

Amidst these proofs of terrestrial commotion, we are more specially interested in those which extended through France into the South of England. The crust of the earth was there thrown into folds which have remained ever since impressed on the surface of the ground. These folds are elliptical bulgings of the earth's crust, arranged in parallel, but not continuous, lines, one ridge dying out while another begins to the right or left. One of these arches of the rocks is seen in the picturesque Pays de Bray to the north-west of Paris, which in many respects, but on a smaller scale, resembles the district in which we are assembled. A fragment of another forms the southern half of the Isle of Wight. Two succeed each other between Worthing and Botley. But the largest and most complete of all is that which runs from the Boulonnais across the counties of Kent, Sussex, Surrey, and Hants, and which has given us the distinctive structure and scenery of the Weald.

In this tract of ground, for a distance of about 120 miles from east to west, with a maximum breadth of some 40 or 50 miles, the crust of the earth, under the stress of great lateral pressure, was forced upwards in an oblong dome, the crest of which may have been originally more than 2,300 feet higher than the ground in the centre of the Weald at present. How far the overlying mantle of Tertiary strata was continuous over this dome cannot be determined. The abundance of

flints in some of the lower parts of the Tertiary series, to which I have referred, obviously proves that certain parts of the Chalk had been considerably denuded and were bare when these gravels were in course of formation. But the subsidence denoted by the thick mass of London Clay and the occurrence of that deposit on the southern side of the South Downs lead to the inference that the London Clay not improbably covered at least some part of the Chalk at the time of the uplift. It is even possible that the succeeding members of the Tertiary series followed here above the London Clay, for they were laid down before the elevation of the Wealden ridge and they were involved, together with London Clay and the Chalk, in the movement.

The great arch or dome of the Weald was not a simple smooth wave-like undulation of the terrestrial crust. It bore on its back a number of minor inconstant folds, running parallel with its main axis. The pressure appears to have been greatest from a southerly direction, for the strata have been thrown into the steepest position on the north side of the ridges, as is strikingly visible on the cliffs at the west end of the Isle of Wight. So enormous was the force of this pressure, that the solid rocks were ruptured in places and driven over each other in a manner similar, on a small scale, to the great inversions and overthrusts of the Alps. Some of these effects are instructively shown on the foreshore near Beachy Head, where the Upper Greensand has been driven over parts of the Chalk. Other illustrations of these dislocations are

conspicuous along the Chalk-cliffs east of Swanage and west of Lulworth Cove.

The question naturally arises whether this great fold in the crust of the earth took place rapidly or slowly. When we contemplate the effects of such powerful disturbances, we are apt instinctively to regard them as the results of sudden and convulsive action. If such was the character of the uplift in this district, the dome of the Weald must have risen quickly into a great ridge as high and as broad as the Pennine Chain of the Northern Counties. But it is not necessary to believe that the movement was of this rapid kind, and an examination of the rocks which have been most intensely crushed, rather suggests that the upheaval was slow and prolonged. Any sudden collapse and serious displacement of rocks in the crust of the earth may be expected to be accompanied by the evolution of much heat, and this rise of temperature may be great enough to produce more or less marked metamorphism in the rocks which have been affected. Nowhere, however, along the Wealden uplift, so far as I am aware, have any traces of such alteration been detected. Perhaps the rise of the ridge and the rupturing of its component strata went on as a long-continued or even interrupted process, during which the heat involved in rock-crushing was conducted away as fast as it was developed.

One prominent result of the rise of the dome was immediately to expose its surface to the various denuding agencies which are ceaselessly wearing down the land. The Weald, from its striking simplicity of structure, has furnished one of the most admirable illustra-

tions of the results of the operation of these agencies, and has consequently become a classic example in the literature of denudation. In the early days of geology, the chief share of the process by which the district has been shaped into its present typography was assigned to the sea. The steep slopes of the Downs as they rise above the great inland plain, with their projecting headlands and retiring bays, were confidently regarded as old coast-lines, between which the sea ran westwards in a long inlet. The sea has doubtless played its part during the various changes of level which the district has undergone since the time of the uplift. But it is now generally admitted that to the action of the atmosphere, of rain, springs and streams, the main part of the work of denudation must be ascribed.

When the dome first emerged from the sea it was far from presenting a smooth surface to the waves and the air. If we liken it to a long broad and lofty ocean-swell, we must remember that it bore on its back not a few minor ripples or waves where the rocks had been wrinkled along lines parallel with the general trend of the axis. Moreover, every here and there, where the crust had been ruptured, the dislocations might appear above ground as lines of rift or scarp. To what extent these inequalities of the broad crest of the dome were planed away by the sea cannot be ascertained. But as they still, in some measure, reveal themselves on the present surface of the Weald, they were probably not ineffective in determining the first lines of drainage when the tract received its earliest showers of rain. Hopkins, in his well-known paper, wherein from a

mathematical point of view, he discussed the denudation of the Weald, conceived that from the central axis of elevation a system of transverse fissures diverged on both sides, and he thought that the positions of these fissures were indicated by the lines of transverse valleys whereby the chalk downs on the north and south sides of the Weald are breached. The diligent investigations, however, which have been carried on since his day, have failed to detect satisfactory evidence of the existence of such fissures. It is now the general conviction of geologists that the supposition of surface fissures is not required, but that the deep trenches in the Chalk, by which the interior drainage of the Weald passes out to sea, across the chain of the Downs on either side, may be accounted for by the action of running water without subterranean assistance.

We are all familiar with the effects produced by heavy rain on the surface of sloping ground, but comparatively few of us try to conceive what must be the ultimate result of this everyday operation at the end of ages of unbroken continuance. A little observation and reflection will, however, suffice to show an intelligent onlooker that a perfect gradation may be traced from the channel that was cut by the last heavy rain to that which, in a longer time, has been scoured out by the nearest runnel, and thence through every grade of furrow, brook and stream, and every stage of progress in excavation, up to the open valley and deep gorge of the river which carries the collected drainage of a wide basin out to sea. We hardly realise how slight may be the initial inequalities of surface which

determine the first channel of a water-course. Yet we have only to watch what takes place on a newly-made roadway to be supplied with an instructive illustration. The road may have been rolled so smooth and flat as to show no appreciable irregularities on its well-compacted surface. But the first thunder-storm will reveal them. Where the road runs down a slope the rain will gather into one or more runnels which will sweep along such loose particles of earth or stone as they can move, and in so doing will scour out channels for themselves until they quit the road for lower levels on either side. In hilly regions, unless the roads are vigilantly kept in repair, the effect of a few seasons may be seen in the way in which the first rain-channels have been deepened and widened into ruts and gullies which, unless filled up, in course of a short time make the roads quite impracticable for wheeled traffic. Anyone who is inclined to be sceptical in this matter may have his doubts set at rest by various examples in my own part of south-western Surrey; or if he should desire a still more convincing illustration I would recommend a visit to the famous road over the Corryarrick Pass in Invernesshire, made in the early half of the eighteenth century. He will there find that the road, left without repair for many years, has in some parts been entirely swept away, its place being taken by yawning chasms and deep gullies which might have been supposed to be the work of many hundreds of years.

When once a watercourse has chosen its channel it will usually retain it, deepening and widening it as time goes on, unless driven out of its way by some

exceptional accident such as a landslip or an earthquake. In this way the original drainage-lines of a land-surface tend to become permanent, so long as the streams are confined to their own basins. But there is a perpetual contest between the streams. While all are engaged in cutting their way downward into the framework of the country, each, after the measure of its ability, is at the same time trying to widen the limits of its basin. The struggle is necessarily an unequal one. Some streams, favoured by greater rapidity of slope, a heavier rainfall, or more easily eroded rocks, gain upon those which work in less propitious conditions. Their watersheds consequently advance and encroach on those of their neighbours, until, in the end, they may rob these neighbours of much of their water-supply, or even capture them altogether and annex them as tributaries.

That this contest has long been in progress over the surface of the Weald cannot be doubted. Its results are to be seen in the present distribution of the streams and the limits of the several drainage-basins. The history of some of its phases have been more or less fully worked out by several writers, especially by Prestwich, Topley and Foster and Elsden. But what seems still to be desirable is a connected study, not merely of individual basins, but of these basins in relation to each other and to the progress of the denudation of the Weald as a whole. A vast amount of evidence is available in the various gravel terraces at different levels, and would probably reward a more detailed and patient examination that it has yet received.

When the first rains fell on the uplifted Wealden dome they would gather into streamlets which flowed along the hollows on the broad crest, working their way to lower levels until they found depressions through which they were able to descend over the outer slopes on either side of the ridge. In their upper courses, running in the same general direction as the axis of the dome, they would slowly erode what have been called "longitudinal" valleys. Where they turned from that direction and followed hollows on the outer declivities towards the sea, they would form "transverse" valleys. At that remote time the progress of denudation had not advanced so far as to expose any escarpments. There were then no North and South Downs. The thick covering of Chalk was probably continuous across most of the crest of the dome. Hence, when the rivers began their work of excavation, their courses lay upon rocks hundreds of feet higher than the present surface of the valley of the Weald. This great thickness of material has been removed in the continual denudation of the district. As the drainage-lines sank deeper and a greater variety of material was exposed by denudation, the distinctive peculiarities of each member of the Cretaceous series, in its capacity of resistance to decay, would make themselves manifest in the prolonged sculpturing of the details of the landscape. The harder bands would gradually emerge into lines of cliff or ridge, while the softer kinds would be worn into hollows. In this way the escarpments would one by one seem to rise out of the ground. The first of them to make their

appearance would be those of the Chalk, which, in those remote days, stood much nearer to each other than do their modern representatives, the North and South Downs. They have ever since been slowly creeping back from each other in opposite directions. In their retreat they have exposed the formations lying below them, and hence have arisen, one after the other, the escarpments of the Upper and Lower Greensand.

But this progressive emergence of the harder bands of rock in the general degradation of the surface of the ground would not divert the courses of the streams. These had already taken possession of their drainage basins and had long been engaged in hollowing out their valleys. It seems at first inexplicable that rivers rising in the comparatively low central valley of the Weald should flow onward through trenches made by them in the escarpments. But the difficulty vanishes when we realise that the rivers are older than the escarpments, and had already fixed their valleys before these features in the landscape had arisen.

When the Upper Cretaceous rocks, the Chalk and Greensand, had been worn off the axis of the dome, the softer and more easily removable sands and clays of the Wealden series would then be exposed to denudation. The rate of waste in that central part of the area would consequently be quickened, and the general level of the ground would be more rapidly lowered there than on the escarpments. As a consequence of this difference, the broad belt of ground between the North and South Downs has been shaped into a long valley varied with parallel ridges, where

the harder sandy bands may mark some of the lines of plication that accompanied the elevation of the dome.

Most of the extensive denudation has probably been accomplished during a protracted period of time wherein the district has remained a land-surface. There is evidence, however, that when the waste was probably far advanced, the eastern part of the Weald sank under the sea. On the crest of the North Downs in Kent, at a height of 600 feet above sea-level, some scattered patches of a deposit known as the Lenham Beds has been preserved in hollows of the Chalk. From the ferruginous sands remaining there a number of marine shells have been obtained, which prove that this part of the district lay under the sea in early Pliocene time, and must have been more than 600 feet lower than it is now. At that time the sea probably stretched for many miles up the Weald valley. Yet it is certainly not a little remarkable that no marine deposits of this time have been recognised anywhere over the floor of the valley. Perhaps the subsidence lasted for too brief a period to afford an opportunity for any serious amount of sea-action either in the way of erosion or of deposit.

This Pliocene submergence may not improbably have had a considerable share in the earlier stages of the process whereby England was isolated from the Continent and became finally an insular part of Europe. It is clear that the long arch of the Weald formed originally a continuous ridge from this country into France, and that there was no Strait of Dover. As the Chalk escarpments were developed in the progressive

denudation of the ridge, the North Downs stretched from Dover into the hills near Calais, and the South Downs from Beachy Head to the hills above Etaples. The portions of these two outcrops of Chalk which are now submerged were doubtless in every respect similar in shape and aspect to those parts which still remain as land.

It would appear either that the Pliocene submergence was deeper over the area of the English Channel than towards the north, or that the re-elevation which brought up the North Downs once more above sea-level never carried the sunken part of the South Downs so far upward. At all events the ridge of Chalk between Dover and Calais, as has been proved by submarine explorations in connection with a proposed Channel Tunnel, lies in a large measure bare of detritus, and nearer to the surface of the sea than the corresponding ridge further south. From various kinds of evidence it may be reasonably inferred that the re-elevation which carried up the Lenham Beds to their present position, at the same time lifted the eastern part of the ridge and restored a land connection between England and France. It was no doubt over this isthmus that the earliest men entered Britain, and that the tribes of large mammals migrated which formed so conspicuous a feature in the fauna of this country in Pleistocene time.

But the connecting neck of land was eventually broken through. How exactly this severance was brought about may be matter for conjecture. Two obvious dangers threatened the isthmus from the first.

The line of Chalk Down between Dover and Calais, as Topley long ago pointed out, must have been breached by the river Rother, which was then a large stream carrying northward the drainage of the eastern part of the broad valley of the Weald. If, as is not improbable, this breach became a wide valley, it would offer facilities for the entry of the sea from the north during any subsequent depression of the district. That at least one such subsidence did take place is shown by the submerged forests of the south coast. Again, the submergence of the eastward extension of the South Down would deprive the more incoherent Greensand and Wealden deposits of the protection afforded by the firmer barrier of Chalk. The strong tidal scour of the Channel and the action of the waves in south-westerly gales would tend to a more rapid destruction of these less resisting strata. Thus, attacked on both sides by the sea, the isthmus may have been finally cut through, thereby opening a passage for the tides and currents through the valley of the Rother. Once an union was effected here between the North Sea and the Atlantic, the subsequent widening and deepening of the Strait would only be a question of time. The process of sawing through the neck of land has been in continual progress ever since, the cliffs on either side slowly retreating from each other until they have reached their present line. But the storms of every winter remind us that the process is still going on, and reveal the operation of the agencies by which it is effected.

In the immensely long period during which the surface

of the Weald has been carved into its present form various geological interludes took place which may have modified the progress of the denudation. Besides the Pliocene submergence to which I have referred, the district may have been more or less affected by the passage of the Ice Age. When thoroughly Arctic conditions of climate prevailed over this country, when the higher groups of our mountains nourished snow-fields and glaciers, and when the great northern ice-sheet from Scandinavia, filling up the basin of the North Sea, impinged on the eastern side of this island, the district in which we are met could not escape sharing in some at least of the consequences of the rigour of the climate. Prestwich, indeed, was disposed to think that the uplands of the Weald may have been a separate centre of snow and ice. But the evidence on which he relied is perhaps not strong enough to warrant his conclusions. The question, however, is one that well deserves renewed consideration. It seems difficult to believe that, when the northern ice reached almost to the Thames, no reliable trace should be left of the severity of the climate among even the high uplands of the Weald. No trace of glaciation has been observed, nor, considering the decaying nature of the various rocks, is any such trace likely to be found. But there may be other indications besides those which Prestwich cited, and it may yet perhaps be possible for some active members of this Union to present a paper on "The Traces of the Ice Age in the Weald."

In connection with this subject I may refer to the problem of the Coombe Rock, for which so ingenious

a solution has been proposed by Mr. Clement Reid. If we accept his reasoning as well founded, it affords an interesting glimpse into the prolonged continuance of Arctic conditions in this district. He has pointed out that the upland valleys in the Chalk are dry, that as the rain at once sinks into the porous Chalk, no running brook can now exist in them, and, therefore, that they were probably formed in circumstances which have long passed away. He has shown that at some places in the Southern Counties the remains of high northern mammals, such as the reindeer, musk-ox, and lemming have been found, which perhaps indicate that the mean temperature in the south of England when these animals lived here, may have been below the freezing point. He conceives that at that time the Chalk was permanently frozen to a considerable depth, and was consequently impervious to water. Hence any summer rains or melted snows, instead of sinking below ground, would then rush down the slopes in rapid torrents which would sweep away to lower ground the loose rubble of broken-up chalk and flints, and thus expose fresh surfaces of chalk to disintegration. He regards the Coombe Rock as a memorial of these conditions.

More directly convincing, however, are the proofs of an Arctic climate furnished by the transported boulders which have been found in such numbers along the south coast from Worthing to Portsea. Blocks of granite, syenite, mica-schist and other rocks, sometimes weighing five or six tons, have there been stranded on the shore. There can be little doubt that they were

brought thither on floating ice, perhaps from the region of crystalline rocks in the north-west of France. It was probably during the later stages of this cold period that the earliest human immigrants found their way into Britain, together with the herds of musk-ox, reindeer and mammoth, which they hunted in the woodlands of the Weald. Before the Arctic conditions finally passed away, there appear to have been some alternations of milder seasons, and the time was further marked by oscillations in the relative levels of land and sea, which are marked on the one hand by lines of raised beach and on the other by submerged forests.

Since the present state of things was established, the chief outward changes which our district has undergone have been due to human interference. The wide forest of the Andredsweald, which for so many centuries served as a barrier between the tribes on its northern and southern borders, has given way to fertile fields, green meadows and pleasant villages. The broad heaths have been invaded by the plough, till they are now reduced to mere scattered patches of common. Marshes have been reclaimed and cultivated. Roads and lines of railway have opened up the district in all directions. The native flora and fauna have been modified by farming and other operations, and the human population has itself been involved in the progress of change. The several races, Briton, Jute, and Saxon, once distinct and kept apart by natural features, have so mingled with each other that their limits are no longer distinguishable, but all are united as citizens of one common nation.

I am afraid that the sketch which I have attempted to give you of the successive revolutions which have brought the Weald to what it is to-day, has been somewhat too crowded with details. My main purpose, however, made this hardly avoidable, as I specially desired to address myself to the members of the different Scientific Societies which form this Union, and to present for their consideration a subject, which, notwithstanding the mass of literature devoted to it, seems to me far from exhausted, if indeed it be ever exhaustible. I have tried to indicate a few of the lines of enquiry which appear likely to open out the most promising prospect of useful additions to knowledge, and if what I have said should induce a few of your number to undertake these investigations, I shall be pleased to have in any small degree contributed to help forward the cause to which your Union is devoted. Probably few movements in our time have done more than the institution of local societies and field-clubs to foster a love of nature and a desire to learn all that can be learnt regarding the world around us. You have carried the movement a step further by not only forming the local societies, but by combining them into such an Union of sympathetic fellow-workers as is now gathered together here. Let me conclude by thanking you for the patience with which you have listened to me, and by wishing long life and prosperity to your Union.

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