# THE HISTORY OF THE DRAINAGE OF THE HAMPSHIRE BASIN
## and the Relation of Prehistoric Man to that History.

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In endeavouring to trace the history of the drainage of the Hampshire Basin, we soon discover that the present physical features reveal few signs of its beginning. In view of the present insignificance of the rivers and the comparative insufficiency of their watersheds, the work, which they, aided by subærial agencies, have accomplished in the excavation of their valleys is stupendous. Their wide, open valleys, the terraces of gravel on their flanks, the sheets of gravel on the plains bordering their valleys are conclusive evidence that the conditions now obtaining are totally inadequate to explain the observed phenomena ; these can only be deciphered by an acquaintance with the geology of the district. Great earth movements resulting in elevation and subsidence, and the formation of water-partings, the origin of the superficial deposits and raised sea-beaches, the effects of marine and subærial denudation, changes of climate and the immense period during which the forces of nature have been at work—all have to be taken into consideration.

The strata drained by the rivers of the Hampshire Basin belong to the Secondary and Tertiary formations. After the deposition of the Tertiary strata, in the Miocene Period, a profound upheaval began, raising the South East of England above the sea and puckering the strata into a series of folds with their long axes running approximately North West and South East, with one great fold, the Wealden anticline, over-topping, and far greater in extent than the others. The effect of this uplift was that the Tertiary strata now lay in two great depressions, the London Basin and the Hampshire Basin, separated by the Wealden arch, which stretched from near Boulogne, through Sussex and Hampshire, into Wiltshire. Where the arch decreased in intensity, the parallel folds of Kingsclere and Pewsey arose. These three ridges formed the Northern boundary of the Hampshire Basin ; and three more, the Sandown, Brixton and Purbeck folds, the Southern borders. Within this extensive and elongated depression the Winchester, Stockbridge, Portsdown and other minor flexures occur. At the time of the uplift none of these lesser ridges stood out as prominent topographic features, for Tertiary strata filled the hollows and covered the folds, and the general surface of the land was apparently a gently sloping plain,

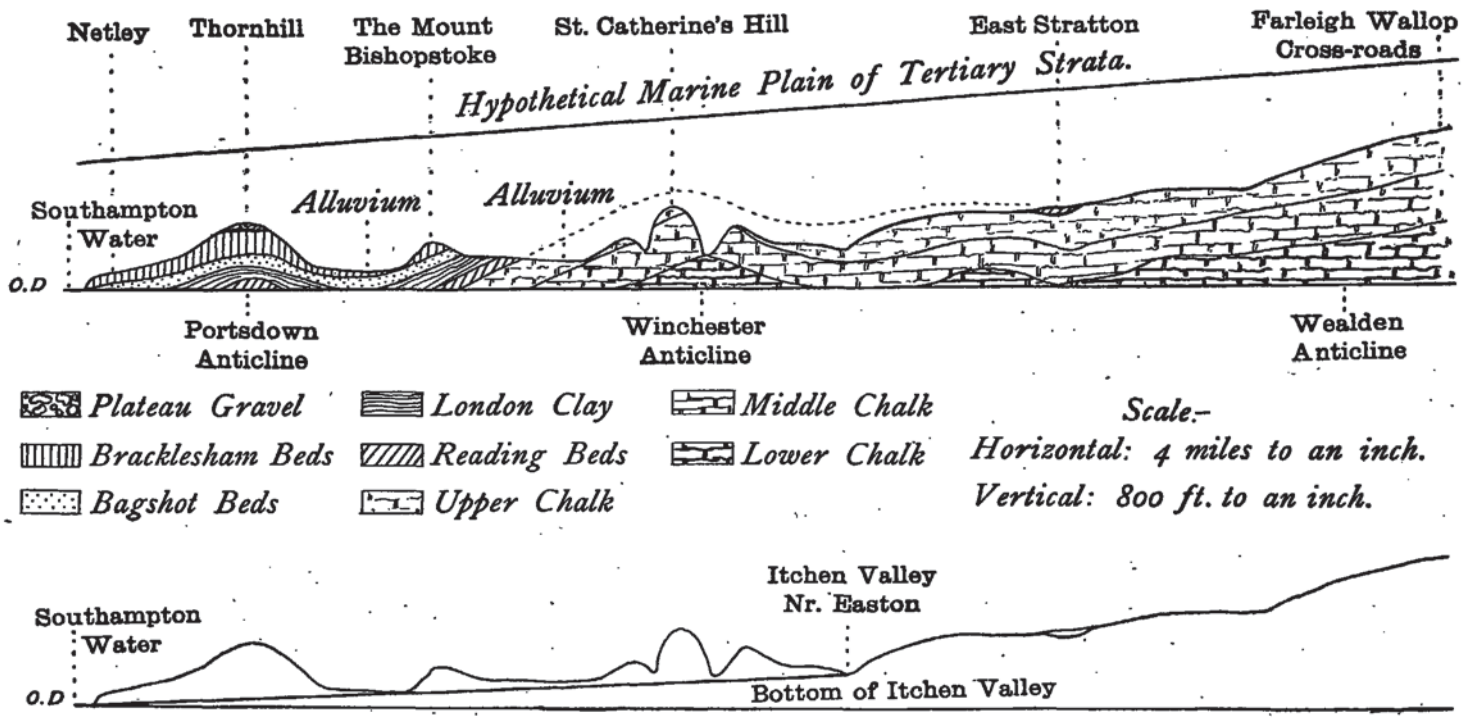


FIG. 1.

SECTION FROM SOUTHAMPTON WATER TO FARLEIGH WALLOP CROSS-ROADS.

(THE HYPOTHETICAL LINE OF THE MARINE PLAIN HAS NO RELATION TO THE VERTICAL SCALE.)

the result of marine denudation. The deepest depression of the Hampshire Basin was at its South Eastern extremity, following the axial line of its main trough lying between the Wealden and Sandown folds. A large part of its area is now submerged under the sea, off the Sussex coast. Thus the Hampshire Basin, since its inception, has been enclosed by high uplands of anticlinal structure on the North, South and West, with a wide opening to the South East into the great English Channel Valley. Here was the only outlet for the drainage of the Hampshire Basin; and as, notwithstanding the local tilt of the beds by the minor folds, the regional dip-slope of the strata is also to the South East, the direction of the rivers has been determined since Miocene days.

Although there is no land surface of Miocene Age existing, nevertheless, taking into consideration these facts, and that rivers once started along the lines of least resistance continue approximately in the same course, we may infer that the Miocene rivers had more or less the same trend as the larger rivers now flowing into the main synclinal trough. That several hundred feet of Tertiary strata then capped the anticlines forming the Northern boundary of the Hampshire Basin is clear, for the restoration alone of the chalk since removed by denudation would not have given the necessary altitude to the rivers flowing off their watersheds to pass over the Winchester, Stockbridge, Warnford and Portsdown[1] anticlines. The crowns of these arches then stood much higher, but, nevertheless, they must have been lower than the watersheds on which the rivers originated. If not, those ridges would have formed an impassable barrier, for the present deep valleys through them were not then excavated, and it follows that, from the high ground of the Northern boundary of the Hampshire Basin, there must have been a continuous, sloping plain (Fig. 1) of Tertiary strata.

At this time the rivers of the Hampshire Basin were all consequent or dip rivers. The River Itchen, for example, had a North and South course above Winchester, and the streams that now supply its head-waters are subsequent streams which then had no existence.

It may well be that the Eastern and Western Yar, Medina, Frome, Trent, Stour, Avon, Test, Itchen, Meon, Arun and Adur are the modern representatives of the Miocene rivers. These were the tributaries of a large river, an extension of the Frome, flowing through the Solent and Spithead Valleys, round the South Eastern flank of the Sandown fold into a great trunk river. The latter was also fed by the various rivers of the South of England and the North of France, West of the Wealden arch. This noble river flowed down the Channel Valley to the Atlantic. (Fig. 2.)

By the Pliocene Period the main lines of drainage had become

[1] At St. Denys.

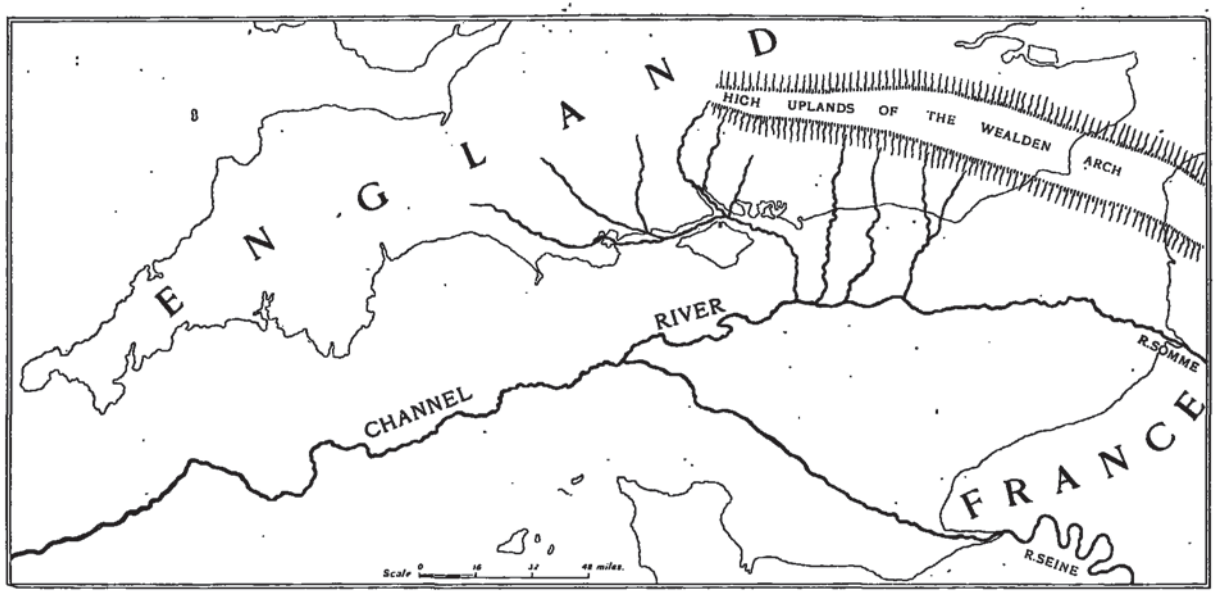


FIG. 2.

THE RIVERS OF THE
HAMPSHIRE BASIN AND THE CHANNEL RIVER IN MIOCENE TIMES.

defined. Later, the South of England, the Channel Valley, together with the Northern coastal regions of France subsided, the result being that the Hampshire Basin, relatively to the sea-level, was apparently several hundred feet lower than it is now. The Lenham Beds of Pliocene Age lying on the chalk of the North Downs prove a subsidence there of 860ft.[1] and the Pliocene deposits of St. Erth, Cornwall, a depression of 340ft.,[2] and there are marine beds of a similar age in the Cotentin, France. The Lenham Beds were not laid down in the same sea as the St. Erth Beds. The two seas were separated by the continuous range of high uplands of the Wealden arch running from France, through Sussex to Hampshire. The inference that the subsidence of Kent, Cornwall and France must have affected the Hampshire Basin is supported by evidence. The plateau gravels of the South of Hampshire and the North of the Isle of Wight have been shown by Codrington[3] to be portions of tablelands, once continuous, having an elevation in some localities, of over 400ft O.D., and all gently inclined to the deepest and main trough of the Hampshire Basin. Throughout the whole area the sheets of gravel are resting on a comparatively even surface of either Secondary or Tertiary strata. The tablelands end in high escarpments at Bramshaw, Chilworth, Bitterne, Bursledon, Sarisbury and elsewhere on the mainland and in the Isle of Wight at St. George's Down and Headon Hill. Without their extension, at some time, much farther towards the chalk country,[4] it is difficult, if not impossible, to explain their abrupt termination and the deposition of the gravel now lying upon them.

It is clear that the denudation of the tablelands could not have been produced by river action or subærial agencies; the sea only could form such plains. As Codrington[5] observed, "the levelling of the tablelands [was] probably effected in an inlet of the sea." Indeed, the tablelands, on which the gravel rests, are inclined marine plains or platforms like, but of greater width than the two marine platforms formed at later stages along the Hampshire and Sussex coasts, the Portsdown-Goodwood raised-beaches being the vestiges of the boundary of the one and the Selsey, Worthing and Brighton raised-beaches of the other. But where are the cliffs and the raised-beaches of the sea which was responsible for the extensive plains at higher levels on the mainland and the Isle of Wight? They were destroyed during the successive glaciations that followed, which is not surprising when we consider that such cliffs would have been composed of the easily

[1] Reid, C., Mem. Geo. Surv., Plio. Dep. Brit., 1890, p. 69.

[2] Reid, C., op. cit. p. 65.

[3] Codrington, T., Q.J. Geo. Soc., 1870, p. 548.

[4] Codrington, T., op. cit. p. 545 and sections on pl. xxxvii., also Woods, Junr., S.V., Q.J. Geo. Soc., 1875, Fig. I., p. 25, also White, H. J. Osborne, Mem. Geo. Surv., Geo. I. of Wight, 1921, p. 170, Fig. 36.

[5] Codrington, T., op. cit., p. 549.

disintegrated Tertiary strata and that the much more recent Portsdown-Goodwood and Worthing-Brighton cliffs and beaches have almost suffered obliteration. There are, however, traces of a Pliocene beach. These are the "large, incompletely rounded beach-pebbles or cobbles of flint and Selbornian chert and cherty sandstone,"[1] contained in the gravel patches on Brading and Mersley Downs, Isle of Wight, 400-415ft. O.D. Mr. H. J. Osborne White[2] powerfully argues that this material could not have been derived from Tertiary strata; that it was formed after the Miocene uplift; that the large cobbles of cherty sandstone could not have travelled far from their place of origin, for that rock yields quickly to attrition on a modern shore; and concludes that probably the Brading and Mersley Down gravel patches comprise, to some extent, "the relics of a Pliocene beach." The Pliocene Sea was the responsible agent and the material came from the Upper Greensand outcrop of the Brading and Mersley Downs. The enormous denudation that had already taken place is vividly brought before us, when we consider that the sheet of gravel on St. George's Down, Isle of Wight, not far away, is lying upon the tilted Lower Greensand beds, proving that upwards of 3,000ft.[3] of younger strata had been removed before its deposition. This gravel was probably laid down in the same sea whose breakers made the Pliocene beach.

It may be asked why no other Pliocene deposits are found in the Hampshire Basin. Some of the plateau gravels over 400ft. O.D. may belong to this period. Any deposits of the Pliocene Sea would have been laid down near its shore-line, which appears to have passed through the district between the escarpments of of the high tablelands and the chalk country, the very area which has suffered the most denudation, as evidenced by the escarpments which now tower from 150-200ft above the low ground beyond them. That Pliocene mammals frequented the regions contiguous to the Hampshire Basin is certain, for teeth and bones of elephants have been discovered in Dorsetshire and Sussex, of *Elephas meridionalis*, an upper Pliocene elephant, at Dewlish[4] and of the lower Pliocene elephants, Mastodon and Stegodon, at Piltdown, Sussex. All these specimens, although found in beds of Pleistocene Age, were derived from some Pliocene deposits that once existed but are now destroyed. If the Pliocene deposits which contained them have been entirely removed, it is not very amazing that no remains have yet been found in the Hampshire Basin. Other facts in support of the foregoing evidence occur in the sequel.

The Pliocene submergence resulted in the gradual entrance of the sea into the Channel Valley as far as the Western slope of

[1] White, H. J., Osborne, Mem. Geo. Surv., Geo. I. of Wight, 1921, p. 167.
[2] White, H. J., Osborne, op. cit. p. 168.
[3] Reid, C., Vic. Hist. Hamp., pt. 1, 1920, p. 30.
[4] Fisher, Rev. O., Q.J. Geo. Soc., vol. xliv., p. 818, 1888, also vol. lxi., p. 35, 1905.

the Wealden arch, which was not yet breached. In time it reached the main syncline of the Hampshire Basin, sweeping past the then Tertiary-covered flanks of the South Downs, leaving Portsdown as an island, across Hampshire, curving round the South-Eastern corner of Wiltshire, over Dorsetshire to the Purbeck Hills, thence along the Tertiary strata on the Northern slopes of the Brixton anticline to the South of Carisbrooke, where it appears to have crossed over the outcrops of these beds, and of the Chalk, Upper Greensand and Gault on to the Lower Greensand, embracing the St. George's, Mersley and Brading Down gravel patches, and following the Sandown anticline South-Eastwards. (Fig. 3.) Its exact bounds cannot be determined, but the area given comprises that suggested by the position of the high plateau gravels and by the prolongation of the tablelands to their probable original extent, after making allowance for the strata since removed from the slopes of the surrounding uplands. The shore of the Pliocene Sea or Solent Sea, as we shall hereafter distinguish it, was nowhere, on the present mainland, in contact with the Chalk, for Tertiary strata were then lying on its dip-slope. In fact, there is reason to believe that the Tertiary beds were still continuous between the London and Hampshire Basins.[1] It appears, from the Pliocene beach and the highest plateau gravels, that eventually the Hampshire Basin, up to a level of 450ft. O.D. or more, was covered by the sea. While this submergence was in progress the inequalities of the earlier Pliocene land surface were obliterated and the plains were formed. The effect on the drainage was that the courses of the rivers were so much shortened that they became comparatively insignificant, with a much reduced velocity and correspondingly lessened eroding power, but for a long period, during which no movement of the land took place, the uplands were subjected to subærial erosion.

It will now be necessary to consider under what conditions the gravels from the high plateaux to about 150ft. O.D. were laid down. In 1862, the Rev. W. Darwin Fox[2] pointed out that the Isle of Wight was once joined to Dorsetshire, and that the rivers now entering the sea at Poole and Christchurch were probably prolonged, through what is now Christchurch Bay and the Solent, to the sea at Spithead. Codrington[3] in 1870, in his well-known paper, concluded that the gravels were spread out in an inlet of the sea during the slow elevation of the land. Some geologists, although agreeing that the high-level plateau gravels may be partly of marine origin, yet consider that, in the main, the gravels were deposited either by the river suggested by Darwin Fox, or by its tributaries. Sir John Evans[4] called this river the " ancient

[1] Jukes-Browne, A. J., Q.J. G. Soc., vol. lxii., No. 546, pp. 159, 160.
[2] Darwin Fox, W., Geologist, vol. v., p. 452:
[3] Codrington, T., op. cit. p. 549.
[4] Evans, Sir John, Anc. Stone Imp., 2nd ed., 1897, p. 692.

River Solent." To explain the presence of greensand-chert and silicified shell-limestone of Purbeck age in the plateau gravels from Woodfalls to near Bramshaw, Clement Reid[1] thought that they "mark approximately the ancient course of a stream, which connected in a direct line, the Salisbury Rivers with Southampton Water." To this he gave the name of the "Old Southampton River," and postulated that the River Avon at that time had its source near Fordingbridge and that, through the separation by the sea of the Isle of Wight from the mainland, which gave it a much greater fall, it captured, by the denudation of the head of its valley, the far greater river, which thus obtained a much shorter course to the sea. His first opinion was that the diversion occurred in the Pliocene Period; later, he held the view that the breach by the sea was accomplished in Pleistocene days. There are good grounds, however—stated hereafter—for believing that it happened in the Holocene or Recent Period, and, if our present premises are justified, then *ex hypothesi* the Southampton River theory falls. Moreover, the rock fragments mentioned were probably derived indirectly from the West, like the similar specimens to be found in the gravels of Beaulieu Heath, and in those around Bournemouth and elsewhere, at some distance from the supposed valley of the "Old Southampton River."

Again, how are we to explain the sheets of gravel on the sloping plains of the New Forest, South of the high plateaux? What river or rivers laid these down? The low-level plateau gravels of the New Forest are represented in the river terraces, but the high-level plateau gravels are not. The high-level gravels are much coarser in texture than those of the lower levels. Why should this be, if both are fluviatile deposits? It cannot be explained by the fact that the rivers contained a greater volume of water than now, for even so, there would be variations from coarse to fine in the gravel, owing to fluctuation in the velocity of the rivers. The flints and other rock constituents are embedded with their long axes pointing in all directions. Codrington[2] pointed out that the fall of the flattest of the tablelands was very great for a river; such a fall would have produced a velocity too great to spread gravel over plains more than 20 miles wide. Prestwich,[3] doubting that the gravels were deposited by the Solent River, considered that "the gravel is wanting in the essential characters of a fluviatile gravel, the gradients are incompatible with the course and fall of a river, the wear of the materials is too small, and there is an entire absence of fluviatile remains," and in a later paper[4] showed that "from Poole to Lymington, a distance of 20 miles, the gravel is nearly a dead level, and for

[1] Reid, C., Mem. Geo. Surv., Geo. of Ringwood, 1902, pp. 30 and 31.
[2] Codrington, T., op., cit., pp. 546,-7.
[3] Prestwich, Sir J., Q.J. G. Soc. 48, 1892, pp. 274, 275.
[4] Prestwich, Sir J., Geo. Mag., Dec. 4, vol. 5, 1898, p. 351.

the whole 35 miles to Stubbington there could only have been a fall of 60 to 70ft. With these gradients, the transport of such a mass of *débris* as constitutes the gravel-beds would have been an impossibility." Moreover, the uniformity of the sheets of gravel over these wide and extensive plains seems of itself to preclude the possibility of their being the work of a river. A river meanders from side to side of its valley, and the supposed Solent River and its tributaries would, by reason of the continual elevation of the area, be constantly getting an increased fall, and, as erosion would go on at the same rate, the formation of bluffs and terraces would be a natural corollary. Yet the gravel sheets are lying on the plains without revealing any sharp gradient, terrace or bluff. It may well be asked where are the escarpments of the valleys of the supposed great river or rivers responsible for this vast mass of gravel, and the watersheds prodigious enough to supply the volume of water required. The hydrographical areas of the rivers of the Hampshire Basin are not great, and they could not have been much more extensive at the date of the initiation of the rivers.

The elongated outlier of gravel on St. George's Down, Isle of Wight, over 400 ft. O.D. and standing high above the contiguous valleys, is thought by some to be of fluviatile origin and to have been deposited by the River Medina, when that river had a much greater bulk and flowed at a far greater height. But here, also, it is impossible to find a watershed of sufficient capacity, for the water-parting dividing the Medina from the Western Yar is not far away.

Realising this, Mr. H. J. Osborne White,[1] although believing that this gravel is of "fluvial origin," says that "one turns to the hypothesis of rapid spring thaws of deep snow-fields, during a sub-arctic phase of the Pleistocene Period as affording a more probable explanation of the anomalous occurrence of a series of deposits, appropriate to a considerable river, in a drainage-area normally capable of nourishing only a little brook." That such conditions did obtain during the inter-glacial phases is without question, but, if we consider this gravel a deposit of the Medina, we have to explain its former continuation with the patches on Stapler's Heath, Osborne and Norris, all of which once formed part of a continuous sheet of gravel spread over a plain sloping to the North. It seems much more probable that these wide plains of gravel on the mainland and in the Isle of Wight, all of which are inclined towards the axial line of the main Hampshire trough, have been deposited in a sea. We have the gravel of the Corfe Hills, 266ft. O.D., and Canford Heath, 200ft. O.D., 2½ to 2 miles from the Stour; the gravel of Pistle Hill, 313ft. O.D., 3 miles from the Avon on the West; and on the East, the gravel of Bramshaw Hill, 414ft. O.D., 5 miles from the Avon and 6 miles

[1] Osborne White. H. J., Geo. I. of W., Mem. Geo. Surv., 1921, p. 172.

from the Test; the large outlier of gravel at Chilworth, 300ft. O.D., over 3 miles from either the Test or Itchen; the gravel of Thornhill, 250ft. O.D., 2 miles from the Itchen; the gravel patch in Parkhurst Forest, 274ft. O.D., 1½ miles from the Medina and 2½ miles from the Solent; the gravel of Stapler's Heath, 286 ft. O.D., 2 miles from the Medina; the gravel at Northwood, 217 ft. O.D. on the West and Whippingham 180ft. O.D. on the East, each 1 mile from the same river. All these are the remnants of former gravel plains, and bearing in mind the great distances of these gravel deposits from the river valleys it is incomprehensible that they could have been deposited by the rivers mentioned, or even by a Solent River.

Large rounded flint-pebbles resembling those formed on a beach, occur in the gravel-pits near Northwood Church, Isle of Wight, 210ft. O.D., and the gravel is much inter-bedded with sand seams. At Stoney Cross in the New Forest, 350ft. O.D., many large sub-angular and rounded pebbles occur. In fact, the gravel of the plains contains, both on the mainland and in the Isle of Wight, water-worn material that could well have been formed under littoral conditions, and it is usually stratified. The foregoing facts taken in the aggregate seem to be sufficient evidence that the gravels of the plains are not river gravels, but were spread out in the Solent Sea during continuous elevation. The extent of this sea had been much reduced since its first occupation of the area.

Codrington[1] pointed out that the evenness of the sheets of gravel shows that the same conditions existed from the date of the deposition of the highest to that of the lowest plateau gravels. What were those conditions? Towards the close of the Pliocene Period, Great Britain was in the throes of an arctic climate, and an ice-sheet covered England as far South as the Severn and the Thames. As the Hampshire Basin was in such close proximity, the cold could not have been much less severe, and where not protected by masses of snow and ice, the land was frozen to a great depth. The rivers ceased to run and denudation was reduced to a minimum, if not altogether at a standstill. When this extreme arctic phase gave way to milder conditions, denudation proceeded apace and amply made up for the period of stagnation. The rocks, to a depth of many feet, had been shattered and disrupted by the extreme frosts and the *débris* above the frost line was swept over the general surface of the land by flood-waters, due to the melting of the ice and snow-fields of the uplands and an excessive rainfall, into the Solent Sea. Such a condition, only less intense, was suggested by Clement Reid[2] for the origin of the Coombe Rock at a much later stage. Direct proofs of glacial conditions are meagre, probably because the area

[1] Codrington, T., op. cit., p. 546.
[2] Reid, C., Q.J. G. Soc., vol. lxiii., 1887, p. 364.

was covered by the sea, but here and there the gravel is folded and contorted, and the stratum of clay or marl upon which it lies is likewise affected. In addition, there is indirect evidence. At Pistle Hill 60 per cent. of the larger stones are pebbles[1] and many pebbles occur at Chalbury Hill, Picket Post, Deadman Hill and various other localities. The presence of these Tertiary pebbles in such large quantities suggests that they are not the result of excavation by rivers, which pass across a comparatively narrow width of any bed, but are rather the disintegration over the whole outcrop by some agency, such as glacial conditions would supply. Similarly, we must account for the origin of the flints, since the vast quantity in the superficial deposits could not have been derived simply by the mechanical action of rain falling upon the chalk. Torrential downpours sufficient to do the work would, under any conditions, be local and exceptional. The amount of rain-water that chalk covered with vegetation will absorb is astounding, as is well known. Under ordinary climatic conditions the enormous masses of flints could never have been obtained. Nor could the cutting by rivers of valleys through the Upper Chalk, have produced a sufficient quantity. Subærial agencies under glacial conditions acting upon the whole line of outcrop of the Upper Chalk would alone be adequate to furnish the supply. Again, a very large number of Palæolithic implements have been discovered in the gravels of the plains about 150ft. O.D., and several have been recorded from heights up to 355ft. O.D. The implements were not dropped or lost in river or sea, but have been derived from the land. They are not like the remains of vegetation, insects, or the carcasses of animals and birds, which easily float. They must have required for their removal a volume and velocity of flood-water, which would make the area uninhabitable by man. Therefore, the implements do not afford the same evidence of contemporaneity as the remains of organisms embedded in deposits of the identical river, lake or sea in which they had been actually living. They yield the same proof as derived fossils that they are of an earlier date than the stratum in which they are found. That is their geological value. Man must have been resident on the uplands of the Hampshire Basin, and have retreated South from the increasing cold. The implements he had left behind, together with the enormous masses of flints and other *débris* comprising the gravels, were swept over frozen surfaces by flood-waters from thawing snow-fields, swollen by torrential rains. No ordinary circumstances could have produced the requisite conditions. The rivers also were loaded with the detritus and much was transported by river-ice. The nature of the material thus removed is strikingly seen in the clay-with-flints deposit, patches of which are found not only on the summits of the chalk downs, but also on their

[1] Reid, C., Mem. Geo. Surv., Geo. of Ringwood, 1902, p. 43.

slopes, even passing on to the Tertiary formations. It is highly suggestive that the greater mass of the flints and nearly all the implements of the gravels are iron-stained. Were they in great part so coloured before they reached the plains and valleys? The writer has handled hundreds of implements from the gravel, but with the exception of several from Kimbridge, which are evenly coated with iron, he could detect no iron deposit upon them, while many of the implements from Dunbridge are quite white. Layers of white gravel occur here and elsewhere, but it is possible for the bleaching of both the gravel and the implements to be due to exposure on the surface. If the bleaching took place after deposit, one would expect this gravel to be, not in definite layers, but in irregular patches. Moreover, if the patination has been altogether subsequent to deposition, why have the white implements escaped? It is probable that much of the iron-staining of the flints is due to their having lain in or on a material such as clay-with-flints, which is largely the residuum of the Reading Beds and highly charged with iron. Many flints are met with on the surface of the Downs, similar in patination to those from the gravels, but we know of no palæolithic implement having been found *in situ* in clay-with-flints, However, Messrs. G. W. Willis, J. R. Ellaway and H. N. Rainbow, who have been for several years conducting systematic researches in the Basingstoke district, have recently found at Ellisfield, 600ft. O.D., Farleigh, 620ft. O.D., Hannington, 650ft. O.D., Popham, 580ft. O.D., and elsewhere, many palæolithic flakes, all patinated from light ochreous to dark reddish-brown. They seem to occur on ploughed fields at the edge of clay-with-flints, as shown on the Geological Survey maps. These gentlemen have also discovered, at heights varying from 660ft. O.D., to 290 ft. O.D., on arable land, also in proximity to clay-with-flints, implements of both Chellean and Acheulean types. From an apparently ochreous colouring these implements, from exposure on the surface, have become partly bleached. Mr. William Dale, F.S.A., F.G.S.,[1] has obtained implements of a palæolithic type from ploughed fields on high ground at Dunbridge and Chilbolton.

We have thus, lying upon the Downs, a heterogeneous mass of *débris*, clay-with-flints, which, if sorted by aqueous agency, would be similar to that found in, and associated with, the gravels of the plains and valleys, while in the soil are found implements with both ochreous and white patination, which no doubt have worked up to the surface from the sub-soil. The clay-with-flints and the implements appear to be the stranded vestiges of the material removed during the different inter-glacial phases.

But to which phase do the plateau gravels belong? Chellean and Acheulean implements have been recorded from the high plateau gravels of the New Forest and the Isle of Wight.

[1] Dale, Wm., Proc. Soc. Ant. L., 2 S., xxv., 46, 1913.

Prestwich[1] discovered an Acheulean implement at Redlynch, 320ft. O.D., and Dr. T. G. Longstaff[2] has found Chellean implements at Stoney Cross, 350 and 355ft O.D. Mr. S. Hazzledine Warren[3] has obtained Acheulean implements near Headon Hill, Isle of Wight, 360ft. O.D. The finding of these palæoliths proves that these gravels are not older than the Acheulean period. No Mousterian implements, as far as the writer is aware, have been recorded from the gravels of the plains, nor in valley gravels at a height greater than 150ft. O.D. Therefore, it appears that the gravels of the plains from 355ft. to 150ft. O.D. were spread out in the Solent Sea during sub-glacial conditions prior to the Mousterian, and later than the Acheulean period. It follows that these conditions continued from the close of the Acheulean period to the approach of the Mousterian period. This was apparently the Mindel-Riss inter-glacial phase, for there is evidence of two later glaciations in the Hampshire Basin. One hesitates to suggest that man was here before the Mindel glaciation, for this would give an earlier date to the Chellean and Acheulean periods than that given by continental authorities, but there seems no alternative interpretation of the facts.

The plateau gravels, other than those of the New Forest area, deposited during the Mindel-Riss inter-glacial phase, are those at Shootash and Cadbury, Chilworth, Thornhill, Sarisbury, Rooksbury, Stapler's Heath, St. George's Down, Northwood, Parkhurst, Hamstead, Headon Hill, etc. The river gravel terrace, 250ft. O.D., of the Test at Chilbolton, where Chellean implements have been found by the writer and others, and the three terraces of the River Avon at 350, 300 and 250ft. O.D.,[4] should be correlated with this period.

The elevation of the land ceased for a time, and the Portsdown and Goodwood raised-beach was formed. The marine platform, upon which this sea-beach lies, extends Eastward along the Sussex coast. The sea must also have had Northern, Western and Southern boundaries. The gravel sheet, capping the cliff of the Northern border of the Solent, rises with a gentle slope towards the New Forest, and at about 140ft. O.D., shows in places a rapidly steeper gradient, denoting a degraded bluff, the equivalent of the Portsdown-Goodwood cliff. In the Isle of Wight the sands at Ruffin's Copse, near Rew Sheet, are of a marine character.[5] Last year in a long section exposed in widening the Newport-Cowes road, near and above Cowes, up to 150ft. O.D., sub-angular and rounded flint pebbles of varying sizes could be observed. These and other flints were lying in a rough-and-tumble manner,

[1] Evans, Sir J., Anc. Stone Imp., p. 632.
[2] Smith, R. A., Prehist. Prob. in Geo. Proc. Geo. Ass., vol. xxvi., pt. 1, 1915.
[3] Geo. Mag., 1900, pp. 406-412.
[4] Reid, C., Mem. Geo. Surv., Geo. of Ringwood, 1902. Fig. 4, p. 34.
[5] White, H. J., Osborne, Mem. Geo. Surv., Geo. of I. of Wight, 1921, p. 175.

and the appearance of the deposit strongly suggested formation under littoral conditions. The gravel near Binstead and at Ryde contains beach-pebbles and in the Oakfield and St. Helen's outliers shingle occurs. These beds are portions of a littoral deposit once stretching from Thorness to Knowles, near Bembridge. Now as the height of these marine formations coincides with that of the Portsdown-Goodwood raised-beach 140-150ft. O.D., they doubtless mark the Southern shore of the Solent Sea at this time. The latter had become considerably contracted and its boundary was approximately Goodwood, Westbourne Common, Portsdown, Netley Common, Southampton Common, Beaulieu Heath, Bournemouth, Poole, thence across what is now Christchurch Bay, under Hamstead to Thorness, Rew Street, Cowes Cemetery, Wootton, Ryde and St. Helen's (Fig. 3).

Marine fossils have been found on the Portsdown-Goodwood shore-line, at Waterbeach, though not in sufficient numbers to prove the climate then prevailing, but the deposit in which they occur, according to Clement Reid,[1] "is of the same age as the deeper-water clay with Southern mollusca found at Selsey," and therefore "a true inter-glacial deposit."

The fossils of the estuarine mud of Stone and West Wittering deposited at this time, also reveal a warm climate. What then is the age of the Portsdown-Goodwood beach? A temperate climate had set in and there are grounds for believing that this was the Mousterian Period and the Mindel-Riss inter-glacial cycle. Implements of Chellean and Acheulean types have been found in contemporary gravels, but they were derived from earlier gravel deposits, for, as we have attempted to show, those periods had passed. Few, if any, Mousterian implements would be found in contemporary deposits. There are several fine implements in the Dale Collection in the Winchester Museum, from the gravels of Coxford, Shirley, Portswood, Woolston, Bursledon, at 100ft. O.D., and from those of Southampton Cemetery, Shirley Church, Shirley Road, and Hill Lane, Southampton, at 70ft. O.D. That these gravels were laid down in the Solent Sea is proved by the fact that there are no bluffs or terraces, but one even plain extending two miles from East to West and at right angles to the Test and Itchen valleys. There are also Mousterian tools in the same collection, from the river gravels at Dunbridge, 150ft. O.D., Belbin's Pit, Romsey, 100ft. O.D., and Kimbridge, 100ft. O.D. Therefore, as the height of the gravels around Southampton in which these implements have been found is not greater than 100ft. O.D., and that of the River Test gravels is 150ft. O.D., neither can be contemporary with the Portsdown-Goodwood beach, for they are at too low a level. We may thus justly infer that this beach was formed when Mousterian man was living in Hampshire and that his implements were swept off the

[1] Reid, C., Mem. Geo. Surv. Chic., 1903, p. 40.

surrounding uplands during the inter-glacial phase, which followed the succeeding Riss glaciation.

The main rivers of the Hampshire Basin had, by the retraction of the Solent Sea, regained some miles of their courses lost in the Pliocene Period. Many of the minor streams were initiated now, and began the carving out of their valleys. All the rivers have since deposited in their valleys gravel partly derived from the marine gravels of the plains. In some localities the sheets of gravel have been so much denuded that outliers only remain, while in others these fluviatile deposits are impossible to distinguish from those of marine origin.

The close of the Portsdown-Goodwood beach era was marked by a re-elevation and a return of arctic conditions—the Riss glaciation. The evidence of this is afforded by the Erratic Gravel of Selsey, the chronological position of which must be discussed. The Erratic Gravel is composed of coarse flints and blocks of rocks foreign to the district and weighing, in some cases, several tons. These boulders could only have been brought there by the agency of drift-ice, and they must have been borne long distances. The Erratic Gravel is found associated with the Mud Deposit, in which occur Mollusca of a Southern type, but these two formations have not yet been observed in true super-position. The important question now arises as to which is the older of the two. To quote Clement Reid[1] "No fragments of Southern Mollusca have yet been found in the erratic-gravel, but the clays with Southern Mollusca often contain re-deposited erratics. The gravel with erratic blocks is therefore the older of the two." The solution of the problem may be exactly the reverse, however, since the absence of derived Southern Mollusca in the Erratic Gravel may be due to the fact that it is not composed of material denuded from the Mud Deposit. The erratic boulders as well as the other constituents, were derived from a different source from that of the Mud Deposit. It seems much more probable that the occasional erratic boulders found in the Mud Deposit were distributed by drift-ice than that they should be "re-deposited" blocks, as the fine sediment of the Mud Deposit shows deposition in tranquil waters, whereas the boulders would require either extremely powerful currents or the breakers of a shore for their removal. The Mollusca found in the Mud Deposit prove that it was laid down in a sea with "a depth of 10 or 25 fathoms,"[2] such a limit as would be required, if contemporary with the formation of the Portsdown-Goodwood beach. Thus it would seem that it cannot be younger than the Erratic Gravel, for the succeeding deposits prove "a gradual shoaling of the water and change from an open sea to a sheltered estuary,"[3] which is

[1] Reid, C., Q.J. Geo. Soc. 48, 1892, p. 354.
[2] Reid, C., op cit, p. 355.
[3] Reid, C., op. cit., p. 356.

in accordance with the renewed elevation that took place after the Portsdown-Goodwood beach era. Moreover, the erratic blocks occur over an extensive area beyond the Mud Deposits, which fact, taken in conjunction with the occurrence of erratic blocks in that formation, seems to imply that the Mud Deposit had been denuded before the Erratic Gravel was distributed. Mr. A. Bell,[1] after prolonged examination of the district, considers that all the facts point to a "much later period of distribution for the erratics" than for the laying down of the Mud Deposit. There is reason therefore to conclude that the Mud Deposit, with its temperate fauna, was laid down at the time of the Portsdown-Goodwood beach, and is older than the Erratic Gravel formed during a glacial climate. It thus appears that the Hampshire Basin was again in the grip of an arctic climate, that of the Riss glaciation. When the extreme cold gave way to a warmer inter-glacial phase, a great lowering of the river valleys and general denudation of the land were once more in progress. Conditions like those under which the Coombe Rock was formed were again in force. The gravel sheets of Selsey, Wittering, Gosport, Lee-on-Solent, Hill Head, those bordering the Southampton Water and the Northern coast-line of the Solent to Lymington, and the gravels West of Bournemouth to Poole were apparently deposited now. At Selsey, Wittering, Portsmouth, Alverstoke and Lee-on-Solent, blocks of sarsen and erratics of igneous rocks are found in the gravels. The gravel in places is contorted. Erratics also occur on the low coastal plains of Sussex. Thus it appears evident that these gravels were spread out during the retreat of the Riss glaciation. The gravel of the Belbin's Stage[2] of the River Test should be correlated with this period. The high escarpments of the gravel tablelands all looking towards the chalk country are obviously not the work of rivers. They originated in part by water drainage soon after the retreat of the sea from the areas now high plateaux, but in the main, they are probably the result of the approach and retreat of the Riss and Würm glaciations. The melting of ice and snow-fields, combined with abnormal rainfall, produced flood-waters which poured off the dip-slopes of the chalk uplands along the lines of drainage thus formed on the gravel tablelands, scooped out the soft Tertiary strata already disintegrated by the frost and carried the material into the river valleys. The sagging of the gravel, to be noticed at the edges of the escarpment and around the outcrops of the outliers of gravel covering isolated high ground, may be the effect of the thawing of the frost in the upper layers of the Tertiary stratum on which they lie, together with the weight of the superincumbent mass of gravel. The Chalk had become, to a great

[1] Bell, A., Yorks. Phil. Soc. Rep. for 1892, 1893, pp. 59, 69 and 77.

[2] White, H. J. Osborne, Mem. Geo. Surv., Geo. of Win., Q.J.G.S., vol. xlix., 1893, p. 328

extent, denuded of Tertiary strata, and the combes on their dip-slopes, which afford clear testimony to glacial conditions, were now well defined. During this inter-glacial cycle the elevatory movement continued until the land was 50-90ft. higher than at the Portsdown-Goodwood beach stage. The uprise appears to have been intermittent, for East of Hurst Castle the gravel sheet from 100ft. O.D., falls by steps.[1] Then came a pause of longer duration, while the Brighton, Worthing, Selsey and Bembridge sea-beaches, now 50ft. O.D., were formed. Their equivalent, a low cliff or bluff under Portsdown, separates the Portsdown-Goodwood beach platform from a lower marine platform. A similar low bluff, about the same level, can be traced from the River Hamble to Southampton. The gravel from Cam's Hall to Portchester Station, 50-30ft. O.D., contains shingle like that of a recent beach.[2] The Portsdown-Goodwood beach stage, it has been inferred, belongs to the Mousterian period and the Brighton, Worthing, Selsey, Bembridge beach stage would seem to coincide with the Aurignacian period. According to previous arguments, implements of that age would only be found in deposits of later date, especially in the Coombe Rock, Head, and the low-level Valley Brickearth, because these formations are the result of the conditions following the Würm glaciation, which were such as would be necessary for the removal of the implements over the land. The fact that an Acheulean implement has been found in the Brighton raised-beach and Chellean implements in deposits of the same age only points to their being derived specimens. It is more than probable that, when the true position of many of the implements found on the surface and now classified as Neolithic has been determined, it will be discovered that they belong to the Aurignacian and later Palæolithic stages.

The sea-beaches and the degraded bluff prove that the Solent Sea had now become contracted into two comparatively narrow branches, one extending to Southampton and the other to Poole. (Fig. 3).

The uplifting movement began afresh, as is proved by the Brighton, Worthing and Selsey raised-beaches being overlain by the Coombe Rock. Clement Reid[3] says that "Subsequent to the formation of the ancient sea-cliff an enormous mass of angular flint and chalk detritus was swept from the Downs, and spread far and wide in a continuous sheet over the lowlands" between the Chalk Downs and the sea in Sussex. He further showed that the Coombe Rock was deposited under glacial conditions when the average temperature in the South of England

[1] Codrington, T., op. cit., p. 532.
[2] White, H. J. Osborne, Mem. Geo. Surv., Geo. of Fareham and Havant, 1913, pp. 74, 75.
[3] Reid, C., On the Origin of Dry Valleys and of Coombe Rock, Q. J.Geo. Soc., vol. lxviiii., 1887, p. 364.

was very far below " freezing point." This appears to have been the Würm glaciation, the last cold phase of the glacial epoch. The effects of this and the Riss glaciation are seen in the combes and dry valleys whose bottoms are covered with angular flints and chalky detritus. The Chalk and Tertiary strata were thus undergoing again as great a denudation as in the preceding interglacial phases. The river valleys were filled with flood-water and river-ice sufficiently thick to carry sarsen-stones over a ton in weight. The writer examined in 1921, in valley-gravel at Highbridge, Brambridge, sixteen sarsens, the three largest of which measured 3ft. by 2ft. 9in. by 1ft. 8in., 3ft. 6in. by 2ft. 8in. by 1ft., 3ft. by 2ft. 1in. by 1ft. 7in. The sheets of gravel in which these blocks occur cover large areas and could only have been carried and spread out under such conditions. Blocks of chalk and chalk rubble are found in these and other low-level valley gravels and testify to the rapid erosion of the chalk that was taking place. The great gravel plains between Eastleigh and Swaythling and around Redbridge, Totton and Nursling appear to have been deposited now. The gravel of the Mottisfont Stage[1] of the River Test should also be correlated with this phase of the Würm glaciation.

On the disappearance of the snow-fields and consequent decrease in the volume of flood-waters, the heavier detritus could not be brought down by the rivers. The finer sediment only was borne, being deposited on the coarser material in the form of brickearth. There was a brickearth stage after each glaciation, for brickearth is found on both high and low-level plateaux, as well as in river valleys. In the brickearth of the Avon Valley, at Fisherton, remains of the mammoth, woolly-rhinoceros, musk-sheep, lemming, etc., have been found.

In September, 1918, the writer found, sticking out of the cliff half-a-mile West of Chilton Chine, Isle of Wight, at the base of two feet of red brickearth of a similar section to that given on p. 225 of the Mem. Geo. Sur. second edition, 1889, an implement made from a large flint beach-pebble (Fig. 4). It is triangular in section; the base has been made by the blow which detached it from the parent nodule. The butt end is the original, beach-battered periphery of the pebble. The point is steep, with fine secondary working, and the sides are boldly chipped. The implement was evidently used as a plane. On the edges produced by the detachment of the flakes are deposits of iron, some in little blobs, the result of the percolation of iron in solution through the brickearth and not of contact with an iron object such as a plough. The implement was *in situ* in undisturbed brickearth 80-90ft. O.D. The writer would place it at the end of the Palæolithic Period, both from its geological position and its character. In the same locality, some few years ago, he discovered a tooth of *Elephas*

[1] White, H. J. Osborne, Mem. Geo. Surv., Geo. of Win., 1912, p. 71.

*primigenius* among scattered gravel lying on a talus of Wealden marls at the foot of the cliff. The tooth and gravel had doubtless fallen from the bed of gravel underlying the sand beneath the brickearth. The gravel was evidently laid down during the


FIG. 4.

Coombe Rock stage of the Würm glaciation and the brickearth when the conditions became less severe. That these valley deposits belong to this period seems to be proved by their being younger than the patches of plateau gravel capping the cliffs near by, which from their position and height appear to be the result of the Riss glaciation. The writer is not aware of any other records of implements from definite and undisturbed brickearth

of the Hampshire Basin. It appears that the low-level river valley brickearth was deposited after the Würm glaciation and that as Prestwich[1] says, "the Glacial times came, geologically speaking, to within a measurable distance of our own times, and that the transition was short and almost abrupt."

The climate became gradually more temperate, and the uprise of the land continued, until it was about 50-60ft. higher than at present. The effect of this elevation on the drainage of the Hampshire Basin is of prime importance, for it was now and now only that the "Old River Solent" of authors had its existence, and that its waters entered the sea at Spithead or thereabouts. Let us first see what result such an elevation would have on the valleys of the Solent, Southampton Water and Spithead. Even with all the denudation, to which they have been subjected by the sea, and with the scour of the double tides, since the separation of the Isle of Wight from the mainland, to which latter agency the deepest depressions are mainly due, the greater part of these valleys would become dry land, if the area were elevated 50-60ft. O.D. A depth greater than 10 fathoms is only found within a few narrow gullies. Thus the Solent Sea of Pliocene days had gradually, through the Pleistocene Period, dwindled in dimensions, until it became an estuary, and at the end of the Palæolithic Period it had become a river valley. The River Frome, with the aid of the Stour, Avon, Test, Itchen, Meon, Eastern Yar, Medina, Western Yar and the smaller streams, which had originated during these changes, and all of which had become its tributaries, had regained this extent of the course, or rather line of flow of its remote ancestor, the Miocene River. However, the latter ran at a higher level by some hundreds of feet than the River Solent That the River Solent continued to flow, until well into the Neolithic Period is proved by the discovery[2] of a fine implement of a late stage of Neolithic culture in peat 20ft. below estuarine mud, at the confluence of the Test and Itchen. Later, the last earth-movement, of which there is record, took place; the land sank to a depth of about 50ft., and the forests around the coast-lines were submerged. One of these forests was observed in excavations at Southampton Docks in 1881-9. Similar submerged forests have been found at Southampton West,[3] Southsea, Portsmouth, Pagham, Bournemouth and Poole.

It was while this subsidence was in progress that the chalk neck connecting the Isle of Wight with the mainland was broken through by the sea. This irruption probably occurred through a valley cut in the chalk downs by a consequent river which flowed Northwards off the dip-slope of the Brixton anticline. The breach was of vital importance to the drainage of the

[1] Prestwich, J., Q.J. Geo. Soc., 1892, p. 343.
[2] Shore, T. W., Proc. Hants Field Club, 1889, p. 54, Pl. II., Fig. 2.
[3] Hooley, R. W., Proc. Hants Field Club, 1905, vol v.; Pt. 1, p. 49.

Hampshire Basin, for the rivers were truncated and had much shorter courses to the sea ; the Solent became a strait and Southampton Water an estuary. The destruction of the Western end of the Isle of Wight and of the cliffs bordering Christchurch Bay has since been enormous, the soft Tertiary strata yielding readily to erosion by the sea. This date for the conversion of the Wight isthmus into an island is strongly supported by the concatenation of the geological events recorded in the preceding pages, and Mr. H. J. Osborne White[1] states that " the character of the flora and fauna . . . . seem to imply the existence of a land-connection within the Recent Period " between the Isle of Wight and the mainland.

The period had now arrived when the sheltered coastal plains were being carpeted with wide sheets of mud. The rush of water on the ebb of the second tide—for double tides began when the Wight became an island—must have been great in so confined a space, and the mud and silt, the finer detritus deposited in the deepest hollows of the Solent Sea since its inception in Pliocene days, were dispersed and re-deposited in the quieter waters covering the coastal plains. Marl, alluvium and peat gradually covered the lower reaches of the river-valleys, and the work of the rivers was almost done, their base-level of erosion being nearly reached.

It is impossible to enter here into a detailed history of each river of the Hampshire Basin. The writer has simply given, as far as possible, a connected and chronological general history of the drainage from the much mutilated geological records, and has shown that there are strong grounds for believing :—

1. That the Solent River had no existence until the Recent Period, but that a trunk river, following approximately the same trend, existed in Miocene days, and that its valley was several hundred feet higher than the present contours of the Solent Valley.

2. That the Rivers Frome, Trent, Stour, Avon, Test, Itchen, Meon, Eastern Yar, Medina, Western Yar, and the minor streams are the truncated tributaries of a comparatively modern river flowing in the same direction and taking nearly the same course as the Miocene River.

3. That a submergence in the Pliocene Period permitted a great influx of the sea, by which the tributaries of the Miocene River were dissevered from the trunk stream.

4. That this sea was gradually contracted throughout the Pleistocene Period by recurrent elevation of the area during three glaciations—the Mindel, Riss and Würm—each succeeded by a warm phase, producing on three occasions conditions similar to those under which the Coombe Rock was deposited.

5. That the detritus was not, like the material composing that Rock, subærially laid down, but was swept by flood-waters

[1] White. H. J. Osborne, Mem. Geo. Surv. I. of W., 1921, p. 186.

into the Solent Sea, where the gravel was spread out in sheets along its shallow borders.

6. That at the end of the Pleistocene Period and the beginning of the Holocene Period elevation had proceeded so far that the rivers were again united to form a trunk river, the River Solent flowing through the Solent and Spithead Valleys to the sea.

7. That during the subsidence at the end of the Neolithic Period the chalk barrier between the Needles and the Dorsetshire coast was breached by the sea, whereupon the Solent valley became a strait, and the Southampton Water an estuary.

8. That there has not been a constant oscillation in the level of the land, but rather that, after the mighty earth-throw that crumpled the strata of the S.E. of England into elongated ridges and troughs, there was a deep subsidence, then gradual elevation with stages of rest, followed by a depression of 50-60ft. in the Recent Period.

9. That the gravels of the tablelands from 355ft. to about 150ft. O.D., were apparently deposited during the Mindel-Riss interglacial and subsequent to the Chellean and Acheulean Periods.

10. That the Erratic Gravel of Selsey was deposited during the Riss glaciation.

11. That the Coombe Rock, low-level valley gravels and brickearth are the results of the Würm glaciation.

12. That the Portsdown-Goodwood raised-beach was probably formed in the Mousterian Period and the Brighton, Worthing, Selsey and Bembridge raised-beaches in the Aurignacian Period.

13. That since the Chellean Period the land has risen over 400ft. and sunk 50-60ft. relatively to the sea-level.