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1.

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ON THE RELATION OF THE WESTLETON BEDS, OR PEBBLY SANDS OF SUFFOLK, TO THOSE OF NORFOLK, AND ON THEIR EXTENSION INLAND;

WITH SOME

OBSERVATIONS ON THE PERIOD OF THE FINAL ELEVATION AND DENUDATION OF THE WEALD AND OF THE THAMES VALLEY, ETC.

BY

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PART I.

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On the Relation *of the* Westleton Beds, *or* Pebbly Sands *of* Suffolk, *to those of* Norfolk, *and on their* Extension Inland; *with some* Observations *on the* Period *of the* Final Elevation *and* Denudation *of the* Weald *and of the* Thames Valley, *&c.* By Joseph Prestwich, D.C.L., F.R.S., F.G.S., &c.—Part I.*

PART I.

§ 1. *Introduction.*

In a paper on the Crag Beds of Norfolk and Suffolk † which I had tho honour of laying before the Society early in 1870, I proposed to term the great bed of flint-pebbles overlying the Chillesford Beds and underlying the Boulder-clay in Suffolk, the "Westleton Sands and Shingle," remarking that "the importance to be attached to those beds does not arise so much from their exhibition here [Suffolk], as from the circumstance that they will serve to determine the position and age of somo beds of sand and gravel, generally without fossils, which have a wide range in tho south-east of England, and the exact [geological] position of which it is important to know in consequence of their bearing on many interesting problems connected with the denudation of the country." I further mentioned that these marine sands and shingle had a much greater extension than had their associated beds on the Norfolk coast, that they ranged through Suffolk, Essex, and far up the Thames Basin, and that the main character by which they were to be recognized was the great preponderanco of well-worn rounded *pebbles of flint* and of *white quartz*, with smaller variable proportions of angular or *subangular chalk-flints*, and of *Lower-Greensand chert and ragstone*, mixed with a few pebbles of quartzite, sandstones, slates, and lydian stone, the wholo indicating the action of currents or streams, not from the north as with the Glacial Drifts, but from the south and south-east.

For some years afterwards various circumstances hindered me from resuming my notes, many of which were made in 1845–1855 during the construction of the Great Eastern Railway and its branches, where the sections are no longer visible. At the meeting of tho British Association in 1881, however, I gave a short account of the extension inland of these beds, and mentioned their occurrence on some of the hills in Essex, Hertfordshiro, Buckinghamshire, Berk-

* Part I. only of this paper, dealing with the coast sections, is here printed. Parts II. and III. will deal with the relation of the beds here described to the Glacial Beds in the Thames Valley, and with some other questions.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 461.

shire, Kent, and Surrey. But that paper was only published in abstract, and without tables or sections.

In the meantime the significance of these beds had not escaped the attention of Mr. Whitaker, who adopted the name of the "Pebbly Series;" but as there are very similar pebbly beds of Tertiary age in the Blackheath, Addington, and Bagshot districts, I think the local name of Westleton, where their typical characters can be best seen, preferable. In 1880 * Mr. Whitaker came independently very much to the same conclusion as myself with respect to certain Pebble-beds on some of the hills around London, as likewise did Mr. S. V. Wood, who gave in his paper of 1880 † a plate of sections and a map showing a number of outliers in the London and Hampshire Basins, but with the drift-cappings marked in many instances doubtfully, and mostly without local descriptions or proofs. I shall have occasion to refer to both these papers at greater length presently.

As regards classification, Mr. S. V. Wood, in his several papers (1866-1872), places the Pebbly Sands of the Bure Valley at the base of the Glacial Series (or of his "Lower Glacial"); whereas Mr. H. B. Woodward, in his Survey Memoir, classes them with the Upper Crag. It is true that in Norfolk they succeed immediately, and in many cases conformably to the Norwich Crag and Chillesford Beds; but, as pointed out by Mr. Wood, there is also often a line of erosion between the two, and although the marine fauna contains similar species, it is poorer and more purely northern than that of the Crag Series. Further the Pebble-beds extend far beyond the area of the Crag, and afford evidence, as I shall endeavour to prove presently, of great physiographical changes having intervened between these two groups. There is evidence also of an equally important, if not a still stronger, break between the "Pebbly Series" and the Glacial Beds. I would therefore assign to the Westleton Beds a position apart, whether in relation to the Crag or to the Glacial Series. They mark a great change not only in the physical geography, but also in the life of the times, for it was then that the existing Mammalian fauna began to supersede the extinct species, and the Molluscan fauna to resolve itself almost entirely into species now common in this country, with a few others, which although still living are, like some of the land animals, relegated to colder climates. This applies also to the flora.

For these reasons and also because this period is one of those coincident, as I hope to show in the second part of this paper, with the time of the final elevation of the Weald and of the genesis of the Thames (the main excavation of the valleys and the great denudation of the Weald being referable to subsequent Glacial and Post-Glacial times), much importance attaches to this geological horizon. I also look upon these beds as the base of the Quaternary Series.

Since 1870 a number of important papers, including several

* Mem. Geol. Survey, "Guide to the Geology of London and the Neighbourhood," pp. 55-57.

† Quart. Journ. Geol. Soc. vol. xxxvi. p. 457.

Memoirs by the officers of the Geological Survey, on different parts of the Eastern Counties, have appeared, and various opinions have been expressed respecting the age, and the correlation, as well as the classification of these beds. It may be desirable therefore, before proceeding to the second part of this paper, to give my reasons for differing from some of these conclusions. The Memoirs of the Survey, to which I shall have frequent occasion to refer, now supply a mass of valuable details, which greatly facilitate the task and do away with the necessity of much local description. I shall confine myself therefore to my own notes and a few typical sections, and to questions of synchronism and classification.

§ 2. *Historical Review.*

In my notice of the Westleton Beds, I referred, but very briefly, to the Bure-Valley Crag of Messrs. S. V. Wood and Harmer, as I touched only incidentally on the beds of north Norfolk *. At the same time, I felt justified in expressing my own views with respect to their general bearing, not only because they differed in many material points from those of Mr. Wood, but likewise on the ground that my paper was the result of independent observations made during the preceding quarter of a century, and our conclusions differed on many material points. It would appear that we were both working independently at the same subject, and the difference of views may have arisen in a great measure, as suggested by Mr. Whitaker, from the fact that whilst Mr. Wood was working from north to south and chiefly inland, I had been working from south to north and chiefly on the coast-line.

That I was not singular in hesitating to accept Mr. Wood's views will be evident from the remarks of Mr. H. B. Woodward, Mr. Clement Reid, and others, who have since surveyed the district.

In 1866 Mr. Wood stated briefly, in the supplement to a paper by his father on the Crag Mollusca †, that in the Bure Valley there was a fossiliferous Crag consisting of sands and shingle with shells (*Tellina obliqua*, *Cyprina islandica*, *Cardium edule*, &c.) in patches, and that this Crag was newer than the Norwich Crag. As these beds in the Bure Valley rest, however, directly on the Chalk, and as the diagrams were only generalized ones, we were, in the absence of detailed local sections, left without the necessary strati-

* I regret that Messrs. Wood and Harmer should have thought that my statement was a misrepresentation of their views. I mentioned, I believe correctly, that they had placed the Bure-Valley Beds on a higher level than the Norwich Crag, though I may have misunderstood, with reference to the Weybourn Crag, the meaning they attached to the term " Lower Glacial," with which they associated these beds. In the absence of more detailed sections and definitions, it was difficult to follow the exact meaning of Mr. Wood's earlier papers. Whether there was anything new in my views, I must leave the reader to judge. There are certainly material differences in our interpretation of the phenomena.

† Quart. Journ. Geol. Soc. vol. xxii. p. 547.

graphical evidence in proof of their exact relationship to the associated strata.

In the following year Mr. F. W. Harmer gave a section of the Yare Valley *, confirming the views of Mr. Wood; and in 1868 these gentlemen read at the Meeting of the British Association in Norwich a joint paper, illustrated with a large map and local sections, but of which an abstract only was published in that year †. In this it was stated that the Pebbly Beds or Crag of Belaugh in the Bure Valley, and the Crag of Weybourn and Cromer, were newer than the Chillesford Beds, and that "the 'sands with pebbles' occupy in the south of Norfolk and the north of Suffolk, the same place relatively to the 'contorted Drift' as is occupied on the Cromer coast by the Weybourn Sand (or so-called 'Crag' of the Cromer coast), the Cromer Till, and the indenting sand (or bed C). These pebble-beds may thus represent in time either the whole or any one of the formations A, B, and C; or they may form merely the closing bed of the true Crag Series, in which case the Weybourn sand, the Cromer Till, and bed C are entirely unrepresented in the south of Norfolk and north of Suffolk." On the next page A is stated to represent the Weybourn Sand with shell patches resting on the Chalk, and "passing up by interbedding into B, the Cromer Till or Lower Boulder-clay," and C the sands which indented into "a deeply-eroded surface of the Till."

In 1869 a paper was communicated to the Norwich Geological Society by Mr. Harmer ‡, which gives a clearer exposition of Mr. Wood's views, and is accompanied by a list of the Belaugh shells, including these of Weybourn (*postea*, p. 93)§. In this Mr. Harmer says that "the only doubt felt by Mr. Wood and himself in connexion with the beds of the Crag Series in Norfolk is, whether or not the pebbly sands of Belaugh and Weybourn are identical with the Pebbly Sands and Pebble-beds which overlie the Chillesford Clay in the neighbourhood of Norwich, of Ladden, of Halesworth, and of Beccles, or whether they do not form a still later deposit," . . . "so that for the present they do not express any opinion on the identity of the Pebble-beds in these two areas."

In other papers published in 1869 ‖ these gentlemen again give the succession of beds about Norwich, and state that the Pebbly Sands and Pebble-beds (a name which they were the first to adopt), which succeed to the Chillesford Clay, "expand northwards into the Weybourn Sand and Boulder Till of the Cromer-Cliff section; this bed is unconformable to the Crag and Chillesford beds, is palæonto-

* Quart. Journ. Geol. Soc. vol. xxiii. p. 89.

† Geol. Mag. Oct. 1868, vol. v. p. 452. The map and sections were not published until 1872, when they appeared in the 'Supplement to the Crag Mollusca.'

‡ Geol. Mag. vol. vi. p. 231.

§ Mr. H. B. Woodward's list of these fossils given at p. 93 is corrected by Mr. Wood up to 1881.

‖ Quart. Journ. Geol. Soc. vol. xxv. p. 446.

logically distinct from them, and is characterized by the first appearance in England of *Tellina balthica*."

In 1870 * Mr. Wood reiterates his opinion that the Pebbly Sands of Belaugh, from which he had then obtained 35 species of Mollusca, are "continuous with the pebbly sand underlying and *interbedded with the Till* along the Cromer coast and yielding similar shells," and he groups these together with the Contorted Drift, as "*Lower Glacial*" (the italics are mine).

In January 1870 my paper on the Norwich Crag and Westleton Beds was read †, although it was not published until 1871, owing to difficulties connected with the lists of fossils. The main object of that paper was to correlate the Westleton with the Mundesley Fluvio-marine Beds, and to show that they passed unconformably *under* the Till of Cromer, with which they have no connexion, and overlay the Norwich Crag.

It was not until 1872 ‡ that Mr. Wood published the detailed sections upon which his conclusions were founded, and gave a full list of the fossils of the "Lower Glacial" beds, including the Bure-Valley and Weybourn Crags. This showed that although we had both arrived independently at the conclusion that the Pebble-beds of both counties were newer than the Chillesford Beds, there were many points, such as in the correlation of the Weybourn Beds, the passage upwards of the Pebbly Sands into the Glacial Beds, the construction to be put on many of the Suffolk Beds, and other points, which I shall have occasion to notice as we proceed, that constituted radical differences.

We have in 1880 § the last expression of Mr. Wood's views with reference to the Pliocene, Glacial, and Postglacial deposits. In this paper he deals with the many theoretical considerations connected with the changes of level and conditions, and the range of the several deposits. He also alters some of his previous determinations in the Suffolk area, and explains his views of the "origin and mode of accumulation of the Pebbly Sand and Cromer Till as one formation." But to obtain a correct knowledge of Mr. Wood's range of work, the reader should consult the several papers here referred to. It is difficult to epitomize them owing to the frequent introduction of theoretical considerations among the questions of fact, and the repeated subordination of the latter to the former.

In 1881 ‖ Mr. H. B. Woodward came to the conclusion that in Norfolk the beds between the Glacial Drift and the Chalk formed an indivisible group—"the Upper Crag or Norwich Crag Series"—composed of a variable group of sands, Pebble-beds, and laminated

* Geol. Mag. vol. vii. p. 17.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 452.

‡ 'Introduction to the Supplement to the Monograph of the Crag Mollusca,' Palæontographical Society, 1872–1874, pp. xv–xviii.

§ Quart. Journ. Geol. Soc. vol. xxxvi. pp. 457–527.

‖ 'The Geology of the Country around Norwich,' Mem. Geol. Survey Expl. of Sheet 66 N.E., S.E. pp. 31–41.

clays, with occasional seams or patches of shells. In this he includes the Pebbly Sands, the Bure-Valley (or Westleton) Beds, the Chillesford Clay, and the lower Fluvio-marine Crag. The Weybourn Crag he considers, with Mr. Wood, to belong to the upper or Pebbly-sands division. He remarks on the importance of the Molluscan fauna and on the fact that the shells are, with few exceptions, of the same species throughout, but varying, though on the same horizon, "in the abundance of particular forms" and "in the number of different species." He dwells on the fact that in the Bure-Valley Crag of Belaugh there are "only two species not positively known to occur in the Crag near Norwich, namely *Tellina balthica* and *Paludina vivipara*," and states that *it is nowhere seen in section in its fossiliferous form above the other "zones" of the Crag** (p. 36). He also considers that the Haddiscoe gravels, "with which the pebble-beds of Halesworth, Henham, and Westleton are correlated, are distinct from the Pliocene Bure-Valley Beds, which I (H. B. W.) group with the Upper Crag" (p. 85).

In Mr. Clement Reid's memoir "On the Country around Cromer," 1882 †, he expressed an opinion that my divisions of the Crag on that coast will not hold good, in that I have placed the Chillesford Clay at different horizons; but as he does not say to which of my sections this observation applies, I am unable to answer the objection. This stratigraphical objection will, however, be met further on in this paper.

In a later paper ‡ Mr. Woodward expresses his belief that the Westleton and Mundesley Beds on the Cromer coast "are not the same as the Bure-Valley beds inland," and he gives an amusing account of "the confused and deplorable condition that the nomenclature of the Pliocene and Post-Pliocene deposits is in." He fears "that the introduction of the words 'Chillesford Clay' had been at the root of nearly all the evil in the shape of confused or complicated classification," but he confesses "that coming from a county where some of the rocks are measured by thousands of feet, he may have contemplated with too little respect divisions that dwindle into inches," no less than five subdivisions having been introduced into 30 feet of strata, and "of these nearly all had two or three names. But most distressing of all has been the indiscriminate identification by some observers of the Chillesford Clay with any micaceous and laminated clay-seam"§.

It may be thought that Mr. Woodward somewhat magnifies the

* The italics are mine.—J. P.

† Mem. Geol. Survey, Explan. of Sheet 68 E.

‡ "Notes on the Bure-Valley and the Westleton Beds," Geol. Mag. dec. ii. vol. ix. p. 452 (1882); and 'Geology of England and Wales,' 2nd edit. pp. 469–508.

§ Laminated clays are common in the Westleton and Mundesley, as well as in the Norfolk Glacial Series. To be sure of the Chillesford Clay, it is necessary to determine it either by superposition or by its fossils, when present, or by following its range on a given horizon. Mr. Gunn named the upper divisions of the Mundesley group "Preglacial Laminated Series."

risk incurred by the adoption of such meagre divisions; but in the absence of more important masses of strata, we have unavoidably to depend on these smaller beds, although it must be with the qualifications he names.

Mr. Woodward states that his conclusions differ from mine in some important particulars, chiefly in the correlation of the beds in several localities. He bases much on the fact that in the general sections I have coloured the Dunwich Cliffs as Glacial Sands *. That, however, in no way affects the special question. Whether the Dunwich Cliffs, which are much obscured, belong to one division or the other is unimportant. Mr. Woodward satisfied himself that they belong to the Westleton Beds, but Mr. Whitaker has since shown reason to believe that the lower part at all events belongs to the unfossiliferous sands of the Crag. At one spot they are capped by a small patch of Westleton pebbles with an overlier of Boulder-clay; while the lower part of the cliff, consisting of sands without fossils, may very probably, as Mr. Whitaker supposes, belong to the Crag †.

Mr. Woodward objects to Messrs. Wood and Harmer grouping the Bure-Valley Beds as Lower Glacial, and sees no satisfactory palæontological reason for separating them from the Norwich Crag, with which he unites them under the name of the "Norwich-Crag Series." He states that "the grounds on which Messrs. Wood and Harmer separated the Bure-Valley Crag from the Norwich Crag have proved to be unsound. The Bure-Valley Crag is palæontologically identical with the Weybourn Crag, as they originally pointed out. Both beds contain the *Tellina balthica*. But as my colleague Mr. C. Reid has shown, the Weybourn zone is to be traced at the *base* of the Forest-Bed Series, at Sherringham and other places; whereas another bed, at a higher horizon, since called the '*Leda-myalis* bed' by Mr. Reid, was also correlated by Messrs. Wood and Harmer with the Bure-Valley Beds. Thus we have a fossiliferous zone at the top and another at the base of the 'Forest-Bed Series,' both of which have been called the Bure-Valley Beds; and this is the reason why some observers have stated that the Norwich Crag overlies the Forest Bed of Cromer, while others have maintained that the Crag underlies it. The true fossiliferous Bure-Valley Zone, however, as just stated, occurs at the base of the Forest-Bed Series, and is represented by the Weybourn Crag. The *Tellina balthica* thus occurs *beneath* beds which Messrs. Wood and Harmer have grouped as 'Pre-glacial,' and their argument that this shell is confined to Glacial and more recent deposits loses all weight." "For the same

* I find that I overlooked one of my early note-books, in which I had noted Boulder-clay and Westleton Shingle at one point on the top of the cliff, as described by Mr. Whitaker in his 'Geology of the Suffolk Coast,' pp. 52-59.

† In 1871 Messrs. E. T. Dowson and W. M. Crowfoot, of Beccles, found a fossiliferous bed quite at the base of this cliff, from which they procured 44 species of shells with a few Mammalian remains. They refer this bed to the Fluvio-marine Crag.

reason, also, the Mundesley and Westleton Beds, identified by Prof. Prestwich on the Cromer coast, are not the same as the Bure-Valley Beds inland."

Mr. Woodward further states that under the term "Lower Glacial Drift" he would include not only the Cromer Till and Contorted Drift, but also the "Middle Glacial," as he regards them as intimately connected; "hence the Westleton Beds would be Lower Glacial, the Mundesley Beds would come in the debatable ground called Preglacial, the Bure-Valley Beds are Pliocene."

In a subsequent paper * Mr. Woodward, in speaking of the Crag and Pebbly Gravel, says "In their notes on the pebbly gravel and its relation to beds above and below, Messrs Wood and Harmer have expressed their opinion that on the coast the Weybourn Sand (=Bure-Valley Beds) passes up by interbedding into the Cromer Till, while the pebbly gravels around Norwich that immediately underlie the Lower Glacial brickearth, were considered by them to be, to some extent, the equivalents of the Cromer Till."

He then observes, "Neither my colleague Mr. Reid nor myself have seen any evidence to corroborate this opinion; on the contrary, the line between the undoubted pebbly gravels (which are grouped by us as Pre-glacial) and the overlying Glacial Drift is generally sharply defined,"—a conclusion in which I quite agree.

I quote these remarks of Mr. Woodward (the bearer of a name so long and honourably connected with the investigation of the Crag and Glacial series of Norfolk) to show how complicated the question has become, and how diverse the opinions on the subject still are. The classificatory objections to Messrs. Wood's and Harmer's Bure-Valley Crag do not, however, affect the question of superposition, on which their main contention on this point is founded.

In 1887, Messrs. W. Whitaker and W. H. Dalton, in their memoir 'On the Geology of the Country around Halesworth and Harleston' †, state that in the area they describe, the beds of the Pebbly Series vary, and "to the west and north-west they change into fine sands and loams, each exposure showing different peculiarities." They express a preference for the use of the lithological name instead of the geographical ones of Mr. Wood and myself, and leave the question of the relation of the Pebbly Series to the Glacial Drift and Chillesford Clay or to the Pliocene below an open question.

The reasons for not pledging himself to the question of classification are given by Mr. Whitaker in a later memoir ‡. In this he makes some pertinent remarks on the "Pebbly Series" and its literature. In explanation of the various names and classifications that have been proposed for these beds by different writers, he suggests that "It seems possible that anyone working southward from the northern part of Norfolk might get into a somewhat dif-

* Mem. Geol. Survey Expl. Qt. Sheet, 68 N.W. and S.W. pp. 11–14 (1884).

† Mem. Geol. Survey Expl. Qt. Sheet 50 N.E. pp. 11–17.

‡ "The Geology of Southwold and of the Suffolk Coast, from Dunwich to Covehithe," Mem. Geol. Survey, Explanation of Sheet 49 N., 1887. p. 22.

ferent mental groove from anyone working northward from the southern part of Suffolk. Both may be locally right; but it does not follow that either must be right generally; at all events the variety of opinion that has been evolved is rather bewildering." This must be my apology for the present digression.

In his memoir of 1884 Mr. Whitaker records the occurrence in the highest part of the Westleton shingle at Henham of a band of iron-stone with casts and impressions of shells; but the species are not named. He likewise announces the discovery of fossils—in the Southwold area—of this age, in one case in a pit on the Lowestoft Road, two thirds of a mile N.N.W. of Southwold Church, and in another in the railway-cutting near the station (p. 29), and gives lists (p. 85) of the species, on the authority of Mr. W. M. Crowfoot and of Mr. S. V. Wood. I am not, however, quite satisfied that these shells, or at least all of them, belong to the Westleton beds. As this is a point of considerable interest, I give the species in the Table at p. 93 for the purpose of comparison with those of other localities.

In the first-named locality casts and impressions of shells were found in an iron-concreted portion of the shingle, whilst at the bottom of the pit actual shells were found. In the second locality the shells occurred in a lenticular mass, 6 inches thick and about 5 feet deep, in a cutting 7 feet in depth, and in another small patch about 12 yards northward. It appears to me, however, possible that some of these shells may belong to the Upper Crag (the Chillesford Sands); for the Chillesford Clay has been much denuded*, so that the Pebble Beds often come into juxtaposition with the Upper or Fluvio-marine Crag. A little north of Southwold, the cliff section, in fact, shows the pebbly (Westleton) beds in contact with yellow sands of this age, owing to the removal of the Chillesford Clay. It may be therefore that the lower part of the sections belongs to the Crag, or that the shells are derived from it.

The following are the species mentioned by Mr. Whitaker as occurring in the above-named places. To these I have added a column for the species enumerated by Mr. H. B. Woodward from the typical Bure-Crag localities of Belaugh and Wroxham, although even there, I think, there is some uncertainty whether the latter beds are free from intermixture with the Fluvio-marine Crag. It must, however, be borne in mind that the range and location of species in the Crag are extremely variable.

* Mr. Whitaker mentions that the Chillesford Clay is wanting in places near Southwold, probably having been cut off by the Pebbly Beds (*op. cit.* p. 62). It was wanting also in the Southwold well, where the underlying Crag was fossiliferous.

Mr. Whitaker's Mollusca of Southwold beds and of the Bure-Valley beds of Norfolk, compiled from the lists of Mr. W. Whitaker * and Mr. H. B. Woodward †.

The third column shows the species that occur also in the Upper or Fluvio-marine Crag of the adjacent localities of Easton Bavant (near Southwold) and of Norwich (near the Bure Valley).

	Southwold. P. Pit; S. Station.	Bure Valley. B. Belaugh; W. Wroxham.	Fluvio-marine Crag of Norwich (N.), Easton Bavant (E.).
Anomia ephippium	......	W.	N.
Anomia striata	......	B.	N.
Astarte borealis	......	B., W.	E., N.
Astarte compressa	......	B., W.	E., N.
Cardium edule	P., S.	B., W.	E., N.
Cardium grœnlandicum	S.	......	E., N.
Cardium islandicum	......	B. fragts.	
Corbula striata	S.	B.	E., N.
Cyprina islandica	P., S.	B., W.	E., N.
Donax vittatus	S.	B.	* ?
Leda oblongoides	......	B., W.	N.
Lucina borealis	S.	B., W.	E., N.
Mactra ovalis	......	B.	E., N.
Mactra solida	......	W.	N.
Mactra subtruncata	......	W.	E., N.
Mya arenaria	S.	B., W.	E., N.
Mytilus edulis	.....	B., W.	E., N.
Nucula Cobboldiæ	......	B., W.	E., N.
Pecten tigrinus, var. lævis	......	W.	
Pholas crispata	......	B.	N.
Saxicava arctica, var. rugosa	......	B.	N.
Scrobicularia plana	......	B.	* N.
Tellina balthica	......	B., W.	
Tellina lata	P., S	B., W.	E., N.
Tellina obliqua	P., S.	B., W.	E., N.
Tellina prætenuis	S.	B., W.	E., N.
Thracia papyracea	.....	B.	N.
Buccinum undatum	......	B.	E., N.
Cerithium tricinctum	P., S.	......	* N.
Littorina littorea	P., S.	B., W.	E., N.
Littorina rudis	S.	B.	w, N.
Melampus pyramidalis	P., S.	......	E., N.
Natica catena	P.?	B., W.?	E., N.
Natica helicoides	......	B.	E., N.
Paludina media	S.	......	E., N.
Paludina ? glacialis	......	B.	
Purpura lapillus	P., S.	B.	E., N.
Scalaria grœnlandica	......	B., W.	E., N.
Trophon antiquus	......	B., W.	E., N.
Trophon antiquus, var. contrarius	......	B., W.	N.
Turritella terebra	S.	...	E., N.

The specimens in the third column marked with an asterisk are also found in the Crag near Southwold; *w* in the Southwold well.

* Mem. Geol. Surv. 1887, pp. 82–84. † *Ibid.* 1881, pp. 42–53.

It thus appears that of the 18 species from the Southwold sections 13 are recorded in the Bure Valley; whilst of the other species, three (*Melampus pyramidalis*, *Cerithium tricinctum*, and *Paludina media*), which are characteristic of the Fluvio-marine Crag, have not been met with in the Bure-Valley Crag. The other two are also Norwich species, but have a wider range. On the other hand, of the 36 species quoted from the Bure Valley, 16 are wanting at Southwold, amongst which is the only characteristic shell of that Crag, *Tellina balthica*, while other such common Westleton and Bure-Valley shells as *Scalaria grœnlandica*, *Natica helicoides*, *Astarte compressa*, *Leda oblongoides*, and *Mytilus edulis* are also wanting.

§ 3. *Choice of Terms.*

The main objection, however, to the adoption of the "Bure-Valley Crag or Pebble-beds" as terms for these geological zones, is that neither their palæontological value nor their stratigraphical relations are in that district free from uncertainty. Where the Chillesford Clay intervenes, there is no doubt of their distinctness: but where this bed is wanting, as is commonly the case in Norfolk, it is almost impossible to distinguish between the beds above and the beds beneath that zone: and as, in consequence of the Pebbly Beds resting upon an eroded surface of the Chillesford Beds, the juxtaposition of the two shell-beds is of frequent occurrence*, their duality then is lost. At Norwich this distinction still exists; but further northward, in the Bure Valley, the Chillsford Clay is either wanting or else exists in a very fragmentary form; so that in such cases, owing to their having many characters in common. the distinction between the Bure-Valley and Norwich-Crag beds might pass unnoticed.

It may, in fact, be a question whether the thin seam of clay which in Mr. Wood's typical sections of Belaugh and Wroxham is intercalated near their base (see Mr. Woodward's memoir, pp. 60 and 62) does not represent the Chillesford Clay, and whether in the same way the thin occasional bed of clay a foot or two above the Chalk in the coast-section is not also of the same age, and whether the lower shell-bed in these several localities should not be referred to the Norwich Crag instead of grouping it with the overlying beds under the term of the "Weybourn Crag," or as the "Lower Glacial" of Mr. Wood. (See Supplement to the Crag Mollusca, pp. 203-219.) To test the point, I would keep the fossils from these beds separate until their exact relationship is ascertained with greater certainty. Mr. Woodward's short lists, at pp. 62 and 63 of his Norwich memoir, show slight but not unnoticeable differences between the upper and lower part of the section. *Tellina balthica*, which is stated by Messrs. Wood and Harmer to be almost the only shell in the Pebbly Sands that does not occur in the Norwich Crag, is not found in the lower bed at Wroxham, although it is at Belaugh; but I think (for reasons to be given hereafter) with Mr. Woodward, that the occur-

* Quart. Journ. Geol. Soc. vol. xxvii. p. 456 (1871).

rence of this one shell is a very insufficient palæontological distinction.

Where the Chillesford Clay is absent, evidence of its former presence often exists at the base of the Pebble-beds in the form of pebbles of clay, derived probably, in some cases, from that clay. The instance recorded by Mr. Woodward in the typical Wroxham district, of a gravelly bed with clay pebbles at the base of beds of buff sands and pebbly gravel (the Bure-Valley Beds*) in a cutting near the station may be of this character. It is easy, therefore, to imagine that, owing to this removal of the Chillesford Clay, the Bure-Valley Crag may often be in contact with beds of the age of the Norwich Crag, and that in the case of beds so much alike it would be difficult to detect the line of separation, while the fossils of the lower beds would be apt to get mixed with those of the upper one.

Therefore, while I admit the value of the distinction drawn by Messrs. Wood and Harmer between the Norwich Crag and the Bure-Valley Pebble-beds, I do not think that either the palæontological or stratigraphical proofs respecting the position of these Pebbly Sands are so well defined and certain in the Bure-Valley district as they are in the Westleton and Southwold districts, or so fitted to be taken as the type of a wide-spread geological zone. For these reasons, although the term of Bure-Valley Crag or Beds may be conveniently applicable to a local fossiliferous condition of the Pebbly Sands, I do not think it to be, for a general term, so suitable as the term of "*The Westleton and Mundesley Beds.*"

This is the term that in 1881 † I proposed to adopt in place of my original term of "Westleton Sands and Shingle," in 1870, for the reason that when a particular series of strata presents, in adjacent and conterminous areas, markedly different palæontological and structural characters, it may be convenient, as in the case of the "Woolwich and Reading Beds," to give them a double geographical name, indicative of the localities where the two types are respectively best developed, and their relation to the overlying and underlying strata best exposed. It will, however, be convenient, when speaking of the inland continuation of these beds, to use merely the term of "Westleton Beds or Shingle," as then we shall have to deal with that type of them alone.

§ 4. *The Structure and Palæontological Characters of the Westleton and Mundesley Beds, in Norfolk and Suffolk.*

Before proceeding with the inland range of these beds, I will describe more fully my view of the relation they hold—on the one

* Similar cases, having reference to this and other underlying clay-beds of the Forest-bed series, are common in the coast sections, and are recorded by Mr. C. Reid (*op. cit.* p. 15 &c.) and by myself (Quart. Journ. Geol. Soc. vol. xxvii. p. 465).

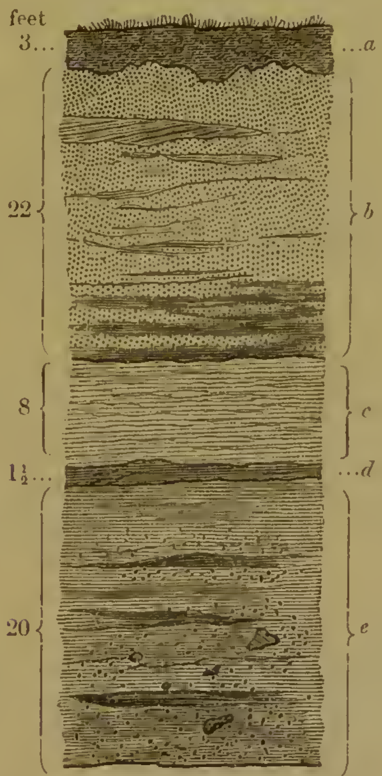
† This paper is an amplification of the one then read before the British Association, and which appeared only in Abstract.

hand to the Fluvio-marine Crag, and on the other to the Glacial beds in Suffolk and Norfolk.

The composition of the shingle will engage our particular attention, as it is an instance in which the evidence afforded by it is of more stratigraphical value than that of the fossils, as the latter are confined to the sea-board of the Eastern Counties, while the former has to be our guide over the wide inland area.

I will now drop the term "Pebbly Beds," which, although convenient as a temporary term, marking, as it does, a very distinctive character, has the inconvenience of defining a feature common to many other strata, as, for example, the Pebble-beds of the Bagshot Sands, or those of the Woolwich and Blackheath Beds. It is like

Fig. 1.—*General Section of the Westleton Beds on Westleton Common.*



a. Surface soil—gravelly.
b. Fine shingle, with lenticular beds of white sand.
c. White sands—quartzose—horizontal bedding.
d. Light greenish clay.
e. White sand passing down into ochreous pebbly sands, with a few large unworn blocks of flint and some ironstone bands and concretions.
No fossils were met with in these pits *.

* In another pit on the common, I found, in digging a few feet lower, a sandy clay with very friable specimens of *Tellina* and *Natica*.

the old designations of "Plastic Clay" and "Mottled Clays," which would specialize characters common in formations of Tertiary as well as of Secondary age.

The localities where the Shingle Beds are most extensively developed, and where the joint lithological and palæontological characters are best combined, will be found in the Ordnance Map, Sheet 49 W. and 50 E. From this centre I will first take their range northward.

Between Westleton and Dunwich there is a large tract of common, formed by low hills of pebbly shingle, which extends with little interruption to Blythburg and Southwold, and thence to Easton Bavant and Covehithe, forming a belt some 2–4 miles wide and 10 miles long. The higher ground is everywhere capped by Boulder-clay, from beneath which the Shingle Beds crop out, whilst on the coast the Chillesford Clay rises from beneath the latter (except where it has been denuded before the deposition of the Shingle), thus defining accurately the stratigraphical position of the Shingle Beds.

The Shingle consists of flint pebbles as well rounded and forming beds as massive as the Tertiary Beds of Blackheath or Addington, with subordinate sands and thin clays. From two of the closely adjacent large pits on the common, the accompanying general section (fig. 1) is constructed from notes taken some years since.

Unlike the overlying Glacial Beds with their northern drift, we have evidence in this Shingle of a decided transport from the southward in the presence of subangular worn fragments of Chert and Ragstone of the Lower Greensand, probably of Kent, a fact to which I formerly drew attention *. With these are associated a considerable proportion of small white quartz-pebbles and a few large flattish ovoid pebbles † of light-coloured Quartzite and Sandstone, with small pebbles of Lydian stone and jasper &c. There is a total absence of the larger darker red and grey rounded quartzite-pebbles (cobbles) of the New Red Sandstone, so common in the Glacial Series. The average composition ‡ of this Westleton Shingle at Westleton may be roughly taken as under:—

	Per cent.
1. Black flint-pebbles	60
2. White quartz-pebbles, with a few rose-coloured	20
3. Subangular flints, not stained	10
4. Subangular fragments of grey pin-hole ragstone and dark yellow chert	4
5. Large flattish pebbles of light-coloured quartzite, light and dark sandstones, and small pebbles of veinstone, Lydian stone, and jasper, with a few subangular fragments of black chert (Carboniferous?), of a dark slaty rock, and of quartz	6
	100

* *Op. cit.* pp. 461 and 477 (1871); and British Association Reports for 1881, p. 620.

† They are very similar in shape and colour to the recent quartzite-pebbles on the Chesil Bank.

‡ The determinations in all cases can only be given approximately. For reasons given in Part II. of this paper these proportions may not be quite correct locally; but as the same error, if any, runs through all the localities, the general result is not seriously affected.

The proportions, as might be supposed, vary in every pit, and even in different parts of the same pit; but the constant presence of the first four constituent parts, and the absence of certain others, is a remarkable feature, and enables us to recognize these beds when other evidence is wanting, and to distinguish them from beds of Lower Tertiary, Bagshot, or Glacial age with which they might otherwise be confounded.

Near Halesworth, 6 miles N.N.W. from Westleton, where subangular flints are more abundant, the shingle consists of:—

1. Flint-pebbles	50
2. White quartz-pebbles	10
3. Subangular flints	34
4. Chert &c.	6
	100

At Henham, on the other hand, the proportion of flint-pebbles to the other constituents is larger. In a pit in the Park, where there were about 20 feet of shingle, the upper 6 feet consisted of horizontal layers, while the lower beds exhibited an oblique lamination as good as that figured by Mr. S. V. Wood in the Red Crag at Bawdsey Cliff as typical of current-bedding*.

At Blythburgh and Reydon, the Westleton Beds are seen in the same relation to the Glacial Beds, and it was in a pit near the latter place (Quart. Journ. Geol. Soc. vol. xxvii. p. 462), that I found in a seam of pebbly sand concreted by iron-peroxide numerous casts and impressions of *Mytilus edulis*, double, and in all stages of growth. The beds generally have, however, been extensively decalcified, so that shells are extremely scarce.

At Easton Bavant cliff, the superposition of the Westleton Shingle on the Chillesford Clay and Sands, both of which latter are here fossiliferous, is very distinct, while the former exhibits very clearly the special characters which serve to distinguish it from Glacial beds.

It is composed as under:—

	Per cent.
1. Flint-pebbles	52
2. White quartz-pebbles	18
3. Subangular flints	20
4. Worn fragments of chert, quartzite pebbles, one large pebble of indurated clay with indistinct vegetable impressions	10
	100

Here also I found, as at Reydon, a thin seam of ironstone intercalated in the upper part of the Pebble-bed with casts and impressions of *Cardium* (*C. edule*?), *Mytilus* (*M. edulis*?), *Littorina*, and *Natica*.

Since I visited this district it has been described by Mr. Whitaker, and allowing for changes in the coast-sections caused by the encroachment of the sea, our observations are in close agreement. He

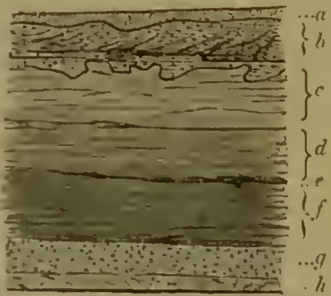
* Ann. & Mag. Nat. Hist. for March 1864, p. 3.

also describes the various interpretations * to which these beds have given rise.

As there is little positive evidence of ice-action during this period, it is interesting to note the discovery, recorded by Mr. Whitaker (p. 77), of a wedge-shaped block, 13 × 13 × 19½ inches, of a micaceous quartzite in the pebbly gravel at Easton. I noticed in 1869 in a farm-yard near Reydon, a rather large boulder of granite, which may also have come from these beds.

At Easton Bavant the Chillesford Clay is well marked with its characteristic shells; but at the extreme north end of the cliff, near Covehithe, there are indications of a change. Some trenches opened at the base of the cliff a few years ago exposed the section annexed (fig. 2).

Fig. 2.—*Section in Covehithe Cliff, north of Easton Bavant.*



		feet.
a.	Dark sandy soil	2
b.	White pebbly sands (Westleton) indenting into *c*	3
c.	Irregular white and yellow sands	4
d.	Laminated brown clay	4
e.	Irregular carbonaceous band	¼
f.	Laminated grey clay (Chillesford ?)	6
g.	Fine gravel and sand	2
h.	Shell-bed (fluvio-marine)	2+

Here the Chillesford Clay is unfossiliferous, and is overlain by a thin seam of carbonaceous matter succeeded by two beds of laminated clays and sands, also without fossils, on which rest the sands and shingle of the Westleton Beds. The beds *c* to *e* may represent a commencement of the Forest Series, and would thus show its relation to the Fluvio-marine Crag (*g*).

Another point of interest in this section is the presence of small pockets or indents of sand filling hollows on the top of the laminated bed *c*, on which rest the horizontal seams of sand and shingle *b*. The sand in the holes is the same as that of bed *b*. Mr. Whitaker (p. 75 of his Southwold Memoir) has described similar small contortions in these cliffs †, and Mr. C. Reid speaks of the

* "Geology of the Suffolk Coast." Mem. Geol. Surv. 1887, pp. 57–59, 68–72.

† It was possibly these contortions which led Mr. Wood to refer the sands and loam in the upper part of the Covehithe cliff to the "Contorted Glacial Drift."

same structure in the Forest Series at Trimlingham and other places. He remarks that the carbonaceous clay and overlying sand are apparently contorted together, and that the contortions are cut off by the overlying evenly bedded freshwater clays, and he suggests that this contorted structure may be due either to the treading of some of the large Mammalia in shallow waters, or else to the lateral thrust caused by alternate freezing and thawing of the beds in winter (p. 33).

In one of my note-books, I have the following sketch (fig. 3) of a similar contortion, but it was there, as at Covehithe and Easton Bavant, immediately under the Westleton Beds *b*.

Fig. 3.—*Section at the base of the Cliff near Trimlingham.*

	feet.
a. Boulder-clay (base of)	—
b. White sand in horizontal layers, with indents in *c*	3
c. Laminated black clay and white sand	8

May not these small contortions be due to floes of river- or shore-ice impinging on beds of soft clay? just as at St. Acheul (Amiens), where there is reason to attribute the contortions (which are, however, on a larger scale) to the action of the river-ice * at the high-level period.

Another section exhibiting similar intermediate characters as at North Bavant, but still without anything definite, was formerly to be seen in a pit one mile W.S.W. of South Cove Church. It was as follows :—

	feet.
a. Westleton Shingle	4 to 5
b. Light-coloured sand	4
c. Light-coloured laminated clay	3
Dark grey clay	3

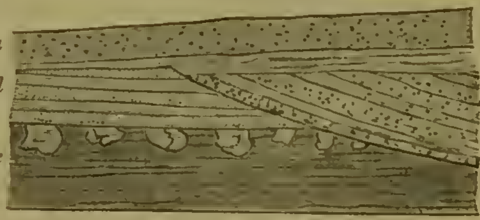
The clay was underlain by loam and then (it was said) by Crag (?). At the Frostenden brick-pit the same dark clay, also without fossils or pebbles, was worked under the Boulder-clay.

The coast-section resumes again, after a break of 1½ mile, at the south end of Kessingland cliff (fig. 4), but it is often obscured, and owing to encroachment of the sea varies considerably from time to time. On the occasion of one of my early visits traces of the Westleton Shingle were to be seen resting on grey clay and sand, showing similar contortions to those before noticed at Covehithe and

* Phil. Trans. for 1860, p. 299, and 1864, p. 269.

Easton. The Shingle *d* is, however, soon replaced by the Middle Glacial sands and gravel *c*, which then rest directly on the Forest-Bed series, and maintain that position as far as Pakefield.

Fig. 4.—*Section at the south end of Kessingland Cliff.*



	feet.
a. Gravelly soil	3
b. Yellow sand	1
c. Irregularly bedded sand and gravel	5
d. Yellow pebbly sands (Westleton) indenting into *e*	4
e. Laminated grey and brown clay and sand	6

The laminated bed *e* is without fossils, and resembles bed *d* of section, fig. 2. Further north the cliff becomes higher, and the Upper Chalky Boulder-clay sets in; while at the base of the cliff there appears a compact greenish clay, with small fragments of flint, traversed to the depth of from 3 to 5 feet by rootlets, generally cut off on the top by the Glacial Sands. Between the beds *b* (fig. 5) and the Pebbly Clay, and forming at one place a shallow depression about 150 yards across, lies the dark carbonaceous clay with plant-remains, at the base of which is a thin seam of gravel and sand with *Unio*, *Cyclas*, &c., which I referred in 1871 to the Forest Series of Norfolk. The Pebbly Clay passes in places southward into a light-coloured sand, and again into clay, while at other places the flint-fragments disappear. Nearer Pakefield Mammalian remains occur in some abundance; but I failed to recognize the exact position of these remains, and was under the impression that the pebbly clay (*e*) represented the Chillesford Clay. Fig. 5 (p. 102) is a part of the section I then gave of this cliff *.

In 1872, Mr. S. V. Wood remarked that all that could be safely averred of those beds (the Forest Beds) at Kessingland is, "that they are anterior to the Middle Glacial and probably posterior to the Crag," an opinion endorsed in his subsequent papers of 1877 and 1880, although in the latter he seems to imply that the Mammalian remains are of the age of the Norwich Crag †.

In 1876, Mr. J. Gunn ‡ concluded, on the contrary, that both the so-called Elephant Bed and the Forest Bed in this cliff were not only beneath the Chillesford Clay, but also beneath the Norwich

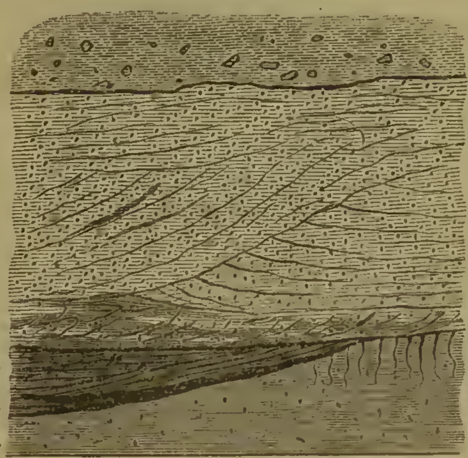
* Quart. Journ. Geol. Soc. vol. xxvii. p. 463.

† 'Supplement to the Crag,' p. xv; and Quart. Journ. Geol. Soc. vol. xxxiii. p. 74, and vol. xxxvi. p. 462.

‡ Quart. Journ. Geol. Soc. vol. xxxii. p. 123.

Crag Beds. In the following year Mr. Harmer questioned that view, and contended that the rootlet-bed does not represent the Chillesford Clay, but that it forms part of a freshwater deposit occupying a basin excavated in the Chillesford Clay, and is thus newer than the latter *. In 1880, Mr. J. H. Blake confirmed the opinion that these beds represent the Forest Bed of Happisburgh, and determined the exact position of the Mammalian remains as

Fig. 5.—*Section at the base of the Cliff north of Pakefield.*



		feet.
a.	Chalky Boulder-clay (base of)	—
b.	White sands with patches of gravel and fragments of shells (one *Tellina balthica* entire), irregularly bedded and ochreous at base	15 to 18
c.	Laminated black carbonaceous clay, with branches of wood and a few small angular fragments of flint	4
d.	Band of freshwater shells (*Unio, Cyclas*, &c.)	$\frac{1}{2}$
e.	Compact greenish clay with fragments of flint, traversed by rootlets *in situ*	5+

"sometimes forming a distinct and separate bed, one stage more recent than the Chillesford Clay, and sometimes apparently passing down into the Chillesford Clay and forming as it were the uppermost portion of the same," and, "with possibly a few trifling exceptions, all the Mammalian remains are to be found buried beneath the more or less denuded surface of the Rootlet Bed and the Chillesford Clay" †.

The only doubt to be felt is whether in this pebbly clay (*e*) we have the Chillesford Clay modified by its approach to land and the Forest estuary, or whether it belongs altogether to the Forest Series. It appears from the sections of the north end of Easton Bavant cliff and at Covehithe (fig. 2) that the laminated beds *c* and *d* overlie a carbonaceous seam *e*, and these may represent the Forest Beds, while the dark clay (*f*) appears to pass southwards without

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 134.
† Proc. Norwich Geol. Soc. vol. i. pp. 157–160.

break and on the same horizon into the fossiliferous Chillesford Clay. At Pakefield we have an expansion of the seam *e* with rootlets traversing the clay, and occupying the position of *f* in the Easton Bavant section. Is it therefore that in the interval between Covehithe and Pakefield that this 'Pebbly Clay' sets in between *d* and *f*, or is it a continuation, modified by altered conditions, of the bed *f*?

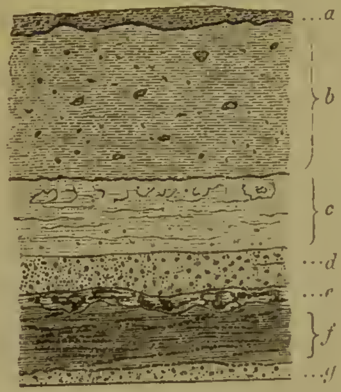
At Alderby, 6 miles inland, the dark clay, which there overlies the Fluvio-marine Crag, also contains angular flints, and the late Mr. Rose had in his collection remains of the Elephant, Deer, and two species of Cetaceans from this same bed. Though it is not there overlain by the Westleton Beds, it was found to be so in a deep well sunk at Beccles on the other side of the valley, and is therefore generally held to be the Chillesford Clay-bed. There are again traces of the Forest Bed at the cliff at Corton with an underlying clay, of the same character as at Kessingland and with rootlets.

If this Suffolk bed is to be considered the equivalent of the Chillesford Clay, then the so-called Forest Bed of Happisburgh, Bacton, and Mundesley, which occupies the same position and contains the same remains, must also be referred to that age; but the peculiar character of its Mammalian remains—its numerous large Deer, its special Elephants, and other Mammalia, all so different from those of the Crag—the absence of Mastodon, which occurs both at Norwich and at Easton Bavant, together with the evident local and exceptional character of the Forest Series, renders it difficult to accept that solution of the problem.

Whatever may be the solution, it does not directly affect the particular question upon which we are engaged, as the Westleton Shingle is newer than the Forest Bed, and passes indiscriminately over it and over the Chillesford Beds. At the same time at the junction of the two former on the Norfolk coast there is to a certain extent a passage between them, land-conditions there alternating with marine during the accumulation of the Westleton Shingle. I shall therefore only refer incidentally to the Forest Bed, which is the less necessary as it has often been well and fully described, and will confine myself to following the range of the Westleton Beds.

The Shingle, which is displaced by the Glacial Sands at Kessingland, resumes its place in the neighbourhood of Pakefield and Lowestoft, where it exists in considerable force, consisting of the usual pebbles of flint and white quartz, with subangular fragments of flint, ragstone, and chert, and an unusually large proportion of other rocks, such as fragments of a mica-schist, of a dark green quartzose rock, and of yellow, green, and brown sandstones. In this part of the cliffs clay pebbles are common at the base of the Westleton Beds, arising probably from the partial destruction either of the Chillesford Clay or of one of the Forest Beds. Glacial sands again occupy much of the Corton and Gorleston cliffs. As the broad estuary of the Yare then intervenes, the Westleton Shingle is not met with again until we reach the Happisburgh Cliffs; and even there little is seen of it, although the Forest Bed with its multitude of old stumps is often well exposed on the shore at low water. At Bacton, where the Westleton Beds are distinct, the section is as under (fig. 6).

Fig. 6.—*Section at Bacton Cliff.*



		feet.
a.	Sandy and gravelly soil	2
b.	Brown Boulder-clay, with a few fragments of shells	10
c.	Light yellow and white sands, contorted on top	5
d.	Pebbly shingle with a few shells (Westleton)	3
e.	A tangle of wood (local)	2
f.	Laminated grey clay and sand	4
g.	Fine gravel	1+

Mr. Gunn informs me that the Forest Bed has been met with about 8 feet lower. The shingle *d* contains * :—

Littorina littorea.	Astarte borealis.
—— rudis.	Mytilus edulis.
Purpura lapillus.	Cardium edule.
Scalaria grœnlandica.	Trophon antiquus.

Another feature that I had occasion to observe here during one of my visits was a singular accumulation of twigs and branches of trees (*Pinus*, *Abies*, *Taxus*, &c.), forming in one place a loose matted mass from 2 to 3 feet thick, composed entirely of drifted wood débris, very little altered except in colour (fig. 6, *e*). Between Bacton and Mundesley the shingle continues with little interruption, and consists roughly of :—

	Per cent.
Flint-pebbles	50
White and rose-coloured quartz-pebbles	20
Subangular flints, not stained †	16
Subangular fragments of chert and ragstone	8
Lydian stone, jasper, quartzite, and sandstone pebbles	6
	100

* This shell-bed was discovered by the Rev. C. Green in 1842.

† I may have under-estimated here and in some of the other places the proportion of subangular flints.

Besides the specimens named above, I also here found specimens of a black chert (Carboniferous?), of a light-coloured encrinital quartz (Carboniferous?), of chlorite schist, of a white fossiliferous chert, and of a dark-coloured slaty grit.

It is, however, at Mundesley, 2½ miles north of Bacton, that we find these beds with their typical estuarine and freshwater conditions best exhibited. They there form a group of strata differing from those further south only inasmuch as they were deposited under local and different conditions, arising from the early emergence of this area, and the consequent introduction of a land fauna and flora.

In 1870 I made the mistake of supposing that the thin seam of gravel at the base of the Westleton Beds (*m*), and overlying the Forest Bed, represented the Elephant Bed of the Norfolk geologists. It is true that a few bones have occasionally been washed out of the Forest Bed, and are found in the gravel and sand overlying it; but the bone-bed proper is the underlying argillaceous sand in which the forest stumps are rooted, and to which the term of "Forest Bed" also applies, for it is in this bed that the remarkable group of mammalian remains with plant-débris are entombed. It has been questioned whether the stumps found on its surface are really *in situ* on the spot where the trees grew, or whether they were drifted there from a distance. Such may have been the case with some, but it is difficult to conceive that it could have been so with all. Their wide-spreading roots *, their position on one and the same level, the presence around them of their cones and branches, and the fact that the same bed at other places, where seen in section, is traversed by rootlets evidently *in situ*, show that the occurrence of such a forest-growth on the surface was both possible and probable. Some trees may doubtless have been overturned and drifted; and some strained by storms may have had their roots torn and broken. The argument that the small fibres which end the roots have generally been wanting at from one to three feet from the stem, has been disposed of by an observer so experienced on this point as Mr. T. M. Reade †, who states that in the case even of the more recently submerged forests of the Lancashire coast, the fine fibres of the roots are not preserved, having generally rotted away. The erect stumps of the Forest Bed, which I have myself from time to time seen, though not examined critically, seemed to me generally as good cases of growth *in situ* as the trees seen in peat-bogs.

I therefore see no reason to question the previous opinion of a forest-growth *in situ*, especially as the existence of a land-surface is confirmed by the presence in many places on the Forest Bed of a clay with land-, freshwater-, and marsh-shells and plants. This land-surface I take as the base on which the Westleton Beds were

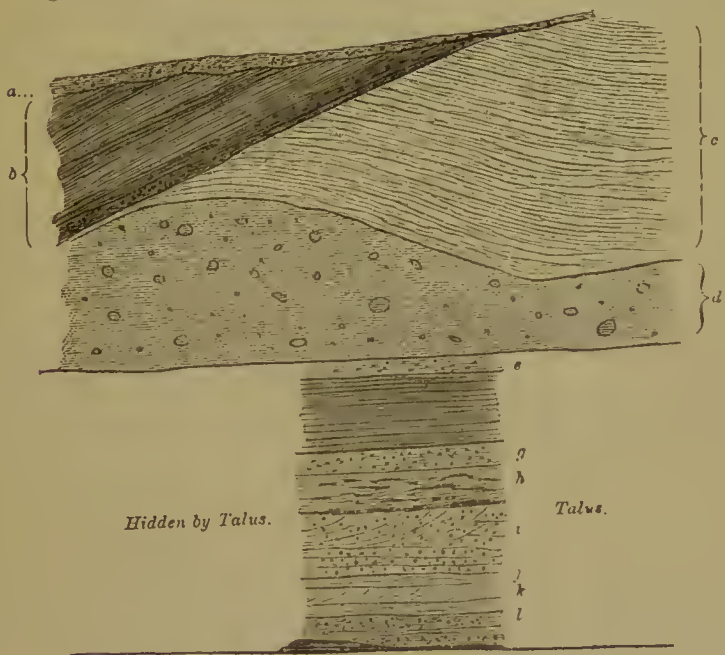
* In one case mentioned by Mr. C. Reid, the circle formed by the spread of the roots was 20 feet across.

† Geol. Mag. dec. ii. vol. x. p. 221 (1883).

spread. It marks a period of slow submergence, succeeded by the return at intervals of a very depauperized marine fauna.

The Forest Bed itself is a distinct and local deposit, beneath the Westleton Shingle; but whether it forms an intermediate deposit between the Shingle and the Chillesford Beds, or whether it is synchronous with, and representative of, the Chillesford Clay, I take to be a still unsettled problem.

Fig. 7.—*Section of Cliff about ¼ mile north of Mundesley.*



 Position of Forest Bed south of Mundesley.

		feet.
a.	Subangular gravel	1 2
b.	Post-glacial fluviatile bed	—
c.	Yellow laminated loam (glacial), blue at base	20
d.	Boulder-clay	12
e.	Yellow sand	
f.	Grey clay, laminated	
g.	Fine pebbly gravel and sand, with *Succinea*, *Cyclas*, &c.	
h.	Laminated clay and sand, with drift wood	
i.	Light-coloured shelly sands and shingle	} 23
j.	Sand	
k.	Fine shingle, with *Mytilus* &c.	
l.	Sand	
m.	Gravelly bed, with mammalian remains, resting on dark sandy clay (Forest Bed)	

On either side of this section of the Mundesley series (*c* to *m*) very variable beds are hidden by talus. The position of the Forest Bed is also shown beneath the beach on the left hand.

It is on this part of the coast that the Forest Bed attains its greatest development. Mr. Gunn had a bore-hole driven into it at Happisburgh to a depth of 12 feet without reaching its base; while Mr. C. Reid, from observations made by dredging beyond low water-mark, concludes that its thickness is not less than 60 feet *. What may form the base of the Forest Series is at present a matter of conjecture. From the presence of drifted peat and plant-remains at its outcrop near Cromer, Mr. Reid infers the presence of another freshwater bed, beneath the main bed, and below that he places the Weybourn Crag.

The flora of the Forest Series has been admirably worked out by Mr. C. Reid and Mr. Carruthers †, and the fauna by the late Dr. Hugh Falconer ‡, Professor Boyd Dawkins §, and Mr. E. T. Newton ‖. I need not further allude to them here, except to mention their extreme interest and importance.

The relation of the Westleton Beds to the Glacial Series above and to the Forest Beds beneath is extremely well shown on the coast at Mundesley, although it is only occasionally that the tree-stumps can be seen. Mr. Dix informed me that on the south side of Mundesley the greenish sandy clay of the Forest Bed crops out beneath the beach. Bones and teeth have often been dug out of it, and shortly before my last visit he had seen at low water the large erect stump of a tree, with, he said, all its roots branching from it. On another occasion, at very low water, a number of tree-stumps were seen with a mass of clotted leaves and branches. The best general section is that presented by the cliff on the north of the village (fig. 7).

Little of the Forest Bed is seen in this section, but in the gravel-bed (*m*) are occasionally found a few bones washed out of it. To this succeeds in places a grey clay, which to the south of Mundesley contains numerous freshwater shells, above which is a gravelly clay with *Mytilus* and *Succinea*. The sand and shingle *i* contain marine shells and fragments of wood. In bed *h* drifted wood occurs, while in the sand and fine shingle (*g*) freshwater shells are common. In the overlying laminated clay (*f*) are some wood and plant-remains. This section differs a little from those of Mr. Reid, owing to the variability of the beds, there having been an interval probably of some 20 years between our observations. The following is a list of the marine shells obtained from bed *k*:—

Cardium edule, *L.*	Littorina littorea, *L.*
Mytilus edulis, *L.*	—— rudis, *Mat.*
Pholas crispata, *L.*	Purpura lapillus, *L.*
Balanus, sp.	Scalaria grœnlandica, *Chemn.*

* It would be very desirable to have a deep boring made at Happisburgh or Mundesley.

† 'Geology of the country around Cromer,' p. 62 (1882). See also a paper by Mr. Reid in the 'Annals of Botany,' vol. ii. p. 178 (1888).

‡ 'Palæontological Memoirs,' vol. ii. chapter ii. and pp. 476–480.

§ Quart. Journ. Geol. Soc. vol. xxxvi. p. 395, and other papers.

‖ Geol. Mag. dec. ii. vols. vii. & viii., and Survey Memoir.

The freshwater shells in beds *i* to *k* consist of :—

Anodonta cygnea, *L.*	Bythinia tentaculata, *L.*
Pisidium amnicum, *Müll.*	Paludina gibba, *Sandb.* ?
Sphærium corneum, *L.*	Valvata piscinalis, *Müll.*
—— rivicola, *Lea.*	

Bed *g* contains fewer species ; the chief are :—

Planorbis complanatus, *L.*	Succinea putris, *L.*
Sphærium corneum, *L.*	—— oblonga, *Drap.*

Beds *e* and *f* represent Mr. Reid's Arctic freshwater beds, in which he has found, in places, *Salix polaris*, *Betula nana*, and *Hippuris vulgaris*, with remains of *Spermophilus*; while bed *i* is on the horizon of his *Leda-myalis* bed*. The lower beds would, I presume, be included by Mr. Reid in his Upper Freshwater and Forest-Bed division. The relation to the lower and the Weybourn beds cannot be seen in this part of the coast-section.

The divisions of the strata under the Cromer Till (Lower Boulder-clay) on the Norfolk coast, according to Mr. C. Reid, are :—

Older Pleistocene (Glacial)	Cromer Till.	
	Arctic Freshwater Beds.	
Newer Pliocene	*Leda-myalis* Bed.	
	"Forest-Bed" Series.	Upper Freshwater Bed.
		"Forest Bed" (Estuarine).
		Lower Freshwater Bed.
	Weybourn Crag.	
Chillesford Clay?		

The minor subdivisions are subject to considerable variations, and are of very restricted range, depending upon local conditions. It seems to me that all the beds *e* to *m* (fig. 7) are members of one series, and I have therefore grouped all down to the Forest Bed under the one term of "Mundesley Beds"; and as I take these beds to be on the same horizon and synchronous with the marine Westleton Beds of Suffolk, the term "Westleton and Mundesley Beds" † will serve to indicate the two types.

Mr. Reid considers that these terms ‡ can scarcely be adopted, because the shingle "at Westleton is now believed to belong to the Glacial Beds, and, at Mundesley, beds deposited under quite different conditions, and showing marked changes of climate, are included." It is quite true that the beds show somewhat different conditions, but that arises solely from the emergence of this area, and the introduction of a land- and marsh-fauna and flora oscillating with a marine fauna as the sea from time to time encroached §.

With respect to the climate, I do not see that the fossils indicate anything more than the continuance of that lowering of temperature which set in with the Crag beds. As the cold increased, many

* *Op. cit.* pp. 37, 48, 83.

† Report British Association, 1881.

‡ *Op. cit.* p. 9.

§ Dr. Sandberger came independently to the same conclusion from an examination of the fossils.

old forms gradually disappeared, the more northern and arctic forms alone surviving, until in the terminal "Arctic Freshwater Beds" both flora and fauna are such as show a climate fitly in accordance with the now near approach of the great ice-sheet.

The sea was probably too shallow to admit of the floating of large bergs with their massive bouldors, yet we are not without evidence of ice-transport and ice-action on a small scale.

Large unworn and unbroken flints and smaller subangular ones are not uncommon. Small blocks of foreign rocks are, as before mentioned, occasionally met with, and Mr. H. B. Woodward records the occurrence in Norfolk of a block of basalt, about 18 inches square, in the Pebbly Sands near Aylsham *, all pointing to transport by ice.

The Forest Bed, with its trees and mammalian remains, may thence be traced northward as far as Cromer, but it finally disappears about one mile N.W. of that place, where the Upper Freshwater Bed and the basement beds of the underlying Forest-Bed series come into contact. Mr. C. Reid states that it is only at this point and at Trimlingham that his Lower Freshwater Bed at the base of the Forest Series is exposed. I cannot, however, agree with him in his interpretation of the Trimlingham section. I take the upper beds, nos. 2 to 4 of his section (p. 33), to be the base of the Mundesley series, nos. 5, 6, and 7 the Forest Bed, and no. 8 the Norwich Crag.

Another point at issue is whether the Weybourn Crag of Mr. Reid, considered by him to form part of his Forest Series, should be thus grouped, or whether it represents the Norwich Crag.

At the south end of the Forest-basin no marine bed underlies the Forest Series † until at a short distance beyond Kessingland the Chillesford Sands (Norwich Crag) set in. In the centre of the Basin at Happisburgh and Mundesley, nothing is known of the lower beds under the Forest Bed of Mr. Reid. As we proceed northward, owing to the thinning out of this latter bed, the base of the Mundesley Series with its pebble-bed (*m*) and derived bones comes, as before mentioned, into contact with the lower part of the Forest-Bed series.

But the sections are mostly obscure, and it is not until we reach the West-Runton Gap (fig. 8) that the upper part of the series is seen clearly as at Mundesley, and the special character of the Westleton Shingle is again well marked. It here consists approximately of:—

	Per cent.
Flint-pebbles	47
White quartz-pebbles	20
Subangular flints	15
Chert and ragstone	10
Lydian stone and quartzite, and light-coloured sandstone-pebbles	8
	100

* Mr. Reid's Memoir, p. 53.

† Except a doubtful specimen of *Buccinum undatum* at Pakefield.

Besides these constant constituents, I found in this shingle, which is sometimes concreted by iron-peroxide, some large subangular fragments of a fine-grained granite and mica-slate; and Mr. Reid mentions the occurrence of "a boulder of greyish granite measuring $2 \times 1\frac{3}{4}$ feet among the clay pebbles and bones," at the base of the Series, a short distance eastward of Runton Gap (p. 28).

Fig. 8.—*Section at West-Runton (or Woman-Hythe) Gap.*

		feet.
a.	Subangular gravel	8
b.	Chalk-rubble	5
c.	Sand and gravel, with patches of broken shells	6
d.	Boulder-clay	15
e.	Sand and ironstone	2
f.	Light-coloured sands	6
g.	Loamy sands, very variable, with a few shells in position	3
h.	Shingle, with shells mostly in fragments	4
i.	Fine sand, variable	2
j.	Peaty bed, with freshwater shells	2

The position of the Crag bed described by Mr. Reid is shown in faint outline below the base line on the left. *g* is not carried far enough.

The section at the Gap (fig. 8) does not show the beds down to the Chalk, but this is shown by the sections in faint lines which are given beneath.

This brings us to the moot point concerning the age and relation of the so-called Weybourn Crag to the other Crags. According to Mr. S. V. Wood it is synchronous with the Bure-Valley Crag or the Pebbly Beds, and therefore newer than the Forest-Bed Series; whereas Mr. Reid places it at the base of, and consequently as older than, that Series, although still newer than the Norwich Crag. Mr. H. B.

Woodward also places it in the same division as the Bure-Valley Crag.

Although the Forest-Bed Series thins off to the north, the freshwater bed at the base of the Mundesley Series is prolonged, and forms a definite zone whereby the relative position of the associated strata can be fixed. These beds are in general thin, and the fossils few and badly preserved, but at one spot, a short distance east of Runton Gap, Mr. Reid found beneath them a bed of Crag abounding in well-preserved shells (fig. 8). The section he gives as under:—

		feet.
"Forest-bed."	Laminated clay full of lignite, small twigs and occasional fir-cones, and fragments of *Mytilus*	?
	Mass of rolled clay-pebbles on uneven surface.	?
Weybourn Crag.	Grey shelly Crag, in the lower part alternating with thin loams	about 4
	Bed of unworn flints mixed with clay, and containing *Mya arenaria* and *Tellina obliqua* in the position of life	about 4½

Soft chalk with Paramoudras and rings of flint.

His list of the Mollusca is the most reliable one we have for the Weybourn Crag, for at this spot it is free from any possible intermixture with the Pebbly Beds * :—

Lamellibranchiata.

Astarte borealis, *Chemn.*
—— ——, oval var.
—— compressa, *Mont.*
—— incrassata, *Brocchi.*
—— crebricostata, *Forbes.*
—— sulcata, *Da Costa.*
Cardium echinatum, *Linn.*
—— edule, *Linn.*
—— grœnlandicum, *Chemn.*
Corbula contracta ?, *Say.*
—— striata, *W. & B.*
Cyprina islandica, *Linn.*
Donax vittatus, *Da Costa.*
Leda oblongoides, *S. Wood.*
Lucina borealis, *Linn.*
Mactra ovalis, *J. Sby.*
—— stultorum, *Linn.*
Mya arenaria, *Linn.*
—— truncata, *Linn.*
Mytilus edulis, *Linn.*
Nucula Cobboldiæ, *Sby.*
Pecten opercularis ?, *Linn.*
Pholas crispata, *Linn.*
Saxicava arctica, *Linn.*
—— ——, gigantic var.
Scrobicularia plana, *Da Costa.*
Tellina balthica, *Linn.*
—— lata, *Gmelin* (*T. calcaria*).
—— obliqua, *Sby.*
—— prætenuis, *Leathes.*

Gasteropoda.

Buccinum undatum, *Linn.*
Bulla alba, *Brown.*
Cancellaria viridula, *Fabr.*
Chiton, sp.
Hydrobia (Paludestrina) subumbilicata, *Mont.*
Littorina littorea, *Linn.*
—— rudis, *Maton.*
Melampus (Conovolus) pyramidalis, *J. Sby.*
Natica catena, *Da Costa.*
—— clausa, *Brod. & Sby.*
—— helicoides, *Johnst.*
Pleurotoma (Clavatula) linearis, *Mont.*
—— turricula, *Mont.*
Purpura lapillus, *Linn.*
Scalaria grœnlandica, *Chemn.*
—— Trevelyana, *Leach.*
—— Turtonis, *Turt.*
Tectura virginea, *Müll.*
Trochus tumidus ?, *Mont.*
——, sp.
Trophon antiquus, *Linn.*
—— ——, reversed var.
Turritella terebra, *Mont.* (=communis, *Risso*).
Velutina lævigata, *Linn.*

Brachiopoda.

Rhynchonella psittacea, *Chemn.*

* Mem. Geol Survey, p. 18.

As the upper part of this section belongs to the base of the Mundesley Series or else to the Forest-Bed Series, this Crag (in the absence of the Chillesford Clay, which may have been denuded, or may be represented by the mass of clay pebbles) occupies the position of the Fluvio-marine Crag of Norwich, while there is nothing to show relation to the Forest-Bed Series. The presence of the pebbles and the eroded surface show, on the contrary, a decided break between this Crag and the overlying beds. For these reasons, and also because all the 51 species in this list, are, with two exceptions, Crag species, I would assign this bed to the Norwich Crag. One exception is *Tellina balthica*, which has been found on this north-eastern coast only in the Crag Beds of the Bure Valley; the other *Astarte crebricostata*, which is only recorded from the Upper Glacial Beds. Besides these, there are found here two shells—*Cardium echinatum* and *Astarte incrassata*—which are Red-Crag species. On the other hand, of the 36 species recorded by Mr. H. B. Woodward from the Bure-Valley Beds, only 23 appear in the above list.

Mr. Reid. on the assumption that this Crag is the equivalent of the Bure-Valley Crag *, considers that Messrs. Wood and Harmer are wrong in placing the latter above the Forest Bed; but if I am right in referring this patch of Crag to the Norwich Crag, then the shingle *h* (fig. 8) above the lower part of the "Forest Bed" would correctly represent, as supposed by Messrs. Wood and Harmer, the Bure-Valley Beds.

It is evident that the palæontological differences are very small. The only marine Bure-Valley shell not found in the Crag at Norwich is *Tellina balthica*. But this shell is extremely uncertain in its habitat, and a slight difference in the quality of the water or of the bottom might account for its presence in the one district and its absence in the other. Dr. Gwyn Jeffreys informed me that at the present day it is abundant in Swansea Bay, although it is not to be found nine miles distant in Oxwich Bay. It prefers brackish waters, and "though in the main a northern shell, it is likewise common in many parts of the south of Europe." It is clear likewise that this Runton Crag presents far closer analogies with the more distant Crag at Norwich than with the Bure-Valley Crag in the intermediate area.

Between Runton and Weybourn, where the Forest Series entirely thins out, or few traces of it remain, the overlying Pebbly Beds come into juxtaposition with the Fluvio-marine Crag beneath that Series. The slight palæontological and lithological differences are then not sufficient to furnish any apparent distinction, except possibly in places where the Westleton shingle retains its more pronounced characters. The true faunal value of these zones can only be correctly determined by selecting localities, such as the one above, where they cannot possibly be in contact.

* Mr. Reid, however, suggests the possibility that the Weybourn Crag, as a whole, is the equivalent of the Chillesford and Aldeby Beds.

§ 5. *Conclusion.*

The plan I have therefore adopted has been to confine myself to those localities where, owing to the Chillesford Clay or Forest Beds intervening, there is no possibility of the Westleton Shingle having come in contact with the Norwich Crag. For this purpose I have limited the list of the marine Molluscan fauna of the Westleton and Mundesley beds (see p. 115) to the species found at Reydon, Easton Bavant, Bacton, Mundesley, and West Runton (the last two being in the *Leda-myalis* Bed of Reid). This gives a list of only 19 species, all living, excepting possibly two, about which the most competent authorities differ. *Tellina obliqua* was considered by Sowerby and Searles Wood to be an extinct species, whereas by Forbes and Hanley and Gwyn Jeffreys it was considered to be a variety of *T. lata*, a living northern species; according to Jeffreys *Nucula Cobboldiæ* is now represented in the seas of Japan by a variety of the same species: whilst Searles Wood considered that they are distinct and that the Crag species is an extinct form. With two exceptions all the others are existing British species, although on the whole they are of northern types—10 ranging to Scandinavia and 9 to the Arctic seas: *Astarte borealis* is Scandinavian and Arctic only. The elimination of the more southern types seems to constitute the distinctive feature of this fauna.

The land- and freshwater Mollusca, of which there are 53 species, are from the freshwater beds (*g* to *m*, fig. 7) of the Mundesley series—the Upper Freshwater and *Leda-myalis* Beds of Mr. Reid. They are, with three questionable exceptions, all living species. All the others except four are species still living in Britain, but having a very ubiquitous range from north to south. Of the four latter, *Valvata fluviatilis* is now living in Belgium and Germany; *Hydrobia Steinii* in the north of Europe; *H. marginata* in the South of France: while *Corbicula fluminalis* ranges from Thibet to the Nile. The three extinct species include a slug (*Limax modioliformis*); *Paludina gibba*, formerly referred to *P. contecta*, a British and Finnish species*; and *Hydrobia runtoniana*: they are found fossil also in North Germany.

The freshwater bed (*j*) at West Runton is rich in Fish-remains. There are 10 species, all still living in the rivers of this country.

The Reptiles (2) and Amphibia (4), found in the same bed are also living British species.

Of the 21 species of Mammalia, 6 are extinct; and it is to be remarked that out of the total number there are 14 which are not met with in the Forest Bed and make their first appearance in this stage, and it is the same with all the Reptiles and Amphibians.

The 24 Plants are of special interest from the rarity of plant-remains in such deposits. They are all living species,—19 still living in this country, 5 being now relegated to more northern latitudes, and, as in the case of the Mammalia, a large proportion (14) are confined to the Mundesley freshwater beds, though this may

* *P. glacialis* and *P. media* are doubtful, and thought by Mr. Reid to be derived.

possibly be due to the circumstance that they consist in large part of small seeds which may have escaped notice or been destroyed from having been lodged in a matrix not so favourable for their preservation as the other bed.

In conclusion, if I am right in my interpretation of these intricate sections, the Crag of the Weybourn Cliffs has no standing *per se*, but results from the junction of the Bure-Valley and Norwich Beds; while with respect to the Bure-Valley Crag, as at present held, I cannot but think it open to the same doubt, although I believe in the existence of an upper division with marine shells, newer than the Norwich Crag, but having a much more limited fauna.

The construction I would therefore put upon the Pre-Glacial strata underlying the Boulder-clay Series on the coast of Norfolk is as under:—

THE WESTLETON AND MUNDESLEY BEDS. (*The Mundesley type.*)	1. Laminated clays, sands, and shingle with plant-remains and freshwater shells (*The Arctic Freshwater Bed of Reid*). 2. Sand and quartzose shingle with marine shells (*The* Leda-myalis *Bed of King and Reid*). 3. Carbonaceous clays and sands, with flint-gravel and pebbles of clay, driftwood, land- and lacustrine shells and seeds. (*The Upper Freshwater Bed of Reid.*)
THE FOREST-BED GROUP *	4. A greenish clay, sandy and laminated in places, containing abundant Mammalian remains and driftwood, with stumps of trees standing on its surface. (*The Forest- and Elephant-bed of authors. The Estuarine division of Reid.*) 5. Ferruginous clay, peat with land and freshwater remains, and gravel. (*The Lower Freshwater Bed of Reid.*)

The marine fauna of the "Mundesley and Westleton Beds" is very limited and often fails us. On the other hand there is a structural feature singularly persistent, that is, the presence throughout, from Southwold to Bacton, Mundesley, Runton, and Weybourn, of a shingle everywhere of the same character. The intercalated clay and peaty beds, with their land and freshwater remains, are subordinate, and confined to the east coast of Norfolk.

Although allied to the Norwich Crag by their marine fauna, and conformable with it in places, the Westleton and Mundesley beds constitute on the whole a distinct and separate group formed under changed physiographical conditions,—conditions that led to their extension far beyond the Crag area †; while, as I shall

* The fauna and flora of these beds are of peculiar interest, and have for years past been the object of active research on the part of many geologists. Large collections of the remarkable Mammalian remains have been made by Miss Anna Gurney, Mr. J. Gunn, and Mr. R. Fitch, and are now in large part preserved in the Norwich Museum. The later careful researches of Mr. C. Reid have made great additions to the smaller life and vegetable forms. (For details and lists, see Mr. C. Reid's Cromer Memoir before cited, and Mr. John Gunn's 'Sketch of the Geology of Norfolk.')

† We have evidence, however, of a similar southern drift in the presence of chert from the Lower Greensand, and quartz, quartzites, and other such specimens either from the Ardennes or the Rhenish Provinces, at the base of the Red Crag, and somewhat similar indications at the base of the Coralline Crag.

hope to show in the second part of this paper, they are separated from the deposits of the Glacial Period by further and equally important physiographical changes. In one case we have currents and drifts from the south and east; in the other, northern drifts solely. The importance of these features will be seen when we come to questions connected with the relative age of the drifts in the London Basin, especially as I take this Westleton Shingle as the base of the Quaternary Series, and as marking the time when the existing forms of life, both animal and vegetable, began to predominate in this country.

Lists of the Organic Remains of the Westleton and Mundesley Beds of Norfolk, compiled in greater part from the lists of Mr. Clement Reid's Memoir on Cromer, but grouped in accordance with the stratigraphical order proposed in the foregoing pages.

PLANTÆ.

Cryptogams.

Chara, sp.	
Hypnum turgescens, *Jens.*	Moss. (Northern regions.)
Equisetum, sp.	
Osmunda regalis, *Linn.*	Fern-royal.

Gymnosperms.

Pinus sylvestris, *Linn.*	Scotch Fir.
—— abies, *Linn.*	Spruce Fir.
Taxus baccata, *Linn.*	Yew.

Monocotyledons.

Carex & Cyperus, sp. (several)	Sedges.
Juncus, sp.	Rush.
Potamogeton flabellatus, *Bab.*	Pond-weeds.
—— heterophyllus, *Schreb.*	Pond-weeds.
—— trichoides, *Cham.*	Pond-weeds.
Zannichellia palustris, *Linn.*	Horned Pond-weed.

Dicotyledons.

Alnus glutinosa, *Linn.*	Alder.
Betula nana, *Linn.*	Dwarf Birch.
Ceratophyllum demersum, *Linn.*	Hornwort.
Corylus avellana, *Linn.*	Hazel.
Hippuris vulgaris, *Linn.*	Mare's-tail.
Menyanthes trifoliata, *Linn.*	Bog-bean.
Myriophyllum, sp.	Water Milfoil.
Prunus communis, *Huds.*	Sloe.
Ranunculus aquatilis, *Linn.*	Water Crowfoot.
——, sp.	Buttercup ?
Rumex maritimus, *Linn.*	Golden Dock.
Salix polaris, *Wahlb.*	Polar Willow.
Thalictrum flexuosum ?, *Bernh.*	Meadow Rue.
Trapa natans, *Linn.*	Water Chesnut. (Central Europe.)
Trifolium ?	Clover ?

INSECTA.

Donacia sericea, *Linn.*
Notiophilus aquaticus, *Linn.*
Timarcha ?, sp.

Entomostraca.

Cypris Browiana? .... (Extinct.)
Candona candida, *Müll.*

Mollusca.

Marine.

Gasteropoda.

Buccinum undatum, *Linn.*
Littorina littorea, *Linn.*
—— rudis, *Maton.*
Natica catena, *Da Costa.*
Purpura lapillus, *Linn.*
Scalaria grœnlandica, *Chemn.*
Trophon antiquus, *Linn.*
—— ——, var. *contrarius.*

Lamellibranchiata.

Astarte borealis, *Chemn.*
Cardium edule, *Linn.*
Cyprina islandica, *Linn.*
Leda myalis, *Couth.*
Mya truncata, *Linn.*
—— arenaria, *Linn.* ?
Nucula Cobboldiæ, *Sby.* ?
Ostrea edulis, *Linn.*
Pholas crispata, *Linn.*
Saxicava arctica, *Linn.*
Tellina balthica, *Linn.*
—— obliqua, *Sby.* ?

Land and Freshwater.

Lamellibranchiata.

Anodonta cygnea, *Linn.*
—— ——, var. *anatina.*
Corbicula fluminalis, *Müll.*
Pisidium amnicum *, *Müll.*
—— (casertanum), *Poli.*
—— pusillum, *Gmel.*
—— nitidum, *Jenyns.*
—— roseum, *Scholtz.*
Pisidium Henslowianum, *Shep.*
—— pulchellum, *Jenyns.*
Sphærium corneum, *Linn.*
—— rivicola, *Leach.*
—— ovalis, *Fér.*
Unio pictorum, *Linn.*

Gasteropoda.

Ancylus lacustris, *Linn.*
Bythinia tentaculata, *Linn.*
—— Leachii, *Sheps.*
Carychium minimum, *Müll.*
Clausilia, sp.?
Helix arbustorum, *Linn.*
—— nemoralis, *Linn.*
—— hispida, *Linn.*
—— concinna, *Jeffr.*
—— fulva, *Müll.*
—— pulchella, *Müll.*
—— pygmæa, *Drap.*
Hydrobia marginata, *Mich.*
—— Steinii, *v. Martens.*
—— runtoniana, *Sandb.*
Limax Sowerbyi, *Fér.*
—— modioliformis, *Sandb.*
Limnæa limosa (peregra), *Linn.*
—— stagnalis, *Linn.*
—— palustris, *Müll.*
—— truncatula, *Müll.*
Paludina gibba, *Sandb.*†
Physa fontinalis, *Linn.*
Planorbis corneus, *Linn.*
—— albus, *Müll.*
—— crista, *Linn.*
—— carinatus, *Müll.*
—— complanatus, *Linn.*
—— vortex, *Linn.*
—— spirorbis, *Linn.*
—— contortus, *Linn.*
—— nitidus, *Müll.*
Pupa marginata, *Drap.*
Succinea putris, *Linn.*
—— oblonga, *Drap.*
Valvata fluviatilis, *Colb.*
—— piscinalis, *Müll.*
—— ——, var. *antiqua.*
—— cristata, *Müll.*
Vertigo antivertigo, *Drap.*
Vitrina pellucida, *Müll.*
Zua lubrica, *Müll.*

---

* *Pisidium astartoides*, being generally considered a variety of *P. amnicum*, is omitted, though Mr. C. Reid shows some reason for its being a distinct species.

† This is Dr. Sandberger's species, determined from specimens sent by Mr. Reid.

Vertebrata.

Pisces.

Acerina vulgaris?	Ruff.
Acipenser, sp.?	Sturgeon.
Abramis brama, *Linn*	Bream.
Barbus vulgaris, *Flem.*	Barbel.
Leuciscus erythrophthalmus, *Linn.*	Rudd.
—— rutilus, *Linn.*	Roach.
—— cephalus?, *Linn*	Chub.
Perca fluviatilis, *Linn.*	Perch.
Tinca vulgaris, *Cuv.*	Tench.
Esox lucius, *Linn.*	Pike.

Amphibia.

Bufo, sp.	Toad.
Rana esculenta	Edible Frog.
—— temporaria?	Common Frog.
Triton cristatus	Common Water-Newt.

Reptilia.

Pelias berus	Viper.
Tropidonotus natrix	Common Snake.

Aves.

Anas?, sp.	Duck.

Mammalia.

Arvicola amphibius, *Linn.*?	Water-Vole.
—— arvalis, *Pallas*	Vole. (Central Europe. Extinct in Britain.)
—— glareolus, *Schreb.*	Bank-Vole.
—— intermedius, *Newton*	Extinct.
—— gregalis, *Pallas*	Vole. (Central Europe. Extinct in Britain.)
Canis vulpes, *Linn.*?	Fox.
Castor europæus, *Ow.*	Beaver.
Cervus Sedgwickii, *Falconer*	(Extinct.)
—— verticornis *Dawkins*	(Extinct.)
Equus caballus-fossilis, *Rutim.*	Horse.
Martes sylvatica, *Linn.*	Marten.
Mus sylvaticus, *Linn.*	Long-tailed Field-mouse.
Myogale moschata, *Linn*	Shrew, var. (Russia.)
Rhinoceros etruscus, *Falconer*	Rhinoceros. (Extinct.)
Sciurus vulgaris, *Linn.*?	Squirrel.
Sorex vulgaris, *Linn.*	Common Shrew.
—— pygmæus, *Pallas*?	Lesser Shrew.
Spermophilus, sp.	Marmot.
Talpa europæa, *Linn.*	Mole.
Trogontherium Cuvieri	Gigantic Beaver. (Extinct.)
Ursus spelæus, *Blum.*	Cave-Bear. (Extinct.)

Discussion.

The Chairman remarked on the importance of the problem of the correlation of the East Anglian Drifts with those of the Thames basin, and of the especial qualifications of the Author of the paper for dealing with this great question.

Mr. Clement Reid noticed that the Author went further than he had previously done in accepting recent results. With regard to the correlation of the beds on the northern coast of Norfolk with those of Westleton, he thought it most dangerous to take the unfossiliferous beds of the latter place as a type. On the Norfolk coast the Weybourn Crag was classed by himself with the Forest Bed as a matter of convenience. Its fauna was sufficiently marked to show that it was slightly newer than the Norwich Crag. It always contained *Tellina balthica*, whilst that shell had never been found in the Norwich Crag. The fauna was also slightly more Arctic than that of the Norwich and Chillesford Crags. The beds which the Author bracketed as the Forest Bed, did not include the Upper freshwater bed. He gave reasons for his having himself included it with the Forest-Bed series. As to classing the Arctic freshwater bed with the Upper freshwater bed, he noted that the floras showed a difference of climate of 20°, and he considered the grouping together of the two unadvisable. He thought it unsafe to use the term Westleton Beds until some definite fauna was found at Westleton. If any definite name for the whole series was used, Mr. S. V. Wood's old term "Bure-Valley Beds" should be adopted.

Mr. H. B. Woodward believed that, for purposes of correlation, the terms Norwich-Crag Series, Forest-Bed, and Glacial Series should be used, while minor subdivisions, such as Bure-Valley Beds, Chillesford Beds, and Westleton Beds, might, with advantage, be dropped. He had himself come to the conclusion that the Westleton Beds were in the Glacial series. He agreed with the Author that the Weybourn Crag was Norwich Crag, for he placed it on the same horizon as the Bure-Valley Beds. Unfortunately beds which belong to a horizon higher than the Forest Bed had also been included with the Bure-Valley Beds by Mr. S. V. Wood. The name Mundesley Beds was a useful local term for these higher beds; but if the term Westleton Beds was associated with them, it might turn out in the end that there were no "Westleton Beds" at Westleton.

Mr. J. A. Brown had obtained a stone apparently worked by human agency from the Weybourn Crag of Runton Gap. He had also found a black flake at Westrand in peat.

Mr. Topley remarked on the indebtedness of the Society to Prof. Prestwich for his many years' labour on this ground. The Survey had now agreed not to mark by any definite name these beds under dispute. Whatever classification might eventually be adopted, the lines on the Geological Map marked actual lithological differences. He would deprecate the re-introduction of the term Bure-Valley Beds.

The AUTHOR, in reply, stated that whilst Mr. Wood was working from north to south, he himself had worked from south to north. He had come to the conclusion that the beds, as he understood them, were distinct, both as regards their association and classification, from those which Mr. Wood had described as the Bure-Valley Beds. *Tellina balthica* is very irregularly distributed at the present day, and has a wide southern range. When the Chillesford Clay is absent, confusion arises from intermixture of Norwich-Crag and Westleton forms, whence the modified fauna known as the Weybourn Crag. Some of the fossils of the uppermost beds of his Forest-Bed series may also have been washed into the Mundesley or Westleton Beds. It is difficult to show that the Forest series is different from the Chillesford Beds; though his impression was that it is different and newer. The subordinate Arctic Freshwater Bed is of small dimensions and shows the setting in of cold, which we should expect as introductory to glacial conditions.

2.

[*From the* Quarterly Journal *of the* Geological Society *for May* 1890, Vol. xlvi.]

ON THE RELATION

OF THE

WESTLETON BEDS,

OR

PEBBLY SANDS OF SUFFOLK,

TO

THOSE OF NORFOLK,

AND ON

THEIR EXTENSION INLAND;

WITH SOME

OBSERVATIONS ON THE PERIOD OF THE FINAL ELEVATION AND DENUDATION OF THE WEALD AND OF THE THAMES VALLEY, ETC.

BY

JOSEPH PRESTWICH, D.C.L., F.R.S., F.G.S., ETC.

PART 2.

LONDON:

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1890.

On the Relation *of the* Westleton Beds, *or* Pebbly Sands *of* Suffolk, *to those of* Norfolk, *and on their* Extension Inland; *with some* Observations *on the* Period *of the* Final Elevation *and* Denudation *of the* Weald *and of the* Thames Valley, *&c.* By Joseph Prestwich, M.A., D.C.L., F.R.S., F.G.S., &c.

PART II.

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1. *Objects of the Paper &c.*

In the first part of this paper * the relation of the Westleton Beds in the Eastern Counties to the Crag Series on the one hand, and to the Glacial Series on the other, was discussed. My object in this part is to trace the extension of the former beyond the area of the Crag, and to show that a Westleton Shingle-bed passes transgressively over the Red Crag, the Tertiary strata, and the Chalk, and ranges westward through the length of the London Basin, while it rises to considerable heights above the Glacial Drifts and exists independently of them; and although it occupies only isolated and detached outliers, if the relation of these outliers to the Pre-Glacial Beds of Suffolk and Norfolk—the position of which has been proved—can be determined, we shall then have a definite base by which to correlate them and establish the order of succession and relative age of the many Drift Beds of the London Basin.

I purpose therefore to proceed step by step and to take each stage separately, confining myself now to the oldest and highest stage, where the distinctive characters of composition are best defined.

* Quart. Journ. Geol. Soc. for February 1890, p. 84.

These are lost in later stages, owing to frequent reconstruction, but we can then follow by levels.

In 1847 * I showed that in the neighbourhood of London there were hill-gravels as distinct from valley-gravels, but I was not then in possession of any clue whereby to fix their separate age. Subsequent observations, especially aided by the cuttings on the Great Eastern Railway then in course of construction, enabled me to follow the Pre-Glacial Beds of Suffolk in their inland range, and to recognize their higher position in relation to the Drifts of the Thames Valley.

In my paper of 1871 on the Westleton Beds † I briefly alluded to their extension into the Thames Valley area, but reserved the details for subsequent description. Other occupations and the need for verification of some of my early observations led to a long delay in publication, though in 1881 ‡ I gave a short preliminary notice of some of the hill-drifts in the London Basin—such as those at Highbeech, Barnet, Southgate, Hertford, Hatfield, South Mimms, St. Albans, Tiler's Hill, Horsington, and Bowsey Hill §—which are capped by Drift Beds of Westleton age. I now purpose giving these in detail, and I only regret that owing to the lapse of time many of the sections I have to describe are no longer visible. The delay, however, gives me the advantage of the observations recorded by other geologists, and especially by Mr. Whitaker and other officers of the Geological Survey, and also enables me to avail myself of the heights and contours given in the last published sheets of the 1-inch Ordnance Survey, so indispensable in an inquiry of this description, and for which I had previously to depend on the observations I had made with an aneroid barometer ‖.

In 1864, Mr. Whitaker, in his account of the Post-Pliocene Series ¶ of parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey, alludes to the occurrence of a "gravel wholly or for the greater part made up of flint pebbles" on the tops of various hills in Hertfordshire and Buckinghamshire.

In 1877 he stated that there were two gravels in East Essex**,

* 'The Ground Beneath us,' p. 30.

† Quart. Journ. Geol. Soc. vol. xxvii. p. 477.

‡ Reports Brit. Assoc. p. 420. I was not then acquainted with Mr. Whitaker's latest Memoir.

§ Other hills were named, but these relate to the Southern Drift, which I now take separately.

‖ I regret also that I find it impossible to revisit, as I had intended, the many localities described, in order to check and revise my early observations, the greater number of which were made before my views were matured. Consequently, there may be inaccuracies which have escaped me, or analogies which I may have overlooked. I could also have wished to have given greater certainty to the percentage values of the Westleton and Southern Drifts—a plan which only occurred to me after much of the work had been done. I fear I may have overestimated the relative proportions of some of the essential constituent materials, but not to such an extent as to vitiate the general argument, while the facts, I trust, are recorded with sufficient accuracy to justify the conclusions at which I have arrived.

¶ Mem. Geol. Survey, Expl. Sheet 7, p. 69 (1864).

** "On the Geology of the Eastern End of Essex (Walton-on-Naze and Harwich)," Expl. of Sheet 48 S.E. p. 16.

one of which he considered to be of Glacial age, and the other Post-Glacial; and in the following year he noticed a small deposit of pebble-gravel capping the hills near Hertford *, which he thought might "be of Pre-Glacial age, but all that is known of it with absolute certainty is that it is older than the Boulder Clay (which occurs over it in other parts), and Mr. S. V. Wood, Jun., has classed it with his 'Middle Glacial.'"

In 1875, and again in 1880, Mr. Whitaker noticed in more detail † this "Pre-Glacial (?) Pebble-Gravel," and assigns to it more definite limits. He says, "On the tops of the London-Clay hills there is often a mass of sandy gravel of an exceptional sort, that is to say, it is almost wholly wanting in the more or less angular pieces of flint that form the greater part of the other gravels to be described, aud, like the far older gravel-beds of the Blackheath and Bagshot Series, its component stones have been rounded into the form of pebbles. Showing at first sight a very great likeness to these old Tertiary pobble-beds, after a more careful examination this gravel is seen to be easily distinguished from them; for whilst the former are made up of flint-pebbles, that is not the case with the latter, which contains also a large proportion of pebbles of quartz and quartzite, and here and there a sub-angular flint." "The flint-pebbles havo probably been derived from the destruction of the old Tortiary pebble-beds; but the pebbles of quartz, quartzite, and other older rocks that occasionally occur must have been derived from beds that are not found anywhere in our district.

"Of the age of this gravel we cannot yet speak with certainty. It is newer than the Lower Bagshot Beds, for it is known to overlie them: and it is older than the Boulder Clay, which is found above it, but botween these extremes we are left to reason by analogy and by the ovidence given by the manner of its occurrence."

"From its occurrence on the tops of the hills, whilst the Middle Glacial gravel often lies at their base, or on their flanks, it would seom that tho pebble-gravel is the older of the two and was deposited long before those hills were cut into their present form, a process which must havo been somewhat advanced before the other gravel was laid down. It is possible, therefore, that the pebble-gravel may represent some part of the 'Lower Glacial Drift' (of Mr. Wood), any known occurrence of which is, however, as far distant as the Crag."

"The chief localities aro Stanmore Heath from Shenley south-eastward, west aud north of Barnet, and at Totteridge, in Middlesex; at Highbeech, Jacks Hill, and Gayne's Park, east of Epping, in Essex, and at Shooter's Hill, in Kent."

In the larger valuable memoir ‡, published since these pages were written, Mr. Whitaker describes these Beds, which he places with

* "Tho Geology of the N.W. part of Essex and the N.E. part of Herts," Mem. Geol. Survey, Expl. of Sheet 47, 1878, p. 32.

† "Guide to the Geology of London and the Neighbourhood," Mem. Geol. Survey (1st edit. pp. 49–51, and 3rd edit. pp. 54–57).

‡ 'Geology of London,' vol. i. pp. 290–298 (1889).

"Doubtful Deposits," in greater detail and with some slight changes, and retains the open term of "Pebbly Gravel."

In 1867 * Mr. Searles V. Wood, Junr., called attention to the relations between the Post-Glacial, Middle, and Upper Glacial deposits of the Valley of the Thames, in connexion with the position of the latter two on the hills and in the valleys of this area. Prof. Boyd Dawkins showed, however, that his contention—based on theoretical grounds, that certain valleys "could have had no existence at the period of the Glacial Clay"—was not in accordance with the Survey observations.

In 1868 † Prof. T. McK. Hughes described an outlier of peculiar gravel he had noticed near Hertford, under the term of "Gravel of the Upper Plain" in contradistinction to the "Gravel of the Lower Plain." The latter he referred to the Glacial Series. Of the other he says, "From their great extent, persistent character, and uniform level, I think these gravels of the Higher Plain must be a marine deposit; but without a careful examination of the old coast-line, and of their behaviour as they approach the Crag country, I should not like to give any opinion as to their age." He further states that they were of great antiquity and older than the Boulder-clay.

Mr. Wood, commenting on this communication, contended that this Gravel of the Upper Plain was of an age intermediate between his "Middle Glacial" and the Boulder-clay; while the outliers of other pebbly gravels at Brentwood, Highbeech, South Weald, Langdon Hill, and others ‡, were "not improbably of Eocene age."

Another paper of Mr. Wood's on the Wealden Denudation §, only bears incidentally on this question, as showing the existence and extent of Drift Beds in the Thames Valley older than the lower-level Valley-gravels.

The most important contributions to this subject by Mr. Wood are, however, those in which he sums up his numerous and extensive observations, and gives his final views on this and collateral questions ‖, accompanied by a map of the area occupied by the Chalky Boulder-clay, and a Plate of Sections showing the range and distribution of the Pre-Glacial, Glacial, and Post-Glacial Beds, with the position and probable relation of the hill-gravels throughout the south of England. The second part is devoted more especially to the consideration of the Post-Glacial Beds, particularly of those in the Thames and Hampshire Basins, and to the elaboration of his views respecting his Periods of Depression, Rise, and Glaciation. These papers, however, are not easy to summarize, but can be consulted with advantage.

The reader will also find in a paper by Mr. F. C. J. Spurrell,

* Quart. Journ. Geol. Soc. vol. xxiii. p. 394 (1867).

† *Ibid.* vol. xxiv. p. 283 (1868).

‡ *Ibid.* vol. xxiv. p. 464 (1868).

§ *Ibid.* vol. xxvii. p. 3 (1871).

‖ "On the Newer Pliocene Period in England, Part I.," Quart. Journ. Geol. Soc. vol. xxxvi. pp. 457–528 (1880); Part II., *ibid.* vol. xxxviii. pp. 667–745 (1882).

F.G.S. *, a notice of many of the hill-gravels of the London district, including the outliers on Shooter's Hill, Warley, Epping, Langdon Hill, and others, which he refers, with Mr. S. Wood, to the wreck of local Bagshot Beds.

The admirable "Drift Edition" maps of the Geological Survey, show the intricate ramifications of the Glacial and Post-Glacial Drifts in Suffolk, North Essex, and part of Herts (Maps 48, 47 †, and part of No. 7); but the Pebbly Gravel (Westleton) in Essex ‡, owing, I presume, to its being almost invariably hidden under Glacial beds, is not represented. Although, however, in that county the Westleton Beds are generally covered by Boulder-clay, the cuttings on the Great Eastern Railway which I had the opportunity of seeing showed that throughout that district they pass under the Glacial Series, and so help to connect the Hertfordshire, Buckinghamshire, and other outliers with the Westleton Shingle of Suffolk. These sections I will now proceed to describe.

2. *Range inland of the Westleton Beds.*

Suffolk.—In the westward range of the Westleton Beds, sands predominate in some places, shingle in others—often finely stratified and false-bedded. Besides their distinctive composition, they may generally be distinguished at sight by their pure white or ochreous colour, in contrast with the red of the Crag or the light drabs of the Glacial gravels. They pass, south of Westleton, from off the Chillesford Clay on to the unproductive sands of the Crag, as shown in the following section (fig. 1):—

Fig. 1.—*Pit on Randell's Farm, Leiston Common* (1860).

a. Trail.
b. Boulder-clay not seen in pit, but showing a short distance higher up on the hill.
c. White sand, with seams of flint and white quartz-pebbles (Westleton).
d. Laminated ferruginous and yellow sands, ochreous and ferruginous sands.

Speaking of this district, Mr. Whitaker notices "a deposit of less certain classification which has been mapped only over the small tract north of the Minsmere Level. This is a gravel, with occasional sand, composed for the most part of pebbles (chiefly of flint, but some of quartz): and whilst it seems to underlie the lowest beds of the Glacial Drift, rests generally irregularly on the

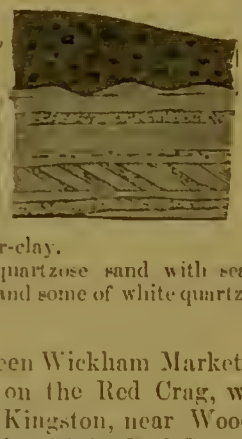
* 'A Sketch of the History of the Rivers and Denudation of West Kent,' 1886.
† Excepting the extreme N.W. corner and Hertford Heath.
‡ Geology of the N.W. part of Essex and the N.E. part of Herts, with parts of Cambridgeshire and Suffolk, 1878.

Crag sand" *. Two pits near East Bridge where it is to be seen are also noticed †. Mr. S. Wood, on the other hand, was of opinion that most of these gravels, as well as those of which we shall have to speak in East Essex, belong to his Middle Glacial.

Eastward of this place the shingly sands pass apparently over the Crag of Sizewell Gap; while to the westward they form part of the sandy commons and heaths of the Snape and Tunstall districts, but definite sections are wanting.

To the west of Wickham Market, a bed of white gravel and sand is worked in several small pits; and in one near Easton indistinct traces of shells are observable in some thin intercalated seams of ironstone. The furthest point inland here at which I have seen the Westleton Beds is under the Boulder-clay at Brandeston (fig. 2). There may, however, be a little doubt about this determination.

Fig. 2.—*Section at Brandeston Brick-pit* (1847 ‡).



b. Dark bluish-grey Boulder-clay.
c. Light-coloured coarse quartzose sand with seams of gravel consisting largely of flint-pebbles and some of white quartz, with a few fragments of shells.

At Ufford Bridge, between Wickham Market and Woodbridge, the Westleton Shingle rests on the Red Crag, with the Boulder-clay above it. At Kyson or Kingston, near Woodbridge, the railway-cutting exposed a fine section of the Red Crag and overlying sands, capped by a bed of Westleton Shingle. The following are the local particulars; a general section is given in Plate VII. fig. 8 §.

	feet.
1. White gravel of flint- and quartz-pebbles (Westleton)	2
2. White and light yellow sand	2
3. Bright yellow sand without fossils.........	28
4. Gritty sand, false-bedded and with local and irregular seams of shells, and an underlie of a few inches of gravel resting on	
5. A thick bed of Red Crag, abounding in shells at the west end of the cutting, but with very few at the east end	
6. A thin seam of Coprolites with flint- and a few other pebbles resting on a floor of London-Clay Septaria	
7. London Clay.	

(Items 3–6 bracketed together: 28 feet.)

* Mem. Geol. Survey, Quarter-Sheets 49 S. and 50 S.E. p. 27 (1886).
† See Quart. Journ. Geol. Soc. vol. xxxiii. pp. 101-111 (1877).
‡ I give dates, because in all probability many of the sections no longer exist.
§ See also Quart. Journ. Geol. Soc. vol. xxvii. p. 334.

The Shingle (No. 1) is approximately composed of:—

	per cent.
1. Flint-pebbles	30
2. White quartz-pebbles	30
3. Subangular flints	20
4. Subangular fragments of chert and ragstone	12
5. Pebbles of light-coloured quartzite, sandstone, greyish arkose, and dark metamorphosed slate	8
	100

Its thickness is uncertain, as the Boulder-clay does not show until the higher part of the hill is reached.

West of Woodbridge the Westleton Beds have undergone considerable denudation, and are generally removed and replaced by Glacial gravels and Boulder-clay. They, however, sweep round to the north of this area, and were to be seen in some small exposures in pits north-east of Ipswich.

At Finnford Bridge the section gave:—

		feet.
b.	Bluish Boulder-clay with chalk pebbles, &c.	6
	Seam of laminated brown clay	½
c.	White sands and gravel, the lower part false-bedded.	12

In the lane leading from Witnesham Street to Tuddenham I took the following section:—

	feet.
b. Ligbt brown Boulder-clay	5
c. White sands and gravel (Westleton)	2 to 4
e. Red Crag	8

In the fine section described by Mr. Whitaker* near Bramford, 3 miles north-west of Ipswich, he expresses an opinion that Bed No. 2 may be of Crag age. I would take it to represent the Westleton Beds. The following is Mr. Whitaker's description of this pit Beds 3 to 6 are given only in abstract†.

	feet.
1. Glacial drift. Gravel and sand, resting irregularly on 2	up to 8
2. Fine light-coloured sand with thin clayey layers; at the bottom a thin layer of gravel with phosphatic nodules (may belong to the Crag)	up to 15
3 & 4. London Clay with a Pebble-bed at base	10
5. Reading Beds with a few flints and pebbles	18 or more
6. Thanet Sands	5
7. Chalk.	

Three miles south-west from the last pit is the village of Burstall, and on the slope of the hill on the banks of the small stream I found (1856) the following section:—

		feet.
b.	Boulder-clay, chalky	3 to 10
c.	White gravel or shingle (Westleton)	8 to 10
	White sands	2

* Mem. Geol. Survey, 'Geology of Ipswich,' &c., 1885, p. 14.

† This pit had not been opened out to its full extent when I last visited it several years ago.

Lower down the hill the yellow sands of the Crag crop out.

The gravel has the well-marked characters of the Westleton Shingle, its approximate composition being as under:—

	per cent.
1. Small flint-pebbles	30
2. White quartz-pebbles	25
3. Subangular flints	23
4. Subangulaar fragments of chert and ragstone	12
5. Pebbles of light-coloured sandstone and quartzite, and Lydian stone	10
	100

Mr. F. J. Bennett has noticed a very similar section at Elmsott, 3 miles to the north-west of Burstall, where the Boulder-clay overlies a "rather coarse sandy gravel, with pebbles of quartz and of quartzite, about 2 to 10 feet," overlying a "fine buff rather clayey sand" *.

The railway-sections in this intermediate district afforded little information respecting the Westleton Beds. The Norwich line, between Ipswich and the valley of the Ottley stream, passes almost exclusively through thick Boulder-gravels and clay very much disturbed and deeply eroding the underlying beds; whilst the Yarmouth line, between the Orwell and the Deben, passes through Glacial loams, with but little gravel or Boulder-clay, overlying the Red Crag and unfossiliferous sands.

My notes, I regret to say, are not sufficiently detailed to give a definite account of the deep cutting on the northern side of the tunnel at Ipswich on the London line. This section, unlike that on the southern side of the tunnel, which was through a mass of Post-Glacial Drift, exposed:—

	feet.
Light-coloured sands with seams of gravel in horizontal layers	40
Red Crag with much false-bedding †	20
Dark brown London Clay.	

But though I failed to note the exact composition of the gravel, my belief is that this bed belongs to the Glacial Series. The next cutting (fig. 3), where the line passes under the London Road, shows how extensive the denudation accompanying the advance of the Boulder-clay has been.

Fig. 3.—*Section on the Railway near Ipswich.*

a. Ochreous gravel. *b*. Boulder-clay. *b'*. Light-coloured gravel. *c*. Red Crag.

* 'Geology of Ipswich,' &c., p. 77.

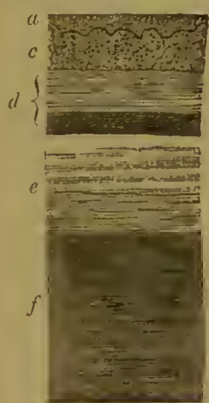
† Here, as at the Kyson Cutting, a layer of Septaria divides the Red Crag from the London Clay.

Essex.—On the south of the Crag area, the well-known cliffs at Walton-on-the-Naze exhibit a small patch of the Westleton Beds, composed of:—

	per cent.
1. Flint-pebbles	36
2. White quartz-pebbles	20
3. Subangular flints	20
4. Subangular chert	14
5. Quartzites, Lydian stone, &c.	10
	100

This gravel caps the cliffs near their western extremity, overlying a bed seemingly of the Chillesford Clay *. At the eastern end of the cliff, the unproductive sands are replaced by very fossiliferous beds of the Red Crag.

Fig. 4.—*Section of Cliff east of Walton-on-the-Naze.*



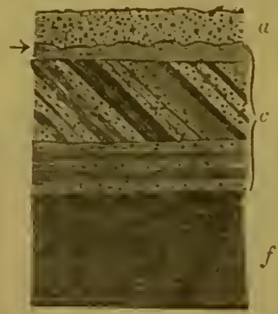
		feet.
a.	Surface-soil and gravel	1 to 2
c.	Westleton Shingle	5
d.	Light-coloured laminated sands and clays	4
	Dark carbonaceous clay with much wood and lignite	2
e.	White and yellow sands. These are replaced at the other end (east) of the cliff by fossiliferous Red Crag	10
f.	London Clay.	

From Walton to Clacton the low cliffs consist of London Clay capped by gravel. There are no Crag Beds. This gravel forms apparently one thick bed (12 to 20 ft.), but in reality it consists of two parts. The upper bed is much disturbed and not stratified, and is derived in considerable part from the *débris* of the lower bed; whereas the lower one is regularly stratified, and often shows well-marked false-bedding. It may be a question whether, although both the Red Crag and the Boulder-clay are absent in these cliffs, the lower gravel should not be referred to the Westleton Shingle. That there is a material difference of age between the two beds of gravel

* Mr. Clement Reid considers it to be something newer.

is evident from the circumstance that at the Clacton end of the cliffs these gravels * divide and admit between them the Post-Glacial mammaliferous deposit described by the late Mr. J. Brown and by the Rev. O. Fisher †.

Fig. 5.—*Section of the Cliff one mile south-east of Clacton.*



	feet.
a. Coarse ochreous Gravel	4 to 6
? *c.* Alternating beds of fine and worn gravel, finely bedded or with oblique lamination. Colours ochreous, white and dark ferruginous	8 to 12
f. London Clay.	

At Clacton the two gravels are divided at → by the Post-Glacial clays mentioned above.

The Lower Gravel, which is imbedded in a matrix of loamy brown quartzose sand, quartz-grit, with innumerable fine fragments of flint, is composed as under:—

	per cent.
1. Flint-pebbles	24
2. White quartz-pebbles	16
3. Subangular fragments of flint, mostly white, but a few stained brown	32 ?
4. Subangular fragments of white and yellow cherty ragstone	10
Subangular fragments of brown and red chert	8
5. Pebbles of light-coloured (?) quartzite, dark sandstone, and Lydian stone	10 ?
	100

I have, however, some doubts about this correlation. The bed may be of Post-Glacial age.

It is also a question whether some of the thick gravels of Central east-Essex may not be of Westleton age ‡. Some well-sections seem to indicate that such is the case in respect to the base of the great spread of gravel west of Colchester. This bank is from 30 to 50 feet thick, and the upper part consists of gravel of Glacial age. It may be seen from the railway-sections how closely associated

* The surface of the lower gravel should be examined for palæolithic flints.

† Mag. Nat. Hist. ser. 2, vol. iv. p. 197 (1840); Geol. Mag. vol. v. p. 214 (1868). See also the Survey Memoir by Mr. W. H. Dalton.

‡ The Rev. O. Fisher informs me that the pebble-gravel is well developed at Elmstead, near Colchester, and at Alresford, near St. Osyth.

the Glacial and Westleton Series are in some parts of Essex, and how difficult, without the intervention of the Boulder-clay, it sometimes is to distinguish between them.

There is no group of sections in Essex more interesting than those adjacent to Sudbury. The Chalk, the Lower Tertiary Beds, together with Pre-Glacial, Glacial, and Post-Glacial Drifts, are there exhibited in the same or in neighbouring pits. Since I visited them they have been fully described by Mr. Whitaker, to whose sections I would refer the reader *. The Pre-Glacial beds are exposed at some of the pits on Balingdon Hill, where the Boulder-clay reposes upon so irregular a surface that in some places it rests on Pre-Glacial Sands, in others on some of the Tertiary strata, and in others on the Chalk.

On my first visit to these pits in 1845, I was inclined to believe that the thick bed of sand and gravel under the Boulder-clay belonged to the Crag; but later, I was led to conclude, on the score of position and composition, that it should be grouped with the Westleton Beds. I found no fossils: but Mr. Whitaker has since then found traces of shells (broken) with unbroken specimens of *Purpura lapillus* (var. *crispata*): and in another pit he discovered a bed of sandy ironstone, with casts of shells, of which 11 species (*op. cit.* p. 31) were determined, though with doubt, by Mr. Etheridge. With them were a few coprolites. On these grounds Mr. Whitaker classes this bed with the Red Crag, with a query.

The Red Crag has not, however, been met with within a considerable distance, and the fossils found are of a negative character. The *Purpura lapillus* occurs in the Westleton Beds of Norfolk and Suffolk—as also species of *Natica*, *Cardium*, *Mytilus*. Or the fossils and the coprolites may have been derived from the Red Crag: for the beds under the Westleton shingle are, as will be shown further on, often greatly eroded. Or we may have here a remnant of Red Crag at the base of sands and gravel belonging to the Westleton Series.

I express this opinion, however, with all reserve, though I think it is confirmed, not only by the section at Burstall, but also by one nine miles to the west of Sudbury, at a place called Burnt House, near Stoke (fig. 6). In the pit there a very similar, but much thicker bed of gravelly sands is seen resting on the Chalk, while the Boulder-clay is worked in another pit just above.

I found no fossils at this place: but they have been since recorded by the officers of the Survey, who give the following description of the pit †:—

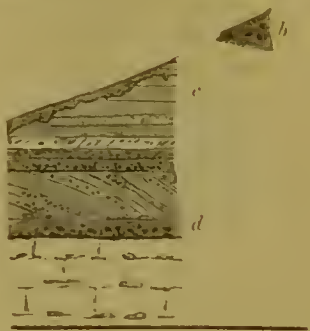
	feet.
"Glacial Drift. White, grey, and yellow false-bedded sand, partly coarse, partly fine, irregularly bedded. A mass of shells (*Purpura lapillus*) said to have been found at the bottom at one spot (? Crag)	30
? Drift or Red Crag. Bed of flints &c. (a piece of phosphatized bone)	1 to 2
Chalk, bedded, with flints........	30"

* Mem. Geol. Survey. Geology of the N.W. part of Essex &c. pp. 14, 16, 31, 57 (1878); and *op. cit.* p. 132 (1885).

† Mem. Geol. Survey. Geology of the N.W. part of Essex &c. p. 49 (1878).

I omitted to notice whether chert and ragstone were present, nevertheless the composition and character of the sands and shingle are, I think, of the Westleton type. Both flint- and quartz-pebbles occur, it is true, in the Red Crag *, but never in such numbers, or proportion, as to form a compact bed of shingle like of Westleton.

Fig. 6.—*Section at Burnt House, near Stoke* (1848).



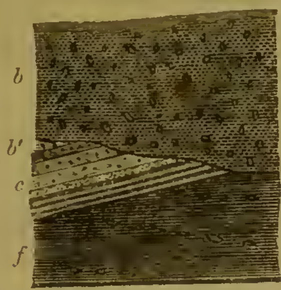
		feet.
b.	Bluish Boulder-clay exposed in another pit a short distance higher on the hill.	
c.	Bright yellow and white micaceous sands, fine at top, coarse below, succeeded by fine gravel or shingle. The sands show oblique lamination, and contain concretions or balls of soft limonite, some 1 foot in diameter	25
d.	Layer of large flints, angular and rounded.	

The railway between Sudbury and Mark's Tey exposed some interesting sections. The first deep cutting, 2 miles south of Sudbury, showed 5 or 6 feet of ochreous flint-gravel and sand, overlying from 5 to 10 feet of greyish-blue clay (Glacial), of which the lower part was finely laminated. Beneath this were 4 or 5 feet (base not reached) of white and yellow sands with seams of small shingle (Westleton ?). The Lamarsh and other smaller cuttings were through Post-Glacial brick-earth and gravel. Between Bures and Chapple, the cutting passed through 12 feet of a blue Boulder-clay, separated from 10 feet of a brown Boulder-clay by 2 feet of ochreous gravel. Below the Boulder-clay was a bed. 4 feet thick, of ochreous gravel, under which were 7 or 8 feet of white sand and gravel (Westleton).

But the most important cutting was that between Chapple and Mark's Tey. It extends for nearly a mile, and reaches a depth of from 20 to 25 feet. At the two ends, the section exposed from 8 to 10 feet of Boulder-clay overlying Westleton Shingle, but in the centre resting on London Clay. The whole section is given at length in Pl. VII. fig. 7. A small enlarged portion is given below (fig. 7).

* Reference will be made to these in the third part of this paper.

Fig. 7.—*North end of the Railway Section between Chapple and Mark's Tey* (1849).



		feet
b.	Bluish-grey Boulder-clay	12
b′.	Coarse ferruginous gravel	2
c.	Stratified sands and shingle, yellow and bright ferruginous ochreous (Westleton)	6
f.	London Clay.	

No fossils were found in any of the sections, except in some Post-Glacial Beds at Sudbury and Lamarsh.

Similar sands and shingle have apparently a considerable development in North Essex; but they are generally hidden by Boulder-clay, or masked by Glacial gravel, which, when fine and stratified, they resemble in general appearance, and sometimes assimilate to it in composition, owing to an admixture of the two beds. On a hill $1\frac{1}{2}$ mile north of Coggleshall there was a section showing 4 feet of Glacial gravel overlying 6 feet of bright yellow and ochreous sand with flint- and white quartz-pebbles (Westleton).

The Witham and Braintree branch line likewise exhibited some very illustrative sections of the Glacial and Westleton Beds (figs. 8, 9).

Fig. 8.—*Section on the Railway, one mile north of Witham.*

a. Brick-earth. } Post-Glacial.
a′. Flint-gravel. }
b. Chalky Boulder-clay.
c. White sand with shingle at base (Westleton).
f. London Clay.

The shingle consisted of—

	per cent.
1. Flint-pebbles	32
2. White quartz-pebbles	24
3. Subangular fragments of flint	35
4. Subangular fragments of chert and ragstone	9
	100

Similar beds were passed through at various cuttings between this point and Bulford; but it was between Black Notley and Braintree that the section of greatest interest was exposed. The cutting, which is 25 feet deep, showed the Chalky Boulder-clay resting upon a deeply indented surface of coarse Glacial gravel, much contorted. This latter had likewise ploughed heavily into the underlying light-coloured Westleton sands and shingle, which were regularly stratified in horizontal layers, and intersected by a number of small faults of ½ to 3 feet throw, which did not pass upwards into the Glacial Beds (Pl. VII. fig. 6).

The shingle consisted mainly of small flint- and white quartz-pebbles with a few subangular flints. No fossils were found. The overlying Glacial gravel consisted of large worn flints and some Chalk-*débris*, with pebbles of sandstone, of red quartzite (N.R.S.), and some small pebbles of flint and white quartz, the latter probably derived from the underlying beds. (See explanation of Pl. VII. p. 152).

The Westleton Beds were again exposed at the ballast-pit near Braintree Station. They are there much more ferruginous than usual, and are deeply indented by the overlying Glacial clay and gravel. In one part of the pit the section was as under (fig. 9):—

Fig. 9.—*Railway ballast-pit, Braintree* (*south end*) (1848).

			feet.
	a. Brown clay with subangular flints...	Very variable and local.	
	b. Very chalky Boulder-clay		
	b'. Ochreous Gravel (Glacial)		
Westleton Beds.	*c*. Finely stratified white sands and gravel, yellow in the lower part		13
	c'. Coarse dark ochreous gravel, with ferruginous concretions		4

The shingle consisted of the following materials, placed in the order of their relative abundance:—

1. Flint-pebbles.
2. Pebbles of white quartz.
3. Subangular flint-fragments.
4. Subangular fragments of chert and ragstone.
5. Large flattish light-coloured quartzite-pebbles.
6. Subangular pieces of Tertiary sandstone and puddingstone.
7. Small Lydian stones and pieces of white quartz.

Beneath *c'*, a hole sunk at the bottom of the pit showed 8 feet of interstratified white and yellow sands, with a shingle composed largely of white quartz-pebbles. This gives a thickness at this spot of 25 feet of Westleton Beds; but these sands and gravels extend nearly to the top of the hill on which Braintree stands, and as the well at the waterworks lower down shows that the base of the sands is there 140 feet above O.D., while the summit of tho hill is above 234 feet, the Westleton Beds, round which the Glacial Beds wrap, would seem to be here not less than from 70 to 80 feet thick (see Pl. VII. fig. 1).

It would appear from this and other instances to be named that these Westleton Beds had a large development in Central and Northern Essex, but that that they have been extensively denuded by the overlying Glacial drifts. The independence of the Westleton Beds in respect to those of the Glacial Series here also becomes more apparent, owing to the rise of the land and its waste before the deposition of the Glacial Beds, in consequence of which the latter, in the districts further to the west, where the rise was greatest, gradually come to occupy a lower level than the former. The separation of these two Drift-series, first clearly apparent in this part of Essex, becomes more pronounced as we proceed westward in the London Basin. The presence of Chalk and Jurassic *débris*, with Quartzite pebbles derived from the New Red Sandstone, readily serves to distinguish the Glacial from the Pre-Glacial drifts.

The Westleton Beds extend to the north-west, though but rarely exposed, by Wethersfield to Dunmow and Thaxted. In a pit just south of the latter place is a section of some interest (fig. 10), as the pebbly sands, which I take to be of Westleton age, and the overlying Boulder-clay are both faulted. This, however, is from recollection. I omitted at the time to note the constituent parts of the gravel. The Survey officers consider it to belong to the Crag.

Fig. 10.—*Section near Thaxted* (1850).

a. Pebbly soil.
b. Whitish Boulder-clay.
c. Coarse white sands with a few patches of gravel.
c'. Ferruginous sand.

The Westleton Beds again showed in a pit at Braxted, 2 miles S.W. of Thaxted, the section of which was as under:—

1. Gravelly sand and clay.
2. White chalky Boulder-clay.
3. Ochreous gravel, consisting essentially of flint- and quartz-pebbles, with very few subangular flints.
4. Ochreous sand.

To return to the main line of railway. The sections from Witham to Manningtree are all through Glacial or Post-Glacial Beds, and are not of importance; while on the branch line to Maldon they are chiefly through London Clay and Post-Glacial gravels.

Maldon stands on a hill about 120 feet high, capped by gravel probably of Westleton age. My notes refer to it as a flint-shingle with quartz-pebbles and fragments of chert.

Danbury Hill, 6 miles S.S.W. of Witham, and 317 feet high, is capped by gravel of an anomalous character. It consists chiefly of subangular flints with a large proportion of flint-pebbles, and a few pebbles of quartzite, quartz, chert, and some old rock having more the character of a Glacial Drift. It may have been a Bagshot outlier invaded by the Glacial gravel. Lower down (about 150 feet) on the southern slope of the hill is another gravel in which chert- and quartz-pebbles are more prominent.

At the cutting on the main line which begins one mile west of Witham, and which reaches in places a depth of 25 feet, a very white chalky Boulder-clay passing down into bluish grey, overlies 5 feet of white sand with a seam of flint- and quartz-pebbles (Westleton) at base. At the western end of the cutting the same gravel, but with ochreous and white seams alternating, lies in hummocks beneath the Boulder-clay. The Hatfield cutting is through 20 feet of gravel at the eastern end, and through chalky Boulder-clay capped by 8 feet of brick-earth at the west end.

The long cutting from Springfield to Chelmsford (30 feet deep in the centre) is of interest from its showing the great erosion of the London Clay and the very irregular distribution of the gravel and Boulder-clay; but my notes relating to the gravel which underlies the Boulder-clay are insufficient for me to say whether it is of Glacial or of Westleton age.

A range of hills, capped by pebble-beds, commences a short distance westward of Chelmsford. But these, though really older than the Westleton Beds, I have relegated to Part III. of this paper. They include Writtlepark, Brentwood, Rayleigh, and other hills.

The Westleton Beds, which thus far have not reached a level of above 160 to 200 feet, now rise more rapidly as they trend westward, capping the hill-tops, and leaving the Boulder-clay and the Glacial gravels at lower levels in the intermediate lower ground. There is thus a considerable break before the next outliers are reached, though there are, I think, traces of the Westleton Beds to be met with near Ongar.

The next well-defined outliers are therefore on the western side of the valley of the Roding, on the range of the Epping hills, which at Highbeech and Jack's Hill attain a height of from 340 to 370 feet. On the top is a well-marked bed of the Westleton Shingle. The following is its approximate composition in a pit near the "Wake Arms," Jack's Hill:—

		per cent.
1.	Flint-pebbles	50
2.	White quartz-pebbles	15
3.	Subangular fragments of flint	20
4.	Subangular fragments of chert and ragstone	10
5.	Pebbles of Lydian stone &c.	5
		100

A bed of white and yellow sand (Bagshot) underlies the gravel.

At Coopersale Common (or Gaynes Park), two miles N.E. of Epping, is another range of hills, from 340 to 360 feet high, on which there is also a capping of Westleton Shingle composed of

		per cent.
1.	Flint-pebbles	56
2.	White quartz-pebbles	20
3.	Subangular fragments of flint	9
4.	Subangular fragments of white Ragstone	12
5.	Pebbles of Lydian stone &c.	3
		100

imbedded in a matrix of light yellow, loamy, quartzose sand.

To the south of these, and extending from Buckhurst Hill to Woodford Hill, is a considerable spread of pebbly gravel, 10 feet thick in places, of a character intermediate between the Brentwood and the Westleton Beds, but more analogous to the former. It consists almost entirely of flint-pebbles (Bagshot), with a very few white quartz- and other rock-pebbles imbedded in a variable matrix of sand and clay. The lower part is roughly stratified—the upper passes into an unstratified mass of brown and ferruginous clay with few flint-pebbles.

Middlsex.—The Drift Beds of the eastern and lower part of the county consist chiefly of Glacial and Post-Glacial gravels; while the higher hills on the north are capped by the Westleton Shingle. Thus the ridges from Barnet and Barnet Gate (410–460 feet), and from Totteridge to Highwood (400–410 feet), and again at Mill Hill, are capped by a poor gravel of this age, from 2 to 5 feet thick, and composed of

		per cent.
1.	Flint-pebbles	50
2.	White quartz-pebbles	15
3.	Subangular flints, stained white and brown	20
4.	Subangular ragstone and chert	12
5.	Lydian stone &c.	3
		100

in a matrix of quartzose sand and greenish clay.

The Boulder-clay, at a level of about 100 feet lower, extends from Whetstone to Finchley and Muswell Hill. The gravel which underlies it in a pit near Finchley Church is of Glacial origin, and is full of northern *débris*. That at the old section opposite to the "Bald-faced Stag" has been referred to the Pebbly Gravels:

I should have placed it also with the same Glacial Beds; but my notes are insufficient.

The Westleton Beds are difficult to follow in this direction. They do not seem to rise so high as further north. Some beds at Hendon (280 feet) may possibly be referred to them, as also a small outlier which caps the hill (278 feet) at Horsington, two miles south of Harrow. This isolated patch, which is a mere remnant scattered on the surface, consists of

	per cent.
1. Flint-pebbles	42
2. White quartz-pebbles	10
3. Subangular flints stained brown	30
4. Subangular chert and ragstone	18
	100

With respect to Highgate and Hampstead Hills, which rise to the height 412 feet, I hesitate how to class them. I have found some fragments of worn cherty ragstone and a few rare quartz-pebbles on Hampstead Hill, with abundant flint-pebbles of local (Bagshot) origin; but the characters are not sufficiently marked to satisfy me. They may be Westleton or they may be outliers of the Southern Drift.

In the north of the county, a well-marked Westleton outlier may be seen in the wood (400 ft.?) 1½ mile north of South Mimms, consisting of:—

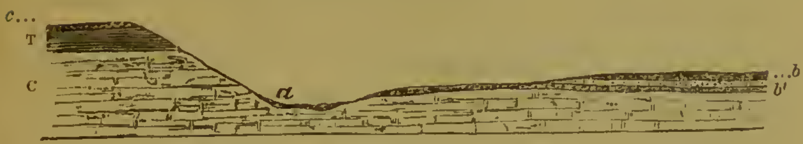
	per cent.
1. Flint-pebbles	38
2. White quartz pebbles	28
3. Subangular flints, not stained	24
4. Subangular chert &c.	6
5. Pebbles of white quartzite, Lydian stone, &c.	4
	100

The adjacent ridge, extending from Potter's Bar to Bell Bar (380 to 400 ft.), is also capped by a thin bed of Westleton Shingle, but there were no sections open at the time of my visits.

The Pebble-Beds of Stanmore, Elstree, and some adjacent hills belong to the Brentwood group.

Hertfordshire.—The London-Clay hills of the north of Middlesex, capped by Westleton Shingle, are continued into Hertfordshire, where they form, between Hatfield and Hertford Heath, a conspicuous range from 320 to 380 ft. high, and overlooking, at a level of from 180 to 240 ft. lower, the broad valley of the Lea and Mimram, over which are spread Glacial gravels and sands, covered in places by the Boulder-clay. The material difference of level and the marked character of the beds here bring out very clearly the discordant relation of these Glacial and Pre-Glacial Beds, as shown in the following section (fig. 11):—

Fig. 11.—*Section from Hatfield Brick-pit to the G. N. Railway near Digswell Junction.*



a. Post-Glacial beds.
b. Boulder-clay.
b'. Light-coloured sands and ochreous gravel.
c. Westleton Shingle.
T. Lower Tertiary strata.
C. Chalk.

Speaking of the characters of these gravels, Prof. T. McK. Hughes * says: "The gravel of the Upper Plain consists chiefly of pebbles; of these, about fifty per cent. are of quartz, about ten per cent. of quartzite, about five per cent. various (such as jasper and a conglomerate of quartz pebbles in quartzite), and the rest flint." These gravels have also been noticed by Mr. Whitaker and Mr. S. V. Wood in the papers before referred to.

This Hertfordshire shingle is remarkable for the large proportion of pebbles of white quartz and of Lower-Greensand débris †. A specimen from Brickenden Hill yielded broadly:—

	per cent.
1. Flint-pebbles	34
2. White quartz-pebbles	28
3. Subangular flints —2 stained brown, and 3 not stained	17
4. Subangular fragments of red and brown chert and of white ragstone	18
5. Pebbles of Lydian stone &c.	3
	100

Further to the south-west similar beds are met with at Shenley Hill and again a little northward at Bernard's Heath near St. Albans, where they form a bed from 8 to 10 ft. thick, capping Lower Tertiary Sands and Clays, at an altitude of 406 feet. They there consist of:—1. Flint-pebbles; 2. White quartz-pebbles; 3. Subangular flints, not stained; 4. Subangular cherty ragstone; 5. Pebbles of Lydian stone, yellow quartzite, &c.; imbedded in a loamy red and yellow mottled sandy clay, disturbed at top.

Notwithstanding the extreme denudation which the high Chalk-plain, extending from Hertfordshire into Bedfordshire, Buckinghamshire, and Oxfordshire, has undergone, a few small outliers of Lower Tertiary strata still remain, rising above the general level of the Chalk-plateau with its scanty Glacial Drifts and its "Red Clay with flints"

These little isolated hills are frequently capped by a gravel- or shingle-bed, which I believe to be of Westleton age. They are

* *Op. cit.* p. 285.
† The chert and ragstone débris does not seem to have been hitherto recognized, or is mentioned under some other name.

very few in number, and gradually become rarer as we proceed northwards, although in a few instances they extend to the edge of the Chalk Downs.

At Collier's End (348 feet) and Sacombe Green (362 feet), five miles north of Ware, are two small Lower Tertiary outliers with a thin capping of quartzose shingle (Westleton). Others lie on some of those near Welwyn,—on Ayot (406 feet) and Burnham Green (407 feet) hills.

North of St. Albans, and between the valleys of the Lea and the Gade, traces of Lower Tertiary strata may be found as far north as Berkhampstead Common, but they are rarely in sufficient force to be worked, or high enough to bring in the Westleton Beds. At Bennett's End, near Hemel Hempstead, the Tertiary strata are capped at a height of 456 feet by a bed of sandy clay with a thin uneven patch of Westleton gravel, consisting in large proportion of flint- and quartz-pebbles with a few subangular flints (not stained), fragments of Lydian stone, and a few flat ovate light-coloured quartzite-pebbles. The bed varies from 1 to 6 feet in thickness, and rests on from 30 to 40 feet of London Clay and Lower Tertiary strata.

There is another Tertiary outlier at Little Heath and Potten, extending to Berkhampstead Common, or rather it is a mass of Tertiary strata preserved in a depression in the Chalk, of great extent. There is some appearance of Westleton Shingle, but too indistinct for description.

The hills to the west of the Gade present similar features. The Tertiary Beds are, however, so mixed up with Glacial débris that they are to be recognized only in a few instances. At Langley Common (440 feet) there are traces of Westleton Shingle, and closely adjacent to the borders of Hertfordshire is the more conspicuous outlier of Tiler's Hill.

South Buckinghamshire.—In this county, as in Hertfordshire, the picturesque high ground of the Chilterns is covered by a sprinkling of Glacial Drifts (but no Boulder-clay), and "Red Clay with Flints," with occasional Tertiary remnants.

Tiler's hill *, 2 miles east of Chesham, rises to a comparatively considerable height above the surrounding Chalk-plateau, and consists of Lower Tertiary strata with an outlier of London Clay†. On the summit, about 600 feet above the sea-level, is a small capping of gravel, composed of:—

	per cent.
1. Tertiary flint-pebbles, small and large, many of them weathered white	55
2. White quartz-pebbles	23
3. Very subangular fragments of flint, stained yellow; others are large, white and little worn	12
4. Chert &c.	5
5. Flat ovate pebbles of light-coloured quartzite and veinstone, with subangular fragments of Tertiary sandstone and pudding-stone	5
	100

* On the new one-inch map this name is altered to Crowcroft.

† Described by the author in Quart. Journ. Geol. Soc. vol x. p. 90 (1854).

The gravel rests on an uneven bed of London Clay. Lower Greensand débris is comparatively scarce, and the débris of Tertiary rock more abundant, while pebbles of the older rocks are rare.

There are several Tertiary outliers on the high Chalk-plateau between the Misbourne and the Wye. One of these, to the west of the village of Penn, near Beaconsfield, rises to the height of about 600 feet, and is capped by a well-marked bed of Westleton gravel like that on Tiler's Hill, while another gravel (Glacial?), derived in part from the Westleton Shingle, lies on the Chalk-plain at Penn (547 feet) and Penn Common. At Lane End (600 feet), four miles west of High Wycombe, there is also an outlier of Lower Tertiary sands and clays, capped by a similar gravel of flint- and white quartz-pebbles, subangular flints weathered white, with a few old-rock-pebbles (see Pl. VII. fig. 1).

South Oxfordshire.—From the borders of Buckinghamshire to the Thames between Pangbourne and Wallingford there are but few Tertiary outliers. The most conspicuous of these is that at Nettlebed hill *. The Westleton Shingle (?) there attains its highest level of about 650 feet. It is but a small patch, and presents a less definite composition than the others, as might be expected from its distance from the main body.

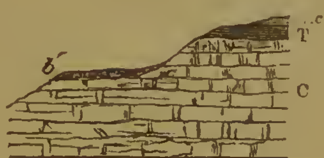
The shingle, which reposes upon a very uneven surface of the Lower Tertiaries, consists approximately of :—

	per cent.
1. Tertiary flint-pebbles	54
2. Small pebbles of white quartz	14
3. Subangular flints, not stained	20
4. Chert &c?	4
5. Pebbles of hornstone (?), veinstone, and Sarsen stone	8
	100

imbedded in a matrix of light quartzose sand.

Five miles S.W. of Nettlebed, and close to the edge of the Chalk escarpment overlooking the plains of Oxfordshire, a thin outlier of Lower Tertiaries (the mottled clays of the Reading Beds) overlies the Chalk at Greenmoor hill (560 to 600 feet) and Woodcote Common, about 3 miles east of Goring. It is capped by a well-

Fig. 12.—*Section on the hill above the Thames, near Goring.*



c. Westleton Shingle. | T. Lower Tertiaries.
b′. Glacial Gravel. | C. Chalk.

defined bed of Westleton Shingle, which is in marked contrast with the Glacial gravel, with its New-Red-Sandstone quartzites, which sets

* Described in Quart. Journ. Geol. Soc. vol. x. p. 89 (1854).

in near Coomb End at a short distance from it westward, and at a level of about 100 feet lower (fig. 12). This is the most distant outlier in this direction, and from its position on the edge of the Chalk Downs overlooking the Great Oolitic plains, possesses more than usual interest (see Pl. VII. fig. 1).

The shingle forms an ochreous sandy gravel, consisting largely of subangular flints much worn, flint-pebbles, and with none of the New-Red-Sandstone quartzites so common in *b'*. I noted at the time that it is much like the gravel on Bowsey hill (*infrà*). Approximately it was composed of:—

	per cent.
1. Tertiary flint-pebbles, of which some were broken	44
2. White quartz-pebbles	10
3. Subangular and angular pieces of flint	30
4. Subangular pieces of Sarsen stone, of a hard dark sandstone, and of ironstone (Tertiary)	9
5. Flat ovate pebbles of light-coloured quartzite, with small pebbles of Lydian stone (?), and of a quartz-grit	7
	100

I failed to note either Chert or Ragstone.

A few miles to the south another Tertiary outlier extending from Chazey Heath to Rose Hill (300 to 350 feet) is capped, but not very distinctly, by a light-coloured gravel very similar to the above, while the intermediate and lower areas are overspread by the Glacial gravel, but Boulder-clay is absent.

Further to the south, as we approach the Thames, the valley-gravels set in and continue to the Berkshire side.

Berkshire and Wiltshire.—Between Reading and Maidenhead * the broad valley of the Thames, with its Post-Glacial gravels, becomes greatly contracted between Henley and Marlow by the high ground of Cookham Dean (350? feet) and Bowsey Hill, which is 467 feet high, or 350 feet above the Thames at Henley. The former of these hills is bare to the summit, whereas the latter is capped by a light ochreous sandy and pebbly gravel, from 5 to 8 feet thick, of a characteristic Westleton type. The following are its component parts, but I failed to note their relative proportion:—

1. Tertiary flint-pebbles, some of them entirely decomposed.
2. Numerous small white quartz-pebbles.
3. Subangular fragments of flint, weathered white.
4. Very few subangular fragments of white ragstone and one of fossiliferous chert.
5. Pebbles of light-coloured quartzite, yellow sandstone, and rose-coloured quartz-grit, with some small pebbles of veinstone, Lydian or hornstone, greenstone?, and red and grey quartz.

The quartzites are not the red and grey quartzites of the northern Drift.

* It would seem probable that the Thames at an early stage may have flowed in a direct line from Twyford to Maidenhead, by way of the valley of White Waltham, which offers a low and straight course, instead of the circuitous course it took in Post-Glacial times through the Henley and Cookham Hills.

The Berkshire Downs, which form the prolongation of the Chiltern Hills of Buckinghamshire and Oxfordshire, rise above Streatly and Goring to the height of from 400 to 600 feet. In the line of the Thames Valley there is a broad high terrace of Glacial Drift, whilst at a little distance further from the river the Westleton Shingle appears on a relatively higher level. The Glacial gravel forms a terrace at Southridge, and between Basildon and Ashampstead, at a level of about 400 to 420 feet, whilst the Tertiary outlier at Upper Basildon is capped by Westleton Shingle. The Tertiary outlier (350 to 380 feet) north of Bradfield is also capped by a gravel which may be of the same age.

The Chalk Downs of Berkshire are much barer than those of Oxfordshire and Buckinghamshire both of Tertiary outliers and of Drift. The former are extremely scarce until we approach the borders of the Tertiary basin near Newbury. Nevertheless it is probable that the Westleton Shingle extended over this area, for I found on the bare Chalk-hills above East Compton a pocket of Tertiary Sands and Drift, with flint- and quartz-pebbles, &c.,—a remnant probably preserved, like the Crag at Lenham, by the chance circumstance of its being in a pipe or hollow in the Chalk.

To the north and north-west of Newbury there are several gravel-capped hills, possibly of this date, such as Donnington Common and the hill east of Basford. One of the most prominent is that at the end of the spur of Tertiaries which extends north-westward from Newbury to Wickham. This hill, which is 560 feet high and rises 100 feet above the surrounding Chalk-plain, consists of Lower Tertiary strata (including the base of the London Clay)*, and is capped by a bed of gravel, from 3 to 5 feet thick, composed of flint-pebbles, with subangular flints imbedded in a quartzose sand and grit very much worn. From its position and general character I think it may be of Westleton age, but I have no note of its exact composition.

The bare Chalk-plains of East Berkshire and Wiltshire offer scant opportunities for determining the presence of the Westleton Shingle. Except in a few rare instances denudation has swept these plains clean of all but the superficial soil and trail. The higher Chalk-hills near Baydon, 8 miles E.S.E. of Swindon, are, however, capped by a gravel consisting of subangular flints and Tertiary flint-pebbles, with some quartz-pebbles; and a similar ridge to the east of Ogburn St. George, on the north-east of Marlborough, is also capped by a little flint-gravel with quartz-pebbles.

Quartz-pebbles also occur in places in flint-drift on the hills about 2½ miles south of Marlborough †. Patches of a pebbly drift again occur on the higher points of the Chalk Downs at Bishopstone near Shrivenham and at Liddington and Basdrop to the south of Swindon, but they are very indistinct.

* Described in Quart. Journ. Geol. Soc. vol. x. p. 86 (1854).

† The Drift-beds of this district have been described by Mr. T. Codrington, in the Magazine of the Wiltshire Archæological and Natural History Society, 1865.

The last trace of such drift I have met with on these Chalk Downs was on Monument Hill above Calne, where there are a few scattered pebbles of white quartz, quartzite, chert, and ironstone, with subangular flints and flint-pebbles, but its exact relation is uncertain.

3. *Westleton Beds on the South of the Thames.*

The Boulder-clay, it is well known, has not been found south of the Thames, though some Pre-Glacial beds have a considerable extension in that direction, and evidence of glacial action is not wanting. Owing, however, to their isolation and want of continuity the classification of these beds is attended with more uncertainty.

Kent.—In the north-eastern corner of Sheppey the cliffs at Draper's Point, there about 170 feet high, are capped by a Drift distinct from that which is spread over a great part of the higher ground of that island. It consists of from 15 to 20 feet of yellow sands with seams of clay and patches of gravel, the bottom bed of gravel being from 1 to 2 feet thick, and composed essentially of flint-pebbles of various sizes, of large subangular flints much worn and stained brown, numerous small flint-fragments, and some very small pebbles of quartz, and at one spot I found a much worn fragment of brown chert. It is not improbable that these beds are of Westleton age. They are overlain by a flint-gravel in small pockets.

I know of no other bed of this character in Kent, except one between Shottenden Hill and Sellings (400 feet), where there is a sprinkling of Drift consisting of Tertiary pebbles and pebbles of quartz. But both these cases are obscure.

I do not refer the shingle on the top of Shooter's Hill or the gravel on Swanscombe Hill to this horizon.

Surrey and Hants.—Further westward traces of the Westleton Beds become very indistinct. There are remnants of a quartz-drift at Englefield Green (264 feet) and on some adjacent hills; but it is another Pre-Glacial high-level gravel-drift (see Part III.) that prevails almost exclusively in this district.

4. *Possible Extension of the Westleton Shingle beyond the Thames Basin into Somerset.*

Passing from the Chalk Downs to the Oolitic Hills further westward, there is at one spot, Kingsdown near Bathford, about 550 feet high and 5 miles from Bath, a Drift of the Westleton character. It forms only a small patch on the otherwise bare surface of the Oolites, and consists of a light-brown sandy loam, with slightly subangular flints, some flint-pebbles, many white quartz-pebbles, and an occasional pebble of sandstone and of a greenish quartz *. It is covered by a brown earth with local Oolitic débris.

* The Rev. H. Winwood, F.G.S., has since found a subangular fragment of Sarsen stone and a pebble of black chert or hornstone.

The whole is only a few (5 to 8 feet) thick, and is preserved in a trough or hollow in the Oolite *.

Still further westward, on the Carboniferous-Limestone Hills near Clevedon, Mr. Trimmer † has recorded the existence of a patch of local débris with, I believe, quartz-pebbles, at a height of 300 feet above sea-level. This may be a continuation of the Kingsdown Bed, but intermediate connecting-links have yet to be discovered, and I was not successful in finding the place myself.

On the Chalk-hills to the south of the area we have described there are a few outliers which may be referable to this geological horizon, such, for instance, as the pebbly sands with worn fragments of hard Tertiary sandstones on Windmill Hill, near Alton, and a pebbly drift on the higher hills west of Andover; but these are too indistinct to pronounce definitely upon.

A better marked case is the one on the Chalk Downs of Copford, 8 miles east of Warminster, where a large Tertiary remnant has been preserved from denudation by having been let down into a cavity in the Chalk. This patch of Lower Tertiary (white sands and mottled clay) is overlain by an irregular spread of Drift consisting of:—

1. Tertiary flint-pebbles—the larger proportion much decomposed, white and very light.
2. White quartz-pebbles and a few rose-coloured ones.
3. Worn fragments of a light-coloured sandstone (Upper Greensand ?).
4. Pebbles of a dark chert and Lydian stone.

These were imbedded in a light sandy matrix, and covered by a sandy clay-drift full of angular flints; this pit at the time of my visit was much obscured.

5. *The Relation of the Westleton Shingle to the Glacial Drifts of the Thames Valley.*

We have thus been able to follow the Westleton Beds from the coast of the Eastern Counties with some certainty as far as the Berkshire Downs, and with some probability as far as the Bristol Channel. On the Eastern coast this deposit lies at the sea-level, but as it ranges inland it gradually rises to heights of 500 or 600 feet. In the first instance the Westleton Beds underlie all the Glacial deposits; in the second they rise considerably above them, and their first seeming subordination to the Glacial series altogether disappears (see fig. 1, Pl. VII.).

The association, which is so close in Norfolk that it had led to the two series being considered members of the same group, becomes less so in Essex. At Braintree, where the Westleton Beds are largely developed, they stand up through the Boulder-clay and gravel which wrap round their base and partly surmount them.

* Mr. C. H. Weston, who first noticed this high-level drift, states also that Chalk-flints mixed with Oolitic débris occur on the surface of Farleigh Down at a height of about 600 feet (Quart. Journ. Geol. Soc. vol. vi. p. 449).

† Quart. Journ. Geol. Soc. vol. ix. p. 282 (1853).

They have there been disturbed and faulted (Pl. VII. fig. 6), before the intrusion of the Glacial Beds, which have deeply eroded them. As they rise to higher and more exposed levels, the Westleton Beds become greatly diminished in importance and are commonly reduced to a mere shingle-bed. On the hills near Epping, where they attain a height of 350 or 400 feet, they form a thin bed of sand and shingle, capping the London Clay, and quite apart from the Boulder-clay, which lies from 80 to 100 feet lower down on the slope of these hills at Theydon Bois and North Weald.

In Hertfordshire the distinction between the two deposits is very marked, as on the hills between Hoddesdon and Hatfield the Westleton Shingle forms a plateau-gravel high above the plain of the Lea, over which is spread the Boulder-clay with its associated sands and gravel. At Bell Bar and Mimms Wood the hills are also capped by this Shingle, while in the valley between them the Boulder-clay in the railway-cutting is at a level of from 100 to 150 feet lower. The Boulder-clay again enters the valley of the Colne at Bricket Wood and Aldenham, whilst Westleton Shingle lies on the neighbouring heights of Shenley and Bennett's End.

Here the Boulder-clay ends, and the Westleton Shingle alone is prolonged westward at intervals on the higher summits of the Buckinghamshire, Berkshire, and Oxfordshire Downs, the Chalk-plain on which these hills rise being in some places denuded, and at others thinly covered by Glacial Drift-beds. The Shingle-bed may, in this way, be traced to the northern edge of the Chalk Downs and to the extreme western end of the London Basin, which shows how extensive the submergence of these districts must have been at a time immediately antecedent to the Glacial period.

The height (500 to 600 feet) to which the Shingle-bed attains is sufficient to carry it over the summit of the Chalk and Oolitic hills of the Warminster and Bath districts. There may thus have been a Pre-Glacial sea bounded on the south by the Wealden anticlinal, and spreading northward over great part of Hertfordshire, Buckinghamshire, and Oxfordshire (and possibly beyond), while it stretched in the other direction from the North Sea to the Severn Basin or the Bristol Channel (see Part III. and Map).

6. *Origin of the Shingle.*

The distinctive features of the Westleton Shingle are of so marked a character and so different from those of the overlying Glacial series, that it is at once evident that their origin must be different. The characters of the latter are so well known that it is unnecessary to repeat them here; suffice it to say that they are essentially Drifts from the north and north-east, whereas that of the Westleton Beds is from the south and south-east, for the reason that the sources whence the several different component pebbles are derived is to be traced in those directions.

Thus:—1. The flint-pebbles are doubtlessly derived from the shingle-beds of Diestian, Bagshot, or Lower Tertiary (Woolwich) age, whether in Belgium, the North of France, or Kent. 2. The Pebbles of white and rose-coloured quartz come apparently from the older rocks of the Ardennes or indirectly from some of the Bolderberg or Diestian beds of Belgium. 3. The subangular fragments of flint, some retaining their natural colour, others more worn and stained brown, are derived, the former directly from the Chalk, the latter from an older Drift, possibly of Pliocene age; or both may have been derived, in part, from the Southern Drift*. 4. The worn and subangular fragments of chert and ragstone are derived from the Lower Greensand of Kent and Surrey; or also, in part, possibly from the "Meule de Bracquegnies," or indirectly from the Southern Drift. 5. The Large Pebbles of a white or light-coloured quartzite and of a flat ovate shape, unlike the red or dark-coloured round ovoid quartzites from the Triassic conglomerates, may be derived indirectly from the shingle-beds of the Woolwich-and-Reading Series, where I have occasionally found them: or they may come from quartzites of the Palæozoic rock of the Ardennes, or possibly from both. 6. The small pebbles of Lydian stone, Jasper, veinstone, and worn fragments of old rocks may be derived, some directly from the Ardennes, and some indirectly from the pebbly beds of the Lower Greensand.

It is obvious, from the fossils found in it in Norfolk and Suffolk, that the Westleton Shingle is a marine Drift, the absence of shells in its inland range being no doubt in great measure owing to decalcification. Even in Suffolk, where the beds are more protected, it is rarely that anything more than casts are found.

But while marine conditions extended as far as the north of Belgium, on the south the Ardennes formed an elevated area of dry land, drained by the old Meuse and its tributaries as well as by the Schelde. The lower range of hills bordering these valleys above Spa and Liége are often capped by a terrace of gravel derived from the quartzose and schistose rocks, hard sandstones, and conglomerates of the Ardennes. Pebbles of quartzite, sandstone, and white quartz are consequently the common constituents of these gravels; while occasionally they contain fragments or pebbles of porphyry, slate, and, very rarely, of granite. Generally the pebbles vary in size from that of a marble to that of an egg, though they are sometimes the size of a man's head. Large blocks, but little rolled, are also occasionally met with.

Such was the old alluvium of the eastern tributaries of the Meuse, while on the terraces of the main stream at Dinant and Namur, pebbles of Triassic sandstones, of Cretaceous, Jurassic, Carboniferous, and Devonian rocks are met with, but a large proportion of them disappear lower down the course of the river, and only the harder rock-pebbles remain in its lower reaches. On the hill above Liége I noted in the flint-gravel palæozoic-rock pebbles very analogous to those found in the Westleton Shingle, namely:—

* To be described in Part III.

(Angular and subangular fragments of flint ;)
White quartz-pebbles (numerous) ;
Flat ovate pebbles of light-coloured quartzites ;
Pebbles of light-coloured sandstones, veinstone, and subangular fragments of a hard micaceous Sandstone, &c.,—

imbedded in a white and ochreous sandy matrix.

In descending the river the terraces become wider, and in the neighbourhood of Maestricht they spread out into plateau-sheets of great breadth, as in an estuary.

Another set of Drift-débris, including flint-pebbles from the Lower Tertiaries together with débris from the Carboniferous and Cretaceous strata, would be carried down by the Schelde, which flows through rocks of that age ; while the Rhine may have furnished débris from the rocks of the Rhenish Provinces, including possibly the basalt of the Rhine borders.

This mass of shingle, transported into the open sea to the north and aided by ice-action, drifted over to the coast of Norfolk and Suffolk, and thence, as the land subsided, was carried westward, in a direction towards the Severn Valley or the Bristol Channel. What, then, turned it aside from the northern sea, where it would seem it might have extended more northward as the Crag did * at the period immediately antecedent ? Could it have been that the great Scandinavian ice-sheet was then ploughing its way across the sea towards the coast of Norfolk, and so blocked up the sea in that direction and diverted the waters of the North Sea through this westward channel ?

On the south, the spread of the Westleton Beds was limited by the anticlinal of the Ardennes and the Weald, which then constituted a low mountain-range, for there are no marine beds of that character south of the line I have described. At the same time palæontological evidence of contemporaneous land conditions is very scanty.

In recent papers by the Rev. O. Fisher † and Mr. J. C. Mansel-Pleydell, F.G.S. ‡, we have accounts of the discovery of the remains of *Elephas meridionalis* on the Chalk-plateau at Dewlish, near Piddletown, in Dorsetshire, in a bed of sand and gravel 90 feet above the level of the adjacent stream. The facts of the case led Mr. Fisher to suppose that the deposit might be Pre-Glacial, while Mr. Mansel-Pleydell considered it to be of Pliocene age.

It is possible also that the high-level fossiliferous Drift on the summit of Portland §, which contains débris derived from the Tertiary and Cretaceous strata of the hills to the north of Weymouth, may be of the same age, and older than I was first led to believe on the evidence of the sparse remains of *Elephas antiquus*, *E. primigenius* ?, and *Equus fossilis*. This view of the greater antiquity of that deposit would be more in conformity with the enormous amount of erosion, probably of Glacial date, that led to the formation of

* Mr T. F. Jamieson, F.G.S., has shown that Crag-beds exist on the east coast of Scotland (Quart. Journ. Geol. Soc. vol. xvi. p. 371).
† Quart. Journ. Geol. Soc. vol. xliv. p. 818 (1888).
‡ Trans. Dorset, vol. x. p. 12 (1889).
§ Quart. Journ. Geol. Soc. vol. xxxi. p. 31 (1875).

the broad valley between Portland and Upway, above six miles wide and from 400 to 500 feet deep, since the deposition of that high-level Drift.

Dr. Mourlon has also recently recorded * the occurrence, at Ixelles near Brussels, of a bed of sand and gravel with Mammalian remains, which he thinks may be of the age of the Forest-bed : but the evidence is yet uncertain, owing to the fragmentary condition of the specimens. Amongst the species on which Dr. Mourlon relies, but which are determined with doubt, are *Elephas antiquus*, *Equus plicidens, Cervus canadensis*, and *Bison priscus*.

Conclusion.

It is clear from its uniformity and its marine origin that the Westleton Shingle must originally have formed a comparatively level sea-floor (or broad coast-line) throughout the area over which its outliers extend, and that all the inequalities of the surface below that level have been formed since it was deposited. If this conclusion be correct, then it follows that all the Tertiary strata, which spread originally over all the Chalk Downs of Hertfordshire, Buckinghamshire, Oxfordshire, Berkshire, Wiltshire. and some adjacent districts, have been removed subsequently to this early Pleistocene or so-called Pre-Glacial period ; also that the gorge of the Thames at Pangbourne aud Goring has been formed since then ; and that most of tho Pre-Glacial valleys in the district, to which no date, except that they were Pre-Glacial, had beeu assigned, are of the same geological age. It follows further that before this date the Thames had no existeuce ; to this point we shall revert on another occasion.

During the Westleton period, we have to imagine a sea, with a coast-line extending from Belgium to the West of England, bounded on the south by the anticlinal range of the Wealden, and open to a yet uncertain distance to the north. This area then underwent an elevation from east to west, and from south to north, whereby it was raised at the extreme points from 500 to 600 feet or more above tho sea-level, whereas it remained nearly at its original level and comparatively undisturbed at its other or eastern extremity ; so that while on the east the chronological orders of succession of the strata continued unbroken, to the west they became discordant, in consequence of the physiographical changes which intervened between these successive stages.

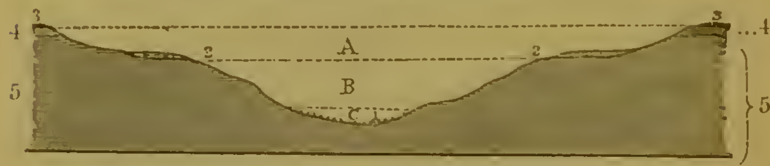
These changes and the action of meteorological agencies on the upraised land, determined the plotting-out of its hills and valleys during the early Glacial epoch. Of the first stago we have now, in some cases, an exact measure. Thus, to take a few examples. it is obvious that at the gorge of the Thames at Goring the Westleton Shingle and Tertiary Strata were continuous from side to side of the valley until the last elevation of the land. As they emerged, and a land-surface was formed, these beds, together with the underlying Chalk, were first denuded in the line of the present Thames valley

* Bull. Acad. Roy. Belgique, 3^e sér. vol. xvii. p. 131 (1889).

to a depth of about 160 feet, and a width of from 2 to 4 miles, when the newly made channel received its covering of Northern Drift (2, fig. 13).

The successive increments of depth *, acquired during the different periods, are exhibited in the following section (see also fig. 12).

Fig. 13.—*Diagram-section across the Gorge of the Thames through the Escarpment of the Chalk at Goring.*



1. Post-Glacial Drift.
2. Glacial Drift.
3. Westleton Shingle.
4. Lower Tertiary strata.
5. Chalk.

		feet.
A. Denudation during the early Glacial Period	about	160
B. Denudation during the later Glacial Period	,,	220
C. Denudation during the Post-Glacial Period	,,	70

Taking the height above the sea-level of the Westleton Beds here at 600 feet, and that of the river at Goring at 150 feet, the above figures give, but very approximately, the depth to which the denudation of the valley at this place was carried during the successive Glacial and Post-Glacial epochs.

The relative depths of B and C may be subject to considerable correction. In the absence of sufficient evidence at Goring, I have been guided by the height of the high-level river-gravels at Oxford and Reading, where they are better developed.

These measures, of course, vary at different places. Lower down the Thames Valley, the channel A above Henley-on-Thames (Bowsey hill giving the Westleton level) is above 200 feet deep, while B is reduced in proportion.

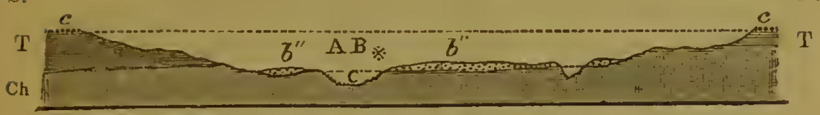
In the valley of the Lea, at Ware (fig. 14), taking the level of the Westleton Shingle at Hertford Heath on the south at 316 feet, and at Sacombe Green on the north at 362 feet, and that of the Lea at 110 feet, A and B together seem to amount, in round numbers, to about 200 feet, whilst C does not seem to exceed 50 feet.

In the valley of the Roding the level of the Boulder-clay is about 100 feet below that of the Westleton Shingle, at Jack's Hill, near Epping, whilst the extent of C is probably less than 30 feet.

Other instances might be mentioned, but these will suffice to show some of the stages in the denudation of this area and the initial step in the formation of its river-valleys. It will appear, from these facts, that the main denudation of the district has been effected after Pliocene times, and that the first stage (A) in the formation of the present gorge at Goring dates back to the time of

* These hold whatever may be the age of the shingle.

Fig. 14.—*Diagram-section of the Valley of the Lea at Ware.*



b″. Glacial sands and gravel with Boulder-clay at*.
c. Westleton Shingle.
T. Lower Tertiaries and London Clay.
Ch. Chalk.

A B. Denudation during the Glacial Period.
C. Denudation during the Post-Glacial Period.

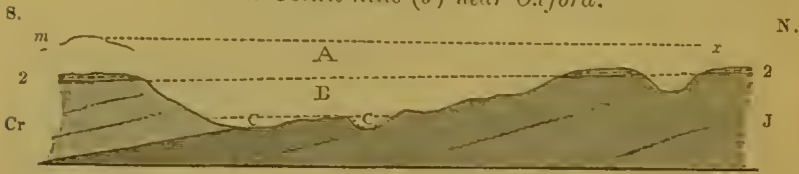
the emergence of the Westleton floor and is due to early Glacial action. To what extent the subsequent denudation (B) is due to continued glacial action it is difficult to say; but as the gravel-bed No. 2 (fig. 13) belongs to one of the earlier stages of the Glacial period, and Post-Glacial river-action (C) is limited to narrow bounds, there is reason to infer that the valley to about the base of B is due to erosion during the Glacial period.

The position of the Westleton Shingle enables us also to suggest a solution of another question, namely, that relating to the age of the great escarpments of the Chalk and Oolites which run through the centre of England. The fact that the Westleton Shingle caps various Tertiary hills on the Chalk-plateau, which Tertiary strata extend to the edge of the Chalk-escarpment, renders it probable that this Shingle had, before the denudation of the Tertiary strata, a range to a certain extent coextensive with that of the Tertiary strata, and extending further northward than at present. This is manifested by the presence of the Shingle on an outlier so near the escarpment as Nettlebed Hill, and still more by the outlier on the very edge of the escarpment at Woodcote. Consequently, if, as this would show, the Westleton Beds had a range over and beyond the escarpment, the origin of that escarpment must be of a date subsequent to that of the Westleton Beds (Pl. VII. fig. 1).

Another argument is, I think, conclusive. The terraces of Glacial gravel (No. 2, fig. 13) which flank and originally spread across the gorge of the Thames at Goring at the height of 440 feet are evidently connected with the outliers capping the Coralline Oolite at Foxcombe and Wytham Hills near Oxford, at a height of about 500 feet, and which, again, cap the Forest Marble and Great Oolite on the higher hills of Wychwood Forest, near Witney. At the time that this spread of gravel took place, the intervening valleys must have been bridged over by a flooring of Cretaceous and Jurassic strata, which have been since removed and denuded to the depth of from 300 to 350 feet, as shown in the following diagram (fig. 15).

If, therefore, the channel through which the Glacial Drift passed from the north into the Thames Valley was formed, as we suppose, subsequently to the spread of the Westleton Shingle, but before the deeper late Glacial erosion, then it is evident that as the valley at the foot of and giving rise to the escarpment could have had no existence at that time, the base of the escarpment must have been limited by the level of the line of 440 to 500 feet. By analogy the further relative heightening of the escarpment was concurrent with the deepening of the valley itself, which would correspond with B in fig. 15. In any case the escarpment could not

Fig. 15.—*Diagram section from the Gorge of the Thames at Goring to the Oolitic hills* (J) *near Oxford.*



2. Glacial gravel with Triassic, Cretaceous, and other rock-débris. *m.* Position of Tertiary strata and of Westleton Shingle (outside the section). Cr. Cretaceous strata. J. Jurassic strata. (See also fig. 13, p. 149.)

at that early Glacial period (A) have had a face more than from 100 to 150 feet high, while at the Westleton period it is more than probable that it formed, with the distant Oolitic hills, a continuous plain (*x*).

Of the escarpment of the Oolites one can speak with less certainty, though if we admit the Kingsdown Drift outlier to be of Westleton age, it favours the conclusion that the escarpment of the Oolites dates no further back than the commencement of the Quaternary or Pleistocene period. The fact likewise that the two escarpments run in parallel lines seems in favour of a common denuding cause in the same direction. The time, geologically measured, is, however, so limited, and the extent of denudation so vast, that it is not easy to realize that these limits can suffice. Nevertheless, I do not see how the conclusions we have arrived at on this subject can well be avoided.

Another point to which I would draw attention is the small amount of erosion by river-action (C) in the area under review, compared with that effected by glacial or other agencies. To the latter are due the broad plains and passes and the isolated hills, whereas the effects of the former are limited to the valleys of comparatively moderate depth and width, which have been subsequently cut through the glaciated and deeply abraded land.

EXPLANATION OF PLATE VII. (see also Map, Pl. VIII.).

Diagram-sections of the Hill-Drifts of Pre-Glacial date in the Valley of the Thames within the Chalk-basin. Owing to the length of these sections and the limits of space the vertical scale is unavoidably exaggerated. In Fig. 1 it is not so important, as the gradients of the Westleton Shingle and Boulder-clay bear a tolerably uniform relation one to another; but in the other figures it misrepresents the incidence of level between the several Hill-Drifts, for which allowance must be made. The relative height of the hills and depth of the valleys are, however, on a true scale, and this is the essential point connected with the question. These are taken from the new 1-inch Ordnance Maps.

Fig. 1. Section from Oxfordshire to the coast of Suffolk. The length of this section is about 140 miles. The dotted lines prolong the levels of the Westleton Bed and Boulder-clay, and serve to indicate the extent of denudation which has taken place since each of these epochs respectively.

2. Section, about 50 miles long, passing from Hindhead through the Bagshot district and across the Valley of the Thames, near Windsor, to the borders of Hertfordshire.

3. Section from the edge of the Weald across the Norwood Hills, the Thames at London, and the Tertiary hills north of London, to the Valley of the Lea near Hatfield: distance about 40 miles.

4. Section from the Valley of the Medway, near Tunbridge, by Cobham, near Rochester, across South Essex to the Brentwood group of hills: distance about 36 miles.

Railway-Cuttings.

Fig. 5. Section of the Great Eastern Railway, through Brentwood Common. This cutting was of greater depth; only the upper 40 feet are represented in the figure. The surface is 360 feet above O.D.

A. Boulder-clay of a dark grey colour, containing fragments and small blocks of chalk, sandstone, Jurassic rocks, angular flints, and flint-pebbles, with a few specimens of *Gryphæa incurva* and a species of large Oyster. Eastward, it passes into a sandy bluish-green clay with flint-pebbles, and then into a brownish clay, roughly laminated and without pebbles. It has a maximum thickness of 30 feet.

A′. Sand and gravel, consisting chiefly of flint-pebbles. The sand contains thin subordinate layers of grey and brown clay.

D. Lower Bagshot Sands.

	feet.
1. Fine white sand passing into bed No. 2	10
2. Ochreous and ferruginous, sandy, with some iron-sandstone	4
3. The upper part of this bed consists of a tough brown laminated clay, with grains of green sand and a few patches of white micaceous sand, passing down into a massive argillaceous dark green sand, with some lighter seams. This bed contains numerous small *Lingulæ*, with casts of various bivalves in iron-pyrites, teeth, and vertebræ of Shark and *Carcharodon*, and fragments of wood pierced by *Teredo* ...	16 to 20
4. Fine light-yellowish sand, interstratified with thin irregular seams of laminated dark-grey clay. Traces of carbonaceous matter. No fossils. This bed varies in thickness, resting on an uneven surface of the London Clay	4 to 12

E. London Clay: dark grey with grains of green sand and concretions of iron-pyrites. Only traces of fossils.

Fig. 6. Section of the Black Notley Cutting on the branch line from Witham to Braintree. This fine and typical section was about half a mile in length, and about 25 feet deep in the centre.

A. Boulder-clay containing numerous large angular flints and chalk-pebbles; it passes from dark brown to a whitish colour.

A′. Boulder-clay gravel, very coarse and much contorted. It consists chiefly of subangular flints, pebbles of flint and white quartz, of dark quartzite and sandstones. The upper part is of a dull brownish-white colour, whilst the lower part is dashed with ochreous, ferruginous, and black seams and streaks, passing in places into a dark ferruginous conglomerate .... 5 to 10 feet.

B. Fine sand and shingle, horizontally stratified, and in places obliquely laminated. It consists essentially of sand, with subordinate seams of shingle, composed of small flint- and white quartz-pebbles with some subangular flints. The upper half of this bed is ochreous, and coarser than the lower half, which is of a light yellow colour with faint ochreous seams. It is traversed by a few small faults of from 3 inches to 3 feet throw .... 15 feet.

Fig. 7. Section between Chapple and Mark's Tey on the branch line to Sudbury.

A. Dark grey Boulder-clay, divided into an upper chalky and light-coloured bed, and a lower one of a dark bluish-brown colour. 14 feet.

B. Sand and gravel; the upper part coarse and ferruginous, the lower part white with ochreous seams and regularly stratified ...... 10 feet.

E. London Clay with seams of Septaria. This cutting is from 20 to 25 feet deep. At the time of my visit the central part was but just commenced, and is filled in from inference afforded by the trial-holes only.

Fig. 8. Section on the Railway at Kyson, one mile South of Woodbridge.

The Boulder-clay does not show in the Section, but crops out a little higher up the slope of the hill, above B.

a. Trail of loam and gravel.

		feet.
B. Westleton.	1. White sand, full of small flint- and white quartz-pebbles, subangular flints, chert, &c. (see p. 125)	2
	2. White and light yellow sand	1
C. Crag.	1. Bright yellow sand, with occasional oblique lamination, without fossils	10
	2. Coarse sand, much oblique lamination, shells in local patches	5
	3. Red Crag; very fossiliferous at the west end of the cutting, but fossils scarce at the east end. At the base is a thin bed of Coprolites, on a denuded floor of London-clay Septaria	12

E. London Clay.

Discussion.

The President said that a paper of this kind was the result of enormous observation and very careful reasoning. There was one point which had occurred to him: if the Westleton series were marine, either the whole area had been depressed uniformly, or there had been a greater depression to the westward. On the first hypothesis, thicker marine strata would probably have been found to the eastward and westward, and in the latter case it was remarkable that no marine beds of this age were found on the Western coast. He had no doubt that the Author had carefully considered the possibility of the subaerial origin of these beds before rejecting it.

Mr. Topley called attention to the section at Hertford Heath, and asked whether the composition of the beds was not peculiar. The evidence as to the southern origin of the pebbles he considered very important. If the older beds and the Westleton Beds are composed of Southern Drift, they are sharply marked off from the Glacial beds. A section exhibited from Hindhead to Windsor was of interest as bearing on the relation of these beds to the Chalk escarpment and the Weald. The escarpments might possibly be older, and the Westleton Beds have lapped over them. Even if older than the escarpments, the beds were evidently newer than the elevation of the Weald.

Prof. HUGHES pointed out the difficulty of correlating unfossiliferous and variable beds when they were separated by considerable intervals. He thought that movements along the Weald-axis and affecting all East Anglia had occurred many times down to a late age. The Glacial beds rest quite irregularly on the higher- and lower-level gravels of Hertfordshire. The Hertford-Heath beds had, he believed, nothing to do with the Glacial deposits, but that between them there had been an elevation, denudation, and resubmergence of that area, and that the ingredients of these beds might have come from the north and west. The pebbles became smaller, tracing the stones from Hertford Heath to Hampstead, where he recognized two Pebble-beds, the upper with quartz being the equivalent of the Hertford-Heath beds, and the lower being the Bagshot pebble-bed. He had traced them along the top of Epping Forest also, and would look for them on the North Downs. The Sheppey gravel was an angular one, and different from that of Hertford Heath; whilst there was a gravel near Chatham on the mainland opposite Sheppey of different origin, being the deposit of a stream flowing northwards from the Weald. He shared the general regret that the Author was unable to be present, especially as he could probably have cleared up some of these difficulties either by reference to parts of the paper which had not been read or by supplementary remarks.

Mr. J. ALLEN BROWN had collected rocks from the high-level drifts of the Thames valley, and there was no doubt as to the occurrence of southern drift therein, though the northern drift preponderated.

Mr. MONCKTON agreed with the criticism of Prof. Hughes. There is a considerable break in the continuity of the proposed Westleton Beds north-east of High Beech, Essex.

The East-Berkshire plateau-gravels were shown in one of the diagrams; they were very different from the High-Beech gravels—quartz was, for instance, very rare in them, and he had placed on the table the only large block of quartz he had found in them.

Dr. IRVING was sceptical as to the identification of the Berkshire gravels with those of Essex and Suffolk. The Author appeared, since his York paper, to have altered his views as to the date of the upheaval of the Weald. He was in accord with Prof. Prestwich as to a certain amount of glacial erosion, by which he meant the work done by floating ice. He believed that the plateau-gravels were themselves fluviatile and of much older date.

Mr. MARR stated that if the paper had been read in full many of the questions raised by the previous speakers would have been answered.

Diagram-Sections of the Pre-Glacial Hill-Drifts of the Thames Basin.

Fig. 1. Section from Oxfordshire to the Coast of Suffolk.

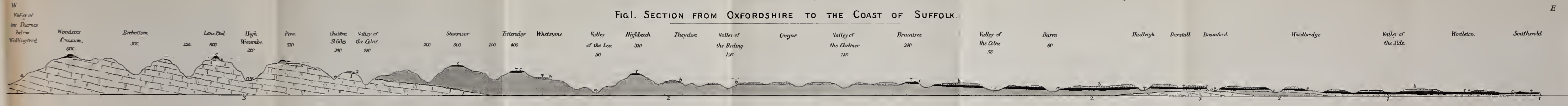


Fig. 2. Section from Surrey to Buckinghamshire.

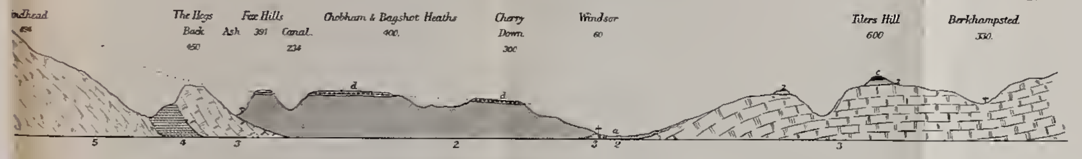


Fig. 3. Section from Surrey to Hertfordshire.

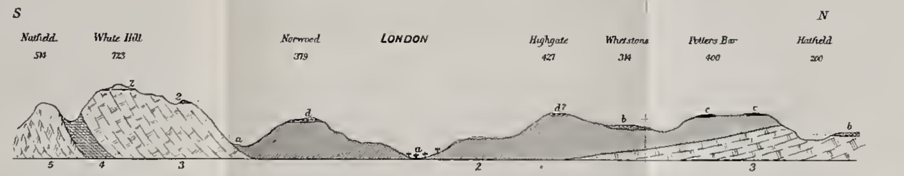
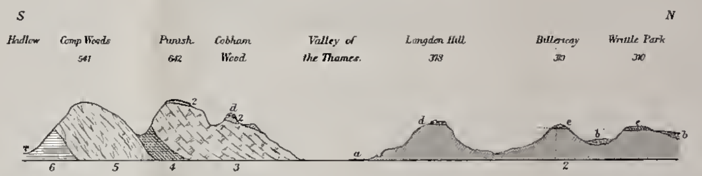


Fig. 4. Section from Kent to Essex.



a. Post glacial Drift (site of)
b. Boulder Clay and Gravel.
c. Westleton Beds
d. Southern Drift.
e. Brentwood Shingle
1. Crag and Chillesford Beds.
2. Tertiary Strata.
3. Chalk.
4. Upper Greensand & Gault.
5. Lower Greensand
6. Wealden.

Scale.
Vertical — 1/8 inch = 100 feet
Horizontal — 1 inch = 5½ miles

Fig. 5. Railway Cutting, Brentwood.

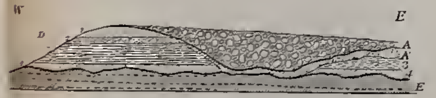


Fig. 6. Railway Cutting, Black Notley near Braintree.

Fig. 7. Railway Cutting between Chapple and Marks Tey.

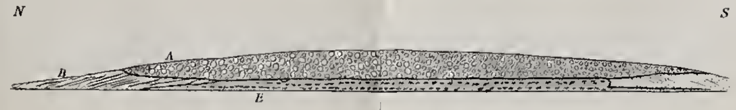
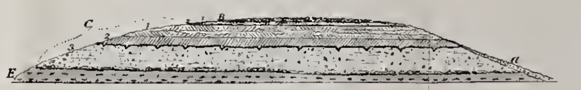


Fig. 8. Railway Cutting, Kyson near Woodbridge.



A. Boulder Clay
A'. Boulder Clay Gravel
B. Westleton Beds
C. Crag Beds
D. Bagshot Sands
E. London Clay

Vertical Scale 1 inch = 60 feet

3.

WESTLETON PAPER.—Part I.

CORRIGENDA.

Page 93, line 1, *insert* "Mr. Woodward's" *after* "and."
Page 99, line 28, *for* "(*g*)" *read* "(*h*)."
Page 101, line 17, *insert* "*c*" *after* "clay."
Page 102, line 7, *after* "of" *insert* "the deposit containing."
Page 103, line 5, *after* "*f*" *insert* "fig. 2."
Page 103, line 13, *for* "be" *read* "represent."
Page 105, line 13, *after* "*m*" *insert* "fig. 7."
Page 105, line 33, *for* "have been" *read* "are."
Page 106, fig. 7, *insert* "*f*" to bed below "*e*" and "*m*" to bed below "*l*."
Page 106, line 3 from bottom, *insert* "these" *before* "very."
Page 106, line 2 from bottom, *dele* "also."
Page 108, line 1, *for* "to" *read* "and."
Page 108, note §, *insert* "as myself" *after* "conclusion."
Page 109, line 40, *after* "Shingle" *insert* "*f* to *i*."
Page 111, line 9, *after* "8" *insert* "in dotted outline to the left."

[*From the* Quarterly Journal *of the* Geological Society *for* *May* 1890, Vol. xlvi.]

ON THE RELATION

OF THE

WESTLETON SHINGLE

TO OTHER

PRE-GLACIAL DRIFTS IN THE THAMES BASIN,

AND ON

A SOUTHERN DRIFT,

WITH

OBSERVATIONS ON THE FINAL ELEVATION AND INITIAL SUBAERIAL DENUDATION OF THE WEALD: AND ON THE GENESIS OF THE THAMES.

BY

JOSEPH PRESTWICH, D.C.L., F.R.S., F.G.S., ETC.

PART 3.

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1890.

On the Relation *of the* Westleton Shingle *to other* Pre-Glacial Drifts *in the* Thames Basin, *and on a* Southern Drift, *with* Observations *on the* Final Elevation *and* Initial Subaerial Denudation *of the* Weald : *and on the* Genesis *of the* Thames.

By Joseph Prestwich, D.C.L., F.R.S., &c.

PART III.

The Southern Drift.

[Plate VIII.]

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1. *Distinctive Characters of the Southern Drift.*

Taking the strata in their order of succession, this paper ought to have preceded the last, but for the fact that for the purpose of classification it was essential to have a base-line of which the position had been previously determined, such as that offered by the Westleton Shingle, before the relation of the other pre-glacial Drift-deposits in the Thames Valley to one another and their relative age could be established. It is for this object that I attach importance to the Westleton Beds last described; but besides these, which are confined almost entirely to the north side of the Thames, there is another closely allied hill-drift, which I propose to call the "Southern Drift," of more limited range and confined chiefly to the south side of the Thames. I at first thought it possible that they might be synchronous *, but now I have come to the conclusion that the Southern Drift is the older of the two, in the sense afterwards to be explained. Both of them are so restricted to outliers, often very small and far apart, and have been so much encroached upon by Glacial Drifts of later date, that the relation they bear to one another is generally much obscured.

The leading points on which we have mainly to depend are the relative levels and the differences in the character and origin of the rock-fragments and pebbles composing the two deposits, and in

* Much hinges upon their relative levels. These I had originally taken with an aneroid barometer, but the new 1-inch Ordnance Maps have now furnished me with the more accurate data required.

the proportion and condition of those which are common to both. For example, the Westleton Shingle is, as before mentioned, characterized by the constant presence of numerous pebbles of white quartz with a few small pebbles of Lydian Stone, Jasper, and others of old rock origin, and some peculiar larger quartzite-pebbles; whereas a similar abundance of quartz-pebbles is wanting in the Southern Drift, which, on the other hand, is characterized by a large though variable proportion of worn fragments of chert and ragstone—not that these are wanting in the Westleton Shingle, but they are in less abundance, more reduced, and hold a more subordinate position. The materials common to both, but present in different proportions, are subangular flints and flint-pebbles; while the absence of quartzite-pebbles derived from the Triassic rocks of Central England equally stamps both, and is one of the marks of distinction from the Northern Drift. The Westleton beds also had a marine origin, whilst the other seems to have been formed in great part under subaerial conditions.

The following are the component materials of the Southern Drift, taken in the order of their relative abundance, and with the sources whence derived :—

1. Angular and subangular fragments of flint, some retaining their natural colour, others much worn and stained uniformly of a deep warm brown colour. The former are derived directly from the Chalk, and the latter from an older Drift, the location of which is still uncertain (probably Diestian). 2. Pebbles of flint derived from the Lower Tertiary strata of Kent and Surrey, which formerly extended over the Chalk-area more generally and also further southward. 3. Subangular fragments in very variable proportions, and more or less worn, of chert and ragstone, derived from the Lower Greensand of Kent and Surrey. 4. Occasional small pebbles of white quartz (smaller and more opaque usually than those of the Westleton Shingle), derived, together with a few quartzites and some old rock-pebbles, from the Lower Greensand or from the Wealden. 5. A few subangular fragments of ironstone-grit and ironstone derived either from the Lower Tertiaries, the Diestian, or the Lower Greensand. No organic remains have been found in this Drift, of which the negative characters are the absence of the white and often chalcedonic quartz-pebbles of the Westleton type, of Triassic quartzite-pebbles, and of Jurassic débris.

2. *Distribution of the Southern Drift.*

This we will take, as in the former paper, in the order by counties.

Kent.—There is a considerable spread of very ferruginous sandy gravel on the Tertiary hills of East Kent, consisting of subangular flints with a small proportion of flint-pebbles. Although fragments of chert are wanting, or extremely scarce, I think it probable that the gravel on some of the higher grounds, such as Dunstead, the hills west of Canterbury (250 to 300 ft.), and a few other of the higher hills of the district, belongs to this Southern Drift, as it is much above the level of the Post-Glacial Drifts, contains no organic remains, and is distinctly a plateau or hill-gravel.

It is not, however, until we reach the neighbourhood of Rochester that the Southern Drift is found well characterized. It there caps the wooded hill extending eastward, at a height of about 400 feet, from the mausoleum in Cobham Park to within a mile of the Medway (see Pl. VII. fig. 4). It is a coarse gravel, lying bare on the surface, and consists roughly of *—

1. Subangular flints but little stained, with others more worn and stained uniformly brown	$\frac{3}{5}$
2. Flint-pebbles, some of them broken and white, with abraded edges, and green-coated flints from the base of the Thanet Sands	$\frac{1}{5}$
3. Subangular fragments of chert and ragstone from the Lower Greensand, and a few pieces of iron-sandstone	$\frac{1}{5}$

There is an absence of white quartz-pebbles.

Traces of similar gravel occur a few miles to the south of the last, on the hills between Halling and Punish Farm, near the edge of the Chalk-escarpment.

On the high Chalk-plateau between the Medway and the Darent there is in several places, namely at Ash, Fairseat, Plastal Green, Wrotham Hill, Cotman's Ash, Bower Lane, and others, a thin sprinkling of this old flint- and chert-drift. But there is no bed of it, except on the isolated Tertiary outlier at Swanscombe Hill †, 3½ miles north of the main Chalk-plateau, where it forms a small patch, 316 feet above the sea-level, and almost identical in composition with the gravel on Cobham Hill.

A much more important bed of this character is one which I met with long ago on the summit of Well Hill, near Chelsfield, a ridge from 550 to 600 feet high, *forming the water-shed* between the Darent and the Cray, and extending about one mile from south to north, with a width of only a few hundred feet. This bed of gravel is from 5 to 12 feet thick, very coarse and unstratified, and consists mainly of :—

1. Subangular flints, many of them very large and very much worn, and having the interior texture altered to an opaque white or brown colour ; with a few smaller ones stained brown on the outside, and still more worn.
2. Numerous flint-pebbles (some of them broken and worn) from the Woolwich and Reading Beds, and a very few green-coated flints from the base of the Thanet Sands.
3. A very small number of subangular fragments of chert and ragstone.
4. A few rare flat ovoid white quartzites.

The whole imbedded in ochreous quartzose sand and clay. This Drift rests on an uneven surface of Lower Tertiaries, which forms an outlier rising above the surrounding Chalk-plateau, see fig. 7, p. 170.

* The relative proportions vary so much in different localities that it is not necessary to describe it very closely.

† I have described this bed in Quart. Journ. Geol. Soc. vol. xlv. p. 291 (1889).

Though Lower Greensand débris is extremely scarce in this gravel, there is, lower down (500 feet above O.D.) on the south side, and resting on the Chalk-plateau, at a spot above the railway-tunnel opposite Colegate Farm, a small patch of gravel composed in large part of fragments of chert and ragstone. Another small patch caps the hill with the clump of trees (366 feet) just north of Lullingstone Park.

More recently, I have discovered a bank of this gravel, very coarse and with much chert and ragstone, some of large size, on the slopes of the hill on the left bank of the Darent, between Eynsford and Farningham. There it does not cap the hill, but extends on its slope from 250 feet nearly to the summit at 350 feet. It is not worked, but, being bare, is easily examined.

Thence westward to the borders of Surrey I know of no well-marked body of this gravel (unless a sprinkling of flint-gravel on the top of Red Hill near Chislehurst should be grouped with it), although here and there on the Chalk-plateau there is, as on the downs east of the Darent, an occasional thin sprinkling of chert-fragments and much-worn brown-stained flints.

Surrey.—Here it is on the Tertiary hills, and not on the Chalk-downs, that we find the best exhibition of this Southern Drift. A thin bed of it resting on London Clay caps West-Ho Hill, Norwood (see Plate VII. fig. 3).

The following is a detailed section taken some years since:—

Fig. 1.—*Section of Gravel-pit on West-Ho Hill**.

		ft.	in.
a.	Surface-soil	2	0
b.	Loamy gravel	1	0
c.	Fine ochreous gravel with veins of grey sandy clay	1	0
d.	Grey sandy clay		6
e.	Yellow gravelly sands	2	0
f.	Grey sandy clay		6
g.	Ochreous sand	1	3
h.	Grey sand		3
i.	Coarse ochreous gravel	2	0+

* This pit is now probably built over.

According to the one specimen I kept, this gravel consists of:—

1. Subangular flints, unstained and stained brown.—in largest proportion.
2. A considerable proportion of Tertiary flint-pebbles—some broken and worn.
3. About 10 per cent. of subangular fragments of chert and ragstone.

With one pebble of a hard sandstone or quartzite (Tertiary ?) and one small pebble of quartz.

This gravel extends southward all along the top of this hill, at a height of from 360 to 380 feet above O.D.

From the Norwood hills we pass westward over a lower tract of country with gravels of later age, as far as Wimbledon Common, which rises to the height of 183 feet above the valley of the Wandle. It is capped by a Drift-gravel, about which I feel uncertain. It has all the elements of the Southern Drift, but in addition it contains quartzite-pebbles, which have the Triassic characters. It is therefore either of Glacial age, or else a Southern Drift invaded by a later Glacial Drift. It consists, in the order of their relative abundance, of:—

1. Subangular flints stained yellow.
2. Tertiary flint-pebbles.
3. Subangular fragments of cherty ragstone and of a yellow chert.
4. Pebbles of white quartz, of dark quartzite, sandstone, and ironstone.

Imbedded in a ferruginous matrix of coarse worn quartzose sand.

The next hill to break the uniform level of the later Thames-valley gravels is the isolated and conspicuous hill known as St. George's Hill, which rises 1½ miles to the south of Weybridge to the height of 245 feet, and is capped by a Drift-gravel much like that of Wimbledon, but without the quartzite pebbles. I have less difficulty, therefore, in referring it to the Southern Drift, although it contains some small white quartz-pebbles, but these may be derived from the Lower Greensand or Wealden. The gravel is composed as under:—

	per cent.
1. White and yellow-stained subangular flints	44
2. Tertiary flint-pebbles, some broken	30
3. Subangular fragments of ragstone and brown chert	15
4. White quartz-pebbles	5
5. Pebbles of sandstone, ironstone, &c.	6
	100

in a matrix of quartzose sand.

The greater part of the Surrey Chalk-Downs are bare, with the exception of a few Tertiary outliers and the red clay with flints. But on Merrow Down, near Guildford, there is a gravel which seems to belong to this Drift. It consists in large proportion of Tertiary flint-pebbles and subangular flints, mostly white, of some subangular fragments of cherty ragstone, and of a hard sandstone (Tertiary), with a few small rough quartz-pebbles, imbedded in a matrix of bright yellow and red sands. The Downs at this spot are from 400 to 500 feet high. The Hog's Back, which rises to the height of 500 feet between Guildford and Farnham, is bare of any Drift.

To the north of these Downs are the extensive heath-covered hills of the Bagshot, Chobham, and Frimley ridges, from 350 to 415 feet high. These are capped by the Southern Drift, with a certain proportion of ragstone and chert, imbedded in a coarse ochreous and ferruginous sand. The gravel is from 6 to 12 feet thick, roughly stratified, and becomes white on exposure. Large blocks of Tertiary sandstone * occur not unfrequently, and in places there are a few small quartz-pebbles (Pl. VII. fig. 2).

Berkshire.—The lower part of the valley of the Thames immediately adjacent to the river exhibits only Glacial and Post-Glacial Drifts. The higher hills which range from Windsor Forest to Sandhurst are covered in great part by the Southern Drift.

The most striking instance I know of is that exhibited on Cherry Down (named Burleigh in the new 1-inch Ordnance Maps), near Ascot. Subangular fragments of chert and ragstone are there so abundant that they almost equal in number the subangular flints, which, with flint-pebbles and a few fragments of iron-sandstone, constitute the other portion of this gravel. These are imbedded in a yellow quartzose sand with some black grains and quartz-grit: in the gravel there are a few intercalated grey and red argillaceous seams as at Norwood. This hill is about 300 feet above sea-level, and 220 to 240 feet above the plain of the Thames at Windsor and Slough (see Pl. VII. fig. 2).

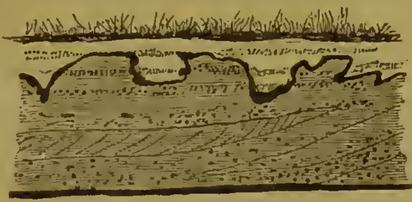
Further westward the ridges are less persistent, and isolated hills more frequent. Several of these are capped with this gravel. On one of them, called "Gravel Hill" on the map, 400 feet high, and 1 mile east of Cæsar's Camp Hill, near Easthampstead, the gravel consists of:—

	per cent.
1. Subangular fragments of flint, part not stained, and part stained yellow and brown	40
2. Tertiary flint-pebbles, of which about one fifth part are broken.	32
3. Much-worn fragments of light-coloured ragstone and yellow chert, and ironstone-grit	18
4. Small pebbles of white quartz	4
5. Pebbles of white sandstone and subangular fragments of Sarsen stone (Tertiary)	6
	100

Long exposure has bleached the upper part of the gravel, which is roughly stratified, as seen in the following section:—

* Some of these are 20 tons in weight. They mostly occur deep down at the base of the gravel, and are derived from the Upper Bagshot Sands on which the gravel rests.

Fig. 2.—*Section of Gravel-pit, Gravel-pit Hill, near Easthampstead.*



a. Black peaty soil .... } 5 ft.
b. Bleached gravel ....
c. Irregular black carbonaceous band ....
d. Ochreous gravel with sandy beds showing oblique lamination.

The same gravel caps Cæsar's Camp Hill, but is not worked there.

Hampshire.—Among the most conspicuous of the gravel-capped hills in this county are Hungary and Cæsar's Camp Hills near Farnham and Aldershot. They are respectively 577 and 600 feet high, and the gravel on the former consists of:—

	per cent.
1. Much-worn subangular fragments of flint weathered white	50
2. Tertiary flint-pebbles, of which about two thirds are broken and worn	36
3. Small subangular fragments of light-coloured cherty ragstone and of ironstone-grit (Lower Greensand)	6
4. Pebbles of Tertiary sandstone and Sarsen stone, some with rude vegetable impressions	8
	100

Imbedded in a matrix of yellow loam with much-worn quartzose sand, passing into coarse quartz-grit the size of peas.

A tract of flat country intervenes between these last hills and the smaller ridges of Hartley Row, Bramshill, and Hazeley. The gravel at the first-named place is roughly stratified and disturbed at top, and is composed of:—

1. Subangular worn brown-stained flints	$\frac{5}{10}$
2. Tertiary flint-pebbles, some of them broken	$\frac{4}{10}$
3. Subangular pieces of ragstone and iron-sandstone with a very few small quartz-pebbles	$\frac{1}{10}$

Imbedded in an ochreous sand with veins of a greenish-grey clay. The whole is roughly stratified, and the upper part much disturbed.

The Confines of Hampshire and Berkshire.—Between Hazeley Heath and Reading the country is flat, with the exception of the hills at Heckfield and Farley, near Swallowfield (300 feet?). These are capped by a little flint-gravel, weathering white.

A low tract of bare London Clay then intervenes at Strathfieldsaye and on to Burghfield, where a bed of flint-gravel commences (on the

Common), and continues past Silchester, Tadley, and Brimpton Commons, to Greenham Common near Newbury. This gravel, which is sandy, roughly stratified, and weathers white, consists essentially of subangular flints with Tertiary flint-pebbles, and some much-worn fragments of a very fine-grained variety of Sarsen stone. There is also a certain number of small blocks of Sarsen stone, or so-called Druid Sandstone, scattered over the district; and one well-known large block (the Nymph Stone) of hard Lower Chalk lies on Silchester Common. Though there is in this gravel an absence or extreme rarity of Lower-Greensand débris, I think, from the level of these plateaux (330 feet on Silchester Common to 402 feet near Newbury), and from its relation to the valley-gravels, that it belongs to the period of the Southern Drift. The Wealden anticlinal did not bring the Lower Greensand to the surface to the south of this district; it only raised the Chalk.

Wiltshire.—Westward of this point there are few traces of this flint-gravel. I have found it capping Upper Kirby Green hill (573 feet), near Inkpen. A little also occurs on the high ground of Martinslee Hill, near Marlborough; but I have not recognized it further westward in this direction, though traces of it extend over some of the Oolitic hills.

3. *Other Pre-Glacial Hill-Gravels: the Warley and Brentwood Groups.*

Besides the two distinctive Pre-Glacial Drifts here described, there are two others not so easily assigned to a definite horizon, although there can be no doubt of their Pre-Glacial age. One has many of the characters of the Southern Drift; and the other, which is better known, has the essential characters of a Bagshot pebble-bed *.

The first of these groups caps Langdon and Rayleigh Hills in South Essex, and Hampstead and Highgate Hills in Middlesex. They are so few in number and are so nearly on the same plane as the other two groups, with which they possess many characters in common, that I can scarcely doubt that they belong to one or the other of them.

Rayleigh.—This range of hills, which is a little to the north-west of Southend, and rises to the height of 250 or 260 feet, is capped by a thin gravel consisting of:—1. Numerous flint-pebbles. 2. Some white subangular fragments of flint. 3. A very few small white quartz-pebbles. 4. Fragments of Tertiary Sandstone (one piece measured 18 × 9 inches). 5. Subangular fragments of brown chert

* See Mr. S. V. Wood, junr., "On the Pebble-beds of Middlesex, Essex, and Herts," Quart. Journ. Geol. Soc. vol. xxiv. (1868), p. 464: Mr. W. Whitaker's "Geology of the London Basin," Mem. Geol. Survey, vol. iv. (1872), pp. 320–328; and 'Guide to the Geology of London,' 5th edit. 1884, p. 55; and Messrs. H. W. Monckton and R. S. Herries, "On some Bagshot Pebble-beds and Pebble Gravel," Proc. Geol. Assoc. vol. ix. (1889), p. 1.

(one small block measured 4 inches each way) and ragstone imbedded in a bright ochreous clayey sand. I found no pebbles of the older rocks.

Bagshot Sands, 30 feet thick, and overlain by from 2 to 3 feet of a ferruginous pebble-conglomerate, cap Boyce Hill (200 feet), near South Benfleet*. Two to three feet of a Drift-gravel overlie the conglomerate.

Langdon Hill.—Eight miles westward of these hills, and separated by a low tract of nearly bare London Clay, is Langdon Hill the highest (373 feet) in South Essex. It is capped by some 40 or 50 feet of Bagshot Sands, over which is a thin sprinkling of gravel, composed almost entirely of flint-pebbles, with which are mixed a few subangular flints, and some very much weathered fragments of chert and ragstone (Pl. VII. fig. 4).

The Glacial Beds to the north do not approach within some miles of Langdon Hill, and then they are on a much lower level (150 to 200 feet), as they are also at Rayleigh.

Hampstead and Highgate.—On the Bagshot Sands at Hampstead there is in places a thin sprinkling of flint-pebbles (Bagshot), mixed with which I have found a few subangular fragments of flint and of a cherty ragstone, whilst at Highgate we can only surmise that similar traces occur: but the ground is too much built over for any sufficient observations to be made. The relation of this Drift to the Glacial Beds is here much the same as that of the Westleton Beds at Totteridge to the Glacial Beds at Whetstone—that is to say, that in both places the Glacial Beds are about 100 feet lower than the top of these hills. At Highgate the Boulder-clay comes in at the foot of the south slope of the hill (Pl. VII. fig. 3), and is not met with higher.

The summits of Hampstead Hill, and of Mill Hill near Totteridge, are nearly on the same plane, whilst the summits of Langdon Hill and Rayleigh Hill differ little from the height of Brentwood and Writtlepark hills. In the latter instances, the Westleton Shingle seems to be on a level somewhat lower, although it is at a sufficient distance for a slight alteration in the dip to lessen or annul the difference. The dip, however, of the Westleton Beds is in general southward, and not northward.

On the whole, these Drift-beds show more analogy with the Southern Drift than with the Westleton Beds. It is possible, however, that in the case of Hampstead Hill the two may have had the same floor and got intermixed. In the case of the Essex Hills, there may be a connexion with the Brentwood group, but further research is required to decide the exact relation of these drifts.

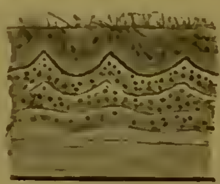
The Brentwood Group.—The other hill-drift of this section may be termed the Brentwood or Warley Group, from its being best developed in that part of Essex, where it forms a number of detached outliers. The most eastward of these hills are those which range from a little west of Chelmsford to near Brentwood,

* This would seem to indicate a fault between this spot and Rayleigh.

with a height of from 300 to 350 feet. These hills consist of London Clay, with remnants of Bagshot Sands on the summits of some of them. The Boulder-clay wraps round the east end of this range at a level of about 150 feet below its summit, but on the northern slope it rises much higher. The Pebble-beds which cap the hills at Writtlepark, Beggarhill, Mill Green, Fryerning, and Norton Heath seem to be little else than Bagshot Shingle more or less disturbed and mixed with a few subangular flints, quartzite-pebbles, and pieces of quartz.

A more conspicuous range of hills is that which extends a few miles further to the south-west, from Brentwood to Warley and Billericay (see Pl. VII. fig. 4). On Brentwood Common (352 feet) the Pebble-bed is thin and very much disturbed, as shown in the annexed section:—

Fig. 3.—*Section of disturbed Pebble-bed, top of Railway-cutting, (west end) Brentwood Common.*



a. Grey clay, with flints and pebbles	....	3 to 4 ft.
b. Pebble-bed disturbed	....	
c. Light-coloured sands	....	

The railway-cutting exposed other features in connexion with the Bagshot Beds, which require some notice. The Warley Pebble-bed does not extend so far as the cutting, or rather it is there hidden by a bed of clay, which displaces the Bagshot strata, and soon acquires a thickness of 30 feet. As it increases in thickness its true Boulder-clay character is apparent; it becomes darker, and contains imbedded large subangular flints, flint- and chalk-pebbles, pebbles of sandstone, and fragments of Jurassic rocks, with specimens of *Gryphæa incurva* and a large Oyster. As this Clay trends further eastward, it passes into a sandy brown and bluish clay with only a few pebbles, and finally thins out as a greenish clay or marl (see A, Pl. VII. fig. 5, and p. 152).

At the base of this Clay is an irregular bed of sand and gravel, thickening as the overlying clay thins out, and consisting chiefly of flint-pebbles, while the way in which the Boulder-clay has mounted the hill and displaced the strata of the Bagshot Beds deserves notice.

The Bagshot Beds themselves, which are here 40 feet thick, will be found described in the explanation of the section (Pl. VII. fig. 5, p. 152). There are no Pebble-beds here *in situ*. They were apparently disturbed and displaced on the north side of the hill and pushed southward.

At Warley Heath (378 feet) the pebble-gravel is thick and little disturbed. The flint-pebbles have a distinctive character of their own. They are unlike those of Blackheath or of the Westleton Beds. Dr. Mitchell speaks of them in his papers (MSS.) as the Warley pebbles. They are larger and less shapely than those of Blackheath, and are often weathered white. Of their derivation from the Bagshot Beds, with which these shingle-beds are in close association, there can be little doubt, for at Billericay there is a thin bed of flint-pebbles intercalated in the yellow sands of the Bagshot which cap the hill, and Mr. H. B. Woodward gives a section at South Weald Park, near Brentwood *, showing a bed of pebbles 15 feet thick *in situ*, and overlain by 6 feet of Drift-gravel. We have, in some cases, therefore, this Eocene Shingle *in situ*, whilst in others it seems to have been affected by the Southern Drift and by subsequent Glacial action.

This range of hills formed here, as did the Hampstead and Highgate on the north of London, and the Bushey and Stanmore Hills to the south of Watford, the boundary to the advance of the Boulder-clay; for though Glacial gravels and evidences of Glacial action are to be found further south, there is no Boulder-clay.

Stanmore.—An important mass of shingle-gravel spreads over Stanmore Heath (400 to 450 feet), from little Bushey to Bentley Priory. It is composed in large part of:—

1. Flint pebbles, a good many being white-coated.
2. Very few subangular flints, stained brown.
3. Some small white quartz pebbles.
4. A few worn green-coated flints, from the base of the Lower Tertiary sands.

Imbedded in a matrix of coarse yellow and ochreous sand, and resting upon an indented surface of London Clay, as though due to pressure (glacial) from above. Many of the pebbles also have their longer axes upright.

I did not notice any chert or ragstone in this shingle, and in other respects it resembles the Brentwood and Warley, more than the Westleton Shingle. The few quartz-pebbles may have been derived from the Lower Tertiaries, which in the Pinner district contain a few such pebbles.

The hill (380 to 400 feet) between Pinner and Watford, as well as Brockley (416 feet) and Elstree Hills (450 feet), on the other side of Stanmore, are capped by a small spread of similar shingle, but it is not worked.

There is no Boulder-clay to the west or south of these hills; and

* "The Geology of the London Basin," Mem. Geol. Survey, 1872, p. 324; and 'Geology of London,' 1889, p. 273.

that at Bricket Wood and Aldenham on the north is on a level of from 150 to 200 feet lower.

The only outlier belonging to this group on the south of the Thames is that on the summit of Shooter's Hill, 424 feet high. The shingle is there composed essentially of flint-pebbles, with only a few subangular flints and a very few rare quartz-pebbles. The flint-pebbles closely resemble those of Warley Heath. The bed is only 2 or 3 feet thick, and is disturbed at the top like that on Brentwood Heath Common and Stanmore.

Fig. 4.—*Section in the Brick-field to the West of Bentley Priory, Stanmore, Middlesex.*

a. Unstratified beds of shingly gravel .... 6 to 7 ft.
b. Upper loamy bed of the London Clay disturbed by the pressing down of bed *a*.

It will be observed that on these hills there are either remnants of the Bagshot Sands, or else the London Clay is of such a thickness that little is wanted to bring them in: or, as the London Clay varies somewhat in thickness, it is quite possible that at Shooter's Hill, Havering Atte Bower, and Buckhurst, there were depressed areas in which the Bagshot Sands and pebbles gained at the expense of the London Clay, and that in these cases, as at Brentwood and Billericay, the Pebble-beds are nearly *in situ*.

That the Pebble-beds have been disturbed and partly reformed is, however, evident from the introduction of materials foreign to the Bagshots. This may have been effected at the time of the Westleton or Southern Drifts, though further changes in their condition seem to be due to ice-action in the Glacial period.

4. *Early Physiographical Conditions of the Wealden Area.*

To understand the relation which the Southern Drift bears to the other Pre-Glacial and Glacial Beds, it is necessary to go back to earlier times to see what were the physiographical conditions previously prevailing in the south of England and the adjacent continental area.

The denudation * of the great dome of the Wealden anticlinal commenced in the early Tertiary period †; but though the Chalk,

* On the general subject of the Denudation of the Weald see chapter 16 in Mr. Topley's 'Geology of the Weald,' pp. 270–301 (1875).
† The author in Quart. Journ. Geol. Soc. vol. xiii. p. 256 (1852).

which then extended possibly over the anticlinal, must have been largely denuded, in order to have furnished the mass of flint-pebbles in the Woolwich Beds, there is no evidence that the denudation reached down to the Lower Greensand and Wealden, as no débris from these sources has been found in the Tertiary strata. For our present object we need, however, only commence with the state of the area in Pliocene times.

It is obvious, as I have shown on a previous occasion *, that in an early Pliocene epoch, before the later denudation of the Weald, the North Downs from Folkestone to Dorking and possibly beyond, together with the adjacent area to the south, were submerged under a sea which extended probably from the North Sea to Brittany and so southward in one direction, and in the other, eastward, over parts of France and Belgium to the foot of the Ardennes. The Pebbly-sands, occasionally fossiliferous (Lenham), that occur at intervals on the edge of the North Downs are proofs of this submergence. On the continent beds of the same early Pliocene age and character are found capping, amongst others, the hills of Mont-de-la-Trinité, near Tournay, and the hills near Boeschepe in Belgium, and of Mont Noir near Bailleul, Mont Cassel near Dunkirk, and the Chalk-hills between Calais and Boulogne, in France, showing the same sea to have extended over that area also.

In these Beds, the Diestian of the Belgian geologists, the fossils have generally been removed by infiltration, and it is only occasionally that a few casts are met with. Where, however, they pass under the newer Crags of the Antwerp district they are very fossiliferous. This deposit, which does not exceed 50 or 60 feet in thickness, consists of pebbly sands, sometimes very ferruginous and passing into iron-sandstone, while the flint-pebbles are often so decomposed that they break under the pressure of the fingers into a white powder.

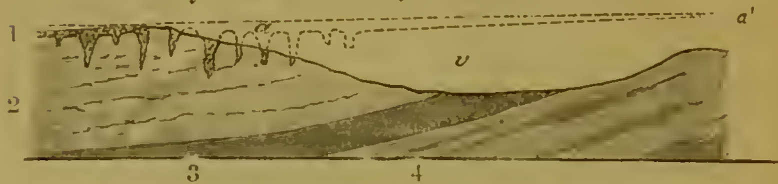
From the position of the Beds at Lenham, we may assume that they originally extended, together with the Chalk, further over the Lower Cretaceous and Wealden strata to the south, as remnants of the Beds are preserved in the sand-pipes, the ends of which occur in decreasing lengths on the bare slope of the Chalk-escarpment, showing that the deposit itself at one time spread over the now denuded area at the foot of the escarpment, as exhibited in the subjoined diagram (fig. 5).

It is clear from that section, that the valley *v* between the Chalk and Lower Greensand hills is of later Pliocene or Post-Pliocene date, and the same reasoning applies to the whole length of this great valley, and in all probability to the Wealden valleys in general.

There can be little doubt, also, that in the early Pliocene times of which we have been speaking, Belgium and the south-east of England and Western France (Normandy and Brittany) were separated, not by the present narrow strait, which was not existent at that time, but by a broad sea-channel extending across

* Quart. Journ. Geol. Soc. vol. xiv. p. 322 (1858).

Fig. 5.—*Section of the Chalk-escarpments above Lenham, showing the former extension of the Lenham Sands.*



1. Lenham Beds (early Pliocene).
2. Chalk. 3. Gault.
4. Lower Greensand.

a. Sandpipes in the Chalk.
a'. The dotted lines represent the former extension southward of the Lenham Beds over the Chalk and Wealden.

the Wealden area and over a part of North-western France and of South-western Belgium, before the elevation and denudation of those areas and the excavation of the Straits of Dover.

As neither the White nor the Red Crag of Suffolk extend over the Lenham Sands, while the sand-pipes could only have been formed after the emergence of the latter and a lengthened exposure to atmospheric agencies, it is evident that the east and west elevation of the Wealden area must have taken place at or soon after the White-Crag epoch, possibly at the insetting of the Red-Crag epoch. The effect of this emergence was to bar the Crag sea of the Eastern Counties on the south, and to establish a land-connexion with the continental area along the line of the Wealden and Boulonnais anticlinal, which then, with that of the Ardennes, probably formed a continuous range.

The final elevation of the broad anticlinal dome of the Weald was therefore subsequent to the deposition of the Lenham Sands, and it must have been after that time that the excavation of the valleys *v*, fig. 5, commenced. Hence we may conclude that the denudation of the Weald, as generally understood, is of a date subsequent to the early Pliocene period, that is to say, after the emergence of the Lenham or Diestian Beds, just as we have shown that the excavation of the valleys of the Thames district took place after the elevation of the Westleton Shingle, or subsequent to the early Pleistocene period.

5. *Origin of the Southern Drift.*

The foregoing conclusion respecting a Wealden barrier in Pre-Glacial and Glacial times is confirmed by the circumstance that the component materials of the Southern Drift consist exclusively of débris derived from rocks in the Wealden area, or from those which formerly extended over it. The deep valley (*v*, fig. 5) now separating the range of the Chalk-Downs from the range of the Lower Greensand could, for a long time, have had no existence, for otherwise the débris of chert and ragstone of the Lower Greensand could not have been carried from the Greensand-range on to the Chalk-plateau on the north. The valley, *v*, must then have been bridged over by the Gault and Chalk to have allowed the transport across it of this débris by streams from the central Wealden area; for there is no reason to suppose it was effected by floating ice.

Let us now try to conceive the condition of the Wealden area at the period of this, its last, emergence. At present, the height of the anticlinal ridge at Crowborough does not exceed 803 feet. To realize the condition of the dome before denudation, we have to add the thickness of the strata removed, which may probably be estimated as under:—

	feet.
1. Chalk. *It is doubtful whether this extended to the centre of the Weald, for, as I have already shown**, *it had before this time been planed down at its edge to a thickness of 300 feet by Tertiary marine denudation. If that rate of wear were maintained, it is probable that the Chalk either did not extend to the central area, or else was greatly reduced in thickness*	100
2. Upper Greensand and Gault	150
3. Lower Greensand......	450
4. Weald Clay	700
5. Tunbridge Beds and Wadhurst Clay	400
	1800
Add present height of Central ridge (Ashdown Sands &c.)...	800
	2600†

There would thus have been, even supposing that there has been no subsequent subsidence, a low mountain-range extending into the Boulonnais, on the site of the present Wealden area. It is probable also that at this time the Ardennes were considerably higher than they are now (2800 feet), for MM. Cornet and Briart have shown that during their diverse upheavals some 12,000 to 15,000 feet of strata have been removed ‡. This, however, was at a date very long anterior to the Pliocene.

The Wealden range having been uplifted in late Pliocene times, it soon became exposed for a vast length of time to the heavy rainfall, snow, and ice of the Pre-Glacial and Glacial periods, when torrents scored the flanks of the hills, and carried down the harder débris to the lower grounds at their base.

Amongst the earlier results of these denuding agencies is, I conceive, the coarse and much-worn gravel of Well Hill. The large heavy flints with their angles greatly worn, and the unstratified character of this gravel, give it the appearance of having been brought down by a torrent, and of not having been spread out under water. This would account for its very local occurrence; for this stream of stones is confined to Well Hill, and the hill itself seems to result from the protection afforded by the mass of flints, while

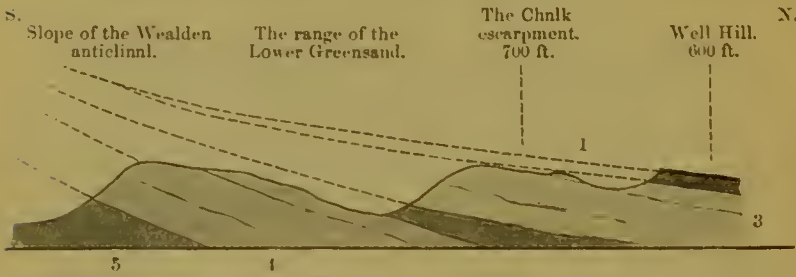
* Quart. Journ. Geol. Soc. vol. viii. p. 256.

† The estimate formed by Mr. Topley, supposing the whole amount of strata removed by denudation to be restored, varies at different parts of the axis from 1000 to 3000 feet ('Geology of the Weald,' p. 217).

‡ Mém. Soc. Géol. de Belgique, vol. iv. p. 71 (1877).

the soft unprotected Tertiary strata on either side have been removed by denudation. That the gravel is of great age is indicated by the extreme weathering of the flints, and by the alteration and discoloration of their substance; while although flint-pebbles from the Tertiary are abundant, débris from the Lower Greensand is extremely scarce, as though the denuding agencies had at that time scarcely reached down to the Lower Greensand, a state of things that may be represented by the following diagrams (figs. 6, 7):—

Fig. 6.—*Theoretical longitudinal Section along the summit of Well Hill (ante* p. 157) *to the flanks of the Wealden Range.*



1. Well-Hill gravel. 3. Chalk and Gault. 5. Wealden strata.
2. Lower Tertiary strata. 4. Lower Greensand.

The dotted lines show the prolongation of the beds before denudation.

The transverse section shows the position of the gravel in relation to the Tertiary strata formerly on either side.

Fig. 7.—*Theoretical Section across Well Hill and the old Gravel-stream.*

The upper dotted line shows the position of the removed Tertiary strata.

The conjecture that at this time much of the Wealden and Lower Greensand were still hidden under a mass of Chalk and Tertiary strata, finds corroboration in the analogous condition of the gravel on some of the other higher and earlier drift-covered hills, where flints from the Chalk, or flint-pebbles from the Tertiary strata, constitute the whole or nearly the whole of the mass of gravel, and Lower-Greensand débris is either absent or very scarce. Thus, for example, on Hungary Hill there are but few traces of Lower-Greensand débris, and in the flint-gravel of the hills near Canterbury it is absent or nearly so.

Later on, as the covering of Tertiary strata and of Chalk was removed, the Lower Greensand became more exposed, and its hard and indestructible siliceous débris was scattered more widely along the base of the old Wealden range of hills. Thus it is that on the Bagshot hills of Hampshire and Berkshire we find the chert and ragstone of the Lower Greensand occurring in quantity, and in Kent also scattered freely, though thinly, in places over the Chalk-plateau, having lodged there after the denudation of the Tertiaries and their removal around Well Hill.

Another and somewhat later phase occurred when the drainage of the Wealden Highlands became restricted to narrower bounds and more defined channels. It was then that some of the main transverse valleys received their first rudimentary channelling, as, for example, in the case of the Medway, where the flint- and chert-gravel above Halling and on some hills above Stroud point to old channels in the line of the present Medway valley, but at heights of from 200 to 300 feet above the existing river; or, in the case of the Darent, the bank of flints and chert on the slope above Eynsford, at a height of from 250 to 350 feet above that stream. Another instance is that of the Wey through the gorge of the Chalk at Guildford. On the east side of this passage, Lower-Greensand and flint-débris cover Merrow Down at a height of 400 feet, or of 300 feet above the Wey. In all these cases this old gravel is considerably above the Post-Glacial gravel more intimately connected with the existing valleys, though at the same time the Chalk around rises to still greater heights than this Drift.

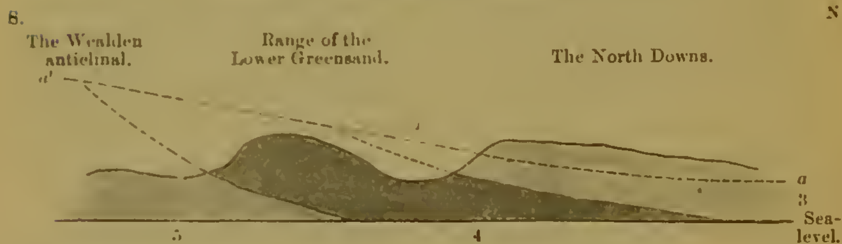
In the foregoing instances, the valleys flanked by this old chert-drift pass through the Chalk-escarpment into the Wealden area, showing that there has been continuity of action along the same lines from the initial stages of the formation of these valleys to the present time, and therefore that it was not, as has been suggested, the present streams which have cut their way back through the escarpment.

There are other instances where the continuity has been interrupted, and the original drainage diverted into other channels, leaving the valleys, as it were, half formed, and the old channels were left dry, but retaining a drift carried in from beyond their present precincts. A good instance of this is to be seen in the narrow valley of Smitham Bottom (fig. 8), which, commencing at Croydon, runs up to the Chalk-escarpment above Merstham, where it is cut off by the transverse valley draining into the Mole, and no longer passes into the Wealden area. At present it is a dry valley, excepting that during certain seasons there is an outbreak for about half its length of a bourne, which continues to run for a few months, but is in no way connected with the old drainage-area. Along the upper part of this valley, and extending to its end above Merstham, is a thin bed of gravel composed of subangular flints, and flint-pebbles, with subangular fragments of *chert*, *ragstone*, and ironstone derived from the Lower Greensand. It is clear, therefore, that this Drift was deposited before the strata beyond the escarpment had been removed, and when the valley was prolonged in a southern direction into the Wealden area, and the drainage brought down the usual complement of Lower-Greensand débris from the hills beyond the Chalk-escarpment.

At this stage, some disturbance connected with the Central Wealden area diverted the drainage in another direction, cutting off the upper part of the valley, denuding the face of the Chalk-escarpment, and leaving the truncated end of the valley at a height of 174 feet above the stream at the foot of the escarpment (*b*, fig. 9) which now drains into the Mole. The bed of the valley at the point where it is cut off is 438 feet above O.D., while the hills on either side rise nearly 200 feet higher, showing the valley to have been in an advanced stage, but still 200 to 300 feet short of the depth subsequently acquired by that of the Medway or of the Darent.

The date of this old transverse valley is, however, far removed from that which has left its traces on the summit of Well Hill, inasmuch as at the latter date the Tertiary strata had not been denuded from the surface of the Chalk floor, whereas at this time not only had the Tertiary strata been denuded from the Chalk-plateau, but the Chalk itself had become channelled to a considerable depth. The position of the valley in its longitudinal course at the time of its arrested growth, when it had its origin in the Wealden area, is shown in the following diagram :—

Fig. 8.—*Course of the Valley of Smitham Bottom, restored.*



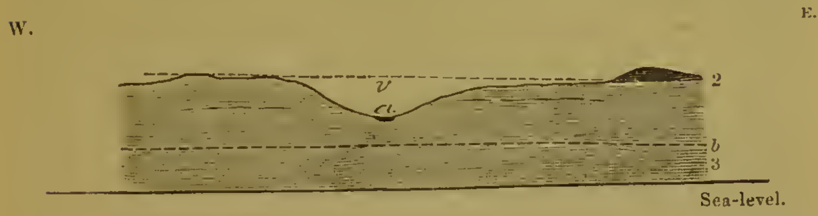
a. Level of the valley of Smitham Bottom through the Chalk-hills.
a'. The same prolonged beyond the chalk-hills southward before the denudation of the area.
3. Chalk. 4. Lower Greensand. 5. Wealden.

The section transverse to the above showing the intersection of the valley in the face of the chalk escarpment is as under (fig. 9).

The gravel at Croydon, which belongs to the earlier stages of the valley, is not that on the lower levels, which is of Post-Glacial age, but that which forms the higher banks on Duppa's Hill on the west, and Park Hill on the east of the town.

We will now revert to the earlier streams of Lower-Greensand Drift, described in pages 156–162, and connected with the primary streams or torrents flowing from off the slopes of the Wealden highlands and over the Chalk-plateau. At this period the Wealden

Fig. 9.—*Section in front of the Chalk-escarpment above Merstham.*



v. Valley of Smitham Bottom.
a. Valley Drift.
b. Level of valley at foot of escarpment.
2. Lower Tertiary strata. 3. Chalk.

anticlinal may have formed a range from 2000 to 3000 feet high, with a drainage north and south.

As the channels of the early streams became deeper and larger, and the Lower Greensand more exposed, the mass of débris carried down increased, and the proportion of chert and ragstone became greater. It was then that were formed the extensive plateaux of gravel of the Chobham and Frimley Downs, and of the other hills we have named in Berkshire, Hampshire, and Surrey.

In the absence of organic remains of any sort in these plateau-gravels, we are without a clue as to whether fluviatile or marine action had to do with their origin. It is not improbable that they are, in part, of subaerial origin; and to compare small things with great, they may have been formed in a manner analogous to the fan-shaped masses of débris carried down by torrents from the mountains bordering the plain of the Indus as described by Mr. Drew *. This would account for the localized form of these sheets of gravel, and for their absence on the intermediate Chalk-hills. It is also possible that the cone may have discharged under water, and so spread out to a greater extent and more uniformly, and with the rough sort of bedding this gravel sometimes shows.

In any case, whatever may have been the manner in which these hill-gravels were formed, there can be no doubt of the source whence the materials have been derived †. They clearly come solely from the Lower Tertiary, Chalk, and Lower Greensand, lying south of the area over which they are spread. Flints and flint-pebbles might have been brought from other directions, but the chert and ragstone are characteristic of the Lower Greensand of Kent and Surrey, and the peculiar character of some of the chert of the

* Quart. Journ. Geol. Soc. vol. xxix. p. 441 (1873).

† Prof. Rupert Jones arrived independently at the same general conclusions as myself with respect to the age and origin of the Bagshot plateau-gravels, though he ascribes more to marine action. I should have liked to give an abstract of his paper, but must refer the reader to the original work (Proc. Geologist's Association, vol. vi. pp. 437–443, 1880). The Rev. A. Irving has also written on the subject, and concluded that these beds were of estuarine origin and pre- or interglacial age (Proc. Geol. Assoc. vol. viii. pp. 161–171, 1883).

Folkestone Beds between Sevenoaks and Maidstone, spread over the Chalk-plateau to the south, renders a mistake impossible.

The time of the first appearance of the Lower-Greensand débris is significant. We have seen that the Wealden anticlinal was uplifted after the deposition of the Lenham Beds, while the first beds in which we find chert and ragstone of the Wealden area are those of the Red Crag—at least I found none in the single small exposure of the Pebble-bed at the base of the White Crag. Hence we may presume that the Wealden range was raised and became exposed to atmospheric waste at some time either towards the end of the White-Crag epoch, or very early in the Red-Crag epoch. But during the time of the Red Crag the waste was still small, and it was not until the time of the Westleton Shingle and Southern Drift, that it acquired larger dimensions—dimensions which had their climax in the plateau-gravels of the Thames Valley. These successive stages are, I imagine, coincident with the increasing cold of the period, and the increased disintegration and denuding action. If, on these limited premises—and we have none others to judge by—we might suggest time-equivalents for these several stages in the early denudation of the Weald, I would take the Well-Hill Drift to belong to the Red-Crag epoch, and the Plateau-Drifts to correspond broadly in time with the Chillesford, Forest Bed, and Westleton Shingle. A more definite concordance is hardly at present practicable: for nowhere are the hill-Drifts found in juxtaposition, and the extensive denudation of the subsequent Glacial period has swept away any connecting-links that may originally have existed, and left only the fragmentary remainders we have described.

While this glaciation was going on in the Thames Basin, it is probable that the Wealden Highlands were the centre of another snow- and ice-field, to which the denudation of that area is to be more particularly ascribed. It was this range of high land which obstructed the advance of the northern ice and the Boulder-clay, for the Tertiary hills of the Thames Valley were then only the outposts of that more important Wealden range. This ice-field may ultimately have been confluent in the Thames Valley with the great northern ice-sheet, though it may have yielded finally to it as the destruction of the Wealden range proceeded, and the obstacles to the further southward progress of the latter were removed.

6. *Relation of the Southern Drift to the Westleton Shingle and other Pre-Glacial Drifts.*

Let us now endeavour to follow the successive changes that took place from the time of the early Crag deposits down to that of the Westleton and Southern Drifts in South-eastern England and the adjacent continental area, and note the relation of these drifts one to another.

There can be but little doubt that a marine deposit of early Pliocene or Diestian age extended generally over a portion of the south-east of England and adjacent parts of France and Belgium, and that the formation of this deposit was followed by an upheaval which brought it to the surface, and gave rise to a low mountain-range on the site of the present Wealden area. We are able to fix the time with tolerable accuracy, by the absence of the later Crags in the upraised district, and by the presence of débris derived from that district in some of the deposits in the area which remained submerged.

Thus at the base of the White Crag, subangular flints, flint-pebbles, a few white quartz-pebbles, some light-coloured quartzite-* and a few sandstone-pebbles, of which one contained the cast of an *Astarte* (Oolitic ?), have been found, and with these one considerable-sized boulder of red felspar-porphyry. These afford but little guide for the direction whence they drifted. There is an absence of chert and ragstone, such as might be expected to be present if the denudation of the Wealden anticlinal had commenced or been far advanced.

With the Red Crag, we have certain proof of denudation of the Lower Greensand and of the earlier Pliocene bed, for in the Coprolite-bed at the base of the Red Crag at Sutton there are found :—

1. Large angular flints from the adjacent Chalk.
2. Flint-pebbles from Tertiary or Diestian Beds.
3. Light-coloured quartzite-pebbles.
4. Pebbles of White or Coralline Crag.
5. Pebbles of white quartz.
6. Pebbles of iron-sandstone (Diestian ?).
7. Pebbles of a light-coloured sandstone with impressions of *Pecten* and *Astarte* (Oolitic ?).
8. Subangular fragments of *chert and ragstone* (Lower Greensand).

And at the base of the Red Crag at Frimley, in addition to the above :—

1. Pebbles of fossiliferous ironstone and box-stones (Diestian ?).
2. Subangular fragment of a white felspathic sandstone.
3. A small boulder of red granite with green and black hornblende.
4. Subangular fragments of brown chert with sponge-spicules.

It is evident, therefore, that the denudation of the Weald had then commenced †, and that the Lower Greensand had been reached, although the quantity of chert- and ragstone-débris had not yet attained the proportions it acquired at a later period, when the Greensand-strata had become more worn down and exposed.

If, then, this Wealden range already existed at the time of the Red Crag, it follows that its denudation which then commenced must have been going on during the later times of the Chillesford Clay and of the Forest Bed. It was at that time probably that the winter snow and spring floods swept down the Lower-Greensand débris over the Chalk-plateau and Tertiary hills to the north. It was a period in all probability of great humidity and heavy rainfall, for there is some evidence that at no great distance to the south of the aforesaid range there were Pliocene seas with warm currents to furnish an abundant evaporation.

* In my earlier papers I used the term siliceous sandstone instead of quartzite.
† Quart. Journ. Geol. Soc. vol. xxvii. p. 353 (1872).

Following on this period, a tract extending from the east coast and reaching either as far as the district near Bath, or possibly as far as the Bristol Channel, was submerged and covered by the waters of the Westleton sea—a sea bounded by the highlands of the Weald on the south, but of which the northern barrier has yet to be defined. I am led, therefore, to conclude that the early stages of the Southern Drift preceded the Westleton Shingle (in its later stages they may have been synchronous), and either that the Westleton sea beating against a land over which the Southern Drift had spread, took up a portion of that Drift with its chert- and ragstone-fragments, or that the streams which still continued to run from off the southern hills carried down thence the Lower-Greensand débris into the Westleton sea. Superposition is wanting, and we have only the relative position and the peculiar composition of the two Drifts to guide us; for although the Southern Drift occasionally contains white quartz-pebbles, they are so few that they may have been derived from Lower Tertiary strata, or from the Lower Greensand and Wealden.

The Westleton Drift, as already explained, is, in the main, confined to the district north, and the Southern Drift to the south, of the Thames. But it is probable that on the southern slopes of the Wealden highlands and their prolongation westward, similar causes were in operation to those we have pictured on the northern slopes, that a similar Drift was there in course of formation at the same time, and that it was there subject to conditions analogous to those experienced by its equivalent in the London Basin.

As instances of such outliers, I may briefly mention Alderbury Hill, near Salisbury, the higher hills between Southampton and Winchester, and those in the New Forest between Lyndhurst and Wimborne: I have, however, now to confine myself to the Thames Basin. I would merely state further that in these districts this drift, like that on the opposite side of the dividing-range, contains a considerable proportion of *chert-* and *ragstone-*débris mixed with the angular and subangular flints of the Chalk.

7. *Main Lines of Elevation and Drainage of the South-east of England: Genesis of the Thames.*

Another point remains for consideration, and that is, the effect produced, not only on the configuration of the country, but also on the lines of drainage, by the elevation on the one hand, at an early Pliocene date, of the Wealden anticlinal, and, on the other hand, of the Westleton sea-floor in early Pleistocene times.

The east and west direction of the anticlinal of the Wealden axis necessarily gave rise to a drainage northwards into the area of the Thames Basin, and plotted broadly the direction of those valleys, which subsequently, with certain modifications, caused by minor disturbances, and by the action of glacial erosion, became the main lines of the transverse valley-system and rivers of the Weald.

The emergence of the floor of the Westleton sea was, on the contrary, effected not by any sharply-defined axis, but by flexures ranging S.W. and N.E. through parts of central England, and of which the direction is coincident with the parallel ranges of the Chalk and Oolitic escarpments in that area. The Westleton beds, when raised, consequently dipped east and south-east on an incline at right angles to these elevation folds.

The result of this has been, that whereas on the Norfolk coast the Westleton Beds are close on the sea-level, they rise westward in Berkshire to the height of from 400 to 500 feet, and northward in Hertfordshire and Buckinghamshire to 500 and 600 feet. Thus a drainage from the raised area was established to the south-east, but diverted eastward as it approached the already raised Wealden area with its northward drainage.

The Thames necessarily resulted from these tributary lines of drainage; but the river must have been restricted at first to the Tertiary and Chalk Basin, with the Kennet (passing round the Tilehurst Hills) as the main stream and source of the river. The Chalk-escarpment was not breached by the Isis until later. This river before that time probably flowed to the north-east, parallel with and between the Chalk and Oolitic escarpments, and emptied itself into the Wash on the east coast *.

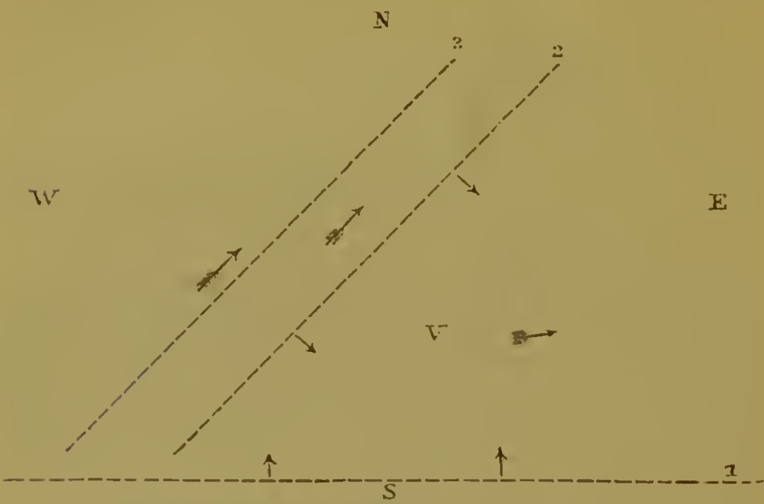
The old landmarks are, however, so obliterated by subsequent Glacial action and earth-movements that this requires confirmation. Of the fact, however, that for some time after the rise of the Chalk-escarpment, the pass of the Thames at Goring did not exist, and that the first breach through the belt of Tertiary strata and Westleton Shingle capping the Chalk-Downs was effected by a Glacial current coming from the direction of Warwickshire and Staffordshire, there can, I think, be little doubt. It was not until the gorge was enlarged by later glaciation, possibly aided by disturbances of the strata, that the Isis was diverted into this new channel, and so formed a junction with the Lower Thames and Kennet.

This may be illustrated by a diagram showing the two lines of elevation with the resultant conditions of drainage (fig. 10).

This is a branch of geology which opens some very large and interesting problems. I have treated it briefly. Owing to the vast erosion of the surface, the evidence respecting the older Drifts is generally very fragmentary, and has often been entirely swept away. Some speculation is therefore unavoidable, though it is essential that the consequences that may result from hypothetical assumptions should be in harmony with the results of observation. In putting together my notes, many new views have suggested themselves to me, and I should much like, as I have before said, to have gone over the ground again, with the object of confirming or, if necessary, correcting my early work; but that is no longer possible, and I must leave the task to my younger colleagues.

* The width of the Wash between Lynn and Boston, and the extent of the Bedford level and adjacent marsh-lands, convey the idea precisely of the estuary and alluvium of a large river, such as the Isis with its tributaries would, in the case here suggested, have been.

Fig. 10.—*Diagram of the lines of Elevation bounding the Tertiary Basin of the Thames, showing their relative Age and Direction.*



1. Anticlinal axis of the Weald (Late Pliocene).
2. Escarpment of the Chalk. } (Early Pleistocene).
3. Escarpment of the Oolites. }
V. Valley of the Thames.
→ Dip of the strata. ⇢ Lines of drainage.

8. *General Summary.*

The results of the foregoing inquiry may be summed up under the following heads:—

1. That the Westleton Shingle ranges from the Crag in Suffolk inland to the Chalk-escarpment in Oxfordshire and Berkshire, rising gradually from the sea-level, until it attains a height of from 500 to 600 feet.
2. That the Tertiary strata were co-extensive with this Shingle at the time of its deposition, and that both extended to the edge of the Chalk-escarpment, where they have been cut off by subsequent denudation.
3. That the upraising of the floor of the Westleton sea, or of the Westleton Shingle, immediately preceded the advance of the Glacial deposits, so that while they are concordant or in conformable superposition in the eastern counties, they become discordant as they range westward, and the Boulder-clay occupies valleys formed, after the rise of the Westleton Shingle, by early glaciation.
4. That the belt of Tertiary strata and of Westleton Shingle on the northern borders of the Chalk-Basin, formed originally a continuous and unbroken zone, and that this was not broken through until after the elevation of the Westleton floor and the inset of the Glacial period.

5. That none of the valleys on the north side of the Thames Tertiary Basin date back beyond the Pre-Glacial epoch, and that the whole of tho valley-system of that area is of later date.
6. That the escarpment of the Chalk, and probably that of the Oolites, in the Midland Counties, is of a more recent date than the Westleton Shingle, and therefore not older than late Pre-Glacial or early Glacial.
7. That there is a Southern Drift as well as a Northern Drift in the Thames Basin: and that this Southern Drift has been derived from the Lower Greensand of the Wealden area and from the Chalk and Tertiary strata formerly extending over portions of that area and the adjacent downs.
8. That during the early Pliocene (Diestian) epoch the Wealden area was partly or wholly submerged, and that a continuous sea extended thence over certain portions of France and Belgium, while the present Strait of Dover was non-existent.
9. That subsequently to this period, but before the in-setting of the Glacial period, the Wealden area and the Boulonnais underwent an upheaval, resulting in the formation of an anticlinal range 2000 or 3000 feet high.
10. That it was from the slopes of this anticlinal that the materials composing the Southern Drift were derived, and spread over the area now forming the southern side of the Thames Basin.
11. That this denuding action commenced at the time of the Red Crag, and was continued uninterruptedly through several successive geological stages.
12. That consequently, though the Southern Drift preceded the Westleton Shingle, the two must at one time have proceeded synchronously, though possibly at times on different levels.
13. That tho valley-system of the Wealden area had its origin after the Diestian or early Pliocene epoch,—the initial direction of the transverse valleys dating from Pre-Glacial times, and of the longitudinal valleys from Glacial times.
14. That the formation of the Thames Basin is the result, on the one hand, of the elevation of the Wealden anticlinal, and, on the other, of the flexures of the Chalk and Oolitic strata in the midland counties, and dates therefore from a period subsequent to that of the Westleton Beds.
15. That the genesis of the Thames dates in like manner from late Pre-Glacial or early Pleistocene times, whilst its connexion with its upper tributaries and the Isis took place during the subsequent Glacial period.

EXPLANATION OF PLATE VIII.

This Map shows the position of the outliers of Westleton Shingle and of the Plateau-gravels in the Thames Basin, with the lines of section given in Pl. VII. A line marks the southern limits of the Boulder-clay, but the other Glacial and Post-Glacial drifts are not given.

Discussion.

The Chairman remarked on the difficulties connected with the identification of gravels over large areas, and with the problems of Tertiary physiography.

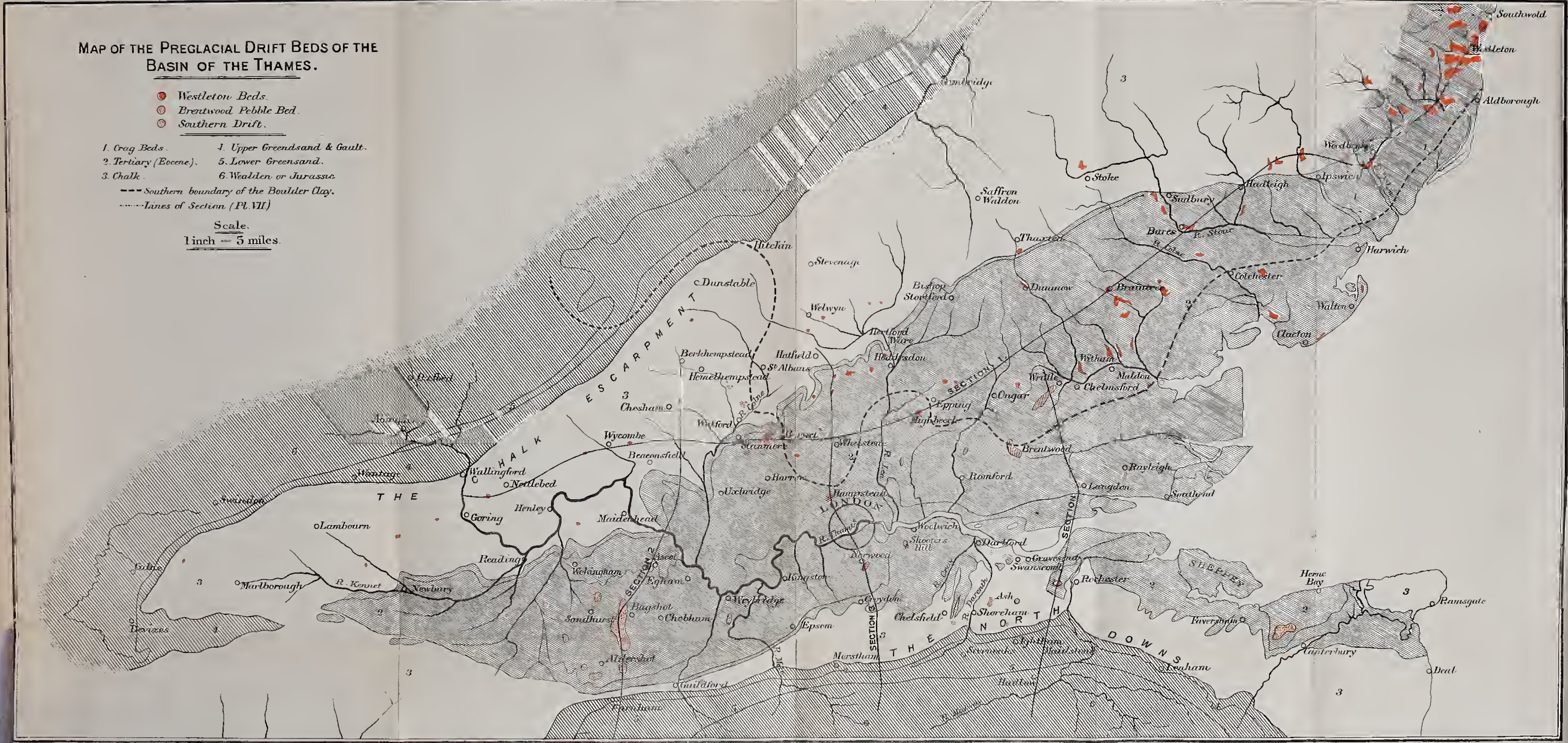
Mr. Whitaker noticed the wide range of the paper, and believed that there was no problem more difficult in the geology of the South of England than the classification of various deposits of gravel. Prof. Prestwich, he understood, put in the same class the gravels of Norwood, Hampstead, Rayleigh, and of the hills between Faversham and Canterbury. The geological surveyors had not felt that they could successfully correlate these various gravels. At Norwood, Mr. Spurrell considered the gravel was an old Wandle gravel, while he himself rather inclined to suppose it an old Thames gravel. The geological surveyors had coloured certain gravels as plateau-gravels, without any attempt to assign them to any definite age. He (the speaker) had noticed pebbles on end in many gravels. When Prof. Prestwich supposed that some gravel was synchronous with Crag-deposits, he could not follow his line of reasoning. As regards the supposed Wealden ice-field, he felt that the beds were not strong enough to carry much wear, and that the hills would soon be denuded. The pebbles in the Red Crag showed that the sea of that age extended to the Lower Greensand, pebbles of *Ammonites biplex* which had been phosphatized in Lower-Greensand times occurring in the phosphate-deposits of Red-Crag age. Between Southampton and Winchester he had seen hardly any high gravel which he was inclined to classify as Drift. He agreed with the Author as to the importance of insisting on the occurrence of a southern drift; but he pointed out the difficulties in identifying gravels by their included fragments. Whether the breaching of the escarpment of the Chalk was so late as the Author had considered it seemed to him doubtful.

Dr. Irving said that he was in accord with the Author as to the age of the plateau-gravels of Berkshire. He had published his views as to the fluviatile character of these gravels, and now brought forward evidence of glaciation at lower levels, proving their preglacial age.

Mr. Topley was interested in the distinction between Southern Drift and Westleton Shingle. He had not altogether appreciated the distinction which Prof. Prestwich had endeavoured to draw, and thought that some of the materials of a river would be eliminated as it flowed further from its source. As regards the denudation of the Weald, the Author had shown that the denudation of the Chalk had extended so far that Tertiary deposits rested directly upon the Lower Greensand. He did not follow the Author's mode of estimating the height of the Wealden hill-range, for much denudation must have succeeded the deposition of the Tertiary beds previous to the formation of the Southern Drift. He thought changes of drainage in the Weald were frequently due to the cutting back of escarpments, and he gave an illustration of the method in which this might be done. He called attention to the important earth-movements which had affected the Weald and surrounding districts, and referred to Mr. Poulett Scrope's views that during the elevation of the Weald the beds glided over others, which would account for the varying thickness of such deposits as the Gault.

Dr. Evans congratulated the Society and Prof. Prestwich on his having been able to sum the results of the observations of so many years in the series of papers which he had lately read. In taking samples of gravel, and attempting to correlate beds of gravel over a large area, mistakes might arise from local variations; but he thought that tho facts brought forward by the Author went to a large extent to confirm his views. Possibly some further confirmation might be found in the country to the west of the axis of elevation that bounded the Westleton Beds. He hoped that Prof. Prestwich would allow a longer period of time to have elapsed for the production of the physical changes he had described than he had previously allowed for Postglacial changes. As one of the older Fellows of the Society, it would have been impossible for him to refrain from saying a few words in congratulation of one with whom he himself had laboured so long.

The Author, in reply, was not surprised at the difficulty speakers had experienced in following all the details of so intricate a subject. He acknowledged the assistance derived from the admirable Drift-maps of the Geological Survey. He had differed from them in venturing upon a chronological classification of the pre-glacial Drifts. He had attempted to describe three kinds of hill-drifts—the Westleton, Brentwood, and Southern Drifts. The Brentwood Drifts certainly originated with the Bagshot Beds, but showed differences which allied them to the other Drifts. He often found a sufficient number of ragstone- and chert-pebbles to show that the Bagshot Beds had been intruded upon and disturbed. In some cases, where infiltration had been suggested to account for the upright position of the pebbles, the pebbles rested upon clay-beds, where infiltration was impossible. He had felt the same difficulty as Mr. Whitaker as to the gravels of Well Hill, and could only suppose they had been derived from a destroyed hill-range. Amongst others Alderbury Hill, three miles from Salisbury, was capped by gravel full of chert and ragstone like the southern drift of the Thames Basin. No doubt, as Mr. Topley had said, the denudation of the Weald commenced in early Tertiary times; but he believed that the great upheaval to which he, the Author, referred took place after the spread of the Lenham Beds.



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