On the age, formation, and successive drift-stages of the valley of the Darent : with remarks on the Palaeolithic implements of the district, and on the origin of its chalk escarpment / by Joseph Prestwich.

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4.

ON THE AGE, FORMATION, AND DRIFT-STAGES OF THE DARENT VALLEY.

On the Age, Formation, *and* Successive Drift-Stages *of the* Valley *of the* Darent; *with* Remarks *on the* Palæolithic Implements *of the* District, *and on the* Origin *of its* Chalk Escarpment.

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

[Plates VI., VII., & VIII.]

Contents.

§ 1. General Character and Age of the Darent Valley *.

In former papers † I have touched incidentally upon the drift phenomena of this district, and on the occurrence of a peculiar group of flint implements found on the adjacent Chalk plateau. I now purpose to limit my observations to the circumscribed valley of the Darent, which I have had more special opportunities of studying since my residence at Shoreham.

This valley, including the district surrounding it, is of peculiar interest, from the circumstance that its geological history, beginning with pre-Glacial times, may, with few breaks, be traced to Neolithic times; as also from the light it throws upon the age of some of the Thames-Valley drifts, and from its distinctive groups of Palæolithic implements. It is moreover free from the complication produced in the valleys north of the Thames by the presence of foreign-drift elements, for here the drift is restricted to débris derived from its own drainage-area.

The Darent Valley is one of the few ‡ which run through the Chalk escarpment into the so-called Wealden area §, though it does

* A general account of the drift-beds and denudation of this valley is given by Mr. Topley in his 'Geology of the Weald,' pp. 188-194, and 270, in Mem. Geol. Survey (1875), to which I shall often have occasion to refer. See also Messrs. Le Neve Foster and W. Topley's 'Superficial Deposits of the Valley of the Medway, etc.,' Quart. Journ. Geol. Soc. vol. xxi. (1865) pp. 443–474, and the Maps of the Geological Survey.

† Quart. Journ. Geol. Soc. vols. xlv. (1889) p. 270, and xlvi. (1890) p. 155.

‡ Another of these valleys, that of the Wey, was described in 1851 by the late R. A. C. Godwin-Austen in Quart. Journ. Geol. Soc. vol. vii. p. 278.

§ Taking the Wealden area to mean physiographically the whole of the area encircled by the escarpment of the Chalk.

not pass beyond the first outworks, being shut out by the range of the Lower Greensand from the central Weald. To the south of the Chalk range, the valley branches westward in the line of the main stream to near Limpsfield, and eastward to near Ightham in directions parallel with the ranges of the Lower Greensand and the Chalk, and is terminated by watersheds which separate it in the one case from the Oxted stream, and in the other from the Ightham stream (the Shode), both of which run from the foot of the Chalk hills, and flow into the central or Medway drainage-area of the Weald. The valley is thus isolated, and its basin is of very limited extent, though at one time it would appear to have been larger, in consequence of the greater importance of the affluents from the Tertiary area (see Map, Pl. VII.).

The first indent of the Darent Valley was, for the reasons given in two papers referred to in the last page, clearly subsequent to the deposition of the Lenham Sands, which are of Pliocene age, of the Red Clay-with-flints, and of the Southern Drift, while it commenced with the general great denudation of the Weald. It is therefore of late pre-Glacial or very early Glacial date *. At the former of these periods, the great valley separating the Chalk and Lower-Greensand ranges of hills was still bridged over by the Chalk and overlying strata, and it is to the denudation of these latter that both valley and escarpment are due (Pl. VI., figs. 1, 2, 3).

As the Lenham Sands are only of local occurrence, our object will be best answered by taking the Red Clay of the Chalk Plateau, with its sprinkling of Southern Drift, as our base-line. Without at present going into the question of the origin of the Red Clay-with-flints †, beyond mentioning that it is of local derivation, I may state that it is newer than the Tertiary strata, the outliers of which it encircles, while it seems to be older than the Southern Drift, with which it is closely associated.

Besides the main valleys of the Medway and Darent, the Chalk Plateau, with its "Red Clay," is intersected by a system of lesser valleys, which, starting near the crest of the escarpment, run northwards into the main valley of the Thames. These valleys commence on the Red Clay in very slight deflections on the surface, which rapidly increase in depth, and enlarge into the deeper valleys above which the Red Clay is left high on the adjacent plateau. These valleys, therefore, like the larger ones before named, are posterior in time to the Red Clay, as well as to the implement-bearing old drift with which the latter is associated. The difference of level between this older drift and the drifts of these other valleys, though

* In further proof of the sub-glacial action before noticed at the time of the Southern Drift (Quart. Journ. Geol. Soc. vol. xlvi. (1890) pp. 157, 174), I should mention that Mr. B. Harrison has since found on the summit of the Chalk escarpment at Terry's Hill above Wrotham, and at a height of 770 feet, some small angular boulders ('as large as quart measures') of the Oldbury chert, and several smaller blocks of Iron-sandstone from the Lower-Greensand range to the south.

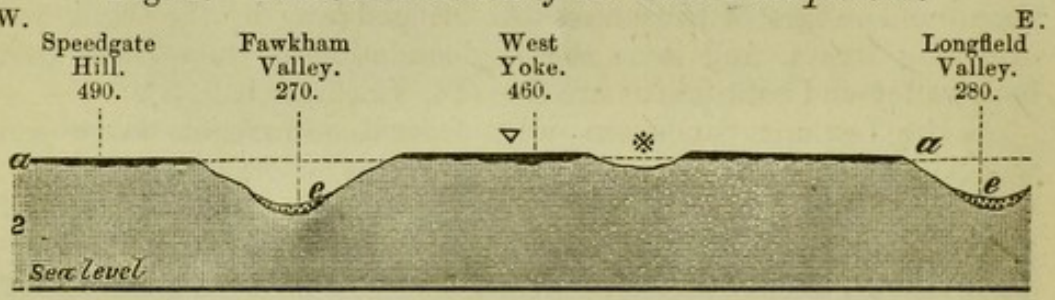
† For an account of this Red Clay, see Mr. W. Whitaker's 'Geology of London,' vol. i. chap. xviii. 1889.

necessarily small at the head of those valleys, equally indicates, as when the difference becomes greater, a marked difference of age. It will be our object to show the relation of both these valley-systems, with their drift-beds, to the Chalk-Plateau drift, and also to the Glacial and post-Glacial drifts of the Thames Valley *.

§ 2. The Chalk-Plateau Drifts and the associated Flint Implements.

Since the publication of my Ightham paper, Mr. Harrison has traced the rude Palæolithic implements of the Chalk Plateau to West Yoke, 1 mile N.W. of Ash, and very near to the line where the Red Clay with flints ends abruptly on the brow of the hill overlooking the lower plain of bare chalk, which, except where the Swanscombe Hills intervene, extends to the Thames (Pl. VI., fig. 2). The relation that the Red Clay with the associated Palæolithic implements here bears to the adjacent valleys is shown in the following section (fig. 1):—

Fig. 1.—*Transverse section of the West-Yoke plateau.*



a. Red Clay-with-flints.
e. Low-level valley-gravel.
2. Chalk.
▽. Site of Palæolithic implements of the Plateau-type.

(The vertical scale of all the general sections in the text, unless mentioned otherwise, is $\frac{1}{12}$ inch = 100 feet. The base-line represents the sea-level, and the figures which give the height above it are taken from the six-inch Ordnance maps, which are indispensable in work of this sort.)

The valleys on either side of the plateau at West Yoke are about 180 feet deep, while the small central depression (*), which eventually joins and belongs to the same valley-system, is here in an incipient state (10 to 20 feet in depth), showing that the mere question of level is not always conclusive in determining the relative antiquity of these drifts.

The great antiquity of the plateau-drifts can, however, be better realised by the N. and S. section (Pl. VI., fig. 2), which extends from the Lower-Greensand hills to the Thames, and shows the

* I use these terms for convenience, meaning to embrace the whole of the cold period from the earliest pre-Glacial to the latest post-Glacial times. The pre-Glacial, Glacial, and post-Glacial cycles pass one into another in a continuous series marked only by different and fluctuating degrees of intensity of cold. The term 'post-Glacial' conveys an incorrect meaning. 'Later-Glacial' would be a better term.

relation that these drifts bear to the river-drifts of the Thames Valley. This section passes through the summit-level of the Swanscombe Hills, which are there capped by Tertiary strata and an outlier of the older drift. Though the height of this hill does not much exceed 300 feet, it corresponds with the level that the gradient of the plateau at West Yoke and Ash should have, if extended thus far. North of this hill, at Milton Street, near the village of Swanscombe, and at a level here 200 feet lower than the plateau-drift, the high-level river-drift of the Thames Valley is met with. It contains flint implements of a distinct and more advanced type than those of Ash and West Yoke, while at a lower level still are brick-earths and gravel with Mammalian remains and implements of a yet later period. This is, I conceive, conclusive of the great antiquity of the Chalk-Plateau drift and implements, and if we are to assume, as there is every reason to suppose, that the great denudation of the valleys has been the work of Glacial times, then these implements may probably be assigned, as I have before suggested, to a pre-Glacial or early Glacial period.

The plateau which constitutes the table-land west of the lower Darent Valley presents features precisely similar to those at Ash, Bower Lane, and other places on the plateau east of the Darent Valley. There is the same spread of Red Clay-with-flints over all the Chalk Plateau, and the same slight sprinkling in places of a drift of much worn brown-stained flints, with a few subangular fragments of chert and ragstone from the Lower Greensand *. I have found this drift on the hills just above Shoreham. Chert and ragstone are particularly abundant in the field over the railway tunnel opposite Colegates Farm. They occur less abundantly around Halstead, and have been found by Mr. Harrison on the very summit of the escarpment, at a height of 700 feet, on Morant's Court Hill (see Pl. VI., fig. 3). Farther west, Mr. De B. Crawshay has found the brown-stained worn flints on Betsom Hill (790 feet) above Westerham, and on Titsey Hill (864 feet) above Limpsfield, both being on the crest, and forming the highest summit-levels of the Chalk escarpment. The intermediate ground between Morant's Court Hill and Betsom Hill has at present yielded no specimens, though the Red Clay-with-flints is continuous throughout. On the hill above Stonehouse, north of Halstead, I have found a considerable proportion of the brown-stained flints with numerous Tertiary flint-pebbles, some Tertiary sandstones, and a little Lower-Greensand débris.

At the time my Ightham paper was read, the only Palæolithic flint-implement known on this western plateau was the one at Currie Farm, south of Halstead †, found 20 years ago and described by Dr. John Evans. Its surroundings and position were such as to lead me to group it with the Ash specimens as of early Glacial or pre-Glacial age. My friend Dr. Evans, however, considered that

* I include any Lower-Greensand débris, such as grit and ironstone.

† The Rev. R. Ashington Bullen, the Vicar of Shoreham, has recently found a very similar specimen in the same field.

although it was found at the high elevation of nearly 600 feet, the position of the site above the extreme head of the valley of the Cray was so slight that this specimen might belong to the later or post-Glacial * drift of that valley, and not to the older level to which I would assign it. The lines of drainage of the Cray Valley being also from south to north confirmed him in this opinion†. If such a view could be sustained, it might invalidate the antiquity of the Currie-Farm specimen, and by inference the antiquity of those of the Ash district. But though it is true that both drifts are due to currents from the south, the one system of drainage which extended from the central Weald was in existence before the excavation of the Holmesdale Valley, whilst the other (the present Cray and its tributaries) dates from a period subsequent to the severance of the Chalk Plateau from the Lower-Greensand hills.

We now, however, have more decisive corroborative evidence of the age of the Currie-Farm specimen. Some time elapsed before any new locality was discovered in this district, but within the last two years Mr. De B. Crawshay has found similar implements at other localities on the N. of Halstead. The interest of these finds is that they occur on the northward prolongation of the Red-Clay plateau at a point where, owing to the valley gradient being more rapid than that of the plateau gradient, the difference of level between them—which near Currie Farm does not exceed a few feet —amounts to more than 100 feet. At one spot, 1½ mile distant from Currie Farm, 480 feet above O.D., and a little north of Stonehouse (fig. 2), Mr. Crawshay has found seven flint implements, two of which are of the rudest Ash type and of the usual dark-brown colour, whilst five are of a light yellow colour and more closely allied to those found at Snag Lane (see p. 145). These latter were found on one of the Broke-Farm fields and may be of later date.

North of the valley and beyond the Halstead station, Mr. Crawshay found a large rude flake on Hewit's Farm at the level of about 470 feet, and more to the east, on the edge of Shacklands Wood (525 feet), two stained flakes. In another direction, on a hill where Tertiary flint-pebbles abound, west of Northstead Farm, he records four implements of the Ash type. All these places are on the Red-Clay plateau, here intersected by the dry upper Cray Valley and its tributaries, between which the Halstead and Northstead hills project as promontories, as shown by the plan and section on the next page, figs. 2 and 3. East of Well Hill, at the level of about 430 feet, Miss H. Waring found a pointed specimen of the Amiens type on Cockerhurst Farm, near Shoreham.

Farther westward, Mr. Crawshay has discovered on the highest summits of the Chalk escarpment three other implement-bearing localities. The first of these is at Betsom Hill, near Westerham, at the height of 750 to 790 feet; the second is a little off the summit

* 'Ancient Stone Implements of Great Britain,' p. 531.
† Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 295.

at Ivy Cottage, near Tatsfield, at the level of 780 feet, and the third at Titsey Hill, where the escarpment attains its greatest height of 864 feet (see Pl. VI., fig. 3).

Fig. 2.—*Plan of the Halstead and Northstead promontories.*

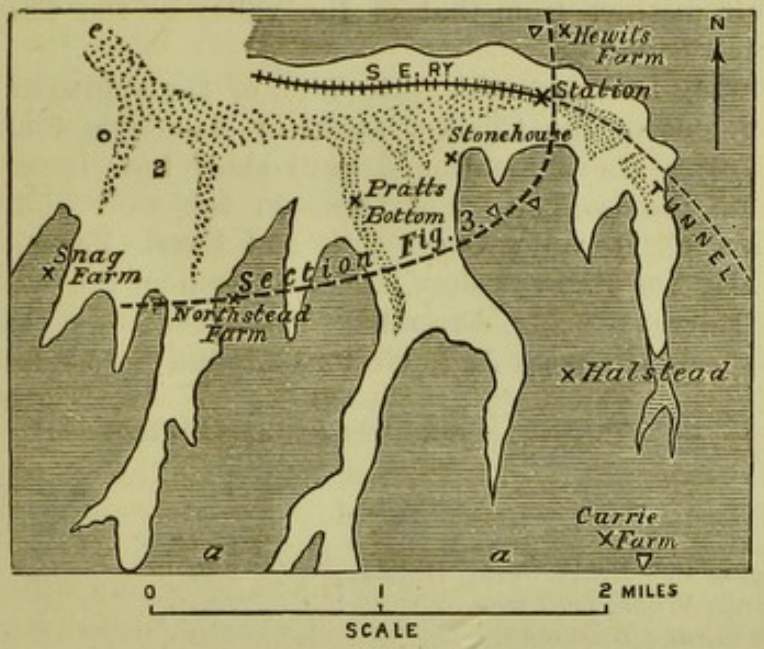
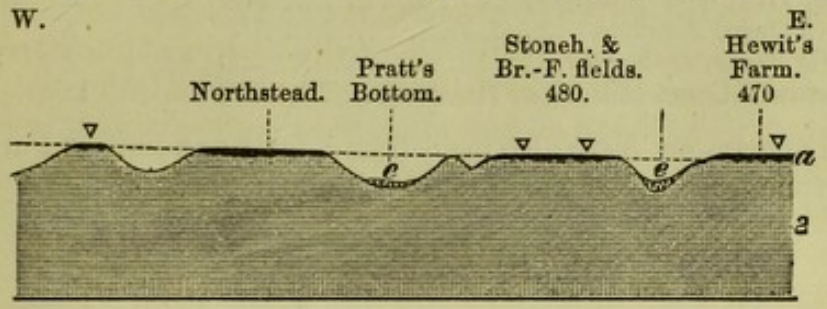


Fig. 3.—*Transverse section* (1) *across the promontories.*



a. Red Clay-with-flints and a sprinkling of the Southern Drift.
e. Unstratified Flint-gravel lying in the dry bed of the upper valley of the Cray and its tributaries. The only trace of fossils in this gravel was a small fragment of bone found near Pratt's Bottom, but at Green Street Green, two miles lower down the valley, where the gravel acquires much greater thickness, bones of Mammoth, Rhinoceros, Musk Ox, &c. have been discovered.
▽. Site of flint implements of the Plateau or Ash type.
o. Site of implements of the high-level River-valley type.
2. Chalk.

Still more recently, Mr. Harrison has found an outlier of the brown-stained-flint drift, together with some scarce rudely-fashioned flints, on the top of Morant's Court Hill, forming the very summit of the escarpment south of, and ¾ mile distant from, Currie Farm. They are scattered on the surface of two fields within the 700-feet contour-line. This ground cannot possibly be connected with any existing line of drainage, as it forms the summit-level of that part of the escarpment. Its position relatively to Currie Farm and Halstead, as

also to the escarpment, is given in Pl. VI., figs. 1 and 3, the former showing the gradient of the plateau from Morant's Court Hill to the Cray Valley, and the latter the relation of the hill to the adjacent part of the escarpment. These make it evident that the older drift is clearly independent of both the valley-systems, and that the drift on this Chalk plateau, like that on the Ash plateau, is of greater antiquity and distinct from that of the valley of the Cray and its tributaries.

The following lists, brought up to date, of the approximate number of specimens of the Chalk-Plateau or Ash type, found at the several localities above mentioned, will show how important this plateau-group has become. For those on the west plateau, with the exception of Morant's Court Hill and Currie Farm, I am indebted to Mr. De B. Crawshay, and for those on the east plateau to Mr. B. Harrison. Mr. Crawshay has likewise a considerable number of specimens from Ash, West Yoke, and Bower Lane.

Chalk Plateau, West. (See Map, Plate VII.)

	Height above sea-level in feet.	Implements.	Flakes.
1. Stonehouse and Broke Farm, Halstead *	480	5	2
2. Shacklands Wood, field west of	535	0	2
3. Hewit's Farm, Chelsfield	470	0	1
4. Northstead, hill west of	485	3	1
5. Betsom Hill, near Westerham	790	15	
6. Titsey Hill, near Limpsfield	864	3	
7. Ivy Cottage, Tatsfield	780	8	
8. Currie Farm, Halstead	590	2	
9. * Morant's Court Hill, S. of Halstead	700	12	

Single specimens have also been found farther north at Park Gate, Lullingstone, and at Cockerhurst, both above the 400-feet level.

Chalk Plateau, East.

	Height above sea-level in feet.	Number of Implements †.
1. Ash	490	80
2. South Ash	520	60
3. West-Yoke Farm (1 mile N.W. of Ash)	460	40
4. Kingsdown	550	4
5. Peckham-Wood Corner	637	2
6. Plaxdale Green	630	2
7. Bower Lane (inclusive of Mr. Crawshay's specimens)	520	30

But these ancient implements are not confined to the central area alone of the broad plateau. They extend, as on the west plateau, to the very crest of the escarpment, up to its highest summit-levels of between 700 and 800 feet (see Pl. VI., fig. 3). Mr. B. Harrison has found them at:—

* I also have found a few specimens at these places.

† A large number were moreover thrown away as duplicates, or as not worth keeping.

	Height above sea-level in feet.	Number of Implements.
1. Wrotham Hill	760	6
2. Fairseat, near Wrotham	690	2
3. Plot Farm (near Fairseat)	697	2
4. Terry's Lodge Hill (above Yaldham)	770	6
5. St. Clere's Hill (the fields by the side of Birches Wood)	760	12
6. Drain Farm, above St. Clere	725	10
7. Porter's Farm (near Romney Street)	698	3
8. Cotman's Ash (above Kemsing)	665	2

In several cases it is noticeable that the implements occur on or near small Tertiary outliers, as though they might have preceded the Red Clay-with-flints, and had been brought to the surface by subsequent denudation. At Ash Lower-Tertiary sands crop up on the surface; at West Yoke the same sands appear at a short distance; near Terry's Lodge a Lower-Tertiary clay was formerly worked; and at Bower Lane Mr. Crawshay found a bed of Mottled Clay (Reading Beds) under a thin bed of the Red Clay-with-flints. On the west plateau, sands and pebbles of the Woolwich Beds constantly appear in close connexion with the Red Clay. I mention this merely to draw attention to the fact and suggest further enquiry.

The question as to the probability of these implements having been dropped, like the Neolithic implements, at these places at a period subsequent to the plateau-drift *, has been before disposed of, for whereas the Neolithic implements have always remained on the surface and have undergone no alteration except a slight weathering and bleaching of their surfaces, these others are stained, spotted, and altered in a manner to show that they have been long embedded in a distinct matrix †, and have all the characters of the flints forming part of the drift with which they are associated. Still we want the confirmation to be afforded by finding them *in situ* in an undisturbed bed ‡.

As before mentioned, the shape of the plateau-implements is also of a peculiar character. They are mostly very rudely-trimmed flint-fragments taken from an old gravel, though there are exceptions to this rule, for, with the many rude specimens, a few of more perfect forms are occasionally met with. Thus a large ovoid implement, as well finished as those of Abbeville, was found at Bower

* One specimen recently found between Bower Farm and Romney Street by Mr. Bullen seems the result of such an accident. It is distinctly Palæolithic, and of the flat spear-head type so common in the post-Glacial beds of the valleys of the Thames and Somme, yet in general external appearance it resembles the Neolithic specimens found on the same ground, being of a uniformly dull white colour, slightly patinated and iron-stained at the edges by plough or spade, and showing none of the ferruginous incrustations or discoloration so general on specimens of the older or Ash type. The point is broken off by an old fracture. When perfect, it must have been 7 inches long by 4 inches wide at the haft.

† See Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 288 and pl. xi.

‡ Since writing the above Mr. Harrison has obtained a well-finished and well-preserved flat ovoid specimen, found at a depth of 2 feet in planting a tree at South Ash.

Lane, and a few better made specimens occur at Ash. Some might pass as specimens of the valley-drifts, but there is so far an almost entire absence of the highly-finished spear-head forms so common at those levels *. Nineteen out of twenty or more are rude ill-shapen stained flints with a small amount of work at the edges. Those figured in Plate VIII. are characteristic forms typical of this plateau-group. (See Explanation of Plate, p. 160 †.)

Fig. 1 in that Plate is merely the broken half of a Tertiary flint-pebble slightly trimmed at the edges for cutting or chipping. Another common form (fig. 2) is a piece of tabular or flat flint with flat edges, notched as though it had been used for breaking or shaping other flints. Others (fig. 3) are rude or natural flakes ‡ worked at the end for graving and scraping. Fig. 4 is a thick natural flake chipped at the edges and brought to a point; this specimen is interesting, as the type out of which the more highly-worked pointed implements so common in the later valley-drifts would seem to have been evolved. A very common form is a scraper in the shape of a crook, sometimes single (fig. 5), sometimes double (fig. 6), such as might have been used for scraping round surfaces like bones or sticks. There are other forms besides, but, with the few exceptions before mentioned, they are all merely rough natural fragments, picked out of the gravel, and more or less worked at the edges to adapt them to the simple wants of a people who seem at that time to have hardly been acquainted with the art of obtaining flints direct from the Chalk, as was done in later Palæolithic times. Such specimens exhibit the very rudiments of artificial work, and are often difficult to distinguish from natural forms. The interest which attaches to them is that they point to the very infancy of the art, and the application of the most common and readily available surface-materials to the fashioning of tools or weapons for use by early Palæolithic man.

It may be objected that the sites in the valleys of the Somme, Thames, &c., yielded so many finished specimens that the ruder forms have been overlooked; but this does not apply to those in this district, where the valley-specimens and plateau-specimens have received equal attention at the hands of Mr. A. M. Bell and Mr. Harrison, and none, however rude, have been rejected. Each series is completely represented in every respect.

The peculiarity of type by itself might not be sufficient, but taken in conjunction with the geological evidence, and subject to the reservation before mentioned, the evidence in favour of the great

* I see no force in the objection that, because a few rare well-finished specimens are found, the whole group must be judged by them. It only shows that there were a few superior workmen among the unskilled many. The suggestion that similar rude specimens may be found in the valley-gravels is at present without any proof.

† Both the rude implements and the brown natural flints with which they are associated are so alike stained, worn, and abraded, that it has even occurred to me whether they might not all have been washed down together from the old Wealden uplands.

‡ Artificial flakes are extremely rare on the Chalk Plateau. This implies the use of natural fragments, as the breaking down of blocks of flint from the Chalk would have led to scattered heaps of waste fragments and flakes.

antiquity of the plateau-specimens is, I think, conclusive. I may further remark that at Ash the Neolithic flints, which are found on the same surface with the Palæolithic flints, are in no wise different from the ordinary Neoliths found elsewhere on the Chalk and other surfaces. They are merely weathered white, have no colour-staining, and are readily distinguishable at first sight from the older forms.

Another feature to notice in connexion with these specimens is the amount of rolling and rubbing they have undergone. The flatter surfaces are sometimes covered with scratches, which occasionally bear a close resemblance to glacial striæ (Pl. VIII., fig. 7; see explanation of Plate); but I have seen none, unless it be the one figured, sufficiently regular to be ascribed with certainty to that cause, though the scratches are evidently of old date.

Occasionally a derived specimen of the older type is to be found in the newer drifts. Though more worn, they retain their dark-brown colour, and are easily distinguishable from the group with which they have become associated. I possess one of the type of fig. 6 (Pl. VIII.), found by Mr. E. Lewis at Limpsfield; Mr. Crawshay has two similar specimens from Snag Lane; and Mr. B. Harrison a rude scraper from West Yaldham, and another specimen from Crowdlesham. Other places might be named, but these will suffice and explain the presence of these ruder implements.

I had often met with stained and worn flints on the Sussex and Hampshire hills, similar in character to those of the Southern Drift on our own Kentish hills, but had not hitherto seen any flint implements of the old Ash type. Recently, however, Mr. Harrison has placed in my hands four such specimens, found by his friend Mr. R. Hilton, of East Dean, on the Chalk ridge * at Friston, near Eastbourne, and at the height of about 390 feet above sea-level, and of 200 feet above the level of the adjacent valley. Three of them are natural fragments of flint, slightly worked at the edges, one being similar to fig. 3 (Pl. VIII.). Another is a better finished pointed form, worked on both sides, and very much worn. They are of the usual dark-brown colour, and show much wear, and on one there are the same traces of ferruginous incrustation as that which is common on the implements found at Ash. This discovery tends to confirm a suggestion I made in a former paper † when speaking of the Southern Drift of the Thames Valley, that it was probable that on the southern slopes (in Sussex and Hampshire) of the Wealden highlands a similar drift was in course of formation at the same time, and that it was then subject to conditions analogous to those experienced by its equivalent in the London Basin.

§ 3. The Initial Stages of the Darent Valley.

I have before shown that in early Pliocene times a plain of marine denudation stretched across from the Chalk escarpment to the Wealden area, passing over the present Vale of Holmesdale, and that

* In the valley at East Dean Mr. Hilton had previously found Palæolithic implements of the ordinary river-valley type.

† Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 176.

in subsequent pre-Glacial times this plain was scored by streams flowing off a central mountain-axis*. The smaller streams, gradually becoming tributary to the larger one, centred in the Darent, and the excavation of the present valley then commenced. There is a gap or break in the sequence between the pre-Glacial drifts and the earliest of the so-called post-Glacial drifts of the valley, which is probably covered by the extreme Glacial epoch. It was then a time of erosion and denudation, and the record of it in this area is to be found, not so much in beds of drift and gravel, as in bared broad valleys and scarped ridges.

Of the earliest drift of the Darent Valley there is little that has escaped later denudation. The bank of coarse gravel on the brow of the hill on the west side of the valley between Eynsford and Farningham—a gravel abounding in a large proportion of Lower-Greensand débris and extending from the height of 280 to 360 feet —affords probably the best example.

The traces of flint drift scattered, in the upper part of the valley, on the slopes of the Lower-Greensand range, may possibly belong to this epoch, but I speak with doubt. Thus at Kent Hatch, above Westerham, at the level of 600 feet, there is a sprinkling of unstained subangular flints, with a few worn brown-stained flints, and there is a similar patch on the same level in the field to the west of the Union Workhouse, above Sundridge. At Fawke Common, near Sevenoaks, the same thing occurs. At the latter place, Mr. Crawshay has found a small, well-shaped flint implement. To these may be added the instance before mentioned of a thin covering of flint drift with some flint implements † at Bitchet and Stone Street, near Ightham, at the height of 530 feet ‡. Although these drifts are mere handfuls, they are significant, inasmuch as their materials are foreign to the area where they are now found.

Another minor fact pointing to an early stage in the erosion of the valley is the indication, which exists on the bare sides of the hill west of Shoreham, of an old line of water-level, at a height of 400 feet above O.D., or of about 200 feet above the present stream. At the point ⁎ (fig. 4) is a band of a compact breccia, about 10 to 12 feet broad, extending horizontally for some distance along the brow of the hill. It consists of angular fragments of chalk consolidated by a calcareous infiltration, and rendered so hard that it requires a smart blow with a hammer to break it. It appears to have been originally a talus of chalk fragments, such as would accumulate at the foot of a chalk slope or cliff, and to have been concreted by a calcareous cement into this brecciated rock by a spring charged with carbonate of lime in the manner of an ordinary travertine. But at this spot there is no impervious stratum to give rise to a spring. The Chalk, which rises to a height of 120 feet above the point (⁎),

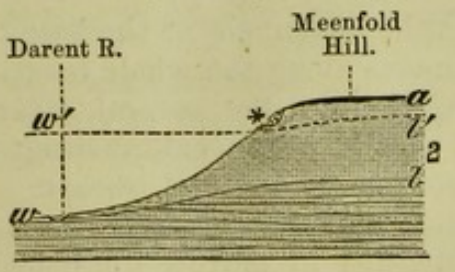
* Quart. Journ. Geol. Soc. vols. xlv. (1889), p. 291, and xlvi. (1890) p. 171 *et seq.*

† They are those which I have placed in the second or 'Hill' division in the Ightham paper.

‡ Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 276.

is perfectly homogeneous, and allows the surface-water to pass through it and descend to the underground water-level, *w l*—a level governed by that of the adjacent stream; and I can only account for a spring in the high position of (*) by supposing that one may have broken out there at the time when the bed of the valley had not been excavated to below that point, when the line *w' l'* would

Fig. 4.—*Section of Meenfold Hill, Shoreham.*



a. Red Clay-with-flints.
*. Compact Chalk breccia.
w l. Present line of water-level.
w' l'. Supposed former line of water-level.
2. Chalk.

represent the then level of the underground water, and consequently of the springs; for in that case springs would be thrown out on the higher level *w' l'*, as they are now on the lower one *w l*, independently of any impervious stratum. This, therefore, may be taken as some evidence of the higher level probably occupied by the stream at that period.

§ 4. The High-Level or Limpsfield-Gravel Stage.

I have already had occasion to notice in a former paper * some of the few drift-beds in that branch of the Darent Valley which runs eastward from Otford to its watershed with the Shode—a tributary of the Medway. Those of the more important western or main branch of the Darent Valley running up to Westerham and Limpsfield Common have now to be noticed. (See Map, Pl. VII.)

The first appearance of a well-marked drift connected with the river-erosion of the Darent Valley is the high-level gravel on the watershed at Limpsfield Common. The denudation of the area had by that time made considerable progress; for the Chalk escarpment rises 200 to 300 feet, and the Lower Greensand 100 to 200 feet, above the level of this gravel-bed. With the exception of the few isolated traces named in preceding paragraphs, there is nothing to record the work of early excavation of the valley, though it is obvious, for the reasons before given, that the valley-erosion, which followed on the pre-Glacial rise of the land, must have continued through the succeeding Glacial epoch; and as there is evidence to show that extreme climatal conditions prevailed during that period in the Thames Valley, it may be presumed that ice and snow were

* Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 270.

then likewise effective agents in the denudation of this adjacent district. Before, therefore, the deposition of this river-drift, a valley of considerable width and 200 to 300 feet deep had been excavated between the Lower-Greensand hills and the adjacent Chalk plateau, by which the future Chalk escarpment was first brought into relief. This channel (which is on the line of the Gault) was subsequently worn deeper, and the escarpment loomed higher when, in later Glacial and post-Glacial times, river- and flood-action played a more prominent part.

But the present valley-channels at the base of the Chalk escarpment are not continuous along the whole length of the escarpment. They each have relation to the several rivers which drain the Wealden area, and each has its culminating point or watershed intermediate between these lines of escape. Thus the Darent, which drains into the Thames, is separated from the adjacent valleys draining into the Medway by narrow watersheds projecting as low ridges between the Chalk escarpment and the Lower-Greensand hills. This is a feature common throughout the great primary valley, which extends all along the base of both the North and South Downs, and is one of the many conclusive arguments against the marine origin of the escarpment, as that would necessitate a uniform level line for its base, whereas the line forms a succession of rises and falls (see line *mn*, fig. 3, Pl. VI.). Amongst the most remarkable of these watersheds or cols is the one which intervenes between the Darent and the Oxted stream—a small tributary of the Medway—at Limpsfield. Whilst in general these passes rarely rise to the height of more than 200 or 300 feet, in the Limpsfield case the summit of the pass which connects the Chalk range with that of the Lower Greensand attains a height of rather more than 500 feet above O.D. The relation of the pass to the adjacent ranges and river-basins is shown in the sections on the next page, figs. 5 and 6.

The position of the gravel on the watershed is so equally balanced between the Darent and the Oxted Valleys that, independently of other evidence, it would be difficult to decide to which of the two it belonged. But, as I shall have occasion to explain farther on, it shows so close a relation with other beds of gravel lower down the Darent Valley that I quite concur with Mr. Topley * in placing it in that valley-system, and we can only suppose that the original ridge separating the two valleys, of which Westheath Hill, which is 516 feet high and bare of drift, may be a remaining portion, has been removed by denudation subsequently to the deposition of the gravel.

The character of the Limpsfield gravel is very distinct. It consists altogether of débris from the Tertiary strata and the Chalk, with the exception of a small portion derived from the substratum of Lower Greensand. A fine section of it is exposed in the old pit on the north side of Limpsfield Common. It is there from 8 to 10 feet thick, and is composed of the following materials—given in the order of their relative abundance—embedded in loam and clay

* Topley, 'Geology of the Weald,' pp. 193 and 289.

of a burnt-sienna colour, in places mottled with yellow, and roughly heaped or piled together without apparent bedding, although there are here and there lenticular seams of sand and loam, and resting on a nearly level base of Lower Greensand :—

1. Tertiary flint-pebbles of all sizes—some very small and some broken—in profusion. Mixed with these in a nearly equal total are—
2. White flints, many in small angular fragments, some subangular and worn, and some in large blocks but little altered.
3. Many angular fragments of through-stained yellow flints.
4. Some subangular fragments and a few large blocks (one 20″×20″×8″) of iron-sandstone.
5. A few brown-stained, much-worn flints.
6. A few worn pieces of Tertiary sandstone and Pudding-stone.
7. A very few rare, light-coloured, flat, ovoid quartzite pebbles.

Fig. 5.—*Section along the watershed at Limpsfield.*

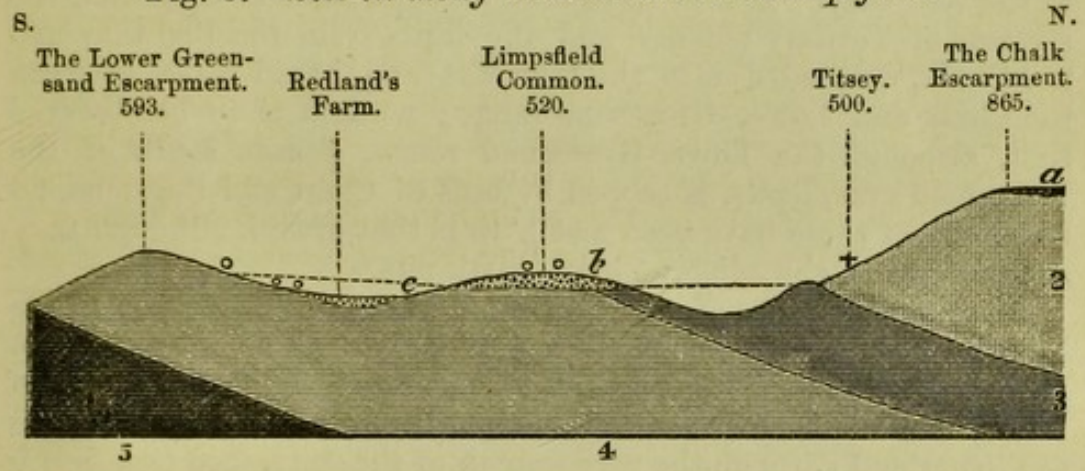
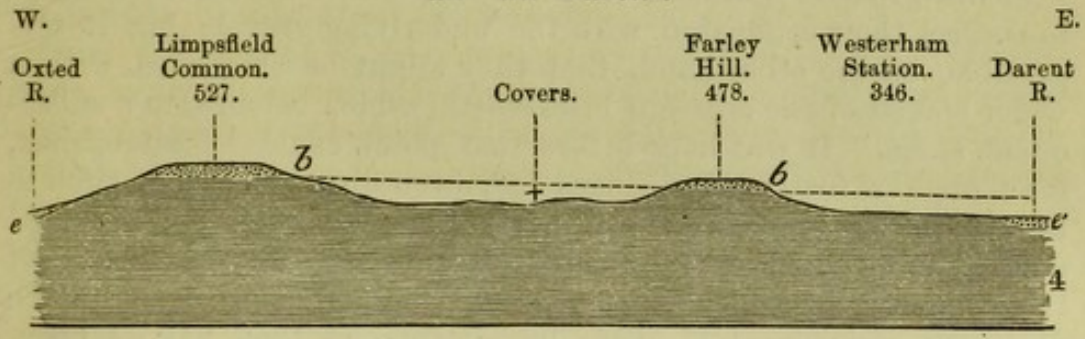


Fig. 6.—*Section across the pass between the Oxted stream and the Darent.*



a. Red Clay-with-flints of the Chalk Plateau.
b. High-level ochreous flint-gravel.
c. Brick-earth and trail.
e. Low-level Gravel.
o. Site of Palæolithic flint-implements of the high-level valley type.
2. Chalk.
3. Upper Greensand and Gault.
4. Lower Greensand.
5. Upper-Wealden strata.

The Iron-sandstone comes from the underlying Lower Greensand, and the quartzite-pebbles are derived, not from the New Red

Sandstone, but from the pebble-beds of Lower-Eocene (Woolwich) age.

The composition of this gravel renders it obvious that it is derived from the Chalk and Tertiaries on the hills to the north of Limpsfield. The escarpment is there capped by the Red Clay-with-flints, with isolated outliers of Tertiary strata. One of the most important of the latter, consisting chiefly of a mass of flint-pebbles, occurs at Worm's Heath, three miles north of Limpsfield. It has there been much disturbed, and the pebbles are mixed with numerous angular and subangular flints. Elsewhere on the escarpment there are some less disturbed pebble-beds. The escarpment at Titsey above Limpsfield rises to the height of 800 feet to 866 feet, but there are depressions where the level is from 50 to 100 feet lower, while near Warlingham there is a gap which is still lower by 100 feet, and bare of the Red Clay. It may have been through some of these that the streams of Tertiary pebbles, and the flints from the Red Clay and the Chalk, descended into the then flat and broad valley between the Chalk and Lower-Greensand range; while it is to be observed that, although the Lower-Greensand range, $\frac{3}{4}$ mile south of the Limpsfield gravel-pits, is capped by beds of Chert and Ragstone, no fragments of these have been met with in that gravel, although they are common in the adjacent brick-earth pits.

No organic remains of any description have been discovered in the Limpsfield gravel *, though it has been worked for many years. Mr. A. Montgomery Bell has, however, found a large number of Palæolithic implements on the Common, and over the adjacent fields of Broomsland Farm on the very summit of the watershed (see figs. 5 and 6). They are mostly of the pointed and ovoid types, similar on the whole to the smaller Amiens implements, or to those I have named "the hill-group of Ightham"†. From their position, there was reason to suspect their connexion with the underlying gravel; but it was possible, on the other hand, that they might be associated with a wider spread of the adjacent brick-earth, which belongs to a subsequent stage. It was long before that point could be established, for though a few worked flakes had been discovered from time to time in the gravel, it was not until last year that Mr. Bell obtained a large, well-finished, pointed implement, grey and patinated, of the ordinary St.-Acheul type. I will not enter further into the discovery and spread of these implements, as they will, I hope, shortly be described at length by Mr. Bell, to whose persevering researches their discovery is due.

As the Drift-gravels of the Darent Valley have been described by Mr. Topley, I need only notice them so far as they assist in connecting the Limpsfield bed with known horizons in the Thames Valley, or with those drift-beds that have been brought to light by sections made since the date of his memoir. He remarks of the Limpsfield gravel that the most interesting point about it is that it

* I first visited this and the adjacent pits in search of Mammalian remains in 1849.

† Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 284, and pl. x.

lies *on the watershed* *, and, though related to the Darent Valley, cannot be referred to that river in its present form †. He observes also that it is quite certain that the gravels of the Darent Valley westward of Westerham have a distinct relation to that of Limpsfield (*op. cit.* p. 193). In this I quite agree, but I would extend the relation considerably beyond these limits; for, although the detached outliers lower down the valley are affected by local conditions, their general characters are alike.

It is in this older and wider floor, of which only few portions now remain, that the present valley-channel has been excavated. One of these remaining portions caps Farley Hill, near Westerham, two miles east of Limpsfield Common, and a short way north of the course of the Darent (fig. 6, p. 139).

The bed of gravel there is not so thick as at Limpsfield, and, like it, is unstratified or very rudely bedded, and consists essentially of angular and subangular flints with Tertiary flint-pebbles, but the latter are in less proportion. Fragments of iron-sandstone from the Lower Greensand are common, with a few rare specimens of Lower-Greensand grit and of pieces of Tertiary conglomerate. There are no organic remains, nor have any flint implements been hitherto found, but there has been no long and sustained search like that Mr. Bell has made at Limpsfield ‡. The difference of level between the two beds is 51 feet, which gives to the old river-channel a gradient of 25 feet to the mile.

On the opposite side of the Darent, in the grounds of Squerryes Court, and at a similar level (478 feet) there are traces of the same gravel. These outliers are on a level of 116 feet above that of the present stream of the Darent. Mr. Topley describes another small outlier on the roadside E. of Squerryes Court and at about the same level, and one on Moorhouse Common, between Limpsfield and Westerham, at the height of 485 feet §.

From Farley Hill no high ground breaks the view for a distance of five miles down the centre of the valley. The few patches of the high-level gravel are all on the south side of the valley, and lie on the slope of the Lower-Greensand hills. One is to be seen in a small pit in the south-east corner of the grounds of Brastead Park ‖, $2\frac{1}{2}$ miles from Westerham, and at a height of about 430 feet above sea-level. The gravel is very similar to that on Farley Common, but is more sandy and with more Lower-Greensand débris, including large blocks of Iron-sandstone, and some fragments

* On the east branch of the Darent Valley there are analogous but more obscure remnants of gravel on the watershed at West Yaldham and on the north slopes of Oldbury (see Pl. VI., fig. 1, and p. 143).

† For Mr. Topley's discussion on this question, see 'Geology of the Weald, pp. 289, 297, 298. He thinks the original river must have taken its course farther to the W. or S.W. than now.

‡ From this hill one has an excellent view down the valley, showing the relation which this gravel bears to the Darent, to the Chalk Downs, and to the Lower-Greensand range.

§ 'Geology of the Weald,' p. 194.

‖ *Op. cit.* pp. 191, 192.

of Ragstone, but there the Lower-Greensand hills are prolonged above the pit. Between Sundridge Place and Dryhill, nearly a mile farther down the valley, is another well-marked outlier forming a small knoll a little above the 400-ft. contour-line. This gravel, which is very sandy, is not worked, and we can therefore judge of its composition only from surface exposures. These show it to consist of:—

1. Angular and white, and other slightly subangular flints.
2. Tertiary flint-pebbles of all sizes.
3. Subangular pieces of Chert, Ragstone, and Ironstone, much worn.
4. Numerous very subangular brown-stained flints.

I could not determine their relative proportions, but the large proportion of Lower-Greensand débris, and of the stained flints, mostly of small size, is very noticeable. Many of the flints show the ragged sponge-structure so common with some of the layers of flint near the summit of the Chalk escarpment. I noticed also a large piece of much-worn Sarsenstone *.

From Farley Hill to the Sundridge outlier (410 feet) is a distance of a little over three miles, and the difference of level amounts to 68 feet, giving a gradient of $22\frac{2}{3}$ feet to the mile, or taking the whole distance from Limpsfield, of 24 feet to the mile.

In descending the valley from Sundridge, the next important outlier is on the opposite side of the Darent, and, like the outlier at Farley, it rises considerably above the surrounding plain. This gravel, which caps Broughton Hill †, near Dunton Green (Pl. VI., fig. 1), is more stratified than the Limpsfield bed, and contains a less proportion of Tertiary flint-pebbles, and a larger proportion of Lower-Greensand débris; but this arises from its being farther from the source of the Tertiary pebbles, and from the increased number of affluents from the Lower-Greensand hills. It more nearly resembles the Sundridge-Knoll gravel, consisting, in the order of relative abundance, of:—

1. Subangular Chalk flints of all sizes, with some angular ones.
2. Numerous Tertiary flint-pebbles.
3. A good many subangular Chert and Ragstone fragments.
4. Much worn and stained brown and ochreous flints.

Embedded in a light brown or reddish clay, with some seams of sand.

This hill is 357 feet high, and $2\frac{1}{2}$ miles distant from the Sundridge outlier, which, taken at 410 feet, gives a difference of level of 53 feet, or a gradient of $21\frac{1}{2}$ feet per mile, but the line here drawn is a little devious.

A short distance beyond, the two branches of the valley meet, and pass through the Chalk escarpment. The few high-level gravels in the eastern branch of the valley are still more fragmentary and imperfect than those in the western branch. I have before mentioned

* Mr. Topley also mentions a patch of gravel in Montreal Park, a little above the 300-ft. contour-line. I have not seen it, and cannot say whether it belongs to this or to the next stage, as may also the traces of gravel on the top of the railway-cutting through the hill adjacent to Riverhead.

† 'Geology of the Weald,' p. 189. Mr. Topley saw the railway-cutting when freshly made.

the patch of gravel on the northern slopes of Oldbury at the level a little above 400 feet, and that on the hill north-west of Seal at about 300 feet *, which seem to belong to this stage. Flint implements occur with both.

A better marked case which I have since had occasion to observe occurs at West Yaldham, near the east-lodge entrance to the grounds of St. Clere (Pl. VI., fig. 2), at the height of about 430 feet. The ground is there thickly covered with gravel (the depth not known), consisting of:—

1. White angular and slightly subangular flints.
2. Some flints of very large size.
3. A few brown-stained subangular flints and Tertiary flint-pebbles.
4. A very few subangular fragments of Chert, Ragstone, and Iron-sandstone.

Some fragments of the Oldbury-Hill stone, and a broken piece of a Palæolithic implement of the flat ovoid form, together with a scraper of the Ash type †, have been found here by Mr. B. Harrison. This bed, with that on the flanks of Oldbury, seems to mark the watershed between the Darent and the Shode; but whereas the centre of the watershed at Limpsfield between the Darent and the Oxted stream is capped by the gravel, it has here been removed from the centre, and only the lateral ends of the bed remain.

Again, in a field between Otford and Kemsing, and at a height of 300 to 330 feet ‡, there is a patch of gravel composed mainly of angular and subangular white flints, with a few brown-stained worn flints and Tertiary flint-pebbles, and very few fragments of Chert and Ragstone. This bed lies on a spur of the Chalk at the base of the escarpment below Beechy Lees.

The more contracted valley through the Chalk north of Otford, on which we now enter, has been so entirely denuded that few traces of the older drift-beds remain.

The best marked outlier is above the paper-mills at Eynsford, on the right bank of the river, close on the 200-feet contour-line, whence it extends to the height of 220 or 230 feet. A small cutting on the lane-side shows a section of this gravel 4 to 5 feet deep, roughly bedded, and consisting of Chalk flints, Tertiary pebbles, subangular fragments of Chert, Ragstone, and Ironstone (L.G.S.), with a few old brown-stained flints. The bed extends northwards towards Beesfield, and reappears on the slope of the hill east of Farningham, where it may be seen in the bank on the roadside at about the same level. The distance between this spot and Broughton Hill being $5\frac{1}{2}$ miles, and the difference of height 137 feet, gives a gradient of 25 feet per mile, an increase probably connected with the more contracted valley-channel and a greater velocity of the stream.

* 'Geology of the Weald,' p. 191.

† This is in all probability derived from the plateau-drift.

‡ From the same level, in the grounds of Wildernesse, near Seal, Mr. Crawshay has two porcellanous-looking small implements, well shaped, with the edges sharp and uninjured.

Below Farningham, beds of gravel are more frequent on the right bank of the valley, while the left bank remains bare until within three miles of Dartford. On the hill above Dartford Powder Mills, a thick and far-spreading bed of gravel sets in; it extends to the high road and the North Kent railway-cutting. The mean height of this bed above O.D. may be taken at 112 to 100 feet; and as the distance from Eynsford Mills is five miles, this is equal to a gradient of about 22 feet to the mile. On the whole, therefore, the gradients from Limpsfield to Dartford show a remarkable agreement, although owing to the few and distant points of observation between Broughton Hill and Dartford, and the greater uncertainty of these levels, the intervening gradients may require some correction. Enough, however, is established to show that the fall of the stream of gravel is continuous, and analogous to that of an ordinary river-bed.

The gravel at Dartford forms part of the great sheet which extends westward over Wilmington and Dartford Heaths, and eastward to Stone and Milton Street, near Swanscombe. It is from 10 to 20 feet thick, is roughly stratified, and consists of subangular flints, with a large proportion of Tertiary flint-pebbles, and numerous worn fragments of Chert and Ragstone—some of which are of considerable size. But in addition to the large contribution brought by the old Darent from the Chalk and Lower-Greensand hills, there is in the gravel of Dartford Heath and Stone a certain proportion of Triassic red quartzite-pebbles, white quartz, and other old rock-pebbles (veinstone, granite, &c.) derived from Boulder-clay series north of the Thames, which serve to connect this bed with the great spread of High-level gravel of the Thames Valley.

From a consideration of the facts now described, there is reason to conclude that the Limpsfield gravel must be correlated, not with the High-plateau gravel with which it assimilates in respect to its level, but with the Upper Terrace of High-level gravel of the Thames, and therefore that it is of later Glacial or so-called post-Glacial age. There are, no doubt, breaks in the sequence, but allowing for the fall of a turbulent stream, the prevalence of a considerable degree of cold, and the subsequent extensive denudation, of which there is sufficient evidence, the separate outliers exhibit so close a relationship that I cannot doubt their common origin. The Palæolithic implements also of the Limpsfield watershed agree in their general characters with those which I designated temporarily as the "Hill Group" of the Shode Valley or the high-level river-gravel, and not with the older group of the Chalk Plateau, or with those of the lower levels of the Thames and Medway.

§ 5. Contemporaneous Drift in the Cray Valley.

Another discovery of Palæolithic implements bearing a general resemblance to those of the Limpsfield gravel, and agreeing with it in geological position, has recently been made by Mr. De B. Crawshay near Green Street Green, in the valley of the Cray. They are spread over the surface of a gravelly field on the side of the lane

leading from the high road up to Snag Farm, and at about ¼ of a mile from the high road. Mr. Crawshay has collected from this locality 40 pointed and ovoid Palæolithic implements, and 18 flakes and scrapers. Two Palæolithic specimens had previously been found near this spot by Mr. P. Norman *. Nevertheless they are rare, for four of us, after a full hour's search, only succeeded in finding five indifferent specimens. These implements are of the "Hill" type, and mostly stained a light yellow colour †.

The stream of gravel at Pratt's Bottom and the upper Cray (fig. 2, p. 131) descends the Cray Valley, and passes by the end of Snag Lane to Green Street Green, where it is very largely developed. Remains of the Mammoth, Tichorhine Rhinoceros, and the Musk Ox have been found in the great pit on the Green, and in a side pit I have discovered a few specimens of *Pupa marginata*, but could find no other shell ‡. The level of this drift at the end of Snag Lane is 276 feet above O.D. The field up the lane where the implements occur is on the level of 320 to 340 feet, or 48 feet higher, whilst farther on the Red Clay-with-flints caps the hill at the height of 450 feet. We there have therefore the three levels of drift perfectly well-marked. I doubt, however, whether the Green-Street-Green gravel is really a river-drift, and hope to describe it on some future occasion.

It is at the farther end of the Cray Valley, near Crayford, that Mr. F. C. J. Spurrell found the remarkable spot where Palæolithic man worked, and fashioned the Chalk flints into shapes most conveniently adapted for his tools and weapons—a spot now covered by 30 feet of Mammaliferous brick-earth and drift §. It is to be hoped that these discoveries will be followed up, and that further evidence of man's early habitation at other places in the Cray Valley may be forthcoming.

§ 6. The Brick-earths of the Darent Valley.

These are few in number. The bed of most importance is the one worked on the south side of Limpsfield Common, a short distance from the gravel-pit (*c*, fig. 5, p. 139). It lies in a slight depression near the head of the present Darent Valley ‖, at a height of 470 feet above O.D., or from 10 to 30 feet lower than the adjacent gravel-

* These implements, together with the Mammalian remains from the pit at Green Street Green, are now in the collection of Sir John Lubbock at High Elms.

† Quart. Journ. Geol. Soc. vol. xlv. (1889) pl. x.

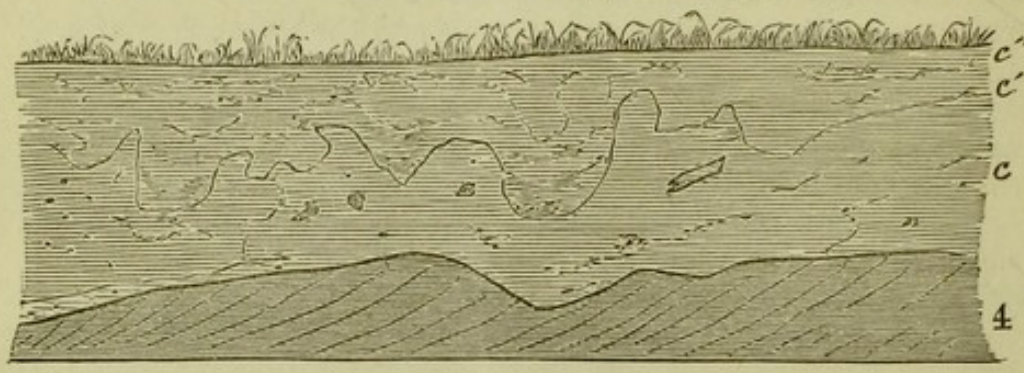
‡ No Palæolithic implements have yet been found in the large pit, though careful search has been made, but from this smaller pit on the other side of the hedge Mr. Crawshay has obtained five specimens. They are of a dark yellow colour, very much rolled and worn, and seem to me derived either from the Plateau drift, or from a high-level valley gravel such as that at Snag Lane. One of the specimens was found at a depth of 16 feet, close on the Chalk.

§ Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 544.

‖ It seems as much related to the Oxted Valley as to that of the Darent, but subsequent denudation may have caused this, and in any case there is a close connexion with the Limpsfield gravel. See also 'Geology of the Weald,' p. 194.

bed, but the two beds are nowhere seen in superposition. The brick-earth attains its greatest height at Gibb's Farm and Trenchleys, rising there above the 500-feet contour-line, while it extends ½ mile westward to Westheath at about the same level, but it is not worked at these places.

Fig. 7.—*Section at the Brick-earth pit, Limpsfield Common.*



c''. Weathered surface, bleached ..... 1 foot.
c Disturbed brick-earth
c. Undisturbed brick-earth, unstratified, } with angular débris... 8 to 10 feet.
4. Lower Greensand—a soft loamy grit.

This brick-earth is very stony, and no fossils of any sort have been found in it. Unlike the gravel, the rock-débris in it consists in greater part of angular fragments of the Chert, Ragstone, and Ironstone (with some of the latter subangular and of large size), from the Lower Greensand to the south of the pit, mixed with which are angular and subangular flints, and Tertiary flint-pebbles derived from the gravel on the north. These are scattered irregularly and at all angles through the brick-earth. The bed exhibits possible glacial influences, not only in the irregular distribution of the stony débris, but also in its indented surface, which shows disturbance by action from above (may be floating ice), causing contortion of the bed, and which has tilted a number of the blocks and pebbles upright on their longer axes. Occasionally a seam of fine gravel has been caught up and dovetailed into the base of *c'*, so making the line of separation between *c* and *c'* more distinct.

In this pit Mr. A. M. Bell has discovered a few Palæolithic flakes and implements. He has also found a well-shaped flake at a depth of 3 feet in undisturbed brick-earth on Gibb's Farm. The brick-earth continues a short distance eastward, following the course of the swale, which gradually enlarges eastward towards the Darent, and it is in a field on Redland's Farm, over which there are traces of this brick-earth or of trail, that Mr. Bell has found the greater number of the flint implements in his collection. These, in his opinion, have been brought to the surface by the circumstance of the ground having, a few years ago, been grubbed up and trenched to the depth of 1 to 2 feet.

Lower down the valley no brick-earth has lodged except in a few sheltered places. There is a small bed worked at Covers, near

Westerham, but this has more the appearance of a wash from the Gault. Mr. Topley mentions that a brick-earth 10 feet deep has been dug near Sudbridge Church, and that brick-earth extends from Dryhill eastwards towards Briton's Farm, which would be near to the 400-feet contour-line. A newer brick-earth is worked at Froghole Farm, near Chipstead, overlying some Low-level ground.

The powerful scour of the waters, as they ran through the narrower pass in the Chalk hills, has either not allowed of the lodgment of brick-earth or else has swept it away, and it was not until the current was checked near Dartford by its junction with the Thames that sedimentation of brick-earth took place*. That period may have been somewhat later.

§ 7. Other Drifts of the Darent Valley: the Chevening and Dunton-Green Gravel.

A sprinkling of gravel is common over much of the lower grounds of the Darent Valley, but it is only in a few places that the quantity amounts to a well-defined bed, and the relation of these to one another is more uncertain than is that of those belonging to the Limpsfield level. I give them in what appears to me to be their order of succession, but with the certitude only that they are all newer than the Limpsfield bed.

The Chevening and Dunton-Green Bed.—It was not until the railway from Dunton Green to Westerham was made (1881–82) that the distinctive character of this gravel, or the fact that it was anything more than a superficial trail, could be determined. The railway sections then made it evident that it formed occasionally a well-defined and more or less continuous bed, resting frequently upon a very irregular surface of Gault—in the form of patches or pockets of lesser or greater extent.

At Dunton Green (the railway-bridge cutting) it forms a compact and continuous deposit, without bedding, about 5 feet thick, and composed, in the order of their relative abundance, of:—

1. Large and small angular or slightly subangular flints (some stained through of a light yellow colour), these form the great bulk of the gravel;
2. Some large, fresh-looking, perfectly angular flints
3. A moderate number of Tertiary flint-pebbles and subangular fragments of Sarsenstone and Ironstone;
4. A very few well-worn brown-stained flints;

embedded without order in a matrix of red loam and sand. No fossils and no flint implements have been found in this gravel. Its level here is 270 feet above O.D., or 87 feet lower than that of the adjacent Broughton-Hill (Pl. VI., fig. 1 and fig. 10) high-level gravel, and there seems to be an absence of Chert and Ragstone. But in a pit recently opened a few hundred feet south of the railway bridge, a few rare pieces of cherty Ragstone are to be

* The high-level brick-earths of the eastern branch of the Darent Valley were noticed in the Ightham paper.

found; and as this stream of gravel sweeps round the hill, it catches up from the eastern branch and other affluents a quantity of Lower-Greensand débris, so that, on the other side of the hill, between New Barn and Rye House, it contains a large proportion of Chert and Ragstone, together apparently with some of the Broughton-Hill gravel trailed down the hill. The features distinguishing these two gravels are:—

1. The larger proportion of Tertiary flint-pebbles, and of brown-stained worn flints, in the Broughton-Hill bed, and its well-marked stratification.

2. The great preponderance of angular and subangular flints in the Dunton-Green bed, and its want of stratification.

The railway-cutting at Dunton Green was too far advanced when I first saw it, and the gravel-bed too massive, to mark the peculiarity of its junction with the Gault shown in the longer shallow cutting between Chevening Cross and Combe Bank Wood, where the sections were at first sight curiously deceptive. The sides of the cutting, which had been reduced to a slope of about 30°, presented the appearance shown in fig. 8, exhibiting loops sloping downwards and sideways towards the west; while on the south side of the cutting they sloped towards the east. But where the side had been left vertical the section was as represented in fig. 9. The appearances of distortion are therefore due solely to the obliquity of the plane intersecting the cylindrical segments of gravel *.

Fig. 8.—*Cutting, 5 feet deep, on north side of the line between Combe Bank and Chevening, after being sloped down.*

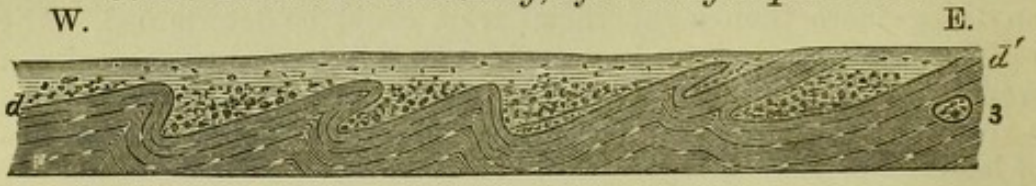
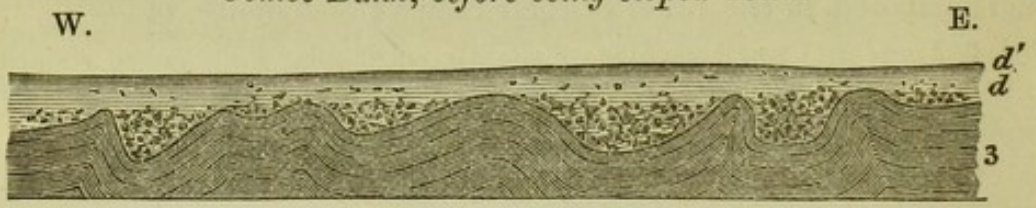


Fig. 9.—*Cutting on north side of the line by the bridge adjoining Combe Bank, before being sloped down.*



d. Unstratified gravel, sand, and clay. This bed consists of two parts, which pass one into the other—a lower one of coarse gravel in a matrix of ferruginous loam and sand, mixed with some clay from the Gault; and a thin upper one, *d'*, which spreads nearly uniformly over the whole, of a light-brown clay (altered Gault) mixed with a few flints.

3. Bluish-grey Gault.

The gravel in *d* consists of:—

Angular and subangular white flints in larger part.
Some Tertiary flint-pebbles.
A few small blocks of Tertiary sandstone and ironstone.

* A full explanation of this phenomenon is given geometrically by the Rev. O. Fisher, Geol. Mag. dec. ii. vol viii. (1881) p. 20.

The ground is nearly level, and from 320 to 340 feet above O.D., or about 60 feet above the Darent at Sundridge, with a slight incline southward, succeeded by a more rapid fall as we approach the river.

The gravel lies in pockets and troughs, having a general strike towards the north-east and south-west, and the line of separation between the Gault and the gravel is clean and sharp. No loose stones penetrate the Gault. It is as though the gravel had been pushed bodily into the clay, which presented on the steep sides of the pockets strongly marked slickenside-surfaces with the striæ directed downwards. Had the cavities been formed by running water they would have inosculated one with another. But such is not the case. Each seems separate and independent, and formed by a process of punching, which could only be produced by force or pressure, such as might be caused by a weight of ice or snow.

The composition of the gravel is also exceptional, many of the flints being of large size, perfectly angular, and identical with those in the Red Clay-with-flints on the summit of the escarpment, which rises at a short distance beyond; while adhering to their interstices was some of the same Red Clay. Besides these, there were a few Tertiary flint-pebbles, which also are common in places in the Red Clay-with-flints, but no Lower-Greensand débris. There seem to be, therefore, grounds for supposing that this drift-bed has been derived directly from the bed of Red Clay on the escarpment above.

Near the outlier of Limpsfield gravel on Sundridge Knoll, but 100 feet lower, there is another bed of gravel capping a low hill at the level of 300 feet, and composed in great part of Lower-Greensand débris, Tertiary flint-pebbles, brown-stained flints, and with comparatively few white subangular flints. Whether this represents the southern or Lower-Greensand border of the Chevening gravel stream, or whether it belongs to a subsequent stage, I am unable to say.

From Dunton Green, the Chevening Drift apparently sweeps round the eastern side of Broughton Hill by Rye-House Farm, but no sections are exposed. On the slightly rising ground ¼ mile S.W. of Otford, and about 20 feet above the Darent, or 220 feet above O.D., a coarse unstratified gravel, 4 to 5 feet thick, possibly of this age, or a stage newer, is worked. It consists of:—

1. Angular and subangular white flints, mainly.
2. Some Tertiary flint-pebbles.
3. A certain proportion of subangular Chert and Ragstone.
4. A few dark brown subangular flints.

The whole confusedly heaped together in a slight matrix of reddish-yellow clay and loam. This bed, which reposes on an uneven surface of Gault, is, however, on a lower level, and contains more Lower-Greensand débris than at Dunton Green; but this may be due to a more rapid gradient, and to the junction of the eastern branch of the valley with other tributaries from the Greensand Hills (see Map, Pl. VII.).

Nor is any bed of this age clearly seen to the west of Combe

Bank. It appears to ascend to a level higher than that of the railway, for it does not show in the cuttings beyond Combe Bank. The only place where I have seen anything like traces of it has been near Ivy House, one mile north of Westerham (430 feet), where there is a sprinkling of drift similar to that of Chevening, but there are no sections to prove it. This would give a gradient from Combe Bank of about 32 feet per mile, while that from Combe Bank to Dunton Green is equal to 35 feet per mile. This gradient, if prolonged, would rise nearly to the summit-level of the depression or gap on the north side of the Limpsfield watershed, corresponding with the one before mentioned on the south side of the summit-level (see fig. 5, p. 139).

The various circumstances I have mentioned in connexion with the brick-earth of Limpsfield Common, and with the Chevening and Dunton-Green Drift, would seem to warrant the belief that they are connected with a temporary return of glacial conditions *, following, after an interval of milder seasons, the more polar cold to which may be ascribed the previous vast glaciation of the district—a glaciation that had already outlined the great physiographical features of the country. It is difficult to account for the disturbed state and the peculiar condition of the brick-earth at Limpsfield, for the blocks of gravel rammed into the Gault at Chevening, or for the presence in the same gravel of the Red Clay with its flints in a state so little altered,—otherwise than by the presence of ice and snow, and by the removal of the original material from the higher to the lower level in a frozen mass. A drift of that character could not have been formed by river-action, as that would show wear, and a structure in accordance with such action, of which this gravel possesses none.

It is also to be noticed that, after the gravel was pressed into the Gault, the surface was apparently planed over, so as not only to level any inequalities of the ground, but also to carry forward some portion of the Gault, and spread it as a top layer, 1 to 2 feet thick, over the whole (*d'*, figs. 8, 9), in a way which suggests the passage over it of a heavy weight. Another feature in connexion with this drift is the number of flints here and at the other places (Wray Common, near Reigate, for example), pitted or pock-marked —a condition owing not improbably to extreme cold.

The prevalence of a temporary cold period might also serve to explain the presence of some patches of angular Lower-Greensand drift on the lower levels between Westerham and Chipstead, and the occasional occurrence of blocks of Lower Greensand of considerable size. Mr. Topley notices several (one $17'' \times 8'' \times 4''$) near Sundridge, and there used to be a block on the side of the road, about ¼ mile east of the Paper Mill. Lower down the valley there are several large blocks of Tertiary sandstone derived from the strata on the adjacent Chalk plateau. Some of these lie in the field on a low level between Otford and the brick-pits, and a block

* I shall have occasion to adduce corroborative evidence afforded by similar conditions in the Thames Valley.

of about a ton in weight of a sandstone-and-flint-breccia (Lower Tertiary) may be seen on the side of the road north of the Kennels at Otford. It is probable that there were others which have been broken up.

Some of the angular Lower-Greensand drift below Seal Chart and at Seal, and the angular flint-débris north of Child's Bridge, may possibly be of this date.

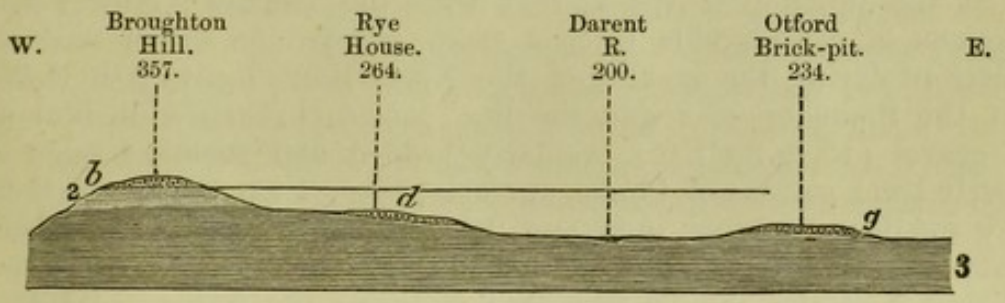
I should here observe that there is not infrequently, in this as in other districts, an apparent passage between one level of gravel and another, caused by a trail passing from the higher to the lower level, and so covering the slopes which separate the two drifts that they appear to form a continuous bed. This might easily lead to mistakes.

[Since writing the above, a cognate enquiry in which I have been engaged has led me to suspect another agency to which the angular patches of drift may be due. This has resulted in a drift which assumes so many phases that a revision of some portion of the lower drift-beds of this district may prove necessary, but it does not interfere with the definition of the higher-level valley and plateau drifts.]

§ 8. The Low-Level Valley-Gravels.

There are other drift-gravels in this valley, but they are more isolated and their correlation more uncertain. The most conspicuous outlier is the one between Otford and the "Bat and Ball" Station at Sevenoaks. It is one mile east of Broughton Hill, and on the opposite side of the Darent. The annexed section gives its position in relation to the several gravel-beds before described.

Fig. 10.—*Section from Dunton Green to the Otford and Sevenoaks Road.*



b. Gravel of the Limpsfield level.
d. Gravel of the Chevening level.
g. Low-level river-gravel.
2. Lower Chalk. 3. Gault.

Although so near, this gravel is very distinct from that on Broughton Hill or at Dunton Green. It is irregularly bedded, with veins of grey sandy clay, and consists in larger part (60 per cent.) of subangular fragments of Chert, Ragstone, and Ironstone from the Lower Greensand, with a lesser proportion of subangular

flints, and some Tertiary flint-pebbles. A few of the pieces of Chert are of the variety known as "Oldbury Stone." The sandy matrix is of Lower-Greensand origin. No organic remains and no Palæolithic implements have hitherto been found in this pit. The surface of the underlying Gault is nearly level.

The gravel has all the appearance of a river-drift formed at the junction of the east and west branches of the Darent Valley, and whether or not it is a stage newer than the Chevening and Dunton-Green gravel it would be difficult to say. The difference of level, though slight, the unstratified condition of one drift, and the rough bedding of the other, point to a difference of origin and time. The surface of the gravel at the Otford pit is slightly contorted as though by the action of river-ice, as at St. Acheul, in the valley of the Somme, though it is here less apparent and on a much smaller scale. I know of no similar bed in the western branch of the valley, unless it be connected with the small drift deposit of brick-earth and gravel at Froghole Farm near Chipstead. In the eastern branch, the small outlier at Child's Bridge * is of the same age.

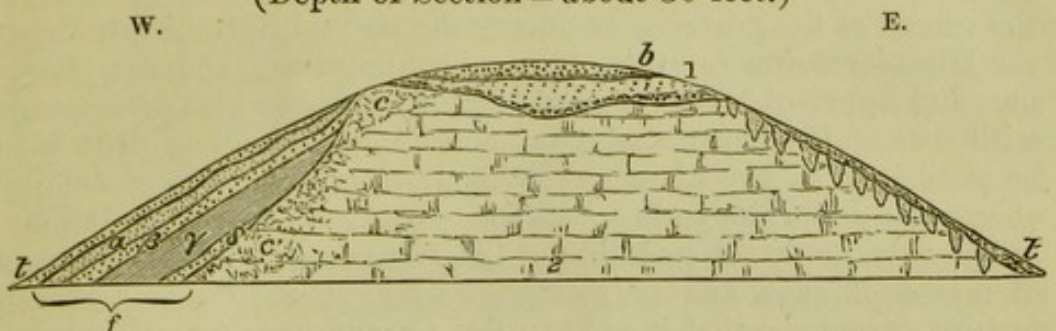
North of Otford, no beds of gravel are to be seen for some miles down the valley, but in laying a drain on the west side of the valley near the paper-mill at Shoreham a thin bed of sand and gravel, consisting of flints with worn fragments of Chert and Rag-stone, was discovered beneath the surface-soil. In this the tusk of a Mammoth was found, with traces of land- and fluviatile shells†. It was 30 feet above the level of the river; and at about the same level and under similar circumstances a tooth of the Mammoth was obtained at Eynsford. These are the only two instances in which organic remains have been found in the Valley of the Darent, though so common in the adjacent valleys of the Medway and Thames. A considerable spread of gravel on a low level is shown on the Geological-Survey maps in the valley between Lullingstone and Eynsford, but there are no pits or sections.

At the junction of the Darent with the Thames Valley, some sections of considerable interest were exposed on either side of Dartford during the making of the North-Kent Railway in 1842. On the Stone or east side, the line passed through a thick bed of gravel (15 to 20 feet), regularly bedded, and reposing upon a nearly level surface of Chalk (*ante*, p. 144). I am not aware that any fossils were found in it, and Palæolithic implements were then unknown and unsought for. It belongs to the great stream of gravel of the old Thames, but it shows the influence of the Darent-Valley stream in the large amount of Lower-Greensand débris there present.

On the west of Dartford there are two short cuttings between the Darent and the Cray, of considerable importance in their bearing on this enquiry. The one adjoining the Darent Valley, and at right angles to it, is as follows (fig. 11):—

* Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 274, 285.
† Geol. Mag. dec. iii. vol. vi. p. 113.

Fig. 11.—*Section on railway ¼ mile west of Dartford.*
(Depth of Section = about 30 feet.)



t. Trail of loam with flints and flint-pebbles ..... 1 to 2 feet
b. Ochreous flint-gravel ..... 3 „
c. Broken chalk. *c'*. Angular flint-rubble.
f. { *a*. Gravel composed chiefly of Tertiary pebbles ..... / *β*. Yellow sand ..... / *γ*. Grey clay ..... / *δ*. White sand with land- and freshwater shells ..... } 10 „
1. Thanet Sands ..... 4 to 5 „
2. Chalk, with a festooned surface beneath the trail on the east side of the cutting. *The indents are drawn too deep.*

The shells were *Pisidium amnicum*, *Valvata piscinalis*, *Pupa marginata*, and a *Succinea*. Some fragments of bones were, I believe, also met with. The bed *f* corresponds with the well-known bed at Erith, from which the late Mr. Grantham and Mr. F. Spurrell obtained so large a collection of Mammalian remains.

We have here a definite horizon with which to correlate several of the beds before described. There is little doubt that the bed with elephant-remains at Shoreham and Eynsford corresponds generally with *f*, fig. 11, and the height above the river of the bed of gravel at the Otford brick-pit (*g*, fig. 10) agrees so closely with the relative levels of the above that it affords grounds for placing it in the same zone. The gravel *b*, which belongs to the high-level gravels of the Thames Valley, is older than *f*, and so therefore is the Limpsfield gravel-bed with which I would correlate it.

This section also throws light upon a feature common in the Chalk districts of Kent and Surrey, and which has yet failed to meet with an explanation. I allude to that peculiar wavy breaking-up of the surface of the Chalk to the depth of 2 to 4 feet, in the form of closely-packed, small spherical pockets with concentric lines of clay and soil, which has been termed the "festooning of the Chalk."

On the western side of the cutting, the Low-level drift (*f*) abuts against a steep low cliff of Chalk, and there is no festooned surface, whereas on the eastern slope, where the Chalk has not been worn back in the same way, the whole length of the slope exhibits, under the thin covering of trail, the festooning as figured. In another railway section, rather nearer to Crayford, the same bed, *f*, again abuts against the Chalk, and overlies a mass of flint and Chalk rubble; and while under this bed the Chalk shows no festooning, that portion of the Chalk slope which rises above it, and extends to the top of the section, is strongly festooned.

It is therefore evident that the festooning took place before the undermining of the slope and deposition of *f*, but subsequently to the spread of the gravel *b*, or during the period intervening between the High-level gravels of Dartford and Limpsfield, and the Shoreham and Eynsford Mammaliferous drift—a period which corresponds with that of the Chevening drift; and if the Chevening drift is to be attributed to glacial agency, this festooning may be one of the effects of cold on the surface, either by repeated freezings and disintegration, or by the puddling of the ground caused by the passage of masses of snow and ice over the surface of the Chalk. It is a feature so common that it must be due to some very general cause—possibly to the same one that formed the Chalk-rubble described in the next section (§ 9).

It follows from the preceding considerations that there are in this district four distinct zones or levels of Drift, and that in three of these Palæolithic implements have been found, namely :—

1. That (*a*) of the High plateau on the Chalk hills, and of which the implements exhibit a distinct difference in type and workmanship from the other two. This is possibly of pre-Glacial or early Glacial age.

2. That (*b*) which accompanies an early stage of the existing river-courses, and includes the High-level gravels of the valleys (the "Hill group" of Ightham).

3. That (*c*) of a Lower-level valley drift. The implements found in this and the preceding zone, *b*, are very similar in character, and can only be regarded as variations of the same group *. They both belong to the so-called "post-Glacial" period.

No organic remains have hitherto been found in the older drift, and they only occur locally in a few places in the second, while they are common in the last.

§ 9. The Rubble on the Sides and in the Bed of the Valley.

Another feature connected with this valley, and very general in the Chalk districts of the South, is the débris of broken chalk and flints scattered over the slopes and at the base of the hills. Its origin is obscure. It has been referred to subaerial action and rainwash—terms which, though applicable in some instances, are too often used in default of a better. Both these terms imply surface-action and effects due to existing causes, and cannot therefore apply to any deposit due to anterior geological causes.

As the "Chalk- and flint-rubble" frequently forms the surface-soil, it might, without further investigation, be referred indifferently to one of the causes just named, did not the irregularity and absence of sorting of the materials militate against its being rainwash, while the occasional presence of materials foreign to the spot is an objection to local disintegration. But though the surface of the "Chalk- and flint-rubble" is often, or rather is more generally, bare, it is occasionally covered by a bed of red loam or clay with flints and

* The main difference seems to be one of size and proportion.

pebbles derived evidently from the Red Clay-with-flints, and from the Lower-Eocene strata on the adjacent hills. This red argillaceous rubble is certainly not rainwash, nor can it be the result of surface disintegration. At present, however, I am only concerned with the fact of its being a drift or covering which precludes us from assigning the Chalk-rubble which underlies it to such existing causes as rainwash or weathering.

Not being worked for any purpose, it is rarely that sections of these "rubbles" are to be seen. Of the few that have come under my notice in this valley, the following (fig. 12) is an example. It occurred in digging a pit about 10 to 12 feet deep for a reservoir in a field on the slope above Sepham Farm, near Otford.

Fig. 12.—*Section on Sepham Farm, on the lower slope of the Chalk hills.*

a′. Red argillaceous rubble with dispersed Chalk flints and Tertiary pebbles.
2′. Chalk-rubble of broken chalk and sharp angular flint-fragments in a chalk-paste, passing into—
2. Solid Chalk with layers of flint.

The two beds (*a′* and 2′) are perfectly distinct, and never pass one into the other; 2′, on the other hand, does not form a sharp line with the underlying Chalk, but graduates into it. The height of the ground is about 280 feet above O.D., and 90 feet above the level of the Darent. The Red rubble is easily recognized in the ploughed fields by its colour. But while this is local and only covers certain areas in the valleys intersecting the Red Clay-with-flints plateau, the white "Chalk- and flint-rubble" is more general *, passing under the Red rubble, as well as over the wider intervening spaces. In those valleys to which it is limited it rises to a considerable height on the slopes and descends to the bottom of the valley.

From the position and character of the White rubble, in which the Chalk forms a pulverized paste with dispersed subangular fragments of chalk, sharply angular flints—broken but otherwise unaltered—and occasionally some Tertiary flint-pebbles, and a few fragments of ironstone and chert from the Lower Greensand, it is, I think, not improbably Glacial waste connected with that stage of valley-erosion which preceded the drift *f*, and of which the festooning of the Chalk is a subordinate feature.

Just east of Otford, at the angle formed at the junction of the Holmesdale Valley with the pass of the Darent Valley through the

* 'Chalk- and flint-rubble' was said to underlie the Mammoth-gravel at Shoreham.

North Downs, a spur of Lower Chalk projects forward. It presents a compact even surface, merely covered by 1 foot of chalky soil, and free from either of the rubble-drifts. The line between the Chalk and the soil is perfectly sharp and clear. There is no passage from one to the other. The surface-layer has the characters of a wash—maybe a rainwash—the slope above being steep and abrupt. This surface is such as might have been produced by ice-action, though it is only by its rounded form and clean-swept surface that we can judge, for of ice-marks on a soft Chalk surface there can be none. This conjecture accords, however, with the supposition that the Chalk-rubble cannot be due to surface decomposition, for were it so it should exist here, whereas the position of the spur at the angle of the two valleys is that where the denuding action of the ice would be greatest, and the surface most likely to be swept bare.

§ 10. The Alluvium and the associated Neolithic Implements.

Of this last phase of the Darent Valley there is little to be said. A small breadth of alluvial clay spreads over the bottom of the valley (see Map, Pl. VII.), and levels the inequalities of the underlying drift. The greatest expanse of this alluvium is between Otford and Riverhead, but in general it is comparatively of little importance. The clay is of a brown colour, and occasionally slightly peaty, but there are no regular beds of peat, nor is the clay, which is from 3 to 8 feet thick, anywhere worked, and little is known of the underlying gravel and chalk débris. At Shoreham Mill the latter was found to be about 8 to 10 feet thick.

But although geologically unimportant, the large number of Neolithic flint implements found on the surface of the adjacent fields testify to the comparative density of the population during the prehistoric epoch. Flakes, celts, scrapers, cores, &c. are common on the Chalk slopes and lower grounds. They are mostly rude, weathered white, and iron-stained at the angles by the plough. Only a very few ground and polished specimens have been found; arrow-heads are scarce, but a few highly finished specimens have been met with. The district was evidently much frequented by Neolithic man, as it had been previously by Palæolithic man. This, however, is a subject for the archæologist.

§ 11. On the Chalk Escarpment within the Darent District.

Although the Darent district is of too limited extent to embrace all the phenomena connected with the structure and origin of the Chalk escarpment, it nevertheless presents a number sufficient to test the accuracy of the hypotheses that have been proposed in explanation of this moot problem, and to show how far the facts we have had to notice are in accordance with them. I do not, however, intend here to enter upon a full discussion of the subject, which is one that requires a wider field of observation, but merely to notice certain objections to both hypotheses that present themselves within the area of the Darent Valley.

Two hypotheses have been proposed to account for the formation of the escarpment surrounding the Wealden area. The one attributes its origin to marine action, and likens the long escarpment to Chalk cliffs surrounding an inland sea; the other refers it to subaerial action and a slow retrocession of the outcropping edges of the Chalk. The first of these hypotheses is now generally considered to be untenable, as no single one of the attendant phenomena is in accordance with such a derivation. There is not a trace of marine action within the Wealden area during the Quaternary period, and the escarpment is not a cliff in the ordinary acceptation of the word, for so far from there being a level shore-line at the base of the escarpment, such as a cliff necessarily presents, the line is in no instance level, but rises and falls alternately the whole length of the escarpment (see line *mn*, fig. 3, Pl. VI.), the difference of level between the higher and lower points amounting in places to as much as 300 feet, a difference impossible on a shore-line. The reader should, however, consult on the Chalk escarpment the writings of Mr. Whitaker, of Sir A. Ramsay *, and of Messrs. Le Neve Foster and Topley (see note, p. 126).

The second and more generally accepted hypothesis † is not so easy to disprove. It will, however, I think, be found incompatible with the phenomena exhibited in this district. I formerly showed that a large portion of the Chalk covering the Wealden area was, in early Tertiary times, planed down and levelled by marine action, forming what Ramsay has termed "a plain of marine denudation;" but I much doubt whether it affected more than a limited littoral area, and whether the Chalk was removed from the whole of the more central area. It is certain that the denudation extended beyond the North Downs, and probably to some distance to the south of the Lower-Greensand area ‡. It is also certain, as I afterwards showed, that both the Tertiary strata and the Chalk along the northern boundary of the Weald underwent a similar erosion during early Pliocene times §. In neither instance, however, is there any proof that the denudation reached far into the Weald, but, on the contrary, the absence in the first period of Lower-Greensand débris in the Tertiary strata, and in the second of Wealden débris, leads me to believe that much of the area remained almost untouched.

In any case, after the withdrawal of the Pliocene sea, and on the land being raised and exposed to atmospheric agencies, a process of weathering commenced, which led Ramsay, writing in reference to the formation of the Chalk Downs, to observe that "immense tracts of Chalk and Lower Greensand in the Weald and in the middle and west of England have been cut away by the slow process of gradual recession due to atmospheric influences, and thus it happens that

* Whitaker, Quart. Journ. Geol. Soc. vol. xxiii. (1867) p. 265; Ramsay's 'Physical Geology and Geography of Great Britain,' 5th ed. (1878) p. 338.

† See Ramsay, *op. cit.* pp. 336, 510, 532.

‡ Quart. Journ. Geol. Soc. vol. viii. (1852) p. 256.

§ *Ibid.* vol. xiv. (1858) p. 330.

their edges now form long escarpments, which are still receding in the direction of the dip of the strata, and therefore at right angles to the slope of the scarp" *.

That a plane surface of unequal resistance should suffer unequal wear from the effects of rain and weathering is not to be contested, but on the hypothesis that the escarpment of the North and South Downs is due to ordinary slow action of this description, we should assuredly expect to find in the valleys below them the harder and indestructible débris of the removed strata, such as the flints in the Chalk and those in the overlying Red Clay, and the pebbles of the Tertiary strata.

Sir A. Ramsay felt the difficulty, for he observes that "the absence of flints over nearly the whole of the Wealden area, excepting near the Downs, is explained by this hypothesis, *for the original marine denudation had removed all the Chalk, except near the margin* (see fig. 73), *long before the rivers had begun simultaneously to scoop out the valleys of the interior, and to cut the transverse valleys across the North and South Downs*" †. In the section referred to the Chalk is shown to extend no farther than the edge of the Lower-Greensand escarpment, a distance of four miles from the Chalk escarpment. But is not this limited range based on the very assumption of a fact which has to be proved?

Taking the range of the Chalk from Crossness in the centre of the Thames Valley, where its thickness is known, to the edge of the Chalk escarpment at Otford, a distance of 14 miles, we find it diminished from 650 ft. to 450 ft., a total reduction of 200 ft., or of 14½ ft. per mile. At this rate the Chalk should have extended 31 miles beyond the escarpment, or, taking only the Chalk-with-flints, some miles (16?) less.

Within this area, if the Chalk had been worn back by ordinary subaerial agencies alone, we ought to find some evidences at the foot of the hills of the wreck of the Chalk with its massive layers of flints, of the pebble-beds of the Tertiary strata, and of the bed of Red Clay-with-flints (both of which latter may have extended farther than the Chalk-with-flints), in the manner represented by Ramsay in fig. 70, p. 336, of his work above referred to; but there is no bed nor any talus of that description. Mr. Topley, however, is of opinion that "we cannot expect to find any *direct evidence* that the escarpments have been formed and worn back by subaerial agencies," but considers that the whole features are such as can be readily explained by subaerial denudation, whilst all other agencies are inadequate to account for the work done ‡.

Nevertheless, if the hypothesis is to be accepted, some such direct evidence ought to be forthcoming, even if we assign a more restricted range southward to the Chalk and confine it to the limits assigned by Ramsay; or, at all events, the drift in the valleys within those limits should be in accordance with that hypothesis. On this point the sections in the Valley of the Darent offer a

* 'Physical Geology and Geography of Great Britain,' 5th edit. p. 351.

† *Op. cit.* p. 344.

‡ Mem. Geol. Survey, 'Geology of the Weald,' p. 300.

crucial test. Though the Gault elsewhere at the foot of the Chalk escarpment often shows a sprinkling of drift, there is no place where the character of that drift has been so well shown as in the sections on the line from Dunton Green to Westerham.

At first sight these sections might seem to corroborate the view of those who hold that the escarpment has been worn back by slow subaerial denudation, for, as I have shown (p. 149), traces of the Red Clay with its flints, together with flints from the Chalk and pebbles from the Lower Tertiaries, are there, though in very small quantity, and only in local patches.

But so far from possessing this uniformity and the special local characters in accordance with such an origin, the drift-beds in the valley present a marked diversity, while there are spaces free from any drift. If we take, for example, the section across the valley at Dunton Green, we find that instead of this uniform débris a chalk-and-flint rubble extends from the slope of the escarpment to Broughton Hill, which, on the other hand, is capped by a gravel of Chalk flints and Tertiary flint-pebbles, with Lower-Greensand débris brought from a distance; at Dunton Green there is the peculiar angular-flint drift with scarcely a trace of Lower-Greensand débris, while the Low-level drift in the valley beyond consists of mixed flints and Greensand débris.

On the rising ground (of Lower Greensand) on the side south of the valley the drift is composed almost entirely of local débris, and there is scarcely the trace of a flint (see Pl. VI. fig. 1). It is obvious, therefore, that here we have not simply a local drift of Chalk flints and Tertiary débris, left behind during a slow weathering and recession of the escarpment, but successive streams of drift-gravel, formed by erosion, and transported from other points higher up the valley. Of course, in a slow recession, the effects of springs, streams, and freshets are not to be overlooked; but it is not to be supposed that these would be of such a character as to remove or alter all the evidence of the primary cause, and until some of that evidence is forthcoming the hypothesis must, like that of the marine origin of the escarpment, fail, not only for want of proof, but also as against such evidence as we have.

Instead of a slow gradual recession, due only to atmospheric influences, in the direction of the dip of the strata, the evidence rather shows that, after the first predisposing causes, glacial agency was the great motor in developing the valleys, and, as a consequence, the escarpment; and that the denudation was afterwards further carried on in the same lines by strong river-action and weathering,—supplemented at times by renewed ice-action. It was, I conceive, by these more energetic agencies, aided by the influence of a heavy rainfall, and the issue of powerful springs on the face of the escarpment, that the escarpment was gradually pared back and brought into its present prominent relief.

[Other observations in connexion with the denudation of the Wealden area, and concerning the course and action of the rivers during its early stages, will be found in my paper "On the Southern Drift," in Quart. Journ. Geol. Soc. vol. xlvi. (1890) p. 166 *et seq.*]

EXPLANATION OF PLATES.

Plate VI.

Sections.—The levels are taken from the Ordnance Maps, but in order to make the sections clear the relations of heights to distances are made as 5 : 1, so that the gradient of the Plateau-Drift is considerably exaggerated.

Fig. 1. This section passes about ½ mile west of Broughton Hill, which is, therefore, represented as in the distance, but the relative levels are maintained. Broke Farm lies a short distance back of the number 480. Snag Lane is 2 miles lower down the valley of the Cray than the point crossed here.

Fig. 2. Extends from Oldbury to Yaldham along the line of watershed (now removed in part) between the Darent and the Shode. Ash lies a little to the east of the line of section between South Ash and West Yoke. The brick-earth and gravel, *e*, with Mammalian remains and Palæolithic implements (⊙), north of Milton Street, lies a short distance east of the line of section, but on the level here represented.

Fig. 3. In this section it will be seen that the Lower Greensand débris (Southern Drift) and the Palæolithic implements (▽) are of frequent occurrence on the highest summits of the escarpment. The dotted line above *e* across the Valley of the Darent gives the level of the Limpsfield drift at the adjacent Broughton Hill. The dotted line *mn* follows the base-line of the escarpment—the summit-level at Limpsfield being near *l* and at Yaldham at *l'*.

Plate VII.

Map.—This is based essentially on the Geological-Survey Maps, with the exception that the Drift-beds are altered and added to in accordance with the interpretation given to them in this paper. The angular gravel, *h*, should probably have greater extension. The Sundridge and Brastead gravels, of which I have never as yet been able to see a section, should possibly be referred to the same zone. It also covers more ground about Seal and below Seal Chart. The Southern Drift is taken as co-equal with the Red Clay-with-flints. The names of places generally indicate the position of their churches.

In the drawing of this map I have been much indebted to the kind assistance and suggestions of Mr. Topley.

Plate VIII.

These sketches, made by Mr. W. S. Tomkin, represent some of the more common forms of the Plateau-Implements. Figs. 1 to 6 will be found described in the text, p. 134. Fig. 7 is an exceptionally good instance of the scratches or striæ, closely resembling glacial striæ, which are not infrequent on the brown-stained flints. In this case the large misshapen flint seems to have been trimmed at the edges so as to form a rude cutting instrument or adze.

In consequence of the uniform brown colour which spreads alike over the natural and the worked surfaces of the flints, independently of the original colour, the distinction between the two surfaces is rendered less apparent than is shown in the drawings, where the originally darker natural surfaces alone are shaded, while the colour on the worked edges is not rendered. Added to this the wear and abrasion which have affected the whole flint, including the trimmed parts, are not made sufficiently apparent. These parts, therefore, show more prominently than in the specimens themselves. The figures in Q. J. G. S. vol. xlv. pl. x. exhibit this feature better, though the general drawing is not so good.

Discussion.

Mr. Topley referred to the importance of this paper as completing the history of the Darent Valley, and also as discussing questions of wider interest. He would not take up time by speaking upon the numerous matters in which he fully agreed with the Author, but would rather refer to a few points which still required consideration or as to which he was inclined to dissent from the Author's conclusions.

Many of the supposed implements from the Chalk plateau might reasonably excite suspicion, but some no doubt were artificial. He wished to know if there was any clear case of these occurring undoubtedly in place in these gravels; for the extremely high antiquity of any gravels in such positions was beyond question: it was clearly older than the excavation of the great Chalk valleys and of the present features of the Wealden area.

The high gravel at Limpsfield Common lies on the watershed, and therefore could not have been formed by the Darent in its present form. The Darent Valley probably once stretched farther to the west and south than now, having been robbed of its area by the recession of the higher tributaries of the Medway; but he was inclined to doubt if even this would explain the occurrence of so great a deposit at so high a point, and was rather disposed to think that the Limpsfield gravel itself had an origin independent of the present valley-system of the Darent. He fully agreed with the Author, however, in regarding the gravels lower down the Darent as river-gravels, largely made up from the waste of the higher and older bed.

Whilst admitting the evidence furnished for some kind of ice-action within the area, he could not follow the Author in attributing the escarpment to glacial action. He failed to see how ice could excavate the deep transverse valleys and cut back the escarpment at the same time, there being no doubt that these two very different kinds of denudation proceeded simultaneously. He showed that glaciation tends to destroy escarpments. Existing escarpments in glaciated areas are such as were too bold to be destroyed, or, if small, are such as may have been developed since the glaciation. Lastly, escarpments are universally distributed over the world, whilst glaciation has influenced only parts of it.

Prof. Le Neve Foster wished to say a few words respecting the denudation of the Weald, having studied that subject carefully with his friend Mr. Topley some six or seven-and-twenty years ago. He did not find his old views shaken by the paper which he had just heard, and was still of opinion that the formation of the Chalk escarpment was due in the main to rain and rivers. Mr. Topley had forestalled him in one remark, viz. that any theory accounting for the Chalk escarpment should also account for escarpments elsewhere. If, by glacial action, Prof. Prestwich meant that glaciers had helped to carve out the Chalk escarpment, ought there not to be some evidence of the fact in the shape of scratched stones? He

had not learnt from the paper that any scratched stones had been discovered. Though the soft chalk, clays, and sands of the district would not permanently retain scratches, yet there are flints and ironstones capable of preserving striations. On the other hand, local ice-action on a small scale was admitted, and Mr. Topley and he had resorted to that explanation to account for the very sharp bending of some beds of gravel near Tonbridge; but this was a very different thing from allowing that the origin of the Chalk escarpment is largely due to ice-action.

Mr. De B. Crawshay had recently discovered the Southern Drift on the top of Botley Hill, near Titsey, the highest point (877 feet) on the North Downs, and had there obtained five rude implements. He had also found rude implements on the Tatsfield Firs at 820 feet, thereby proving the four highest patches in that locality to yield implements. He remarked upon the Betsom-Hill patch at 750 to 790 feet being on the south side of the escarpment, thereby differing from all the others. With regard to implements *in situ*, he observed that Mr. B. Harrison had found a flake on the side of a pond at Ash, below the level of the surrounding plain. He hoped to open sections in the course of the year, and would be very pleased if Fellows of the Society would come and see them. Many of the flints were scratched, but he did not advance them as glacial striations, and would leave the Author to deal with them.

The President, after alluding to the Author's researches many years ago, which threw so much light on the origin of the river-terraces and topography of the South-east of England, and revealed to geologists important evidence of a former extremely cold climate in that region, asked for information regarding the nature and operation of the glacial action to which it was proposed to refer the formation of the Chalk escarpment. He confessed himself unable to realize how any operation of ice could have played a material part in the sculpture of that part of our topography. At the same time, he thought that geologists made a great mistake who looked in the Southern Counties for any such traces of ice-action as they were familiar with farther north. There was assuredly no ice-sheet in the south of the island; the Boulder-clay and scratched stones may be entirely absent, nor could the speaker see any satisfactory evidence of floating ice. Yet there could be no doubt that thoroughly glacial conditions did spread over south-eastern England, giving rise, however, to a different class of results from those that attended the more Arctic glaciation farther north. He reminded the Fellows of the suggestive paper communicated to the Society a few years ago by Mr. Clement Reid, which showed how a period of intense cold might be inferred to have prevailed along the South Downs, though that ground is quite bare of anything in the nature of true "Drift."

The Author, in reply to the comments on the paper, admitted that it was very desirable that plateau-implements should be found *in situ* in the drift, but the fact that there were no pits and that excavations were rare in the plateau-drifts accounted

for the search being limited to the surface*. These implements were, however, always found in close association with those drift-beds, and confined to the area over which they spread. These are never met with in the intervening valleys, except an occasional derived specimen in the newer drifts. Besides this, the colour and incrustation of the specimens show that they have been embedded in a surface-drift, which, with others, has suffered denudation, and it is probable that a large number of the specimens have been brought to the surface on which they are now found in course of working the land.

With respect to the Limpsfield gravel, it certainly wanted some of the characters of a river-drift, but ice and snow may have had a good deal to do with its lodgment. It is evident also that it has been derived from the Tertiary outliers on the adjacent Chalk escarpment 300 to 400 feet above Limpsfield Common, whence the fall would be exceptionally rapid. At the same time, the Limpsfield gravel assumes much more the character of a river-gravel as it descends the valley, in consequence of receiving tributary streams and acquiring greater water-power and deeper waters.

Respecting the brick-earth and the Chevening gravel, the Author pointed out that the disturbed condition of the former could be best explained by floating ice, and of the latter by a covering of ice and snow. That there should be an absence of striated surfaces and scratched stones was no more than might be expected, considering the want of hard rocks. Other evidence would, however, be found in the paper, which, from its length, he had found it necessary to omit in reading. There was certainly an appearance of striæ on some of the implements and older flints, but whether that arose from ice-action or from the rubbing and knocking about they received in the old drift-streams he would not at present like to pronounce.

The formation of the Chalk escarpment presented great difficulties. In the North of England, where the great ice-sheet passed over high hills, the escarpments would no doubt suffer defacement, but here the character of the ice-action would be different. The Author did not suppose that the great northern ice-sheet extended over this area. A southern central ice-area may then have existed in the Wealden highlands, and the ice and snow in these valleys have been local. The height of the glacial period preceded the Limpsfield gravel, and the W. and E. and the S. and N. directions of the flows were the result of different physiographical conditions at different periods.

The Author then expressed his obligations to the three gentlemen who had so greatly assisted him by their researches in the field, the results of which were to be seen in the large collection of Flint Implements exhibited.

* I have now seen the fine specimen mentioned on p. 133. It is 6 inches long by 3¾ in. wide, very flat and round-pointed, and shows no wear. It more resembles one of the large St. Acheul types. It was found on the top of the soil last thrown out of the hole.

Diagram-Sections showing the Relative Levels of the Plateau- and Valley-Drifts, and of the Three Groups of Palæolithic Implements.

Explanation.

1. Tertiary Strata.
2. Chalk.
3. Upper Greensand and Gault.
4. Lower Greensand.

⊗ Stained Flints. ● Chert & Raystone Fragments. † Localities.

a. Red Clay with Flints.
b. Upper Valley-Gravel.
d. Chevening and Dunton Green Gravel.
e. Low-level Valley Gravels.

▽ Implements of the Plateau type.
○ Implements of the High-level Group.
⊙ Implements of the Low-level Group.

Scale.

Horizontal ..... 1 inch = 1 mile.
Vertical ..... ½ inch = 100 feet.

Fig. 1. Section from the upper part of the Cray Valley to Sevenoaks.

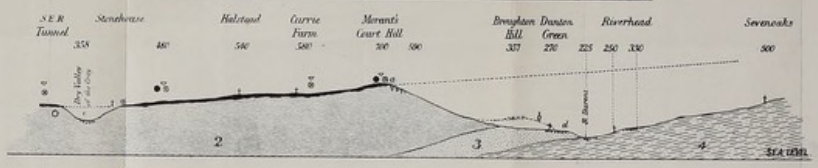


Fig. 2. Section from the Thames to Oldbury Hill near Ightham.

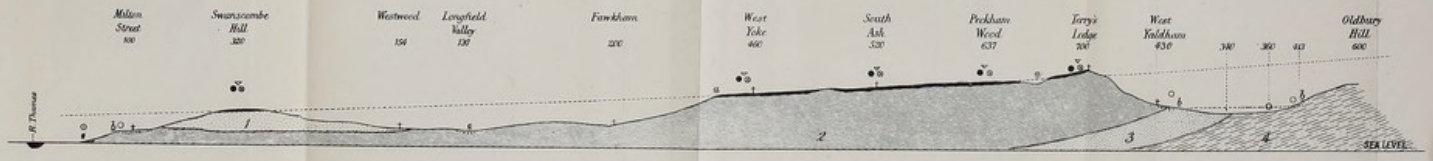
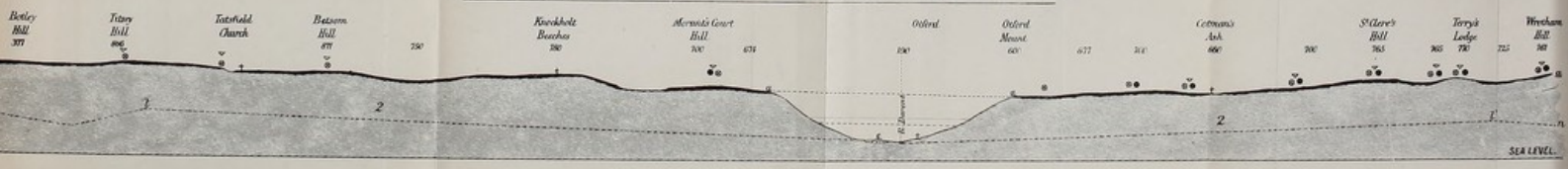
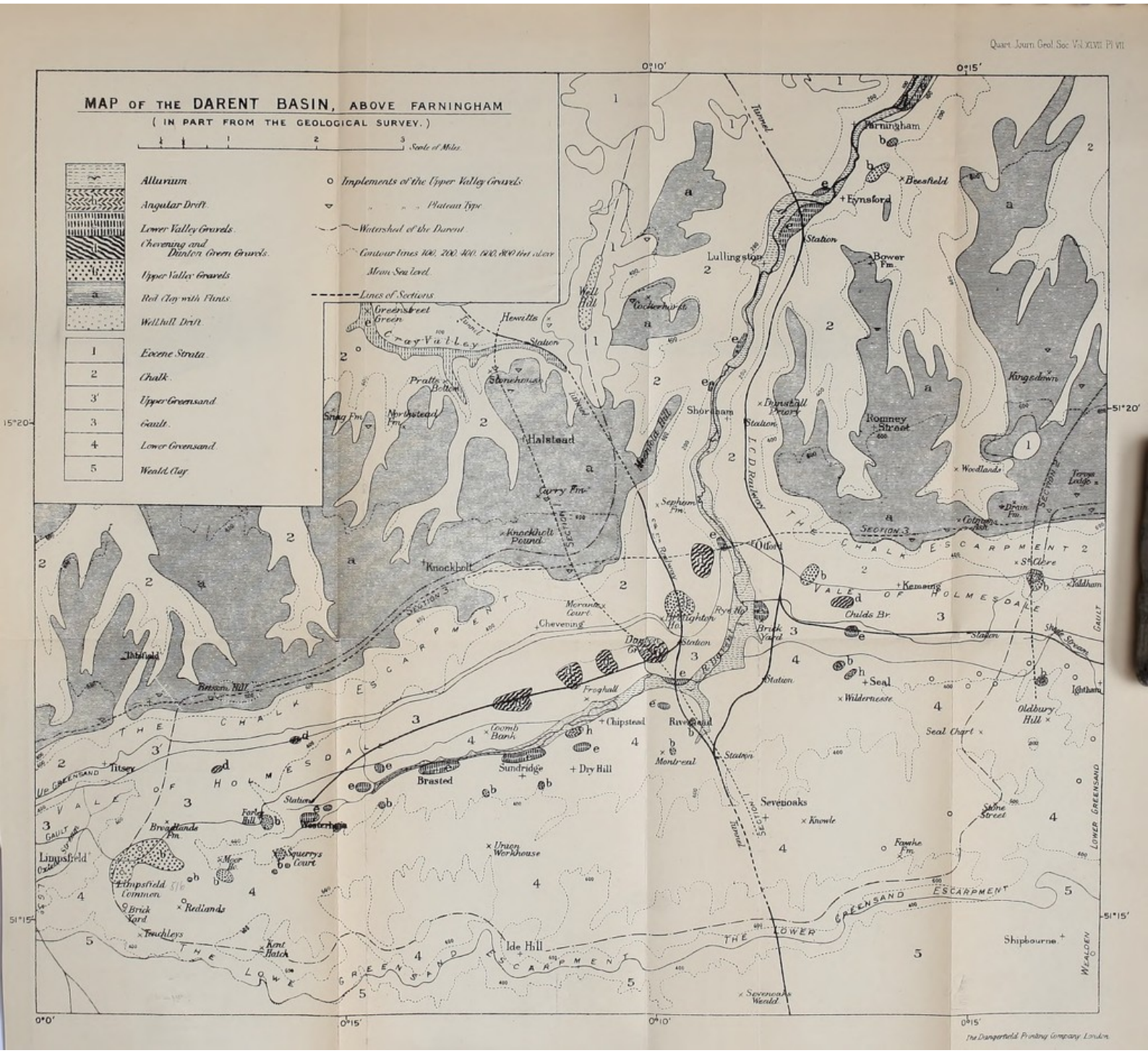


Fig. 3. Section along the Crest of the Chalk Escarpment from Limpsfield to Ightham.





The Dangerfield Printing Company, London.

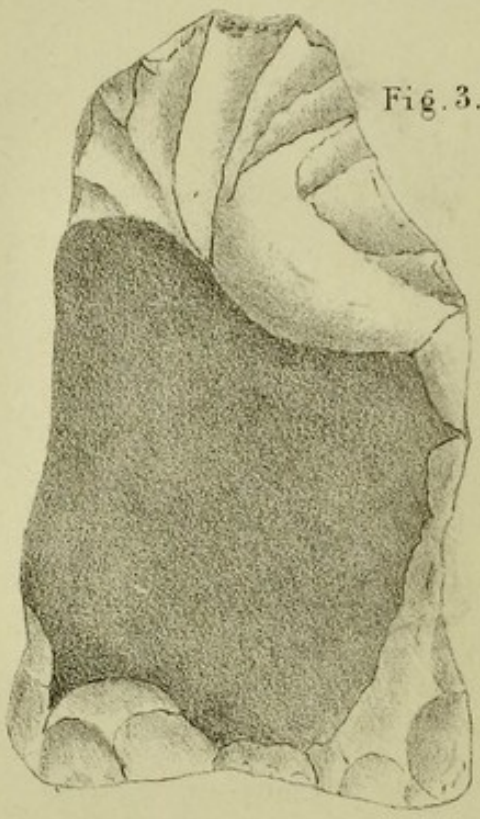


Fig. 3. (110).

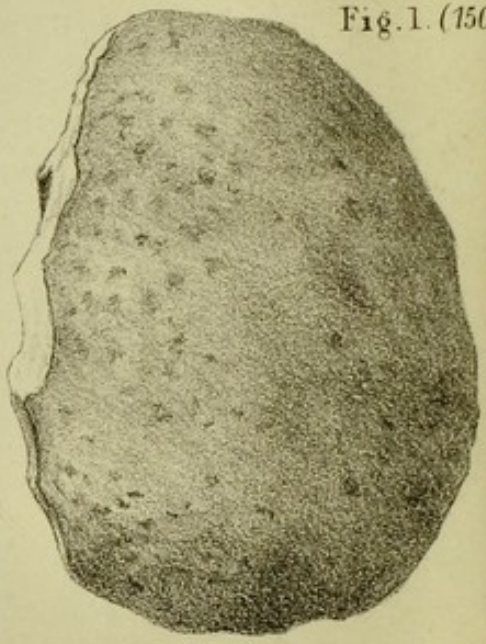
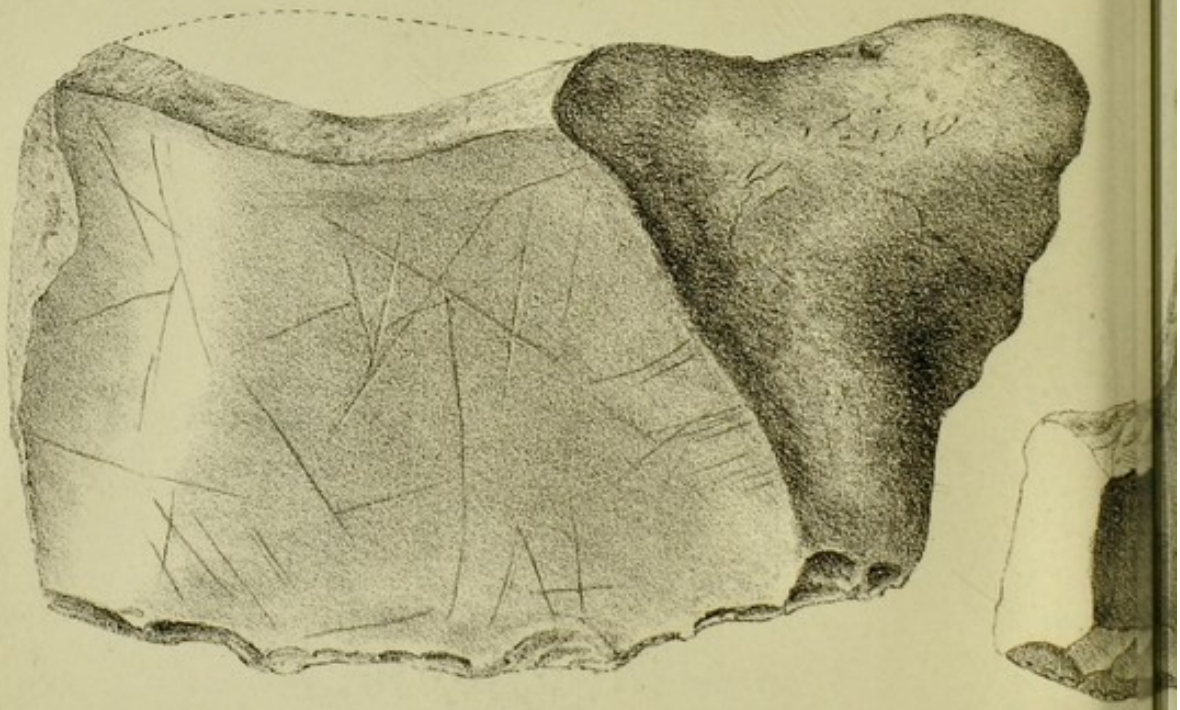


Fig. 1. (150).

Fig. 7.



W. S. Tomkin del.

FLINT IMPLEMENTS

Type Specimen

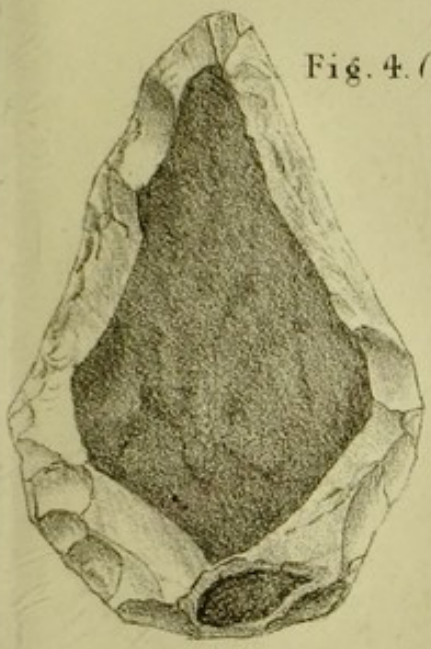


Fig. 4. *(112).*

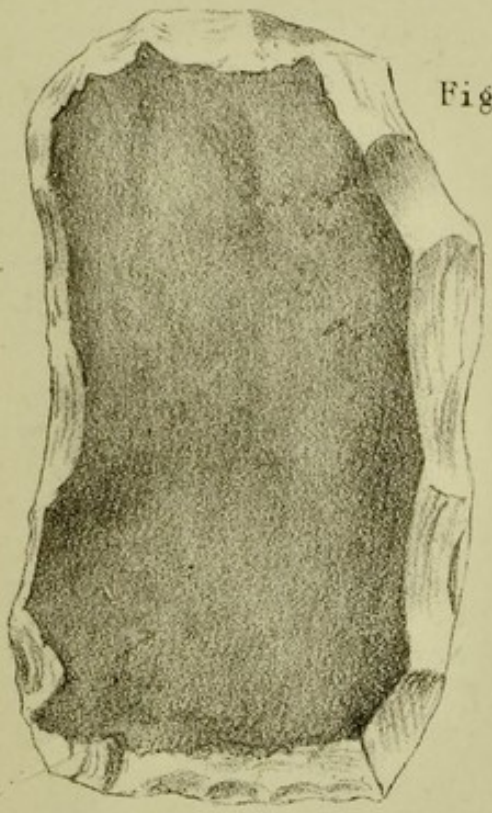


Fig. 2. *(406).*

Fig. 5. *(57).*

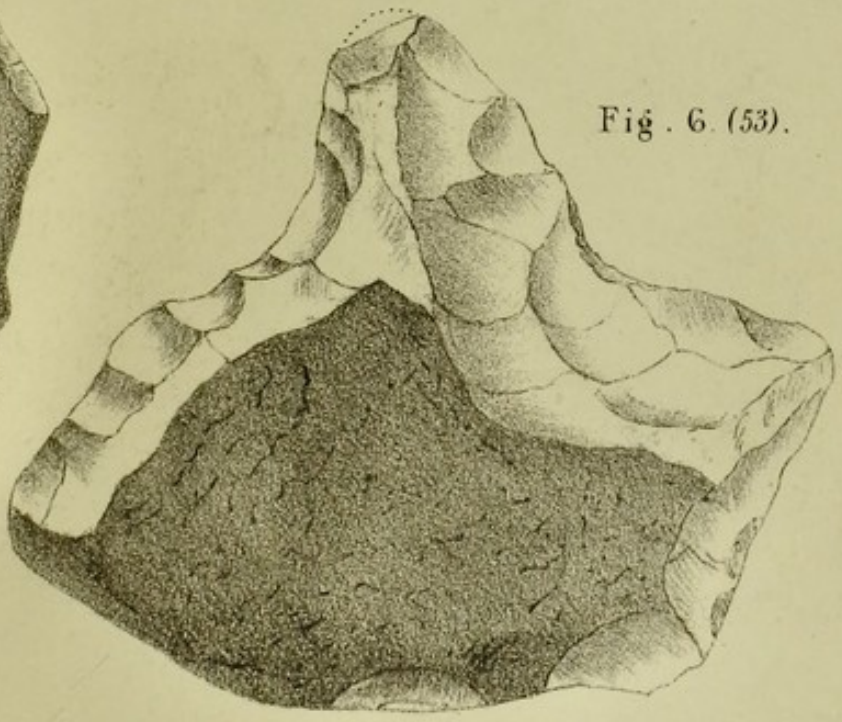


Fig. 6. *(53).*

Mintern Bros. lith.

E CHALK PLATEAU.

natural size.