

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

SOME FUTURE WORK FOR THE GEOLOGISTS' ASSOCIATION.

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Based on the Presidential Address for 1918.*

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*The substance of this paper was read at the Annual Meeting of the Geologists' Association on the 2nd of February, 1918. Owing to ill-health it was not then read in full, and many points were not so well put as they should have been, owing to want of information which it was not possible to obtain during the war. Some important additions have since been made, for which no apology is required, as this paper is based mainly on what is already known and published and does not so much profess to be an original paper, as an incentive to further organised work.—
G.B., August, 1919.

INTRODUCTION.

OUR field work and Excursions have both been greatly restricted by the War, so that when the happy times of peace come once more, we, as Geologists, shall be full of pent-up energy and eager for new work. The present occasion thus seems specially suitable for directing attention to some of the problems that require further special investigation.

Within the London District the main features of the Lower Greensand, the Gault, the Upper Greensand and the Chalk are fairly well known. The same is true of the whole of the Eocene Beds on the south side of the Thames, but on the north side of the river it holds good only so long as we deal with the main or connected outcrop of these Tertiary deposits. When we come to deal with the disconnected outcrops or outliers resting on the Chalk table-land difficulties arise. In a number of cases the basement beds of the London Clay have been wrongly identified, while material made up of the waste of the Reading Beds has been claimed as Reading in situ.

In the belt of ground over which these outliers are scattered, there is a large amount of Reading Beds detritus, forming a drift which may or may not have been glacially reconstructed; for our present purpose it is sufficient to say that the detritus consists of more or less sandy clay often enclosing a great number of well rounded Reading pebbles. At the surface the enveloping clay is partly washed away and partly carried down by the rainfall, thus leaving a thin coat of massed rounded pebbles at the surface, which in some cases has been claimed as the basement bed of the London Clay, in others as Pebble Gravel, etc. It may thus be well to say a few words about these basal beds of the London Clay.

There is usually no difficulty in identifying the base of the London Clay in our area; for it appears to be always fossiliferous if a fair-sized section is exposed, though the species seem to vary with the nature of the deposit. Though these beds are always more sandy than the main mass of the formation, there is considerable local variation in their appearance. Thus in one type of section a bed of flint-pebbles is present; in another, the flints are small or absent. In the latter case gasteropods are generally present in fair number, though they are very friable and difficult to extract. There is generally a gradual change, and the pebbles increase in number and eventually form a bed in which the pebbles are packed fairly close together. In this type of deposit a species of *Ostrea* is usually present and often in considerable numbers, while *Ditrupea plana* occurs a few feet below, often in cemented masses. The *Ostrea* is rarely present where there are no pebbles.

The first type was well shown in the Gerrard's Cross rail-

way cutting ; the few pebbles present were quite small and scattered, fragile gasteropods were common and (I believe) the oyster was absent. In the Piccadilly Tube Railway near Convent Garden, the sandy base of the London Clay contains no pebbles and rests directly on the brilliantly coloured Reading Clay. As the tunnel was pushed northward, pebbles were encountered towards Holborn, and near Russell Square the characteristic pebble-bed appeared with its associated oyster. In the Rotherhithe Tunnel pebbles were also absent from the base of the Clay for a considerable distance ; a few were met with later on, and here again the pebbly base with its typical oyster eventually comes on, for it was passed through in a well close by. There is good reason to believe that these pebbles, when massed, occur in channels through which stronger currents flowed. Possibly, these have a definite trend or direction over considerable areas, and it may be worth while trying to ascertain the trend of some of these channels.

READING BEDS.

There are several problems suggested by the Reading Beds that require elucidation, and various lines of evidence that should be more strongly insisted on.

The Reading Beds are not composed of nearly uniform or continuous beds ; in many localities, channels were cut in the clays and finer sands after their deposition, and these were subsequently filled up with coarser material, varying from sand to pebbles or shingle. The whole group is thus largely built up of so-called lenticles, but these are only seen to be such when the exposed section is approximately at right angles to the length of the channels ; if parallel to it, the beds would in most cases appear to be parallel and of nearly uniform thickness. Over a large part of the area within and to the west of London there is (or was) a deposit of brilliantly coloured tenacious clay or marl ; it is usually a brilliant pink, but locally it is mottled with green. Over much of the centre of London this clay or marl is about 40 feet thick, but its original thickness is locally reduced by the erosion within it of channels subsequently filled with loam or sand. More than 400 wells and borings and a number of underground tunnels have proved that this brilliantly coloured material, as an original deposit, is rigidly restricted to the upper half of the Reading Beds ; if it appears to occupy any other position it is not in place. This is confirmed by the evidence of many brickpits situated within the main Tertiary outcrop as well as by the larger outliers. Instances of the bodily displacement of this material by ice-action will be dealt with later on ; for the present, attention may be drawn to what has proved a common source of trouble. It

is not as well known as it should be that this brilliantly coloured clay and the London Clay are carried as a fine silt by rainfall or floods to lower ground and far beyond the point to which stones or even fine sand will travel. Considerable accumulations of this pink clay have been thus formed in the area north-west of London, where the Reading Beds occur as isolated outliers, and have been taken to be in situ. Moreover, in many places they have been involved in the Glacial drift, but here as elsewhere the material is always identifiable owing to its intense colour. In the case of the London Clay a specially interesting illustration was afforded when the Post Office Tube Railway was made. When the tube was being driven across the old Fleet Valley, after being apparently in solid London Clay for a considerable distance, the tunnel suddenly entered a bed of gravel containing much water. This gravel was deposited in the old bed of the Fleet River, and the apparently solid London Clay, nearly 30 feet thick, was not in situ at all, but downwash, held up by the blocking of the Fleet Valley. The material was absolutely indistinguishable from London Clay in situ, the reason being that from a little above this point the Fleet flowed entirely through London Clay and could deposit nothing else.

So far as is known at present the brilliantly coloured Reading Clay seems to taper off about Rotherhithe. However, its exact eastern limit is worth tracing more minutely than has been so far done, and it will probably be found to be of very irregular form.

The middle and lower part of the Reading Beds are composed of marls, loams, and sands of which a full account has been given in Whitaker's *Geology of London*. A little above the base (when the Thanet Sand is absent) there is often a bed of sand, pale coloured to white, but how far west this continues is not clear. Quite at the base is a special bed to which reference will be made later on.

Associated with the marls and sands are a number of water-worn and well-rounded flint-pebbles, the large ones showing beach-hammering (nodding). They occur either scattered along lines (when seen in section), or massed together to form pebble-beds of varying thickness and breadth; in one instance two of these were found only a few yards apart, neither being much more than two feet across and about two feet deep. From this type all stages can be traced to shingle-beds (Pebble-Beds) several feet thick and of considerable extent; thus these Pebble-Beds may be present or absent in any given area. The absence of any distinct Pebble-Bed over a considerable area has been proved by numerous excavations at and about the Cowcroft brickfield, near Chesham, though scattered pebbles are fairly common. On the other hand, over the whole of the Swillet

hill, near Chorley Wood, excavations and numerous cess-pits have proved the persistent presence of a Pebble-Bed (shingle-bed) having an average thickness of about 6 feet. An old quarry on the south side of the hill shows well the persistent black outer skin and the rounding and nodding of the pebbles, all of which are composed of flint.

This persistent black skin or interior of the pebbles in situ is of great importance in field-geology ; loose pebbles, or pebbles in drift that have this character have been derived directly from the Reading Beds in situ ; that is, they have not been through some more recent deposit, nor have they been exposed for any great time on or near the surface. In some cases there are " sunk " patches on the faces of the larger pebbles and these are paler and often bluish in colour ; on breaking the pebble, the part inside the bluish skin is invariably very pale coloured or white (see the paragraph on Puddingstone below). These patches are usually small, and it is extremely difficult to find a small pebble in situ wholly of this nature, though they are known to occur. The persistent black skin is not easy to explain ; it does not signify that the interior is of fresh flint ; on breaking the pebbles open all stages may be found, from fresh varieties to those that are pale brown and considerably decomposed.

If exposed at the surface for any considerable time, the black-skin is gradually lost and the interior becomes brownish, yellowish or nearly white ; apparently the last change requires the longest exposure. White patinated rounded flints generally indicate the lapse of a very long period since the pebbles left the Reading Beds in situ.

These Pebble-Beds are locally cemented by siliceous material into a hard conglomerate, commonly known as Hertfordshire Puddingstone. Whether the cementing material is exclusively that originally filling the spaces between the pebbles is not clear ; there may have been some infiltration of siliceous material. In some cases the cement is partly ferruginous and this probably is an infiltration. On the north side of the Thames blocks and pebbles of this Puddingstone are scattered over a wide area lying to the north-west of the main Tertiary escarpment, while the uncemented stones of the Pebble-Bed are scattered in vast numbers over the same area. Some valuable information on the cementing material and the Pebble-Bed was obtained when the Rotherhithe Tunnel was made. While driving this, the engineers came on the taper-end of a fine hard sandstone, which slowly thickened to about three feet. This material is commonly known as Sarsen ; it has been met with underground at several other localities, notably in the Tube Railway between King's Cross and the Angel. At Rotherhithe, after a considerable length had been cut through, the Sarsen began

to contain small scattered flint-pebbles. These became larger and more numerous till the rock finally passed into a pudding-stone. It did not retain this character further on; patches only were cemented, the rest was loose, thus becoming the normal Pebble-Bed. A fairly large wedge of Sarsen was cut through at Gerrard's Cross when the railway was made. Over the whole of the North London area all the pebbles in the Reading-Beds are apparently composed of flint, derived from the Chalk, though in one or two cases pebbles of white quartz are said to have been met with. It is possible that a few may be present, just as boulders and large stones have been found in the Chalk; but none have been noted in the several hundred wells and borings that have passed through the Reading-Beds, nor has anyone recorded their presence in the numerous brick-pits in the Reading Marls, etc. In all probability, the supposed pebbles of white quartz are really the white flint described above, for small pebbles of this are found in the Puddingstone, when the other and ordinary flints are mostly small. A specimen and section of this type have been deposited in the collection of the Geological Survey.*

Since the address was delivered, attention has been called to a paper by Mr. Osborne White,† describing what he believes to be Reading Beds overlain by the basement-bed of the London Clay, *both* containing pebbles of white quartz, some bands in considerable numbers. The paper is so clear that those familiar with the area to the north-west of London, are convinced that the whole belong to Mr. Whitaker's Pebble Gravel, or the (? Pliocene) High-level Gravel, and that they may be correlated with the gravels on Little Heath, recently described by Mr. C. J. Gilbert‡ and recently visited by the Association. This view is strongly supported by the occurrence of numerous silicified fragments of *Inoceramus*; fragments so altered have rarely been met with elsewhere. (See the section on the Pliocene, pp. 36-48).

The idea that some great changes occur in the lithological character of the Reading Beds at Lane End is rendered unlikely in view of Blake's§ record of the occurrence of the Reading Pebble-Bed close by. It is eight feet thick and composed entirely of flints, thus agreeing in composition with that of the same bed, six feet thick, at the Swilket, 10 miles away to the north-east. If there are any lithological changes it is in the Pebble-Bed that we should expect them to first occur. Obviously

* Prof. Garwood has kindly promised facilities for a small collection to be kept at University College, to assist the Association in field-work in the London area. Specimens to illustrate this paper will be deposited.

† On the Occurrence of Quartzose Gravel in the Reading Beds at Lane End, Bucks, *Proc. Geol. Assoc.*, vol. xix, part 9, 1906, p. 370. Also A. J. Jukes-Browne and H. Osborne White, *Mem. Geol. Survey*. Explanation of Sheet 25, (Henley and Wallingford), 1908, pp. 4, 61-4.

‡ For the Report of the Excursion directed by Mr. Gilbert, see pp. 87-91 of this volume.

§ *Geology of London*, vol. I., p. 183.

Lane End is one of the localities that the Association should carefully examine, as part of an organised programme of work.

The cemented Pebble-Bed or Puddingstone passes laterally into cemented sand or Sarsen ; and, in addition, it may pass either above or below into Sarsen, for loose blocks have been found in great numbers containing the junction of the two, the matrix of the Puddingstone and the Sarsen having exactly the same composition and structure. Such blocks are extremely numerous to the west of Great Missenden ; on a fractured surface the rock is of fairly uniform grain, with a somewhat crystalline, almost saccharine, aspect. This seems to be much the most common type of the larger blocks of loose Sarsen on the north side of the Thames. Another type of structure is recognised, in which the larger sand grains in the matrix are surrounded by the still finer material ; once seen, this is very easy to identify and a fine exposure of the Puddingstone with this matrix has been visited by the Association under the guidance of Mr. R. W. Pocock* at Radlett.

THE BULL'S HEAD BED.

Between the Eocene and the Chalk there is almost always present a curious deposit composed mainly of flints from the Chalk. When the bed is freshly exposed, the flints are usually green-coated and show few or no signs of erosion ; their aspect suggests that they have been set free by the washing away of the originally enveloping chalk and have moved but little since their exposure. Many of the flints are irregular in shape and have projections like horns ; possibly the presence of these horns may have suggested the name of *Bull's Head* for the deposit. In any case, it has proved important to note that these flints have their horns for the most part unbroken and unworn.

Within the belt of ground to the north-west of London that will be specially dealt with, the Bull's Head Bed lies at the base of the Reading Beds, and the flints are embedded in a rather dark sandy clay, sometimes showing traces of bedding, which generally contains a variable amount of glauconite, green when fresh, but nearly black when decomposed. A feature of the clay is the large number of very small pebbles of varying composition that it contains locally ; they are highly polished, almost burnished, and have all the appearance of pebbles swallowed by fishes, a view of their origin which is supported by the fact that fairly large fish-teeth (?shark's teeth) are often found associated with them. These small stones and teeth cannot have descended from above and been left with the flints ;

* *Mem. Geol. Survey. Summary of Progress for 1913*, pub. 1914, p. 32 ; and *Proc. Geol. Assoc.* vol. xxv, part 1, 1914, pp. 77-8.

they must be contemporaneous with the setting free of the flints, which cannot in this case be due to solution. The point is of importance when we come to deal with the Clay-with-flints in which the flints have also unbroken horns at the base of the deposit; the clay being often also dark coloured and the flints black externally.

Attention has been called to the above points in the Reading Beds because they are vitally important in the problems to be discussed in the sequel.

THE POST-EOCENE DEPOSITS OLDER THAN THE RIVER TERRACES.

The least satisfactory part of our knowledge of the London district is that dealing with the deposits that intervene between the highest known Eocene and the comparatively recent River Terraces, especially the pre-Glacial portion. This is more due to want of co-operation in our work than anything else, and it is this co-operation in field work for which the Geologists' Association was largely designed. It is scarcely too much to say that workers in one area rarely pay an extended visit to others some distance away; there may be a great hiatus in the evidence over a large area, leading to conclusions that are based on insufficient evidence, but which could be supplied at least in part from another district.

Thus in the area due south of London there is little if any true Glacial Drift, and this often leads to workers in that area ignoring it and the great time interval it represents. In this area a special type of High-level Gravels is well represented. In a number of these the condition of the pebbles contrasts so strongly with that of the great bulk of the pebbles in deposits of much the same age to the north of London* as to suggest that they suffered a far longer exposure at or near the surface. This striking difference rarely appeals to workers in either area, because they are not aware of it. North and north-east of London, Glacial deposits (Chalky Boulder Clay and Fluvio-glacial sands and gravels) are well developed. For the most part these rest cleanly on the Chalk or Eocene Beds, and since as a broad rule nothing intervenes, the idea has gradually grown up that nothing of importance ever did intervene. This is well brought out by Mr. Whitaker's admirable account of the "Pebble Gravel" on the north side of the Thames.† It clearly states the idea that if there are any pre-Glacial deposits, they are but slightly older than the Glacial Epoch. His perfectly correct statement of the facts does not justify this view; there is not sufficient evidence to justify any view.

* This statement may have to be modified for the belt of ground about 650 feet above sea-level in part of the North London area. See p. 23.

† *Geology of London*; vol. i., pp. 290-298.

It is, however, in the area north-west of London, and of the main Tertiary escarpment, that we find our present knowledge most deficient, and most unsatisfactory. Here occurs the most complicated series of the deposits now being specially dealt with, but this fact at once suggests that in it the greatest number of different deposits are present, and if we can unravel their history, some at least of the missing links are sure to be found. For that reason the area was specially chosen for examination, the work being undertaken during winter, when the crops were off and the ground was wet. The results have a special bearing on the age of the High-level Gravels and the evolution of the Thames valley.

Within what may be conveniently called the London Area, these deposits, intervening between the Eocene and the highest River Terraces, are usually shown on the Old Series maps of the Geological Survey as follows :—

GRAVELS :—(a) *Deep pink* for Pebble Gravel (High-level Gravel). In some cases these are called “Plateau Gravel,” but generally preceded by the words “High-level ” to distinguish them from the next.

(b) *Pale pink* for the (Fluvio-) Glacial Gravels, usually well-bedded and containing abundant far-travelled stones. This is called Plateau Gravel more often than (a).

CLAYS :— (c) *Blue* for Chalky Boulder Clay, never bedded, and of undoubted Glacial origin ; largely made up of far travelled-material.

(d) *Two shades of brown* to indicate local drift ; i.e., made up of local materials, and containing no far-travelled stones.

(1) The deeper shade for Clay-with-flints.

(2) The paler shade for the associated so-called Brickearth. In some areas the two are not separated.

At the outset this assumes that there is no clay of glacial origin containing far-travelled stones other than the Chalky Boulder Clay, an assumption that is wrong. The only one of these divisions that has been satisfactorily represented on the published geological maps is the Chalky Boulder Clay ; the reason being that the deposit is easily recognised and all the men engaged in the mapping used the term for this one deposit only. In all other cases the names given above were used by the different surveyors on different lines ; the work on the older one-inch maps was really well done, but it should either have been done wholly by one man, or under the constant supervision of one man. Pebble Gravel and Plateau Gravel are al-

most meaningless terms, unless we know what each mapper meant by the terms, and that is now impossible. To take the most important of all,—the “Pebble Gravel” as defined by Mr. Whitaker in his *Geology of London*: this is not a drift at all; it is almost certainly marine, once covered a very wide area, and, as will be shown in the sequel, is far pre-Glacial. Yet the same term has been applied to deposits that are of much more recent age.

THE HARD MATERIALS IN THE DRIFTS.

As the work progressed it was found that there is a considerable amount of hard material in the “drifts,” which though foreign to the London District, has not come from any great distance beyond it; and which should therefore be separated from such materials as Bunter-pebbles, Red Chalk, Carboniferous Limestone, etc., or Scandinavian boulders which are essentially “Far-travelled.” It thus becomes necessary to make three divisions of the hard material in these deposits, as follows:

- (1) *Local*, or gathered within the Chalk escarpment; such as Flints and Tertiary-pebbles, Sarsen, Puddingstone, etc.
- (2) *Neighbouring*, or gathered not far outside the Chalk escarpment, such as pebbles from the Lower Greensand, etc.
- (3) *Far-travelled*, such as Bunter-pebbles, Carboniferous Limestone, Red Chalk, Scandinavian rocks, Liassic and other fossils, separately or in blocks, etc.

An accurate knowledge of these pebbles, fossils or rocks, is essential to the interpretation of Glacial and other drifts, and only by this means can the path be traced by which they entered the London District. Their state of preservation, whether fresh or decomposed, should be carefully noted. Their presence in a fresh state suggests that they have been derived directly from the deposit in which they originally occurred, or that the decomposed portion has been ground away by Glacial action; in the latter case they are often glacially striated.

DIVISIONS OF THE DRIFTS.

The true drifts in the area north of London may be conveniently divided into two groups;

- (a) Those containing far-travelled material, undoubtedly Glacial.
- (b) Those containing only local material; *i.e.*, gathered within the Chalk escarpments; much of this is Glacial, but how much is at present unknown.

This would seem to leave out one important type of drift,

that containing local material with stones originally derived from neighbouring districts. As a matter of fact, it does not do so because the whole of the neighbouring pebbles, mainly small white quartz-pebbles, were already *in* the district when the drift was formed. They are not derived directly from the Lower Greensand, but from the destruction of the once wide-spread Pebble Gravel already referred to. One of the main objects of this address is to stimulate members to undertake a thorough investigation of this deposit.

DRIFTS WITH FAR-TRAVELLED MATERIAL.

The drifts with far-travelled material as shown on the published maps may be roughly divided into Chalky Boulder Clay and Glacial Sands and Gravels. There are minor divisions associated with these, which will be referred to in describing the drifts as a whole.

The drifts with far-travelled material within the London District and on the north side of the Thames may be conveniently described as occurring in three areas :

- (1) *The Eastern Area*, where the containing ice entered from the north, and under the influence of gravity descended the Colne Valley ;
- (2) *The Western Area*, where the ice entered the district through and about the side of the Goring Gap ; and
- (3) *The Central or Intermediate Area* within which the two ice-sheets met.

Within this last area the drift now left is englacial, that is, it is both free from bedding and unwashed. It is, in fact, a true Boulder Clay, and though approximately of the same age as the bedded Glacial gravels, it is totally unlike them when seen in sections. It is not shown on any published maps, and its existence, which has been proved but recently, is now demonstrable by a whole series of sections, though its exact extent will be very difficult to determine. This deposit will be termed *Drift of the Intermediate area*.

(1) THE EASTERN AREA.

The Glacial drifts of the Eastern Area, belonging to this division, with the local exception of some laminated clays, etc, all contain a large proportion of far-travelled material. Of the stones in them the best known is probably the liver-coloured quartzite from the Bunter. In many districts it is extremely common, and in consequence the bedded Glacial gravels have often been called Bunter-pebble gravels ; the name is less often applied to the Chalky Boulder Clay, as that deposit is more easily identified by its contained chalk. The chalky clay

is never bedded, while the sands and gravels almost always are, until we approach their highest margins. Over most of the ground above the valleys the sections show one bed of Chalky Boulder Clay resting on the bedded sands and gravels, and in the Stapleford section of the new Great Northern Railway to Stevenage this simple type of section is only once departed from in a distance of several miles.* In some cases a rise in the underlying floor of the Chalk or Tertiary Beds causes the clay to overlap the gravel, so that the latter is absent.

The sections in the valleys are often more complicated. The first change, and the one most often seen, is the occurrence of lenticles of chalky clay within the bedded-gravels. In a number of cases it has been proved that they are simply lenticles, but their occurrence is not so easy to explain. Much more complicated sections are met with, but they do not usually extend far within the area here dealt with.

Still more complicated sections occur locally, within the broader valleys. One showing the greatest known number of divisions in the Lea Valley was recently visited by the Association in the Excursion to the Ware Gravel-pits;† these sections are of special interest, as they show the only known occurrence within the London District of a true Lower Boulder Clay.

The far-travelled stones in these Glacial deposits are of extreme interest as indicating the course of the ice-sheet that brought them into the district; though many observations have been published about them, there is no systematic record, and it is specially urged on the members of this Association that they should establish a catalogue or record of these stones and fossils, somewhat on the lines adopted some years ago by the Boulder Committee of the British Association. Probably, a small standard collection will be made and kept at the University College, so that newly collected specimens can be compared with the standard types, and each new occurrence noted in the catalogue. The identifications need to be very carefully made and the possible localities thoroughly known. At present the far too widespread assumption is often made that certain rocks (e.g. Rhaxella Chert) can only come from a few specific localities. This assumes that we know all possible localities for this Chert, an assertion that lately-gained experience shows to be highly improbable. On the other hand, in the case of a rock such as the Red-chalk, we do now know its southern limit and its possible outcrop, so that we can get a fair idea of the direction of ice-travel from its occurrence at a given pit. Similarly with Laurvikite, it can only be of Scandinavian origin,

* There are several descriptions of these sections; by Dr. Sherlock in the Summary of Progress for 1914 (1915), pp. 27-32; and in the *Proc. Geol. Assoc.*, vol. xxvi, 1915, pp. 78 and 273; see also the account by W. Hill, *Proc. Geol. Assoc.*, vol. xxvi, 1915, p. 286.

† Dr. Sherlock, *Mém. Geol. Survey. Sum. Progress*, 1914 (1915), pp. 31-32. G. Barrow, *Proc. Geol. Assoc.*, vol. xxix, (Parts 1 and 2) 1918, pp. 42-45.

though the exact point at which it was involved in the ice-sheet that brought this rock to Ware is not by any means clear.

The Relations of the Clays to the Bedded Gravels.—It is not at all uncommon to see the Clays and Gravels spoken of as being merely modifications of the same material; *i.e.*, that they were both derived from the same ice-sheet. Evidence from the area to the north of Hertford and Ware has shown this to be incorrect, for the sections about the new railway from Hertford to Stevenage prove in the clearest manner that a great and persistent difference exists between the two types; in the Chalky Boulder Clay, for mile after mile, flints derived directly from the Chalk (unworn or little worn flints) are almost entirely absent, while they occur in vast numbers in the underlying gravel, at times, indeed, forming at least one-third of the whole deposit. The junction between the two is often singularly even and though the gravel must have been frozen, it does not seem likely that this is the real cause of the sharp separation. It seems more probable that the gravel was covered with local ice (locally deposited snow), which was over-ridden by that coming from a distance; and that an ice parting remained more or less persistently throughout; thus, only when this melted did the two actually come together.

The Chalky Boulder Clay of this area is simply the south-westerly termination of great masses that extend northward and eastward over a large area. It enters what may be conveniently termed the London Area, about Stevenage, and passing near Codicote, Wheathampstead and St. Albans, apparently terminates, so far as is known at present, on the south side of the Colne, about the Colne Valley Waterworks, just south of Watford. The base of the deposit here occurs at a height of only 210 feet above sea-level and about 30 feet above the Colne. It should be pointed out that this is much below the base of the Glacial Gravels on the north side of the Colne no great distance away, suggesting that erosion had already been at work on the gravels before the chalky clay was deposited.

The phenomena occurring along this northern and western margin of the Chalky Boulder Clay deserve minute survey; in particular, the butting of the old pre-Glacial valley of Harpenden (now a dry-valley) against the clay and the deflections of drainage are worthy of a detailed description by some member of our Association.

The Bearing of the Drifts on the Age of the Valleys.—In what may be conveniently called the St. Albans-Hatfield Area these drifts form a large unbroken sheet, roughly triangular in shape and bounded on the north-west by a line from Digswell to St. Albans; on the north-east by one from Digswell to Hertingfordbury, and on the south by a line from St. Albans, passing through Hatfield, to Hertingfordbury. The Lea roughly

bisects this area and the geological maps show that in this part of its course the banks are composed entirely of drift, neither Chalk nor Tertiary being anywhere exposed, and in this respect this portion of the Lea valley differs totally from all the other valleys in the district.

Prolongations from this mass extend some distance up the valleys of the Mimram and the Lea, penetrating the area where the western Local Drift first comes on ; indeed, a little south-east of Wheathampstead the Chalky Boulder Clay is in direct contact with the Clay-with-flints.

It is in connection with the projection up the Mimram that the most valuable information has been obtained. When Dr. Sherlock mapped this ground he found that the portion of the stream that forms a right-angle bend to the south of Codicote* has cut a post-Glacial valley, the former valley which was in a straight line with the rest of the present valley being now filled with drift, which rises not merely to the lip of the valley, but considerably above. This vital piece of evidence shows conclusively that the valley is not modern, but pre-Glacial, so far as this part of the country is concerned. The drift, and the ice containing it, completely filled these old valleys, except possibly the largest ; and when the ice melted, the streams resumed for the most part their former courses and swept the glacial deposits out of them.

There is, however, one notable exception to this rule, in the large drift-covered area of St. Albans-Hatfield already defined. Here the old upper Colne did not succeed in re-establishing its course, which was filled with drift, and the stream is now deflected into the present Lea valley ; but nevertheless the whole of that valley from Digswell upward was originally the head of the Colne. This is clearly shown by the great depth of the drift in what would be its old channel ; evidence of deep wells have proved this, but it is desirable to obtain all possible records of any boring or wells in all parts of this triangular mass of drift.

The completeness with which the lower courses of the main branches of the Thames and the Thames itself have cleared their valleys of drift need cause no surprise ; they would of necessity do so, for the whole country has experienced an uplift, or a fall in sea-level, of over 100 feet. This must have been accompanied by so great a deepening of the lower portions of the pre-Glacial valleys, that for the most part the drift must of necessity have been entirely removed, except where above the lip of the deepened valley.

An important piece of work left for the members of this Association to carry out is the determination in the case of each stream of the points where this over-deepening now termin-

* *Geol. Surv. Map, New Series, One-inch Sheet, No. 239.*

ates. An example will be given to show exactly what is meant and wanted.

About Taplow, the *Taplow Terrace* is roughly about 50 feet above the river, but on following it up it is gradually found to occur at a lower level until at Marlow it becomes the *Flood Plain Terrace*. At Marlow, then, we reach the limit of cutting back to at least 50 feet of the post-Glacial uplift, but this is not the limit of the whole deepening due to the total uplift, which has been fully 100 feet. There is always a chance of finding some trace of pre-Glacial deposits, such as old Alluvium or possibly the remnant of some old Terrace when we are well above this point of recent deepening, for it is in these sections alone that there is any chance of the drifts and anything beneath them being preserved in the base of the higher portions of the pre-Glacial Valleys. There is little doubt that the extreme heads of many of the minor valleys are still choked with drift of some kind.

(2) DRIFTS OF THE WESTERN AREA.

The Drifts introduced or formed by the Western ice and to which the term *Western* is applied are shewn on the Old Series One-Inch Map by two shades of pink and two of brown. As before, the deposits coloured pink are gravels, those coloured brown being clays. The paler pink is meant to indicate the bedded sands and gravels containing abundant far-travelled stones (Bunter, etc.) The deeper pink is restricted to gravelly material, generally unbedded or but faintly bedded. Actually, however, the material thus indicated varies greatly in composition, origin, and age, and the present use of the tint is most unsatisfactory. The clays coloured brown are all mainly of local origin, and though there is a difference between the two, it is often impossible to draw any line between them, and the name applied to the lighter coloured is often misleading.

The Bedded Sands and Gravels with Far-travelled Stones.—In the Western Area the bedded Sands and Gravels with far-travelled stones are shown fairly well on the older maps. It will be shown that the area so coloured is far too great; but as the evidence for this has been quite recently obtained, it will be discussed later on. The deposits themselves contain many foreign pebbles common in the Eastern gravels already described, such as the well-known Bunter quartzites, but these are far less abundant in the Western bedded sands and gravels. No Scandinavian boulders ever occur and hard Palæozoic sandstones are far more common than true quartzite. The most marked difference is the much greater proportion of angular vein-quartz present in the Western gravels; it is not only abundant, but often occurs in large fragments, pieces four inches long being common, while occasionally small boulders

10 inches long have been met with. In addition the quartz is often associated with schorl, indicating originally a Cornish or Devonian source, though it is probable that they were brought directly from some deposit in which the hard debris of the Devonshire rocks had accumulated, such as the Permian Breccias; they might even have been derived from beds which obtained their hard material from the Permian; in any case, they have lost little of their original angularity. It may be noted that this excess of angular vein-quartz over other foreign pebbles is more marked in the ground further north of the Thames Valley than in that nearer the River on the north side. Though vein-quartz is common in the Eastern gravels, it never forms so large a proportion of the hard material. The stones in this Western Drift were introduced through the Goring Gap district; none came through the Wendover Gap, but it has not yet been proved that none came through the gaps of the Princes Risborough district, though this is unlikely.

(3) DRIFTS OF THE INTERMEDIATE AREA.

As the northern limit of the Bedded Glacial-gravels is approached, in the area about Beaconsfield, Chalfont, Chorley Wood, etc. (see map, Plate 1), it is seen that the deposits present differ greatly from those present at Hertford, Ware, etc. in the Eastern Area. There the undoubted Glacial deposits generally rest cleanly on the underlying Chalk or Eocene beds, nothing intervenes. Further, to take a clear and easily accessible instance, the Chalky Boulder Clay at North Finchley contains a very large proportion of chalk right down to its base, although it not only rests on London Clay, but also is miles from any outcrop of the Chalk.

Now in the Western Area a vast amount of pre-Glacial material, a detritus or drift of some kind, not only covered the greater part of the area when the ice entered it or accumulated on it, but this drift, composed mainly of local material, is still left in many cases, and one of the main difficulties of mapping is to know how best to represent it. We select a special area where the phenomena are clear owing to large exposures, and within it we see phenomena that may be called *Intermediate*, as in history and composition and distribution they lie between the bedded Glacial gravels of the Eastern and Western districts.

CHORLEY WOOD COMMON, HERTS.

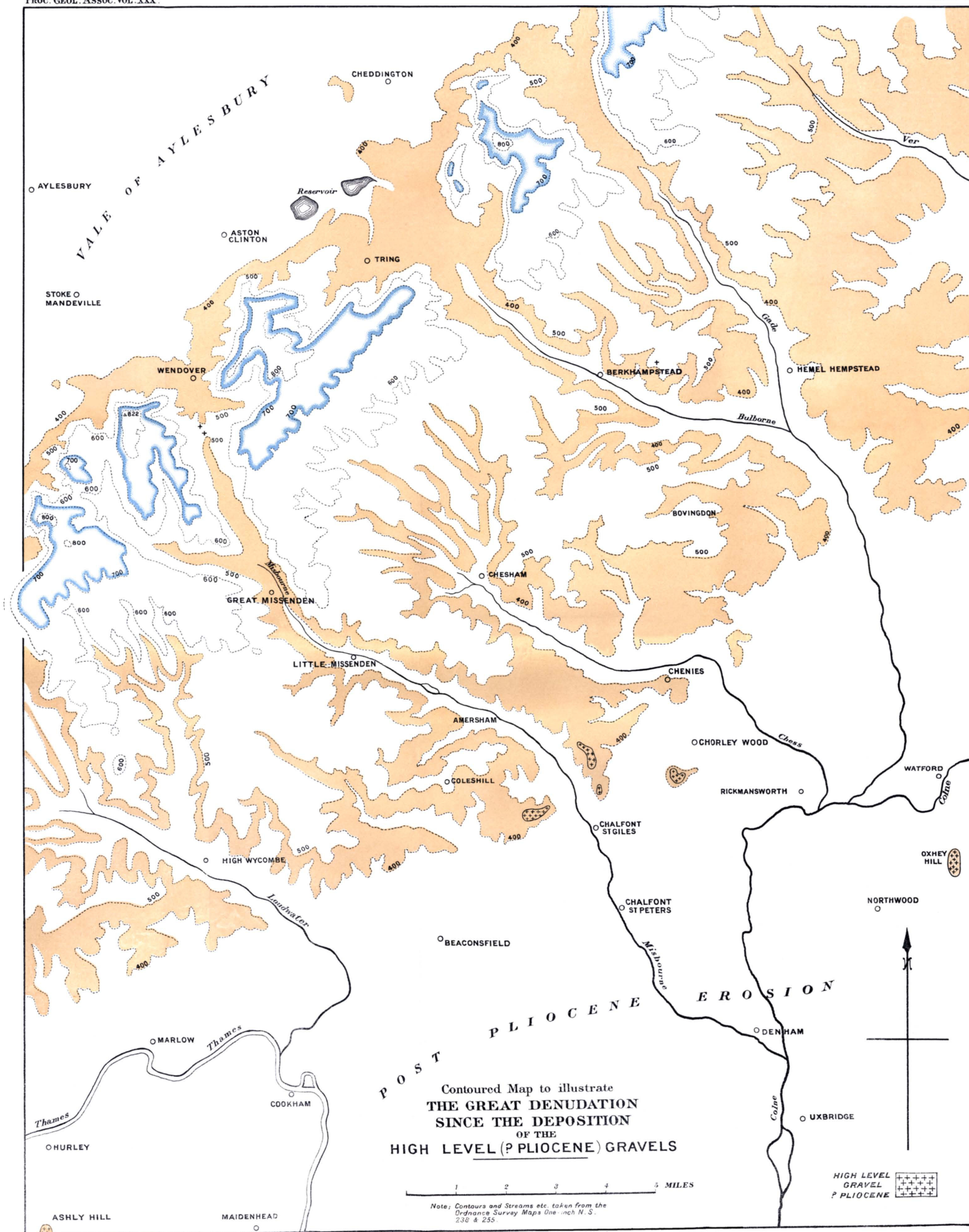
A series of long trenches were cut on Chorley Wood Common, Herts., which lies on the north-east side of the Metropolitan railway station. These trenches, roughly about six feet deep, have thrown much light on the composition and origin of the

material excavated. The surface of the ground in dry summer weather is gravelly and dusty—it is thickly strewn with stones of which by far the greater number are Reading-pebbles, more or less bleached. With them are associated a large number of far-travelled pebbles, a moderate number of flints and many small pebbles of white quartz; in this belt of ground these are always plentiful and locally they are present in abundance; it is specially important to note that these white pebbles are almost invisible in dry, dusty weather, which is the sole reason for no previous mention of the vast number of them present in this area; the area was mostly surveyed in summer. For this reason the area of Chorley Wood Common is shown on the Old Series Map, Sheet 7 as fluvio-glacial gravel, though the number of scattered ponds should have suggested the clayey nature of the sub-soil.

The trenches showed that the dominant component of the ground was a rather reddish sandy clay, containing a great number of Reading-pebbles (Clay-with-Reading-pebbles). But a considerable number of far-travelled stones are scattered, on the whole uniformly, through it. "The preponderance of angular fragments of vein-quartz, often several inches long, showed that the ice that transported them came from the west. The whole deposit is thus a portion of the Western Drift, and is a true Boulder Clay. By far the most abundant pebbles in it were derived originally from the Reading Beds, but they had long been set free from their original matrix, for the majority have lost their typical black exterior; small white quartz-pebbles are abundant, but are not easily seen in a vertical clay face. The general matrix is a yellowish sandy clay, sometimes with redder streaks in it; there is no reason to doubt that it is mainly composed of the waste of the Reading Beds.

"Scattered all through this deposit, but at a small depth below the surface, are a great number of lenticles of the Reading Beds unmixed with any other material or pebbles. The most easily identified of the lenticles are patches of the Pebble-Beds, in which every stone is well-rounded and has the typical black exterior; they thus contrast strongly with the pebbles in the enveloping clay, for most of these have lost their black exterior and many are greatly altered and broken. Lenticles of the bedded marls and sands are also present; they are easily identified by the total absence of any far-travelled stones, and in most cases they are free from pebbles of any kind. It would thus appear that the ice-sheet, already loaded with evenly mixed local debris and far-travelled stones, picked up lenticles of the Reading Beds in situ, but did not continue in movement far enough for these to be homogeneously mixed with the other material already present.

"The finding of these lenticles has proved of considerable value,



for similar lenticles of the (?) Pliocene deposit (to be described in the sequel), have been met with in drift also containing many far-travelled stones, and until the trenches explained their mode of occurrence, they were difficult to account for. These trench sections also show the deception produced by the surface washing of the Reading Drift with its abundant pebbles. The clay matrix at the surface has been completely washed away, or washed down into the underlying part of the deposit; the extremely stony residue left at the surface is practically a gravel, and has been mapped as such over large areas; indeed in this special case, as there are many far-travelled stones associated with the Reading pebbles, the whole deposit has been taken to be fluvio-glacial gravel, and coloured pale-pink on the old maps. As a matter of fact it is of the same age as this gravel and is the northward and rather higher extension of it, its distinguishing characters being due to the fact that it had not been washed by strong currents when the ice melted, and so shows no trace of bedding; it is, in fact, a true 'englacial' Boulder Clay."*

This mixture of the local Clay-with-Reading-pebbles and far-travelled stones covers a wide belt of ground, the southern part being usually coloured pale pink (Glacial gravel) on the Old Series Map, Sheet 7. In this more southerly part the far-travelled stones are mixed with the local material almost to the base of the deposit; a cess-pit showed 15 feet of this mixture of local and far-travelled material. Even the Clay-with-flints at the base had been disturbed by the passage of the ice-sheet. The pit is specially referred to, as the excavated material contained thousands of the little white quartz-pebbles to which reference will be made in the sequel (p. 36).

As we go further north (strictly north-west), the depth to which far-travelled stones occur in the "Clay-with Reading pebbles," or "Brickearth" diminishes, and though they are still common at the surface, cess-pits and the roots of blown-down trees show that they rarely descend more than two or three feet, and later on not more than a foot. This decrease and final ending off of the far-travelled stones is best shown at present in the Chorley Wood district, because there happen to be more temporary sections there. In the trenches on the Common they descend to a depth of at least six feet, and on the whole they seem to occur in much the same manner up to the hollow marking the county boundary; northward of this there is a marked change, for the blown-down trees near Green Street farm show that they rarely descend to a depth of three feet. Northward they seem to be scattered over the surface only, becoming

* Quoted with modifications from *Proc. Geol. Assoc.*, vol. xxix, 1918, p. 141.

† This was made for a house situated about a mile and a half south of Chalfont Road station on the west side of the road to Chalfont. The house may be recognised by the conspicuous thatched roof of the entrance lodge.

isolated and ending off before Amersham Station is reached. The greatest height they here attain is about 430 feet. In the area north of Great Marlow, there are fewer sections in the critical zone ; but here also, after extending to a depth of a few feet only, they again occur further at, or close to, the surface only, but they now end off at only a little below 500 feet above sea-level.

On the Eastern side of the Misbourne they are mixed with the local material, here more gravelly, to a depth of at least five feet, at a height of at least 460 feet above sea-level ; they die away as before, but the wooded nature of the ground makes this more difficult to trace. It will thus be seen that these far-travelled stones occur in a varying manner as we go from south-east to north-west. First they are most abundant in the bedded fluvio-glacial gravels ; this passes almost insensibly to a non-bedded gravel in which the proportion of local hard material is greatly in excess. Further north-west we come to the unwashed clay, composed mainly of local Reading material with a quite subordinate amount of far-travelled stones all through it. Eventually a still smaller number occur, confined to the upper foot of the local deposit, and finally they are scattered at the surface only. To illustrate these different deposits on a map, when they have no definite boundaries, is no easy task. The most feasible plan would be to divide the whole into three groups as follows :—

1. The Bedded Gravels with abundant far-travelled stones.
2. The local clay and stoney material with far-travelled stones almost to the base. The Intermediate Drift.
3. The local material in which far-travelled stones extend only a foot or two down ; or occur at the surface alone, becoming altogether absent before the 500 foot contour is reached.

CLAY-WITH-READING PEBBLES AND CLAY-WITH-FLINTS.

The greater part of the local material that falls under the head of No. 3 is shown on the western half of the Old Series Map, Sheet 7, by two tints of brown ; the paler is used for the so-called Brickearth (much of it our Clay-with-Reading pebbles), which is much the more extensive ; while the darker indicates Clay-with-flints, shown on the map largely as a fringe to the Brick-earth. There is considerable variation in the composition of the materials thus shown, and consequently it is advisable to get a more accurate knowledge of them and to ascertain if there be any order or arrangement in the variations noted.

BRICKEARTH OR "CLAY-WITH-READING-PEBBLES."

Under the heading of *Brickearth* associated with the Clay-

with-flints Mr. Whitaker* gives a description of the local drift or detrital material covering a large area. Within this are pits made in deposits that seem on the whole free of stones and which often make good bricks. He states that it is largely composed of Reading material, and suggests that as now seen, much of it may be of glacial origin. After noting the difficulty of separating it from the Clay-with-flints, he suggests treating the whole as Brickearth bordered by Clay-with-flints.

If the area coloured pale-brown on the map be examined on the ground, considerable variation is seen in its composition. Woodward says that much of the Brickearth near Chesham, especially to the west, contains many large unworn flints. So abundant are these that the deposit may sometimes be mistaken for Clay-with-flints. In other words the material mapped as Brickearth here contains many flints derived directly from the Chalk.

In the area north-west of High Wycombe, the Brickearth is remarkable for the Sarsens in it, and in the neighbourhood of Walters Ash they are so large and abundant and often so close together that Prof. Prestwich† thought they must be nearly in place.

Westward of Great Missenden (see map, Plate 1.), loose blocks of Sarsen are abundant, so that in this area the Brickearth contains a large amount of identifiable Reading material still in good sized coherent patches.

The varying nature of the Brickearth or our "Clay-with-Reading-pebbles," can best be understood by examining its south-eastern part, which occurs in the belt of ground bordering a line drawn from south-west to north-east through High Wycombe, Amersham, Berkhamstead, etc. (see Plate 1. and the Old Series Map, Sheet 7). Within this belt are a number of outliers of the Reading Beds, the larger ones being shown on the geological map referred to, though their bare outcrops only are represented in colour, their continuation under the Brickearth being shown by dotted lines. This really means that the Brickearth covers the Reading Beds in exactly the same way as a Glacial drift would. In some of these outliers the Pebble-Bed is well developed, while in others it is absent. Thus to the south-west of Chorley Wood (see Plate 1), this bed has been proved to be present over the whole of the Swillet Hill; it is often six feet thick and rarely less than four. It would obviously supply a vast number of pebbles when being denuded. At Cowcroft, to the north-east of Chesham, repeated openings have proved there is no Pebble-Bed present and here the Reading Beds would supply few pebbles when being denuded. Thus along the belt of ground in which these outliers occur, there would be a considerable difference in

* *Geology of London*, vol. i, pp. 287-289.

† *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 127.

the number of pebbles in the debris of the Reading Beds, unless it were mixed or churned up in some way, so as to modify or obliterate these original differences. Indeed, on a small scale, the minor differences have been obliterated, but not on the larger scale. There are extensive patches of the material in which Reading pebbles are present in smaller number, but on a small scale the material is in most cases fairly homogeneous. Along its true south-eastern portion the Clay-with-Reading-pebbles (No. 3) at first differs solely from the Intermediate Drift (No. 2) in the absence of all far-travelled stones; indeed, along its extreme southern margin they are at first still present for a foot or two beneath the surface. Sections in this southerly type of Brickearth or "Clay-with-Reading-pebbles" show that it is a red or yellowish clay usually containing a great number of Reading-pebbles, some of which retain their original black and noded surface, while the rest show varying stages of alteration, many being bleached and broken. Except near the base, flints are not an important constituent; almost all are broken and all have lost the original termination of their projections or "horns." Very few, if any, either of broken flints or of Reading-pebbles show signs of attrition in water. Small fragments or pebbles of Sarsen are not uncommon, while in all large excavations, blocks of Sarsen and cemented Pebble-Bed (Pudding-stone) are always met with from time to time; in the western part of the area Sarsen is the more common. In addition to the hard material there are streaks and lenticles of a very red clay that is clearly of Reading origin, though possibly downwash. While far-travelled stones are absent from most of this Clay-with-Reading-pebbles, there are present in it a great number of small white pebbles of quartz associated with a smaller number composed of lydite. The white ones are always common, and in certain localities are present by thousands; but, as stated before, they can be well seen at the surface only when the ground is wet in autumn or winter. There is no doubt that owing to the ground having been surveyed in summer their presence in such large numbers has not hitherto been recognised.

As in the case of the Intermediate Drift (No. 2), already described, the clay at the surface is either washed away or worked down, leaving a sandy gravel in which Reading-pebbles are by far the most important constituent. Although the little quartz-pebbles are present, they are often difficult to detect, as they lie in the interspaces between the far larger Reading-pebbles. In certain good sized patches of ground representing detritus derived from an outlier from which the Pebble-bed is absent, the surface is comparatively free from these larger stones, and the white quartz is then easily seen. A good example of this occurs west of Chenies (see Plate 1), where thousands of them are visible at the surface; although these pebbles are so small, one could

gather half a pint of them without moving from the place on which one is standing. The failure to recognise the true origin of the gravelly surface of the Clay-with-Reading-pebbles has led to many blunders in mapping. It is often coloured pale pink (Glacial gravel) when there are no foreign stones in it, though it still contains many of the white quartz-pebbles. But this composition of the residual stones is almost identical with that of the true Pebble Gravel as defined by Mr. Whitaker* and for which it has been mistaken in many places. It is shown as Pebble Gravel in the map accompanying the paper by Dr. Sherlock and Mr. Noble† “On the Glacial Origin of Clay-with-flints.” One of the best-known mistakes is shown on the Geological map (Old Series, Sheet 7) at Coleshill ridge. From the days of Prestwich this ridge has been represented as capped with Pebble Gravel (Westleton Beds of Prestwich), while in reality it is simply the gravelly residue of the Clay-with-Reading-pebbles. This has been placed beyond doubt by the excavation of a large reservoir at the east end of the hill. A similar mistake has been made in the case of the gravelly material capping Cowcroft Hill, east of Chesham, where again large recent excavations have proved the true nature of the deposit.

The exact north-west extension of this Clay-with-Reading-pebbles has yet to be determined, and will provide much work for the Association.

The gravelly aspect of the material capping the two hills just referred to, illustrates a phenomenon that is fairly common in this area. Where a stony clay caps a ridge or margin of a hill with steeply sloping sides, the rainfall entering at the surface can, in this case, issue at its edges carrying the clay with it. The deposit can here be washed right to its base; the process is continued further and further in from the margins of the deposit, till on a narrow ridge the whole is converted into an unbedded gravel. The south-west end of the Coleshill deposit comes to a taper end and is completely altered to sandy gravel; the east end is much broader, and only the edges are so altered, the reservoir having been made in clay that has undergone surface washing only. The “Intermediate Drift,” the “Clay-with-Reading-pebbles,” and the “Clay-with-flints” all undergo this form of washing when at the edge of a steep hill, and the resultant gravel is shown occasionally on the maps as Pebble Gravel; it obviously has no connection with this deposit as defined by Mr. Whitaker, and affords a good reason for the maps being often unintelligible. This form of washing is totally different to that which resulted in the formation of the bedded Glacial Sands and Gravels and it might be advisable to distinguish this special type as “Static-gravel,”

* Guide to the Geology of London and the Neighbourhood. *Mem. Geol. Survey*, 1875-1901. Also *Geology of London*, vol. 1., pp. 290-292.

† *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, pp. 199-209.

to imply that the material had not been moved during the process of its conversion by "Static-washing" into gravel. They serve to bring out strongly the necessity for another term for the deposits that were originally indicated by the term "Pebble Gravel"; the name has been applied by different surveyors to all sorts of gravelly deposits, without any reference to their age, origin or present height above sea-level. This point will be discussed later, as it is the most important question here raised.

CLAY-WITH-FLINTS.

The term *Clay-with-flints* has been applied to a considerable range of deposits, varying from one composed solely of clay and flints derived directly from the chalk, to one differing little from the Clay-with-Reading-pebbles or part of the material mapped as brickearth. To begin with, it is advisable rigidly to restrict the use of the term to the composition implied in its name. On the present occasion it is not intended to discuss the occurrence of this material in pipes in the Chalk; this is so large a question as to need treatment by itself and will repay very careful study.

An excellent account of the type material is given in the *Geology of London*, vol. I., pp. 281-287, where the various theories of its origin are discussed. In the belt of ground specially examined, where the Reading outliers occur, the deposit is shown for the most part as a fringe to the Brickearth (Clay-with-Reading-pebbles), and in contact with the Chalk.

The area about Chorley Wood affords special opportunities for investigating the mode of formation of the deposit, as there is a considerable number of small valleys branching from the larger ones in the Chalk. The steeper sides of the valleys are mostly formed of bare Chalk, but directly the slope flattens, the Clay-with-flints appears as a markedly red clay with large unworn and often unbroken flints.

"Its mode of occurrence is exceptionally well known at and about Chorley Wood, partly because of the extensive gardening and allotment work, and partly because many cess-pits have been sunk through it into the chalk below. The Director himself had frequently dug down to it, and even through it, and there was very little variation in the phenomena observed. Taking a case where the chalk is about three or four feet below the surface, the latter in its original state is almost always very stony and sandy; distinctly light, and in summer it is said to 'burn' badly. The dominant constituents of the pebbles are 'Reading' and show all gradations from black and well-rounded types to decomposed varieties in which the original external colour has been completely destroyed; moreover many of the pebbles are broken. Though present, broken flint

is subordinate, and on the whole less common than the far-travelled stones, which are often abundant. In addition there are a great number of the small white-quartz pebbles derived from the (?) Pliocene deposits; but they are so small that in spite of their number they do not bulk largely. The whole deposit is drift, and certainly Glacial Drift, but in most cases it is *remanic*, i.e., it has gradually been washed down the hill slope to a point considerably below that at which the Glacial Drift was left when the ice melted. It may be noticed that here a large number of fragments of sarsens are associated with this drift; there is scarcely a garden in which at least one has not been dug up, and three are now visible in the Station Road, just about the outcrop of the 'Clay-with-flints.' They are interesting because they must have been brought some distance from the west, and across at least one deep valley, for no sarsens are known to occur in the neighbourhood of this hill.

"At about 18 inches down, the Reading and other pebbles mentioned above decrease in number, except flints, which become more numerous and less broken. From this point to the Chalk surface the pebbles rapidly diminish and die out, generally at from six inches to a foot above it. The clay steadily becomes tougher and more compact, while the flints are at first little broken and finally unbroken and devoid of any traces of weathering; in many cases they are partly, and in some cases wholly, coated by a black film. In this particular area the lowest clay has a chocolate-red tint, and is extremely tough; it does not show the dark, almost black, colour seen at the base of the 'Clay-with-flints' in many other localities. The lowest layer, and in places the lowest two layers, of flint show a feature that is likely to prove important in further investigations; the peculiar horn-like projections from the larger flints are absolutely intact, and it is proposed in future to describe these as *flints with 'unbroken horns.'* The lowest layers of flints are seen to be arranged, relatively to one another, almost, if not exactly, as they were when in the chalk and in bulk they often greatly exceed the clay; further, the spaces between, through which pebbles could pass, are often quite small. This arrangement of the lowest flints seems impossible unless we suppose that the chalk surrounding them was dissolved away, and dissolved so slowly that the flints were practically undisturbed. One sees clearly that there was good reason for the supposition that the 'Clay-with-flints' resulted from the slow solution of the chalk; that it is, in fact, a residual deposit. So far as the lowest flints are concerned this clearly must be the case; but the clay has a very different origin. The bulk of it is derived originally from the Reading Clay, which has formed most of the clay in the pebbly deposit seen at the surface. This clay contains so many stones that the latter act like a sieve, and in wet seasons the clay passes

down between them, becoming more concentrated as it passes through the smaller spaces between the flints. That the clay does so descend has been placed beyond doubt in many of the gardens. It is a stock expression here that the 'stones grow'; many gardeners dig a depth of two feet and this brings up the clay, greatly improving the arid surface. But the clay will not stay up; in a year or two it has again descended, and the surface is as stony and sandy as ever; the stones have 'grown' again. But, if the large flints are dug out almost to the chalk surface; and all the larger stones sieved out, the result is that the stones no longer 'grow' and the clay no longer descends; after a wet season not more than an inch of the material below the surface is appreciably more sandy than when it was turned over.

"Thus in this special area the 'Clay-with-flints' near its outcrop is rarely more than two feet thick; it is succeeded above by 'Clay-with-Reading-pebbles'; the 'Clay-with-flints' is formed in situ by the dissolution of the chalk; the flints are left undisturbed and unbroken, while the clay slowly descends and fills up the interspaces between them. In the ground thus specially examined the 'Clay-with-Reading-pebbles' is largely downwash, *i.e.*, post-Glacial, and the 'Clay-with-flints' at the present outcrop is partly, possibly entirely, post-Glacial. Further, as the downwash descends the chalk slope, the formation of 'Clay-with-flints' is set up, *pari-passu*.

"There is a little reason to doubt that the 'Clay-with-flints' in this area of Reading outliers on the Chalk is thicker further up the hill slope and under a greater thickness of cover, whether the latter be of Glacial origin or older. There is of course no 'Clay-with-flints' beneath the Reading Beds in situ. Though numerous cess-pits have penetrated the Clay-with-flints, more accurate details of it are wanted*" where it is under a thicker cover, whether composed of the Intermediate Drift or of the "Clay-with-Reading-pebbles." To what extent is the basal clay dark coloured, as it is in many areas, and to what extent has it been disturbed by ice-movement as the overlying material has been at least to a considerable depth from the surface?

Some distance north-west of the belt of Reading outliers the Clay-with-Reading-pebbles greatly in excess passes gradually to Clay-with-flints greatly in excess; but the latter over a considerable breadth of ground always contains some of the rounded flint-pebbles and locally a considerable number. In addition, small white quartz-pebbles are present, though not generally abundant over much of the area. Broadly speaking, this *passage material* is further distinguishable from the typical Clay-with-flints as it contains a greater amount of clay in proportion to

* Quoted with slight modifications from *Proc. Geol. Assoc.*, vol. xxix, 1918 pp. 142-144

flints, (see p. 24). It will be easier to obtain an idea of the northern limits of this passage belt by reversing the order of examination and commencing to the north-west on the highest accessible area. On the crest of the hill, about a mile south-east of Wendover and 800 feet above sea-level, a reservoir is being constructed (see Plate 1) and the excavations show a deposit of typical Clay-with-flints, containing no trace of any other hard material. It caps the whole of the hill, setting on at about 50 yards from the steep edge and thickening towards the crest to at least 7 feet. The whole of the ground above 800 feet is similarly covered, and starting from this altitude and proceeding south-eastward toward Chesham, through Buckland and Cholesbury, no alteration was detected until the 700 foot contour was almost reached. Some small distance further on, at 650 feet, there are several old pits in the true Brickearth, (see p. 31), one of which close to Buckland Common is still open. This will be referred to again on p. 33, but for the present it is sufficient to say that the material on the sides of the pit now shows a moderate number of rounded flint-pebbles and a good number of white quartz-pebbles. However, flints are far more abundant and more clay is present than in the deposit capping the highest ground. The minor stages of the change from the type Clay-with-flints have yet to be traced; and again this Association has a difficult problem to solve. Two miles west of Great Missenden, but at the same height above sea-level, another brick-pit which is still open shows a clay with many flints, but also containing some rounded flint-pebbles and occasionally a fair number, (see p. 33). This pit is three and a half miles south of the great Chalk escarpment and separated from it by a deep valley, but the material on the sides of it is closely related to that seen at Buckland.

GLACIAL ORIGIN OF THE CLAY-WITH-READING-PEBBLES.
(BRICKEARTH IN PART.)

There is nothing suggestive of a glacial origin in the composition or structure of the true Clay-with-flints that caps the highest ground to the south-east of Wendover (see Plate 1) and descends to at least 750 feet above sea-level. On the other hand, the Drift of the Intermediate area (No. 2), which lies mostly about the 400 foot contour, is undoubtedly Glacial, for it contains far-travelled stones often to its base. The question now arises to what extent the material between the two is of glacial origin, or churned up by glacial action. According to the old nomenclature, this material comprises the greater part of the deposit shown on the Old Series Map, Sheet 7, as Brickearth and coloured pale brown. It includes the two ill-defined belts of ground here defined as the "Clay-with-Reading-pebbles" (No. 3) and the passage belt composed of clay

containing flints in excess (often greatly in excess) of the rounded flint-pebbles and the small quartz-pebbles, which we may call No. 4.

The Brickearth in the neighbourhood of Walters Ash has been described by Dr. Sherlock* in his paper on "The Glacial Origin of the Clay-with-flints," in which he gives reasons for believing that as it now exists the deposit represents the glacially churned-up debris of the Reading Beds, mixed with flints from the Upper Chalk that once covered the sloping Chalk platform. Without further examination it is not easy to decide whether the material described belongs to the typical Clay-with-Reading-pebbles or to the passage belt between it and the typical Clay-with-flints. Whatever it may be, it clearly is not Clay-with-flints.

The typical Clay-with-Reading-pebbles, such as that which forms the more southerly part of the Brickearth of the old map, is composed in the main of Reading-Beds-debris and contains quite a subordinate number of flints. Had this not been disturbed after its first deposition, it would have resembled the "head" of non-glaciated districts such as Devon and Cornwall. Though this "head" shows no sign of deposition by streams or in a lake, yet it often locally has a somewhat bedded aspect owing to the occurrence of lines (seen in section) of pebbles or coarser material in it. These appear to be due to sudden and heavy rains carrying coarser material down quite low slopes, while normally only fine silts or clays would be so transported; the lines are usually short and are often separated by considerable intervals. This structure is absent from all but some small patches of the Clay-with-Reading-pebbles; when actually seen it is suggestive of patches of an older structure that has escaped churning up by ice owing to the occurrence of the material in a somewhat protected hollow. The observed structure thus suggests its glacial origin or re-arrangement and that such processes have taken place at times right to the base of the material has been clearly proved at the Cowcroft Brickfield, near Chesham.

COWCROFT BRICKFIELD, CHESHAM.

This Brickfield is situated on the east side of the hill at Cowcroft, about a mile and a half east of Chesham. (One inch map, New Series, Sheet 238). There are many openings on and around the hill in sand as well as clays used for brick and tile making. Some of the workings must be of considerable age, for they were already disused in part and obscured at the time when they were visited by Prestwich. The hill is one of the most northerly of the Tertiary outliers on the gently sloping

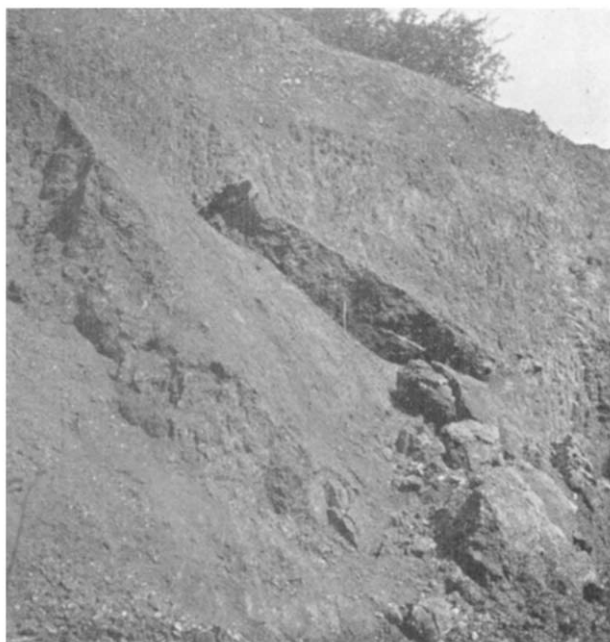
* *Quart. Journ. Geol. Soc.*, vol. lxviii., 1912, pp. 199-203.

Chalk-plane and is capped by London Clay, which is unusual in one so far north. The crest of the hill is 520 feet above sea-level and it dominates the surrounding ground for some distance. Numerous sections show that the Reading Pebble-Bed is absent, and though this is in part counterbalanced by the occurrence of the basal Pebble-Bed of the London Clay, the small extent of this would not account for one-tenth part of the rounded pebbles on and about the hill; they occur in vast numbers on the eastern side. It is possible that the London Clay pebble-bed may account for a small increased thickness of the pebble skin on the crest of the hill and over part of the brickpit. Three visits* have been paid to these pits by the Association and accounts of two have been published; the last suggested the presence of a small fault on the eastern side of the hill dropping down the Chalk and thus lessening the resisting power of the overlying soft Tertiary beds on the western side.

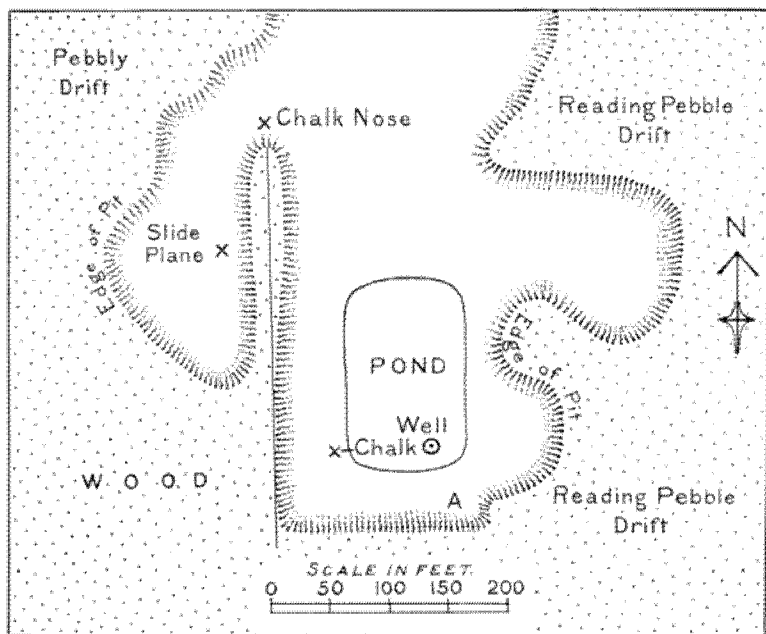
A plan of the pit is here reproduced (Plate 2, Fig B) showing the southern extension that has taken place within the last few years, in order to exploit the pinkish clays that were found when driving in a southerly direction. The ground surrounding the pit (see plan) is thickly strewn with pebbles and these are shown by the excavated margin of the pit to be simply the residue left by static washing of the Clay-with-Reading-pebbles, which is here a homogeneous grey clay with abundant well rounded but more or less bleached pebbles. The weathered surface shows well how one may be misled into supposing the whole ground to be a form of Pebble Gravel if these clear sections had not been exposed; as a matter of fact much of it has been so coloured on the maps. In excavating this cover of stony clay(' callous' of the workmen) a fair number of unworn flints was met with, as well as fragments of Sarsen and blocks of Puddingstone, one of the latter weighing several hundred-weight. All of these constituents must have been carried up to the top and over the crest of the hill, and as they occur in totally unbedded clay the deposit must be of glacial origin. Numerous sections show that the Puddingstone does not occur in or about the hill and the geological maps show that the blocks must have been brought from a considerable distance. It is especially important to note that this top drift passes over everything beneath it, without being in any way affected in composition, and any phenomena suggestive of movement or faulting cease at its base; it is a true boulder-clay or englacial material left by the ice when it melted, unaccompanied by washing of any kind; it must, in fact, have melted after the ice had come to rest.

Foreign or far-travelled stones, such as Bunter-pebbles, are entirely absent from this clay. There is, however, a sprink-

* *Proc. Geol. Assoc.*, vol. xxvi, part 5, 1915, pp. 330-340; and vol. xxviii, 1917, pp. 40-43.



A.—COWCROFT BRICKFIELD, SOUTH-WEST END.
(The Slide-plane shown at X in B.)



B.—PLAN OF PART OF THE COWCROFT BRICKFIELD, CHESHAM.
—G. Barrow.

ling of the small quartz-pebbles already referred to, but they are not present in anything like the number met with in the typical High-level gravels of Stanmore, Shenley and Barnet ridges, or in other parts of the area here specially investigated.

" The southern extension of the pit (shown in Plate 2, B) is irregular in shape, and the westerly part is separated from the rest by a spur projecting north and south. Much of the spur, beneath the top drift, is composed of gravelly material crowded with pebbles, many of which have been exposed to surface weathering. These are set in a clay matrix that varies from pinkish-brown to brown. It is useless for brick-making, and its continuance right through the spur to the western bank of the pond is the cause of the spur being left. The excavations in this western part of the pit have revealed the presence of a number of overthrust or glide-planes, along which heaping up of the material originally at or near the surface has taken place. Several of these were pointed out, and the photograph (Plate 2 A) shows the best exposed at the time of the visit.

" At the top of the photograph and forming the sky-line is the Clay-with-Reading-pebbles, which, as usual, goes over everything. Beneath this, at the right, is the pink Reading clay, which has probably been somewhat churned up and contains a few stones, but not enough to interfere seriously with its use for brick-making. The stones are probably forced into it, but some may have entered it down cracks when it originally lay close to the surface. Near the centre is the edge, in shadow, of a bed of the pink clay containing specially few stones, and to the left of this is the polished undulating surface of the glide or thrust-plane, along which the clay has been forced over the now underlying bed, the edge of which forms the second shadow. This bed is the gravelly clay so full of pebbles that have once been at the surface, and which is useless for bricks ; it passes right through the spur shown in the plan. (In the photograph the hammer-handle rests against the edge of the bed of pink clay, while the head rests on the slide or thrust-plane that forms the top of the gravelly bed.)

" The position of this slide-plane is shown in Plate 2, B ; the photograph (Plate 2, A) shows its high dip in a direction slightly south of west, the strike being slightly west of north. The continuation of the plane was cut open on the west side of the pit and photographed soon after, but the loose pebbly material soon began to trickle down and obscure the section. Beneath the drift this showed pink clay with few stones resting at the same high angle on the stony clay with the slickened plane between ; beneath the stony material is a brown loamy sand, almost a clay, the bulk of which is free from mixed material and is probably a patch of the Reading Beds ; it also seems separated from the

bed above by a thrust-plane, but these are not so clearly defined in the sandy material as in the clays."

A second visit was made to the pit to ascertain the nature of the material that lay above the pink clay with few stones and the pink large excavations showed to be Reading material mainly marl. The final result shows that

- (i) The band full of stones, mostly surface-weathered and associated with little clay is overlain by and separated by a thrust-plane form.
- (ii) The band composed of Reading Clay with few stones again overlain by and separated by a thrust-plane form.
- (iii) Reading material, largely the marl, containing no pebbles of any kind.

It is thus clear that material originally well below the surface has been forcibly driven over material that originally occurred at the surface, for it is composed mainly of Reading pebbles, many of them much weathered.

"An examination of the rest of this part of the pit shows numerous slide or thrust-planes; they are most easily seen in the pink clay; all have a high dip and are approximately parallel to the one shown. All these movement-planes are also approximately parallel to a long, narrow strip of Chalk to be described next, which is clearly out of place, for the main outcrop of the Chalk here lies at a depth of some 40 ft. or more below it.

"At the north end of the spur this strip of Chalk is clearly exposed (see Plate 2, B) and the following facts can be made out. It contains the true original top of the Chalk, or rather the basement bed of the Tertiaries, for the glauconitic bed here rests on the Chalk, and is succeeded upward by substantially the same beds as were met with in the pit where the glauconitic bed is so clearly displayed. But every band shows signs of disturbance, in the first place the Chalk itself is traversed by a thrust-plane, parallel to those previously described. If this plane be followed to the top of the Chalk, it will be seen that here the glauconitic bed has been sheared off for a short distance. If we followed farther up, it will be seen that immediately above this point of maximum stress both the clay and the sand-bed, worked in the other pits, thin considerably as they pass over this resisting point formed by the crest of the hard Chalk. Moreover the Chalk is overturned at its left or eastern side, as is shown by the accompanying turn over of the glauconitic bed; the idea of this being in some way due to a swallow-hole is not tenable, for in such case the glauconitic bed would be cleaned away as the swallow-hole is entered; a more conclusive point is that, if a swallow-hole, it would have one side only, for there is no other side visible or known. The debris covers the last point seen of this bed, but it is intended to remove this later on.

"The Chalk has been met with at the other end of the spur, close to the side of the pond; the exact spot is marked x on the plan (Plate 2, B). Within the pond itself a well has been sunk some 40 ft. without reaching the Chalk, showing how greatly out of place is this long narrow strip of Chalk underlying the gravelly material of the spur. The fundamental reason for the existence of the spur is now seen to be this core of resisting Chalk, against and partly over which the material nearer the original surface has been driven. At the south-east side of the pond, at the point A on the plan, the section below the top drift is: First the pink clay with few pebbles and showing well-marked prismatic weathering; then bedded, brownish clay with no pebbles, being part of the original succession in the Reading Beds; while at the base of the bank and forming the floor of the pit is a considerable thickness of apparently undisturbed brown sandy loam. It is close to this edge of the pond that the well was sunk. It is now seen that at this side of the pit only the material nearest the pre-drift surface has been seriously disturbed. We have reached the side of the hill opposite to that from which the movement came (here attributed to the impact of a sheet of ice), and the normal thickness and succession in the Reading Beds is being regained."*

The result of this evidence is to show that not only has the Clay-with-Reading-pebbles been glacially churned up, right to its base, but the underlying ground has been torn into strips as well.

Thus the belt (No. 3) of Clay-with-abundant-Reading-pebbles of glacial origin has resulted from the churning up of the Reading debris, mixed with a quite subordinate number of flints. To what extent has the next belt (No. 4) been similarly churned up? It consists of much clay containing abundant flints, but a quite subordinate number of rounded flint-pebbles, accompanied in most cases by a varying but generally small quantity of the little white quartz-pebbles. It is best seen about the 650 contour above sea-level and in one opening has a somewhat bedded aspect and contains short lines of stones. One of these is largely composed of mahogany flints (see p. 33) of such size as to suggest a "Coombe-rock," formed under glacial conditions, rather than normal "head;" its present structure does not suggest glacial churning up. The belt of ground between 600 and 700 feet above sea-level is little known and deserves careful investigation; it will probably be some years before it will have been properly mapped and explained.

THE TRUE BRICKEARTH.

The more carefully we examine the southerly and greater part of the material shown on the old map as Brickearth, the

*Quoted with slight modifications from *Proc. Geol. Assoc.*, vol. xxvi, 1915, pp. 336-39.

more difficult it becomes to understand why this term was ever applied to it. The great mass of it is so stony as to be useless for brickmaking. It seems probable that the whole was so named on account of the great number of excavations for Brick-earth that have been made in it at one time or another ; but if the whole of these were accurately shown on the map, it would be at once apparent that they form a small portion only of the area coloured pale-brown. But they were not only numerous, they were almost the only excavations made within the area, as the stony material was of no economic value. Thus the material to which the term Clay-with-Reading-pebbles is naturally applicable has come to be named after a deposit that occurs simply as a series of quite small patches in the pebbly material, and in the majority of cases they have no connection with it.

Brickearth of the same nature and origin has been worked to the north-west in the material (No. 4) which forms a kind of " passage " to the Clay-with-flints ; in it flints are abundant, but more broken on the whole ; there is a varying but smaller number of Reading-pebbles, while some small white quartz-pebbles are dispersed through a considerably larger proportion of clay than in the typical Clay-with-flints. This more clayey material is similarly called Brickearth, as brickearth occurs within it in the form of small patches or inliers. There is never any passage from it to the worked brickearth, neither is there from true Brickearth to Clay-with-flints ; but there is a fairly good passage from the latter to the less pebbly clay (No. 4) just described. It will be interesting to ascertain if true Brickearth occurs within the true and typical Clay-with-flints that occurs at the highest altitudes.

While the true Brickearth may have originated in various ways and may be of slightly different ages, the most common origin is probably connected with the solution of the Chalk surface. In addition to the well-known pipes, hollows of considerable length and of varying but smaller breadth are sometimes formed.

The sinking of these was a very slow process and the gradient at any time would generally be too small for anything but clays and fine loams to be washed down into them. As the sinking proceeded the underlying chalk surface would acquire a greater and greater dip towards the hollow. And this is precisely what is known to be the case in many examples. The patches of true Brickearth are not separated in the area contained within the western half of Sheet 7 until the neighbourhood of Berkhamstead is reached, and its occurrence at Ashlyns Hill is shown by a special colour (yellow). There is little doubt that no such large coherent mass as that shown on the map really occurred ; a number of patches of different size have been grouped together.

Mr. C. J. Gilbert has for some years studied these deposits of almost stoneless clays and loams, known locally as fat clays, and was the first* to suggest this origin for them; he was led to do so by the invariable phenomenon of the sudden and sharp rise of the chalk-surface as the margins of the deposit were approached.

Two good sized pits are still open; the first is close to Buckland Common, three miles and a half in a direction a little south of east from Wendover Station, and 650 feet above sea-level. The material worked is a rather confused mixture of clay and loam, and the sides consist of very variable material, which at first appears to be inexplicable. Its true significance may be understood, however, if we consider that the material adjacent to the stoneless loams is in places almost on end, owing to the solution of its original base. Thus the original sides are incessantly slipping as the excavation proceeds. In one place the true basal Clay-with-flints, including the characteristic black clay is exposed, this basal material being exposed because the original cover of clay, containing a considerable number of Reading-pebbles and some white quartz-pebbles, has slipped down; while at other points it is in position, originally above, but now by the side and in front of the Clay-with-flints. There are many points of special interest to be seen in this excavation.

The second pit occurs about 2 miles due west of Great Misenden again about 650 feet above sea-level. The sides of the pit are often confused, but in a small portion it is seen that the nearly stoneless Brickearth comes to the surface. The other portions of the sides show sometimes true Clay-with-flints, but more often abundant flints in such clay, mixed with a varying proportion of rounded flints (probably Reading originally) and a few pebbles of white quartz. A noteworthy feature of this part of the material is the condition of the flints and pebbles; they are in the main totally unlike those (primarily of the same origin) that occur in the Clay-with-Reading-pebbles to the south-east and at lower levels. At the higher elevation the pebbles are generally quite white and have a thick patina, closely resembling that of the similar pebbles of the gravels at about 600 feet elevation to the south of the Thames. The flints often show the same thick white skin; both are very old and were exposed at or near the surface for a long time before they were buried in the clay now containing them. Mahogany flints are also locally abundant, again confirming the view of the long period that has elapsed since they were set free from the parent rock. The greatest mystery is the source of the almost stoneless sand; it is probably Reading material, but it could not have come from the Reading Beds direct, for there could have been

* A somewhat similar suggestion has, I believe, been made before, but the author has not been traced. Mr. Whitaker also adopts the idea, but it does not fit the map. G.B.

none in existence within a mile at least of the present pit, when the stoneless loams were deposited. The pit is at the crest of a low ridge and with the present form of the ground no material now occurs which could provide any downwash or debris. It seems more likely that the greatly altered stones and the loams were both derived from some material that was itself formed from the earlier destruction of the Reading Beds and that this was of Pliocene age. In any case these old brick-pits are of great interest and require organised and minute investigation. In particular it is desired to know if this true stoneless Brick-earth ever occurs within the typical Clay-with-flints in the highest levels, from 700 to 800 feet.

From the foregoing account of the area here specially dealt with it will be seen that so far five different deposits have been recognised and that they are usually traversed as we proceed from the south-east to the north-west. They are as follows :—

- (1) *Fluvio-glacial Gravels* with abundant stones derived from the west. The deposits are well-bedded until their north-western margin is approached, when the bedding is lost ; they remain as gravels for the clay originally associated with them has been removed by static washing. Local stones always form a large proportion of the gravel and this proportion increases as we proceed to the north-west.
- (2) *The Intermediate Drift*, which mostly lies about the north-west margin of the gravel, although in places it underlies that deposit. How far south the latter occurs is not yet known. The Drift is called "Intermediate" as it occupies an area intermediate between that of the eastern and western Glacial gravels. It contains far-travelled stones, often to its base, all of them being of western origin. It is composed of material of the same age as that of the Fluvio-Glacial gravel of western origin, but while the latter was strongly washed on being set free from the ice, that of the Intermediate Drift was not ; it is a true englacial drift, like the Chalky Boulder Clay. Either the Drift, or the ice that contained it, diverted the waters that washed and deposited the gravels. If this water be claimed as the former Thames, then the very existence of this material negates the possible eastern course of that river, for this deposit deflected it to the lower Colne. The ice that brought in this material travelled much further eastward than did the streams that accompanied its melting. By "static" washing this stony clay has been and still is converted to gravel at the surface and so has been mistaken on the one hand for true

Glacial Gravel and on the other for Pebble Gravel. It passes gradually to :—

- (3) *Clay-with-Reading-pebbles*, in which the far-travelled stones gradually disappear until the deposit is entirely of local origin, though it often contains locally thousands of small pebbles of white quartz. Reading-pebbles greatly exceed flints in amount. By static washing this deposit also is converted to gravel at the surface and has been often mistaken for true Pebble Gravel and in at least two cases for the basement bed of the London Clay. It has been glacially reconstructed and is now in the most part a true glacial deposit. It passes insensibly to
- (4) *Clay with abundant flints and far fewer Reading-pebbles (rounded flint-pebbles.)* A few white quartz-pebbles are present, but the distribution of these is not yet known. It is doubtful if the greater part of this deposit is of glacial origin, although it may have been formed during a cold period. The appearance of many of the flints and pebbles suggests they were set free from the parent deposit at a distant and probably pre-Glacial period. The deposit is typically developed between the 600 and 700 feet contours. It lies within a rather inaccessible district, but is worthy of special and detailed examination. It is not too much to say that at present it is almost unknown.
- (5) *Typical Clay-with-flints or clay containing flints and no other hard material.* This type of material is best developed on the highest ground, about 700 feet above sea-level and upwards. It is peculiar in that the most recently formed portion is probably at its base. This material is still forming over a large part of the area at the base of (2), (3), and (4), but its actual outcrop is usually limited to a mere fringe between their base and the Chalk.

Scattered over the whole area covered by these three types are numerous occurrences of *Brickearth*, and by far the greater proportion of these are formed by sinkings in the Chalk. Some are in the main pre-Glacial, at least in their lower part; but like the Clay-with-flints this material is probably still in process of formation. The Brickearth and the margins of the pits where it is worked are worth very careful investigation, for such work may throw much light on the former extension of the (?) Pliocene deposits.

It is to these (?) Pliocene deposits that we next turn our attention.

DEPOSITS OF (?) PLIOCENE AGE.

Attention has already been drawn to the persistent occurrence of small pebbles of white quartz disseminated through the Clay-with-Reading-pebbles; they are locally met with in great numbers, but in this deposit are unaccompanied by any far-travelled stones. It was for a long time difficult to trace their source, though it soon became clear that as now distributed they were gathered entirely from ground within the Chalk escarpment and must represent the waste of a once widespread deposit characterised by an abundance of these little quartz-pebbles. They were found to be most numerous on and about the sides of certain flat-topped hills, the crests of which are rather more than 400 feet above sea-level. But in this position they are accompanied by far-travelled stones and it took some time to puzzle out the explanation, which appears to be as follows: In pre-Glacial times these flat-topped hills were capped by the white quartz-bearing deposit which contained no far-travelled stones; the latter were introduced by the ice-sheet coming from the west, which, at the same time, churned up the underlying material and mixed the foreign stones with it. The first of these deposits to be located was on the hill of the Swillett, about a mile west of Chorley Wood station. (See Plate 1) The crest of this hill is about 410 feet above sea-level and the top is practically flat. At the surface there are a considerable number of far-travelled stones, and in some cases not so many quartz-pebbles as on the east slopes of the hill, a little below the crest. This is not due simply to the passage of the ice, for an opening at the entrance to the village shows that there is a deposit of sand in some places overlying the bed with the quartz-pebbles, which are thus locally absent at the surface. The pebble-bed was formerly exposed in a small pit* on the south-west side of the hill, which showed that far-travelled stones were present in small number only and confined to the surface layer; below this the material is practically identical with the small quartz-pebble gravel of Hampstead Heath; it is also at almost the same height above sea-level. The deposit thus belongs to the High-level or Pebble Gravels, but the bearing of this will be discussed later.

SOURCE OF THE SMALL QUARTZ-PEBBLES.

The question now arises, what was the source of the small quartz-pebbles so abundant in the High-level Gravels. It seems almost certain that, in the area about Rickmansworth, they must come from the north, and as the Lower Greensand seemed the most probable source, a visit was made to Leighton

*Probably a lenticle, similar to those in the trenches of Chorley Wood Common, See pp.16-17.

Buzzard, where the sand is dug and passed through a rotating screen. The coarsest material issues from the end of this, and was found to consist of pebbles of quartz and lydite, many of which are almost dreikanter-like in form. A considerable number are polished, at times almost burnished, while a fair number of the small rounded quartz-pebbles are semi-translucent. The pebbles in the deposit on the Swillett differ from the above solely in having a somewhat worn aspect, such as one would expect as a consequence of the distance they must have travelled from their source.

About a mile and a half to the west of the Swillett, there are two more isolated hills rising to a height of rather more than 400 feet above sea-level, both on the east side of the Bulbourne Valley (see Plate 1). The first is a little north of the Vache, and is easily found as Captain Cook's monument stands on it; it is not so flat as usual, being covered with the Glacial clay containing far-travelled stones. The small quartz-pebbles are thus best seen round the sides of the hill and especially on the west, where the drift has been more washed away. A little way inside this wood, to the west of the monument, we had the rare good fortune to find a large fragment of Sarsen with the base of the quartz-pebble bed firmly cemented to it, both on top and about its edges; the bed is here composed mainly of small quartz-pebbles. The Sarsen has been broken open and there are no pebbles of any kind inside it.* The presence of the distinctive high-level deposit as originally laid down on this hill is thus conclusively established. The cause of the Sarsen forming the base of the deposit here may be described as follows: Starting from the Vache the base of this quartz-pebble-bed transgresses almost the whole of the Reading beds as we go north to Pollards Wood, where the base of the gravel rests on the lower beds of the Reading Series; it thus transgresses the band in which the Sarsens occur when present. Doubtless by its hardness this rock projected slightly above the adjacent softer sand, and the base of the quartz-bearing gravel rested cleanly on and partly round it. The specimen of the adherent fine quartz-gravel is absolutely unmistakable, for there is no other deposit in the whole region to which it could be referred.

A little further north is the third outlier (see Plate 1) again with its peculiar features. Here the Bunter-pebble-bearing ice has ridden right over the hill top 460 feet above sea level, which overlooks the Misbourne Valley near Chalfont St. Giles. It has carried sufficient material to leave a fairly thick deposit in which Bunter-pebbles are not uncommon, and the distinctive large angular fragments of vein-quartz are moderately abundant. There is fortunately a fairly large pit still open in this material, enabling it to be examined. As before, the small quartz-pebbles

*This has now been deposited in the Museum in Jermyn Street.

are abundant, and probably represent much of the pre-Glacial downwash from its west side, caught up by the ice and brought back to the crest of the hill again. As before, small more or less coherent lenticles of the quartz-pebble gravel in situ were involved in the ice, and on melting these have been left and may be seen at the surface here and there, the ground being locally strewn with little else than these pebbles. A small opening was made in one of these and a washed sample showed that the pebbles in it were all small and fully 70 per cent. of them were of white quartz. The gravel in the pit referred to, which should be visited by the Association, is another perfect example of the type of deposit to which alone we would now apply the term "Pebble Gravel," *i.e.*, a deposit composed mainly of stones, with a quite subordinate amount of clay, which has been washed in situ (*Static-washing*) mainly by percolating rainfall; the position for this is here ideal, being the crest of the margin of the deep and steep-sided valley of the Misbourne.

In the same neighbourhood, and again at a little more than 400 feet above sea-level, a fourth outlier or remnant of this gravel occurs, now on the opposite or west side of the Misbourne valley (Plate 1), capping the greater part of the large flat-topped hill of Hodgemoor Wood. Fortunately there is a brick-pit at the north-east end of the hill, showing the Reading Beds capped by the quartz-pebble gravel, somewhat churned up by the passage of the ice over it, and in consequence mixed with a considerable number of far-travelled stones; it is an excellent example of the mixture claimed by Prestwich as Westleton Beds (see p. 44.) As at the Vache, the ice carried the *débris* mainly eastward, and a small pit opened recently below the farmhouse (Hill Farm) shows again a great number of the quartz-pebbles mixed with the drift. At the top of the hill not only do the quartz-pebbles far exceed in number all others, but together with the associated lydite-pebbles, they now show their original characters as fragments derived from the Lower Greensand much better preserved than at lower levels. They retain in many cases their dreikanter-like form and in part their glossy appearance; while the semi-translucent quartz-pebbles are also common.

The most important point connected with this outlier is its occurrence on the side of the Bulbourne valley opposite to the Vache; *i.e.*, this deposit occurs on both sides of the valley at almost exactly the same level, and in each case dominating the immediately surrounding country. They clearly formed part of a once continuous sheet, and were deposited before the present valley existed. It has already been shown that these valleys in the Chalk are pre-Glacial (see p. 13), and it is now proved that these quartz-pebble gravels are separated from the Glacial epoch by the time required for the formation of almost the whole of the

present valleys ; these gravels then are far pre-Glacial and must be at least of Pliocene age and possibly of middle or early Pliocene.

However, it is clear that the gravels were laid down in a hollow of some kind, and it is possible that there was here the commencement of an older Bulbourne valley to the north, the general level of the surrounding country being considerably higher than at present. But the sides would be composed of Reading Beds unprotected by the gravel and in the immediate neighbourhood have since been denuded to a lower level than the remnants of the old valley-base. In these gravels about the Vache, the number of pebbles of white quartz is so much greater than that of the other constituents that we must obviously be proceeding towards the point at which they entered the district. They could not have come over the Chalk hills, these are far too high ; so as a first step towards achieving an explanation, a map was made of this part of the district showing the contours from 400 feet above sea-level upwards. (See Plate 1) The critical zone between 400 and 500 feet, was coloured, and a colour band drawn along the 700 foot contour. The map at once suggested that the pebbles of the particular area just described must have come through the gap above Wendover, and further that the other gaps also probably admitted Lower Greensand debris to enter the area within the Chalk escarpment.

A party of five, acting on this suggestion, went to Wendover to examine the deposit shown on the geological map at the crest of the gap as Dry Valley Gravel. The deposit is of considerable interest, but at first it suggested no clue to the origin of the quartz-pebbles. A very few examples of the latter were found after a careful search, and then the idea of investigating the formation underneath the Dry Valley Gravel occurred to us. Fortunately the railway, only a few yards off, cuts through the base of this gravel into the underlying Middle Chalk. On searching the sides and base of the cutting it was found that at the base there was a trickle of white quartz-pebbles and other small, well-rounded stones, totally unlike the extremely coarse angular material of the Valley Gravel, so that they must come from underneath the Gravel, and rest on the Middle Chalk. In other words there is still left on the crest of the divide between the Misbourne and the many small valleys draining into the Vale of Aylesbury, a small scattered remnant of the old quartz-pebble gravel ; that a portion of the distinctive pebbles entered the London area through this gap thus becomes clear. The base is approximately 500 feet above sea-level, showing a further rise above the last noted remnant at Pollards Wood, the base of which is slightly below 460 feet.

ORIGIN OF THE GAPS IN THE CHALK ESCARPMENT.

In order to pass through the Wendover gap the pebbles from the Lower Greensand must have crossed the outcrop of the Gault and the surface of this could not have been at a height appreciably less than that of the crest of the gap, now 500 feet above sea-level. There are a series of gaps in the Chilterns, with crests now at varying heights, through some of which it is now known that the small quartz-pebbles also entered the area within the escarpment, though how often this occurred has yet to be found out. Without going into minute details it will be sufficient for the present to say that this type of transit across the Gault could hardly have taken place unless that had an almost even surface and formed the bottom of a shallow sea, which passed through the gaps, breaking up the Chalk escarpment into a series of islands. So long as the Gault remained below sea-level it would retain a fairly even surface, sloping slightly toward the open sea, all denudation ceasing at a certain depth, but continuing in the bed above water. When the elevation above sea-level took place, the relative hardness of the beds attacked by erosion would prove a dominant factor in the subsequent moulding of the country. In the first stage, local streams would tend to form, flowing through all the gaps. Owing to some of the gaps being broader, and so letting more water pass than others, or for some similar reason, some gaps were lowered more rapidly than others. As the Gault is relatively easily denuded, this enabled the more rapidly cutting streams to eat quickly into the Gault area and so to capture the smaller streams flowing across the Gault and through the minor gaps; these were then left dry, and became wind-gaps. An examination of the contoured maps shows that one after another were cut off in turn, for the crests of the gaps now stand at different levels, which indicate roughly the time of capture of their streams.*

AREA NORTH OF THE CHALK ESCARPMENT.

If we restore the old Gault surface to 500 feet above present sea-level, *i.e.*, restore the conditions when the Wendover gap was formed, the entire present shape of the country, north of the Chilterns, would be obliterated and there would be no Vale of Aylesbury as we now know it. The whole valley has been eroded since the time that the little quartz-pebbles were passing through the Wendover gap to form the northern edge of the great mass of quartz-pebble gravel. The broad shallow hollow in which this was deposited was subsequently elevated at least 400 feet, so that small portions only of this low level deposit are now left; they form the small-pebble phase of the High-level Gravel, or the Pebble Gravel of Mr. Whitaker.

* See J. W. Gregory, "The Evolution of the Thames," *Nat. Sci.*, vol. v, 1894, pp. 97-108; also "The Chiltern Wind Gaps," *Geol. Mag.*, 1914, pp. 145-148.

INSIDE THE CHALK ESCARPMENT.

Inside the escarpment we are unable as yet to determine the form of the southerly portions of the islands produced by the cutting of the gaps. Did the gaps continue as narrow straits connecting the shallow sea of the Gault area with that of the great Tertiary area well inside the Chalk escarpments, or did the gravels encircle the islands not far from their crests on the south side? The extreme straightness of the 700 foot contour (see Plate 1), suggests that at least the highest beach-deposits did so encircle the islands, but the ground south of the escarpment between the gaps may easily have been a kind of backwater into which the quartz-pebbles did not penetrate, and so the deposit would be difficult to recognise. In the brief note on the ground at the 650 foot contour (see p. 31), it was pointed out that there are clear traces of some remnants of an old deposit, and we repeat the former statement that this is likely to prove one of the most profitable areas for examination. It cannot be too clearly understood that where the gravels were deposited on the softer Tertiary-beds, with a sloping bank of Tertiary above, denudation has in many places destroyed the soft sloping bank and left as outliers portions of the once lower gravel; thus the relative positions of the two are in time reversed.

THE HIGH-LEVEL GRAVELS (?PLIOCENE) WITHIN THE MAIN TERTIARY AREA.

In describing the small pit on the Swillet (see p. 37), it was stated that the small quartz-pebble gravel there exposed was substantially identical with that at Hampstead Heath, and at much the same height above sea-level, while the occurrences at the Vache, etc., are equally parts of the same formation. We are now in a position to discuss more fully the bearing of the information gathered above on the former widespread occurrence of the High-level (?Pliocene) gravel, which immediately preceded the formation of the present Thames valley or rather the development of the Thames itself, the course of which was defined when this gravel was laid down.

THE HIGH-LEVEL GRAVEL OR PEBBLE GRAVEL.

The small patch of quartz-bearing gravel on Hampstead Heath is a detached portion of a once widespread deposit to which Mr. Whitaker has given the name of "Pebble Gravel." The largest remnants of this, on the north side of the Thames, now occur scattered over the rudely triangular-shaped plateau, nearly 14 miles long, and at one point nearly four miles broad, extending from Stanmore Common (Bushey Heath)* through

*See *Proc. Geol. Assoc.*, vol. xxx., 1919, Part 3.

Shenley and Barnet to Potters Bar, and thence onwards towards Hatfield, Bayford and Northaw. Westward of Stanmore is the more isolated occurrence on Oxhey Hill (see Plate 1), which links on with the area already specially dealt with; while the still more isolated patch on Hampstead Heath forms a link with occurrences south of the Thames.

So far back as 1847 these deposits were described by Prestwich, who much later on described them as Westleton Beds; among other earlier observers are Searles V. Wood, Hughes and Mr. Whitaker. All these authors were agreed that the occurrences referred to were either early Glacial or pre-Glacial, and on the whole the pre-Glacial view is dominant. Since their day much work has been done on these deposits on both sides of the Thames; the results have been published, often in papers dealing with special localities, and in this work the members of the Association have taken a large part. A very useful summary will be found in Dr. Salter's work* "On the Superficial Deposits of Central and Parts of Southern England," and its value is enhanced by the large number of references to authors given in it.

The best short account of these deposits is given by Mr. Whitaker†, who bases the first part of his account on his own observations, so that this part is excellent. Unfortunately he had, as usual, to incorporate the notes of others on what they took to be Pebble Gravel, much of which is simply a stony deposit or gravel left from the static washing of stony clays (see p. 22); this has led to great confusion and prevented the true meaning of the typical deposits from being grasped.

Mr. Whitaker notes the absence of the Bunter quartzites and the persistent presence of the small quartz-pebbles and at times of chert, but unfortunately he omits the most important point, namely, that the smaller pebble facies of the gravel now occurs mostly at an elevation of a little over 400 feet above sea-level, and forms remnants of an old plateau. This fact was insisted upon by Hughes,§ who called these deposits the "Gravels of the Upper Plain," and claimed them as undoubtedly marine. It is true that the Pebble Gravel does occur on Stanmore Common at a height of 510 feet above sea-level, but it is on the whole coarser and so far from militating from the value of the 400 foot-level, serves to connect the finer or floor deposits with the coarser or beach-deposits on both sides of the Thames at a higher level.

These gravels afford a good illustration of the importance of determining the source of the pebbles of which they are composed (see p. 10). So far as is known at present they were, as originally laid down, composed of materials derived from two areas only: one within the Chalk escarpment (or local), the

* *Proc. Geol. Assoc.*, vol. xix., 1905, pp. 1-56.

† *Mem. Geol. Survey*, The Geology of London. 1889, vol. I., p. 291.

§ *Quar. Jour. Geol. Soc.*, vol. xxiv, 1868, pp. 284-285.

other beyond this escarpment, but within that of the neighbouring Lower Greensand. The local constituents are Reading or other Tertiary pebbles, and flints; the latter constituent is small in quantity where the gravels rest on Tertiary Beds, but it becomes much increased when on, or close to, the Chalk. In addition, pebbles of Sarsen are not uncommon; they have been wrongly identified as quartzite. The pebbles to which the term "neighbouring" is applied consists of white quartz and lydite, and all are small. They have been proved to have been derived from the Lower Greensand, and this identification is corroborated by the fact that over considerable areas small fragments of chert from the same formation are associated with them often in great numbers.

"Far-travelled" stones, derived from the Bunter Carboniferous Limestone, Red Chalk, etc., etc., are entirely absent from these deposits as originally laid down. Thus the fundamental definition of these true High-level Gravels is that they are composed of "Local" and "Neighbouring" material only, at least within the London area. Broadly speaking, when not much over 400 feet above sea-level the gravels are on the whole composed of rather small pebbles, and it is convenient to define this more widespread portion of the deposit as the "small-pebble gravel"; when they occur at a higher level they usually contain larger flints or Tertiary pebbles. This is fairly well shown by the gravel on Stanmore Hill (Bushey Heath), a typical example of the Pebble Gravel of Mr. Whitaker, occurring at one point at a height of 510 feet above sea-level. Since this Address was given, an outcrop has been found by Mr. C. J. Gilbert* on Little Heath, and resting on the Chalk, at a height of 550 feet, which shows much larger flints and Reading-pebbles.

An important discovery was made by Mr. R. W. Pocock in connection with the numerous large remnants on the Stanmore-Barnet and adjacent plateau. About Barnet and to the north-east, the finer gravels contain a large number of small fragments of chert derived from the Lower Greensand, while westward, toward Shenley, they become far less common and are practically absent about Stanmore Common. These chert fragments, accompanied by a vast number of the small quartz-pebbles, must have come from the south, as so far no chert has been found in the Lower Greensand to the north of the Chilterns. No appreciable amount of chert or white quartz occurs in any of the Eocene deposits till we reach the Upper Bagshot (Barton), and though this may have supplied some portion of the gravel, it could only have occurred locally, and such a source for any serious portion is impossible in view of what has already been stated as to their distribution. The bulk of the chert and associated small pebbles must have come through a gap in the Chalk

*See *Abs. Proc. Geol. Soc.*, No. 1032, 1919, p. 40; and *Proc. Geol. Assoc.*, vol. xxx., 1919, p. 87.

escarpment to the south of the Thames, probably that at Dorking, just as it has been shown that they came through the Wendover gap to the north. In the area about, and to the south of Barnet, the Eocene Beds could not have been denuded appreciably below what is now the 400 foot contour, for then these small fragments of chert could not have crossed ; as before, the softer beds (now Eocene in place of the Gault) formed the fairly level base of a shallow sea and probably these small chert fragments were drifted across by the overhead lapping of the waves ; they are so soft that they would probably be ground to pieces in the running water of a river. Indeed one may go further, and assert that the water must have been marine, as salt water tends to harden chert of the Lower Greensand type, while fresh water rapidly rots it.*

The study of these deposits has been greatly impeded by mistaken identifications of them and inaccurate descriptions of their original contents ; a mistake of the latter kind having been specially harmful. It arose from an idea of Prestwich† that two deposits at Westleton were intimately connected and almost of the same age. But as pointed out by H. B. Woodward,‡ the lower was of Pliocene age and the upper simply a fluvio-glacial gravel and there was no real connection between them. But being firmly persuaded of the truth of his view, Prestwich applied it to the London Area. To take the classic case of Ashley Hill, the crest of which is a little more than 400 feet above sea-level : This is capped by a gravel that in the main has the composition of Mr. Whitaker's Pebble Gravel ; but it is mixed with far-travelled stones. Now this mixture Prestwich regarded as original and clear proof of the one-ness of his Westleton Beds. In reality it is a repetition of the phenomena of the Swilket, the Vache, Hodgemoor Wood and other localities (see p. 36). The original capping of the hill consisted solely of these (?) Pliocene gravels, which stretched across in an unbroken sheet to the Vache, etc. The far-travelled stones were introduced by the passage of the western ice. Turning to the map, Plate 1., the blank area shows how great was the denudation between the two epochs ; all but the post-Glacial portion of the Thames valley was eroded between the two. This case has been specially chosen because near Marlow it is becoming singularly easy to estimate exactly the amount of post-Glacial erosion ; further east it becomes far more difficult.

* This has been abundantly proved on the Yorkshire coast where such rocks are hardened and form great scars projecting far into the sea ; whereas inland they are rapidly decomposed when acted on by rain.

† *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, p. 461 ; *Ibid.*, vol. xlii, 1890, p. 96.

‡ *Geol. Mag.*, Dec. iv. vol. ix, 1902, p. 27.

HIGH-LEVEL GRAVELS SOUTH OF THE THAMES.

(1) *The 400 Foot Platform, South of Newbury.* In order to follow further the investigation of the old Platform, roughly 400 feet above present sea-level, a visit was made to the gravel pits at Newbury Common about a mile south of the Town. The plateau-like aspect of the ground is singularly striking, and it at once recalls the area about Barnet at approximately the same level. But on examining the gravel, scarcely a trace of anything like Greensand-debris could be found; quartz-pebbles seemed entirely absent; there are no far-travelled pebbles, and for all practical purposes the gravel is made up of flints from the Chalk and Tertiary pebbles, *i.e.*, entirely of 'local' material. This is in the main composed of small pebbles and fragments, though this statement requires verifying. The absence of quartz-pebbles seems due either to the intervention here of the great Chalk ridge, shutting out all material from its outer side or escarpment,* or to there being no outcrop of the Lower Greensand to the west that could supply the quartz-pebbles.

2. *North of Aldershot.* A large spread of these High-level Gravels occurs to the north of Aldershot on both sides of the Blackwater, forming the Fox Hills, Cobham Ridges, Easthampstead Flats, etc. The gravel conforms strictly to our definition, being composed of local and neighbouring material only. As it occurs in an area where the higher Bagshot Beds (Barton Beds) are present, some of the originally Greensand material may have come through these beds, instead of directly from the Lower Greensand, as the bulk probably did. A description of a portion of these gravels is given by Mr. Dewey,† to which the reader is referred. In view of the evidence obtained from the Wendover gap, there seems little doubt that in the original deposit the Lower Greensand material came mainly through the neighbouring wind-gap in the Chalk. Indeed, one would quote it as one of the most perfectly preserved illustrations of the phenomena of these gaps. Bearing in mind that these deposits were formed at the base of a shallow sea, when this was first uplifted, a number of streams would be formed, coalescing into one main river. As these rivers lowered their beds, stream gravels would be formed on their margins and these would descend as a series of steps as the streams continually lowered their bases. In this way the remnants of pre-Glacial gravel having the same composition as the original deposit, but occurring at decreasing heights, is easily accounted for. Probably there are far more of these old bordering stream gravels than is generally supposed, because their origin has not been recognised. The chert-gravels

*The deposit in this case is a good illustration of a 'backwater' as described on page 41.

† The Geology of the Country around Windsor and Chertsey; *Mem. Geol. Surv., Explanation of sheet 269*, by H. Dewey and C.E.N. Bromhead, 1915, p. 59.

capping St. George's Hill at 250 feet above sea-level may be quoted as an illustration of this phenomenon; they are probably pre-Glacial, but deposited when the lowering of the old base-level, now at O.D. 400, had proceeded a long way.

3. *Woolwich*. Far to the east of the last locality is the gravel capping of Plumstead Common, near Woolwich. Many accounts of it have been published; one of the most recent is that by Mr. A. L. Leach,* in which he classes this deposit with the High-level Gravel, the Pebble Gravel of Mr. Whitaker.

THE COARSER GRAVELS AT HIGHER LEVELS.

The view so far taken of the smaller-pebble gravel is that it was laid down over the bottom of a shallow sea. This sea must have had a high-water mark, and about this level beach deposits must have been formed, while all experience shows that they must be coarser than the material at the lower level. This, in fact, is what is well-known to occur: there are a number of remnants of these coarser gravels at higher levels on the south side of the Thames, most of which will repay organised examination; as a first step it is necessary to ascertain which really belong to the deposits here dealt with. Most of them are shown on the Old Series geological maps, and many descriptions have been published, largely by members of our Association. Two of these have been personally visited under the guidance of our members, one to the east, the other to the west, of the Dorking Gap. The western one is on Ranmore Common at a height of about 600 feet above sea-level. It is largely a coarse gravel in which Tertiary pebbles are extremely abundant; together with flints from the Chalk. A feature of the deposit is the occurrence of lenticles almost entirely made up of pebbles of Lower Greensand, showing that the great modern hollow in the Gault could not have existed when the gravels were deposited, or these pebbles could not have reached their present position. As before, the gravel is composed of local and neighbouring material. The one to the east of the gap, on Headley Heath, is also, in part at least, a coarse gravel, and many of the flints were being rounded at the time this deposit was being formed. They also show the *thick* white decomposed outer portion, so characteristic of pebbles long exposed at or near the surface. Both of these deposits near Dorking rest on the Chalk, and the decomposed state of many of their pebbles is due to their long exposure, as they have never been covered by Glacial or other more recent deposits. To the north of the Thames, where there is much drift, it was predicted that similar beach-gravels resting on the chalk would occur at similar heights above sea-level, but covered by drift. This prediction has since been proved to be correct

**Proc. Geol. Assoc.*, vol. xxiii., 1912, p. 112.

by Mr. Gilbert's discovery of the High-level gravels on Little Heath, near Berkhamstead; the pit excavated in them has already been visited by the Association.*

Much work remains to be done to complete the mapping of the older High-level deposits, and, if possible, a series of maps should be made similar to Plate 1, showing their reference to the contouring, and by the *large blank portions*, the enormous denudation that has taken place since their deposition.

In particular it is desirable to see if the gravels of Newbury Common, etc., can be traced further west, and if the High-level gravels of the Thames Valley can be proved ultimately to link on to the Pliocene at similar heights in Devon and Cornwall.

CONCLUSION.

The map, Plate 1, may be taken as one of a series to be used in mapping these old gravels and in tracing the history and origin of the Thames valley, which is briefly as follows:—

Long after the cessation of all the bending movements which produced the present structure of the Thames Valley, there was a fall of sea-level or a rise of the sea-bottom that brought the beds within reach of marine erosion. As a result the sea steadily ate its way far inland along the outcrops of the two masses of soft material, the Eocene Beds and the Gault, leaving four projecting ridges, the two inner ones formed of Chalk, now the Chalk escarpments, and two outer ones formed of Lower Greensand. In course of time the sea breached the Chalk ridges in a number of places (the majority of which are now wind-gaps), and through the gaps thus formed a great quantity of quartz-pebbles, etc., from the Lower Greensand were carried. They later on became mixed with the "local" material, the flints and Tertiary pebbles; the whole being finally deposited in the shallow sea or estuary cut in the soft Eocene Beds, where it formed the gravel deposits, which subsequently became Mr. Whitaker's Pebble Gravel, or our High-level Gravel. Around the margins of the shallow sea, beach deposits were formed, naturally of coarser material; remnants of them have now been found on both sides of the Thames, all at heights of more than 500 feet above sea-level.

As the elevation proceeded the base of the shallow sea was brought within reach of subaerial denudation; a great number of small streams were started that coalesced to form the inception of the modern Thames. At this stage streams would begin to flow through the gaps in the Chalk, probably in all of them; but those through which most water flowed would lower their bases in the more resisting Chalk most rapidly. In consequence they were able to set up small streams in the Gault parallel

* *Proc. Geol. Assoc.*, vol. xxx, 1919, p. 87.

to the escarpment, and in time captured the water flowing through an adjacent gap ; thus it was left dry and became a wind-gap. This process went on until a majority of the gaps were left dry, the height of their crests depending on the time that elapsed before their waters were captured. Since the formation of the oldest dry-gaps an enormous amount of denudation has taken place, and if we proceed any serious distance from the main Thames this is easily seen to be in the main pre-Glacial.

This view of the initiation of the Thames Valley is in the main that put forward long ago by Prestwich, but he ruined his case by the curious blunder of thinking that the mixture of glacial stones and High-level Gravel was original. This idea makes the Thames Valley almost wholly interglacial or post-Glacial and to anyone knowing the ground traversed by the minor branches of the Thames the idea is utterly untenable.

There is one point that we wish to insist on ; the distribution of the "small-pebble" and main component of the High-level gravels makes the idea of any serious post-Pliocene bending of the beds in the London Basin out of question, and these deposits are dotted about all over it and always attaining approximately the same level. The beach deposits are also at much the same level on both sides of the Thames. That these deposits are of Pliocene age we have very little doubt. Our own view is that they are but little newer than the Lenham Beds ; we must prove their age by fossils, and this Association must do its utmost to find them.

VISITS TO THE BRITISH MUSEUM (NATURAL HISTORY), SOUTH KENSINGTON.

SATURDAY, JANUARY 18TH, 1919.

A PARTY of 44 members assembled in the Entrance Hall at 2.15 p.m. Dr. A. Smith Woodward, F.R.S., F.G.S., Keeper of the Department of Geology, gave a very interesting demonstration on "Whales."

SATURDAY, FEBRUARY 8TH, 1919

A PARTY of 35 members assembled in the Entrance Hall at 2.15 p.m. Dr. W. D. Lang, Sc.D., F.G.S., gave a detailed account with demonstrations, of "The Evolution of Ammonites." A full report of the demonstration will be found in *Part 2*.