PEBBLY AND OTHER GRAVELS IN SOUTHERN ENGLAND.

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THIS paper deals with the various High Level gravels of the Thames Valley and the South of England generally. Those on the north side of the Thames Valley have already been described by the author,* and one of the objects of the present paper is to show that the results obtained by a study of the drift gravels of Southern England are in accord with those already published.

PRELIMINARY REMARKS ON GRAVELS AND OTHER FLUVIATILE ACCUMULATIONS.

(a) Gravels, when laid down, were at the lowest level in their immediate district, whatever the position they may now occupy.

(b) The presence of a bed of gravel implies the existence, at the time of its deposition, of a force able to convey material, often of considerable weight,† from a great distance, to its present position.

(c) Denudation acts far more slowly upon strata protected by gravel than upon that which is not so protected. In course of time, the bed of a stream depositing much gravel may become the summit of a hill, owing to the strata forming its banks having been more easily denuded, one large valley being divided into two smaller ones, with a ridge down the centre. In this way *the lines of drainage in one cycle of river action MAY become the water-partings of a succeeding one.* In other cases terraces of varying height may be produced, by means of which a rough estimate of the comparative age of the gravel can be obtained, which estimate, in rare cases, may be further strengthened by the finding of remains of animals, among which may occur indications even of man himself.

(d) The constituents of a gravel often give a clue to the tract of country which furnished them, and enable us to correlate various scattered deposits, especially when considered in connection with the altitude of, and angle of slope between, the various patches of gravel. In the absence of palæontological evidence, this method of correlation is the best available. The size and condition of the components of a gravel give indications of the force operating and the distance travelled.

* "Pebble Gravels from Goring Gap to the Norfolk Coast," *Proc. Geol. Assoc.*, vol. xiv, pp. 389-404.

† Cf. Mr. H. W. Monckton's paper "On Some Gravels of the Bagshot District," read before the Geological Society on January 19th, 1898.

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(e) Gravel accumulates in streams chiefly where, for some reason, the current is checked—*e.g.*, when a tributary enters the main stream, in which case there is often a mingling of two distinct classes of constituents. It is quite possible for a small stream, acting for a long time, to deposit a considerable amount of gravel, although at any one time it may be carrying but a few stones. The effect of denudation in a case like this would be to leave the gravel as an isolated patch.

(f) The character of a gravel, whether stratified, unstratified, or contorted, the occurrence in it of sandy or other patches, the kind of matrix, if any, and the condition of the uppermost layers of the underlying beds, all help us to form some idea of the conditions under which the gravel was deposited.

(g) Owing to slipping, redeposition, etc., it is advisable to take the *highest* point in a bed of gravel when forming any deductions based on difference of level. Allowance must also be made for any earth movements which may have occurred since the deposition of the gravel in the area under consideration.

(h) The highest and presumably oldest gravel beds, while themselves subject to addition and alteration, have supplied some, if not all, the materials of the lower and more recent beds of gravel in their vicinity.

(i) Beds of gravel may consist of the sweepings of an area which, after being gently denuded for ages, is subjected to more severe conditions for a time. As an instance of this may be mentioned the occurrence of large boulders* (*e.g.*, sarsens) and flint implements† *at the base* of beds of gravel.

(j) During the excavation of a valley by a river system, the main and tributary streams will frequently alter their positions; but some idea of their former courses will be afforded by the existing beds of gravel left high above the present streams, owing to the differential denudation referred to in (c). It follows from this that gravels deposited by the main stream during the earlier stages of valley excavation may now be found at some distance on one or the other side, *e.g.*, Dartford Heath, Ashley and Bowsey Hills, Hampstead Heath, etc.

(k) Since the effect of denudation is to lower the source of a river while the sea level at its mouth remains practically constant, the several gravel terraces will each have a smaller angle of slope than the one immediately above it. At the same time the relative distances between them in any particular district would be fairly constant.

(l) Neighbouring valleys or river systems in which the climatal conditions are similar, should, allowing for the differences in rock texture, be similar also in the evidence they show

* As at Chobham ridges.

† As at Broom, Somerset; Wrecklesham, Surrey, etc.

of former denudation. Should one valley be more affected than the other, the existence of the denuding agent in greater force might be inferred. Correlation between the drift stages of one valley with those of another may thus be possible.*

THE THAMES VALLEY GRAVELS (SOUTH SIDE).

1. High Level or Early Drifts.

At the following places, patches of gravel are found resting on Tertiary outliers (which owe their preservation to the super-incumbent drift deposits), at heights varying from 400 ft. O.D. near the middle of the valley, to over 600 ft. O.D. on its margin :

- (a) Cobham Park, Kent,† near the Mausoleum, 400 ft. O.D.
- (b) Swanscombe Hill, near Northfleet, 300 ft. O.D.‡
- (c) Around Ash on the Plateau near Eynsford and Ightham.
- (d) Well Hill, near Halstead, 600 ft. O.D. This small deposit contains Tertiary pebbles, subangular and green-coated flints, chert, small quartz pebbles (dull, translucent, and pink), jasper, etc. It is situated opposite the gap of the Darent through the North Downs.
- (e) Hill above Farningham, Kent.
- (f) Shooter's Hill, 424 ft. O.D.
- (g) West Ho Hill, Norwood, 360-380 ft. O.D.
- (h) Chipstead, over 500 ft. O.D., in pockets overlying the sands found there. The gravel is almost entirely made up of Tertiary pebbles.
- (i) St. Anne's Hill, near Chertsey, 300 ft. O.D.
- (j) Burgh Heath.§
- (k) Headley Heath,|| 600 ft. O.D.
- (l) Juniper Hill, 600 ft. O.D. The valley leading up from the Vale of Mickleham to Headley has much gravel on its highest slopes.
- (m) Ranmore Common, 600 ft. O.D., on the opposite side of the Vale of Mickleham.
- (n) Netley Heath,¶ over 600 ft. O.D. On the left side of the road, running from East Horsley to Shere, is a sand-pit, where about 12 ft. of sand is worked. Above the sand, and in pockets, is a gravel containing rounded, porous, and compact chert, iron-

* For further remarks on this subject see "The Development of Certain English Rivers," by Prof. W. M. Davis, of Harvard University, *Geog. Journal* for Feb., 1895.

† For descriptions of this and several other localities see Prof. Prestwich's papers on the "Southern Drift," etc.

‡ Cf. "Excursion to Swanscombe," *Proc. Geol. Assoc.*, vol. xiv, p. 395.

§ Cf. "Notes on the Gravels of Croydon and its neighbourhood," by G. Jennings Hinde, *Trans. Croydon Microscopic and Nat. Hist. Club*, 1896-7.

|| Cf. "Excursion to Headley," *Proc. Geol. Assoc.*, vol. xiv, pp. 124-128, by H. W. Monckton.

¶ *Proc. Geol. Assoc.*, vol. x, p. 182; also "On the Sands and Ironstones of the North Downs," by Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xiv, pp. 321-335; "Geology of the London Basin," W. Whitaker, vol. iv, pp. 336-342; and *Quart. Journ. Geol. Soc.*, vol. xviii, p. 271 et seq.

stone pebbles (polished and containing small pebbles of flint and quartz), unworn flints, small quartz, Tertiary pebbles, sandstone, and pieces of marcasite nodules. Quite close to the pits, and probably derived from them, was a large sarsen

(o) Newland's Corner, near Guildford, nearly 600 ft. O.D.

(p) Upper Hale, near Cæsar's Camp,* Aldershot, 470 to 605 ft. O.D. The upper part of the deposit is far more sandy than the lower, in which several sarsens are embedded in a clayey matrix.

Some of the foregoing consist of Tertiary *débris* only and were derived from strata previously existing in the Thames basin; others, however, contain material from a wider area, e.g.,

(a) Chert, which may be of a white, brown, or red colour, and either porous or compact. This is derived from the Lower Greensand area, and, together with other material mentioned later, show that the drainage area of the Thames has been curtailed towards the south.†

(b) Ironstone. Three distinct kinds are met with in the above localities, viz., a compact variety, evidently derived mediately or immediately from the Wealden area; a coarser variety, containing well-rolled flint pebbles, pieces of quartz, small flakes of mica, etc., which must therefore be of post-Cretaceous age, and is probably derived from pre-existing Pliocene beds on the North Downs; and a rougher variety, derived probably from the Bagshot sandy beds.

(c) Small quartz pebbles. These vary in size from half an inch long to sand, and consist of the dull, translucent, and pink varieties. Similar quartz pebbles occur in layers in the Wealden sandstones, e.g., those at Tunbridge Wells, near which place Dr. Abbott has found small pebbles of jasper, quartz, sandstone, etc., associated with them. These quartz pebbles are quite distinct from those found in the Westleton Drift on the north side of the Thames Valley, excepting those found on Hampstead Heath.

It would appear, therefore, that this series of deposits was laid down while the southern slopes of the Thames Valley were still mantled by Tertiary deposits, and when these slopes continued without break to the Wealden area. At first beds of gravel, made up of the wreckage of Tertiary beds, would be deposited, but soon material from a greater distance would appear as the streams deepened and cut back their channels, or earth movements brought the lower strata under the influence of denuding agents. The harder Chalk range would be breached at a few points by the streams running northward from the Weald, and thus initiate the series of gaps in the North Downs.

* Cf. H. W. Monckton "On the Gravels South of the Thames from Guildford to Newbury" *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 39, etc.; also Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 161; and Dr. Irving in *Proc. Geol. Assoc.*, vol. viii, p. 143.

† Cf. F. G. Spurrell, "A Sketch of the History of the Rivers and denudation of West Kent." *Proc. West Kent Nat. Hist. Soc.*, Jan. 27, 1886.

In the east the Darent commenced, and deposited the Well Hill and other gravels of West Kent. In the west several smaller streams appear to have fed a larger one which flowed westward close to Burgh, Headley, and Netley Heaths, towards the Merrow Downs and Upper Hale, Aldershot.* High land, above 600 ft. O.D., must then have existed over the Bagshot country, and prevented the streams flowing direct north as the Mole and Wey do now. This range supplied the sarsens from its upper portions since, at Upper Hale, we first find them embedded in the gravel near the base. The presence of this range would enable us to account for the curious sands associated with the gravels at Netley and Headley Heaths as being drifted from it in the higher courses of the tributaries of the main east-to-west stream. I shall hereafter refer to this high land as the Bagshot sarsen range, and to the main stream flowing east to west as the Bagshot

FIG. 2.—SECTION ALONG THE HIGHEST GROUND BETWEEN GORING GAP AND THE LAND'S END (*Vertical Scale much exaggerated.*)

stream, since they are both intimately connected with the past history of the Bagshot country.

Further to the west, the gravels near Inkpen (Upper Kirkby Green, 573 ft. O.D.) and Hungerford on similar Tertiary outliers, and the Southern Drift at Snelsmore and Greenmore Commons, 440 ft. O.D., near Newbury,† seem to point to a stream from the west, while on the north side of the valley a very similar set of gravels are met with. The "A" series, described by the author, corresponds to the drift containing local materials only, while closely connected with it is a series of gravels containing material derived from a distance. These were included in the "C" series, or Westleton Drift proper. The series "B" of that paper, the author thinks, was mainly derived from the south.

Before the succeeding series of gravel deposits were laid down, a vast amount of denudation took place. Some of the streams which brought quartz pebbles, etc., from the Wealden area were

* Cf. H. W. Monckton's remarks, *Proc. Geol. Assoc.*, vol. xiv, pp. 124-128.

† Cf. P. E. Richards in *Quart. Journ. Geol. Soc.*, vol. liii, p. 420.

diverted owing to the formation of the Chalk escarpment and the longitudinal E. and W. valleys at its base. Those traversing the Chalk range greatly deepened their channels and the sides of the Downs became furrowed by what are now dry Chalk valleys. The valley of the Darent became restricted to Lower Greensand and younger strata, while the Bagshot stream appears to have lost its upper feeders (the Mole, etc.), which flowed more directly northward to the central main stream.

Recently Mr. Clement Reid* has put forward the view that the removal of the flints from the Chalk has been brought about by the porous Chalk being temporarily converted into a hard compact rock by being frozen. This is quite feasible, and would most effectually lead to the sweeping of the hard insoluble residue from the Chalk down the valley. It is quite possible, however, that flints were not abundant. At Wrotham Chalk-pit, in the face of the escarpment, they are very scarce now. Beside this it is well to notice that in the formation of these transverse and dry Chalk valleys, we are dealing with a rock which under certain conditions is soluble in water. The solubility of calcium carbonate in water depends on the amount of carbon dioxide present, and the amount of this substance depends on temperature and pressure. The latter need not be noticed as the action we are considering took place at the surface. The former, however, is important. More carbon dioxide is taken up by cold water than by hot. It follows, therefore, that the amount of soluble bicarbonate of lime produced depends upon the temperature. For this and other reasons mentioned later, it is highly probable that the transverse and dry Chalk valleys were formed during a period when very cold water was continually acting upon the Chalk. In the more northern parts of England the Glacial period has mainly left its mark in the various effects of *solid* ice, in the south the effects are those of *liquid* water. This would lead to great denudation in the warmer portions of the country since the ice further north remaining longer unmelted would act as a rock, possibly cause great deviations in the lines of drainage, and certainly cause those which lead south to become inordinately swollen.

It is interesting to note that those parts of the North Downs† on which these drifts occur have been subsequently denuded the least, and it is there that Mr. B. Harrison and others have found those remarkable chipped flints (eoliths) described by the late Prof. Prestwich. Rolled specimens of them are found in the next series of gravels. It seems probable that these implements were scattered on the surface during the interval between the High Level and Lower Plateau Drifts.

* *Quart. Journ. Geol. Soc.* vol. xlviii, p. 360.

† For other localities, etc., cf. A. S. Kennard on "The Authenticity of Plateau Man," "Nat. Science," vol. xii, p. 277, and the Rev. A. Bullen in "Nat. Science," vol. xii, p. 106; also "Excursion to the Kentish Plateau," W. J. Lewis Abbot, *Proc. Geol. Assoc.*, vol. xiv, p. 196.

2. Lower Plateau and Glacial Drifts.

This series of gravels has a closer connection with the present river valleys than the preceding. It will be convenient to take the deposits in the tributary valleys first, and then those more directly connected with the main stream.

(a) In the Darent Valley, which was so thoroughly investigated by the late Prof. Prestwich, deposits occur at

1. Limpsfield Common,* above 500 ft. O.D.
2. Farley Hill, two miles E. of the Limpsfield patch, and 450 ft. O.D.
3. Boughton Hill, near Dunton Green, 357 ft. O.D.

The gradient given by these patches is 25 ft. per mile, which, if continued down the valley, would coincide with the level of the Dartford Heath gravel, which consists of material derived from the south, mingled with northern material.† Since the Limpsfield gravel is on the watershed of the Darent, and consequently at the top of the slope indicated, it is possibly rather older than the others, as may be inferred from the type of implements found there.

The gravels at Dunton Green and Chevening, in the Darent Valley, at slightly lower levels, 270 ft. O.D., than those already mentioned, appear to indicate a second stage, and the Chevening gravel is interesting, since it shows contortion, which also occurs in the Clay Pit on Limpsfield Common.

(b) The Wandle Valley, which at an early date was deprived of its Wealden drainage area by the recession of the Chalk escarpment northward and the cutting back of their valleys by the upper feeders of the Mole and Medway,‡ contains, as far as I know, nothing equivalent to the gravels at Limpsfield, unless those at Foxley Wood, 350 ft. O.D., and others near Caterham Junction, a few feet lower, mentioned by Mr. Spurrell,§ should be placed with them. Dr. G. J. Hinde, in an exhaustive account of the gravels of this valley, makes no reference to anything equivalent.|| The Chalk pit at Purley formerly showed numerous pipes filled with an ochreous gravel, which might possibly be referred to this stage.

(c) The Bagshot District. The gravels connected with the basins of the Mole, Wey, and Blackwater, will be considered together, the soft Bagshot strata having suffered greatly from denudation during and after this period.

Owing to the researches of Mr. H. W. Monckton, Dr. Irving,¶

* Cf. W. Topley, *Proc. Geol. Assoc.*, vol. xi, p. 32.

† For other patches in the Darent and Cray valleys mentioned by Prof. Prestwich, see *Quart. Journ. Geol. Soc.*, vol. xiv, pp. 270 *et seq.* (especially the diagram on p. 272) and vol. xlvii, p. 126.

‡ W. Topley, "Geology of the Weald," *Geol. Survey Memoir*.

§ F. G. Spurrell. *Op. cit.*

|| *Op. cit.*

¶ "On Bagshot Strata of the London Basin and their Associated Gravels," *Proc. Geol. Assoc.*, vol. viii, pp. 143-171.

Prof. Rupert Jones, and many others, the gravels of this district have received a great deal of attention, and I shall merely state such facts as are necessary, in my opinion, to show their position in connection with the other gravel deposits of the South of England. The Bagshot sarsen range still persisted, though probably of much less altitude, and continued to contribute large sarsens from its upper beds to the Bagshot stream which flowed along where the Chobham and Frimley Ridges and East-hampstead Plain, 426-390 ft. O.D., now remain. The bulk of the material composing the gravels in this district is derived from Tertiary strata, and but little from the Wealden. This is another indication that high ground composed of Tertiary strata existed to supply it. As denudation proceeded, this line of drainage became a watershed between the Bagshot stream flowing N.W. to join the main stream, and another flowing N.E. to join the same stream at a point nearer its mouth. By the first of these, the Hartford Bridge Flats and Finchampstead Plain gravels would be laid down at levels varying from 300 ft. to 333 ft. O.D., while the other would deposit the patches mentioned by the authors named, at Windlesham 310 ft. O.D.; the hills above Ascot, 301 ft. to 320 ft. O.D.; Chavey Down, 302 ft., etc. It is interesting to note that only small, rolled pieces of sarsen are found in the Hartford Bridge Flats gravels to the west of the ridges, while at Ascot Heath (especially near the Royal kennels) and St. George's Hill, 245 ft. O.D. to the east, they are large and plentiful.* From this it would appear that the sarsens came mainly, if not wholly, from the East side of the Bagshot stream.

The gravels further west contain no chert, and but very few quartz pebbles. They are referred to the "Silchester type," by Mr. Monckton, and belong, I think, to another stream altogether, which drained the area on the western side of the Bagshot stream watershed, and correspond to the High Level Drift in that area in a similar manner to that in which the Chobham ridges, etc., do to the gravels at Upper Hale, etc. Mr. P. E. Richards describes a gravel 300 ft. O.D. at Donnington Grove, Newbury, which belongs to this stage †

In this district, then, there are distinct indications of two stages during this period, with a difference of about 100 f between them.‡ Mr. O. Shrubsole§ has found rudely chipped

* Cf. H. W. Monckton, *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 42. See also Dr. Irving in "Science Gossip" for May and June, 1891, and *Proc. Geol. Assoc.*, vol. viii, pp. 143-171; and W. H. Hudleston, *Quart. Journ. Geol. Soc.*, vol. xlii, p. 147.

† "Gravels and Associated Deposits near Newbury," *Quart. Journ. Geol. Soc.*, vol. liii, p. 420.

‡ Cf. Prof. Rupert Jones in *Proc. Geol. Assoc.*, vol. viii, p. 442; and Dr. A. Irving "On the Bagshot Strata of the London Basin and their Associated Gravels," *Proc. Geol. Assoc.*, vol. viii, p. 143-171.

§ "On Flint Implements of a Primitive Type from old (preglacial) Hill Gravels of Berkshire," *Journ. Anthropological Inst.*, vol. xxi, p. 241; and *Quart. Journ. Geol. Soc.*, vol. xlix, p. 322.

flints in these gravels, and most suspicious-looking specimens have been obtained by the author from the Chobham Ridge Plateau at High Curly, near Bagshot.

(d) The main stream (Thames). In the central portions of the valley are found several gravel deposits corresponding in level to the preceding, containing, in addition to the materials already described as coming from the South, a quantity of other material derived from the North, and probably also some from the West of England. They mark the position of the confluence of the Southern streams with the main one at that time. Dr. Buckland* and Prof. Phillips showed that Triassic *débris* entered the Upper Thames Valley through the gaps at Moreton in the Marsh,† and above Banbury. An admirable summary of former work on this part of the subject has recently been laid before the Association by Mr. Osborne White.‡

The characteristic constituents of these gravels are quartzites of various colours, quartz, grits, radiolarian chert, schorl-rock, jasper, and igneous rocks. The chief localities where these deposits occur are :

(1) In Oxfordshire, near Moreton, Wightam and Bagley Woods, the high parts bordering the Evenlode and Cherwell valleys, at heights above 500 ft. O.D. (2) Around Goring Gap at Upper Basildon, 426 ft. O.D. ; Tilehurst, 290-341 ft. O.D. ; § The Hockett, near Quarry Woods, 351 ft. O.D., and Littleworth Common on the opposite side of the river ; Shiplake, 340 ft. O.D. ; Cookham Dean, 300 ft. O.D. || (3) The Mount, Ealing, 210 ft. O.D. (4) Kingston Hill, Coombe Wood, ¶ 178 ft. O.D. ; Richmond Hill, 181 ft. ; Wimbledon Common, 180 ft. (5) Dartford Heath, ** 136 ft. Rolled Gryphæa, brown, light coloured, and variegated quartzites, quartz pebbles, schorl-rock from the W. and N. and chert, ironstone, flint, etc., chiefly from the S., occur here. The gravel is 10-20 ft. deep on the Heath ; but at Wansunt Pit, near Crayford Station, it is 40 ft. thick.

During this period Goring Gap was apparently further deepened in two stages, †† during the first of which the gravels on Ashley and Bowsey Hills were deposited, and the remainder of the deposits rather later. The influx of water, etc., from the Bagshot stream led to the deposit of much material in the Reading and Maidenhead districts, and, as far as I am aware, no

* "Reliquiæ Diluvianæ," p. 279, etc.

† This gap is now 420 ft. O.D.

‡ "On the Origin of the High Level Gravel with Triassic *débris* adjoining the Valley of the Upper Thames," *Proc. Geol. Assoc.*, vol. xv, p. 157.

§ See "Valley Gravels near Reading," by O. Shrubsole, *Quart. Journ. Geol. Soc.*, vol. xlv, p. 582.

|| "On the distribution and relations of the Westleton and Glacial Gravels," *Proc. Geol. Assoc.*, vol. xiv, p. 11.

¶ "Visit to Great Gravel-pit South of Warren House," *Proc. Geol. Assoc.* vol. vi (1880).

** "Excursion to Dartford Heath," *Proc. Geol. Assoc.*, vol. xiii, p. 70, by F. G. Spurrell.

†† The stream depositing the Westleton Drift had already cut down a considerable depth.

similar deposits are found corresponding in height for some distance. This will be explained if we remember that the next tributary, draining what is now the basin of the Mole and part of the Wey, had not joined the main stream. The gravels at Kingston Hill, probably mark the position of this confluence. Not only the character of the larger constituents testifies to the correctness of this view, but the sandy matrix is evidently derived from the green, sandy beds in the Bagshot area.* The gravels at The Mount, Ealing, described by Mr. Allen Brown,† stand at another such junction; in this case probably with a stream flowing southwards from the northern Chalk range, and they may be connected with the deposits at Harefield and St. Albans. Further east another important stream from the north joined the main stream, by the Hitchin and other gaps, which deposited the Finchley and Oakleigh Park gravels, containing Gryphæa, etc. The gravels at Hendon,‡ described by Dr. Hicks, containing sarsens, porous and compact chert, and other southern drift material, may have been laid down by the main stream at and near its junction with that coming *viâ* the Hitchin and other gaps. The stream passing through Bishop's Stortford Gap also yielded its *quota* of foreign material to the main stream.§ The next important tributary was the Darent, and at its junction with the main stream the Dartford Heath|| and other gravels, at similar heights in the neighbourhood, were deposited. These gravels, although now South of the Thames, contain northern *débris*, some of which can be traced through the Hitchin and Bishop's Stortford Gaps (*e.g.*, Gryphæa, Belemnites), and cannot be found in deposits higher up the main valley.

No contemporaneous fossils, such as large mammalia, have been recorded from this set of gravels, and in this respect they differ from gravels at lower levels. Rude Palæoliths and rolled Eoliths are found in the Darent gravels, in the Bagshot stream, and quite recently by Mr. Llewellyn Treacher,¶ at the Hockett, near Goring Gap.

This series corresponds to the series D and E (two stages) of the author's previous paper.

* *E.g.*, those seen during the recent Excursion to Woking. *Proc. Geol. Assoc.*, vol. xv, p. 185.

† "The Thames Valley deposits of the Ealing district," by J. A. Brown, *Quart. Journ. Geol. Soc.*, vol. xlii, p. 192; also "Excursion to the Mount, Ealing," *Proc. Geol. Assoc.*, vol. x, p. 361, and vol. xiv, p. 153.

‡ "On some recently exposed sections in the Glacial Deposits at Hendon," by H. Hicks, *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 575; "Excursion to Hendon," *Proc. Geol. Assoc.*, vol. xiv, p. 328.

§ "Excursion to Bishop's Stortford," by Dr. A. Irving, *Proc. Geol. Assoc.*, vol. xv, p. 193; and Dr. Gregory, "Excursion to Walthamstow," *Proc. Geol. Assoc.*, vol. xii, p. 339.

|| "Excursion to Dartford Heath," *Proc. Geol. Assoc.*, vol. xiii, p. 70.

¶ *Proc. Geol. Assoc.*, vol. xv, p. 101.

3. The River Drifts.

Below the High Level Drift and Lower Plateau Gravels, are several gravel deposits which are distinguished from them by their lower level, their closer connection with the present valleys, and by the bones of extinct mammalia and Palæolithic implements often found in them. They are all, in my opinion, newer than the latest of the Glacial deposits in the valley, viz., the Chalky Boulder-Clay, which can be seen resting on the Lower Plateau gravels in the Lea Valley at Hatfield Hyde,* in the Stort Valley, near Hockerill,† in Herts, on the Hendon Plateau,‡ at Whetstone§ and Oakleigh Park,§ near Finchley, etc.; and Mr. T. V. Holmes has shown|| that this same deposit *underlies* the *highest* river terrace at Upminster. As before, it will be convenient to take the tributary valleys first, and then the main one.

(a) The Darent and Cray.

Remains of *Elephas* have been found at Shoreham and Oford. In the neighbouring Cray valley, gravel beds occur at Pratt's Bottom, where there is a small pit of flint gravel with a capping of 4 ft. of soil. Quite close were large pieces of pebbly ironstone, obtained from similar pits, but evidently drifted down from the higher ground. Lower down the valley are large pits with great flints and pieces of ironstone, while still lower down (276 ft. O.D.) at Green Street Green is a pit 20 feet deep of a similar character¶ which has yielded *Elephas primigenius*, Blum., Rhinoceros, Musk Ox, etc. Further west, near Hayes Station and on the left of the road leading to West Wickham, are pits in similar gravel 11 ft. thick. It is an ochreous gravel, containing large flints, some but little worn, flint pebbles, ironstone, and a good-sized block of pebbly conglomerate.

(b) The Wandle Valley.

Dr. Hinde** has recently published an account of the gravels of this valley. They all belong to the series we are now considering. Flint implements occur in the neighbourhood of Thornton Heath.†† Near Upper Warlingham Station are large pits, from which I was shown a tooth of *Elephas* obtained at a depth of 12 ft. The gravel consists almost entirely of flint, with small pieces of ironstone, but I saw little or no chert or flint pebbles. Just behind a farm, near the old bourne, was a gravel containing flints up to 1 ft. × 1 ft., marcasite nodules, blocks of rolled conglomerate (2 ft. × 1 ft. 9 in.) and

* Visited by the Association on May 14, 1898.

† "Excursion to Bishop's Stortford," and also "The Geology of the Stort Valley," *op cit.*

‡ *Proc. Geol. Assoc.*, vol. xii, p. 3, 4.

§ "Excursion to North Finchley and Whetstone," by Dr. Hicks, *Proc. Geol. Assoc.*, vol. xiii, p. 367.

|| *Proc. Geol. Assoc.*, vol. xii, pp. 316-319.

¶ "Excursion to Down," *Proc. Geol. Assoc.*, vol. xii, p. 393.

** *Op. cit.*

†† I obtained one fine specimen nearly 8 in. long.

small Tertiary flint pebbles. Quite recently *Rhinoceros antiquitatis*, Blum., and *Elephas* have been obtained near Carshalton.*

(c) Bagshot Country. Prof. Rupert Jones long ago † recognised that three distinct ledges or benches of gravel occurred between the Chobham ridges and the Blackwater, and Mr. H. W. Monckton, in the section he draws from Farnham Park to the River Blackwater, ‡ recognises three series of gravel deposits below the Hartford Bridge Flats gravels, and again, on the East side of the Chobham ridges in his section from them to the Hale Bourne, two deposits at 200-224 ft. O.D.§ and 102 ft. O.D. are recognised. In a paper by the same author on the Farnham district|| a section is given from Upper Hale to Wrecklesham, where three divisions below the Lower Plateau Gravels are apparent. The highest of these, viz., that at Wrecklesham 360-380 ft. O.D. and 25 ft. thick, is extremely interesting as being the patch from which Mr. Mangles and Mr. F. Lasham¶ obtained such a large number of Palæolithic implements, the majority of which, it should be noted, come from near the bottom of the gravel. The direction, N.W. to S.E., height, composition, and stratified character of this deposit, mark it as having been deposited by the Bagshot stream after the deposition of the Hartford Bridge Flats gravels.

Dr. Hicks recently referred to the finding of remains of *Elephas primigenius* and *Rhinoceros* resting on the London Clay between Hendon and Edgware,** and, again, Mammoth, etc., at 80 ft. O.D. at Endsleigh Street,†† London.

Further down the main stream the classical deposits at Crayford and Ilford might be cited, together with the remarkable discovery of human bones and implements made by Mr. Elliott at Galley Hill.‡‡

HANTS AND DORSET.

Corresponding to the synclinal fold known as the London Basin, the gravels of which we have just considered, there is in the South of England another and roughly parallel example, due probably to the same series of earth movements, running from the neighbourhood of Dorchester to Breading in the Isle of Wight. The river Frome drains the upper portion of the valley

* Cf. W. W. Watts at Meeting of the Geological Society, November 3rd, 1897, *Quart. Journ. Geol. Soc.*, vol. lv, p. ii.

† *Proc. Geol. Assoc.*, vol. viii, p. 442, and vol. vi, pp. 329 and 429.

‡ *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 31.

§ The large spread of gravel at Walton Common at 100 ft. O.D. and 145 ft. below St. George's Hill, probably should be placed here. Cf. W. H. Hudleston *Quart. Journ. Geol. Soc.*, vol. xlii, p. 147 *et seq.*

|| *Proc. Geol. Assoc.*, vol. xiii, pp. 74-81.

¶ Cf. "Palæolithic Man in West Surrey," by F. Lasham, in *Coll. Surrey Arch. Soc.*

** See *Quart. Journ. Geol. Soc.*, vol. liv, p. ii.

†† "On the discovery of Mammoth and other remains in Endsleigh Street," etc., *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 453.

‡‡ See *Proc. Geol. Assoc.*, vol. xiv, p. 305, and *Quart. Journ. Geol. Soc.*, vol. li, p. 72.

thus formed, the lower portion having been denuded by the sea.*

The gravels of this area are as follows :

1. High Level or Early Drifts occur :

(a) In the Isle of Wight, on St. Boniface Down, St. Catherine's Hill, and other places, an angular flint drift is found. In a few places Tertiary flint pebbles and quartz can be obtained.†

(b) On the water-parting between the Thames and the streams flowing into Southampton Water, at Meadstead, 650 ft. O.D. Mr. S. V. Wood records a drift 20 ft. deep, consisting of large water-worn flints mixed with loam.‡

(c) On the highest points of the hills overlooking Weymouth and at Portisham on Blackdown, there is a good section close to Hardy's Monument, 777 ft. O.D. Like the two previous examples, it is on the watershed of the Frome. The deposit is from 15 ft. to 20 ft. thick, and contains, among others, the following : well rolled Chalk flints, Tertiary pebbles, white and pink quartz pebbles up to 2 in. $\times$ $1\frac{1}{2}$ in. (abundant) jasper (comparatively plentiful), porous chert, dark chert, pieces of schorl-rock, fragments of reddish, glassy quartzites, etc. Mr. Clement Reid§ regards these as of Bagshot age, coupling with them some lower sands and gravels 146 ft. O.D. at South Moreton, about 12 miles N.E. The similarity in composition between these gravels and others to the west, leads me rather to regard them as belonging to a previous cycle of river action, and to have been derived from a source further west.

2. Lower Plateau Drifts.

Both in Hampshire and the Isle of Wight a distinct series of gravels, similar to those in the Thames basin, are found sloping on either side toward the main channel.|| They consist chiefly of flint, both unworn, subangular, and as pebbles, Greensand-chert, ironstone, quartz pebbles, and blocks of greywether sandstone, a very similar mixture to that of the Thames area.

Two stages appear to exist in the high ground bordering the Test valley and Southampton Water, which district has come more particularly under my observation. In the neighbourhood of Romsey the Plateau gravels are found at heights between 300 and 242 ft. at the Tower of Winds, Chilworth, where they are

* See "On the Physical History of the Isle of Purbeck," by A. Strahan, *Proc. Geol. Assoc.*, vol. xiv, p. 405.

† *Mem. Geol. Survey*, "The Isle of Wight," 2nd edition, p. 208, etc.

‡ "The newer Pliocene in England," by S. V. Wood, *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 667.

§ "The Eocene deposits of Dorset," *Quart. Journ. Geol. Soc.*, vol. lii, 1896.

|| For full descriptions see "On the superficial deposits of the South of Hampshire and the Isle of Wight," by T. Codrington, Esq., *Quart. Journ. Geol. Soc.*, vol. xxvi, p. 528, and *Memoir Geol. Survey*.

contorted,* and near Shootash and Embly Park.† At Baddesley Common is a bed of gravel 148 ft. O.D., and along the edge of the valley at heights above 100 ft. O.D. similar deposits occur at Green Hill, Pauncefoot Hill, 160 ft., Winchester Hill, Ganger Wood, etc. Two stages are thus apparently present as in the Bagshot area, with a difference of level of over 100 ft. The same thing occurs lower down the valley, on the hills on both sides of Southampton Water, at Beaulieu Heath 133 ft., and Titchfield Common, about the same height.‡

No Palæolithic implements, or remains of large mammals, as far as I know, have ever been found in these deposits. Plateau gravels of a similar nature are recorded from the high ground above the Avon; these attain their greatest elevation at Downton Common, 420 ft. O.D.

At Cams' Wood, near the Nelson Monument, Portsdown Hill, 100 ft. O.D., and near Cowes 130 ft., which would be on or near the main stream at this period, large liver-coloured quartzites, from the New Red Conglomerates of the West, have been found.§ The cliffs between Lymington and Christchurch and again from Hengistbury Head towards Bournemouth, are capped with an ochreous flint gravel with little or no quartz. These are succeeded by gravel of a totally different character, containing besides flint, much quartz, chert, and schorl-rock.|| Similar deposits are also recorded on the road between Bournemouth and Poole at 160 ft. Some of these contain implements and belong to the series to be next described, others may be the southern prolongations of the Plateau gravels. The gravels at Bournemouth are evidently made up of the redeposited materials from the Blackdown (Hardy's Monument) High Level Drift, laid down by the old Frome, at its junction with the Glacial stream from the North.¶ We have here in fact the counterpart of the junction of the Bagshot stream with that from the Upper Thames, bearing the northern drift of Triassic and other *débris*, and there can be little doubt that the climatal conditions necessary for the one were present when the other was deposited.**

It is interesting to note that at a corresponding level (about 350 ft. O.D.) on a ridge forming the high ground between two

* Cf. Dunton Green and Chevening Gravels in the Darent Valley, and St. George's Hill, near Weybridge.

† At Alderbury Hill, 3 miles E. of Salisbury, a similar flint gravel with small quartz pebbles is found at 300 ft. O.D.

‡ See also "On the presence of Raised Beach on Portsdown Hill," by Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xxviii, p. 38, and "Geology of Portsmouth and Ryde," by C. Evans, *Proc. Geol. Assoc.*, vol. ii, p. 170, where similar gravels are described at Bourne Common 142 ft. O.D.

§ Prof. Prestwich also describes in his paper on the Southern Drift, a drift on a Tertiary outlier at Copford (? Codford), 8 miles E. of Warminster, which contains Tertiary pebbles, white and rose quartz, light sandstone, dark chert, and lydian stone pebbles.

|| See *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 4, for a section showing these gravels.

¶ It is worthy of notice that the valley of the Avon is connected with a gap in the North which is 364 ft. O.D. at its highest point near Etchelhampton Hill. Cf. Mr. W. H. Bell's remarks, *Proc. Geol. Assoc.*, vol. xii, p. 324.

** See Sir Charles Lyell's remarks on T. Codrington's paper, *op cit.*

recent valleys* and about 90 ft. above the present stream, occurs the remarkable and unique deposit at Dewlish,† in which remains of *Elephas meridionalis*, *Nesti*, were found associated with flint, quartz, and Palæozoic (? schorl) pebbles. The occurrence of this Upper Pliocene fossil seems to indicate that the period immediately preceding the Lower Plateau drifts may have been Upper Pliocene.

3. The River Drifts.

With the exception of *Elephas meridionalis*, no remains of mammals have been found in the High Level gravels of this valley; but in the lower deposits both implements‡ and bones are met with. In general three terraces are evident, as in the Thames Basin.

The upper part of the Test Valley does not contain much gravel; but after its junction with the Anton, near Dunbridge, there is plenty; and along the last-named river many patches occur.§ At Belbins, about two miles from Romsey and 90 ft. O.D., is a thick gravel patch in which Palæolithic implements occur. Similar gravel occurs at Nursling and below the junction of the Itchen and Test. On the east side of Southampton Water, by Netley, Hill Head, and at Lee-on-the-Solent, thick beds of gravel, containing implements overlain by brick-earth, are seen. Sarsens|| are frequently found in these river gravels, especially at Lee-on-the-Solent. The Bembridge¶ gravels, which occur between H.W.M. and 60 ft. O.D. on the Isle of Wight, correspond in level and composition to them, and were, I think, laid down at the same time. If this be the case, it signifies that the Frome still continued its course uninterrupted beyond the Solent towards what is now Selsea Bill, which was then probably near its mouth. It is here that those interesting deposits of *Elephas*,** etc., in association with southern shells occur, as described by C. Reid,†† Godwin Austen, and others. ‡‡

At about 146 ft. O.D. near South Moreton, 8 miles east of

* The Chalk down to the N. of Dewlish can be crossed at 356 ft. O.D. This probably indicates that a stream passed from N. to S. during this period.

† Cf. "Pliocene Deposits of Great Britain," by C. Reid, *Mem. Geol. Survey*, 1890, pp. 206-208; see also W. H. Hudleston's remarks in his Presidential address to the Geological Society, 1893, vol. xlix, p. 67 *et. seq.* Note Mr. Mansel Pleydell's letter there quoted.

‡ Cf. "Flint Implements of the Hants Basin," Sir J. Evans, *Quart. Journ. Geol. Soc.*, vol. xx, p. 188; also his Presidential address to the Geological Society, *Quart. Journ. Geol. Soc.*, vol. xxxi, p. lxxi.

§ "On the Discovery of Flint Implements in the Drift of Milford Hill, Salisbury," by H. P. Blackmore, *Quart. Journ. Geol. Soc.*, vol. xxi, pp. 250-252. See also *Quart. Journ. Geol. Soc.*, vol. xxviii, p. 38, and T. Codrington's paper previously quoted.

|| Cf. *Geol. Mag.*, vol. iii, p. 296.

¶ *Quart. Journ. Geol. Soc.*, vol. xii, p. 136, and vol. xv, p. 215; *Proc. Geol. Assoc.*, vol. ii, p. 170, in which Caleb Evans mentions similar gravels at St. Helens, King's Quay, and E. of Ryde.

** An interesting comparison suggests itself between these deposits and those of the Lower Thames Valley.

†† "The Pleistocene Deposits of the Sussex Coast and their Equivalents in other Districts," *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 344.

‡‡ "On the Newer Tertiaries of the Sussex Coast," *Quart. Journ. Geol. Soc.*, vol. xiii, p. 40, etc.; see also "A Fossiliferous Pleistocene Deposit at Stone, on the Hampshire Coast," by C. Reid, *Quart. Journ. Geol. Soc.*, vol. xlix, p. 325.

Dorchester, and about 60 ft. above the present river, occurs a patch of sand with gravel seams, differing in many respects from those of the Bagshot strata found in that district. Mr. C. Reid classes it with the Bagshot, and considers it to be of the same age as the gravel at Hardy's Monument, 777 ft. O.D. Overlying the sand is a gravel deposit made up of flint, mostly subangular, a few Tertiary pebbles, some 2 in. but mostly small, small pieces of schorl-rock, Purbeck marble, and quartz up to 2 in. It rests unevenly upon the sands, apparently in a channel, is covered by a brick-earth in one part, and appears to be a low-lying drift deposit of Pleistocene age derived from the Bagshot gravels and the High Level Drift on Blackdown.

Prof. Prestwich* has recorded Mammoth and other remains from Portland, 400 ft.,† and Encombe Park, 240 ft., on the Isle of Purbeck. Drift gravels also occur on the hills above Portisham, near the Hellstone, about 600 ft. O.D., and at lower levels 300, 150, and 70 ft., near Weymouth, pointing to another valley system now almost entirely swept away.

It appears that the valley of the Frome has had a similar history to that of the Thames, allowance being made for greater denudation.

4. WEST DORSET AND DEVON.

(a) High Level or Early Drifts.

(i.) The drift at Hardy's Monument on the watershed already referred to.

(ii.) The drift on the Haldon Hills.‡ This is on the western side of the series of valleys now under consideration. It is over 800 ft. O.D., and while its composition, closely resembles that near Hardy's Monument (777 ft. O.D.), the Haldon deposit differs in some respects. It appears to have been deposited by separate streams draining neighbouring areas of Dartmoor, rather than by parts of the same stream. The two deposits are about 45 miles apart. Judging from the slope and the nature of the materials, the Haldon gravels would appear to have been deposited by a stream flowing south, and those on Hardy's Monument by one flowing west. Good sections are to be seen on Great Haldon, near the Race Course, about 7 miles from Exeter, where there are extensive workings on the upper

* "The Raised Beaches and Head or Rubble Drift in the South of England, their relation to the valley drifts, etc.," Prof. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 264.

† "Notes on the phenomena of the Quaternary Period in the Isle of Portland," *Quart. Journ. Geol. Soc.*, vol. xxxi, p. 29, etc.; see also *The Dorset Natural History and Antiquarian Club Reports*, vol. xvi, p. 76.

‡ *cf. Geol. Mag.*, vol. iv, p. 390 *et seq.*, "Railway Geology from Exeter to Newton Bushell and Moreton Hampstead," by D. Mackintosh; see also "Eocene Beds of Devon and Dorset," by C. Reid, *Proc. Geol. Soc.*, vol. liv, p. 71.

slopes and summit of the ridge. The gravel consists chiefly of flint up to 2 by 1 in., some angular, some partially or completely rounded. No Tertiary pebbles or jasper were seen, but numerous blocks of granite, up to 12 by 6 in., containing much schorl; pieces of dark schorl-rock, up to 9 by 6 in.; quartz, up to 6 by 3 in., and many other kinds of rock. The larger transported blocks came from the top pits, in the lower pits they were fewer and smaller.

On Little Haldon, 5 miles south of the preceding sections, the gravel is about 6 ft. deep in the pits examined; blocks and fragments of angular flint, up to 24 by 12 by 3 in., made up the greater portion. I saw no Tertiary flint pebbles, or chert, but there was plenty of quartz up to $2\frac{1}{2}$ in. Some of the flints were partly rolled. Numerous pebbles of granite, up to 5 by 4 by 3 in., and schorl-rock, up to 5 by 4 in., were seen, and one fairly large piece of jasper. In one pit, near the base, a patch of white pipe clay was seen, and sandy patches occurred in the gravel.

(iii.) The Blackdowns are capped by a chert drift containing small pieces of quartz lying on the Greensand. A section at the top near the Wellington Monument, 892 ft. O.D., and Hemyock showed 2 to 3 ft. of chert drift in an earthy matrix.*

(b) Lower Level Plateau Gravels.

(i.) Between the valleys of the Brit and the Axe, on the hills between Charmouth and Axminster, and near Lyme Regis, is a drift at about 500 ft. O.D., consisting of chert and flint in an ochreous clayey matrix. Sections can be seen near the tunnel at the top of the hill, through which the road from Charmouth to Axminster is made. In places the gravel was very irregularly deposited, and contained dark greenish, sandy, clay patches. Other sections occur nearer Axminster, in one of which, blocks 2 by 1 ft. were observed. Its position on the watershed of two recent valleys, and opposite the Chard Gap, its composition and its height, 500 ft. O.D., all seem to point to its being a Lower Plateau gravel, which formerly may have extended much further south, since it caps the hills on the sea-shore.

On the slopes of Shute Hill (567 ft. O.D.) above Kilminster on the right bank of the Exe, similar flint and chert drift in a clayey matrix was observed.

(ii.) On the high ground west of the Otter above Fairmile, 388 ft. O.D. near Sidmouth Junction, a drift occurs, full of erratics, derived probably from New Red Sandstone Conglomerate, and further south, at the top of the hill between Exmouth and Budleigh Salterton, is a large deposit of drift material 20 ft. thick containing an abundance of red quartzite pebbles, and blocks

* For other gravel deposits see "The Drift of Cornwall and Devon, its Origin, etc.," by T. Belt, *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 80; "Notes on the Geology of the Valley of the Upper part of the Teign and its Feeders," by G. W. Ormerod, *Quart. Journ. Geol. Soc.*, vol. xxiii, p. 423.

up to 12 in. long. Quartz pebbles are plentiful, but I saw no flint.

(iii.) On the western side of the Exe, at Woolborough Hill,* south of Newton Abbot and Milber Down, is a drift derived, in part, from the Haldons. Pieces of rolled schorl-rock and small quartz occur, also large flints which are more rounded than those on the Haldons.

The drift between Charmouth and Axminster is directly south of the gap at Chard, and is made up of the sweepings of the upper Plateau drift on the Greensand at Blackdown. The drifts on the east side of the Exe are also directly opposite open communication to the north *via* the Culm Valley, and the low pass west of the Blackdowns. The position of these deposits, therefore, seems to have been determined by a strong current or stream from the North. The Woolborough gravels appear to denote a similar stage in the history of the Teign Valley, which has been formed between the Haldons and Dartmoor, since the deposition of the High-level drift upon them.†

(3) River Deposits.

(i.) The valley of the Exe above Chard Junction is comparatively free from drift, containing even local material. From this point however, and at levels of about 150 ft. O.D. much drift gravel is found. At Broom Ballast Pit it is very extensive, and over 30 ft. thick, and is made up of the *débris* of the High and Lower Level Plateau drifts, such as chert, flint, quartz, and schorl-rock pebbles. It is regularly stratified in places, has sandy or clayey partings here and there, and is covered by patches of a brick-earth deposit. Roughly shaped chert implements are abundant, *mostly in the bottom layers*.

At Chard Junction Station, G.W.R., is an old section of a similar gravel. Nearer Axminster a deposit occurs, containing worked flints. Twelve feet of this gravel was being worked, but there is more below. Near the top were some sandy layers. On the opposite side of the Axe valley at Kilminster, it again occurs and is well seen in a roadside section, 16 ft. deep, having patches of sand in places. Rudely chipped cherts also occur here, large blocks of chert up to 10 × 8 in. schorl-rock, etc. Another section occurs near Colyton Station at 100 ft. O.D.

In the lower part of the Otter Valley at Fairmile, 164 ft. O.D., at the back of an inn, is a fine section in a drift derived presumably from the New Red Sandstone Conglomerates. It is about 30 ft. deep, and contains a very varied assemblage of rocks. Quartz and quartzite are plentiful, also pebbles of a dark kind of rock. The boulders vary in size up to 2 ft. long.

* Cf. "Notes on the gravels, sands and other superficial deposits in the neighbourhood of Newton Abbot, Devonshire" by H. B. Woodward, *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 230.

† For further interesting remarks on this district, see "On the Bovey deposit," by J. H. Key, *Quart. Journ. Geol. Soc.*, vol. xviii, p. 9.

Lower down the same valley, about half a mile from Budleigh towards Salterton, on the right of the road, is a similar gravel to that at Fairmile, 184 ft. O.D. It is about 8 ft. deep, with quartzites to 12 × 9 in. ; black veined stones, quartz, chert, flint, etc. In the Culm Valley close to Tiverton Junction Station is a very similar deposit.* Mr. Godwin Austen states† that remains of *Elephas*, etc., are found in the valleys leading out from Charmouth Bay and from the Exe and the Brit.‡

Between Kingskerswell and Newton Abbot, at lower levels than the gravels on Woolborough Hill, are extensive deposits of gravel (in one place 45 ft. deep) derived from the higher drifts, etc.

At Bovey Heathfield, overlying the pipe-clay deposit containing beds of lignite, a gravel 6—8 ft. deep occurs, of a rather more complex character than that at the Haldons. Quartz fragments up to 3½ in. were seen, and numerous granite pebbles up to 5 in. long, together with many pieces of schorl-rock, but no flint.§

The three stages observed in the Frome Valley are present in this series of valleys, and the greater thickness of the River Drift gravels tells of greater denudation as we proceed westward.

WEST DEVON AND CORNWALL.

Further west the character of the country changes entirely. Evidence of glacial action,|| more or less reliable, has been cited by various authors, and deposits of gravel have been noticed up to 900 ft., O.D. I saw very little drift to the south between Newton Abbot and Plymouth. At Brent Tor, on the western side, blocks of jasper were formerly plentiful, but on the occasion of my visit, I could only find fragments built into garden walls. This fact is mentioned owing to the presence of rolled pebbles of that substance further east. The Tamar flows at low levels, dividing the high ground around Dartmoor from that around the Bodmin moors. It is possible to cross the country here along the valley of the Tamar and the Bude Canal without rising more than about 322 ft. O.D. This would lead us to suspect that, formerly, a stream drained the west of Dartmoor, and to this stream is probably due the quartz gravel described as occurring at the Hoe, Plymouth,¶ and at Cattedown, 60 to 70 ft. O.D.**

* Cf. *Trans. Devon Assoc.*, vol. xv, p. 346.

† *Op. cit.*

‡ See also "The Chronological value of the Pleistocene Deposits of Devon," by W. Ussher, *Quart. Journ. Geol. Soc.*, 1877.

§ For section see *Quart. Journ. Geol. Soc.*, vol. xviii, p. 9.

|| "Glaciation in Devon and its Borders," J. B. Jukes, *Geol. Mag.*, vol. ii, p. 473; *Trans. Devon Assoc.*, vol. ix, pp. 177, 230. See also vol. viii, p. 48, *et seq.*, and vol. xii, pp. 301-311.

¶ *Trans. Royal Geol. Soc. of Cornwall*, vol. xi, p. 151. "Some detrital deposits associated with the Plymouth Limestone," by R. N. Worth; and *Trans. Devon Assoc.*, vol. xxi, p. 97, and vol. vii, p. 250.

** "Evidence of Glacial Action in Cornwall," by N. Whitley, *Trans. Royal Geol. Soc. of Cornwall*, vol. x, p. 132; "The Post Tertiary Geology of Cornwall," by W. Ussher, 1879; "Glacial conditions in Devon," by R. N. Worth, *Trans. Devon Assoc.*, vol. xiii, p. 351.

The deeply cut valleys running down from the Bodmin moors point to greater denudation than can be seen east of Dartmoor, and the almost total absence of high level gravels in Cornwall is to be accounted for in the same way. The agents of denudation seem to have acted on the country to such an extent that any such drifts must have been carried down to the valleys, or even to the sea, giving rise to quite a different series of deposits known as Raised Beaches, followed by a "Head" of local materials. That High Level Drifts were once present is shown by the fact that two or three deposits remain. On the slopes of St. Agnes' Beacon, at 300 ft. O.D., are to be seen 8 ft. of loam with angular blocks, and near it is a sand-pit 6 ft. deep, with quartz-sand and angular pieces of quartz.

On the Crouza Downs in the Lizard District, near Lanarth, close to the road running north to Helstone from Coverack Cove, at 360 ft. O.D., is an extensive deposit of quartz gravel 8 ft. to 10 ft. thick. There are several extensive old pits now filled with water, but only one was in use. The contents were mainly quartz fragments in an ochreous, sandy matrix. Covering the gravel, and in channels cut through it, was a more argillaceous deposit without gravel.* A flint and quartz drift also occurs on the Scilly Islands.†

The more acute denudation which has become apparent the further we have gone west, now requires explanation. At the present time, owing to the prevailing winds from the S.W. being laden with moisture, the rainfall increases towards the west. It would therefore be expected that if similar conditions existed in Cornwall during Glacial times we should have greater denudation. The scouring action brought about by the constant formation and melting of ice would be greatly intensified in such a district as Cornwall. The heights of the deposits at St. Agnes and Crouza Downs show that the gradual upward tendency on the east of Dartmoor is not maintained to the west of it, but rather indicate a slope in the opposite direction.

The order of deposition seems to have been as follows :—

- (a) High Level Drifts, *e.g.*, Crouza Down.
- (b) Formation of so-called Raised Beaches arising from the destruction of the High Level deposits.
- (c) Formation of the "Head," the conditions becoming so acute that when all the superficial deposits had gone, the solid rock was broken up and carried down.
- (d) Deposition of Stream-Tin Gravels containing remains of mammals.‡

* W. Tyack, *Trans. Royal Geol. Soc. Cornwall*, vol. ix, p. 177.

† *Trans. Royal Geol. Soc. Cornwall*, vol. vii, p. 343, "On the Chalk flints and Green sand fragments found on the Castle Down, Tresco, one of the Islands of Scilly."

‡ *Trans. Royal Geol. Soc. Cornwall*, vol. iv, pp. 55, 395.

In (a) we still have the representative of the High Level Plateau Drifts further east.

In (b) and (c) possibly the two stages noticed in the Lower Plateau or Glacial gravels, while (c) corresponds to the River Drifts.

The Westleton Drift.

Indications of streams flowing east and south from Dartmoor in Pliocene or earlier times have been shown to exist, but nothing has been said about streams flowing in a northerly or north-easterly direction during that period. In all probability, as stated in dealing with the valley systems of the South of England, high ground once existed from Dartmoor to what is now the Norfolk coast. The gaps which at present exist were then either absent or trivial, as shown by the altitudes of the various gravel beds deposited around them at subsequent periods. The chief gaps occurring W. of Goring Gap, are:

(1) The Avon Gap, near Etchelhampton Hill, is 364 ft. O.D., with associated gravels to the S. of it over 400 ft. O.D.

(2) The Stour and Cale Gap, 178 ft. O.D. Judging from the character of the strata, the absence of gravels, and the height at which mammalian remains occur at Blandford, this gap may be considered to be of recent date. The absence of the hard Chalk has led to rapid denudation.

(3) Chard Gap, 300 ft. O.D., with associated drifts to the S. 500 ft. O.D.

(4) The Culm and Spratford Stream Gap, W. of the Blackdowns, 400 ft. O.D., with associated drifts to the S. 500 ft. O.D.

It is quite possible that a river system draining this high ground existed, in other words, a peneplain was probably formed in a S.W. to N.E. direction. Such a stream from its southern tributaries would receive, among others, the following materials, which would go to make up its gravel deposits further east:

(1) Quartz pebbles of various kinds, as found on the Haldons and at Hardy's Monument; (2) jasper; (3) schorl rock at Hardy's Monument; (4) rolled and subangular pieces of chert from the Greensand hills of Dorset and Devon which supplied the Blackdowns, etc.; (5) red quartzite pebbles from the uppermost beds of the New Red Sandstone Conglomerates, (6) *débris* from rocks in West Devon, such as radiolarian chert, pebbles with crinoid stems, etc., etc.; (7) *débris* from Tertiary strata encountered further east.

Now these actually do occur in the Westleton Drift, and can be traced right away to the Norfolk Coast, as previously shown.*

In the Thames Basin these materials are found in a drift

* *Op. cit.*

which has in all probability come through the gaps in the Chalk range. It has, in fact, been *re-drifted* at a subsequent period.

Mr. Osborne White, in a recent communication to this Association,* was able to follow Prof. Davis' theory in all but one point. The Professor required for the full development of his theory a peneplain, such as I have above indicated. The Westleton Drift is not necessarily of marine origin, as I have previously pointed out.† Its contents, its position and its age show it to be but the re-drifted deposits of a stream running across Central England in Pliocene or earlier times. As far as I know at present, no undisturbed deposits of the actual stream have been found. They have all apparently disappeared during the periods of acute denudation which followed.

In conclusion I beg to thank the writers of the numerous papers quoted, to acknowledge my indebtedness to the recently published Index to vols. 1—50 of the *Quarterly Journal of the Geological Society*, and to the contoured maps issued by the Ordnance Survey.

* *Op. cit.*

† *Op. cit.*

ORDINARY MEETING.

FRIDAY, 4TH MARCH, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Mr. A. E. Salter, B.Sc., F.G.S., read a paper, entitled "Pebbly and other Gravels of Southern England," illustrated by numerous specimens, maps, and sections.

A series of photographs presented by Mr. Thomas Parker, C.E., F.G.S., of Rockhampton, Queensland, were exhibited, showing the workings at the Mount Morgan Gold Mine, Queensland.

ORDINARY MEETING.

FRIDAY, 1ST APRIL, 1898.

J. J. H. TEALL, M.A., F.R.S., President, in the Chair.

Prof. A. M. Edwards, M.D., H. Stanley Jevons, B.Sc., Charles St. Arnaud Coles, and Miss Margaret I. Gardiner were elected Members of the Association.

Addresses dealing with the Excursion Programme for 1898 were delivered by H. W. Monckton, F.L.S., F.G.S., the Rev. Prof. J. F. Blake, M.A., F.G.S., Aubrey Strahan, M.A., F.G.S., and W. Whitaker, F.R.S., Pres. G.S., their remarks being illustrated by maps and sections.