

Kincardine, since the base in South Perthshire is composed of a conglomeratic mass fully equal in thickness to the lower conglomerates of the country south and east of the Moray Firth. In Forfar and Kincardine the lowest members are composed of Forfarshire flags and inferior red shaly sandstones; but in the district under consideration we have, underneath the representatives of the Forfarshire flags and beds equivalent to the inferior red shaly sandstones, a thick conglomeratic series, differing in the nature of its fragments from the higher conglomerates; and this, both in position and thickness, can only be parallel with the base of the Old Red, as occurring in the countries which margin the Moray Firth.

Organic remains.—Reference has already been made to the discovery of *Pteraspis* by Mr. Powrie in the grey beds at Westertown Quarry, near the Bridge of Allan. This form, I learn from Prof. Huxley, is probably *P. rostratus*. I have also stated that Mr. Bryson has procured from the same locality a specimen of *Cephalaspis*. This specimen has unfortunately been mislaid. From this spot I have likewise obtained, along with remains of *Pteraspis*, the head of a *Cephalaspis*. This specimen is not in a very perfect condition, and the species cannot be satisfactorily made out by Prof. Huxley; it is therefore desirable that the fossils from the Bridge of Allan should be carefully looked after in order that the form of *Cephalaspis* which is associated with *Pteraspis* here may be determined.

No traces of Plants, so far as I am aware, have been found in this neighbourhood, nor are there any remains of Crustaceans.

With reference to the strata which overlie the grey sandstones reposing on the inferior conglomerates, I have seen it stated that the brown sandstones of Doune afford *Cephalaspis Lyellii*; but this is a matter on which I am in doubt, as I can get no satisfactory evidence of the occurrence of this fish in this portion of the Old Red Sandstone area of Scotland.

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2. *On the WESTERN END of the LONDON BASIN; on the WESTERLY THINNING of the LOWER EOCENE BEDS in that BASIN; and on the GREYWETHERS of WILTSHIRE.* By WILLIAM WHITAKER, B.A. (Lond.), F.G.S., of the Geological Survey of Great Britain.

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Introduction.—The above three subjects are closely akin to one another. The sections that will be described in the first part of this

paper show that the "thinning" treated of in the second is greater than has been hitherto thought; and the extent of this latter must much change our notions as to the formation from which have come the greater part of those loose blocks of Greywether-sandstone that, in many places, lie on the surface of Cretaceous and Tertiary beds.

The age of the sands noticed in the third part may also have some bearing on that of the Greywethers.

The data on which a great part of this paper is founded have been in my hands for some time; and the conclusion that I have come to with regard to the age of the Greywethers at the western end of the London Basin has been shortly given in the Geological Survey Memoir on Sheet 13 (p. 48). I have great pleasure in knowing that Prof. Ramsay wholly agrees with my views of the beds in that district, to which this paper chiefly refers. The thinning-out of the London Clay in Marlborough Forest has also been noticed at p. 54 of the above-mentioned memoir.

The new points of this paper, which treats of the *London Tertiary District* alone, are—the proof of the occurrence of the London Clay and the Lower Bagshot Sand further westward than they have been before noticed*; the thinning of the Woolwich and Reading Beds west of Hungerford; the proof that the London Clay thins much more quickly westward from Reading than has been hitherto thought, and that in Marlborough Forest it has thinned out altogether; the inference from the above that further westward, where the Greywether-blocks abound, the Bagshot Beds probably rested at once on the Chalk; the natural conclusion that the greater part of those blocks came from that formation, and the further evidence in support of this theory that *may* perhaps be given by certain sands, as yet of doubtful age, that are found here and there on the Chalk of Surrey and Kent.

I must state, however, that the idea that the Greywethers once formed a part of the Bagshot Beds is not by any means new; but it has of late years been given up in favour of Mr. Prestwich's theory that they for the most part belonged to the Woolwich and Reading Beds. With the data that Mr. Prestwich had, I do not see how he could have come to any other conclusion than the one so ably and logically worked out in the latter part of his paper in vol. x. of the *Society's Journal* (p. 123); but I think that the further data given in the first part of the present paper, and the conclusions to which I have shown that they lead, in the second part, must lead us back again to the old doctrine that the greater part (not the whole) of the Greywethers are of Bagshot age. The Hertfordshire "pudding-stone" I agree with Mr. Prestwich in referring to the Woolwich and Reading Beds.

PART I.—The first part of this paper refers chiefly to the neighbourhood of Bedwin and Savernake (or Marlborough) Forest, in Wiltshire, mapped in the north-eastern corner of Sheet 14 of the Map

* Except on Sheets 12 and 14 of the Map of the Geological Survey, and in the Memoirs on the former and on Sheet 13. The most western Tertiary outliers in the London Basin (in Sheet 14) have not been hitherto described with any detail.

of the Geological Survey of Great Britain. As that sheet, which was published in 1857, is not illustrated by a memoir, like those descriptive of many of the sheets of later date, and as some changes were made in the mapping of the Tertiary beds in its north-eastern part in 1859, I shall give a short notice of the ten Tertiary outliers that have been there mapped. The country included in the S.E. corner of the sheet to the north (Sheet 34) will also be noticed. Here also the Tertiary beds have been resurveyed, which has made needful some corrections in the next edition of the Memoir illustrating that sheet.

The Tertiary beds that are found in this district are—the “Lower Bagshot Sand,” the “London Clay,” and the “Woolwich and Reading Beds” (or, for shortness, the “Reading Beds”). It will be convenient to work from the east westward, and to notice all the formations together, as they occur, instead of treating of each separately.

It is well first to state that it would seem that, when Mr. Prestwich examined this district, before the publication of his papers on the Lower Tertiary beds, sections were neither so plentiful nor so clear as when the Geological Survey was in progress (1858–59). Thus Mr. Prestwich says (in 1850), “The first” (that is to say, the most westerly) “point where we meet with some uncertain indications, without sections, of the basement-bed of the London Clay is capping the summit of Bagshot Hill, between Great Bedwin and Hungerford*” (Map 12); and again (in 1853), “In Marlborough Forest the Tertiary beds are so thin, and so disturbed by, or mixed with, drift, that no good section can be obtained†.” I shall show that there is London Clay three miles or more to the west of Bagshot Hill, and moreover that the Bagshot Sand ranges still further westward.

Tertiary outliers in Sheet 14 of the Geological Survey Map.—At the western edge of the map (14), east of Great Bedwin, there are three patches of the Reading Beds, the middle one capped with London Clay, forming parts of a large and well-marked outlier, the greater part of which is in the map to the east (Sheet 12). There is a section of the Reading Beds in the brickyard at Folly Farm, and northwards there are two other brickyards, the pits in which show the junction of the London Clay and the Reading Beds. An account of these sections will be found at p. 26 of the Geological Survey Memoir illustrating Sheet 12.

At Castle Hill, south of Great Bedwin, there is an outlier of the Reading Beds, probably capped by London Clay at the top of the hill (judging by its height alone, there being no section of the latter formation). This outlier, which is about a mile and a quarter in length from north to south, but nowhere half a mile in breadth, is well marked; the Tertiary beds, for the most part covered with wood, rising sharply from the Chalk. On its eastern side, in a chalk-pit half a mile E. of S. of Broil Farm, there may be seen an irregular junction of the “bottom-bed ‡” of the Reading Beds with

* Quart. Journ. Geol. Soc. vol. vi. p. 257.

† Ibid. vol. x. p. 85.

‡ For an account of this bed, see Memoir illustrating Sheet 13 of the Map of the Geological Survey of Great Britain, p. 23.

the Chalk. The former, here many feet thick, consists, in descending order, of bluish-grey clay (partly mottled yellow), light-green sandy clay, and light-green sand. I saw no flints in it. South of this there are "swallow-holes*" at the junction of the Reading Beds and the Chalk.

West of Castle Hill there is another outlier, equally well marked, forming the wooded hill that stretches for three-quarters of a mile from the northern end of Wilton Common nearly to Broil, and the top of which consists, without doubt, of London Clay; for at Wilton Kiln, at the southern end of the outlier (where the dip is sharp to the north), whilst in places the brown and light-coloured sands of the Reading Beds are found at the surface, I saw, close by the edge of the wood, and near the middle of the brick-field, about four feet of stiff bluish-grey and brown London Clay, with a line of ironstone containing fossils. The fossils were all casts, and amongst them I made out *Nautilus* (casts of detached chambers), *Calyptræa*, *Fusus* (or *Pleurotoma*), *Cardium*, and *Ostrea*.

On the line of hill to the west of the Bedwins there is a large outlier of Lower Bagshot Sand, London Clay, and Reading Beds, forming the high ground from Chisbury Barrow to the south-eastern part of Tottenham Park, a distance of about two and a half miles nearly N.E. and S.W. The outlier is from a quarter to three-quarters of a mile in breadth; its boundary is for the most part well marked, and along it there are many swallow-holes, especially within a radius of half a mile from Stoke Farm to the west of Great Bedwin. At the southern end, near the Chalk escarpment, the dip is fairly sharp; but it soon lessens northward, and the beds become flat or nearly so: perhaps, indeed, the direction of the dip may have changed from north to south at the northern end of the outlier; but not having any datum-heights by which to judge, I cannot say with certainty. Down the northern flank of the hill just south of Stoke Farm deep drains were made in January 1859, and I was fortunate enough to see part of the work in progress. The following beds were cut into, beginning at the bottom of the hill, and taking them in ascending order:—

1. *Chalk* (and the reconstructed bed described in Quart. Journ. Geol. Soc. vol. xvii. p. 527).
2. *Reading Beds*.—Variously coloured mottled plastic clay, with a little sand.
3. *London Clay*.—Stiff blue and brown mottled clay, not plastic, with large rounded flints at the lower part (basement-bed). Higher up the clay is sandy.
4. *Lower Bagshot Sand*.—Brown and buff sand, partly clayey.

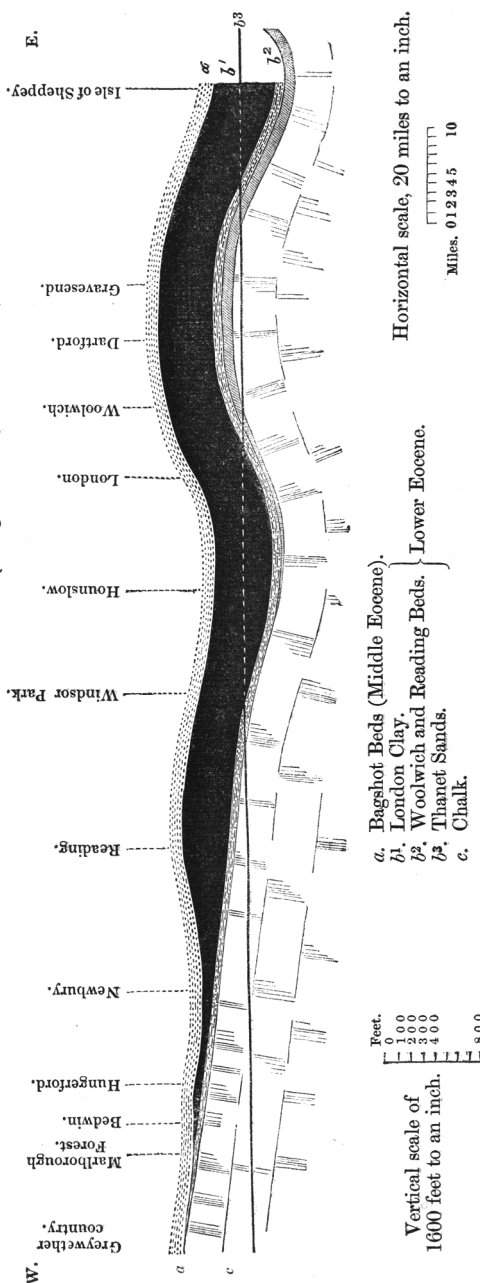
* For an account of these underground water-courses, see a paper by Mr. Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 227; and also the Memoir illustrating Sheet 13 of the Map of the Geological Survey, p. 24. In the latter their frequent occurrence near the junction of the Tertiary beds and the Chalk is noticed.

This section shows that *neither the London Clay nor the Reading Beds are here more than from 12 to 15 feet thick, and therefore that the Bagshot Sand is only 25 or 30 feet from the Chalk.* In the London Clay there were many pieces of ironstone, as at Wilton Kiln; and in one of them I found a cast of an *Ostrea*. This formation covers the Reading Beds over a great part of the outlier; but the patch of Bagshot Sand, the boundary of which is partly marked by a slight rise of the ground, only stretches about a third of a mile both northward and southward of Stoke Farm. On the south-west of the farm, I saw a deep and long ditch, freshly cut, in the sand; and along the road, a quarter of a mile north-east of the farm, sand is again shown. Further northwards the beds are much hidden by pebble-gravel (drift) and by wood. At Chisbury Barrow there is a section along the road-cutting up the southern side of the hill, showing sands, with a little clay, from the top of the Chalk up to the gravel that caps the hill. These must altogether be some 40 or 50 feet in thickness. As I have shown that, in another part of the outlier, the Reading Beds are not more than 15 feet thick, it seems unlikely that here they should be three times that thickness; I should conclude, therefore, that the sands of Chisbury Barrow do not belong wholly to that formation; but rather that the upper beds, which in look are like those above the London Clay at Stoke Farm, are also like them in age, that is to say, are a part of the Lower Bagshot Sand, *which formation therefore here rests directly on the Reading Beds, the London Clay having thinned out.* I should not have ventured, however, to colour those beds as Lower Bagshot on the Geological Survey Map, had not such a step been confirmed by a section in an outlier further west, where a thin pebble-bed, representing the basement-bed of the London Clay, is all that separates the Reading Beds from an overlying mass of sand.

A little west of the large outlier just described are three smaller outliers of the Reading Beds. Tottenham House stands on one, from below which the Chalk rises sharply to the south; another caps the Chalk over a great part of Bedwin Common, but is much hidden by a clayey drift; and between these two there is a small patch, barely separated from the first.

Further westward is a more important outlier, stretching from the house at the western end of Terrace Hill in a north-westerly direction for a mile and a quarter. At its southern end the Chalk rises up sharply to the south from beneath the Tertiary beds; but, as usual, the dip soon decreases towards the north. At the brickyard on the eastern side of the outlier, the sections in different parts of the pit seem to show that the Tertiary beds here rest unevenly on the Chalk; for although the junction is not seen, the waved lines of bedding in the sands, &c., look as if caused by the beds having given way here and there, and filled pipes and hollows in the underlying Chalk. The section does not show an unbroken series of the Tertiary beds from top to bottom; but the upper beds are clear. Plastic clay, of the Reading Beds, chiefly green, has been found above the Chalk; but

Diagram-section from the Isle of Sheppey to a few miles west of Marlborough Forest, showing the Westerly Thinning of the Lower Eocene Beds in the London Basin. (Length nearly 120 miles.)



The section shows the thickness of the Lower Eocene beds in the London Basin, from the Isle of Sheppey to Marlborough Forest, after the deposition of the Bagshot (Middle Eocene) Beds upon them, but before any denudation had taken place through the latter, and does not, therefore, show the present surface of the country. As some of the beds are thin, and the horizontal scale is small (owing to the length of the section), it was needful to use a comparatively large vertical scale, which has been made just 66 times as great as the horizontal. Any unconformity that there may be between the Chalk and the Tertiary beds is not taken into account, there being but few data to guide one in showing it, and it having nothing to do with the subject of this paper. The distance of the junction of the Chalk and the Tertiaries above or below the sea-level has been drawn as it now is.

The basement-bed of the London Clay runs right on to the western part of the district (though I am not sure that it is always present towards the east); but I have no means of settling the question whether that formation thins off to the west by the loss, step by step, of its higher beds in that direction, or whether the same bed is at the top throughout its greater extent, the thinning being caused by the absence of the lower or middle beds.

whether the "bottom-bed" occurs here or not, I do not know. Higher up, the sands and clays of the Reading Beds are overlain by a continuous bed, a few inches thick, of black flint-pebbles of various sizes, many large; and above this pebble-bed there are white and light-coloured sands, with thin seams of pipe-clay, about 12 or 15 feet thick. Now in the sections of the Reading Beds in the western part of the London Basin pebbles are very rarely seen, except in the green sand ("bottom-bed") lying directly on the Chalk; in that bed they are not always found, and when they do occur it is not in great numbers nor of large size: I have never seen, in that district, any regular pebble-bed in the Reading Series*. The basement-bed of the London Clay, however, usually contains pebbles, and generally many of large size, as was found to be the case at Stoke Farm, in the mass of London Clay nearest to the section now under notice; and very often there is a layer of them at the lowest part of this bed. I have therefore no doubt whatever that the pebble-bed of this section belongs to the basement-bed of the London Clay; and therefore that the overlying sands are part of the Bagshot Beds, and that the London Clay proper has here thinned out. The section would then stand thus:—

1. Lower Bagshot Beds.—Light-coloured sands, with seams of pipe-clay about 12 or 15 feet.
2. Basement-bed of the London Clay.—A pebble-bed . . a few inches.
3. Reading Beds.—Sands and plastic clays about 15 feet.

I will now try to show that the above conclusion is borne out by other facts. We have seen that at Stoke Farm the Reading Beds and the London Clay are neither more than 15 feet thick. That the latter thins westward from London has been shown by Mr. Prestwich†, although he seems to have underrated the extent of the thinning; and as from Reading to Great Bedwin, a distance of about 28 miles, it has dwindled from 350 feet to 15 (or at the rate of about 12 feet in a mile), one can have no difficulty in inferring that two miles further westward it has thinned out altogether (with the exception of part of its basement-bed). Moreover the upper sands of the section in question, with their seams of pipe-clay, are lithologically more like Lower Bagshot Beds than anything else.

At the brickyard on the western side of the outlier (close to the yard just noticed) the section was not very clear when I saw it (in May 1859). Chiefly sands were shown; and at one part there was, at the top, a small irregular patch of green sand: could this be a part

* The statement of Mr. Prestwich (in Quart. Journ. Geol. Soc. vol. x. p. 79) with regard to Marlborough Forest, that "the greater part of these fine woods are planted on a thin and irregular capping of the clays and pebble-beds [of the Reading Beds] on the Chalk," is likely to mislead, although, in a foot-note, Mr. Prestwich includes also "a clay and gravel drift." Only a small part of the Forest, not more than a square mile indeed, is on Lower Tertiary beds; but a very large part is on the drift-clay, brick-earth, and clayey pebble-gravel so abundant in this neighbourhood.

† Quart. Journ. Geol. Soc. vol. x. p. 401.

of the Bracklesham (or Middle Bagshot) Beds?—if so, the Lower Bagshot Sand must be thin here.

A little to the north-west of the northern end of the above outlier there is a patch of sand, thickly overgrown with wood.

At Leigh Hill is another sand-outlier, the boundary of which is not quite clear. There are some very large and fine Scotch-firs on and near this the most western mass of Lower Tertiary beds in the London Basin.

Surface-deposits on the Chalk of this District.—These are of two sorts—the more widely spread being a stiff clay of a brown or red colour with angular flints, which I term “Clay-with-flints*”; the other and more valuable one being a loam or sandy clay of various colours, mostly fit for making bricks of, and known therefore as “Brick-earth.”

The Clay-with-flints lies very irregularly on the Chalk, for the most part filling pipes in that rock. The Brick-earth is generally underlain by the clay.

As there is no Survey-memoir illustrating Sheet 14, it will be well to note here the range of these surface-beds, which were at first mapped and published as Eocene in that sheet. The Clay-with-flints rarely occurs on the top of the great Chalk-escarpment overlooking the Vale of Pewsey; but it covers the Chalk over nearly the whole of the higher grounds from the eastern part of the district westward to near East Kennet—not, however, in one continuous sheet, but forming many separate patches. The Tertiary beds are free from it; indeed the Clay-with-flints does not seem to occur elsewhere than on the Upper Chalk, as I have before noticed (in the Geological Survey Memoir on Sheet 13, p. 55).

Over this widespread bed of clay there is here and there a mass of the more sandy Brick-earth. Near Tevals Farm, about two miles S.S.W. of Marlborough, there is a brickyard; there is another by the turnpike-road about a mile S.E. of the same town; and a third on the west of Hens Wood, some three miles to the E.N.E. Without doubt there are many other masses of Brick-earth, which perhaps may be too thin or too full of pebbles to be worked. The bricks made from this bed in the neighbourhood of Marlborough are remarkable for their beautiful rich crimson colour, as may be seen in many of the buildings in that town. These surface-beds are not marked by features as the outliers of true Tertiary beds are for the most part. Thus whilst the latter rise from above the surrounding Chalk, the former merely fill hollows in that rock, and have only been saved from denudation by their sheltered position. As to their age and origin I do not feel able to give an opinion with any certainty.

PART II.—This part does not refer to structure, but simply to thickness; in it I shall make use largely of the sections given by Mr. Prestwich in his papers “On the Thanet Sands†,” “On the

* See Memoir illustrating Sheet 13 of the Map of the Geological Survey, p. 54.

† Quart. Journ. Geol. Soc. vol. viii. p. 235.

Woolwich and Reading Series *," and "On the Thickness of the London Clay †." It will be better to begin with the lowest formation, and to work upwards.

The Thanet Sand.—Mr. Prestwich has fully noted the westerly thinning out of this bed of fine soft light-coloured sand; and I cannot do better therefore than quote his words on the matter, from the first of the above-mentioned papers (p. 241). "In some parts of the neighbourhood of Canterbury they cannot be much less than 80 to 90 feet thick. They then apparently maintain a tolerably uniform thickness of from 60 to 70 feet, as far as Chatham, Upnor, and Gravesend. At Bexley Heath they have been ascertained to vary in thickness from 45 to 55 feet, and at Woolwich I find that they are 60 feet thick. Beneath London their thickness averages from 30 to 40 feet. They then become more rapidly thinner as they trend underground further westward, being only 20 feet thick at Wandsworth, 17 feet at Isleworth, 7 feet at Twickenham, and 3 feet at Chobham, beyond which they thin out, although I believe that originally they probably had a range westward coextensive in some measure with the green-coated flints overlying the Chalk ‡."

Along its line of outcrop in Surrey, the Thanet Sand thins westward from Croydon and Beddington (where it is full 30 feet thick), until at Ashstead it is but a few feet in thickness. Further to the west I know of no section in it.

Its thickness beneath London and the country to the west is known by means of well-sections: thus near Westbourne Grove it was found to be 18 feet thick §. Mr. Prestwich says, "At Willesden there are several deep wells, but I have not been able to obtain an exact section of any of them. From a good supply of water, however, being obtained before reaching the Chalk, it is probable that the Thanet Sands have here commenced ||." At the Hyde, 2½ miles north of the village, the following beds were found:—

1. London Clay, and its "basement-bed" 66 feet.
2. Woolwich and Reading Beds.—Sands, clays, and pebbles 34 ft. 8 in.
3. Chalk.

* Quart. Journ. Geol. Soc. vol. x. p. 75.

† Ibid. p. 401.

‡ I hardly think that such is the case; for the bed of green-coated flints above the Chalk in Berkshire, &c., is a part of the "bottom-bed" of the Reading Beds, which lies on the top of the Thanet Sand when that formation is present, and is therefore not to be confounded with the bed of flints at its base. It is possible, however, that (as Mr. Prestwich believes) the two beds may join together to the west of London where the Thanet Sand has thinned out, and thus that the roughly laminated grey clay and the clayey green sand, with oyster-shells and green-coated flints, that overlie the Chalk at Reading and Newbury (see Memoir illustrating Sheet 13 of the Map of the Geological Survey, p. 23, and also the Memoir on Sheet 12, p. 27) may represent the bottom-bed not only of the Woolwich and Reading Beds, but also of the Thanet Sand. Speaking generally, where the Thanet Sand is present the bottom-bed of the Woolwich and Reading Beds does not contain the green-coated *angular* flints so common in Berkshire, &c., but the flints are in the state of pebbles: this need cause no surprise, however, as where the latter formation was not deposited directly on the Chalk, it is not likely that it should contain *unworn* flints that must be derived directly from that rock.

§ Quart. Journ. Geol. Soc. vol. x. p. 96.

|| Ibid. p. 95.

So that the Thanet Sand is absent, as is also the case further northward.

At Castlebear Hill, near Ealing, and at the Hanwell Lunatic Asylum, the Woolwich and Reading Beds were found directly above the Chalk *; and the Thanet Sand does not occur anywhere further to the west.

The Woolwich and Reading Beds seem to have their greatest thickness near London, but do not vary much in this respect eastward of Hungerford (not taking into account any northerly thinning).

With regard to the beds S.E. and E. of London, I do not agree with Mr. Prestwich in classing the thick pebble-bed of Blackheath &c., with the basement-bed of the London Clay: I take it rather to be the top part of the Woolwich and Reading Beds. In the neighbourhood in question the former really consists of a clayey pebble-bed, from a few inches to rather more than three feet in thickness. It may be seen at Loam-pit Hill (Lewisham), in the cutting on the London and Brighton Railway south of the New Cross Station, in that (on the Croydon and Epsom Railway) S.W. of West Croydon Station, in that (on the Mid-Kent Railway) east of Beckenham, and in a brickyard about half-way between the Bromley and Bickley Stations. At the eastern end of the long cutting at Bickley, I saw it (in November 1860) overlain by London Clay, and overlying a sandy pebble-bed, like that of Blackheath, which is here the top bed of the Woolwich and Reading Series. In the clayey "basement-bed" the pebbles were, as usual, without any orderly arrangement; whilst those of the underlying bed were arranged in lines of false bedding (with a westerly dip of 10° to 20°) through the whole length of the section (about 400 yards). The sides of this cutting have since been covered up.

I am also inclined to think that in a more eastern part of Kent Mr. Prestwich has again been too generous to the basement-bed of the London Clay. In the neighbourhood of Herne Bay he includes in it a bed of sand underlying the true London Clay, but which, for my part, I would rather class with the Woolwich and Reading Beds. At the southern end of the large cutting on the Sheerness Branch Railway, about a mile and a quarter north of Sittingbourne, I saw, in December 1860, the following section (quite clear, and of some length):—

London Clay, partly of a greenish colour; no pebbles at the base, and nothing like the usual basement-bed to be seen.
Light-coloured sand; at the base a bed of shells, in a bad state of preservation about 6 feet.
Brown clayey sand, with obscure casts of shells (*Cyrena cuneiformis*? and *C. cordata*?) and a few flint-pebbles about 1 foot.
White and light-coloured sand, with beds of shells, very perfect, but very easily broken (*Cyrena cuneiformis*, *C. cordata*, *Ostrea*, *Melania inquinata*, *Cerithium*), of which there was to be seen
about 8 feet.

* Quart. Journ. Geol. Soc. vol. x. p. 94.

That this lower sand belongs to the Woolwich and Reading Beds there can be but little doubt, as it abounds in some of the characteristic fossils of that formation. The upper sand groups itself naturally with the lower, the only difference being that the former contains but few fossils. If such be the case, it follows that the basement-bed of the London Clay is here altogether absent. It is possible, however, that the upper sand and the loamy bed beneath may belong to it, although the former is utterly unlike the undoubted basement-bed wherever I have seen it, that is, from Marlborough Forest to near Hemel Hempstead on the northern side of the London Basin, and from Peckham and Croydon to Chiselhurst on the southern.

It is but right to state that Mr. Prestwich is very doubtful in separating the Blackheath pebble-bed from the Woolwich and Reading Beds, and that he has also some doubt as to the place which should be given to the sands that underlie the London Clay near Herne Bay. Thus he says, "The difficulty is, whether we are to consider any of the peculiar, fossiliferous, sandy, or conglomerate beds of Woolwich, Bromley, and adjacent districts as a fuller development of the basement-stratum of the London Clay, or whether they all belong to a distinct and underlying series. *I am rather inclined, on structural evidence, to the latter opinion*; nevertheless on palæontological grounds it might be presumed that a passage here exists between the two series*:" and again, "I feel slightly doubtful whether some of the thick pebble-beds under and around Shooter's Hill may not belong to the upper part of the Woolwich series, rather than to the basement of the London Clay; the beds which at Upnor and Herne Bay I have included in the 'Basement-bed' may also possibly belong to the upper section of the Woolwich series. I mention these doubts, which, however, do not affect the superposition and grouping of the three divisions here proposed" (Basement-bed of London Clay, Woolwich and Reading Beds, and Thanet Sand), "although it would modify the exact lines of separation, in order to direct attention to any new facts which may arise to throw light upon those questions where I consider the evidence not quite conclusive†."

If the upper sands of Upnor, &c., be classed with the Woolwich and Reading Beds, we need feel no surprise at so many fossils of that formation being found in them.

If the above-noticed beds be classed with the Woolwich and Reading Beds, that formation will have a thickness of about 50 feet near Herne Bay, instead of only 30; and at Croydon of 45 feet, instead of 36. At New Cross they are 54 feet thick; under parts of London from 40 to 70 feet; at Ealing 60 feet; at Hanwell 75 feet, and at Isleworth and Chiswick as much as 87 and 90 feet respectively‡.

From London westward, by Windsor, Reading, Newbury, and Hungerford, the Reading Beds have a general thickness of from 40 to 60 feet (being subject to slight local changes), until near Great Bedwin, to the west of which place I have shown, in the first part

* Quart. Journ. Geol. Soc. vol. vi. p. 262.

† Ibid. vol. x. p. 130, *foot-note*.

‡ Ibid. pp. 94, 96, 105, and 142 to 151.

of this paper, that they are not more than 15 feet thick. They do not increase further westward in Marlborough Forest, the last point where they occur in the London Basin.

There is one other fact that seems to point to a thinning of the Reading Beds, though in what direction is not clear. In the western part of the London Basin, the basement-bed of the London Clay is remarkable for the common occurrence of large rounded flints in it (generally in a line at its lowest part), often 6 or 8 inches in their longest diameter, and sometimes as much as 14 inches*, besides the ordinary flint-pebbles. Now, where any pebbles are found in the Reading Beds in the same district, they are not of large size. The most westerly place† where I have seen rounded flints of any great size in that formation is at Chorley Wood Kiln, about two miles W.N.W. of Rickmansworth (in an outlier); and these were in the "bottom-bed," which there consists of 10 or 12 feet of green sand full of pebbles. It would seem likely, therefore, that *the large rounded flints of the "basement-bed" of the London Clay were derived at once from the Chalk, or that, if they came from the Reading Beds, it was from the lower part of that formation*; or, in other words, that *the London Clay sea stretched over the Chalk where the latter was either wholly uncovered, or but slightly covered, by any older Tertiary formation*. In confirmation of this, I may quote Mr. Prestwich's words: "It is probable that the denuding action (which accompanied the formation of the basement-bed of the London Clay) acted not only on the mottled clays and the pebble-beds forming the upper part of the underlying series, but that it in places extended to the Chalk itself‡." Mr. Prestwich, however, thinks that the rounded flints were all derived from older Tertiary beds, and not directly from the Chalk.

The Basement-bed of the London Clay.—This bed§ seems to reach its greatest thickness near Reading, where the light-brown loam, with green sand, shells, flint-pebbles, and masses of limestone and of iron-stone, of which it there consists, is 5 to 12 feet thick, whilst at Northcot (to the west) and at Nettlebed (to the north) it is 9 feet||.

In well-sections in and near London it has been found to be from 2 to 5 feet thick. Near New Cross it is only about a foot (in one of the sections at Loam-pit Hill, near Lewisham, it is, however, only three inches), and near Bromley from a foot to 3 feet. Further

* This great size is noted by Mr. Prestwich in Quart. Journ. Geol. Soc. vol. vi p. 259 (explanation of fig. 4).

† I speak of the northern outcrop of the Reading Beds. According to the sections given by Mr. Prestwich (in Quart. Journ. Geol. Soc. vol. x.) and by Mr. Bristow (in the Geological Survey Memoir on Sheet 12), clay chiefly prevails along the southern outcrop at the western part of the London Basin, and the sands do not contain pebbles.

‡ Quart. Journ. Geol. Soc. vol. vi. p. 277*

§ Not including therein the pebble-bed of Blackheath, &c., nor the sands just beneath the London Clay near Herne Bay. (See above, p. 267.)

|| See Memoir illustrating Sheet 13 of the Maps of the Geological Survey, pp. 49, 40, 52. Mr. Prestwich is mistaken in saying that "westward of London in no case does the basement-bed of the London Clay present a thickness of more than 5 feet" (Quart. Journ. Geol. Soc. vol. vi. p. 280).

eastward it seems to be thin; and if we class the upper sands near Herne Bay, &c., with the underlying Woolwich and Reading Beds, "the basement-bed itself might be considered in this area to merge into the thin seam of sandy clay just at the base of the great mass of the London Clay*." Westward of Reading it is from 2 to 5 feet thick, and in Marlborough Forest it has been shown to consist merely of a line of pebbles (see p. 262).

London Clay.—Of the London Clay itself Mr. Prestwich has observed the westerly thinning, as before stated. To quote his words, "It would appear that the London Clay gradually expands as it ranges from west to east, at first rather rapidly until it attains a thickness of from 300 to 400 feet, and then very gradually until, in the neighbourhood of London, it averages from 400 to 440 feet thick. In the Isle of Sheppey, and on the opposite Essex coast, however, it reaches its greatest development, being there apparently as much as 470 to 480 feet thick†." The thinning is, however, much sharper on the west of Reading than Mr. Prestwich has supposed. He shows that a few miles to the south-east of that town the London Clay cannot be less than 370 feet thick; and says, "there exist no definite measurements in the neighbourhood of Hungerford or Newbury; taking, however, into consideration the dip of the beds and the height of the hills, I do not think that the entire thickness of the London Clay there exceeds 200 to 250 feet‡." During the progress of the Geological Survey the data wanted for the measurement of the thickness of the London Clay were found, and my friend and colleague Mr. Bristow tells me that its thickness on the south of Newbury is not more than 50 or 60 feet, and that westward towards Hungerford it is, if anything, less. I have shown that at Oare, on the north of Newbury, it is less than 20 feet, the Bagshot Sand being there within that vertical distance of the Reading Beds§. On the west of Great Bedwin it has been proved to be not more than 15 feet thick; and in Marlborough Forest the London Clay proper seems to have wholly thinned out||, all that there remains of the formation being a pebble-bed forming part of its "basement-bed."

Of the Bagshot Beds, which belong to the Middle, and not to the Lower Eocene Series, I do not now treat. Enough to say that Mr. Bristow tells me that south of Newbury the Lower Bagshot Sands are at least 100 feet thick; but that, as they are not capped by any of the Middle Bagshot Beds within some miles distance, their full thickness cannot be given.

Effect of the Westerly Thinning of the Lower Eocenes.—The result of the westward thinning of the Lower Eocene strata is, that in that direction the Bagshot Beds gradually get nearer to the Chalk. In Marlborough Forest we have seen (p. 262) that there is but 15 feet

* Quart. Journ. Geol. Soc. vol. x. p. 130, *foot-note*.

† Ibid. vol. x. p. 407.

‡ Ibid. vol. x. p. 402.

§ Memoir illustrating Sheet 13 of the Map of the Geological Survey, p. 54.

|| This thinning-out does not necessarily indicate the original edge of the basin, but may be for the most part due to denudation before the deposition of the Bagshot Beds.

between those formations. Now, if the thinning should continue (as there is good reason to suppose, from its constancy in the districts where enough of the beds to show their order and thickness has escaped denudation), still further west *the Bagshot Beds would rest directly on the Chalk, all the Lower Eocene strata having thinned out.* This will, perhaps, be made clearer by the diagram-section, p. 263, which shows the thickness of the various Lower Eocene beds from Woolwich to Marlborough Forest.

PART III. *Age of the Greywethers.*—Mr. Prestwich has inferred * that the blocks of Greywether-sandstone scattered over the surface of the Chalk and other formations have once formed part of the Woolwich and Reading Beds. His reasons are, that their distribution is “in accordance with the range of the Lower London Tertiaries” [the basement-bed of the London Clay, the Woolwich and Reading Beds, and the Thanet Sand] “rather than with that of the Bagshot Sands;” and that, as there is no reason for supposing them to have come from either the basement-bed or the Thanet Sand, they must be referred to the intermediate Reading Beds;—that this conclusion is borne out by the facts that the occurrence of the greywethers “is exactly coincident with the development and preponderance of the sand-beds of the mottled clay” (that is, the Woolwich and Reading) “series,” and that “the lithological structure of each variety is respectively in accordance with the mineral components forming the strata in the immediate vicinity i.e. that the concretionary stone in each case represents the component parts of some portion of the adjacent Woolwich and Reading series;” thus, “in the neighbourhood of Hatfield, Hertford, and Ware, the sands of the Reading Series are often glutted with flint-pebbles; it is over this area more particularly that the Hertfordshire pudding-stones are so abundant.”

Speaking of the gravel-drift around Newbury, which contains many blocks of greywether-sandstone, Mr. Prestwich says, “The course of this drift is towards, and not from, the area of the Bagshot Sands; and as we have no proof of the extension of this formation over the chalk-downs, whereas we know that detached outliers of the Lower Tertiary sands extend far over those hills, we should expect to find in the drift the *débris* derived from the latter and from the Chalk, and not from the Bagshot Sands.”

I think, however, that what has been said in the former parts of this paper must lessen the force of Mr. Prestwich’s argument, founded as it is on evidence “circumstantial rather than direct.” I have not only proved the extension of the Bagshot Sand over the chalk-downs, but have shown that in Marlborough Forest, owing to the dying-out of the London Clay and the thinning of the Reading Beds, that formation is but 15 feet or so from the top of the Chalk. If the Reading Beds became still thinner further westward, as is most likely to have been the case (unfortunately there are no outliers of any Tertiary bed on the Chalk in that direction), *the Bagshot Sand would gradually*

* Quart. Journ. Geol. Soc. vol. x. pp. 123–130.

get nearer to the Chalk, and at last would lie on that rock. Now it is just at the part where one would expect this to happen that the greywethers occur in by far the greatest number, which naturally leads to the inference that they have some connexion with that formation, and indeed have most likely been derived from it.

On the surface of the chalk-country westward of Marlborough (Sheets 14 and 34 of the Geological Survey Map) there are literally tens of thousands of greywethers. Speaking of their occurrence in this district, Prof. Ramsay says,—“A few of the places where they are most numerous are marked ‘large stones’ on the Ordnance Map; but these yield no idea of their surprising number, or of the extent of ground they cover, no indication being given of their occurrence over many large areas where they strew the ground so thickly that across miles of country a person might leap from stone to stone without touching the ground on which they lie. Many of these flat masses of grit are four or five yards across, and they are often four feet in thickness*.” I saw one block, in a valley on the northern side of the Kennet, that measured $13 \times 10 \times 7$ feet, that is to say, contained, allowing for irregularity of surface, about 850 cubic feet. In the distance it looked like a small hut.

Greywethers are not only found on the surface of the Chalk and older formations, but also on the London Clay (though not in such large numbers), and that too at a distance of some miles from the outcrop of the underlying Woolwich and Reading Beds, as is the case to the north-west of London; which fact favours the notion that they have come from the overlying Bagshot Beds rather than from a formation below the London Clay.

As it is known that here and there sandstone occurs in various parts of the Bagshot Series, there is nothing unlikely in the view that greywethers may have been thence derived. Indeed Mr. Prestwich has noticed that most of the stones have “a lithological structure very similar to that of the blocks found irregularly dispersed sometimes in the lower, but more especially in the upper division of the Bagshot Sands between Esher and Strathfieldsaye.”

I do not think, however, that all greywethers came from the Bagshot Sands. Many, I have no doubt, have been derived from the Woolwich and Reading Beds; indeed I have seen a large mass of sandstone in place in an outlier of that formation at Langley Park, near Beedon, to the north of Newbury†. Again, on the south-east of London there is a thick pebble-bed in that formation, which in the neighbourhood of Bromley is often hardened into a pudding-stone, large blocks of which may be seen in the railway-cutting at Beckenham. The blocks of pudding-stone so common on the surface of the chalk-district of Hertfordshire, &c., I think (with Mr. Prestwich) also belong to this Series. Other greywethers possibly, but not large ones, came from the Basement-bed of the London Clay, which in some places contains a bed of sandstone. But I hold that the occurrence, in vast numbers, of these sandstone-blocks westward of Marl-

* Memoir illustrating Sheet 34 of the Geological Survey Map, p. 41.

† See Memoir illustrating Sheet 13 of the Geological Survey Map, p. 35.

borough, just where we should expect, on quite independent grounds, that the Bagshot Sand at one time rested at once on the Chalk, proves, as far as indirect evidence can, that there they have come from that formation; and it seems to me that their sudden abundance in that neighbourhood, where they almost form a giant pavement along some of the valleys, cannot be in any other way so well accounted for as by that westerly thinning of the Lower Eocene beds treated of in the second part of this paper, and the result of which has been to bring the Bagshot Series without doubt very near to, and most likely actually on, the Chalk in that neighbourhood.

According to this view, it is in that district where the greywethers have suffered least vertical displacement (through the denudation of the softer beds of the formation to which they belonged), in their subsidence from their original position to the one they now occupy, that they occur in the greatest abundance.

On the Sands of Netley and Headley Heaths.—It may be as well to mention here that Mr. Godwin-Austen is disposed to class with the Lower Bagshot Beds some outliers of sand that occur on the Chalk of Surrey, to the east of Guildford. For my own part, however, I do not think that the sands of Netley Heath and Headley Heath are of so great an age. I take them to belong to the same set of beds as the sands of Chipsted (south of Croydon) and Paddlesworth (near Folkestone), which have been referred by Mr. Prestwich to the age of the Crag*. I think that their method of occurrence, or their "lie," is too irregular to allow us to class them with the Lower Bagshot Beds. At Headley they seem to abut against an outlier of the Lower Eocene Beds, with which series most surely they have no kinship; and they here and there spread some way down the slopes of the valleys.

From what has gone before it is clear that, just to the north of the district where these sands are found (in Surrey), the London Clay is not less than 400 feet thick: I cannot think it likely that that formation should thin off so suddenly southwards, without any sign, and that the Lower Bagshots should also cut through the Woolwich and Reading Beds and the Thanet Sand to the Chalk. This would show a great unconformity between the Middle and Lower Eocene Series, which we have no other reason to look for; the resting of the Bagshot Beds on the Chalk, that I have shown to be most likely to take place at the western end of the London Basin (see p. 262), being caused chiefly by "overlap."

Nevertheless, as all that one can say of the Headley Sands is that they are newer than the London Clay, there is just a possibility that they may belong to the Bagshot Series; but, from what I have seen of them (in many places), I take this opportunity of stating my belief that they are much more likely to belong to the Crag, or even to a later formation, though I can as yet see no evidence as to their exact place in the geological series.

However, should they turn out to belong to the Bagshot Beds,

* Quart. Journ. Geol. Soc. vol. xiv. p. 322.

they will give further evidence in favour of the theory that the greater part of the Greywethers have come from that formation; for patches of them occur in many places along the Chalk-range of Kent, in which, and on the surface of the older cretaceous beds rising from its base, there are many greywether-blocks, that in this case would here, as near Marlborough, have some connexion with the range of the Bagshot Beds, being more plentiful where that Series is least separated from the Chalk.

I have noticed the sands of Netley and Headley Heaths but shortly. A more detailed account of them will be given in a memoir (now preparing) to illustrate Sheet 8 of the Map of the Geological Survey of Great Britain. All that is needful here is to note the bearing that they *may* have on the Greywether-question.

3. *On a Deposit with INSECTS, LEAVES, &c., near ULVERSTON.*

By JOHN BOLTON, Esq.

[Communicated by the President.]

THE deposit described in this communication has been sunk through during the progress of works undertaken by the Lindale Cote Iron-ore Company, for drainage-purposes. The mines are situated in the well-known hamatite district of Low Furness, about three miles S.W. of Ulverston, in a valley between two ranges of low hills belonging to the Mountain-limestone series. The physical geology is varied in character,—a fine sequence of the following beds in descending order from the Upper Silurian occurring in the hills lying north of this valley, viz., Lower Ludlow Rocks, Upper Ireleth Slates, Lower Ireleth Slates, Coniston Grit, Coniston Flags, Coniston Limestone (equivalent to the Bala Slates), and Green Slates with Porphyry, which last rocks extend northward for many miles beyond the boundary of Furness. South of the valley in which these mines are situate, the Mountain-limestone is developed on a large scale, being upwards of six miles in breadth. The exact position of Lindale Cote Mine, upon the promontory of Furness, is about halfway between Morecombe Bay and the estuary of the Duddon.

In sinking shafts to a water-way driven from the Lindale Cote to Urswick Tarn, in 1855, down the course of a valley lying about 100 feet below the table-land, and receiving the drainage of about 600 acres, a deposit of greenish-drab clay, six feet in thickness, was met with at a depth of forty feet from the surface, in the shaft nearest but one to the mines, and at the highest “level.” This clay-bed contained pieces of unfossilized wood, associated with numerous leaves, seed-vessels, and other vegetable remains. Among the few which can be determined are, leaves of Beech, with the epicarp of the fruit-receptacle, and a well-preserved branch of Sphagnum. A few well-preserved Insects also occurred in the deposit. Of these some have been determined by Mr. Stainton, F.G.S., as fragments belonging