ON PROBABLE GLACIAL DEPOSITS, OR EVIDENCE OF THE ACTION
OF ICE NEAR EALING, MIDDLESEX.

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During the past two years my attention has been directed to the apparent evidence of ice-action on the elevated land in the vicinity of Ealing, and more particularly at Horsington Hill and The Mount.

I have observed indications of Glacial Drift (as I believe it to be) on the former ; but as no disturbance of the surface has taken place, except at one spot, where there is a small excavation from which gravel seems to have been taken, and which is now nearly overgrown with grass, there has been no means of observing the deposits at its summit. Still, the capping of gravel containing rolled pebbles, small sub-angular pieces of flint, quartz, quartzite, chert, Lower Greensand, Bargate stone, limestone, &c., and the remarkable structure of the hill itself, with its two terraces towards the south, having the appearance at first sight of raised beaches, which, however, I do not believe them to be, give promise of its affording evidence of glacial action, if sections should hereafter be exposed.

On the Mount, however, the geologist has had more evidence open to him, a large reservoir being in course of construction at its summit for the Grand Junction Water Company ; and it is through the kindness of the chief engineer of this Company, Mr. A. Fraser, who sent me specimens of the trial borings to the depth of 20 feet, and who gave me every opportunity of examining the cuttings, that my attention was drawn to this spot, and I have since been able to make drawings of the sections from the sides of the excavation.

The Mount is one of a range of low hills forming a separating ridge between the Brent valley and the Thames deposits, ranging from 180 to 210 feet above Ordnance Datum, the country extending in a gentle incline, with some undulations, to the ancient banks of the river Thames. It is on this ridge that the indications of the last glacial period, or at any rate evidences of the action of ice, are met with ; and, as far as I am aware, they have not hitherto been noticed so far south in Middlesex. I am not without hope that these deposits may furnish some new facts in relation to Glacial Drift or marine glacial action, as they

occur on the high ground immediately overlooking the old bed of the Thames, while the underlying stratified bed—whether it be Lower Bagshot, as supposed by some geologists, or not—seems to be quite unconnected with the London Clay beneath, and to owe its formation to other conditions than the deposits above. Without wishing to decide on the correlation of the latter, I may venture to compare them with similar forms of “trail,” as such deposits are now called. Under the name of “trail,” beds of different ages, and occurring under different conditions, have been described, and with some of these only do those I have examined appear to agree, though there is a certain similarity in all.

Whatever be their connection with the trail of the Rev. O. Fisher and others, there can hardly be a doubt that such deposits here, as well as at Finchley, Watford, Muswell Hill, &c., give us some idea of the condition of the land-surface and of the Thames Valley at its final period of emergence, which we associate with the close of the second glacial epoch, allowing of course for sub-aërial denudation, which has since taken place.

I will first describe the stones scattered on the surface of the country, and afterwards the sections on the Mount, in order to see how far the observations on trail and ice-action in Middlesex generally, as described by others, indicate a similarity of formation. The Mount is 210 feet above Ordnance Datum. Ascending it from Ealing by the path leading to the old signal-tower at the top, the capping of laminated sand and loamy clay is very distinctly seen. A few stunted trees indicate its limit towards the south, while the colour and general appearance of the soil composing the plateau-like top of the ridge is markedly in contrast with the ground at a lower level where the field is ploughed. A closer examination shows that the cap of loamy clay and sand is about 22 or 23 feet thick, extending down the hill to the west almost as far as Princess Helena college, while to the north the limit is seen about 400 or 500 feet on the opposite side of the lane. To the south of the capping there is denuded London Clay, septaria and selenite being found within two or three feet of the surface.

The various cuttings for roads and sewers which I have examined show that this denuded London Clay, with the exception of a sandy bed (sandy London clay containing *Modiola*, &c., found about 10 feet below the surface in the Montpellier Road and Eaton Rise), follows the incline down to the deposits of brick-earth and gravels

which mark the old bed of the Thames. I have been able to trace with some approach to accuracy the banks of this old river, from a spot half way between Castle Hill Station on the Great Western-Railway and St. Stephen's Church, along the north side of the railway, to Haven Green.

The surface at the top of the hill, where the reservoir is made, is strewn with a profusion of sub-angular and much weathered flints of the same type as those I have noticed in undoubted glacial deposits in Essex. There are also other similar rolled flints, many of them black, apparently derived from the Bagshot deposits, having a much battered rough surface, which is not so noticeable in pebbles from river-channels. Some of the flints, though much weathered, are nodular, and still retain their white crust; and so have clearly not passed through the condition of gravel, but have been brought more directly from the chalk. Interspersed with these flints—which occur in various sizes, from small pebbles to nodules several inches long—are rock specimens of various age and of all sizes up to 9 or 10 inches in diameter, and of the forms characteristic of ice-borne boulders, some of which show indications of striæ, and others are split by frost. In my collection from this field are specimens of quartz, quartzite (one a round, flattened boulder 5 inches in diameter), greenstone with veins of quartz, trap rock, probably toadstone, granite (one piece 5 or 6 inches across), Carboniferous Shale, Carboniferous Limestone, cherty limestone in abundance, red sandstone (probably Carboniferous or Permian), Upper Oolite, Forest Marble, Lower Greensand with glauconite, Bargate stone, chert, hard chalk, tabular and nodular flint, sarsen-stone, or greywether, in abundance (one specimen containing impressions of roots), and others which I am unable to identify.

The excavation for the reservoir is at the N.W. corner of the field, and the sections are all of the same character as that in the diagram, and are of the depth of 10 feet; the specimens of the bed beneath are from trial borings made by the Water Company.

(S) The surface-soil is, as I have mentioned, very stony, and contains the various rocks described above, the gravel and stones found on the surface descending into the channels at B. The deposit (A) appears to be re-deposited puddled London and Mottled Clay, of various colours, with occasional thin layers of sand. This deposit, which is 3 or 4 feet deep, seems originally to have capped

the hill, and now lies unaltered beneath the channels, and it appears to be pressed laterally where it is traversed by them. At B are shown the irregularly-formed channels; and from the correspondence of the pit-like forms on the sides of the excavation I estimate the length of the furrows or channels at from 130 to 150 feet, extending like grooves 4 or 5 feet deep into the original surface, up to which they may be traced. They generally present a jagged appearance at the base, and are often very sharp in outline. In these channels, as seen in the sections, is a very pebbly gravel composed of rolled and much battered pebbles, as well as angular and sub-angular pieces of chert, Lower Greensand, sarsen-stone, quartz, quartzite, &c., extending to the surface, but distinctly crowded into the depressions and more scattered higher up. This deposit resembles the pebbles and boulders I have already described as being spread over the fields. The general direction of these channels is from N.E. to S.W. They have the appearance of having been scooped out by some angular mass, and afterwards filled in with gravel and the débris of various rocks. As the sides of the excavation are now being covered with concrete, I may mention that they can be well observed in the road by the college.

Underlying these channels is a stratified bed of loamy clay (C) and sand, or sandy clay of buff and yellow colour, some bands being very sandy and nearly white, and all being deposited very regularly except where the depressions occur; where the many lines of loamy clay and sand follow the form of the channels, and are distinctly pressed out of the line of deposit, the nearly horizontal lines being close together under the furrows, and very much bent beneath them, often breaking the laminated beds into a curved pie-crust structure. There is no appearance in any of the sections of false bedding, and these stratified beds seem to have been laid down in still water, and afterwards bent by the action of some heavy body which then filled the depressions. This effect is probably due to large masses of ice, which, stranding on this elevated land at the period of its last emergence, afterwards melted, depositing beneath and around them the gravel, and whatever kinds of rock they had gathered in the North during their passage here. The compression of the underlying strata is singularly distinct under all these furrows, which fact, taken in conjunction with the débris contained in the channels and on the sur-

face of the land, leaves no doubt in my mind of the deposits being due to the action of stranded ice.

No organic remains have been found either in the furrows or in the deposits beneath them—but in the silty clays and loam there is a remarkable abundance of small plates of black mica with much dendritic manganese beneath the laminae. The general dip of the strata is towards the south.

The deposit (D) is very clayey, increasingly so probably, as the base of the excavation is reached. It is very evenly and horizontally bedded, and contains much mica, and large iron concretions have also been found in it as well as masses of sarsen stone. A specimen of the latter which I have is flat on one side, with rolled edges.

The bed (E), as shown by the results of the trial borings, is strong, loamy clay, reaching to the depth of 10 feet at least below the base of the excavation, and containing mica in minute flakes. The lower deposits are now being used in the adjoining field, on the opposite side of the lane, for making bricks.

The question at once arises what is the age of the 22 or 23 feet of strong loamy clay and stratified beds. The presence of mica and of white clay bands, as well as their general character and position, would seem to point to the deposit belonging to the Bagshot series, did not the low level at which they occur appear at variance with that hypothesis. At the visit of the Association on the 26th May last, I described these beds, and we examined a small section, the only portion left of what I had seen previously on all the sides of the excavation, reaching to the depth of 10 feet. A discussion then took place, and I think those present who were much more able to form a judgment upon this matter than myself, agreed in the opinion that these stratified beds probably belonged to that formation. The occurrence of boulder-like masses of sarsen-stone, or greywether, in them seems, however, to be remarkable on that supposition. With regard to the channels, I feel a difficulty in admitting that they have been formed by the removal of underground sand or gravel by running springs, as, on such an hypothesis, the curvature of the beds should be most marked nearest the place where the substances were removed, and should extend upwards to the top of the overlying beds; whereas in fact, the lowest strata or laminae are quite horizontal or parallel, and the curvature takes place only at the top, while the compression or squeezing together is greatest

just beneath the gravel, where, it is presumed by me, the pressure was actually exerted. It is further noticeable that 10 feet of strong loamy clay underlie the parallel laminated beds; and there is no evidence of gravel or sand beneath them. The presence of water in the brick-field may be due to percolation from the channels which reach the surface.

Taking these difficulties into consideration, the hypothesis of ice-action from above appears to me to be the most probable. Is there a connection between the uppermost deposits on the Mount and those to the north at Watford, or with the remarkable well-known glacial reliquæ at Finchley, &c.? I have not found Lias or Oxford Clay *Belemnites* and *Gryphæa*, which are so markedly characteristic of the Boulder Clay at those places, but if the surface had been more open to examination, and more time had been given to it, I should not despair of finding the harder fossils from these formations. I am aware that I cannot actually show the existence of the Chalky Boulder Clay, and the horizon is, of course, much lower than in those localities where it is seen; but too much weight ought not, in my judgment, to be attached to that circumstance.

The Rev. O. Fisher ('Geol. Mag.,' Dec. 1, Vol. iv., 1867) recognized in the apparent Glacial deposit capping the brick-earths at Ilford and Grays Thurrock, the same deposit which he noticed and described as filling troughs on the general surface of the country at Wivenhoe, Chillesford in Suffolk, Woking in Surrey, and other places ('Quart. Journ. Geol. Soc.,' Vol. xxii.), consisting of materials transported from higher ground in the rear by some agent, which he believed to be land-ice, and which he calls "Trail." "Whatever its origin may be," he says, "it is evidently connected with the last denudation of the surface."

Most of us have noticed similar deposits at Crayford. A section I made from one of the pits there certainly presents a like appearance, but without the disturbance of the underlying stratified loam and sands, due, in my opinion, so clearly, in the case of the beds on the Mount, to pressure from above. This deposit at Crayford overlies the brick-earths, or Mammaliferous bed, and Mr. Fisher does not assign to it the high antiquity attached to it by Mr. Maw ('Geol. Mag.,' Dec. 1, Vol. iv., No. 3), and even intimates that it may be due to sub-aërial conditions. In the case of the deposits at Ealing this explanation appears to me to be quite untenable.

Prof. Boyd Dawkins, commenting on the age of the trail and underlying beds at Crayford, Erith, and Thurrock, says—"The direct relation of the lower brick-earths to the Boulder Clay not being exactly proved, it is very probable that the trail may be its equivalent in point of time." The superposition of the trail over the lower brick-earths indicates, he thinks, a far lower temperature at the time of the accumulation of the former deposit than of the latter. ('Quart. Journ. Geol. Soc.,' Vol. xxiii., 1867.)

From Mr. Searles Wood jun.'s very elaborate and remarkable paper, in which, I believe, his latest views are expressed ("Newer Pliocene in England," 'Quart. Journ. Geol. Soc.,' Vols. xxxvi and xxxviii.), the reader may be disposed to consider his opinion to be that these deposits probably belong to his seventh stage, "the Minor Glaciation," but how far he may be inclined to accept the action of land-ice as the agent, remains an open question.

This eminent geologist has a passage in the concluding remarks of his paper on the structure of the Thames Valley ('Geol. Mag.,' Dec. 1, Vol. iii., 1866, p. 105) which is worth quoting, although his theory has been somewhat modified. He states it thus:—"That the original valley of the Thames [was] formed subsequently to the deposit of the Upper Drift or Boulder-clay, and by denudation during emergence from the Upper Drift sea." "That in the trough so formed, and after its complete excavation, the fresh-water deposit of the Lower Brickearth was accumulated, having a very limited extension. That after this the valley underwent a considerable depression by which the sea was admitted, rising up the sides of the valley to a height very far above the limits of the Lower Brickearth, and covering that deposit, by which an uniform sheet of closely bedded fine gravel (composed of materials brought mostly from other areas than those draining into the valley) was deposited, while changes of level occurred during this depression which gave rise to the bands of clay and sand, yielding fresh-water shells, which occur at a few places near the margins of the deposits, and are intercalated with the gravel. And that, after the completion of this formation, a change ensued by which the sources furnishing the gravel were cut off, the mud brought down by the surrounding streams—instead of being, as heretofore, carried off by the tide that brought the gravel-freighted ice—being intercepted and allowed to subside in deposit.

. . . Finally" [after a long interval and many convulsions] "the Thames found its way . . . to the sea . . . by the downthrow forming Sea Reach."

To judge fully of this theory in regard to the Ealing deposits, Mr. Searles Wood's paper should be read *in extenso*.

The Director-General of the Geological Survey, Mr. A. Geikie, in his lately published 'Text-Book' (p. 890), says, in speaking of "Interglacial Beds":—"The boulder clay is not one uniform mass of material. In a limited section, indeed it usually appears as an unstratified mass of stiff, stony clay. But it is found, on further examination, to be split up with various inconstant and local interstratifications, and in fact to consist of a group of deposits of different ages and formed under very various conditions. Beds of sand, gravel, and fine clay, and peaty layers on different platforms in the boulder-clay bear witness to intervals when the ice retired from the land," and after alluding to the higher level which before prevailed in N.W. Europe, he says:—"The Ice-fields were carried down below the sea-level, where they broke up and cumbered the sea with floating bergs," and "the proofs of this phase of the long glacial period are contained in the sands and gravels, erratic blocks, and stratified clays which overlie the coarse older till."

Mr. A. Tylor ('Quart. Journ. Geol. Soc.,' Vol. xxv., 1869, "Quaternary Gravels") considers that the gravels were spread out after the excavation of the valleys to their present depth, and supposes the Glacial Period to have been succeeded by a Pluvial Period, so that the river floods reached far above their present limits and deposited gravels high up the slopes of the valleys, suggesting that the gorging by ice of the mouth of the Somme, Seine, and Thames may have assisted in the production of the gravels.

This hypothesis somewhat prepares us for the late Mr. Belt's rather startling and improbable theory, stated in his paper "On the Superficial Gravels and Clays around Finchley, Ealing, and Brentford" ('Quart. Journ. of Science,' Vol. xv., pp. 316-360). Mr. Worthington G. Smith has called attention, in an article in 'Nature' (October 12th, 1882), to some remarkable deposits of trail on the slopes of the Hackney Brook (which he supposes may possibly follow some old depression left by previous denudation) on the north bank and bed of the ancient Thames, and also 270 yards west by north from Clapton railway station. In the

sections he describes, there appears to be some similarity to the deposits on the Mount, the Palæolithic sand and loam being crumpled and disturbed by the trail, but he does not mention any boulders or transported matter except gravel, nor the micaceous deposits in the loamy clays and sands which are so marked a feature of the underlying beds near Ealing. Looking then to these differences, and to the much higher horizon of the latter, they would appear to be of a different age—the trail on the Mount being probably older and more allied to the deposits at Watford, Finchley, &c.

It may be well to add that our highest authority on the Geology of the London Basin, in the last edition of his valuable memoir, in speaking of the Boulder-Clay, with the upper division of which it seems not improbable the trail deposits at the Mount may be classed, says :—" While Geologists agree that the Boulder Clay has been formed by ice-action, they are far from agreeing as to the form of ice that has done the work, and three theories have been advanced with much controversy. According to the first, it is held that this wide-spread deposit—only the southern edge of which enters the tract just north and north-east of London—has been dropped from the melting icebergs that have floated southwards from the ice-capped north country—bergs that have been heavily laden with scratched stones and the glacial mud of that region. . . . Of late years many Geologists have strongly advocated the theory that boulder-clay has been formed by land-ice—not by mere glaciers, but by vast ice sheets underneath which a " bottom moraine " has resulted from the constant grinding action of the thick moving mass, and others again hold that the agent employed was coast-ice, acting on a slowly sinking area."*

After carefully considering the trail deposits on the Mount and the rocks with which they are associated they appear to me to be due rather to the first of these causes.

* 'Whitaker's Guide to the Geology of London. Mem. Geol. Survey,' 3rd Edition, 1880, p. 60.