22. *An* Estimate *of* Post-Glacial Time. By T. Mellard Reade, Esq., C.E., F.G.S., F.R.I.B.A. (Read February 29, 1888.)

Of late several attempts have been made to show that the close of the Glacial period was very recent*.

Having personally devoted considerable attention to what is called Post-glacial or "superficial" geology, I am much struck with the imperfect knowledge with which the question of Post-glacial time is frequently approached.

The writers seem to be unaware of, or to insufficiently appreciate, the grand sequence of events recorded in the deposits on the Lancashire and Cheshire coasts which have taken place since the snow and ice of the Glacial period disappeared †.

On the borders of the coast-line between the Dee, the Mersey, and the Ribble, the student who cares to pursue the subject can do so with great advantage. But through the horizontality of the deposits, and their general low level, none occurring above the level of the 25 feet Ordnance datum and all reaching down to below the level of the lowest spring-tides, the study has to be pursued through the medium of excavations and borings. This I have done in observations extending over many years, and I now propose to show their bearing upon the absorbing question of recent geological time.

Denudation of the Low-Level Marine Boulder-clay.

The whole of the country to which these notes specially refer was formerly entirely covered with a mantle of Low-level marine Boulder-clay and sands. These I have described at length in several papers ‡.

That the valleys of the Dee, Mersey, and Ribble were at one time filled with Low-level marine Boulder-clay, we have, I think, indubitable evidence. The ancient or Pre-glacial course of the Mersey was, as I have shown, under the site of the town of Widnes in Lancashire, and, as numerous borings have disclosed, it is now, with the exception of some superficial deposits of estuarine mud, entirely filled with Low-level marine Boulder-clay and sands. There is strong reason to believe that even here a considerable amount of Boulder-clay was removed before the deposit of the recent silt; but,

* Professor Prestwich estimates that the final melting away of the ice of the Glacial period took place within from 8000 to 10,000 years of the present time (Q. J. G. S. vol. xliii. 1887, p. 407). Mr. Mackintosh estimated it at not more than 6000 years (see Geol. Mag. 1883, p. 189 and pp. 191, 192).

† Professor James Geikie, in 'Pre-historic Europe,' is one of the few who appear to have made themselves acquainted with the remarkable and important changes it is attempted in this paper to explain.

‡ "Drift beds of the North-west of England," Q. J. G. S., part 1, 1874, part 2, 1883. See also C. E. De Rance, Q. J. G. S. vol. xxvi. p. 657; 'Memoirs of the Geological Survey,' &c.; G. H. Morton, 'Geology of the Neighbourhood of Liverpool;' and various papers by D. Mackintosh, Robert Bostock, Dr. Ricketts, and several local archæologists and geologists.

in the present course of the river, the Boulder-clay has been scoured out in places down to the bed-rock. That the Mersey Valley was filled with Boulder-clay, at least to the level of that in the pre-glacial channel at Widnes, will not, I think, be disputed by any-one who knows the locality. There can be little doubt that the Boulder-clay originally filled up the channel of the estuary between Liverpool and Birkenhead. A remnant of it lying in a Pre-glacial channel, the existence of which I ventured in 1872 to predict, was bored through in 1884 by the Mersey Tunnel Works.

That Wallasey Pool, now occupied by the Birkenhead Docks, was formerly levelled up with Boulder-clay is equally evident. The Boulder-clay also exists, or formerly existed, in a thickness sufficient for brickmaking, at Edgehill, on the Lancashire side of the Mersey, at a level of 200 feet above Ordnance datum.

When we consider the proximity of this locality to the Mersey, and the tendency of deposits to work down to and accumulate at lower levels, together with the proved instance of levelling up at Widnes, we can hardly refuse to believe that the Mersey Valley was formerly filled with Boulder-clay. To be assured that such a levelling up takes place in a sea-bottom, we have only to examine a chart of the Irish Sea, which represents a slightly undulating floor or vast plain having no irregularities of level even approximating to those of the valley of the Mersey. That there exist in this sea-area, could we bare it down to the bottom rock, river-valleys or considerable irregularities of contour, is shown by the "ditch" opposite Wigton-shire, where the tide, which here flows very fast, has scooped out a channel from 400 feet to 600 feet deep. The evidences that the Mersey Valley was once levelled up with Boulder-clay is further confirmed by the boring at Halewood, about three quarters of a mile from Hunts-Cross Railway Station, which penetrated 137 feet of drift presumably lying in a former tributary of the Mersey, of which there was no evidence on the surface.

The same may be said of that at Hooton, Cheshire, which went through 169 feet of drift, lying in a valley. A bore-hole at Ilches-ter wharf, Birkenhead float, penetrated 166 feet of alluvium and drift, and I have little doubt that these are only a few out of many examples of the general levelling up that took place during the submergence of the Glacial period.

It is thus quite clear that an enormous mass of glacial deposits has been swept out of the Mersey Valley. That this was mainly done by subaerial agents, when the land was at a higher level than at present, is proved by the numerous tributary streams which branched into it and are now partially filled with Post-glacial deposits. Everywhere below the Post-glacial deposits, to be pre-sently described, the Glacial beds are deeply eroded and show evidences of long subaerial waste.

How much time can be reasonably put down for these changes will be presently discussed.

Post-glacial Beds.—In a few places on the Boulder-clay surface are found remains of vegetation, and above them a series of estuarine

deposits containing marine shells, such as *Tellina*, *Mytilus*, *Turritella*, &c., and in certain laminated clays *Scrobicularia piperata* in the vertical position in which it lived. These Post-glacial deposits, where they occur, have levelled up the inequalities produced by the previous subaerial erosion of the Boulder-clay, and they cover an extensive area amounting to some 75 square miles between the Ribble and the Mersey. It is difficult to say what their maximum thickness is, but they are known to be, in places, 50 feet deep. The deposits thin out landwards towards the ancient shore-line, so that the borings in the centre of the Moss-lands show less than this thickness *.

None of these deposits, which are very general and are found even as high up the river as Warrington, reach above the level of the 25 feet Ordnance contour. It is manifest that they represent a period of subsidence probably long continued. Mammalian remains are found in these beds, but no extinct animal is represented.

Lying upon these silts and blue laminated clays is a very extensive peat-bed containing the stools of trees with the roots ramifying into the clays or silts below. They are mostly oak, birch, and pine.

That these trees have grown in the position in which they are now found we have ample evidence. It therefore follows that the Post-glacial estuarine beds in which they are rooted, after being laid down, were elevated sufficiently for the efficient drainage of the land, and there is strong reason to believe that at this time Great Britain was united to the continent of Europe. Similar submarine forests can be traced all round Great Britain and Ireland, the Isle of Man, and the north coast of France, and I believe that most of them are synchronous with our Lancashire and Cheshire submarine forests. These forests represent, then, a period of general elevation extensive in area, but of unknown vertical range.

Since the growth of these extensive forests, there has again been a subsidence, so that many of them became submerged beneath the sea, and it is to this cause that we owe their partial preservation. Along the littoral margin they are frequently found beneath blown sand, and have, in places, recent estuarine silts deposited upon them.

That all these changes occurred, there is evidence amply sufficient to satisfy any unprejudiced mind. I know of few events in geology more clearly recorded than those just detailed †.

The channel of the Mersey, as proved by borings made during the opposition to the Manchester Canal, is largely filled with Post-glacial gravels. The precise age of these it is difficult to determine, but probably they are the remnants of the Boulder-clay washed out during the subaerial excavation of the present channel. Some of

* See "Borings on the Southport and Cheshire Lines Extension Railway," Proc. of Liverpool Geol. Soc. 1884–5, p. 93.

† See "Post-glacial Geology of Lancashire and Cheshire," Proc. of Liverpool Geol. Soc. 1871–2; "The buried valley of the Mersey," ibid. 1872–3; "On a section at Hightown," ibid. 1881–2; "The Mersey Tunnel, its Geological Aspects and Results," ibid. 1884–5; "Some further Notes on the submarine forest at the Alt Mouth," ibid. 1877–8; "A problem for Irish geologists in Post-glacial Geology," Scientific Proceedings of the Royal Dublin Society, 1879.

the gravel may have been reworked up by the sea. Borings from Weston Point to Hale Head showed the presence of gravel, peat, and sand below the present bottom *.

Length of Time represented by the foregoing Post-glacial Geologic Changes.

That these changes represent a very considerable lapse of time, seems to me almost self-evident; but how can we obtain a true scale with which to measure it? In making the attempt it will be better to reverse the order in which we have described the events, and begin with the latest deposits.

In a paper on "The date of the last Change of Level in Lancashire" †, I have attempted to show, from observations made of the rate of accumulation of blown sand at Blundellsands, that the minimum time required for the accumulation of the 22 square miles of blown sand between Liverpool and the Ribble must be put down at 2500 years, and that no appreciable change of level has taken place in the coast-line within that period. History does not go quite that far back; but so far as it does (that is to the time of the Roman occupation of Britain), there is no evidence of any value pointing to any change of level having taken place; nay, what evidence there is is strongly the other way. The Roman fords on the river Dee show plainly that the state of things then was much as it is now ‡.

The Roman remains found at Hoylake came from a stratum of soil above the peat-and-forest bed. It is evident from this that the peat-and-forest bed was in existence in Roman times in much the same condition in which it appears now. It is in consequence of being buried by blown sand that such numerous evidences of Roman tenancy have been preserved at Hoylake. The Roman station was probably situated just inside of the sand-dunes, which have since encroached upon it and entombed its remains. I know of no implements or other evidences of human handiwork having been found either imbedded in the superior peat or in the silts below, but I have found them in the superficial layers lying on the peat. I am satisfied that 2500 years is a reasonable minimum limit to the beginning of the present condition of level of land and water; but it may be much older. The superior peat-and-forest bed represents, as I have attempted to show §, a continental connexion with these islands, and if so, the land must have subsided not less than 200 ft. since the connexion existed.

Now comes our difficulty: What rate must we allow for the sub-

* "The Mersey Tunnel, its Geological Aspects and Results," Proc. of Liverpool Geol. Soc. for 1884–5.

† Quart. Journ. Geol. Soc. Aug. 1881, vol. xxxvii. pp. 436–9.

‡ See paper by the late Mr. R. Bostock, Proc. of Liverpool Geol. Soc., March 8th, 1870. An examination of the Roman Wall lately disclosed by excavations in the Roodeye has satisfied me that the level of Chester, in relation to the sea, is practically now what it was in Roman times.

§ See "Post-glacial Geology of Lancashire and Cheshire," before referred to.

sidence? We have really very little evidence to go upon excepting that regional changes of land and sea are extremely slow. If we put it down at 2 feet per century, the subsidence would be completed in 10,000 years; let us, however, be generous and say 4 feet per century, which would give 5000 years.

But then land-movements are not always going on; we have seen that the land has been practically stationary for the last 2500 years. If we allow another 2500 years for a pause before the subsidence began, we shall, I think, make a very low estimate.

The elevation of the estuarine silts (Formby and Leasowe beds) must have preceded the depression, and as they were mainly laid down at approximately the same relative level of land and sea as now obtains, we shall have to allow 5000 years for the elevatory movement, estimated at the same rate as the subsidence *. Working backwards from the present time we arrive at the conclusion that (2500 + 5000 + 2500 + 5000 =) 15,000 years is a very moderate estimate for the time which has elapsed since the completion of the laying down of the Formby and Leasowe estuarine silts. Working still backwards in time, if we allow another 2500 years for the pause during which the estuarine silts underlying the peat- and forest-bed were laid down, a parsimonious estimate I consider, we shall arrive at a total of 17,500 years for the time occupied by the Post-glacial changes represented by the Formby and Leasowe and accompanying forest-beds.

But, as I have indicated, the denudation of the Boulder-clay upon which these deposits lie is very great and represents a much greater lapse of time. Measured in the centre of the valley, at least 100 feet, and probably more, of glacial deposits had been swept out of the Mersey Valley before these Post-glacial beds were laid down. Again we are in a difficulty for a time-modulus to apply to the excavation of the valley, which would be more rapid than the general lowering of average ground, the rate of which may be taken at 1 foot in 4000 years †. Let us assume that the valley was swept of its deposits at the mean rate of 1 foot in 400 years, or 10 times the general mean rate; the time occupied in the denudation of 100 feet would be 40,000 years. Considering that the Mersey Valley was widened out to nearly its present extent before the estuarine beds were laid down, a mean rate of 1 foot in 400 years is, to my mind, very rapid. As there are no indications of glacial action during the course of these events, I think that the estimate of 57,500 ‡ years (17,500 + 40,000), say in round figures 60,000 years, for Post-glacial time a reasonable one and, as represented by these changes, well within the mark.

The calculation includes the time occupied in the elevation of the glacial deposits from beneath the sea, as it is assumed that the

* There are no known instances affecting so large an area of a rate of elevation or subsidence so great as this. The observations in Sweden showed a mean rise of 3 ft. 6 in. in 134 years. 'Nature,' Dec. 18, 1884, p. 150.

† "A Delta in miniature," Quart. Journ. Geol. Soc. May, 1884. "Denudation of the two Americas," Presidential Address, Liverpool Geol. Soc. 1884–5.

‡ Dr. Croll, from entirely different data, estimates it at 80,000 years.

denudation went on *pari passu* with the elevation. It may be urged that the mean lowering of the ground in a Boulder-clay area would proceed much more rapidly than in average ground composed of a variety of rocks. I am not prepared to admit this. Boulder-clay is a very tenacious substance, and, if only attacked from the top surface, takes long to denude.

The valleys would be excavated at a greater rate than in rock, provided there were a sufficient gradient, as the clay is more readily undermined. This I have allowed for in the increased rate of valley-excavation. No ordinary rock would be worn down so quickly as 1 foot in 400 years. Again the rate of vertical excavation by a river would not be uniform; it would proceed with greater rapidity at first and decrease as it reached the base-level of erosion, then it would cease entirely.

All this time the valley would be widening and would continue to widen, though the vertical excavation ceased. Other things being alike, the widest valley must be the oldest. The Mersey Valley is distinguished for its width in the upper estuary, and, in this, tidal action has helped. When we look at the River Ribble below Ribchester, we cannot help being impressed with the idea that there has been little change since the Roman times. I found in 1882 Roman tiles 3 feet below the surface-soil, on the river-cliffs, resting on the Boulder-clay. There are Boulder-clay cliffs on either bank, so that the lateral movement of the river at this part since Roman times cannot have been great.

It is quite apparent that there has been in the area under consideration considerable general denudation of the Boulder-clay. Rocky knolls once covered have been laid bare. Here and there we find patches of Boulder-clay as indications of its former presence. The surface of the clay below the soil is full of ramified channels and holes filled with the sand left from the destruction of the clay above *. Unfortunately there are no *zones* in the clay by which we might be enabled to say how much of it has been removed in particular areas. We are thus driven to the valleys for an answer. They are in many cases remarkably wide, with Boulder-clay at the bottom and on the plateau above, while the flanks often display the rock surface. This is the case at many points in the Mersey Valley and in its tributaries.

When we consider that at the rate of 1 foot in 4000 years the *mean general lowering* would only amount to 10 feet in 40,000 years, we may well consider our estimate based on valley-denudation a moderate one.

When first investigating the Post-glacial deposits of south-west Lancashire and Cheshire, I was much impressed with the great lapse of time they indicate; and a long acquaintance with this class of geological investigation has not lessened the impression.

As I have before stated, in none of the Post-glacial beds have any remains of extinct animals been found. If at a future time any

* See "Subsoil Denudation of Boulder-clay," Geol. Mag. 1882, p. 265.

should be found, it will probably be below the estuarine beds on the surface of the Boulder-clay.

There is little doubt that this surface was occupied by a fauna now partially extinct; but the subaerial conditions, which lasted so great a length of time, were apparently unfavourable to the preservation of their remains. Sir Charles Lyell states that the skulls of two Mammoths were taken out of the excavation made for the Holyhead Railway, near the harbour, two feet below the surface of a bed of peat, which was covered with stiff blue clay. This peat was continuous with that exposed at low water in the harbour of Holyhead, in which were seen stumps and roots of trees *.

The basis on which we have had to construct our estimate is naturally imperfect; but against any possible overestimate of time which may have crept in from the imperfection of the time-measures applied to the events, is to be set the possibility of other events having happened which are unrecorded or unreadable in the deposits which we have been considering.

Discussion.

The President anticipated a considerable amount of discussion on a question which had already engaged the attention of so many writers.

Prof. Prestwich thought the sections of much interest, but wanted to know the terms of the discussion. What was meant by the so-called post-glacial deposits indicated in the column? There was no evidence of their being of post-glacial age, either in the presence of extinct Mammalia or of boreal Mollusca.

The Author explained that all the deposits between the Marine Low-level Boulder-clay and the recent deposits were included in his "post-glacial."

Prof. Prestwich remarked that these deposits contain only recent shells: they are in fact merely ordinary alluvial deposits with the submerged forests, so common round many of our coasts. The dates the Author proposed to assign to these neolithic deposits were founded on estimates entirely his own. But little reliance was to be placed on the thickness of beds accumulated at the mouth of a river.

Mr. De Rance observed that his first paper before the Society dealt with this area and subject. It was a satisfaction to him to agree with Mr. Reade's descriptions, though their conclusions were at variance. The Mersey was a case of a valley within a valley, a pre-glacial valley filled in with glacial deposits, a post-glacial one fringed with river-terraces. The case was somewhat different as regards the Ribble, west of Preston. He pointed out the great thickness of the drift in the Fylde, its base being below sea-level for many miles. He described the position of the peat-bed and its vertical range, and the amount of excavation effected in the valley since the period of the Upper Boulder-clay, the several stages being marked by terraces,

* 'Principles,' 10th ed. vol. i. p. 545.

the last being the alluvial flat. He corroborated Mr. Reade's statement as to the small change of level since the time of the Romans, but thought that in arguing with respect to the amount of time, he was reckoning without his host; for the valleys had reached their negative gradient before the Roman period. There were no links for the calculation of time for the formation of deposits older than the Roman era.

Dr. EVANS had himself abstained from reducing geological time to years, but he admired the Author's ingenuity. However, he had left out of his calculation certain stages. There was no evidence as to the time elapsed between the Boulder-clay and the base of these deposits, and very little as to whether they were marine or alluvial. If marine shells are absent these beds are probably alluvial and comparatively modern. He contrasted the estimate of the time required for their deposition with the short period allowed by some recent authors for the interval between the Glacial epoch and the present day.

Mr. CLEMENT REID remarked that there was a very similar succession in the deposits of the Humber. A rough calculation had shown that the highest buried forest in that district may have been submerged about 3000 years ago; and the pile-dwelling at Ulrome seemed to prove that it occurred before part of the Neolithic period. He thought that the Author had overlooked the fact that when the land was higher, denudation, and consequently deposition, would be more rapid. This seemed to invalidate any calculations based on the present rate of deposition of silt. He had found it impossible to make any estimate of the time represented by the deposits below the highest submerged forest.

Mr. WHITAKER thought that Mr. Reade's post-glacial beds were newer than the valley-gravels of the south-east of England. The terms post-glacial and glacial have a different meaning in different places; some of the post-glacial drift of one district may be as old as some of the glacial drift of another district; thus southern post-glacial drift may be as old as the Boulder-clay in the column. He spoke of the rapid accumulation of alluvial marsh-clays and peat-beds, as at Tilbury Docks.

Mr. TOPLEY pointed out that the beds under discussion, which upon any view of the case represented a long period of time, were later in date than those of the Cae-Gwyn Caves.

Prof. PRESTWICH remarked that there was considerable correspondence between Mr. Reade's section and that at Tilbury Dock, but at the latter place the alluvial deposits were under 100 feet thick, and rested, not on Boulder-clay, but on the latest of the valley gravels, or true so-called post-glacial beds.

The AUTHOR scarcely expected that any one would fully agree with him on the question of lapse of time. There had been some misapprehension amongst the speakers, who had confined their remarks mainly to the time occupied in the formation of what he called the post-glacial deposits. But he had largely relied upon the time occupied in the clearing out of enormous quantities of marine

Boulder-clay in the valleys of the Mersey, Dee, and Ribble. This post-glacial erosion preceded the deposition of the estuarine and Peat- and Forest-beds, which lie on the denuded surfaces of the remnants of Boulder-clay now occupying the valleys. His estimate of 1 foot in 400 years for the valley-erosion was not excessive, being ten times more than the present general rate of denudation. He referred to the proofs of the surface of the Boulder-clay being much eroded. He only pretended to give an approximate estimate, which was really below the mark. He thought it possible to apply a time-scale to certain beds.