that its depth seems not to have increased, as the lake waters by themselves have little or no denuding powers. That after the general features of the country had been formed by marine denudation, and previous to the Glacial period, subaërial agencies may have excavated part of the Rock-basin; the drainage at that time finding an exit through one or more subterranean passages; but that the greater part of the "Rock-basin" was cut out by ice; first, by the movement of the ice-field that once covered Ireland, and afterwards by the local glaciers, those of the valley of Lough Corrib and Maum, and the transverse valleys.

That the subaërial denudation was not since the end of the Glacial period seems evident, for as before mentioned, all the rocks that can be seen under the water are ice-rounded and scratched; also the last movement of this part of Ireland appears to have been upward, not downward:¹ it might possibly have taken place in the Glacial age, that is, after the ice-field ceased to move in one general direction, but while glaciers flowed down the different valleys and slopes.

V.—THEORETICAL REMARKS ON THE GRAVEL AND DRIFT OF THE FENLANDS.

By HARRY G. SEELEY, F.G.S.

Of the Woodwardian Museum in the University of Cambridge.

1. Boulder-clay.

THE cliffs of the Norfolk coast give conclusive evidence that, before the denudation which formed the drifts had begun, the level of Eastern England was not lower than it is now. On that coast, at Weybourne, is seen the western end of a shell-bed which holds the place of the Norwich Crag. But along to Hunstanton, up the Wash, over the flat lands of Cambridgeshire, so little above the sea-level, there is no trace of Crag, and no evidence that it was ever there. At Norwich, and south and north, the Crag is covered with thick gravels, which do not appear to affect its preservation. And hence it may be inferred that the absence of Crag in the Fenlands is, probably, due to something more than "moving accidents by flood and field." The way in which the Forest-bed extends down to the water side, and the bones dredged from it out at sea; the nature of the lacustrine deposit over it, and the fluviatile strata at Mundesley, seem to show that before the Drift age came on, that part of Norfolk extended further north. If the Crag was not formed in the Fens or on the adjacent coast, it could only have been because the sea had not access. What little is known of the laws of elevation and subsidence of land does not favour a gratuitous assumption that

¹ In places on the north shore of Galway Bay, peat with the roots of trees is found below high water mark; however, this does not prove that the land has sunk, because, at the present day, about two miles west of Galway, between Blackrock and Blake's Hill, there is a morass in which peat and trees are growing. This latter is divided from the sea by a barrier of sand and gravel, and in the places where peat is now found below high water mark, similar barriers may once have existed.

an elevation affected Western Norfolk. But were it so or not, at Hunstanton there terminates a cliff which reappears over the Wash at Wainfleet with the same rocks; and were these cliffs connected, a Cretaceous barrier would dam out the sea, and no Crag could be formed in the Fens. And as there is no evidence that it could have been exposed to the sea during the Tertiary periods, I am prepared to suggest that, before the Drift began, this barrier was not broken through.

At the close of the Crag age, as the island was subsiding, every part of it must have come successively under the action of the breakers; and the result—denudation. But of the detritus the traces are not clear. For when the Boulder-clay appears, so far as may be judged from included fragments, it is not to any extent a drift of local detritus, but came sweeping down from the land of Plutonic and old-life rocks, whose hills seem to have been sawn and grated with ice. It may be that, during this earliest Drift age,—

Ice, mast-high, came floating by,
As green as emerald,—

but I have not found in this locality a vestige of iceberg action. Of glacier action the deposits of the Fenlands offer no traces, unless the fragments of northern rocks be held to prove that one great glacier stretched from the Tweed to the Thames, of which there may be as much likelihood as that the ice of the Caucasus excavated the Black Sea. This may have been a long, slow period, for under the Norfolk drift are shells; in the Boulder-clay are shells; and marine shells are met with at every elevation up to the top of Moel Tryfaen. Some may have come with the drifted material; but whether living near where found, or brought from afar, they equally indicate a continuous sea shore changing so slowly that the life of the margin followed it.

In the typical section at Hasborough, in Norfolk, Boulder-clay covers the laminated beds, and is overlaid by the contorted drift; above this is an Upper Boulder-clay, and finally gravels. The Boulder-clay of Muswell Hill, near London, that of Ely, and the Lower Boulder-clay of Norfolk, contain the same rocks, and present substantially the same characters. The Hunstanton Red Rock occurs at Muswell Hill, at Ely, and on the Norfolk coast. The Ely Boulder-clay contains thick specimens of *Tellina*, exactly like those so characteristic of the Norfolk Boulder-clay. This, to me, suggests that the Ely deposit is as old as the old Boulder-clay of the Eastern Counties. I am, moreover, led to believe that it is the oldest drift of the Cambridge district, from the fact that it rests on beds which have since been removed from the country round, and that it would almost have disappeared but for the fault letting down a wedge of it into the Roswell pit, where it is at least some 60 feet thick. And measurements show that, at the date of the fault, Ely Hill must have been from 100 to 200, or more, feet higher than it is now.

The regular character of the Boulder-clay on the Norfolk coast would lead to the conclusion that it was somewhat uniformly spread

over the country, and originally did not merely cap hills or fill valleys as it does now—at least, in this district. If this is assumed, it is difficult to explain what has become of all the solid substances which would be contained in a regular stratum of even 20 feet of drift, or whence such a deposit could have come. And I should rather be prepared to believe that the Boulder-clay was only partially spread than that its solid rocks and fossils could melt into thin air. In many cases what is now the higher land may have arrested the passage of the drifting ice, and the melting would thicken the Boulder-clay.

I am far from asserting that all the Boulder-clay was formed during this period of subsidence; or, in this manner, some at least was constructed during the subsequent age of uprising.

There can be no doubt that the gravels of Hunstanton came from the Yorkshire area. The presence of a sandy variety of the Hunstanton Rock, rounded into water-worn boulders, would seem to indicate a similar origin for the coarse gravel of the Gog-magogs. The brown Boulder-clay of Elsworth, where it rests on the stratified beds, has a large percentage of Oxford and Kimmeridge clay fossils with some of the Lias. Bluntisham abounds in Liassic fossils, with a few from Upper Chalk. This too may indicate a northern origin. Fossils from the clay at March are more local. At Bourn and Longstow, with many local forms, there is a large proportion which may have come from the northern oolites. So that the contents tend to show that much of the material of Fenland Boulder-clay came from the Yorkshire area. Against this is the fact that on all the hills in the Fens and its borders the drift and coarse gravels are found only on the south and south-east slopes, which, however, shows that by subsequent denudation they were removed from the sides facing the old sea.

2. Coarse Gravel.

The Fenlands offer few memorials of what happened during the succeeding age of elevation. There is no contorted drift as in Norfolk and Suffolk.

In this area Boulder-clay is rarely overlaid by gravel. One instance may be seen in the Ely Clay pit; others on the Hog's Back, going to St. Neots; others on the Gog-magogs. All are cases of gravel on hills. The gravel of Ely is partly a fine deposit, and shows abundant evidence of having been regularly arranged in water. It does not cover the Boulder-clay, but only fills a cavity in it; and from its small extent looks as though denuded: it is largely made up of flints.

In the gravels are found, only more sparingly, all the rocks which compose the Boulder-clay. But there is something more, for in this district, where the hills are of Chalk, the mass, especially of the low land gravels, consists of flint. At Peterborough, where the high land is oolite, the gravel consists, to some extent, of rounded calcareous pebbles. At Hunstanton it is chiefly sand.

I do not suppose that the existence of coarse gravels on hills, like

the Gog-magog, Harston, and Stapleford, indicates that before the gravel was deposited these hills were a continuous table-land. But as the rocks making the gravels are the same as those of the old Boulder-clay, and, as in the case of the Gog-magog, the Boulder-clay itself can be seen a little further down the hill, these seem rather to be examples of reconstructed Boulder-clay, washed of its mud, and converted into gravel. Seeing that these deposits were arranged during upheaval, it may be said as a rule that the oldest beds will be at the higher levels.

As the country arose from out the icy sea, many Upper Chalklands must have come under the power of the moving water. And so flints must have been floated out, and sunk or stranded on the low hills. As the land rose higher, these in their turn would be washed, and this would explain the larger proportion of flints at the lower levels.

Thus by stranding of flints and washing away the mud from Boulder-clay, the coarse gravels may be accounted for. Many considerations show that the Boulder-clay was at this time more widely spread. And while the effect of the upheaval has been to wash the Boulder-clay into gravel at high levels, at low levels it must have been swept into holes and valleys, with the addition of much new mud and many local fossils.

3. Deposits newer than the Fine Gravel of the Plains.

Out in the Fen there is little evidence of gravel, except near high places which are built upon; but the black-peat covers the country like a pall, hiding everything. One section indicates, at Drayton, peat under clay, and gravel under peat. Professor Pryme has told me of other similar sections, and Mr. Marshall, of Ely, has communicated one from near by, which, as typical of all, I will here give. First, he found peat eight feet thick, under which is a clay known to the workmen as "Buttery-clay." Under this a yew-tree stood erect, well preserved as high as the clay reached, but rotted off in the peat, which was filled with its branches and splinters. The tree stood on a foot of gravel, below which was Kimmeridge-clay. Two similar sections from near Whittlesea are given by Dr. Porter, in his *Geology of Peterborough*, in one of which, in place of gravel, was a bed made up of shells of the common edible cockle. But the mammalian remains are chiefly found at the top of the lower bed of peat, and the marine ones in the Buttery-clay, in which are also found *Ostrea Cardium Scrobicularia*, etc. The Marl-bed described by Mr. Hamilton between the upper and lower peats, appears to be a freshwater condition of the Buttery-clay. Half a mile nearer St. Ives than Drayton Gate House, was a section,

Earth	...	...	...	...	...	...	...	1 foot.
Blue-black Clay	...	...	...	...	...	...	...	1 foot.
Peat	...	...	...	...	...	...	...	3 feet.

Below which was black gravel, from which, at eight feet from the surface, was obtained part of the antler of a red deer. And at

Wisbeach St. Mary's, three miles west of the town, in a clayey bed at a depth of fifteen feet, were found—

Tellina obliqua,
Cardium edule,
Scrobicularia piperita,

examples of which are preserved in the Wisbeach Museum. The mammals of this clay are the Walrus and Grampus, and a large Whale. The *upper* bed of peat is long anterior in date to the formation of Whittlesea Mere, seeing that it exists on the site of the Mere, capped with two feet of gravel. The gravel and shell bed below the lower peat are clearly marine. The Buttery-clay and shells above that layer are also marine, while the erect position of the trees show that the peat was not drifted, but clearly an old land surface. Thus there is evidence of several alternations of level and different conditions of the country since the gravel. In the upper peat Mr. Carter found a *Bos primigenius* slain with a large chipped flint (of late aspect) which was driven into the brain.

Nor would the fauna approximate the old peat period to the present time.

Bos frontosus,
Bos primigenius,
Cervus megaceros,

are old peat species now extinct, which also belong to the gravel and cave deposits.

<i>Canis lupus</i> .	<i>Castor Europeus</i> ,	<i>Sus scrofa</i> ,
<i>Cervus elaphus</i> ,	<i>Cervus capreolus</i> ,	<i>Lutra vulgaris</i> ,

are Fen Fossils, which also occur in the gravel and caves of other localities, though not near Cambridge.

The only animal in the Fens which does not occur in cave or gravel is *Ursus arctos*.

Other remains, such as teeth of hippopotamus and rhinoceros, may have been washed out of the gravel.

A fauna is found in the uppermost gravel, which in preservation would appear to be no older than this, whilst all the species seem to be now living.

4. Fine Gravels of the Plains.

a. Physical considerations throw little light on the relations of these deposits. The top of gravel is often undulated, and nearly every gravel pit shows some indication of this darker layer, out of which so often descend the structures called pipes. The flexures have sometimes been attributed to coast ice, but from numerous sections and observations on ground from which trees have been removed, I believe that they merely mark the site of an ancient forest. The bedding too may deceive. In a section of Potton sands, at Potton, I was able to see the process going on by which the beds were coloured. Between two oblique and comparatively impervious bands of oxide of iron, there was loose sand, and stretching over this in curves were films of colour evidently de-

posited by percolating water; and where the sand is coarse, there the colour is dark. Hence I would suggest that the gravel may have been coloured, since it was deposited, by waters draining into it.

The comminution and angularity of the flints of course indicates the action of force, but whether of water only, or water and frost, there is nothing to show.

The physical geography demonstrates that the action of water could only have been marine. And it could only have been by a grand extension of the Wash over the Fenland, that the Upper Chalk, and local rocks, and the old Boulder-clay were denuded to form the gravels. A common section of false bedding from Barnwell represents such conditions of currents as are indicated by the shoals of estuaries.

β. In the Cambridge area land and freshwater shells are found in the gravel of most places. At Overton and Whittlesea the shells have a land and brackish water character. At Hunstanton they are marine, and such as now live on our coasts. At March they are not only marine, but have an arctic aspect. At Doddington and Drayton they are also marine. Those of Barnwell occur in the marl-band, which Mr. C. M. Doughty finds to consist largely of Chalk and Upper Greensand foraminifera. This, like the physical geography, suggests a southern and S.E. origin for the Cambridge portion of the gravel. The shells are generally well preserved, but there is no evidence that they lived near where now found. There are sometimes other thin marl beds above the main one. Now this may either indicate that by upheaval the country became fluviatile and lacustrine, or that from some unknown cause—such as silting up, the sea lost its tidal action, and the estuaries only brought down fine mud. Perhaps in some cases the former of these suppositions best explains the sum of the facts; but the other view may also be true. Therefore, though the deposit is in the main marine, the fresh water band shows that the change was gradual, and that since the period of coarse Gravel the country had become capable of supporting many kinds of life.

The marine shells of Hunstanton by their aspect belong to the close of the Gravel age. Those of March are in gravel, which is contained between Boulder-clays, and obscure in age. Judging from their arctic aspect they might belong to the Boulder-clay age, but the Wash would be a very likely place to cut off and retain a retreating colony. Reconstructed Boulder-clay and gravel may both be results of the same cause, and as those of Doddington are in no way connected with Boulder-clay, their relation to that bed is probably accidental. There is no reason for giving a different age to the sea shells from Drayton; and here, though Boulder-clay is near, gravel is the superficial bed. The aspect of the country, the shells of March, and considerations from the freshwater beds of Cambridge gravels, induce me to regard this as the oldest of the Fen gravels, probably formed between the coarse gravel and the marl beds of the Gravel of the Plains.

Summary.

1. The brown Boulder-clay corresponds with the brown Clay of the Eastern counties, and is oldest.

2. Then the hill gravel, the blue Boulder-clay, and perhaps the shell bed of March corresponds to the contorted drift.

3. As elevation progressed, the Fenlands would become one great fiord, ramifying at the Cambridge end up the southern valleys in the Chalk. First the coarse gravels of low levels were formed, and finally, during a long period—for the flints are wonderfully worn—the fine gravel of the plains. After which the country was elevated, and the sea denuded the superficial beds and retired. This corresponds to the Upper Boulder-clay and coarse gravel of the Norfolk section.

4. Now rivers cut their channels, and there commenced luxuriant vegetable growth, which corresponds with the excavation of the Mundesley river and the Mundesley peat.

5. Then a depression, during which was formed the Buttery-clay of the Fens. This corresponds with the Upper Sands and Gravel of Mundesley.

6. And, finally, comes the second peat and the present state of nature.

I believe this succession is true for a far larger area than the Fenlands, perhaps for all Great Britain.

VI.—ON A BED OF CHALK-FLINTS NEAR SPA.

By J. A. BIRDS, Esq.

THE fashionable Belgian watering place, Spa, is situated 1000 feet above the sea, in the centre of a circle of hills called the High Moors (Les Hautes Fauges), a wild and desolate tract covered with peat-bogs and heaths, themselves some 600 to 800 feet above the town. Immediately above Spa, and opposite to it, there are two other distinct hills, of lesser height, the limits of which are definitely marked out by streams or deep valleys, and these, together with the "High Moors" and their rock, constitute the leading geographical features of the immediate neighbourhood.

The chief geological constituents of the district consist of Silurian *Rhenan*, Devonian, and Carboniferous rocks, together with the alluvium of the Wayai,¹ and the diluvium descending to it from the summits of the High-Moors Hills. But, upon the crest of the latter, a little to the right of the road from Spa to the village of Francorchamps, there is a thin bed of chalk flints, of perhaps a mile square in extent, strewn over the peat or embedded in it, forming one of the most interesting geological phenomena in the neighbourhood.

The bed, as far as I am aware, is completely isolated, the nearest cretaceous deposits being those of Maestricht and Aix la Chapelle,

¹ The Wayai is a small stream, having its source in the Moors eastward of Spa, which, after flowing by the town, turns sharply to the north and continues its course in a line parallel with the railway to the Vesdre, a tributary of the Meuse.