V.—FURTHER REMARKS ON THE SEQUENCE OF THE GLACIAL BEDS.

By SEARLES V. WOOD, JUN., F.G.S.

THE paper of Mr. Hull, "On the General Relations of the Drift Deposits of Ireland to those of Great Britain," in the July number of the *GEOLOGICAL MAGAZINE*, induces me to recur to one by myself on the Sequence of the Glacial Beds, Vol. VII. p. 17 of the same *MAGAZINE*.

In that paper I adverted to what seemed to me to be illusory in the classification of the Glacial beds, viz., the intercalation of a formation of sand or gravel between an under and an overlying Boulder-clay (Vol. VII. p. 20, foot-note); and I endeavoured to show that, though to be received with due care, the evidence of organic remains should have its weight, and go hand in hand with the physical evidence in this classification; and attention was called to the antagonism that seemed to exist between the molluscan evidence afforded by the Middle Sands of the North-west of England and that afforded by the Middle Sands of the East. Since then this antagonism has come out more distinctly; for while Mr. Harmer and I have made considerable additions to the fauna of the Middle Glacial Sands of East Anglia, the former took the opportunity, when attending the British Association Meeting in 1870, of collecting from the Middle Sands of Blackpool Cliff; and Mr. T. M'K. Hughes (who sent me all he could collect) has tried to obtain the same molluscan evidence at St. Asaph; down to which place, and over the northern portion of Wales, it would seem (from the observations of Mr. Hughes around St. Asaph, and of Mr. H. F. Hall about Llandudno), the Lancashire arrangement of an Upper and Lower Boulder-clay, divided more or less by sand, prevails.

In the paper referred to, I ventured to suggest with some confidence that a parallelism might perhaps be found between the fauna of the East Anglian sands and that of the so-called Crag gravels of Aberdeenshire, described by Prof. Jamieson; but this also has failed, as Prof. Jamieson kindly sent the specimens he had obtained up to me for examination; and they proved to be derivatives in the gravels in question, many of them being filled with a matrix foreign to this gravel, which had been rolled with the shells prior to their deposit in it; and although they clearly showed that some bed of Crag, or, more probably, of very early Glacial age, had existed in the North-east of Scotland (and been destroyed probably by the ice-grind of some later Glacial epoch), yet they threw no light on the relation of the Aberdeenshire gravel to the East Anglian Mid-glacial.

Last year Mr. Harmer and I made a superficial examination of the Glacial beds from Yorkshire (which was the northernmost limit to which our field knowledge of those beds previously extended) as far north as Inverness and Cromarty; and the conclusion we came to was that these so-called Crag gravels of Aberdeenshire were but a part of the great expansion of Boulder-bearing sand and gravel which, overlapping (and about Inverness resting on) the Red Boulder-clay of Cromarty, occupies a great part of the maritime borders of the

counties of Inverness, Nairn, Moray, Banff, and Aberdeen, on the North-east of Scotland, and penetrates the Highland valleys in all directions, down to Perthshire and to Argyllshire on the West; in-osculating with and passing into the gritty obscurely stratified (and sometimes *unstratified*) Boulder Drift of the mountain region; and that their overlay on the Aberdeenshire coast by red clay—a feature which we did not detect throughout the mountain districts—is probably one of those peculiarities which seem to us incidental to Glacial deposits, without possessing any classificatory value. These Highland sands seemed to us to be probably the same as those alternating with clays at Gamrie, on the Banffshire coast, which yielded Mr. Prestwich some shells that were all of living species, and were described by him in the Transactions of the Geological Society upwards of thirty years ago;¹ all these sands, etc., appearing to Mr. Harmer and myself to belong to the latest part of the Glacial sequence, and to have been accumulated after the land-ice had disappeared from Britain, and when the mountain districts of Scotland and Wales formed a snow-clad archipelago of mountain tops which was beset with floe ice; and it is to the same period, I think, that the sands of Moel Tryfaen, and those at high elevations (and possibly those also at low elevations that intervene between Boulder-clays) in the North-west of England and Wales, belong.

Mr. Binney adheres to the opinion originally advanced by him, that although sand extensively intervenes between Boulder-clay in Lancashire, that arrangement is not structural, but accidental; and he has recently published some notices of borings to corroborate this view. The same opinion is entertained by Mr. Rome, Mr. Harmer, and myself, respecting the sand and gravel beds in the Purple-clay of Yorkshire; and Mr. J. W. Judd (late of the Geological Survey), who has quite recently been at work in the counties of Lincoln, Rutland, and Leicester, also tells me that the sands and gravels in those counties pass horizontally into Boulder-clay; and he repudiates altogether any classification based upon the alternation of Boulder-clay with sand; while Mr. Wilson's description of the drift about Rugby (Quart. Journ. Geol. Society, vol. xxvi. p. 192) seems to suggest a similar conclusion.

Under these circumstances, I should have begun to entertain a doubt of the propriety of the classification of the Glacial beds into Lower, Middle, and Upper, which I have for some years been endeavouring to substantiate, were it not for the distinct evidence of this division upon far more striking grounds than the intervention of sand between Boulder-clays, which the Survey of Essex, Suffolk, and Norfolk, made by Mr. Harmer and myself (now, I am glad to say, almost finished), has led us; for this Survey has shown us that the Lower Glacial formation of East Anglia (which is mainly not Boulder-clay at all) was, prior to the accumulation of the sands and gravels, which we term Middle Glacial, enormously denuded and swept away, the part remaining being furrowed into valleys, some of them

¹ More shells from this locality have been since obtained, and are given in Prof. Jamieson's lists.

150 feet deep, which then had their inception, and down into which these sands and the subsequent great Chalky Boulder-clay of the Eastern and Midland Counties have gone.

As this denudation seems to us to have been due, not to an elevation of the Lower Glacial sea-bottom, but to an extension of the land-ice over it, by increment of cold; and the accumulation of the Middle Glacial sands in these troughs, and generally over the denuded area, to have been permitted by a melting back of this ice (due either to a material increase in subsidence, or else to an augmentation of temperature), the deposit of these sands seems to us to mark a great change in the conditions of North-western Europe, which is worthy of a distinctive appellation; and we cannot, we think, better make this than by preserving the appellation I have for several years past applied to it, of "Mid-glacial," while, at the same time, rejecting any classification based merely upon the intervention of sand or gravel between Boulder-clays.

Further, I may add, that though we do not venture to assert its absence, yet we cannot at present see anything indicating that the Lower Glacial formation of East Anglia is represented elsewhere in the British Islands; and although we repudiate the hypothesis of the formation of either the Scotch or the North of England Boulder-clay on a terrestrial surface, believing it to be all of submarine deposit (though produced by land-ice), yet, for the purpose of contrasting the Lower Boulder-clay of Mr. Hull's tabular classification with the East Anglian beds, let this be admitted; and then see how the two sides of England would agree. Mr. Hull describes his lower division, that of the Lower Boulder-clay of Scotland, of the North of England, and a large portion of Ireland, as of the period of greatest elevation; *portions of existing seas being then land*, and covered by ice; but it is apparent to even a casual observer that the pebbly sands (containing *Mya truncata*, with its valves united and in vertical position, as it lived), the stratified Till, and overlying contorted drift, which Mr. Harmer and I group together under the term Lower Glacial, and which are exposed in a section of twenty-two miles' length along the Cromer Coast, were there accumulated under the sea; since, where not contorted, even the contorted drift is finely stratified, and contains marine shells,¹ and where contorted presents clear evidence, from the included masses of marl almost invariably associated with the contortions, of having been a sea-bottom ploughed up by grounding bergs, which brought and left in the contorted mud masses of an entirely different material, viz., marl or ground-up chalk. Such evidences appear to Mr. Harmer and myself to negative the possibility of England at that time standing even at so high, far less a higher, level than the present. We obtain evidence, first in the fluvio-marine fauna of the pebbly sand forming the base of the Lower Glacial formation—a fauna showing a very slight departure from that of the Upper Crag beds, on whose denuded surfaces this

¹ From the centre of one of these contortions, Mr. Harmer and I took a perfect valve of *Tellina Baltica*.

pebbly sand reposes—and afterwards in the deeper water deposit of contorted drift which forms the top of the Lower Glacial formation, that on the East side of England the period of the Crag was followed, and the Glacial period was commenced, not by an elevation, but by a gradual subsidence; which first giving rise to a littoral and fluvio-marine deposit of rolled pebbles and sand, was rapidly succeeded by a submergence sufficient to float bergs over the area previously occupied by these pebbly sands. The extent to which that subsidence reached before the denuding land-ice to which I have adverted pushed over this seabottom, may be approximately inferred from the circumstance that one of these intruded marl masses (immediately North-west of Woman Hythe) is 800 feet and upwards in length, and 60 in height, and has been so tranquilly intruded into the contorted drift, that it has sunk through it down to the fundamental Chalk, squeezing out the stratified beds on either hand. It must be obvious that in order to float a berg adequate to such a marl-freight as this, many hundred feet of water is necessary. The accompanying section of three miles of the Cromer Cliff will show the position of these beds, of some of the included marl masses, and in particular of this enormous transported mass, of which there are, inland from this cliff, many examples to rival it, in which lime-kilns and marl-pits are worked over North-east Norfolk.

In order to call the attention of the Geologists of Lancashire to the divergence of the faunas, Mr. Harmer and I read a paper at the British Association in 1870, pointing out the facts as far as then

THREE MILES OF THE CLIFF WEST OF CROMER.

(Vertical Scale about $\frac{1}{4}$ times the Longitudinal.)

obtained. As some additions to this fauna have since been made, and in order to render the particulars of it better known, it may be useful to enumerate the satisfactorily identified specimens here; omitting several others to whose identification any uncertainty is, from their imperfect condition, attached.¹ *Cypræa Europæa*, *Buccinum undatum*, var. *tenerum*, *Trophon muricatus*, *T. antiquus* (dextral form), *T. scalariformis*, two new small species of *Trophon*, *Purpura lapillus*, ditto var. *incrassata*, *Nassa incrassata*, *N. granulata*, and a new Crag species of *Nassa* not yet named, *Mangelia turricula*, *M. linearis*, and a new Crag species of *Mangelia* not yet named, *Natica clausa*, *N. helicoides*, *N. Alderi*, *Scalaria Trevelyana*, *S. Grælandica*, *Turritella incrassata*, *T. terebra*, *Cerithium tricinatum*, *Cerithiopsis tubercularis*, *Chemnitzia internodula*, *Odostomia unidentata*, *Rissoa semicostata* (of Woodward, non Mont.), *Littorina littorea*, *L. rudis*, *Margarita undulata*, *Trochus cinerarius*, *Capulus Ungaricus*, *Tectura fulva*, *Calyptræa sinensis*, *Dentalium dentale*, *Anomia ephippium*, ditto var. *aculeata*, *A. striata*, *Pecten opercularis*, *P. pusio*, *P. varius*, *Mytilus edulis*, *Pectunculus glycymeris*, *Limopsis pygmæa*, *Nucula Cobboldiæ*, *N. tenuis*, *Leda oblongoides*, *L. lanceolata*, *Cardium edule*, *Cardita scalaris*, *C. corbis*, *Loripes lacteus*, *L. divaricatus*, *Lucina borealis*, *Woodia digitaria*, *Astarte borealis*, *A. sulcata*, *A. compressa*, *A. Burtinii*, *A. Omalii*, *Erycinella ovalis*, a new Crag species of *Lasea* not yet named, *Montacuta bidentata*, *Cytherea rudis*, *Cyprina Islandica*, *Venus fluctuosa*, *V. fasciata*, *V. ovata*, *Tellina obliqua*, *T. calcarea*, *T. Balthica*, *T. crassa*, *Scrobicularia piperata*, *Macra ovata*, *Panopea Norvegica*, *Mya arenaria*, *Saxicava arctica* (smooth small form), *Solenensis*, *Pholas crispata*, *Corbula nucleus*, *C. contracta* (Say.), and *Pandora inæqualis*. Of these the new *Trophons*, *Nassa*, *Mangelia*, and *Lasea*, *Cerithium tricinatum*, *Rissoa semicostata* (of Woodward), *Nucula Cobboldiæ* (which is very common), *Astarte Burtinii*, *A. Omalii*, *Erycinella ovalis*, and *Tellina obliqua*, are not known living; while *Nassa granulata* (if indeed it be living), *Turritella incrassata*, *Chemnitzia internodula*, *Dentalium dentale*, *Limopsis pygmæa*, *Cardita Corbis*, *Woodia digitaria*, and *Cytherea rudis*, are known living only in the Mediterranean, the Azores, the Canaries, or in abyssal recesses of the Atlantic; and *Cardita scalaris* (as *C. ventricosa* of Gould) lives only on the Pacific Coast. All of them, except the new *Trophons*, *Venus fluctuosa*, *Tellina Balthica*, and *Loripes lacteus*, are shells of either the Coralline, Red, or Chillesford Crags.

Now, contrasted with the above, the only species that I have been able (from papers of Mr. Binney, and from the collecting of Mr. Harmer and of Mr. Hughes) to ascertain have occurred in the Middle Sands of Lancashire are the following 25 species, viz., *Nassa reticulata*,^{*} *Buccinum undatum*, *Fusus Bamffius*,^{*} *Aporrhais pespelicani*, *Murex erinaceus*, *Turritella terebra*, *Purpura lapillus*, *Littorina littorea*, *Mangelia turricula*, *Dentalium dentale* (or else *D. tarentinum*), *Natica catena*? (*monilifera*), *Patella vulgaris*? *Venus*

¹ The specimens having all been re-examined in reference to the forthcoming Supplement of the Crag Mollusca, one or two names will be found to differ from those in the list published in the British Association Reports, 1870.

*striatula** (*gallina*), *Astarte borealis*, *Artemis (exoleta)?* *Mastra subtruncata*, *M. solida*, *Cardium edule*, *C. tuberculatum*? *C. aculeatum*? *Corbula nucleus (inequivalvis)*, *Tellina Balihica*, *Psammobia Ferroensis*, *Ostrea edulis* and *Mytilus edulis*. All of these shells inhabit common ordinary depths of British or contiguous Arctic seas, and those which have an asterisk placed against them have not occurred in the Crag.

I have not included the shells from the Moel Tryfaen or Macclesfield sands (see Mr. Darbyshire's Article in Vol. II. of this Mag., p. 293) in the above list, because it has not been satisfactorily shown that these sands are identical with the Middle Sands of the Lancashire Coast; but however that may prove, these shells, like the others, all inhabit ordinary depths of British or contiguous Arctic seas.

I have also carefully compiled from the best authorities I can find, including papers of Prof. Jamieson, with lists of shells identified by Mr. Jeffreys, and papers by Messrs. Crosskey and Robertson¹ and by Mr. Peach, a list of the mollusca from all the Glacial or so-called Glacial beds of Scotland, including the localities of Invernettie, Ellishill, Ednie, Annoehil, Auchleuceries, Belhelvie (all in Aberdeenshire), King Edward, and Gamrie (both in Banffshire), Montrose (in Forfarshire), Errol, Tyrie, and Elie (in Fifeshire), Fort William (in Inverness-shire), the Kyles of Bute, Dalmuir, Loch Gilp, Cumbræ, Paisley, and other localities on or near the Clyde, and the Boulder-clay of Caithness. This list comprises about 130 species of mollusca, and the whole of them are still living at *ordinary depths* in that part of the ocean which, lying North of the 50th parallel of North latitude, is bounded by the East coast of America on the one side, and the North-west coast of Europe on the other; while about one-fifth of them are not found in any part of the Crag. How much this fauna of 130 species contrasts with the East Anglian Mid-glacial one of 80, especially if the Scotch species (the names of which I have not set out) be considered with the Mid-glacial ones above named; and how much it negatives the probability of any of the Scotch beds which yield molluscan remains (inclusive of the Caithness Boulder-clay)² belonging to a period as remote as the East Anglian Mid-glacial, with its Crag-like fauna, those familiar with the mollusca of the Newer Tertiaries and (so-called) Post-tertiaries of Britain will, I think, appreciate.

I have made efforts in various quarters to get at the mollusca of the Wexford gravels, and so far as I can learn there is nothing from these gravels to point to any period so ancient as the East Anglian Mid-glacial, or even as the Bridlington bed, with the exception of a

¹ The lists of the late James Smith, of Jordan Hill, are not, except so far as they have been confirmed by Messrs. Crosskey and Robertson, altogether reliable.

² Those who (unlike myself) believe in Mr. Croll's ice-filled North Sea, and in its having brought the shells of the Caithness Boulder-clay from some anterior sea-bottom into that clay, will perceive that any such sea-bottom, as well as the Caithness clay, must, from these Caithness shells belonging to the category mentioned in the body of the paper, be, according to palæontological probabilities, newer than the East Anglian Middle Glacial.

fragment of *Nucula Cobboldia*, to which some doubt is attached, all the rest of the Wexford shells being living species of ordinary depths, and of not distant shores. If *Nucula Cobboldia*, however, be really present in them (not of course as a derivative, as it is in the Aberdeenshire gravel), it would suggest a greater antiquity for those sands than any Glacial bed of the North-west of England or of Scotland seems to possess.

If any of the readers of this MAGAZINE have the opportunity of collecting from the Wexford beds, I should esteem it a favour if they would send anything they can find by post (duly secured against injury) to me at the subjoined address, when they would be carefully examined by my father and myself, and promptly returned to the sender.

In conclusion, I should add that the possibility of the shells from the East Anglian Mid-glacial being derivative has been duly weighed; and for several reasons, intrinsic and extrinsic, which I have not space to set out, that possibility has been rejected as inadmissible.

BRENTWOOD, ESSEX.

VI.—ON THE GLACIATION OF THE NORTH-WEST OF ENGLAND.

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IN bringing the last of a long series of papers on the Surface Drifts of the Lake District of Cumberland and Westmoreland to a close, Mr. Mackintosh sums up the general results at which he has arrived. All will agree with the first of his conclusions, "that land-ice *may* have planed, smoothed, polished, and striated rock surfaces, and pushed loose *débris* forward. . . ." But I cannot see his reason for adding, "to the nearest *protected* situations," for one would expect to find a terminal moraine at the *open* entrance of a valley, on a plain, or even on what can be proved to have been a true sea-bottom.

Thus, Mr. Lamont, F.G.S., described in 1861 a glacier in Deeva Bay that was separated from its terminal moraine by two miles of water, mostly covered with "fast ice;" the moraine being three and a half miles long, 200 to 400 yards broad, and twenty to thirty feet in height. As Mr. Lamont observed in this bay bones of the whale, of apparently no great age, at an elevation of forty feet above the sea, the whole of this moraine would appear to have been formed under the sea, being pushed along the sea-bottom by the backward weight of the glacier, which formerly extended further than at present, and filled up what is now the space between the "island moraine" and the land. And, in another instance, he observed a glacier extending *into the sea*, and actually in the process of pushing before it "a huge moraine of mud and *débris*, the base of which is washed by the sea, . . ." which becomes muddy "for several miles around."

All scratched and polished surfaces of rock *in situ*, now covered by deposits, which, from stratification, the presence of marine shells or of rounded boulders, can be proved to be *marine*, I consider to