

to find pebbles of rocks of various ages. He commented on the difficulty palæontologists seemed to labour under in determining a fossil if it came out of a pebble instead of from a rock the position of which was definitely known. He adverted to the statement that the beds containing the pebbles had been deposited in the New-Red-Sandstone sea, whereas Mr. Godwin-Austen had regarded the New Red deposits as formed in large inland lakes; and the local character of the beds supported this latter view.

Dr. DUNCAN defended the caution of palæontologists, and remarked on the uncertainty attending the determination of casts.

Mr. PRESTWICH was glad that some other source had been suggested for the quartzite pebbles. He had found somewhat similar quartzites between Lisieux and Cherbourg, in France.

The PRESIDENT observed that he would like to see the rise of a new race of palæontologists relying simply on zoological characteristics, and not on geological position. A considerable simplification of our classification would probably result.

Mr. ETHERIDGE briefly replied.

2. *On the RELATION of the BOULDER-CLAY, without CHALK, of the NORTH of ENGLAND to the GREAT CHALKY BOULDER-CLAY of the SOUTH.* By SEARLES V. WOOD, JUN., Esq., F.G.S.

PLATE VII.

IN a paper read before this Society by myself and the Rev. J. L. Rome, F.G.S., and published in the Journal, we described the Glacial clay of the Yorkshire coast as consisting of two main parts*. Of these, the lower, distinguished both in our sections and in the vertical section accompanying the present paper (see Pl. VII.) by the letter *a*, presents characters identical in all respects with the ordinary Boulder-clay, with chalk as its prevailing constituent, which forms the uppermost member of the Glacial series of the east and east centre of England; while the upper (*c*) is a purple clay, in which chalk is only a subordinate constituent, even in the lower part, and which, gradually losing its chalk upwards, is in the upper part entirely destitute of it. We also endeavoured to show that, north of Flamborough Head, the whole of the clay, (which is destitute of chalk), belonged to this upper part only—and that, though lying at the foot of the northern escarpment of the chalk, as well as enveloping both the escarpment and the Wold, this clay, thus destitute of chalk, was not deposited until, by the complete submergence of the Wold, all source of chalk débris had been removed. We also suggested that the absence of any clay with chalk débris in these parts was due to their having been occupied by ice during the time that the clay containing that material was accumulated, and to this ice not having been removed until the Wold had been completely covered by the sea; and we identified this chalk-

* Vol. xxiv. p. 146. The Hesse clay there described is a separate deposit from the *Glacial* clay referred to in the paper, and is regarded by us as of *Post-glacial* age.

less clay of the north of Flamborough with a similar clay, also wholly destitute of chalk, of which outliers cap the purple clay with some chalk in Holderness, where, as at Dimlington and near Mapleton, the cliff-section shows the Glacial series to have undergone less denudation than elsewhere along that coast. We further pointed out that the long-known fossiliferous bed of Bridlington belonged to the Yorkshire Glacial formation; and we placed its horizon immediately superior to the chalky clay (*a*)—that is to say, in the lower part of the purple clay, wherein there is chalk, and at the horizon indicated in the accompanying vertical section (Pl. VII. fig. 1).

Now, while in Yorkshire we find the Glacial clay exhibiting the distinct feature of a gradual decrease and final disappearance of the chalk débris, succeeded by a deposit of considerable thickness, in which there is not a trace of chalk, the whole of the beds of the east and east centre of England indicate not only that débris from the chalk prevails throughout the series, but that it is to the full as copious in the uppermost layer that denudation has spared of the highest member of the series there as it is in the lowest.

It is therefore only with the highest member of that series, the common wide-spread Boulder-clay of East Anglia, that I propose to discuss the relationship borne by the Yorkshire Boulder-clay. As regards the very considerable and, I think, important series of deposits which are older than this wide-spread Boulder-clay, but are absent in Yorkshire and the north, I shall only have occasion to refer to them to the extent of pointing out the great distinction existing between their fauna and that of the bed at Bridlington, and of indicating their place in the vertical section accompanying this paper, as the structure and distribution of these older series will, I hope, form the subject of a future communication by myself and Mr. F. W. Harmer, F.G.S., who has cooperated with me in working them out.

The particulars of the considerable fauna obtained from Bridlington, and of the fauna collected from the Middle and Lower Glacial deposits of East Anglia, have received much attention from my father, and they will be tabulated by him with the fauna from the several horizons of the Crag and from the Postglacial beds of the eastern side of England, in his supplement to the Monograph of the Crag Mollusca. In the meantime, however, for the purposes of this paper, and to show, on the one hand, how entirely distinct these deposits are in their palæontological aspects from that of Bridlington, and, on the other, how closely they are connected in those aspects with the Crag, the following list, embodying our results up to the present time, as far as they concern the beds under consideration here, has been revised by him* :—

* The fauna of the Lower Glacial has been obtained with the assistance of Mr. Harmer, and that of the Middle Glacial with the same assistance and with that of Mr. E. T. Dowson, of Geldeston; while Mr. Leckenby has rendered my father most valuable assistance in verifying the Bridlington shells.

Name of the Shell.	Lower Glacial.	Middle Glacial.	Bridlington (or Upper Glacial).	Crag.	Living or extinct : see note at foot of list.	Remarks.
<i>Buccinum undatum</i> , Linn.	*	*	*	*	B, A, S.	
<i>Tritonium antiquum</i> , var. <i>carinatum</i>			*	*	A.	On authority of Woodward's list.
—, var. <i>carinatum con-</i> <i>trarium</i>			*	*	O.	
—, var. <i>striatum</i>	*	*	...	*	B, A, S.	
—, var. <i>striatum con-</i> <i>trarium</i>	*	*	B, A, S.	Nearly extinct.
— <i>propinquum</i> , Alder			*	*	B.	
— <i>consociale</i> , S. Wood		*	...	*	O.	
— <i>gracile</i> , Dacosta			*	*	B, A.	Behring's Straits also.
— <i>ventricosum</i> , Gray			*	...	A.	
— <i>Sabini</i> , Hancock			*	...	A.	Not the <i>T. Sabini</i> of Gray.
<i>Trophon clathratus</i> , Strom.			*	*	A.	Probably the <i>Fusus scalariformis</i> of Woodward's list.
— <i>Gunneri</i> , Lovén			*	?	B.	Given in Woodward's list as from Norwich crag; <i>sed quere</i> , Norway coast?
— <i>muricatus</i> , Mont.	*	...	*	*	B, S.	
— <i>truncatus</i> , Strom.			*	?	B.	<i>Fusus clathratus</i> of Woodward's list? <i>M. Bamfus</i> of the Clyde beds.
— <i>craticulatus</i> , O. Fab.		*	A.	<i>T. Fabricii</i> of Woodward's list?
<i>Trophon</i> ?, new species		*	O.	Three specimens of a shell half an inch in length. It comes nearest to a minute representation of <i>Trophon costiferum</i> .
<i>Purpura lapillus</i> , Linn.	*	*	*	*	B, A, S.	
— var. <i>incrassata</i>		*	...	*	O.	
<i>Columbella Holböllii</i> , Möll.			*	...	B, A.	Not found south of Shetland.
<i>Nassa incrassata</i> , Müll.			*	*	B, S.	
— <i>granulata</i> , J. Sow.		*	...	*	O.	Not uncommon in Middle Glacial.
— <i>reticosa</i> , J. Sow., var. <i>costata</i> ..		*	...	*	O.	
— <i>pusilla</i> ? Phil.		*	...	*	O.	A (somewhat rare) shell of the Red and Fluvio-Marine Crag, but common in the Middle Glacial, seems, from Philippi's figure, to be this species. It will be figured in the supplement to the 'Crag Mollusca.'
—, new species?	*	O.	Several specimens from the Middle Glacial.
<i>Mangelia turricula</i> , Mont.	*	*	*	*	B, A.	
— <i>Trevelliana</i> , Turt.			*	*	B, A.	
— <i>cylindracea</i> ? Möll.			?	...	A.	Given on authority of Woodward's list. The shell cannot be found.
— <i>cinerea</i> , Möll.			?	...	A.	On authority of Woodward's list.
— <i>exarata</i> , Möll.			*	*	A.	
— <i>elegans</i> , Möll.			*	...	A.	
— <i>nobilis</i> , Möll.			*	...	A.	
— <i>pyramidalis</i> , Strom.			*	*	A.	<i>M. Vahlui</i> , sec. Jeffreys.

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Name of the Shell.	Lower Glacial.	Middle Glacial.	Bridlington (or Upper Glacial).	Crag.	Living or extinct: see note at foot of list.	Remarks.
<i>Mangelia linearis</i> ?, <i>Mont.</i>	*	...	*	*	B, S.	The Middle-Glacial shell departs from the Crag <i>linearis</i> in being less slender, and in having more numerous costæ.
<i>Cancellaria viridula</i> , <i>O. Fab.</i>	*	*	A.	<i>Admete viridula</i> of Woodward's list. <i>C. costellifera</i> , J. Sow., of 'Crag Mollusca.'
<i>Trichotropis borealis</i> , <i>Brod. & Sow.</i>	*	?	B, A.	This species occurs in the Coralline Crag only; but the Coralline-Crag form is a very distinct variety from the Bridlington shell.
<i>Natica clausa</i> , <i>Brod. & Sow.</i> ...	*	*	*	*	A.	
— <i>Montagui</i> , <i>Forbes.</i>	*	...	B, S.	Iceland and Norway also. Naples, sec. Jeffreys.
— <i>grœnlandica</i> , <i>Beck</i>	*	?	B, A.	
— <i>occlusa</i> , <i>S. Wood</i>	*	*	A?	Recently identified by Mr. Jeffreys with a Spitzbergen shell.
— <i>helicoides</i> , <i>Johnston.</i>	*	...	*	*	B, A.	
— <i>catena</i> , <i>Dacosta</i>	*	*	*	*	B, S.	
<i>Scalaria grœnlandica</i> , <i>Chemn.</i> ...	*	*	*	*	A.	
— <i>Trevelyana</i> ? <i>Leach</i>	*	B, S.	The Middle-Glacial specimen is too broken for certain identification.
<i>Turritella polaris</i> , <i>Beck</i>	*	...	A.	<i>T. erosa</i> of 'Crag Mollusca' and of Woodward's list. <i>T. clathratula</i> of 'Crag Mollusca.'
— <i>incrassata</i> , <i>J. Sow.</i>	*	...	*	*	O.	Very abundant in Middle Glacial.
— <i>terebra</i> , <i>Linn.</i>	*	*	*	*	B, S.	<i>T. communis</i> of 'Crag Mollusca' and of Woodward's Bridlington list; one fragment only from Middle Glacial. Mr. Leckenby knows no other form of <i>Turritella</i> from Bridlington than <i>T. erosa</i> . Given therefore on the authority of Woodward's list. Very rare in Crag.
<i>Chemnitzia internodula</i> , <i>S. Wood</i> ...	*	*	O?	Several broken specimens from the Middle Glacial. Said by Mr. Jeffreys to have recently been dredged living.
<i>Odostomia unidentata</i> , <i>Mont.</i>	*	*	B.	Unique in Crag. One specimen, with mouth perfect, from Middle Glacial.
<i>Rissoa obsoleta</i> , <i>S. Wood.</i>	*	*	O.	Coralline Crag only.
— <i>semicostata</i> ? <i>Woodward</i>	*	?	O.	Two specimens from the Middle Glacial, but too imperfect to show whether they be the extinct <i>R. semicostata</i> , with the denticulated lip, of the Crag, or the living <i>R. inconspicua</i> , a B, S form.
<i>Littorina littorea</i> , <i>Linn.</i>	*	*	*	*	B, A, S.	
— <i>rudis</i> , <i>Maton & R.</i>	*	*	...	*	B, A, S.	

Name of the Shell.	Lower Glacial.	Middle Glacial, Bridlington (or Upper Glacial).	Crag.	Living or extinct: see note at foot of list.	Remarks.
<i>Margarita elegantissima</i> , Bean	*	...	A.	<i>M. plicata</i> , Sars.
<i>Cemoria Noachina</i> , Linn.....	...	*	...	B, A.	<i>Puncturella Noachina</i> of Forb. & Hanl., and of Jeffreys.
<i>Calyptraea chinensis</i> , Linn.	*	...	B, S.	One young specimen from the Middle Glacial.
<i>Dentalium abyssorum</i> , Sars	*	...	A.	
— — —, var. <i>tarentinum</i>	*	...	B.	
— <i>dentalis</i> ? Linn.	*	...	S.	<i>D. costatum</i> , J. Sow. Two specimens from the Middle Glacial. The costæ are as broad as, but less prominent than, in the Crag shell; but this may be due to wear. It is possible that the specimens may be only the upper portions of <i>D. abyssorum</i> .
<i>Rhynchonella psittacea</i> , Chemn.....	...	*	*	A.	<i>A. squamula</i> of Woodward's list. Common in Middle Glacial.
<i>Anomia ephippium</i> , Linn.	*	*	B, S.	Sitka and Norway.
— <i>striata</i> , Brocc.	*	...	B?	Lower beds of Red Crag only. Middle Glacial of Stevenage, Herts, only.
<i>Ostrea edulis</i> , Linn.	*	...	B, S.	Very common in Middle Glacial, but fragmentary.
<i>Pecten opercularis</i> , Linn.....	...	*	...	B, S.	
— <i>islandicus</i> , Müll.	*	...	A.	
— <i>pusio</i> , Pennant.....	...	?	*	B, S.	A specimen in Brit. Mus. said to be from Bridlington.
<i>Mytilus edulis</i> , Linn.	*	*	*	B, A, S.	Worldwide.
<i>Modiola modiolus</i> , Linn.	*	*	B, A.	<i>M. vulgaris</i> of Woodward's list.
<i>Pinna pectinata</i> , Linn.....	*	*	*	B, S.	Fragments in Cromer Till.
<i>Pectunculus glycymeris</i> , Linn.....	*	...	*	B, S.	Very common, but small, in Middle Glacial; dies out in the upper beds of the Crag.
<i>Arca lactea</i> , Linn.....	?	...	*	B, S.	The hinge of the Middle-Glacial (perfect but small) specimen is too worn for certain identification.
<i>Nucula Cobboldiæ</i> , J. Sow.	*	*	*	O, P.	The Lower- and Middle-Glacial and Bridlington specimens show a tendency to depart from the Crag form in having the peculiar ornamentation more confined to the upper and central part of the shell. Represented by <i>N. Lyalli</i> on the N.W. coast of America.
— <i>tenuis</i> , Mont.	*	*	B, A, S.	
<i>Leda limatula</i> , Say	*	*	*	A.	<i>Yoldia oblongoides</i> of Woodward's British also? [list.
— <i>pernula</i> , Müll.	*	...	A.	
— <i>myalis</i> , Couthouy.....	*	...	*	N. A.	Three specimens in Brit. Mus., two from Postwick, a Crag locality, and one from Runton, which (except the forest freshwater bed) is Lower Glacial only.

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Name of the Shell.	Lower Glacial.	Middle Glacial.	Bridlington (or Upper Glacial).	Crag.	Living or extinct: see note at foot of list.	Remarks.
<i>Leda caudata</i> , <i>Donov.</i>	*	*	*	B, A.	<i>L. minuta</i> of 'Crag Mollusca.'
<i>Cardium edule</i> , <i>Linn.</i>	*	*	*	*	B, A, S.	
— <i>islandicum</i> , <i>Linn.</i>	?	A.	Given in Woodward's list; but the fragments in the British Museum are not sufficient for reliable identification.
— <i>norvegicum</i> , <i>Spengl.</i>	*	B.	*Breydon (Bradwell cutting), sec. Jeff. vol. ii. p. 296 of Brit. Moll.
— <i>grœnlandicum</i> , <i>Chemn.</i> ...	*	*	...	*	A.	
<i>Cardita analis</i> , <i>Phil.</i>	*	O.	The Bridlington shell called <i>C. scalaris</i> by Forbes, in Mem. Geol. Survey for 1846, was most probably only <i>C. analis</i> .
— <i>scalaris</i> , <i>Leathes</i>	*	...	*	O, P.	Probably represented by <i>C. ventricosa</i> , Gould, on N.W. coast of America.
<i>Lucina borealis</i> , <i>Linn.</i>	*	*	...	*	B, A, S.	
<i>Astarte borealis</i> , <i>Chemn.</i>	*	*	*	*	A.	
— —, var. <i>Withami</i>	*	O.	
— —, var. <i>semisulcata</i>	?	A.	On authority of Woodward's list only. Believed by S. Wood to be only <i>A. sulcata</i> , var. <i>elliptica</i> .
— <i>mutabilis</i> , <i>S. Wood</i>	*	*	*	O.	
— <i>sulcata</i> , <i>Dacosta</i>	*	*	*	B, A, S.	Rare in Crag. Common in Middle Glacial. Mediterranean, sec. Jeffreys.
— —, var. <i>elliptica</i>	*	*	?	B, A.	*Bradwell. Given from Crag only on authority of Woodward's Norwich Crag list.
— <i>crebricostata</i> , <i>Forbes</i>	*	A.	"North of Hebrides, in cold area, 550 fathoms," sec. Jeffreys.
— <i>compressa</i> , <i>Mont.</i>	*	*	*	*	B, A.	
<i>Woodia digitaria</i> , <i>Linn.</i>	*	...	*	S.	Two imperfect specimens from Middle Glacial.
<i>Tapes virgineus</i> , <i>Linn.</i>	*	...	*	B, S.	Hinge-fragments of one or other or both of these species common in Middle Glacial; but which of them, cannot be said. Both in Crag and B, S.
— <i>pullastra</i> , <i>W. Wood.</i>	*	...	*	B, S.	
<i>Cyprina islandica</i> , <i>Linn.</i>	*	*	*	*	B, A, S.	
— <i>rustica</i> , <i>J. Sow.</i>	?	O.	*Bradwell.
<i>Venus fluctuosa</i> , <i>Gould</i>	*	...	*	N. A.	
— <i>fasciata</i> , <i>Donovan</i>	*	...	*	B, S.	Abundant in Middle Glacial. Japan, sec. Jeffreys.
— <i>ovata</i> , <i>Penn.</i>	*	...	*	B, S.	Profuse in Coralline Crag; rare in Red: three imperfect specimens from Middle Glacial.
<i>Tellina lata</i> , <i>Gmel.</i>	*	?	*	*	A.	<i>T. calcarea</i> of Wahl. A few doubtful fragments only from Middle Glacial. Rare in Red Crag, profuse in Fluvio-marine Crag and Chillesford beds.
— <i>obliqua</i> , <i>J. Sow.</i>	*	*	*	*	O.	Profuse in all Crag beds and in Lower Glacial; not common in Middle Glacial. Only one specimen known from Bridlington.

Name of the Shell.	Lower Glacial.	Middle Glacial.	Bridlington (or Upper Glacial).	Crag.	Living or extinct: see note at foot of list.	Remarks.
<i>Tellina prætenuis</i> , <i>Leathes</i>	*	*	O.	Profuse in Red and Fluvio-marine crag and Chillesford beds. Rare in Lower Glacial.
— <i>balthica</i> , <i>Linn.</i>	*	*	*	...	B, A, S.	Profuse in Lower and Middle Glacial, and in all Glacial and Postglacial beds.
— <i>crassa</i> , <i>Gmelin</i>	*	...	*	B, S.	Common in Crag, and fragments. Common in Middle Glacial.
<i>Donax vittatus</i> , <i>Dacosta</i>	*	*	B, S.	
<i>Scrobicularia plana</i> , <i>Dacosta</i> ...	*	*	...	*	B, S.	<i>S. piperata</i> , <i>Gmel.</i> Hinge-fragments common in Middle Glacial.
<i>Mactra ovalis</i> , <i>Sow.</i>	*	*	*	*	B, A, S.	<i>M. elliptica</i> of British authors.
— <i>subtruncata</i> , <i>Dacosta</i>	*	...	*	B, S.	*Bradwell.
— <i>solida</i> , <i>Linn.</i>	?	...	*	*	B, S.	Doubtful fragments only, in Middle Glacial.
<i>Thracia papyracea</i> , <i>Poli</i>	*	*	B, S.	One perfect specimen from Lower Glacial.
<i>Mya truncata</i> , <i>Linn.</i>	*	?	*	*	B, A, S.	
— <i>arenaria</i> , <i>Linn.</i>	*	*	*	*	B, A, S.	
<i>Panopæa norvegica</i> , <i>Spengl.</i>	*	*	B, A.	
<i>Saxicava rugosa</i> , <i>Linn.</i>	*	*	...	*	B, A, S.	
— <i>arctica</i> , <i>Linn.</i>	*	...	A.	The gigantic form of Uddevalla and the Clyde beds.
<i>Pholas crispata</i> , <i>Linn.</i>	*	*	*	*	B, A.	
<i>Corbula striata</i> , <i>Walk. & B.</i>	*	*	...	*	B.	<i>C. gibba</i> , <i>Oliv.</i> Profuse in Coralline and Fluvio-marine Crag, Chillesford bed and Lower Glacial. Common in Middle Glacial. Rare in Red Crag.

Note.—O, P signifies that the form is extinct unless represented by a Pacific shell; O, not known living; N. A, occurs no nearer than North-east America; A, only within the Arctic Circle; S, only to the south of the British Seas; B, A, S, in British, Arctic, and Southern Seas; B, A, in British and Arctic Seas only; B, in British Seas only, the Norway coast being included under this letter. The shells marked * Bradwell are inserted in the Middle-Glacial column on the authority of a list of identifications made by Mr. Gwyn Jeffreys of some shells and fragments obtained by Mr. G. B. Rose from the Middle-Glacial cutting of Bradwell (by Breydon), supplied by Mr. Rose.

N.B. In the foregoing list the Crag column embraces all the divisions of that formation from the Coralline Crag up to, and inclusive of, the Chillesford beds.

SUMMARY.

	O.	O, P.	B, S.	B, A.	B, A, S.	B.	S.	A.	N. A.	Total.
Lower-Glacial Shells	2	1	5	3	15	2	—	6	1	35
Middle ditto	13	2	19	4	15	3	2	5	—	63
Upper ditto (Bridlington) ..	5	1	4	15	11	5	—	28	1	70

N.B. In the case of the Middle-Glacial shells, the number in column O is swelled by the two new shells and by two marked with ? being included in it.

A considerable number of these shells have been found living at depths ranging down to 100 and even 150 fathoms; our knowledge of the range of the others is, for the most part, merely negative.

From the foregoing list it appears that the Bridlington fauna consists of 70 forms of mollusca. Of these, after discarding all with regard to which there is any doubt, either as to their occurrence at Bridlington or as to their representation in the Crag, but including the distinct variety of *Trichotropis borealis*, no less than 19 are unknown to the Crag.

These 19 comprise 13 purely Arctic, 1 British and Arctic, 1 British, 1 British, Arctic, and Southern, and 1 North-American, and 2 not known as living.

The mollusca hitherto obtained from the Middle Glacial, *i. e.* from the sands and gravels which, overlying the Cromer contorted drift in the north of Norfolk, pass under the great chalky Boulder-clay of which I have been speaking in other parts of that county and in North Suffolk, in Essex, Herts, Buckingham-, and Leicestershires, and some other localities, comprise 63 forms, all but one of them collected within a radius of a few miles around Yarmouth, from the sands (where they are *in situ*) between the contorted drift and the great chalky Boulder-clay. Of these 63 forms, the foregoing list shows that, besides the 2 apparently new forms and perhaps the shell referred to *Mangelia linearis*, there is only one, *Tellina balthica*, which does not occur in the Crag, and also that, with the exception of this shell, not one of the 19 peculiar shells of Bridlington are among them.

The fauna of the Lower Glacial has been obtained from the thick body of pebbly sands which forms the base of, and is extensively interstratified with, the Cromer Till, and of which, in fact, the Cromer Till is itself only a local modification. The few worn and fragmentary examples which this till, and the contorted drift that overlies it, have yielded to a search so diligent that it has been carried on for years, all over Norfolk and North Suffolk, are all readily recognizable as belonging to the commoner species occurring in the pebbly sands. This fauna comprises, as the list shows, 35 forms; and though I fully expect that further search will augment the number of forms from the Middle Glacial sands, I fear, from the time which my father and myself, as well as others, have devoted to the search, that the Lower Glacial beds will not yield any considerable addition to the number of species which we have obtained. Of these 35 forms also, there is only one, the same *Tellina balthica*, which does not occur in the Crag; and, with the single exception of this shell, there is also the like absence of all the 19 forms peculiar to Bridlington that obtains in the case of the Middle Glacial.

Further, of the 63 Middle, and 35 Lower Glacial forms, 26 are common to each of these two formations, so that there remain 72 distinct forms yet obtained from the two together to set against the 70 of Bridlington. Now it is most remarkable, as the converse

of the fact of all but one of the 19 peculiar and mostly exclusively Arctic forms of Bridlington being absent from the Lower and Middle Glacial, that of these 72 forms no less than 46 do not occur at Bridlington; and even yet more striking is it that, of this 46, only 1 is exclusively Arctic.

I may add that the difference in latitude between Bridlington and these Lower and Middle Glacial shell-localities does not exceed one degree*, and that the actual distance between them and Bridlington is from 100 to 120 miles.

I defer any remarks upon the striking, Crag-like, and seemingly southern *faunes* of the Middle-Glacial fauna, because I expect to add materially to the number of that fauna, and because it will be more advantageously considered when describing the structure of the Lower and Middle Glacial formations.

We see however, that, as the evidence at present stands, the fauna yet obtained from the Lower and Middle Glacial deposits (especially that from the latter) presents almost as much dissimilarity to the Bridlington fauna as the mollusca of the German Ocean do to those of the Greenland and Spitzbergen seas; so that no grounds exist for identifying, upon palæontological evidence, those Glacial beds of the Eastern Counties which are inferior to the great chalky clay, and whose structure and physical relationship to the Crag we have the advantage of studying in immediate contiguity to the Crag itself, with any of the Glacial series of Yorkshire, but, on the contrary, that the palæontological evidence points to their complete distinction. The uppermost of the East-Anglian series, the great chalky clay, with which Mr. Rome and myself identified the basement-clay of Holderness (*a*), has never yielded any other than derivative fossils; but this basement clay at Dimlington cliff, teeming with chalk (*a*), has, near to its junction with the base of the purple clay (*c*), lately yielded Sir Charles Lyell a few forms of mollusca which, he informs me, he regards, as far as they go, as resembling those of the Bridlington bed. The position of the base of Dimlington cliff, whence Sir Charles obtained these, is indicated, according to my view of the case, in the vertical section, the basement-clay from which these shells came appearing, from adjacent borings, to descend upwards of 100 feet below the base of the cliff.

I now propose to examine, on physical grounds, what part of the Yorkshire clay may, and what may not, be regarded as identical with the uppermost or great chalky member of the East-Anglian series.

The absence of chalk débris in the clay lying to the north of the Wolds seems to have been regarded by geologists as evidence of a drift from north to south, though the hypothesis never appears to have been brought to the test of critical examination until Mr. Rome and I, in our quoted paper, cursorily endeavoured to refute it. Nor do geologists ever appear to have noticed the fact, so con-

* In the case, however, of one shell, *Ostrea edulis*, obtained only at Stevenage, the difference in the latitude is nearly two degrees.

flicting with this hypothesis, that purple clay entirely destitute of chalk, but identical in most other respects with the purple clay containing chalk, extends for many miles over the extreme north-east of the Wold, ranging there from the sea-level up to altitudes of 450 feet—and that at intervals along the Holderness coast-section as far as Dimlington, and 42 miles south of the northern limit of the Wold, outliers of this purple clay without any chalk cap the purple clay with chalk that diminishes in quantity upwards.

If we merely examine the position of the clay where it lies at the Wold-foot near Speeton, more than 500 feet below the contiguous Wold-summit, without even enlisting into the argument the fact that the same clay extends over the Wold itself*, we shall, I think, perceive the impossibility of a sea-drift in any direction whatever preventing the introduction of chalk débris into it.

In the accompanying sketch map (see Plate) I have delineated, by a strong line, the exact trend of the Wold-scarp, and indicated by shading the respective positions where the clay without and that with chalk occur; and, to render the position of the clay without chalk relatively to the Wold more clear, I have added a small section (No. 2, see Plate) that will answer for the direction A to B, or A to C, indifferently.

If the Wold was uncovered by the sea (which it must have been to have supplied chalk débris), it is apparent that it must have formed a shore to any sea extending where this chalkless clay occurs, and must have arrested any drift, causing this to go off in the direction of the arrows—that is, either south-east in the direction of Flamborough, or south-west in the direction of York. Nevertheless in both these directions the clay is destitute of chalk. In the former it is so, both at high and low levels, for nearly 15 miles south-east of the northern apex of the Wolds near A, and in the latter for a much greater distance, viz. beyond York, even to the southern part of central Yorkshire†. The northern apex of the Wold rises to elevations of between 400 and 575 feet, the very highest summits (which are towards the north-west angle of the Wold), ranging between 600 and 800 feet. If we reflect what a copious source of débris this scarp-shore of chalk, indented with several valleys opening through it into the great vale beneath, must have been, and how such débris must have been swept into a sea occupying this great vale, it seems to me to be repugnant to the operation of natural causes to suppose that clay wholly destitute of chalk could be deposited in this great valley, while clay teeming with chalk was being deposited in Holderness. So obvious does this appear to me, that it is unnecessary to add to the case by appealing to the fact that the same clay without chalk envelopes both the high and low parts of the chalk Wold down nearly to Flamborough.

When we come to consider the volume and origin of the chalk

* The upper representation of the triple section (Pl. VII.) shows this.

† The clay in the vale of York is, in some parts, overlain by *Postglacial* sands, containing flint derived from the Wold. *Postglacial* gravel, with flint, also occurs in the vale of Pickering, which skirts the northern Wold-scarp.

débris that makes up so large a part of the chalky Boulder-clay, it will, I think, be apparent that had there been either a sea or a dry valley unoccupied by ice to receive it, the chalk débris, so far from being entirely absent in the clay would have been extremely abundant. None but those who have spent years in the examination of it over the greater part of the east of England can form an idea of the enormous volume of the chalk contained in the great Boulder-clay of the south-east. The proportion of this material may be estimated at from 10 to 90 per cent in different localities, the proportion being usually greatest in the counties of Norfolk, Suffolk, Essex, Hertford, and Lincoln—in the latter county, for a great distance along the western flank of the Wold, the clay being so nearly chalk itself as to be quarried for lime; and the quantity is still considerable in other counties, such as Huntingdon, Cambridge, Rutland, Leicester, Northampton, Warwick, Bedford, and Buckingham. Most of this chalk débris consists of lumps of rocky chalk of various sizes, unlike the soft material of which the upper Cretaceous formation of the south is principally composed, and so hard as to require a hammer to break it*. In these characters it is identical with the chalk of the Yorkshire Wold, which is all of this hard kind; and in it I have found, in sections where this chalky clay overlies the middle Glacial sands, rolled lumps of the red chalk which forms the base of the northern chalk, but is absent from the southern. The highest position at which the red chalk crops out in England is more than 300 feet below the higher elevations to which the chalky clay attains, and which were therefore under the sea when the red-chalk lumps, coming from a much lower level, were imbedded in its deposit.

If we consider the soluble nature of chalk, it must, as it seems to me, be evident that none of this débris can have been detached from the parent mass either by water-action or by any other atmospheric agency than moving ice.

The action of the sea, of rivers, or of the atmosphere upon chalk would take the form of dissolution, the degraded chalk being taken up in minute quantities by the water, and held in suspension by it, and in that form carried away; so that it seems obvious that this great volume of rolled chalk can have been produced in no other way than by the agency of moving ice; and for that agency to have operated to an extent adequate to produce the quantity contained in the great chalky clay before its denudation (a quantity that I estimate as exceeding a layer 200 feet thick over the entire Wold) nothing less than the complete envelopment of a large part of the Wold by ice for a long period would suffice. Nor, as it seems to me, can we explain the detachment of lumps of the red chalk from the outcrop of the parent stratum, far below the level reached by the sea that de-

* Quite different is the chalk in the Lower Glacial of Norfolk. The marl into which the contorted drift passes, and of which great masses are also imbedded in the coast, or silty development of that deposit, is a soft greasy accumulation, formed out of the soft chalk of the cretaceous districts south of the Wold.

posited the clay which contains them, in any other way than by the occupation by an ice-sheet of the great vale that extends along the scarp of the Wold where the red chalk crops out.

Another important feature bearing upon the relationship of the chalky to the chalkless clay, is the absence in the one and the presence in the other of boulders of the well-known peculiar granite of Shap Fell in Westmoreland. During the several years that I have occupied myself in examining and mapping the Glacial beds over the east of England, I have never seen such a thing as a fragment of this granite either in the various sections examined or among the numerous boulders which, exposed by atmospheric agencies, have been collected from the fields and placed by the roadside or by farmhouses &c. Neither Mr. Rome nor myself ever observed one along the Holderness coast, where the chalky clay and the purple clay with some chalk occupy the cliff; but immediately that we passed these limits and entered, about Flamborough Head, upon the region of the purple clay *without* chalk, we found them in plenty; and Mr. Rome informs me that he has seen them along the whole coast north of Flamborough, where this purple clay without chalk alone occurs, as far as the mouth of the Tees; and it is to him that I am indebted for pointing out to me (which he did more than two years since) the restriction of these boulders to the clay without chalk.

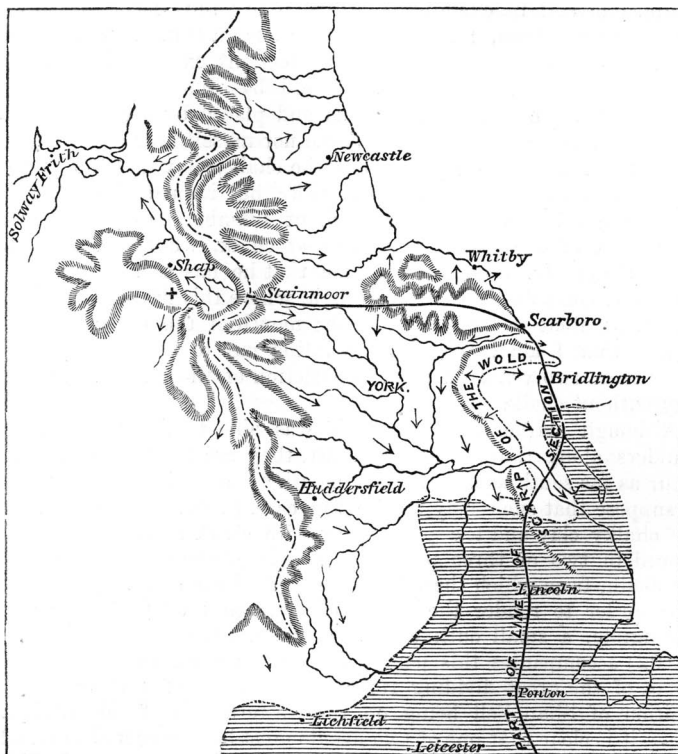
Although neither he nor myself was able to find any of these boulders along the Holderness coast, they are nevertheless said to occur as far south as the Humber mouth*; and there is no reason to suppose that such may not be the case, though rarely—because the chalky clay and the purple clay with chalk are, on this coast, capped in two or three places by outliers of the purple clay without chalk, from which these boulders might be derived.

In order to render the explanation which I offer of these facts intelligible, a small outline map of the north of England (fig. 1, p. 102) accompanies this paper, and in it are carefully shaded the slopes of the great dividing ridge of the north of England. The position of Shap Fell being on the western side of this dividing ridge, it is clear that one of two events must have occurred to enable its boulders to pass over the higher ground which separates the Shap country from the eastern side, over which the purple clay containing these boulders is distributed. The one event would be their transit by land-ice moving, not as it usually does from higher to lower ground, but upwards against the acclivity, and over the dividing ridge into the eastern area; the other would be the submergence of the country to an extent sufficient to permit the floating over of masses of ice freighted with these boulders.

With respect to the first of these alternatives, although we know that ice impelled by the force of the rearward mass of the sheet will, when this mass derives sufficient force by a descent from elevations considerably higher than the intervening obstacle, rise and pass over that obstacle—and though we may find traces of

* Quart. Journ. Geol. Soc. vol. xxiii. p. 44.

Fig. 1. Outline Map showing the Dividing Ridge of the North of England and the distribution of ice and sea during the deposit of the chalky clay.



The part shaded in lines represents the northern part of the area over which the chalky clay is distributed, and consequently the part regarded by the author as being sea during the deposit of that clay—the unshaded part being regarded as enveloped in ice, the sea-foot of which is indicated by the dotted line bounding the line shading. The arrows indicate the supposed direction of the ice-motion. The broken line indicates the division between the eastern and western slopes of the great ridge of the north of England. The purple clay with chalk overlaps the chalky clay up to a limit (inclusive of outliers) indicated by the dotted line on the east side of the Wold-scarp.

The + near Shap denotes the place of Wasdale Craig, where the Shap granite is *in situ*.

such a mounting, in the form of the lower elevations intervening between the Cheviots and the Northumberland coast, yet it does not appear to me that the conditions of that part of the western slope in which Shap Fell lies, offer any indications of such an upward transit*, or that the position of the dividing ridge generally would allow of the possibility of it.

We have therefore but to fall back upon the explanation of a floating-ice transit, permitted by an adequate submergence; and this explanation is strengthened by the absence of these boulders in the older or chalky part of the clay, since otherwise they ought to be present in this part equally as in the other.

Mr. Archibald Geikie, in the year 1863†, put forth his theory that the origin of the Scotch Boulder-clay was due to the extrusion, from the sea-foot of an ice-sheet enveloping the land, of the miscellaneous material which such a sheet would in its motion seaward have degraded‡. This hypothesis is that which for a long time I have entertained as the only true one of the origin of the Glacial clays of the east of England; and I venture to suggest that the application of it to the case now under consideration will not only harmonize with all the facts, both palæontological and physical, but explain that otherwise inexplicable circumstance, the positions of the purple clay without chalk, to which attention has been called.

In the same outline map I have indicated, by tint shading, that area which I regard as sea during the deposit of all but the earliest part of the chalky clay, the unshaded part having been enveloped in an ice-sheet, which barred out the sea from all those depressions which, being below its level, would otherwise have been occupied by it, just as is the case at the present day along the west coast of Greenland according to Arctic voyagers§. The same shading that indicates sea indicates also the area over which the chalky clay occurs, except that, to curtail its dimensions, the map does not extend south-

* The whole of the great basin drained by the rivers Lowther and Eden (on the side of which Shap Fell lies) is furrowed by a numerous set of small parallel ridges, with their prominences in *roches moutonnées*. These all run from S.S.E. to N.N.W., and a glance at the beautifully shaded contours of the Ordnance map shows at once, by a *coup d'œil*, that a great ice-sheet has moved down this basin towards the Solway shore. Similar features are afforded by the contour-shading of the slopes on the other (or eastern) side of the dividing ridge north-west of Newcastle, where the motion has been similarly outward from the dividing ridge, being there from W.S.W. to E.N.E. Mr. T. M^r. K. Hughes, of the Geological Survey, kindly indicated for me such striations as he had observed on the rocks of this neighbourhood; and they agree generally with the ice-motion which the map-contours indicate.

† Trans. of the Geol. Soc. of Glasgow, vol. i. part 2.

‡ The Rev. J. B. Watson too, in his memoir on the Glacial beds of Arran (Trans. Royal Soc. of Edinburgh, vol. xxiii.), adopts the same hypothesis, and adds some valuable information as to the causes in operation at the ice-foot of the Norway glaciers, derived from personal observation. The Glacial conditions of the period of the chalky clay were, however, far in excess of any thing now obtaining in Norway, and more analogous to those on the west coast of Greenland, and along the skirts of the ice-bound land of the Antarctic continent.

§ See Dr. Sutherland in Quart. Journ. Geol. Soc. vol. ix. p. 301.

wards beyond Leicester—whereas the chalky clay extends to the southern parts of Essex and Middlesex*, and the sea depositing it extended still further, as is proved by the way in which the clay is cut off from denudation at elevations reaching up to 350 feet on the northern brow of the Thames valley; but to what distance it may have gone, the denudation has been too complete in that direction to justify an assertion, though, from the structure of the Thames gravel, I believe it to have stretched beyond the limits of England.

The long triple section, No. 3, traverses the entire length of this clay from its southern termination to its overlie in Holderness by the purple clay with chalk, and thence to the purple clay without chalk, which begins about Flamborough, and, crossing one of the lowest parts of the dividing ridge at Stainmoor, terminates at the Westmoreland Fells. The upper representation of this triple section is drawn to the existing sea-level, and shows, as nearly as the small scale will allow, the relative elevations along the line taken, the older formations forming the floor of the deposit, and the distribution of the clays in question along the line taken. The Lower Glacial series (which together forms a separate and unconformable deposit) lies to the east of the line of section taken, and may be altogether omitted from consideration in this question. The Middle Glacial, although it was a deposit formed under a marine climate very different from that obtaining at the time of the chalky clay which overlies it, yet appears to have been a deposit formed during the commencement of the submergence under which the chalky clay was accumulated, since in many parts it passes up by interbedding into that clay. Features in its structure and position, which I hope to enter upon in detail on a future occasion, indicate, moreover, as it seems to me, that although the marine climate was so different from that obtaining when the chalky clay was deposited as to have permitted neither the formation of Boulder-clay† nor the transport of rock-boulders, yet the land was occupied with ice in places which were afterwards covered deep below the chalky clay, these places being far south of the ice-limit indicated in the outline map. The line of section crosses this deposit at one part only, the bulk of it lying to the east of the line, though a considerable development of it also occurs to the west of it.

The middle representation of this triple section indicates what I conceive to be the conditions obtaining when the deposit of the chalky clay was taking place. This representation supposes a depression of from 600 to 700 feet below the present level, and it shows this clay as forming southwards from the foot of the ice-sheet on the western side of the Lincolnshire Wold, and supplied by material

* The purple clay *with* chalk forms a belt in Holderness and East Lincolnshire that overlaps a little the unshaded part, and also overlies there the chalky clay which the shading represents. See sections 1, 5, and 11 of the paper of Mr. Rome and myself (Quart. Journ. Geol. Soc. vol. xxiv. pp. 148, 160, and 169.)

† A band of Boulder-clay (chalky) does occur in the Middle Glacial gravels at one or two localities, and serves as an exception to prove the truth of this rule.

extruded by that sheet and carried away by floating ice from the ice-foot during summer and distributed over the south of England, there to intermingle with material brought from other parts of the ice-foot; and it is just at the part where the section so encounters this foot, on the south-west side of the Lincolnshire Wold, that the chalky clay is in the condition of almost pure chalk and is quarried for lime. The middle representation then, after leaving the northern portion of the Lincolnshire Wold enveloped in ice, intersects the ice-foot again where the chalky, or basement, clay of Eastern Holderness (*a*) indicates that the Wold débris was also extruded. It then exhibits the Yorkshire Wold, over which the purple clay without chalk extends, as well as the great vale beneath the Wold where the same chalkless clay occurs, as entirely occupied by the ice, and the sea blocked out by it.

The lowest representation of this triple section indicates what I conceive to have been the position when the purple clay without chalk, and with Shap boulders, were deposited. This representation supposes a further depression of the land to have taken place, so as to bring it about 1500 feet below its present level, and that in consequence so much of the ice-sheet as had before enveloped the Wold, and filled the great vale below it, had been floated up and wasted away by the sea, so that only the higher elevations of the north and north-west of England, and the extreme summits of the eastern moorlands, remained enveloped in ice. This depression having also covered the lowest parts of the dividing ridge with sea and placed the Wolds many hundred feet under water, floating ice, carrying Shap boulders, was enabled to pass over the lowest parts of the dividing ridge; and thus, coincidently with the termination of all supply of chalk by the retreat of the ice-sheet from the Wold, consequent upon its deep submergence, we have the formation of a clay destitute of that material and containing Shap-boulders, which was thrown down direct on the floor of old formations over the great vale that skirts the Wold-escarpment, and generally over the north of England previously occupied by the ice.

This deposit of 1500 feet submergence is represented as extending over the purple clay with some chalk, because we can prove its extension there by outliers still remaining: but how much further it may have spread in a southerly direction I would not venture to conjecture. It may have thinned out greatly in that direction—probably it did so—so that the commencement of the denudation wrought by the sea as the land rose removed it, and with it went the Shap boulders; for it is a remarkable fact that, wherever any great area of denudation has occurred in the Boulder-clay, the various boulders of that formation have disappeared along with the clay itself.

The immense volume of the chalk débris which has been shed out to form the chalky clay appears to me to necessitate the admission that there was a long period in which the land and its enveloping ice-sheet remained stationary, at about the limits indicated in the map and in the middle representation of the triple section. I

should, however, mention that the formation of this clay must, I think, have commenced when much of the country to the south of the sea-limit, represented in the sketch map (p. 102), was uncovered by sea, because the junction of the chalky clay with the Middle Glacial sands indicates an uninterrupted succession of deposit, the change, abrupt as it is, being only in the material deposited, viz. from sand to Boulder-clay. Coupling this with the indications everywhere pointing to the circumstance that, during the Middle Glacial period, the sea does not appear to have stood more than from 400 to 450 feet above the present sea-level*, we must suppose the area of sea represented in the map, to the south of the ice-sheet, to have been considerably less at the commencement of the chalky-clay deposit than at the stage selected for illustration. Moreover I hope, when describing the Middle Glacial structure, to be able to show that land much below this elevation was, during the Middle Glacial deposit, occupied with ice which blocked out the sea of that formation, precisely as I have represented it (in the triple section) as doing in Yorkshire during the chalky-clay deposit. It seems to me also to follow, from the facts touched upon, that it was during this interval of pause in the subsidence, when intense cold prevailed, that the truly Arctic fauna of Bridlington, which so contrasts with that of the Middle and Lower Glacial formations, gradually became established, and that thus, the Arctic forms having become denizens of this part of England by the close of this interval, we find it in full force in the Bridlington bed†, at an horizon in the deposit which indicates a very early stage in this renewed subsidence—that is to say, in the lowest or chalky part of the purple clay. On the other hand, so far as the mollusca yet obtained afford an indication, there is ground for supposing that during the period in which the whole of that thick body of deposits forming the Cromer cliff was accumulated, and during that of the Middle Glacial sands which succeed and overlie it, no arctic mollusk, beyond such as occur in the Crag‡, except *Tellina balthica*, established itself in these parts. The introduction of *Tellina balthica* constitutes a very clear palæontological horizon, marking the commencement of the Glacial formation, which (as I hope on a future occasion to show) exactly coincides with a physical break and unconformity with the Chillesford beds and Crag that takes place at the horizon where this shell first makes its appearance; and that

* The highest point I know of at which this deposit occurs is 420 feet, which is on the north side of Rugby.

† Many of the peculiar shells of Bridlington have been found at depths equal to, and even exceeding, that supposed to have been the depth of Bridlington at the time of the setting in of the renewed submergence. It is, however, highly probable that molluscan life extends to much greater depths than we have been in the habit of supposing. The ice-foot is a favourite habitat of molluscan life (see Watson, Trans. Royal Soc. of Edin. vol. xxiii. p. 538, note); and Dr. Sutherland speaks of the extreme depths (1800 feet) at which the Esquimaux fish for halibut, whose food doubtless consists of mollusca living at those depths.

‡ One other new shell besides has been obtained from the Lower Glacial, but it seems to belong to a genus of freshwater mollusca, and is therefore omitted from the list.

break I find to be greater and more complete than I once thought. It appears also, as shown by the list before given, that during the Middle Glacial formation several Crag shells (the greater part of which are non-Arctic) of which we get no trace in the Lower Glacial returned to their former habitat. This may perhaps be due, in part (though it is far from being probable that it is so in the whole, looking at the non-Arctic character of the returned group, and the abundance of some of the shells in both the Crag and Middle Glacial), to the incompleteness of the series of mollusca obtained; but it is very significant that amongst this group of apparent returns are two shells (*Pectunculus glycymeris* and *Ostrea edulis*, neither of them Arctic) which disappeared even during the deposition of the upper beds of the Crag itself.

The recommencement of subsidence I conceive so far altered the movements of the ice that a material of which we find no trace in the great chalky clay became extruded over Holderness, viz. that reddish-brown or brownish-purple sediment in which some chalk occurs. The beds of sand and bands of blue and blackish chalky clay, alternating with bands of purple clay, which mark the junction of the purple with the great chalky clay along the Holderness coast, and which are indicated in the sections of Mr. Rome and myself as well as in the accompanying vertical section by the letter *b*, seem to me to indicate the termination of this long stationary interval, or pause in the subsidence during which the great volume of chalk was shed out, and the setting in of the renewed depression, the first result of which was the limited deposit of purple clay, wherein the chalk débris, tolerably abundant at first, rapidly diminishes in quantity upwards, and the eventual result the passing over of the Shap boulders and deposit of the purple clay without any chalk.

The transition from a depression of 600 or 700 feet to one of 1500 and upwards would, we may infer, produce a great change in the conditions under which the mollusca existed. Our ideas about the depths which mollusca inhabit are undergoing much change from the dredging expeditions, and our knowledge on the subject is too defective at present to justify any conjectures as to what results might in this respect be expected to ensue on the purple-clay submergence. Our knowledge, moreover, of the mollusca of the purple clay without chalk is very restricted. Mr. Leckenby enumerates* ten species as obtained by himself and Mr. Jeffreys from the Glacial beds of the cliff about Scarborough and Whitby, which belong to the purple clay without chalk and with Shap boulders and with gravel intercalations (*c'* and *c̄* of the vertical section). The species so enumerated are as follows:—*Cardium edule*, *Mytilus edulis*, *Cyprina islandica*, *Venus linctā*, *Astarte borealis*, *Astarte sulcata*, var. *elliptica*, *Tellina lata*, *Tellina balthica*, *Mya truncata*, var. *uddevallensis*, and *Pholas crispata*.

These are too few in number to afford any reliable comparison with the Bridlington fauna; but, as far as they go, they agree satisfactorily with the newer age of the purple clay without chalk

* Geol. Mag. vol. ii. p. 348.

which I have been deducing from physical evidence; for though we do not find any one of the peculiar shells of Bridlington amongst them, all of them belong to existing forms, and one, the *uddevalensis* variety of *Mya truncata*, is unknown either to the Crag, to the Lower, or to the Middle Glacial, and is also unknown at Bridlington, while it occurs in the yet newer beds of the Clyde, and is still living.

Very unlike the Bridlington fauna also is that of Moel Tryfaen, given in detail by Mr. Darbishire*. The list from that place is moreover equally unlike that of the shells from the Middle and Lower Glacial and from the Crag. The Moel-Tryfaen fauna, however, must have lived when this country was depressed nearly as much below the present sea-level as it was when the Shap boulders came over into the purple clay; but we must recollect that equal degrees of depression do not necessarily, even if the movement were uniform, imply an identity in age between deposits accumulated under them, since the one deposit may have been formed when the land was going down, and the other when it was rising, and the two be thus separated by a not inconsiderable interval of time, during which material changes in temperature may have occurred. The Moel-Tryfaen bed therefore, instead of being synchronous with the purple clay without chalk, may not improbably belong to the epoch of emergence—that is to say, to the very earliest part of the Post-glacial period, that, in fact, to which Mr. A. Geikie refers the stratified drift of Scotland.

The prevalence of high land throughout Scotland, coupled with its higher latitude, concur to suggest that the ice-sheet would cling to that country after the far less elevated and more southern districts of the east and east centre of England had become freed from it; and the belief is therefore strong with me that the Glacial beds of Scotland belong, if not wholly, yet in greater part, to such later deposits as the north-of-England Glacial clay. One remarkable exception, however, exists to this, in the Aberdeenshire bed described by Mr. Jamieson in the 16th vol. of the Society's Journal (p. 347), which, both in its physical structure and organic contents, seems to agree with the Middle Glacial formation of England.

Note.—Since this paper was sent in with the lower representation of the triple section drawn to such a supposed submergence (1500 feet) as would cover Stainmoor Pass with sea, I have been enabled, by the kind assistance of Mr. Thos. M.K. Hughes (who is engaged on the geological survey of the district), to point out what other routes than that of Stainmoor Pass exist by which floating ice bearing Shap boulders could, so far as elevation is concerned, have passed the dividing ridge under such a submergence as represented. These routes are as follows:—

1. Up the valley of the Eden, and so over into the valley of the Ure, and thence into Wensleydale.

* Geol. Mag. vol. ii. p. 298.

2. Down the valley of the Lune to Sedbergh, thence up the valley of the Rawthey, or up that of the Clough, and so over into the valley of the Ure.
3. From Sedbergh up the valley of the Dee, and so over into the valley of the Widdale beck, and thence into Wensleydale.
4. Down the valley of the Lune to below Kirkby Lonsdale, thence up the valley of the Greta and that of the Dale beck, over into the valley of the Gale beck, and thence over again into the valley of the Widdale beck.
5. From the Gale beck up the Cam beck, and so over into Wharfedale.
6. From the valley of the Greta (as in No. 4) up that of the Wenning, and thence either by the valley of the Anstwick beck, or that of the Fen beck, over into the valley of the Ribble, and thence over again into the valleys of various becks that are tributary to the Aire.

In the first and second of these routes, the highest ground required to be covered by the sea seems about 1200 feet, in the third and fourth it seems about 1500 feet, in the fifth between 1200 and 1300 feet, but in the sixth there seems to be no barrier above 800 feet, while Stainmoor Pass is 1400 feet above the sea-level. The height of the top of Wasdale Craig (the original source of the boulders, according to Prof. Phillips) is marked on the Ordnance map as 1479 feet.

The lowest of these several elevations would accord with the phenomena discussed in this paper, since it would place the chalk Wold below the sea-level. I conceive, however, that a considerable depth of sea-water would be necessary to waste the ice out of the valleys along the transit route previously occupied by the ice-sheet; and until this was effected a floating transit could not take place; but it is remarkable that, according to those who have studied the distribution of the Shap boulders, they do not seem to occur in Airedale, along which dale the route requiring the least submergence passes, and that it is by the more elevated route of Stainmoor that most of these boulders have come into the east of Yorkshire. These apparently conflicting phenomena, and similar phenomena attending the non-transit of the blocks over the watershed between the Lune and the Kent, referred to by Prof. Phillips*, appear to me susceptible of a satisfactory explanation by supposing the lower routes to have continued blocked by ice after a higher route by which the blocks have passed, such as Stainmoor, had become free from it, and so remained until the source of the blocks had become submerged†. If that explanation be the true one, it would seem to follow that, during the Postglacial emergence, no ice existed in these parts adequate to the transport of the blocks until after the lowest of these routes had reached the surface otherwise we should expect their transit by the lower routes to have occurred

* See Report of Brit. Assoc. for 1864, p. 65. The Professor argues that the *relative* elevations of the country around Wasdale Craig must have greatly altered since the diffusion of the blocks, in order to reconcile the places of their occurrence.

† The depth at which ice floats would enable it to pick up blocks even after the parent source of them had become submerged; and these, by the many turnings over and squeezings up which occur to floating ice, might become transferred to ice of so much less draught of water that they could pass even higher elevations than the original source.

at that time. Later than this, considerably, however, and when far larger tracts had become established as land, we get from the Hesse clay evidence that ice adequate to the transport of blocks of 2 or 3 cubic feet in dimensions was in existence, though such blocks are but very rare in it.

DISCUSSION.

Mr. GWYN JEFFREYS had found the shells of Kelsea and elsewhere in Yorkshire to be mainly arctic, and Mr. Prestwich, in his paper on the Boulder-clay near Hull, had first pointed out their glacial character. In the late dredgings in H.M.S. 'Porcupine' several of the species before known as fossil at Bridlington, but not as existing in the British seas, had been discovered. In fact he believed that the Bridlington species, with but few exceptions, had now been found in the British seas. Similar species had also been found in the Boulder-clay in Scotland.

Prof. RAMSAY was pleased to find the author's views so closely correspond with his own published some years ago as to the glacial phenomena of North Wales, though based on another part of the country. He thought that shells might be found by careful search in the low-lying Boulder-clay in other places than those enumerated, as they had been discovered in the western part of England.

Mr. PRESTWICH, though inclined to accept the divisions of the Boulder-clay in Yorkshire as suggested by the author, was not so clear as to his divisions in the south. He thought the presence of chalk in the clay might be traced to the contiguity of the outcrop of the chalk stratum. The shells being to a very great extent recent, the grouping might be due to accidental or local circumstances. The Chillesford clays, in his opinion, marked the commencement of the great Glacial period.

Mr. ETHERIDGE suggested that *Nucula Cobboldiae*, *Cardita similis*, and some other shells not found in the British seas, proved the arctic character of the Bridlington fauna.

Sir CHARLES LYELL remarked that if the fauna of the Lower and Middle Glacial really corresponded so closely with that of the Crag, it afforded a strong argument against their being of the same age as the Bridlington beds. Perhaps eventually some palæontological connexion might be traced throughout the series, and a chronological scale established.

The PRESIDENT suggested a difficulty in the marine transport of ice from Shap Fell to Bridlington, not only from the wind blowing rarely in the necessary direction, but from the current caused by the great submerged ridge also tending to carry any bergs in another direction. He thought the transport by sheet-ice more probable.

The Rev. J. L. ROME had traced the Shap granites over the valley of the Eden, across Stainmoor to the Yorkshire side. There might have been difficulties in their transport, but there they are. Though they were found in Teesdale, yet the intervening ridge of millstone-grit, 2000 feet, had prevented their finding their way into Swale Dale.

1869.]

SEARLES WOOD—BOULDER-CLAY.

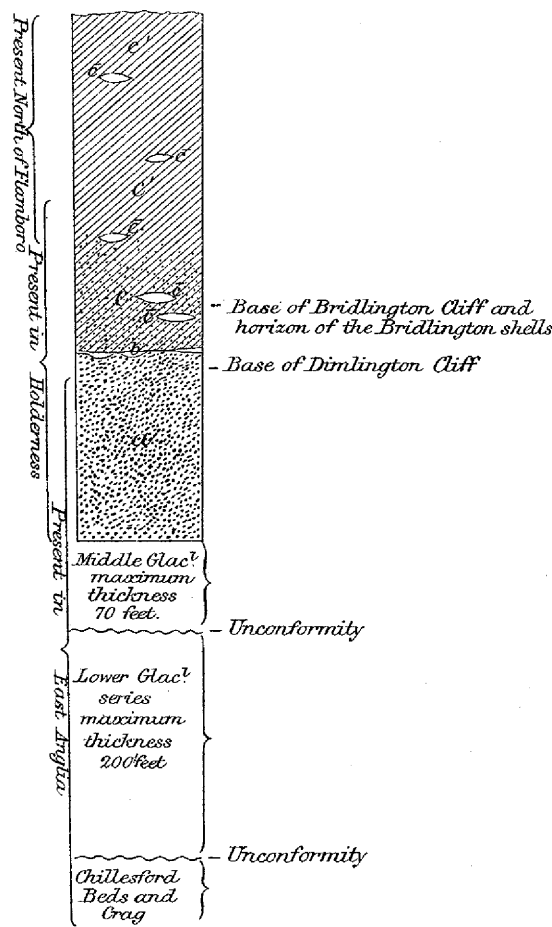
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Mr. SEARLES V. WOOD, Jun., stated that he had relied on Mr. Gwyn Jeffreys's works for his classification of the shells as being arctic or otherwise. He regarded the succession of the various members of the Glacial series of the eastern side of England as well founded, and borne out also by the molluscan remains. He utterly repudiated the notion that the Chillesford, Bridlington, and Kelsea-Hill beds were on the same horizon. He believed nearly the whole of the Scotch beds to be newer than those of the Middle and Lower Glacial. He quoted Prof. Phillips as suggesting a change in the relative elevations around Shap Fell since the dispersion of the boulders, and offered as his own explanation the hypothesis that the passes by which the boulders travelled were those which, though at the higher levels, were the soonest freed from ice. He thought that the direction of the current was influenced by other causes than the general trend of the rocky dividing ridge.

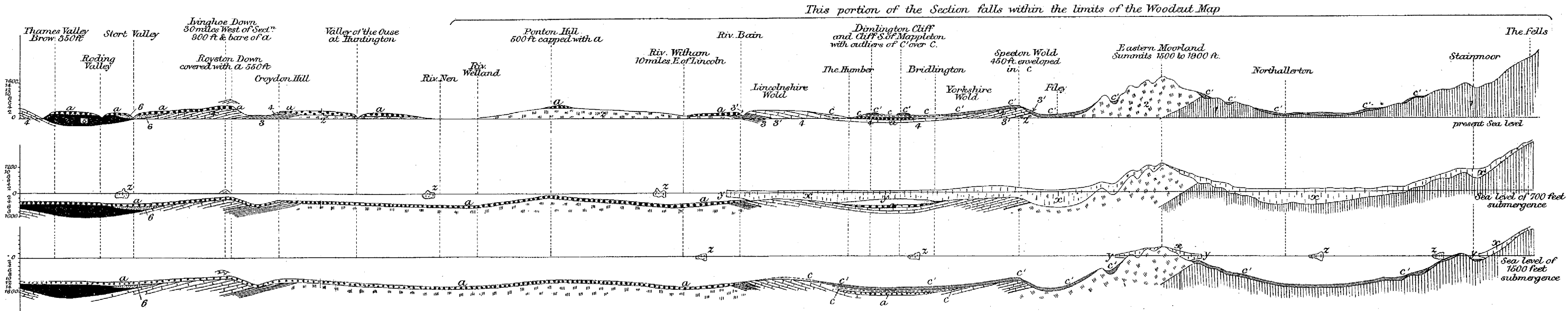
(Triple) Section N° 3.

(Vertical) Section N° 1.

N.B. The Hesse beds omitted.



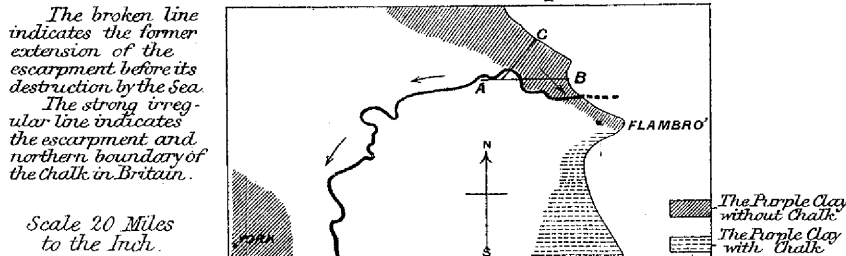
a. The Chalky Clay. b Beds of Sand and alternations of a and c. - c The purple Clay with chalk diminishing in quantity upwards. - c' The purple Clay without Chalk c Sand and Gravel intercalations in c and c'.



Reference. 1 Various formations older than the Oolites. 2 Oolitic series. 3 The lower Cretaceous series and Gault 3' The red Chalk. 4 The Chalk. 5 The lower Tertiaries. 6 The middle Glacial. a The Chalky Clay. c The purple Clay with Chalk that diminishes in quantity upwards. c' The purple Clay without Chalk and with Shap boulders. x The Ice sheet. y The Ice Foot. z Floating Ice.

The Hesse and other Post Glacial beds omitted.

Sketch Map.



Section 2.

