II. On the Interglacial Submergence of Great Britain.

1. The marine clay at Cleongart, Kintyre, SW-Scotland.

by

Henr. Munthe.

Since long time pleistocene marine shells are known in older pleistocene deposits (older than the late-glacial time) at high levels in several districts of Great Britain. At the well known locality Moel Tryfaen, in North Wales, such marine shells occur at a height of 1350 feet (442 metres) above the present sea, in Cheshire, at some localities, at about 1200 feet (393 metres), in Irland at heights of 1300 feet (426 metres), in Ayrshire at 1261 feet (413 metres) etc., while in those just mentioned and other districts shell-bearing deposits of about the same age are also found at lower levels.

The deposits in question are described partly as *boulder-clay*, partly as *sand* and *gravels* (often in close connection with the boulder-clay), partly also, but more rarely, as *veritable marine clay*. The greater shells, as of *Mollusca*, met with in these petrographically different deposits are often broken and fragmentary, sometimes also striated, while the minute ones, as *Foraminifera*, *Ostracoda* etc., are usually in a good preservation. The *character of the fauna* also shows differences, being sometimes more *northerly*, or even *arctic*, sometimes more *temperate*, while in places representatives of both these kinds are met with. The *bathymetrical* character of the fauna sometimes also shows considerable differences. — In a word, *the fauna in these shell-bearing deposits usually has a mixed character.*

With regard to the *origin* or *mode of formation* of these shell-bearing deposits, there are principally two different views. On the one hand some geologists are of opinion that the shells and shell fragments have been carried from a lower level (an old sea-bottom) to the higher places, where they are now found, *by land-ice;* on the other hand the deposits in question are supposed to be of *a true marine origine*, indicating a submergence of land to an amount, corresponding to or exceeding the heights above the sea where they occur now. Other geologists go the middle course, adding some occurences of shell-bearing deposits the former, others the latter origin.

In order to get better information regarding the question just mentioned, a Committee were elected to investigate some localities of high-level shell-bearing deposits in Scotland »with the view of re-examining the evidence bearing on the submergence of Scotland during the glacial period» [1]. Two such localities have been hitherto to a greater extent examined, and the results of these examinations are to be found in the two following Reports of the Committee: — 1. On the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other localities. — Report of the Committee, consisting of Mr. J. Horne (Chairman), Mr. David Robertson, Mr. T. F. Jamieson, Mr. James Fraser, Mr. P. F. Kendall, and Mr. Dugald Bell (Secretary). (Drawn up by Mr. Horne, Mr. Fraser, and Mr. Bell; with Special Reports on the Organic Remains, by Mr. Robertson.) [1] — 2. The Character of the high-level Shell-bearing deposits in Kintyre. — Report etc. (The Committee consisting of the same geologists that are mentioned in the title of the preceding paper) [2].

With regard to Clava (the only locality described in the Report 1) »the majority of the Committee are strongly inclined to infer, from the assemblage of organic remains and their mode of occurence, the proved extension of the bed and its apparently undisturbed character, that the shelly clay is *in situ*, indicating a submergence of land to the extent of over 500 feet. A minority of the Committee (Messrs Bell and Kendall), however, do not consider the evidence sufficient to establish this conclusion, or at all points in harmony with it» [3], beeing of opinion that the ice-transport theory better accounts for the occurence of the shelly clay at Clava than the submergence does (Report 1, p. 30—32).

Regarding Cleongart (and the other two localities in Kintyre) the Committee have given only »an impartial statement of the evidence bearing on the nature of these deposits; leaving those interested in the question of their origin to draw their own conclusions from the ascertained facts» (Report 2, p. 22).

Of late years this very interesting and important question of the »great submergence» of Great Britain in old pleistocene time has given rise to a lively discussion. Further on I shall have an opportunity of discussing this question, but I must even now say, that I adopt, though with

[1] Report of the British Assoc. for Advanc. of Science. Nottingham Meeting, 1893, Section C. p. 1 (Separate print).

[2] British Assoc. Advanc. Science. Liverpool Meeting, 1896, Section C.

[3] Report 1, p. 30.

a certain reservation, the submergence theory. In the first instance I shall give an account of the Cleongart section and my own examination of it.

Last year (1897) when I had the opportunity of visiting England and Scotland during a few weeks — as an holder of »Riksstatens mindre utrikes resestipendium» from the University of Upsala — Mr. J. HORNE at Edingburgh, the above mentioned Chairman of the Committees, advised me to go to Cleongart as the best known and most easily accessible locality of older pleistocene shell-bearing marine deposits in Scotland[1]. This proposal I embraced the more readily as from the mixed character of the fauna, found in the marine clay at Cleongart (see Report 2), one might reasonably expect to find a difference of the composition of the fauna at different levels of the section. In fact it was not probable that such northern species as *Pecten islandicus*, *Leda pernula* and so on should have lived here at the same time as the southern *Ostrea edulis* etc., besides some species showing changes of level during the formation of the clay. Most likely therefore a closer palæontological-stratigraphical examination of the section would reflect the physical-geographical changes which seemed to have succeeded to one another during a long period — in a similar manner as has been proved for some interglacial deposits in North Germany and Denmark[2].

As we shall see in the following pages, this supposition was also confirmed.

Before giving an account of my preliminary surveys at the section and of the results yielded by the later examination of the samples collected, I think fit to give a review of the Committee's Report referred to above.

»The shell-bearing deposits in Kintyre, investigated by the Committee during 1895—96, occur at three localities on the west side of the peninsula and to the north of Machrihanish Bay» (see map. fig. 1 p. 371). »They are exposed in three stream sections: (1) in Tangy Burn; (2) in Drumore Burn; (3) in a stream near Cleongart, which run more or less parallel with each other in a westerly direction towards the Atlantic» (l. c. p. 1).

Tangy Glen and Drumore Glen are only of relatively small importance, whereas Cleongart is of very special interest and therefore may be made the object of a more detailed account than the two other localities.

Tangy Glen. — From this locality Messrs Robertson and Crosskey in 1873 described shell-bearing marine clay[3], the greatest part visible being

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[1] In this place I gladly embrace the opportunity of expressing my heartfelt gratitude to Messrs HORNE and PEACH, of Geological Survey of Scotland, for their valuable assistance during my visite to Scotland.

[2] See MUNTHE: Studien ü. ältere Quartärablagerungen im südbaltischen Gebiete. (Bull. geol. Inst. Upsala. No. 5 p. 27). FRITHIOF ANDERSSON: Über die quartäre Lagerserie des Ristinge Klint auf Langeland. Eine biologisch-stratigraphische Studie (l. c. p. 115).

[3] Trans. Geol. Soc. Glasgow, Vol. IV, p. 134 (Report p. 2).

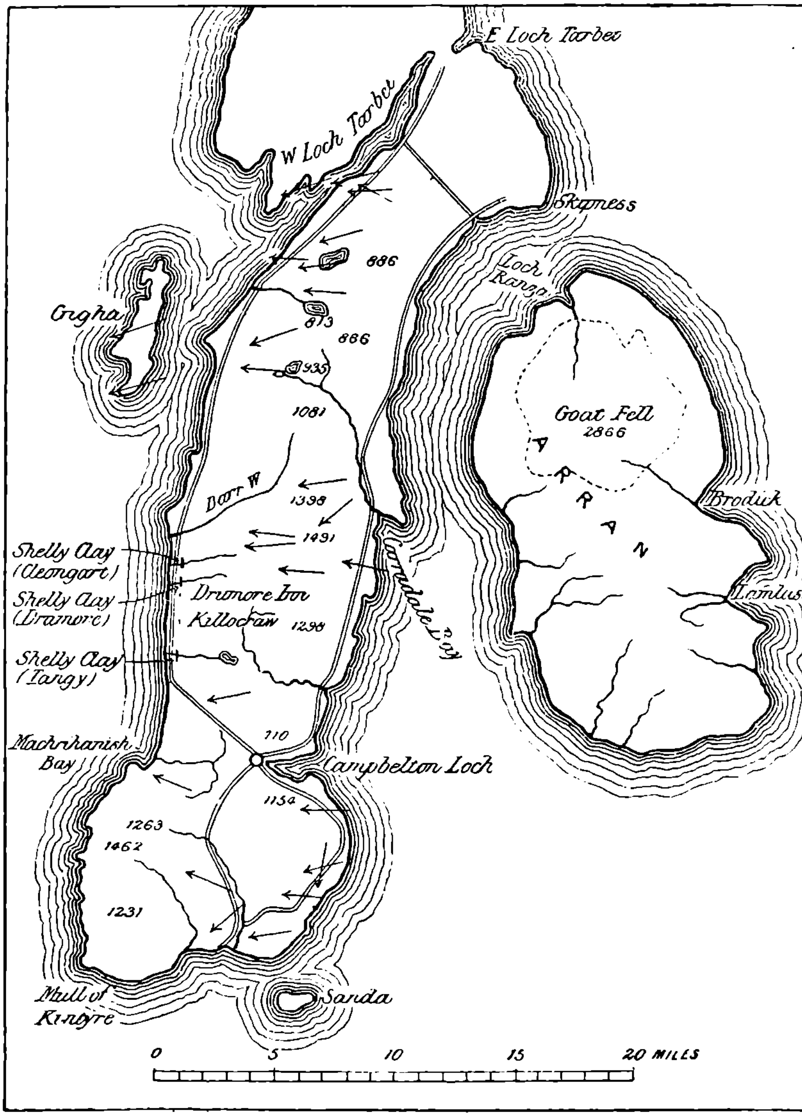

Fig. 1.

Map of Kintyre and Arran, showing the direction of the Ice-flow [1].
(From Report 2, p. 9.)

[1] The heights of hills are marked in feet. The Arran granite boundary is dotted.

13 feet high, overlaid by boulder-clay, that the Committee found to be about 30 feet in thickness. »The top of the shelly clay — — was found by the Committee — — to be $135\,^{1}/_{4}$ feet» (44 metres) above the level of the sea. (Report p. 4).

Drumore Glen. — This locality is of still less interest than that of Tangy Glen. The top of the shelly clay (also here overlaid by boulder-clay) was found to be 199 feet (65 metres) above the sea.

The shells observed in the marine clay at these localities will be mentioned further on.

Cleongart. — This locality, that was discovered by Mr. ALEX. GRAY, at Campbelton, is by far the best section of shelly clay hitherto observed in Kintyre, and the Committee therefore »confined their detailed observations chiefly to it».

The main section [see fig. 2, p. 380! (from Report 1, p. 6)] that is constructed partly on the base of the visible layers, partly (and especially) on the base of digging and boring operations (the latter, as will be seen from the diagram) to considerable depths, shows the following layers:

Boulder-clay	74 feet	(= 24.3 metres) +	(at the southernmost bore).
Shelly clay	$27\,^{1}/_{2}$ »	(= 9.2 »).	
Course Sand and Gravel	11 »	(= 3.6 »).	
(Mica Schist?).			

The surface of the shelly clay is situated $178\,^{3}/_{4}$ feet (59 metres) above the level of the sea.

The overlying *boulder-clay* »is of a reddish-brown colour, charged abundantly with boulders» (»mainly of local origin»), »some of which are striated».

The *shelly clay* is described as »a stiff, dark, bluish clay, comparatively free from stones in the upper part, though here and there throughout the section well-rounded stones are met with» — — chiefly of local origin. — — No striations were observed on any one of the stones.

»Shells were found in abundance during the first visit of the Committee in 1895, a feature which was probably due to long exposure of the materials to the action of the weather, and the removal of the clay from the surface by the rain» (l. c. p. 4).

»Some of the species were particularly abundant — as, for example, *Turritella, Cyprina, Astarte, Leda* &c. Many were in excellent preservation, but others were broken and fragmentary. Some of the smallest shells, *Ledas* and others, were entire» (p. 5). A complete list of the fossils found in the clay will be given further on.

The clay was (by digging) found to rest upon — »a bed of compact *coarse sand* and *gravel*, cut open to a depth of 3 feet 10 inches, no shells being visible. The boundary between the compact shelly clay above and the sand and gravel below was sharply defined, and to all appearance horizontal» — — »Owing to the percolation of water from the stream, the cutting was not continued downward to the solid rock; but the mica schist is visible in the bed of the Burn a few yards further down or west of the main section.»

»The shelly clay is also visible at one or two points on the north bank of the Cleongart Burn, where it is in like manner overlaid by reddish-brown boulder-clay. It has not proved so fossiliferous there as in the section on the southern bank — —.»

»With the view of proving the extension of the shelly clay along the stream in an easterly direction, the Committee put down a series of shallow bores — —. Blue clay, resembling the shelly clay, was recognized in the samples obtained from the three bores Nos. 1, 2 and 3, 22 yards» (21.6 metres), »44 yards» (43.2 metres), »and 66 yards» (64.9 metres) »respectively east of the main section» (p. 5).

»No shells or other organic remains, except one or two fresh-water Foraminifera, were found in the materials from these bores[1].»

»A small exposure of a similar clay was visible still further east, or 88 yards» (86.4 metres) »distant from the main section. This contained some small fragments of shells, and a few Ostracoda and Foraminifera» (p. 5).

With regard to the *deep bores* south of the main section a few words may be said. At the first bore, 34 yards in horizontal direction from the top of the exposed face of the shelly clay, this clay was reached at a depth of 45 feet (14.7 metres), »and after passing downward through 10 feet» (3.3 metres) »they (the borers) struck upon a rock or boulder, which arrested their progress[2].» »The Committee did not think that they had reached the bottom of the shelly clay.»

At the other deep bore, 70 yards south of the former »after a good many difficulties and delays, the shelly clay was struck at a depth of 76 feet» (24.7 metres) »from the surface, which also corresponded very well with the estimate that had been made beforehand». — — »The clay was found to continue downwards, with some variations in colour and composition, for a depth of about 20 feet» (6.6 metres) »from the point where first met with» (p. 8). Samples of the clay from various depths were laid aside by Mr GRAY and sent on to Dr. Robertson for examination.» »A good many Ostracoda and Foraminifera were found in it — —, and a few fragments of shells» (see further on). »The bore was sunk to a depth of 97 feet» (31.8 metres), »the deposit becoming very stony towards the bottom,

[1] In Dr. ROBERTSON's special-Report (see p. 16) these remains (three in number) are thought to be "Deflugi" (= Difflugia?) Regarding the material of the bore No. 3 he otherwise says: "The 'floats' were full of vegetable fragments that had much of the appearence of being waterlogged". It is therfore probable that also the *Difflugia*-specimens were in a secondary position.

[2] In all probability the latter (see further on!).

and finally resembling the hard, compact gravel underlying the shelly clay in the main section» (p. 8).

»The Committee regard the proved extension of the shelly clay thus far, under the boulder-clay, as a point of much interest, and as favouring the conclusion that it may extend more or less continuously, about the same level, from one glen to another.» This conclusion is, in my opinion, rather risky, the marine layers having probably been on a great scale destroyed during the following glaciation. If we say that *it may have originally extended* more or less continuously from one glen to another, it is more likely to be true. I think, however, that the great extension and the relatively undisturbed character of the shelly clay, as proved by the interesting examination of the Committee, is sufficient to establish the conclusion that the shelly clay here is really *in situ*.

With regard to the *ice-flow in Kintyre* it is worth mentioning that both the ice striæ and the transport of boulders show a glaciation, crossing on a large scale the peninsula in a westerly direction from the Firth of Clyde to the Atlantic (see map, p. 372!). »Indeed, one of the remarkable features connected with the glaciation of that region is the occurrence of granite boulders derived from the mass in the north of Arran» (p. 11—12). — In my opinion, the occurrence of the shelly clay in a glen at a low level in this westerly and »lee»-side (in relation to the ice-direction) of Kintyre has been the very cause of its being still preserved.

As will be seen from the following pages, the *stratigraphical appearances* of the fossils of the shelly clay also confirm the conclusion that the clay is really *in situ*, and it was chiefly with a view to decide this question, to which the Committee had not paid sufficient regard, that I resolved to go to Cleongart. As will be seen from the Report, the fossils had been collected chiefly on the weathered surface of the shelly clay at the main section, without due respect to the stratigraphical appearances of the species, save to a certain extent regarding the materials from the southernmost bore, these samples, however, being too small to give exact information as to the character of the fauna at different levels of the clay, and the more so because the samples in question were destitute of determinable *Mollusca* — the best marine organic remains when you want to form an idea of the physical-geographical conditions, more particularly in pleistocene times.

On my visit to Kintyre I had the good fortune to be taken care of by Messrs. ALEX. GRAY and LATIMER MC ENNES, of Campbelton, who not only accompanied me to the Cleongart section, but also kindly showed me some other geologically interesting places in the neighbourhood of Campbelton[1].

When examining the main section at Cleongart, Mr GRAY and I at first collected the shells and shell fragments on the surface of the

[1] For their kindness and valuable assistance I express my best thanks.

shelly clay, and in this way I got a »general-sample», in which a great number of *macroscopical* species (of *Mollusca* and *Cirripedia*) enumerated in Dr. ROBERTSON'S list (see Report p. 16—18) are represented.

It may, I think, be of some interest to know my observations regarding the frequence of some species as being in some cases an addition to Dr. ROBERTSON'S accounts, and I shall therefore give a list of all the species found here. Besides I have found a few species which are new for the locality, and these are marked with an *. The letters *S*, *N* or *w* attached to the species refer to the present geographical distribution of the species, as far as that depends in any great degree on conditions of *climate*. Thus *S* denotes species extending *southwards*, i. e. having their northern boundary in West Finmark (North Norway); *N* those extending *northwards* into the arctic districts and southwards about as far as Great Britain; *N (a)* = more *arctic* species which at the present day do not reach so southern districts as Scotland, and *w* = *widely-extended* species existing both in S- and N-districts. The references are principally from G. O. SARS: Mollusca regionis arcticæ Norvegiæ, Christiania 1878. The figures in the second column regarding the modern bathymetrical distribution refer to Britain and Norway, and the references are from JEFFREYS: British Conchology (1863—1869) and SARS (l. c.).

The Table shows that of 37 determinable species, found in the »general-samples» at Cleongart, 11 (or 29.8 per cent.) have a *southern*, 11 (or 29.7 per cent.) a *widely-extended*, 9 (or 24.3 per cent.) a *northern*,

List of Mollusca from »general samples» of the Cleongart section.

	From ROBERTSON'S Report	MUNTHES Collection	Horizontal distribution	Bathym. distribut. in *metres* Norway—Britain	*Remarks:*
1. *Ostræa edulis* L.	Several perfect and a few fragments.	A few fragments.	S.	5—90	Most northern occurrence = W-Norway.
2. *Anomia ephippium* L. . . .	One small valve, and a large fragm.	A few fragments.	w.	0—785	
3. *Pecten opercularis* L. . . .	One small fragment.	?	S.	10—195	Most northern occ. = Lofoten Islands.
4. » *islandicus* MÜLL. .	Two small fragments.	?	N(a)	10—100	Most southern occ. = Lofoten Islands and Bodö (more Southerly as dwarf-forms).
5. » *maximus* L.	One small fragment.	A few fragments.	S.	10—150	Most northern occ. = W-Norway.
6. *Mytilus edulis* L.	One small fragment.	Two fragments.	w.	0—20	
7. *Yoldia lenticula* FABR. (? = *Leda pygmæa* MÜNST., ROB.)	A few valves, and some attached.	A few valves.	N(a)	40—600	Most southern occ. = Bodö (Relict in Mediterranean?).

	From Robertson's Report	Munthes Collection	Horizontal distribution	Bathym. distribut. in *metres* Norway—Britain	*Remarks:*
8. *Leda pernula* MÜLL. (incl. var. *macilenta* STEENSTR.)	Many valves, both broken and perfect.	Many valves, both broken and perfect.	N(a)	40—300	Probably now extinct in British seas.
9. **Nucula* sp.	—	4 fragments.	—	—	
10. *Astarte banksii* LEACH (= » *compressa* MONT.)	Many valves, mostly perfect.	Many valves, mostly perfect.	N.	10—200	
11. » *borealis* CHEMN. .	A few valves.	A few fragments.	N(a)	10—40	Most southern occ. = W-Norway. (Relict in Kattegat—Southern part of Baltic).
12. » *elliptica* BROWN (? = *sulcata* DA C., ROB.)	Many valves, mostly perfect	Many perfect valves, and fragments.	N.	10—100	
13. *Montacuta bidentata* MONT.	One valve.	—	S.	10—200	
14. **Cardium norvegicum* SPGL.	—	One imperfect valve.	S.	10—95	Most northern occ. = W-Norway.
15. » *fasciatum* MONT.	One valve.	—	w.	10—330	
16. » *exiguum* GML. . .	One valve.	—	S.	6—60	
17. » *edule* L.	Fragment of a young shell.	One small, nearly perfect valve. 3 fragments.	w(?)	0—10	
18. » *tuberculatum* L. .	Several fragments and one perfect valve.	Several fragments.	S.	0—25	Most northern occ. = Britain.
19. *Cyprina islandica* L. . . .	Many valves broken in all directions.	Many fragments.	N.	10—200	
20. **Venus gallina* L.	—	Two fragments.	w.	0—200	
21. » *ovata* PENN.	A few valves, perfect and broken.	Several valves, perfect and broken.	w.	10—285	
22. *Tellina calcarea* CHEMN. .	Moderately common, broken and perf.	A few fragments.	N(a)	0—80	Rare as living, common as fossil along the S- and W-coasts of Norway. Common in Finmark and more northerly.
23. * » *baltica* L.	—	On valve.	w.	0—20	
24. *Saxicava rugosa* L.	To small valves.	Fragments (?)	w.	0—600	
25. *Mya trunestu* L.	One hinge fragment.	Several fragments, four with hinges.	w.	0—100	
26. *Trophon truncatus* STRÖM.	Four perfect specimens.	One perfect specimen.	N.	10—100	
27. *Purpura lapillus* L.	One perfect specimen.	—	N.	0—20	
28. *Fusus contrarius* L.	One perfect specimen.	One fragment.	—	—	
29. *Buccinum undatum* L. . . .	Several, large and small, more a less imperfect.	One imperfect specimen.	N.	0—300	
30. *Natica grönlandica* BECK.	Two specimens.	sp. One specimen.	N.	40—100	

	From ROBERTSON'S Report	MUNTHES Collection	Horizontal distribution	Bathym. distribut. in *metres* Norway—Britain	*Remarks:*
31. *Natica clausa* BROD. & SOW. (= *affinis* GML. p. p.) . . .	One specimen.	—	N(a)	20—100	Most southern occ. = Lofoten Islands!
32. *Odostomia* sp.?	One specimen, imperfect.	—	—	—	
33. *Bela* (= *Pleurotoma*) *turricula* MONT.	One specimen.	One specimen.	N.	20—200	
34. * » sp.	—	One specimen.			
35. *Litorina litorea* L.	Two perfect and two fragments.	Three fragments.	N.	0—6	
36. » *rudis* MATON . .	Two perfect and one fragment.	—	W.	0	
37. *Hydrobia ulvæ* PENN. . . .	One perfect specimen.	One specimen.	W.	0—6	
38. *Turritella terebra* L. . . .	Very abundant, scarcely one perfect.	Very abundant, several nearly perfect.	S.	6—200	Most northern occ. = Lofoten Islands.
39. *Trochus tumidus* MONT. .	Two imperfect specimens.	—	S.	6—200	
40. *Dentalium entalis* L. . . .	Many, mostly imperfect.	Several fragments.	S.	6—285	
41. » ? *Tarentinum* LAM.	One fragment.	—	S.	0—50	Most northern occ. = Britain.
(? *striolata* STIMPS. = *abyssorum* M. SARS)	—	One specimen.	—		

and 6 (or 16.2 per. cent.) an *arctic distribution.* Among the first named group there are *two* species (*Cardium tuberculatum* (common!) and *Dentalium Tarentinum* (?) (rare) which do not reach more northern districts nowadays than Britain. Probably, therfore, the climatic conditions cannot have been severer at the coasts of Britain during the space of time when the part of the clay containing those species was deposited, than they are at the present day in that district, or at all events not severer than at the west coast of Norway, where *Ostræa edulis, Pecten maximus* and *Cardium norvegicum* have now their northern boundaries. On the other hand such species as *Pecten islandicus, Leda pernula, Yoldia lenticula, Astarte borealis, Tellina calcarea,* and *Natica clausa,* which all are now extinct in British seas [1], show that the climate was severer than now at the Scottish coast during the formation of another part of the Cleongart shelly clay probably,

[1] Certainly they are met with in Scandinavin seas more southernly, but here (as in Skagerak, Kattegat, the Sound and Belts, and in South-Baltic) they are to be regarded as *"relict forms"*.

at all events not better than that of north-Norway now-a-days (cf. *Pecten islandicus*, *Yoldia lenticula*, *Tellina calcarea* and *Natica clausa*) or even more northern districts. With regard to the preceding and the following utterances (on the bathymetrical conditions), it ought to be insisted that I start from the probable view that the *climatic conditions* in the older pleistocene Atlantic have been on a large scale as so to say »*normal*» as those of the present day in the Atlantic district *Britain to West- and North-Norway*. A comparison between the character of a pleistocene fauna and that of the present one in a certain north-atlantic district may therefore be scientifically justified.

As regards the *bathymetrical conditions* during different periods of the formation of the shelly clay, the table also gives some hints. *Leda pernula* and *Yoldia lenticula* which both frequently occur at Cleongart live at a *minimum-depth of 40 metres;* hence it follows that that part (or parts) of the clay which contains shells (in situ) of these species has been formed at a depth of *at least about 40 metres*. Some other species as *Cardium tuberculatum* (not uncommun) *Cardium edule*, *Mytilus edulis*, *Tellina baltica*, *Purpura lapillus*, *Litorinas* and *Hydrobia ulvæ*, on the other hand, point to the opposite direction, or that those parts of the clay which contain these species are formed at a lower depth than 25 metres. With regard to these litoral species it is, however, probable that a transport of shells from the litoral region by floating ice or (the Gastropoda) by Algæ has partly been the cause of their occurrence in the clay, more particularly as many of the forms mentioned do not live on a clay-bottom. They are also *very rare* in the shelly clay, except *Cardium* and *Litorina*. The occurrences of rounded and angular stones at different levels of the shelly clay also confirm the supposition of a transport by floating ice [1].

Thus from the very »general-sample» we may infer that the physical-geographical conditions during the formation of the shelly clay at Cleongart have been, to a certain extent, varying, but from those dates only we are not able to form a correct idea of the *course* of these *variations* [2].

With a view of ascertaining this question (on the *course* of *varitions* above mentioned) Mr. GRAY and I collected a series of fresh samples of clay in situ from the exposed surface of the main section which samples I have afterwards washed and the organisms of which I have more closely examined. The samples had a size of 500—700 cm^3 and about the half of the samples has been used for examination.

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[1] Mr. JOHN SMITH has previously made about the same explanation as to the litoral shells and stones in the Clava clay (Geol. Magazine, 1896, p. 501).

[2] Besides it is worth mentioning that the following species of *Mollusca*, not met with at Cleongart, are found at *Tangy: Pecten grönlandicus* SOWB. (one fragment), "*Leda* var. *Gouldii*"? (common), *Montacuta elevata* STIMP. (one specimen), *Corbula gibba* OLIVI (one valve), and *Fusus antiquus* L. (one very young shell). — At Cleongart I also found a *fish-otolith*, 22 *mm* in length and 11 *mm* in breadth.

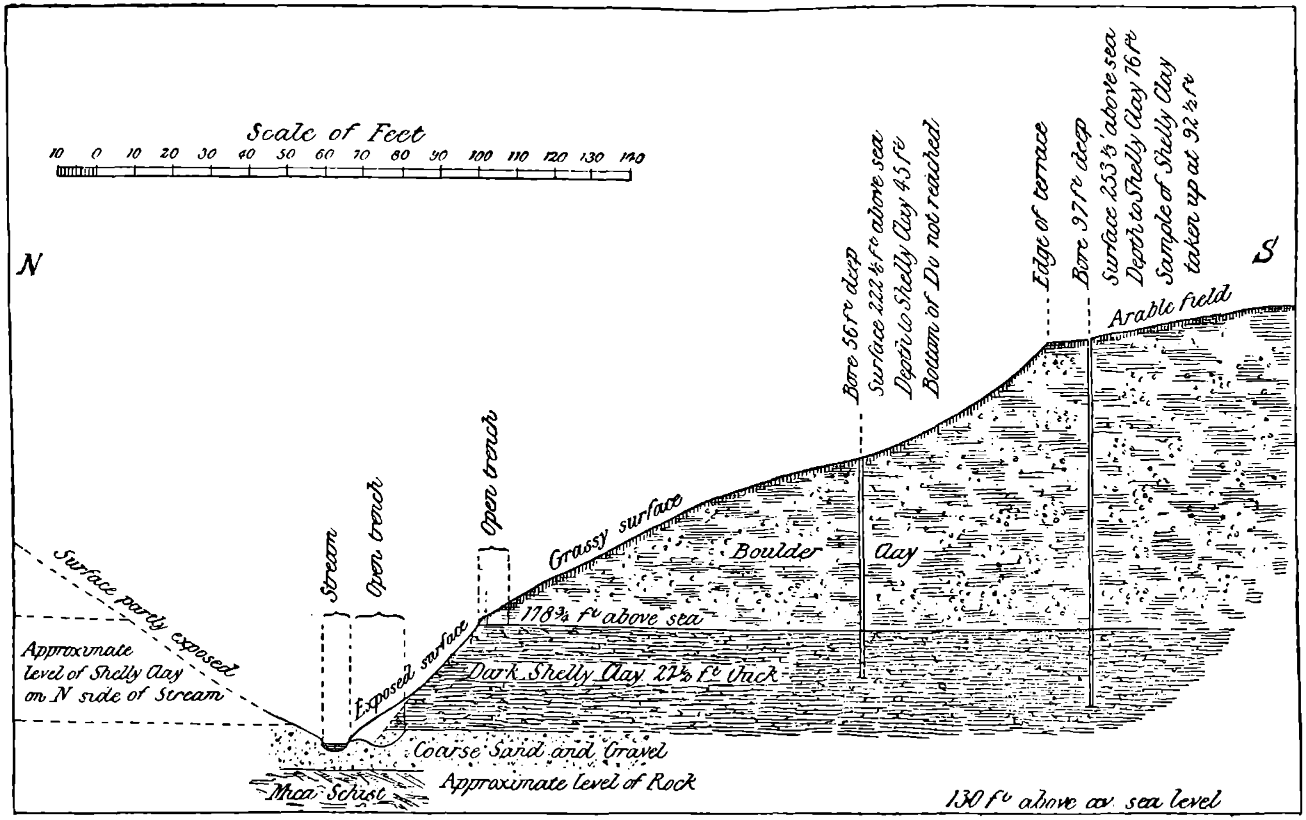

Fig. 2. – Section showing Shelly Clay at Cleongart, Kintyre, 1896 (From Report 2, p. 6).

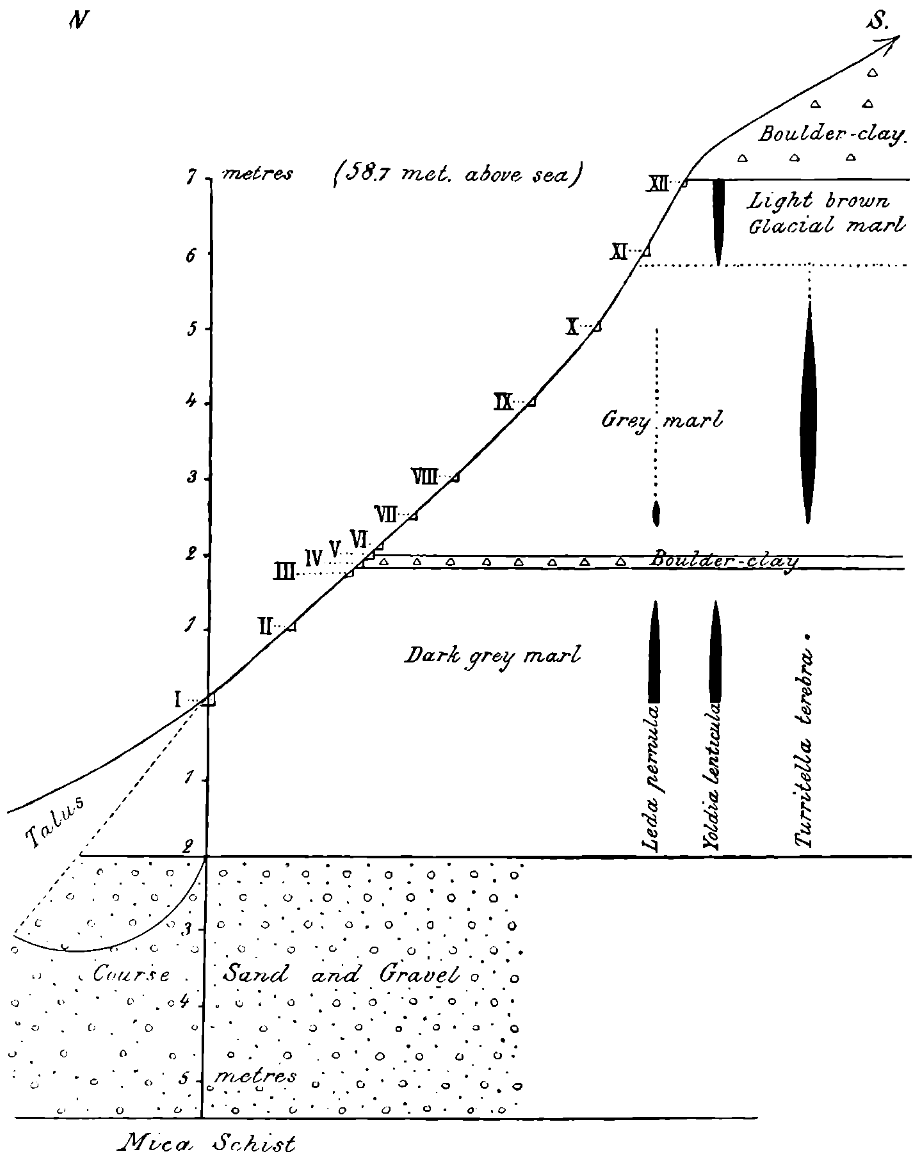

Fig. 3. — Section showing the levels of the samples collected 1897 at Cleongart, and the frequency of the most characteristic species of Mollusca, graphically illustrated.

The undermost part of the shelly clay being concealed by a talus, we could not get any samples from a lower level than about 2 metres above the bottom of the deposit. In all 12 samples were collected at levels which are to be seen in the following diagram, No. I being the undermost sample, collected 2 metres above the bottom of the layer, No. XII collected 7 metres above No. I &c. (see fig. 3! Cf. also fig. 2).

I shall now give a description of the *petrological character* of the different parts of the marine marl or clay, and then I shall pass into an account of the *fossil remains* found in them.

The two lowest samples, Nos. I and *II,* being pretty similar, they may be treated together. The marl is of a *dark* grey colour, rich in mica, a little sandy and contains very few small rounded and angular stones, one of which was striated. It shows a brisk effervescence by acid. Shell-bearing.

The sample No. III. is of a grey colour, rich in mica and sand, and contains a greater number of small (rounded and angular) stones than the two preceding samples. Brisk effervescence by acid. It contains only a few shell fragments and forms a transition to the following samples.

Nos. IV and *V* have the character of a veritable *boulder-clay,* though the small rounded stones in them, as consisting of very hard rocks, do not usually show any striations. No effervescence by acid, and no shells whatever are observed.

No. V is directly overlaid by *glacial clay* without fossils.

No. VI. This sample is a clay of a grey colour, somewhat sandy and micaceous, and contains a few small rounded and angular stones. It shows very fine slickensides, effervesces very little by acid and is almost destitute of *macroscopic* shells, only a few indeterminable fragments having been found.

Nos. VIII, IX and *X.* Those three samples are of about the same petrological character as that of Nos. I and II. They also show a brisk effervescence by acid. Colour grey. Shell-bearing.

Nos. XI and *XII* in strong contrast with the preceding samples are of a *light brown,* nearly *chocolateous* colour and resemble some varieties of our Swedish late-glacial marl. They are but little sandy and micaceous and contain only a few mostly angular small stones. The marls show a brisk effervescence by acid. Shell-bearing.

The overlying *boulder-clay,* that has the character of a veritable bottom-moraine, is of a reddish-brown colour. It does not effervesce by acid. No fossil remains at all are found in this deposit.

In examining the samples I have used the methods which I have described in Geolog. Fören:s i Stockholm Förhandl. (G. F. F.), Bd. 16 (1894) p. 17. The aim of these methods is to remove by means of washing operations all the clay and sand and to preserve all the organic remains from the smallest (as Diatoms, Foraminifera, Ostracoda &c.) to the largest (as Mollusca &c.).

The examinations of the samples on *diatoms* have given a completely negative result. No *siliceous* fossils at all have been met with here.

I shall now communicate the details of my examinations of the samples on *calcareous fossils*, and in the first instance I shall give a list of the *Mollusca* and *Cirripedia* found in the different samples. The letters *S, w* &c. have the same sense as in the list, p. 376—378. XXX = *common*, XX = *moderately common*, X = *rare* in the samples. An * denotes, as above, that the species in question has not been found at Cleongart before.

The molluscan shells are often in a fragmentary condition, hardy, but the smaller of them, as *Yoldia*, young specimens of *Cardium* &c., are in an excellent state of preservation. Sometimes also complete examples of *Leda* and *Astarte* are met with.

As may be seen from the list, p. 384—387, only a few species occur in a *greater number*, and in the following discussion on the physical-geographical conditions under which the different parts of the marl have been formed, we therefore shall have regard more particularly to those species, some of the others (rarely occurring) probably being in a secondary place. Among these more common species the following two have a more northern distribution and are not now found living in British seas, namely *Leda pernula*, and *Yoldia lenticula*. Of these species *Yoldia lenticula* is limited to the undermost (Nos. I and II) and uppermost (Nos. XI and XII) parts of the section, whereas *Leda pernula* is relatively common in the two former samples (I and II). Among the rarer species met with in the section, the northern *Yoldia frigida*, and the arctic *Cardium grönlandicum* (both now extinct in British seas) are limited to the two uppermost and the undermost (I) samples respectively. Add to this that the other species found at those levels (I—II and XI—XII) now-a-days live also in districts where the northern species just mentioned are at home, from which fact one may draw the conclusion that these parts of the »shelly clay» have been formed under *northern* (or partly even *arctic*) conditions, corresponding probably to those prevailing now in the North Norwegian seas.

Some other *northern* or *arctic* forms, such as *Pecten islandicus* and *Natica clausa*, which are met with in the »general sample» (see list above p. 376—378) are probably also from the same parts of the section, as will be evident from the following pages.

On the other hand one may conclude that those parts of the »shelly clay» which correspond to the samples Nos. VIII, IX and X (and intermediate layers) have been deposited under *temperate* conditions, these parts of the marl being nearly destitute of the more northern species above mentioned, but containing as marked *southern* species as *Turritella terebra* (very common in Nos. VIII and IX) and *Cardium tuberculatum* (rare). The climatic conditions under which these layers may be supposed to have been formed correspond, I think, to those prevailing now-a-days in the W- or SW-Norwegian seas or even more southerly. Certainly, *Leda per-*

List of Mollusca and Cirripedia met

Mollusca: Sample No.	I	II	III	IV – V	VI	VII
1. *Anomia* sp.	÷	+	—	—	—	+
2. *Pecten maximus* L.	—	One fragm.	—	—	—	—
3. *Mytilus edulis* L.	—	—	—	—	—	One fragm.
4. *Leda pernula* MÜLL.	+++	+++	—	—	+	++
5. * » *minuta* MÜLL.	+	One fragm.	One valve	—	—	—
6. *Yoldia (Portlandia) lenticula* FABR. (= *Y. abyssicola* TORELL; *Y. pygmæa* var. *gibbosa* SMITH, M. SARS; =? *Leda pygmæa* MÜNST., ROBERTS). (See G. O. SARS l. c.)	+++	++	—	—	—	sp. (2 fragm.)
7. **Yoldia (Portlandia) frigida* TORELL (= *Yoldia nana* M. SARS)	—	—	—	—	—	—
8. **Nucula tumidula* MALM	—	—	—	—	—	—
(*Nucula* sp., fragments)	—	—	—	—	—	4 small fragm.
9. *Astarte elliptica* BROWN (? = *Astarta sulcata* DA C., ROBERTSON)	++	+	—	—	—	+
10. *Astarte banksii* LEACH (= *Astarte compressa* MONT. non LINNÉ)	+	+	—	—	—	—
11. *Cardium tuberculatum* L.	—	—	—	—	—	—
12. » cfr *edule* L.	—	One small valve (1.5 *mm.*)	—	—	—	—
13. * » sp. indet.	One small valve	A few small fragmens	—	—	One fragm	2 small fragm.
14. * » cfr *norvegicum* SPENGL.	—	One fragment (9.5 *mm.*)	—	—	—	—
15. * » *grönlandicum* CHEMN.	One valve (3.4 *mm.*)	—	—	—	—	—
16. *Cyprina islandica* L.	++	++	+	—	—	+
17. **Venus gallina* L.	—	—	—	—	—	—
18. » *(Timoclea) ovata* PENN.	2 fragm.	1 fragm.	—	—	—	+
19. *Tellina (Macoma) calcarea* CHEMN.	1 fragm.	2 fragm.	—	—	—	—
20. **Abra* sp.	—	—	—	—	—	—

ifferent levels of the Cleongart section.

VIII	IX	X	XI	XII	Bathymetrical distrib. in metres. Norway a. (or) Britain	Horizontal distribution	*Rema ks:*
—	One fragm.	+	—	—	—	—	
—	—	—	—	—	10—150	S.	Most northern occurrence = W-Norway.
—	—	—	—	—	0—20	w.	
+	+	+	—	—	40—300	N(a)	Probably now extinct in British seas.
—	—	+	—	—	20—300	N.	
—	—	—	++	+++	40—600	N(a)	Now extinct in British seas. Most southern occ. = Bodö (Norway) about lat. 67° N. (Relict in Mediterranean?)
—	—	—	+	+	40—1200	N.	Now extinct in British seas. (Relict in Mediterranean?)
—	—	—	—	One perfect valve	60—1200	S(w?)	
1 fragm.	3 small fragm.	A few fragm.	1 fragm.	—	—	—	
—	1 fragm.	+	—	—	10—100	N.	
sp. (4 small fragm.)	—	sp. (2 small fragm.)	—	—	10—200	N.	
1 small fragment	—	—	—	—	0—25	S.	Most northern occ. = Britain.
—	—	—	—	—	0—10	w(?)	
—	—	—	—	—	—	—	
—	—	—	—	—	10—95	S.	Most northern occ. = W-Norway.
—	—	—	—	—	10—18	N(a)	Most southern occ. = Vadsö & E-Finmark (only small specimens. See Sars l. c. p. 49).
+	—	+	—	—	10—200	N.	
—	—	1 fragm.	—	—	0—200	w.	
+	+	++	(+)	—	10—285	w.	Now extinct in British seas. Rare as living, common as fossil along the S- and W-coasts of Norway. Common as living more northerly. (Sars l. c.).
+	—	1 fragm.	—	+	0—80	N.	
—	—	1 fragm.	—	—	—	—	

Mollusca: Sample No.	I	II	III	IV—V	VI	VII
21. *Natica* sp.	—	1 small specimen	—	—	—	—
22. *Litorina* sp.	—	—	—	—	—	—
23. *Rissoa* sp.	—	—	—	—	—	—
24. *Turritella terebra* L.	—	1 fragm.	—	—	—	2 small specim.
25. *Dentalium (Antalis) entalis* L.	—	—	—	—	—	1 fragm. specimen
26. » » cfr *striolata* STIMPS. (= » *abyssorum* M. SARS)	—	—	—	—	—	1 fragm. specimen
Sum of species:	11	15	2	—	2	12
Percentage of 26:	42.3	57.7	7.7	—	7.7	46.2
Cirripedia (determined by Dr. CARL AURIVILLIUS, at Upsala):						
Balanus sp.	—	—	—	—	—	—
Verruca strömia O. F. MÜLLER	—	—	—	—	—	+

nula and *Tellina calcarea* (both of which are now extinct in British seas) occur in these samples, but owing to the fact that they are represented only by a few small fragments they may probably be considerad to have been in a secondary way embedded in the marl. On the other hand some *southern* species, enumerated in the list of the »general-sample», such as *Ostræa edulis* and *Cardium tuberculatum* (both moderately common), may be supposed to have been from the beginning at home in these »temperate» parts of the section. It is probable even, therefore, that the marl in question has been deposited under climatic conditions corresponding to those of Scotland now-a-days.

In the sample No. VII *Leda pernula* is already more common and represented by some perfect valves, hence it is likely that the species lived in the place at the time when the layer that contains them was deposited. That sample may therefore be considered as representing a transition stage to the nearest underlying samples (VI, V and IV), of which No. VI is almost totally wanting in Mollusca (only a few fragments of *Leda pernula* and *Cardium* are found in it), whereas Nos. V—IV are entirely destitute of organic remains, having the character of a veritable *boulder-clay*, about 15 centimetres in thickness. The sample No. III, that is, like No. VI, also nearly without shells of Mollusca (it contains only one

VIII	IX	X	XI	XII	Bathymetrical distrib. in metres. Norway a. (or) Britain	Horizontal distribution	*Remarks:*
—	2 small specim.	—	—	—	—	—	
—	1 fragm.	—	—	—	—	—	
—	—	1 fragm. specimen	—	—	—	—	
+++	+++	++	(+)	—	6—200	S.	Most northern occ. = Lofoten Islands.
—	—	—	1 small fragment	—	6—285	S(?)	
—	—	—	—	—	50—500	N.	
8	8	13	6	4			
30.8	30.8	50.0	22.2	15.4			
+	+	+	—	—	—	—	
—	one fragment	—	—	—	0—80(?)	N(?)	

valve of *Leda minuta* and a few fragments of *Cyprina islandica*), in its turn represents a transition stage between the marl below, that is much richer in Mollusca, and the boulder-clay above.

On the diagram, fig. 3, the frequency of the most characteristic molluscan species is graphically illustrated. The spots in the continuation of the black figures denote that the species in question is probably in a secondary place at the respective levels of the section.

I shall now attempt an interpretation of the *bathymetrical* conditions which have likely succeeded to one another during the time when *the different* parts of the section were deposited.

In the first place I maintain, that the layers which contain *Leda pernula* and *Yoldia lenticula* as common may have been deposited at a *minimum-depth* of about 40 metres because these species do not live in the Norwegian seas at the present day at a lower depth than 40 metres (see SARS l. c.). *Yoldia frigida* (though certainly uncommon at Cleongart) belonging to the same category also confirms that conclusion. As the two species of *Yoldia* are limited to the undermost and uppermost portions of the section (samples Nos. I—II and XI--XII) and *Leda pernula* is very common in the samples Nos. I—II we may suppose that all these layers have really been deposited at a depth of *at least 40 metres*. The other

Mollusca met with in these layers do not contradict this supposition, except perhaps *Cardium grönlandicum*. Of this species G. O. SARS has found only a few relatively small specimens off Vadsö (NW-Norway) at a maximum-depth of 18 metres, while in the sea at Novaja Semlja this form is met with at depths varying from a few metres to 30—90 metres[1], and off the SE-coast of Greenland at depths of 45 to 70 metres[2]. As the species occurs only in one very small specimen (in sample No. I), one cannot, however, bathymetrically speaking, attach too much weight to it. At what depths the other layers (especially Nos. VIII, IX and X) have been deposited is more difficult to say, their characteristic species *(Turritella* and *Venus ovata)* being generally of a wider bathymetrical distribution. As *Cardium tuberculatum* (common in the general-sample!) is probably also pretty frequent in the layers with a temperate fauna (or in one of them), this species may be taken into a special consideration here. About 25 metres being the maximum-depth in which this species lives at Britain now-a-days, that depth is likely the maximum-depth at which the layers in question have been deposited. As to the *minimum-depth* several species found there, such as *Astarte, Cyprina,* and *Venus ovata,* which at the present day live at a minimum-depth of about 10 metres point to that amount, whereas *Leda pernula* (and *L. minuta*?), as above mentioned, is surely in a secondary place here.

According to the evidence of the molluscan fauna found in different levels of the section above described, *the course of the climatic and bathymetrical conditions* which seem to have succeeded to one another during the surely long period of the deposition of the whole section, may be as follows:

— at first, while the deposition of the undermost portion of the marl took place, the *climate* was likely *arctic* (obs. especially *Cardium grönlandicum*), and the depth of the sea was probably *at least about 40 metres* at this place (cf. *Leda pernula* and *Yoldia lenticula*). The land-ice or local glaciers surely covered the higher portions of Kintyre;

— when the layer represented by No. II was formed, the *climate* seems to have been *a little better* than before (obs. the certainly rare occurrence of *Turritella. Cardium* cfr. *norwegicum*, and *Pecten maximus*); the *depth about the same;*

— by degrees the *climatic conditions* must have been for some time *severer* and *local glaciers filled up the præpleistocene* (?) *valleys* of West-Kintyre, giving rise to the thin layer of *boulder-clay* (samples Nos. IV and V). When the layers immediately below and above the boulder-clay were

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[1] See W. LECHE: Öfversigt ö. de af svenska expedit. t. Novaja Semlja och Jenissej 1875 och 1876 insamlade hafs-mollusker, K. Sv. Vet.-Akad. Handl., Bd 16, N:o 2, Stockholm 1878, pag. 78.

[2] See HENR. J. POSSELT, Östgrönlandske Mollusker, in Meddel. om Grönland XIX, Kjöbenhavn 1895, p. 70.

deposited, the molluscan fauna was very scanty or no one (the few fragments found in III and VI being possibly in a secondary place). The depth of sea probably about the same as before;

— at a little higher level of the section (No. VII) some species make their appearance, such as *Leda pernula* (moderately common), *Yoldium* sp. (rare) *Astarte elliptica* (rare), *Cyprina* (rare) — all of them apparently in situ, the others probably not so, but the fauna was still scanty. *Climate moderately severe; depth as before?;*

— at the level of the sample No. VIII *Turritella* is already frequent, being the most characteristic fossil of the deposit. *Climate temperate. Maximum-depth* possibly *about 25 metres* (obs. *Cardium tuberculatum*), *minimum-depth 6—10 metres (Turritella, Astarte);*

— Nos. IX and X show about the same climatic and bathymetrical conditions as No. VIII and probably during a certain part of the formation of the layers represented by Nos. VIII—X that is not nearer to be fixed the *best climatic conditions on the whole* during the deposition of the Cleongart layers occurred, *Ostræa edulis*, *Cardium tuberculatum*, and *Turritella terebra* being chiefly at home here;

— then there was a change of climate, and *arctic conditions* prevailed during the deposition of the uppermost layer (Nos. XI—XII), consisting of *glacial clay* with *Yoldia lenticula* (common) &c. Land-ice or local glaciers in the immediate neighbourhood, *minimum-depth about 40 metres;*

— then *a great land-ice* extended more and more and at last covered the whole region, giving rise to the *overlying boulder-clay* that reached the considerable thickness of at least 25 metres!

At the advance of the land-ice the underlying marine layers were exposed to an immense pressure, which was the cause of the slickensides in the layers and partly also of the broken condition of a great part of the shells. The petrographical character of the different parts of the »shelly clay» does not contradict the above given figures with regard to the bathymetrical conditions. Commonly the marls are rich in mud, and the small rounded or angular stones in them may very well be supposed to have been transported by floating ice in winter from the coast-districts which have, no doubt, always been at a short distance.

As the »shelly clay» below the level of the sample No. I as well as the »Coarse sand and gravel» underneath the shelly clay (which layers I had no opportunity of seeing) have not been examined in detail by the Committee, its true character is very little known. It seems, however, probable that this undermost part of the shelly clay really has an *arctic* stamp, the more so because the underlying »coarse sand and gravel» according to Dr. ROBERTSON'S description (Report p. 16) is likely a kind of »boulder-gravel» (»morän-grus» in Swedish). Dr. ROBERTSON says about it: »This bed of coarse sand and gravel was 3 feet 10 inches thick, very hard; — —. The clay (!) consisted of — mud, 28 per cent.; gravel, 72 per cent.» On the other band the relation between mud and gravel (+ sand) from the »shelly clay» at Cleongart is very different from that of the coarse sand and gravel, namely, according to Dr. ROBERTSON (l. c., p. 15) in the one sample — mud, 83 per cent.; sand 6 per cent.; gravel, 11 per cent., in the other — mud, 95 per cent.; sand, 2 per cent.; gravel, 3 per cent. If the coarse sand and gravel had been a veritable *shore- or river-deposit*, one might have expected not to find any *mud* in it, which is on the other hand a characteristic of a *bottom-moraine*. In this layer (»coarse sand and gravel») no shell fragments were visible (Report p. 5).

If the interpretation of the formation of the coarse sand and gravel is correct, a glaciation of the area took place also before the deposition of the marine layers; hence it follows that those latter should be of a *true interglacial age*, being during a space of time of a veritable *temperate* character, and followed by a new glaciation (see further on). During a part of this interglacial epoch the district, as is shown above, was submerged probably *at least* about 100 (59 + 40) metres lower than at the present day.

ROBERTSON in his Report has already called attention to variations of colour etc. in different portions of the shell-bearing clay, and it may be of interest here to give an account of his utterances, which are to be found in the Report pages 20 and 21. He says: »By whatever means the shelly clay was laid down, it will be seen from the following Table that there had been at least three distinct changes in the deposition of the sediment.» This Table embraces the »Results of examination of Material from Deep Bore at top of Bank, south side of Cleongart Glen» that is to say at the southernmost Deep Bore (see figure 2 above), the height of surface at that place being 253 $^1/_3$ feet above the level of the sea.

Of the upper bored 21 feet (= 6.9 metres) of the »shelly clay» the uppermost part, 9 feet (2.9 metres) is said to be of a light brown colour, the uppermost 3 $^1/_2$ feet (1.15 metres) of the clay being »hard, and disintergrated slowly» (= the uppermost 1.2 metres of my light brown samples from the exposed surface of the section). About the next 5 feet (1.6 metres) being »less hard, and disintegrated more freely», differ in coulour from my samples which are not light brown but greyish.

The next two feet (0.65 metres) beneath the previons layer are not examined by Dr. ROBERTSON. Then there follow 5 $^3/_4$ feet (1.9 metres) of clay »of a dark bluish slate colour, hard and difficult to break» = including my samples Nos. VIII, VII, VI (grey marl) V and IV (boulder-clay) and III (grey marl).

The next 1 $^1/_2$ feet (0.5 metres) is not examined.

Then there follows again light brown clay, »friable and easily broken» 3 feet (1 metre) in thickness, which layer, as regards the colour, does not agree with my samples [Nos. I and II (?)] at the corresponding level.

As will be seen from the above mentioned facts, there is only in part an agreement between the colour-character of ROBERTSON'S samples and that of mine. That fact is probably due either to a different thickness of the corresponding layers at the two places, being at a distance from each other of about 174 feet (57 metres) on an average or to displacement of the layers.

This method of examination (by boring operations) is naturally not so accurate as excavations from the surface of a section. »Even with the most careful manipulation of the tubes it is almost impossible to prevent minute organisms such as Foraminifera being carried down to lower levels from overlying deposits. Again, shells might occur in a bed of clay, and yet the sample of the material brought up by the boring tube might not yield any traces of such organisms» (see Dr. ROBERTSON in Report 1, page 14!).

Dr. ROBERTSON has also examined this material from different levels of the shelly clay with regard to its fossil remains, but the results are of too little interest for us to give an account of them here. Foraminifera are the most common fossils met with, and all of them, except *Lagena variata* BRADY and *Nonionina scapha* FICHT. & MOLL, have been found in his »general sample» (see further on).

I shall now proceed to give an account of my examinations of the *Foraminifera* met with in the samples.

By the classification of them I have chiefly followed H. B. BRADY'S classical work: Report on the Foraminifera dredged by H. M. S. Challenger, during the years 1873—1876[1], and AXEL GOËS': A Synopsis of the arctic and Scandinavian recent marine Foraminifera hitherto discovered[2]. From these works I have also taken nearly all the references to the geographical distribution etc., Goës' work giving good information on the occurrences of many forms in arctic seas, especially those of Spitzbergen.

In the following list the abbreviations etc. generally have not the same sense as above in the case of Mollusca. With respect to the frequency of the species the principles are as follows.

The numbers from 1 to 5 are marked by figures.
» » » 5 » 10 » » » a X.
» » » 10 » 20 » » » » XX.
» » upwards of 20 » » » » XXX.

In the column *Rob.*(ertson)'*s general-sample*, embracing species common to his and my samples, *C.* denotes »common»; *M.C.* = »moderately common»; *R.* = »rare»; *M.R.* = »moderately rare», and *R.R.* = »very rare». (See Report of the Committee — — p. 19.) A + denotes that the species is certainly met with in ROBERTSON'S sample, but

[1] in Report on the scientific Results of — — Challenger — —. Zoology — Vol. IX. London 1884.

[2] in K. Sv. Vet.-Akad. Handl., Bd 25, No. 9. Stockholm 1894.

List of Foraminifera foun

Sample No:	I	II	III	IV – V	VI	VII	VIII
1. **Biloculina lævis* DEFR.	—	—	—	—	—	—	—
2. » *elongata* D'ORB.	1	5	—	—	—	×××	××
3. » *ringens* LAMK.	—	—	—	—	—	3	—
4. **Miliolina agglutinans* (D'ORB.)	4	×	—	—	—	—	—
5. » *auberiana* (D'ORB.)	—	1	—	—	—	×	1
6. » *circularis* (BORN.)	—	×	—	—	—	3	1
7.* » *concava* (REUSS)	2	2	—	—	—	—	—
8.* » *contorta* (D'ORB.)	2	××	×	—	—	—	—
9. » *cuvieriana* (D'ORB.)	—	—	—	—	—	—	2
10. » *oblonga* (MONTAGU)	××	3	—	—	2	×	××
11. » *seminulum* (LINNÉ)	4	××	—	—	—	4	1
12. » *subrotunda* (MONTAGU)	—	××	—	—	—	××	××
13.* » *tricarinata* (D'ORB.)	—	4	—	—	—	1	—
14.* » cfr *undosa* (KARRER)	—	—	—	—	—	—	—
15. » *venusta* (KARRER)	—	—	—	—	—	2	4
16. » sp. [? *tenuis* (CZJZEK)]	—	××	4	—	—	×××	—
17.**Cornuspira involvens* REUSS	—	—	—	—	—	1	—
18.**Textularia agglutinans* D'ORB.	—	×	2	—	—	—	—
19.**Bulimina aculeata* D'ORB.	—	××	××	—	××	1	—
20. » *elegans* D'ORB.	2	1	××	—	4	×	4
21.* » *elegantissima* D'ORB.	—	1	2	—	4	2	3
22.* » *elongata* D'ORB.	—	—	—	—	1	—	—
23.* » *inflata Seguenza*	—	—	—	—	—	—	1
24. » *marginata* D'ORB.	4	××	×××	—	××	—	××
25. » cfr *pupoides* D'ORB.	1	—	1	—	—	—	—
26.**Virgulina schreibersiana* CZJZ.	1	1	3	—	—	1	—
27.**Bolivina ænariensis* COSTA sp.	—	—	1	—	—	—	—
28.* » *beyrichi* var. *alata* SEG.	—	1	1	—	—	1	—
29. » *dilatata* REUSS	2	2	—	—	—	—	4
30.* » cfr *limbata* BRADY	—	—	—	—	—	—	—
31.* » *plicata* D'ORB.	—	××	××	—	3	×	—
32. » *punctata* D'ORB.	2	3	2	—	—	×	×
33.* » *robusta* BRADY	? ×	—	—	—	—	3	—
34. *Cassidulina crassa* D'ORB.	×××	×××	×××	—	×××	×××	××
35. » *lævigata* D'ORB.	××	××	×××	—	—	1	×
36.* » cfr *subglobosa* BRADY	—	1	2	—	—	—	—

Cleongart in 1897.

IX	X	XI	XII	ROB.'s "general-sample"	Found in British seas	Horizontal distribution	Bathymetric. distribution (metres)	Pelagic species	*Remarks:*
—	1	—	—	—	—	—	—	—	
2	××	—	1	M. R.	+	w.	lit. & sh. w.	—	
2	1	4	2	M. C.	+	w.	w.	—	
—	—	—	—	—	+	w.	sh.w.-(d.w.)	—	
2	8	—	—	? R.	+	S.	w?	—	
3	2	—	—	R.	—	—	—	—	"Hab. in Kilsund Norvegico sinu profund. metr. 60—70 rara". (GOËS p. 111).
—	—	—	—	—	—	—	—	—	
—	—	—	—	—	?	w?	25-100	—	GOËS l. c. p. 111.
—	—	—	—	R.	?	S.	sh. w.	—	=? *M. auberiana* (D'ORB.), ROBERTS. (See GOËS l. c. p. 109).
××	×××	2	4	M. C.	+	w.	w.	—	
4	××	1	2	M. C.	+	w.	w.	—	
×××	×××	×××	×××	M. R.	+	w.	sh. w. t lit.	—	
—	—	—	—	—	+	w.	w.	—	
—	1	—	—	—	—	—	—	—	
1	3	2	2	R.	?	S?	d. w.	—	
××	××	××	××	—	—	—	—	—	
—	—	—	—	—	+	w.	14-d. w.	—	
—	—	—	—	—	+	w.	10-d. w.	—	
1	1	—	—	—	+	w.	w.	—	
××	×	1	—	M. R.	?	S?	20-d. w.	—	
1	4	1	—	—	+	N.	w.	—	
—	—	—	—	—	—	—	—	—	
—	—	—	—	—	+	—	—	—	
×	×	—	—	M. C.	+	w.	w.	—	
—	—	1	—	M. C.	+	—	w.	—	
—	—	1	×	—	+	w.	20-d. w.	—	Most northern locality known = Faröe Channel (BRADY l. c. p. 423).
—	—	—	—	—	+	S.	sh. w.-d. w.	—	
—	—	—	—	—	—	—	—	—	
3	3	2	1	R.	+	w.	sh. w.-d. w.	—	
—	1	—	—	—	—	—	—	—	
—	—	—	×	—	+	—	—	—	
×	×	—	1	M. C.	+	w.	w.	—	Even found at Bergen, Norway (See BRADY, l. c. p. 421).
—	—	—	—	—	—	S.	—	—	
×××	××	×	×××	M. C.	+	w.	w.	—	
1	×	—	—	+	+	w.	sh. w.-d. w.	—	
—	—	—	—	—	—	S.	—	—	

Sample No:	I	II	III	IV--V	VI	VII	VIII
37.* *Lagena acuticosta* REUSS	1	—	2	—	—	—	×
38. » *apiculata* REUSS	3	×	—	—	—	—	2
39.* » cfr *castrensis* SCHWAGER	—	—	—	—	1	1	—
40.* » *clavata* D'ORB.	—	1	1	—	—	1	2
41. » *distoma* PARK. & JONES	1	×	—	—	2	×	1
42. » *feildeniana* BRADY . .	4	—	—	—	—	—	—
43. » *fimbrata* BRADY	—	2	1	—	2	×	—
44. » *globosa* (MONT.)	2	—	—	—	—	1	2
45.* » *gracilis* WILL.	—	—	—	—	—	—	1
46. » *gracillima* (SEG.) . . .	2	—	—	—	—	? 1	—
47. » *hexagona* (WILL.) . . .	—	1	2	—	—	4	2
48. » *lævis* (MONT.)	4	3	3	—	—	—	1
49.* » *lagenoides* (WILL.) . .	—	—	—	—	—	—	—
50. » *lineata* (WILL.)	—	—	3	—	—	—	—
51. » *lucida* WILL.	—	—	—	—	—	—	—
52. » *marginata* (WALK & BOYS	××	×××	×××	—	×	×××	×××
53.* » *orbignyana* (SEG.) . . .	—	—	2	—	2	—	—
54.* » *quadricostulata* REUSS	—	—	—	—	—	3	—
55. » *semistriata* WILL. . . .	—	1	—	—	—	—	1
56. » *squamosa* (MONT.) . . .	—	2	—	—	—	—	3
57. » *striata* (WALK. & BOYS)	×	××	×	—	—	×	2
58.* » *striatopunctata* PARK. & JONES	1	×	—	—	—	—	1
59. » *sulcata* (WALK. & JAC.)	1	1	×	—	1	1	×
60.* » *trigono-marginata* PARK. & JONES	—	—	—	—	—	—	—
61.* *Nodosaria calomorpha* REUSS . .	1	—	—	—	—	—	—
62. » *communis* D'ORB. . .	—	—	—	—	—	—	—
63. » *pauperata* D'ORB. . .	—	—	—	—	—	—	2
64. » *pyrula* D'ORB.	2	—	—	—	—	—	—
65. *Vaginulina legumen* (LINNÉ) . .	—	1	—	—	? 1	×	—
66.* *Cristellaria articulata* REUSS. .	—	—	—	—	—	2	? 1
67.* » cfr *crassa* D'ORB. . . .	1	—	—	—	—	—	—
68. » *crepidula* (FICHT. & MOLL.)	1	—	—	—	—	—	—
69. » *gibba* D'ORB. . . .	—	—	—	—	—	1	2
70. » *rotulata* (LAMK.) . .	2	1	—	—	—	1	1
71.* *Polymorphina augusta* EGGER . .	1	2	—	—	—	—	2
72.* » *communis* D'ORB.	—	1	—	—	—	—	—
73. » *compressa* D'ORB.	1	—	2	—	1	—	×

IX	X	XI	XII	ROB.'s "general-sample"	Found in British seas	Horizontal distribution	Bathymetric. distribution (metres)	Pelagic species	*Remarks:*
2	1	—	—	—	—	—	—	—	
×	×	—	—	+	+	w.	w.	—	
—	—	—	—	—	+	—	—	—	
—	2	—	—	—	+	w.	w.	—	
—	1	—	—	R.	+	w.	w.	—	
—	—	—	—	R.	+	w?	sh. w.-d. w.	—	
1	1	—	—	R.	+	—	—	—	
—	2	—	1	M. R.	+	w.	w.	—	
—	—	—	—	—	+	w.	sh. w.-d. w.	—	
4	2	—	—	M. C.	+	w.	sh. w.-d. w.	—	
—	1	—	1	M. C.	+	w.	sh. w.-d. w.	—	
—	—	1	1	M. R.	+	w.	w.	—	
1	—	—	—	—	+	w.	w.	—	Most northern occurrance known = Faröe Channel (BRADY).
2	—	—	—	M. R.	+	S.	w.	—	
×	—	—	—	M. C.	+	—	—	—	
×××	×××	2	×	M. C.	+	w.	w.	—	
—	1	—	—	—	+	w.	w.	—	
—	—	—	—	—	—	—	—	—	
3	—	—	—	M. R.	+	w.	w.	—	
3	2	—	—	R.	+	w.	sh. w.-d. w.	—	
×	4	1	—	M. C.	+	w.	sh. w.-d. w.	—	
—	1	—	—	—	+	w.	sh. w.-d. w.	—	
2	4	—	—	M. R.	+	w.	w.	—	
1	—	3	—	M. R.	+	—	—	—	(= ? *N. consobrina* D'ORB., ROB. (See GOËS, l. c. p. 72).
1	—	—	—	(?)	—	—	—	—	
—	1	—	—	R.	+	w.	w.	—	
—	1	—	—	+	+	w.	w.	—	
—	—	—	—	R.	+	w?	sh. w.-d. w.	—	
—	—	—	—	+	+	w.	w.	—	
—	—	—	—	—	—	—	—	—	
—	—	1	—	—	—	—	—	—	
1	—	—	1	+	+	w.	w.	—	
1	1	—	—	M. R.	+	w.	w.	—	
1	1	—	—	+	+	w.	w.	—	
—	—	1	1	—	+	w.	sh. w.-d. w.	—	
—	—	—	—	—	+	w.	w.	—	
2	3	—	—	+	+	w.	w.	—	

Sample No:	I	II	III	IV – V	VI	VII	VIII
74. * *Polymorphina gibba* D'ORB. . .	—	—	? 1	—	—	—	—
75. * » *lactea* WALK. & JAC.	—	—	—	—	1	—	? 1
76. » *lanceolata* REUSS	—	? 1	—	—	—	—	2
77. » *oblonga* D'ORB. .	—	—	1	—	1	—	—
78. » *ovata* D'ORB. . . .	—	—	1	—	—	—	—
79. * » *rotundata* (BORN.)	1	1	1	—	—	—	1
80. » *sororia* REUSS . .	1	2	—	—	—	—	×
81. * *Uvigerina angulosa* WILL. . .	×	××	2	—	1	4	×
82. » *pygmæa* D'ORB. . .	××	××	×	—	3	1	—
83. * *Dimorphina tuberosa* D'ORB. . .	—	1	—	—	—	—	—
84. * *Globigerina æquilateralis* BRADY	—	—	—	—	—	—	—
85. » *bulloides* D'ORB. . .	4	3	4	—	—	2	4
86. *Patellina corrugata* WILL. . . .	2	×	1	—	2	2	××
87. *Discorbina globularis* (D'ORB.)	1	1	—	—	—	—	—
88. * » *orbicularis* (TERQUEM)	—	—	? 1	—	—	—	—
89. * » *vesicularis* (LAMK.) . .	—	—	—	—	—	1	—
90. * » *vilardeboana* (D'ORB.)	3	1	—	—	—	×	—
91. * *Truncatulina* cfr *culter* PARK. & JONES	—	—	—	—	—	—	—
92. » *lobatula* WALK & JAC.	××	×	××	—	1	×××	×××
93. * » *pygmæa* HANTKEN	—	—	1	—	×	1	—
94. * » *refulgens* (MONTF.)	1	3	—	—	—	—	—
95. * » *ungeriana* (D'ORB.)	—	—	—	—	—	—	—
96. * *Anomalina ammonoides* (REUSS)	—	—	—	—	—	—	—
97. * » cfr *grosserugosa* (GÜMB.)	—	1	—	—	—	—	—
98. * *Pulvinulina* cfr *concentrica* PARK. & JONES	—	—	—	—	—	—	1
99. * » cfr *exigua* BRADY	—	1	2	—	—	—	—
100. » *karsteni* (REUSS)	—	1	—	—	—	—	—
101. * *Rotalina beccarii* (LINNÉ) . . .	××× (small ex. p. p.)	×× (small. ex.)	××	—	××× (small examp.)	×××	×××
102. » cfr *papillosa* BRADY . . .	—	—	—	—	—	1	—
103. *Nonionina depressula* WALK. & JAC.	××	1	×	—	××	××	×××
104. » *orbicularis* BRADY. .	—	×	××	—	×	××	—
105. » cfr *stelligera* D'ORB. . .	—	—	—	—	—	1	—
106. » *umbilicatula* (MONT.)	—	1	—	—	—	—	—
107. *Polystomella arctica* PARK. & JONES	2	—	—	—	—	—	1

IX	X	XI	XII	ROB.'s "general-sample"	Found in British seas	Horizontal distribution	Bathymetric distribution (metres)	Pelagic species	*Remarks:*
—	—	1	—	—	+	w.	sh. w.-d. w.	—	
2	2	1	—	—	+	w.	sh. w.-d. w.	—	
—	—	—	—	M. R.	+	—	—	—	
—	1	—	—	M. C.	+	w.	w.	—	
—	—	—	—	+	—	—	—	—	
—	—	—	—	—	+	—	—	—	
—	×	—	—	+	+	w.	sh. w.-d. w.	—	
3	×	—	1	—	+	w.	w.	—	
—	1	—	—	+	+	w.	w.	—	
—	—	—	—	—	?	—	—	—	
—	—	—	1	—	+	S.	—	+	
4	2	×	××	R.	+	w.	—	+	
×	×	1	1	+	+	w.	w.	—	
—	1	—	3	R.	+	w.	sh. w.-d. w.	—	
—	—	—	1	—	+	S.	w.	—	
—	—	—	—	—	—	—	—	—	
2	—	—	4	—	?	w.	sh. w.	—	= ? *araucana* D'ORB. (See BRADY l. c. p. 645).
—	—	—	1	—	—	—	—	—	
××	××	×	3	M. R.	+	w.	w.	—	Mostly small specimens.
—	—	—	—	—	?	—	—	—	
—	—	—	—	—	+	w.	90 *m*.-d. w.	—	
—	—	—	2	—	?	S.	50 *m*.-d. w.	—	
—	×	—	—	—	—	—	—	—	
—	—	—	1	—	—	S.	—	—	
—	—	—	—	—	+	S.	sh. w.-d. w.	—	
—	—	—	—	—	?	—	—	—	
×××	××	×	—	C.	+	N.	sh. w.-d. w.	—	Small examples sporad. in deeper water (BRADY). At all Norwegian coasts (M. SARS)?
×××	×××	××	1	+	+	S.	lit.-100 *m*	—	
×	—	1	—	+	—	—	—	—	
××	××	×	3	M. C.	+	w.	lit.-100 *m*	—	
×	1	2	—	M. C.	+	N.	sh. w.-d. w.	—	
—	—	—	—	R.	+	w.	w.	—	
—	—	—	—	R.	+	w.	40 *m*.-d. w.	—	
—	2	—	1	R.	+	N.	sh. w.-d. w.	—	Southern limit = W-coast of Scotland (BRADY).

Sample No:	I	II	III	IV–V	VI	VII	VIII
108. **Polystomella crispa* (LINNÉ) . .	—	4	2	—	—	3	—
109. » *macella* (FICHT. & MOLL.)	××	××	××	—	2	×	×××
110. » *striato-punctata* (FICHT. & MOLL.)	××	××	×××	—	×	—	××
111. » *striato-punctata* var. *incerta* WILL.	××	—	×××	—	×××	×××	×××
112.* » *subnodosa* (V. MÜNST.)	—	2	××	—	×××	×××	?1
Sum of species:	49	63	46	0	29	53	52
Percentage of 112:	43.8	56.2	41.1	—	25.9	47.3	46.4

no information has been given as to the frequency of the species in question. With regard to the *bathymetrical* distribution the returns are usually not fixed by figures, hence in most cases the following terms will be used: *litoral* (»lit».), that is to say between tidemarks; *shallow-water* (»sh.w.») = depths ranging from the lower limit of the litoral region to about 200 metres, and *deep-water* (»d.w.») = below the shallow water region. A *w.* (= widely bathymetrical distribution) denotes a distribution ranging from the litoral region to the deep-water one inclusive.

In several cases the returns as to the horizontal and (or) bathymetrical distribution are far too scanty to be taken notice of; the species in question will be marked only with a —, the same being the case with regard to some forms whose classification is not very certain.

The shells of the Foraminifera are usually in a very good preservation.

Before enlarging upon the value of the above table on the Foraminifera, a few remarks may be made with respect to the classification of some species.

— As *Miliolina* sp. I have until further notice registered a *Miliolina*, that I have not yet been able to identify. It greatly resembles *M. tenuis* CZJZEK[1] the number of the chambers visible, however, being only four and three respectively. Probably, it is the same form called by Dr. ROBERTSON *M. tenuis*, that occurs as »moderately rare» in his »general sample» (see Report, p. 19).

Curiously enough Dr. ROBERTSON mentioned in his list on Foraminifera met with in the marine deposit at Cleongart only the two follow-

[1] See BALKWILL and WRIGHT in Trans. R. Irish Acad. Sci. Vol. XXVIII, Pl. XII, fig. 3–5.

IX	X	XI	XII	ROB.'s "general-sample"	Found in British seas	Horizontal distribution	Bathymetric. distribution (metres)	Pelagic species	*Remarks:*
—	—	—	—	—	+	w.	w.	—	
××	×××	×	—	C.	—	S.	w.	—	
×	×	×	—	C.	+	w.	w.	—	
××	×××	××	×××	—	+	N?	w?	—	
××	3	××	—	—	—	N?	?	—	
50	58	32	33	—	—	—	—	—	
44.6	51.8	28.6	29.5	—	—	—	—	—	

ing *Rotalina*-forms: *R. orbicularis* D'ORB., and *R. papillosa* BRADY, the former of which is said to be »a prevailing species in the deposit» (l. c., p. 20). As far as I have been able to ascertain that species is not with any certainty to be found in my samples. A few specimens of a *Rotalina*-form met with in my samples certainly resemble BRADY'S fig. 5, Pl. 107 »*R. orbicularis*? D'ORB.», but it may be questioned whether these forms are not rather to be considered only as a variety of *R. beccarii*. In several of my samples typical specimens of *R. beccarii* are usually met with in abundance, though in some of them a dwarf-form of this species is prevailing or even the only one found. Nor *R. papillosa* either has been found with any certainty. A few specimens resembling to a certain degree that species (or *R. papillosa* var. *compressiuscula* BRADY) are met with, but they may possibly more correctly be considered as only a var. of *R. Beccarii*, transition stages being found. Dr. ROBERTSON'S list and mine also differ in some other respects, Dr. Robertson's list embracing a good deal of species which are not to be seen in my table and vice versa, a circumstance that is with all probability partly due to the different levels at which our samples may have been collected, and the size of the samples partly also to a different view with regard to the classification of some species. In my series of samples there are surely too many gaps for us to get a nearer information of the very course of the changes of the fauna. The following species enumerated in Dr. ROBERTSON'S list have not been met with in my samples (»*Biloculina simplex* D'ORB.,» ROBERTSON is = *B. ringens* LAM. according to BRADY l. c., p. 142):

1. *Miliolina brongniartii* D'ORB. R. (=? *M. bicornis* W. et B., according to GOËS, l. c., p. 113).
2. » *ferrussacii* (D'ORB.). R.R.

3. *Miliolina secans* (D'ORB.). R.
4. *Planispirina exigua* BRADY. R.
5. *Psammosphæra fusca* SCHULZE. R.
6. *Rhabdammina cornuta* BRADY.
7. *Lagena costata* (WILL.).
8. » *interrupta*. R (= *L. sulcata* var. *interrupta* WILL.; BRADY, l. c., p. 463).
9. » *caudata* D'ORB. M.R.
10. » *favoso-punctata* BRADY. R.
11. » *melo* (D'ORB.). M.R.
12. » » var. R.
13. » *ovum* (EHRENB.).
14. » *williamsoni* (ALCOCK).
15. *Nodosaria lævigata* D'ORB. R.
16. » *rotundata* RSS. R.
17. » *consobrina* D'ORB.
18. » *simplex* SILV.
19. *Marginulina glabra* D'ORB. R.
20. *Cristellaria latifrons* BRADY. R.
21. » *cultrata* D'ORB. R.
22. » *arcuata* D'ORB. R.
23. *Discorbina polystomelloides* P. et J.
(24). *Rotalina orbicularis* D'ORB. (M.R.) and (25) *R. papillosa* BRADY (see above!)
26. *Nonionina boueana* D'ORB. M.C.

The twenty four (or twenty six) species, just mentioned, are, however, in most cases, such as are denoted as »*rare*» in ROBERTSON'S sample, a couple of exceptions being left, embracing forms met with as »moderately common» or »moderately rare»; nor of them either I have, curiously enough, seen any traces in my samples.

On the other hand, not less than fifty-two species are found in my samples which are not met with in ROBERTSON'S one, a few of them such as *Rotalina beccarii*, *Bolivina plicata*, and the little delicate species *Bulimina elegantissima* being »common», »moderately common» and »moderately rare» respectively in some of my samples.

The species common to Dr. ROBERTSON'S and my lists are 59 (57?) in number.

The whole number met with in my samples is 112. The geographical distribution of 83 of them is generally well known and characterised in the table, whereas the distribution of the remaining 29 species is still too little known to allow us to judge of their value with respect to the character of the samples containing them.

Of the 83 species above mentioned, *61* (or *73.5* per cent.) have a *wide*, *17* (or *20.5* per cent.) a *southern*, and *5* (or *6.0* per cent.) a *northern* distribution. The first group having no special interest as far as the climatic conditions during the deposition of the different portions of the marl are concerned, they may be set aside.

The *southern* forms in some cases are limited to the levels that, according to the evidence afforded by the Mollusca, are of a more temperate character, while in other cases such forms are also met with in more northern or even arctic samples. To what extent that fact is due to a *secondary* deposition, it is not easy to say. For these small shells, that are often of an inconsiderable specific gravity, must sometimes on a much larger scale than the Mollusca and other big forms have been transported by the waves over a large space. The Foraminifera, therefore, do not by any means throw light upon this question to the same extent as the Mollusca etc. do. A couple of these southern Foraminifera, however, are of a greater interest as indicating about the same character of the different samples as the Mollusca, namely *Rotalina Beccarii* and *Polystomella macella*. The former ist most frequent and attains its best dimensions in more temperate districts and at smaller depths, and in consequence the samples with a more decidely temperate character (Nos. VIII, IX and X) contain a relatively great number of large specimens of this form, the other samples containing a smaller number of (often only) the *dwarf-form*. About the same is the case also with *Polystomella macella*.

As regards the *northern* species nearly the same remarks may be made as with respect to the southern ones.

Bathymetrically speaking, the Foraminifera give as scanty and uncertain information as regarding the climatic conditions; so I desist from discussing that question.

As will be seen, however, from the table on the Foraminifera and from that of the Mollusca, the percentage of species in the different samples upon a large scale has a tendency to be analogous. Thus the samples IV and V are destitute of molluscan shells as well as of Foraminifera. As to the immediately underlying and overlying samples (Nos. III and VI) there is in both cases a comparatively small percentage of species, and that also holds good of the two uppermost samples (Nos. XI and XII). The highest percentages as well of Mollusca as Foraminifera we find in the samples Nos. II and X.

As we have seen, the Foraminifera are of comparatively little value to give information respecting the physical-geographical conditions under which a pleistocene marine layer has been deposited. This fact, I think, may first and foremost partly be due to the circumstance that their present horizontal as well as bathymetrical distribution is still too little known in some districts where we can expect to find conditions similiar to those under which certain pleistocene layers have likely been formed. In the case before us the result would, no doubt, have been more accurate, had the fauna round the Norwegian coasts been better known. While the Foraminiferan fauna in the seas of Great Britain has been in such an exellent manner examined, the reverse is namely the case with regard to the norwegian ones, especially the more northern parts of that district.

Like Dr. ROBERTSON in his »general-sample» I have also in my samples, except in Nos. IV—V, found a number of *Ostracoda*, which I had delivered to Mr. JOH. GUNNAR ANDERSSON, at Upsala, for determination. Mr. ANDERSSON, as a member of the Swedish Polar-expedition during this summer under the direction of Professor A. G. NATHORST, having been much engaged with preparations for the expedition, got but little time for the examination of my collection and at last he could only give me the following communications on the character of the Ostracodan fauna of some samples.

The faunas of the samples Nos. I and II bear a close resemblance to eachother containing chiefly *widely distributed* species common also in British and Scandinavian seas. Save *Cythere mirabilis* BRADY that occurs rarely in both samples and is probably to be considered as a veritable arctic species, no arctic forms are met with at these levels of the Cleongart section.

The fauna of the sample No. VIII has about the same character as that of Nos. I and II, only one specimen of the more northern or arctic *Cytheropteron montrosiense* BRADY, CROSSKEY and ROBERTSON having been found here. The specimen, however, is possibly to be considered as in a secondary place.

In the sample No. XII that contains a relatively scanty fauna of chiefly widely distributed species also some specimens of *Cytheropteron montrosiense* are found whence the character of that sample is likely more arctic [1].

As is seen from the facts just mentioned the Ostracodan fauna seems not to contradict the results obtained from the Molluscan one.

Until we have got much better information as to the biology and morphology of the present fauna (and partly also the flora), and more especially the species which are most important as to the pleistocene geology — as in the first hand many *Mollusca* (and *Ostracoda*?) and these researches have been extended to many different districts round the atlantic coasts of Norway and in more arctic areas, we cannot be able in a more accurate manner to conclude regarding the physical-geographical conditions of older pleistocene times. Since the hydrographical conditions during the last years have been in such a large scale studied in our northern seas, that important part of the question has got a desiderable illustration. At all events, however, the detailed biological examinations have to be nearly joined with detailed hydrographical ones.

[1] *Cythere mirabilis* and *Cytheropteron montrosiense* are not met with in Dr. ROBERTSON's samples from Cleongart, but the latter species is found at Tangy Glen (See Report 2, p. 14).

Then, to the Cleongart marine deposits we have, I think, every reason to apply the majority's utterance on the Clava shelly clay, that, »from the assemblage of organic remains and their mode of occurrence», »the shelly clay is *in situ,* indicating a submergence of land to the extent of» 100 metres or more. And we have still greater reason to do so I think because we cannot well suppose a layer like that of Cleongart — showing such a distinct series of different layers deposited under different climatic conditions — to have been neither transported even a short distance by an ice-sheet nor deposited »in an *extra-glacial* lake, formed — — along the side of the ice-sheet [1]».

Probably the marine layers are of an *interglacial* age corresponding with one of the two interglacial epochs which have, in all porbability existed not only in the Alps but also in North-Europe [2].

The marine shelly clay at the two other localities of Kintyre are likely to be parallised with the Cleongart shelly clay though the Committee's supposition »that it (the shelly clay) may» yet »extend more or less continuously, about the same level, from one glen to another» is not probable, as I have before insisted on.

2. The marine clay at Clava, near Inverness, Scotland.

Thinking that the results arrived at with respect to the Cleongart section may to a certain extent throw light also on the above mentioned Clava section, near Inverness, I will give a short review of the more important results arrived at regarding this locality and add a few remarks to it. As we have seen in the preceding pages, there is still a divergence of opinions as to the origin of the shell-bearing clay here. I think, however, that the majority of the Committee have given good reasons for their conclusions, that the shelly clay is really in situ, indicating a »great submergence» of land.

— *Geographical position.* »The shell-bearing deposit at Clava occurs on the east side of the valley of the Nairn, and six miles due east of the town of Inverness.» (Report 1, p. 1).

Also here digging and boring operations were made, the results of some of them being the following section at the »main pit»: —

[1] Mr. BELL's later exploration of the formation of the Clava shelly clay in a secondary way. See Geol. Mag. 1895, p. 354—355.

[2] See especially C. GOTTSCHE: Die Endmoränen und das marine Diluvium Schleswig-Holsteins. Theil I, in Mittheil. d. Geogr. Gesells. in Hamburg, Bd. XIII, 1897.

1.	Surface soil and sandy boulder clay	43 feet	(14 metres)
2.	Fine sand	20 »	(6.6 »)
3.	Shelly blue clay with stones in lower part	16 »	(5.2 »)
4.	Coarse gravel and sand	15 »	(4.9 »)
5.	'Brown clay and stones'	21½ »	(7.15 »)
6.	Solid rock, Old red grit	—	—

»The accompanying section, drawn to a scale of 48 feet to an inch, shows the above result in diagram form.»

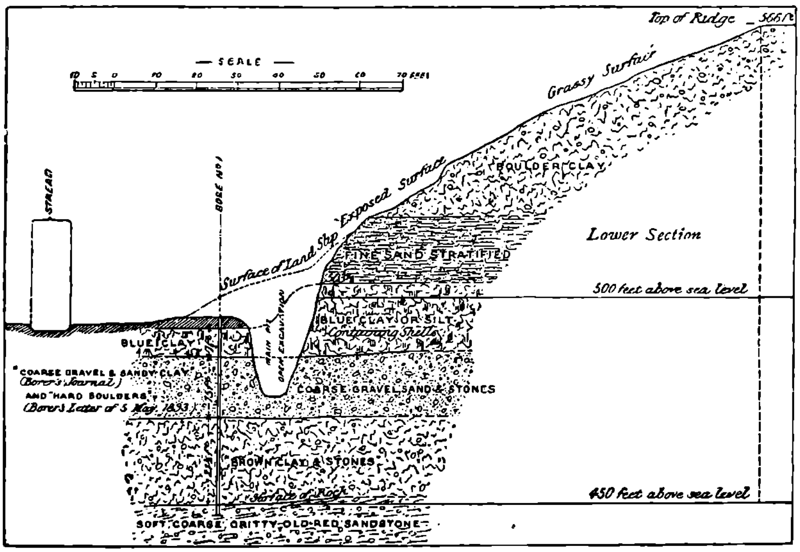

Fig. 4. — Section at 'Main Pit', Clava, to Solid Rock, (From Report 1, p. 15).

The shelly clay is described as »a tenacious clay or silt of a blue dark grey colour, save the lowest 2 feet, where the tint is brownish grey. At this lower level there is an admixture of fine gravel. The boundary line between the shelly clay and underlying gravel is clearly defined. — — There are slight traces of stratification in the blue clay. — — At a depth of 6½ or 7 feet, horizontal streaks or thin layers of sand or fine gravel occur, but not in continuous layers.»

»The upper 12 feet of blue clay is almost free from stones.» Especially near the bottom of the layer a few stones are found with marks of *balanus*, »two small stones with several nearly entire balani.» The stones met with are usually well-rounded, only a couple of them are striated.

»Shells are found throughout the whole of the blue clay — — most abundant at a depth of 2 or 3 feet from the top. Many of the shells are quite whole at all depths — — fragments of *Mytilus* rather numerous — —», the prevalent species being *Litorina litorea*.

»In the case of many of the shells the epidermis is in perfect preservation — — — some of the bivalves, such as *Astarte*, with both valves attached, showing no signs of abrasion — —» but »with both valves crushed together.»

»The absence of icemarkings on the shells is a remarkable feature, which serves to distinguish the Clava shelly clay in one particular from the shelly boulder clay of Caithness and Orkney. In the latter many of the shells are striated like the stones in the deposit» (l. c. p. 5).

The fossil remains found in this shelly clay belong for the most part to *Mollusca*, *Ostracoda* and *Foraminifera*. As the *Mollusca* are of the greatest importance for deciding the question of the physical-geographical conditions under which the layer is deposited, it will suffice to have regard only to them.

	"From upper part of main section"[1]	From various parts of section ("general-sample")[2]	Horizontal distribution (Britain a. (or) Norway)	Bathymetrical distribution (Britain a. (or) Norway)	*Remarks:*
				Metres	
1. *Mytilus edulis* L.	×	×× (?)	w.	0—20	
2. *Leda pernula* MÜLL. (incl. var. *macilenta* STEENSTR.)	×× (?)	××	N(a)	40—300	
3. *Yoldia lenticula* FABR. (= ? *Leda pygmæa* MÜNST.). .	×	×	N(a)	40—600	
4. *Nucula tenuis* MONT.	×	×× (?)	w.	10—280	
5. *Astarte elliptica* BROWN (= ? *sulcata* DAC.)	×	××	N.	10—100	
6. *Astarte banksii* LEACH. (= *compressa* MONT.)	—	×	N.	10—200	Most northern occ. = W-Norway.
7. *Lepton nitidum* TURT. . . .	×	—	S.	20—175	
8. *Cardium edule* L.	—	A small fragment	w ?	0—10	
9. *Axinus flexuosus* MONT. . .	One	—	w.	20—850	
10. *Tellina calcarea* CHEMN. . .	×	A small fragment	N(a)	0—80	
11. » *baltica* L.	×	××	w.	0—20	

[1] Dr. ROBERTSON's and Mr. BENNIE's list (1893) embracing shells "from the uppermost 6 feet of the shelly clay".

[2] Dr. ROBERTSON's and Mr. FRASER's List (1882).

	"From upper part of main section"	From various parts of section ("general sample")	Horizontal distribution (Britain a. (or) Norway)	Bathymetrical distribution (Britain a. (or) Norway)	*Remarks:*
				Metres	
12. *Trophon clathratus* L. . . .	—	×	N(a)	10—570	Common in N-Norway; rarer and smaller towards South (W-Norway). (Cf. SARS, l. c., p. 248). Not known in British seas?
13. *Neptunea antiqua* L. (= *Fusus antiquus*)	One, young	—	S.	40—95	Most northern occ. = W-Norway.
14. *Buccinum undatum* L. . . .	+	××	N.	0—300	
15. *Natica grönlandica* CHEMN.	×	×××	N.	40—100	
16. *Bela (Pleurotoma) turricula* MONT. (= *B. harpularia* COUTH, SARS).	×	×	N.	20—200	
17. *Bela (Pleurotoma) trevelyana* TURT.	+	One	N.	12—190	Most southern occ. = Island Lofoten. Not known in British seas. (Cf. SARS, l. c., p. 228—229.)
18. » » *nobilis* MÖLL.	+	—	N(a)	40—230	
19. *Litorina litorea* L.	×××	×××	N.	litoral	
20. » *rudis* MATON. . .	×	×	W.	litoral	
21. *Homalogyra atomus* PHIL.	—	One	W.	litoral	
22. *Margarita (Trochus) helicina* FABR.	×	× (?)	N.	0—40	
23. *Margarita (Trochus) grönlandica* CHEMN.	×	× (?)	N.	0—190	

The number and parentage of species belonging to the different areas of horizontal distribution are as follows: —

		Number.	Percentage.
Species with *wide* distribution	=	7	*30.4*
» » *arctic* »[1]	=	5	*21.8*
» » *northern* »	=	9	*39.1*
» » *southern* »	=	2	*8.7*

With respect to the character of the fauna the Committee are, in the main, right in saying that »Though the fauna is not intensely Arctic, it implies colder conditions than the present» (Report, page 29). The two *southern* forms, however, (and especially *Lepton nitidum*, that is met with

[1] These species now extinct in British seas.

in »one entire and a few valves») indicate that the part of the clay which contains them has been diposited under less severe climatic conditions than the other layers, the most northern known occurrence of these two forms now-a-days being W-Norway. Probably, therefore, a difference of the character of the fauna at different levels is to be found also in the Clava section, though that difference is likely not so distinct as that of the Cleongart section with its richer temperate fauna in the layers between the samples No. VIII to X [of more than 6 feet (2 metres) in thickness].

Regarding the bathymetrical conditions under which the Clava shelly clay has been deposited, the Committee say as follows: — »The shells are chiefly shallow-water species; some might have lived at depths varying from 15 to 20 fathoms» (30 to 40 metres) »or in shallower water near the shore, but the majority are littoral forms».

According to the common definition of »shallow-water» and »litoral» (see above page 398) it is a contradiction to say that the shells are »chiefly shallow-water species» and »the majority are littoral forms», unless »the majority» has regard to the number of the individuals, the litoral *Litorina litorea* being in this case the prevalent shell». Such species as *Leda pernula* and *Natica grönlandica*, both »moderately common» and »common» respectively in the Clava clay, indicate, I think, a deposition of the clay containing them at a *minimum-depth* of about 40 metres[1]. As *Litorina litorea* is said to be very common in »various parts of section» I feel inclined to favour Mr. SMITH's opinion[2] so far, that the clay has been formed (not in »deep water» but) *in the shallow-water region* and that litoral shells and stones have been transported by ice (and algæ) from the adjacent litoral belt and dropped at greater depths in the clay.

Before a detailed stratigraphical-palæontographical examination of the different layers has been made, one cannot decide whether alterations of the shoreline have taken place during the deposition of the shelly clay.

The highest part of the shelly clay in the »main pit» being $503\frac{1}{2}$ feet (165 metres) above the level of the sea, the clay (at least partly) has probably been deposited when the district was submerged to an extent of *at least about 540 feet (177 metres)*.

The majority of the Committee are right, I think, in assuming that the clay is really *in situ*. Except the »assemblage of organic remains and their mode of occurrence» referred to above, »the proved extension of the bed» — *beeing at least 190 yards (187 metres)* — »and its apparently undisturbed character» point in the same direction.

Add to this that (as Mr. ROBERTSON points out, Report p. 21) »if

[1] In fully arctic districts these and some other northern forms are certainly found at lower depths, but as we in the case before us have probably not to do with such fully arctic conditions, we may take regard only to the present bathymetrical distribution in the district "Britain and (or) Norway".

[2] Geol. Mag., 1896, p. 498—502.

we suppose that a transportation of the deposit has been effected by ice action, it is difficult to see how — — the sand overlying the shelly clay (could be) so fine and so free from stones (those found in it being not much greater than a pea), or how the different strata of the shelly clay, the sand, and overlying boulder clay could be laid down so sharpely defined, the one over the other, if crushed up to their present position by ice in any form».

These other layers in the Clava section may now be briefly mentioned.

The undermost layer No. 5, that rests directly on the solid rock, is described as 'brown clay and stones', 21½ feet in thickness, and is known only from boring operations. The only organisms obtained by Mr. ROBERTSON from the sample of this deposit are some Foraminifera. »From the evidence at their disposal the Committee do not feel justified in forming a definite opinion regarding this deposit» (Report p. 14). Professor JAMES GEKIE (in his »Great Ice Age» 3 Edit.; 1894, p. 140) does »not suppose there can be much doubt that it is 'boulder-clay'». Mr. SMITH (Geol. Mag., 1896, p. 501) is of the same opinion, and I am inclined to agree with them. The occurrence of Foraminifera in it need not astonish us, this kind of fossils, as is well known, being common in the boulder-clay of many districts.

For the determination of the real age of the shelly clay it would have been of a very great interest, had the true character of the layer No. 5 been decided. In case the layer should be proved to be representative of an older glaciation, it would follow, that the shelly clay is really of an *interglacial* age.

No. 4: — Coarse gravel, sand and stones, 15 feet in thickness, of a yellowish brown colour, in some parts roughly stratified; a few of the blocks were striated, most of them rough and angular at the edges. A few *Foraminifera* were also here the only organisms met with. Mr. SMITH considers this layer to be the »basal (marine) gravel of the interglacial Period», but I hold it more likely that it is of about the same origin as the former (No. 5), that is to say probably a more sandy bottom-moraine. According to ROBERTSON a bore-sample of it contains mud, 40 per cent; sand, 30 per cent, and gravel, 30 per cent (Report p. 10), which result seems to justify its being set down as a boulder-clay. Their are at all events no reasons of any greater importance for regarding it as a shore-gravel.

The sand-layer (20 feet in thickness) over the shelly clay, according to Mr. ROBERTSON, »had much the character of blown sand» (Report p. 20). It contains a few small stones, but no organic remains have been found in it. The boundary line between the underlying shelly clay is nearly horizontal, and clearly defined, but between the sand and the overlying boulder-clay less distinct[1].

[1] Mr. SMITH's interpretation of the sand-layer as formed by "bottom-currents" and as a sand, "that was at one time filled with shells, which have been dissolved away by acidulated water", seems to be very unlikely.

In the boulder-clay too no organic remains have been found.

I shall now touch upon the most important »difficulties» objected to the opinion that the Clava shelly clay is *in situ*, partly by Messrs. BELL and KENDALL, the minority of the Committee (in Report, p. 30—32), partly also by Mr. BELL in later papers, and to a certain extent discuss that important question und illustrate it partly by my own experiences from North Germany and Denmark.

»On the one hand» the minority say, »if we conclude that it (the deposit) is really in place as part of an ancient sea-bottom, and so indicates a submergence of over 500 feet, then it is hard to account for the absence, not only of shell-beds, but of all other traces of the sea over the country generally at a similar level, and at hundreds of intermediate levels down to that of existing tides.» — — — »It seems difficult to believe that a 'second glaciation' — — could remove *all* such traces from hundreds of localities all over the country — —» and »It is also difficult to see how the 'upper boulder clay', said to have been formed by the 'second', or post-submergence, glaciation could fail to be thickly charged, in almost every locality, with remains of marine organisms derived from the miles upon miles of former sea-bed over which the ice must have passed.» Dr. JAMES GEIKIE (l. c.) has raised some objections to these opinions of the minority, pointing out that the rare occurence of marine deposits and shells of the date in question is due to the succeeding glaciation. Dr. GEIKIE says (l. c. p. 142) »— — so long as the ice-movement continued sub-glacial erosion would be carried on, and ground-moraine would travel outwards from what are now our coast-lands. Thus, by-and-by the supply of shelly deposits at and below the level of 600 ft. would tend to become exhausted, and the boulder-clay continually passing outwards from the land would eventually contain no shells. — — The ground-moraine formed during the earlier stage, when the ice-sheet first advanced over the shelly sands and clays, must now lie beyond our coast-line. — — The shelly till of Caithness was formed under exceptional circumstances. The ice that overflowed that region reached it only after travelling continuously for a long distance across a sea-bottom. It is worthy of note, moreover, that the shells in that till become gradually less common as we recede from the east coast, suggesting, as I think, that they tended to be crusted and obliterated as the till was dragged forward.»

In my opinion Dr. GEIKIE's interpretation of the conditions above mentioned is the most probable and in a simple and natural way explains the »difficulties» in question.

The rarity of traces of interglacial fossiliferous deposits is not, in fact, peculiar to Scotland and the whole of Great Britain. On the contrary, it is or — as far as certain districts are concerned — until recently has been a common feature of most previously glaciated countries. I said »has been», because in some districts as North Germany, Denmark etc.

the rarity of traces of veritable interglacial deposits is only seeming, such deposits having of late years been met with in a far greater number than one would have expected some 10 or 15 years ago. Probably, therefore, this is also the case with respect to (some districts of) Scotland etc., the very interesting locality at Cleongart having been discovered only a few years ago!

Also in North Germany and Denmark the »upper boulder-clay» in places directly overlying the interglacial veritable marine »Cyprina-clay» is commonly wanting in larger shells of Mollusca etc., while on the other hand shells of Foraminifera are often met with. Sometimes all the *calcareous shells* in the »Cyprina-clay» are dissolved, only the epidermis of the shells being left in closed cavities, which were previously taken up by the shellfragments, while the siliceous skeletons of Diatoms are in a good preservation [1]. Singularly enough, the reverse is sometimes the case, as I have found by the examination of shell-bearing marine interglacial clays for e. from Hiddensö, island Rügen (see MUNTHE l. c. p. 43) and — from Cleongart (see above!).

As has been said before, a deposition of the Cleongart marine layers cannot well be supposed to have taken place in an *extra-glacial lake* and on account of the great agreement that seems to exist between the shelly clays at this locality and that of Clava I cannot but think with Mr. SMITH (l. c.) that Mr. BELL's hypothesis is not at all applicable even to the Clava deposit.

Like the Cleongart shelly clay that of Clava may also be a veritable marine deposit in situ, indicating a submergence of land to the extent of *at least* 540 feet (177 metres). If this be so the marine clay at both these localities has in all probability been formed during the same interglacial epoch during a space of which the climate was nearly as temperate as that of Scotland at the present day.

As has been proved by the examination of the Cleongart section, the climatic conditions were arctic or nearly so at the beginning and the end of that epoch. It has, without doubt, been truly remarked by Mr. BELL that »submergence, by diminishing the extent of high land and more freely admitting the ocean-currents, must have been favourable to milder climatal conditions» and not *vice versâ* as Dr. GEIKIE thinks. The Cleongart section also illustrates that fact.

To what extent other parts of Great Britain too have been subject to the interglacial submergence, is, it seems, not easy to decide at present; I shall not, therefore, now enter on that question more narrowly. With many geologists I think that a good deal of the so-called »shelly

[1] See MUNTHE, in Bull. geol. Inst. Upsala, No. 5 (1896) p. 56.

[2] Geol. Mag. 1895 p. 278—279.

boulder-clay», »shelly till» and »shelly gravel» at different levels (as in Wales, in Ireland and partly also in Ayrshire) may in many cases really be considered as transported by an ice-sheet often from lower levels to higher. The» old sea-bottom», however, from which those shells and shelly deposits have been derived, may in many cases have been of the same age as that at Cleongart and Clava described above.