

VIII. *On the Shell-bearing Clay in Kintyre.* By A. JESSEN, of
the Geological Survey of Denmark.

(Read 18th January 1900.)

IN the spring of 1899, when I visited Scotland, Mr J. Horne, F.R.S.E., F.G.S., and Mr B. N. Peach, F.R.S., F.G.S.—to whom I am much indebted for assistance during my journey—advised me to go to Kintyre, where some of the best sections in Pleistocene shell-bearing deposits occur.

Amongst the exposures of these deposits on the west side of Kintyre, north of Machrihanish Bay, the two southern localities, in Tangy Glen and Drummore Glen, are of less interest, partly because the sections are very indifferent. Only the northern locality, in Cleongart Glen, close to Bellochantuy, shows a good section with an abundance of shells.

The shell-bearing deposits were investigated by a committee¹ appointed by the British Association in 1895-6 with the view of ascertaining whether these layers are marine and *in situ*, showing a submergence in Pleistocene (interglacial ?) time, or if they have been carried to their present place by ice.

I shall briefly recapitulate the results of the Committee's examination.

In the main section on the south bank of the burn, the Committee found in the bottom of the glen, crystalline schists, which, a short distance westward, are covered with Upper Old Red Sandstone. Above the mica-schists "a bed of compact coarse sand and gravel," probably 10 feet thick, was found by digging, but owing to the percolation of the water, the cutting was not continued downward to the solid rock. Resting upon the gravel lies the shelly clay with a thickness of 27½ feet; this again is covered with boulder clay, 74 feet thick.

No shells were found in the gravel. The boundary between the gravel and the overlying shelly clay was sharp, and to all appearance horizontal. The lowest part of the clay was a fine shelly mud; higher up, the deposit "a stiff, dark, bluish clay" contained an "abundance of shells and a very few small water-worn

¹ "The Character of the High-level Shell-bearing Deposits in Kintyre," Brit. Assoc. for the Advancement of Science, Liverpool meeting 1896, Section C. Report of the Committee, consisting of Mr J. Horne (Chairman), Dr David Robertson, Dr T. F. Jamieson, Mr James Fraser, Mr P. F. Kendall, and Mr Dugald Bell (Secretary). (Drawn up by Mr Bell, Mr Fraser, and Mr Horne; with Special Reports on the Organic Remains by Dr Robertson.)

stones; one stone, the largest found in the trench, appeared to be finely striated." The included blocks, the average size of which varies from 1 inch to 3 inches across, are commonly well rounded, a few are angular, but none striated; they are chiefly of local origin, but no fragments of the Old Red Sandstone, occurring to the west of the section, were found. The top of the clay was, like the lowest part, comparatively free from stones.

The shells were found in abundance; "many were in excellent preservation, but others were broken and fragmentary. Some of the smallest shells, *Leda* and others, were entire."

The overlying boulder-clay "is of a reddish-brown colour, charged abundantly with boulders, some of which are striated. These consist mainly of crystalline schists of local origin, with a marked absence of fragments of red sandstone." On the surface of the boulder-clay in the neighbourhood boulders of the Arran granite are common, thus proving westerly movement of the ice, which agrees very well with the evidence furnished by the ice striæ on Kintyre, which nearly all have a direction from E. or E.N.E.

With the view of proving the extension of the shell-bearing clay, a series of bores was put down. The results show that the surface of the clay, which, in the section, lies 178½ feet above sea, is nearly horizontal, and that the clay probably extends more or less continuously from one glen to another, results which favour the conclusion that the clay is *in situ*.

Dr Robertson has appended to the Report a list of the organic remains from the shelly clay and some remarks on his examination of the samples. Dr Robertson mentions the occurrence at Cleongart of numerous Ostracoda, Foraminifera, etc., and 37 species of Mollusca, partly from the Committee's own collection, partly from the collection of Mr Alex. Gray, the discoverer of the section. With regard to the mollusca Dr Robertson writes: "On our visit to the Cleongart deposit no whole shells with their valves together could be seen, except one or two of the very smallest. This may be very well accounted for." The most common shells are *Astarte compressa* Mont. (= *A. banksii* Leach), *Astarte sulcata* Da C., *Cyprina islandica* L., *Leda pernula* Müll., *Tellina calcarea* Chem., and *Turritella terebra* L. Several entire specimens of the two species of *Astarte* and partly also of *Leda* were found. The two species *Cyprina* and *Turritella*, the most common shells in the section, occur only as fragments. Only *Leda pygmaea* Münst. (= *Yoldia lenticula* Möll.) has been found with the shells attached.

In Dr Robertson's opinion the samples from one (the deepest)

of the bores show three different horizons, and "that there had been at least three distinct changes in the deposition of the sediment." The lowest division contains clay "of a light-brown colour, friable and easily broken," in the next section the clay was "of a dark-bluish slate colour, hard and difficult to break," while the uppermost section, when dry, was of a light-brown colour.

The report of the Committee ends with some remarks, amongst others that "the members of the Committee have endeavoured to give 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."

This has recently been done by the Swedish geologist, Dr Henr. Munthe, who in 1897 visited the section, and who afterwards wrote a paper on it.¹

Dr Munthe has laid particular stress on the stratigraphical conditions in order to explain the mixed character of the fauna. He gathered twelve samples, each about 40 cubic inches, which were washed and later on more closely examined. These were gathered from different horizons of the section.

Dr Munthe arrived at the view that the clay is *in situ*, as formerly maintained by the Committee, and that the lower and upper parts of the clay were laid down during varying climatic conditions. The climatic conditions were northern "or partly even arctic," corresponding probably to those prevailing now in the North Norwegian seas. The clay in the middle of the section was, on the contrary, laid down during a temperate climate resembling that at present "in the W. or S.W. Norwegian seas or even more southerly."

During Dr Munthe's visit to Cleongart the undermost 6 feet of the clay were concealed by a talus; the two lowest samples (I. and II.) were therefore taken, 21 feet and 18 feet respectively below the surface of the clay. They showed a shell-bearing dark grey marl with isolated stones, one of which was striated. In No. III. sample, 16 feet below the surface, several stones were met with, but only a few shells. Nos. IV. and V. samples, 15 feet below the surface, "have the character of a veritable boulder-clay." The clay does not contain shells, but many stones, generally unstriated. The sample VI. from the layer directly above this boulder-clay contained very few shells and stones. The samples VIII., IX., and X. from 12 feet, 9 feet, and 6 feet below the surface of the clay respectively, showed a grey

¹ "On the Interglacial Submergence of Great Britain." Bull. of the Geol. Inst. of Upsala, No. 6, vol. iii., part 2, 1897.

marl with shells and stones. The two uppermost samples, XI. and XII., close to the overlying boulder-clay, are "in strong contrast to the preceding samples, being of a light brown, nearly chocolate colour, and resemble some varieties of our Swedish late-glacial marl." They are shell-bearing, but contain only a few stones, mostly angular.

Dr Munthe then examined the organic remains, *Mollusca*, *Cirripedia*, *Ostracoda*, and *Foraminifera*, found in these samples.

"The molluscan shells are often in a fragmentary condition, but the smaller of them, such 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." Only a few species occur in great number, and these are of principal importance, while "some of the others (rarely occurring) probably occupy a secondary place."

In the two undermost samples (I. and II.) the shells of *Leda pernula* Müll. and *Yoldia lenticula* Möll. (= *Leda pygmaea* Münst., Robertson) were common. These two species, now probably extinct in British seas, have a northern occurrence, and especially *Yoldia lenticula* is typically northern or even arctic (most southern occurrence: Bodö in Norway). Amongst other species of northern occurrence were found: *Leda minuta* Müll., *Astarte sulcata* Da C., *Astarte banksii* Leach (= *A. compressa* Mont. Robertson), one valve of the arctic *Cardium grønlandicum* Chem., *Cyprina islandica* L. (common), and one fragment of *Tellina calcarea* Chem.

From these facts Dr Munthe concludes that "while the deposition of the undermost portion of the marl took place, the climate was probably arctic, and the depth of the sea was probably at least about 40 metres" (132 feet), because *Leda pernula* and *Yoldia lenticula* do not live at present in the Norwegian seas at a less depth than 40 metres. "The land-ice or local glaciers surely covered the higher portions of Kintyre."

When the layer represented by No. II. was formed, Dr Munthe means that the climate must have been "a little better than before," because some fragments of species of southern occurrence (*Turritella terebra*, *Cardium* cfr. *norvegicum*, *Pecten maximus*) have been found here. In a little higher horizon of the section (No. III.) only fragments of *Cyprina islandica* and one valve of *Leda minuta* were found. Above this the thin layer of boulder-clay (IV. and V.) occurs, and over that the clay (sample No. VI., only contained *Leda pernula* and a fragment of *Cardium* sp. Dr Munthe therefore concludes that "by degrees the

climatic conditions must have been for some time more severe, and local glaciers must have filled up the pre-Pleistocene (?) valleys of West Kintyre, giving rise to the thin layer of boulder-clay." "When the layers immediately below and above the boulder-clay were deposited, the molluscan fauna was very scanty or absent (the few fragments found in III. and VI. being possibly in a secondary place)."

"At a little higher level of the section (No. VII.) some species make their appearance, such as *Leda pernula* (moderately common), *Yoldia* sp. (rare), *Astarte elliptica* (rare), *Cyprina* (rare)—all of them apparently *in situ*, the others probably not so. Amongst "the others" are *Venus ovata* and two small specimens of the southern *Turritella terebra*. "Climate moderately severe."

In the sample VIII. (12 feet below the surface of the clay) *Turritella terebra* is very common, "being the most characteristic fossil of the deposit." Besides that there have been found one small fragment of the southern *Cardium tuberculatum*, and of northern species: *Leda pernula* (rare), *Astarte banksii* (four small fragments), *Cyprina islandica* (rare), and *Tellina calcarea* (rare). From this Dr Munthe concludes: "Climate temperate. Maximum depth possibly about 25 metres (obs. *Cardium tuberculatum*), minimum depth 6 to 10 metres (*Turritella*, *Astarte*)."

The next two samples (IX. and X.) show nearly the same conditions as VIII. In both samples *Turritella terebra* is predominant, but no other extremely southern species has been found here. Amongst the more northern species are both *Leda pernula* and *Astarte elliptica*, met with in IX. and X., and also in the sample X. *Leda minuta* (rare); two small fragments of *Astarte banksii*?, *Cyprina islandica* (rare) and one fragment of *Tellina calcarea*. Dr Munthe supposes that during the formation of that part of the clay, represented by the samples Nos. VIII. to X. (between 12 feet and 6 feet below the surface of the clay) "the best climatic conditions of the whole during the deposition of the Cleongart layers occurred," and that the shells of *Ostrea edulis*, *Cardium tuberculatum*, and *Turritella terebra*, found on the surface of the section, belong to this horizon.

"Then there was a change of climate, and arctic conditions prevailed during the deposition of the uppermost layer (Nos. XI. and XII.). In these layers the arctic *Yoldia lenticula* is the most common and characteristic shell; amongst other northern species were found *Yoldia frigida* (rare) and *Tellina calcarea* (in XII., rare), and amongst southern species one perfect valve of *Nucula tumidula* Malm. (in XII.); *Turritella terebra* (in XI., rare), and one small fragment of *Dentalium entale* L. (in XII.). Dr Munthe supposes that land-ice or local glaciers occurred in

the immediate neighbourhood, and that the minimum depth of the sea must have been about 40 metres.

"Then a great sheet of land-ice at last covered the whole region, giving rise to the overlying boulder-clay." "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."

From the Cleongart section Dr Robertson and Dr Munthe determined 136 or 138 species of Foraminifera, of which 112 species are met with in Munthe's collection. Amongst these, 17 have a southern, and 5 a northern distribution. The southern species occur as commonly in those layers which contain northern and arctic mollusca as in the other parts of the clay; the most common southern species, however, are rare in the uppermost horizon (XII.) of the clay. With regard to the northern species, it looks as if they are most frequent in that part of the clay which contains temperate mollusca. "To what extent that fact is due to a secondary deposition is not easy to say." Dr Munthe "desists from discussing that question."

With regard to the Ostracoda, the examination has given results which partly but not altogether agree with the results obtained by examination of the molluscan fauna.

From the results of his examination—principally the examination of the mollusca—Dr Munthe concludes that the uppermost and the undermost parts of the clay at Cleongart "have been formed under northern (or partly arctic) conditions, corresponding probably to those prevailing now in the North Norwegian seas," and at a depth of at least 40 metres, whereas the middle part must have been deposited under conditions which correspond "to those prevailing now-a-days in the W. or SW. Norwegian seas or even more southerly" or—as Dr Munthe writes in another place—"to those of Scotland now-a-days." The stones in the clay "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 off." As shown by the overlying boulder-clay the country at a later date was covered with a great sheet of land-ice. Farther, referring to Dr Robertson's examinations, Dr Munthe thinks that the gravel, underlying the shelly-clay, is a boulder-gravel (a ground-moraine), in consequence of which he concludes that the Cleongart clay has been deposited on the spot where it is now found during an interglacial period.

Visiting Kintyre in the spring 1899 I found the section in Cleongart Glen much obscured and partly covered with talus,

in consequence of the rainy winter. Most of the talus was removed during my visit, but the lowest part of the clay, nearest the underlying gravel, I have not seen. The two foregoing investigations, however, by the Committee and by Dr Munthe, are so good and exact, and agree so well, that another detailed examination would scarcely give any new results with regard to the facts.¹ My main purpose was to get an independent view of the section, and to test the conclusions and the theory, proposed by Dr Munthe, that the section shows a variation from northern or arctic climate, through temperate to northern or arctic climate, and in this manner should represent the whole progress of one of the North-European interglacial periods. As will be seen from the following, I do not agree with Dr Munthe's theory.

The difference, specially shown by Dr Munthe to exist between the upper 3-5 feet of the clay and the lower part, both with regard to appearance and to the included organic remains, was very conspicuous. On the other hand, no line between the two horizons could be drawn; the upper part of the clay passing gradually into the lower part. The upper light-brown clay contains only very few stones, and resembles varieties of the Scandinavian late-glacial, marine clay. The molluscan fauna only showed northern or arctic species. *Yoldia (Portlandia) lenticula* Möll was especially common. The small, thin shells were all perfect; most of them had their valves united (also mentioned by Dr Robertson), and on several of the specimens the bright and shining epidermis was still seen. With the exception of a single specimen of *Astarte banksii* found on the surface of the section, I saw no other species with valves attached. I agree with Dr Munthe that this upper part of the clay was, no doubt, deposited under a northern or arctic climate, and under very calm conditions.

The underlying bluish-grey clay, of which the main part of the section consists, has a different character. The stones occur in abundance, and the shells are generally very numerous, but nearly all fragmentary. *Turritella terebra*, in particular, is very plentiful; but in spite of its frequency no entire shell has been found. Dr Robertson writes—"It is the prevailing shell of the deposit occurring in great abundance, yet I did not see one perfect specimen"; and in his list of Mollusca: "very abundant, scarcely one perfect." Dr Munthe writes—"Very abundant,

¹ In this connection I may state that—besides a great number of those species of mollusca, mentioned by Dr Robertson and Dr Munthe—I found two gastropods, new to this locality. They were determined by Mr Adolf Jensen, of the Zoological Museum in Copenhagen, as *Bela pyramidalis* Ström? and *Admete viridula* Fabr. (= *Cancellaria costellifera* Low.), both of them typical arctic species, now extinct in British seas.

several nearly perfect" The same can be said about *Cyprina islandica*, which is also very common in this part of the clay.

Sometimes small patches of coarse sand, not larger than an egg, were found in this part of the section. The stones were usually evenly distributed through the clay, some horizons, however, being more stony than others; but in no case did I see anything which could be called boulder-clay, as stated by Dr Munthe. A sample of such very stony clay almost without shell-fragments, when examined by itself, may, it is true, appear very like typical boulder-clay; but if one examines it *in situ* at Cleongart and pays attention to the surrounding clay, one is unable to draw any line between the pseudo-boulder-clay and the marine-clay. It is, no doubt, one and the same deposit.

A remarkable feature is the fragmentary condition of most of the shells. Dr Robertson tries to explain this phenomenon with respect to *Cyprina islandica* by the effect of severe frost; an explanation, however, which he thinks is insufficient to explain the broken condition of all the shells—for instance, *Turritella*. But even with regard to *Cyprina* Dr Robertson says that the case is very rare, because this shell in all the late-glacial and post-glacial Clyde-beds examined by him "is generally common, and a broken valve is quite exceptional."

Upon recent beaches it is well known that thick shells—for instance, *Cyprina*—often are found as fragments in consequence of rapid variations of heat and cold, sun and frost. But the mollusca in the Cleongart-clay have lived at the bottom of the sea in a depth of at least 100 feet, where such changes of the temperature are impossible; and not only the thick shells are broken, but nearly all the others, with the exception of a few species.

Dr Munthe explains the phenomenon by "an immense pressure" produced by the great sheet of land-ice, which deposited the overlying boulder-clay. That land-ice, advancing over shell-bearing deposits, has crushed shells in clay or sand is well known from examples in Great Britain, Germany, and Denmark. It is further well known that the clay is preserved under different conditions; sometimes with the stratification intact, sometimes contorted or completely crushed and without stratification. But a common feature of all these deposits, thus more or less destroyed by the immense pressure of the ice, is that the shells, except the smallest and most solid, are broken, but in a different way from that in the Cleongart-clay. Everywhere in disturbed shelly clay, even where the shells are broken to atoms, the fragments will be found to remain together in such a manner that the original contour of the shell is pre-

served. This is the case in the *Cyprina*-clay in the countries around the southern Baltic Sea; in the older *Yoldia*-clay in northern Jutland, in Weybourne-crag, and several other of the Cromer-deposits, etc. In the Cleongart section I dug everywhere in the clay, but I did not succeed in finding a single shell with the fragments lying together; the fragments were always found apart as "erratic boulders."

I therefore maintain that these shell-fragments of *Turritella*, *Cyprina*, etc., never existed in the Cleongart-clay as entire shells; but have been deposited there as fragments, whereas those mollusca whose shells are now found with the valves attached, or of which unbroken shells are of frequent occurrence, belong to the clay and have lived on the spot where we now find them.

A detailed examination of Dr Munthe's paper shows that the difference between the faunas in the upper, middle, and lower horizons of the clay is not so well marked as was to be expected, if those horizons represent different periods with such different climate as claimed by an interglacial period. Amongst northern species several—for instance, *Leda pernula*—are found in the horizons of the clay, indicating temperate conditions; and the opposite is also the case—for instance, *Turritella terebra*, a southern species, is found in horizons denoting northern or arctic climate. Trying to explain these facts, Dr Munthe supposes that such fragments are not *in situ*, but are derivative. Their state of preservation, however, is exactly alike in both horizons. If they are supposed to be derivative within the one horizon, they ought justly to be considered to be so within the other; no limit can be drawn.

Further, it deserves notice that in the upper part of the clay, where foreign admixture (boulders, gravel, sand) is rare, specimens of the arctic *Yoldia lenticula* are found with the valves attached, while fragments of temperate shells are absent or very exceptional, and, on the contrary, in the middle part of the section, characterised by great admixture with foreign material (boulders, etc.), fragments of temperate shells are numerous. As most of the temperate shells are only found as fragments, and their frequency in the main coincide with the frequency of foreign material (boulders, etc.), the conclusion is obvious that both shell-fragments and boulders have been borne to this place.

Dr Munthe holds that the boulders have been transported by floating ice in winter from the coast districts; but in that case the stones ought to be most frequent in the horizons of the clay indicating arctic conditions. This is not the case. In the upper and lower part of the clay the stones are rare, while they

are very frequent in the middle horizon, which indicates a temperate climate.

I suppose the conditions must have been as follows:—The country was partly covered with land-ice or local glaciers; the temperature of the sea in West Scotland, which at that time lay at a level of, at least, $178 + 132 =$ ea. 300 feet lower than at present, was nearly the same as in the north Norwegian seas now-a-days. The rivers from the glaciers carried mud and clay into the sea, where a fauna lived, characterised by *Leda pernula*, *Yoldia lenticula*, *Astarte banksii*, *Astarte sulcata*, etc. During an occasional and temporary increase of the glaciers, the ice-margin was pushed forward to the immediate vicinity of the shore. By this an older, marine, shell-bearing deposit, with a fauna characterised by *Turritella terebra*, *Litorina*, *Cyprina islandica*, *Ostrea edulis*, *Cardium*, etc., was eroded, and most of the shells crushed. The fragments, together with great quantities of clay, sand, and gravel, were carried by glacial rivers to the sea and the small bays, and deposited there in what are now glens. The distance to which they have been transported cannot have been far, as only few of the shell-fragments are rounded. For a short time the transport of clay and boulders was very considerable, the deposits formed at this period being very like boulder-clay (Munthe's samples, IV. and V.).

In consequence of the rapid supply of clay, gravel, and boulders, the animal life on the adjacent sea-shore was restricted. In the horizons of the clay (Munthe's samples, VI. to X.) deposited at this period, arctic mollusca *in situ* are very rare, and only shell-fragments derived from the denuded deposits containing the temperate fauna are found together with arctic and temperate foraminifera, etc.

At a later date the glaciers diminished, the ice-margin retreated inland, the glacial rivers decreased, the coarse material was deposited on land close to the ice-margin, and only mud and clay were carried into the sea. The arctic fauna again appeared, and the upper brown clay (Munthe's samples, XI. and XII.), with few stones, but with arctic mollusca and of typical arctic character, was deposited.

Later again the country was covered with a great sheet of land-ice, which laid down the immense layer of boulder-clay, covering the shelly clay or—as in Drummorie Glen and Tangy Glen—partly destroying it and carrying it away.

As formerly noticed by the Committee, no shells are found in the overlying boulder-clay, which is probably much younger than the shelly-clay, and the two deposits are scarcely in connection with each other.

Dr Munthe thinks that the shell-bearing clay at Cleongart is of interglacial age. Referring to some expressions in the Committee's report, he concludes that the sand and gravel lying beneath the shelly-clay is a boulder-gravel, a sandy and stony ground-moraine. This is possible, but not certain; we only know that the clay is older than the time of the formation of the overlying boulder-clay, and younger than a pleistocene marine deposit, with a temperate fauna from which the shells are transported to the arctic or northern Cleongart-clay.

Regarding this temperate fauna, characterised by *Turritella terebra*, I shall only call attention to the great resemblance between this fauna and the molluscan fauna in the boulder-clay around the Irish Sea (east coast of Ireland, Isle of Man, north coast of Wales, etc.). The shells, which are often found in abundance in this boulder-clay, are frequently as well or even better preserved than the fragments in the clay at Cleongart.

A deposit which bears a close resemblance to the shell-bearing clay in Kintyre is the "older *Yoldia*-clay" in the northern part of Jutland (Denmark). This deposit is a stiff bluish-grey clay, partly without stratification, probably laid down in connection with the greatest extension of land-ice (*Saxonian*), and showing unmistakable traces of ice action. The clay contains a marine arctic fauna *in situ*, characterised by *Yoldia* (*Portlandia*) *arctica*, *Tellina calcarea*, *Saxicava rugosa*, etc., where most of the shells are crushed, but where the small fragments are nearly always found lying together in such a manner that the contour and original form of the shells are preserved. Besides these arctic shells, however, the clay contains fragments of shells with a more southern distribution, characterised by *Turritella terebra*, *Cyprina islandica*, *Tellina balthica*, *Zirphæa crispata*, etc.; the fragments of these temperate shells are always found singly. That they occur in a secondary place and originate from older, eroded deposits is evident from the fact that they are not only found singly in the clay, but in many cases occur in patches of gravel, sand, and boulders of a morainic character embedded in the arctic clay, and probably dropped from icebergs or floating ice.