TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

I.—NOTES *on a TILL or BOULDER CLAY with BROKEN SHELLS, in the Lower Valley of the River Endrick, near Loch Lomond, and its Relation to certain other Glacial Deposits.* By ROBERT L. JACK, F.G.S., of the Geological Survey of Scotland.*

[Read 15th Jan., 1874.]

THE eastern angle of Loch Lomond is at present being rapidly silted up with the detritus carried into it by the River Endrick. Many acres of land have been gained from the Loch during the lifetime of some of the present residents on its shores. From the eastern extremity of the Loch there stretches, for some miles inland, a broad alluvial flat, through which the lower part of the Endrick pursues its crooked course. It is impossible to doubt that when the great icy graving tool was withdrawn, an arm of the newly made lake covered the site of this extensive alluvial flat. During the intensest cold of the glacial period, the valley of the Falloch (the site of Loch Lomond) was filled by an ice-sheet of immense thickness, which scored the side of Ben Lomond with striæ (parallel to the direction of the valley) to the height of 2,250 feet above, while it grated over a bottom no less than 600 feet below the present level of the sea. At this period the Menteith Hills, which rise to 1,400 feet, and whose tops present a perfect example of a *moutonné* outline on a large scale,†

* Of the facts mentioned in the following paper, those which were discovered in carrying on the Geological Survey are communicated, with the permission of the Director-General, in anticipation of the official Maps and Memoirs.

† This appearance is so marked from the southern side of the Carse of Stirling, that the range is known to the inhabitants of Kippen and Buchlyvie as "The Scolloped Hills."

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were overridden, and the Campsie and Kilpatrick Hills, though rising to 1,894 feet, were buried beneath the sheet of ice which flowed south-eastward out of the Highland glens. By contouring the bottom of the lake (from the data afforded by the soundings on the Admiralty Chart), I have found that there are no less than twelve separate basins between Ardlui and Balloch. These hollows are, without exception, elongated in the direction of the valley, and follow pretty nearly the sinuous line laid down on the Ordnance map as the boundary of the counties of Dumbarton and Stirling—a line which probably corresponds pretty closely to the course of the Falloch before Loch Lomond existed. The hollows are divided one from another, not by steep scarps, but by undulations so gentle that when the contour of the bottom is drawn to a true scale, they are hardly appreciable by the naked eye.* The shallows and deeps, when the geology of the neighbourhood comes to be examined in detail, will probably be found to correspond respectively with the outcrops of harder and softer bands of the upturned Silurian strata, which strike across the lake from south-west to north-east, and they may also be supposed to depend in some degree on the varying width of the preglacial valley.

It is not, however, my intention at present to recapitulate the evidence on which Loch Lomond is claimed as an example of a glacier-formed lake, but merely to make such a sketch of the physical geography of the district as will render intelligible the peculiarities of the deposits to be described.

It has already been observed, that when the ice-sheet was at its thickest it overflowed the Menteith, Campsie, and Kilpatrick Hills, and this is attested by the glacial striæ and the “carry” of the drift. But, as Mr. Dugald Bell has pointed out,† there were periods when the attenuated ice-sheet was divided by the minor hill-ranges that opposed its course, and was forced to round them and to stream through the valleys intersecting them from west to east. This view, I may say, is amply supported by the striæ mapped by myself in carrying on the Geological Survey;‡ the high grounds being crossed by striations from

* See Mr. J. Geikie's *Great Ice Age*. Appendix D.

† “Notes on Cross Striæ at Possil, near Glasgow.”—*Trans. Geol. Soc., Glasgow*, Vol. IV., pp. 223 and 304.

‡ The striæ referred to will be found in the forthcoming Geological Survey Sheets, Nos. 30 and 31.

N.W. to S.E., while the lower Clyde Valley, the Blane-Glazert Valley, the Endrick-Carron Valley, and the Forth Valley are swept by east and west striations.

When the ice had degenerated from a continuous "*nappe*," bearing down (in this district) from the N.N.W. to a series of separate glaciers streaming from west to east over the low passes of the Campsie Hills, the erosion of a new set of lakes would be begun nearly at right angles to the older set, and this erosion would be much facilitated by the circumstance that the courses of the protruding tongues of the shrinking ice-sheet would lie mainly among Sandstones of Lower Old Red and Lower Carboniferous age, much softer than the Silurian rocks enclosing Loch Lomond in its upper part. Theoretically, we should look for lakes in localities where the ice-streams or glaciers would be subjected to strangulation from the narrowing of their respective beds, and accordingly we find broad alluvial flats in several such situations, which it requires no great stretch of imagination to regard as silted-up lake basins, viz. :—in the Endrick-Blane Valley, the one above referred to as flanking the lower reaches of the Endrick, and which is merely a prolongation of Loch Lomond ; in the Blane Valley proper, the one extending from the confluence of the river with the Endrick to Duntreath Castle; and in the Endrick Valley, the one stretching from Newtown of Fintry to the Gonachan. In the case of the Duntreath Castle basin, the cause of "strangulation" is obviously to be found in the hard trap escarpments and magnificent volcanic "necks" overlooking Strathblane. The sudden contraction of the Endrick Valley at its issue from between the fine trap escarpments at Fintry could not fail to increase the intensity of the erosion on the site of the Gonachan basin. It is not impossible that the rock-basin of Loch Lomond may be continuous from the mouth of the Endrick up the Blane Valley to Duntreath Castle, as the rock is nowhere seen in the bottom of the valley, and the lower part of the valley is flanked by deep drift deposits, which may conceal a broad rock-basin. It is, however, probable that a gentle rise of the Sandstone bottom about Catter Burnfoot, divides this corner of the rock-basin (which, had the country beyond offered a level bed for the passage of the ice, would naturally have terminated the loch), from the depression higher up the valley, due to the strangulation of the glacier.

The elevation (20 feet) of Loch Lomond above the sea is so

trifling that there is no difficulty in classing it with the sea lochs which indent the western coast of Scotland. All these sea lochs are shallow at their outlets, and would become fresh-water lakes, like Loch Lomond, on a very slight elevation of the land. In fact, it may be regarded as in a manner an accident that Loch Lomond is not now an arm of the sea. A depression of 20 feet, or the removal of the superficial deposits traversed by its short outlet, the Leven, would restore it to its former condition.

In the course of my work on the Geological Survey to the south of the eastern angle of the Loch, and its silted-up continuation above referred to, it fell to my lot to map out a deposit whose relation to the already known members of the glacial series seemed to deserve particular attention.

The deposit is a true typical Till, in every respect analogous to the Old Boulder Clay or Till of the Lowlands of Scotland. In a matrix of stiff unstratified clay, brown in colour, like the subjacent Old Red Sandstone rock, are scattered stones of varying sizes up to several feet in diameter. These are blunted, smoothed, and marked with striations in all directions, but most frequently in the direction of their longer axes. The Till undergoes local variations, but on the whole may be described as above. It presents, however, one remarkable peculiarity to distinguish it from the common Till of the country. It contains worn and broken fragments of marine shells.

I shall now describe briefly the various exposures of the Till which have come under my observation. I am indebted to Mr. Robert Etheridge, Jun., F.G.S., Acting Palæontologist to the Geological Survey of Scotland, for naming some of the shells mentioned in this paper, and for many valuable notes. Messrs. J. Bennie and A. Macconochie also obliged me by washing a quantity of the Till for minute organisms.

ROSS BURN, ROSS PRIORY, RIGHT BANK, ABOUT 400 FEET NORTH OF 100 FEET CONTOUR LINE.—Altitude above sea level, judging by the fall from the contour line, say 80 feet. Six feet of brown Till, exhibiting—what is occasionally noticeable in the common till—a tendency to horizontal arrangement in the scratched stones. One layer, somewhat more gravelly in appearance than the rest, yielded a fragment of *Cyprina Islandica*.

ROSS BURN, RIGHT BANK, AT 100 FEET CONTOUR LINE.—20 feet of Till. Not otherwise distinguishable from ordinary till than by a rather smaller proportion of stones to clay than is usual. Stones almost all well scratched. (Observed a few of granite.) A small proportion rounded. Shell fragments scattered throughout. *Cyprina Islandica* and *Trophon clathratum* recognisable.

ROSS BURN, RIGHT BANK, BESIDE TULLOCHAN MILL LADE.—Estimated height 320 feet. Six feet of ordinary Till, with well-scratched stones in a brown matrix. Shell fragments rare, and much worn. *Astarte sulcata* recognisable.

KILMARONOCK VILLAGE, BETWEEN BRIDGEND AND UNITED PRESBYTERIAN MANSE, IN ROADSIDE DRAIN.—Height, say 125 feet. Brown Till, with shell fragments.

BLAIRRENICH BURN, KILMARONOCK —ANGLE WEST OF CAMBUSMOON COTTAGE, RIGHT BANK.—Say 130 feet high. Eight feet of Till. Matrix stiff brown sandy clay. Stones fairly numerous and large, and well scratched. Of 100 stones split up for the purpose of striking an average, 34 were Silurian, 9 quartz, and 57 Old Red, the latter being the rock *in situ*. Shell fragments numerous. The upper half of the Till rather less stoney in parts than the lower, but the shells equally distributed throughout. *Cyprina Islandica* and *Astarte sulcata* recognisable. This section is clear, and unobscured by the usual *talus* of rubbish, which is here constantly cleared away by the stream. I should particularly advise any geologist who may wish to get a fair idea of the deposit, to visit this section.

BLAIRRENICH BURN, ON RIGHT BANK BETWEEN LAST SECTION AND BLAIRRENICH COTTAGE.—Two more Sections, the lower shewing a tumbled face of about 12 feet, resting on brown flaggy Old Red Sandstone. The surface of the upper exposure is about 160 feet above the sea level. The shell fragments in both sections much broken, and rare.

CATTER BURN, BETWEEN CATTER OLD MILL AND LOW GARTACHORRANS.—Height of surface, say 125 feet. 40 to 50 feet of well-marked brown Till, full of scratched stones, and containing a few fragments of *Cyprina Islandica*, and a whole valve of *Astarte compressa*.

RIVER ENDRICK, RIGHT BANK, BETWEEN RAILWAY BRIDGE AND PARK OF DRUMQUHASSLE.—Till like that on Catter Burn, from level of river up to about 8 feet higher. Altitude of surface of Till, say 35 feet. Fragments of shells numerous, but very frail and imperfect. *Cyprina Islandica*, *Astarte sulcata*, and a fragment of *Balanus* were recognisable. The following were got on washing the clay (the list is by Mr. Etheridge):—

Globigerina bulloides, D'Orb.

Lagena globosa ? Montagu.

„ *marginata* ? Montagu.

„ *sulcata* ? W. & J.

Polystomella striato-punctata, F. & M.

„ (*nonionina*) *depressula* ? W. & J.

In addition to the foregoing, the remains of the spine of an echinoderm, and a small roundish body which has the appearance of a much worn case of an entomostracan, were found; and also what appears to be the seed of a plant with a triradiate star on the surface, closely resembling the seed of the Carboniferous genus *Flemingites* of Carruthers.

In the above description nothing has been said of the relations of the shelly Till to other deposits. I shall now indicate what was observable on that point.

In Catter Burn, Ross Burn, and the higher sections on Blairrenich Burn, the shelly Till, although only in a few places

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actually seen in contact with the rock, is generally seen so near the latter that no other superficial deposits of importance can be supposed to intervene. It is possible that farther to the south-east the shelly Till may shade into the "true Old Boulder Clay;" and I confess that but for the shell fragments of the one, I should be unable to distinguish it from the other. On the other hand, it may be that the remains of a "true Old Boulder Clay" will be found to underlie the shelly Till; but I have not yet recognised them there. I believe, nevertheless, on grounds to be presently stated, that the shelly Till has its place *above* the Old Boulder Clay.

I am well aware that it is sometimes difficult to distinguish a clay of marine origin, when it happens to be crowded with dropped stones, from a true Till, the product of land-ice, and that careful investigation has often proved that animal remains said to have been found in the till, really came from stratified beds separable from that deposit. But I am confident that in this case the fact of the dispersal of worn shell fragments through the Till itself will stand any test to which it may be put. Moreover, the deposit, although fossiliferous, so exactly resembles the true Till elsewhere, that there is no good reason why an origin of a different nature should be assigned to it.

On referring to the Ordnance map,* it will be observed that the shells have been nowhere detected in the Till more than a mile south of the eastern part of Loch Lomond and its silted-up continuation. The farther the Till is traced from the Loch, the more rare and fragmentary do the shells become. The shells in the Till are as much boulders as the scratched stones themselves; and just as the boulders decrease in size the farther they have travelled from the parent rock, so also do the rubbed and crushed shells of the Endrick Valley Till.

The explanation which, I believe, agrees best with the facts observed with reference to the Till in question, is the same in principle as that supported by Mr. James Croll for the Shelly Till of Caithness.† The Till is, I believe, a product of land ice—the *moraine profonde* of a large glacier which filled up

* In the preceding and following descriptions of sections it is intended that the exact localities referred to should be capable of identification with the aid of the 1-inch Ordnance map.

† "The Boulder Clay of Caithness, a product of land ice."—*Geol. Mag.*, Vol. VII., p. 209.

the lake, covered the islands—two of which rise to over 200 feet in height—and climbed the rising ground between the Leven and the Endrick to the height of 320 feet at least.

This glacier, in all probability, existed during the latter portion of the period (preceding the “great submergence” of the land) to which the confluent ice-sheet is referred. Professor A. Geikie, F.R.S., Mr. James Geikie, Mr. Bennie and others, have adduced proofs that the great ice-sheet period was interrupted by several intervals of milder conditions, when the ice melted from land and sea, and marine and terrestrial faunas and floras were re-established. Professor Geikie first drew attention to the stratified beds intercalated with the Till,* and Mr. James Geikie has recently given them a new importance by bringing forward evidence of the presence in Britain of palæolithic man at the time they represent.†

At the height of the glacial period the Irish Sea and the North Sea were both filled up with true land-ice, so that probably every form of marine life, except perhaps a few minute and hardy Foraminifera and Entomostraca, was banished for a time from our shores, at least as far south as the Bristol Channel. Whenever, therefore, the remains of a marine fauna are found among the deposits of this period (prior to the submergence), a mild interval must have intervened of sufficient duration to admit of the northward migration of the species from the habitats to which they had been driven by the protrusion of the ice. When, however, shells are found diffused throughout the Till itself, they must either, (1) have been derived from stratified beds deposited before the glacial period or during one of its milder intervals, or (2) they must have been living when the ice-sheet protruded itself over the sea bottom which they inhabited. If we account for a “shelly till” by the latter theory, we must suppose that the outer submarine edge of the glacier ploughed up the superficial deposits, including living and (if any) fossil marine animals, and that the confused mass thus pushed forward by the ice would be further augmented by the properly so-called terminal moraine—the accumulation of rock debris which had travelled *on* or *in* the glacier from the inland mountains to its outer edge. But such an accumulation, and especially its upper portion (the terminal moraine), could not fail to present a recog-

* *Trans. Geol. Soc., Glasgow*, Vol. I., Pt. 2 (1862).

† *Geol. Mag.*, Vols. VIII. & IX. (1871-72). See also *The Great Ice Age*.

nisable stratification, the characteristic mark of arrangement by water. The Endrick Till at least, as has been already insisted on, possesses by no means this character. Moreover, instead of being distributed throughout the Till pretty equally over an area of a good many square miles, as in the case in question, the shells would be found only along one or more lines or bands, marking the successive limits of the extension of the glacier. This will be better understood by reference to diagram, fig. 1.

Fig. 1.—End of Glacier at three successive stages.

Let us suppose that after a mild period the ice has retired and the sea has resumed possession back as far as the point x . A marine fauna has been established over the sea bed back to x . The glacier now advances to the line A, where it leaves a belt of superficial deposits (mingled with exuviae of animals) ploughed up from the space between x and A. The glacier once more retires to x , and re-advances to B, to which line it pushes the deposits accumulated between x and B. A similar sequence of events takes place when the ice retires to x and re-advances to C. If the ice at its second or third advance reaches as far as A or beyond it, the debris (including animal remains) is pushed forward, and forms a belt as before. As I understand this theory, it demands that shelly boulder clays (perhaps *all* boulder clays) can only occur in heaps along the outer limits of a glacier, and can only be formed while the outer edge of the glacier is *advancing*.

We are forced, therefore, to return to our first assumption, viz., that the broken shells in the Till have been derived “from stratified beds deposited before the glacial period, or during one of its milder intervals.” It seems much more probable that the shells lived during one of the mild intervals towards the close of the “pre-submergence” period, than that they are of pre-glacial age. In the latter case, the shells would have been

crushed, and jostled, and ground along with the other materials of the *moraine profonde*, under the enormous pressure of an ice-sheet thick enough to leave on the sides of Ben Lomond the markings already referred to, and to surmount the Campsie Hills. In such circumstances they could hardly have escaped being crushed to powder. Further, the shelly boulder clay would in that case surely have been, at least in parts, eroded and cut into by an unfossiliferous Till belonging to some of the subsequent periods of glacial extension. Besides, the long eastern tongue of the Loch, now silted up, would not be eroded till the ice-sheet had ceased to be confluent, and had sent a spur up the Endrick-Blane Valley; and judging from the direction of the glacial striæ and the positions where the shelly Till has been observed, for instance, in the Catter Burn, the latter is more likely to have derived its shells from the silted-up corner than from a fjord of the dimensions of the present lake.

On Ross Burn, at a lower level than the lowest exposure of the Till on that burn—say 65 feet above the sea—there is a section as follows:—

- b. Coarse gravel, old alluvium of burn. 2 feet.
- a. Stiff iron-bound gravel: stones not large, generally of shingly shape, many scratched; alternating with clayey sand. The whole full of broken shells, of which the following were alone recognisable:— 4 feet.

Cyprina Islandica.

Mytilus edulis.

Astarte compressa, Mont.

Littorina litorea.

Trophon, *Sp.*

This deposit has a sort of dip or cross-bedding inclined towards the Loch. From the fact that the shells of the Till are all present in this deposit, and are also in better preservation, it is possible that those in the Till were derived from the stratified beds, and not *vice versa*. It is possible, in short, that we have here a fragment of the marine bed that supplied the shell-boulders to the Till, the scratched stones accompanying the shells having been washed from an older boulder clay. In that case its deposition would imply a depression of 65 feet with reference to the present sea level. I could, however, see no direct evidence on this point from superposition.

I have been careful to give the heights of the various expo-

tures. At all events, it is useful knowledge. But, on the assumption that the shelly Till is a product of land ice, the mere altitude at which the shells are found proves nothing as to depression of the land, but only gives a minimum thickness for the glacier whose *moraine profonde* it is supposed to be. The presence of the shells in the Till proves, however, that when they lived the land was, at or below its present level, as a very slight elevation of the land would have made the fjord a fresh-water lake.

In its passage over the bed of a fjord, such as interglacial Loch Lomond, a glacier would sweep up dead shells, whether lying loose on the bottom or buried in clay or gravel beds. These, and many rolled water-worn pebbles, would be mixed up with striated stones and other materials of the *moraine profonde*. No Till that I know of is entirely free from rounded water-worn pebbles, and the shelly Till contains no more of these than are to be accounted for by its passage over an arm of the sea, and across the strike of the quartz conglomerates that go to form a great portion of the lower islands and shores of the lake.

During the construction of the Forth and Clyde Railway, some beds were discovered at Croftamie (Drymen Station),* which have an important bearing on our present inquiry. The locality is a few yards east of the stone bridge on the road from Catter Mill to Kilmaronock Parish Church.

The section in the railway cutting was as follows, the height of the surface being 121 feet above the sea:—

“Stiff Till containing a large quantity of stones, some of a round form, apparently water-worn, others angular, and many of them of great size.” 12 feet.

Blue clay, containing “a small round stone,” and near its base, which rests on broken sandstone, a fragment of a deer’s horn, $11\frac{1}{2}$ inches in length, and the following shells:— 7 feet.

Cyprina Islandica.

Astarte compressa.

Fusus antiquus.

Littorina litorea.

Balanus.

* “Memorandum of shells and a deer’s horn found in cutting of the Forth and Clyde Junction Railway, Dumbartonshire.” By James Macfarlane, W.S., communicated by John Alex. Smith, M.D.—*Proc. Roy. Phys. Soc., Edin.*, Vol. I. pp. 163 (26th March, 1856) and 247. See also Geikie, *Trans. Geol. Soc., Glasgow*, Vol. I., Pt. 2, p. 70.

Fig. 2.

Section from Catter Burn, near Gartocharrans, to Forth and Clyde Railway.

(Scale 120 feet to the inch.)

c. Shelly Till 12 feet thick at the railway cutting—40 feet at the burn.

b. Clay with marine shells and reindeer's horn—6 feet thick.

a. Old Red Sandstone.

Professor Owen described the antler as being that of "a young or female reindeer of the existing species; and it, as is most probable, a female, of the large variety called 'Carabou' by the Hudson's Bay trappers."

The railway cutting at this point is only 220 yards to the north of the bluff of Till with a few shell fragments already described as occurring in Catter Burn. At the present day, the "facing" of the cutting obscures the geology, but the Till may be seen here and there at the top of the section, and the rock at the bottom. In one place (west of the bridge) a laminated clay is seen resting on the rock. The Till of the cutting, as far as one could judge from digging with a hammer, exactly corresponds with the Till of Catter Burn close at hand; and I have no doubt whatever that it is the same deposit. The shells, as already mentioned, are very scarce in the Catter Burn Till, and I do not wonder that in the neighbouring Till of the railway cutting they should have escaped observation. Indeed, I should have been much surprised if they had been discovered except by a person who came to look for them, convinced that they were to be found. I confess that I had mapped the Catter Burn Till as an ordinary till, nothing unusual having been observed in it, until on finding shell fragments elsewhere I came back to look for them there.

Unfortunately the section on the burn is tumbled and confused at this point by débris; but from what is to be seen, I infer that the shelly Till occupies the whole bank from the top to the rock, near the level of the stream. Fig. 2 is a section on a true scale from Catter Burn to the railway.

We have here additional evidence of an interglacial period before the great depression, when the sea resumed its sway over the Loch Lomond fjord and the reindeer browsed on its shores. The depression at this time amounted to a minimum of 108 feet (120 - 12). Afterwards—still before the great submergence—the glacier again filled up the valley, and mounted the rising ground between the Lower Endrick and the Leven to a height of at least 320 feet.

The chief reason for dating the shelly Till before the great submergence has not yet been touched on. It is found in the direct infraposition of that deposit to a series of sand, gravel, and clay beds so thick, and rising to such a height, that no other submergence of which we have any proof is sufficient to account

for it. On the bank of the River Endrick, near the Park of Drumquhassle, the shelly Till is succeeded by a considerable thickness of mud, finely laminated clay, sand, and gravel. The section has been rendered rather indistinct by landslips, but the superposition of the stratified bed on the Till is unquestionable. Mounting the bank at this point, the stratified beds can be traced north-eastward along the railway nearly to Balfron Station; northward they can be traced beyond Drymen; eastward (in a fragmentary and denuded condition) to near Killearn; and southward to Craighat on the Stockiemuir Road. It thus covers, either continuously or in detached fragments, an area which I estimate at about five square miles. Its junction with the shelly Till, on the bank of the Endrick, stands about 35 feet above the sea, and the deposit rises near Cairnlee to 262 feet, it being continuous between these two localities. I have only seen the shelly Till underlying it at the railway bridge spanning the Endrick; but the railway cuttings and several streams, which make deep sections of the superficial deposits, expose an underlying till which is, so far as I have seen, without shells. Among these streams are Drumbeg Burn, east of Drymen, the Allt Quhar, the Endrick, near Gartness Corn Mill, and the Carnock and Dault (Dhu Allt) Burns. According to the theory of the origin of the shelly Till above presented, I should consider it possible, though not very probable, that in the two last localities that deposit should be present. In the other cases I should think it hardly possible.

It will be obvious that a stratified deposit of the extent and at the altitudes of the one above referred to, is of great importance and deserves close investigation. I cannot, however, in the meantime, do more than refer to some of its most salient features. To a geologist who could have been on the spot while the excavations for the railway were going on, much information, now lost, would doubtless have been accessible.

Generally speaking, the stratified sands, clays, &c., form soft, undulating, round-backed hills, very much resembling the "drums," which form a characteristic feature of the Till in some parts of the country. The drum in the case of the Till, however, I believe, with the majority of geologists, to be the shape in which the deposit was made; while in the sand and clay "drums" the manner in which the stratified beds are cut off by the slopes of the surface proves that their shape is due to denudation. (It

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must be remembered that I am not describing kaims.) Occasionally, as at the Dunmore Tilework, near Gartness, the surface is flat, a circumstance due, I believe, to the fact that the denuding forces—probably subaërial—found it easier to remove a sand bed from the top of a clay bed, than to excavate the clay bed itself. The stratified beds generally, as seen in the railway and stream cuttings, are approximately horizontal, those of sand and gravel being frequently cross-bedded and abruptly cut off, as if denuded by streams or currents. The sand is sometimes a remarkably fine, white, soft dust, like flour. Perhaps, however, the most remarkable portions of the beds now exposed are those to be seen in the railway cutting near Gartness Station, where “ballast” is being dug. Here is seen a thickness of about 15 feet of sand, with cross-bedded patches and nests of gravel and clay, having near the top (covered in one place by 2 feet of stratified clay) a bed of stiff clay full of stones, some of them water-worn, the greater proportion blunted, like the stones of a till, and a few striated. The stony clay probably indicates the agency of ice—possibly floating ice—during the submergence period; but I do not care at present to hazard any more definite suggestion regarding it. At Drumquharn Tileworks, 8 to 12 feet of fine laminated clay overlies a bed of sand and gravel, which is iron-bound at top, 18 feet deep at least. I was informed that shells are sometimes got in the sand, but the manager of the works had seen none.

On the north side of the road above the railway, between Gartness Station and the Allt Quhar viaduct, the gravel has yielded shells. These were found in a fragmentary condition, and much rolled and water-worn. The following shells were recognised by Mr. Etheridge :—

- Balanus*, Sp. (fragment).
- Anomia*?
- Pecten Islandicus*?
- Cyprina Islandica*.
- Mytilus*? (fragment).
- Astarte compressa*, Mont.
- A. sulcata*, Da Costa.
- Littorina litorea*.
- Trophon clathratum*, Linn. = *Fusus scalariforme*, Gould.
(A worn specimen.)
- Buccinum* (fragment).

Mr. Thomas F. Jamieson, F.G.S., in his well-known paper

"On the History of the Last Geological Changes in Scotland,"* describes shortly the stratified beds above referred to, and gives the following list of shells obtained, in 1864, from a point on the railway cutting about 120 feet above the sea-level :—

SPECIES.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the E. Coast of N. America.	Living in the N. Pacific.
<i>Anomya ehippium</i> , Linn.	x	x	x	x	
<i>Astarte compressa</i> , Mont.	x		x	x	
<i>A. sulcata</i> , Da Costa, var. <i>Elliptica</i> , Brown.	x		x	x	
<i>Baculum undatum</i> , Linn.	x	x	x	x	
<i>Cardium echinatum</i> , Linn.	x	x	x	x	
<i>Cyprina Islandica</i> , Linn.	x	x	x	x	
<i>Littorina litorea</i> , Linn.	x	x	x	x	
<i>L. squalida</i> , Brod. and Sow.			x	x	
<i>Mya truncata</i> , Linn.	x	x	x	x	x
<i>Natica affinis</i> , Gmelin = <i>N. clausa</i> , Brod. } and Sow.			x	x	x
<i>Pecten Islandicus</i> , Müller.			x	x	
<i>Tectura virginea</i> , Müller.	x	x	x	x	
<i>Trophon clathratus</i> , Linn.			x	x	
<i>T. truncatus</i> , Strom.	x		x	x	

	Per cent.
British,	71·4
Southern,	50·0
Arctic,	100·0
N. E. American,	92·8
N. Pacific,	14·2†

The Rev. H. W. Crosskey, F.G.S., also made a list of the shells from this locality, which has, however, not yet been published.

In a gravel pit at Wester Gateside, near Drymen, on the road to Gartness, I found, at the height of 210 feet, rolled fragments of the following shells :—

* *Quart. Journ. Geol. Soc., Lond.*, Vol. XXI. (1865), p. 161. See especially p. 172, and Appendix, No. 4.

† Since the above was written, I learn that Mr. Jamieson also saw in 1864, "near the Endrick Water, at the railway bridge, fragments of shells imbedded in hard stony mud, and also in a silty clay containing small stones, some of which were glacially striated." This, Mr. Jamieson thinks, was on the south side of the Balloch Railway, between Gartness and Drymen. (Letter from Mr. Jamieson to Mr. D. Bell, 16th July, 1874.) The section of Till with shells underlying clay and sand beds referred to in the text, is on the north side of the Endrick Railway bridge.

Astarte sulcata, Da Costa.
Cyprina Islandica.
Nucula, *Sp.*

The stratified drifts above described probably date from a period subsequent to the deposition of certain kaims which occur to the north of the Drymen and Stirling Road, at a higher level, and when the cold which strewed the surfaces of these and other kaims with travelled blocks, dropped from floating ice, had much abated. The shells probably lived during the re-elevation of the land.

It may be remarked, that when the gravel was deposited at the height of 262 feet, a narrow strait at the low water-shed of the Bog of Ballat, near Balfron Station, must have connected the basin of the Clyde with that of the Forth.

To the retreat of the ice-sheet which produced the shelly Till, are probably to be referred some at least of the moraines which extend up the Falloch from the head of Loch Lomond to the very watershed, dividing the Falloch from the more important valley of the Fillan. The watershed is little over 600 feet above the sea, and is less than 100 feet above the alluvial flat at Crianlarich Inn, Strathfillan. The latter valley, it will be seen from the Ordnance map, makes a curve below Crianlarich Inn, nearly at right angles to its former course; and thereafter receives the name of Glendochart. Whenever a thick glacier came down Strathfillan into the narrower Glendochart, and abutted against the steep slope of Stob-Coire-Bhuidhe, it must have found farther progress in undiminished volume down the glen very difficult, and an arm would certainly escape down the Falloch. To the last such glacier I ascribe the *moraine profonde*, referred to above as the shelly Till, and to its retreat the moraine mounds resting on the watershed. Had these watershed moraines been deposited in its retreat by any prior glacier, they could not have failed to be at least flattened, if not swept away, by the glacier which left the shelly Till behind it. My reason for believing that the shelly Till was produced by a glacier which had its gathering ground partly in the region drained by the Fillan, is that a glacier nourished solely in the Loch Lomond valley could not have climbed the rising ground between the Leven and the Endrick to the height (320 feet) to which the shells have been traced, but would have made its way down the Leven valley ;

and moreover it could not have left its moraines on the watershed. That the Till in question was produced prior to the great submergence, is proved by the superposition of deposits of that age.

I do not wish to be understood to indicate a doubt that a glacier occupied Glen Falloch during the period of local glaciers which followed the re-elevation of the land, or that the moraines of the lower part of the valley may have been deposited by such a glacier.

So far back as 1822, Mr. J. Adamson described* several accumulations of shells on the margin of Loch Lomond. The first of these was a calcareous "tuff" or stalagmite in cavities and joints of the Silurian limestone at Arrochymore Point, *Mytilus edulis* is the only shell he names from this locality, which stands 8 or 10 feet above the lake. I lately saw a piece of this "tuff" in the hands of Mr. A. Macfarlane, Balmaha. The shell named by Mr. Adamson was the only one which I could recognise, although there were several others. In other two localities, one on Inch Lonaig, opposite Luss, and the other "on the lands of H. M'D. Buchanan, Esq., near the south-east angle of the Loch," the shells occurred between the highest and lowest levels of the water in a bed of brown clay, under a covering of coarse gravel. The list he gives is as follows :—

Mr. Adamson's List.	Species to which Adamson's may be referred.
ECHINODERMATA.	
<i>Echinus esculentus.</i>	
CRUSTACEA.	
<i>Balanus communis.</i>	Forbes considered this to be identical with <i>Lepas balanus</i> , Linn. (<i>Mem. Geol. Survey</i> , Vol. I., p. 430); which is regarded by Darwin as a synonym of <i>Balanus porcatus</i> , De Costa, of the Mammalian and Red Craggs and glacial deposits of Scotland, Uddevalla, and Canada.
<i>B. rugosus.</i>	<i>B. crenatus</i> , Bruguiere.

* "Notice of Marine Deposits on the margin of Loch Lomond."—*Mem. Wern. Soc.*, Vol. IV. p. 334 (14th Dec., 1822).

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Mr. Adamson's List.	Species to which Adamson's may be referred.
<p style="text-align: center;">LAMELLIBRANCHIATA.</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><i>Anomya ephippium</i>, young of. <i>Pecten obsoletus</i>. <i>Cardium edule</i>? <i>Nucula rostrata</i>, young of.</p> <p><i>Tellina tenuis</i>. <i>Venus Islandica</i>. <i>V. striatula</i>.</p> </div> <div style="width: 45%;"> <p>Probably <i>P. tigrinus</i>, Müller.</p> <p>If this be <i>N. rostrata</i>, Macgillivray, it is considered by Jeffreys to be only the compressed form of <i>Leda minuta</i>, Müller, a living British form (<i>Brit. Conch.</i>, Vol. II., p. 158), and found in many upper tertiary deposits.</p> <p><i>Cyprina Islandica</i>. Probably <i>V. Gallina</i>, Linn., both a British living and glacial form.</p> </div> </div> <p style="text-align: center;">GASTEROPODA.</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><i>Buccinum reticulatum</i>. <i>Nerita glaucina</i>.</p> </div> <div style="width: 45%;"> <p><i>Natica reticulata</i>, Linn. Probably <i>Natica catena</i>, Da Costa.</p> </div> </div>	

Mr. David Robertson, F.G.S., who has already rendered important services to this department of geology, is now engaged in investigating these beds; and I am content to wait for his results before saying more than that the Loch Lomond deposits are evidently of a much later date than the shelly gravels at Gateside and Gartness.

Mr. Robertson has given an account of some fossiliferous clay beds on the edge of the lake at Ross Arden, opposite Inch Tavanach.* He describes them as "the common mussel, the common whelk, and I may say the common *Rissoa ulva*," together with a species of foraminifer. The shell bed, Mr. Robertson writes, is "covered by a soft vegetable mould about 20 inches thick, being itself fully that thickness, and resting on what seemed to be vegetable mould. It was seen, I understand, at or near the level of the water, and is said to extend 30 to 40 feet into the Loch. It is evidently a very recent deposit of estuary shells, probably dating from a time immediately prior to the last elevation of the land."

Mr. James Bennie informs me that shells have also been found in a fine brick clay in the bed of a streamlet some little distance from Balmaha. They were mostly *Cyprinae*, and in fragments, but their state of preservation was good, the epidermis still retaining its place and its natural colour.

* "On the Clay beds of Ross Arden on the banks of Loch Lomond" (*June*, 1864).—*Proc. Nat. Hist. Soc., Glasgow*, Vol. I., p. 92.

Several cases of shelly Tills in maritime districts have been noted by various observers. A glance at these will suffice to shew how much they have in common with the Till of the Endrick Valley.

The well known Till of Caithness, which has yielded many shells to the labours of Messrs. C. W. Peach, Cleghorn, Dick, Smith, and Jamieson, bears evidence of having come from the south-west, and consequently across the Moray Firth. The striæ point from south-west to north-east, and some of the included stones could only have come from the region between Elgin and Peterhead.

Mr. John Carrick Moore, so long ago as 1850, announced* that shell fragments had been found by him in the till of the western part of Wigtownshire. Mr. R. D. Irvine, in carrying on the Geological Survey, has recently detected a similar till at different points in the same locality,† and has added considerably to the list of fossils. The striæ proved that the ice-sheet came from north to south, up Loch Ryan, to the Mull of Logan.

A till containing fragments of *Cyprina Islandica* occurs in the County of Durham.‡ The striæ are sometimes from the north and north-east, and sometimes east and west (probably from west to east). Those from the north-east prove that the ice-sheet crossed a part of the bed of the North Sea, the ice from the north of England and south of Scotland having been doubled back on the coast by the resistance of the Scandinavian ice-sheet.

In West Lancashire, the "lower boulder clay" of Blackpool has yielded shells. Mr. De Rance, who describes the deposit,§ regards it as of marine origin; but it is easy, from his description, to identify it with the lower till of Scotland. The striæ of North Lancashire run from north to south, the lake district having sent off an ice-sheet which would be compelled by the pressure of Scotch and Irish ice to hug the coast.

* "Notice of the occurrence of Marine Shells in the Till."—*Quart. Journ. Geol. Soc.*, Vol. VI., p. 388.

† *Memoirs of the Geological Survey of Scotland*. Explanation of Sheet I. (1872), Sect. 12; and Explanation of Sheet III. (1873), Appendix.

‡ "On the Glaciation of the Counties of Durham and neighbourhood. By R. Howse."—*Proceedings of the North of England Inst. of Mining Engineers*, May, 1864.

§ "On the Glacial Phenomena of West Lancashire and Cheshire." By C. E. De Rance, F.G.S. of the Geological Survey of England and Wales (22nd June, 1870).—*Quart. Journ. Geol. Soc.*, Vol. XXVI., p. 641.

Mr. Mackintosh* found a similar shelly till at Dawpool in Cheshire—a locality to which the same remarks apply.

Commenting on the Lancashire and similar shelly tills, Mr. R. H. Tiddeman,† who gives a sketch-map shewing strise parallel to the coast-line, makes the following remarks:—

“It is a point insisted on by some geologists that wherever either rolled stones or marine shells are found in the boulder clay, it must be of marine origin. I do not think that either of these characters is infallible. Mr. Croll has shewn that the Caithness Till, which contains shells, need not necessarily be marine, but may have been formed by the ice-sheet working over a previous sea-bed, and pushing the shells on to the land. In this way shells scratched and broken may be found at very much higher levels than the sea in which they lived and died. They are there as much boulders as the scratched stones alongside of them, and are no more evidence of the drift in which they lie having been formed under the sea than *Spirifers* and *Producti* found in limestone river gravel would be proof of its being marine. In very many places the ice-sheet must have passed over what had previously been the sea-bed, and if its course took it thence inland, we should be surprised not to find sea-shells mixed with the drift formed by it. Nor can rolled stones be considered a better test, for, under similar circumstances, they must be brought up from the old sea-bed on to the land.” I quite agree with these observations.

It will be seen that the various beds which it is the immediate object of this communication to describe end with the great submergence. They may be summed up as follows—(the table should be read upwards, or in chronological order):—

c. A great extent and thickness of stratified mud, clay, sand, and gravel, resting on the shelly Till (*b*) at the level of 35 feet above the sea, and reaching a height of 262 feet above the sea, containing, in the shape of beds of stiff clay with stones, indications of the presence of ice—perhaps floating ice—during part of the time. At three localities, 120, 160, and 210 feet respectively above the level of the sea, this deposit has yielded water-

*“On a Sea-coast section of Boulder Clay in Cheshire.” By D. Mackintosh, F.G.S. (8th May, 1872).—*Quart. Journ. Geol. Soc.*, Vol. XXVIII. p. 388.

† “On the evidence for the Ice-Sheet in North Lancashire and adjacent parts of Yorkshire and Westmoreland.” By R. H. Tiddeman, M.A., F.G.S., of the Geological Survey of England and Wales (19th June, 1862), *Quart. Journ. Geol. Soc.*, Vol. XXVIII., p. 471.

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worn marine shells of species almost all now living in the British seas. The deposit indicates, therefore, a climate little more severe than our own. It is referred, for reasons stated above, to the later stages of the great submergence period, when, after the deposition of kaïms at higher levels, the land had risen so much as to be only about 260 feet below its present level.

b. A Till containing broken shells, resting on the stratified bed (*a*). The Till is traceable by means of the shells to a height of 320 feet above the sea-level, and is believed to be the *moraine profonde* of a large glacier or ice-sheet, which, in crossing the south-east corner of the Loch Lomond fjord, mingled the remains of an interglacial or preglacial shell-bed or beds with stones and clay, and crushed and rubbed them exactly as it did the included boulders. It is referable to the later stages of the first period of the glacial epoch, prior to the great submergence of the land.

a. A stratified clay (Croftamie) containing marine shells and a reindeer's horn. The shells indicate a climate not severe, though probably a little colder than the present climate of these latitudes. All the shells specifically distinguished are living in British seas. The land must have stood 109 feet lower than at present.—This deposit is interglacial, or preglacial—most probably interglacial. It underlies the shelly Till (*b*).

II.—On the MICROSCOPICAL STRUCTURE of RED QUARTZ-PORPHYRY, from the Old Red Sandstone of Logan Water, above Lesmahagow. By EDWARD HULL, M.A., F.R.S., Director of the Geological Survey of Ireland.

[Read 11th Dec., 1873.]

THOSE who have followed the windings of the Nethan and Logan waters above Lesmahagow must have been struck by the beauty of the red porphyries which are interbedded with the Old Red Sandstone near its junction with the upper Silurian beds. This ground has been rendered classic for geologists through the labours of Mr. Robert Slimon, who has brought to light so many forms of extinct Crustacea, some of which are figured and described in Murchison's *Siluria*.

Having some years ago made a pilgrimage to this shrine of the