II.—*First Notice of a Post-Tertiary Shell-Bed, at Clava, in Nairnshire, indicating an Arctic Climate, and a Sea-Bed at a height of 500 feet.* By JAMES FRASER, C.E., Inverness.

(Read 17th November 1881.)

OLD CLAY PIT.

The subject of the following notes is an old clay pit on the farm of Drummore of Clava. The pit is at the base of a broad terrace, about 70 feet in height, and has not been used for about thirty years; and the stratum of clay containing the shells has been covered by a landslip for more than twenty years, until the author succeeded in exposing the shell-bed by an excavation through the overlying earth in June last (1881).

SITUATION OF SHELL-BED.

Clava is situated on the east side of the river Nairn, and about six miles due east of the town of Inverness; and the shell-bed is half a mile east of the river, and nearly 200 feet above its level. The spot is shown on Mr Richardson's map, p. 200 of this volume. The accompanying section across the valley of the Nairn, and passing through the spot where the shells are found, shows the geological position of the shelly deposit. Another section, on a larger scale, gives an enlarged view of the shell-bed itself, and of the face of the terrace above it. The shelly deposit appears to lie on the eastern margin of the Old Red Sandstone formation, which extends in a south-westward direction from it.

PARALLEL RIDGES.

The terrace under which the shelly deposit has now been exposed corresponds with the upper one of the "two long gravel ridges with marshy hollows behind them, that run parallel with the river on the east slope of the valley," as described in the author's paper on the "Recent Formations and Glacial Phenomena of Strathnairn," at page 62 of the "Transactions of the Edinburgh Geological Society," 1881. At the point where the shells occur the broad terrace extends back to the hillside, and thus forms a break in the general line of the hollow behind the upper one of these parallel ridges. The lower, and smaller, ridge is that which is followed for a considerable distance by the district road, and is composed, generally, of a later gravelly till, but based, at some points—especially near the bridge of the Dalroy Burn—on a mass of true boulder clay.

SECTION ACROSS THE NAIRN VALLEY AT CLAVA.

SECTION ENLARGED ~~SECTION~~ OF SHELL-BED AT CLAVA.

DESCRIPTION OF STRATA.

Boulder Clay.—Referring to the enlarged section of the face of the terrace at the shelly deposit:—the top is composed for a depth of 40 or 45 feet of yellowish boulder clay, having a covering of soil with a gravelly subsoil. This boulder clay—geologically so called—consists of a mixture of gravel, sand, and stones, with a small proportion of clay, and containing fragments of Old Red Sandstone, and of gneiss and its allies, in nearly equal proportions, many of the sandstones being finely scratched. A small stone, distinctly but irregularly scratched, was submitted to the Society with these notes, along with samples of the shells and clays.

Sand.—The boulder clay gradually passes downward into a bed of fine yellowish sand, about 20 feet in depth, and showing marks of stratification. This stratum of sand has not yet been found in the exposed faces of the terrace, east or west of the shell-bed. In every other spot, on the same level, the terrace seems to consist of boulder clay. This, however, may be owing to the difficulty of getting complete sections exposed to view. The fine sand is compressed into an exceedingly hard mass for about 4 feet from the bottom, but is more friable above that height. An experienced and skilful moulder in Inverness has tested a small quantity of this sand for iron casting, and has found it to be of a very fair quality, although its suitability for fine moulding cannot be held as established until a larger quantity of it is tried.

Shelly Clay.—Below the bed of fine sand just described is found the shelly deposit, consisting of a stiff blue clay, or silt, which is rather more friable and sandy from 4 to 5 feet below the surface, and again firmer below that level. The line between the blue clay and the fine sand above it is sharply marked. A depth of 5 feet of the blue clay has been exposed, and from 2 to 2½ feet more bored with an iron bar, followed by a tube of smaller diameter, without reaching the bottom of it; so that the shell-bed is, at least, from 7 to 8 feet in depth. The author has not yet been able to find the same deposit at any other point, nor to ascertain what it rests upon. The section across the valley shows the general arrangement of the rocks in the locality; and, at the shell-bed, the succession of strata, beginning at the top, is as follows:—

	Feet.
1. Soil and gravel, }	
2. Boulder clay, }	50
3. Fine sand, stratified, . . .	20
4. Shell-bed of blue clay, bottom not reached, 7½	
5. Boulder clay?—not seen, . . .	?
6. Old Red Sandstone, . . .	?
7. Silurian Gneiss, . . .	—

THE SHELL-BED.

The blue clay contains a slight proportion of small stones, finely polished, and mostly well-rounded and water-worn, and all, unless with very few exceptions, consisting of gneiss rock. The shells are most plentiful at a depth of about 2 feet from the surface of the clay; and none have as yet been found at the surface, nor among the fine sand or boulder clay overlying it. A careful search has been made in the boulder clay in the immediate neighbourhood for fragments of shells, but without success. Many of the shells are quite entire, although in a very delicate condition; and there is no doubt whatever that the shells are *in situ* in this bed. The delicately preserved condition of their epidermis, or outer skin, and of their markings, proves that they have been subjected neither to glaciation nor abrasion of any kind.

HEIGHTS ABOVE SEA LEVEL.

The height of the shell-bed has been verified by the author, by actual measurement from one of the levelling bench marks of the Ordnance Survey; and the height of the top of the shelly clay is found to be 501 feet, and the top of the fine stratified sand 520 feet, above Ordnance Datum, or average sea-level. The top of the terrace, at the same place, is about 570 feet above sea-level. This appears to be the highest marine deposit of the same geological age yet found in the north. The only other case in Scotland where a shelly deposit of the kind has been found as much as 500 feet above the sea is that of the shell-bed near the Monkland Iron Works, at Chapel-hall, Airdrie, Lanarkshire, described by the late Mr James Smith, of Jordanhill, in 1850, as being 510 feet above the high water level of the sea, by barometric measurement, which is not to be relied on for minute accuracy.* The Rev. Henry W. Crosskey, F.G.S., Birmingham, then of Glasgow, in his paper on the Airdrie bed,† gives the height of it as 526 feet, his information having been derived from Mr Russell, who originally discovered the shells. Mr M. Æ. MacBean, C.E., of the Public Works Office, Glasgow, has kindly ascertained for me that the exact height of this shell-bed is $518\frac{1}{2}$ feet above average sea level, the surface of the ground being $532\frac{1}{2}$ feet. Mr Crosskey tells us that the shelly stratum was only 2 feet thick where it was pierced through, and that only two species of shells were found in it—*Tellina calcarea* and *Cyprina Islandica*, and a *Balanus*, or barnacle.

FOSSILS OF SHELL-BED.

The character of the shelly stratum at Clava will be best

* See Mr Smith's paper in his "Researches in Newer Pliocene and Post-Tertiary Geology," pp. 17 and 141, and "Proceedings of Geological Society," vol. vi., p. 386.

† See "Proceedings of Geological Society," vol. xxi., p. 219.

understood from the lists of its fossils kindly furnished to the author, first, by Mr Thomas F. Jamieson, F.G.S., of Ellon, Aberdeenshire, and afterwards by Mr David Robertson, F.L.S., F.G.S., Glasgow, and from the analyses of the clay and overlying sand kindly prepared by Mr W. Ivison Macadam, F.C.S., F.I.C., Edinburgh, all of which are given below.

(1.) *Shells.*

I.—*List of Shells identified by Mr JAMIESON, in the samples of the clay first taken up.*

1. *Mytilus edulis*, or common mussel—fragments.
2. *Littorina litorea*, or common periwinkle—most plentiful species.
3. *Littorina rudis* (Maton)—one specimen.
4. *Leda pernula* (Müll.)—several, some of them complete with epidermis, but crushed.
5. *Natica Grænlandica*, or *N. Pallida*—several examples, but mostly crushed.
6. *Mangelia* [or *Pleurotoma*] *turricula* ()—one specimen.
7. *Nucula tenuis* (Mont.)—a few specimens.
8. *Tellina Balthica* (Linn.)—three or four, and fragments.
9. *Buccinum undatum* (Linn.)—fragments of several, size not large.

II.—*List of Shells identified by Mr ROBERTSON, in samples of clay last dug out.*

1. *Mytilus*, sp.—fragments.
2. *Littorina litorea* (Linn.)—common.
3. *Littorina rudis* (Maton)—two examples.
4. *Leda pernula* (Müll.)—fragments.
5. *Leda pernula*, var. *macilenta* (Steenst.)—one and a valve.
6. *Leda pygmæa* (Münst.)—one example.
7. *Natica Grænlandica* (Beck.)—moderately common.
8. *Pleurotoma turricula* (Mont.)—two young examples.
9. *Nucula tenuis* (Mont.)—one example and a valve.
10. *Homalogyra atomus* (Phil.)—one example.
11. *Trophon clathratus* (Linn.)—one, in pieces.
12. *Cardium edule* (Linn.)—a small fragment.
13. *Astarte compressa* (Mont.)—one example.

By comparing the above two lists together, it will be seen that no less than fifteen different kinds of shells have been found in this shell-bed.

(2.) *Microzoa.*

Mr Jamieson found by a partial examination of the clay sent to him one example of *Balanus*, and some *Foraminifera* of the

genus *Polystomella*, or *Nonionina*, but he did not further pursue the search for minute organisms. Mr Robertson, who made a full examination of some of the clay, has not found a great variety of *Foraminifera* or *Ostracoda*; but those he has found are such as occur in the glacial clays of the west of Scotland. His first search gives the following:—

Foraminifera.

1. *Quinque loculina seminulum* (Linn.)—one broken example.
2. *Lagina Marginata* (F. & M.)—one example.
3. *Lagina hexagona* (Will.)—one example.
4. *Polymorphina lactea* (W. & T.)—moderately common.
5. *Polymorphina acuminata* (Will.)—rare.
6. *Uvigerina angulosa* (Will.)—one example.
7. *Polystomella striato-punctata* (F. & M.)—moderately common.
8. *Polystomella artica* (P. & J.)—moderately common.

Ostracoda.

1. *Cythere pellucida* (Baird)—three valves.
2. *Cythere viridis* (Müll.)—rare.
3. *Cythere lutea* (Müll.)—two valves.
4. *Cythere castanea* (G. O. Sars.)—rare.
5. *Cythere angulata* (G. O. Sars.)—two valves.
6. *Cytheridea punctillata* (Brady)—moderately common.
7. *Cytherura striata* (M. Sars.)—two whole examples.
8. *Cytheropteron latissimum* (Norman)—rather rare.
9. *Cytheropteron nodosum* (Brady)—moderately common.

Cirripedia.

1. *Balanus crenatus* (Brug.)—small and rare.
2. *Balanus balanoides* (Linn.)—rare.

It may be stated here, that Mr Robertson has made a careful examination of two samples taken at different depths from the fine sand above the shelly clay without finding a vestige of a marine organism in it. He remarks that both the sand and the blue clay are full of mica scales, with this difference that they are tinged with yellow in the sand, while those in the clay are white.

ANALYSES OF CLAYS.

The following are the analyses of the shelly clay or silt, and of the sand bed above it, and also of a mass of very strong and fine yellow clay, found under the boulder clay about 100 yards south of and on the same level as the shell-bed, kindly prepared, as has been stated, by Mr W. Ivison Macadam, the Honorary Secretary of the Society, whose interesting and valuable remarks in connection with the analyses are also given.

POST-TERTIARY SHELL-BED IN NAIRNSHIRE.

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"Analyses of Samples of Clay received from JAMES FRASER, Esq., C.E., Inverness."

"SURGEONS' HALL, EDINBURGH,
14th November 1881.

	The Shelly Clay or Silt.	Compressed Sand above Shelly Clay.	Upper part of Sand above Shelly Clay.	Clay under Boulder Clay.
<i>"I.—Soluble in Acid—</i>				
Ferric oxide,	4·763	3·397	4·172	17·234
Aluminic „	0·746	0·385	0·353	0·486
Calcic „	0·839	0·371	0·316	0·282
Magnesian „	0·691	0·502	0·368	0·457
Sulphuric anhydride, .	0·212	0·102	0·101	0·148
Potassic oxide, . . . }	0·179	0·112	0·108	0·121
Sodic „				
Carbonic acid, &c., .	1·404	0·845	0·672	0·747
	8·834	5·714	6·090	19·475
<i>II.—The residue after fusion with an Al- kaline Carbonate yielded—</i>				
Ferric oxide,	6·739	5·975	6·672	14·402
Aluminic „	8·077	7·718	2·203	0·647
Calcic „	0·614	0·620	0·191	0·461
Magnesian „	0·428	0·380	0·227	0·270
Silica,	70·192	75·737	83·605	60·789
	86·050	90·430	92·898	76·569
Water,	5·116	3·856	1·012	3·956
	100·000	100·000	100·000	100·000

"The Shelly Clay or Silt is similar to clays found in other parts of the Highlands, and bears a close resemblance to clays obtained from mixed gneiss and schist districts.

"The Compressed Sand above Shelly Clay is a mixture of the above clay with a large proportion of sand.

"The Sand above Shelly Clay has a composition similar to ordinary sea sand.

"The Clay under Boulder Clay is very peculiar on account of the extremely large proportion of iron, part of which is present as oxide and part as silicate. It is not a clay, strictly speaking, but a sand bound together by the iron.

"From the above results, I am of opinion that the 'shelly clay or silt' ranks as a true Arctic clay, and as such will yield good results.

"W. IVISON MACADAM, F.C.S., F.I.C., &c.,
Lecturer on Chemistry and Analytical Chemist."

CONCLUSION.

The Arctic character of the deposit is established by the presence of the *Leda pernula*, *Leda pernula* var. *macilentā*, and *Natica Groenlandica*, all of which are decidedly Arctic.

That this shell-bed, again, represents a part of the sea-bed, not far from the shore line, seems to be as clearly shown by the abundance of the *Mytilus* and *Littorina litorea*. It is differently with the Arctic shell-beds at a lower level at Gamrie and King Edward, near Banff, where, as Mr Jamieson has pointed out, the shallow water shell, *Littorina litorea*, so plentiful at Clava, is entirely absent.

Dark marbled streaks, which are thought to be traces of seaweeds, can be seen in portions of the shelly clay, when the lumps are freshly broken.

The author regrets that he has not been able to ascertain, with any degree of certainty, what the shelly clay rests upon, nor the extent of it; but he hopes, at some future time, to extend his observations on the ground.

In parting with the subject, the writer begs to express how very much he is indebted to the gentlemen whose names have been mentioned in this paper, and to others, for their great kindness and readiness in furnishing him with information, and that at no small amount of trouble to themselves.