

*J. C. Russell*

TRACES IN SCOTLAND

OF

ANCIENT WATER-LINES

MARINE, LACUSTRINE, AND FLUVIATILE

WITH

*SOME ACCOUNT OF THE DRIFT MATERIALS ON WHICH  
THESE TRACES ARE IMPRINTED*

AND

*SPECULATIONS REGARDING THE PERIOD IN THE WORLD'S  
HISTORY TO WHICH THEY MAY BE REFERRED, AND  
THE CLIMATIC CHANGES THEY SUGGEST*

BY

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EDINBURGH

DAVID DOUGLAS, CASTLE STREET

1882

NEIL AND COMPANY, EDINBURGH,  
GOVERNMENT BOOK AND LAW PRINTERS FOR SCOTLAND.

# ANCIENT WATER-LINES, &c.

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## INTRODUCTION.

ATTENTION has been from time to time drawn to the traces of sea-terraces, more or less horizontal, at various levels. These traces occur in many countries, especially in those bounded by the sea. Dr Chambers, in his "Ancient Sea-Margins," published in the year 1848, gave a list of many in our own country, and he added a notice of some in other countries. So much interested was he in the subject, that not content with a special inspection of the coasts, and also of the valleys of the principal rivers in Scotland, he made a tour round and through many parts of England, and even went to France to visit the valley of the Seine. Dr Chambers had previously been in Norway, and had been much interested in the terraces of the Altenfjord, described first by M. Bravais. He, however, did not confine himself to Europe,—he alluded also in his book to the existence of terraces in North America, as described by Lyell and others.

The subject was one which had about the same time begun to engage my own attention;—as may be seen from references in Dr Chambers' book, to information he obtained from me.

I am not aware that since Dr Chambers' publication, there has been any serious attempt to make further progress in the inquiry. In the publications of American geologists, there are frequent allusions to terraces at high levels surrounding the great lakes; and in some very recent reports by them on the geology of particular districts, there is a notice of terraces far up on the sides of mountains, which, being horizontal, have suggested the opinion that they are old sea beaches.

During the last five or six years, the Surveyors of the Royal Engineers engaged in the Ordnance Survey have been struck by discerning horizontal lines of terraces among the mountains of the West Highlands, at heights varying from 800 to 1700 feet above the sea. Captain Burke—when he was at the head of the Survey—was so obliging as to acquaint me with his Surveyors' reports. He also went himself to one or two of the districts, and verified the existence of the flats. I afterwards went, and came to the conclusion that these flats had been formed by the action of extensive bodies of water.

In these circumstances, it has occurred to me, that it might facilitate, and even perhaps stimulate, further inquiry, were I to give a list of places in Scotland where terraces round our coasts, and also in other places, have been observed by me and others.

For many years I have, when travelling, carried instruments for indicating heights and levels. My first instruments were Adie's symptomometer and a pocket spirit-level. For special investigations, as at Glen Roy Parallel Roads, I had also a mercurial barometer, which, on account of its weight, has long since been superseded by the aneroid.

I kept a geological diary, in which I jotted down the names of places, where I descried what appeared to be a horizontal terrace.

This diary has enabled me to supply the notes, which I now offer, in reference to this matter.

The measurements represent the height above high-water (spring) tides. The medium between high and low-water mark, as adopted in the Ordnance Survey, would of course have been better, as being on the same level all round the island, or very nearly so. But a geologist cannot, in a hasty survey, discover this level. To him no level is available, except the line of high water, which in most cases he sees indicated on the beach by sea weed or other rubbish left by the last tide.

Of course, in such circumstances, the height above high-water mark can be only approximately ascertained, because it is not always distinguishable by the eye with accuracy.

There is another element of uncertainty. The line of an old sea cliff is generally obscure, in consequence of what had once been a

nearly vertical cliff, being by lapse of time converted into a sloping bank, from which earth, gravel, or rocks have fallen, thereby obliterating the line to which the sea formerly rose at the foot of the cliff.

There is even a third element of uncertainty, which occurs in some parts of the coast. The line of high water round any coast does not form a line absolutely horizontal. In the Bristol Channel the line of high water slopes upward, so that at the head of the estuary, it is about 40 feet higher than at the mouth. In many of the narrow sea straits, among the Western Islands of Scotland, the level of high tide is above the level of high tide on the same coast elsewhere. This may be seen from the following cases taken from the "Admiralty Tide Tables," which show the difference of level between low and high water, at spring tide :—

In Sound of Islay, $6\frac{1}{2}$ ft.	Loch Carron, 16.
Loch Seaforth (Harris), $2\frac{1}{2}$ ft.	Kyle-a-Kin (Skye), $15\frac{1}{2}$ ft.
Loch Crinan, 6 ft.	Garliestown (Wigtownshire), 17 ft.
Loch Etive, $5\frac{1}{2}$ ft.	Silloth, 26 ft.
Mull of Cantyre, 4 ft.	Isle of Man, 20 ft.

So, also, the contour lines of the Ordnance Survey show that the level of high water at Stirling is 5 ft. 9 in. higher than the level of high water at Fisherrow Harbour, near Musselburgh.

From these examples, it will be seen that there will not be always an exact coincidence in the height of the base of an old sea cliff at different parts of a coast, though formed by the sea when it stood at its highest level.

These elements of uncertainty will obviously occur more in higher and older sea cliffs than in those at a lower level, as in the latter, the configuration of the coast does not materially differ from the present, and there has been less time for the wearing down of the cliffs.

The question may be asked, What do the lines referred to indicate? They indicate, of course, the indentation made by the sea, and at the highest point to which it reached, *i.e.*, when it stood at *high-water spring tides*;—for of *neap* tides, all traces would be obliterated.

Another question remains,—which may be not so easily answered.

There are lines of beach at various levels,—as at 11 feet, 25 feet, 33 feet, 40 feet, 83 feet, &c. Do these lines indicate, that, as the land rose out of the sea, there was a *halt* in the process of elevation, at certain periods, during which indentations of the land were made, so as to form beaches at these levels? or,—May not these indentations have been made, whilst the land was undergoing continuous gradual elevation? The indentations could be effected in a short time, where the materials were so abundant and so loose, as to yield readily to the action of the waves. Along many miles of coast, there might be beds of gravel, clay, or friable rocks, which would be easily indented;—whilst at other parts of the coast, at the same level, the materials might consist of hard unimpressible rock. In that case, the old sea margin would along a coast, show great interruptions. Then, as the land continued to rise, a like partial distribution of favourable materials would occur, and afford occasion for another and lower line of beach,—but also interrupted.

In these remarks, I have supposed that the change of level arose from the elevation of the land, and not from the subsidence of the sea. The reasoning just suggested would not be affected, by either supposition.

Whether it was the land which rose, or the sea which fell, is too large and difficult a question for me to discuss. I only venture to say, that if these old sea-margins are everywhere found to be absolutely horizontal, it may be more easy to adopt the supposition that the *sea* sank, than that the *land* rose.

In specifying the *localities*, I begin with the west coast of Scotland in the south, and follow the coast line to the north, then crossing to the east coast.

The subject of ancient *sea*-margins not unnaturally suggests notice of traces also existing of *lakes* which stood, and *rivers* which flowed, at higher levels in Scotland. In fact, these three sets of water-lines are so related that they throw light on one another—the subsidence of lakes and rivers from higher to lower levels being in most cases referable to the subsidence of the sea, whereby, through greater steepness of gradients, more power is given to rivers to cut through and remove the materials blocking lakes and forming river beds. I have therefore, in a separate chapter, described

such of these ancient lake and river margins as came under my notice.

I have also put into a separate chapter notes on the terraces and other physical features of the *Glen More nan Albin*, or Great Glen of Scotland, as it has characters of its own which distinguish it from every other district.

It will be convenient here to state the different heads under which these notes are arranged.

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A. *Sea-terraces* (between H.W. and about 20 feet above H.W.)

1. *Kirkcudbrightshire*.—At Kirkmabreck, sea shells found 18 feet above High Water (Wern. Soc. Trans., vol. viii. p. 110.)

*Annan*.—The town stands on an extensive flat about 28½ feet above H.W.\* But there is a lower flat between the town and the sea, bounded by a cliff, the base of which is about 12 feet above H.W.

This cliff runs for some distance E. and W. on the south side of Annan. It surrounds a mossy tract, in which there are several brick-

\* Under this heading, notice is taken of terraces above the 20 feet level,—when seen at or near the same place as terraces at or below that level.

works. In the clay beds of these works, about 5 feet below the surface, there are numerous mussel and other sea shells.

An estuary has evidently at one time reached up towards Annan.

2. *Dumfriesshire—Dumfries.*—A very perceptible cliff, the base of which is from 12 to 13 feet above H.W., occurs along the river Nith on both sides towards the sea.

There is also an extensive flat from 30 to 32 feet above H.W., on which stand Holm House and Lincluden Manse.

This flat, consisting chiefly of sand and fine gravel, and containing beds generally horizontal, extends for several miles up the river Nith on both sides, viz., as far as Blackwood bridge (6 or 7 miles from Dumfries), where it abuts against old cliffs, consisting in some places of rocks, in others of coarse gravel.

I find that in 1865, Dr Gilchrist investigated the old sea-margins in Dumfriesshire; but the only one specifically described by him (*Geol. Magazine*, vol. ii. p. 374) he states as “commencing on the left bank of the Nith, immediately below the cauld at Dumfries.” He says that on the opposite side of the river there is a corresponding terrace, on which St Michael Street is built. He observes that there can be no doubt of the terrace being marine, as sea shells had been found on it near the brick-work at the shooting range. He stated that he would at some future time give a further account of these terraces, but I have been unable to learn whether he was able to carry out his purpose.

3. *Ayrshire.*—To the south of the town of Ayr, the lowest sea cliff is very striking, especially at Mount Charles, where the public road runs along its base at from 12 to 13 feet above H.W.

This cliff is traceable for some miles to the south. It inosculates with the rocky cliffs of Greenan Castle.

Above this cliff there is a flat, which I did not measure; apparently from 40 to 50 feet above H.W. Castle Hill House is upon it.

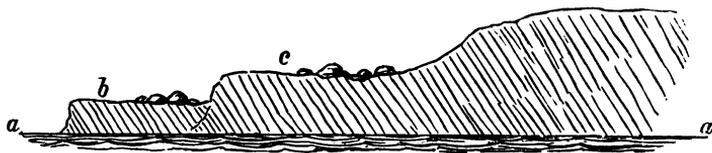
At Kilwinning there is a bed of clay containing Arctic sea shells and rolled flint pebbles. At “Heads of Ayr,” to the south of the town, a bed of drift occurs, about 6 feet above H.W. and 15 yards from high-water mark, containing *rolled flint pebbles* (Walter Burns, Glasgow). The towns of Ayr, Troon, Prestwick, and Kilwinning are on a higher terrace, about 25 feet above H.W.

4. *Arran*.—To the north of Corrie on the east coast, the old sea cliff attracts notice with its base about 12 feet above H.W. I observed it also on the west coast at Loch Ranza, and at various other places. It is on this 12 feet beach near Corrie that the angular granite boulder called "*The Catstane*" rests. Its weight I estimated at 262 tons.

In Holy Isle there is a cave (where the patron saint of the island is said to have lived). Its floor is from 12 to 14 feet above H.W.

North of Lamlash, there are several caves in the rocks on the shore. The floors of these caves are from 11 to 12 feet above H.W. Their roofs are from 18 to 20 feet above H.W.

The *Big Cumbrae Island* is girt by an old cliff, at the same level, viz., 12 feet above H.W. I measured it at Balloch Martin, in the north end of the island, and also near Millport in the south end. At both places there is a higher terrace about 70 feet above H.W., with boulders of mica schist on each terrace. Thus *a* is the present



sea-level, *b* is the 12 feet, and *c* the 70 feet terrace, with boulders on each. The cliff *c*, which consists of Old Red Sandstone strata, may at one time have extended further towards the sea, when the sea stood at or above that level. When the sea sank to the level of *b*, the waves might abrade and remove the sandstone rocks forming the seaward part of the cliff *c*, and have caused the boulders to drop to the lower terrace at *b*.

5. *Dumbarton* is situated on a low flat about 12 feet above H.W.

To the west of the town, there is a striking line of old sea cliffs in the soft Red Sandstone rocks.

The base of the lowest cliff is from 12 to 15 feet above H.W.

A higher flat (apparently about 31 feet above H.W.) is to be seen at the *Bar Toll*. The towns of Renton and Alexandria appear to be on this flat.

6. *Glasgow and Firth of Clyde.*

(1.) West of Glasgow, two well-marked flats occur; one from 12 to 15 feet, the other 35 to 40 feet above H.W.

Partick hill rises from this higher flat. Yoker village is situated on it.

From this flat there rises a steep bank, which has probably been a sea cliff. Dalmuir House and Duntocher House are on the top of this bank.\*

(2.) Between Greenock and Gourock there are two flats, one about 12, the other about 70 feet above H.W.

(3.) Kilcreggan Village. The old sea cliff is visible here, with its base 11 feet above H.W.

(4.) On *Loch Long*, between Blairmore and Ardentenny, two flats are observable, one 11 feet and the other 40 feet above H.W.

On the east side of the Loch opposite to Ardentenny, a number of large boulders rest on the 40 feet terrace. (See Third Report of Royal Society's Boulder Committee).

(5.) The 11 and 25 feet beaches are noticeable all through the *Kyles of Bute*, but more particularly on the sides and at the spots where there are villages or villas, the terraces having been found to afford favourable sites for dwellings and gardens.

\* Mr John Dougall has drawn out a statement of the several "ancient sea margins" (as he terms them), in and around Glasgow. In this statement, which is published in the 2d vol. p. 30, of the "Transactions of the Glasgow Geological Society," eight horizontal terraces are specified, with their heights "above the level of mean tide at Liverpool." In order to convert these measurements into heights above high-water spring tides, I have in the following statement deducted 8 feet, so as to allow of comparison with the heights of the terraces mentioned in this paper:—

	Above High Water.
1. Saltmarket, . . . . .	12 ft.
2. The Cross, Exchange, and Dumbarton Road, . . . . .	23 to 24 ft.
3. High Street, Queen Street, &c. . . . .	31 to 32 ft.
4. Seen most extensive on both sides of Clyde valley, } including Rutherglen, . . . . .	63 to 64 ft.
5. High Street at Rottenrow, Stirling Road, Woodside } Terrace, and many other places, . . . . .	104 ft.
6. Castle Street, Partick Hill, Renfrew Street, &c. . . . .	136 ft.
7. Garnet Hill, Observatory Hill, &c. . . . .	166 to 173 ft.
8. Springhouse Road, Long Side, &c. . . . .	180 to 182 ft.

At *Lochgilphead*, at a height of about 10 feet above H.W., sea shells in a blue mud are found, most of them Arctic. Mr Alexander, of that town, has sent specimens to me (July 1879).

7. *Oban and coasts adjoining.*

The 11 feet sea cliff and also one at 25 feet above H.W., is well seen from the steamboat in passing along these coasts.

About a mile to south of Easdale, there is a conspicuous range of cliffs (about 80 feet high), whose base runs for at least two miles continuously, parallel with the existing shore, and at a height of about 18 or 20 feet above H.W. A flat lies between this ancient sea cliff and the present line of H.W., which in some places is a quarter of a mile wide. There lie on this flat, boulders of grey granite and whinstone, which apparently have come from north or west, and have been intercepted in their further progress by these sea cliffs.

The old beaches are generally most distinct, when the land consists of gravel or other detrital matter.

Occasionally, at each of these levels there are caves in the sea cliffs, which being generally on or about the same level, suggest sea action.

On the voyage from Oban to Fort William, the 11 feet terrace is visible at various places on the coast, as at Barrymore, Stacka, Port Appin, and Corran Ferry. At a place about  $1\frac{1}{2}$  mile west of Fort William, where a small stream crosses the road, sea shells occur in a bed of clay 8 or 10 feet above H.W. which I examined.\*

8. At *Kinlochmoydart*, the 11 feet old beach occurs. Mr Robertson, the proprietor, informed me that a bed of sea shells occurs there at about that height.

This beach is visible along the Linnhe Loch on both sides. On the north shore, about a mile to the east of Corran Ferry, a burn descends the mountain side, with a delta at the level of the 11 feet beach.

Along the south shore, the cliff is seen to the east of Port Appin at places marked on the map Cuttie, Dalnatrad, and Keill. The cliff consists here of strata nearly vertical, and running about S.W. and N.E. They form part of that remarkable series of rocks, described in the well-known memoir by Murchison and Geikie on the altered rocks of the North-West Highlands. In that series, a

\* These sea shells were first taken notice of by Mr Jamieson, of Ellon.

beautifully pure white quartz rock occurs, large blocks of which form conspicuous objects at the side of the high road near Keill. These blocks I was invited to visit, as being supposed to be boulders transported from some distant point. But when I discovered that in the hilly ridge, at the base of which these blocks lie, the quartz rock occurs *in situ*, I could not be sure that they were erratics. The base of this ridge is about 11 feet above the sea; and I think it probable that the sea when at that level had undermined a portion of the quartz strata, and caused fragments to fall on what had then been the sea beach. This supposition is confirmed by the circumstance that the west sides of these huge blocks are rounded and polished, whilst the east sides are sharp and rough. The west sides must have been the most exposed to storms. The action of the waves, and of sand and gravel driven by the waves upon the blocks when the sea reached them at its higher level, would have the effect of rounding and polishing them on their west sides only.

9. *Mull*.—In the "Edin. New Phil. Jour." (vol. xxix. p. 95.) an account is given of a sea cliff on the east side of the island, running continuously for many miles. The height of its base above H.W. is there stated to be 12 feet 7 inches, and the top of the cliff 24 feet 9 inches. A terrace at the height of 40 feet is also mentioned.

North of Saline, in Mull, I observed (from the steamboat, in 1876) the 11 feet beach.

10. *Loch Nevis*.—When on a visit to the late Mr James Baird, at Inverie, I found the old sea cliff at a height of about 12 feet above H.W., and running for some miles continuously.

11. *Glenelg*.—The coast between Glenelg and Glenbeg presents a line of rocky cliffs, the base of which is from 200 to 300 yards from the sea, and about 11 feet above H.W.

At the mouth of Glenbeg, not far from the sea, there is on each side of the valley a flat about 50 feet above H.W. It has originally been apparently continuous across the valley, and may have formed the blockage of a fresh water lake. A small river now runs through the valley, having the above-mentioned flat on each side of it. The flat consists almost entirely of gravel.

12. *Balmacarra*.—On the carriage road, about a mile west of Balmacarra, there is a rocky cliff, the base of which is about 11 or 12

feet above H.W., with several caves,—now about a hundred yards distant from the sea.

13. In various parts of Loch Carron (in particular at Plockton, Port Chullin, Strome Ferry, and towards Strath Carron Railway Station), as also at Kyle-a-Kyn, the 11 feet cliff is visible.

14. In *Lewis*, the village of Laxdale, about a mile to the north of Stornoway, is on a flat 12 or 14 feet above H.W.

15. *Tarbat* (east coast of Ross).—The 11 feet beach is very visible, and runs for several miles up the estuary towards the town of Tain. Many large boulders lie along its base. The gravelly detritus in which they had been imbedded, having crumbled down and been removed by the waves, the boulders remain.

The Rev. Mr Campbell, minister of the parish, pointed out to me several ancient places of sepulture situated between the 11 feet old beach and the present beach. This shows that the last change of sea-level had occurred before the district was inhabited.

16. *Dingwall and Inverness*.—Between these towns, the coast shows the 11 feet terrace at many places; also to the east of Inverness, the 11 feet old cliff can be seen from the railway carriage.

17. *County of Nairn*.—Loch Spynie, now a fresh-water lake, was formerly a sea loch. There is a place 3 miles from the head of the loch called by the Celtic name "*Kintraigh*,"\* which means "Head of the Loch." When that name was given, did the loch extend that much beyond its present limits? At "*Kintraigh Bridge*" the surface of the land is on the O.S. map marked as being 11 or 12 feet above the medium sea-level, and therefore about 3 or 4 feet above H.W. Sea-shells (especially *Mya arenaria* and *Littorina*) are frequently dug up at a distance of  $1\frac{1}{2}$  mile inland from Loch Spynie.

Mr P. Duff of Elgin informed me, that at Loch Spynie (beginning from below) there are the following deposits:—

- (1) A bed of marine sand with sea shells;
- (2) A bed of peat;
- (3) A bed of mud containing *Planorbis*;
- (4) A bed of oysters.

\* On the west coast of Argyle, the same word "*Kintra*" denotes a flat moss situated between Loch Shiel and the sea, called the "*Sands of beach of Kintra*."—(Stat. Acct. of Scotland, Ardnamurchan Parish, vol. xii.) The same word occurs in the *Glen na Albin*, at the summit level between the east and west seas,—as indicating the head of the old estuary, or at all events the popular belief that the sea had once reached to that point.

From this succession of deposits, he inferred that the sea had first filled the valley; that the sea having been by some means excluded, peat grew in such quantity as to become a bed; that a fresh-water lake was next formed; that after this, the sea broke in; and lastly, that the sea was excluded, and the existing fresh-water lake formed.

The appearance of the district suggests that a river may once have flowed through the shallow trough now occupied by the Spynie Loch. Was this river the Findhorn?

Near *Kincorth House* there is another trough, where an old beach is visible about 13 feet above H.W. It is now separated from the existing sea-shore by the Culbin sandhills. These sand-hills have apparently been formed by drifting and blowing of fine sand under the influence of westerly gales of wind.

At *Lossiemouth* there is an old cliff whose base is 20 feet above H.W.

*Duffus Castle* has been formerly surrounded by water,—perhaps the sea, let in by deep trenches, cut through the soft beds of clay and sand which abound here.

In Nigg Bay, and also at Stonehaven, I found an old bank, the base of which is from 10 to 12 feet above H.W.

18. *Montrose*.—There is a cave on the coast half a mile from the estuary of the Esk, the floor of which is 15 feet above H.W. (Trans. Soc. Ant. Scot., vol. x. p. 476).

Dr Stuart, in his “Sculptured Stones of Scotland” (vol. ii. p. 88), states that “in the parish of St Vigeans, on the coast near Arbroath, there are several caves.” He gives the height of the floor of one as 10 feet above H.W.

19. *Fifeness*.—A little to the north there is Constantine’s cave, the floor of which I found to be 10 feet above H.W. The height of the roof above the floor is 12 feet. It extends inward from its mouth about 30 feet.

At *Anstruther* I visited a cave on the shore, whose floor is about 10 feet above H.W., and its roof about 30 feet above the floor. The caves at this height were most probably formed when the sea stood at 11 or 12 feet above the present level.

Dr Stuart describes several caves along the Fife coast. He says

they are generally about 100 yards distant from the existing H.W. line ("Sculptured Stones," vol. ii. p. 91).

*Largo*.—I found a bed of sea-shells here at a height of 10 feet above H.W.

*Elie*.—Along the shore, and up the banks of the small stream which enters the sea, flats occur at 11, 15, 26, and 56 feet.\* It is on this last-named terrace that the town of Elie was built.

The Rev. Mr Brown has given an interesting account of the sea shells found in the clay beds here (Edinburgh Roy. Soc. Trans. for 1866-7). The shells are of two kinds—1st, Some which live chiefly or entirely in the mouths of rivers flowing into the sea—such as the *Scrobicularia Piperata*; and 2d, some found only in the deep sea, as *Tellina*, *Rissoa*, *Littorina*, *Pecten*, *Leda*, &c. Several of these implied a sea of an arctic character. The inference was, that when these last-named shells lived, the sea at this place must have been at least 200 feet above its present level. I examined the clay bed containing these shells. It contained numbers of boulders, which were true erratics.

*Pittenweem*.—I visited the old cave in the sandstone rocks on the sea-shore. Its floor is 18 feet above H.W. At the end farthest from the sea, there is a hole in the roof, communicating with what had been the priory garden.

About a mile to the west of Pittenweem, the sea-cliff is continuous for about a quarter of a mile. Its base is about 15 feet above H.W.

20. A cliff whose base is from 10 to 15 feet above H.W. is noticeable also at the following other places, viz., North Queensferry, Crombie Point, Torryburn, Kinning Point, Alloa, and Airth village. The high road from Stirling towards Falkirk by Livilands passes along a terrace 22 feet above H.W. At Bridge of Allan, the High Street is at the same level, bounded by a steep bank about 70 feet high. The house of Carron Hall (near Airth) is on a terrace 18 feet above H.W.

Along the shore at Granton, Wardie, and Newhaven, the old cliff, formed in the boulder clay, runs along the shore at a height of from 12 to 15 feet, with beds of shells at 7 or 8 feet above H.W.

At Portobello, both north and south of the town, the base of the old cliff is from 11 to 12 feet above H.W. At Joppa (at south

\* Some of these terraces may be due to river agency.

end of Portobello) I found shells of the *Pholas* in rock at a height of  $12\frac{1}{2}$  feet above H.W.

Along the shore for two miles to the east of Musselburgh Links, there is a bed of shells at a height of 7 or 8 feet above H.W., near the base of the old sea cliff.

At the mouth of Dunglass Burn, near Cockburnspath, Berwickshire, the old cliff consists of a mass of indurated shingle, at a height of  $11\frac{1}{2}$  feet above H.W. I found imbedded in it the *tibia* of an ox of small size.

At Eyemouth, there is an old cliff whose base is 12 or 13 feet above H.W.

#### B. Terraces (20 to 30 feet above H.W.)

1. *Kirkcudbrightshire*.—On the coast near Borgue there is a cave, the mouth of which is 27 feet above H.W. and 98 feet distant from the existing beach (Pro. S.A. Scot., vol. x. p. 479).

2. *Wigtownshire*.—Around Luce Bay, there are traces of terraces about 25, 75, and 95 feet above H.W.

3. *Ayrshire*.—At Ballantrae, Girvan, and Ayr, a cliff whose base is about 25 feet above H.W. is well marked on the boulder clay when this deposit occurs near the shore;—but on the hard rocks it is not visible.

At Ballantrae, there is some appearance of higher cliffs at 40 and 75 feet.

Near Ardrossan, there is a cliff whose base is from 24 to 26 feet. Beds of sea shells occur near the foot of the cliff.

Professor Heddle of St Andrews informs me that, “to the north of Stinchar Valley, near Lendalfoot, the coast displays two raised beaches, at 25 feet and 80 feet respectively. The higher exhibits an unusual feature, in respect of its terraced slope not terminating when it abuts upon a projecting hill-spur, but partly envelopes it, on what is now the shoreward side. This is seen where, stretching north from Burnfoot, it impinges upon the steep sided Knock of Carlton. Here, instead of ceasing, or even being replaced by a gash in the hill slope, it maintains its usual course, running partly round the hill, hanging on to its skirts, with what appears to be a precarious hold.”

On the island of Arran, on both east and west side, there is a

sea terrace from 20 to 30 feet above the sea, mentioned by Dr Bryce, "Geology of Arran" (4th ed. pp. 136, 149). At the mouth of Glen Catacol, he refers to two other terraces, each 40 feet in height,—by which I suppose he means above the sea-level.

4. *Firth of Clyde*.—At Cove, opposite to Dunoon, there is a cave about 200 yards from the shore, the floor of which is about 20 feet above H. W.

The Rev. Mr Landsborough has published an account of a find of sea-shells about 20 feet above H. W. at Ardrossan and 30 feet at Kelly (Lond. Geol. Soc. Jour., vol. iii. p. 444).

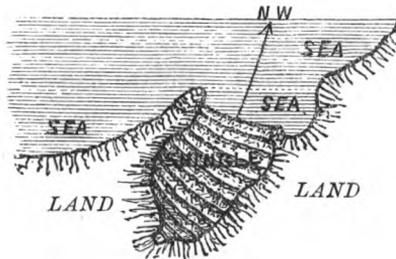
Along the shore, where stand the villages of Dunoon and Innellan, and round Toward Point into Loch Striven, there is a steep bank, more or less parallel with the existing shore line, and at a distance of from 100 to 300 yards, whose base is from 21 to 24 feet above H. W. At Rothesay, on the south side of town, this old beach is very distinct.

5. *Islay*.—A paper in the Wernerian Transactions, vol. xxix. p. 110, describes an old beach 25 feet above H. W.

6. On the *Island of Jura* there are several remarkable beaches, the lowest being a little more than 20 feet above H. W.

On the west side of the island, about 4 miles to the north of Port Askaig Ferry, there is a sandy bay called "Traigh-nan-Fennaig," which I believe

means "Sea-shore of Crows," on account probably of the number of these birds frequently seen there eating the shell-fish thrown up by the waves. The bay faces the N. W., from which direction the heaviest waves now come. When the sea stood at a higher level, the waves would roll in here with even more force. A sheet of shingle composed of beautifully rounded white quartzite pebbles stretches up from the sea-shore to a level of about 21 feet above H. W. The distance of the highest point is about 350 yards, the breadth on an average about 250 yards. Across this sheet of shingle there is a series of ridges and troughs, about ten or twelve in number, more or less parallel to one another. Those nearest the shore are parallel with the present shore line. They gradually change in



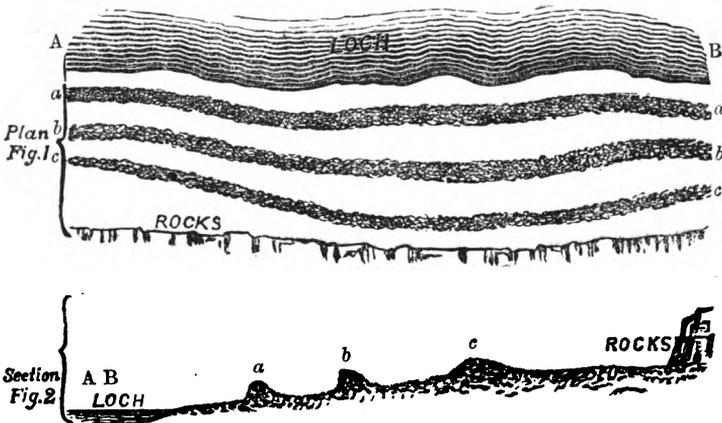
direction as shown in the prefixed diagram. The depth of the troughs is from 2 to 3 feet beneath the adjoining ridges. The tops of the ridges are flat, from 15 to 20 feet in width, and the troughs between the ridges about as much in width. These troughs and ridges at once arrest attention by their regularity and singularity. They are not absolutely straight, but curve or bend gently, and all much in the same way. The pebbles are about the size of a man's head and less, never larger. They consist entirely of quartzite; and as the rocks on the sea cliffs adjoining are quartzite, the probability is that they have been derived from these rocks. The shingle has no doubt been heaped up by the action of the waves, when the sea stood at least 20 feet above its present level. The series of parallel ridges and troughs is to be accounted for in the same way as the ridges of sand and shingle which are now occasionally seen, along a beach, where pebbles or sand is thrown up by the force of the waves.

In driving along the south side of Lochs Lochy and Oich (Oct. 1877), I observed that similar ridges of fine gravel and sand had recently been formed on the existing beach. These fresh-water lochs, in rainy weather, occasionally rise from 4 to 5 feet above their usual level. On the occasion referred to, I noticed three ridges of fine gravel. The one nearest the loch was about 3 feet distant from it, and it was continuous for more than a mile, with occasional interruptions by projecting rocks. The next ridge, on a higher part of the beach, was about 3 feet distant from the first-mentioned ridge, and was parallel with the first ridge. The third and highest ridge was also generally parallel, but in some places presented a deviation, and then, instead of being 5 or 6 feet distant from the middle ridge, it was 10 or 12 feet. In this diagram (fig. 1) the very black wavy line A B represents the loch, and the dotted lines *a*, *b*, *c*, the three ridges, as on a ground plan. Fig. 2 shows these features in section.

The want of parallelism in fig. 1 is due to the circumstance that the beach does not slope down everywhere at the same angle.

Some time previously to my visit, the weather had been rainy and stormy, so as to raise the general level of the lake. The wind was in such a direction as to blow the waves on the shore, and to force the gravel up on the shore into ridges.

It is probable that each ridge represents a storm at different levels of the loch.



The well-known "Standards" of Lossiemouth have presented a problem not yet solved. Will the principles, which are suggested by the ridges on the old beaches of Jura, and on the existing beach of Loch Lochy, not apply to the Lossiemouth gravel ridges?

7. *Loch Fyne*.—The following is from my note book, dated 1843:—"Along Loch Fyne, a 30 feet beach or cliff very perceptible, near Dunderawe Castle, and at the Ferry towards the east. It is also pretty well marked to the west of Inveraray."

8. At the north end of the Crinan Canal at Duntroon Castle, a line of beach and an old cave were pointed out to me by Rev. Mr Mapleton (August 1879) at a height of about 23 feet above H.W. This 23 feet cliff is well seen running along the south shore of Duntroon Bay to the Crinan Canal.\*

9. *Coast of Lorn*.—In the Wernerian Transactions (vol. viii. p. 110) there is notice of a terrace at about 30 feet above H.W., which, it is stated, can be followed for about 8 miles.

When passing in the steamboat, I observed (Oct. 1877) a 22 feet

\* I find from my notes that I made the base of old sea cliff in Loch Fyne 25 feet, whilst in Loch Crinan it seemed to be only 22 or 23 feet above H.W. Perhaps in former times a difference existed, as there is now, between the levels of the sea in these lochs. Mr Davidson, the manager of the Crinan Canal, informed me that the rise and fall of the spring tide is at Ardrishaig 11 feet, and at Crinan only 5 to 6 feet. The Admiralty Tables so far confirm this, giving for Ardrishaig 9 feet and for Loch Crinan 6 feet.

sea cliff continuous for several miles, being a rocky cliff in which caves occasionally occur.

10. *Oban*.—In the part of the town behind the Caledonian Hotel, when excavations were made for new gas works, a bed of sea shells was found at a height of about 25 feet above H.W.

Along the coast both north and south of the town, for more than a mile, a terrace, bounded by a steep bank, occurs,—the base of the bank being from 22 to 25 feet above H.W. and from 300 to 500 yards distant.

To the north of the town, at the gate to Dunolly House, the conglomerate rocks present smoothed surfaces, as if worn down by water. A flat runs up against these rocks to a height of about 25 feet above H.W. The flat is composed of water-borne gravel and small boulders, as may be seen, where streams have cut through the beds near the shore.

The carriage road between Oban and Loch Etive passes over an extensive flat, called in Gaelic “Saul More” (*i.e.* Big flat), which is about 22 feet above H.W., and is bounded for a mile or more by a steep cliff.

I visited (August 1877) the island of Kerrera opposite to Oban, landing at the north end. A 25 feet sea cliff is very distinguishable. Numerous boulders lie on the terrace bounded by that cliff, most of them grey granite. I noticed one quartzite boulder  $7 \times 5 \times 4$  feet, which probably came from the north, as it is only in that direction that quartzite rocks abound.

Along the coast, both in the island of Kerrera, and on the mainland, there are many caves at a height of about 30 feet above H.W.

At both the Corran Ferry (Loch Linnhe) and the Connel Ferry (Loch Etive) a 30 feet beach is visible.

Along the west side of Loch Leven, near Ballachulish, a 17 feet and a 40 feet beach is visible. They are on both sides of the loch.

11. On the north side of Linnhe Loch, opposite to Fort-William, lines of terraces at 20, 120, and 494 feet above the sea-level occur (Edin. Roy. Soc. Second Boulder Report, p. 161).

In Kilmallie parish (near Fort William) the 30 feet bank runs along the shore. The Rev. Dr Clark pointed out to me (Oct. 1877) a spot where he had seen sea-shells excavated at a height of 20 feet above H.W.

12. *Island of Mull*.—At Saline, Duart Castle, and Achnacrosh a cliff, running sometimes continuously for several miles, was noticed by me from the steamboat. Its base seemed to be about 25 feet above H. W.

This cliff is probably the one referred to in a paper in the Edinburgh New Philosophical Journal, vol. xxix. p. 94.

13. *Island of Rum*.—A 25 feet cliff noticed by me from steamboat.

Since this sentence was written, I have received (Feb. 1880) from Professor Heddle of St Andrews a letter, in which he says—"Some sketches were made by me of a 30 feet raised beach, cut into the south shore of Rum. I regard this as one of the most interesting beaches in Scotland, as it is cut for nearly two miles far back into the acidic igneous rock, which Dr Macculloch has called 'Syenite.' There is no locality seen or read of by me, which speaks to the ocean having stood for so great a length of time, at the above height. All has been cut clean away down to a uniform level, flat as the waters which now lie 30 feet below."

14. *Dingwall*.—To the west of the town for about 2 miles, there are two terraces,—one from 28 to 30 feet, the other about 12 feet above H. W. The town of Beaully stands on a flat 28 feet above H. W. The skeleton of a whale found in a bed of clay near Dingwall, at a height of 12 feet above high-water mark, of course indicates a sea which must there have reached a level of more than 20 or 30 feet above the site of the skeleton (Wern. Trans., vol. ix. p. 110; and Edin. Roy. Soc. Trans., vol. x. p. 105).

It is mentioned in Wernerian Transactions, vol. ix. p. 110, that sea shells were found at Cromarty about 30 feet above H. W.

15. *Inverness*.—On line of railway between Dingwall and Inverness, there is at different places a well-marked range of cliff, some hundred yards distant from the existing shore, from 20 to 25 feet above H. W.

At Kessock Ferry, this old cliff is conspicuous. By levelling, I made its base from 25 to 28 feet above H. W.

The lower part of the town of Inverness is on the 25 feet terrace.

Below Raigmore House, there is a steep bank running parallel with the shore, whose base is about 30 feet above H. W.

All the way between Inverness and Dalcross Railway Station, the 25 feet bank is very visible.

16. *County of Nairn*.—Near Duffus Castle, an old cliff runs by Drynie, whose base is 25 or 26 feet above H.W.

Cawdor Castle is on a flat about  $25\frac{1}{2}$  feet above H.W.

At Burgh Head, in company with the Rev. Dr Gordon of Birnie, I examined a deposit of sea shells 30 feet above H.W. The shells of young cockles and oysters were unbroken, and were in a coarse blue clay. In this blue clay were boulders of mica slate, transported probably from the N.W.

At Lossiemouth, the old cliff seemed to be about 20 feet above H.W. But it is not distinct.

Notice may here be taken of "The Standards" of Lossiemouth. They consist of four or five long ridges of gravel, approximately parallel with the existing shore line, and rising to a height of from 18 to 21 feet above H.W. They are about 1200 yards distant from the present shore line. It has been surmised that they may have been formed by a river such as the Spey, or by the action of the sea waves.

A ridge somewhat similar near the existing shore line was forming when I visited Lossiemouth in 1872. I was told that it had been thrown up by the sea storms during the previous thirty years.

A similar ridge was noticed by me at the mouth of the North Esk near Montrose, and also at the mouth of the river Cowie near Stonehaven. At each of these places, the gravel, sand, and mud brought down by the river is by the action of the sea forced up into long ridges which divert the stream into a new course parallel with the beach. The action of the sea on the one side, and of the river on the other, forms the ridge.

A similar ridge many years ago I noticed at the mouth of the Peaths Burn, between Dunbar and St Abb's Head. A ridge was formed about a hundred yards in length,—the sea heaping up shingle, and the burn scooping out a longitudinal trench parallel with the shore line.

17. *Aberdeenshire*.—On the authority of the late Professor Fleming, I give three terraces, on the coast, a little to the north of Aberdeen, at 12, 50, and 80 feet.

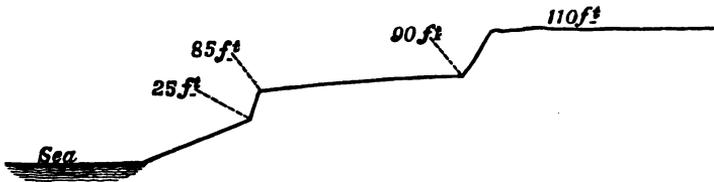
18. *Firth of Tay*.—At Broughty Ferry and Newport, there are two ranges of old cliffs, the base of the lowest, 26 feet above H. W.

There is also at both of these places one of 107 feet.

On the river Earn, a tributary of the Tay, a cliff runs for some distance above its junction with the Tay, at a height of 30 feet above H. W.

19. *Firth of Forth*.—Along the south coast of Fife generally, there is a cliff whose base is from 26 to 30 feet above H. W.

Between Crombiepoint and Torryburn there is a large accumulation of detrital gravel, on which there are several terraces, as shown in this section.



Near M'Duff's Castle, situated about a mile east of Wemyss Castle, there are the celebrated caves with old sculpturings on the inner walls. Their floors are 25 feet above H. W. Their entrance is about 200 yards from the existing shore. The cavities go back from the entrance about 30 yards. Their width varies from 6 to 12 yards. Their height is from 3 to 4 yards. They have evidently been inhabited, judging from the contrivance for barricading the entrances, and from the recesses excavated in the sides as if for cupboards.

Between Kinning and Crombiepoint, there is a cliff whose base is about 20 feet above H. W.

At Elie, there is a promontory on the shore on which a bed of marine shells was seen for about 80 yards, chiefly in mud, and partly in sand, at a height of 12 to 14 feet above H. W. The sea must have been some fathoms deep here, when these shell-fish lived.

20. At Falkirk, there is a cliff whose base is 27 feet above H. W.

At Inneravon, near Grangemouth, the old cliff has at its base numerous beds of sea shells from 22 to 25 feet above H. W.

At Caroline Park, Granton, and Newhaven, beds of sea shells were found at from 15 to 19 feet above H. W., consisting chiefly of *Patella*, *Solen*, *Cardium*, and *Ostrea*.

At Musselburgh, a bank more or less steep can be traced from Joppa (south of Portobello), crossing Magdalen Burn, New Hailes policy, the river Esk, the fields north of Inveresk Church, and the grounds of Inveresk House, eastward by Pinkie Burn, and as far as Drumore Lodge at the east end of Musselburgh Links. The base of this bank is about 28 feet above H.W. At Newbigging, the bank is distant about  $1\frac{1}{2}$  mile from the existing shore. It is cut through by the Magdalen Burn, the river Esk, and also by Pinkie Burn. This bank is in the boulder clay. It seems probable, that when the sea stood at the above level (of 28 feet), the River Esk did not follow its present course to the sea, west of Inveresk Church, where there is now a vertical cliff. If that passage near Monkton village were blocked, a great lake would be formed, whose west margin would coincide with the long ridge of gravel running north from *Campend* (properly *Kaim-end*), and the outflow of the lake would be by the small valley at Pinkie Burn, situated to the east of Inveresk.

In Aberlady Churchyard (East Lothian) razor and other sea shells were found by me at 18 and 25 feet above H. W.

At Lochbridge Toll, near North Berwick, the base of the old cliff is 33 feet above H.W.

### C. *Terraces* (between 30 and 50 feet).

1. In Campbelton Loch (Kintyre), the 40 feet cliff is very conspicuous on both sides, as well as the 25 and the 11 feet cliff.

2. In almost every sea loch which runs up from the Firth of Clyde, a 40 feet terrace is visible, as in the Gairloch, the Holy Loch, Dunoon, Rothesay, and Wemyss Bay.

Along the west coast of Bute, the 40 feet sea-cliff I traced for many miles. The absence of the lower cliffs there may be accounted for by denudation, the coast being exposed to the full force of south-westerly gales.

About 4 miles from Glasgow, on the line of the canal to Ardrossan, and at about 40 feet above the present channel of the Clyde, *i.e.*, about 30 feet above H. W., beds of sea shells were found of the species now existing at the mouth of the Firth, where the sea is entirely salt (Wern. Trans., vol. iv. p. 568).

3. *Loch Lomond*.—There is a terrace along both sides about

20 feet above the average surface of the loch. The surface of the loch is in summer about 17 feet and in winter about 23 feet above H. W.

Sea shells, chiefly *Mytilus* and *Planorbis*, have been found at various places and at various heights in and round Loch Lomond ;— as near Buchanan (on the north side of the loch), at from 20 to 40 feet above the sea; at Arden (on the west side), at about 40 feet above the sea; and on the island of Inch Lonach. Many of the shells occur with the valves entire.

These last mentioned shells, as reported by Mr Robertson of Glasgow, consist of several Arctic species. Flint pebbles were also found amongst them, supposed to have been transported from Mull.

Of course when the sea stood at the height of 40 feet or more above its present level, Loch Lomond was an arm of the sea. When the sea sunk to the level of 25 feet,—at which height there are many traces of a terrace round the coast,—was Loch Lomond still an arm of the sea? If at and near Balloch the bank of detritus was high enough, the loch might have then become a fresh-water lake by blockage.

Along the margin of the loch, there is a line of cliffs and escars whose base is about 20 feet above the loch.

These escars are composed of coarse gravel. At Cameron House, many of the pebbles in the gravel pits are of conglomerate, a rock forming a band which crosses the lake north of Cameron in its course towards Callendar. There are also pebbles of granite, both red and grey, derived, no doubt, from the hills situated 10 or 12 miles to the N. or N.W.

At Cameron and Auchendenny, there was once a continuous escar of half a mile in length running parallel with the shore of the loch. It has now been cut through at several places for roadways. Its top reaches to a height of 52 feet above the lake. If it was a submarine deposit, the sea, of course, must then have been at a higher level than now, and, accordingly, a steep bank, with a flat running out from it, occurs in Auchendenny policy, at a height of 73 feet above the lake, or 93 feet above the sea. This flat would then be the sea bottom.

These escars along the sides of lakes, which were formerly arms of the sea, may be due to various agencies. In narrow channels,

they may be thrown up by storms, or may be gradually formed by tidal currents. To this last agency probably, are due the "whale's back shoal" now in the Firth of Forth, and the bars of sand and gravel in Campbelton Loch. But it is also possible, that after the loch, by the subsidence of the sea, had become a fresh water lake, torrents rushing down the adjoining hills may have scooped out the submarine detritus lying along the base of the hills, leaving escars more or less parallel with the hills.

The above 40 feet flat is traceable to the south of Loch Lomond by Tillichewan Castle, on the west side of the valley, and by Renton Railway Station and Bowling on the east side. At Renton, the cliff which bounded the terrace is represented by Old Red Sandstone rocks. They had formed an island when the sea stood at the 40 feet level.

4. In *Loch Long*, a sea cliff is well marked at Blairmore and Ardentinny. Its base is from 40 to 45 feet.

At the head of *Loch Goyle*, there is an extensive meadow or swamp, the head of which is about half a mile from shore. This flat abuts against the hills at a level of 40 feet above H. W.

5. In *Loch Fyne*, the 40 feet cliff and terrace is seen at numerous places. Inveraray Castle stands on it. To the north-east of Inveraray, a cliff of old Red Sandstone runs parallel with the loch, about 100 yards distant and with a base about 40 feet above H. W. At Outer, (in July 1839) then the residence of Mungo Nutter Campbell, a bed of oysters was found in the garden 30 feet above H. W., and 100 yards distant from the present sea line. A line of rocky cliffs, with caves in them, at a height of 40 feet above H. W., runs for 2 miles east of Inveraray on the road to Cairndhu.

6. Captain Bedford, R. N., for many years Admiralty Surveyor on the West Coast of Scotland, sent to the London Geological Society a note of raised beaches as follows, (vols. xi. and xii.) :—

Lunga Island, in two places, at a height of 40 feet 8 inches above H. W.

North Fullah, in one place, at the height of 40 feet 10 inches.

Kerrera Island, do. do.

Colonsay, do. do.

Oransay Island, do. the height of 38½ feet.

Jura Island, at S. W. point of, do. 34 feet 8 inches.

Do. Loch Tarbert, do. 42 feet 1 inch.

This Loch Tarbert cliff is stated to be traceable for 8 miles, and having at its base a terrace varying in width from 100 yards to three quarters of a mile from the present shore. The Admiralty Sailing Book mentions, that "on the eastern side of Jura, there are some singular caves of spacious dimensions, with dry level floors, and lofty roofs beautifully arched."

Captain Vetch had previously noticed the succession of terraces in Jura, and states that there are six or nine of them, the highest being about 40 feet, and three-quarters of a mile from the present shore line. He also notices the caves on the north side of Loch Tarbert, about 100 yards from the shore, and about 20 or 30 feet above H.W. (Lond. Geol. Soc. Trans., Second Series, vol. i. p. 416). One of these caves was pointed out to me, as having been lived in during the grouse shooting season, not many years ago, by a gentleman who had a lease of the shootings, but in connection with which there was no dwelling-house which he could inhabit.

On Islay Island, a sea cliff whose base is from 40 to 43 feet above H.W. is mentioned in Wernerian Transactions, vol. viii. p. 101.

7. On the south side of the *Island of Shuna* (Linnhe Loch), the 40 feet beach is easily noticed from the steamboat.

Along and near the Crinan Canal, at various places, the 40 feet beach is well marked, as at Auchendarroch (near the south end of the canal) and at Dunadd (near the north end).

*The Lewis*.—In Loch Seaforth, on the east coast, an old sea cliff, whose base is 36 feet above H.W., runs for several miles. Ardvourlie Castle stands on the terrace between the cliff and the sea. It is visible also at the shooting lodge on the Matheson estate, called Ath-an-Linne,—to the north of Ardvourlie.

Along the north coast, between Barvas and the Ness, I observed at several places an old beach line going round what had formerly been arms of the sea, at a height of about 40 feet above H.W.

8. At *Glenshiel*, north of Glenelg, there are banks of detritus, showing a terrace at a height of 40 feet above H.W.

9. *Oban*.—At Dunolly, about half a mile north of Oban, caves and hollows in the conglomerate rock occur at a height of about 44 feet above H.W. The avenue to Dunolly House runs for a considerable distance along a terrace at this height.

What is called "*the dog stone*" is on this avenue. It is a pyramid of this shape, about 50 feet in height. Its width half way up is about 32 feet, and near the base about 25 feet. The lower part, for about four feet up, is smooth, the effects of friction by the sea, when the sea, encircling the stone, stood at 30 or 40 feet higher than now.



10. On the left bank of *Loch Etive* a terrace prevails extensively. The hotel at Taynult, and a large boulder called Rob Roy's Putting Stone, are on it. Its level is not quite 50 feet above H.W. Gravel knolls and escars are numerous here.

On both sides of *Loch Etive*, from its mouth up to its head, the 40 feet flat is very conspicuous. On its north side, the extensive plain of *Auchnacree* is at the same level.

11. *Loch Creran and Appin*.—Aird House (Robert Macfie, Esq.) is situated on a terrace about 40 feet above H.W., bounded by rocky cliffs on each side. The rocky hill to the north terminates at its west end, in a point called "Craig-oul," meaning "Hole in Rock," where at a height of about 40 feet above the sea, there is a cave and tunnel through the rocky ridge, probably formed by the sea when it stood at a higher level.

To the east of Aird House, there is a strath or bit of flat land 30 to 40 feet above the sea, running for a mile. It has once been a sea loch.

12. At the upper end of *Loch Creran*, a river runs into the sea out of a fresh-water lake, whose surface is from 25 to 30 feet above H.W.

This lake had formerly been an arm of the sea. Robert Hall, the tenant of "Fas-na-Cloich" farm (situated on the east bank of the lake), informed me that in almost every part of this lake, round it, and under its water, there are sea shells in great abundance. He said that not long ago, Mr Mackay, the tenant of *Glenure*, on the west side of the lake, carted from the river running into the lake, quantities of clay full of sea shells, which he spread on his fields. The word "Creran" means ("crer") clay ("an" or "Avon") river. Hall pointed out to me, that the existing blockage of the

lake, where its surplus waters flow to the sea, consists of a bank of sea sand more than 4 feet thick, containing sea shells, and that above this sand, there are layers of gravel. Those I saw, reach up to an extensive flat 40 feet above H.W.

*Appin House.*—Policy grounds show the lines both of the 25 and the 40 feet sea-margins.

13. *Ballachulish Bay.*—On the east side of the bay, there is the church of Onich, with a few cottages along the side of the road which leads from Ballachulish to Fort William. There is a considerable flat, which I had often noticed from the steamer between this road and the sea shore, running for half a mile in length and about a quarter of a mile in width. The terrace is bounded by a vertical range of rocks, having all the appearance of an old sea cliff. Its base is from 35 to 40 feet above H.W. The terrace between the cliff and the sea is composed chiefly of gravel and sand.

At the ferry, near Ballachulish Hotel, the 40 feet terrace is visible on both sides; and it runs along the west shore of Loch Leven. In the policy grounds of Lady Beresford's residence (north of Ballachulish Hotel) this terrace and a lower one at 17 feet are visible.

The captain of the steamer told me of a popular belief that Loch Leven was once a fresh-water lake, and that the overflow of its waters to the sea gradually cut a passage, by which communication with the sea was effected. Circumstances favour this idea, and may have suggested the belief. The passage at the mouth of Loch Leven is about 150 yards wide; its depth at low water only 6 to 7 feet. Here may have been the blockage which formed the lake. The depth of the *loch* inside is in one place 60, and in several places 30 fathoms. On the sea side of the entrance to the loch, the depth of the sea is only 17 fathoms.

It is very likely that when the sea stood say at or about 100 feet above its present level, sediment was deposited in the whole of this bay, and formed an accumulation, of which remnants are now to be seen in the 40 feet terrace before described. When the sea sank to its present level, there might have been a barrier between the present Loch Leven and the sea, which barrier would in time be cut through by the stream issuing from Loch Leven. It would be a narrow channel at first; but when it became low enough to allow the sea to enter, the action of the tide would widen the passage.

To the east of Onich there is an extensive meadow on the farm of Inchree, with a height of from 35 to 40 feet above H.W., which may also have been first a sea-bottom and ultimately a fresh-water lake. Thick beds of mud form the banks of the stream issuing from this meadow, probably part of the bottom of the ancient lake.

There is also to the north of Onich church, a hollow with a stream running through it, where a lake has formerly existed. Culchcanan House is at this ancient lake mouth.

14. *Argyleshire*.—On both sides of *Corran* ferry, two terraces can be made out, one 21 and the other 50 feet above H.W. This higher terrace at the ferry may correspond with the 45 feet terrace which occurs so generally elsewhere; because, as the two sides of the Linnhe Loch here approach one another, the tidal wave will rise higher than elsewhere. The rise of the tide at Corran Ferry even now is 12 feet, whilst elsewhere it is only 8 or 9 feet.

In *Ardgower* policy, situated to the north of Corran Ferry, there is an escarp about half a mile long, parallel with the axis of the Linnhe Loch. The base of the escarp is about 40 feet, and its ridge from 75 to 80 feet above H.W. A terrace comes off from the escarp along its south side, of which terrace advantage has been taken to form the avenue to Ardgower House.

In this part of the Linnhe Loch, there has at one time been an enormous amount of detritus, through which troughs or valleys have been cut by the scouring action of the tides, now and always hitherto rapid here, owing to the narrowness of the loch. The deepest of these troughs is 60 feet below the surface of the sea, as shown by the soundings. The other troughs are only a few feet above high-water mark, and are partly occupied by fresh-water lakes. On each side of Corran Ferry the water deepens rapidly.

It is not improbable, that after the sea fell to its present level, the part of the Linnhe Loch situated to the east of Corran Ferry, was a fresh-water loch, as Lochs Oich and Ness are now. In that case, a river would flow through the detrital blockage at Corran Ferry, being the overflow of a very large body of fresh water, extending up to Fort William and Corpach. The cutting through of the detritus at Corran Ferry, down to the sea-level, would of course

cause a subsidence of the lake, and the conversion of it into a sea loch.

The surface of Loch Oich (part of the Caledonian Canal) is about 100 feet above the sea. When the sea after standing at that height, or a little higher, round the coasts of Scotland, sunk to a lower level, the configuration of the sea-bottom, in Loch Oich, must have been such as to retain water at that level, and convert it into a lake; whilst in those parts now occupied by Loch Lochy and Loch Ness, the configuration of the sea-bottom must have been such as not to retain water at so high a level. These levels would depend on the amount of detritus in the Great Glen at different places.

15. At *Gairloch* and Loch Ewe (west coast of Ross) there is a well-marked old bank parallel with the shore, whose base presents a horizontal line about 42 feet above H. W. spring tides. At Flowerdale, about 2 miles from Gairloch, on the road to Loch Maree, there is an extensive meadow, apparently at one time a lagoon, 45 feet above H. W. The growth and decay of aquatic plants has probably contributed to raise its surface.

16. Under the head of E terraces notice may be taken of a terrace at 33½ feet near *Strome Ferry*.

17. *Ross-shire*.—On the east coast, near Tain, an old cliff runs towards Tarbat, whose base is about 32 feet above H. W.—the cliff showing on its top a flat about 70 feet.

The sea shells reported as found in *Cromarty*, at a height of 30 feet above the sea (Wern. Trans., vol. ix. p. 110), of course indicate sea at a higher level.

18. *Beaully Firth*.—Sea terraces at 40 feet along coasts, and also at Lentrán and Clunes Railway Stations, near Tain.

Between the towns of *Nairn* and *Forres* there is an extensive flat, stretching for several miles, at an average height above the sea of 45 feet, consisting almost entirely of gravel and sand, in beds more or less horizontal. This flat is well covered by boulders, much rounded, and all from the west. The probability is that these boulders were spread by floating ice on the sea-bottom, which formed the flat above referred to, though by denudation much of the gravel and sand has been removed, leaving the boulders more conspicuous.

19. *Fifeshire*.—Along the south coast, and in particular at Buck-

haven, Largo, and Culross, an old cliff is visible, with its base from 30 to 40 feet above H.W.

At Elie, Cellardyke, Leven, Kilconquhar, and Cameron Bridge, a terrace from 54 to 58 feet is very well marked. At Tullybody, near Alloa, a steep cliff of boulder clay is well seen with a terrace running from it towards the River Forth, at a height of 40 feet above H.W.

At Cambus Railway Station, near the Ochils, there is an extensive flat bounded by a cliff 43 feet above H.W.

In the low-lying district called the "*Carse of Stirling and Falkirk*,"—extending in an east and west direction from Kippen to Tillicoultry, and in a north and south direction from the Ochil hills to Callendar Park, there are distinct traces of levels at 25 feet, 40 feet, 54 to 58 feet, 70 feet, and 110 to 115 feet.

Thus at Dunmore and Airth, there are ranges of sandstone cliffs facing seaward, whose base is exactly 40 feet above H.W.

At Airth, I found a bed of large sized oyster shells about 6 or 8 feet above H.W., which probably lived when the sea stood at the 40 feet level.

A little to the north of Dunmore, the entire skeletons of two whales (one 85 feet long) were found, each about 3 or 4 feet below the surface of the land, and 20 feet above H.W., three quarters of a mile distant from the present sea shore. The exact position in which one of these Dunmore whale skeletons lay, was noted by a gentleman, who at the instance of the late Professor Jameson, of Edinburgh University, went to examine it. He states in a letter to the Professor, that "the *tail* lies in a north-easterly direction from the *head*, and just in such a situation as the animal would probably acquire, had it run aground when coming up the estuary.\* By measurement, it has been ascertained that the place where the remains lie, is between 23 and 24 feet higher than the highest tide of the Frith at present" (Edin. Phil. Journal, vol. xi. p. 416).

On the east side of Airthrey policy (Lord Abercromby's), near the Bridge of Allan, another whale skeleton was discovered. The following particulars are given in Mr Charles Rogers' Guide-Book (page 177):—The bones lay in regular order, and had suffered little

\* During the last half century, whales have run themselves ashore at various places in the Firth of Forth, as at Long Niddry, Burntisland, and Alloa.

from decay, the jaw-bones only excepted. Some of the ribs were 10 feet long. The total length of the animal was 72 feet. The skeleton lay nearly east and west, the *head being towards the east.*

The bones were in the soft blue silt found everywhere under the strong adhesive clay which tops this part of the Carse, at a depth of  $4\frac{1}{2}$  feet from the surface, and 22 feet above the level of the highest stream tides of the Forth.

The field where the skeleton was, goes by the name of the "*Whale field.*" It is a few hundred yards distant from the old cliff, whose base is about 40 feet above H. W.

Close beside the skeleton, there was a perforated stag's horn, which might have been used as a harpoon; but whatever was its use, this relic seems to indicate, that it was within the human period when the whale was stranded, and when the sea was at, or rather considerably above, the 40 feet level.

That the animal had run itself aground, and had not been killed when swimming in the sea, and thereafter drawn ashore, may be probably inferred from the fact, that it was lying with its *head* in an *easterly* direction.

It probably came up the estuary, which then extended west of Stirling for 8 or 10 miles. As it would find itself getting into shallow water when on the south or east side of the Abbot's Craig, it might turn towards the north, and coming there near the shore, change its course towards the east, when it would get again into water still more shallow. In fact, the present levels of the land show, that what had been a submarine bank was between the course of the whale and the sea, and would intercept its return seaward.\*

Along the foot of the Ochil range at this place, viz., between Logie church and Blair Logie village, there is a hollow, as if

\* In September 1862 I saw some of the bones of this whale in the Stirling Museum, with a label attached, from which I give the following extracts:—  
 "Part of the skeleton of a whale, upwards of 70 feet long, found in 1819 at Airthrey, embedded in the blue silt under the clay. Levels were taken at the time, from which it appeared that the skeleton lay 22 feet higher than the pitch of the present highest stream tides of the Forth. Therefore, the highest tides of the river are now 26 feet lower than when the whale was stranded, which must have been many centuries before the Roman invasion, as there was till lately on the banks of the river, near Manor farmhouse, a Roman fort."

scooped out by a current,\* whilst half a mile to the south, the ground is about 12 or 15 feet higher, showing less depth of water there. It was in this hollow that the whale's skeleton was found.

Whale skeletons were also found at the following places :—

(1.) At Christie's Brick-work (Stirling), In the "sleech" or mud below the brick clay, two were found, about 15 feet above H.W.

(2.) At Cornton Brick-work, one was found partly in the brick clay, partly in the blue soft mud beneath, about 16 feet above H.W.

(3.) At Blair-Drummond, 6 miles north-west of Stirling, one was found in the Carse clay, about 30 feet above H.W. ; and close to it a fragment of a stag's horn, with a piece of wood in the hollow of the horn, which had been apparently a handle or shaft for using the horn.

In connection with this whale, it deserves to be mentioned, that its bones lay in the Carse clay forming a bed here 4 feet thick, and in which *there occurred sea shells* forming a layer 4 or 5 inches thick. This fact proves, that the whale died and left its bones, on what was part of the sea-bottom. The finding of the stag horn among the bones shows, that the body of the whale was not beyond the reach of the inhabitants of the adjoining shore.

(4.) Near Gargunnoch, about 4 miles west of Stirling, in the year 1817, another skeleton of a whale was found in the mud or "sleech" of the district, about 33 feet above H.W. †

The 40 feet old sea-margin is well seen, at numerous places, along the southern base of the Ochil range, and also to the westward by Keir, Ochertyre, Blair-Drummond, and Coldoch up to Thornhill.

Near Blair-Drummond, and within the area of the Carse, there is a low hillock called "Naid's



Knoll," of this shape. It is in length about 98 yards at its base ; its greatest width is about 40 yards, viz., near the top, which is

\* The smoothed rocks behind Logie Kirk, show that when the sea stood at a higher level, there must have been a strong current, which, besides smoothing the rocks, would scoop out the sea-bottom near these rocks.

† Lately Professor Turner, of Edinburgh University, informed me of another skeleton of a whale having been found at Gargunnoch in the year 1877, and among the bones, an *article of apparently human workmanship* was picked up, which is now in Professor Turner's custody, but I have not seen it.

flat. It consists chiefly of Old Red Sandstone rock. The longer axis AB, is W.N.W. and E.S.E. The base of this knoll is 40 feet above the sea, and its surface at the highest part 80 feet above the sea.

Its external character seems to indicate that its present shape is due to the action of a current which has swept over it from the westward. The inference is strengthened by the circumstance that the lowest part of the high ground or ridge which divides this district from the western part of Scotland bears W.N.W. from the knoll. This point is the Pass of Bolat, 220 feet above the sea, and distant about 13 miles. When regard is had to the direction of the Gargunnoch hills on the south, and to the range of hills on the north, it is probable that any current flowing through this valley would flow over the "Naid's Knoll," in a direction E.S.E.

With reference to this 40 feet terrace, notice deserves specially to be taken of a range of sandstone cliffs in the River Teith, and to east of it, where it reaches the Carse district. The base of these cliffs is about 41 feet above H.W. On the east side of the river, and at some little distance above its mouth, they are about 30 feet in height, and face west. But at the mouth of the river the cliffs turn eastward, so as to face the south, and are there from 40 to 50 feet in height. The difference in direction and height may be due to the fact, that the last-mentioned cliffs would be more open to the force of the waves when the sea stood at the 40 feet level; whereas the former facing the west, and being in a narrow inlet from the sea, would be less exposed to such action.

The 40 feet terrace, bounded by a cliff, is also well seen along the south side of the old estuary. At Carronhall (5 miles S.E. of Stirling) it forms a steep bank, facing N.E., where it is about 2 miles distant from the present line of sea beach. At Gargunnoch there is a conspicuous range of sandstone cliffs, facing the north, whose base I made 48 feet above H.W. The same range of cliff can be followed to Kippen.

At Boquhan Brickworks, there is a bed of clay, the top of which is 44 feet above H.W. The bed of clay is about 5 feet thick. Under this bed there lies a thick deposit of bluish coloured mud, known provincially by the name of "*sleech*." It is too thin or fluid to be workable for bricks. I saw a tree about 30 feet in

length which had been taken out of these deposits at Boquhan. The "sleech" may have been deposited in deep water, the clay in shallower water.

It may be added, that at multitudes of places along the coast of the Firth of Forth, on both sides, and especially to the west of Queensferry, beds of oysters occur. These beds are now from 10 to 15 feet above H.W. But when they lived, the sea covering them must have been from 30 to 40 feet deep at least.

#### D. *Terraces* (between 50 and 75 feet).

1. *Solway Firth*.—Near Canonby, Arthuret, and Longtown, there are immense sheets of gravel, sand, and some boulders.

The following terraces or flats, beginning with the lowest, are distinguishable:—

At Longtown, one at 64 feet.

Near Arthuret Church, one at 65 feet, probably the same as that at Longtown. I walked along it for two miles, north from Longtown.

A remarkable kaim or escar of gravel and sand occurs near Arthuret Church, running N.W. and S.E., and continuous for a quarter of a mile. Its base is about 75 feet above H.W. The height of the ridge above the adjoining flat ground, is at one place as much as 70 feet. The steepness of its sides is at several places indicated by an angle of 60°. Boulders occasionally project on its top and sides—among which both red and grey granites occur. I believe that Criffel, in Dumfriesshire, consists of grey granite, and that there is red granite in the Kirkcudbrightshire hills. The boulders, therefore, probably came from the W. and N.W.\*

If the Arthuret kaim be, as I suppose it to be, a submarine bank, it indicates a sea which reached a level several hundred feet above the present level.

\* In looking into the Government Geological Survey for Dumfriesshire, I find the following statements, which harmonise with my conjecture as to the quarter from which these boulders were transported. It is there stated (page 39) that "boulders of *Cairnmore granite* are scattered over the hills to the south-east. One is on the west face of the Nether hill, at a height of 1100 feet, and eight miles distant from its source. It cannot be doubted, *from their presence on the tops of kames*, that boulders were scattered far and wide during the great submergence."

Another terrace at 107 feet runs up both banks of the River Esk and, crossing it, passes not far from Arthuret Church.

2. *Wigtownshire*.—On the south shore there are two cliffs, one at 40 to 50 feet, the other at 70 to 80 feet above H.W. Both have been formed on the boulder clay.

3. At *Glenelg*, I had pointed out to me by Mr Fraser, parochial schoolmaster there, two very distinct terraces, one 44 to 48 feet, the other 72 feet above H.W.

In walking up along the River Elg, which here flows into the sea, I found a terrace about 16 feet higher. But it may be due to river action, when the sea stood at the 72 feet level.

4. *Glenshiel*.—The rocks at mouth of this glen show strong marks of smoothing by some agent (such as ice), which has come down the valley. The height of these smoothed rocks above the sea-level, is about 20 feet. There are banks of detritus flattened on the top, on each side of the glen, 40 feet above H.W. There are, farther up the glen, detrital terraces 118 feet above H.W. Sea shells have been found in Glenshiel 50 feet above the sea.

At the mouth of *Glen-beg*, about half a mile from the sea, a series of flattened knolls of gravel occur, whose tops are about 50 feet above the sea. The River Beg has cut through them. They appear to consist of detritus brought down from the mountains, and spread when the sea stood at a higher level. When the sea-level fell, a lake may have been formed, and afterwards drained by the cutting down of its gravel blockage.

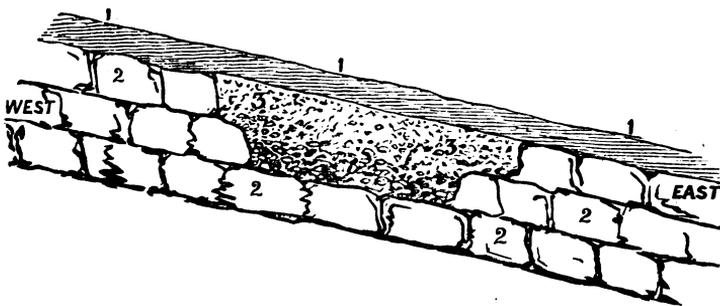
5. *Easter Ross*.—At Tain the 70 feet terrace is traceable for some miles. The large boulder, honoured with the name of Sir Walter Scott, to the north of Tain, is at that height above the sea. The same flat runs through the Muir of Ord. To the north of Inverness, at Clachnaharry, there is a remarkable boulder called "*The Watchman's Stone*," which rests on a terrace of drift at a height of 73 feet above H.W. It is 30 paces in girth, and about 15 feet high.

6. At *Bervie* and *Johnshaven* (Aberdeenshire), and on the south side of Montrose Bay, there is a well-marked flat at 70 feet above H.W.

7. *Perth*.—To the west of the town, on the road towards Crieff, two flats, one above the other, are very observable; one at 50, the other at 108 feet above the sea.

8. There is a very noticeable terrace from 70 to 80 feet above the sea, at the following places:—Arbroath, St Andrews, Pittenween,\* Kirkcaldy, Alloa, Stirling, and on both sides of the Carse to the west of Stirling, as at Blair-Drummond, Thornhill, Bucklyvie, Port of Monteith, and Cambusbarron.

At Dalgetty there were sea shells in a position of some interest, as shown in the following diagram:—



Deposit of sea shells among gravel in sandstone cliff, near Dalgetty, Fife, 62 feet above sea.

1. Vegetable soil.
2. Sandstone rock.
3. Cavity, 4 × 2 feet in the rock, filled with gravel and shells of oysters, limpets, and whelks.

The cavity in the rock, and the smoothed surfaces of its sides, indicated the agency of water, and still more so a quantity of gravel filling the cavity. The sandstone pebbles, chiefly angular, had probably been broken off the sandstone rocks. The greenstone pebbles were rounded, as if washed in from a distance. The shells were tolerably entire; some had barnacles on them, and some had been pierced by a minute *Pholas* or other such borer.

At Tullibole village, near Alloa, there is a flat at that height, on which a large granite boulder stands. The boulder must have come from the west, and probably through the gap between Damiat and the Abbot's Craig, which bears from boulder N.W. by W.

9. The late Professor Fleming and Charles Maclaren found sea

\* In the clay worked at Tyree for bricks, the bones of a seal were found 18 feet below the surface and 30 feet above the sea. When this seal lived, the sea must have stood here at least 50 feet above its present level.

shells at Bo'ness and other places along the south shore of the Firth of Forth, at from 30 to 40 feet above high water; as also at Paisley—all in brick clay. I found shells at about the same height, near Blackness and Inveravon. These finds, of course, betoken a level of sea from 20 to 30 feet higher.

The 70 feet terrace occurs on the west of Stirling Castle, south of Raploch village, and also east of race-course in the King's Park.

At Cambusbarron, to the west of Stirling, the same terrace occurs lying over immense beds of gravel and sand. It is also seen to the westward as far as Thornhill.

A large granite boulder near Dunmore House (east of Stirling) lies on a flat at this level.

10. This 70 feet flat occurs also extensively in the counties on the south of the Firth of Forth, as at Caroline Park, Newhailes, Stoneybank (near Musselburgh), Inveresk, Smeaton, Tranent, Drumore, Preston, St Germain's, Longniddry, Linton, Phantassie, North Berwick, Dirleton, Dunbar, and Beltonford.

#### E. Terraces (between 75 and 130 feet).

1. *Buteshire*.—In Arran, on the east side of the Island as well as in Loch Ranza (on the west side), there are flats bounded by gravel cliffs from 90 to 105 feet above H. W.

Large erratic boulders are on this terrace; they are most numerous on the eastern slopes of the island.

Dr Bryce (*Geology of Arran*, fourth edition p. 109) says, that "Brodick Castle stands on a terraced platform at an elevation of 125 feet above the sea-level, towards which several successive terraces descend to a distance of 400 yards, ending in the old sea cliff, here about 25 feet in height."

In several other parts of the Firth of Clyde (Bute and Gourock) a terrace at about this height is visible.

2. *Dumbartonshire*.—There is a notice of sea shells found near Loch Lomond, at from 100 to 103 feet above the sea. (*Roy. Phys. Soc. Proceedings*, 26th March 1856.) Shells have been referred to as found along the banks of the loch at lower levels also.

At Cameron House and Balloch Castle, on Loch Lomond, there is a terrace 92 feet above the sea.

Near south end of Loch Lomond (as at Tillechewan and Auchendenny), a flat occurs at 83 feet above the sea.

On the peninsula, lying between the Firth of Clyde and Loch Striven, the dwelling-houses of Ardyne and Knockdhu are on an extensive flat exactly 100 feet above H.W.

3. *Crinan Canal*.—At the summit level, a terrace on both sides occurs about 140 feet above the sea, being about 70 feet above the water in the highest canal lock. This terrace is faintly traceable to the north of the summit level, on the west side of the canal.

At the summit level, on the west side, there is an accumulation of boulders. As this occurs at the narrowest part of the valley, it may be reasonably conjectured that floating ice, brought by a sea-current from the north, may have been obstructed here in its further progress, and may have discharged its cargo of boulders. It was suggested to me that these boulders may have been brought down a side valley from the *west*, where are situated the reservoirs for supplying the canal, and which burst a number of years ago. But they are not in positions which correspond with what was the course of this debacle. Their positions show transport from the *north*. The Silurian rocks at this narrow point of the valley are nearly vertical, and run across the valley. The sides and edges of these strata are smoothest on their sides facing the north, and show the effects of an agent moving over them from the north.

3. On the high ridge between *Lochs Fyne and Goyle*, I found traces, on the slope facing Inveraray, of a flat from 90 to 100 feet above H.W.

4. In the "London Geological Society Journal," vol. ii. p. 549, Captain Bedford refers to sea shells found by him at *Loch Turbert* (Jura) at 105½ feet above H.W.

*Jura*.—After listening to the interesting account of the raised beaches in this island, given by the Duke of Argyll, at the Glasgow meeting of the British Association in 1876, I was induced to visit some of them.

In August 1877, I proceeded in a boat from Port Askaig (Islay), supplied by David Sutherland, ferryman, and accompanied by Mr Fletcher, the factor of Mr Campbell of Jura. I have already described one of these old pebble beaches among the B Terraces, as reaching to a height of 21 feet above H.W. Those now to be

described are in Loch Tarbert, about 10 miles to the north of Port Askaig, on the north shore. There are here several raised beaches, all having the same general features. Seen from the boat, at a distance of about half-a-mile, they resemble great white sheets of linen tablecloths on a bleachfield. The shingle of these beaches is composed of white pebbles, more or less rounded, of all sizes, up to the size of a man's head. The pebbles are of quartz or quartzite, so hard and impenetrable that no vegetation, not even a lichen, grows on them. I examined two beaches on the north side of the estuary. The shingle commences at or near the top of the existing sea-cliff, which may be from 40 to 50 feet above the present sea-level, and covers an area of about from 300 to 400 yards, measured along the coast, and of about 350 to 450 yards inland from the coast. The shingle slopes upwards in each case to about from 100 to 110 feet above the sea-level.

The pebbles are so well rounded, that it is hardly possible to walk on them, on account of their spherical shape, and their remarkable smoothness, which causes them to roll or slide under the weight of the foot.

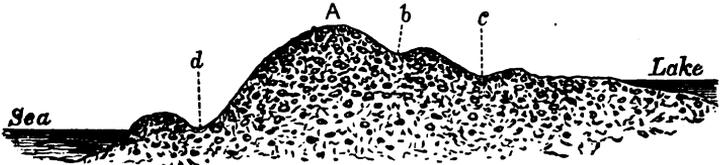
These shingle beaches are traversed by a series of ridges and troughs, similar to those previously described under the head of B Terraces. They are more faint, the troughs being less deep and wider, whilst the ridges are flatter. This difference is probably due to the greater antiquity of these higher beds. In other respects they are similar—the ridges and furrows being parallel to one another and to the existing shore.

At both of the spots visited by me on the north side of Loch Tarbert, I found the sheet of shingle to be situated between two reefs or ranges of quartzite rock, running into the sea at right angles to the shore, and standing up from 50 to 150 feet above the general surface. The pebbles were probably derived from these rocks whilst they were submarine reefs. The quartzite rock is much fissured by natural cracks, so that fragments could have been easily detached by tides and waves of the sea. These fragments, driven about by the sea, naturally assumed spheroidal forms owing to the molecular structure of the rock.

The only speciality which characterises these Jura raised beaches is the whiteness and hardness of the pebbles. In the other beaches,

which prevail generally round the Scotch coasts, the materials are very miscellaneous, and are generally so soft as to afford nourishment for some sort of vegetation. On the *south* side of Loch Tarbert, near its mouth, there is an example of both of these kinds of raised beaches at the same place. There is the white shingle beach reaching up from the sea shore to a height of about 100 feet.\* I viewed it only from the sea in a boat, and therefore can give no exact measurement. Where the white shingle beach stops, at the above height above the sea, a horizontal line on the east side continues along the hill, covered with herbage. I inferred, therefore, that the quartz pebble sheet did not extend beyond where the white colour indicated its existence.

Near the head of Loch Tarbert, on the south side, there is an immense accumulation of shingle. It stretches across the mouth of a glen, and has so entirely blocked it, that a fresh-water lake has been formed inside of the blockage, whose surplus waters now filter through the shingle into the sea.



The Admiralty chart represents the top of this raised beach—A as 42 feet above low water, and therefore about 30 feet above H.W. The surface of the lake is 33 feet above low water, and about 11 feet above H.W. At *d*, *b*, *c* there are troughs running across the shingle more or less parallel with the existing beach. The one at *d* had water in it, and may possibly be reached by the waves in very stormy weather.

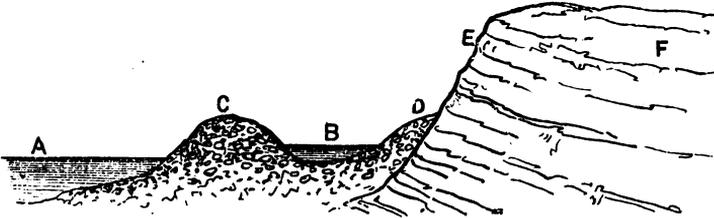
The mouth of the glen, where choked by this shingle blockage, is about three-quarters of a mile across. The glen opens seaward towards the W.N.W., so that the westerly gales drive waves in upon the glen, and push before them gravel of considerable size. But the shingle bank could not have been formed by the sea at

\* It is probably this old beach which Captain Bedford, R.N., describes as at 105 feet above H.W.—(Lond. Geol. Soc. Journal, vol. ii. p. 549).

its present level. The sea must have then been at least 50 feet higher.

Here, and at numerous other places along the coasts of Jura and Islay, there are caves in the rocks facing the sea, the floors of which are from 30 to 40 feet above H.W. These must have been formed when the sea stood at a higher level than now. That many of these caves were inhabited, is highly probable. An exploration of them would be certain to reveal some interesting information.

5. Between Onich Church and Corran Ferry there is an elongated hill, running E. and W., well covered with sand and gravel,—on both sides of which a natural terrace exists at a height of from 100 to 105 feet. On the west side of *Corran Ferry*, a high shingle beach has recently been thrown up, which deserves notice, as serving to explain what occurs on some of the old sea beaches—



E F is part of the sea cliff which skirts the coast, its top being about 40 feet above H.W. D is the line of lowest old beach at 12 feet above H.W. A is the sea at H.W. ; C is a bank of shingle thrown up by the force of the waves when westerly gales prevail at spring tides, reaching to a height of about 3 feet above high-water mark. The width of the shingle bank C varies from 30 to 40 feet ; B is a trough or trench about 12 feet wide, running for some hundred yards parallel with the existing shore line, and filled with sea-water. The explanation probably is that, when the waves throw up the shingle, a part of the sea-water passes over and beyond the ridge, and lodges in it sand or mud. When the sea falls to low tide, the water at B filters through towards the sea, taking with it the finer sediment, and thus ultimately forms a trough or trench of gravel parallel with the shore line.

West of *Fort-William*, a high flat is seen at a height of 100 or 110 feet above the sea; and a higher one at 187 feet. At the head of Loch Etive, there is a flat at 92 feet.

6. *The Lewis*.—When in the “Long Island,” as it is termed, in the summer of 1878, I had occasion to travel along the high road, between Tarbert and Stornoway. Having remained a short time at Ardvourlie (a shooting lodge of Mr Scott, banker, London), situated on Loch Seaforth, I took notice of several terraces bounded by banks or cliffs between Ardvourlie and the town of Stornoway.

The one at the lowest level was about 36 feet above H.W. Ardvourlie House is situated on it. It can be followed for some miles round the present coast line.

It can be well seen also at “Ath-an-Linne,” to the north, a shooting lodge of Sir James Matheson, also on Loch Seaforth.

There is an immense mass of drift along this district, debris probably brought by oceanic currents from the mountains situated to the westward. Some of the burns crossed by the high road presented along their course cliffs of drift 50 feet thick.

To the north of Loch Seaforth about 4 miles, there is a fresh-water loch, called in the Ordnance Map “*Loch-nah-Aimhue Ruaidhe*,” which is within a mile of the sea, and about 40 feet above the level of the sea. A terrace or flat round this lake is visible at a height of about 40 feet above its waters. A terrace at the height of 81 feet above H.W. is traceable for many miles along this part of the coast, suggesting the idea, that it is an old sea-margin. In that case, the present fresh-water lake must have been then an arm of the sea. A blockage, where its surplus waters now discharge, has prevented the lake being drained off entirely.

At a place marked on the Ordnance Map “*Ceann Tarabhaidh*,” there are two flats, at 36 and 81 feet respectively above H.W. This higher terrace shows itself also at “*Airidh Bruthach*” and the village of “*Balallan*.”

At and near *Soval* shooting lodge, patches of the 81 feet terrace occur.

In the north part of the *Lewis* there is a terrace at from 100 to 120 feet above H.W.

7. In travelling along the south side of *Loch Duich* (a sea loch

on the mainland of Argyleshire), situated to the north of Glenelg, two flats were seen and measured, one at a height of 80, the other of 120 feet above H.W.

8. *Skye, Kyle-a-Kin, Loch Carron.* — Captain Burke, R.E., in charge of the Ordnance Survey in Scotland in 1876, knowing my interest in sea-terraces at high levels, informed me of a remarkable one which his surveyors had observed at the ferry between Skye and the Mainland.

Having gone to examine that part of the coast in October 1876, I have to state, that in approaching Kyle-a-Kin, along the road from Balmacarra, and when within a mile of the ferry, I found that I was on a bit of flat land, at a height of about 90 feet above H.W.

After crossing to Skye, and walking along the road towards the town of Broadford, I came to an extensive flat under Mr M'Innon's farm-house, about 32 feet above H.W.

We then rose up to a more extensive terrace or plain, lying

#### Top of Terrace.



between high rocks on our left (towards the east) and the sea coast on our right. This terrace is about half a mile wide between these rocks and the sea, and it stretches towards the town of Broadford, apparently 3 miles distant.

This terrace or plain, where it abuts on the rocky hill bounding it on the south, is 98 feet above the sea. It slopes gently towards the sea, and forms there a precipitous cliff 83 feet above H.W.

Several streams make their way to the sea through this extensive terrace, and in one of them, the Altanasig burn, I found a vertical cliff of about 60 feet above the channel of the stream. The cliff was composed entirely of gravel and sand, the lowest beds being horizontal, the uppermost irregular, inclined, and confused. They are shown in the prefixed diagram.

The horizontal beds had been deposited most probably when the

sea was deep; the upper beds when the sea, by reaching a lower level, became shallower, and was more affected by currents.

The Island of Pabbay I observed, at a distance towards the west, at a distance of 3 or 4 miles. It seemed to consist of a flat terrace about the same height above the sea as that just described.

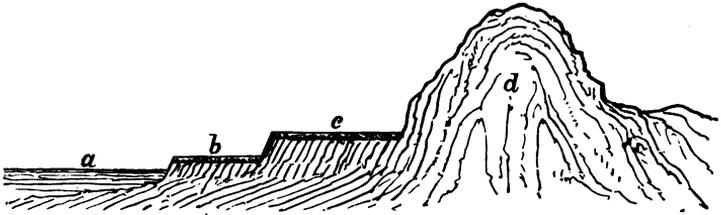
The 83 feet terrace is seen also to the south of the small village and Port of Kyle-a-Kin; but it is not visible on the mainland immediately opposite. On the mainland there, the coast consists of hard rock. On the Skye side, the coast is deeply covered with drift, on which a sea-terrace and cliff is more easily formed.

Duncraig House, the residence of Alex. Matheson, Esq., M.P., is on the road from Kyle-a-Kin to Strome Ferry. It is on a flat adjoining the sea on the south side of Strome Ferry, which is about 90 feet above sea-level.

From Duncraig I could, by telescope, see across the estuary, that at Plocton and Ardenisken a corresponding terrace exists.

The Ordnance surveyors had previously indicated on my map that this terrace exists at these places, and also at Rairais.

At Port-Chullin, near Strome Ferry, the same terrace is well seen from the high road, and is represented in the annexed dia-



gram, where *a* is the sea, *b* a terrace about 25 feet, *c* the 90 feet terrace, and *d* a rocky hill about 300 feet high. It was not in my power to set foot on the terraces here, to measure their exact heights, but I have no doubt of the existence of the two terraces, and of the great probability of the heights above the sea being as now stated.

Since the foregoing paragraphs were written, I have received from the Ordnance Survey Department, Edinburgh, a tracing of measurements on this part of the coast, which Captain Burke had kindly ordered to be taken for me.

At Kyle-a-Kin in Skye, his surveyors make the height of the terrace, along the shore for about 2 miles on each side of the *Allt Anasig* burn, 91 feet above the medium sea-level, *i.e.* about 83 feet above H. W.

At Port Chullin and Rairig on the mainland, opposite to Skye, the Ordnance Surveyors report at each of these places a corresponding raised beach, the measurements of which give an average of 91 feet above the medium sea-level.

The Surveyors' tracings of these two last-mentioned places give also measurements of a lower beach, the average of which is at Chullin 33·6 feet, and at Rairig 33·8 feet above the medium sea-level. These belong to the series already mentioned under the letter C.

It is not irrelevant to refer here to what Dr Macculloch, in his geographical survey of the Western Islands, says of the terrace or plain above referred to (vol. i. p. 294-8). He calls it an alluvium, and says that it has been "formerly much more extensive," and even supposes "that Skye *was once united to the mainland by means of this alluvium.*" He says it exhibits "precisely the same appearances which characterise the terraces that line alluvial valleys through which active rivers have cut their way." But, on the other hand, he admits that "no rivers flow in the vicinity of this plain; nor is there, from the form of the ground, any reason to suppose that they ever have flowed, so as to enable us to account for the deposit of loose materials. It must also be added, that the uniformly level surface of the plain is an insurmountable obstacle to this supposition."

It is interesting to see the perplexity of so eminent a geologist as Dr Macculloch, in a matter which now creates no difficulty. The idea of a change in the relative levels of sea and land had not in Macculloch's time occurred to geologists.

Passing the valley of Auchmore, on my way to Strome Ferry, I found that the 83 feet terrace runs up this valley from the sea for some distance.

It occurs also at the village of Duirness, and forms an extensive plain there.

At Strome Ferry the same terrace is well marked on the north bank, opposite to the railway station.

I viewed it, however, only from the inn there, having had no opportunity of crossing the arm of the sea to measure its height by the aneroid. But the same object was effected by means of the spirit-level, looking across the estuary from the south side.

There seemed to be below it, another terrace, less defined, at a height of about 75 feet above H.W.

In passing along Loch Carron, from Strome Ferry, by railway, I observed occasional vestiges of what appeared to be the old cliffs and terraces at 11, 75, and 83 feet, but I had no opportunity of taking measurements.

These terraces in Loch Carron having previously obtained the notice of other observers, it is only proper that I refer to what they have stated.

From a paper by Mr J. G. Jeffrey, in the "Journal of the London Geological Society" (vol. i. p. 217), I extract the following:—

"About 11 miles below the termination of Loch Carron and 2 miles above Craig Inn, there is a level platform about 50 feet above the present sea-level, and sloping at an angle of 45°. It extends for some distance in a line parallel with the valley. The breadth is the same as that of the present heads.

"At a distance of 16 miles from the terminus of the loch, there is a similar platform, with the same direction and slope;—but apparently at a higher level.

"On the opposite side of the loch, about 2 miles below Strome Ferry, there is a corresponding platform.

"At Plocton, some miles farther down the main channel of the sea, the same appearances occur; but the elevation is 60 feet above H.W. mark." Under this latter platform, Mr Jeffrey found a bed of sea shells of the existing species, 2 or 3 feet thick.

"At Applecross, there are similar indications of an old beach;—as also at Shieldaig, Gairloch, and near the mouth of Loch Torridon."

From the foregoing statements, it will be seen that whilst Mr Jeffrey testifies to the occurrence of the terraces, his measurements do not agree with mine. This point, therefore, needs further inquiry.

On Loch Long, which unites with Loch Duich (north of Glenelg), a terrace on its banks at 120 feet above H.W. is visible.

In Glenbeg, near Glenelg, and at a distance of about 1¼ mile from

the sea, there are several detrital mounds with extensive flats at 120 feet above the sea. A river now cuts through these mounds. They had originally filled up the entire breadth of the valley at the above height.

In like manner, at Glenshiel (north of Glenelg), mounds and knolls of detritus, flattened on the tops, occur at from 115 to 120 feet above the sea.

At *Inverie (Loch Nevis)*, some years ago, I was taken by Mr Baird, the proprietor, to the mouth of Gussern Valley, where it joins the sea, about 6 or 7 miles to the north of Inverie. There I found traces of a lake, whose waters had stood at a height of about 40 feet above the sea. The embankment which had formed the blockage of the lake next the sea, having been gradually cut through by the stream from the lake, its waters had been drained off, leaving on each side traces of the old lake margin. The lake had probably existed when the sea stood at a level, say from 120 to 130 higher than now. When the sea subsided, the stream from the lake acquired more cutting power, and drew off the lake waters,—till nothing remained but the existing swamp, which indicates what had been the bottom of the lake.

Between the top of the old lake blockage (which is about 145 feet above sea-level) and the line of the present shore, there are several horizontal lines visible, showing successive subsidences of the sea.

9. *Beaully*.—The Muir of Ord is an extensive plain, near Beaully, formed of beds of white sand and small-sized gravel, at a height of 108 feet above the sea.

The sea shells found near Tain, at a height of 60 feet above H.W., indicate probably a sea-level of at least 100 feet (Wern. Trans., vol. viii. p. 6).

About two miles west of *Alness*, there is an extensive flat 110 feet above H.W. A corresponding flat is visible on the opposite side of the Cromarty Firth.

At Kessock Ferry, near Inverness, there is a flat 106 feet above H.W., which continues eastward by Allengrange and Rosemarkie.

The greater part of the town of Inverness is on a flat, about 106 feet above H.W.

10. This flat can be traced for some distance west of the town, and also for a long distance eastward through the counties of Nairn

and Moray. About 4 miles west of the town of Nairn, it appears and continues till within 2 miles of the town. It occurs also about 5 miles east of Nairn. At Auldearn, there is a flat 100 feet above H. W.

In the county of Elgin a succession of terraces can be traced at 55, 65, 77, 95 and 105 feet. They have been formed on the enormous accumulations of gravel and sand which prevail in that county as well as in Nairn. The beds of gravel and sand present sections, where cut by the railway, of from 20 to 30 feet in height, and show horizontal stratifications. These layers of gravel and sand continue on each side of the railway from Forres to Grantown up to a height of at least 1060 feet above the sea, and may be traced over the adjoining hills to about 2000 feet.

The late Mr Patrick Duff of Elgin, who was a correct observer, pointed out to me between Elgin and Covesea, four terraces crossing the public road there at the following heights :—At Westgate of Findrassie, 123 feet ; another at 105 feet ; another at 69 feet ; and the fourth, rather less than 20 feet above the sea-level. The 69 feet terrace can be traced eastward very distinctly for some miles.

About 4 miles to the east of Elgin, there is a terrace corresponding with the highest of the above four.

On the N. W. bank of the river Spey, about 2 miles from Fochabers, there are three terraces ; the highest of which crosses the Edinburgh road, about a mile south of Fochabers, at a height of 123 or 124 feet above the sea.

At Forres, there is an extensive flat at about 100 feet.

This flat between Nairn and Forres surrounds a number of gravel knolls, whose tops are from 20 to 30 feet above the flat ; these are the remnants of an ancient sea-bottom at a still higher level.

The Culbin Sands, near Forres, form hills and ridges of a pure white sand, easily blown by the wind. They seem to have been originally a thick bed, deposited at the bottom of a deep sea before the sea fell to its present level. This bed of sand, consisting of very minute particles, being acted on by wind and rain, became changed into new forms all over this district. Boulders have been strewn from the west, being of rocks which exist only among the mountains in that direction. The circumstance that they lie upon

the surface of the sand and gravel beds, shows that they must have been dropped on these beds by floating ice. The glacier theory for the transportation of these boulders would in this district be quite untenable. It also deserves notice, that all these deposits change in character towards the east. The boulders become fewer and smaller in size. The gravel and sand become more fine-grained; and farther east, the gravel and sand cease, whilst a finely stratified blue clay takes their place,—a deposit indicating absence of currents and considerable depth of water.

11. I extract from a note-book the following further information:—

“The town of Nairn stands on the 40 feet flat;—the 100 feet terrace on which Inverness stands, reaches to Auldearn, 3 miles beyond Nairn.

“To the east of Nairn, there are great boulders of granite (both red and grey), besides gneiss and conglomerate rock strewed over the district. The rocks *in situ* here, are entirely different, being Old Red Sandstone. The parent rocks of these boulders are to the W. or N.W. at distances exceeding 30 miles. But what makes the occurrence of these boulders more remarkable here, is that they rest on beds of sand and fine gravel.

“Incheoch Castle is situated on a knoll, which seems at one time to have been an island.

“At Milton Brodie, 6 miles east of Forres, there are oblong ridges or banks of sand with intervening low ground, consisting of clay, above which the sand has been deposited.

“Farther eastward, there is the farm of Moorhead, where apparently the land consists entirely of stratified beds of sand.

“Farther east, the sand thins off and almost disappears, suggesting that the sand has come from the westward. Beds of fine clay next predominate. All the way to Duffus, there is an absence of sand and an abundance of fine blue stratified clay or mud.

“As we approach Findrassie and Loch Spynie, the boulders become smaller. Instead of being as large as carts, they dwindle to the size of a man’s hat. They are, however, of the same nature, as regards composition, viz., granite, gneiss, and conglomerate.”

“Near Lossiemouth, boulders, even of a small size, disappear.

“There is an extensive flat, about 25 feet above the sea, on which Duffus Castle stands. The upper strata consist of beds of fine clay

lying on sand. It is plain that the castle has been formerly surrounded by water."

"The Standards of Lossiemouth are ridges, about 18 feet high on an average, composed sometimes of sand, sometimes of rounded pebbles. They seem to have been formed by the competing action of the sea, when it stood at a higher level, and the River Spey, which probably flowed into the sea at or near this part of the coast."

12. To these notes, I may add some farther information given by Mr Patrick Duff. He pointed out to me that the town of Elgin had originally been built on a large knoll which formed an island in a great lake, now dried up, along the bottom of which the river Lossie meanders. The lake had been drained, as many others have been, by its embankment being cut through, here the more easily effected, because of the sandy materials which had formed the sides and blockage of the lake.

A lake at a lower level seems to have existed farther east, through which also the Lossie flowed, and from which it passed on to Loch Spynie, then an arm of the sea.

About three miles to the east of Elgin there was a third lake, at the east end of which the village of Lhanbryde was situated. This lake also drained into Loch Spynie.

About four miles to the west of Fochabers, there are enormous knolls of sand and fine gravel, among which are numerous lakelets, having no visible outlet, but whose surplus waters ooze through the porous materials confining them. These knolls are the remnants of what had once been an extended plain—an old sea-bottom.

Near Fochabers, both east and west of the town, there are several remarkable terraces. On the banks of the river Spey four of these may be seen, rising like steps above one another. The highest, from 100 to 150 feet above the sea, extends over a wide district of country.

On the N.W. bank of the Spey, about 2 miles south of Fochabers, there are three terraces visible, above one another. The highest coincides with the Edinburgh road, about a mile south of Fochabers, at a height of from 120 to 125 feet above the sea.

Along the course of a small stream which flows into the Spey from the south, there are cliffs or scaurs of sand and clay at least 100 feet in depth.

As a proof of the fineness and looseness of the sand in this district, it was mentioned to me, that a ditch 4 feet deep had been cut along the march between the estates of the Duke of Richmond and the Earl of Seafield. In the short space of eleven years this ditch, from mere atmospheric agency, had deepened into a great fissure 25 feet deep, with sloping banks on each side.

In the upper parts of the river Spey, there are terraces of considerable interest, but which have not yet been sufficiently investigated.

In the year 1858 Mr Jameson of Ellon, in a paper published by the London Geological Society, referred to these terraces. He says that near Cairnty and Rothes, the surface strata consist of finely laminated clay, capped by sand and gravel. These terraces he found at Cairnty to be 247 feet above the river, and 375 feet above the sea. He adds, that as he ascended the river towards Aberlour and Ballindalloch, the terraces reached a higher level. He considered that they had all formed parts of an "ancient sea-bottom."

I have examined the banks of the Spey from Cluny Castle down to Loch Inch (some miles below Kingussie), and satisfied myself that there are at least two terraces, which occur on each side of the river, the one at 782 and the other at 750 feet above the sea. I could see nothing to indicate whether they were due to sea or to lake, not having had time to examine the river farther east, where, I understand, the valley becomes narrow, and where a blockage might be expected to have existed so as to form a lake.

As there were lakes in the Lochaber district, which is not far off to the west, and at a far higher level, the suggestion of a lake filling the valley of the Spey, deserves inquiry.

On travelling along the public road from Fochabers to Aberdeen, extensive beds of stratified sand and gravel to the north of Keith are visible, even up to 1000 feet above the sea-level.

Near Keith, there are traces of a lake of considerable extent, now drained, on the south bank of which the town is built. The height is from 350 to 400 feet above the sea.

A few miles south of Inverurie there are traces of another large lake, now extinct, apparently at a level of about 180 or 200 feet above the sea. The town of Kintore is situated at the south end, apparently at a height of about 180 feet above the sea. Round

almost the whole of this valley, traces of two old lake margins are visible, one about 50, the other about 78 feet above what had been the bottom of the lake. The north end of the lake had been at or near the place where the rivers Urie and Don unite.

The country here is well covered by beds of detritus and boulders, so that the blockage of the lake, if composed of these materials, could be easily cut through.

At Peterhead sea shells have been found at 60 feet above the sea;—a proof that it had there reached a higher level.

13. *Perth*.—To the north and west of the town two flats are observable, one about 50 feet and the other about 105 feet above the sea. On this higher flat, Pitcairn Bleachfield is situated, as also Pithaylist Castle. This flat, south of the castle, is bounded by a range of rocks, apparently a sea cliff, formed before the sea sank to a lower level.

These two flats are traceable also to the south of Perth. They occur on the east side of the river Tay and to the south of Moncrieff Hill. Scone Palace and Belwood are on the higher flat. Moncrieff House is on a terrace 103 feet above H.W.

At Broughty Ferry, near mouth of the Tay, I found a terrace at 117 feet; at St Andrews, one at 115 feet.

In the Museum of the United College, St Andrews, there is the skeleton of a seal found in the clay bed of a brick work near Cupar, at a height of 60 feet above the sea. Of course when this animal lived and died, the sea must have stood at a greater height.

14. Along the south base of the Ochil range, at a height of from 70 to 80 feet above the sea, there are several villages, viz, Blair-Logie, Menstrie, Alva, and Tillicoultry, built on elevated deltas of streams, which flow down the sides of the Ochils. The deltas were probably fixed on for villages, that the houses should be on dry positions when the whole of the flat district below was swamp. For the same reason, the first public road (and traces of it still exist) was made along the south slope of the hills, just above the low ground. The deltas attract notice in consequence of the present public road, which is on the flat ground, rising in level as it comes near the villages. The deltas are also shown by the contour lines of the Ordnance Survey sweeping round the towns on their

south sides, indicating that the deltas had been formed, or at all events that they existed, when the sea stood at a height exceeding 50 feet.

At Alva village, where the delta is larger than the others, even the 100 feet contour line bulges round it from the hills, showing that the sea must have stood at that height or more, arresting the debris which the stream was then bringing down from the hills.

At Blairgowrie and Menstrie, the upper parts of the deltas, if they ever reached the level of 100 feet, have been washed away,—probably because composed of smaller sized materials.

About  $\frac{1}{2}$  mile to the east of Tillicoultry village, there is a remarkable accumulation of sand, which at its north end abuts on the Ochil range, and crosses the valley in the form of a broad escar. Tillicoultry church stands on it. The top of this sandbank is a little above the 100 feet contour line of the Ordnance Survey; and if it be a submarine deposit, as is probable, it testifies to a sea-level exceeding that height.

There is on the north side of the high road, an extensive excavation in this escar, in which the strata of sand are seen to form continuous beds of large extent, implying considerable depth of water. These beds rise up to the south and west at an angle of about 20°. The escar, where quarried, presents a section of about 50 feet in height, and about 100 yards in length. It is crossed, having been evidently cut through, by the River Devon, whose channel is here about 20 feet above H.W.

Beds of gravel occur in this escar—the materials all evidently water-worn. There are well-rounded pebbles of quartz,—some indeed so spherical as to resemble the shingle on the beaches of the islands of Islay and Jura, formed by the grinding action of the sea waves. Some of the hard pebbles are Silurian, a few are Granite and Mica Slate. There are also rounded fragments of coal.

With regard to the origin of the escar, there can be little doubt that it is a submarine deposit,—as are also the accumulations of equal extent and depth in other parts of the district, viz., at Cambusbarron to the *west*, and Livilands to the *south* of Stirling.

The probability is, that after the sea fell to 120 feet above the

present level or thereabouts, a lake was formed to the east of Tillicoultry. This submarine deposit, when the sea left it, would be scooped out by the River Devon, in its course to the sea. As the sea fell, the greater cutting power thereby acquired by the river would enable it to form a lower channel across and through the blockage of the lake, till ultimately the lake was drained, and a marsh formed, of which there are even yet manifest traces.

Along the south flank of the Ochils, when the sea stood at a higher level, there are various indications of some agent which moved along the hills and over the estuary in an easterly direction.

The great bank of sand, just referred to, half a mile long, some hundred yards wide, and 60 feet deep (so far as seen), containing beds of rolled pebbles, from rocks situated to the westward, is one proof of this remark. But the rocks on the Ochils, and especially the hard conglomerate rock west of Meustrie village, up to about 110 feet, shows a large amount of chafing and rubbing by some agent passing from the west. The smoothest parts of the rock face the west, and the individual pebbles contained in the rock, in like manner, are smoothed chiefly on their west sides.

The following is a list of the localities in the neighbourhood of Stirling which seem to be all on the same flat, or very nearly so :—

- (1.) Terrace between Airthrey Castle and rocky cliffs to the north, 109 feet.
- (2.) Flat on which Logie parish church stands, 97 feet.
- (3.) Mineral well north of Bridge of Allan, 103 feet.
- (4.) Westerton House flat, 110 feet.
- (5.) Causewayhead and Spittal Toll, 101 feet.
- (6.) Keir House policy, with boulder on flat, 101 feet.
- (7.) Doune, town of, with boulders, 104 feet.
- (8.) St Ninians, two miles south of Stirling, 96 to 100 feet.
- (9.) Airth House policy, six miles east of Stirling, 101 feet.
- (10.) Camelon village, near Falkirk, 110 feet.

When the hard conglomerate rocks behind Westerton, the Mineral Well, Airthrey, and Logie Kirk are examined, it will be noticed that there is much smoothing on them, and that in some

places the land adjoining the cliffs seems as if it had been scooped out by the action of a current chafing against the cliffs.

In the *Stirling* district, there are also traces of a higher terrace, at 120 to 123 feet above the sea. Thus, near the Stirling Race-course, at that height, there is a flat, with a granite boulder on it. If this boulder came from the N.N.W., as is most probable, a slight knoll situated to the N.W. of the boulder may have stranded and intercepted the transporting agent, probably floating ice.

Near *Doune* (town of) there is a flat at 120 feet, with granite boulders on it, which must also have come from the N.W. They are lying on gravel.

At *Hillhead*, about 122 feet above the sea, about eight miles S.E. of Stirling, there is an extensive flat, with several sandstone rocks, smoothed and striated from the N.W. A current flowing S.E. past Stirling Castle rock would pass over and mark these rocks.

At *Glenbervie* (west of Carronhall), where there is an old cliff whose base is about 140 feet above the sea, there is a square conglomerate boulder about 6 feet on each side, at a height of 220 feet above the sea. It has probably come from *Aberfoyle* or *Port of Monteith*, about 12 miles to N.W.

On *Drum* and *Kerse Brook* farms, there are rounded knolls of hard sandstone rocks at from 90 to 100 feet above the sea, which had been rocky islets or submarine rocks in the ancient estuary.

It is, of course, not to be inferred that because there are extensive flats or terraces at the above or any other height, these indicate the exact level at which the sea stood. They must have been the bottom of the sea, when its shore was at some higher level; and there are in this district traces of such higher levels.

15. A terrace, about 100 feet above the sea, is traceable from *Edinburgh* eastwards at the following places, viz. :—

Near *Granton*, there is an extensive flat at 98 feet; and it is traceable also at *Wester Warriston*, *Redbraes*, and near *St Mary's Church*. At these last-mentioned places there formerly were enormous banks of sand, occasionally containing sea shells.

A terrace at about the same height is visible at *Piershill Barracks*, *Craigentenny*, *Easter Duddingston*, *North Berwick*, *Dirleton*, *Gullane*, *Longniddry*, *St Germain's*, and *Dunglass* (East Lothian).

At Dirlerton I found various marine shells of existing species at a height of from 60 to 110 feet above the sea.

F. *Terraces* (130 to 200 feet).

It is not to be expected that terraces at high levels should be so extant as those at lower levels. Being more ancient, they have been longer exposed to denuding agencies. Much uncertainty must therefore prevail concerning them. All that I can offer, is a list of the places where flats bounded by steep banks, are so extensive as to deserve notice. Whilst I mention them, it is chiefly for the sake of affording to other observers an opportunity of seeing whether elsewhere flats occur at or near the same level.

1. 130 to 140 feet.

(1.) A line is traceable along the south slopes of the Ochils, at about this height, below which the rocks are smooth, and above which the rocks are rough. At several places the exposed rocks consist of conglomerate. Not only does the general surface show smoothing, but many of the pebbles in the rock indicate abrasion, and chiefly on their west aspects.

Alva village has been built on a delta of a stream from the Ochils when the sea stood at a height of about 184 feet above H.W. On this delta, at a level of from 123 to 130 feet, a terrace exists indicating a subsidence of the sea; and this terrace is found to correspond with one on the south side of this Devon valley.

At Lecropt church the flat continues. There, it is only about 200 yards wide, whilst at Westerton it is three or four times wider, owing to the relative position of the adjoining hills.

To the N.W. of Blair-Drummond House, a flat exists at the height of 138 feet. The strata on its surface consist of thick beds of sand, —probably marine.

On the south side of the valley, and nearly opposite to Blair-Drummond, at Cambusbarron, there is a flat at a corresponding height, and also at St Ninian's, a few miles south of Stirling.

In connection with these flats at from 130 to 140 feet, notice may be taken of the hill of Airth, situated about 8 miles E.S.E. of Stirling. It is composed chiefly of carboniferous sandstone rock, in strata nearly horizontal. A section from E. to W. is of the form

shown in the diagram. The height of the rocks at *c* is about 133 feet above the sea. The surface of the rocks between *a* and *b* is smooth,—the effect probably of friction by some agent passing over from the west.



2. 160 to 185 feet.

(1.) In the Stirling district a terrace occurs, at from 170 to 190 feet, at the following places—viz., Tillicoultry (on both sides of the valley), 184 feet; Keir policy, 190 feet; Doune, 180 feet; Lady-bank, 178 feet.

The Racecourse, on the S.W. side of Stirling Castle rock, is also about 170 feet above H.W. On its south side several smoothed rocks occur, sloping down N.E. (towards the Castle rock) at angles of from 20° to 30°. Stirling Castle bears from these rocks N.E. by N. A strong current, if any passed here from the N.W., might produce these features.

(2.) In the following other parts of Scotland, I observed flats at about the same height, viz., (1) at *Balmacara, Coillamore, Kyle-a-Kin* in West Argyleshire; (2) near *Stonehaven*, and (3) at *Easter Duddingstone*, near Edinburgh.

At Canonby, near Dumfries, a flat at about 160 feet occurs.

(3.) On the west coast of Jura (as the Duke of Argyll states) there is an old sea-margin at 160 feet.

(4.) In the valley of the Tweed, there are many places where a terrace is visible at a height of from 170 to 180 feet above the sea-level. (See *Trans. of Edin. Roy. Soc.*, vol. xxvii. June 1875).

(5.) Mr Duff in his geology of Moray, refers to several terraces similar to those in Lochaber, near Relugas and Kellar, at heights from 150 to 200 feet above the sea. The first-mentioned, he informed me, is at *Downduff*, and runs for about 1½ mile.

(6.) Around Loch Awe, in different parts, a terrace exists at 179 feet above the sea; and there are indications of a higher terrace at 230 feet.

These Loch Awe terraces were first noticed by me in the pass of

Brander, through which Loch Awe discharges its surplus waters to the sea. They are on the east side of the pass. Each terrace is traceable for about half a mile, and well covered by boulders. The boulders are manifest erratics, being chiefly of granite (both grey and red), whilst the rocks of the pass are a slaty schistose rock. As Ben Cruachan is not far off to the north, these boulders may have come from that mountain—transported on floating ice.

These terraces have been as usual formed on masses of drift, and, being horizontal, are undeniably due to the action of water.

West of Port Sonnachan, on the south bank of Loch Awe, I found a flat at 179 feet above the sea; and at Kaim, about 8 miles farther west, an extensive meadow communicating with the lake, and about 68 feet above its level, which gives 179 feet above the sea. Near the centre of this meadow, there is a remarkable knoll of gravel, with a huge boulder of gneiss upon it  $24 \times 11 \times 9$  feet, at a height of 188 feet above the sea;—the boulder probably had protected the knoll from denudation.

In proceeding by the steamboat to the west end of Loch Awe at Ford, I recognised what appeared to be traces of a terrace, on both banks of the loch, which might be from 60 to 70 feet above the lake,—*i.e.* 171 to 181 feet above the sea.

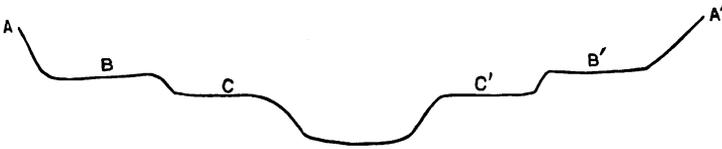
When I landed at Ford, I was at once struck by the great abundance of detritus, shaped into huge mounds and horizontal terraces. Having ascended to the top of several of these, I found by aneroid that they were from 55 to 65 feet above the lake,—which in consequence of much rain was 8 feet higher than usual, and showed a level for these terraces of 173 to 183 feet above H.W.

At several places along the road towards Kilmartin, I examined the detrital beds, and found they consisted of sand or mud lying over smoothed rocks;—and above the sand, masses of gravel—small-sized below, and coarse near the top. The gravel contained well-rounded boulders of considerable weight.

A narrow winding valley exists between Loch Awe and Kilmartin. The small river at Kilmartin does not come from Loch Awe, but from hills to the west. There is at present no stream in this valley which can account for the formation of the valley;—all that the stream has done is to cut through the detritus in the lower part of the valley. The surface at present in this valley rises from Loch

Awe for about two miles, and there, at the summit level, a tall pillar stands by the road side, about 15 feet high, the relic of a bygone age, whose origin no one can tell. At this point, the land is only about 130 feet above the sea, or about 12 feet above Loch Awe. A trench, therefore, exceeding that depth cut across the summit level, would allow of the waters of the loch to flow into Loch Fyne.

In this valley, about a mile from Loch Awe, the terraces shown in the following diagram, are noticeable :—



A, a steep rocky hill on west side of valley.

A', a hill on the east side of the valley.

B, a terrace on the west side of the valley, 84 feet above Loch Awe.

B', " east " 84 "

C, " west " 68 "

C', " east " 68 "

Both of the terraces shown in this section have been formed on detritus of gravel and sand. Auchandennan House is on C, and Ederline House (Bruce) on C'.

The 68 feet flat, C C', was ascertained by measurement and spirit-level to exist at other places in the valley nearer Kilmartin. It corresponds in level with the terrace on the River Awe in the Pass of Brander—viz., 186 feet above the sea.

As the terrace at BB' reaches to a height of (84 + 118 + 8) 210 feet above the sea, it may on a more precise measurement be found to correspond with the terrace in the Pass of Brander at from 223 to 235 feet above the sea.

This valley becomes contracted in width at Euroch, by reason of the rocky hills on each side at this place approaching one another to about 200 yards.

At this part of the valley the rocks in the bottom of the valley, and at its sides, show that they have undergone an enormous amount of rounding, scooping out, and smoothing.

In fig. 1 a section is given across the valley, A and B being the rocky hills on each side. At C and D there are smoothed rocks, C

being about 40 feet below D. The level of D above the sea, I calculated by aneroid to be 213 feet (assuming the terrace at Kilmartin to be 55 feet above Loch Awe, and D to be 50 feet above Kilmartin terrace). Between D and B, there is a flat a few feet higher, formed apparently on detritus. E is the high road between Loch Awe and Kilmartin.

Fig. 1.

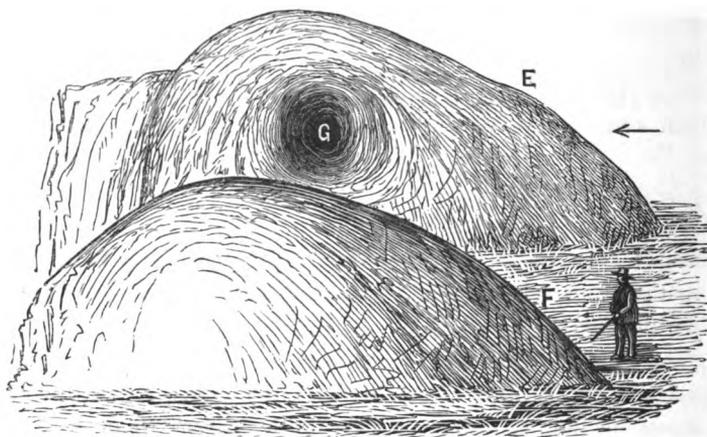
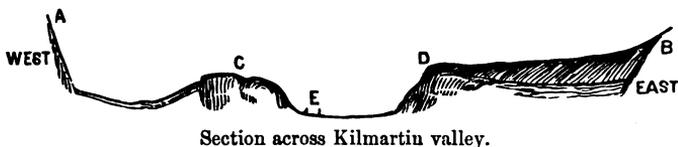


Fig. 2.

Rocks moulded and hollowed out in Kilmartin valley.

It was on C, in fig. 1, that the effects of the agency which had passed through the valley and over these rocks were most manifest.

In fig. 2 a sketch is given of the rocks at C, to show that the agent, whatever it was, which passed over and smoothed them had come in the direction of the arrow, viz., from Loch Awe.

That this agent was water, probably with ice floating in it, seemed manifest on a study of the rounded shapes of the rocks, and still more of the curious hollows, with smooth surfaces, which seemed to have been formed by violent eddies or whirls of water. One of these hollows, about 2 feet in diameter and depth, is attempted to be shown at G. There were several others of a

similar character. Such hollows in rocks, over or among which a rapid river flows, are not uncommon; and even on the sea-shore, between high and low water mark I have seen and studied similar scoopings, due, I have no doubt, to the action of stormy waves on rocks, where some portions are of a softer texture.

In this part of the valley the amount of detritus is small. The violent action of the water may have swept most of it from the rocks; where the valley widens nearer Kilmartin, there is an extensive terrace at one and the same level on each side of the valley formed on drift matter. Kilmartin Castle, in ruins, is on this terrace, on the east side of the valley. Evidently the terrace had, when formed, been continuous across the valley; a cut through it had been made by the small river which flows past Kilmartin. If it was a sea deposit, it would, of course, not become liable to river erosion, till it had become dry land. The Kilmartin terrace I found by aneroid to be about 55 feet above Loch Awe, making it  $(110 + 55 + 8)$  173 feet above the sea at H.W. If at any period the valley near Kilmartin Castle and village had been filled with detritus, forming a continuous flat or table land, this circumstance would of itself prove that it had been a deposit formed under a large body of water, salt or fresh, which had stood at a level a little higher than what the above measurement indicates. When this body of water subsided, the streams which flowed over and upon it from the adjoining hills would begin the work of cutting channels through the detritus, and hence the hollow, with steep banks on each side, of from 40 to 50 feet high, through which the Kilmartin River now flows.

That the body of water in and by which the detritus forming these terraces was deposited was the sea, is suggested by the impossibility of conceiving a lake with the requisite blockage in this wide-mouthed valley. Moreover, I learned from a medical gentleman, whom I met in the district, that about 25 or 30 years ago, when the course of the Kilmartin River was being straightened, several kinds of sea shells were found in beds of clay in the valley above the village of Kilmartin.

These terraces I followed down to near the sea-shore. When at the house of Mr Martin (Poltalloch's commissioner), about a mile to the south of Kilmartin village, I found myself in an extensive

meadow, through which the Kilmartin River meanders in such extensive sweeps, as to show that ages must have been spent, in removing the detritus, of which a large portion still remains on the west side of the meadow, forming a terrace with a steep bank about 50 feet high.

On ascending this terrace, and travelling on it towards Poltalloch and Duntroon, I descried on looking across the meadow about two miles towards the east, a terrace at a corresponding level, along which the Oban and Ardrishaig high road has been formed.

The terrace here, judging by the aneroid, seemed about 6 feet lower in level than that at Kilmartin, and in the valley leading to Loch Awe. But (even supposing that this aneroid measurement could be trusted) there are reasons why the shore line should be higher at the head of an estuary and in a contracted channel, than at the foot of an estuary on the open sea coast.

The question, however, recurs—If this valley between Kilmartin and Loch Awe were filled by an arm of the sea, how can the appearances on the rocks in the narrow part of the valley at Euroch be explained, as shown on diagram No. 2, where there is evidence of a strong continuous stream from the direction of Loch Awe? Do these appearances not indicate river rather than sea agency?

This is a question not easily answered. But some light may be thrown on it by the facts contained in the Fifth Report of the Boulder Committee of the Edinburgh Royal Society.

From this report it appears, that such of the boulders as by their own position, or by the position of the parent rocks, indicate the directions from which they came, suggest transport from the N.W. Moreover, these boulders in many cases preclude the possibility of any other agency than ice floating in a sea, which reached in the first instance to heights exceeding 2000 feet above the present sea-level, and which subsided from time to time to lower levels.

If then it be assumed that whilst the West Highlands of Scotland were submerged under a sea at a level of several hundred feet above the present level, and in which sea a N.W. current prevailed, what would in such circumstances occur in the district of Loch Awe? That current would flow in upon what is now Loch Etive, and would pass through the Pass of Brander into Loch Awe. Though directed upon the S.E. portion of the loch where Dalmally is situ-

ated, the waters could obtain no outlet there, but would have to flow along the range of hills to the south of Loch Awe towards the sea at the S.W. end of the loch, viz., at Ford, and would rush violently through the narrow valley, smoothing the rocks, and scooping them out so as to form the hollows above described.

In corroboration of this suggestion, I may take notice of the extraordinary numbers of boulders strewed over the surface of the hills adjoining Dalmally, and occupying particularly those sides of the hills which face the N.W. They probably had been brought there by a current from the N.W. when the sea stood at some hundreds of feet above its present level.

Another circumstance deserves notice which, when on the spot perplexed me, but of which I now see a probable explanation. On the hills to the south of Port Sonnachan, at a distance of about two miles, and at a height of from 800 to 900 feet above the sea, I found numerous large boulders lying in such positions as to indicate that they had come from the N.N.E. The hill-slopes face towards that quarter, and the longer axis of the boulders was generally N. and S. One of them measured  $18 \times 10 \times 10$  feet. I found that Loch Etive bore from this point about N.N.E. The rocks on the hills also showed smoothings apparently from the same direction.

These facts suggest the existence of a strong current from the north, which first impinging on the hills near Dalmally, would flow to the outlet between the hills at Ford in a S.W. direction, and reaching the sea there might produce the smoothings of the rocks in the valley above described. So long as the sea stood at a level of 180 feet, there would be an estuary through what is now Loch Etive, Loch Awe, and Crinan Bay. But when the sea subsided to say 120 feet, then Loch Awe would become a lake, with no outlet at Brander, but one at Ford; and we have seen that at many places there is evidence of the sea having stood long at a height of about 120 feet. The lake would then discharge its surplus waters by the S.W. end at Ford. But ultimately the barrier at Brander became lowered, and the lake flowed out to the sea, as it now does, by that Pass.

Whilst I offer this explanation, I do so with some misgiving, as I find that Professor Geikie has given one totally different. In his "Scenery and Geology of Scotland" (page 177), he says that Loch Awe did not originally discharge by the Pass of Brander. "The

terraced valley from Kilmartin to Loch Awe must have been the old outlet of the great valley of that loch." On this point I agree with the Professor. But the succeeding remarks seem to me to suggest grave doubts. "One cannot but wonder when, on ascending the valley from Kilmartin, he at last finds himself on an *ice-worn* barrier of schist, and sees stretched before him the shores of Loch Awe. The smoothed and polished surface of the barrier, and the parallelism of its striations with the length of the valley, show that the *mass of ice*, which once filled up the present basin of the lake, *passed on down the continuation of the valley towards Kilmartin*. All along the sides of the loch, and on its rocky islets, the same traces may be seen of the steady march of the ice. The rocks are worn into smooth mammilated outlines, and covered with ruts and grooves that trend with the length of the valley. It is, in short, a rock basin, of which all that can be seen is ice-worn; and *if farther proof of the old glaciers were needed*, it would be found in the *moraine rubbish* along the sides of the valley."

What is here represented as "moraine rubbish" are beds of gravel and sand, horizontally stratified, and therefore evidently marine deposits.

The whole of this Kilmartin valley is to the geologist of a most interesting character; and I lamented that I had not more than one day to devote to the examination of it, and even this I could not have accomplished, but for the guidance and kind assistance of Mr Alexander of Lochgilphead.

3. 185 to 200 feet.

(1.) Along the south flanks of the Ochil range, traces of sea action are visible between these heights.

The flat surface of the Tillicoultry Sand Escar, is at a height of about 186 feet.

At Alva there is a flat at about 184 feet; at Craigforth the rocks show smoothing up to 194 feet, which corresponds also with a flat on the south side of the Devon valley.

In Keir policy, and also near Doune village, there is a flat at 190 feet.

(2.) In Aberdeenshire (a few miles south of Inverurie) there are traces of an old lake, now entirely extinct, which stood at a height of about 180 feet above the sea. There are two lower beaches, showing successive subsidences.

Near Aberdeen, on the Edinburgh road, about half a mile from the River Dee, a flat at 180 feet above the sea was noticed.

A few miles north of Stonehaven, there are flats at about 140 feet, 200 feet, and 230 feet above the sea.

(3.) In East Lothian, on North Berwick Law, and at Lensie, there is a flat at about 196 feet.

G. *Terraces* (from 200 to 400 feet).

1. 200 feet.—In company with Mr Martin of Elgin, I visited the Rev. Dr Gordon of Birnie, whose manse is situated some miles to the south of Elgin. On our way there, Mr Martin expressed his opinion that the plain of Elgin had first been an arm of the sea, thereafter a lake, and ultimately a marsh.

Dr Gordon pointed out that his manse was situated on a patch of boulder clay; and that it corresponds with several knolls round about, the tops of which are all about 200 feet above the sea.

In following the high road from *Forres* to Caliper, I observed a well-marked terrace, at about 203 feet above H.W. The following diagram shows a number of knolls reaching to the above height, composed of gravel and sand, the spaces between them being occupied by streams, which have scooped out small valleys in the drift.



In Glenbeg, on the west coast of Argyle, there is a terrace at about 200 feet above the sea (Edin. Roy. Soc. Fourth Boulder Report, p. 6).

2. 220 feet.—In the Black Isle (Cromarty) and near Dingwall (Ross-shire), there are a number of small flats at about this height.

3. 229 feet.—Reference has already been made, in describing the Pass of Brander (north of Loch Awe) to a terrace at this height.

4. 230 feet.—Dr Gordon of Birnie informed me that in his parish of Birnie, patches of an extensive terrace at this height above the sea are extant. It is on a part of this terrace, viz., at Bogton farm, that there is a remarkable conglomerate boulder called the Carlin Stone. About a quarter of a mile to the N.W. there is another conglomerate boulder of smaller dimensions, called the young Carlin

Stone. The conglomerate composing these boulders is much harder than the conglomerate rocks existing in this county to the south and east. But rock of equal hardness, and containing pebbles of a similar colour exist, in Ross-shire, about thirty miles to the N.W. near the east end of the Great Glen bearing about due west.

This flat is composed chiefly of coarse, rounded pebbles, in which are imbedded hundreds of boulders of granite, gneiss, and clay slate. The nearest rocks of the same kind exist also to the west and N.W.

The surface of the flat slopes down towards the N.W.; and in that direction there is an opening towards the sea, between Carden Hill on the north, and Pluscarden Hill on the south. If floating ice came through that opening, carrying boulders, it might have stranded on the high ground near Birnie, and dropped the boulders where they now lie.

Hugh Miller, in his "Old Red Sandstone," refers to an extensive flat near Gamrie, in Banffshire, replete with marine shells at about 230 feet, and recognisable at different places for five or six miles along the coast.

5. At a height of 240 feet (by aneroid) I found an extensive flat, near *Balfron* (on the line of the Clyde and Forth Railway). I presume it is the same as that referred to in a paper by Mr Jack (Glasgow Geol. Society Trans., vol. v. pp. 17-20), under which he found horizontal beds of gravel, sand, and clay, containing sea-shells (several of them Arctic in type). Mr Jack observes, that these "stratified beds can be traced north-eastward nearly to Balfron station, northward beyond Drymen, and eastward to near Killearn, comprehending an area of about five square miles." He further observes that, assuming the general level of the flat to be (as he states) 262 feet above the sea-level when the gravel was deposited, a narrow strait, at the water-shed of the Bog of Ballat (which is 222 feet above the sea) "connected the basin of the Clyde with that of the Forth."

At a height of 290 feet there is a terrace in Loch Creran, a valley on the south side of the Linnhe Loch (Edin. Roy. Soc. Fourth Boulder Report, p. 13).

6. Along the south slopes of the Ochils, a flat at from 310 to 315 feet is visible at the following places:—At Alva, both east and west of the town;—at Boquharn farm, where there are also boulders

on the flat, and smoothed rocks (facing the west);—at Lipny, on the old Sheriffmuir road, where the conglomerate rocks are smoothed up to that height;—on the hill to the west of the Bridge of Allan, where the rocks are also smoothed from the west, and several granite boulders occur;—in Keir policy;—on the top of the Abbot's Craig, at the above height, the rocks show smoothings and striations from the N. W.;—on the south side of Stirling Castle the rocks show smoothings from the west.

7. In the valley of Glen-beg (west coast of Argyleshire) I found on the right bank of the river a terrace at 338 feet above the sea. Captain Burke of the Ordnance Survey, so far confirms this observation, by informing me that in this valley he had seen traces of a terrace on both sides at a height of 333 feet. The river is here about 40 feet below the flat. The flat may, however, have been formed by a lake, and not by the sea.

On the island of Kerrera (opposite to Oban) I found terraces on the hills, on the N.E. part, at heights from 357 to 437 feet, several of them the sites of grey granite boulders, so rounded as to show they had travelled some distance.

#### H. *Terraces* (from 400 to 600 feet).

1. At Eaglesham (a few miles south of Glasgow), Mr Gilmore's new house stands on a distinct flat about 400 feet above the sea. It is seen on both sides of the river Cart.

2. To the north of Campsie hills, and about two miles south of Bucklyvie village, there is a flat at about 400 feet above the sea, well covered with smoothed Old Red Sandstone rocks, and boulders of conglomerate, gneiss, and granite, which probably came from the Aberfoyle hills, situated to N.W. and N.N.W.

3. In July 1872, the Rev. Dr Gordon, of Birnie, informed me of a terrace which he had seen in the Glen of Rothes, in the valley of the Spey, at from 440 to 470 feet above the sea.

At Culloden Muir, near Inverness, there is an extensive flat 450 feet above the sea.

Near Inverie, on the west coast of Ross, there is a flat between 400 and 500 feet above the sea (Edin. Roy. Soc. Second Boulder Report, Proc. vol. viii. pp. 158–165).

4. On the south slope of the Ochils between Crook of Devon and Cleish turnpike road, there is an extensive flat, which my aneroid

showed to be 440 feet above the sea. Its surface is well covered with fine gravel and sand. Several boulders lie on it,—one or two of a flesh-coloured Felspar, which I think I have seen in hills to the westward.

In the valley of the Devon, and especially near the old castle of Whitehills, several terraces on both sides are visible.

They occur again, on the east side of the Glencagles Road, near the place known as the Gates of Muckhart. They occur on both sides of the summit level passed over by the road to Crieff. One terrace occurs at a level of 575 feet above the sea—being that on which Muckhart Church stands; the other is at a level of 756 feet above the sea.

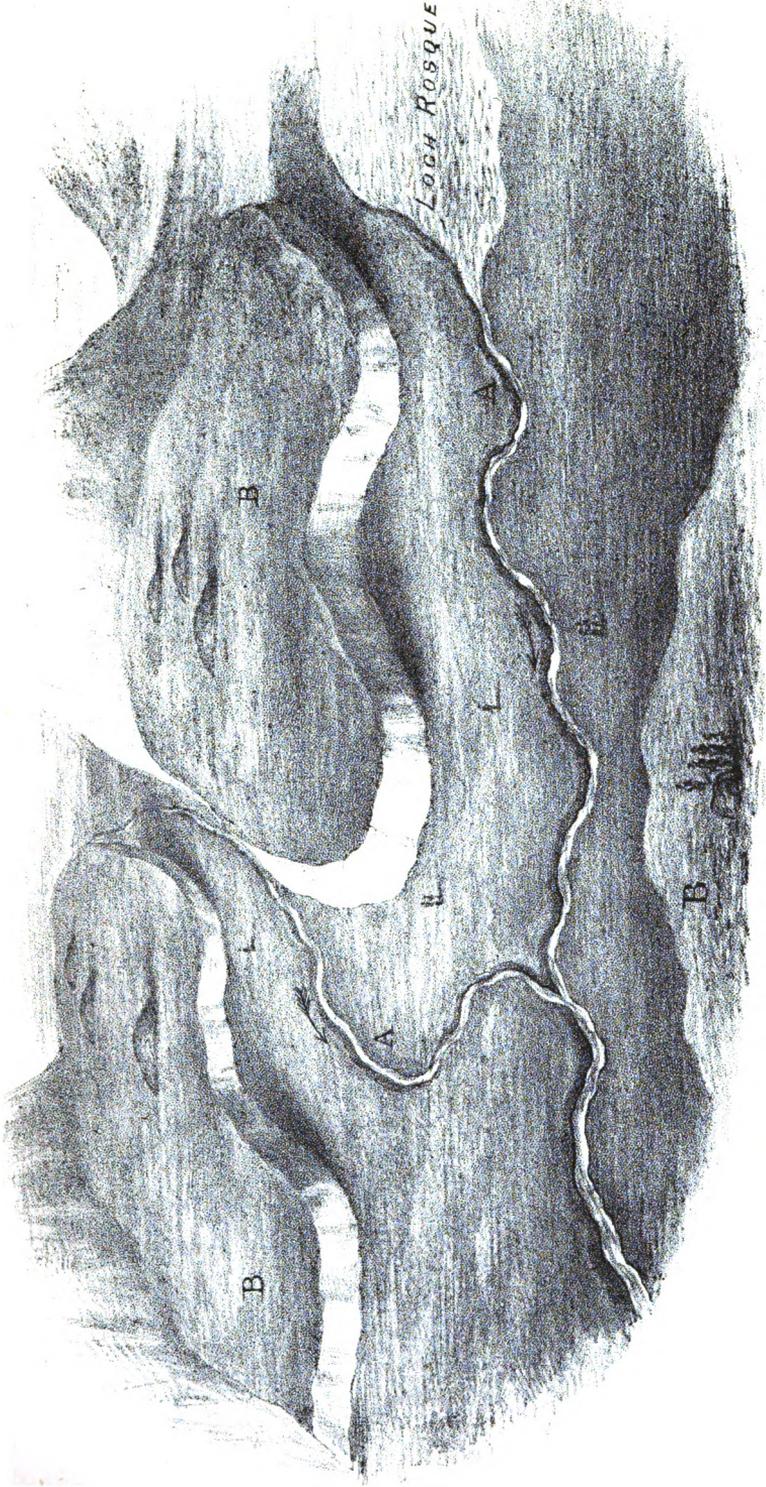
5. In the valley of Glenbeg (Argyleshire) I visited a terrace, made known to me by Captain Burke of the Scotch Ordnance Survey, at a height of 528 feet above the sea (Edin. Roy. Soc. Fourth Boulder Report, p. 6).

6. Near Crieff junction railway station, at a height of 570 feet above the sea, there is a series of Kaims or Escars, whose general direction is E. and W., or parallel with the general range of the Ochil hills, not far off to the south. These Kaims abound in boulders and coarse gravel, of gneiss, granite, and other rocks situated mostly to N.W. The rocks at Crieff Junction are old red sandstone.

7. Several terraces at about 600 feet at Auchnasheen and Loch Rosque in Ross-shire, near the Dingwall and Strome Ferry Railway, deserve notice.

Some of these terraces have been referred to in guide books. The only geologist who within my knowledge has written about them, is the late Professor Nicol of Aberdeen. Referring to the immense beds of sand and gravel composing them, he attributed their formation (Geology of the North of Scotland, p. 69), to “a large river from the west, which has thrown them down on the corner of the mountain.” To that opinion I cannot subscribe. There is no country of sufficient extent to have produced “a large river” in this elevated district, and the beds of gravel and sand are not in the least like those deposited in rivers.

The accompanying rough sketch (from memory) will give some general idea of the appearance of several of the terraces,—taken from a position on one of the terraces on the east side of the river flowing out of Loch Rosque, and near a large granite boulder resting



PORTION OF TERRACES AT AUCHNASHEEN.



on the terrace. It is about a quarter of a mile to the north of Auchnasheen railway station.

The terraces marked B are all on one level, apparently they have formed one continuous flat, before having been cut through by the two small streams now meandering below them.

These terraces occupy a space or area of about one and a half miles east and west, and one mile north and south.

Along Loch Rosque, and particularly at its north end, and along its east side, the highest of the terraces is at about 610 feet above the sea. The other terrace along the lake is about 40 feet lower, and continues to the railway station.

The river channels (A, A in sketch) are about 460 or 470 feet above the sea.

The meadow land adjoining the river, is about 16 or 17 feet above the channel, showing the height of occasional floods.

The meadow is bounded by a striking range of cliffs, some of which are well seen from the railway, composed of sand and gravel; the sand being almost always below the gravel.

On the two distant terraces, there are knolls or mounds (C, C,) from 30 to 40 feet high, consisting of coarse gravel with boulders. As the tops are pretty nearly on one level, they may be the remnants of the higher and more ancient terrace 610 feet above the sea, as seen on the east bank of Loch Rosque.

There are patches of gravel and sand on the adjacent hills. To the east of Auchnasheen Railway Station, on the hill sloping down to the north, a horizontal beach line is visible at above 570 feet above the sea.

On the south side of the same valley, there is a well-smoothed rock, at about 789 feet above the sea; and on turning my level across the valley to the north, I descried on the hill-slope traces of a horizontal line at the same level.

If these terraces are all due to the action of a large body of water, was it lacustrine or marine? Lacustrine it could not well be, unless at the summit-level between Auchnasheen and Loch Carron (which is I think about 650 feet above the sea), there was a barrier at least 170 feet high, and half a mile wide, and a still larger barrier at the east and lower end of the valley towards Dingwall. The more probable view, therefore, is that these Auchnasheen terraces, are due to the sea, which subsided from one level to another.

I. *Terraces* (600 to 800 feet).

1. Travelling along the north bank of Loch Tay, I observed at many places a flat at about 380 feet above the lake, with a width from the lake of about a quarter of a mile. Assuming the lake to be 300 feet above the sea, this would give a level of 680 feet.

On looking across the lake, I thought that I could discern traces of flats at a corresponding level on the south bank.

2. In Berwickshire on Barnside farm, situated on the north side of Cockburn Law, I noticed a pretty extensive flat at a height of about 680 feet.

3. Near Moffat, in a valley where Frenchland Tower is situated, I found a plateau or terrace formed on drift, at a height of about 750 feet above the sea (Edin. Geol. Soc. Trans., vol. iv. p. 72).

4. In the hills of Edderton parish, near Tain, Ross-shire, there is a well-marked terrace at 750 feet with boulders on it (Edin. Roy. Soc. Second Boulder Report, Proc. vol. viii. p. 174).

5. I have already referred to the terraces in Spey valley at a height of from 780 to 790 feet above the sea.

6. At the head of Loch Goyle, near the road leading to Loch Fyne, there are flats composed chiefly of sand at about 760 feet.

At exactly the same height, I found an extensive terrace in the upper part of Glen Rosedale (Argyleshire), first made known to me by Captain Burke, R.E. The Ordnance Surveyor made its height 750 feet above the sea (Edin. Roy. Soc. Fourth Boulder Report, p. 6).

6. On the north slope of Nairn valley, about five miles from Inverness, there is a terrace apparently horizontal, at a height of about 774 feet above the sea; with several large boulders on it; pointed out to me by Mr Jolly of Inverness.

7. On or near the high road leading across the Ochils by Yetts of Muckhart, at Ballylisk, there is a flat at about 800 feet above the sea.

K. *Terraces* (800 to 1000 feet).

1. In Glenbeg, on both sides of the valley, a terrace with boulders on it occurs at about 858 feet above the sea (Edin. Roy. Soc. Fourth Boulder Report, p. 7).

2. In Flichity valley about eight miles to the S.W. of Inverness, there are several terraces on the surrounding hills. They greatly

reminded me of the Lochaber parallel roads. The lowest is from 800 to 830 feet above the sea. The next higher is 985 feet. In the middle of the valley, a conical hill stands up, reaching to about 1200 feet, with smoothed and striated rocks on its south side. The striæ run at one place E.N.E., at another N.E. by E. In this part of the valley, the general axis of the valley, which in the upper part is about due E. and W., changes to about E. by N.; so that the striating agent (whatever it was) had moved nearly parallel with the axis of the valley.

The whole valley has at an early period in the world's history been covered, if not filled, with sand and gravel; for at a height of about 1500 feet I could distinguish (though at a distance) beds of white sand on the hills bordering the valley on the south.

At the east end of the valley, the river Nairn, which traverses the valley, passes out of it at a very narrow gorge. At this place there is a huge embankment crossing the valley, suggesting the idea of a blockage. Its top, near where the river cuts through it, is 840 feet above the sea. But near the enclosing hills on the south, it reaches to a height of 870 or 900 feet.

The channel of the river, where it cuts through the embankment, is about 203 feet below its present upper surface. The side of the embankment facing Flichity valley, is somewhat steep, as if it had been acted on by a running stream.

The width of the gorge is about 500 yards. The materials forming the banks on both sides of the river, consist of coarse gravel and boulders.

The opinion formed after two visits to this interesting valley, accompanied by Mr Jolly of Inverness, was, that the sea at first prevailed over the district to the height of 1500 feet or more; that when the sea subsided to a level below 800 feet, the valley was occupied by a lake which discharged at its east end;—kept in there by the embankment just referred to; and that when the river cut through the embankment, the lake disappeared; leaving, however, much muddy matter, which forms the meadows and arable fields, now the lowest part of the valley.

This Flichity valley, would in that case present a series of changes exactly similar to those which occurred in the Lochaber valleys, where the *Parallel Roads* occur.

3. In Glendoe, a branch of the Invermorriston valley to the north

of Loch Ness, I found a terrace at 890 feet, as will be more fully explained under the next heading.

At the summit between Lochs Tay and Erne, there is a trace of a terrace at about 800 feet above the sea.

4. Having in Mr James Geikie's remarkable book, called the "Great Ice Age," seen a notice of terraces at a high level near Eaglesham, situated to the south of Glasgow, I went to examine them.

At the height of about 810 feet, there is an extensive tract of flat land, with shallow lakelets. On this tract there are several Kaims or banks of gravel, all running in nearly the same direction, viz, east and west, with boulders of trap and porphyry lying upon or near to them.

At about 900 feet, I found a deep bed of sand, which was being excavated for building purposes.

At about 980 feet, I observed in two places, to the east of Balligoch hill, a terrace not mentioned by Mr Geikie.

With regard to the character of the body of water which produced these terraces, it is right to notice that Mr Geikie confesses to a change of opinion. At first, he considered them to be "*relics of old sea beaches*;"—for in the first edition of his book, he described or referred to them as such. But now he thinks they have been formed by *lakes*, which have been blocked by *ice* in some form or other. He accounts for successive lowering of the lakes, by the "giving way at some part, of the glacier" (p. 231). Elsewhere, he speaks of the melting of the *mer de glace* (p. 332).

The area of the lake which Mr Geikie supposes to have formed these terraces, is indicated in the following passage in his book (last edition, p. 229).

"When the upper terrace was being formed, water washed the slopes of the Dunlop and Strathavon Hills, at a height of 800 feet above the sea." The terraces skirt the open hill side. They lie not in any deep valley. Standing on the terraces, we find ourselves overlooking the broad vale of the Clyde, with no higher ground between us and the Campsie Fells." "The water that spread them out, behind Eaglesham, must have stretched away north for sixteen miles at least, until it abutted against the Kilpatrick Hills and the Campsie Fells."

Assuming that there are terraces on the Kilpatrick and Campsie

Hills, at the same levels as on the Dunlop and Strathavon Hills, it remains to be explained, what kept in this supposed lake along its east and west banks? The summit level on the east at present is only about 200 feet above the sea, with a stretch of about thirty miles from the east end of the Campsie to the Lanarkshire Hills, requiring *therefore a blockage of that extent, and 600 feet high!* On the west, there is the deep valley of the Clyde, which would require a blockage *at least 900 feet high* and nearly as many miles in extent!

The marine origin of the terraces, in conformity with Mr Geikie's original opinion, seems to be attended with the fewest difficulties.

#### L. Terraces (above 1000 feet).

1. Mr James Geikie states (in his "Great Ice Age," p. 231), that "Terraces resembling those at Eaglesham have been detected in other hilly districts. I have met [he says] with good examples in the *Moorfoot hills*, at a height of 1050 or 1150 feet; which I believe have been formed in the same way, as the gravel flats of the Dunlop and Strathavon hills."

"Still further south, high shelves of gravel and sand have been detected by my colleague Mr Skae in Nithsdale, at a height of 1250 feet above the sea" (page 232).

2. *Invermorriston*.—There are traces of an ancient lake existing in the valley through which the River Morrison flows into Loch Ness. These traces were seen by me (Oct. 1877) when travelling along the road from Invermorriston to Glendoe. The lower end of the lake, where it discharged, is at Turgoyle Bridge, about 390 feet above the sea. The valley there is very narrow, and consists of high rocks. The beach lines of the lake are about 50 feet above the meadow through which the river meanders, which meadow was probably the lake bottom. The south bank of the valley, sloping down to the old lake margin, is covered by enormous masses of detritus, and also by boulders. These boulders are round-shaped at the level of the old lake, and angular in parts above that level. This lake appears to have extended westward to a place a little above where Glendoe joins the main valley, 3 or 4 miles above Turgoyle Bridge. There the outlet of the lake probably became more deeply cut in the course of time, causing the entire drainage of the lake. Below Turgoyle Bridge, a second lake, at a lower level, seems to have existed, as I recognised traces of horizontal flats

on each side of the valley. It is quite possible that before the Turgoyle lake was formed, and when the sea stood at 500 feet or more above its present level, a salt-water loch extended up this valley.

In a higher part of the same valley several very distinct terraces were observed. The Ordnance Surveyors had apprized me of two, in an amphitheatre of hills covered with sand and gravel, where the River Doe takes its rise. The highest of these hills is known as Ben Doe, and reaches to a height of about 2000 feet above the sea. These Surveyors had kindly marked on my map the position of two horizontal lines which, they said, were deeply graven on the detritus, at the heights of 1140 and 1280 feet. A snow-storm (17th Oct. 1877) unfortunately occurred on the day that I visited Glen Doe, which prevented me getting nearer than a mile from the place. But I reached an intervening hill at 1190 feet, and had a distant view of the particular slope on the hill, called by the gamekeeper (who guided me) English Hill, on which the surveyors said the two horizontal lines had been seen by them. I did not recognise them; the snow was so thick as to conceal any lines existing there. But on the hill from which I viewed English Hill, I found immense beds of stratified sand and gravel, and the gamekeepers informed me that sand and gravel prevailed over all the hills round about. On my explaining to these men, what I had expected to find on English Hill, they said that at this place, they had in the previous autumn been shooting grouse with some English gentlemen, one of whom, struck with the beds of sand there, exclaimed, "*surely Noah's flood has been up here!*"

On my return down the glen, I distinctly recognised four separate terraces on each side, of which the highest was 1204 feet and the lowest 895. Boulders of large size lay on several of these terraces (see Fourth Report of the Edinburgh Royal Society Boulder Committee).

3. In the valley of the Lednock, below its junction with Glenmeg, above Invergeldy House (Perthshire), several terraces are conspicuous, which (in August 1840) I roughly estimated at 1120, 1220, 1280, and 1320 feet above the sea, assuming Loch Erne to be 300 feet, and Invergeldy House to be 380 feet above the sea.

4. At the west end of Loch Tay above Killin village, there are several terraces, the lowest of which is 1190 feet, assuming the loch to be about 300 feet above the sea.

On these hills, to nearly the top, beds of sand and gravel abound ; and in several different directions, there was the appearance of flats up to a height of 1800 feet ; but they were seen only through the telescope.

5. In Glenbeg (Argyleshire), the Ordnance Surveyors reported to me a horizontal line on the left side of the valley at a height of 1500 feet, and marked its exact position on my map (Edin. Roy. Soc. Fourth Boulder Report, p. 7).

I went there to inspect the terrace, but was unable to approach it nearer than half a mile ; but at that distance, I could discern a horizontal line from the opposite side of the valley.

6. Mr Jamieson, in his paper "On the Drift of the North of Scotland" (Quart. Jour. of the London Geological Society, vol. xvi. p. 347), refers to several localities in the valley of the Tay, where, at considerable distances apart, he found drift forming horizontal beds of sand and gravel, and reaching to about the height of 1500 feet. Thus below Killiecrankie, he traced these beds up to a height of 1550 feet (p. 300), and showing "the mass to be regularly *stratified* in an *almost horizontal manner*" to "the depth of no less than 500 feet." "It has (he says) been all evidently accumulated under water ; and the great number of seams of fine laminated silt would seem to show, that its deposition had been very gradual, and had occupied a great lapse of time."

In a separate valley near Loch Tummel he found drift beds on a mountain side, the uppermost limit of which was 1520 feet, being *at nearly the same level as in the valley previously mentioned* (p. 362).

To these facts he refers, as "proofs that in these later times the sea waters had rolled over the hills and valleys of Scotland" (p. 362).

7. On several of the Lochaber hills, there are terraces and escars, evidently marine, because they are at higher levels than the lake beaches of the "Parallel Roads." Thus, on Craig Dhu, the Ordnance Surveyors indicate a horizontal line at 1306 feet above the sea. Dr Chambers, in his "Ancient Sea-Margins," indicates other lines at 1337 and 1495 feet. Mr Jolly of Inverness discovered one at 1750 feet (Edin. Roy. Soc. Trans., vol. xxvii. p. 624).

I discovered on Ben Erin a horizontal line at 1877 feet, and in Corry N'Eoin three horizontal lines at from 1700 to 1800 feet above the sea (Edin. Roy. Soc. Trans., vol. xxvii. p. 624).

On the hills south of the mouth of Loch Treig, there are terraces and escars, evidently marine, at 1489 feet above the sea.

On Ben Chlinaig, opposite to Craig Dhu, I found several escars at different levels, from 1253 up to 1700 feet above the sea (Edin. Roy. Soc. Trans., vol. xxvii. p. 636).

It is not irrelevant here to allude to the fact, that in Wales and elsewhere in the West of England, sea shells of various species have been found at a height of about 1450 feet above the sea; and that at about the same height marine shells have been found in Ireland. (Geological Magazine for June 1881, where there is a paper by D. Mackintosh, Esq., on this subject).

8. Near Loch Skene (Moffat) I found boulders on a terrace at about 1800 feet above the sea (Edin. Geol. Soc. Trans., vol. iv. p. 72).

9. On the west side of Maum Saul, a mountain in Ross-shire, on the property of Baron Tweedmouth of Guisachan, and reaching to a height of about 3800 feet, the Ordinance Surveyors reported to me the existence of a horizontal terrace on gravel and sand at a height of about 2800 feet. They marked it on my map to be sought for on the west side. I attempted in October 1877 to ascend the mountain in search of this terrace, accompanied by Mr Jolly of Inverness; but we were driven back by rain, fog, and violent wind.

*M. Notes on some of the Physical Features of the Glen-More-nan-Albin, or Great Glen of Scotland, extending from Corran Ferry on the West Coast, to Fort-George on the East Coast.*

I. The Valley to the extent above indicated, is about 75 miles long, and is occupied at its east and west ends by the sea, and in its intermediate portions by rivers and lakes, viz.—Lochs Dochfour, Ness, Oich, and Lochy. The portion between Loch Ness and the sea, on the east coast, is for 7 miles partly occupied by the River Ness and Loch Dochfour. The portion between Loch Ness and Loch Oich is for 5 miles drained by the River Oich, which conveys the surplus waters of Loch Oich into Loch Ness. The portions between Loch Oich and Loch Lochy, a distance about  $1\frac{1}{2}$  mile, is now traversed by part of the Caledonian Canal; and the portion between Loch Lochy and the sea, a distance of about 4 miles, by the River Lochy. Loch Ness is, when at its usual height, about 46 feet above high-water spring-tides at Inverness. Lochs

Lochy and Oich are not now at exactly their *original natural* levels. Originally, Loch Oich was at a level of 98 feet above the sea (med. level). For the purposes of the canal, it was raised to 100 feet. Originally, Loch Lochy was 81 feet above the sea (med. level). It was raised to 93 feet.

It is believed that before the canal was made (completed in 1822) Loch Oich had an outlet at each end—a feature of comparatively rare occurrence. A portion of its waters thus flowed into Loch Ness, and a portion into Loch Lochy; but, when the canal was made, an embankment was formed at the west end of Loch Oich, so as both to raise its level and cause its surplus waters to discharge, as they now do, exclusively at the east end.

The Great Glen has a range of mountains on each side, whose general direction is about E.N.E. (true) or N.E. (magn.).

These mountains have an average height of 1500 feet. The highest is Ben Nevis, 4406 feet, on the south range near the west end of the valley. The next highest is Mealfourvonie, about 3060 feet, situated on the north range about the middle of the valley.

The two mountain ranges approach nearest to one another at Loch Oich. There at the level of the lake, viz., 100 feet above the sea-level, the distance between the two mountain ranges, where they begin to rise steeply, is about a mile, whilst elsewhere, at the same level above the sea, the respective base lines are about 3 or 4 miles apart.

If the width of the Glen be taken at the extreme east and west ends, where there is sea, as at Corran Ferry and at Fort-George, there is of course only the distance between the two opposing shores, which at Corran Ferry is about a quarter of a mile, and at Fort-George about one mile. At both of these places, the mountains, on opposite sides of the Glen, are five or six miles apart, a low level district being between these mountains and the sea.

II. The whole of the Glen has originally been filled with *drift*—that word being held to signify gravel, sand, or clay.

1. The *gravel beds* are well seen at several places, forming “scours” of great depth and extent.

Thus, at the east end of the Glen, there are two hills composed entirely of gravel and sand, well seen from the steamboat as it passes along the canal which lies between them,—Tomnahurich being

one of these hills, reaching to a height of 270 feet; and Torvain the other, reaching to a height of about 200 feet above the sea. On Torvain, sections are seen 130 feet long and about 60 feet high. The lower 40 feet consist of beds of sand, nearly horizontal. The upper 20 feet consist of gravel; small pebbles below (next the sand), and large pebbles above. On the west side of Torvain the gravel beds slope down to the west. These present the usual feature of being much coarser in the upper, than in the lower beds. In the upper beds, there are even boulders of considerable size.

At the west end of the Glen, there are also sections of gravel on the banks of the River Spean, at various places between Spean Bridge and Gairloch. Some of the scaurs of coarse gravel through which the river has cut, exceed 40 feet in depth; but, as the scaurs are at different levels above the river, the total depth of gravel cut through, cannot have been less than 150 or 160 feet.

At Ardgower, near Corran Ferry, there is a remarkable gravel escarp, running about N.E. and S.W. Its base is about 40 feet above the sea, and its top about 40 feet above the base,—though it probably is now lower in height than it once was.

But gravel beds at greater heights occur. Thus in Glen Gluoy and Letter Finlay Hill (on south side of Loch Lochy), I found them at 1700 feet above the sea.

On the hills along the south side of the main Valley, opposite to Invergarry, gravel beds occur at a height of 1560 feet above the sea.

In the hills of Stratherrick, among which the Foyers river rises, about 4 miles south of Loch Ness, I found gravel beds at a height of 1774 feet, and could see that two miles farther south there were similar beds 300 feet higher.

On the Moy hills, north of Gairloch, gravel occurs up to the very top, viz.—from 1800 to 2000 feet.

At numerous places, deep gashes are visible on the mountain sides, as they slope down towards the lochs, caused by streams which have cut through the beds of gravel.

The gravel occupying positions in or near the lower or flat parts of the valley, is frequently in the form of elongated heaps, nearly parallel with the axis of the valley. The gravel at Corran Ferry at the west end, and at Torvain and Tomnahurich at the east end, presents that feature.

There is a kaim or escarp of gravel and sand, on the south side of

the hill between Inverness and the Upper Nairn valley, above Gack, at a height of 820 feet above the sea. Its direction is N.N.E., *i.e.*, parallel with Nairn valley.

2. There are *beds of sand* in numerous parts of the Glen, and generally, though not always, lying below gravel.

A bed is extensively worked at Kilmonivaig Church, about 300 feet above the sea, which is believed to extend to many acres. Another bed occurs in Glen Gluoy, also about 300 feet above the sea. On Invergarry estate on north side of Loch Oich, as I was informed by the late Mr Ellice, the proprietor, an extensive bed of sand exists at the height of about 1000 feet above the sea.

On the north side of Loch Ness, at Urquhart, about 500 feet above the sea, there are enormous beds of sandy clay. On the south side of Loch Ness, at about the same level and about two miles south of Foyers Hotel, I found a sand bed which was being worked.

At Glendoe, Invermorriston, there are thick beds of sand 2000 feet above the sea.

3. There are at multitudes of places in the Glen, great sections of *clay*, containing well-rounded boulders of all sizes.

On the south bank of Loch Ness, the river Farrigaig flows into the loch by a deep cut, which it has made for itself through clay in many parts of its course. One scaur is about 250 yards in length and about 40 feet deep, situated on the west side of Dun Jardel, the hill on whose top stands a vitrified fort. The clay is stratified, and has evidently been formed of sediment deposited in water of considerable depth. As there are boulders embedded in the clay, some of them from 7 to 8 feet in diameter, it is evident that these boulders must have been brought to the spot, and dropped into the clay bed. No agency can be imagined here except floating ice, which, if it came from the westward, would strike against Dun Jardel and thereupon discharge its cargo. Hence the unusually large accumulation of boulders at this spot.\*

Another place where there is a deposit of clay on a large scale, is at Rosemarkie, near Fortrose, opposite to Fort-George. My friend, Mr Jolly, school inspector, Inverness, conducted me to the spot. Fig. 1 may give some idea of this deposit. It represents a section about

\* It was when examining this locality that the late Dr Bryce lost his life. I had unfortunately suggested the visit. When standing on or close beneath a large boulder, which he probably had been striking with his hammer, he loosened the boulder from its bed on the side of the glen, and was crushed by it.

200 feet high and about 150 yards long. The upper part of the deposit has been cut out into fantastic pyramids,—the effect of rain and frost on the soft gravelly materials. The Burn of Rosemarkie runs at the foot of the section, and most probably has been the means of forming the vertical cliffs on each side of it, by cutting through the bed. The hills adjoining, to the height of 600 or 700 feet, seemed all to be composed of the same clay deposit. A few boulders occur in the section, the largest from 2 to 3 feet in diameter; some were of granite,—the kind, as Mr Jolly thought, which is abundant on Ben Wyvis, a hill situated N.N.W. of this point, and about 25 miles distant. The deposit was full of pebbles, most of them ir-

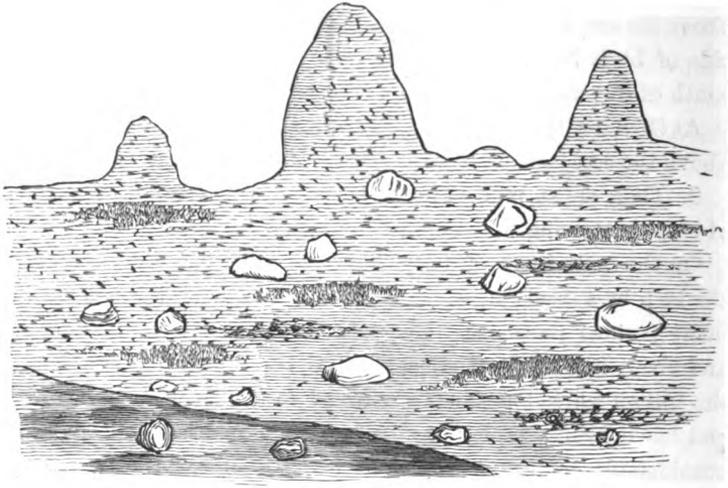


Fig. 1.—Rosemarkie Boulder Clay.

regularly scattered, but some forming short continuous beds. These beds were generally horizontal, and occasionally sloping down east at an angle of  $3^{\circ}$  or  $4^{\circ}$ . Beds of sand also occur in the deposit, inclining or sloping much as the beds of pebbles.

This clay deposit probably extends across the valley here, as at Fort-George, which is only about 2 miles to the S.E., borings were made for water (some years ago), to the depth of about 100 feet, in clay containing boulders, without reaching the bottom of the bed.

There can be no doubt that these immense masses of clay at

Rosemarkie and the adjoining district are a sedimentary deposit from water.

4. The drift deposits of gravel, sand, and clay are most abundant in the parts of the Great Valley where the valley is wide, and least abundant where the valley is narrow.

(1.) Thus at Cullochy, which is at the very narrowest part of the entire Glen,\* by reason of the two opposite mountain ranges being nearer each other there than elsewhere, the quantity of drift is small;—and instead of drift, there are on both sides of the Glen, and especially on the north side, rocks of hard gneiss, which have been ground down by some agency moving over, pressing upon or forcing its way between them. The movement has been from the westward. This is shown distinctly by the rocks having their rounded and smoothed sides facing the west, and their angular and rough sides facing the east. On the surface of one or two of the smoothed rocks, there are deep ruts rising up towards the east, which may be explained by supposing that the rubbing agent when passing through this narrow neck of the Glen, was forced upwards to effect a passage. The height of these Cullochy smoothed rocks above the sea-level is 120 to 160 feet.

Another place where rocks smoothed like those at Cullochy occur, is on the south bank of Loch Ness near Inverfarigaig. Drift extends from the level of the water up to about 98 feet, or about 148 feet above the sea. Above that line, hard gneiss rocks project and form a band on the bank, for about 100 yards, and from 10 to 12 yards in vertical depth. These rocks where they project have



Fig. 2.—Rocks on Loch Ness smoothed on west sides.

evidently undergone some process of rubbing, being rounded and smoothed on the parts (*a, a, a*) facing the west, but rough in the parts (*b, b, b*, fig. 2) facing the east.

On Craighadrig Hill, 2 miles west of Inverness, the hard conglomerate rocks are rounded and smoothed at a height of 500

\* The Rev. Mr Cameron of Kilmonivaig informs me that "*Cul*" is the Gaelic for "*narrow*," and "*Oich*" the Gaelic for "*neck*."

feet and upwards. On the south side, the rocks are angular and rough. On Duntelchaig hill, situated on the east of Loch Ness near north end, I saw that the rocks presented their smooth faces to west and rough faces to east. In Stratherrick, near Loch Faraline (a valley parallel with the great glen on the south side and distant about 2 miles), the rocks present smooth faces towards W.S.W. In Glen Urquhart, there are rocks visible from Loch Ness, which have smoothed surfaces towards S.W. and W.S.W. On the top of Auchindaal hill, situated to the S.W. of Gairlochy, and at a height of about 760 feet above the sea, the rocks there also present smoothed faces to the west and rough faces to the east.

To the north of Kessock Ferry, on an old unfrequented road leading to it, and at a height of about 300 feet above the sea, there is a mass of conglomerate rock which has been ground down into a flat smooth surface, dipping gently towards the west. On this surface Mr Jolly and I found striæ bearing E. and W. (magn.) Looking towards the west, I observed that the N.E. opening or mouth of the Great Glen bore from this point about S.W., and that due west there was also a depression in the general surface of the land, which might allow of the striating agent (whatever that was) moving from either point, towards the east in the line of the striæ.

In the hill between Glens Gluoy and Fintaig on the south side of Loch Lochy, I fell in with a well-striated rock 1700 feet above the sea. The direction of the striæ was E. and W. (magn.)

(2.) The parts of the Glen where the drift is now in greatest quantities are towards the east, as along Loch Ness, and especially at the north end of the loch.

Along the north side of the Valley there are several natural glens now occupied by rivers or streams, as at Invermoriston, Lein, Ruiske, and Urquhart. Along the south side, there are similar lateral glens, as at Foyers and Inverfarigaig. All these glens are filled with drift, and up to high levels. Where these glens at their junction with Loch Ness form bays, drift abounds down to the edge of the loch; but when the sides form points or capes projecting into the loch, the drift then forms a very thin covering to the rocks.

It is at the east end of Loch Ness, viz. at Craig Dearg, Dochfour, Aldourie, Torvain, and Tomnahurich, that the drift deposits are most abundant and conspicuous. The width there of the Great Glen, between its sides, is fully 2 miles.

The inference which these facts seem to suggest is, that after the whole Glen had been filled, or nearly so, with drift deposits, an agency of some kind passed through it, scouring out much of these deposits, and doing so with greatest effect at the narrow parts of the Valley. In confirmation of this view, it may be mentioned that the gravel of Torvain hill contains numerous pebbles of rocks situated only to the westward. This fact I state on information given to me by the late Mr Anderson of Inverness, who was a good geologist, and intimately acquainted with the rocks and physical features of the district.

5. Another point of interest is the occurrence of *boulders brought from distant regions*. I am not sufficiently familiar with the various rocks of these Highland mountains to be able to indicate the position of the *parent* rocks. To any one who is well acquainted with the geology of the district, a study of the boulders on the two sides of the Great Glen would probably be rewarded by important discoveries.

(1.) Conglomerate boulders occur abundantly on sides of the valley near the east end of Loch Ness.

Thus on the hill east of Urquhart, in walking casually up from Loch Ness to a height of 800 feet above the loch, I fell in with six conglomerate boulders lying on drift which here covers *gneiss* rocks.

A band of conglomerate rocks some miles west of Urquhart, runs obliquely across the Great Glen in a direction N.N.E. and S.S.W. Mealfourvie, a hill 3000 feet high, situated on the north side of Loch Ness, is largely composed of this rock. Between that hill and these boulders, there is no obstruction. It is distant from them about 8 miles, and bears W.S.W. (*magn.*), which is a line parallel with the axis of the valley in this part of it.

There is an extensive plain about 6 miles S.W. of Inverness, and 645 feet above the sea, covered with drift. On it several large conglomerate blocks occur—one, about 10 feet above the ground, called "Brownie Stone," near Banachton, and of cubical shape. Another is 10 × 6 feet; its longer axis points W.N.W. Another boulder is in size 24 × 21 × 8 feet. In these boulders there are quartzite pebbles both liver-coloured and white, and there are pebbles of granite containing mica. The conglomerate hills are towards the W.S.W., about 8 or 10 miles distant; one of these is Duntelchaig hill. The rock there has in it the liver-coloured

quartzite, which are in the boulders. I examined this hill with Mr Jolly of Inverness.

On Craig-a-Chlachan, a hill to the S.W., at a height of 1100 feet above the sea, I examined a large conglomerate boulder called "Watch Stone," which had been made known to me by Mr Jolly. This boulder lies on *gneiss*, and is close upon the edge of a precipice about 100 feet deep. Being on a very precarious site, it must have been deposited without undergoing pushing or rolling. To get into this position, it had to come in a direction between W. by N. and W.N.W.

On the same hill there are multitudes of other boulders, not so large, which, as their positions show, must have come also from the westward.

(2.) Some miles further south, there is a lake bearing the name of Loch Clachan, probably on account of the number of boulders lying on its banks and the hills adjoining.

Most of these boulders are of grey granite. By reference to Professor Geikie's Geological Map of Scotland, it will be seen that the nearest position for granite rocks *in situ*, is about 15 miles to the S.W. at and about Loch Faraline.

The following are examples of these boulders :—

One, 21 × 20 × 14 feet, at a height of 983 feet above the sea. There is an opening or depression of land towards the N.W., by which this boulder might have reached its site.

One about the same size, resting on a large gravel knoll, at a height of 1169 feet above the sea.

One about the same size, at a height of 1259 feet above the sea. This boulder has its sharp point looking west; its east end is broad, and lies butted up against a *gneiss* rock, which would obstruct its progress farther eastward. On this rock, at a few feet to the west of the boulder, there are *striæ* pointing due east and west. These *striæ* may have been formed by the boulder pushing and pressing hard gravel over the rock.

(3.) In the valley where Loch Faraline lies, there is a considerable number of boulders. Those of an elongated form, have their longer axis generally W.S.W., which is the direction of the valley, and also of the Great Glen, about 3 miles distant from it.

(4.) Duntelchaig hill, about 8 miles west of Inverness, is composed of *conglomerate rock*, to which reference has already been

made. It is about 900 feet above the sea. On the N.W. slope of this hill, there lies a *granite* boulder  $7 \times 4$  feet. Its longer axis lies N.W. and S.E. Its sharpest end points N.W. There are no granite hills except to the west of this spot, and they are more than 10 miles distant.

(5.) At the head of Glen Urquhart (on the west side of Loch Ness) there is a boulder lying in an instructive position. Its size is  $5 \times 4 \times 3$  feet. Its height above the Loch is 600 feet, and above the sea about 650. It is on a bed of *muddy sand*,—manifestly a water deposit (fig. 3). Its position is at the base of a hill rising

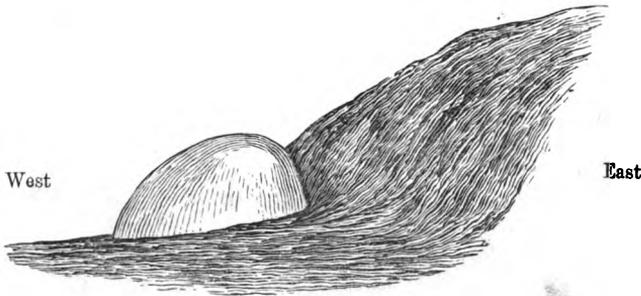


Fig. 3.—Boulder on its east side intercepted by hill.

towards the east, against which it seemed to have been brought from the west, and there stuck. The slope of this hill faces W. by S. The west side of the boulder is well rounded and smoothed as if by something which had long been passing over it. In the immediate neighbourhood of this boulder, there are numerous thick beds of *sandy clay*.

There is rock a few yards distant from the boulder at a height of 570 feet above Loch Ness, on the smoothed surfaces of which there are *stria*, pointing E. and W.

Many of the rocks show smooth faces on the west side, up to the summit level, which here is 657 feet above the sea.

The whole of Glen Urquhart has been filled and choked with drift materials. These have been since, to a great extent, scoured out by the action of the main river and side streams; but there are beds of gravel, sand, and clay still on the sides and tops of the hills which, covering the rocks, provide good soil for the beautiful woods and fertile pastures of this pleasant valley.

(6.) To the S.W. of Fort Augustus, on the Corryarrack Road, the following boulders were seen :—

(a.) A boulder of *gneiss*,  $15 \times 12 \times 10$ , at a height of 234 feet above Loch Ness. The longer axis is W.N.W. It lies upon *drift*. The boulder is in a hollow, or *cul-de-sac*, but the country is open towards all points between N.W. and E.

(b.) A grey *granite boulder*,  $6 \times 5 \times 3$  feet, on a *gravel knoll* at a height of 243 feet above Loch Ness, its longer axis bearing E. and W.

(c.) A boulder of grey *gneiss*,  $3 \times 2 \times 2$  feet, lying on *gravel*, which slopes to N.W. at an angle of  $30^\circ$ , at a height of 207 feet above Loch Ness. This diagram (fig. 4) represents the boulder—A A—

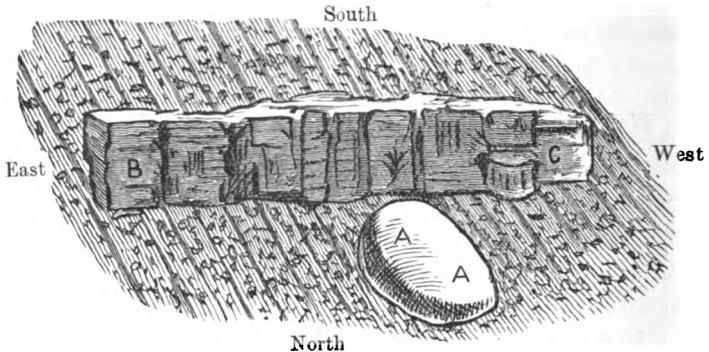


Fig. 4.—Boulder on *gravel bank* sloping down towards the N.W.

lying on a slope below a projecting ledge of a buff-coloured felspathic rock, B C. The boulder, judging by its position, had come from a N.W. direction, and been intercepted in its farther progress eastwards by the rocky ledge.

(d.) Not far from this last-mentioned spot, I fell in with another *granite boulder* ( $10 \times 8 \times 6$  feet) lying on *gravel* sloping to the west at an angle of about  $30^\circ$ , blocked or obstructed on its east side by rocks,—suggesting the idea that it also had come from the westward. The fact of all these boulders lying on beds of sand and gravel creates a strong presumption that they were transported by ice floating on a sea current flowing through the Great Glen from the westward.

(7.) On Ben Nevis (near the footpath generally taken by tourists from Fort William who desire to reach the top of the mountain)

there are hundreds of boulders. The boulders are chiefly granites, both red and grey.

The following are the sizes of a few which I had time to measure :—

One 16 × 10 × 10 feet, in so far as above ground, which is here gravel and clay.

One 15 × 7 × 5 feet, in so far as above ground.

One 13 × 7 × 4 feet.

All of these had their longer axis N.W. They were on a slope of the hill facing N.W., and at a height above the sea of from 900 to 1200 feet. The probability therefore is that they came from some north-westerly direction.

At a distance on the same hill-slope, there are boulders of still larger size which I had not time to examine.

I was informed by a person conversant with the rocks of Ben Nevis,—who accompanied me to the top of Ben Nevis,—that there are no *granite* rocks in, at all events, this part of the hill. Where the boulders had come from, he could offer no conjecture.

This person was a builder, having great experience of rocks and boulders. He stated that he had broken up one grey granite boulder, four or five times larger than any of the above boulders, to obtain materials for building the front wall of Belford Hospital, near Fort-William. The boulder was situated within a mile of the town, to the east of it, and about 40 feet above the sea.

From the foregoing notices of the boulders observed in the Great Glen, it may be reasonably inferred that whatever was the agent of transportation, they had all come from the W. and N.W.

Confirmation of this view is afforded by facts stated in a paper by Mr George Anderson of Inverness, who had a good personal knowledge of the Great Glen. This paper, having been written so far back as the year 1821, when no theories had been started to account for the transport of boulders, is valuable for its facts. He says, referring to the alluvial deposits near Inverness, that they “exhibit not only all the varieties (of rock) found in the mountains of the neighbourhood, but also many that *appear to have come* from very *distant* parts of the country. *Such are the white stone\** of

\* What Mr Anderson calls “the *white stone* of Ben Nevis” is a light-coloured porphyry, forming the summit of the mountain, and almost peculiar to it.

*Ben Nevis, and Strath Conon in Ross-shire, and the quartz rock of Foyers.\**

Another observation by Mr Anderson is mentioned by Chambers in his "Ancient Sea-Margins," which warrants the same conclusion, viz., a movement of detritus through the Great Glen from the westward. Chambers, referring to the gravel hill of Tomnahurich, to the west of Inverness, states that in it Mr Anderson had "detected some far transported rocks, and among them a reddish small-grained granite which occurs *in situ* near the mouth of one of the burn-glens at Dochfour." Dochfour is situated about 6 miles to the west of Tomnahurich.

### III. *Horizontal Beaches in the Great Glen and adjoining valleys.*

It might have been anticipated that these traces would be numerous and distinct, when regard is had to the large amount of detritus covering the slopes of the mountains. But, on the other hand, there are conditions unfavourable to the preservation of beaches, had any been formed. The district of country referred to is characterised by a large amount of annual rainfall. At Glen Quoich and Glencoe, the amount of rain exceeds annually 100 inches. The steepness of the hills gives great power to streams flowing down the slopes; of which, proof is afforded by the enormous gashes on the sides of the hills, and the piled-up heaps of detritus at the mouth of almost every stream along the bottom of the Great Glen.

The lines of terrace observed, may conveniently be classified under several heads.

#### 1. *Between the present sea-level and 50 feet above sea-level.*

The 11 feet line, so common around the coasts of the United Kingdom, is seen at each end of the valley; viz., on the east coast, between Fort George and the mouth of the river Ness; and on the west coast, between Corran Ferry and Banavia.

On the east coast, near Beauly, there is a terrace at 17 feet, and another at 36 feet above high water.

I found at Kessock Ferry, a terrace at 25 to 30 feet; at Inverness, terraces at 25 and 40 feet; below Raigmore House, a steep cliff, with a base 30 feet; and at the railway stations of Clunes, Lentrán, and Bunchrew, a terrace at 40 feet above high water.

\* Transactions of Wernerian Society, vol. iv. p. 205.

On Loch Eil, there is on the north side, opposite to Fort William, a terrace about 20 feet, and another on the south side at 40 feet.

On the west coast at Corran Ferry, where the north and south shores are so near each other as to leave a strait less than one-quarter of a mile in width, there are several terraces at different heights. The lowest I made about 21 feet, and the next higher about 50 feet;—they occur on both shores.

These terraces, I allow, are higher than those usual in other parts of the coast,—which perhaps may be explained by having regard to their geographical position. Even at the present level of the sea, the line of high water at Corran Ferry rises above the line of high water in other parts of the coast. The rise and fall of the tide is here 12 feet, whereas elsewhere it is only 8 feet. This difference is caused by the narrowness of the strait at Corran, which, to allow of the tidal wave to pass, forces it vertically upwards.

It is right, however, also to notice that whilst Chambers in his "Sea-Margins" mentions the two sea-terraces at Corran Ferry, and as seen by him on both sides of the Ferry, he makes their heights respectively 43 and 64 to 70 feet. Whose measurement is the more correct, it will be for future observers to say.

There is one feature at this ferry of some interest which I think Chambers overlooked.

About a mile to the north, and in the policy of Ardgower, there is a remarkable escarp of gravel (already referred to) running due E. and W. for about a mile. Its top is about 80 feet above the sea, and its base about 40 feet. A flat comes away from its south side, of which advantage has been taken to form the avenue to Ardgower house. On the north side, there is a hollow reaching down to about 20 feet above the sea, and occupied by a lake.

Chambers observed this hollow, and gives in his book a section to show it; but he offers no suggestion to explain it.

What occurred to me when examining the place was, that when the sea stood some hundreds of feet above its present level, the escarp had been a submarine bank, formed by the east and west tidal current, which scooped away the detritus in a corresponding direction.

The soundings of the Linnhe Loch, show that even now, there are hollows in the channel running E. and W., probably due to the existing tidal currents.

A little to the west of Corran Ferry on the south side, at Onich, there is a range of rocky cliffs whose base is about 40 feet above the sea, and separated from the sea by a sandy plain about a quarter of a mile wide, and about 32 feet above the sea.

To the east of Onich, and along the Fort William road, there is an extensive meadow on the farm of Inchree, at a height of from 35 to 40 feet above high water, which may formerly have been an arm of the sea, subsequently a lagoon, and ultimately a fresh-water lake. Thick beds of fine mud, form the banks of a stream issuing from this meadow and running into the sea to the east of Corran Ferry.

With reference to the 40 feet terrace in Loch Linnhe, I may refer to the testimony of Mr Jamieson of Ellon. He says (Lond. Geol. Soc. Jour. for 1863, p. 253):—"A fine old coast-line occurs along the border of Argyleshire, about 40 feet above the present beach. It fringes the head of Loch Eil distinctly on both sides up to Fort William, and can be traced on to the entrance of Glen Nevis. It is well marked beside the bridge at the mouth of the glen, and appears to extend quite across it on towards Bannavie. On the east side of Loch Eil, half a mile to the south of Fort William, I came upon a section of the 40-foot beach, laid open by a small stream cutting through it, which seemed especially interesting on account of the number of marine shells it contained. The shells are at a height of about 11 feet above present high-water mark, and about 50 yards from the shore. They are imbedded in the lower part of a greyish stone clay 5 feet thick, which is covered by sand and gravel. The shells are mostly empty or 'dead' shells, filled with mud, and many have been pierced by boring mollusks. The shells, as reported on by Mr Gwyn Jeffreys, were of a decidedly more northern character than what now haunts our coasts.

"As the assemblage is a littoral one, I see no reason for doubting that it belongs to the period represented by this 40-foot old coast-line. It is just the sort of collection that might be expected at the depth of a few fathoms along such a line of shore were the sea somewhat colder than it is now."

## 2. *Between 50 and 100 feet—*

At a height of from 50 to 55 feet above high water a terrace encircles the Tomnahurich gravel hill, and runs along the south side of Torvain gravel hill, situated to the north of Inverness. The terrace runs westward on both sides of the river Ness, and seems

to rise very slowly in that direction. It is visible at Dochfour about 6 miles to the west, where there is a flat about 60 or 70 feet above high water, with which it may be connected. This 70-foot flat can be traced at intervals along Loch Ness, on both banks, as far as Fort Augustus, where a flat exists about 19 feet above Loch Ness, on which the old barracks were built, and where a Roman Catholic seminary now stands.

At Kessock Ferry, there is a flat about 86 feet above the sea, which I followed eastward along the coast by the manse and church of Knockbain, and beyond, to Allangrange, and Drummore. The public road by Gateside, Avoch, and Rosemarkie is upon this flat.

At a height of 40 feet above Loch Ness, or 90 feet above H. W., I observed a terrace at Glen Urquhart (on north side), and also at the west end of the lake to the south of Fort Augustus.

### 3. *Between 100 and 200 feet—*

At Kessock Ferry I found a flat at about 106 feet. At Dingwall and Muir of Ord, there is a very extensive plain at from 108 to 116 feet.

At the western end of the Great Glen, near Corran Ferry, on the south side, there is a hill which runs eastward from Onich church, on whose side, covered with gravel, I found a well-marked terrace at 100 or 105 feet above high water.

Returning to the east end of the Glen we find the higher part of the town of Inverness on a flat, which, commencing at the east end of Loch Ness at about 110 feet, runs through the town and stretches away towards the east through the counties of Nairn and Elgin.

Along Loch Ness on the south side (viz., at Foyers), and along much of the north side, a flat is very visible at about 100 feet above high water. The high road between Fort Augustus and Invermorriston, and also to the east of Invermorriston, runs much along it.

To the west of Fort Augustus and stretching towards Loch Oich there is an extensive plain, consisting almost entirely of gravel, at about 106 feet above the sea. A place called "*Kytra*," more correctly spelt "*Kintraigh*," is on the plain, which the Rev. Dr Clerk of Kilmallie informs me is the Celtic word for "*head of tide or estuary*." Was the name suggested by the sea having then reached so far up the glen? But is it likely that there were Celtic inhabitants, at the period when Scotland was so deeply submerged?

At Fort Augustus there is a gravel escar, whose ridge reaches to a height of about 110 feet.

Chambers in his "Ancient Sea-Margins," referring to the mass of gravel lying between Lochs Oich and Ness, takes notice of a terrace at the mouth of the river Tarf, which flows into Loch Ness to the south of Fort Augustus. He says he found it to be 59 feet above the level of the lake, which gives 106 feet above the level of the sea, corresponding therefore with the flat above mentioned.

Chambers also specifies a terrace, and gives a section of it, at 110 feet on both sides of the valley; on the north side at Borlum Gardens; and on the south side at Milton (p. 86).

My note-book records a terrace on north bank of Loch Ness at Urquhart, at 60 feet above loch, or 110 feet above sea.

At Loch Oich near its east end, on the north bank, a terrace is discernible at 15 feet above the loch, giving a height of 104 feet above the sea.

Along Loch Lochy on its south bank, a terrace is visible about 16 feet above the loch, and therefore 105 feet above the sea. Letter Finlay house seemed to be on this terrace.

My note-book mentions "a very manifest terrace of sand and gravel on the south bank of Loch Oich, near the east end, at a height of 30 to 40 feet above the lake," and therefore 119 to 129 feet above H.W. Another horizontal line from 60 to 70 feet above the lake was noticed, and there seemed to be another at the same level on the north side of the Great Glen.

At a height of from 140 to 150 feet a terrace occurs at the following places, viz. (beginning with those at the east end of the valley), at Dochfour house, Urquhart, Inverfarrigaig, Fort Augustus, Culloch, Loch Lochy, Gairloch, and Macomer.\*

Under a previous heading (No. 4) reference has been made to a range of hard gneiss rocks at Inverfarrigaig showing smoothed surfaces, and whose base forms a line about 148 feet above the sea. If the sea had at any period stood at a height exceeding 200 feet, ice might have been floating through the Great Glen and chafing these rocks.

\* The Rev. Dr Clerk of Kilmallie informs me, that this word in Celtic means "Plain of the waters meeting," it being at or near what had been the confluence of the rivers Spean and Lochy, before the course of the latter was changed to suit the Caledonian Canal.

At Dochfour and Aldourie, places at the east end of Loch Ness, the amount of detritus is much greater than in other parts of the glen, and the lines of terraces are more numerous. I see that I noted two terraces at or near Dochfour house, one at 140 and the other at 150 feet.

At a height of about 165 or 175 feet a terrace is visible on the south side of Loch Oich, and stretching down towards Loch Ness.

It is probably at the same level as a terrace mentioned by Chambers when he refers to "the *Tor hill*, a vast compost of sand, gravel, and silt," of which he gives a sketch, showing the river Ness flowing "between a terrace of 165 feet at Borlum house on the one hand and *Tor hill* (that is *Torvain*) on the other, as it appears from a spot 3 miles S. W. of Inverness" (p. 84).

The next higher terrace of which I have a note is at from 180 to 185 feet. It was seen by me on the west of Dochfour House and along the north bank of Loch Ness near Urquhart, and the south bank at Inverfarragaig and Foyers.

It is probably at the same level as the terrace which at 183 feet I found at the south end of Loch Arkaig, where it is well seen on mounds of gravel on each side of the rather remarkable pass called "*The Dark Mile*," running between Loch Arkaig and Loch Lochy.

At the south end of Loch Arkaig the beds of detritus form great mounds reaching up at least 300 feet. Similar accumulations are on the banks of the canal, between Loch Oich and Loch Lochy. The steamer passes through a deep trench formed in immense masses of detrital matter, all evidently water borne.

Near the south end of Loch Arkaig there are many interesting examples of rocks ground down and smoothed by an agency which passed over them apparently from the westward. These smoothings must have been produced antecedently to the deposit of the gravel.

I regretted very much not having been able to examine this locality more extensively, as it probably would have afforded important information on many questions of interest. Some persons maintain, that the two sets of "*Parallel Roads*" in Glen Gluoy on the south side of the Great Glen, and whose mouth is alleged (I think incorrectly) to open out towards Loch Arkaig, were formed by a lake in Glen Gluoy, kept up to the level of the "*roads*" by a glacier

from Loch Arkaig. This theory of a glacier is quite irreconcilable with the enormous heaps of gravel at the mouth of Loch Arkaig. If a glacier ever moved down Loch Arkaig it must have been at a period long anterior to the deposit of detritus in the Great Glen and its lateral valleys, for it is on the detritus in Glen Gluoy as well as in the other Lochaber glens, that the *Parallel Roads* were formed. Moreover, any glacier from Arkaig flowing out into the Great Glen would never have crossed the glen and ascended up into Glen Gluoy. It would have flowed down towards Fort William. That a lake had existed in Glen Gluoy up to a height of 1100 feet (the level of the highest *Parallel Roads* there), is indubitable; and that a blockage of some kind or other existed, so as to dam back the waters of a lake and allow it to subside from one level to another, is also undeniable. The more probable supposition is, that this blockage consisted of detritus, which originally filled the Great Glen, choking the mouths of its side valleys, and that this detritus was lowered and scoured out by the action of mountain torrents, so as to drain off the lakes in, at all events, the high-level side valleys.

The next terrace, in proceeding upwards, is one noted by Chambers as occurring at Dunain (west of Inverness), 189 or 194 feet above the sea (p. 85). This probably agrees with one I observed running along the south bank of Loch Ness for 2 or 3 miles opposite to Dochfour, and traceable also on the north bank to the west of Urquhart.

It is worthy of remark that the gravel hill of Torvain, with its long flat top, reaches to a height of exactly 200 feet. The adjoining gravel hill of Tomnahurich reaches, at its highest point, to 220 feet, but there is a flat on its east slope at 200 feet.

With reference to the foregoing terraces, their occurrence at Inverness is thus referred to by the late Mr Anderson in his sketch of the Great Glen, published in 1821 :—

“ Between the Moray Frith and Loch Ness the alluvial deposits form *three* flats or banks. The lowest is the one through which the river Ness and the canal run, and on which the greater part of the town of Inverness is built.”

(This, probably, is the terrace described by me as at 40 feet above high water.)

“ Removed a little way back, and rising above this to the height of 50 or 60 feet, and occupying the space between the south bank of

the river and the edge of the Leys, appears the *second* flat or table-land."

(This probably is the terrace described by me as at 100 feet above high water.)

"Lastly, on the opposite side of the Ness, proceed from the confines of Dochfour a series of low waving and steep hillocks not surpassing 200 feet in height, which terminate, after a run of 6 miles, with the celebrated Torvain and Tomnahurich.

"Agreeable to this account, a person proceeding from the river towards the south would first pass over the lower flat, which appears in the form of a beautiful strath, of from 1 to 2 miles in breadth; and then after ascending a steep bank (of from 40 to 60 feet in height), he would come upon a fine smooth plain, bounded on the south by the Leys, and containing on its surface many of the richest and most beautiful farms in the country. This second flat, which is the most interesting of the three, commences near Loch Ness, and runs all the way to Fort George, a distance of from 14 to 18 miles. It comes close in on the back of Inverness, forming the Castle hill and the site of the ancient castle of Macbeth; and then turning towards the east it proceeds along the coast, towering above the sea or retiring into sweeping and verdant banks. Its breadth between the Leys and the sea varies from 1 to 4 miles. But the most interesting circumstance attending it is, *that a similar gravel bank, of the very same height and character, can be traced with very few interruptions along the whole of the Beaully Frith and on the opposite shore of Ross-shire.*"\*

These observations by a good local geologist are all the more important that he had no theory to suggest in explanation of them.

But we now know that horizontal terraces, traceable on opposite sides of a valley, and extending such distances as Mr Anderson mentions, can be due only to the prevalence of the sea at these heights.

#### 4. *Between 200 and 300 feet—*

At Duradin (between Loch Ness and Inverness) the high road passes over a pretty extensive flat which is from 210 to 220 feet above the sea; and at the same place, another was observed by me from 60 to 70 feet higher.

\* Transactions of Wernerian Society, vol. iv. pp. 204, 205.

Chambers notes a flat on which Dunain farm offices stand at 217 feet above the sea (p. 86).

There is a flat which in several successive years attracted my attention along the south side of the valley between Loch Lochy and Fort Augustus. My first measurements gave 129 feet above Loch Lochy, and therefore 214 feet above the sea. In a succeeding year, with more precision aimed at, the aneroid gave 245 feet. On directing the spirit-level across the valley to the north, I found marks of a terrace there at about the same height. On the same day, when at Invergarry house, on the north bank of Loch Oich, I found on the policy and home farm a flat at 240 feet, which probably corresponds.

This terrace on the south side of the valley, where opposite to Culloch, is well covered by boulders—some of large size. Excavations had been made at a number of places, apparently for sand, which showed that clay or silt largely prevailed, with occasional nests of sand. This being the narrowest part of the Great Glen, there would be more obstruction here than anywhere else to the agent, whatever that was, which was transporting boulders through the glen from the westward; and hence the numbers of boulders at this spot.

At the heights of 248 and 280 feet, two flats were noticed by me about 2 miles north of Inverness. At Glen Urquhart, on the north bank of Loch Ness, I found a flat at 277 feet, and at Fort Augustus one at 280 feet.

It is the highest of these, probably, which corresponds with that at 279 feet mentioned by Chambers as occurring at Dunain house.

5. *Between 300 and 400 feet—*

On Dunain hill, about 2 miles N.W. of Inverness, there are several terraces, as first pointed out by Chambers, which I afterwards visited and verified in company with Mr Jolly of Inverness. The heights of two of these, as given by Chambers, are respectively 320 and 345 feet.

Chambers refers also to a terrace at Fort Augustus, in the valley of the Tarf, "forming a strong projection from the hillside, and corresponding with a bench on the other side of the river, on which Abertarf house is situated. This terrace (Chambers says) is known

by the name of Tom Voit (hill of the court), justice having been dispensed on it in ancient times. It is 377 feet above the sea."

In the district of the river Spean, at the west end of the Great Glen, there are several terraces at so nearly the same height as the one just mentioned, that they at all events deserve to be noticed.

Thus on the N.E. side of Achandaal hill, and about 2 miles to the S.W. of Gairloch, there is a small valley about half a mile in length, running E. and W., whose sides present unmistakable marks of a horizontal beach. The beach is well covered by boulders, which may have been rafted into the valley, or may have fallen from the adjoining hills forming the sides of the valley. The height of this beach-line I made 374 feet above the sea. At first I accepted the idea that a lake had once filled the valley; but finding that the valley was equally open at each end, and seeing no traces of any blockage, I ultimately adopted the idea that the beach-lines were due to sea action.

In the district through which the river Spean flows, there are several distinct fragments of a terrace at nearly the same height. Thus at a height of 380 or 390 feet there is a terrace surrounding a conical hill called "Brackletter," on the left bank of the river. At a spot a little higher up the stream, Unachan hill comes in view, sloping up towards the south at a distance of 3 or 4 miles, and on it a line of terrace with boulders is distinctly visible, corresponding with that on Brackletter. On proceeding to Unachan hill, I found a terrace at the requisite height, and on looking towards the east, observed a corresponding flat on which Kilmonivaig church is situated. Chambers notices this correspondence (p. 123), and points out also that the hamlet of Achnaderry, situated near the junction of the rivers Roy and Spean, is on a flat at the same level.

6. *Between 400 and 500 feet—*

Near Inverness on the east end of the hill called Craig Phadrig I found a terrace at 418 feet.

On Loch Ness near Urquhart, on the north bank, there is a well-marked horizontal line at about 470 feet.

Immediately opposite, viz., at Erchet and Drummond, there is a still better marked terrace, of which Chambers gives a striking sketch, at 497 feet. He describes it as "a remarkably fine example of the long flat line occasioned by the terrace-like meeting of the

cultivable ground with the bare sterile rock above" (p. 88). The rock above, had been denuded of most of its detrital cover; and the detritus which remained, had been levelled into a plateau of some miles in extent.

On the river Spean, Torr-an-Ess is a small conical gravel hill whose base is 426 feet above the sea. On the opposite or left bank of the river, Brackletter hill at its top, corresponds nearly in level. The spirit-level on Tor-an-Ess, when turned N.E., shows a flat in that direction about one mile distant; when turned W.S.W., it shows a flat on Achandaal hill; when turned south, it shows several flats on Unachan hill; and when turned S.E., it shows a flat at Blairour shepherd's house, about one mile south of Tor-an-Ess.

In the higher parts of the river Spean, viz., near the Roman Catholic Chapel, there are several flats between 400 and 500 feet above the sea.

With reference to these terraces and horizontal lines in the valley of the Spean, notice may be taken of some of the Celtic names. In "Memoir on the Parallel Roads of Glen Roy" (Edinburgh Royal Society Transactions, vol. xxviii. p. 103), I pointed out that several of these names implied the presence of the sea at places now more than ten miles distant, and at a height of 400 feet above the sea. One of these names is "*Ceann-na-mara*" (i.e., *Head of the sea*); another is "*Mur-laggan*" (i.e., *Hollow by the sea*). These places are on the river Spean above Roy Bridge. I have since discovered another Celtic name of a place below Spean Bridge, at 122 feet above high water, called "*Stochd-mara*," which the Reverend Dr Clerk of Kilmallie informs me means "*Pit or deep hollow of the sea.*" Dr Clerk in his note to me states, that "there are also along the river Lochy, and even up by Loch Arkaig-side, names which suggest that within the historic period, the sea occupied all these depressions."

Another way of accounting for these names would be, that the places in question had been, even to the popular eye, so manifestly at one time occupied by the sea, that in inventing names for these places, words were chosen to record that interesting fact. In the Highlands, there are numerous examples of attempts, not only by names given to places and boulders, but by legends, to account for phenomena of an abnormal character.

Perhaps a more probable explanation would be, that the word "*Mur*" or "*Mara*" means in Gaelic any large body of water, whether salt or fresh; just as originally, in our own language, the word "*Sea*" had the same range of meaning, as shown by its use in describing the fresh-water lakes of Tiberias. In that view the Gaelic names would indicate only lakes.

On the Spean river, there are at the places last mentioned, several terraces at higher levels.

On Unachan hill, near Corry N'Eoin, there is a flat with boulders on it at 556 feet.

Reference may here be made to a series of lakes, which at a former period seem to have existed in the valley, through which the river Morrison now flows. In the upper part of this valley, traces of one of the upper lakes are very manifest. Its lower end had been at Torgoyle Bridge, where the valley is contracted by rocky cliffs, which had at one time formed a blockage for a lake about 50 feet deep. To the west of Torgoyle Bridge, the old beach line is very visible, especially on the south side. Boulders lie on this terrace and help to indicate it. This old lake apparently reached up to a place called "*Cean-a-Croll*," where two gamekeepers reside, and at which point the river Doe joins the river Morrison. The height of this old lake seems to have been about 570 feet above the sea. What had been the bottom of the lake is now a flat meadow through which the river Morrison meanders.

8. *Above 600 feet.*

In Stratherrick valley, at Gorthleck, there is a terrace at 620 feet, which, with the kind assistance of Captain Fraser of Balnain, a resident proprietor there, I was able to follow for six or eight miles. It has probably been the beach of a great lake, of which all that remains is Loch Faraline, about 570 feet above the sea, and about half a mile in length.

The ancient and extensive lake which formerly filled the whole of Stratherrick, must have had a blockage to the west of Boleskine Manse, at which place the river Foyers now runs through a narrow gorge, with high rocky ground on each side. The blockage may have consisted of detritus, as there are still enormous masses of clay, gravel, and sand in the district. The extensive haughs of "*Compass*" on the right bank, and "*Dell*" on the left bank, may be what

remains of the old lake bottom, or may have been formed by the river itself when flowing at a higher level. Some of the upper haughs of this river are figured in the "Transactions of the Edinburgh Royal Society," vol. xxviii. p. 95.

The small lake of Killin is in the upper part of this valley, at a height of about 1400 feet above the sea. This lake has a terrace at its lower end from 40 to 50 feet above the existing level of the water, showing a subsidence to that extent, caused by a lowering of its detrital blockage.

Loch Clachan is about ten miles to the S.W. of Inverness, 683 feet above the sea. There is a terrace round parts of the loch at a height of 90 feet above its level, showing that the lake had formerly been much more extensive.

Along the valley of the Nairn, in the district of Farr, several lines of terrace are visible at about 700 feet level. But I have not been upon them.

In the valley of Flichity, to the west of the district last mentioned, there are lines of terraces on the hills which enclose the valley at the heights of 800, 835, and 985 feet. Not having reached the summits of the enclosing hills, I cannot affirm that there may not be terraces at even a higher level. Whether they are due to sea or to lake, I am not prepared to say; whilst the higher terraces may be due to the sea, the lower terrace may be due to a lake, after the sea subsided to a point lower than 800 feet. In Lochaber, the lowest of the parallel roads (generally now admitted to have been formed by lakes which subsided from one level to another), is 856 feet above the sea. At the east end of Flichity valley, an embankment of detritus crosses the valley at right angles, and has sides about 200 feet high. This embankment reaches to a height of from 840 to 870 feet above the sea, so that it might have formed a lake blockage before it was cut through by the river Nairn, which now crosses it, at about 203 feet below the present ridge of the embankment.

On the south side of Loch Lochy, a lateral valley called Laggan runs up from the Great Glen. A farm-house, called "*Creagan-na-Goibhne*," is at the foot of this valley. I walked up this valley in company with the Rev. Mr Cameron of Kilmonivaig, in search of a shelf or horizontal sea margin first described by Mr Charles

Darwin, at a height of 1300 feet above the sea, according to his measurements.

On our way up, we passed a terrace which appeared to us about 700 or 800 feet above the sea; but of this measurement, I cannot speak precisely, in consequence of my aneroid having been put out of order by a fall.

At the height of 1319 feet we found the shelf referred to by Mr Darwin; but instead of being confined to the valley of Laggan, as Mr Darwin supposed it to be, it passes eastward over the summit level by about 20 or 30 feet. (See "Memoir on Glen Roy Parallel Roads," Edinburgh Royal Society Transactions for 1876, p. 612). Whether this terrace is due to sea, as Mr Darwin supposed, or to lake, has not yet been decided.

In the parts of the Spean river, near Monessie, there are terraces at a level of about 700 feet, which must have been formed either by the Glen Roy lake, when it partially subsided by the lowering of its blockage, or have been formed by the sea, after the lake blockage had been destroyed and removed.

As the Lochaber glens are, as it were, tributaries to the Great Glen, reference may be made shortly to the "*Parallel Roads*" which have made these glens so famous.

It is now admitted by all who have studied this geological question, that these "*Roads*" are the beaches, not of the sea as Darwin, Chambers, and others at first supposed, but of ancient lakes;—the only question, still matter of debate, being the nature of the materials which formed the *blockage of the lakes*.

IV. The foregoing notes of horizontal terraces in the Great Glen make no pretensions to accuracy. The measurements of heights were all by the aneroid, and often without the correction necessary for changes in atmospheric pressure, as it was hardly ever possible to obtain a knowledge of these changes during a hasty tramp over hills. Moreover, the horizontality of the terraces was sometimes a result merely of observation by the eye, though the spirit-level was used as often as practicable.

Notwithstanding these risks of inaccuracy, the indications of the terraces mentioned, may be a guide to future observers who resume the inquiry with more opportunity for precision.

In regard to terraces at high levels, it cannot be expected that they should be in good preservation, having undergone denudation for so long a period.

At lower parts, the terraces might be expected to be more distinct, and to be recognisable at a greater number of places.

The facts justify this inference. Thus between 300 and 400 feet above the sea, as the foregoing notes indicate, there are only five or six places, with a terrace clearly discernible at a height of from 375 to 385 feet.

Between 200 and 300 feet, there are six or seven places, with two well-marked terraces, at a height of 245 and 280 feet respectively.

Between 100 and 200 feet, there are thirty-one places, where terraces are recognisable; six, where the terrace is from 180 to 200 feet; ten, where the terrace is from 140 to 150 feet; and fifteen, where the terrace is from 100 to 110 feet above the sea.

So long as the sea stood above the level last mentioned, there must have been salt water in the entire length of the Great Glen, so that above that level, horizontal beach lines might have been and probably were formed by the agency of tides and storms. But when the sea stood below that level, there would be no sea action of any kind, inasmuch as the summit level of the land (*viz.*, between Loch Lochy and Loch Oich) at about 120 feet, would form a barrier to the free passage of the sea through the valley.

Hence the reason, why the lower terraces at 83, 40, 25, and 11 feet, which are so well marked on the open sea coast, are scarcely distinguishable in any part of the Great Glen.

V. The facts narrated in the foregoing notes, seem to warrant the following conclusions:—

1st, That sea prevailed over the district now traversed by the *Glen-more-nan-Albin*, at which time were deposited the beds of gravel, sand, and clay now seen, up to the level of at least 2000 feet above the sea.

2d, That the sea subsided or the land rose vertically, and that horizontal indentations were made by the action of the sea on the drift deposits.

3d, That the sea was cold enough to bear floating ice, which carried boulders and lodged them on the sides of the hills.

4th, That judging from the position of these boulders, and also the probable position of the parent rocks, there was an oceanic current which flowed over this part of Scotland in a direction from the N.W. or W.N.W.

5th, That until the sea fell to a height of say 120 feet above its present level, there was a passage from sea to sea through the Great Glen; and that, owing to the current just mentioned, as well as to the greater frequency and force of westerly winds, ice flowed through the Glen, smoothing the rocks on each side, and scouring away the gravel in places exposed to the floating ice.

6th, That in almost all the valleys adjoining the Great Glen, lakes were formed, the streams from which gradually cut through the blockages of these lakes, and caused them to subside, so that some of them were drained altogether.

7th, That the boulders which lie in valleys, generally have their longer axis parallel with the axis of the valleys,—a result due to the action of the current flowing through the valleys.

#### N. *General Summary of Principal Levels.*

Having under the foregoing headings, indicated the different districts in Scotland, where flats and terraces attracted my notice, I admit that it would have been desirable had I been able to specify with more precision the levels at which they occurred. I cannot claim for my observations the accuracy necessary for this information. In this respect, others who have worked before me in the same field (Robert Chambers and Principal Dawson of Montreal), have had the same confession to make, having, in regard to sea action, endeavoured to discover only approximately the levels where flats were most frequent.

With the view of endeavouring to classify the information given in the foregoing notes regarding the supposed sea-beaches, I have gone carefully over them, and will now present a summary of the levels indicated at the greatest number of places at which they occur.

##### 1. Terrace up to 20 feet above H.W.

This occurs everywhere on the coast which I have visited, and where the materials are such as were suitable for impression by sea action. (Measurements at forty-four places).

##### 2. Terrace at from 20 to 30 feet above H.W.

Seen on coasts of Kirkcudbright, Wigtown, Ayr, Arran, Firth

of Clyde, Hebrides, Argyle, East Ross, Inverness, Nairn, Aberdeen, East Lothian, Firths of Tay and Forth, Islands of Mull and Rum. (Measurements at fifty-three places).

3. Terrace at from 30 to 50 feet above H. W.

Seen in Kintyre, Bute, Loch Lomond, Firth of Clyde, Loch Fyne, Hebrides, Linnhe Loch, East Ross, Fife, Stirlingshire, and Firth of Forth. (Measurements at seventy-three places).

4. Terrace at from 50 to 75 feet above H. W.

Seen on Solway coasts, Wigton, Dumbarton, Argyleshire, Easter Ross, Inverness, Aberdeenshire, Perthshire, Firth of Forth. (Measurements at forty places).

5. Terrace at from 75 to 130 feet above H. W.

Seen on coasts of Bute, Arran, Dumbarton, Loch Fyne, Jura, The Lewis, Skye, Loch Carron, Easter Ross, Inverness, Nairn, Moray, Aberdeenshire, Stirlingshire, East Lothian. (Measurements at twenty-five places).

6. Terrace at from 130 to 200 feet above H. W.

Seen in Ochil Hills, Argyleshire, Loch Awe, Aberdeenshire, Berwickshire, and *Glen-more-na-Albin*. (Measurements at ninety-three places).

7. Terraces at from 200 to 400 feet.

Seen in Morayshire, Balforn, Ochils, Glenbeg, Kerriva. (Measurements at six places).

8. Terrace at from 400 to 600 feet.

Seen at Eaglesham, Culloden, Rothes, Glenbeg, Ochils, Auchnasheen. (Measurements at seven places).

9. Terrace at from 600 to 800 feet.

Seen near Moffat, in Berwickshire, Loch Goyle, Nairn valley. (Measurement at six places).

10. Terrace at from 800 to 1000 feet.

Seen at Glenbeg, Flichity, Glendoe, Eaglesham. (Measurements at seven places).

11. Terraces at from 1000 to 1800 feet.

Seen on Moorfoot hills, Nithsdale, Lochaber, Tay Valley, Loch Tummel, Glendoe, and *Glen-more-na-Albin*. (Measurements at ten places).

12. Terrace at from 1800 to 2800 feet.

Said to have been seen on *Mawm Saul* (Easter Ross) by Ordnance Surveyors.

The following table gives a more detailed list of the measurements

of the several terraces. The numerators indicate the heights in feet; the denominators the number of places measured or seen.

Terraces	$\frac{11 \text{ to } 12}{44}$	$\frac{21}{2}$	$\frac{25}{51}$	$\frac{30}{19}$	$\frac{40}{32}$	$\frac{40 \text{ to } 50}{3}$	$\frac{50}{4}$	$\frac{62}{4}$	$\frac{70}{14}$	$\frac{72}{10}$		
	$\frac{75}{2}$	$\frac{70 \text{ to } 90}{4}$	$\frac{80 \text{ to } 85}{11}$	$\frac{90}{1}$	$\frac{90 \text{ to } 95}{8}$	$\frac{100 \text{ to } 110}{19}$	$\frac{107 \text{ to } 108}{2}$					
	$\frac{110}{3}$	$\frac{107 \text{ to } 118}{3}$	$\frac{110 \text{ to } 120}{12}$	$\frac{130 \text{ to } 140}{20}$	$\frac{140}{2}$	$\frac{160 \text{ to } 180}{7}$						
	$\frac{180 \text{ to } 200}{7}$	$\frac{187}{1}$	$\frac{220}{4}$	$\frac{230}{3}$	$\frac{240}{1}$	$\frac{262}{1}$	$\frac{312}{2}$	$\frac{337}{1}$	$\frac{360}{1}$	$\frac{375}{1}$	$\frac{400}{2}$	
	$\frac{440 \text{ to } 470}{2}$	$\frac{528}{1}$	$\frac{575}{2}$	$\frac{600}{1}$	$\frac{680}{2}$	$\frac{750}{2}$	$\frac{756}{1}$	$\frac{760}{2}$	$\frac{773}{1}$	$\frac{782}{1}$	$\frac{785}{1}$	$\frac{800}{2}$
	$\frac{830}{1}$	$\frac{858}{1}$	$\frac{890}{1}$	$\frac{895}{1}$	$\frac{900}{1}$	$\frac{980}{2}$	$\frac{1086}{1}$	$\frac{1120}{1}$	$\frac{1140}{1}$	$\frac{1150}{1}$	$\frac{1190}{1}$	
	$\frac{1204}{1}$	$\frac{1220}{1}$	$\frac{1250}{1}$	$\frac{1280}{2}$	$\frac{1306}{1}$	$\frac{1320}{1}$	$\frac{1500}{2}$	$\frac{1520}{1}$	$\frac{1750}{1}$	$\frac{1800}{2}$	$\frac{2800}{1}$	

It may be asked whether the results shown in the foregoing summary, correspond to any extent with those obtained by the late Robert Chambers, and published in his "Sea-Margins." He gives a summary of the levels at which, according to his observations, the sea appears to have "paused," more than at intermediate levels. These levels, by Chambers, are the following, showing feet above H. W. :—

11\* feet, 26\* feet, 71\* feet, 90\* feet, 108\* feet, 112\* feet, 123\* feet, 128\* feet, 141\*-146\* feet, 165\* feet, 186\*-192 feet, 280\* feet, 303\* feet, 392\* feet, 545 feet, 826 feet, 914 feet, 996 feet, 1024 feet, 1104\* feet, 1135 feet.

I have affixed a star to the levels which come near those in my summary. But there is and can be no absolute identification.

If the sea stood at these higher levels on the coasts and hill sides of *Scotland*, an inquiry suggests itself whether there are any corresponding traces of sea-action in *England*. Mr Chambers visited several districts in the west and south of England, with the view of answering this inquiry. I have also discovered some measurements by Mr Austen.

#### ENGLAND.

The following table of heights of terraces are given on the authority of these two authors; the letters A and C respectively indicating the authority for the measurements :—

A 10* to 12 feet,	Plymouth, and generally along the south coast of England, also on opposite coast of France.
A 30* to 40 feet,	Somerset and Devonshire (mentioned also by De la Beche).
C 32* to 43 feet,	Brighton.
A and C 60* to 70 feet,	Lewes, Southampton, Devonshire, Exeter, Cheshire, Liverpool, Chester.
A and C 80* feet,	Liverpool and Cardigan.
C 90* feet,	London, suburbs of.
C 101* feet,	Liverpool (Geol. Mag. for 1876).
C 112* feet,	Deptford.
C 118* to 128 feet,	Chichester.
C 120* to 128 feet,	Chesham, Weston-super-Mare, Toxteth, Preston.
C 145* to 150 feet,	Greenwich, Woolwich, Deptford, Blackheath, Exeter.
C 168* feet,	Isle of Wight.
C 170* to 180 feet,	Redscar near Preston, Brixham, Babbicombe, Torbay.
C 190* feet,	Isle of Wight, Bath, Bristol.
C 278* feet,	Babbicombe.
300 feet,	Lancashire.
C 342 feet,	Weston-super-Mare.

I have in the foregoing table affixed a star to the levels which seem to correspond with some in my summary.

#### IRELAND.

Robert Chambers having in like manner visited some districts of Ireland, gives the following list of heights, at which terraces were seen by him, with the names and the districts.

Terrace, 15 feet,	. . . .	Antrim and East Coast.
„ 60* „	. . . .	Belfast and West Coast.
„ 70* „	. . . .	Belfast and Dublin, &c.
„ 96* and 101 feet,	. . . .	Belfast.
„ 107* feet,	. . . .	Dublin, &c.
„ 120* „	. . . .	Belfast.
„ 130* „	. . . .	Belfast.

Terrace, 139* feet,	. . . . .	Dublin, &c.
„ 170* „	. . . . .	Dublin, &c.
„ 200* „	. . . . .	West Coast.
„ 277 „	. . . . .	Dublin, &c.
„ 288 „	. . . . .	Dublin, &c.
„ 600* „	. . . . .	Antrim and East Coast.

2. On applying to Mr Kinahan of the Irish Geological Survey, I obtained from him some notes, an abstract of which he kindly permits me to give.

There are in numerous parts of the coast what Mr Kinahan terms the 25 feet beach. I gather from his notes, that this measurement is above the *mean* sea-level, which may generally be assumed to be about 5 feet below H. W. mark. The beach referred to is therefore about 20\* feet above H. W.

Mr Kinahan specifies the following places where the above beach may be seen :—

(1.) In the east coast between Wicklòw and Wexford, especially at Wicklow Head, Mizen Head, Black Water near Cush Gap.

In Ovoca Valley and the Auohrim River Valley.

In the Wexford Estuary, especially in the cutting for the Wexford and Dublin Railway.

In the valley of the Slaney, especially in places between Enniscorthy and Newtown barry.

In the valley of the Barrow. In the valley of the Nore. In the valley of the Suir, near Tramore.

In numerous places on the coast of Cork and Kerry.

In the Burren, forming a well-marked terrace cut in the rock.

In the valley of Kylemore, N. W. Galway.

In Killarney Harbour.

In various places on the east coast, between Ballycastle, County Antrim, and Howth, County Dublin.

(2.) There is an old beach, termed by Mr Kinahan the 100\* feet beach. If it, like the other, be measured from the sea mean level, its height above H. W. may be assumed to be about 95 feet.

Mr Kinahan enumerates the following places for it :—

Several spots in the Ovoca Valley.

In the valley of the Slaney between Enniscorthy and Donegal.

In the valley of the Barrow, near Goresbridge.

In the valley of the Nore, and in that of the Suir.

Near the town of Galway. (See "Geol. Survey Memoir.")

In the valley of Killarney Harbour. (See do.)

Valley of Loch Corrib, Galway, 110\* feet (105 ?).

Tarmon Hill, N.W. Mayo.

On the east coast, especially about the Mourne mountains.

(3.) There seem to be beaches or terraces in Ireland at greater heights. Mr Kinahan terms them the "Esker Sea Beaches." The following are taken from his notes:—

"In most of the valleys of West Galway—Kylemore Valley, 285 feet; Maum Valley, 255 feet; North slope of Shannaunafeola, rising gradually from about 250; North slope of Lekhavea, about 280 feet.

"In various places in the central plains of Ireland, about 280 feet.

"In the counties Derry and Tyrone (especially about Dungannon), where it forms circles round the different drift-hills so numerous in these counties."

(4.) Mr Kinahan, in the "Geol. Mag." for 1875, p. 547, remarks, with regard to the Irish drifts:—"We have different gravels. 1st, under the 25\* feet contour line; 2d, under the 110\* feet contour line; and 3d, under the 350 feet contour line,—all more or less containing marine shells. Then, older than the Esker gravels, there are gravels at about the following respective heights:—550 feet, 750\* feet, and 1200\* feet, some of which contain fossils."

Mr Hull, in his "Physical Geology and Geography of Ireland" (p. 87), mentions, that in the north-east of Ireland, as pointed out by Professor Harkness, "beds of stratified gravel and sand occur with sea shells, belonging for the most part to existing species, but indicating somewhat colder conditions than those which obtain at present. In County Antrim, these beds form continuous *terraces*, rising on the flanks of the hills to an elevation of 600\* feet. They rest on lower boulder clay, and appear to be overlaid by an upper similar deposit. A similar succession of beds occurs near Glenarm."

Mr Hull, at p. 97, states that "*a terrace exists* in the valley of the Kilkeel River, skirting the base of Slieve, Lough Shanagh, in the Mourne Mountains, at 1000 feet above the sea."

"Facing the head of the harbour above Leenane, are two distinct terraces of gravel, one at 60\*, the other at 200\* feet above the sea."

Mr Hull further states (p. 108), that in County Donegal, at Inishown, "there is an old sea-beach 15 feet above H.W.; and that on the south shore of Lough Foyle, this beach extends over a wide area" (p. 110). "On the Antrim coast, near Larne Harbour, the raised beach forms a terrace from 15 to 20\* feet above H.W."

The Rev. Mr Close, in a paper in the "Geol. Mag." of 5th May 1874, after describing the occurrence of sea shells, chiefly Arctic, in gravel beds in various Irish counties up to heights of 1100 and 1200 feet, states that he does not mean to say that "the upper limits of these gravel beds are sea-beaches;" but, nevertheless (at a certain place named), "there is an approach to a horizontal upper boundary at the height of about 1100\* feet, extending for about a mile; and (at another place named) a less near approach to such a boundary at 1200\* or 1300 feet, extending for two or three miles." He adds, that "many pieces of foreign material can be found (on a mountain named) at the height of 1760 feet."

The opinion formed by the Rev. Mr Close is, that these elevated gravels, with the marine shells contained on them, had been brought by floating ice, and from a north-west quarter.

From these measurements of terraces in England and Ireland, there seems every probability that they correspond with, at all events, many terraces in Scotland, the differences in height being due to differences of local conditions, such as tides, estuaries, &c.

#### NORWAY.

1. The late Robert Chambers was the first English writer who called attention to the sea-terraces in Norway. He had visited several of them, and in his "Old Sea Margins," he specifies the following:—

656	feet above the sea.
597	do.
515	do.
206	do.
147	do.
60	do.

2. At Kherulf, a sea-terrace occurs at a height of 600\* feet. (See "Geol. Mag.," vol. viii. p. 74.)

3. A very interesting account of Norwegian terraces is given in the

"Geol. Mag." of Feb. 1877, by Mr J. R. Dakyns of the English Geological Survey.

He mentions having seen a terrace at 180\* feet and another at 270 feet above the sea-level in the Stor Fiord. In the Hardanger Fiord he saw one "between 280 and 300\* feet." At Sogndal, the highest terrace of sand and gravel is 374 feet above the sea. "Above this level (he says) the solid rock shows; through the spirit-level, a step at 460\* feet looks like an old sea-margin."

Mr Dakyn says he "found sands and gravels, apparently precisely similar to the lower terraces, at a height of 1100\* feet above the sea." This terrace was at the watershed between two fiords named by him. The land here, he "judged (by the eye) to reach as high as 1200\* feet;" and his impression was, that the terrace in question "was merely a part of a terrace stretching for a great distance along the hill side well over the watershed."

Mr Dakyn next specifies a still higher terrace on or near another watershed. It is at a height of 2000 feet above the sea, and is seen for miles continuously, on both sides of more than one valley. It is chiefly formed on beds of sand and gravel; but at one place, "the mark runs horizontally along the solid rock for miles, across the bedding" of the rocks. "The terrace and its accompanying water-mark, are therefore up to the level of the watershed, if they are not actually higher. This is a point which can only be settled by a proper examination of the ground; and a very important point it is, for it makes all the difference between the terrace being due to marine action, or else the waters of an ice-dammed lake. If the top of the terrace is above the summit level of the pass, it will be difficult to avoid the conclusion that it is an old sea margin." "If, on the other hand, the terrace is on a level with the watershed (and there is no great difference between them), one is irresistibly led to think of the *Parallel Roads* of Glenroy."

Mr Dakyn adds, that "there is in the same district a second horizontal mark on the solid rocks, several hundred feet higher than the 2000 one. This too appears to correspond with sand terraces in the recesses of the high glens."

"This plateau probably is more than 3100 feet above the sea. It is covered with large gravel mounds." "Here again it is striking that the water-mark would seem to correspond with the level of a

watershed. But it is useless to speculate, and would be absurd to offer an opinion on the subject without examining the ground."

#### NORTH AMERICA.

Robert Chambers, in his book (p. 304), specifies raised beaches in the *United States* at heights above the sea of—1st, from 30 to 40\* feet; 2d, from 80 to 100\* feet; and 3d, of 188\* feet above the sea.

In *Canada*, on the St Lawrence, he specifies beaches (p. 307) at—1st, from 33\* to 40 feet; 2d, from 64\* to 76 feet; 3d, from 130\* to 190\* feet above the sea.

With regard to *Canada*, I have obtained more information from my friend Principal Dawson of Montreal. With reference to his measurements he states, in a letter to me of 11th January 1877, that they were rather rough, having been taken by aneroid or only pocket level. They are from half-tide:—

"1. We have, all along the St Lawrence, a low terrace corresponding to your 11 or 12\* feet. One of our best marked and most continuous, is what I have called the 60\* feet terrace, being about 60 to 70 feet above the sea."

From Principal Dawson's printed notes on the Post Pliocene Geology of Canada, I make the following extracts:—

"At Montreal there are four principal sea-margins, with others less distinct.

"(1.) The lowest is about 120\* feet above the level of the sea. It corresponds with the general level of the great plain of Leda clay in this part of Canada. On this terrace, in many places, the Saxicava sand (a sand containing Saxicava sea shells) forms the surface; the Leda and boulder clay is beneath it.

"(2.) Another terrace is about 220\* feet high, and is marked by an indentation in the lower Silurian limestone.

"(3.) Three other terraces are at heights of 386, 440,\* and 470\* feet. The latter has at one place a beach of sand and gravel, with Saxicava and other shells.

"(4.) On the Lower St Lawrence, below Quebec, the series of terraces is generally very distinctly marked. The lower ones are, for the most part, cut in the Boulder and Leda clays."

Principal Dawson gives the following Table of heights at four places :—

LOWER ST LAWRENCE.			UPPER ST LAWRENCE.
Eboulements.	Mal Bay.	Murray Bay.	Montreal.
Ft.	Ft.	Ft.	Ft.
900*	...	...	...
...	748*	...	...
660	...	...	...
...	505	...	...
479	...	...	...
...	...	...	470*
...	...	448	...
...	...	...	440*
...	...	...	386
...	...	378	...
325	...	...	...
..	318	...	...
...	...	312*	...
...	...	281	...
...	239*	...	...
226	...	...	...
...	...	...	...
...	145*	...	...
...	...	...	120*
116*	...	116*	...
...	...	81*	...
...	...	30*	...
...	26*	...	...
22*	...	...	...

Principal Dawson adds that :—“ In various parts of Canada two principal lines of old sea-beaches occur at about 100 to 150 feet and 300 to 350 feet” (p. 44).

He specifies (p. 22) seven places where sea-terraces occur from 250 to 350 feet above the sea.

With regard to the above measurements, Principal Dawson remarks upon the difficulty of fixing on a proper part of the terraces from which to take the measurements, in consequence of there being occasionally slopes on the terraces, and at varying angles. From personal examination of the terraces, he has no doubt “ that three of the principal terraces at Montreal correspond with three at Murray’s Bay,” though the measurements, it will be seen, differ from 4 to 8 feet.

Principal Dawson has been so obliging as to send to me proof sheets of an official report on the physical features of the district between the Canadian and American territory, from which I make a few extracts:—

“ East of the Red River, we find the great drift plateau stretching southward and eastward from the Lake of the Woods, with an average elevation varying from 1600 to 1000 feet, and which, though doubtless everywhere based on the Boulder clay, shows in its upper layers a considerable thickness of *roughly stratified sand and gravel, indicating the action of rapid and varying currents*. On these rest the scattered Boulders deposited at a later period.

“ Probably contemporaneous, in origin with the plateau just referred to, are the terraces with a level of 1435 feet, which Professor Hind describes at Dog Portage, *200 miles east of Lake of the Woods* on the Lake Superior side of the watershed. These he afterwards *compared with high-level terraces found on the hills west of Manitoba Lake*, with an estimated height of 1428 feet, and 500 miles distant.”

“ We have, therefore, most satisfactory evidence of the depression of the land to this extent in the eastern region, and it is difficult to understand by what waters it was covered, *if not those of the sea*.”

“ On passing up on to the higher levels of the prairie, we continue to find proof of the former action of the sea at yet greater elevations. On the summit of the third prairie steppe, with an average altitude of about 3000 feet, debris of Laurentian and its flanking Silurian limestones is found, over nearly the whole area.”

“ The estimated height of the highest terraces observed, those in the mouth of the South Kootaine Pass, is 4400 feet, and I have little doubt but that *these are of marine origin*” (p. 258). “ Above this, no reliable sea-mark was found. From the position of the terraces in this Pass, it would appear that they cannot have been formed by any smaller sheet of water, nor would the nature of the locality allow me to explain their formation on any hypothesis of a former moraine blocking up the valley” (p. 245).

In giving these notices of terraces in Norway and America, I have not attempted to identify any with those in Scotland or England. But they show that similar terraces exist in these countries, and that some of them are apparently at or very near the same levels.

O. *Traces of Ancient River Courses and Lake Margins.*

In the course of my investigations, I occasionally came upon terraces, especially in the Highland valleys, which did not at first indicate whether they were marine, lacustrine, or fluvatile. Of these I took notes, some of which seem sufficiently interesting to deserve being mentioned.

Along the banks of almost every river, lines of cliff with terraces at their base are noticeable above their present channels.

1. The Rev. Mr Brown has described them as existing in several rivers in Perthshire (Edin. Roy. Soc. Trans., vol. xxvi. p. 149).

2. I have traced many at different heights along the valley of the Tweed (Edin. Roy. Soc. Trans., vol. xxvii. No. 25), up to 50 or 60 feet above the present channel.

Two or three places are pointed out, where the River Tweed ran in a different channel altogether.

3. Along the banks of the River Findhorn, in Morayshire, there are traces of an old channel through which the river flowed in by-gone times. It is well seen at Sluie, a little below Relugas. I examined the place at the suggestion of Mr Martin, teacher, Elgin, and satisfied myself that it was an old river channel, about 120 feet above the present channel, and distant from it about 300 yards.

4. The River Spey appears to have more than once changed its course. The late Sir Thomas Dick Lauder was of opinion that it had once flowed down the valley through which the Elgin Railway now passes, and entered the sea at or near Lossiemouth, instead of passing by Fochabers, 6 or 7 miles to the eastward. The enormous amount of detrital matter spread over that district, scours of which above 100 feet high are frequent, gave great facilities for the river cutting for itself new courses and deepening its channel.

In the upper parts of the Spey, about Kingussie, I have found lines of cliff on each side of the valley at a distance from the river. These lines of cliff, however, appeared to me to be horizontal, and to have been formed by a lake which subsided, as the blockage at the east end of the valley was worn down.

Of the existence of lakes, now extinct, the most remarkable examples occur in the Lochaber district, where the *Parallel Roads of*

*Glen Roy* are situated. It is only necessary to refer to the various published Memoirs in which these are fully described (Edin. Roy. Soc. Trans.).

5. It is probably owing to the deeper channels made for themselves by the Spey and the Findhorn, that there are evidences of so many lakes and morasses having existed in the counties of Nairn and Moray, which have disappeared.

Between Elgin and Birnie, there is an extensive flat, about 2 miles long by 1 mile broad, with an average height of about 180 feet above the sea, which is so surrounded by high grounds (except at the N.W. corner) as to indicate a lake margin. The overflow may have been at the N.W. corner, where there is still a large amount of silt, mud, and gravel. At that N.W. corner, very ancient oaken piles were found, which seem to have supported some structure, as a dam or a bridge, whilst the lake existed. But there is another proof. The flat in question is now arable, having been drained, and it supports a number of separate farms with suitable buildings. The names of these farms on the flat are Saxon, whilst the names of places on the high grounds are Celtic.

Remembering that the Rev. Dr Gordon of Birnie had, a good many years ago, when I visited Morayshire, mentioned the above facts to me, and pointed out the flat in question, I wrote to him lately for further particulars. As examples of the *Saxon* names on the flat grounds, he mentions the following places—Boggs, Boghead, Mossend, Stankhouse, Dykeside, Haughland, Broomhill, &c.

As examples of the *Celtic* names of places on the higher grounds, surrounding the above flat land, he mentions Pittendrieh, Knockma-sting, Tammyleurach, Shanchry, and Manhean.

At the south end, where the River Lossie enters the flat, there is Cloddach—a Celtic word for gravel or shingle.

Dr Gordon suggests that the blockage of the lake had been cut through and lowered by the river which flowed out of the lake, whereby the whole lake was ultimately converted first into a morass, and ultimately into meadow land.

Another example of words indicating the presence of a large body of water which no longer exists, is afforded by the prefix of "*Inch*" to the names of many places in Scotland. That word is a corruption of the Celtic word "*Inis*," which means an island

surrounded by water. There is a place called "The Inch" situated to the south of Edinburgh. It consists of a knoll on which a mansion house has been built. The flatness of the district surrounding the knoll, speaks unmistakably of a large body of water, probably connected in former times with Duddingstone Loch, when the latter stood at a higher level.

6. Another example of a valley once occupied by a lake, and where now only fertile fields are to be seen, is *Strathloch* in Perthshire, to the north-east of Pitlochrie. Its name is said to be derived from the fact of the Strath having once been occupied by lochs or lakes. Along the south side of the valley, the old lake margin is visible about 50 feet above the meadow land.

7. The whole of the valley near *Callander* and the *Trosachs*, occupied partly by *Lochs Lubnaig, Vennacher, Achray, and Katrine*, has once been filled by a lake whose blockage was to the east of Callander. Lochs Lubnaig and Katrine are exactly on the same level, viz., 400 feet above the sea. In travelling by railway from Callander northwards, one can easily observe three horizontal terraces, respectively 20, 30, and 36 feet above the present level of Loch Lubnaig, along the opposite, i.e., the east bank of the loch. *Loch Voil*, situated a few miles from Loch Lubnaig to the N.W., I have not visited; but Mr Dugald Bell, in a communication made by him to the Glasgow Geological Society (vol. v. p. 236), gave it as his opinion that Loch Voil had once been united with Loch Lubnaig. The numerous mounds and escars of drift which occur throughout the valley, including the "*Moat*" of Callander, and the kaim, called in some guide books "*Roman camp*," are no doubt the remains of the former bottom of the lake, partially scoured out by the streams which now run through the valley.

8. The town of *Lauder* (Berwickshire) is situated in a valley (through which the river Leader meanders), once filled by a lake, whose blockage existed about three miles down the valley. Thirlstane Castle, when originally built, was protected on its east side by the river, and on its west by a marsh left by the lake. Two horizontal terraces, one 10 and the other 20 feet above the river, may be seen on the east side of the valley.

9. *Loch Tulla*, in Perthshire, shows traces of water several hundred feet above its present level. I had no doubt that the terraces which

surround this lake, were formed by the lake itself, before being lowered by the cutting through of the blockage in Urchay Valley. But Robert Chambers, who maintained to the last, the *marine origin* of the *Lochaber* shelves, even after Darwin who suggested that explanation had abandoned it, maintained that the Loch Tulla high shelves were also marine. He gives their heights above the sea at 814, 907, 948, 1025, 1104, and 1132 feet above the sea. ("Ancient Sea-Margins," p. 130.) The old terraces of this lake have been particularly described by the late Robert Chambers and myself in separate publications.

10. *Loch Gwynac*, near Kingussie, I found shows no less than five horizontal terraces above its present level,—viz., 26 feet, 44 feet, 52 feet, 96 feet, and 132 feet.

11. The flat district north of *Dunkeld*, where the Dalguise and Balinluig Railway Stations are situated, was formerly a lake, of which the old beach lines (from 50 to 60 feet above the present meadow lands) are distinct for some miles. A part of the blockage by which the waters of the lake were retained at that height is still visible.

Very many of the features in the physical condition of Scotland can be accounted for by the supposition that the whole country was once under a sea which covered its highest hills, and which deposited on them the beds of sand and gravel now seen on these hills.

As the sea subsided, lakes were formed among the hills, where the waters would accumulate till they reached a ridge or *col*, over which they flowed to lower grounds. Rivers also, strengthened by mountain streams, found their way by channels, which they cut through sedimentary deposits, or through rocks once the sea-bottom. If the sea continued to subside, the descent of the rivers would become more rapid, and their cutting power greater, so that lake blockages would be gradually lowered and removed, lakes would subside or be drained off, and as the rivers cut for themselves deeper channels, the lines of the old river banks would be seen occasionally high up on the sides of valleys.

Whilst the sea prevailed over the land, currents would no doubt exist, as now, caused partly by tides, partly by those other agencies which create oceanic movements. The direction of these currents would probably be influenced by ranges of hills, then submarine ;

and the effect of these currents would be in some places to scour out the beds of sand and gravel previously deposited, and in other places to form new accumulations. Hence the long troughs or trenches in some parts, the long escars or embankments in others.

The subsidence of the sea was probably not uniformly continuous, but subject to pauses, continued long enough to allow of the formation of the sea-cliffs and flats which have been described under the head of terraces at different levels.

#### P. *Escars or Banks of Drift Materials.*

In the course of my surveys of terraces and flats, I often encountered long embankments of gravel and sand, of which I now give a few examples :—

1. To the east of *St Ninians* (Stirlingshire) a ridge of sand and gravel extends for several hundred yards in a direction N.W. and S.E. (which is parallel to what was then the ancient shore line adjoining). It was probably formed by the current which flowed past the S.W. end of Stirling Castle rock from the N.W., when the sea stood at 170 or 180 feet above its present level.

2. Near *Carstairs* Railway Station, in Lanarkshire, at a height of about 600 feet above the sea, there are numerous ridges of gravel and sand, some reaching a height of from 50 to 60 feet above the adjoining gravel surface, and containing boulders.

3. On the west side of *Loch Lomond* there is a line of escars consisting of coarse gravel. Some of the ridges reach a height of 70 feet above the adjoining land. Their direction is approximatively parallel with the axis of the Loch Lomond valley.

4. To the east of *Lennoxtown* (Stirlingshire), an escar of gravel runs for about a quarter of mile, in a direction parallel with the general range of the adjoining hills.

5. At *Ardgour*, on the north side of the Linnhe Loch at Corran Ferry, an escar of gravel is situated along the north side of the avenue to Ardgour House. It runs in a straight direction (about due east and west) parallel with the general axis of the valley. Its base is about 40 feet above H.W., and its ridge from 70 to 80 feet above the base, with very steep sides. Its length is a quarter to half a mile (also referred to on page 30).

6. In the valley of the *Nairn*, about 5 miles south of Inverness,

there is an escarpment running east and west, or parallel with the general axis of the valley, at a height of about 900 feet above the sea.

7. In the counties of *Nairn* and *Moray* there is an immense accumulation of detritus in various forms. At *Auldearn* I followed a kaim for about three-quarters of a mile. It is somewhat serpentine in its course. But its average direction is east and west, which is also that of the range of hills to the south. Its ridge has an average height of 30 feet above the adjoining land, and the sides are steep. The gravel composing it consists largely of granite, mica schist, and conglomerate—rocks existing chiefly to the westward. At *Auldearn* it is on ground which is about 130 feet above the sea. Dr Gregor of *Nairn* informed me that this kaim could be, with occasional interruptions, traced for nearly 30 miles from *Croy* at its west end to *Fochabers* at its east end. He expressed an opinion that after being formed, it had been cut across by the *River Findhorn*.

8. To the south of *Forres*, as may be seen from the railway carriage, the knolls, mounds, and short kaims of detritus are very numerous. They abound all the way up to near *Dava Railway Station*, which is about 760 feet above the sea. There, at about 900 feet above the sea, rocks occur on the east side of the railway, showing smoothed surfaces sloping down towards the N.W.

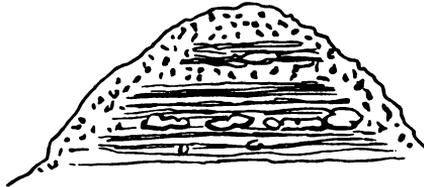
9. In *Forfarshire*, near *Baldovan* (Sir John Ogilvie's residence), in the valley of the *Dighty*, there are three ridges of gravel and sand, each some hundreds of yards in length, now cut through by the river.

10. There are in the county of *Stirling*, south and south-west of *Falkirk*, numerous kaims, all more or less parallel, running in a direction approximatively east and west, though they occasionally deviate. Some of them run for several miles, in one sense continuously, for such they seem to have been originally, though now cut across by streams which flow towards the estuary of the *Forth*. The *Polmont* kaims run for about 3 miles in an E. and W. direction, and are cut across by two streams. Generally these kaims are formed of large-sized gravel, and contain well-rounded boulders. Most of the pebbles and boulders belong to rocks situated to the west. It was in one of these kaims that the bones of a seal and also marine shells (*Solen Ensis*) are said to have been found by Mr *Reddock* near *Camelon* at a height of 90 feet above the sea. In

one of these kaims I found a bed of sand about 4 feet thick and 20 feet long.

In several places these kaims have been quarried, and there the materials are seen to have been deposited in beds, generally, though not always, horizontal. The sides of the kaims are coated with materials which might be derived from the interior of the kaims themselves, acted on by currents of water.

The following diagram gives a section of the kaim near *Polmont*, showing the external form, and also the layers of gravel and sand.



Some of these kaims are continuous over the surface of the ground, though the ground may rise or fall in level. Thus, one of these kaims has its west extremity in Callender Park, where the land is only 140 feet above the sea; whilst at or near its east end, in West Quarter Policy, the land is 212 feet above the sea.

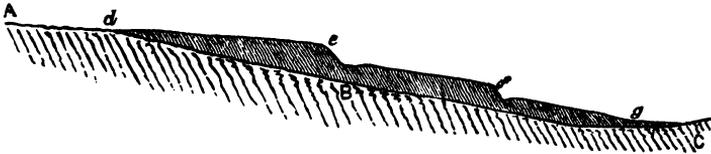
11. In *East Lothian*, about a mile to the east of Haddington, a small kaim exists, running in an east and west direction, which is the general direction of the Firth of Forth valley.

12. In *Mid-Lothian* there are several examples; as, north of *Dalkeith*, where the escarp runs north and south continuously, forming a crescent for half a mile, about 100 feet above the sea; at *Morton Hall*, running east and west for a few hundred yards, at a height of about 500 feet; and at *Arniston*, where it is at a height of 940 feet above the sea. This last-mentioned kaim is about half a mile in length, and is composed of gravel, the materials of which have come chiefly from the westward. Its direction is about east and west, or parallel with the range of the Moorfoot Hills, situated not far off to the south. The height of the ridge above the adjoining ground is 40 feet on the north and 20 feet on the south side, where it lies on the hill sloping down to the north.

13. In *Berwickshire*, and oddly enough at a height above the sea nearly the same as that of the Arniston kaim, there is on *Greenlaw*

*Muir* a magnificent kaim, forming a curve of about 2 miles in length, cut across by two small streams. It runs also in a direction approximately E. and W. The height of this ridge is 20 feet at some places and 80 feet at the highest.

14. Another example of a kaim in the same county, is at *Oxendean*, in the parish of Dunse, which can be followed for more than a mile. It also is crossed by a small river; though manifest, that when the kaim was laid down, no such river existed.



Kaim in Dunse parish.

There is a separate kaim, called the *Skarting Kaim*, near the one last mentioned, running for about a quarter of a mile, which presents some features distinct from the two first-mentioned cases.

It is similar in composition, consisting of beds of gravel and sand more or less stratified, and forming a ridge which runs in a direction nearly east and west. It is on nearly the same level above the sea as the one last mentioned, viz., about 750 feet.

The *Skarting Kaim* differs from the other two in respect that it has been formed not on flat land but on the side of a hill which slopes down at an angle of about  $20^\circ$ , as in the diagram. A B C is a section of the hill dipping to the eastward, on which the kaim is situated, and running S.E. and N.W., the kaim being shown by the letters *defg*. The distance from *d* to *e* is about 200 yards, from *e* to *f* about 100 yards, and from *f* to *g* about the same distance. The upper part of the kaim at *d* is 730 feet above the sea, the base of the steep cliff at *e* is 640 feet, the cliff itself about 50 feet in height. The kaim terminates at C, where the hill becomes flat at about 580 feet above the sea. The height of the kaim above the hill is on its north side about 80 feet, and on its south side about 50 feet. The angle of slope on the north side is about  $50^\circ$ , and on the south side about  $30^\circ$ .

The break at *e* and *f* in the continuity of the kaim, I cannot

account for, except on the supposition that after it had been formed, or when, in the course of formation, a sea current from the north had flowed across the kaim and scooped off portions of the ridge more friable than the rest.

The kaims just mentioned are on the south side of a broad valley through which the River Whitadder flows. On the north side of the valley, and opposite to these kaims, there are great *trenches in the detritus* covering the hill, apparently eroded by a current which flowed in a line parallel with the axis of the valley and from the westward. The height of these trenches in the slope of the hill above the sea is about 600 feet, and above the River Whitadder about 200 feet.

A mass of coarse gravel called the Whinny Knowe, forming a kaim, exists in the adjoining parish of *Langton* on the farm of *Hardens*, on the same hill which bears the kaims just described. It is, however, on the south side of the hill, whilst the others are on the north side, the hill between reaching to a height of about 1000 feet. It runs for a few hundred yards only; but its ridge is higher above the adjoining land and its sides steeper. Its height above the sea is about the same as that of the Kaims before described, viz., about 750 feet. The gravel composing the Whinny Knowe contains well-rounded boulders of a small size and pebbles, among which I recognised the felspar and porphyry of the Dirington and Kyles Hills, situated a few miles to the west.

All these kaims appear to me to have been formed by sea currents out of pre-existing drift on the sea-bottom. The circumstance that their direction is generally parallel with the axis of the valley in which they occur, and with the range of adjoining hills, can best be explained by this hypothesis.

15. In the lower parts of Berwickshire and Roxburghshire, the drift deposits form a series of banks of an elongated form, running approximatively in an east and west direction,—*i.e.*, nearly parallel with the valley of the Tweed. In my paper on the drift deposits of these counties (*Edin. Roy. Soc. Trans.*, vol. xxvii.) a diagram is given, taken from the Ordnance Survey maps, which shows the general parallelism of these banks, and which also indicates how their direction changes, in accordance with the ranges of the hills on each side of the Tweed valley. In that paper, reasons are

given for attributing the formation of these elongated banks to the action of the sea, when the country was submerged.

16. Having referred to the occurrence of *ridges* throughout the country, and ascribed their formation to the action of sea currents, it is not irrelevant to notice, as another effect of sea currents, the formation of *hollows or troughs*, owing probably to the scouring action of currents. Thus, in the policy of Airthrey Castle, near Stirling, there is a hollow running east and west, with a lake in part of it, which may have been formed by a strong and rapid current between the Abbot's Craig and the hills to the north.

On the farm of Raploch, to the west of Stirling, bores were put down in search of coal. A trough or trench was thereby found filled at one place with clay and mud to the depth of 80 feet, whilst the same bed of clay, lying above the rocks, at only 20 yards distant, was but 4 feet thick above the rocks. The trough runs in an east and west direction, corresponding with the axis of the valley.

There is a remarkable trough which crosses Scotland in its narrowest part, viz., between the estuaries of the Clyde and the Forth. It is particularly described by Mr James Bennie in the "Proceedings of the Glasgow Geological Society" (vol. iii. p. 133). Some parts of this trough are more than 200 feet below the present sea-level, and it is in some places several hundred yards wide. Mr Bennie reasonably suggests, that, when Scotland was partially submerged, "this channel must have existed as a kyle or strait, through which tides and currents flowed with force." He also remarks on the number of boulders lying in the channel, and observes, that "ice in great quantity must have passed through the channel, ere such a multitude of boulders could be collected together in it."

In East Lothian, along the north-east side of a range of rocky cliffs at Balgone, at Smeaton, and North Berwick, there are hollows (now filled with water), formed probably by the action of sea currents in scooping out drift materials.

Having given some general account of the terraces and kaims, as regards level above the sea, I would next offer some remarks as to the nature of the deposits forming these terraces and kaims.

1. *Clay.*

The clay occurs in three different forms—boulder clay, brick clay, and mud.

(1.) The boulder clay is the well-known tough deposit taking its name from the numbers of boulders so often found in it.

The boulders are generally well rounded, the effect no doubt of much friction; and as in numerous cases the boulders are fragments of rocks, existing at great distances, it is manifest that they must have been by some means pushed over rough surfaces by a powerful agent.

Whatever was the agent which so pushed the boulders, it is probable that it also pushed the clay containing the boulders.

But the origin of the boulder clay is still a puzzle to geologists. Some contend, that it has been formed on the dry land under the weight of heavy glaciers, which, grinding the rocks, formed the debris into the deposit. On that view of the matter, it has been called "*Moraine profonde.*"

Others suggest, that it was originally sediment at the bottom of the sea, and subsequently ploughed through and toughened by the weight of floating ice. Thus in Morayshire, there is a limestone quarry (at Cothall) where the boulder clay has been by great pressure forced in between the strata, and into the fissures of the rocks.

True boulder clay has now been discovered in many places, not only in Scotland, but in England and Ireland, containing beds of sea shells. In these cases, therefore, it is pretty certain that it was a marine deposit. In some of the localities, the shell-beds have been broken up, as if by the intrusion of some ponderous extraneous agent ploughing through the beds and crushing the shells. In these cases, boulders and pebbles are also found scratched, as if pushed forward and made to grate on harder bodies. Very many of the shells belong to species of an arctic type, which suggest the idea that ice may have then floated in the sea, and pressed on the sea-bottom in such a manner as to produce these effects. As an example, reference may be made to the boulder clay in Caithness, which was carefully examined by the Rev. Mr Crosskey and Mr David Robertson, who, in an instructive paper read in the Glasgow Geological Society (Trans., vol. iii. p. 126), describe the bed as

varying in thickness from 4 to 25 feet, and "generally overlaid by shingly gravel." "The shells are thinly interspersed from top to bottom, and are of a very water-worn and fragmentary character. They appear very equally distributed, as if the whole mass had been mixed up and kneaded together."

Boulder clay is found in Scotland, at all heights above the present level of the sea.

The embedded boulders are not only generally well rounded, but often present on their smoothed surfaces parallel striations. Those on the bottom surface are probably caused by the passage of the boulders over stones or rocks, hard and sharp;—those on the upper surface, probably by the passage over the boulder of other blocks pressing heavily on it.

(2.) The brick clay is not only free from boulders, but is stratified in beds mostly horizontal.

A certain amount of sand is often mixed with the clay, and in that case it is much employed for the making of bricks.

This brick clay occurs generally at low levels. It has at all events not been worked at levels so high as where the boulder clay occurs.

There is no doubt that this brick clay is a submarine deposit; especially as in many places sea shells and the bones of marine fauna occur in it.

(3.) Clay exists also as "mud." In the Carse of Stirling it goes by the name of "sleech"—possibly a corruption for sludge.

It is unfit for brick-making, on account of its semi-fluid condition, and the total absence of sand.

It is dark in colour,—sometimes blue, sometimes black.

It has the odour often of bilge-water, probably caused by the disengagement of sulphuretted hydrogen. There have been found in it quantities of decayed trees and other vegetable matter, as well as beds of sea shells.

At Boquhan Tile Work, about 8 miles west of Stirling, the manager showed to me a portion of the stem of a large tree, which he had found in the bed of clay worked there. The lower part of the tree was in the bed of sleech or mud below the workable clay.

At Cornton Brick Work, near Stirling, in like manner, I was

shown a portion of a tree 5 feet long taken out of the mud bed lying below the worked clay bed. It was 10 feet below the top of the mud bed. It had all the appearance of having been drifted. It seemed to be oak. In this bed of mud I saw leaves and nuts of hazel.

This mud has been bored through at various places in order to reach the rocks. In some of the bores it shows a thickness of 70, 80, and 90 feet.

## 2. Sand.

It occurs in all parts of the country, forming beds which are tolerably free from boulders and pebbles. The beds are generally stratified, though not always horizontal.

At Spittal-Croft, near Stirling, the sand bed is 73 feet deep, and lying over brick clay.

At Cambusbarrow, 2 miles west of Stirling, the sand pit showed a vertical section of 30 feet; how much deeper, was not visible.

At Tillicoultry, there is a bed of sand showing a depth of 30 feet without reaching the bottom. The beds there slope down eastward at an angle of about 20 degs.

In the parish of Temple (Mid-Lothian), as Mr Leslie, C.E., informed me, a bore by his orders was put down in search of water, which went through a bed of pure sand to the depth of 130 feet without reaching the bottom of the bed. The height of this place above the sea is 300 feet.

Beds of sand occur also on the Highland hills at great heights. The following are examples:—

At the summit level of the Highland Railway between *Forres* and *Grantown* at a height of 1100 feet.

On the hills between *Tyndrum* and *Inverournan* at a height of about 1500 feet.

On the hills at the west end of *Glen-more-na-Albin* at a height of about 1700 feet.

On the hills between *Stratherrick* and *Strathspey* at a height of 2000 feet.

To the south of *Killiecranky* Pass, and on the east side of the valley, there are cliffs of sand and gravel, formed by small streams which have cut through the beds, and reaching to a height of 1500 feet above the sea. The drift here, so cut through, forms horizontal

beds at least 100 feet thick. Similar beds of sand, I learned from the minister of the parish, exist on *Ben-y-Gloe*, a mountain 3000 feet high, situated about 2 miles to the N.E.

On the hills which skirt *Flichity* Valley, on the south side (about 10 miles S.W. of Inverness), there are beds of sand and gravel at a height of 2100 feet above the sea.

On the hills west of *Killin*, at the head of Loch Tay, I found beds of sand and fine gravel at a height of 1800 feet above the sea.

At *Dalnaspidal*, the summit level of the Highland Railway, the hills up to 1700 feet are covered with sand and gravel.

At *Drumnachdier* (which is near Dalnaspidal and at about the same level), as Mr John Robertson, factor at Old Blair, informed me, the sand is in great deposits, and is so "pure, fine, and soft," that it cannot be used for building.

In *Glendoe*, situated to the north of *Glen-na-Albin*, at the head of the Invermorriston Valley, there are deep beds of sand at a height of 1500 feet above the sea; and I was informed that on "*Bendoe*," at a still higher level, there are beds of sand.

### 3. Gravel.

It occurs almost always in stratified beds. It is to be seen at all heights, as for example in *Glen Lyon*, in the valley of the Var, at a height of 2700 feet, on *Schehallion* at a height of nearly 3000 feet, and on *Mawm Saul* (according to the Ordnance Surveyors), at about the same height above the sea.

Setting aside the boulder clay as still an unsolved problem, there can be no doubt that the other clays above referred to, as well as the sand and gravel, have been deposited in the sea.

A rough estimate has been made of the depth of the sea, indicated by the nature of the sediment at the bottom. It has been stated that fine sand, mud, or ooze, indicates a depth of at least 60 to 80 fathoms; coarse sand with broken shells, a depth of at least 40 to 60 fathoms; and coarser sand, mixed with pebbles or small stones, a depth of 12 to 40 fathoms.

The bores which have been made in numerous places in the Carse of Falkirk and Stirling so far verify the above estimate as to show that generally the gravel beds lie above the sand, and the sand above the clay.

The sleet or mud which abounds in these districts, would on the same principle indicate great depth of water, when deposited.

The boulders occur most frequently in the peculiar tough clay before referred to. But they occur also, occasionally in the brick clay and beds of sand, and even on the surface of the land above



all these beds. The boulders generally lie on their broadest surfaces; but I have also occasionally seen them in this position, giving the impression that they had fallen from the agent which had transported them, with their heaviest end downmost, and on reaching the sand or mud on which they fell, had stuck there, till covered up by more drift materials.

That they have in many instances been transported from great distances, and been dropped from the agent which carried them into their present positions, there can be no doubt.

Q. *Changes each way in the relative beds of sea and land.*

In the preceding notes, I have referred only to the *sinking* of the sea from one level to another. But there seem to be strong grounds for believing, that as the sea-level approached the present condition of things, the process of constant though intermittent sinking was interrupted; and that the sea *rose to a higher level*, submerging what had been land, and covering with sediment the vegetation then on the land.

This inference seems fairly deducible from several borings through the superficial strata in Stirlingshire and elsewhere, which were made known to me by the persons who conducted these operations, and which I will now shortly refer to.

(1.) When excavations were made for the Stirling Gas Works, a bed of fine coarse clay, 8 or 10 feet with *sea shells*, was found, and *beneath it a bed of peat* 1 to 1½ feet thick.

(2.) Mr Black of Falkirk supplied me with the following section of a pit sunk by the Carron Company on the Kinnaird estate, near that town:—

	Ft.	In.
Surface rubbish and vegetable soil, . . . . .	11	0
Brown earthy mud, . . . . .	2	0
<i>Shells and sea mud</i> , . . . . .	1	0

	Ft.	In.
Soft blue mud, . . . . .	1	0
<i>Shells and sea mud,</i> . . . . .	3	0
Soft fine blue mud with sand, . . . . .	5	0
<i>Shells, sand, and gravel,</i> . . . . .	2	0
Blue clay mud, . . . . .	1	6
<i>Hard clean compressed moss, with birch, hazel, and oak trees, with branches,</i> . . . . .	2	3
Light green sandy clay, . . . . .	7	0
Gravel and sand, . . . . .	1	6
Clay with boulders, . . . . .	15	0
Rock.		

(3.) At *St Ninians*, 2 miles south of Stirling, a bore was made in quest of water for a well. The following were the beds passed through :—

- Surface soil.
- Brick clay, 6 or 8 feet.
- Mud with fetid smell, 12 feet.*
- Moss, containing branches of hazel, 2 feet.*
- Clay, with large boulders.
- Sand, thin stratum of.
- Rock.

(4.) At another spot near *St Ninians*, the following beds were passed through :—

- Surface soil.
- Clay, 20 feet.*
- Bed of peat.*
- Boulder clay

(5.) At *Fall-in*, near Polmaise, 16 feet above high-water mark :—

- Surface soil.
- Carse clay, in beds sloping gently eastward, 8 to 10 feet thick.
- Bed of sea shells, 6 or 8 inches thick.*
- Peat earth, with bits of wood and bark, 14 to 18 inches thick.*

(6.) Dr Chambers, in his "*Sea-Margins*" (page 17), refers to a bed of peat, 1 foot thick, near Edinburgh, 70 to 80 feet above the sea, which bed of peat was overlaid by a bed of sea sand 10 feet thick. The peat bed contained roots of trees, which evidently had grown in the blue clay below the peat.

Excavations through deep beds of sand were made for the railway between Edinburgh and Granton. In one of these, at a height of about 60 feet above the sea, I found a bed of peat, continuous for about 20 feet, and covered by sand about 10 feet. The peat contained seeds which the late Mr M'Nab, of the Edinburgh Botanic Garden, attempted to germinate, but without success.

(7.) The Rev. Mr Crosskey refers to a bed of clay containing *vegetable* remains, at Chapelhill, near Airdrie, and covered by boulder clay. Holding this boulder clay to be a marine deposit, he says it is a proof that the land, with vegetation on it, had been depressed beneath the sea, and afterwards uplifted. (Glasg. Geol. Soc. Trans., vol. ii. p. 136.)

Mr Crosskey, comparing "the glacial deposits of Scotland and those of Canada (Trans. Glasg. Geol. Society, vol. ii. p. 132), says:—"A bed is noted beneath the boulder clay, for which we have a Scottish equivalent. A peat deposit, with fir roots, is found beneath boulder clay at Cape Breton;—while at Chapelhall, Airdrie, we have vegetable remains in the same position, indicating the existence in both countries of land, in parts afterwards depressed beneath the sea, and again uplifted."

(8.) The depression of the land surface in Stirlingshire is further indicated, by the position of the skeleton of the whale found at Blair-Drummond. Mr Home Drummond, the proprietor, sent to the Wernerian Society an account of the discovery. "In this paper, he states, as a general fact, that in many places a stratum of *moss* comes to the surface near the margins of the dryfield, which *dips under the clay* towards the (river) Forth.

"It was upon the surface of this lower stratum of *moss*, below the clay, that the (whale) bones were found. They were *embedded in the clay*, and did not penetrate into the moss below.

"Specimens of the peat moss containing the remains of wood, particularly alder, and of various water plants were sent with the whale bones to the Edinburgh Wernerian Society. The *stratum of peat moss* was 6 feet deep, and under it a bluish sand was found, with little or no admixture of clay" (Wern. Trans., vol. v. p. 44).

Mr Ballingall, the factor at Blair-Drummond was present when the excavation was made, and he informed me, that there were *sea shells* in the bed of clay *lying over the stratum of moss*.

These facts show that the land surface in this district had been depressed beneath the sea, and to such an extent as to give sufficient depth of water for a whale to come up to the west of Stirling.

(9.) Mr Jamieson of Ellon describes a *bed of peat, with remains of trees*, in the Firth of Tay, near the village of Newburgh, overlaid by clay and estuarine sand 8 feet thick, containing remains of *Scrobicularia pipereta* and other estuarine shells. He adds, that this extensive bed of peat with trees, beneath the Carse of Tay, in his opinion, "represents a *land-surface preceding the deposition of the old estuarine mud*" (Lond. Geol. Soc. Jour. for 1865, vol. xxi. p. 185).

With regard to these cases of peat beds covered by sand and clay, I confess that once I doubted whether they could be relied on as affording evidence that they indicated dry land first covered by vegetation and afterwards submerged by the sea. In my little treatise, "Estuary of the Forth," I suggested (page 22) that these peat beds might perhaps have consisted merely of masses of peat drifted off the land by rivers, and accumulated in neighbouring estuaries in sufficient quantity to form beds. But on now reconsidering the subject, I acquiesce in the view adopted by others, that the beds are really vegetable matter which grew where they now are whilst the land was above the sea. If the beds were composed of merely drifted matter, it is likely that they would have formed detached fragments rather than continuous beds; whereas, in one of the last-mentioned cases, the peat bed was 6 feet in thickness, and with roots of trees in it.

This view of the matter is strongly confirmed by the cases of "*submarine forests*," as they have been called, found around the coasts of Scotland, England, and Ireland. A few of these may be referred to :—

(1.) In the district now occupied by the *estuary of the Tay*, there are the remains of a forest, which forms a bed, buried under a mass of clay, with marine shells, forming a deposit from 10 to 40 feet thick.

The best account which I have seen of it, is given by Dr James Geikie, in his recent work, entitled "Prehistoric Europe";—a work of astonishing research, and forming a storehouse of valuable information.

This buried forest has been examined by Dr Geikie, and he says it consists of an accumulated mass, containing trunks and branches

of oak, birch, pines, willows, hazel, and other trees, now indigenous in Britain.

The position of this vegetable deposit is between the present levels of high and low water mark. The roots of many of the trees have been traced for several feet in the clay on which this forest-bed rests, showing that the trees grew where the trunks are now.

This forest is covered, and greatly concealed by clay and silt, from which "*marine shells have been obtained in considerable numbers, belonging to species which are now characteristic of high northern latitudes, and possessing arctic forms*" ("Prehistoric Europe," pages 387, 395).

Dr Geikie states, that this overlying clay deposit "often contains scattered stones and large erratics," one of these measuring 4 feet across, which he supposes may have come from Kinnoul Hill, near Perth, or even from the Grampians near Dunkeld. He observes that "the presence of these stones and boulders shows, that floating ice was not unknown at this late period" (pages 388, 396).

(2.) A submerged forest occurs in the *Firth of Forth*, on the north side, at Largo, as described by Rev. Thos. Brown, in a paper read to the Royal Society of Edinburgh on 4th March 1867.

Mr Brown states that this forest bed, where best visible, is almost 4 feet in thickness, "sweeps for miles all round Largo Bay" (page 625), and that remains of willow and hazel, with various seeds and mosses, have been recognised. "Dr Fleming has described trunks of trees standing in it, rooted in the soil beneath." "The plants in this bed have grown on the spot, as is shown by the traces of their roots going down vertically into the underlying beds" (page 617).

Mr Brown gives a section, showing the relative position of the beds. Below the forest bed, there is boulder clay with a layer of arctic marine shells in its upper part, where it forms "a peculiarly stiff, tenacious, unstratified clay. It is here the shells occur, and in considerable quantities. All the portions of the shells are, in many cases, beautifully perfect" (page 620).

*Above this submerged forest, there are beds of sand and clay, containing marine testacea, indicating the presence of the sea, at least 14 feet above the present level. These shells, however, have not the arctic type of those in the subjacent beds of boulder clay.*

This case agrees in its principal features with those on the Tay

estuary. It shows first a period when,—judging by the nature of the shells in the boulder clay,—there was a great depth of sea, and sea of an arctic temperature; and after the sea subsided to a level lower than that now occupied by it, there was land covered with trees, and of the kinds now growing in Scotland; after which another subsidence of the land occurred, which continued long enough to allow of the deposit of detrital beds, and of the appearance of shells in these deposits.

(3.) In further proof that when these “*buried forests*” existed in Scotland the land must have been higher above the sea than at present, reference may be made to what have been termed “*buried river courses*.” Dr James Geikie, as an example, mentions the existence of an old river channel in the neighbourhood of Glasgow, which is 80 feet below the sea-level (“*Great Ice Age*,” first edition, p. 187). Another example is the ancient bed of the river Yare at Yarmouth, 100 feet below the present sea-level. Another case is an ancient river course traced for 14 miles through the Durham Coalfield, which is 140 feet below the present sea-level (“*Great Ice Age*,” second edition, p. 388).

Dr Croll and Dr Geikie think that another buried rivercourse occurs in the district between Grangemouth in the Firth of Forth and Bowling on the Clyde; and as at these places the trough is about 260 feet below the present sea-level, their view, if correct, would indicate that amount of a still higher level of the land. I have ventured (“*Estuary of the Forth*,” page 95) to suggest whether this trough, connecting the two seas, may not rather have been an arm of the sea when the land was submerged.\*

4. As the cases of “*buried forests*” in England are more numerous, and have been more thoroughly investigated, it may not be out of place to refer to a few of them:—

Thus there is the celebrated forest of Cromer, on the Norfolk coast, which has been traced for more than forty miles in a north and south direction, with trunks of trees having a diameter from 2 to 3 feet, and containing the bones of many species of animals which had lived in the forest.

That this forest was engulfed by the sea is evident from the fact that it is covered by thick beds of sand and clay, evidently

\* This matter is also referred to on page 125 hereof.

once a sea-bottom, because containing marine shells ; that above these beds there is boulder clay also containing sea shells, and large blocks of granite and other rocks, which could only have been transported by floating ice ; and that above the boulder clay there are drift beds, so contorted and bent as to draw from Sir Charles Lyell the following remarks :—“ If called upon to explain how any force can have been exerted against the upper strata, so as to produce movements in which the subjacent strata have not participated, it may be answered, that if we conceive the till and its boulders to have been drifted to their present place by ice, the lateral pressure may have been supplied by the stranding of ice islands. In the polar regions such islands, when they run aground, push before them large mounds of shingle and sand. It is, therefore, probable that they often cause great alterations in the arrangement of pliant and incoherent strata forming the upper part of shoals or submerged lands, the inferior portions remaining undisturbed ” (“ Antiquity of Man,” p. 264). Sir Charles adds, that the facts “ lead us to infer that the subsidence of the country after the growth of the (Norfolk) forest bed exceeded 400 feet. The re-elevation must have amounted to nearly as many feet, as the site of the ancient forest had been brought up again to within a few feet of H. W. mark ” (“ Antiquity of Man,” p. 271).

The submarine character of these beds of clay and sand overlying the Norfolk forest bed is farther established by a fact mentioned by Dr James Geikie (“ Great Ice Age,” p. 343), that “ the clay is not unfrequently *laminated*.” “ Here and there I picked out of the clay bits of broken shells, which occurred in precisely the same way as the fragmentary shells in the boulder clays of Lewes. Towards the top, the clay becomes distinctly *bedded*, and seems here and there to inosculate with and shade up into the overlying contorted drift.” “ Lenticular and irregular patches, and sometimes considerable beds of sand and gravel, are now and again intercalated in the clay ” (“ Great Ice Age,” second edition, p. 344).

The sequence of events which Dr Geikie thinks these facts justify are :—

1. “ A preglacial land-surface which supported a vigorous forest growth, and an abundant mammalian fauna.”
2. “ A gradual submergence, when what had been forest land became the bed of an estuary.”

3. "As that submergence increased, the climate became colder, as shown by the presence of boulder clay with its scratched stones" ("Great Ice Age," second edition, p. 346), and (he might have added) the arctic marine shells.

One other example from England may be given to show submergence. It occurs on the Lancashire and Cheshire coast. Dr James Geikie ("Prehistoric Europe," p. 434) mentions that this forest bed is in some places 10 feet in thickness, and exhibits trunks of trees, many of them rooted in the subjacent boulder clay. This forest was engulfed, for it is covered with beds of marine sand about 25 feet thick containing *Cardium edule* and other molluscs.

The next facts to be mentioned, also proving submergence, are supplied by *mammalian* remains.

Thus the skeletons of seven or eight whales found in Stirlingshire and Easter Ross, already referred to, at heights between 25 and 35 feet above the present H.W. mark, imply (if the animals ran themselves aground) that the sea must have stood at least 50 or 60 feet above the present level.

The skeletons of seals found in various districts of Scotland up to 150 feet afford evidence of the same kind; and the sea shells found in Scotland up to 520 feet, and in England up to 1300 or more, afford evidence of a still more complete submergence.\*

*Terrestrial* animals also were drowned, judging by the way in which their remains have been found. Thus, Mr Boyd Dawkins ("Early Man," p. 138) refers to the "*pouched marmot*" and "*musk sheep*," animals indicative of arctic conditions, whose "bones were in such a position as to prove that the animals had been *surprised* by *floods* when hibernating and drowned."

But the most interesting fact of this kind is the discovery of the skeletons of several elephants at Kilmaurs, in Ayrshire. The late Mr Bald, C.E. was the first person who reported on this case. He states that in 1817 one "entire animal was found in a bed of clay with 'marine shells' at a depth in the clay of 17 feet" (Wernerian Trans., vol. iv. p. 60).

A few years afterwards (viz. in 1865) more elephant's tusks having

\* A number of cases of seal remains are mentioned by Professor Turner of Edinburgh University, in "Journal of Anatomy," vol. iv. p. 270.

been found at this place, besides the horns of a reindeer, the late Dr Bryce of Glasgow proceeded to the spot, and ascertained that the bones were all in a fresh-water deposit of mud; which *had been covered by a bed of marine sand with arctic shells*, and thereafter, with a great mass of till containing scratched boulders.

More recently, in consequence of additional excavations at Kilmaurs, Messrs Craig and Young went there to clear up some points. They then ascertained that the bed of mud or clay containing the bones contained also the *seeds of two species of fresh-water plants*, which they recognised and named; and on a more minute inspection, they discovered portions of these seeds and plants in the *cavities and fissures of the elephant's teeth*.

This fresh-water bed was overlaid by a bed of sand 6 to 18 inches thick, *containing 10 different species of sea shells*, some of them decidedly arctic. Above this marine bed *lay boulder clay 16 feet thick*, which is described as "a thick mass of tumultuous unstratified till."

From these facts, Messrs Craig and Young, who described them in a paper to the Glasgow Geological Society (vol. iii. p. 319), drew this conclusion, that "the bed of sand, with arctic marine shells, which overlies these beds (containing mammalian and other land remains) clearly shows that *the district was depressed under the sea-level before it [viz., the sand bed] was deposited.*" They farther infer, that the bed containing the land remains, had been formed in a lake, or at the mouth of a river, which underwent subsidence, to allow of a deposit over it, first of a bed of sand containing arctic sea shells, and secondly of a thick deposit of boulder clay.

This case reminds us of the discovery of the skeletons of elephant, reindeer, and rhinoceros, in circumstances somewhat similar, in Siberia. These are found, and most abundantly, in the *islands* which form the Archipelago of New Siberia. The multitudes of the skeletons are so great as to render it incredible that they would have been nourished and lived on these islands. The islands must originally have formed part of a mainland, and by the elevation of the sea, a large portion of that land had been submerged so as to drown all the living animals and destroy the forests in which they lived. Of the *trees* composing these forests, remains have also been found *in the same beds of sand and mud*. Since that time, there has been a re-emergence of the land to a certain extent.

Several cases are mentioned of mammoth skeletons having been found in *upright positions*, showing that they had sunk in soft soil;—soil most probably softened by the submergence of the land under the waters of the ocean (Geol. Mag. for May 1881, p. 198).

In the "Quarterly Journal of the London Geological Society" for 1st Feb. 1848, there is an interesting letter from Professor Brandt to Humboldt, mentioning that out of the *mouths of several mammoths and rhinoceroses, half-chewed food was taken*, consisting of pine leaves, seeds of plants, and fragments of coniferous wood. From the state of the blood-vessels in the head, an inference was drawn, that death was produced by asphyxia—such as would be produced by drowning in the mud. In several cases, where skeletons were found, sea shells occurred.

If the facts in Scotland are analagous to those in Siberia, it is not unimportant to keep in view, that to account for the Siberian phenomena, no one has invoked the agency of glaciers. In his work, entitled "The Great Ice Age," Mr James Geikie says:—"it is remarkable that nowhere in the great plains of Siberia, do any traces of glacial action appear to have been observed. If cones and mounds of gravel and great erratics, like those that sprinkled so wide an area in northern America and northern Europe, had occurred, they would hardly have failed to arrest the attention of explorers. Midden-dorff does indeed mention the occurrence of large erratics along the banks of some of the rivers; but these, he has no doubt, were carried down by river ice" (page 555).

The destruction of the elephants, both in Scotland and in Siberia, seems to have been caused by a sudden rising of the sea, which engulfed them.

From the foregoing considerations, two conclusions seem deducible,—*First*, When the terraces described in the foregoing notes were formed, the sea must have been subsiding from off the land, or the land was being elevated. *Second*, a period occurred when the very opposite process took place,—that is, the sea rose upon the land, or the land subsided under the sea.

Evidently the last-mentioned change must have occurred first. If it had occurred last, the terraces would have been obliterated.

But if all the growing forests and living animals in Great Britain were destroyed by the supposed submergence, when and how

was the country again clothed with vegetation and occupied by living creatures?

All geologists are agreed that when the forests existed, but now covered by marine deposits, the land must have been so elevated that there would be no sea between England and the Continent, or Ireland. The various animals, including man, in conformity with the usual tide of westerly migration, then undoubtedly crossed into England, and ultimately into Ireland and Scotland. In no other way can their appearance in these countries originally be explained. But if after these animals for a length of time had been occupying England, Scotland, and Ireland, a submergence took place, which drowned all animals occupying these countries, there must have been a subsequent migration, attributable to the same event as before, viz., an elevation of the land to such an extent as to unite England with the Continent.

Whilst this explanation seems inevitable, and plainly to show that man must have been an inhabitant of Britain before submergence took place, and that he shared the fate of other mammalia then on the land, it is satisfactory to see separate proofs of this, in the way in which the remains both of man and of these mammalia are found associated.

It is true that no human bones or products of man's industry have yet been found in the Cromer Forest bed. But most of the animals whose remains are there, are clearly proved to have been contemporaries of man, as the remains of both are found together in numerous places elsewhere.

Thus in Brixham Cave, near Torquay, tools constructed by man occur in conjunction with the remains of eighteen mammalians, seven of which are the same as in Cromer Forest bed, and one (the cave bear) of an older period. ("Antiquity of Man," p. 102.)\*

So also at Wokey Hole, Somersetshire, flint implements and arrow heads of bone are associated with mammalian remains of about a dozen species, half of them the same as in Cromer Forest bed. ("Antiquity of Man," p. 109.)

\* Sir Charles Lyell points out that some of these Brixham caves were "filled to the roof with mud" (page 101), "but the currents charged with such mud must have run at a level of 78 feet above that of the stream now flowing in the valley" (p. 103). It does not, however, appear to have occurred to him that the *sea* might have brought the mud.

In the Gower caves (South Wales), knives of flint were found associated with the same two kinds of elephant and hippopotamus as found at Cromer. In regard to these, Sir Charles Lyell remarks that "the Gower caves in general have their floors strewed over with sand containing marine shells" ("Antiquity of Man," p. 112). So also, referring to the Somersetshire cave, where mammalian remains and human implements were found together, Mr Boyd Dawkins observes, that whilst he "sees no evidence of water having *brought* the bones and implements into the cave," he allows that "the horizontality of the layers should show that water certainly was an agent in rearranging and introducing some of the contents of the cave" (Lond. Geol. Soc. Journ., vol. xix. p. 374). "In the absence of the beaver, otter, and water-rat, we must assume (adds Mr Dawkins) there was no *river* in the immediate vicinity" (Lond. Geol. Soc. Journ., vol. xix. p. 272).

Another case is at Caldy Island, in the Bristol Channel, where many flint tools were found with the remains of mammoth, rhinoceros, Irish elk, bison, wolf, lion, and bear, most of which also occur in Cromer Forest bed. Mr Boyd Dawkins observes, that these remains existing "on so small an island indicate, that a considerable change had taken place in the relation of the land to the sea in that district since those animals were alive. It would have been impossible for so many and so large animals to have obtained food on so small an island. It may therefore be concluded that when they perished, Caldy was not an island, but a precipitous hill overlooking a broad valley now covered by the waters of the Bristol Channel, but then affording abundant pasture, supporting herds of reindeer, horses, bisons, elephants, and now and then a hippopotamus, which would afford abundant prey to the lions, bears, and hyenas inhabiting all the accessible caves, as well as to their common enemy and destroyer, *man*" ("Cave Hunting," p. 289).

As the cases just referred to show the existence of man at or about the time of the engulfing of the Cromer Forest bed, the natural inference is that human inhabitants then existing must have shared the same fate.

There is also another set of facts which at all events show, that when man occupied England the sea stood on the land much above its present level.

(1.) In his "Principles of Geology," and afterwards in his "Antiquity of Man" (page 221), Sir Charles refers to the finding of *flint implements in a great bed of gravel in Hampshire*, consisting of half-rolled chalk-flints and rounded pebbles washed out of Tertiary strata. The bed of gravel was from 8 to 12 feet thick, and *was not an old river gravel*, but formed tabular caps on adjoining hills at a height of about 35 feet above H.W. mark. In this gravel bed were blocks of sandstone of various sizes, some of enormous dimensions, —more than 20 feet in circumference, and from 1 to 1½ feet thick. "To explain how *these blocks* and the *implements* became enveloped in the debris of chalk-flints," Sir Charles says, "we must have recourse to ice, which may have been frozen on to them in winter, so as to give them bouyancy, and enable rivers or the sea to transport them." "The occurrence of unrolled chalk-flints in the gravel in places where they must have travelled twelve miles from their nearest source, also implies the aid of ice action."

When the gravel beds containing these "flint implements" were deposited, the sea must have stood higher than 35 feet above its present level, *and the land must then have been occupied by man.*

(2.) Another case is mentioned at and near Bournemouth, where, at about 100 feet above the sea, several flint tools were found in a bed of gravel of considerable extent. Sir Charles states that the gravel consists in great part of pebbles derived from Tertiary strata; and if it was originally spread out by rivers, the course of the drainage must have been such that it is not easy to trace any connection between the old water-courses and those of the existing valleys."

If not spread by rivers, the only alternative is of course sea-action.

(3.) In the Isle of Wight, at a height of about 80 feet above the sea-level, *flint implements* and remains of the mammoth occur in a bed of gravel, which apparently had once reached to Gosport; "in which case, we should have to infer, that the channel called the Solent had not yet been scooped out, *when this region was inhabited by Palæolithic man.*"

In the passages just quoted, Sir Charles considered it necessary in some of the cases, to explain the transport alike of the flint-implements and of the erratics by means of floating ice; whether this ice floated in sea or in a river, he gives no opinion; though, as he

states that some of the erratics must have come a distance of twelve miles, the probability is that the sea was the carrier of the ice ; the land being submerged.

Even in the less probable case of the ice having floated down a large river, the sea must have been greatly above the present level, to have allowed a river to deposit gravel beds at the height stated.

The finding of *articles of human workmanship in stratified gravel-beds*, evidently marine, implies the existence of man at a time when the sea covered a large part of what is now the south of England.

Facts of the same kind occur in Scotland.

(1.) Thus there is the finding of bone implements with the skeletons of three whales in Stirlingshire, already alluded to, when the sea must have stood at least 50 feet above its present level.

(2.) There is the finding of a rude ornament made of cannel coal on the surface of the boulder clay, covered by gravel containing sea shells, at a height of 50 feet above the sea ("Antiquity of Man," p. 61).

(3.) There is in the Museum of Scottish Antiquaries a piece of cannel coal about three inches long and about one quarter of an inch wide, pointed at one end, intended apparently for making marks of a black colour. It was found in a thick bed of sand under gravel, by the gardener at Ayton Castle, Berwickshire, who pointed out the place where found, and gave the article to me. The locality is 120 feet above the sea.

When these pieces of cannel coal were dropped into the sea, and lodged in the sea-bottom, the sea probably stood at least 100 feet above its present level ; and man of course then existed in Scotland.

These facts, then, so far answer the question, Did man exist in England and Scotland when the sea stood above its present level ?

Another kind of proof to the same effect has recently been suggested, founded on the names of places.

(1.) Thus there is an article in the "Scottish Naturalist" for April and July 1880, by the Rev. Adam Milroy, in which he attempts to show, that it must have been whilst the sea stood over the Carse of Gowrie from 30 to 40 feet above its present level, that names were given by the inhabitants, which imply such higher elevation of the sea.

He adverts to the numbers of places in that district having the Celtic prefix "*Inch*" or "*Inis*," meaning an island, such as Inchtute, Inchmartin, Inchmichael, Inchconans, Inchyre, &c. He infers from these names, that when they were given, the sea must have stood on the Carse of Gowrie from 30 to 40 feet above its present level, to account for such names.

He supports his argument by linguistic inferences from the Celtic words, "*Aber*" and "*Inver*," prefixed to the names of rivers flowing now through the Carse of Gowrie into the Firth of Tay. On the River Nyte, which flows in from the north,—he says there are two places called Abernyte and Invernyte. He says of the former name, that it must have been given to a place then at or near what was the mouth of the river;—and that when Invernyte was given, it was after the sea had retired, and the mouth of the river was at or near the present confluence of the river with the Firth of Tay. This inference is founded on the assumption, that *Aber* is a word belonging to an earlier period of history than *Inver*,—both meaning the mouth of a river.

So also on the River Nethy which flows into the same Firth from the south, there are two places called respectively Abernethy and Invernethy; the former with the old prefix "*Aber*," indicating a place at or near what was the mouth of the Nethy, when the sea stood at a higher level; the latter with the less ancient prefix "*Inver*," indicating a place at or near the mouth, at the present confluence of the river with the firth.

This is a new line of inquiry which Dr Milroy has the merit of originating. On consulting some friends versed in Celtic literature, I find that there are other rivers in Scotland, with names of places, bearing the prefix of "*Aber*" and "*Inver*," but in which (unfortunately for Dr Milroy's theory) "*Aber*" is not the uppermost and "*Inver*" not the lowest as regards situation. Moreover, Mr Skene, so well known for his Celtic historical researches, does not give to these prefixes exactly the same meaning as Dr Milroy. He allows that "*Inver*" most frequently indicates the confluence of a river with another river, or with a lake, or with the sea. "*Aber*," he thinks, indicates not the mouth of a river, but the part of a river where there is a ford ("*Celtic Scotland*," vol. iii. p. 222).

Other examples occur in the Highlands, of names indicating the

presence of the sea, or proximity to it, though the sea is now far distant, or at a lower level.

Thus "*Kintray*," or, as spelt in Gaelic, "*Ceunn-traigh*," meaning "*head of the tide*," occurs near Loch Spynie (Elginshire), and is the name of a place now  $3\frac{1}{4}$  miles from the sea, and 11 or 12 feet above the present H. W. mark. The same word (*Kytra* or *Kintra*) occurs in a part of the Caledonian Canal, which is about 100 feet above the sea-level, and many miles distant.

So also there are many places in Scotland bearing the name of *Kenmore*, or, in Gaelic spelling, "*Ueann-Mara*," meaning head of the sea, though these places are distant from the sea. But it is right to add, that as in Gaelic, the word *Mara* means only a large body of water, whether fresh or salt (just as was the original meaning of our own word *sea*), these terms may refer at the time they were given to lakes which have disappeared.

On the River Lochy, there is a place bearing the Gaelic name of "*Eas-nan lang*," meaning "*rapid of boats*," as if the sea had formerly reached there, allowing boats to come to the place. (This I give on the authority of Rev. Mr Clerk of Kilmallie, and the Rev. Mr Joass of Golspie.)

These data, founded on the meaning of old Celtic words, it must be admitted afford very slender evidence of the existence of a higher level of the sea on our Scottish coasts; and I have referred to them merely as a new line of inquiry, which may perhaps, if farther followed, lead to more satisfactory results.

With regard to the amount of submergence, Sir Charles Lyell, in his "*Antiquity of Man*," 4th edit. p. 325, gives a map which he says "will give some idea of the great extent of land which would be submerged, were we to infer, as many geologists have done, from the joint evidence of marine shells, erratics, glacial striæ, and stratified drift at great heights, that Scotland was, during part of the glacial period, 2000 feet below its present level, and other parts of the British Isles 1300 feet. A subsidence to this amount can be *demonstrated* in the case of North Wales and Ireland," *i.e.*, in respect of the marine shells found there at that height.

With regard to Scotland, Sir Charles elsewhere observes, that "it seems difficult not to embrace the conclusion that a subsidence (*i.e.*, of the land) took place not merely of 500 or 600 feet, as demonstrated

by marine shells, but to a much greater amount, as shown by the present position of erratics and patches of stratified drift. The absence of marine shells at greater heights may in part be ascribed to the action of glaciers which swept out marine strata from all the higher valleys, after the re-emergence of the land" ("Antiquity of Man," fourth edition, p. 290.)

Since the publication of this last volume by Lyell, it has been discovered that numerous boulders lie on the tops and ridges of our Highland hills at more than 3000 feet above the present sea-level, to which positions, it is most probable, they could not have been brought, except by floating ice.

That the sea in like manner prevailed over the middle and north of England, is clearly proved by the presence of sea shells of an arctic type in Wales and adjoining counties, even up to the height of 1450 feet.

On the other hand, it is undeniable that glaciers did exist at some time or other both in England and in Scotland. The striations in numerous Highland valleys which are more or less parallel with the direction of the valleys, and the occurrence of blocks of stone at the foot of these valleys, derived apparently from rocks in the upper parts, establish that proposition. In several of these valleys there are also proofs of oceanic submergence, inasmuch as stratified beds of gravel, sand, and clay have been found lying over the glacier traces.

One of the questions suggested by these post-pleiocene deposits, both in England and in Scotland, is, *What was it that changed the climate so completely, causing the disappearance of the flora and fauna which previously inhabited the country?* The trees of the submerged forests, as well as the animals both on land and in the sea, indicate a temperate climate, almost the same as that which now prevails. We know, more particularly from the deposits in England, that this period was followed not only by a prodigious fall of temperature, but also by oceanic submergence. Either of these changes would be sufficient to account for the extinction of the races then existing in Great Britain. This inference is to a certain extent corroborated by the circumstances or conditions in which many of the remains of the animals are found.

We have, therefore, clear evidence of a most remarkable change

in the climate and physical conditions of the British Islands, even from the very short summary of facts given in these notes.

When the forests grew, which are now buried in the estuaries of the Tay and Forth, at Cromer, Lancashire, and other places, they must have occupied positions at least 500 feet higher than at present. The climate was then exceedingly temperate, as proved, not only by the nature of the trees, but by the nature of the mammalia, and, it may now be added, by the nature of the shells found in the river gravel of adjoining districts.\*

A change then took place, indicating not only a subsidence of the land, but colder conditions of climate. An immense body of sand was deposited over the forest, in which a shell called *Tellina Balthica* after a time made its appearance, now living chiefly in boreal regions. After this, the land seems to have risen; for in what had been the sea-bottom, plants "now only known within the arctic circle" began to grow. Again subsidence occurred, when boulder clay was deposited, in which Dr James Geikie states that he found sea shells and also erratics, confessedly transported from some far distant northern region.

No doubt the effect of these repeated oscillations must have been entirely destructive of all life in Great Britain. Complete submergence must ultimately have ensued; and when the time came for the waters again to subside, terraces would be formed on the mountains as referred to in the foregoing notes.

In the higher parts of the country, before they were reached by the sea, glaciers would probably be formed, making marks on the rocks, which are found covered over by beds of sand and gravel; and when the sea began to subside, glaciers would probably again be formed, which would sweep out from the valleys and hill sides much of what the sea had left.

#### R. *Changes of Climate in Great Britain, probably due to Oceanic Currents.*

There is one point to which in these notes I have not adverted, and which I hesitate to touch,—I mean what it was which brought

\* In the adjoining county of Essex, the old alluvia of the river Thames have *Cyrena fluminalis*, *Unio littoralis*, *Cyclas amnica*, and *Paludina marginata*, which are no longer British shells, but live in the South of France ("Antiquity of Man," p. 204).

about the changes in our country from temperate, or even semi-tropical, to arctic, and back again from arctic to temperate. One thing seems very obvious, that the rise and fall of the ocean was in some way connected with these climatic changes. When the sea rose so high as to cover the forests at Cromer and other parts of the coast, the climate became colder, so cold as apparently to destroy animal and vegetable life. Then, glaciers abounded in the Scottish Highlands; but when the sea subsided so as to allow a junction of England and the Continent, then the climate became again so temperate as to allow England to be again repopled by new tribes of mammalia, including man. When England and Scotland were so submerged, ice floated on the waters, and carried boulders which, all who have studied the subject allow, must have come from distant northern points. But in that case, there must have been a great oceanic current, similar to currents which exist now, flowing persistently for thousands of miles in one direction; and if it did flow from the north, it is quite intelligible how, loaded with ice, it should from the very first change the climate from temperate to cold.

If a cold climate in Great Britain was brought about by an oceanic current flowing on or over it from the arctic regions, why might not a temperate climate at some other period have been due to an equatorial current of warm water from the south? The climate in Scotland now is 20° warmer than it would be, were there no gulf stream flowing past it on its way from Florida to Spitzbergen.

Certainly there could have been no gulf stream, flowing as it does now, when Great Britain was submerged beneath the waters of an arctic sea. The isthmus of Panama, if then 350 or 400 feet lower than at present, would have allowed that "Sea River" (as it has been called) to flow into the Pacific, and finding its way to the north, through what are called Behring's Straits, would add so much to the amount of ocean in the northern hemisphere, as to give rise to a strong current of ice-cold water upon northern Europe.

These views are, I think, much in accordance with the opinions of Sir Charles Lyell; and I observe that they are adopted by Mr Russel Wallace in the interesting and instructive volume on "Island Life," who also mentions, that they were coincided in by the late Professor Dana, one of the most eminent of American geologists.

But there is one question which these views leave unanswered. They account for changes of climate by different oceanic currents; but they do not explain the rise of the sea, so as to reach to a height of 3000 feet above its present level. I am aware that Adhemar and Dr Croll have attempted to show that it is possible that the sea might in northern Europe rise several hundred feet, by the accumulation of ice to an enormous depth, about the North Pole; and that this might be greatly enhanced by astronomical causes. This, however, is a part of the subject which has not as yet obtained general assent; and I feel that it would be presumptuous on my part to do more than allude to it.