

FIFTH REPORT OF THE BOULDER COMMITTEE OF THE ROYAL SOCIETY OF EDINBURGH.

THE Committee had submitted to them Notes by the Convener of two visits to the West Highlands (including the Outer Hebrides) which he had made during the summer and autumn of 1878. These Notes, accompanied by diagrams of boulders and striated rocks, afford a large amount of information bearing on the subject of boulder transport, the direction of transport, and the agent of transport.

There has also been laid before the Committee a report by William Jolly, of Inverness, one of its members, "On the Transportation of Rocks found on the Shores of the Moray Firth;" as also Notes by Messrs Somervail and Henderson (Edinburgh), "On Boulders and Striated Rocks in the Pentland Hills."

The Committee have had an opportunity of seeing these Notes and Reports in printed proof sheets. The Convener, on his own responsibility, sent the MSS. to the printer; and the Committee approve of his having taken this course.

NOTES BY CONVENER OF TWO VISITS TO THE WEST HIGHLANDS AND HEBRIDES IN SUMMER AND AUTUMN OF 1878.

I.—ISLAND OF IONA.

The Convener having occasion to be in this island for a few hours, went to the boulder referred to in the Committee's Second Report, situated on the west side of Dun-Ii hill.

Its peculiar position appearing to him to deserve a more special notice, he gives in fig. 1 a sketch of it taken from the north.

The boulder consists of a coarse-grained granite. But in Iona there is no granite rock of any kind. The prevailing rock is a fine-grained gneiss, approaching in many places to clay slate.

Captain Stewart of Coll was with the Convener when he examined the boulder. On breaking off portions from it, and also from another small boulder lying below, exactly similar in composition, he at once said, "This is Coll granite."

These Iona boulders, in respect both of situation and position, undoubtedly indicate, that they were lodged by some agent which brought them from the N. or N.W. That agent had stranded upon the hill and stuck there till the boulders dropped from it.

From no eastern quarter could the boulders have reached their position. Their site is 250 feet above the sea. The hill on which they are, being 350 feet high, and forming a ridge of about a quarter of a mile running north and south, would preclude access from any eastern point.

The granite in the Ross of Mull, situated to the east of Iona, is different in composition from that of the boulders now referred to. On the east side of Iona there are granite boulders, similar to the Mull granite, as mentioned in the Committee's second Report. But the boulders on the N.W. shoulder of "Dun-Ii" are larger grained and of a different colour; and they occupy a level considerably above most of the granite rocks at the Ross of Mull.

With reference to Captain Stewart's remark, as to the large boulder above referred to being of the same kind of granite as in the island of Coll, the suggestion is so far favoured by the position of Coll, which bears about N.N.W. from Iona, and is distant about 20 miles. But on the other hand, the Convener must state that when he visited the island of Coll a few days afterwards, he found that the *rocks* everywhere were gneiss, and with only occasional veins of granite. The boulders he saw on Coll were of granite.

II.—ISLAND OF TIREE.

1. Heynish Hill, situated near the S.W. end of the island, reaches a height of about 600 feet above the sea-level. This hill consists chiefly of gneiss rock, though in some parts the ingredients become so coarse as to pass into granite.

The hill was ascended from the south side, under the guidance of Mr M'Quarrie, who is tenant of an extensive farm, on which the hill, or the greater part of it, is situated.

The hill on its west side abuts on the sea cliffs. The slope of the hill there has on it a number of rocky knolls.

Almost every knoll has on its N.W. side, facing the sea, boulders, more or less rounded.

The following are the dimensions of some of the larger boulders:—

(1.) $11 \times 8 \times 5 = 440$ cubic feet, resting on the side of a knoll facing W.N.W.

(2.) $9 \times 4 \times 5 = 180$ cubic feet, resting on the side of a knoll facing W. by N., at height of 360 feet above the sea, which is a quarter of a mile distant, and open between S. and N.N.W. This boulder is a coarse granite;—the knoll is gneiss.

(3.) $8 \times 7 \times 5 = 280$ cubic feet, resting on the side of a knoll facing N.W. by N., at height of 365 feet above the sea. Sea is quarter of a mile distant, and access from it is open at any point between S.W. and due north.

(4.) Two clusters of large boulders were met with, the uppermost so placed as to show that it must have come from the westward. The sea is within half a mile to the westward.

On this Heynish hill, the boulders are more numerous on the sides facing the W. and N.W. than on any other side. On the slopes facing the E. and S.E. there are also boulders, but in numbers not nearly so great.

2. After examining Heynish hill, the Convener passed through the island about due north along what is called the Big Cornaig Road. To the eastward of this road there are several rocky knolls, the tops of which are from 80 to 110 feet above the sea. Most of them present bare rock on their west sides, and have boulders also on these sides. One of these knolls was ascended, called “Drum-buim” (meaning yellow rock), for the examination of a boulder observed to be very near its top. Its dimensions were $10 \times 6 \times 6 = 360$ cubic feet. It consisted of a light coloured gneiss;—the rock of the knoll is also gneiss, but dark coloured.

Another rocky knoll, about a mile to the N.E. of the last, was visited to see some boulders, nicknamed, in Gaelic, “The Giant’s Pebbles.” The legend, as related by a native resident near the

place to the Rev. Mr McDonald of Helipol, who was the Convener's guide on this occasion, is that three giants living in Barra, wishing to try how far they could throw a stone, took the largest pebbles they could find at Barra, and flung them in the direction of Tiree, which is situated S.E. of Barra, and about 40 miles distant. The story goes, that the stones reached Tiree, and fell very near one another. The knoll referred to is clustered over with huge boulders. Three or four are from 8 to 10 feet high, and from 20 to 25 feet along each side. There may be about 20 or 30 boulders of all sizes; they are on the knoll, and none on the flat ground adjoining, a circumstance suggesting that the knoll, by being above the adjoining surface of the land, had intercepted the agent which was carrying the boulders, and caused them to be deposited there.

3. "*Ben Gott*" hill, on the north side of Tiree, forms a ridge running north and south for about a quarter of a mile, and is from 120 to 130 feet above the sea. A very large number of boulders, chiefly gneiss, are on its N.W. flanks. A few occur on the flat summit, and some are also on the S.E. slope, as if they had been pushed over the top from the N.W. On the flat ground beyond the limits of the hill towards the S.E. there are few or no boulders.

4. In Tiree, the evidence of the sea having stood recently at a higher level is very striking. On a great part of the island there are extensive beds of a stratified muddy sand, sometimes 15 to 20 feet deep, evidently a sea deposit. In other parts of the island there are huge beds or banks of shingle, composed chiefly of well rounded pebbles of hard gneiss rock, similar to what occurs on the existing shores of all the Hebrides, at places exposed to the action of heavy sea waves. The pebbles in these shingle banks sometimes are twice the size of a man's head, but the great mass of the pebbles are half of this size. They point to a period when the sea must have stood here at least 40 feet, probably more, above the present level, and when, by the force of the waves, fragments of gneiss rock were worn down into elliptic, and sometimes even perfectly spherical, forms. The Convener brought away a few specimens.

III.—ISLAND OF COLL.

1. Under the guidance of the Rev. Mr Fraser, Free Church minister, the Convener visited Bein Hock, a hill on the west side of

the island and very close upon the sea. Its highest point is about 290 feet above the sea.

At the foot of this hill there is another low hill, called Bein Meanach, above 80 feet above the sea. Fig. 2 gives a sketch of both hills. Ben Hock has two boulders on its top, the smaller one, A, 260 feet, the larger one, B, 270 feet above the sea. Enlarged views of these are given in figs. 3 and 4, to show their size and position, and the fact (which Mr Fraser thought curious) that each rests on three smaller boulders. A rests on a rock surface sloping down N.W. at an angle of 16° . The rock on which B rests is nearly flat.

The boulder C on Meanach has nothing peculiar about it, except for size—it being $16 \times 20 \times 13$ feet.

These boulders are a coarse granite, which, however, in some parts passes into a dark-coloured gneiss. The rock of the hill is also gneiss; but they are all veritable erratics, and must have come from some region in the N.W.

2. Mr Fraser next guided the Convener to a spot situated about half-a-mile to the east of Ben Hock, at Grassipol, that he might look at what he (Mr Fraser) considered to be an immense accumulation of boulders.

The Convener, on viewing the place from a distance, thought that the blocks might be only fragments from a cliff adjoining, and not erratics; but, on going to the spot, he found they were boulders, and in positions of much interest. They were lying in many cases over one another on a flat meadow, and formed an elongated heap, more or less parallel with the line of a hill distant thirty or forty yards from them to the S.E. The meadow extended N.E. and S.W. about 350 to 400 yards, and towards the N.W. about 200 yards—viz., in width. The height of the meadow above the sea was about 80 feet. The sea was situated to the N.W., and distant about three-quarters of a mile. The height of the hill above the meadow on the S.E. was about 80 feet. A few boulders were lying scattered on the slope of this hill facing the N.W. It was manifest that the great accumulation of boulders on the meadow along the base of the hill could be best explained by supposing that the boulders had all come from the N.W., and had been stopped by the hill in an easterly movement. One of the boulders

on the meadow was 30 feet in height. (Fig. 5 gives a view of this spot.)

Near the west end of the hill just referred to there was a projecting knoll which had apparently intercepted a number of boulders. There were about twenty altogether piled on one another, and so piled as to indicate that the uppermost could not well have obtained its position except by coming from a N.W. direction. (Fig. 6 is intended to show this cluster of boulders.)

Close to this place there was a vein of quartz, which showed a smooth surface, sloping down towards the N.W., as if polished by some agent which had pressed heavily over it from that direction.

3. In crossing the island, from Arinagour on the east coast to Bein Hock on the west, by the road leading past Arnibost schoolhouse, there is a manifest difference in the size and number of the boulders. At and near Arinagour the boulders are few in number, and small. At and near Arnibost, which is about a mile inland, they become numerous, and occupy significant positions, many being on smoothed rocks facing the west.

At Grassipol, and on the sea-coast adjoining Bein Hoek hill, there are boulders of enormous size. The rock on which most of these boulders lie is about 90 feet above the sea, and slopes down towards the W.N.W. at an angle of about 10° . It presents a surface due apparently to some powerful agency which has levelled and smoothed it. Many other examples of this can be seen, close to the highroad near the schoolhouse of Arnibost, and particularly on the low rocky hills south of the road.

These smoothed rock surfaces, sloping down towards the northwest, are easily distinguishable from the natural surfaces of the rock strata. The gneiss rock, especially in this part of the island, is seldom in the form of regular beds. Where such occur, the dip is not towards the N.W., but towards the S. and S.E.

At the S.W. end of the island there are several granite boulders lying on gneiss rocks. One, which was the largest he saw, attracted the Convener's special attention, lying close to the mansion-house of Coll, belonging to Mr Stewart. Its length was 35 feet, its width 15 feet, and its height above the surface of the ground 8 feet. It was leaning on, or at all events pressing against, a mass of gneiss rock on its S.E. side. The granite was coarse-grained

and reddish, because of the felspar in it. Preparations were being made for blasting the boulder. As Captain Stewart was well acquainted with this huge block, he had been probably thinking of it when he saw the Iona Boulder, and compared it to Coll granite.

4. Macculloch, in his account of the geology of Coll, refers to a "block of *augit*" which, he says, he found at a great distance from the shore, and which he thought must "be a *transported* block," as he had seen no such rock *in situ* in the island, and he throws out a conjecture that it may somehow have come from Rum, of which island augit, he says, forms a large portion. This block of augit the Convener did not meet with.

The island of Rum is situated north by east of Coll, and distant about twenty miles.

5. It is somewhat curious that two of these Coll boulders should be described in Dr Johnston's narrative of his tour through the Western Highlands, and in Boswell's Diary. The passages are as follows :—

Johnston says :—"For natural curiosities, I was only shown two great masses of stone, which lie loose upon the ground—one on the top of the hill, and the other at a small distance from the bottom. They certainly were never put into their present position by human strength or skill ; and, though an earthquake might have broken off the lower stone and rolled it into the valley, no account can be given of the other which lies on the hill, unless (which I forgot to examine) there be still near it some higher rock from which it might have been torn. All nations have traditions that their ancestors were giants, and these stones are said to have been thrown up and down by a giant and his mistress."

Boswell, in his notes referring to these boulders, says :—"Coll and I passed by a place where there is a very large stone—a vast weight for Ajax. The tradition is, that a giant threw such another stone at his mistress up to the top of the hill at a small distance, and that she, in return, threw this mass down to him—all in sport. *Malo me petit lasciva puella.*"

Again Boswell writes, 9th October 1784 :—"As in our present confinement, anything which has even the name of curious was an object of attention, I proposed that Coll should show me the great

stone, mentioned in a former page as having been thrown by a giant to the top of a mountain. Dr Johnston said he would accompany us as far as riding on horseback was practicable—which he did. Coll and I scrambled up the rest. Dr J. placed himself on the ground, with his back against a fragment of rock, while we were employed examining the stone, *which did not repay our trouble in getting to it.* Dr J. amused himself reading a book which he found in the garret of Coll's house."

The stone mentioned in these extracts as at the "top of a mountain," is the one at the top of Ben Hock, marked B, and shown in fig. 4.

The other stone, mentioned as being at a "small distance from the bottom," is C.

Boswell observes that an examination of the boulder at the top of the hill did not repay his trouble in getting to it; but, if he had been able to elicit, from a study of the boulder and its site, the information which geological science now reveals, he would have thought that the trouble of getting to it was well repaid, and he would have been able to give a more probable explanation of how it came to the top of the hill, than that a giant threw it up there at his mistress.

IV.—ISLAND OF STAFFA.

In the Committee's second Report notice is taken of a hasty visit to this trap island by the Convener, which, having occurred on a stormy day, afforded an opportunity of discovering only one or two blocks of red granite.

On account of the interest of finding on an island boulders or even pebbles of rocks, not existing there *in situ*, the Convener, in June last, paid another half-hour's visit to Staffa, by means of the passenger steamboat, which takes tourists to the caves.

He remembered that, on the occasion when he formerly visited the island, the boulders fallen in with were chiefly in the foundations and walls of ruined cottages and sheep stalls. The basaltic rocks of the island were no doubt found less suitable for building purposes. On this occasion, by the advice of the captain of the steamer, the Convener sought for pebbles and boulders in a small bay on the east side of the island. He found several small boulders

lying on the surface, not only of red granite, but also of gneiss, quartzite, and limestone, none of which occur as *rocks* or *strata* in Staffa.

About fifty yards from this place, a bank of consolidated shingle was observed, apparently an old sea beach about 36 feet above high water-mark, from the breaking up of which, in all probability, the boulders above specified were derived.

Dr Macculloch, when he visited Staffa in 1818, noticed these boulders, and was much puzzled to account for them. He says—“I must not quit Staffa without describing a bed of matter which, however foreign to the structure of the island, is by no means foreign to its mineral history, giving rise, at the same time, to geological questions of considerable importance. This is an alluvial deposit, consisting of various *transported stones*, which may be seen on the surface in different parts of the island. It is particularly conspicuous near the landing place, and on the western abrupt edge of the cliff. The fragments are of various kinds—quartz, granite, and blue schist, intermixed with blue quartz rock, and trap—all of them substances which enter into the composition of the neighbouring islands of Rum, Skye, and Mull; but which are found *in situ* no nearer than in the latter island. The distance of Staffa from Mull is not less than seven miles. The surface of the Earth everywhere presents appearances indicating great changes and revolutions, of which none are more unquestionable than the existence of transported stones and alluvial substances in countries far removed from those where similar rocks are now found in their natural situations. The insular position of the example now under consideration, proves that it could not have resulted from the flow of water, whether that flow was gradual or sudden, without at the same time supposing a state of the surface in which Staffa was continuous, at least, with the neighbouring island of Mull.” (Vol. ii. p. 22.)

Macculloch here evidently alludes to the theory originally propounded by Sir James Hall for explaining the transport of boulders by a diluvial current. To render such a theory applicable to the Staffa boulders, Macculloch assumes the necessity of joining the island to Mull, though there are now seven miles of sea between them, with a depth of 50 to 60 fathoms. At that time, the idea

of ice, in any form, as a medium of transport had not been thought of.

V.—ISLAND OF BARRA.

This island, near its north end, contains a magnificent boulder. Its size exceeds that of any seen by the Convener in Scotland, and the site it occupies is full of interest. The legend, before referred to, of giants in Barra throwing large boulders to Tiree, may have been suggested to the Tiree people, by hearing that very large boulders existed in Barra.

On figs. 7 and 8, two views of this boulder are given, both from the north. The first view is taken at about 200 yards, the second about 50 yards distance.

The boulder rests on a broad mass of gravel and sand, with numerous cockles in it, at a height above the sea of 230 feet. It is distant from the sea about a quarter of a mile. The present shore is to the north. The great open ocean is chiefly to the N.W., and very partially to the N.E.

The Convener dug below the boulder in several places, and found everywhere sand and fine gravel. A number of rabbit burrows, under and about the boulder, confirmed this observation regarding the materials of the site.

The height of the boulder is about 25 or 26 feet. Its extreme length is from 37 to 38 feet; and its width about 18 feet—assuming two tons for a cubic yard, the weight of the boulder would be nearly 890 tons.

The longer axis of the boulder was found to be N.W. by N.

The flat on which the boulder rests, consists apparently of a sea deposit.* Patches of a similar deposit occur in several spots round and near the boulder, and at higher levels. For example, there is a rocky knoll, about 100 yards to the west, clustered with boulders, 255 feet above the sea. These boulders are lying partly on rock, partly on the shelly gravel. Ben Erival is a hill adjoining the big boulder on the south, and reaching to a height of about 600 feet above the sea. Sand with shells was found among the rocky crevices of the hill, up to a height of 457 feet.

The boulder consists of a coarse gneiss almost approaching granite.

* See note on page 67.

The gneiss of Ben Erival, and of the other adjoining rocky knolls, is more close-grained in composition.

On fig. 9 there is a ground plan, from memory, showing the position of the boulder in relation to adjoining hills. Ben More, which reaches a height of 330 feet above the sea, and is about a mile to the north, is covered with thick beds of sand and fine gravel, full of cockle and other sea shells.

It is also worthy of notice that at present, the bay, immediately to the north of Ben Erival, has in it an immense bed of living cockles—so immense that it is found profitable to gather them from time to time, and send them to Glasgow for sale.

There is something therefore in the sea or the sea-bottom in this district, which now as formerly favours the growth of the *Cardium edule*.

That this “Big Rock of the Glen” forms a veritable boulder, and that, when it was brought to the spot which it now occupies, it was deposited on what was then a submarine bank, not much doubt can be entertained.* The boulder must therefore have been floated to the spot where it now lies—but from what quarter? From the S., S.E., or S.W., come it could not;—as Ben Erival, on whose north flank it rests, and which ranges for about two miles east and west, precludes that idea. There being open sea to the N.W. and N.E., from either of these quarters it might have come, but from no other.

The plan on fig. 9 explains more clearly how the boulder might have been floated from these quarters, and been intercepted in its further progress to the south by Ben Erival.

An examination of the numerous smaller boulders in this district, also indicated transportation from some point between west and north. The following are cases:—

1. To the west of the big boulder, and about 100 yards distant, there is a small but steep rocky knoll (fig. 9, letter *b*) whose top reaches to a height of 255 feet above the sea, and which is covered with boulders, especially on the N.W.

On a minute study of the relative positions of the boulders on this

* The submarine character of the bank does not depend solely on the presence in it of sea shells, for they might have been blown up from the existing sea-shore by storms. But the materials forming the bank being found, by digging under the boulder, to consist of sand and gravel, they afford the strongest evidence of a submarine origin.

knoll, it was found that those which were uppermost must have come from the N.W., otherwise they could not have got into the positions they occupy.

There were no boulders near the top of the knoll on the S.E. side ; but at the base of the knoll on that side, several boulders were lying, which might have fallen from the top. They were not heaped on one another, as they were at the top of the knoll, but lying separate.

2. About 200 yards to the N.E. of the big boulder there is a boulder on smoothed rock which dips due north at an angle of 20° . The size of the boulder is $5 \times 4 \times 4$ feet. The steepness of the rock surface on which it lies, is so great, that it would have a better chance of obtaining and retaining its position by coming from the north, than from any other quarter.

3. About 300 yards to the S.E. of the "big boulder" there is a boulder $8\frac{1}{2} \times 6 \times 5$ feet, at a height of about 228 feet above the sea, shown on fig. 10. The boulder at its east end presses closely on a rock, which has prevented it moving further in an easterly direction.

4. On the N.W. side of Ben Erival, where its sides slope down steeply to the sea, there are numerous boulders, and many of them pressing in like manner against the rocks of the hill, in such a way as to show that they must have come from some point between west and north. They are at various heights, from 400 to 500 feet above the sea.

5. There is a low hill to the N.N.W. of Ben Erival, adjoining "*Traighe Vore*," or Great Strand (a narrow neck of sand which here separates the east and west shores), through part of which an open fissure in the solid rocks runs for some distance. It has evidently been one of those rents alluded to by Macculloch in his Account of Barra, which had once been filled by trap, but "of which the exposed portions have been washed out." (Vol. i. p. 89.)

The height above the sea-level is about 120 feet.

For about 80 yards, this rent or fissure now presents two vertical walls of gneiss, from 11 to 12 yards apart, and from 8 to 14 feet high.

The direction of the rent is (by compass) N.W. and S.E. The rocks on the *north* wall are rounded, and in many places present

smoothed surfaces. The rocks on the *south* wall are rough and jagged. The appearances on the north walls can be naturally accounted for by the action of a strong sea current moving from W.N.W., which would, with any bodies floating in or swept along by it, grate against the north, but not against the south wall. (See fig. 11.)

6. Ben More is a hill on the farm of Eoligarry tenanted by Dr MacGillivray. Its west end forms a steepish sea cliff, rising up to a height of 330 feet above the sea. Half way up this sea cliff, there is a boulder, $20 \times 10 \times 5$ feet, resting on the rocky surface, which here dips towards the W.S.W. But the rock, judging by the marks on it, has been smoothed by something passing over it from the N.W., and the boulder is blocked at its S.E. end by a vertical portion of the hill, as shown on fig. 12.

7. At Castle Bay, which is at the south end of Barra, the hills are seen to be more covered with boulders on their N.W. sides than on any other. This observation, however, was made only from the steamboat.

Mr J. F. Campbell, in his paper on the "Glacial Phenomena of the Hebrides," states that, in Sept. 1871, he took rubbings of striæ at Castle Bay, showing that the striating agent had come from N. by W. (magn.)

He mentions also that on the small island of Bernera, above 12 miles to the south of Barra, "the last of the Hebrides," he got striæ at a height of 720 feet above the sea, crossing the strike of the rock, from N.N.W. (*Lond. Geol. Soc. Journal*, vol. xxix.)

In coasting along the east shore of Barra it is perceivable, from the deck of the steamboat, that the rocks on the sea cliffs which face the N.W. have been smoothed, whilst the rocks facing the east are rough and jagged.

8. On the hill called Scurrival, whose west side rises abruptly up from the sea to a height of about 240 feet, the hard gneiss rocks present many proofs of grinding, and also of transporting agency from the N.W.

The rock-strata here are tolerably horizontal and form blocks lying about north and south. The vertical sides facing the sea present frequent smoothings, which could have been made by the action of a strong N.W. current, especially if loaded with

ice. (See fig. 13.) The surfaces facing the east present no smoothings.

The examples are numerous on this hill of boulders blocked on their S.E. ends or sides. They are cases exactly similar to that shown on fig. 12. These boulders are within 200 yards of the open ocean, and less than 100 feet above its level. The situation and position of these boulders combine to show that they *must* have come from the westward—though in that direction there is only the wide Atlantic.

At the very top of the hill, which consists of well rounded and smoothed surfaces of gneiss, numerous boulders lie scattered—most of them on that part of the top facing W.N.W.

VI.—ISLAND OF SOUTH UIST.

1. Beginning near the south end, notice has to be taken of a well striated gneiss rock, recently exposed by the removal of materials for the high road. The spot is on the east bank of Loch Dunkellie and at the west side of a hill called Carshavaule, which is marked on the Admiralty map as 226 feet high. The striated rock is only about 20 feet above the sea-level.

The rock had been covered by a bed of coarse sand intermixed with clay, so that its surface had been protected from the weather. The protecting cover contained numerous pebbles, hard and angular, the pressure of which on the rock, if they passed over it, would probably cause *striæ*.

The rock consists of strata which dip W.S.W. at an angle of about 10°. They were thus conveniently situated for being struck and pressed on by any striating agent from the west.

The lengths of the blocks rounded and striated were respectively, 4, 7, and 5 feet.

The *striæ* run in a direction N.W. by N. and slope up towards S.E. by S.

If these *striæ* were caused by rough stones carried in a strong current flowing from the N.W., or pushed by floating ice, the *striæ* would slope upward in the above direction, because the current would in this low lying spot have to rise, to pass through a valley situated close at hand, immediately to the south of Carshavaule hill.

Mr J. F. Campbell in his paper (before referred to) states that in

a quarry by the roadside of Boisdale in South Uist, he observed "striae running from N. 40° W. (magn.) pointing at a gap in the hills." This is probably the same spot as that noticed by the Convener. It was shown to him by Mr Drever, factor to Mrs Gordon of Cluny.

2. Loch Boisdale, a sea loch, is situated on the east coast. On the north side of the loch, there is a hill called Kennet, reaching to a height of about 890 feet.

The rocks on its N.W. side, from bottom to top, present numerous examples of flattened and rounded surfaces. The surfaces facing the S.E. on all sides of the hill are rough and angular. On the west side of the hill, at various levels between the bottom and the top, there are numerous boulders, some of them, by the way in which they lie, affording unmistakable evidence of the direction from which they came.

For example, there are two boulders on a narrow shelf of rock which slopes down S.W. at an angle of 40° . The shelf is 96 feet above the sea, and quite close to the sea. The shelf is on the sea cliff, which is so steep, that the wonder is, how the boulders could have found a cleft in it to hold them. (Fig. No. 14 shows these boulders.) On the east side of the boulders there is a projecting ledge, against which the eastmost boulder (A) presses, and which had stopped its farther progress eastward. Another boulder (B) lies upon (A), and which, to get on the top of (A), must have come from some westerly point,—probably the N.W. A line through the chief points of contact and the centres of bulk runs in a direction N.N.W. A study of the boulders on the spot showed that, if they had been brought to this site from any other direction, they would inevitably have slid down the steep rocky bank into the sea. These blocks are nearly equal in size, viz., about $5 \times 3 \times 2$ feet.

Fig. 15 shows a large boulder of coarse granite resting on a wedge of gneiss rock. The wedge or knob is under the boulder at its east end, and tilts up the boulder slightly so as to show daylight under the boulder at that end. It rests on the ground chiefly at its west end. By this wedge (*a* in the figure) the boulder has evidently been stopped in its progress from the N.W. From its rounded shape, one might infer that the boulder had been rolled or

pushed for some distance before it was stopped. The west side is much rounder and smoother than any other side; so, probably after it had stuck, the current which brought it, beat and chafed on its west side, and smoothed it. This boulder lies on a level plateau of rock about 202 feet above the sea. It is all open country towards the N.W. and N.E., whilst the Kennet hill, reaching to a height of 890 feet, is within half-a-mile of the boulder to the S.E. and E.S.E.

On the west slope of this hill, at a height of 300 feet above the sea, the gneiss presents a rocky surface sloping down towards the west at an angle of about 10° . A boulder of coarse granite, $7 \times 6 \times 4$ feet, rests partly on it and on another smaller boulder underneath. This boulder, at its S.E. end, abuts against the rock. It has come, therefore, almost certainly, from some north-westerly point and stuck there. (Fig. 16 represents this case.)

Not far from the top of the hill, viz., at 712 feet above the sea-level, there is a very large angular boulder on a flat ledge of rock, on the N.W. side, with open country in that direction. This boulder is $19 \times 13 \times 8$ feet. Its further progress eastward has evidently been stopped by a projecting cliff of the hill on its south-east side, as shown in fig. 17.

3. Several large boulders may be seen at a small village, where the Free Church and Roman Catholic Church are situated at a junction of the roads from Barra and Loch Boisdale, about two miles to the south of Askernish. There is here a whole cluster of boulders. One, $16 \times 6 \times 5$ feet, leans slanting upon the others, and must have come from the N.W. to attain its position.

4. On the hill to the east of Askernish, and on its side facing the west, there is a surface of rock, sloping down W.S.W. at an angle of 30° , well smoothed. A boulder rests on this slope, partly on the surface of the rock and partly on some smaller boulders which lie between the rock and it, near its S.E. end. The boulder has evidently obtained its position by coming from the N.W.

This is more clearly proved by a number of ruts or *striæ*, visible on the rock a few feet below the boulder, which run, as shown on fig. 18, by the arrows, in a direction from N.W. to S.E. That the striating agent first struck the rock from the N.W., is made evident by the circumstance that most of the *striæ* are deeper and wider at

their N.W. than at their S.E. ends. This change in the striae can be accounted for by supposing that the striating agent as it moved over the rock, acted with a lessening pressure, by having rebounded from the rock after the first impact.

5. On Mingary Hill, reaching a height of about 600 feet above the sea, three miles N.E. of Askernish, many boulders occur, especially, as usual, on the N.W. flanks. Most of them occupy separate spots—but in some places they are in clusters—heaped on one another. In this last class of cases, there is generally a knoll of some kind standing up above the general surface, on or round which the boulders lie.

One of the most interesting spots on this hill is a spur from it projecting N.W., to which Mr Drever (who resides at Askernish), conducted the Convener. His object was to point out there a boulder of considerable size which had shortly before been seen by Mr Jolly of Inverness. The hill in question is shown in fig. 19. The hill here reaches to a height of 270 feet above the sea, and it slopes down at an angle of about 15° to the N.W. But about 30 or 35 feet from the top, there is a horizontal plateau, on which a number of boulders lie together. Has this been an old sea-margin, from which the smaller stones have been washed away, leaving on it, as on a beach, the heavier boulders? The largest boulder in the figure, lower than all the rest, is $11 \times 9 \times 8$ feet. It lies on bare rock sloping down towards the N.W., from which quarter it, as well as all the others, had apparently come. The transporting agent seems to have struck upon the hill, and discharged its cargo there.

Very near the top of the hill, there is a rocky surface, rounded and striated, the striae running N.W. by N. A vein of quartz about 3 inches wide crosses this rock, and for about 12 inches it presents a beautifully smoothed surface.

6. At a place called Jocdar, situated on the main road one and a half mile south of the Ferry between Uist and Benbecula, smoothed rocks have been exposed to view by the removal of gravel, &c. These rocks are at a height of about 25 feet above the sea. The rocks are literally covered by parallel striae, ruts, and grooves, the direction of all which is N.W. by W.

On these rocks there are twelve or fourteen deep ruts and

grooves, some of them 4 or 5 feet in length. One of them, at its N.W. end, measures 8 inches across, and 2 inches in depth; another measures at its N.W. end, 12 inches in width, and $1\frac{1}{2}$ inch in depth; another 9 inches in width, and $1\frac{1}{4}$ inch in depth. These, and most of the others, show a greater depth and width at their N.W. than at their S.E. ends. In fact, they all gradually lessen and disappear towards the S.E.

At this place, the smoothed faces of the rock slope at an angle of 10° or 12° to the westward.

7. There is another exposure of well rounded, smoothed, and striated rocks, close to the Ferry between Benbecula and Uist—*i.e.*, about half a mile to the west, on the south side of a bye road. The rocks are here, as at the place last mentioned, of hard gneiss, and most beautifully polished. They had been covered by a bed of clay containing numerous hard pebbles, a portion of the bed still remaining upon the polished rock. Here, as at Jocar, some of the grooves are several inches in width, and as much as 2 inches in depth, and several feet long. The deepest and widest ends are also, as before, at the N.W.

One of the rounded rocky bosses is polished not only on the top but at the sides, as shown on fig. 20. Having regard to the bearings of the knoll, which is elliptic in shape, the polishing and striation on both sides could have been effected only by a current flowing from the N.W.*

8. On the road between Grogarry (the mansion-house of Mrs Gordon of Cluny) and Loch Skiport (on the east coast), the following places of interest were observed:—

At about $1\frac{1}{2}$ mile from Grogarry, on the south side of the road, the hard gneiss rock, which had recently been uncovered, was found to have been ground down and polished into extensive surfaces dipping N.N.W., at an angle of about 20° . These surfaces were covered by innumerable striae, and by several ruts and grooves—all running in a direction E.S.E. up the face of the rock at an angle of 7° or 8° . It is very probable that a current from the N.W., loaded

* These two beautiful examples of rocks, smoothed and striated, at Jocar and at the Ferry, were pointed out by Alexander Carmichael, Esq., Creagorry, who resides near the Ferry. Both he and Mrs Carmichael took much interest in the Convener's researches, the latter kindly giving to him sketches which she had made of several interesting boulders.

with hard gritty materials coming against the rock dipping as above explained, would be deflected in its course along the face of the rock from S.E. to E.S.E. At the N.W. end one groove measured 2 inches wide and $\frac{1}{4}$ inch deep; another, 2 inches wide and $\frac{1}{8}$ th inch deep. They became fainter towards their S.E. ends.

At another place on the road side, the striæ ran W.S.W., but the surface of the striated rock faced the south, and it was in a confined valley only about 30 feet above the sea.

On the hill adjoining, 122 feet above the sea, a granite knoll on an open moor showed a deep rut about 18 inches long, running from W.N.W., its west end being deepest and widest.

At another place the boulder had in its progress eastward been intercepted by a vertical ledge of rock at its east end, and it was resting on a horizontal bed of rock, just as in figs. 10 and 12.

At another place there were 5 or 6 huge boulders piled over one another, all resting on a rocky knoll, standing above the general surface of the adjoining district. The topmost boulder, lying in a slanting position on the others, could have obtained that position only by coming from the westward. This spot was 80 feet above the sea.

About 3 miles to the north of Askernish, on the east side of the main road, there is a perched block of granite, on the pointed summit of a rocky hill about 130 feet above the sea. Two views are given in figs. 21 and 22. The base on which the boulder stands is exceedingly narrow. The boulder is in size $14 \times 12 \times 8$ feet, and its contact with the rock is only 6×4 feet. A steep hill rises near the boulder on its east side, but the boulder could not have fallen from it. That hill would arrest an iceberg or ice-floe, if the boulder came in that way from the west. As the ice melted, the boulder might have subsided gently on the peak. Some smaller boulders cap a rocky knoll below, as shown on the figures. All these indicate transport from the N.W. by some means.

9. *Loch Eport* is a remarkably narrow arm of the sea, on the east coast, which runs more than half-way across North Uist, towards the west coast. From the deck of the steamboat numerous boulders were seen, most of them resting on knolls. The smooth faces of the rocks were all strikingly towards the N.W., whilst the rough and jagged rocks all fronted the S.E.

(10.) *Loch Maddy*, a sea loch on the east side of North Uist. A walk for about a mile among the hills, during an hour that the steamboat was discharging cargo, showed that the rocks had their smoothest sides towards the N.W., and their rough sides towards the S.E. Boulders in great numbers were lying on these smoothed surfaces, and on the N.W. sides of the hills.

Before concluding his notice of Uist, the Convener may advert to one feature in the physical aspect of the island, viz., the extraordinary number of small lakes. When any of the hills are climbed, which afford even a tolerable view of the low grounds, it would almost seem that more of the island consists of lakes than of dry land. The cause of this feature probably is, that the general level of the island is so little above the sea, that the hollows occupied by these lakes can never be emptied. It is another striking feature, that most of these hollows lie in the same direction, viz., W.N.W. and E.S.E.

VII.—ISLAND OF CANNA.

The Convener when in the steamboat made the acquaintance of Mr William Bain, generally residing at Tiree, who takes contracts for erecting buildings in the Hebrides. He mentioned that he had lately built a new schoolhouse in Canna, an island situated near Rum. He told the Convener that he had found on the islet of Sanda, which forms the south side of Canna Harbour, blocks of a red sandstone which he made use of for the lintels and corners of the school doors and windows. The largest of these blocks was about $6 \times 4 \times 2$ feet. He knew that these sandstone blocks differed from the rock of the island, which he described as a sort of blue slaty schist, ill-adapted for building. He recognised these red sandstone blocks as of the same nature as rocks in the island of Rum, which were good for building purposes, as he had quarried them for that purpose.

This statement by Mr Bain is confirmed by Macculloch. He says—"Sandy isle, like Canna, presents examples of a circumstance rare in the Western Islands, viz., loose fragments of a different rock from that of which it is formed, lying on the surface. There are large blocks of red sandstone somewhat rounded, and they are found in considerable abundance on the flat shores of both. 'The

rock of which they consist is that which forms so large a portion of Rum and of Skye.' " (Vol. i. p. 467.)

With reference to the conjecture that these red sandstone boulders in Sandy may have been transported from Rum or Skye, a probability of its correctness is afforded by the circumstance that the red sandstone rocks of Rum and Skye are situated on the sides of these islands facing Sandy and Canna.

VIII.—HARRIS.

1. At Rodel, the south end of Harris, there is a hill called Strondaval, 638 feet high. It is steep and rocky on all sides, especially the west and south. The Convener, under the guidance of Lord Dunmore's gamekeeper, scrambled along its south and east sides, and found that the smooth faces of the rocks all looked towards the W.N.W. On the east side of the hill there was an entire absence of smoothed rocks. That side had apparently been the lee side, not having been grated upon by the agency, whatever that was, which had smoothed the west side.

There were many boulders on the hill, chiefly angular; some pretty large, but none of any special interest.

2. At Borve, on the west coast, about half-way between Rodel and Tarbert, there is a remarkable accumulation of boulders on the side of the hill, sloping down to the sea. The general dip of the hill (which reaches a height of about 800 feet) is towards the west or west by north (magn.). The rocks are of gneiss, and present a series of beds, layers, or benches more or less horizontal, forming, as it were, a gigantic staircase along the hill face for about half a mile, several hundred feet high—all more or less covered by boulders. These benches of rock, in many places, show that they have been rounded by severe pressure from west by north. The boulders which lie on them give evidence of transport from the west.

Fig. 23 is intended, by a sectional view of the hill, to show the disposition of its rocks and the position of the boulders on them.

Fig. 24 gives a view of two boulders lying on a portion of the rocks forming the hill just mentioned. The position of both indicates blockage and stoppage on their east sides. Their own relative positions afford similar evidence.

3. Near Lach Castle valley, *i.e.*, about $1\frac{1}{2}$ mile south of it, and about 2 miles north of Borve, a striated rock was observed on the roadside. It had recently been uncovered by the removal of road materials. The rock was Silurian. It was well smoothed, and sloped gently to the west. The *striæ* were minute, but quite discernible, and running N.W. The rock was on the N.W. side of the hill called in the Admiralty chart Carron Hill, and close to the sea, which was all open toward the N.W. As Carron Hill, with a height of 786 feet, was to the S. and S.E., the presumption afforded by the surrounding land features was that the striating agent had come from the north.

4. Lach Castle bay and valley is shown on figs. 25 and 26. When the tide is out, the road between Borve and Tarbert crosses a sandy flat; but when the tide is up, the margin of the land is indicated by the dotted line. There is an immense accumulation of boulders on the S.E. side of the hill marked A, where Carron Hill, above referred to, is situated. The X on the fig. indicates the spot where the striated rock was observed.

If, when the sea stood say 1000 feet or more above its present level, boulders were brought by a current from the N.W., the facts observable in this Lach Castle valley could be explained.

In that case, the current would flow through the valley, pressing most upon the range of hills on the east side, and smoothing its rocks; whilst the rocks on the west side of the valley would remain rough. This is found to be the case on an examination of the two sides of the valley.

Icebergs or floe ice carrying boulders may have flowed up the valley from the north, discharging them chiefly on the hills along the east side of the valley. These hills bear on their sides and ridges numerous boulders, some of large size. Several of these were examined, and one or two gave indubitable proof, by their sites and by their own positions, that they had come from the north or N.W.

In the centre of the valley there is an elongated ridge (as shown on fig. 25, *l.c.*) which bears far more boulders than the depressed portions between it and the sides of the valley. There may be two ways of accounting for this. If the valley was originally of its present form, any ice borne on a current flowing through the valley

from the N.W. would strand more frequently on the central ridge and on the east side than elsewhere. If the valley was originally filled up to the level of the central ridge, the debris at its two sides must have been scoured out by the rivers now flowing through it; and in this case, whilst the boulders in these parts would gradually find their way to the channel of the rivers and to the sea, the central ridge would retain most of the boulders originally lodged on it.

On this ridge the smoothed rocks face due N. and not N.W. This deviation may be accounted for by the valley here being between two elevated ranges of hills running almost due north and south, which would cause the current to flow in a direction due south.

One of the boulders on this central ridge measured $16 \times 14 \times 12$ feet, = about 200 tons in weight.

It will be observed that on the S.E. side of A there is a large accumulation of boulders. These might have been floated there by an eddy occasioned by the projecting headland near A.

5. Almost $1\frac{1}{2}$ mile to the south of Tarbert, there are several large boulders, on the east side of the high road leading from Tarbert to Lach Castle. The Convener, on examining them, found them to be granite of a grey colour, whilst the rocks in the hills about them are gneiss.

These boulders being within half a mile of the sea, which is to the eastward, and being at a height of about 100 feet above the sea-level, it might have been presumed that they could have come from the eastward. But these boulders were on hill slopes facing the west; and as the slopes were steepish, it was not easy to understand why, if the boulders had come from the east, they had not rolled to the foot of the slopes. On the other hand, there were towards the west and north, ranges of hills, reaching to heights above the level of the boulders, viz., to about 200 or 300 feet. But towards the N.W., and at a distance of three-quarters of a mile, there was a gap or depression in the hill range; and, in applying the spirit-level, it was found that the depression was about the same level as the boulders, so that they might have come from that quarter by flotation, and been lodged on their present sites.

Fig. 27 is intended to represent what has just been described. B are the boulders, AAA a range of hills to the westward, with a gap in those at G, bearing N.W. from the boulders.

6. On the hills north of Tarbert there are many unmistakable signs of a N.W. current up to the highest level which the Convener was able to climb to, viz., 800 feet above the sea.

(a.) There are multitudes of knolls or bosses of rock, rounded and smoothed on their west sides, but rough on their east sides. There are none which show opposite markings.

(b.) There are many cases of boulders lying in such a way as to show that they had been stopped there in their progress eastward. One example is given in fig 28, where hard gneiss rocks had been rounded and smoothed from the westward, and a number of boulders—several of granite—were lying at the base of these rocks. A westerly current, if it smoothed the rocks, might have also brought the boulders.

(c.) At Avon Sue, or Fineastle, the handsome mansion-house of Mr Scott, banker, London, on the sea-shore about 11 miles west from Tarbert, the following observations were made:—

A little way up the hill, above the stables, a striated rock was met with. The smoothed rock sloped down towards the sea in a direction S.S.E. Three ruts on this smoothed surface when measured were found to be from 18 to 23 inches long, and about 2 inches wide. Their direction was due east and west. The ruts were deepest and widest at the west end. In consequence of the direction in which the smoothed rock sloped, a N.W. current, coming against it, would be diverted into a direction nearly due east. The lines of the ruts in that direction ran up on the rock surface at an angle of about 8° or 10° .

On this hill slope there were several boulders whose position indicated clearly that they had come from the westward,—that is, from the sea. These proofs were the same as those explained in regard to other cases (see figs. 10 and 12), and therefore need not be repeated here.

IX.—ROAD FROM TARBERT TO STORNOWAY.

1. Where the road leaves the sea and strikes north there are enormous boulders, partly buried in drift, on the west flanks of the hills. This road reaches its summit level at about 650 feet—a distance of about 2 miles. The valley is narrow, between ranges of high hills on each side, and runs in a direction E.N.E.

As the summit was approached, it was observed that the boulders became less in size and fewer in number. This is quite intelligible if all the country had been under the sea, and a current flowing from the W.N.W., as this valley, on account of its direction, would have no great force of current in it, and the passage would be too narrow for much ice to pass through it.

At the summit level, a striated rock was observed, the striæ running W.S.W., *i.e.*, parallel with the general axis of the valley.

2. At Ardvourlie there is a *trainée* of boulders extending for at least half a mile, running in a direction east by north. On examining several clusters of boulders, it became apparent that the boulders had come not from the east but from the west.

Ardvourlie, to which this *trainée* reached, is close to the sea, viz., on a branch of Loch Seaforth, and the valley rises in a direction about west by south. In following with the eye the line of the *trainée*, it was seen to point towards a gap or depression in the range of hills at the west, distant about two miles. The Convener regretted very much that it was not in his power to follow this *trainée* and investigate the correctness of his conjecture—that the boulders may have come from the westward through the gap.

3. Soval is a shooting lodge of Sir James Matheson, on the road to Stornoway, and about 12 miles from it. To the east of Soval there is a rocky ridge, distant about half a mile, and at a height of about 220 feet above the sea.

On this rocky ridge the smooth faces of the rocks look towards the N.W. Indeed, in the whole of the district north of Ardvourlie, a distance of about 15 miles, this was the case with all the hills passed.

On the ridge just mentioned there was a boulder close upon its edge, which gave clear indication of a N.W. current. The rock forming the site of the boulder had been smoothed, and it sloped towards W.N.W. at an angle of from 20° to 25° . The boulder is in size $5\frac{1}{2} \times 3\frac{1}{2} \times 2$ ft. The longer axis of the boulder is W.N.W., and its sharpest end is towards the west. It is shown in fig. 29.

4. For 7 or 8 miles to the south of Stornoway, the district passed through by the high road from Tarbert, Ardvourlie, and Soval, consists of an extended plain covered by peat and coarse pasture. The height above the sea is from 200 to 230 feet. No hills or even

rocks are visible. There is an entire absence of boulders. From the banks of the small streams and the ditches by the side of the road, it was plain that sand and gravel lies in great beds immediately below the surface.

X.—NORTH PART OF THE LEWIS.

The Convener, through the courtesy of Mr M'Kay of Stornoway, Sir James Matheson's factor, was enabled to visit Lochs Ourn and Sheil, arms of the sea, to the south of Stornoway, on the east coast of Lewis. He landed from the steam yacht at both of these places, and had time to ascend several hills.

The rocks here, as at most other places, present their smooth faces to the W.N.W., their rough faces to the E.S.E.

At Loch Ourn, one of the boulders at a height of 200 feet above the sea (size $7 \times 5 \times 4$ feet) lay on the west side of the hill upon a rock surface sloping down to N.W. at an angle of 20° .

At Loch Sheil, at a height of 325 feet above the sea, the only boulder of any size ($10 \times 6 \times 4$ feet) was on a hill-side facing W.N.W., and on a rock surface sloping down in that direction at an angle of 15° ; but 5 or 6 yards below the boulder, the slope down of the rock was 30° . The longer axis of the boulder pointed west by north.

The yacht steamed round the "Shiant" Islands, to afford an opportunity of seeing their magnificent basaltic columns. They are on a grander scale than those in Staffa, and exhibit remarkable curvatures. These islands are partly composed also of schists and stratified rocks, more susceptible of diluvial action than the hard basalt; and it was easy to see even from the deck of the steamer that a N.W. current had acted on them. Boulders also of considerable size were observed on the slopes facing the N.W.

The Convener regretted much that there was no opportunity of landing.

4. *Uig*, on the west coast of Lewis. On the hill near the parish church, about 186 feet above the sea, all the smoothed rocks front W.S.W., and on many rock surfaces sloping down towards west boulders were lying.

At two places, rocks were found with ruts and striæ. As at both, the general features were the same, one only may be illustrated by

a diagram, fig. 30, and on account of a peculiarity that the ruts crossed a fissure in the rocky surface.

The general surface of the smoothed rock at both places dipped due west at an angle of 12° , and looked out on the Atlantic Ocean, which was only a quarter of a mile distant. The direction of the ruts and striae was the same at both places, viz., W.N.W., and rising up E.S.E. on the surface of the rock at an angle of about 10° . Probably owing to the obstruction which a current striking the rocky surface, dipping due west, would meet, a W.N.W. direction would be the result of a current from the N.W. At both places the ruts were wider and deeper at the west ends than at the east ends. One of the ruts was carefully measured, and showed at the west end a width of 2 inches and a depth of $\frac{3}{4}$ of an inch; at the east end a depth of $\frac{1}{8}$ th of an inch; and there, the width ceased to be distinguishable.

The peculiarity before referred to was a small fault or fissure crossing the rocky surface as shown on the figure by the letters *a*, *b*, *c*. The fissure had caused, as it were, an upthrow of the rock, of about $\frac{3}{4}$ of an inch. Where the rut crossed the fissure, there was a slight deviation in the line of the rut, as shown in the figure. The hard pebble or stone which produced the rut, meeting with the obstruction caused by the upthrow, had been slightly diverted from its course, but it had eventually passed over the upthrow, breaking off the edge of the rock.

5. *Miavig* is a small hamlet situated on an arm of the sea, branching up from Loch Roag on the west coast of Lewis. About half a mile to the N.W. of Miavig a hill called "Dramamin Voltas" (height above sea 270 feet) rises above the general surface of the district, and has been the means of arresting a multitude of large boulders. They are clustered and piled over one another upon the north and west sides of the hill (see fig. 31). A few lie on the east side, a little way below, as if they had tumbled or slipped down from the top.

6. On the road from "Garry-na-hine" to Loch Carlowrie there are several objects of interest.

The hills are rocky. Their smoothed faces are all, as elsewhere, on and towards the west; their rough faces on and towards the east. There seems, however, to have been a slight change here in the direction of the current; for whilst at Breasdeit village the smoothed

rocks faced W.N.W., towards the north there was a gradual change to due west, and then ultimately at Carlowrie to W.S.W. and S.W. These deviations from the normal direction occur at low levels. Near the hill tops, at from 300 to 400 feet above the sea, there was little deviation from W.N.W.

The Convener examined a striated rock near the north end of Loch-na-Muilve mentioned by Mr James Geikie in his paper on the glacial phenomena of the Hebrides ("London Geological Society's Journal" for 1873, p. 537). As there are some points of interest on this rock not included in Mr Geikie's notice of it, a representation of the rock is given in fig. 32.

The rock dips down towards W.S.W. at an angle of about 30°. There are two portions of smoothed rock visible as shown in the figure—the space between them consisting of a stony clay, which probably lies on rock, though the rock is not visible. The part of the rock which is visible has evidently been smoothed by the passage over it of some material—such as the clay, of which a portion remains, containing pebbles and stones. The striæ and ruts are not all parallel. The lowest rise upwards across the rock at an angle of about 8°. The ruts in the upper portions of the rock surface rise up more quickly till at length, in the highest part, they rise at an angle of about 26°. Another feature is, that some of the ruts are deeper and wider at their west end than at their east end. The directions of the lowest ruts is N.W., of the highest W.N.W. If the general line of the current was W.N.W., the highest ruts would be more likely to indicate that direction than the lowest.

At Garry-na-hine, and also on the hills about two miles north of it, there are numerous cases of boulders on smoothed rock surfaces facing the west, the boulders being blocked at their S.E. ends by special obstructions, which were in each case distinctly observable.

7. Mr James Geikie refers to a water shed called "Beinn à Bhuna" on the road between Stornoway and "Garry-na-hine," where he says there are "smoothed and glistening domes of gneiss."

The Convener examined all the rocky knolls at the place referred to, on both sides of the summit level, which is about 400 feet above the sea. The smoothed surfaces are numerous, and particularly on the west side, where they face the N.W. The boulders are also more numerous on that side, and are generally on rock surfaces

dipping toward W.N.W. at angle of 10° or 12° . The longer axis of the boulders was mostly in the same direction.

8. About two miles east of "Garry-na-hine," a quarry on the road side at a height of about 160 feet above the sea had been opened for road materials. A tough strong clay covers the gneiss rocks here; and above the clay there are beds of gravel and sand, all evidently sea deposits.

9. The Convener visited the rocking stone on a hill 358 feet above the sea near Tolsta, about 12 miles to the N.E. of Stornoway. Resting on the gneiss rock, at a part of its base near the centre, it can be moved a few inches up and down by the hand only. It is about 18 feet long, 5 feet high, and 4 feet wide. Its longer axis points N.N.W. There is an opening among the hills in that direction, through which it might have been floated to its site; whilst towards the S.E. the hills reach to a greater height, and would prevent the boulder coming from that quarter. The boulder is extremely angular, and has undergone no rolling or pushing.

10. About five miles to the N.E. of Stornoway there are three hills called the Barvas Hills, each from 800 to 900 feet high.

The Convener examined the two eastmost hills, and found as follows:—

Both hills on the N. and especially the N.W. sides, present precipitous cliffs, and surfaces well rounded and smoothed; but no striae were seen.

On the W. and S.W. sides of the middle hill, there are also a few smoothed rocks.

There are boulders on both hills on all sides, and up to nearly the top, but they are in greatest numbers on the N.W. sides.

On the middle hill, very near the top on its N.W. side, one of the smoothed rocks is traversed by a thick vein of quartz. The quartz also presented a smoothed surface. A specimen of it was brought away.

There was one boulder ($6 \times 5 \times 4$ feet) lying on a side of the middle hill facing N. by E. It might have come from the N.W., as in that direction there was no obstruction. From N.E., E., S.E., or S., it is difficult to suppose it could have come, on account of the interposition of the eastmost hill.

On the eastmost hill, at a height of 700 feet on the north side,

rocks were found smoothed from the N.W. A portion of smoothed quartz was found here also.

11. The Convener drove along the coast from Barvas village to Dalbeag, a distance of about 9 miles. He was unable to reach Dalbeag hills, about 2 miles farther on. He could see, however, that these hills presented large surfaces of bare rock on their west sides. He ascended one or two other hills of granite situated close to the sea, and up to a height of about 380 feet. On these hills he found abundance of smoothed rock surfaces sloping down to W.N.W. In one case only, the direction was somewhat abnormal, viz., west by north.

About half a mile to the east of Dalbeag farm-house there is a steepish bank facing the sea (which is due west, and only a quarter of a mile distant), surmounted by a cliff, as shown in fig. 33. The bank is about 50 feet high, and is covered by boulders and gravel. On the very top, viz., about 285 feet above the sea, the bare granite rock has been planed down and is occupied by a number of boulders. The only boulders which showed direction of transport indicated a N.W. direction.

At Sheabost, a place between Dalbeag and Barvas, notice was taken of a remarkable assemblage of gravel knolls on both sides of the road, but not forming a continuous kaim. These knolls were approximately elliptic in shape, the longer axis being about 50 or 100 yards, their breadth 10 or 12, and their height from 20 to 30 feet. Most of these gravel knolls have their longer axis running in nearly the same direction, viz., north and south. Large boulders lie on these knolls, and mostly on the west sides.

The boulders were in some places piled above one another. The uppermost showed from their position that they had come from the westward. The height of these knolls above the sea is about 130 feet. The distance from the sea-coast is about half a mile.

Nearer Barvas village there is a lake called Urraghay, on the west side of which there is a remarkable assemblage of large boulders, some of them granite, forming a sort of *trainée* running W.N.W. No rock is visible here. The ridge on which the boulders lie seems to be composed of coarse water-borne gravel. One of the largest boulders measured $12 \times 10 \times 5$ feet. Its longer axis lay W.N.W. The uppermost boulders indicated transport from the N.W.

At Shadir, about 4 or 5 miles to the east of Barvas, there is a lake whose longer axis runs N.N.W.; its west bank has on it a considerable number of boulders, at a height of 240 feet above the sea.

At Galston farm and shooting-lodge there are some rocky cliffs, reaching to a height of 120 feet above the sea, bared as usual on the N.W. slopes, and having a few small boulders on these slopes.

A new school was built last year near Shadir, the stones for which consisted entirely of boulders extracted from under the peat. One of the masons employed on the school stated that many of the boulders consisted of Dalbeag granite, a variety which, on account of being better adapted for building than most of the rocks in the island, is well known to the native masons. One of the gateways to Stornoway castle was built of it. Dalbeag is distant from Shadir about 14 miles, and bears from Shadir west by south.

The scarcity of boulders in the district between Barvas and the Ness, when compared with their numbers almost everywhere else in the Lewis, may probably be accounted for by the absence of any ranges of hills in the north end of the island. If the sea stood 1000 feet or more above its present level, with a current in it from the N.W., and this current loaded with ice carrying boulders, it is to be expected that these ice floes, when obstructed in their progress by submarine rocks, would discharge their stony cargoes on these rocks, whilst in the districts where there were no submarine rocks, the current would flow on unimpeded.

12. In the neighbourhood of Stornoway there is the peninsula of Eye, on which the Convener found some smoothed rocks, and some boulders deserving of notice. Smoothed rocks occur to the west of Phabaill village, their smooth sides facing the west. Boulders of gneiss and of a hornblendic rock lie on the moor to the S.W. of the village. The rock *in situ* here is a species of conglomerate or breccia. The gneiss boulders most probably come from the Barvas hills, as they consist of gneiss. The Convener was told of a hornblendic rock, similar to that of the boulders, being on the N.W. shore of the Eye peninsula, but he had not time to go in search of it.

The Convener was informed by Henry Caunter, Esq., a gentleman of scientific knowledge resident at Stornoway, in the employment of

Sir James Matheson, of a sandstone boulder near the brickwork at Garabost, unlike any rock at present known in the Lewis; and he pointed out to the Convener some building stones brought from Loch Broom on the coast of Wester Ross, which he thought exactly resembled the rock composing the boulder.

As the occurrence of this sandstone boulder at Garabost is of importance, by its bearing on the question of transport, the Convener made a special inspection of it.

The Convener, having been introduced by Mr Caunter to M'Fadzyen, the manager of the brickwork, was taken by the latter to the boulder, and was informed by him that some years ago it had been partially blasted with gunpowder for building purposes. It had originally weighed about 8 or 9 tons, but the lower half still remained, showing its shape and position. The boulder was a coarse brown sandstone, full of quartz pebbles about the size of a small pea.

The boulder was on the side of a hill sloping towards the sea, on the N.W. side of the Eye peninsula, and facing the west. It was buried in a bed of gravelly clay, which had all the appearance of being a marine deposit, and it was within a mile's distance from Garabost brickwork. The height of the boulder above the sea was about 50 feet, and its distance from the sea about a quarter of a mile.

The Convener found on the surface of the same hill, sloping to the west, another sandstone boulder about the size of a man's head, exactly similar in composition.

The hill on the side of which these boulders were lying, rises up gently towards the S.E. to a height of about 160 feet above the sea.

Now it appears, from what Mr Caunter stated, that no sandstone rock, exactly similar to that of these boulders, had been seen in the Lewis; but, on the other hand, the geological formation or class of rocks to which these sandstone boulders belong, does exist in the Lewis. Dr Macculloch, in his geological map of the West Highlands, indicates, by its appropriate colour, this formation as occurring for many miles on the east coast of the island, near Stornoway.

The Convener had pointed out to him by Mr Caunter a long range of high cliffs along the shore, to the north and south of Stornoway, of a sandstone breccia or conglomerate, identical in composition with

a breccia or conglomerate occurring on the mainland, and which Dr Macculloch and Professor Nicol ("London Geological Society's Journal" for 1856, p. 37) concur in representing as "*the bottom beds*" of the great sandstone formation which lines the north-west coast of Scotland, and which constitutes the entire mass of a number of small islands lying off the coast, extending from Cape Wrath to Skye, a distance of about 100 miles. Dr Macculloch mentions having observed a similar conglomerate on the west side of the Lewis. ("Western Islands," vol. i. p. 196.)

These breccia sandstone cliffs extend along the east coast of Lewis for about 15 miles. Referring to them, Mr James Geikie ("London Geological Society's Journal" for 1873, p. 534) says that "red sandstone and conglomerate of Cambrian age cover a portion of the Eye peninsula and the shores of Stornoway harbour at Arnish point. The same deposits are continued north as far as Gres."—Gres is about 15 miles to the north of Arnish.

This sandstone formation is not confined to the coast. It extends some distance inland, though how far has not been ascertained. Mr Caunter showed to the Convener a bed of the breccia in the channel of a stream which runs through his garden on the north side of Stornoway. Mr Geikie, in his paper before referred to, suggests that "red sandstone may occupy the sea-bottom at no great distance from Cellar Head, and hence we are not compelled to suppose that these sandstone fragments have travelled from the mainland" (p. 539). The "sandstone fragments" here alluded to by Mr Geikie, are "red sandstone boulders, lying in the fields, which we found at the Butt" (the northern extremity of Lewis), and also on "the sea-beach at Barabhaïs" (a place about 20 miles from the Butt, on the west coast). Cellar Head is a point on the east coast of Lewis, 5 or 6 miles south from "the Butt."

Mr Caunter told the Convener that he had seen the sandstone boulders on the shore between the Butt of Lewis and Ness, and that they occur there inland up to a height of 300 feet.

Now, a presumption arises, from the number of these sandstone boulders at and near the Butt, that there must be in that district rock *in situ* of the same nature. The Convener regretted having been prevented searching the coast and fields between the Butt and Barvas, to examine these boulders and see if any sandstone rocks

occurred there on the shore. He, however, saw Mr M'Farquhar, the intelligent ground officer at Barvas, and learnt from him that about a mile or more to the west of the mouth of the Barvas river, where it flows into the sea, there are rocks which seemed to him to have the appearance of sandstone rocks, but that he was not competent to judge of such a matter.

In these circumstances, the presumption is that the sandstone boulder at Garabost came, like all the other boulders in the Lewis, from the westward, and not from the mainland of Ross-shire.

13. The Convener (IX., art. 4) referred to the flatness of the district to the south of Stornoway. Between Stornoway and Barvas and also both towards Dalbeag and the Butt of Lewis, the island presents similar tracts of flatness. The general height above the sea is much the same over both districts, viz., from 200 to 300 feet. The deposits forming these extensive plains consist of great sheets of gravel, sand, and stony clay,—the clay being generally the lowest bed. In these flat districts, there is a remarkable scarcity of boulders when compared with their number to the south, and these few are much below the average size.

A great many sections of these deposits were examined for sea shells ;—but the only place where shells were seen by the Convener was at the brickwork of Garabost above referred to. These shells —chiefly the *Cardium edule*—have long been an object of interest, and were examined by the late Dr John Davy of London, as well as by Sir Charles W. Thomson and Dr Carpenter. At one time they were thought to be arctic ; but the latest opinion is, that they are of the type now existing in the adjoining sea.

Mr James Geikie gives an account of this Garabost deposit in the memoir read by him before the London Geological Society in April 1878. But his account is founded, as he says, chiefly on information supplied by Mr Caunter, whose letter he quotes. As the Convener made a careful examination of this clay-bed, he gives, with the aid of fig. 34, the following description of it :—*a*, is gneiss rock ; *b*, is coarse shingle ; *c*, is the bed of clay now worked ; and *d*, is sand covering the clay.

The Convener picked up fragments of the shells from the bed *b*, as also several well-rounded boulders of gneiss, about the size of a child's head.

The manager of the brickwork pointed out how the upper part of the clay-bed appeared to have been scooped out in some parts ; the hollow thus made being filled with sand and mud. The bottom of the clay-bed was not sufficiently exposed when the Convener visited the place, so as to show the bed of shingle ; but there was a heap of coarse gravel near the work, which the manager stated had come from the bottom of the clay-bed. The Convener had also explained to him the vegetable remains said to have been found in the upper part of the clay, to which Mr Geikie alludes, as supposed by Mr Caunter to have been "*common sea tangle* ;" but of this the Convener saw no specimen.

Mr Geikie mentions that the clay-bed at Garabost is "in all probability of the same, or approximately the same, age as the similar beds in the north of the island" (*Lond. Geol. Soc. Quarterly Journal*, vol. xxxiv. p. 827).

The Convener made an attempt to reach the north of the island, to see those shelly clay-beds referred to by Mr Geikie ; but, from want of time, he failed to get so far north. He therefore may be permitted to refer to Mr Geikie's account of these beds, and to quote one or two passages:

"At Port of Ness the boulder clay contains patches of sand. But the most remarkable feature is the presence of broken *arctic and boreal shells*, which occur in an irregular manner through the mass. The *upper surface of the boulder clay is denuded*; a character better shown in fig. 37, which is taken from the same locality. The stratified beds contain *shells, most of which are in a fragmentary state, but some perfect specimens may be detected*. They belong to arctic and northern species." Another place is mentioned where "the beds consist of an upper series of sand and gravel deposits, more or less separated from an underlying deposit of imperfectly laminated dark blue and grey clay, and silt or mud. *Shells occur in both.*" ("Great Ice Age," 2d edition, p. 170.)

These shelly beds of boulder clay, according to Mr Geikie, extend over a considerable tract in the north of Lewis. He states, p. 183, "*The shelly tills in the sea cliffs near the Butt stretch across the island from shore to shore, a distance of two miles or thereabout, forming a narrow belt of low ground, which does not rise more*

than 90 feet or so above the sea. The deposits extend for somewhat less than a mile along the east coast, but on the *west* side of the island one can trace them for a distance of *three miles*."

In connection with this northern part of the island, it is proper to notice several remarkable lines of kaims or gravel ridges and knolls. The Convener's attention was first called to these by Mr Mackay (Sir James Matheson's commissioner), who pointed them out from the high road between Stornoway and Barvas, as a feature of the district he had seen nowhere else. The Convener observed these ridges on both sides of the road, and a few days afterwards he had an opportunity of walking along one of them to the north of the Barvas hills. The ridges consist of gravel and sand, and reach a height of 30 to 50 feet above the adjoining level ground, from which they are the more easily distinguished by the uniformly green colour of the herbage on them, whereas the flat district they traverse is covered with brown peat and moss. Each of these gravelly ridges is continuous for more than half a mile, and they deviate very little from one direction, which is about W.N.W. (magn.) When on the top of the Barvas hills, the Convener was able to trace the line of one of these kaims, for at least two miles, running in a direction N.W. and S.E. It passes Loch Scarabhat at its south end. In several parts of their course, boulders occur on the ridges and sides of these kaims. At one place, two or three miles north of the Barvas hills, to which the Convener was conducted by Mr M'Iver, an intelligent gamekeeper, well acquainted with the district, he found the kaim expanded into a number of grassy knolls, much resorted to in summer for the good pasturage they afford to cows. These knolls were, in some spots, well covered with boulders : the highest knolls being those where the boulders are most numerous. The boulders were sometimes on the east sides of the knolls, but more frequently on the west sides. At two places, the boulders were heaped and piled on one another. The Convener attempted to elicit from their relative positions, the quarter from which they had come. Most of the boulders showed unmistakably that they had come from the N.W., but some also from W.S.W. One boulder indicated transport from N.N.E.

An old man who was looking after the cows at this shieling noticing the attention paid by us to the boulders, volunteered to

mention that robbers used to live in the recesses among the boulders. The Convener's man-servant crept into one of the recesses pointed out, which was so large as not only to admit him, but conceal him when in it from our view.

Another observation by the Convener in connection with this district may be mentioned. On the north side of the middle Barvas hill there is a deep hollow, like a huge trench, close to and parallel with the northern contour of the hill, suggesting the idea, that when the country was submerged, an oceanic current from the N.W. striking on the hill may have scooped out the drift forming the sea-bottom at this place.

14. The Convener was as much impressed as Mr Geikie appears to have been with the number and direction of lakes in the Lewis. In his "Great Ice Age" (2d ed., p. 168), under the head of "Lakes occupying hollows in the till or other superficial deposits," Mr Geikie states,—“They rest sometimes in the hollows between banks of till, and not unfrequently in cap-shaped depressions of sand and gravel. The most considerable assemblage of these lakes of which I know, is in the Island of Lewis; the low lying tracts of which are literally peppered with lakelets. Not a few of these belong to the drift-dammed series. But hundreds of them appear to rest in hollows of the till, their longer axis pointing by N.W. and S.E.” The Convener remembers that when on the road from Stornoway to Garry-na-hine, he stopped the carriage to count the lakes spread out before him. They were 17 in number—though seen from a point only about 300 feet above the sea. To the north and north-east of the Barvas hills the lakes are even more numerous.

The Convener also concurs with Mr Geikie in his remarks (*Lond. Geol. Soc. Journal*, vol. xxix. p. 541) that, “with one exception, all the longest and most considerable lakes range in a direction from S.E. to N.W.” “They extend in long lines, often for a mile or two, with an insignificant breadth.”

When Mr Geikie proceeds to suggest a cause for the formation of these lakes, and for their persistency in a N.W. and S.E. direction, the Convener is unable to concur. He says—“When the ice that swept across the Lewis finally vanished, it left as marks of its power not only rounded and fluted hill tops, but hollows scooped out in the solid gneiss. The till that accumulated below the ice was also

at the same time found arranged in long parallel banks, running in the exact direction followed by the ice striae and *roches moutonnees*. The arrangement of the till into long parallel mounds is a feature with which I have long been familiar." "The N.W. and S.E. lakes then rest in true rock basins, and also in hollows between parallel banks formed wholly of till, or partly of rock and till" (page 542).

The Convener walked along the banks of many of the lakes in the northern part of the Lewis. He does not remember having seen much or indeed any rock on those banks. At all events, the banks certainly in most cases consist of gravel and till, forming "*long parallel mounds*," as stated by Mr Geikie. On some of the heights, as at Bein-na-Bhuna, there are domes of smoothed rock. But because they are round and smooth, the Convener does not admit that they thereby prove glacier agency. The main facts mentioned by Mr Geikie the Convener quite admits, viz., that most of the lakes are "occupying hollows in the till and other superficial deposits"—that the axis of these hollows is, generally speaking, N.W. and S.E.—and that this also is the direction of the ruts and flutings on smoothed rocks. Mr Geikie assumes that these lake hollows, and these ruts and flutings, were made by one and the same agent, viz., ice, which came from the S.E. The Convener, on the other hand, ventures to suggest that the ruts and flutings may have been made by an agent which came from the opposite direction, viz., the N.W.; and that this agent may have been an oceanic current loaded with ice, which ploughed through the old sea-bottom, pushing hard stones over submarine rocks, which were thereby smoothed and striated.

There is one general view put forth by Mr Geikie with which the Convener agrees. Mr Geikie, after traversing the whole of the Outer Hebrides, from the Butt of Lewis to Barra Head, has formed an opinion that the phenomena of smoothed and striated rocks and boulders in all these islands can be best explained by one agent, which embraced and spread over the whole, and reached up to at least 1600 feet above the present sea-level. The Convener concurs in that view. In all the Hebrides which the Convener was able to visit he found a remarkable agreement in the direction of boulder transport and of rock striations, and in the disposition of superficial deposits. This agreement does certainly suggest the agency of some general agent embracing all the islands. The only

question is, What was this agent? Was it a sheet of ice from Ross-shire, crossing the deep channels of the Great and Little Minch and flowing from the S.E. with a breadth of 120 miles? Or was it an ice-loaded oceanic current from the N.W. when the sea was, say, 2000 feet above its present level?

As reference has been made to the low-lying level plains occurring in the Lewis, and to the beds of sea-shells in the till, it may not be deemed irrelevant to mention that there are on many parts horizontal terraces, bounded by cliffs which seem to indicate old sea margins. Along the east coast, from Loch Seaforth to Stornoway, there are cliffs at heights of 11, 40, 81, 180, and 220 feet above the sea. The road from Stornoway to Garry-na-hine, for some miles, passes through a valley exhibiting a sea cliff at a height of from 210 to 220 feet. The valley through which the River Barvas flows to the sea, exhibits distinctly two terraces with cliffs, one 40 feet and the other 170 feet, above the sea.

The theory of an ice-sheet from Ross-shire overspreading all the Outer Hebrides is too large a question to be discussed in this Report. But as having an important bearing on the question, the Convener may advert to the way in which the boulders are distributed in these islands. It has been already remarked that boulders are scanty on the east coasts of those islands, and in particular on the low-lying districts in the north of Lewis. It may be supposed that it is only natural that the boulders should be most abundant on the west coasts, as the highest hills are there. But it does not follow that the boulders, because they rest on these hills, were generated there. For example, the large boulder on the west flank of Dun-Ii in Iona, the numberless boulders on the sea cliffs on the west coasts of Tiree, Coll, Barra, Uist, Harris, and the Lewis, must have come from the westward, and been stranded on the first islands, or submarine rocks or shoals, which impeded the farther progress of the ice which brought them. On that theory, it would not be difficult to explain why the boulders, whilst abundant on the mountains which fringe the west coast of the Hebrides, should be generally absent from the eastern and northern portions of the Lewis, where there are no hills, or any other obstruction to the ice in a sea, if one prevailed, about 1000 feet above the present level.

If glaciers ever existed among the hills of Harris, their effects

must have been confined to their own valleys. Though Mr James Geikie, in his valuable Memoir on the Glaciation of the Hebrides, assumes that there were such glaciers, he not only admits but maintains, that "the ice, with which the mountain valleys of Harris and the south were filled, *had no share whatever in the glaciation of the northern part of the island*, extending from the base of the mountains to the Butt, a distance of not less than 35 or 40 miles. Where, then, did the ice come from which overflowed this by far the largest part of the island? There is only one place whence it could have come,—the *mainland*." Mr Geikie "contends that it was amongst" the "mountains of Wester Ross, fringing the borders of the Minch, that the glaciers which overflowed the Lewis were nourished" ("Lond. Geol. Soc. Journal" for 1873, p. 544). In his second Memoir, read in April 1878, Mr Geikie extends this theory to all the Outer Hebrides, maintaining "that *the whole of the Long Island, from the Butt of Lewis to Barra Head*, has been overflowed from the Minch by ice that moved outwards from the inner islands and the *mainland*" (p. 861.) If this had been the case, one would have expected to find boulders chiefly on the *east* coasts of the Hebrides, and few on the *west* coasts. But the facts are entirely the other way. Not only is it on the hills of the *west* coasts that boulders most abound, and are largest in size; but it is also on the slopes of the hills facing the Atlantic that these boulders are mostly seated. On the hills of the east coast next the Minch, the boulders are few and small, and they are chiefly on the west flanks of these hills, and therefore unlikely to have come across the Minch.

XI.—OBAN AND ITS NEIGHBOURHOOD.

In the immediate neighbourhood of this town, there are some facts of interest.

(1.) There, as among the Hebrides, the smoothed rocks on the hills above Oban face the N.W.

A little above the Craig-Ard Hotel, there is a fissure in the hills from 12 to 20 yards wide, and running due north and south for 200 yards, at an elevation above the sea of about 180 feet. The fissure has apparently been occupied by a trap dyke, which, from the sea or other natural agencies, has decayed and disappeared. The walls of

the fissure are from 12 to 20 feet in height. The east wall of the fissure presents numerous portions of rock well rounded and smooth. The west wall is rough and jagged. These appearances suggest the action of a current which has grated on the east wall and not on the west wall.

As this is a case exactly similar to that referred to as occurring in Barra, and shown by figure 11, it is unnecessary to give another diagram.

(2.) Not far from the foregoing spot there is a coarse-grained conglomerate rock. It is at the junction of three roads. It is the same species of rock which forms what is called the Dogstone on the avenue to Dunolly, at Oban. The included boulders and pebbles are well rounded, and consist of hard gneiss and quartzite.

Fig. 35 represents a portion of this conglomerate rock,—about 20 feet across—viz., between east and west, and 5 feet between north and south. On the side of the rock facing the N.W. the hard pebbles and boulders in the rock have all been ground down to an even surface; whilst on the side facing the S.E. the pebbles and boulders retain their original shapes, and stand up above the clay matrix of the rock.

(3.) About $6\frac{1}{2}$ miles from Oban, at a place called "Lait," there is a boulder of considerable size called "Clach-a-Curail" or Perched-up Boulder. Its height is 14 feet, and its girth about the middle 29 feet. Its situation is extremely critical, being on the edge of a precipice which goes down at an angle of about 75° for 50 feet. The rock of the boulder is peculiar,—a dark chocolate-coloured porphyry. No rock of that description elsewhere could the Convener hear of.

How the boulder got into the site it now occupies, or from what quarter it came, it would be difficult to say. Judging from the position of the boulder, the presumption is that it came from the S.E., *i.e.*, down the valley leading up to Loch Awe. But it may have come from the N.W., as in that direction there is a valley by which it could have floated to its present position.

About half a mile to the N.E. of this boulder there are fragments of what had been a much larger boulder, which a year ago had been blown up for building purposes. It was a coarse granite, whilst all the rocks in the district are gneiss. Its position suggested trans-

port from the S. or S.W. as the most probable quarter, though the N.W. was not impossible.

Most of the small hills in this neighbourhood are bare on the N.W., and are smoothed on that side only.

(4.) The Convener paid a visit to a glen called Glenlonnian, the mouth of which comes down to Loch Etive near Taynuilt. He had been told of there being several large boulders on a hill called Bein Glas in that glen, about 1700 feet high. This is the glen referred to in the last Report of the Committee, page 12 and section 5. He was guided to these boulders by Mr Clerk, a son of the tenant of the farm of Duntonichan, of which Bein Glas forms part. In ascending the north flank of the hill, it was observed that the smoothed rocks here as elsewhere distinctly sloped down towards the N.W., and that rounded boulders were often on these rocks. The rock of the hill was gneiss, and most of the boulders were also gneiss; but there were also some of granite, a few of mica slate, and a very small one of quartzite. The largest granite boulder passed measured $6\frac{1}{2} \times 4 \times 3$ feet. The longer axis pointed N.N.W. The rocky surface on which it rested dipped due north.

When a height of 1619 feet was reached, which was near the top of the hill, it created some surprise to find that there were smoothed rocks facing the *south*, besides others facing the north.

Several large boulders were found occupying positions on slopes facing the south. One of these was a well-rounded grey granite, at a height of 1573 feet.

At a height of 1637 feet there was a boulder, $8 \times 5 \times 5$ feet, very angular. It was a dark purple claystone, in appearance similar to the boulder, shortly above mentioned, seen at Lait. It was resting on a shelf of gravel, but the general slope of the hill was exceedingly steep, viz., forming an angle of about 35° , sloping down S.E.

Judging by the position of these boulders, and the steepness of the hillside facing the S.E. or the S.S.E. which they occupied, the presumption is, that they had come from that direction. The rocks of the hill at this spot are also smoothed in that direction. Towards the south there are high mountains in the distance.

Another grey granite boulder, $3 \times 3 \times 2$ feet, was found at a height of 1645 feet on a rocky slope, less steep, but still facing the south.

At a height of 1683 feet, about 11 feet below the summit, smoothed rocks were still found sloping gently towards the south.

On descending the hill towards the north, by a more westerly path than that followed in ascending, it was observed that, at a height of 1554 feet, the smoothed rocks faced the north.

Some of the boulders met with on the descent were of the same dark purple porphyry seen at Lailt.

(5.) On reaching Loch Etive, the Convener visited the Airde point, a projecting cape or headland on the west side of the loch. At this point there were many well-smoothed rocks up to a height of 276 feet above the sea, and facing up the glen towards Loch Awe. There can be no doubt that these rocks had been smoothed by glacier action. On this Airde point there were numerous boulders, chiefly of grey granite. They may have been pushed down the glen by a glacier;—indeed it seemed the most probable supposition. But they might have been floated up from the N.W. None of the boulders seen were in such a position as to indicate with any certainty the quarter from which they had come.

It may be added that the rocks on the south shore of Loch Etive, as far down as Connel ferry, and even lower, show smoothings all facing up toward the head of the loch, suggesting glacier action from the upper part of the valley.

(6.) In the Fourth Report by the Committee (p. 11), reference was made to boulders observed in the Island of *Kerrera*, at the north end. This year the Convener had an opportunity of examining the boulders in the middle of the island, where it is traversed by the high road leading from Ballimore farm to the ferry for Mull on the west side of the island, called “Bal-na-Bok.”

On his way across the Island, he had pointed out to him by Mr M'Dougal, tenant of Ballimore farm, three or four well-rounded boulders of a coarse granite, having a red tinge, imparted from the felspar crystals. They were from 2 to 3 feet in diameter. Mr M'Dougal stated that there was no granite rock in Kerrera which he knew of; and that the nearest place where he had heard that granite of that kind was worked was at Morven, about 12 miles across the sea to the north. He was sure it was not the same as any he had

seen in Mull. He referred the Convener to Mr John McDougal, builder, Oban, as one who had a practical knowledge of granite rocks.

On the hill sides facing the north and west, the Convener observed here and there several boulders. They were all mostly of the same coarse-grained granite. There was one of a purple claystone porphyry. When he reached "Bal-na-Bok," he passed several boulders of coarse-grained granite, and one block of mica schist, which had been hollowed out for some domestic use. He learnt from the old ferryman (M'Kinnon) and his daughter, that there were boulders of granite about 4 feet high at or near the tops of the hills to the south of the ferry. Rainy weather prevented access to them.

On returning to Oban, the Convener called on John McDougal, the builder, and showed to him specimens of the granite boulders which he had found in Kerrera. On asking him if he knew where there were any *rocks* in the hills of a similar description, he said that he knew of two places,—one to the south of Ben Cruachan, the other in Morven,—and that he thought the Morven rock more nearly resembled the specimens shown.

He was not acquainted with any granite exactly similar existing in the island of Mull. He knew very well the red granite of the Ross of Mull; and he added that, at a place which he called the "North Bay of Mull," there was a grey-coloured granite, much lighter in colour than that in Loch Etive.

In these circumstances, it is still matter of doubt from what quarter these red granite boulders in Kerrera were transported.

(7.) The Convener next day paid a short visit to Easdale, and was conducted by Mr John Clerk, blacksmith, Kilbride, to several places in the neighbourhood, for an inspection of boulders which had been reported by him in one of the circulars to this Committee. The district visited was that traversed by the high road to Clachan Bridge, situated about 3 miles to the N.N.E. of Easdale. The rocks of this district are all a blue clay slate, extensively quarried for roofing. Most of the boulders examined were of grey granite, but their position did not indicate clearly the quarter from which they came. They probably came from the north or west, as there was less in these directions to obstruct them in their transport than in any other direction.

To the south of Easdale, there is an extensive terrace along the coast, about 18 or 20 feet above high-water mark, and some hundreds of yards wide, bounded by a range of high rocky cliffs, with caves which evidently had been formerly reached and undermined by sea waves. On this terrace lay a cluster of boulders, several of them of grey-coloured granite, which most probably had been lodged where they now lie by ice floating from the north, and arrested in its further progress south by these rocky cliffs. Several boulders were noticed by the Convener at and near the tops of these cliffs, which he regretted not having had time to inspect.

Mr Clerk informed him that on the hill immediately to the east of Easdale, about 1200 feet in height, there were near the top several large boulders, which he hoped would be examined at some future period.

Whilst it seemed probable that these Easdale grey granite boulders came from the north, there was one large claystone boulder, of a purple colour, which, from its position, seemed to the Convener to have come from the south. Its size was $12 \times 7 \times 6$ feet. It lay on the shore near Clachan Bridge. On asking Mr Clerk if he knew of any rock *in situ* similar to that of the boulder, he pointed to a hill about a mile distant, situated to the south.

The Convener has referred to several boulders of a purple-coloured claystone, very similar to this one, as having been seen by him at "Lait" (3) above, and "Duntonichan" (4) above, which also suggested transport from the hills to the south.

(8.) The Convener on 1st July ascended Ben Cruachan from Inverawe, up as far as 2725 feet, and made the following observations :—

Until a level above the sea was reached of about 1330 feet, few boulders were met with. At and above that height the boulders were numerous, and many of them of large size. They were most numerous on the N.W. shoulder of the hill. In that direction there was the least obstruction to transport. Due N., N.E., E., S.E., S.W., due W., there were hills of formidable height which would obstruct. Towards the W.N.W. and N.W. there were only the hills in Mull and Ardnamurchan, distant from 30 to 40 miles.

The possibility of transport by a glacier down from Loch Awe or

Dalmally, was not overlooked. But if any glacier had filled the valley to the height of 1330 feet, bringing down boulders, these boulders would have much more probably been lodged on the hill to the north of Cruachan, called Daranish, opposite to Bonawe, where there is now a great quarry of granite. But on that hill, at least on the side opposite to and looking up towards Loch Awe, only a few boulders were discernible.

On the other hand, if boulders were brought by a N.W. current, the part of Cruachan which would be first and chiefly struck would be its N.W. shoulder, where the boulders now lie in great heaps, whilst that part of Daranish hill, which faces about south by west, would be sheltered from the current.

The following boulders of considerable size indicated by their position that they probably had come from the N.W.:—

One at a height of 1890 feet, resting on gravel, $15 \times 9 \times 5$ feet.

Another at a height of 1943 feet. It was 13 feet long \times 7 feet high. Its longer axis bore N.W. by W. At its west end, its width was 2 feet, at its east end 5 feet. It also lay on gravel and small boulders.

At a height of 2194 feet, the rocks of the hill—a coarse reddish granite—presented extensive smoothings facing W. by N.

At a height of 2386 feet, there was a boulder $7 \times 6 \times 5$ feet, evidently blocked on its E.S.E. side by the rock of the hill.

At a height of 2428 feet, a grey granite boulder was found near a summit level, where the rock—a red or yellow felspar—showed smoothings from the N.W.

The hill to which these observations apply was not one of the central peaks of Cruachan, but situated to the N.W. This hill is known in Gaelic by a name which in English means “hill of the horse heel.” Its top was not reached by about 100 feet. Boulders were, however, descried on it reaching to the very top.

Descent from this hill was made on the side next to Cruachan, *i.e.*, on its S.E. and S. side. No smoothed rocks were observed on these sides, and but few boulders.

If a glacier descended the valley from Loch Awe, grating on Cruachan, it is natural to suppose that the rocks on these flanks of Cruachan would have shown some smoothings. There is a

vertical cliff of rock, about 60 feet above the River Awe, on Cruachan, which did suggest glacier friction; and at a height of 334 feet above the sea, above Inverawe, the Convener found rocks which seemed to have been smoothed from the W.S.W. But above that height the rocks presented smoothings successively from N.W. by N., from N.N.W. and W.N.W.,—the W.N.W. being in the highest parts of the hill, apparently the most persistent direction.

(9.) The Convener afterwards proceeded to the head of Loch Etive in a steamboat, and then travelled by coach nine or ten miles to the head of Glen Etive, to a height of about 600 feet above the sea. The whole of this valley has at one time been filled with gravel and boulders of grey granite. A great part of this mass of drift had apparently been scoured out by the action of the numerous streams which descend from the high steep mountains on each side of the glen. Terraces were occasionally visible on the south side of the glen, up to a height of about 500 feet above the present channel of the river, consisting of clay, gravel, and sand, which may have been the bottom of an estuary in former times.

XII.—LOCH CRERAN.

The Convener paid a visit to Loch Creran, having last year seen that there were there more objects of interest than he had then been able to overtake.

At the mouth of Loch Creran, where it joins the Linnhe Loch, the rocks are all smoothed when they face the W.N.W. at about 70 feet above the sea, and also at Craigan Ferry. But about a mile higher up the loch, the smoothed rocks face W.S.W., at a height of about 80 feet above the sea.

Near the sea-level, the smoothing of the rocks seemed attributable to the action of some force moving down the valley, whilst rocks at a higher level, say 100 feet and more above the sea, grinding from the N.W.—*i.e.*, up the valley—seemed undoubted.

On going up the glen towards Carroban hill, notice was taken of a *trainée* of boulders which appeared to go over a summit level to the east of that hill. The boulders are all of a dark-coloured fine-grained granite, and are apparently the same as the Fasnacloich and Appin boulders referred to in last year's Report. Mr Hall, the intelligent tenant of Fasnacloich, who from boyhood has lived in

the district, mentioned that the *trainée* of boulders could be followed for some distance over the hill, towards Glen Etive and Glencoe.

A very large boulder exists in a *cul de sac* formed by lofty hills near Carphin at the head of the valley. It goes by the name of the Ardshiel boulder, in consequence of having been made use of by the proprietor of Ardshiel for concealment in the time of the Rebellion. This boulder is $40 \times 27 \times 15$ feet = about 1000 tons.

A fissure exists through the middle of it, which is large enough to allow of a man getting into it from the top, where, however, the fissure is not discoverable at any distance in consequence of beech-wood growing on it. This boulder is, in composition of rock, the same as all the rest of the boulders in the glen, and it has undoubtedly been floated like the rest, up the glen. It is blocked on its west side by a large mass of rock, which stopped its further progress up the glen. Its height above the sea is 506 feet. On account of its weight, the ice which rafted it was probably so deep in the water that it could not get over the summit level by which smaller boulders passed to the east of Carroban hill.

The boulders in Glen Creran are mostly on coarse gravel. At one place above Salar House, there is a cluster of boulders on a rocky knoll.

The summit level on the east side of Carroban hill is about 800 feet above the sea. If the sea, when these boulders were being transported, stood, say 2000 feet higher than at present, any current from the N.W. would flow through and over that Carroban pass. On that supposition, it would not be difficult to account for the *trainée* of boulders in Glen Creran and for the presence of the gigantic boulder in the *cul de sac* at Carphin.

If Robert Hall's statement that the black granite boulders are traceable up the Carroban valley, and over the summit level which separates Glen Creran from Glen Etive, some of these boulders should be found in the upper parts of Glen Etive. As the Convenor passed up that valley on the coach which travels between Loch Etive and Glencoe, he observed several boulders on the moors, near the road, exceedingly like the Loch Creran boulders; but he had no opportunity of particularly examining them.

With the view of so far testing the statement by Hall, the Con-

vener at a subsequent date walked across the moors from Ballachulish Hotel to Carroban hill, to see if there were any black granite boulders in that quarter. He fell in with several at a height of about 800 feet above the sea, and he saw that boulders were thickly spread up the valley to the summit level, but unfortunately, he was prevented reaching them for examination on account of distance.

It is worthy of remark, however, that in this side valley, running up from Glen Creran, grey granite boulders are also numerous, whilst in Glen Creran itself there are none. Now, at this place the rocks *in situ* are slate rocks. The nearest mountain of grey granite is situated to the N.W., about four miles distant. A N.W. current would bring fragments of rock to the place where the Convener found them, but not to Glen Creran, at least to its lower parts.

XIII.—GLENCOE.

This valley is quite as remarkable for objects of geological interest, as for picturesque scenery and for stirring historical deeds.

It contains many phenomena of extreme importance, connected with the transport of boulders and the grinding down of rocks.

The Convener began his examination of the glen, at "Alt na Fay," a place about 17 miles distant from Ballachulish Hotel, and about 3 miles distant from King's House.

Having introduced himself to John Matheson, a young shepherd residing at "Alt na Fay," the Convener obtained his services as a guide for some distance down the glen.

The first place visited was a gravel knoll, near Matheson's house, having on it a cluster of boulders, the largest and uppermost being well seen from the coach road. Its size is $8 \times 4 \times 4$ ft., and it consists of a hard clay slate similar to that of the neighbouring hills in the north. Underneath this boulder, there was one of smaller size, consisting of a red felspar, of which, as Matheson informed the Convener, there was also rock in the hills. But there were no hills within a quarter of a mile of this gravel knoll, and no cliffs from which the boulders on it could have fallen. The top of the knoll was about 30 feet above its base, and was of a somewhat conical shape. An examination of its *side*, showed numerous boulders, half buried in the gravel composing it. On the *west* side, there were from

twenty to thirty boulders, on the *east* side only one or two. The greatest number consisted of grey granite—of which rock, however, as Matheson assured the Convener, there was none in Glencoe ; the nearest being, as he said, on the shore at Ballachulish Hotel, at the mouth of the Glen, and farther westward towards Duror.

Matheson then conducted the Convener *down* the valley on the north side to some larger boulders. Several were pointed out from 10 to 12 feet long, at heights of 1200 to 1400 feet above the sea. These also were of grey granite, their longer axis being about east and west, or parallel with the direction of the glen, at this place, and about 400 feet above the bottom of the glen.

About 50 feet above these grey granite boulders, smoothed rocks were observed. There were no *striæ*; but the smoothing seemed due to a frictional agent which had come *down* the glen.

On the same (north) side of the valley, the Convener had pointed out to him by Matheson, at one or two places, about 1183 feet above the sea, a mass of conglomerate rock *in situ*, similar, as he said, to the "Dog-stone" at Oban. The Convener observed that two fragments had been detached from the rock, and been formed into boulders. One was on the slope of the hill, about 50 yards *west* of the parent rock, and 30 feet below it in level; the other of these boulders, and larger in size, was resting on the schist rock of the hill, about 200 yards *west* of the parent rock, and about 45 feet below it in level. These observations indicated that some agent had here been *moving down the glen*, and had both broken off and transported portions of the conglomerate rock.

On the other hand, there is a cliff of this conglomerate rock which holds in a cleft of it a grey granite boulder, and in a position which shows that *it* had *come up the glen* from the west. Fig. 36 A represents this boulder leaning on the hill rock, the view being taken from the south, about 500 yards distant. Fig. 36 B represents the same boulder, viewed from the north, at a distance of about 10 yards.

Matheson next informed the Convener that if the latter wished to see the biggest boulder in Glencoe, he would have to cross to the opposite side, at a place about a mile further down, and at a considerable height above the river channel.

The Convener went to the place and found the boulder in

question. A path from the cottage occupied by Buchanan (a shepherd) led to it. The boulder being of very irregular shape, its exact dimensions were not ascertained. Its girth at the level of the ground was ascertained, by walking round it, to be 22 yards. Its height seemed to be about 15 feet. The rock composing it was a coarse conglomerate. It was resting on a flat or terrace of gravel. Its height above the channel of the river was about 450 feet, and above the sea 1215 feet.

The position of the boulder seems to be indicated on the Ordnance map by the words "Meannar Clach."

The Convener was unable to form a distinct opinion on the question, whether this boulder had come down the glen, or had come up the glen. Its height above the sea was nearly the same as the conglomerate cliff higher up the glen, before spoken of. But, if a fragment from that cliff, it must have crossed the valley. The following considerations favoured the idea that it had been floated *up* the valley. It was resting on the shoulder of a hill facing the N.W.; and on the same shoulder there were multitudes of smaller boulders of conglomerate rock, apparently due to the same mode of transport. A plan of the position is shown on fig. 37, where B represents the big boulder. Some boulders, apparently of a similar character, were visible at A, though they were not visited. If a N.W. current, bearing boulders, came up the glen, it might lodge the boulders at A and B. The Convener believes that conglomerate rock occurs near the foot of Glencoe, as, when there, he saw fragments which appeared to have fallen from a cliff. If this be the case, the theory which ascribes transport of these boulders *up* the glen would be strengthened.

It was observed, that the above "big boulder" rests on a terrace of gravel. It is rather a bed of stony clay, as such seemed to be the character of sections cut through by streams for about 200 feet above the boulder; and this stony clay contained numbers of pebbles and small boulders. It was plainly a water deposit. Above this stony clay, there appeared to be extensive beds of sand; and on several of the hills, near the foot of Glencoe, even up to the height of 2000 feet, sand in large quantities was observed; but it was only through a telescope that the observation was made.

About half a mile below Buchanan's cottage, at the ninth milestone from Ballachulish, the Convener observed a rock well smoothed

and striated ; it was at the side of the highroad. The surface of the rock sloped due south at an angle of about 15° . The striae had a direction N. 55° W. ; whilst the axis of the valley here was N. 65° W. There was nothing to indicate whether the striating agent had moved up or moved down the glen.

One of the most interesting spots in Glencoe is where the valley is narrowest, *i.e.*, where the hills on each side approach so near, that their respective rocky cliffs front each other at a distance of only about 300 yards. This narrow defile occurs about a mile to the west of Buchanan's cottage. The river here has cut through the slaty schist rocks to a depth of about 60 feet.

Fig. 38 will give some idea of this defile. There is a large plateau of rocks, consisting of slaty schist, which has been evidently ground down by a heavy body or bodies passing and pressing over it from the *east*, *i.e.*, down the valley. There are elongated shallow hollows also on these rocks parallel with the axis of the valley, which hollows are near the middle, as if the pressure there had been much greater (*viz.*, at A and B) than higher up at C. The smoothing and the hollowing seem to have commenced on the *east* side, as the edges of the strata are mostly smoothed on the edges facing the east. On the west side they are somewhat rough and jagged.

The figure represents a boulder lying on the smoothed rocks on the north side. It had not fallen from the cliffs. If it had, it would assuredly not have stuck in its present precarious position. It is a true erratic, and must have been brought up the glen at a period subsequent to the smoothing of the rocks. The surface of the rock on which it lies, slopes down towards the west.

About a quarter of a mile lower down the glen another smoothed rock occurs, which in like manner shows frictional agency over and upon it *from the eastward*. The rough parts of the rock face the west, and there form a cliff about 50 feet high, which has evidently stopped a number of erratics in their progress up the glen, as they lie in great numbers at the foot of the crag, some resting on others. Fig. 39 represent these boulders, showing how they have been obstructed, and how the uppermost boulder of the two must have come from the west to obtain its position above the other. The rocks in the cliff are a reddish felspar. The boulders are a fine-grained gneiss.

The Ordnance Surveyors having reported to the Boulder Committee a very large boulder seen by them at the foot of Glencoe, and having had the goodness to indicate its exact position on their map, the Convener made an attempt to find and examine it. On the map the boulder is indicated by the name of "Craig Bhatan," which it is believed means "*rock with trees.*" The Convener saw the boulder, at the distance of about a quarter of a mile, with bushes growing on it; but he was prevented reaching it, in consequence of being unable to ford a river between him and it. The size of the boulder was stated by the Ordnance Surveyors to be 90 feet in circumference, and about 10 feet high, and it appeared to the Convener to be of that size. It lies in a meadow adjoining the River Coe, about half a mile to the S.W. of the Glencoe Hotel. The meadow is about 200 feet above the sea, and is closely surrounded by mountains exceeding in height 2000 feet on all sides except two. One of these sides, to the east, is the valley of Glencoe. The other side, to the north, is the valley leading to the sea at Loch Leven, distant about 13 miles.

As the boulder seemed to be resting on an extensive mass of gravel, it seemed to the Convener very probable that it had come from the north, *i.e.*, up the Loch Leven Valley.

On the right bank of the River Coe, nearly opposite the large boulder just referred to, there is a rocky knoll standing from 20 to 30 feet above the adjoining district. This knoll has had lodged on its north side, a number of boulders, whose relative positions indicate transport from the north, *i.e.*, up the glen. One of these is a dark micaceous rock, glistering with abundance of mica. A few hundred yards to the north of the knoll, there is a rocky conical hill, reaching to a height of about 90 feet above the adjoining district. It is on the map called "Tom a Grianain." It consists of vertical strata of mica schist,—the only place where, in the course of this day's perambulation, that kind of rock was seen. There can be little doubt, therefore, that the mica schist boulder just mentioned had come from "Tom a Grianain," *i.e.*, from the north, and been torn from the hill by floating ice.

The facts ascertained in Glencoe seem to indicate two separate agencies. In the first place, there was a glacier, which planed down the rocks, so as to produce the extensive smoothings and groovings

seen at the narrow defile and elsewhere. In the second place, and subsequent to that epoch, the whole of the mountains in this district underwent submergence beneath the sea, in consequence of which not only was the Glencoe valley filled and choked with gravel, clay, and sand; but the highest hills adjoining were under water, and subjected to a great sea-current, loaded with ice, which flowed from the N.W. This glacial current brought from hills in the west, fragments of rocks from these hills, and dropped them in the valley at various points.

XIV.—GAIRLOCH.

In this district, the hills adjoining the coast present on their west slopes, even to their tops, numerous examples of large boulders.

1. Fig. 40 indicates the hills immediately above the Hotel, with coloured dots to represent the boulders on them.

One of these, the Convener found to be in the position and of the dimensions shown in fig. 41.

Its height above the sea is 675 feet; but the important feature is that it is on the verge of a precipice, which goes sheer down vertically about 100 feet. The boulder is a coarse-grained reddish brown sandstone, entirely different from the rocks of the hills, which consist of a slaty schist—being a variety of gneiss. The longer axis of the boulder lies N.W. by W.

There are several other boulders visible along or near to the verge of the cliffs, most of them consisting of the same sort of sandstone, and some consisting of a reddish granite—all evidently erratics.

On the lower slopes of these hills, facing the west, there are hundreds of similar boulders. They are mostly rounded at the ends, and in that respect are quite distinguishable from the rock fragments lying also on the hill slopes, which have fallen from the cliffs above.

2. To the N.E. of Gairloch Hotel there are other perched boulders. Fig. 42 shows one of them resting on a small ledge of gneiss rock, whose general slope is due west at an angle of about 50° . It rests on the rock only at its east end; the west half for about 5 feet does not touch the rock of the hill at all. Its height above the sea is 657 feet.

This boulder could have been deposited on its narrow site only by floating to it from the westward.

3. Fig. 43 represents a boulder on another hill near Gairloch, 747 feet above the sea, on the edge of a high cliff facing the west, and partially resting on two small boulders at its east end. It is a coarse-grained granite, whilst the rock of the hill is a schistose gneiss. It projects $2\frac{1}{2}$ feet beyond the edge, and it in like manner could not possibly have obtained its position except by being brought from the west.

4. Fig. 44 represents a hill about one mile N.E. from Gairloch Hotel, at the top of which (585 feet above the sea) two boulders attract notice. The largest is a block of close-grained Silurian rock, blue in colour and very hard. The smaller is a small block of reddish-brown sandstone, with minute pebbles in it of quartz and felspar. The rock of the hill here is a bluish clay slate, the strata of which are almost vertical.

Fig. 45 is a representation of the largest of these boulders taken from its N.E. side at a distance of about 10 yards. The Convener, on a minute examination, found that the boulder was resting on the rock of the hill, at three points, and that at the lower end it projected 2 feet beyond one of the points of attachment. The boulder sloped down towards the N.W. at an angle of 15° . The points of attachment to the rock seemed so slight that the Convener thought he would have little difficulty with a crowbar in precipitating the boulder down the precipice.

The red sandstone boulder is about 10 yards distant from the large boulder, and lay on a rocky surface facing the W.N.W.

5. Near the foot of the hill just referred to, there is a rocky knoll on the top of which a number of true erratics are clustered. The uppermost is $6 \times 5 \times 3$ feet in size, and lies in such a position over the others as to show that it had most probably come from the N.W. This cluster is shown on fig. 46.

6. There was only one place where striae on a smoothed rock surface were observed. It was about half a mile to the N.E. of Gairloch Hotel, its height above the sea 340 feet. Fig. 47 represents this rock surface. It slopes about due west at an angle of 30° , till it comes to a nearly vertical cliff. The boulder is 10 feet high, 6 feet wide, and about 4 feet thick. It is within 2 or 3 feet of the edge of the precipice, which is about 50 to 60 feet high. On one side of the boulder, several striae are visible, running E. by N. They had apparently com-

menced at or near the edge of the precipice, viz., at their west ends, as they are deeper and wider at that end than at the east end.

Between Gairloch and Loch Fionn, a distance of about 10 miles, all the hills have abundance of boulders on their sides up to their tops, and generally these are most numerous on the west sides ; but at one place, 600 feet above the sea, two boulders were observed on a rock surface sloping towards the W.S.W., and which apparently had come upon the hill from that quarter.

At first the Convener was surprised to find that the smooth rock surfaces, and some of the boulders in the district between Gairloch and Loch Fionn indicated agency not from the N.W. but from the W.S.W. He ultimately saw an explanation of this deviation from the normal direction, by the existence of a high range of hills due east of Gairloch, which might have deflected a N.W. current, and caused it to flow E.N.E. instead of S.E.

It has been mentioned that most of the boulders on the hills near Gairloch are composed of a reddish brown sandstone rock with small pebbles in it, and that this rock is entirely different from the rocks of these hills.

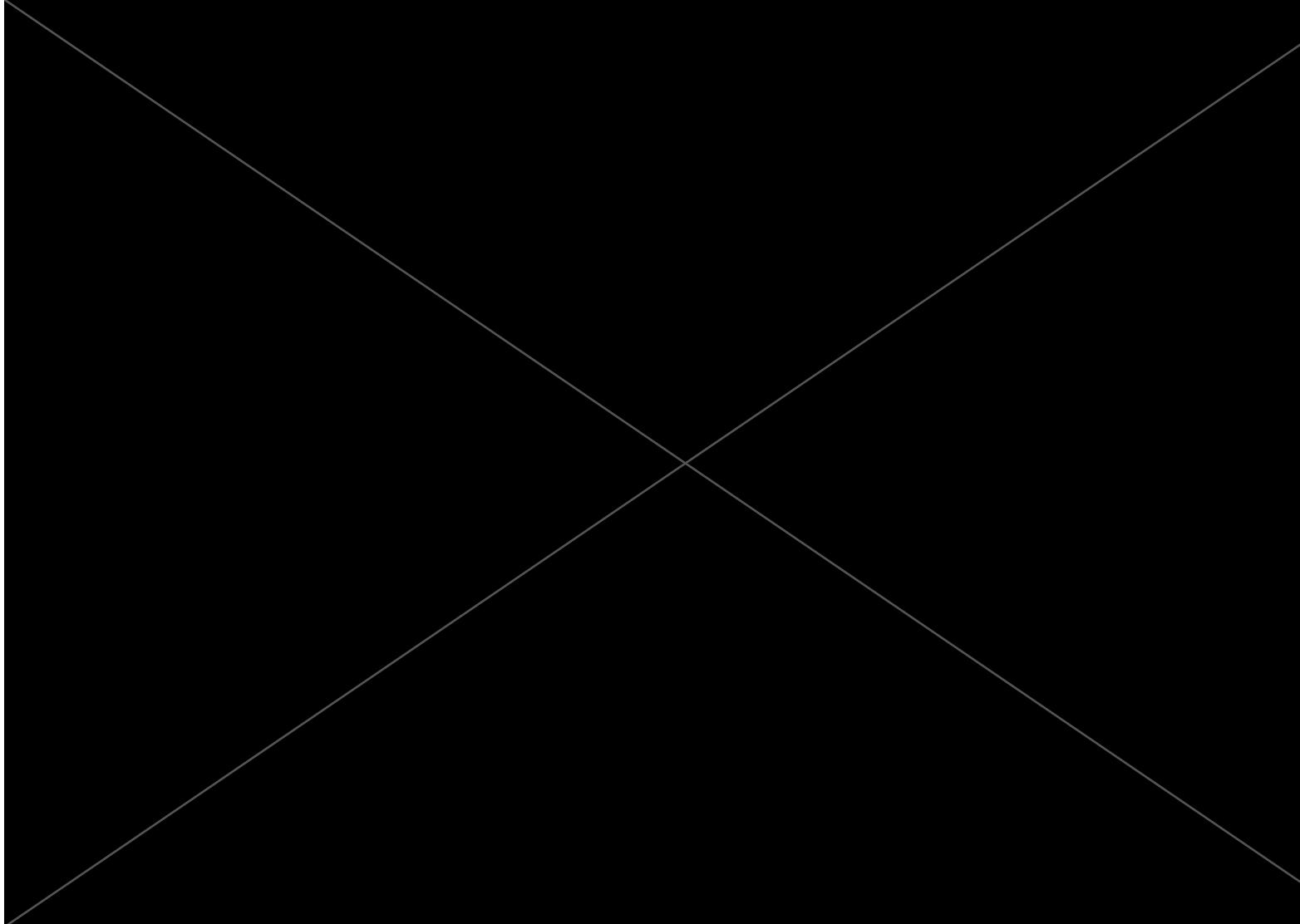
This reddish-brown sandstone rock exists largely *in situ* along the coast to the N.W. of Gairloch. Professor Geikie, in his recent Geological Map of Scotland, states this to be the case. It is also spoken to, as existing in that quarter, by Professor Nicol and by Robert Chambers. There can be no doubt, therefore, that these Gairloch sandstone boulders, as seen by the Convener at levels exceeding 700 feet above the sea, have come from that district—as indeed the boulders themselves indicate alike by their situation and their altitudes on the hills.

XV.—LOCH MAREE.

The road from Gairloch to Loch Maree passes through a valley running for a mile or more in a direction pretty uniformly W.N.W. and E.S.E. At several places on the roadside smoothed rocks were observed with striæ running in that direction. There was nothing to show whether the rock had been smoothed and striated by a glacier or by sea ice.

On the hills to the west of Loch Maree Hotel, reaching to a height of about 1000 feet above the sea, multitudes of red sandstone

boulders occur, more particularly on the N.W. sides of the hills and on their tops. On one hill (950 feet above the sea), presenting on its top a nearly level surface of about 80 yards diameter, the Convener counted twenty boulders, each exceeding 2 or 3 feet in diameter. Most of these were a coarse pebbly sandstone, the same in its general character as the Gairloch boulders; whilst there were amongst them, just as on the Gairloch hills, a few of a reddish-coloured granite. These boulders, when on or near hill tops, were



lying on the bare *well-rounded gneiss rock*, and when on the sides of hills, were generally *on* or *in* beds of coarse gravel. One of the boulders, $4 \times 3 \times 3$ feet, lying near a hill top on the N.W. side, had its longer axis pointing also N.W. On another gneiss hill (also west of the Hotel), and at about 310 feet above the sea, a sandstone boulder was found perched near the top, at its west side, as shown in the above section (figs. 1 and 2).

Professor Nicol, in his paper on the "Rocks of the North-West of Scotland,"* with reference to the hills about Loch Maree and Gairloch, adverts to their being "still strewed with innumerable fragments of red sandstone, perched, like sentinels, in the most exposed and perilous positions, on the very edge of some lofty cliff, or on the polished summit of the domes of gneiss." In a footnote he remarks it as "a curious fact that, on these gneiss hills, by far the majority, probably nine-tenths or more, of these 'perched blocks,' are red sandstone."

The fact would be "curious," if these sandstone boulders had been, as Professor Nicol supposed, "floated on icebergs from the mountains from the east" (page 39), because, to the east of Gairloch and Loch Maree there are no mountains of red sandstone. Professor Nicol, in this paper particularly adverts to "the red sandstone as forming a narrow band along the western shore, never reaching to the watershed of the country." Again (page 37), he repeats, that "the red sandstone on the west forms a narrow band along the shore, and never extended far into the interior."

That being the case, it would indeed be "curious" if the red sandstone boulders which cover the hills about Gairloch and Loch Maree had all been "floated on icebergs from the east." But assume that they had been floated from the N.W., and an explanation is at once obtained.

A curious belt of sandstone rocks occurs to the south of Loch Maree Hotel. Through and across this belt the high road passes for about two miles, so that an excellent view is obtained of the remarkable dislocations and denudations of these rocks which have occurred. These rocks differ in many respects from the rock of the sandstone boulders to which reference has just been made.

Professor Nicol explains that the sandstone of the west coast is "a coarse *grit*, graduating into a *fine conglomerate*, with fragments rarely an inch or more in diameter" (page 19). That is the character of the rock, forming the boulders; but the sandstone rocks which occur near the south end of Loch Maree are correctly described by Professor Nicol as "a very remarkable *brecchia* of quartz and gneiss in sharp, angular fragments," the largest of which fragments noticed by him he measured, and found it to be "16

* Proceedings of the London Geological Society, for 1856, p. 29.

inches long by 9 broad and 7 thick, but the generality are much smaller" (page 28).

Referring to this peculiar rock, Professor Nicol observes:— "The red sandstone in this district has undergone enormous denudation. On the shore of Loch Maree it is often broken up into huge masses or divided by gaps and fissures, some of them 20 to 30 feet deep. The surface of the beds is strewed with immense angular and ruin-like blocks, some of them poised on a single corner on the very edge of a cliff. All this indicates extensive destruction of the strata. Detached fragments of the breccia are found in hollows of the gneiss hills, far from the main masses, evidently left there in the general denudation."

Now in what direction were these "fragments carried," and from what quarter did this "general denudation"—this "enormous denudation"—come?

The following facts leave no doubt on the subject:—The smoothed surfaces of these breccia rocks face N.W.; the rough sides are towards the S.E. Fragments lie on the surface to the south, beyond the line which separates these rocks as a formation from the quartzite rocks of Ben Eay. Within the limits of the formation, huge masses, weighing hundreds of tons, are lying at the north base of cliffs—not having fallen from these cliffs, but apparently brought there from the north, and left there, in consequence of having been obstructed and arrested by the cliffs in their further progress to the south.

These facts are in entire consistency with the theory of a strong ice-laden sea current which flowed from the N.W. The valley now occupied by Loch Maree, with mountains on each side exceeding 1000 feet in height, happens to run N.W. and S.E., so that when this district was submerged, a glacial current flowing from a northerly point would produce all the effects on these breccia rocks which have been described.

Before passing from the district of Gairloch and Loch Maree, the Convener thinks it only due to his friend the late Robert Chambers to advert to the observations which he made in districts adjoining to the north. He makes this reference, as the facts observed by Chambers have a close relation to those which the Convener has just been describing.

Dr Chambers' paper was read before this Society in December 1852, and was published in the "Edin. New Phil. Journal" for 1853. The author's chief object was to point out that there were, in his opinion, two sets of phenomena in regard to boulders and smoothed rocks. One set he considered to be the effects of local glaciers, the other he ascribed to a general glaciation of the entire country.

The Convener does not mean to discuss this theory. He wishes only to notice the facts which Dr Chambers brought forward in support of it.

Dr Chambers states—

1. That on Cuineag and Canish (quartz hills in Assynt, situated about thirty miles to the north of Gairloch), he found, "up to a height of 1700 and 1800 feet, striæ running from about N. 60° W., with certain exceptions. One of these exceptions was at the base of Cuineag, where the streaks are from the direct north, apparently by reason of the turn which the agent had there received from the base of the adjoining hill. Another exception was at the hollow dividing the mass of the hill from its loftiest top, where another system of streakings had come in from the direct west."

2. "On a summit south from Ben More, fully 1500 feet high, and four or five miles to the S.E. of Cuineag, there are streakings on the quartz, observing the normal direction of this general movement, viz., from N. 60° W."

3. On the gneissic platform between Coul More and Sulvean (south part of Assynt), Dr Chambers says he "found polished surfaces striated from N.W. to W. To the west and north of the latter mountain are markings in all respects similar. These are situations where no local glaciers could exist."

4. "Streaking, precisely the same as that of Cuineag and Canish, exists at an elevation of at least 2000 feet on the similar quartz mountain named Ben Eay, south of Loch Maree, and forty miles from Assynt—this striation being from N.W. or thereabouts, and totally irrespective of the form of the hill."

5. "Passing northward to Rhiconich, we find near that place striæ coming in from the coast, viz., from the N.W., and passing across a high moor, with no regard whatever to the inequalities of the ground."

6. "A little further north, at Laxford, a fine surface is marked with striation from the N.W., being across the valley in which it occurs. At an opening in the bold gneissic coast which looks out upon the Pentland Firth, there is strong marking in a direction from N.N.W."

7. "The high desolate tract called Moin, between Loch Eribol and Tongue bay, where there is nothing that could restrain or guide the movement of the ice, exhibits striation from N. 28° W.

8. "Striae, N. 25° W., occur four miles to the east of Tongue bay."

Thus at all these localities north of Gairloch visited by Chambers, the rock striations were such as to satisfy him that some vast agent from the N.W.—*i.e.*, from the Atlantic Ocean—had struck upon the country, and left its marks on hills up to a height of at least 2000 feet above the present sea-level.

XVI.—STRATHGLASS AND GLEN URQUHART.

The Convener, in September last, proceeded up Strathglass, with the view of ascending the mountain called "Mam Saul," about 3880 feet high, in quest of what was supposed by the Ordnance Surveyors to be an old sea terrace. Weather both stormy and hazy defeated this attempt; but whilst in the district, the Convener, accompanied by Mr Jolly of Inverness, made some observations perhaps not undeserving of being recorded.

On the hill above Affric Hotel, on the east side of the River Cannich, a rock was met with, planed and striated, at a height of 450 feet above the bridge across that river, and about 720 feet above the sea. The striae were running north by west, a direction coinciding with that of Cannich valley.

At a height of 970 feet above the sea a granite boulder was lying on the upturned edges of the gneiss rock of the hill, lying in such a position as to indicate that it had probably come from a west by north direction.

At the summit of the hill, about 1170 feet above the sea, numerous boulders were found, chiefly on slopes facing the N.W.

On the high road to Drumadrochit and Urquhart, at two or three places a few miles from Affric Hotel, rocks ground down and striated on the south side of the road were noticed. The striae were running about east and west, or parallel with the axis of the valley.

At the top of the hill, about 660 feet above the sea, several boulders were found, the largest being $4 \times 3 \times 3$ feet. These boulders were resting on a bed of sandy clay, and on a slope of the hill facing west by south. The west side of the boulders was well rounded, as if ground down and smoothed by the friction of bodies passing over it from the west.

All the rocks exposed on the hills here, up to the summit level of the road, which reached about 927 feet above the sea, showed smoothings on their west sides.

The whole of Glen Urquhart has evidently, at some former period, been choked with drift. Beds of gravel, clay, and sand still remain on the hills on each side up to the very top. Hence, probably, the luxuriance of vegetation which this beautiful glen manifests.

On the north bank of Loch Ness, about half a mile to the east of Urquhart, a number of conglomerate boulders lie on the hill side. In walking up the hill the Convener counted six, of which the largest was $7 \times 5 \times 4$ feet, from a level of 200 feet to a level of 800 feet above Loch Ness.

The rocks of the hill here are gneiss, so that these boulders have been brought to where they now lie, most probably from Mealfourvounie, which consists entirely of conglomerate rock, and is situated a few miles to the west.

One of the boulders is at a height of 340 feet above Loch Ness, which corresponds with the line of an old horizontal terrace, visible along the south bank of Loch Ness to the eastward.

At the height of 450 feet above the loch, deep beds of a fine sandy clay occur, just above the landing pier at Urquhart.

XVII.—FORT AUGUSTUS.

On the Corryarrick road (about two miles S.W. of the town) one boulder was noticed which seemed to indicate the direction in which it had come. Fig. 46 shows this boulder of grey gneiss lying on a steep bank of gravel at the base of a rocky cliff, which is a buff-coloured felspathic rock. The slope of the hill is towards N.W. The boulder, therefore, probably came from that direction. It happens to be at the same height above Loch Ness (viz., 207 feet) as the lowest of the conglomerate boulders above mentioned seen to the east of Urquhart.

XVIII.—BEN NEVIS.

The track commonly followed by tourists ascending the mountain leads up the N.W. shoulder of the hill. Boulders of enormous size occur on each side of the track. The following measurements will give some idea of the size of these masses; they happened to be within from 20 to 30 yards of the track; but larger boulders were seen at a greater distance: A boulder $16 \times 10 \times 10$ feet, partially sunk in a gravel bed; a boulder $15 \times 7 \times 5$ feet, lying on rock; a boulder $13 \times 7 \times 4$ feet; a boulder nearly cubical, the sides being about 4 feet square. The three first mentioned had their longer axis N.W. and S.E.; and this was the rule with almost all the boulders, whose length was much greater than their breadth. The boulders measured were at levels above the sea between 900 and 1200 feet. But there were boulders of great size up to 2000 feet or more, and there were some near the base of the mountain. Many of these last-named had, however, been utilised for building purposes. Mr Doig, builder in Fort-William, who accompanied the Convener in his ascent, mentioned, that having been contractor for the Town Hospital, he had made use of one boulder, situated at the foot of the hill, which was four times as large as any of those above mentioned, and that all the rubble-work of the front wall of the hospital—extending to about 80 yards—had been obtained out of this boulder.

Mr Doig, who evidently was intimately acquainted with both boulders and rocks on Ben Nevis, had no doubt that all the boulders on the N.W. shoulder of the Ben were different from any rock in the mountain. He stated that the boulders were mostly all granite, both red and grey granite, but mostly grey. Those examined by the Convener were all grey granite, very similar to the rock worked at Ballachulish and Duror, about 30 miles to the west.

XIX.—SKYE.

The Convener regrets not having had an opportunity of visiting Skye, except at one spot on the west coast, viz., Loch Scavaig, where the steamer stops for an hour to allow tourists to visit Coruisk. Dr Macculloch's book, published in 1818, and the paper which the late Principal Forbes read in this Society on the Cuchullin hills ("Edin.

New Phil. Journal" for 1846) show that in different parts of the island there are boulders and smoothed rocks well deserving of careful study.

After what Principal Forbes said about the existence of smoothed rocks, and of grooves or *striæ* on these rocks (which he unhesitatingly ascribed to glacier action), it is impossible to dispute that on this island, small as it is, there must have been ice enough in the different corries to form glaciers. Perhaps there would be less difficulty in adopting the theory, were it supposed that Skye had stood much higher out of the sea at the time when these effects were produced.

Principal Forbes in his paper, among other effects ascribed by him to the Skye glaciers, speaks of "the occurrence of large angular detached masses of hypersthene *rock poised upon others, or fantastically balanced on the insulated tops of the elliptical domes of rock*" (page 92). He also, on this point, quotes Dr Macculloch, who supposed that these detached masses were merely fragments which had fallen from adjoining hills. But he admits that "the mode in which these fragments lie is remarkable. The bottom of the valley is covered with rocky eminences, of which the summits are not only bare, but often very narrow, while their declivities are steep and sometimes perpendicular. Upon these rocks the fragments lie, and in positions so extraordinary, that it is scarcely possible to conceive how they have risen so high after the rebound, or how they have remained balanced on the very verge of a precipice. One weighing about 10 tons has become a rocking stone. Another of not less than 50 tons stands on the narrow edge of a rock 100 feet higher than the ground below, which must first have met it in the descent" ("Western Islands," vol. i. p. 388).

One of these boulders, perched "on the narrow edge of a rock," was noticed by the Convener near where the boat takes passengers ashore at the head of Loch Scavaig. Fig. 48 represents this boulder—*a* shows its position relative to Lake Coruisk and the sea; *b* shows its position more exactly on the rock where it stands.

Dr Macculloch's idea of the boulder having fallen from an adjoining cliff, and *rebounded* on to the top of the rock where it stands, of course cannot be entertained.

On the other hand, if the boulder was brought by a glacier from

the eastward, and projected from the glacier's surface, would the boulder have rested where it fell? Is it not probable that it would have slid down the smooth rock into the sea?

The surface on which it lies, slopes steeply towards the sea, in a direction W. by N.; and under its S.E. end, there are two small boulders which seem to have obstructed progress in that direction. These circumstances conveyed to the Convener's mind the impression that the boulder may have been brought by floating ice, and been thus landed on the rock which it occupies.

It is right to add that the smoothed rocks, which occur near the shore adjoining the lake, have all the appearance of a great amphitheatre, into which floating ice may have entered, and in which ice may have circulated as in an eddy, abrading the rocks forming the bottom and sides of the amphitheatre.

This view of the matter is not inconsistent with the theory, that before the land was submerged, a glacier had existed in the valley, and formed smoothings and groovings also on the rocks as observed by Principal Forbes.

The Convener, seeing the importance of ascertaining beyond all doubt the true character of the materials forming the site of the "Big Boulder," in Barra (p. 12), wrote lately to Dr MacGillivray of Eoligarry, the tenant of the farm on which the boulder is situated, to request that he would dig under the boulder as far as could be done with safety, and send a written report of what was found. Since these sheets were printed, the Convener has received a letter, from which the following are extracts:—

"Having at length got milder weather, we proceeded to the 'Big Boulder of the Glen,' and made the cuts or drains under it, as you directed, to the depth of three feet on both sides, and also at the west end of the boulder.

"The first substance found for about a foot deep, was black soil or earth and cockle-shells, mixed up with a few stones. Below that, as deep as we could conveniently go, very hard gravel and lumps of stone, extremely firm and difficult to pick out,—I should say, because being so much compressed by the enormous weight of the boulder.

"The rock of the hill did not appear at all on any side, or under the boulder for three feet at least. It seemed resting entirely on soil and gravel; site very high, almost on the surface, so that a spade can be pushed nearly to the centre in one or two places.

"The stone, to even an ordinary observer, would appear to have been brought to its present situation by some agency or other, as the place looks quite unnatural to it."

NOTES BY WILLIAM JOLLY, ESQ., INVERNESS, ON THE TRANSPORTATION
OF ROCKS FOUND ON THE SOUTH SHORES OF THE MORAY FIRTH.

(Sent to Boulder Committee, October 1878.)

Along the south shores of the inner portion of the Moray Firth, certain movements of rocks have taken place in geological times which are interesting as bearing on the inquiry into the general transportation of boulders over Scotland. These rocks are, happily, of very distinctive varieties, which renders the question of their source and movements a comparatively easy one. On these, I beg to offer some rapid notes, in connection with the work of the Boulder Committee.

I.—THE GRANITE OF THE DIRRIE MORE.

At the back of Ben Wyvis, on the road to Ullapool, between the Ben and Strath Vaich, there exists a development of a peculiar granite *in situ*, easily seen in passing along the road. The granite occupies a considerable area in the centre of the valley, and is seen in great extent in the bed of the river, to which it imparts a wild and picturesque character, as the water dashes and foams amongst its projecting masses. The rock consists of the usual ingredients of trinary granite, but its distinctive feature is the existence of lenticular pieces of dark mica, arranged throughout its pinkish mass in pretty regular layers, which give the rock somewhat of the general aspect of a stratified deposit. It is peculiar in general appearance, and is easily distinguished wherever seen by its *kenspeckle* character, even when not broken up. This rock is found scattered all over the country to the eastward of its parent position, and would seem to have been carried down the Blackwater valley in which it is found, and also right through the deep glen which exists in the very centre of the great bulk of Ben Wyvis, and which forms its most distinctive feature as seen from the Dirrie More, or Great Slope, as the long road to Ullapool is called. Thus viewed, Ben Wyvis seems cleft into two mighty masses by this great gorge, and has from this point, perhaps, its grandest and most commanding aspect. This granite is found scattered abundantly all over the Black Isle, where it exists as the most abundant surface rock, being imbedded in the debris and boulder clay that clothes the whole of

its surface. It may be seen in boulders which have been broken up for fencing purposes, showing the interior composition very well, along the road from Conan village to Ferintosh, where it forms the greater part of the dyke that skirts the highway. It occurs right on the summit of the Mulbuie, or Yellow Ridge, which forms the backbone of the Black Isle. It can be seen there to good advantage, along the old road between Dingwall and Inverness, which ran right over the Mulbuie between Conan and Tor Inn, a path which must now be traversed on foot, and which commands a magnificent prospect. These granite blocks are scattered all over the eastern slopes of the Mulbuie, and may be seen on the Black Isle coast of the Moray Firth, as at Avoch, Fortrose, and along the district traversed by the high road leading to Cromarty.

The blocks have been carried across, not only the ridge of the Black Isle, but what is now the Moray Firth, to beyond Elgin, and they may be seen on the coast between Burghead and Lossiemouth. At Lossiemouth, on the high ridge of Stotfield above Branderburgh, several masses may be observed in the dyke above the Public School. I have no notes of its appearance east of this point.

II.—THE LOCH NESS GRANITE.

At the northern end of Loch Ness, on its western side, a large patch of red granite exists along the shore—from a point a little south of Loch End Hotel, at a burn just opposite Dores, to a point about a mile south of the mouth of the Abriachan Burn—and extends westwards from the loch in a triangular outline some two or more miles broad, forming the mass of the high hill between Loch End and Abriachan, which there bounds the loch. This granite is fine-grained and of a light pinkish colour, and is used for commercial purposes, numerous examples of it being to be seen in Tom-na-Hurich cemetery near Inverness, and elsewhere. The smallness and compactness of its component ingredients are its chief peculiarities. It occurs in the abundant gravel deposits to the eastwards of Loch Ness, in Tom-na-Hurich for instance, as noted long ago by George Anderson, the eminent geologist and joint author of Anderson's excellent guide-books to the Highlands; and eastwards of this, on beyond Nairn and Forres. It is found less in large boulders, though it occurs in considerable masses, than as forming part of

the gravel deposits which form so marked a feature on the south shores of the Moray Firth.

III.—THE LIVER-COLOURED CONGLOMERATE.

On the east shore of Loch Ness, opposite this granite, extending from Loch Ashie to a little south of the Fall of Foyers, stretches a high ridge formed of Old Red conglomerate, of which also the great mass of Mealfourvounie on the opposite shores of Loch Ness wholly consists, up to its very summit (3060 feet), which is the highest point attained by this basal deposit of the Old Red of Scotland. This conglomerate, on the east side of the loch, is best seen on the Stratherrick road from Inverness, where it runs above Loch Duntelchaig, south of its junction with the road to Dores, and along the side of Loch Kecklish (Ceo-glash), which lies between Loch Duntelchaig and Bochrubin. Here it forms a series of very striking precipices, vertical, bare, and cracked, overhanging the road and loch, and having a remarkable appearance, arising from their form and composition. This conglomerate happens to contain in great abundance, imbedded in its matrix, a certain dark-purplish or liver-coloured quartzite, in pieces of considerable size. This quartzite is so marked and peculiar that it can be easily distinguished in any boulders in which it occurs, and it seems, so far as I have seen (and I have examined the most of the country minutely), to be peculiar to the conglomerate on this part of Loch Ness; so that its existence in any conglomerate block is a very sure evidence of its parent site. A very good place to see it *in situ* is an abrupt little hill close by the junction of the Stratherrick and Dores roads, crowned by an ancient hill fort, called *Cuistean-Duin-Riabhaich*, or the Castle of the Grey Hillock, with rough enclosing walls, easily noted from the highway. The fort is also worth visiting, on its own account, and for the fine view obtained from its summit; and there this liver-coloured quartzite may be well seen embedded in the conglomerate which forms the mass of the hill.

This special conglomerate is scattered to the N.E. of this point, in very numerous masses, onwards beyond Elgin. One peculiarity of this rock is that it is found so frequently in large blocks, often of immense size,—so large that they have attracted the attention of the old inhabitants and have received local names; and

they not seldom occupy conspicuous and elevated positions. They are very abundant, on the flat Old Red Sandstone ridge of the Leys, lying between the valleys of the Ness and the Nairn, where they are frequently very large. The great boulder near the battle-field of Culloden, known as Cumberland's Stone, is formed of it, being rubbed, rounded, and grooved on the upper side; the splendid angular, cubical mass of Tom-Reoch, on the opposite bank of the Nairn near Cantray Doon, one of the largest and finest blocks in this part of the country, is a worthy specimen; several large boulders in the fine woods of Cawdor, one of which, the Grey Stone, stands on the edge of the river, near the junction of the two streams that form the burn of Cawdor, a little above the castle, are composed of it: while, east of this, it is represented by exceedingly numerous blocks, the chief of which are *Clach-an-oidhe*, or Stone of the Virgin, 20 feet \times 15 \times 9, close by the Public School of Geddes; another, near the top of the Hill of Urchany, at a height of 580 feet, called *Clach-na-Calliach*, or Stone of the Old Woman; the fine boulder right on the crest of the hill, a little to the east of this, called *Clach-nan-Gillean*, or Stone of the Boys, at a height of 690 feet; several big blocks on the high ground of Moyness, one in particular lying close by the roadside below the U.P. Church of Moyness or Boghole; the splendid block on the high ridge on which stands the picturesque ruin of Burgie Castle, east of Forres, a short distance beyond the castle, called the *Douping Stane*, from a burgess ceremony performed on it, as lying on the extremity of the town lands of Forres; and a very large mass, still partly imbedded, on the crest of the hill of Roseisle, perhaps of the same rock. Examples of it may be seen on the south shore of the loch of Spynie, not far from the castle, between Elgin and Lossiemouth. The whole country between Loch Ness and Lossiemouth is literally strewed with pieces of this easily distinguished conglomerate. Several of the larger specimens of it have already been visited, described, and figured by Dr Milne Home, in former reports of the Boulder Committee.

IV.—THE GRANITE OF STRATHERRICK.

In the elevated hollow strath, or plateau, known as Stratherrick, which runs parallel to Loch Ness on its eastern side, occurs a large

patch of grey granite, occupying nearly the centre of the strath. It is very well exhibited near the Roman Catholic chapel, where it occurs *in situ* in large masses, and where it has been worked. It is a granite of very good quality, and has been greatly used for building ; and it would be much more used if it were more accessible from lines of public communication. It extends down the pass of Inverfarigaig, where it forms the rock of its upper portion, the lower being the Old Red conglomerate. This grey granite is found in blocks of different sizes, some of them large, all over the country east towards Elgin, intermingled with the conglomerate just mentioned ; but it never occurs in such large masses as the conglomerate, which, from its nature and original position, it could not do. It is remarkable that this granite is also found in blocks scattered *over the very top of the ridge of conglomerate between Loch Kecklish and Loch Ness*, already described, sometimes finely perched on its very summits, which range between 1400 and 1500 feet, and I have numerous notes of big boulders of it found there.

V.—THE GNEISS OF STRATHERRICK AND THE MONAGHLEA MOUNTAINS.

Parallel to the line of conglomerate blocks scattered between Loch Ness and Lossiemouth, often intermingled with it and the granite of Stratherrick, but occurring much more abundantly to the east of it, is found a broad band of boulders of grey gneiss. These are of all sizes, frequently large enough to have claimed popular notice and to have received local names, and are often placed in remarkable and elevated positions. The character of the rock may be well seen on the side of the road between Inverness and Farr, in the dyke near the Free Church of Farr, and in the fine group of boulders in the centre of the valley, which forms so striking and interesting a geological feature there. They occur in astonishing numbers round *Loch-na-Clachan*, or the Loch of the Stones, into which the stream from Loch Duntelchaig flows, near the old parish church of Dunlichity. There they form grand and picturesque groups of all sizes and forms, on the east side of the loch and up to the elevated summits of the hills, above 1400 feet high, and where they may often be seen, right on their crests, standing in a serrated line against the sky. Altogether, this is one of the most remarkable aggregations of blocks that I know, and it has already been referred

to by Dr Milne Home, in his valuable paper on Glen Roy. Farther up the Nairn, near Farr House, stretches a long flat plateau of gravel and other debris, which stretches right across the valley, and through which the river has had to cleave its way in the narrow gorge below Flichity Castle. On this plateau is found another striking and numerous assemblage of huge blocks, well worth a visit, often of large size and peculiar forms, scattered singly and in groups, some of them standing erect like great pillars. Frequently these gneiss blocks have been left in remarkable places. On Craig-a-Chlachan, which overlooks the church of Dunlichity, on the west shore of Loch-na-Chlachan, near its top, on the edge of a steep precipice, is poised a block of gneiss 14 feet long, 10 feet in height, which catches the eye of the traveller from all points, and is known as *Clach-na-Fhreiceadan* or *Faire*, or the Stone of the Watch, on account of its elevated station (1120 feet), standing, as it does, like a sentinel, to guard the surrounding region.

To the east of the Free Church of Farr, right on the peaked top of the highest hill seen from that part of the valley, may be observed what seems a shepherd's cairn marking its summit. This provoked my curiosity for years, and this season I ascended the mountain and found that it consisted of a great block of gneiss split in two, and known, from this circumstance, as the *Clach Sgiolte*, or Split Rock. It has been originally a cube of stone, 9 feet square and 5 feet high, now split at two-thirds of its breadth, the larger part having remained in its original position and the smaller having fallen over. It stands nearly 1000 feet above the valley below, and nearly 1600 feet above the sea. Another *Clach Sgiolte*, on or very near the top of the great mountain, overlooking the narrow gorge of Conaglen, near Dunmaglass, at the very head waters of the Nairn, called Ben Dhu Choire, at a height of 2260 feet. This block I have not yet ascended to.*

Another striking example of these gneiss blocks is found beyond the inn of Flichity above Farr, on the north slope of the finely crested ridge that lies between the valley of the Nairn and Loch Ruthven. It is called *Clach-a-Bhonat*, or the Stone of the Bonnet. This is a very large block, worth a visit. In this part of the valley of the Nairn, numerous other blocks occur singly and in groups in

* There is another *Clach Sgiolte*, about $1\frac{1}{4}$ mile from the source of the Findhorn, called the Eskin, some 2070 feet above the sea.

the bottom of the valley, and high on its sides up to the crests of the enclosing hills, on which they may be seen standing against the sky line.

Farther down the valley, below Daviot and not far from the mansion of Nairnside, a very fine boulder is perched on the top of a steep rock overlooking the river, on its eastern bank. It is 21 feet \times 12 feet \times 15 feet in height, and forms a fine object as seen from below, from the peculiarity of its position and great size. It is called *Clach-an-ullaith*, or the Stone of the Treasure-Trove, from the prevalent idea that treasures lie concealed under such remarkable rocks; for there are numerous blocks with the same name and tradition, in various parts of the Highlands.

On the same side of the Nairn, and not far from the block just mentioned, another is found, high up on the hill bounding the valley, and seen against the sky from below, very distinctly so from the Cumberland Stone, and from the road to the far-famed Clava, with its cairns and standing-stones. It is called *Clach-a-nid*, differently interpreted to be the Stone of the Nest, an unlikely meaning, and more probably the Stone of the Whistle, as the point to which the herd ascended to whistle and call on the cattle scattered over the hill slopes there, when he went to drive them home for the night. It is a very fine block, measuring 21 feet \times 21 feet \times 20 feet high, and has a commanding position (950 feet), with a splendid prospect, over the pastoral Nairn, away to the distant N.W. Highlands.

There are numerous other blocks of the same gneiss worthy of mention, but the foregoing will suffice as examples. They are found extending to the eastwards like the rocks already mentioned.

VI.—THE KINSTEARY GRANITE.

Near Nairn, on the estate of Kinsteary, occurs a considerable development of granite, of distinctive character and great value. It is of a rich flesh-colour, and its chief feature is the existence of fine large crystals of orthoclase felspar, which give it its special beauty, approaching in appearance as it does to a rich-coloured marble. It has only been recently worked for the market, but has already taken a high place, and is largely used in London and elsewhere for fine ornamental purposes. It may be seen *in situ*, quarried at different places, at a short distance from Nairn, on the road to Ardclach.

This peculiar granite, which can easily be distinguished wherever it occurs, is found abundantly to the eastwards of its original position. In all the dykes and houses in and round Auldearn, and all over the Moyness district, it may be seen as the most abundant rock. It extends eastwards beyond Forres, gradually lessening in amount but still abundant, over the flats of Kinloss and up on the high ridge of Burgie to its summit above the *Douping Stone*, and beyond Elgin to Lossiemouth and further east. Pieces of it may be seen on the shores of Loch Spynie near the blocks of conglomerate already mentioned.*

The foregoing are the chief examples of travelled boulders found on the south shores of the Moray Firth. Many others occur, but these have been mentioned because they consist of rocks of a more or less pronounced character, easily distinguished where seen; therefore furnishing important evidence as to the direction and extent of the transporting agents. From the map, it will be seen that the general direction of movement of these blocks has been eastwards, but chiefly from S.W. to N.E., parallel to the trend of the coast of the Moray Firth at this part. None of these rocks are found to the *west* of the points *in situ* where the parent rock is found; at least, I have found none, and I speak from a pretty extensive knowledge of the district. What the transporting agent or agents were—whether glaciers, or icebergs, or ice-floes, or water currents, or one or more of these together—however interesting and important—it would be foreign to the purpose of the present paper to consider; but that these rocks were carried from their native sources and scattered widely and numerously to the eastwards, over a large extent of country, cannot for a moment be doubted. †

WILLIAM JOLLY,
H.M. Inspector of Schools, Inverness.

* I have no notes of the distribution of these boulders east of Lossiemouth. Mr Wallace, head master of Inverness High School, and a good geologist, tells me that he saw recently large blocks of both the Dirrie-More and Kinstearny granites at Buckie in Banff, dug out of the new harbour. It would be interesting to ascertain how far east these easily distinguished rocks have been carried.

† The author purposed entering into greater detail in regard particularly to the remarkable carried blocks of the valley of the Nairn, in a special paper on the glaciation of that valley.

I.

OBSERVATIONS ON BOULDERS AND DRIFT ON THE PENTLAND HILLS.

By ALEX. SOMERVAIL, Stationer, Edinburgh.

Besides the boulders described by the late Mr Charles Maclaren in his "Geology of Fife and the Lothians," and also by Professor Geikie in the "Edinburgh Memoir of the Geological Survey," as having been carried from the Highlands, there are others which would indicate a transport from a different direction.

On the highest summits of the Pentland Hills (Scald Law, Carnethy, South Black Hill, North Black Hill, and others which are composed of various varieties of porphyrites) are found numerous boulders of fine conglomerates, grits, and sandstones, intermingled with a few boulders of quartz, greenstone, and other rocks, all partially or entirely covered by a deposit of peat, which in some places on and near the summits of the hills attains a thickness of nearly six feet. The sandstone boulders vary in size from mere fragments up to large masses which I was unable to dig up. They are common on the very highest point of Carnethy (S. 1),* more so on Scald Law (the highest of the range) and South Black Hill, and still more abundant on the West or North Black Hill. They are smaller in size and less numerous as we approach the hills in the neighbourhood of Edinburgh—viz., towards the east.

On a careful examination of the above-mentioned sandstone boulders, with regard to mineral composition, texture, and colour, there can be no doubt that they have been derived from the sandstone strata which form the Cairn Hills. The highest point of the Cairns is 1844 feet, or 46 feet below the level of Carnethy, and 54 feet lower than Scald Law, which is 1898 feet above the sea-level.

It would follow from this, that the transport of the sandstone boulders has taken place from S.W. to N.E., or very near this direction. There are other indications which confirm this movement. Mr John Henderson has, in the "Transactions of the Edinburgh Geological Society," vol. ii. page 365, described the occurrence of a

* A plan of a portion of the Pentland Hills, to illustrate Mr Somervail's and Mr Henderson's notes, is appended. On this plan the localities mentioned by Mr Somervail and Mr Henderson are indicated by the letters S. and H. respectively.

large slab of sandstone lying in the gorge of the Bonally Burn, derived from beds of the same rock about half a mile to the S.W.

In a deep cutting recently made in the boulder-clay at Alnwick Hill, near Liberton, I observed many boulders of Old Red Sandstone, which must have been carried from the vicinity of the Carlops, where the same rock occurs *in situ*. There were also boulders of various varieties of porphyrites, which form the hills to the S.W. The same remarks hold good with regard to boulders I saw dug from very deep excavations made two years ago at Seafield, near Leith, all bearing out a transport of some kind along the trend of the Pentlands, or from S.W. to N.E.

A fact in connection with the Old Red Sandstone boulders I observed at Alnwick Hill appears worth recording. Many of these boulders were very round and smooth, so much so that they suggested the idea that the agent which transported them to their present position could not have produced this effect during transport, as the distance from their source is so very small, but in all likelihood found them worn and rounded before being carried along.

NOTE ON THE BOULDER CLAY.

There is, in my opinion, no true till or boulder-clay resting on any of the Pentland summits. What has been described as such by Dr Croll on the top of Allermuir Hill seemed to me simply a peaty soil formed by the decomposition of the underlying rock and debris, and the decay of vegetable matter, making up a heterogeneous deposit which, however, has no connection with the true boulder-clay occurring at lower levels.

II.

NOTES ON DRIFT AND GLACIAL PHENOMENA ON THE PENTLAND HILLS.

By JOHN HENDERSON, Curator of the Phrenological
Museum, Edinburgh.

The following phenomena were noted by me during a number of visits I made to the Pentland Hills; but as my chief object then was to examine the older rocks, my observation on the recent deposits are by no means complete.

Striated Rock Surfaces.—Only two localities were observed. Dr Croll, in a paper on “The Boulder Clay of Caithness,” first made known that he had discovered a striated rock on the top of Allermuir Hill, at a height of 1647 feet above the sea. I visited Allermuir Hill some time after this discovery, and was fortunate enough to find a portion of the striated surface. The rock of the summit of the hill is felstone, very much weathered and broken up, and it is only in the little hollows, which are covered with a blackish earth, that indications of rubbed or scratched surfaces are found. The portion I discovered, although it was only a few inches square, was finely striated, and I had no difficulty in making out the direction of the striæ, and the direction from which the striating agent had come, which was about W.S.W. (See Plan, H. 1.) The other locality I discovered during a very dry summer, when the water in Bonally Pond was very low. The striæ occur here on a reddish sandstone, which crops out along the south-east side of the pond, at an elevation of about 1100 feet above the sea (H. 2). There is here a much larger surface of striated rock than on Allermuir Hill, but it is mostly always covered by the water of the pond. I had an opportunity, however, of seeing a portion of it again last summer. I then took the direction of the striations, and found them, as on Allermuir Hill, W.S.W. I may remark that this agrees with the direction of the striæ on the rocks of at least twenty localities that I have examined in the neighbourhood of Edinburgh, and in no instance in this neighbourhood have I observed the rocks striated in a direction N.W. and S.E.

Boulders occur at all heights up to 1400 feet, and all sizes up to 10 or 12 tons. Several very large ones lie on the north side of Capelaw Hill, at about 1200 feet above the sea (H. 3). They are of a dark crystalline greenstone, unlike any of the igneous rocks in this district. Further west, on the west side of Harbour Hill, there is a great number of smaller blocks of the same greenstone (H. 4). They appear to me to lie on about a uniform level along the hill side, at about 900 or 1000 feet above the sea. The prevailing boulders in the northern portion of the hills are of greenstone, while those further to the S.W. are mostly sandstone.

Boulder Clays.—I have observed two localities where these occur in considerable quantities, one at the north-west corner of Glencorse

Reservoir, at an elevation of 900 feet (H 5). It is a stiff reddish clay, full of well rubbed and scratched stones, and differing in no way from the boulder clay of the lower districts. The other locality is about three miles to the S.W. of this, in the same line of valley between the hills, at an elevation of about 1100 feet. It is of the same character as the last, but is covered by a great deposit of gravel and boulders, which extends across the broad valley between Hare Hill and South Black Hill (H. 6).

Another large deposit of gravel and boulders is at the mouth of the broad valley in which the Bonally Pond lies, at an elevation also of 1100 feet above the sea. This deposit encloses some very large boulders of greenstone (H. 6).

III.

The Convener appends to the foregoing Notes by Messrs Somervail and Henderson, the References by the late Charles Maclare, by Professor Geikie, and Mr Jas. Croll, to Striae and Boulders on the Pentlands, as the localities are embraced in the same map.

1. Mr M'Laren, in his "Geology of Fife and the Lothians," states :—

(1.) "There are few opportunities of observing 'groovings' on the Pentland Hills. I noticed them, however, at Westwater of Dunsyre, on the top of a thick bed of hard sandstone, from which 12 or 14 feet of alluvium had been removed. The dressings pointed exactly east and west ; and the evidence was the more satisfactory, as the direction of the stream on whose bank the rock was situated, and of the valley in which the stream flowed, was south and north. They were very distinct, the larger groovings being about $1\frac{1}{2}$ inch broad, and $\frac{3}{10}$ ths of an inch deep. The locality must be 800 or 900 feet above the sea" (page 294).

(2.) Travelled blocks are important in two respects:—*first*, as indicating the action of currents or other transporting agents no longer operating; and *next*, as illustrating changes which have taken place subsequently to their deposition in the spots where we find them.

a. "In the Pentlands there is a boulder of mica slate, weighing 8 or 10 tons, on the east end of Hare Hill (see plan annexed, M. 1). It reposes on the surface of the west side of the glen leading north from Habbies How to Bavelaw, on a declivity about 80 feet above the bottom. The nearest spot from which this mass could be derived is the portion of the Grampians about Loch Vennacher or Loch Earn, 50 miles distant" (page 301).

Further, this block tells us that the surface of the hills where it now rests must have been in a different condition when it was deposited. It lies on the side of a declivity, where a large stone, either hurried hither by a current, or dropped from an iceberg, would not stop, but roll down to the bottom of the valley. The reasonable inference is, that the valley between Hare Hill and North Black Hill was then filled with "materials which have since been washed away" (p. 302).

b. Half a mile south from this, three greenstone boulders of 2 or 3 tons weight each are lying on the edge of a precipice, about 200 feet above South Burn. (See plan, M. 2.)

These have certainly travelled some miles, and the bed of clay seen below them is no doubt a remnant of that which then filled up the ravine, and prevented them descending to the bottom.

c. On the east end of West North Black Hill there is a sandstone boulder of 8 tons weight. (See plan, M 3.)

This block may not have travelled far. But it rests on a surface as steep as the roof of a house (inclined both above and below at 45°), and about 400 feet above the bottom of the valley.

It is impossible that it could be dropped here, or brought to the spot by a current, without descending to the bottom, unless sustained in its place by matter since removed.

This single block informs us that the ravine about 100 yards wide at the surface of the marsh, which separates Black Hill from Beild Hill, must then have been filled up with alluvial matter to the height of 400 feet at least above its present bottom, which is probably 50 feet above the true bottom in the rock (page 302).

d. On the south declivity of Harbour Hill, about 300 feet above the level of the Compensation Pond, there is a very large boulder of greenstone weighing 12 or 14 tons. (See plan, M. 4.)

The surface it rests on is not steep. But the boulder must have

travelled many miles; for there is no greenstone of the kind in the hills, and none near them, except in situations 500 or 600 feet lower.

This block has probably been transported in the same manner as the mass of mica slate (*a* above).

e. The same remarks apply to a greenstone boulder lying half a mile N.W. of Logan House, on the south side of West Black Hill, about 1400 feet above the sea. It is of 12 or 14 tons weight. (See plan, M. 5.)

There are many others in elevated situations of 3 or 4 tons weight.

The substance is generally greenstone, the least brittle probably of all rocks, and of course the best fitted to resist fracture. Nearly all the blocks have their angles rounded off.

f. On the banks of Eight Mile Burn, in the low ground, there is a mass of alluvium about 100 feet thick, containing hundreds of trap boulders of all sizes up to 10 tons weight. It consists of two beds,—the older, a blue unctuous clay, the newer a red clay. The large blocks are chiefly in the latter.

There are many similar travelled blocks in the burn flowing from the old Reservoir to Bonally, and probably in all the streams of these hills (page 303).

2. Professor Geikie, in his Memoir "On the Geology of the Neighbourhood of Edinburgh," published in 1861, observes (1) that "boulder-clay lies along the north-west flanks of the Pentlands, rising to a level of at least 1300 feet."

When the clay has been recently removed, we usually find the rock below polished, grooved, and scratched in a direction nearly E. and W., or E.S.E. and W.N.W. These markings even remain distinct on hard greenstones which have remained exposed to the weather for an indefinite period.

The parallelism of the striations throughout the present district shows that the floating ice must have moved in a pretty uniform direction; and that it was from the west is rendered clear by the striation of the western face of the hills, by the great depth of drift on their eastern sides, and by the fact that the transported boulders, when traceable to their parent rock, have been carried from west to east (page 126).

(2.) Of boulders which have undoubtedly been transported either from Cartyre or the Grampian Highlands, I may refer to the mass of mica slate about 8 or 10 tons, on the S.E. side of Hare Hill above Habbie's How, which was first noticed by Mr Maclaren.

(3.) On the other side of the valley, on the S.W. slope of North Black Hill, several smaller masses of white quartz rock occur, fully 1300 feet above the sea-level.

Masses of gneiss, mica-slate, and a hard metamorphic conglomerate, are found in tolerable abundance all over the district.

3. Mr Croll, in "Climate and Time," gives the following observations :—

"On ascending *Allermuir Hill* (1617 feet), Mr Bennie and I found its summit ice-worn and striated. The striae were all in one uniform direction, nearly east and west. On examining them with a lens, we had no difficulty in determining that the ice which affected them came from the west, not from the east. On the summit of the hill we also found patches of boulder clay in hollow basins of the rock. At one spot it was upwards of a foot in depth, and rested on the ice-polished surface. Of 100 pebbles collected from the clay, just as they turned up, every one, with the exception of 3 or 4 composed of hard quartz, presented a flattened and ice-worn surface, and 44 were distinctly striated. A number of these stones must have come from the Highlands to the north-west."

"On ascending *Scald Law* (1808 feet), 4 miles S.W. of *Allermuir*, we found in the debris covering its summit hundreds of transported stones of all sizes, from 1 to 18 inches in diameter" (pp. 441, 442).