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SIXTH REPORT

OF THE

BOULDER COMMITTEE

OF THE

ROYAL SOCIETY OF EDINBURGH.

1880.

June 30 1882.
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letter on
Glaciation
1882

BOULDER COMMITTEE.

Sir Robert Christison, Bart.

Sir Charles Wyville Thomson, LL.D.

Rev. Thomas Brown, Edinburgh.

Andrew Fleming, M.D., Edinburgh.

Professor Archibald Geikie, Edinburgh.

Professor Forster Heddle, St Andrews.

William Jolly, School Inspector, Inverness.

Arthur Mitchell, M.D., Edinburgh.

Ralph Richardson, Edinburgh.

Thomas Stevenson, C.E., Edinburgh.

David Milne Home, LL.D. (*Convener*).

SIXTH REPORT

OF THE

BOULDER COMMITTEE

OF THE

ROYAL SOCIETY OF EDINBURGH.

(WITH THREE PLATES.)

From the Proceedings of the Royal Society of Edinburgh, Session 1879–80.

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MDCCCLXXX.

CONTENTS.

SIXTH REPORT

OF THE

BOULDER COMMITTEE OF THE ROYAL SOCIETY OF EDINBURGH.

The materials for this Report have been obtained from the Convener, Professor Forster Heddle of St Andrews University, William Jolly, Esq., H.M. Inspector of Schools, Inverness, and William Wallace, Esq., High School, Inverness.

To make the descriptions of the boulders more intelligible, it has been found necessary, as in former Reports, to annex a few diagrams, which will be found at the close of the Report.

I. *NOTES BY CONVENER.*

Argyleshire.

1. In consequence of information in the schedule issued by the Committee, and filled up by Mr Montgomery, schoolmaster at *Southend*, near Campbelton, I went to Southend, and had pointed out by Mr Montgomery boulders at several places there.

Mr Montgomery considered these boulders to be granite. If granite, they were different from any I had ever before met with. They were certainly an igneous or primitive rock of some kind, and composed of different ingredients, the chemical nature of which I am unable to state. There appeared to be crystals of white felspar. I could detect no mica. The general mass was a whitish-grey colour.

These boulders were pointed out to me at many places. I saw two in the River Conn (about half a ton in weight), one on Penny serach farm (3 or 4 tons), another on the adjoining farm of Bruneri-

can ($1\frac{1}{2}$ ton), another at Macherioch (about half a ton in weight). I heard of many more lying on the sea-shore adjoining these farms.

I was assured by Mr Montgomery, and by the tenants of these respective farms, that there was no rock in the south end of Cantyre similar to that of these boulders.

Along the east coast between Campbelton and Southend, a distance of 8 or 10 miles, I descried many boulders of the same nature; and in a gravel pit near Campbelton gas-work, I saw the fragments of another, which had weighed probably 3 or 4 tons.

In this same gravel pit I found a boulder of grey porphyry, containing crystals of white felspar, somewhat similar to the Southend boulders. The gas manager informed me that he believed there was rock of the same nature a few miles to the north.

In the valley of Brackerie I found rock of a crystalline nature somewhat similar in composition to the boulders above described; and at a place in the same valley, called Collielangart, I saw a monumental pillar, about 8 feet high, similar in composition, said to have been obtained from Glenlissa, a place about 3 miles to the N.W. of Campbelton. I was informed also that boulders of this same rock, weighing 2 or 3 tons, had lately been observed in a recent cutting into boulder-clay to the north of Campbelton.

Professor Nicol, in a short account of the Geology of Cantyre in the "London Geological Society's Journal" for 1852 (vol. viii. p. 421), refers to the boulders at and near Southend. He describes them as *white granite*, and as resembling a granite in Arran, from which, therefore, he supposed these Southend boulders had somehow been transported. Professor Nicol takes notice of several striated rocks on the east coast of Cantyre, one of which showed a direction of E. 10° N. by compass, which he remarks is nearly parallel to the line of coast, and in the direction of Arran, 25 miles distant.*

There was only one spot where I found a smoothed rock, viz., about a mile to east of Campbelton. It sloped down to N.N.W. at an angle of 40°. There were no striæ.

* With reference to Professor Nicol's view that the white granite boulders seen on the east and south coast of Cantyre came from parent rocks in Arran, it is right to notice that the late Rev. Mr M'Bride of Rothesay, who was a good geologist, and well acquainted with the rocks of the West Highlands, suggested a more northern source (Bryce "On Arran," 4th edition, p. 337).

NEW CLUB EDINBURGH

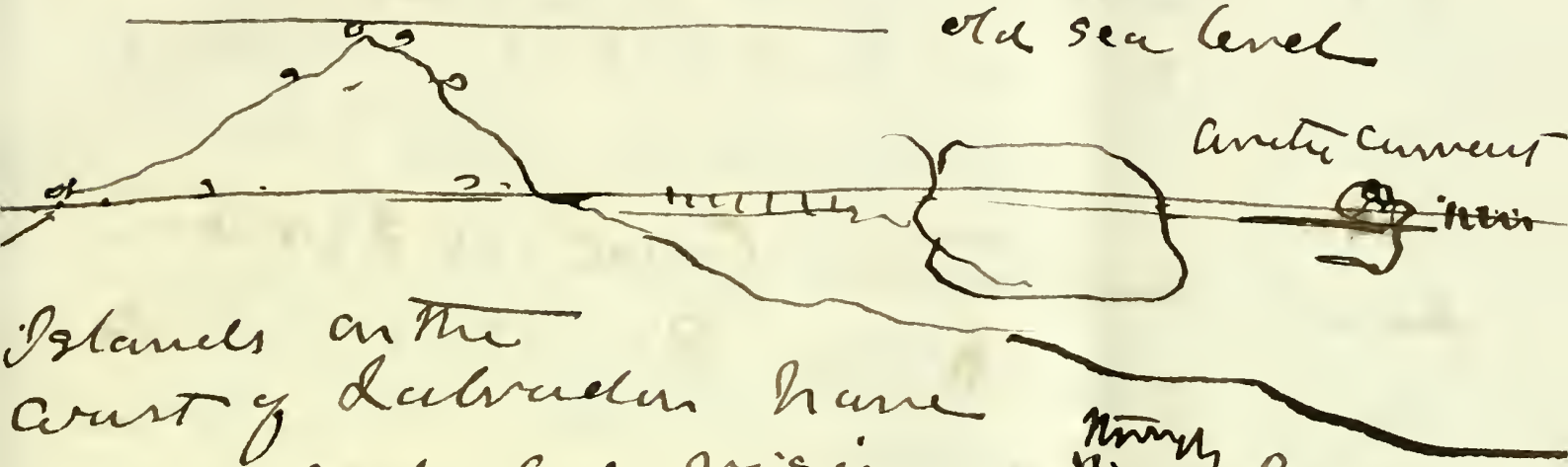
June 23 1882

My dear Sir

Your three boulder reports have set me on an old subject, which I shelved when I finished my last paper in Q. J. G. S. & took to Thermography. There is so much genuine stuff in your reports that ought, as I think, to be sorted and mapped. I suggest that the sites of the highest Scotch erratics found, be taken as a centre level, and the country above that level shaded as land above water. I have done that for a limited ~~scale~~ area. It then appears that Scotland may have been to Scandinavia as Labrador is in fact to

Greenland :- a group of Islands in an arctic current. The present state of things on the West ~~coa~~ side of the atlantic, then accounts simply and reasonably for the facts observed on this side. Unless Boulders fall from the sky, ~~as~~ which has been suggested, none can get to the dry tops of Islands. But when sunken hills rise to be Islands, & grow to be mountain tops, then ice borne drift stones may be lifted on the ~~If~~ When chilled rocks rise through iced water, high enough, they may condense enough of snow to make local ice systems. That visits is in fact the state of things on the American side; and accordingly

to my observations on both sides, that was the state of things on the European side of the atlantic



Islands on the coast of Labrador have risen, and are rising, by the arctic current; where ice afloat now is continually moving beach boulders. The tops of many of the islands which were sunken rocks, are crowned with erratics. But there are no glaciers, till higher & more northern lands are reached. From them icebergs are launched, and the whole arctic current of the atlantic now is cumbered with

ice of all sorts; starts
as it appears by excess of during that short period
Solar Radiation. If the en masse Labrador
land which has risen, and is
rising, rises high enough; a
local ~~Labrador~~ american land ice system
may grow in Swiss latitudes.
Then Labrador glaciers may flow
down hollows now firths, like
Hamilton Inlet; and ~~cover~~ pass
rounded tops with sea borne
boulders where I have seen
them upon Labrador Islands in ~~Scotland~~ welsh
latitudes. Boulders on high
tops in Scotland if sea borne
as I suppose may have come from other Scotch
tops or from Scandinavia
or Iceland or from any other
land then above water

NEW CLUB EDINBURGH

Boulders on low hills
on shoulders in glens &
on coasts may have done
likewise. The last swirl of the
last tide gave the last
direction of movement
to ice rafts ~~afloat~~. But when
a peculiar rock is at the
head of a glen, and stones
like it are strewn along
the run of water, the odds
are that a flowing glacier
carried these stones down
hill, over sunken undulations.
and scored them
The pierre a Bot on the Jura,
and il Gran Sasso di Lentezza,
which I have seen near Como
on opposite sides of the Alps

together with moraines
in Lombardy & Germany prove a
local alpine ~~Swiss~~ glacial system
of vast size. But the Greenland
System which exists; and
the arctic current which
is a fact, are big enough
to account for all the European
glaciation that I have studied
since 1848 between the North Cape and
~~the~~ White Sea, & the Caucasus,
Black sea and Caspian ~~and~~ & Mediterranean. I have
hunted ice marks round
the world, and up & down
many meridians to the Equator.
from the Polar Basin

My last hunt was all about Indian and the secrets Gave printed.

You asked me to write something about your Boulder reports I say that they contain right good work and you may make any use you please of this letter.

Yours Very Truly
J F Campbell

David Milne Home Sq 22.D.

16 York Place

I offer no positive opinion regarding the position of the parent rock from which these *white granite* boulders came. It is pretty clear, however, that those at Southend must have travelled from the north, and many of them there are lying on the Old Red Sandstone strata which fringe the south-west coast of Cantyre.

Another part of Cantyre visited by me was the district between Campbelton and the west coast at *Drumlenbie and Balahunty.*

Near *Kilhenzie*, a few miles west of Campbelton, there are hills reaching to a height of from 500 to 600 feet, well covered with detritus; and on their western slopes there are numerous boulders of gneiss and mica schist. I measured several, the largest contains about 150 tons.

The Old Red Sandstone formation occupies the west coast for some miles. It is well covered by detritus, and on the detritus, especially when it slopes to the west, there are many boulders of granite and gneiss, which from their position appear to have come from the N.W.

Fig. 1, plate XVII., represents a bank of gravel, at a height of about 50 feet above the sea, and sloping to the sea in a N.N.W. direction at an angle of about 25°, well covered with gneiss boulders, of which three are represented. There was no rocky cliff from which they could have fallen. They were true erratics. Thick turf had formed on the bank, which partly covered the boulders.

Fig. 2, plate XVII., represents, near the above spot, another boulder of gneiss, at a height of about 40 feet above the sea, lying on a mass of reddish coloured mica schist, blocked at its south end. Its longer axis lay N. by E. and S. by W. It had apparently come from the north, and been stopped in its further progress by the rocks at its south end.

On the shore, I found a boulder partially in a fissure which cuts through the mica schist strata, here forming tablets or sheets nearly horizontal. Figs. 3 and 4, plate XVII., represent a fissure running N.W. and S.E., about 6 feet wide. The boulder, very hard gneiss, $10 \times 5 \times 4$ feet, was sticking in this fissure. Fig. 3 represents the fissure running N.W. and S.E., and the upper part of the boulder projecting above it. Fig. 4 represents the interior of the fissure partially filled with pebbles, and the boulder resting partly on them and partly on the S.W. wall of the fissure, whilst

the other end of the boulder, outside and above, was resting on the N.E. edge. The boulder had clearly been pushed from the northward (from B in figs. 3 and 4), and on reaching the fissure had partially fallen into it, and become jammed there.

If the idea of a sea-current from the north, with ice floating in it, be entertained, there seems to be no difficulty in explaining the above facts. The weight of the boulder was about 15 tons.

On the same part of the shore, there were many other hard gneiss boulders. The largest measured was $12 \times 6 \times 6$ feet, its longer axis pointing north and south.

Specimens of these boulders, found by me in Cantyre, I submitted to Professor Heddle of St Andrews University, so well known for his acquaintance with the igneous rocks of Scotland, and their mineralogical composition. He has kindly supplied the following notes :—

(1) Most of the Southend boulders, and those along the east coast between Campbelton and Southend, are identical in composition with one variety of the coarse porphyritic rock of Davar Island, situated at the mouth of Campbelton Bay.

(2) One specimen is a small-grained white granite, which I think I have seen somewhere in Arran.

(3) One specimen from the west coast is a coarse grey granite, identical in appearance with the granite of the Mourne Mountains in the N.E. of Ireland. I observe in this specimen two crystals of topaz. This granite, from containing also crystals of albite and of a lithian mica, should be easily recognised.

2. *Loch Lomond.*—On the west side of the lake, near Arden, a lateral valley runs up towards the west. There is a horizontal terrace in this valley about 70 feet above the lake, bounded by a steep bank, showing that at one time the lake had filled the valley up to that height. On this flat lie a number of quartz, granite, and mica schist boulders, which most probably all came from the westward, as the rocks in the valley are Old Red Sandstone. The head of the valley reaches to about 150 feet above the sea. The land then slopes down westward towards the sea in Loch Long. If these boulders were floated from the westward, it must have been when the sea was at a greatly higher level than 150 feet. The largest of these boulders, a mica schist, I found to be

5 × 3 × 3 feet, with its longer axis lying E. and W., and its sharpest end towards the west.

On the east bank of the loch, nearly opposite to Arden, on the farm of Over Balloch, and at a height of about 337 feet above the sea, I found a grey granite boulder, 5 × 4 × 4 feet, much rounded. Its longer axis lay in like manner E. and W. It was on a bed of boulder-clay. It most probably had come from the west or north-west, crossing therefore the valley now occupied by Loch Lomond.

3. *Loch Long and Gareloch.*—On the ridge between Gareloch and Loch Long I found several boulders. At a height of 160 feet above the sea, there is one of mica slate, 11 × 6 × 6 feet, lying on rocks of clay slate. Its longer axis is N. by E. and S. by W., its sharpest end being to the north. The axis was parallel to the valley of Loch Long. Its south end was pressing against a knoll of gravel as shown on fig. 7, plate XIX., which seemed to have intercepted its farther progress to the south. This boulder had apparently come down Loch Long, though whether floated by ice or carried by a glacier, is a question. But the knoll of water-borne gravel at its south end, favours the former theory.

Another boulder on this same ridge, 8 × 6 × 5 feet, occurs at about 360 feet above the sea, also blocked at its south end by a rocky knoll.

In the Gareloch, on the east side, a little below Shandon, on the beach, a gneiss boulder occurs, 18 × 15 × 12 feet, with its sharp end pointing N.N.W. The boulder on that side presented a very smooth surface. Every other side was rough.

The foregoing boulders as regards *position*, may all be accounted for by the supposition of the transporting agent having passed through the yalleys in which they are situated, in a southerly direction.

The boulders in the Gareloch and Loch Long were reported on by the late Charles Maclaren, and the opinion which he formed was that they had been brought to their present position by floating ice.

It appears that the late Sir Roderick Murchison visited this district, and gave an opinion against the theory of glaciers as applicable here.—(Chambers in "Edinburgh New. Phil. Journ.," vol. lv.)

4. *Loch Fyne.*—I was invited by Mr M'Killop, schoolmaster at *Loch Gair*, situated about 7 or 8 miles west of Inveraray, to inspect some large boulders in that district.

The first block seen was situated about 3 miles to the north of

Loch Fyne, surrounded by hills, most of them covered by drift. It was 23 × 17 × 12 feet, its longer axis lying N.N.E. and S.S.W. It was resting on a knoll of gravel, and at some distance from any hills. It was clearly an erratic,—a coarse gneiss. At first I was puzzled to account for its position being so exactly on the apex of the gravel knoll. It struck me eventually, that its great size and weight had been the means of protecting, by covering the knoll on which it originally had been dropped. The denuding agencies which could loosen and sweep away the gravel and sand in the surrounding parts of the valley, probably did not move the boulder, and so would leave it in its original position or nearly so.

I proceeded next towards *Loch Glashan*, and was rather surprised to see the hills on its south side, which sloped down towards the N.E., well-covered with boulders, and also striated rocks, facing N.E. and N.N.E. In fig. 5, plate XVII., there is a view of one of those boulders, 8 × 4 × 3 feet, on Knock farm, resting on a smoothed rock, dipping N.N.E., at an angle of about 30°, and at a height of about 400 feet above the sea. At this place, looking towards the N.N.E., there seemed to be a sort of low level district for some miles, with high hills on each side. On examining the map, I found that Loch Awe and Loch Etive were in that direction.

5. A few weeks after being at Loch Gair, I visited *Loch Awe*, and remained for a few days at *Port Sonnachan*, situated on the south bank of the lake.

On inquiring of the innkeeper, I was informed of a remarkable boulder situated among the hills to the south, and distant 3 or 4 miles. Having obtained the services of a shepherd as guide, I proceeded on foot across the moors, and came to a high corry, with a ridge in the middle, on which ridge the boulder stands at a height of 1026 feet above the sea. The boulder is so distinguishable from every other in the district, that the corry takes its name from it, viz., *Corry na clach.*

Fig. 7, plate XVII., gives a distant view of the boulder among the hills to the south of Loch Awe. Fig. 8 shows its position on the ridge where it stands. This ridge is narrow and has steep sides, so steep that they can be climbed with difficulty. The side facing the south is about 80 feet, the side facing the north is about 50 feet, in height, above the level ground adjoining.

The ridge, shown in figs. 7 and 8, is composed entirely of a soft arenaceous mica schist, in thin slaty strata, which stand up vertically, and form a table about 3 feet above the ridge, as shown in fig. 9. This table, on which the boulder sits, is about 5 feet square. The surface of the table slopes down to W. by S. at an angle of 22°. The boulder on this table of rock occupies a most precarious position. Stooping below the boulder, to examine the strata forming the table, I saw daylight across, under the boulder, and observed that it touched the rocky table at three points, each point of contact consisting of a few square inches.

The boulder was 13 feet long, 12 feet wide, and about 6 feet high. Its longer axis lay across the ridge, viz., about N. and S. Neither the nature of the rock composing the boulder, nor its own position, gave any indication of the direction from which it had come. It was a hard compact gneiss, the rock which prevails in most of the hills of the district on all sides. One feature in the position of the boulder offered a suggestion, though slight, as to the direction of its transport. If the rocky table on which it lay was sloping as now (at an angle of 22° to the west) when the boulder landed on the table, it is probable that it must have come from a westerly rather than from any other point. If it came from an easterly direction, it would, by its own weight when still in motion, have slid off the table altogether. But the assumption that the table on which it rests was originally sloping as now, may not be correct. On this ridge denudation may have changed the surface—except where protected by the boulder. Moreover, it is possible that the boulder itself, by the mere action of the wind upon it, might cause it to move on and abrade the rock. The space between it and the rock may also have been acted on by frost. Certain it is, that at present the stability of the boulder is most precarious. With a lever, I could easily have moved the boulder off its site. The innkeeper at Port Sonnachan informed me that there had actually been a proposal by some travellers staying at his inn, to perform this exploit, and that he had prevented it.

I am unable to explain how the boulder could have got on the apex of the hill, except on the supposition that a sheet of thick ice, strong enough to float the boulder, may have stranded on the hill; and that when it melted, the boulder might have subsided on the part where the ice had stuck.

6. Having asked my guide, whether there were any other large boulders in the neighbourhood, I was conducted by him to the side of a hill, about $\frac{1}{4}$ of a mile to the eastward, well-covered with boulders. The height above the sea was about 900 feet. I was rather surprised to find the boulders here in such positions as to indicate that they had come from N.N.E. The largest measured 18 × 10 × 10 feet, and its longer axis lay N. and S. I observed that most of the other boulders lay in a similar position. The rocks presented smoothings which faced N.N.E., being the direction in which Loch Etive lies.

I remembered that in walking up from Loch Awe on this occasion, I had seen several smoothed rocks with striæ running much in the same direction, but I omitted to take the exact bearings.

I felt surprised at this direction, as, when last year in the Hebrides and the west coast of Argyleshire, I had been accustomed to see that N.W. was the usual direction both of boulder transport and of rock striations.

7. This N.N.E. direction of transport appears, however, to characterise all the boulders and the rock striation at the *Gareloch*, *Loch Gair*, and *Loch Awe*. It will be observed that these places form a band or line across the country about N.N.E. and S.S.W. It is no doubt premature to theorise on so small a number of facts recorded in these notes. But they seem to suggest that in this district there may have been a current of floating ice, moving in a S.S.W. direction, dropping boulders where the ice which bore them was stranded or obstructed.

Is it not probable that, when the Highlands of Scotland were covered by the sea, up to a height of say 2000 feet, and when they presented an archipelago of islands, there may have been currents moving in different directions, and these directions changing as the sea fell from one level to another?

The valley through which the Highland Railway passes, between *Killin and Dalmally*, presents, on the sides facing and sloping down to the north, many examples of large boulders and striated rocks, which, even from a railway carriage, are seen to be well-deserving of special investigation. Thus at *Luib* station, and for some miles both to the east and west of it, there are numerous large boulders resting on the hill sides sloping down to the north; as also great masses of boulder-clay and water-borne gravel, with huge boulders, and occa-

sionally under these beds, surfaces of rock, well smoothed and striated. A special examination of this district would be rewarded by many important discoveries. Similar features occur at and near *Crianlarich* and *Tyndrum*. But at Tyndrum, while there are knolls and escars of gravel, so numerous indeed that they have given a name to the place (in Gaelic),* there is a sudden and remarkable cessation of boulders. This absence of boulders continues west of Tyndrum till about 2 or 3 miles east of Dalmally, when they again begin to make their appearance, and they are very numerous on the hills there facing the N.W.

May the reason of this be, that at or near Tyndrum there is the valley (traversed by the high road) running in a N.N.W. direction between high mountains, passing through Glencoe, whilst near Dalmally there is a similar opening towards the sea by Loch Awe and Loch Etive. When the sea stood at say 2000 feet above its present level, currents may have flowed through both of the openings just described, but not over the high ground between Dalmally and Tyndrum, the land there being so high that it may have prevented a current. It will be remembered that in the Committee's Fifth Report facts were stated, which seemed to show that in Glencoe current had passed up the glen carrying boulders towards the S.E.

The current which passed through what is now Loch Etive and across Loch Awe, towards the S.S.W., may have continued till the sea sank below the level of the hills lying in that quarter. Along the banks of Loch Awe there are sea-terraces at a height of at least 200 feet above the present sea-level; and in the narrow pass at the south end of the loch, near Ford, there are indications of a current which flowed through it from the north.

Whilst on the subject of Loch Awe, I may notice a boulder on the south bank of the loch, at a place called Kaim, about 10 miles west of Port Sonnachan. The boulder is of mica schist, and is $24 \times 11 \times 9$ feet. Its longer axis is N.W. by N. It rests on a knoll of gravel which is about 20 feet above the adjoining meadow. This meadow is surrounded by hills (from 400 to 600 feet in height) on all sides but one, where there is an opening due west from the boulder, and by this opening the boulder may have entered the *cul de sac* where it lies, though, if brought when

* *Tigh*, dwelling; *Drum*, ridge or back.

the sea was 400 to 600 feet higher than now, it may have come from any other direction.

The hills to the south of this meadow are, on their sides sloping down to the north, well-covered by boulders; and they apparently had come from some northerly point.

Along the south bank of Loch Awe, between Port Sonnachan and Kaim, striated rocks occur, almost all of which present surfaces towards the N.W. Fig. 8, plate XIX., gives an example of one of these rocks. It slopes down N. by W. at an angle from 60° to 70°. The striæ upon it run E. and W., dipping down east at an angle of 20°. In one part of the surface there is a hollow, A, over which the striating agent has passed without marking its sides. The striating agent had moved from the west, as the striæ were deepest at their west ends.

8. *Ardrishaig.*—This place is on Loch Gilp, a small branch from Loch Fyne. There are hills here on the west side of Loch Gilp which rise to a height of from 700 to 800 feet. Fig. 1, plate XVIII., gives a bird's-eye sketch of the loch and these hills. No. 1 is the town of Ardrishaig. No. 2 is Loch Gilphead. A lateral valley comes down from the S.W. marked AB.

At *a* and *b* many of the rocks (a sort of clay slate) are (at a height of 420 feet above the sea) well smoothed, the smooth faces being parallel with the axis of the loch, which here runs about N. and S. The smoothing had evidently come from the north. On reaching *cd*, at a height of 600 feet above the sea, the smoothed rocks were more abundant, and evidently from the same direction.

A Boulder of dark-coloured granite, $12 \times 6 \times 4$ feet, was found between *ab* and *cd*, whose position implied transport from the north.

At a height of from 500 to 600 feet between *a* and *c* there are numerous whinstone knolls, sloping down towards the north as indicated on fig. 2, plate XVIII., beautifully smoothed and polished on the north sides, but rough and precipitous on the south sides. On some of them a few boulders were lying, evidently intercepted in their farther progress southward by these knolls, because on the south side there were numbers of boulders which, having been pushed over, had remained there, as shown in the figure.

At one place indicated on the sketch, fig. 1, plate XVIII., by the letter *e*, a smoothed rock was met with sloping down S.E. by S. at

an angle of 35°. Two sets of striæ were on it, one running N.W. by W., the other running N.E. and S.W.

This spot was very near the corner where the lateral valley AB joins the main valley of Loch Gilp. The two sets of striæ indicated of course two several currents, one apparently parallel with the axis of the lateral valley AB, and the other nearly parallel with Loch Gilp valley.

At the mouth of this lateral valley, at *f* on the sketch, a number of boulders were found at a height of about 670 feet above the sea, lying on the hill slopes facing the N.W. Some of these were in such positions as showed transport from the N.W. One example is given in fig. 3, plate XVIII., where a boulder A, 4 feet high by $2\frac{1}{2}$ feet wide, was resting against the N.W. sides of rocks B, on their W.N.W. sides.

On proceeding to the head of this lateral valley, about 1 mile distant, and at a height of about 795 feet above the sea, I found numerous boulders, many of large size, resting chiefly on rocks and hill slopes, facing W.N.W., and with their longer axis lying much in the same direction. One of these measured $12 \times 6 \times 5$ feet.

There were several smoothed but no striated rocks. At one place, however, at a height of 650 feet above the sea, I found a mass of softish Silurian rocks traversed by a hard quartz vein about 2 inches thick, standing up above the Silurians, as shown by A in fig. 4, plate XVIII. This vein had been evidently ground down by something which had passed over it from W.N.W. The quartz retained a beautiful polish, but the Silurian rock, though it had once presented a smooth flat surface, had become rough by atmospheric action. Being softer than the quartz vein, it had been ground down more effectually by the agent which had passed over.

9. *Loch Killesport.*—Having been informed by Mr J. F. Campbell of Islay (author of "Frost and Fire") that the largest boulder he had seen in Scotland was on the south side of *Loch Killesport*, near Ormsary House, I went there in company with Mr Alexander of Lochgilphead, who was so obliging as to undertake to be guide. His local knowledge was of much service to me.

We went first to some boulders a little beyond Ormsary House on the sea-shore. One (of gneiss) had a girth of 65 feet and a height of 16 feet. It was tolerably well rounded, its sharpest end pointing

N.W. Another measured 17 × 13 × 5 feet, its longer axis lying N.W. by W. Another measured 24 × 12 × 5 feet, its sharpest end pointing W.S.W.

The largest boulder was situated about ¼ of a mile east of Ormsary House, on the south side of the coast road, adjoining a ruinous cottage. The boulder was in two pieces, having evidently been broken by some natural agency. Before it broke, it must have measured in length 52 feet, in width 36 feet, and in height 20 feet, containing 1387 cubic yards or about 2770 tons.* It was extremely angular in shape. Its narrowest end was to the west. This immense boulder was at the foot of what was evidently an old sea-bank, whose base is about 40 feet above the sea at high water. The bank is about 35 feet in height, and consists chiefly of gravel and boulders.

Fig. 5 on plate XVIII. is intended as a sketch from memory of this spot, AAA being the old sea-bank, B the large boulder, and CD the high road along the south shore of Loch Killesport.

Along the line of this old sea-bank, there were great numbers of boulders above it and at its base. The measurements of a few may be given. A boulder at base of the bank, measured 23 × 14, lying E. and W.; another measuring 20 × 12 × 10 feet, lay on the slope of the gravel bank, which here faces W.S.W.

Another boulder on top of bank measured 24 × 16 × 13 feet; and another 18 × 10 × 8 feet, lying on gravel with its sharp end to the W.N.W. There were about twenty more, smaller than these, scattered on the fields above the old sea-bank.

At a little distance from the top of the bank, I found a rock of mica schist well smoothed, with striæ running E. by N. and W. by S.

Near the village of Ballibayach, in a field to the north-east, there is a gneiss boulder, 33 × 18 × 12 feet, resting on a smoothed rock of mica slate, which slopes down towards the west. This boulder weighed probably above 400 tons. Along the range of hills and up to their summits, at a height of about 600 feet above the sea on the south side of Loch Killesport, numerous boulders were seen from the road; but I was prevented going to them.

* In the "American Journal of Science and Arts" for 1877, reference is made to a boulder in Vermont, called "The Green Mountain Giant," weighing about 3400 tons; and to twelve still larger in New Hampshire—the largest measuring 62 × 50 × 40 feet, and estimated to weigh nearly 6000 tons.

About 3 miles to the east of Ormsary, the road passes through the narrow valley of Auchloss, which runs in a direction about east and west. Smoothed rocks occur in this valley, on one of which Mr Alexander pointed out striæ running in a direction W. by N. These striæ seemed deeper at their west ends, as if the tools which cut them, had struck the rock first at these ends.

The boulders on Loch Killesport appeared to me, from their positions, to have all come from the westward. If they came on floating ice, the sea must at that time have stood at a high level to have floated ice of sufficient size to carry and deposit boulders of such weight as those above described. On that point there need be no difficulty, as there is abundant evidence that the sea prevailed over the Highlands of Scotland to a height of at least 2000 feet, and thereafter subsided, whether gradually or rapidly is not yet known. The sea-bottom on which the boulders were dropped, would of course present a very different surface from what forms the present dry land. What are now valleys in the land would be formed (after the sea subsided) by the detritus which filled these hollows being scoured out by rivers; whilst the boulders which had occupied the old sea-bed, when too heavy to be moved by river floods, would remain in the newly formed valley, though sometimes at lower levels. In like manner, the boulders which are now on the shores of sea lochs, may in many cases have been undermined by the scouring out of detritus by tides and storms, and sunk to a lower level than they originally occupied. Hence it is that along the *present* line of high water the boulders are generally more numerous than elsewhere; and the same circumstance occurs everywhere along the *old* sea-margin, as in Loch Killesport.

10. Another place visited was *Loch Swin*, an arm of the sea on the west coast of Argyleshire, about 16 miles west from Lochgilphead. Mr Alexander of Lochgilphead kindly accompanied me to this district also. At *Keills*, on the north bank of the loch, close to its mouth, there are several boulders of a light-coloured grey gneiss, and one or two of a fine-grained granite. The rocks on which they rest are a coarse dark-coloured Silurian.

The first boulder examined was on the shore facing the island of Jura, here distant about 4 miles to the west. Its size was $12 \times 10 \times 9$ feet. It lay on a bank sloping down towards the sea at an angle of about 15° to the W.N.W. It rests on Silurian rock,

at a height of about 50 feet above the sea, and about 100 yards from the beach.

About a mile to the eastward, and not far from the old ruinous church of Keills, there is another grey gneiss boulder, 18 × 15 × 12 feet, resting on a terrace about 150 feet above the sea. Another boulder, of fine-grained granite, lies near it on the same terrace.

Another boulder is on the shore here, 16 × 10 × 9 feet, with the longer axis lying E. and W. I learnt from Angus, shepherd at Keills (and who also acts as post messenger), that on the *Island of Dana*, at the south side of Loch Swin, there are three boulders larger in size than any on the north side.

On my return to Lochgilphead, I walked to *Carig Bay*, in the parish of North Knapdale, and on the hill to the S.W. facing the island of Jura was shown a fine-grained gneiss boulder, 12 × 6 × 6 feet, similar in composition to those at Keills. It was resting on a rocky surface sloping down to N.W. Its position suggested transport from N.N.W. Its height above the sea was 270 feet.

At *Taycallich*, on the north shore of Loch Swin, I fell in with boulders forming two groups of 3 and 4 in number, whose relative position indicated transport of the uppermost from the west.

At *Scotnish*, also on Loch Swin, found an old sea-terrace at 42 feet above the sea, with a boulder on it, 18 × 11 × 8 feet, besides many others of smaller size.

In a short lateral valley opening into Loch Swin at *Loch Mhurrich*, I had shown to me by Dr J. M'Leod of Tayvallich an immense boulder, 36 × 15 × 13 feet, weighing about 500 tons. It rests on a knoll of shingle, and is about 30 feet above the sea-level, and distant from it about $\frac{1}{5}$th of a mile. This knoll is in the centre of a marshy meadow, which is surrounded by hills of from 260 to 300 feet in height, whose sides show beds of sand and gravel. The mouth of this small loch opens on Loch Swin to the W.S.W. The boulder is many hundred yards distant from the adjoining hills, so that there is no doubt that it is an erratic. But from what quarter, and by what means has it come? One naturally supposes that it must have come in by the mouth of the valley, of course at a time when the sea was deep enough to float it and lodge it in this *cul de sac*. The sea-bottom on which it dropped may then have been higher than the existing meadow; and as the detritus was washed away, the

boulder may have protected the bed on which it rested, so as to form the present knoll.

I may add that there are numerous small lateral valleys along the north side of Loch Swin, extending a few hundred yards, and running in a N.E. and S.W. direction. They open into Loch Swin, and are well filled by boulders. These are generally most abundant on the south sides, and on the slopes of hills facing towards the N.W.

Berwickshire.

1. In *Ayton* parish, on Whitfield farm, 2 or 3 miles N.E. of the village, several small boulders of grey granite occur, about 270 feet above the sea. Nearest rock of same kind is on Cockburn Law, about 10 miles to W.N.W. Near Ayton Castle a bed of sand was excavated to the depth of about 20 feet and removed. Bits of coal (including cannel) were found in the bed, about 200 feet above the sea. Nearest place where coal strata occur, is in Mid-Lothian, on north side of Lammermuir Hills, about 30 miles to N.W.

2. In *Coldingham* parish, on Crosslaw farm, well rounded masses of hematite were turned up by the plough at a height of about 500 feet above the sea. Nearest place where hematite has been found is in East Lothian, about 30 miles to N.W. But the range of Lammermuir Hills intervenes. On this same farm, a boulder of white coal sandstone occurs, which must have come from East Lothian. Lumps of coal have also been found there in the boulder clay on Blackhill farm.

"On the heights east of Coldingham Loch, the rocks lie in separate and parallel ridges. The ridges are much rubbed and planed, especially on the N.W. exposures, as if some mighty force had battered and grated them down. There were also indications of striæ, which bore by compass nearly north, or N.$\frac{1}{2}$-W.—in this agreeing exactly with the striæ at St Abb's Head and the Farne Islands."—(*Address by Jas. Scott Robson, President of Berwickshire Nat. Club*, vol. vii. p. 175.)

3. In *Chirnside* parish, at Old Castles, there are numerous boulders of grey granite, from 1 to 2 tons in weight, and about 300 feet above the sea. Nearest rock of same kind is at Stanchal and

Cockburn Law hills, visible from Old Castles, and about 8 miles distant to N.W.

4. At *Blackadder*, in Edrom parish, a boulder of blue whin or greenstone is on a knoll of gravel, on the west side of knoll. Its height above ground is about 4 feet, and its width 2 feet. Level above the sea about 250 feet. Nearest rocks of same kind are at Hardens, about 5 miles to N.W., and about 500 feet above sea.

5. In *Hutton* parish, at Paxton brick-work, buried in boulder clay, a blue whinstone boulder, $7\frac{1}{2} \times 4\frac{1}{2} \times 3$ feet, weighing about 12 tons, was found. Its longer axis pointed N.W. by N. In that direction, Borthwick Hill near Dunse is situated, distant about 10 miles. It is the nearest spot for whinstone rock *in situ*. In the same brick-work, small boulders were found of old conglomerate, greywacke, chert, and white sandstone. Rocks of these kinds occur in Berwickshire to the westward. The brick-coloured porphyries of Kyles and Dirrington hills, situated about 15 miles to the west, were found there also.

Blocks of the same blue whinstone occur on the farms of Broadmeadows and Sunwick. Blocks of a peculiar greywacke, of a concretionary character and black in colour, occur in the Pistol plantations. The only rock of that kind known to exist is in the channel of the Whitadder, near Cockburn Law, about 14 miles distant to the N.W. Blocks of the same peculiar rock occur in great numbers on all the farms in the same line. There are specimens of them at Paxton House.

6. At *Stitchell Craggs*, pebbles of Old Red Sandstone are lying on the whinstone rocks, at a height of about 600 feet above the sea. Nearest place where Red Sandstone strata occur is some miles to the west. On the west sides of these craggs there are smoothed surfaces of whinstone rock dipping towards W.N.W. None are seen on any other side. At *Baillie Knowe*, in same parish, about 300 feet above the sea, a whinstone hill occurs, presenting on its west side similar smoothed portions of rock dipping W.N.W.

Cowdenknowes Hill, situated in Earlston parish, consists of felspar porphyry. Large blocks of this rock are strewed over the muirs situated to the east, resting on Old Red Sandstone strata.

On *Smailholm Craggs*, about 3 miles west of Stitchell, at a height of 570 feet above the sea, rocks facing W.N.W. show striæ made by some agent coming from W.S.W.

On *Hume Castle Craggs*, at height of about 740 feet above the sea, there are rocks smoothed and striated, in an E. and W. direction.

"Boulders, carried a hundred miles and more from their native localities, are still found in many parts of Berwickshire, though by far the greater number, especially of the smaller ones, have been broken up for road metal. This is particularly the case along the post road between Reston and Ayton, where fragments of gneiss, mica slate, pure vein quartz, porphyries, and other rocks of Grampian origin, were, a few years ago, to be seen in every depôt by the road-side. The current which brought the ice upon which these were conveyed, must have come from the westward, where these rocks occur *in situ*. Among the more remarkable of these boulders may be mentioned a rounded block of gneiss on the road at the top of Ecclaw Edge,—a large block of mica slate on the slope of the hill east from Burnhouses,—several smaller masses at Windshiel, Kidshielhaugh, and Abbey St Bathans,—and a block of a very peculiar diorite, formerly one of the stepping-stones in the River Whitadder at Ellenford. This diorite, which is composed of greyish quartz, red felspar, and a little chlorite, occurs *in situ* in the neighbourhood of Aberfoyle. Rounded pebbles of the same have been found in the Whitadder below Preston Bridge, where also mica slate, quartz, sandstone from the Lothians, &c., are to be met with in the river shingle."—(*Wm. Stevenson on Ice Action in Berwickshire*, "Berwick. Nat. Club Trans." vii. p. 209.)

Buteshire.

Arran.—Some years ago I spent a few days at Brodick and Corrie, and made the following observations:—

1. In travelling along the high road between Lamlash and Brodick, I observed thick beds of boulder-clay containing numerous boulders, the most prevalent being granite, and also a conglomerate, with large quartz pebbles in it. The height of these clay-beds was about 387 feet above the sea. Rocks *in situ* of the same nature are situated to the N.N.W.

To the south of Brodick Bay, there is a large number of Boulders, along and near the coast; but in Brodick Bay itself, there is a total absence of boulders, whilst to the north of Brodick Bay they are numerous.

This circumstance suggests a theory which will be mentioned, after some account has been given of individual boulders remarkable for size or position.

One of the boulders to the south of Brodick Bay is known by the name of the Corriegill Boulder. It lies near the shore. Its highest point is about 15 feet above its base, and its girth is about 60 feet. Its shape is indicated by fig. 1, plate XIX., representing a section through it horizontally a little above the base. Its longer axis lies N.W. and S.E., with its sharpest end to N.W.

The boulder is granite of a grey colour, the ingredients being crystals of quartz, felspar, and mica, which are all rather larger than usual in size, and give to specimens a very coarse and rough aspect. It has a vein of finer grained granite running through it.

The top of the hill called Goatfell bears from this boulder N.N.W., and is distant about 4 miles. Granite occurs *in situ* on Goatfell.

Another boulder was measured, situated about half a mile to the north of the above on the shore at half-tide. It was $12 \times 9 \times 8$ feet. Its longer axis lay due north and south.

From this part of the coast, where these boulders begin to be numerous, the northern horn of Brodick Bay, at the sea-shore, bears N. by E. This horn is a continuation of a steep ridge which runs up to Goatfell.

2. To the south of Corrie (about a mile) two boulders of considerable size are situated on a plateau or terrace, which is from 89 to 96 feet above the sea.

The largest is shown on fig. 2, plate XIX., A being a horizontal section near the base, to show dimensions of the sides and their position by compass; B indicates the position of the greatest mass which is at the south end, the highest point there being 15 feet above the base.

The longest axis is in a direction about N. by W. and S. by E.

I calculated the weight of this boulder to be about 620 tons.

I omitted to mark the nature of the rock composing these two boulders; but they are, according to my recollection, grey granite.

Goatfell from their position bears about W. by S., and is distant about 3 miles.

The rocks of the district where these boulders lie are sandstone,

apparently carboniferous. There is a quarry for building purposes not far off.

These two boulders must have been *carried*, for there are no adjoining hills from which they could have fallen. Carried by a glacier they could not be, as they are not in a valley nor near any from which a glacier could have issued.

3. To the north of Corrie, about 2 miles, the road passes a large boulder called the Catstane, which is about 18 feet in height and 56 feet in girth. The late Dr Bryce estimated its weight at above 200 tons. I calculated its cubical contents to be 131 yards, and therefore its weight about 262 tons. It is very angular in shape; but I could not ascertain correctly the length and direction of its different sides.

On the beach near the last-named boulder, there is a granite boulder which I was able to measure with exactness. It is in height about 12 feet. Its longer axis lay in a N. and S. direction, its narrowest end being to the north. Its shape and the length of its sides are shown in fig. 3, plate XIX. I estimated its cubical contents at 106 yards, and its tonnage about 212 tons.

The boulder next larger in size at the same place is shown in fig. 4, plate XIX., A and B, where A represents the lengths of the different sides, and B gives an idea of the height, which was about 10 feet. The direction of the longer axis and of the narrowest end was much the same as in the other boulder.

Another granite boulder on the shore (at the old sea-margin of 12 feet above the present sea-level) is shown on fig 5, plate XIX., where A gives a horizontal section to show its shape and direction of its longer axis, and B its peculiar position, resting as it does on a mass of Red Sandstone (coarse) conglomerate strata, rising up towards the north. The position of the boulder, blocked as it is at its south end by the sandstone, shows that it has come from the north. The girth of this boulder is about 33 feet, its length about 9 feet, its width 8 feet, and its height 8 feet.

Many blocks of the conglomerate sandstone on which this boulder rests are found along the shore to the south, none to the north. It will not fail to be observed that one feature characterises all the cases of boulders just mentioned. The narrowest end points towards the north, suggesting the idea that, after being deposited, they

had been subjected to some agency which put them into a position enabling them to withstand any farther dislocation.

That this agency came from the north, their position clearly indicates, an inference confirmed by the transference towards the south of the sandstone blocks above mentioned.

4. On ascending the hills to the west of Corrie, I found smoothed surfaces on the sandstone rocks and traces of striæ at a height of about 158 feet above the sea. The direction of the striæ was N.W. and S.E.

On these hills, up to a height of about 587 feet above the sea, the boulders are very numerous. All that I examined were of grey granite, except three, and these were of conglomerate.

Between these hills and the high granitic boss to the west, reaching to a height of about 1800 feet, there is a valley running N. and S.

The high hill on the other side of the valley to the westward is composed of grey granite. I climbed this hill up to a height of 1270 feet. The ground passed over was thickly strewed with grey granite blocks. I could here distinguish two sets of boulders—*one* set angular, which may have fallen from the mountain—*another* set well rounded, which seemed to be erratics, not only because of their shape, but because they were of a harder texture than the rock of the hill. The ingredient crystals were also larger in size. These rounded blocks I observed to be on the hill-side for at least 100 feet above the point reached by me.

One of the boulders arrested my attention on account of its size and position. It was 25 feet long, 9 feet wide, and 12 feet high. This boulder and many others were lying with their longer axis N. and S., and could not, as it seemed to me, have fallen from any rocks on the hill above.

5. I went across the island to Loch Ranza, the summit-level being about 660 feet above the sea.

I was unable to examine any individual boulders. But I noticed that there were many more on the east side of the summit-level than on the west side.

I saw on the hills facing the N.W. numerous "perched blocks," at heights of from 1600 to 2000 feet. But they were too far off to admit of examination.

Near Loch Ranza some remarkable terraces, with boulders, arrested my attention, at heights of from 80 to 100 feet above the present sea-level. Great scaurs of gravel and sand, which were in beds, sometimes flat, sometimes dipping at a high angle, were under these terraces.

6. In connection with the Arran boulders, reference may be made to the following :—

Ailsa Craig (Ayrshire) is a mass of trap,—much of it (as I understand from Professor Heddle) being columnar porphyry of a white colour. It reaches to a height of 1114 feet. Not having visited it myself, I may be allowed to refer to information given by others.

In a paper by Mr W. N. Macartney, in the "Proceedings of the Glasgow Nat. Hist. Society for 1868," it is stated that the Craig bears many marks of glaciation, up to near the top. On the north side there is, at the height of about 600 feet, a deposit of boulder-clay in a slight depression of the rock, and guarded by a boss of rock from any currents, which, when the Craig was submerged, may have flowed from the N.W. This deposit is of a red colour, and composed of sand and clay, derived probably from the Old Red Sandstone rocks situated in Arran and other islands to the north. In this deposit, Mr Macartney says he gathered a number of pebbles, striated or scratched, consisting of quartz, and metamorphosed slates and shales.

Mr Wünsch of Glasgow informed me that he had found granite pebbles on Arran.

(2.) At Ardrossan (Ayrshire), on the beach, there are numbers of conglomerate boulders, distinguishable by the prevalence of white quartz pebbles in the rock.

At Lamlash Bay, in Arran, I noticed boulders of a similar conglomerate.

Have they all come from some northern quarter?

(3.) At Millport (Buteshire) there are two large boulders of coarse grey granite, which are used in the harbour there as "*pauls*" for ropes from ships.

(4.) Near Beith (Ayrshire) there is a hill called *Cuffs*, which Mr Craig of Beith took me to visit. On the north side of this hill he pointed out many small-sized boulders of grey granite at a height of about 560 feet above the sea. The felspar crystals in it are

of a large size and very white colour, much resembling those found in the Arran boulders. Cuffs Hill consists of porphyry. It is surrounded by Carboniferous strata.

7. On a review of the facts stated in these notes regarding the Arran boulders, it seems probable that those described had been brought from the north, judging by the way in which they lie, and also by their composition.

With reference to the absence of boulders from Brodick Bay, and to their abounding along the coast both north and south of that bay, what occurred to me was, that if the boulders were brought from the north by floating ice, the rocky ridge running down from Goatfell peak (a mountain 2874 feet high) to the north point of Brodick might have had the effect of diverting the current in a S.E. direction, which would carry the ice beyond the bay. That bay is at the lower end of a valley which runs up among the highest hills; and if the theory of glacier from these hills be adopted, the bay should have been crowded with boulders, instead of being free from them.

Big Cumbrae.—I was guided to the north end of the island by the Rev. Mr Lytteil. There, on the farms of Figgatoch and Balloch Martin, I found several large boulders of mica schist lying on Old Red Sandstone rocks. The largest measured $12 \times 6 \times 3$ feet. But it may have been larger, much of it being below the surface of the ground. The longer axis lay N.N.E., which was also the direction of the hollow or small valley in which it lay.

On the 70 feet terrace one of the schist boulders was about 5 feet square.

At the S.W. point of the island (viz., Kennery point), above half a mile to the west of Millport, I found several other schist boulders, on the old 12 feet sea-terrace.

Little Cumbrae.—The rocks of this island are entirely a brittle claystone trap. The rocks at the highest part (near an old tower), at a height of about 400 feet above the sea, are very distinctly smoothed and grooved. Most of the smoothed surfaces slope down towards and face N. by W.

The only part of the island on which striæ were found is at the east side, near a small ruined fortress. A hollow or trench occurs between the knoll on which that ruin stands and the main body of

the island. Fig. 6, plate XIX., shows the trench apparently scooped out in the rock by some heavy agent which has passed through, smoothing it on both sides and striating it on one side. The direction of the trench is N.E. by N. As it is only the east side which shows striation, the striating agent, if it came from the north, must have moved from a north-westerly point.

The striæ can be traced longitudinally for about 30 yards.

The figure shows a boulder, B, resting on an upper part of the trench, where there happens to be a sort of shelf where it has originally been lodged.

This is the "Split Boulder" first noticed and described by Mr Smith of Jordanhill. Before it broke into its two fragments, its size must have been $8 \times 7 \times 6$ feet. Though the boulder is a claystone trap, viz., the same rock as that composing the main body of the island, I do not think it has rolled down to its present position, but agree with Mr Smith, that it is a true erratic, having been brought by ice which probably jammed in the trench as it was passing through.

The island has a number of Old Red Sandstone and also of conglomerate boulders on various parts of it, very similar in mineralogical character to the strata which are seen on the shore to the N.N.W. at Rothesay and Toward. One of these conglomerate boulders is of archæological interest. It bears the name of the Belstane, and is supposed to have been in former times connected with the Beltane fires. There are markings on the stone which have evidently been made for some special purpose. One of these boulders, about 5 feet square, rests on rock, and may have been used as a "Rocking Stone." The Rev. Mr Lytteil pointed out this stone to me.

East Lothian and Mid-Lothian.

1. For a notice of several boulders see paper by Convener in "Proceedings of Edinburgh Royal Society" (7th July 1877).

2. Extract from paper on the "Physiognomy of the Lothians," by R. J. Hay Cunningham, in "Trans. of Wernerian Society for 1838," vol. vii.

"In this district little extent of country can be passed without

numerous rolled masses of rock occurring, which are not found *in situ*, but only in distant localities.

"On the coasts of Linlithgow and Mid-Lothian, in the valleys of the Pentlands and on their acclivities, and on the flanks of the Lammermuirs and Moorfoot range, we easily detect rolled fragments of granite, syenite, porphyry, mica slate, gneiss, quartz-rock, and varieties of greywacke, which are met with only in the central districts of Scotland, while an examination of them shows that they decrease both in magnitude and frequency, as we advance southward; a fact indicating that the aqueous currents (for to such only can they be referred) diminished in intensity as they were removed from the central parts of the island."

Professor Nicol of Aberdeen (in the "London Geological Society's Journal" for 1848, vol. v. p. 23) refers to "one angular block of mica slate, near Habbie's How, on the Pentlands, weighing (according to a measurement I made) 6 or 8 tons. Farther west, I found another block, also angular, of the same sort, weighing about $\frac{3}{4}$ of a ton. When it is considered that these masses must have been carried upwards of 40 miles, floating ice seems to be the only agent to which their transport can be ascribed. Blocks of a smaller size are very common;—some are of kinds of rock *which I have never seen in Scotland*. On one hill, 1500 to 1600 feet high, I found these travelled stones particularly abundant, *and apparently increasing in number from below upwards*. In some places they appeared to form broad bands running nearly in straight lines from N.N.W. to S.S.E., and without any reference to the present declivity of the ground, except *becoming more numerous towards the summit of the ridge*. These blocks consisted chiefly of trap rocks, especially basalt; the hill on which they rested being a red felspar or clay-stone porphyry."

3. On 29th Oct. 1879, the island of Inchkeith was visited, under the guidance of Colonel Moggridge, R.E., superintending the erection of fortifications there. The rocks consist chiefly of basalt and porphyry intruded among the Coal-measures of Fife and Mid-Lothian. In various places the rocks are covered with beds of boulder-clay, gravel, and occasionally sand. The inspector of works (Mr Beck) mentioned that at the east end of the island, when removing a bed of shingle (about 60 feet above the sea), he

picked up two pebbles of red granite about the size of a hen's egg. Thinking it curious that granite should be found there, he laid the pebbles aside and kept them for some time, but they had since been mislaid.

Having been told that a number of large pebbles of various kinds were seen at the west end of the island, on the beach, I went there, and found numerous pebbles of granite (both red and grey), gneiss, quartz, and hard Silurian rocks.

On the highest part of the island (which is 182 feet above the sea), and on portions facing the N.W., the rocks have been well planed down to even surfaces by some agency from the west. But no striæ were observed.

4. A short time ago I went, on the invitation of Captain John Macnair of Edinburgh, to examine two boulders lying at the side of the Water of Leith, on the farm of Whelpside, near Kaims and Dalmahoy hills, about 9 miles S.W. of Edinburgh. One boulder was $13 \times 10 \times 6$ feet, and the other $10 \times 8 \times 5$ feet; but the depth of either could not be well ascertained, being deeply sunk. They were both of them a hard porphyry, containing minute crystals of a black mineral like hornblende, in a basin of white felspar. The longer axis of both was E. and W. They were covered with striæ, long and deep, running also E. and W., and indicating a movement over them from due west.

I ascended the Kaims hill, situated about a mile to the N.W. of the boulders, and found its west side swept bare, with numerous large fragments of the rock of the hill (a hard sandstone) strewed over its eastern slope.

On my way back to Edinburgh I examined the whinstone quarry of Ravelrig, and found, on the natural surface of the rock composing the hill there, numerous examples of ruts and scoopings, all indicating an agency which had passed over the hill from due west.

Kirkcudbrightshire.

Large rounded fragments of granites and syenites are abundantly scattered over the Stewartry, and so arranged as to indicate that they have been dispersed by a force proceeding from the N.W.—

(Robert J. Hay Cunningham, "Highland and Agricultural Society's Trans." vol. viii. p. 716.)

Peeblesshire.

Reference made "to the boulders of gneiss, granite, and mica slate, which belong to rocks unknown in the hills of that county, and several tons in weight." They "seem to require for their transport more powerful agents than mere currents of running water. We can scarcely conceive these possessed of sufficent velocity to convey masses of such a shape and size along a level plain, still less over the summit of hills 1500 or 1600 feet above the level of the sea, and across many winding valleys. The most probable means of conveyance, not only for these, but for many of the smaller fragments, seems to be masses of ice floating in an ancient sea, by which the highest summits of these hills were then submerged."—(Professor Nicol, "Highland and Agricultural Society's Trans." vol. viii. p. 197.)

Roxburghshire.

1. Near Castleton, many blocks of granite—both red and grey—lie on the greywacke and also the carboniferous rocks, which must have come from hills to the westward in Dumfriesshire or Kirkcudbrightshire, 30 to 60 miles distant, crossing the valley of the Esk.

2. On Ruberslaw, a hill of greenstone, about 200 feet below the top, I fell in some years ago with a large block of greywacke. It was lying on Old Red Sandstone strata. The nearest greywacke rock is situated to the westward about 3 miles. Between these rocks and the position of the boulder, there is low ground, at least 800 feet below the level of the boulder, which it must have crossed to reach its site.—("Edin. Roy. Soc. Trans." vol. xv. p. 454.)

3. Near the village of Nesbit, about 8 miles S.W. of Kelso, there is a boulder of small-grained greenstone $8 \times 7 \times 5$ feet, identical in composition with the rock of Penielheugh, a hill on which stands the Waterloo pillar, a structure of about 120 feet in height. The rocks where the boulder lies consist of Old Red Sandstone;

and they are well covered by beds of gravel and sand. The boulder is on a knoll, near the top, but a little to the N.W. of it. The longer axis is in a direction S.W. and N.E. Penielheugh Hill is situated to the S.W. and distant about a mile from the boulder. The hill is 774 feet above the sea—the boulder 224 feet above the sea. The exposed rock of the hill on its west side reaches down to about 400 feet above the sea.

That the boulder has been brought to its present site from Penielheugh, is evident,—the composition of the rock being the same in both. The Old Red Sandstone rocks which prevail generally in the district, reach up to within about 100 feet of the top of Penielheugh, but only on the *east* side. These strata are entirely absent on the *west* side, suggesting, therefore, the probability that the west side of the hill has been denuded of them by some agency which has come against the hill from the westward. This inference is confirmed by the fact, that on the sides of the hill facing the west, the igneous rocks are all *bared*, and many of them *smoothed;* whilst on the sides facing the east, no igneous rocks are visible, being covered by sandstone strata, with drift materials over these.

These facts will be better understood by reference to plate XVII. fig. 6, where P represents Penielheugh Hill, B the boulder. The strata in dark colour is the Old Red Sandstone formation.

On looking from the top of Penielheugh westward, a wide valley is seen in that direction, the Eildon Hills on the north, and the Minto Hills on the south.

Through that valley some agency has undoubtedly come, impinging with great force on Penielheugh; but whether a local glacier or a sea-current with floating ice, there is nothing to show, though the extensive beds of gravel and sand which abound in this district, at no great distance from Nesbit, seem rather to favour the latter theory.

Selkirkshire.

On the top of Meigle Hill, about 2 miles from Galashiels, there is a boulder which I was requested to come and examine. It is of this shape, and its size is $6 \times 4\frac{1}{2} \times 3\frac{3}{4}$ feet.

Its longer axis lies N.W. and S.E., the sharp end pointing N.W. The person who invited me to visit the boulder, and guided me to it, told me that he had, by means of a lever, moved the boulder about 9 inches from its original natural position. The boulder is a hard grey Silurian rock, much harder than the rock of the hill, which is also Silurian.

The boulder, being well rounded, seems to have undergone much friction; and there are hollows and scoopings on several parts, such as frequently occur on rocks long subject to the eddying action of water. The boulder is about 58 yards east from the apex of the hill. It appeared to be lying on gravel or other drift materials, and about 12 feet below the apex of the hill. The hill reaches to a height of about 1430 feet above the sea. Many other boulders occur near the top of the hill, all of the same Silurian rock, well rounded, but none quite so large as the one above described. Meigle Hill stands by itself, *i.e.*, there are no other hills of equal altitude within some miles. There can be no doubt that all the above mentioned are "*erratics*," but from what quarter brought there is nothing to show. It would be difficult, however, to conceive any other medium of transport than floating ice.

Perth and Stirling Shires.

In looking through the Committee's previous Reports, I find reference made to a boulder near Doune, a *conglomerate*, weighing about 900 tons. A full account of this boulder, of the gravel beds on which it lies, and of its probable parent rock, is given in my little book called "Estuary of the Forth" (Edmonstone & Douglas, 1871), to which it may be allowable to refer (page 41). There are,

besides many other *conglomerate* boulders—as at the following places:—

On Landrick Estate, one weighing about 360 tons (p. 43).

At Keltie Bridge (a mile east of Callander), one weighing about 60 tons (p. 45).

On Gartincaber estate, one weighing about 16 tons (p. 43)

On north side of Teith, below Landrick Castle, one weighing about 13 tons (p. 44).

In the Burn of Cambus, two weighing about 13 and 24 tons respectively (p. 44).

In the district traversed by the hill road between Doune and Callander, there are multitudes of *conglomerate boulders* of smaller size (p. 44).

At Cornton brick-work (between Stirling and the Bridge of Allan) I saw a small *conglomerate boulder* found in the clay-bed there.

On the rocks adjoining Stirling Castle on the north, I observed small *conglomerate boulders*, besides some of gneiss and greywacke (p. 39). At Loch Coulter and Gillies Hill, places about 3 miles south from Stirling, and from 400 to 600 feet above the sea, I found several *conglomerate boulders*, besides some of mica slate and felspar porphyry, evidently all brought from the N.W.

On Plean estate (4 miles S.E. of Stirling), besides boulders of granite, gneiss, greywacke, and whinstone, there were some of *conglomerate* (p. 46).

At Glenbernie, near Torwood (5 miles S.S.E. of Stirling), I found a *conglomerate boulder* about 6 feet square (p. 48).

On Dunmore estate (about 9 miles S.E. of Stirling) there is the Carlin Stone, a *conglomerate boulder* weighing about 10 tons.

This list of *conglomerate* boulders may be considered interesting, as the position of the parent rock is known, viz., the band which traverses the country at Callendar, running from that point N.E. towards Brackland, and S.W. towards Aberfoyle and Loch Lomond.

Assuming that the boulders have all come from this band of conglomerate rock, they show a transport from the N.W. They also show that they cover a wide district of country towards the S.E., not a district forming a valley, in which a glacier might have moved,

but a district at various heights above the sea from 20 to 600 feet or more.

The boulders seem to increase in size and number the nearer they are to the parent rocks.

In the accounts given of these boulders it will be seen that those which are somewhat elongated in shape, have their longer axis lying N.W. and S E., and that where striæ occur, either on boulder-clay or on rocks, these striæ lie in the same direction (pp. 46, 60, 61, 64).

The conglomerate boulders are chiefly referred to, because they are the most numerous, and the position of their parent rocks is best known. But the other boulders of the district—granites, silurians, and porphyries,—all yield confirmatory testimony, as will be seen from the positions of their parent rocks, and also their own position.

One other feature in this district may be mentioned, viz., the direction in which the gravel-beds have been by some means scoured out, leaving escars or kaims. Thus (1) at and near Bucklyvie (10 miles west of Stirling) there are three elongated knolls of gravel, sand, and boulders, lying in an E. and W. direction, reaching a height of from 60 to 70 feet above the adjoining district.

(2). On Blair-Drummond lands, there is a knoll composed chiefly of sandstone rock, but partially covered with gravel. It is known by the classical name of the Naidds' Knoll, given probably by Lord Kames, a former proprietor. It is in length 90 yards, and in extreme height about 50 feet, with a width of about 40 yards at its greatest width, which is near the east end. The direction of the longer axis of this knoll is W.N.W. and E.S.E. At the head of the valley towards the west, the lowest level is what is called the Pass of Bolat, and that point bears W.N.W. from the knoll. The rock of the knoll is a soft red sandstone, which could have been worn into its present shape by a current flowing through the pass in an easterly direction.

(3). About 2 miles south of Stirling, there is a gravel hill called Coxit. Its length is about $\frac{3}{4}$ of a mile, and its greatest width 300 yards. Its height is from 80 to 100 feet. Its longer axis runs about N.W. and S. E. A current flowing from the westward down the valley upon Stirling Castle rocks, might have had a branch diverted towards the S.E., and have scoured out the drift deposits, as it flowed near St Ninians and Sauchie, leaving Coxit Hill as a

remnant of the drift. Between Sauchie and Gillies Hills (chiefly whinstone), which are near Coxit, there is a narrow valley running in a direction N.W. and S.E., which would help to guide a current running in the direction supposed.

(4). The long escar of gravel passing through Callendar Park and Polmont, extending for about 2 miles, runs in an east and west direction, because there, any current would flow in a direction approximatively parallel with the axis of the valley of the Forth.

II. *PROFESSOR HEDDLE'S NOTES.*

Ayrshire.

1. In the *Valley of the Stinchar*, a boulder of fine-grained claystone, about a cubic yard in size, lies near the hamlet of Poundland.

It seemed to be in its mineralogical character identical with the rock of the hill of Glassal, situated to the N.E., and also with a rock on the shore to the west near Bennane Head.

2. About half a mile to N. of Colmonell, at a height above the sea of about 200 feet, a dolerite boulder occurs $27 \times 23 \times 12$ feet. Its longer axis lies N. and S.

It lies on till, and the till covers the serpentine rock of the S. slopes of Belhannie Hill.

A small boulder, apparently a fragment of the larger, lies to the south.

About 600 yards E. by S. of this boulder, viz., up the valley, a spur of the same kind of rock projects out of the serpentine of the hill.

3. Lower down the valley there is another boulder of the same rock. It has been rent into four pieces, and the impression is suggested that it had been rent in consequence of falling from a height. It also rests on till. The fragments indicate the boulder before being broken to have been $21 \times 21 \times 10$ feet in size. Its long axis is also N. and S.

4. On the shore, a little to the north of Lendalfoot, there lies an Old Red Sandstone conglomerate boulder, $8 \times 6 \times 6$ feet. It is undis-

tinguishable from the conglomerate of Wemyss Bay, situated about 30 miles to the north.

Argyleshire.

Colonsay.—The rocks near the place in this island where the steamboat calls, viz., on the N.E. side, were found to have been smoothed in a line bearing W.N.W. and E.S.E.; but from which direction the smoothing agents had come was not ascertained.

North Uist.—At Loch Maddy the rocks were found to have been smoothed every where, and in the same line as at Colonsay.

There are localities which show unmistakably that the smoothing agent had followed a course from west to east, or rather from the north of west. But the hollows or trenches between the higher grounds and the strike of the old gneiss strata have exercised some influence in diverting the smoothing agent, sometimes one way and sometimes another.

The two trap islets, Maddy More and Maddy Beg, porpoise-nosed to the west, and cliffy to the east, vouch for the direction of flow of the agent which conferred upon them their striking forms.

Whilst at Loch Maddy, I was accompanied by Mr Harvey Brown, who has written several well-known works on the natural history of Scotland, and has noted glaciation with an active eye, and an intelligent and independent mind.

Mr Brown had lately returned from a visit of some duration to Newton, on the coast of North Uist, where he had Mr James Thomson of Glasgow as a companion. He furnished me with a sketch and description of a boulder which lies on sloping ground to the S.E. of Newton. It is $13 \times 5 \times 4$ feet. It lies with its longer axis pointing N.N.W. and S.S.E. Another is $9 \times 5 \times 5$ feet. He stated that Mr Thomson and he had spent some time in examining the glaciation of the neighbouring shore, and found that all the rocks were glaciated from the N.W. He suggested my applying to Mr Thomson for farther information. Mr Thomson, in reply, stated that the glaciation on the west shore of the Long Island was all from the west, varying occasionally between N.W. and S.W., and he added an expression of surprise that any one could have made the mistake of not seeing this fact, it was so palpably evident.

Harris.—On Gilebhal Glass, the southern flanks are striated up

to a height of 500 feet, apparently by ice which came through the gorge of Tarbert from the west. Above this height the glacial striæ strike down the slopes of the hill in every direction.

On the S.E. slopes of the hill, there are portions of the ribbed and striated rock which have been torn up, and carried but a short distance, then let down and fractured in the fall.

Clisham and Langa have but few boulders; those on the south spur of Langa reach a height of 1400 feet, which is nearly the upper limit of the glaciation of these hills.

While the glaciation of the east and west trenches between the Harris hills shows a course of transit from west to east, the valleys of the *highest* hills showed ice to have passed down them from the higher level, whatever the direction of these valleys may be.

West Loch Tarbert.—Though rock does appear between the eastern and western arm of the sea which impinge here so closely upon one another as to warrant the above common appellation, yet the isthmus is for the most part made up of boulder-studded till. One or two of the boulders are of a close-grained hornblendic rock, and doubtless have been portions of a band of rock of an identical character situated a few hundred yards westward on the north shore of Loch Tarbert.

As the nature and structure of this crypto-crystalline bed is very marked and unmistakable, I regard the above as unimpeachable evidence of the course of the ice through the pass; and it must stand as such till a similar bed is found on the shores of East Loch Tarbert. For such I searched without success, though I found a characteristic bed of graphic granite, no fragment of which, however, did I find in the till which plugs the throat of the pass.

Glen Scramble.—This deep glen lies between Gilabhal Glass and Skiam Hill. At the bridge which crosses the stream issuing from the glen, I found a number of loose masses of an igneous rock, identical with a rock forming a dyke coming out above the bridge. These masses, therefore, have come down the glen, viz., from the east; but if they were brought down by ice, there could have been no great mass of ice, the distance of conveyance being quite trifling in amount.

Scalpa Island.—Walking eastward from the village, I fell in with a boulder, $7 \times 6 \times 6$ feet, of a characteristic granite, butted up against the rocky steps of a small knoll of gneiss rocks on its east side, about 35 feet above H.W. mark. A sketch of this boulder is given

on plate XVIII. fig. 6. On the face of the hill directly opposite on the Harris shore, situated to the N.W., a great bed of the same granite rock is distinctly visible. Two other granite boulders similarly "stopped" occur to the east of this one.

Shiant Islands.—On the *upper* surface of these islands, three in number, all of basaltic trap, and reaching to a height of about 500 feet, there are no boulders of any *foreign* rock. On the southern island there is a line of boulders not much rounded, which lie directly east of a spot where there has been a palpable rending.

Two of the islands are connected by a ridge or "ayre" of loose materials, over which the waves now occasionally roll. On the western slope of this "ayre" there are much worn fragments of two foreign rocks, viz., hornblendic gneiss and Cambrian sandstone.

The gneiss blocks are about 2 cubic feet in size. The conglomerate blocks are sometimes as small as eggs; two of these, but none of the gneiss, were found on the east side of the "ayre."

On a stretch of shore along the N.W. side of the most northern island, conglomerate blocks also occur.

The only place in this part of Scotland where I know of a similar conglomerate rock is on the Eye Peninsula of Lewis, a short distance east of Stornoway, and about 30 miles to the north of the Shiants.

There is one other feature about the Shiant Islands which seems worthy of notice. The two highest islands, viz., *Garbh Eilan* (rough island), and *Eilan an Tighe*, lie north and south of one another; whilst the third, viz., *Eilan Mhuire*, lies to the east, and does not reach so high a level as the other two.

The upper surface of the two largest and highest islands, both when viewed from a distance and when examined in detail, present such soft and gently-sweeping risings and hollows that ice in some form or other appeared to have passed over and pressed on the surface of the rocks. It had evidently gone over *Eilan an Tighe* from W. to E., and over the southern part of *Garbh Eilan* (lying to the north) in the same direction, but over the higher parts and main bulk of the island from the S.W.

This movement and direction of the ice on these islands is corroborated by the position of a number of boulders on both of these islands consisting of the basaltic rock of the islands, which are all on the east side of the most southerly of these islands, and in the

more northerly to the east of one or more spots where there has been a palpable rending of rocks by some powerful agent moving on them from the westward.

Now, it is rather remarkable that the island of *Eilan Mhuire*, situated to the east of the other two islands, presents on its surface no traces of the same smoothing which occur on the other two islands. It is lower in level than the other two. If it was ice which passed over and rubbed on them moving towards the east, why did not it also pass over and rub on *Eilan Mhuire?* If it was a sheet of land ice, the fact of *Eilan Mhuire* being a little lower in level should rather have ensured contact by the ice. If, however, the ice was floating, it may have passed over the lower island without reaching it.

Skye.—An examination of the north-east part of the island from Aird Point to Portree was made, chiefly along the coast, and partially among the hills.

While there was found throughout evidence of vast denudation with frequent rounded contours (as along the line of cliffs above the Kilt rock), the rocks nowhere bore groovings or even scratchings.

The cols between the numerous heights of the central range of hills were narrowly examined, as, in the case of a movement across the island from either N.W. or N.E. these hills must have been subjected to a great amount of "scour."

At the several cols, averaging about 1300 feet above the sea, the water-sheds which fall to the south commence with the most singular precipitancy, there being hardly a yard or two between the brink of the precipice (which falls sheer to the N.E.) and the trickling of a marshy stream flowing in the opposite direction. Between many of these cols, peaks of rock shot up to a height of 2000 feet and more.

There were no hollows and no contours which could be assigned to ice. The slope on both sides of the stream-trench was such as would result merely from the sliding soak of water.

No true boulders were any where to be seen. That the summit of this range has not been ice-worn, may be deduced from the abruptness with which fragments of an upper bed of basaltic columns shoot up with a pillared steepness which show no rounding of their angles, or abrasion of any of their terminations.

A loose pillar (of which a sketch was taken) points the same way.

This pillar, retaining all its original sharpness of angle, lies on its side at the very highest part of the whole range.

Though there is no evidence that ice has been over the top of these cliffs, there is evidence that it has been at the *bottom*.

The southern shore of Stainchol Bay is, with the little island at its eastern horn, stretched like a half-opened hand, so as to catch everything which may have been carried from the north along the eastern shore.

Among the rounded masses lying on the beach, there are blocks of the same Cambrian conglomerate which occurs at the Shiant Islands, and of a larger size.

On account of the position of Stainchol Island, it is not likely that these could have come from any point east of north.

On the island itself, no boulders were seen except on the S.W. shore; several consisting of dolerite, in which labradorite is well seen, lie here. A rock of the same nature occurs about 50 yards to N.N.W.

Loch Torridon and Loch Maree.—The position of "*The thousand hills*" (consisting of dirt cones and delta heaps) in Glen Torridon, and the smoothed rocks at the head of the glen, leave no room for doubt that a true glacier had descended this glen from the north and east. But, on the other hand, the till at the very summit-level between Glen Docharty and the head of Loch Roisk, has indubitably been water-dressed, and the dressing agent seems to have come up Glen Docharty.

The ice had apparently come out of every corry of the eastern sides of Leagach and Eye, to merge into the Torridon glacier.

But, on the other hand, there were found on *Scuir na Conraran* (a N.E. quartzite spur of *Ben Eye*) boulders of hornblende rock, hornblendic gneiss, and of Cambrian sandstone.

The hornblendic boulders were very similar to the hornblende of *Ben Arrichar* on the north shore of Maree, 13 miles to the westward.

As they lay much in line, in order to ascertain that they were not merely the turned-over fragments of a vein, though such a thing was most improbable, the ground was carefully scanned by several pairs of eyes, but no fixed mass was found.

An opposing spur of *Miall Ghubhais*, called *Carn a liadh* (grey

cairns), which lies N.W. of this, was distinctly hummocked at a height of about 950 feet above the sea.

Black Mount district,—having Loch Levin on the north, Moor of Rannoch on the east, and the Linnhe Loch on the west.

1. A train of boulders having been noticed by me on the north slopes of the valley of the *Beathard*, west of Loch Tulla, viz., on the low slopes of *Stob Ghabhar* and *Ben Toaig*, and also several huge blocks upon the shores of *Loch Dochard*, I felt a desire to seek for the parent rocks.

The boulders on *Stob Ghabhar* were of a pecular white granite, and were in size on an average up to $10 \times 10 \times 7$ feet.

Ben Toaig and *Ben Terrick* are hills of gneiss. In the col between these hills, at a height of 2530 feet, the same variety of white granite boulders were found, with an average size of about a cubic yard, much worn. There was glaciation on the rocks (but much effaced), from S.W. to N.E.

Stob Ghabhar is also a gneiss hill. No boulders were seen except on its southern slopes, *i.e.*, at the spot already mentioned.

Ben Starrav was ascended. Its rocks were different from that of the boulders, as they consisted of a flesh-coloured granite.

The hills called *Scon Ghearraen* and *Meal Odhar* were next examined, forming west spurs from *Stob Ghabhar*. The rocks on them, as well as on *Glass Bein Mohr*, were found to be granite, but not exactly the same as that of the boulders.

Albannach hill was found, from its first eastern cliff to its summit, to consist of granite *identical with that of the boulders*. Blocks of the rock strewed its cross-corries in numbers; and the whole process of boulder formation may be said to be still displayed upon its slopes.

On the east and south-east sides of the hill there seemed to have been ice moving towards the south and towards the east.

On its northern side, similar traces were visible in the great corry under the sharp peak, showing a movement first to the north, and then a confluence with glaciation from a west corry of *Meall Targuinn*, thereafter curving westward, and sweeping towards Glen Etive.

This great hill, reaching to a height of 3425 feet above the sea, seems to have been the cradle of local glaciers, and also the source from

which the boulders near Tulla had been carried about ten miles in a direction E.S.E.

As it was thought desirable to see whether these boulders could be traced farther to the eastward, I tracked them back to the west and north shores of the lake, and thereafter for 2 or 3 miles up the course of the water of Tulla. They evidently diminished in numbers towards the east. Some of the boulders at Loch Tulla were about 8 cubic feet in size.

A search was next made along the southern range of hills, of which Meal Buidh, Ben Creachan, and Ben Achallater are the highest. But no boulders of the same or of any kind were found on them.

These boulders, therefore, had been carried, as it were, in a stream, and one of no great width, towards the S.E.

The valley, which gradually ascends westward from Loch Tulla towards the great massive hill of Starrav, becomes very narrow immediately to the east of Loch Dochard.

If any powerful agent passed through this valley eastward, it is probable that there would be great obstruction and a violent pressure on and rending of the adjoining rocks.

The lower part of the pass contains much till, and occasionally rock rises up through the till with finely smoothed hunches, showing striations from the W.N.W.

On the south side of the lake there are some enormous boulders, mostly angular, several of which are broken or fractured, as if by falling from a height. A sketch is given of one of these, fig. 7 on plate XVIII., as it is the largest I have seen or heard of in Scotland, except one in Arran. Its size is $45 \times 22 \times 26$ feet, and amounting therefore in weight to about 1900 tons. It consists of mica gneiss, and lies upon till. The view in the figure is taken from N.N.W. Other boulders of a similar rock occur at the same place, nearly equally large.

The hill immediately to the south of this boulder is composed of a similar sort of rock; so that very possibly, nay probably, the boulder may have been detached from the hill. But it is so far from the hill, and the intervening ground is of such a nature, that nothing but ice could have brought it into its present position.

The rocks at this place are much rounded, and show striæ running

W.N.W. and E.S.E. The striating agent unquestionably here came from the westward.

2. *Loch Creran.*—On the east side of this loch there are a number of boulders, some of very large size, of which notice was taken in the Committee's two last Reports.

My attention was drawn to these by our Convener, so that in the event of my visiting that district during the past summer I might endeavour to discover from what quarter these boulders had come.

I was glad to find myself able to comply with this request, and I spent several days in examining the district in question.

On the banks of the Creran there are two distinct classes of boulders, differing in mineralogical composition.

Those in the lower part of Glen Creran, near the bridge at the head of the loch and between Invercreran House and Fasnacloich, are much weather-worn, dense in structure, and dark in colour. The hornblende in them is dark-brown in colour, with but little felspar, and they contain a little bronzy biotite.

In a higher part of the glen, at and above Fasnacloich House, the boulders have much felspar, which is pale in colour; also hornblende which is always green, sometimes light-green, and a little quartz, but almost no biotite.

The rocks of the glen adjoining the places where both sets of boulders lie are quite different from the rocks composing the boulders; I therefore made a diligent search among the hills in the neighbourhood for the parent rocks.

The first-mentioned set of boulders, which I may call the *Invercreran* boulders, I found as regards mineral composition to be the same, or very nearly the same, as a band of rock in the *Coire Dhu* of *Fraochaid*, at a height of from 1500 to 1700 feet above the sea. This corry leads up from Glen Creran about 4 or 5 miles to the N.N.E. of Invercreran. The only mineralogical difference which I could detect was, that in the rocks on the hill, there was perhaps rather less biotite.

The place where the rock composing the Fasnacloich boulders was found is in a col lying a little north of the fountain-tarn of the River Durer, a river running into the Linnhe Loch at Coil Bay. The col lies between *Stob Coire Dhu* and *Stob Coire Ruadh*, at a height

of 1940 feet. A number of blocks of this rock were found by me at the west foot of *Miall an Aodain*, a hill situated to the eastward.

How these two sets of boulders have been carried to their present positions is a question on which I have yet formed no decided opinion. As perhaps bearing on that question, however, it is right to mention that the rocks near the fountain-tarn of the River Durer, at a height of 1940 feet, are much glaciated and apparently from the west.

Striæ occur on a clay-slate rock about $\frac{1}{4}$ of a mile south from the place just mentioned, just before the ascent of *Stob Coire Ruadh* commences, and at a height of nearly 2000 feet, which show a movement from a little to the north of west. These facts seem to suggest that some powerful smoothing and striating agent had passed over this district from the west, and at a level exceeding 2000 feet above the sea. But west from the place where these smoothed and striated rocks occur, there are no hills so high as to produce a glacier, unless, indeed, a glacier had come through Glen Tarbert, which is a continuation of Loch Sunart, and crossed what is now the Linnhe Loch. Loch Sunart and Glen Tarbert occupy a hollow in the district which runs in a direction about W.N.W. and E.S.E.

It is, however, proper to add, that on the rock where these W.N.W. striæ occur, there are cross striæ overlying and cutting into these, which cross striæ indicate a movement from the S.W. These cross striæ being more sharp and minute than those first made, indicate more recent and also less powerful action. Can it have been that a sea existed at a level exceeding 2000 feet above the present level, with ice in it which was floating about in eddying currents, among what are now high peaked hills, tearing rocks out of the shallows, and pushing them over what were then submarine reefs?

In regard to the boulders at Ivercreran and Fasnacloich, they manifestly have come from the particular hills above specified; but whether dropped from floating ice, or carried by glaciers, it is with our present information impossible to say.

The striæ last mentioned, as occurring at the height of 2000 feet, pointing about W.N.W., bear on the top of *Fraochaidh*, a hill 2883 feet high.

But between that hill and the rock on which the striæ appear,

there is the deep gorge of the *Coire Ruadh*, which if it then existed would have conducted any glacier from that hill in a different direction, viz., towards the N.W., and not towards Loch Creran, which lies almost due south from *Fraochaidh*.

3. Upon the south slopes of *Stob Coire Ruadh* there is a boulder of the peculiar *porcelain porphyry* worked at Kentallen in Appin. The boulder is about a square yard in size. That it is a boulder, is evident from the fact of the rocks of the hill where it lies being totally different. Its height above the sea is 2250 feet. Now, a porcelain rock of exactly the same kind occurs among the *Ben a Bheithir* hills, at exactly the same height above the sea, about midway between *Craig Ghorm* and *Sgorr Dhonuill*, which is 3 or 4 miles to the N.N.W.

Assuming that the boulder came from that point, it must have crossed two valleys, each of which is less than 700 feet above the sea. How it could have crossed these, except on floating ice, it is difficult to see.

4. There is another boulder among these hills deserving notice. It is one of *Schistose Breccia*, lying on the east side of *Fraochaidh*, at a height of 2235 feet. The rock of the hill here is a *Schistose Gneiss*. Now rocks of *Schistose Breccia* occur between the two peaks of *Ben a Bheithir* just mentioned, situated to the N.N.W. This boulder in like manner must have been carried across the deep valley of the Durer to have reached its present position.

5. The col between *Creran* and *Allt na Gaorran* showed glaciation coming down from the corries of the rough *Sgorr na Ulaidh*, and out of a corry on *Ben Fhionnlaidh*. Many loose and angular blocks of the hills themselves, much confusion, and smashing of every kind, and the glaciated contours, twisting away to go down both glens in opposite directions, S.E. and S.W., is all that this locality discloses. The deep cut of *Glen Ure* showed evidence of movement down it.

In reviewing the information obtained by me regarding these Creran boulders, I feel that there ought to be farther study of them, before their mode of transport can be said to have been discovered. On the one hand, the clustered manner in which the boulders lie on the west of *Miall an Aodain*, and at two spots on the east side of Glen Creran, is suggestive of blocks having rolled over the terminal

front of glaciers; or perhaps of a lateral moraine, when regard is had to there being in some places a train of blocks in almost single file. But, on the other hand, I cannot shut my eyes to the possibility of these boulders having been carried or pushed into position by ice in another form, which came from the west through Glen Tarbert; and which, when it reached the Durer valley, was blocked by the huge masses of *Scuir na Ulaidh* and *Ben Fionnlaidh*, and then forced to sweep down the trench of *Glen Creran*, carrying boulders, and lodging them where they now lie.

District of Glencoe.—On the western grass clad slopes of *Sron Coire Odhar Beg*, a hill north of *Glen Coe*, in the higher part of the glen, a number of small boulders, much rounded, were observed of a peculiar granite. It was whiter and coarser grained than the well-known Ardshiel granite, and had a little hornblende in it.

They were in composition altogether different from the rocks of the hill on which they were first noticed, which consists of schistose breccia.

The hills to the eastward I had previously examined (*Ben a Chrulaiste* and others), and knew that they consisted of epidotic gneiss.

I therefore thought it probable that the birthplace of the boulders would be somewhere to the westward, so in that direction I proceeded.

On reaching the *Aonach-Eagach* range, I found the same boulders, fewer in numbers but markedly larger in size.

They were lying almost exclusively on the eastern side of the narrow ridge leading up to the summit, and almost on the summit of the nameless peak marked 2938 feet on the 1-inch Ordnance map. On the next rounded haunch (2880 feet) they were not seen; but they reappeared on the ridge as it ascended to the eastern peak of *Meall Dearg* (3090 feet), and almost up to the summit of the western peak (3118 feet).

Their position here was most peculiar. They lay upon a ridge not many times wider than their own bulk, and only on the eastern slopes of that ridge; while on the lower hills where they were first seen, the same boulders lay on the west slopes.

The parts between *Meall Dearg* and *Meall Garbh*, extending to about half a mile, are quite inaccessible, and could not be examined. But so far as the peaked rocks composing this district could be seen, no

boulders were on them, and, indeed, on account of their sharp-edged ridges boulders were not likely to have lodged on them.

On the hills of *Sgornan Fiannaidh* (3188 feet) and *Sgor an Caiche* (2430 feet), situated farther west, these boulders were not found, nor any rock of the same description.

I proceeded to the next hills, of somewhat greater height, about 6 or 7 miles to the west, to the south of Balachulish, viz., *Bhein Bahn*, *Sgorr Dherag*, *Sgor Dhonuill*, and *Creag Ghorm*.

In the bed of a stream which descends the steep eastern face of *Creag Ghorm*, at about 1500 feet above the sea, a belt of rock occurs identical with that of the boulders; also along a great part of the semicircular ridge which connects *Creag Ghorm* with *Sgorr Dhonuill*, at a height averaging 2250 feet, there is rock very similar to that of the boulders, there being rather less mica in it, and only occasional hornblendic crystals. *Biddian nam Bian* (3786 feet) was twice ascended, but it presented no trace of the rock sought for. But though the rocks at the two other places indicated were found to be almost identical in mineralogical composition with that of the boulders, I am not satisfied that they supplied the boulders. The spots where these rocks occur are only from 1500 to 2300 feet above the sea; whereas the boulders on some parts of the *Aonach Eagach* to the eastward were at a height of 3100 feet above the sea.

Therefore I admit that there must still remain some uncertainty as to the birthplace of these boulders. An attempt has been made by some geologists to explain how boulders may be transported to positions above the level of the parent rocks; and if that theory be correct it may overcome the difficulty referred to.

It is possible also that the rocks at *Creag Ghorm* and *Sgorr Dhonuill* may have formerly reached a higher level; and in that view it may be remarked that at present the rocks of these hills are even now, under the action of the weather, breaking off into huge blocks.

Of course it may still be possible to find the peculiar rock of these boulders on more elevated hills elsewhere. Ben Cruachan and other hills to the south and west reach a height of more than 3100 feet; but I have been on most of these hills, and I do not think that on any of them there are rocks which would produce the boulders.

It is therefore a fact of considerable importance bearing on any theory of transport, that these boulders on *Aonach Eagach* occupy positions much higher in level than any of the hills in a very wide extent of country; so that it is difficult, if not impossible, to adopt for them the explanation of any local glacier.

I have adverted to the peculiar position of the boulders on *Meall Dearg*, where at a height of 3100 feet they lay upon a ridge not many times wider than their own bulk, or rather on the sides of that ridge facing the E. or N.E. I am not able to offer any satisfactory explanation of this feature. I would like again to study the positions of these boulders. They must have been brought there by ice, which may have come from the N.W., and stuck there among the high peaks till it melted, and allowed the boulders to subside on or near the top of the ridge. My explorations about Glen Creran led to the supposition of a flow of ice through Glen Tarbert on the N.W. side of Linnhe Loch. This might possibly also account for the boulders on *Aonach Eagach*. But in that case, where could the parent rocks be?

(Though it does not seem to have any direct bearing upon the question, yet it may be well to record the fact that the bed of the Cona is, for a short distance, about midway between the little lake and the hamlet of Clachach, cut through a rock very similar to, if not identical with, that of the boulders.)

III. *NOTES BY WILLIAM JOLLY, Esq.*

On the Carried Boulders on the South Shores of the Moray Firth.

In answer to your request, I send some notes, supplementary to those of last year, on the above subject.

The Dirriemore Granite seems to be more widely distributed towards the east than I anticipated. Since last year, I visited the place where I had formerly found it *in situ*, on the road between Dingwall and Ullapool, where it appears in the valley of the Blackwater, about and below its junction with Strathvaich. *None of it*

has been carried *westwards* between this part of the valley and Loch Broom, a tract which I have examined more than once. It has been carried altogether *towards the east*, in accordance with the general slope of the country. This granite would seem, however, to occupy a wider and more elevated area in the Ben Wyvis mountains than is shown in the Blackwater, from which it has been borne and dropped along the south shores of the Moray Firth, after being carried down the several valleys that drain this range into the Cromarty Firth, as well as down through Strathpeffer, and down the lower valley of the Conon below its junction with the Blackwater near Tor Achilty, in Contin.

In the valley of the Alness, for example, it is widely distributed, having evidently come from some centre near its head waters. Good specimens of it may be seen round the village of Alness, and along the shore between it and Invergordon, skirted by the public highway. It has been carried across the Cromarty Firth, and scattered abundantly in large and striking masses *over the whole of the Black Isle*, from end to end. Good examples of it may be seen at its northern extremity round Cromarty, and along its central ridge on the road between that town and Fortrose, large pieces being easily seen on the moor near Peddieston, a few miles south of Cromarty, and along the road between Invergordon Ferry and the Sutors. It is also found extensively along the whole of the east shore of the Black Isle, and has been carried thence eastwards towards Buckie. It exists plentifully all over the Laigh of Moray, and may be well seen along the seashore there, especially between Burghead and Lossiemouth.

The Strathcrrick Liver-coloured Conglomerate I have found numerous additional examples of, from its source on the east shore of Loch Ness north of Inverfarigaig, onwards to Lossiemouth.

There would seem, however, to be two varieties of conglomerate distributed throughout the Laigh of Moray—the above easily distinguished rock, and another consisting of more angular components and entirely without the liver-coloured quartzite or porphyry. Examples of the latter may be seen in the old quarry of Oolitic limestone at the classical Linksfield, near Elgin, embedded in the boulder-clay there, one of the masses on the south side of the quarry being very large. The Douping Stone on the top of the Califer Hill, east of Forres,

mentioned in my notes of last year, is certainly of the Stratherrick liver-coloured variety; but the block on the top of Roseisle Hill, also mentioned by me, may be of the other. This second conglomerate would seem, from various indications, to have been transported at an earlier period than the Stratherrick, for it is found embedded at greater or less depths in the prevalent boulder-clay of Morayshire; whereas the Stratherrick rock is seldom, if ever, thus buried, being confined more to the upper surface of the country. The glaciation of Morayshire shows two main directions of the scratches, indicating two lines of ice movement from the westward, as exhibited admirably on the ridge of Carden Moor, near Alves station. These scratches point respectively 13° N. of W., and 6° S. of W., as the directions from which the ice has come. The second conglomerate may have been carried across the Moray Firth from Ross-shire, like the Dirriemore granite, in the line of the former scratches.

The red orthoclase Kinsteary Granite, found *in situ* near Nairn, is very abundantly distributed from this point towards the east, onwards beyond Buckie.

Mr Linn of the Geological Survey, at present engaged in mapping the district round Elgin, has found these three rocks widely spread all over the Laigh of Moray, and has taken the fullest notes of the composition and positions of the various carried blocks there, which will be embodied in his map of the region, and will form an important contribution to the question of the transportation of rocks along the south shores of the Moray Firth.

I append some notes supplied to me by Mr Wallace of the High School, Inverness, mentioned in last year's notes, regarding their distribution on the north coast of Banffshire. These carry the account of the transport of boulders eastwards to Cullen. It would be most desirable that the Committee should, if possible, obtain information regarding their farther distribution through Aberdeenshire, and thus complete their story to the German Ocean.

IV. *NOTES BY THOMAS D. WALLACE, Esq.*

On the Carried Boulders in the Parishes of Enzie and Rathven, Banffshire.

Having revisited this district at Christmas 1879, and examined it more carefully than on former occasions, I found further proof of the eastern flow of the great ice-sheet that at one time traversed the whole of the southern shore of the Moray Firth. In the neighbourhood of the Enzie post-office, I found numerous boulders of the Dirriemore granite, none of them so large as those that were dug out during the excavations for the Buckie Harbour, and mentioned last year in the Committee's Report.

Numerous small boulders of the Elgin Cornstones lie scattered all over the lower part of the district. Several are to be seen in the Gollachy Burn, a little to the west of Buckie.

Conglomerate boulders are rather rare. Except the few remaining stones forming the "Stone Circle of Dryburn," near Portgordon, I found only one, about a quarter of a mile east from Dryburn.

A very characteristic specimen of Kinsteary Granite is seen close beside the harbour of Buckie. Smaller pieces may easily be picked up on the fields along the shore. A well-marked feature of the schists which underlie the Old Red Sandstone in this district, is the frequent occurrence of large veins of calc spar, quartz, and quartzites. Specimens of these are also numerous in the drift.

A fine specimen of Cairngorm (water-worn) was picked up by a labourer on the high ridge to the south of the district, locally known as the "Hill of Altmore." It measures 2 inches thick at the one end and 3 inches at the other. It is about 4½ inches in breadth. This man, ignorant of its value, took it to Aberdeen and had it polished on both sides by some friend at the granite works. This has rendered it quite transparent, so that one can read with the greatest ease anything placed under it.

One section of Boulder-Clay is deserving of notice. It is in the wood of Pathhead, on the estate of Cairnfield, a little to the south of the Enzie post-office. It consists of a fine plastic clay of a dark bluish-black colour, overlaid by the well-known red boulder-clay. The blue clay represents the denudation of the schists, and the red that of the Old Red Sandstone. Notwithstanding a very minute

examination of every burn in the district, I failed to find any of the blue clay on the lower ground. This I take to be an additional proof of the easterly flow of the ice.

As far as the boulder evidence in this district goes, it proves conclusively that the ice-flow was from the W., or a little to the S. of W.

All along the south shore of the Moray Firth there are scattered boulders of conglomerate, hornblende, and dirriemore (besides other) granites. In the neighbourhood of Inverness, these would indicate a drift from the N.N.W. and one from the S.W., both tending E., or a little to the N. of E. The boulders of hornblende might have come from the N.W. The only place where I have seen hornblende *in situ* in the neighbourhood of Inverness, near which are found numerous boulders of that rock, is at Raven's-Rock near Strathpeffer.

(Signed) David Milne Home, *Convener.*

Mr Milne Home, Chairman of the Boulder Committee, after presenting the preceding Report, made the following remarks:—

I may explain that, to save the time of the meeting, and also to afford to members information regarding the operations of the Committee during the past year, copies of the Report were circulated with the billets for the present meeting;—and for the same purpose, as Convener of the Committee, I now proceed to give an abstract of the chief features of the Report.

I. *Boulders in Nairn, Moray, and Banffshire.*

I begin by alluding to the boulders in these counties, because the notes applicable to them are in some sense a continuation of the part of last year's Report applicable to these counties.

In these counties there are two classes of important boulders,—*Granites* and *Conglomerates.*

Of granites there are four kinds, distinguishable by the ingredients, and by the different districts where their parent rocks are situated.

There are, *First*, the boulders, consisting of a very peculiar granite, with lenticular pieces of dark mica, arranged in pretty regular layers, through a pinkish mass, giving to it some resemblance to a stratified deposit. The granite of these boulders has been identified by Mr

Jolly of Inverness with the granite rocks of the Dirrie Muir, a tract in Ross-shire situated to the west of Ben Wyvis, and lying about half-way between the east and west coasts. These boulders have been transported in a E.S.E. direction across the Cromarty Firth, over the district of the Black Isle, and across the Moray Firth, into the low grounds of Moray and Banff. The distance travelled must be nearly 100 miles. *Second*, there are two other granites, one red and the other grey, which have been transported from the hills forming the sides of the great Caledonian Valley,—called the Loch Ness granite and the Stratherrick granite.

These boulders also are found in Moray- and Banff-shires, and show a line of transport not quite the same as the Dirrie Muir granite, viz., about E. by N.

Mr Jolly says, that the Stratherrick granite boulders have been seen by him on the hills south of the Great Valley, up to a height of 1500 feet. But the Boulder Committee, three or four years ago, received through Captain White of the Ordnance Survey, notice of these boulders, having been found by his surveyors at heights of 2250 feet, the parent rocks being on hills 2900 feet in height. This fact is mentioned in the Committee's second annual Report.

These boulders, before reaching Morayshire, must have travelled also about 100 miles.

A fourth class of granite boulders in Morayshire and Banffshire is a beautifully pink-coloured rock, quarried at a place called Kinsteary in Nairnshire. No boulders of this peculiar granite are seen *east* of the parent rock.

What has now been said of *Granite* boulders, as regards transport, applies to the *boulders of Conglomerate.* There are two kinds of conglomerate rock forming them, and they come from different districts,—one in the Great Valley itself, which it crosses near the hill called Meal Fourvounie; the other in Ross-shire, at some distance to the north of the Great Valley.

The Committee have, in regard to these Moray- and Banff-shire boulders, obtained valuable notes from Mr Jolly and Mr Wallace, both resident in Inverness. The information given as to the position of the parent rocks is gratifying in this respect, that when, three years ago, many of these boulders were examined by myself, I drew an inference regarding the quarter from which they

had probably come, founded solely on the position and attitude of the boulders themselves, the correctness of which inference has now been confirmed by the discovery of the particular districts where the parent rocks are situated.

II. *Professor Forster Heddle's Explorations.*

The Professor's survey last year began on the West of Scotland, and extended from Ayrshire to Loch Torridon in Argyleshire; and also into the interior, near the districts called the Black Mount and Glencoe.

I was especially glad, on receiving the Professor's notes, to find that he had visited several of the islands of the Hebrides; because, as was explained in our last year's Report, the problem of the mode of transport becomes less complex on islands where there are neither hills nor valleys suitable for the formation of local glaciers.

1. The first island visited was *Colonsay*,—on which, however, nothing seems to have been found, beyond rock striations running W.N.W. and E.S.E., but which way the movement was, did not appear.

2. The next island was *Uist*. There, in like manner, the rock striations were W.N.W. and E.S.E., and it was there seen that the striating agent come from the westward. The Professor adds, that "the hollows or trenches between the higher grounds and the strike of the old gneiss strata have exercised some influence, in diverting the smoothing agent, sometimes one way and sometimes another."

At Loch Maddy in Uist, Professor Heddle met with Mr Harvey Brown, who had been for some time surveying there for objects of natural history, in company with Mr James Thomson, a member of the Glasgow Geological Society. Both of these gentlemen had also been studying the phenomena of boulders and striated rocks in the north part of Uist. Mr Brown supplied Professor Heddle with a note of the size of several boulders (which are specified in this Report), and he recommended the Professor to write to Mr Thompson for farther information. The Professor did so, and the answer he received from Mr Thompson was, "That the glaciation on the west shore of the Long Island was all from the west, varying occasionally between N.W. and S.W.;" and he "added (the Professor says) an expres-

sion of surprise, that any one could have made the mistake of not seeing this fact, it was so palpably evident."

3. In *Harris*, Professor Heddle found that on the southern flanks of the hill called *Gilebhall Glass*, rocks were striated up to a height of 500 feet, apparently by ice which (he says) came through the gorge of Tarbert from the west.

At this gorge, he found in the Till, boulders of a close-grained hornblende rock, doubtless (as he says) portions of a rock of identical character situated a few hundred yards to the westward.

The Professor adds, that as this crystalline rock is very marked and unmistakable, he regarded it as unimpeachable evidence of the course of the ice through the gorge.

4. *Scalpa* was next visited,—an island half a mile or so off the east coast of Harris. Here a granite boulder was "found *butted up* on its east side against the rocky steps of a knoll of gneiss rocks." A sketch of this boulder is given in the Report. With reference to the direction of transport, Professor Heddle mentions that the same rock of which the boulder is composed forms a bed in a high cliff on the mainland of Harris to the N.W.

5. *The Shiant* islands, which were next examined, are three in number. They also are off the east coast of Harris, about twenty miles to the N.E. of Tarbert.

On the surface of these islands, which are of basalt, no foreign erratics of any size were found. But on the shore of two of these islands, he found blocks of conglomerate and Cambrian sandstone, which had probably come from near Stornoway, about 30 miles to the north, where these rocks are *in situ*.

The Professor saw in the two largest islands, which lie N. and S. of each other, that some agent—it might be ice—had passed over them from the west, smoothing them, and pushing fragments of the trap rock towards the east. But he observed particularly that there was no such smoothing on the third island lying to the east; and the only explanation of this fact which occurred to him was, that the third island, being much lower in level than the other two, the ice may have passed over, without touching it—an explanation suggesting the agency of floating ice.

6. The next island visited was *Skye*, but the Professor was able only to examine the N. and N.E. portions, viz., from Aird Point to Portree.

He was surprised to find no boulders either on the coast or on the hills adjoining the coast, except on the small islet of *Stainchol*, at the mouth of Loch Staffin. On the shore of this loch there were blocks of Cambrian sandstone, a rock of which he had found pebbles on the shore of the Shiant Islands. On Stainchol, he also found a boulder of dolorite, containing much labradorite;—a rock of the same nature, was *in situ* about 50 yards to the N.N.W.

Professor Heddle further attests, that the rocks on the hills examined by him, which he ascended to above 1500 feet, "nowhere bore groovings or even scratchings;" and he states that "the *cols* between the numerous heights were narrowly examined by him."

Now these facts seem to have an important bearing on the question of boulder transport. Mr James Geikie, in his "Great Ice Age," p. 77, says, that "most of the islands which lie off the coasts of Scotland plainly indicate, by striations and other glacial markings, that ice has swept over them." He adds that "The most striking example of this is furnished by Lewis, the northern portion of the Long Island, which (says he) I found to be glaciated across its whole breadth *from* S.E. to N.W. The land-ice that swept over this tract, must have come from the *mountains of Ross-shire*—a distance of not less than 30 miles. Leaving the mainland, it must have filled up the whole of the North Minch (60 fathoms in depth), and overflowed Lewis to a height of 1300 feet at least."

This statement, made in 1877, was repeated in two elaborate papers read before the London Geological Society in 1878, in which it was maintained, "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."

Now this theory seems entirely at variance with the facts ascertained by Professor Heddle last year, and by myself in the previous year. If a mass of ice came from the Ross-shire hills, so great as to fill the Minch, overflow the Long Island to the height of 1300 feet, and to stretch from the Butt of Lewis to Barra Head, a distance of about 80 miles, it must have impinged on the island of *Skye*, and especially on the north-east part of it. But there, according to Professor Heddle, no boulders are to be seen, and even no groovings or striations of the rocks.

On the other hand, boulders and striated rocks, which in the

Long Island are plentiful, all indicate a movement from the N.W. —a direction the very opposite of that requisite for a great glacier from Ross-shire.

Mr Geikie, in a footnote (page 60), says that "Mr Campbell of Islay considered that the Hebrides Islands had been glaciated by sea-ice coming from the N.W. ;—while, on the other hand, my observations in Lewis compelled me to believe, that the glaciating agent was land-ice streaming outwards from the mainland. My colleague, Mr Etheridge, Jun., who accompanied me during my last visit to the Long Island, also concluded, that the glaciations had been effected by land-ice coming from the S.E."

Whilst much weight is proper to be given to the observations and opinions of such experienced geologists as Mr James Geikie and Mr Etheridge, on the other hand it is only right to keep in view that the late Robert Chambers and Dr Bryce, though they wrote no papers on the subject, are known to have concurred with Mr Campbell; and I have reason to believe, that Mr Jolly of Inverness is of the same opinion.

7. *Black Mount District.*

(1.) Some white granite boulders, which were noticed by Professor Heddle on the shores of Loch Tulla, were, after a minute and laborious search, traced by him to a hill called *Albannach*, situated about 10 miles to the W.N.W. Professor Heddle having ascertained the line of transport, next tried to find whether the boulders covered a large space transversely. The result of this search was to show that (to use the Professor's words) "these boulders had been carried, as it were, in a stream, and one of no great width, towards the S.E."

(2.) Notice was next taken of several large boulders, one weighing no less than 1900 tons, in a valley, which becomes very narrow to the east of Loch Dochard. The Professor says, "If any powerful agent passed through this valley, there would be great obstruction and a violent pressure on and rending of the adjoining rocks. The lower part of the pass (he says) contains much till; and occasionally rock rises up through the till with finely-smoothed hunches, showing striations from the W.N.W." In reference to the large boulder above referred to, Professor Heddle gives his opinion that "nothing but ice could have brought it into its present position."

(3.) The *Glen Creran* boulders having been referred to in the two last Reports of the Committee, with a confession of uncertainty as to the source from which they had come, Professor Heddle, in compliance with my request, kindly undertook a renewed survey of the district.

The result has been that the Professor has found rocks on the hills 4 or 5 miles from Glen Creran to the N.N.E. identical in composition with the boulders. But how the boulders were carried from these hills, where the parent rocks are from 1700 to 2000 feet above the sea, to Glen Creran, which is only about 200 feet above the sea —*i.e.*, "whether dropped from floating ice, or carried by glaciers," "it is (observes the Professor), with our present information, impossible to say."

He found on the hills containing the rocks of the boulders numerous *striæ*, which showed "that some powerful smoothing and striating agent had passed over this district from the west, and at a level exceeding 2000 feet above the sea. But west from the place where these smoothed and striated rocks occur, there are no hills so high as to produce a glacier, unless, indeed, a glacier had come through Glen Tarbert, which is a continuation of Loch Sunart, and crossed what is now the Linnhe Loch. Loch Sunart and Glen Tarbert occupy a hollow in the district which runs in a direction about W.N.W. and E.S.E.

"It is, however (he says), proper to add that on the rock where these W.N.W. striæ occur, there are cross striæ overlying and cutting into these, indicating another and more recent agency from the S.W. These cross striæ being more sharp and minute than the first, indicate more recent and less powerful action. Can it have been that a sea existed exceeding 2000 feet above the present level with ice in it, which was floating about in eddying currents among what are now high-peaked hills, tearing rocks out of the shallows, and pushing them over what were then submarine cliffs?"

(4.) In this part of his notes applicable to the Glen Creran district, Professor Heddle refers to what he calls "*a boulder of the peculiar porcelain porphyry* worked at Kentallen in Appin." That it is a boulder is evident from the fact of the rocks of the hill where it lies, being totally different. Its height above the sea is 2250 feet. Now, porcelain rock of the same kind occurs among the *Ben a*

Bheither hills at exactly the same height above the sea, about midway between two other hills whose names are given, 3 or 4 miles to the N.N.W.

Assuming that the boulder came from that point, it must have crossed two valleys, each of which is less than 700 feet above the sea. How it could have crossed these, except on floating ice, it is difficult to see.

(5.) There is another boulder in the same district of *Schistose Breccia* at a height of 2235 feet. The parent rock was found at some distance to the N.N.W. "This boulder (the Professor says) in like manner must have been carried across the deep valley of the Durer to have reached its present position."

(6.) A very interesting account is given of boulders in the neighbourhood of *Glencoe*. Being much rounded, they suggest a long transport, and were "of a peculiar granite," somewhat like "the well-known Ardshiel granite," only "whiter and coarser grained."

Being "altogether different from the rocks of the hill on which they were first noticed, consisting of a 'schistose breccia,' the Professor resolved to seek for the parent rock."

Thinking, from his knowledge of the rocks to the *eastward*, that they were not likely to have come from that quarter, he set out on a hunt in a westerly direction. On reaching the *Aonach-Eagach* range of hills, he recognised the same boulders on them, "fewer in number, but markedly larger in size."

He followed them up to the first summit of the hill, which was 2938 feet; and, proceeding still further west to a hill called *Meall Dearg*, he found the same boulders first at 3090 feet and eventually "almost up to the summit of the western peak at 3118 feet."

The Professor says that "their position here was most peculiar,—they lay upon a ridge not many times wider than their own bulk, and only on the eastern slopes of that ridge."

Proceeding still farther west to other hills (which are named in his notes) at from 2400 to 3200 feet, the Professor did not find either boulders, "or rock, of the same description;" but on proceeding to the next hills, of somewhat greater height, about 6 or 7 miles to the west, he found at two spots, the kind of rock he was in quest of. He however adds, that "though the rocks at these two spots were almost identical in mineral composition with that of the

boulders, I am not satisfied that they supplied the boulders,—for the spots where those rocks occur, are only from 1500 to 2300 feet above the sea,—whereas the boulders on some parts of the *Aonach Eagach*, to the eastward, were at a height of 3100 feet above the sea.

"An attempt has been made by some geologists to explain, how boulders may be transported to positions above the level of the parent rocks; and, if that theory be correct, it may help to overcome this difficulty."

"But it is a fact of considerable importance, bearing on any theory of transport, that these boulders on *Aonach-Eagach*, occupy *positions much higher in level than any of the hills in a very wide extent of country*, so that it is hardly possible to adopt for them the explanation of any local glacier."

"I have adverted" (says the Professor) "to the peculiar position of these boulders on *Meall Dearg*, where, at a height of 3100 feet, they lay upon a ridge not many times wider than their own bulk, or rather on the sides of that ridge facing the E. or N.E. I am not able at present to offer any explanations of this feature. I would like again to study the position of these boulders. They *must have been brought by ice*, which may have come from the N.W. and stuck there among the high peaks, till it melted and allowed the boulders to subside on or near the top of the ridge. My explorations about Glen Creran, led to the supposition of a flow of ice through Glen Tarbert on the N.W. side of the Linnhe Loch. This might also possibly account for the boulders on *Aonach-Eagach;* but, in that case, where could the parent rocks be?"

This query by the Professor, Where could the parent rocks of these boulders be? he leaves unanswered; and, no doubt, it is a query more easily asked than answered. It would, therefore, be presumption in me even to suggest an answer. But the query reminds me that, two years ago, I sent specimens of the Loch Creran boulders to Professor Judd of London, an eminent geologist well acquainted with the rocks of the West Highlands, to ask him, whether he knew of rocks anywhere like those of the boulders, and he gave a decided opinion that rocks of exactly the same kind existed in Mull and Ardnamurchan. Now, these places are to the west of the boulders referred to by Professor Heddle, and

it is from the west that he thinks they came. Moreover, in Mull, the hill of Benmore is 3180 feet above the sea, whilst in Ardnamurchan there are hills nearly that height. It strikes me, therefore, that it would be very desirable, if Professor Heddle could, in the course of this summer, visit Mull and Ardnamurchan to see whether he agrees with Professor Judd's surmise on this subject.

III. *Convener's Notes.*

The points brought out in these, are very unimportant, compared with those of Professor Heddle and Messrs Jolly and Wallace of Inverness.

1. The boulders in *Cantyre* I found had, on the south and east coast, come apparently from some point due north; those on the west coast, from points varying between N.W. and N.N.W.

2. In *Arran*, the boulders on the east coast, which were all that I examined, seem to have moved in a direction from about due north.

3. In the *Cumbrae* islands, they seemed also to have come from due north.

4. In *Loch Long* and the *Gairloch*, the boulders showed transport from points varying between N.N.W. and N. by E., which happens also to be about the axial line of the valleys in which the boulders lie.

5. In the hills to the north of *Loch Fyne*, I was rather surprised to see the smoothed rocks facing N. and N.E., and the boulders lying with their longer axis in much the same direction.

6. When I reached *Loch Awe*, I found the boulders among the hills, at from 900 to 1000 feet above the sea, indicating in like manner transport from the N.N.E.

This deviation, at several places in the interior of the country, from the N.W. direction which is so prevalent elsewhere, at first rather surprised me; but it probably does not on principle differ materially from the fact, that occasionally on the same rock, or on the same boulder, there are separate sets of striæ. If these striæ are produced by currents which run first in one direction and thereafter in another, a similar explanation might apply to the variations of direction over a large district of country.

For example, Professor Heddle, as we have seen, takes notice of

such variation in *Uist*, and on a larger scale among the hills at Glen Creran; and the boulders in Nairn and Morayshire have evidently been brought by currents which came from different points.

If in the North of Scotland, the normal direction of the current was to the S.E., it is probable that the deep trench of the Great Caledonian Valley running about E. by N, with a range of hills on each side 2000 feet high, would there cause a deviation in the direction of the current. As the sea subsided from one level to another, the currents would change in directions.

Examples were seen by me last year in the Lewis, of a change even on the same hill. At the top, the direction was as usual N.W., near the bottom, it was from due W. or W.S.W.

Among the hills south of Loch Awe, I found a large boulder perched on a peak of rock in a remarkably precarious position. It is shown on the diagram. By a glacier it certainly could not have been brought, there being neither hills nor valleys to form a glacier. If it came by floating ice, the ice might be arrested by the peak, and when it melted, the block which the ice carried, might remain.

7. The largest boulder which I have yet seen, was found by me on the west coast of Argyle, in Loch Killasport. Calculating by its cubical contents, it weighed about 2770 tons. This boulder, and many others of large size, were on the sea shore, and half a mile at least from any sea cliff, old or recent. I felt convinced from their situation, and also from the direction of their longer axis, that they had all come across the sea from the N.W.

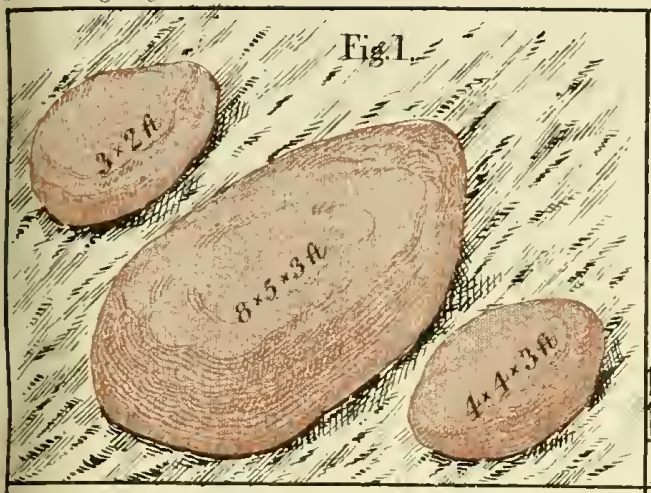
8. A short time ago, my attention was called to a boulder, $9 \times 8 \times 6$ feet, in Roxburghshire, weighing about 16 tons. On examining it, I found that it was of exactly the same rock as that which composes the Penielheugh, the hill on which the Waterloo Pillar stands. It is about a mile to the east of the hill, and has evidently been floated to its present position by ice. The hill also presents other facts of no small interest bearing on the transport of boulders. The west side of the hill has been swept bare, so that the trap rocks stand out like the bones of a skeleton with the skin and flesh off, whilst the east side of the hill is covered by soft Old Red Sandstone, as well as by sand and gravel. This place affords undoubted evidence of sea with floating ice, which stripped the hill and carried fragments to the eastward.

Whilst the view I take in regard to the transport of boulders, and the striation of rock surfaces in Scotland is, that these phenomena were in most instances due to ice in a sea, which reached to our highest mountain tops, I admit that there are traces also of land ice in the form of local glaciers. In last year's Report I pointed out what appeared to me clear evidence of glacier action in Glencoe; and Professor Heddle also recognised glacier action on the west coast near Loch Torridon. But my idea is, that these glaciers must be referred to a period antecedent to the submergence of the land, for we find those traces of glaciers in many places covered over by thick beds of gravel, sand, and clay which could only have been deposited by the sea.

David Milne Home, *Convener.*

On 21st May 1880, at a meeting of the Council of the Society, the Committee was reappointed, with the addition of General Bayley and Professor Duns, D.D.

Fig. 1.



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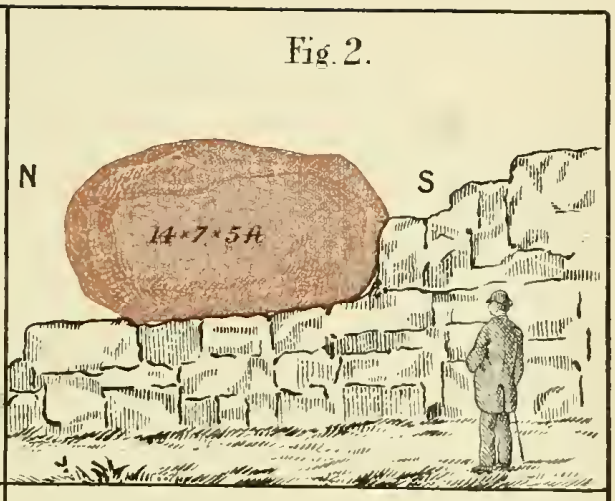

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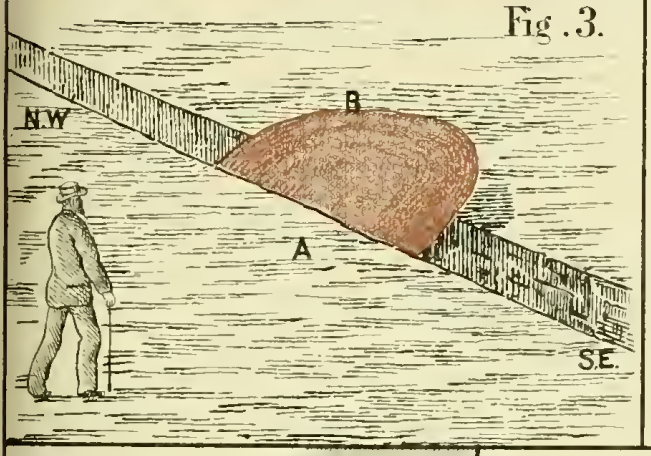

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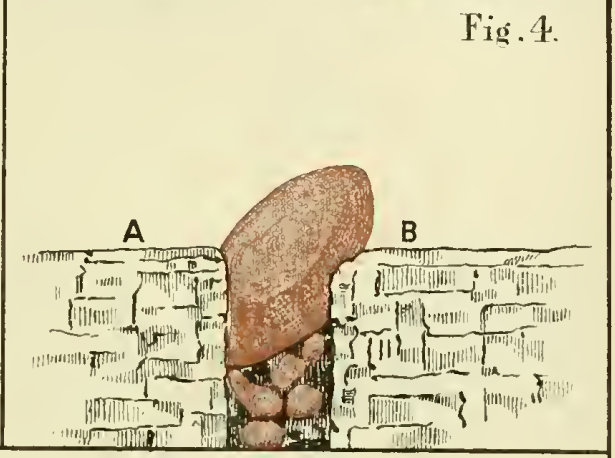

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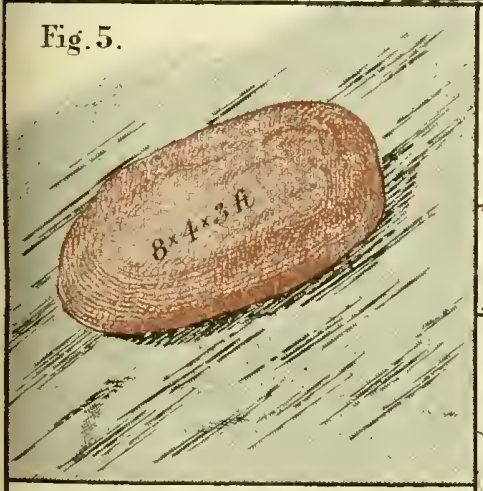

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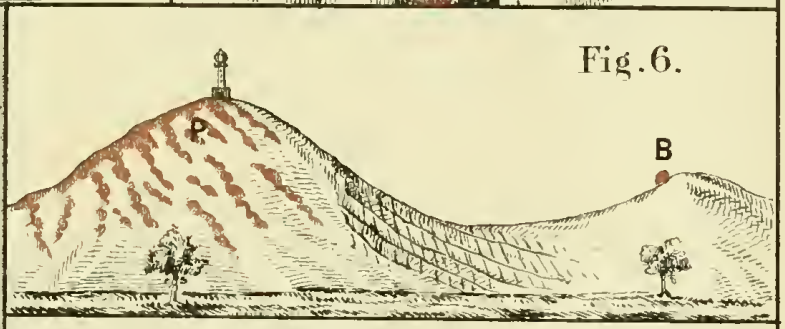

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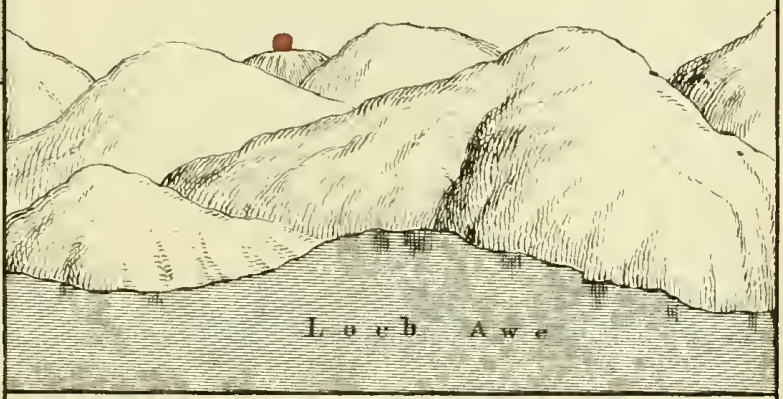

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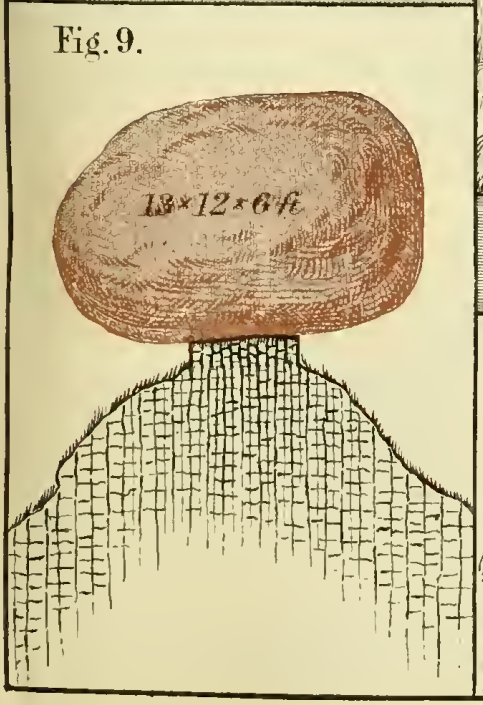

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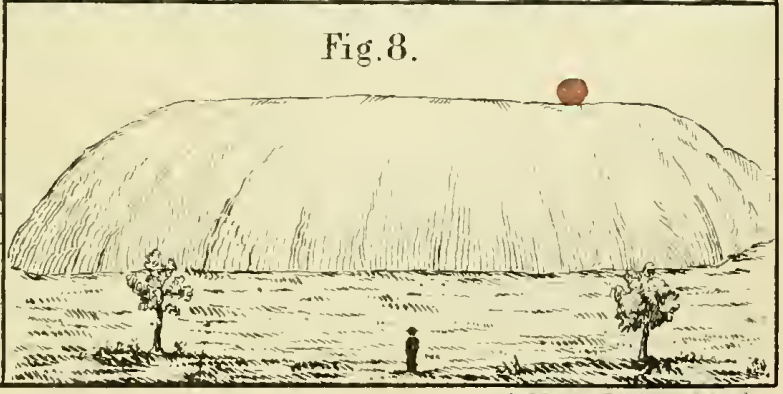

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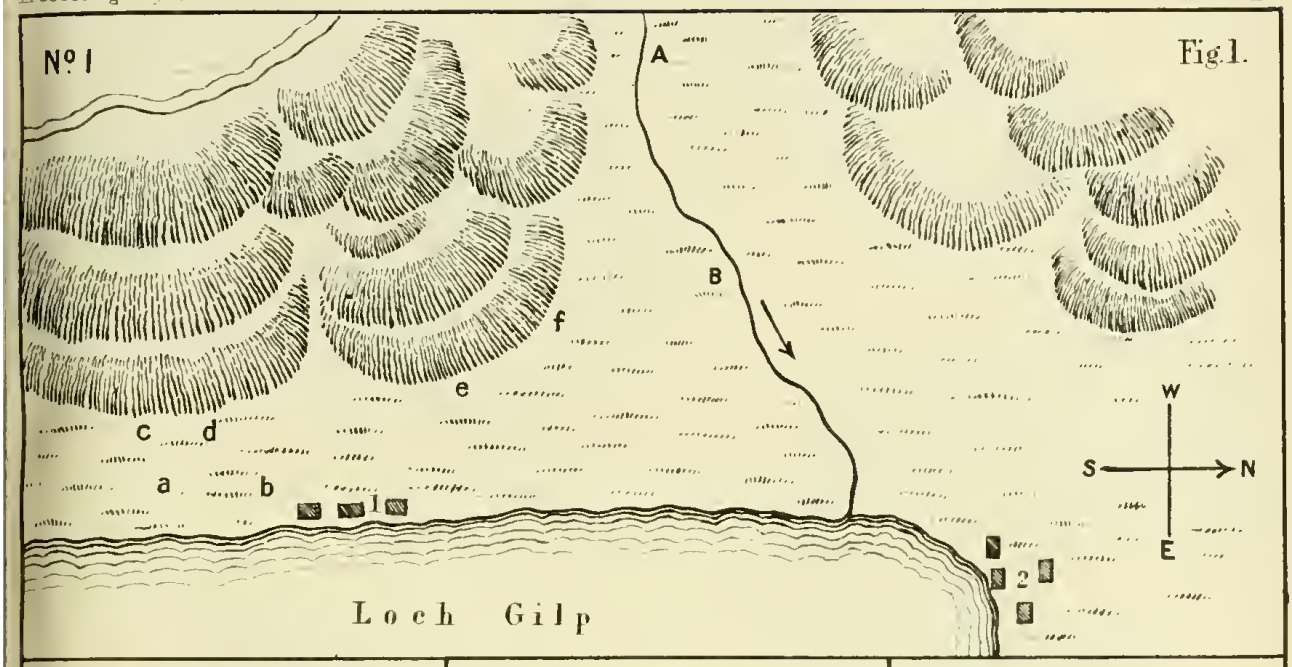

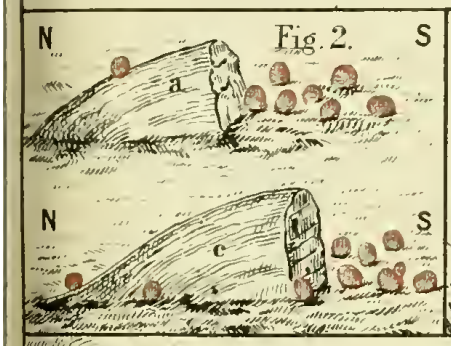

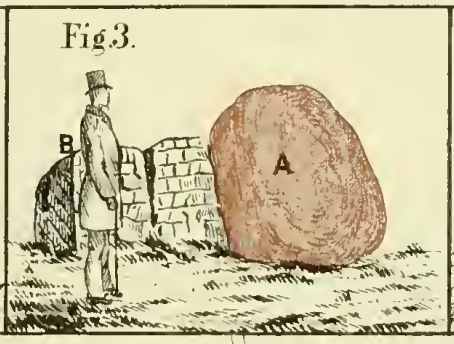

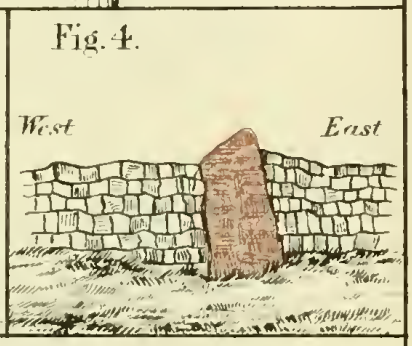

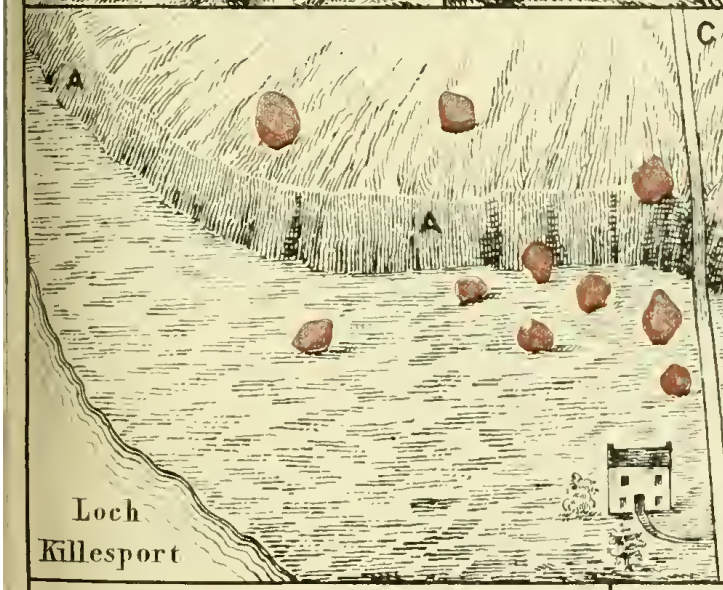

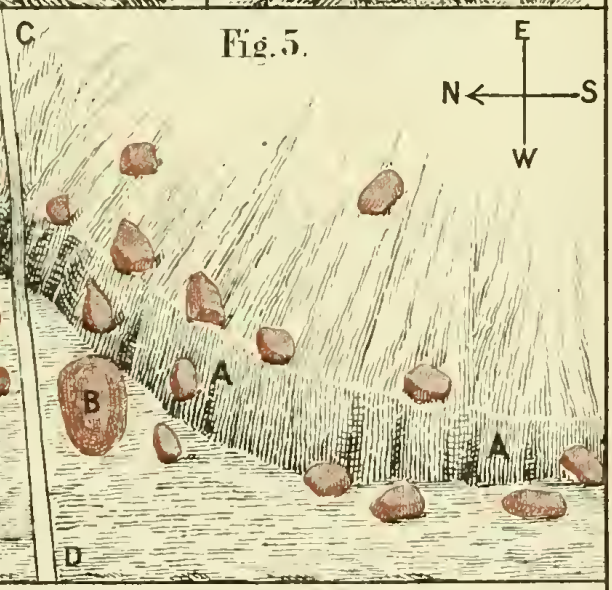

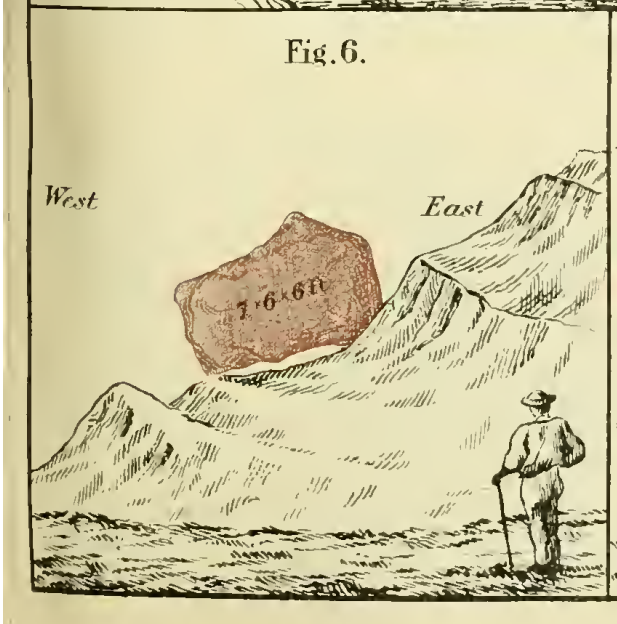

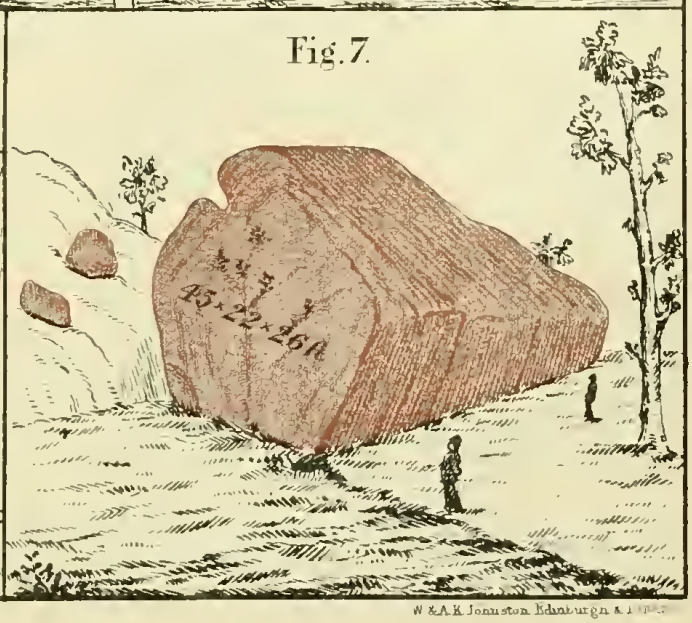

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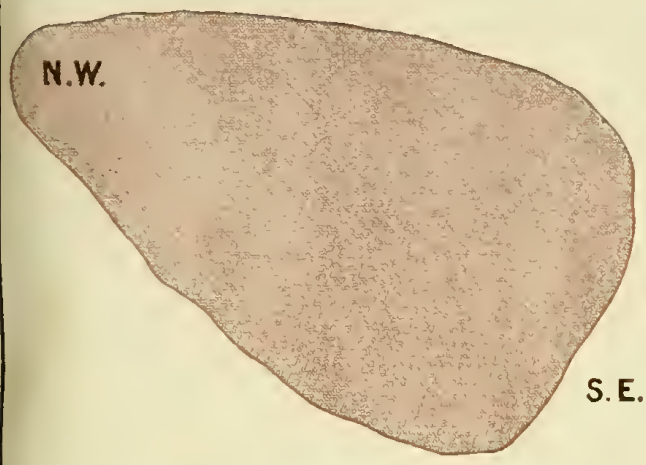

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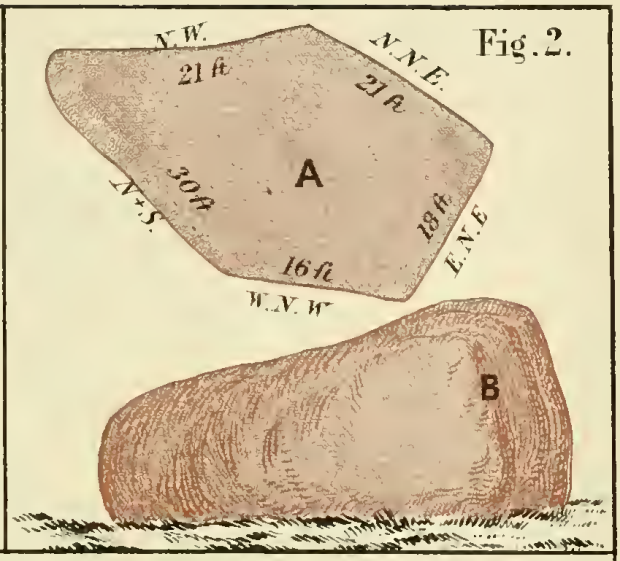

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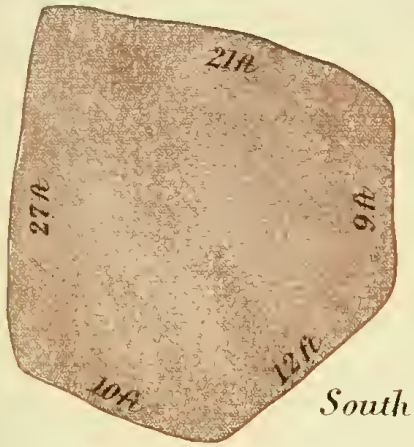
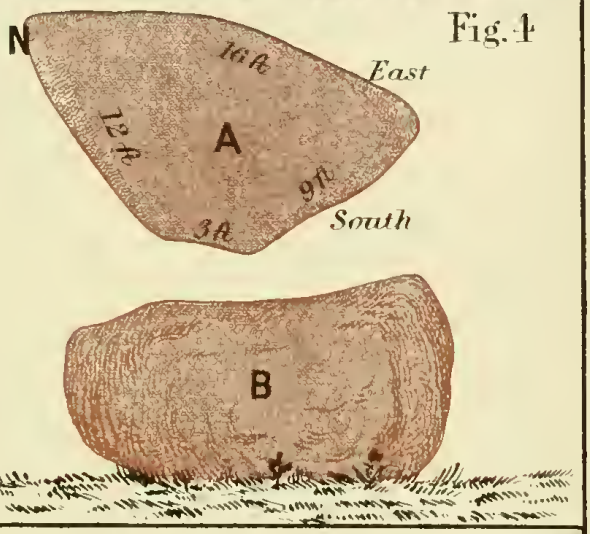


Fig.4.



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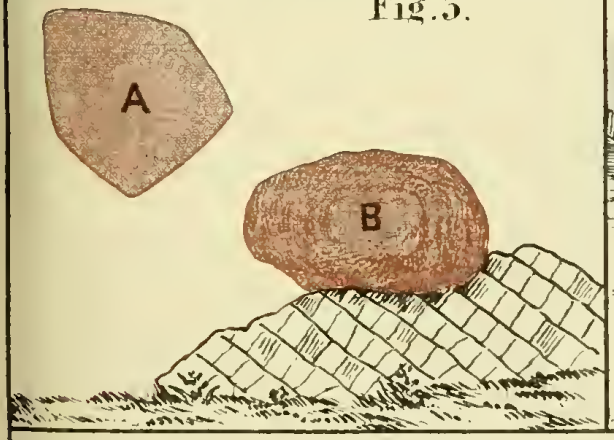

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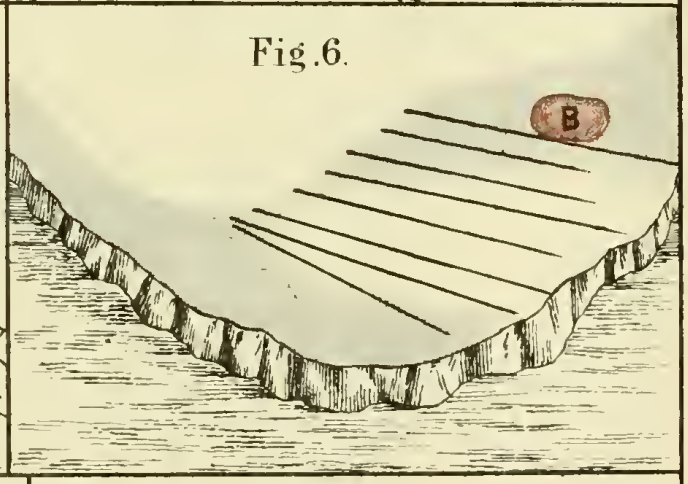

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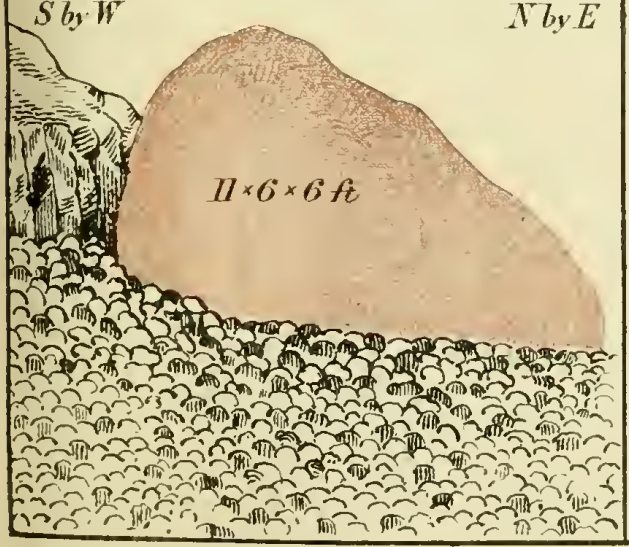

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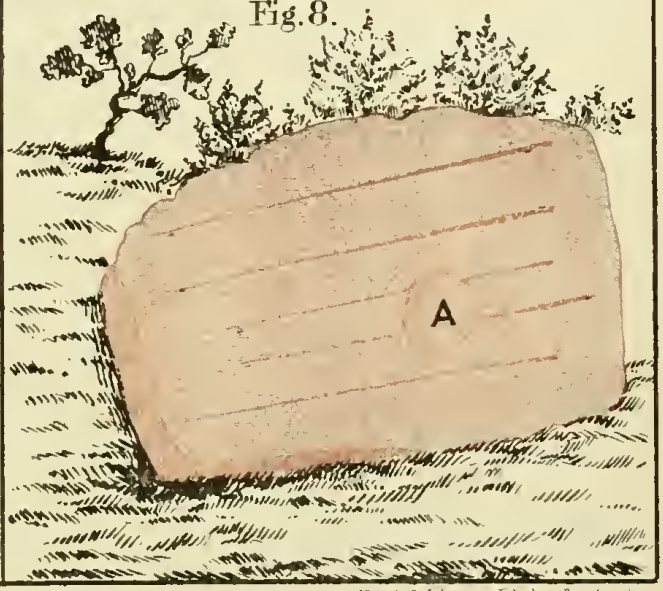

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