

although the pectoral fins were present as horizontal folds with a semicircular outer border.

It is obvious that unless the pre-anal ventral fin in the cases mentioned can be explained as a secondary arrangement of certain Teleosteans (a supposition which is not rendered more probable by the fact that the herring is a physostomous form with pelvic fins in their original position), its presence forms an obstacle to the universal application of Dohrn's theory; and a re-examination of this most interesting subject is necessary in view of the facts I have pointed out. From Dohrn's point of view the coexistence of functional intestine and median ventral fin in the same part of the body is impossible.

4. Tenth and Final Report of the Boulder Committee; with Appendix, containing an Abstract of the information in the Nine Annual Reports of the Committee; and a Summary of the principal points apparently established by the information so received. (Plates VIII. to X.)

The Committee are of opinion that it is now time to submit a final Report to the Council. Nine Annual Reports have already been presented, extending altogether to about 400 pages, as printed in the *Proceedings* of the Society. The appointment of the Committee took place in April 1871, and the first Report was presented in April 1872, by which time a considerable number of answers were received to circulars sent by the Committee, first to the parochial clergy, and next to the parochial schoolmasters, asking for information.

The Committee do not expect that, by continuing inquiries on the lines available to them, much additional information of importance would be obtained. At all events, it is now desirable to arrange the information which has been obtained, in such a way as to make it more readily accessible—as, for example, to show, in what districts the most interesting Boulders are situated, and also to indicate the conclusions which the positions of the Boulders, or any markings on them, suggest.

Before, however, explaining the means which the Committee have agreed to adopt for classifying the information obtained, the Committee think it right to record, in a few sentences, the circumstances which led to the appointment of the Committee.

The subject of the transportation across the country of masses of rock by some natural agency, has from a very early period been discussed in the Royal Society of Edinburgh. In the year 1812, Sir James Hall, the Society's President, was the first to break ground, by reading a valuable Memoir, afterwards published in the Society's *Transactions*. The subject was from time to time again brought before the Society by different Fellows,—whose names merely may be mentioned,—viz., Principal James Forbes, Professor Fleming, Professor Nicol, Mr James Smith of Jordanhill, Mr Charles Maclare, Mr Robert Chambers, Rev. Thomas Brown, and Mr Milne Home. The facts brought forward in this way, of course, were only such as happened to have been noticed in particular districts by individual observers. But as it was known that the distribution of Boulders was universal over Scotland, not only on the Mainland, but on the Islands of the Hebrides, Orkneys, and Shetland, it was felt, in order to pave the way for a complete discussion, that inquiries of a more comprehensive character were desirable.

In the year 1870, Mr Milne Home received a communication from Professor Favre of Geneva, stating that an inquiry of this character had, with the co-operation of the Swiss Geological Society, been commenced in Switzerland; that the Geological Society of France had resolved to follow the example; and he expressed a hope that Mr Milne Home, who he heard had taken some interest in the Boulder question, would endeavour to institute a similar inquiry for Scotland.

Mr Milne Home submitted this correspondence to the late Sir Robert Christison, and he having expressed approval of Professor Favre's suggestions, Mr Milne Home read a paper in the Society, embracing his correspondence with the Swiss Professor, and suggesting the appointment of a Committee, with power to make the requisite inquiries. Such a committee was shortly thereafter (April 1871), on the motion of Sir Robert Christison, appointed by the Society's Council.

Altogether about 1500 circulars were issued by the Committee; answers to a considerable number of which were, in the course of the

following year, received. About one half of these answers supplied information, which gave materials for the two first Reports. Most of these answers were useful also, by indicating the localities of remarkable Boulders, and thus enabling members of the Committee to visit them.

In recording the information from time to time obtained, the Committee could do no more in preparing the Annual Reports than mention the particular county where the Boulder was reported to be situated. The consequence is, if any one wishes to discover what or where are the Boulders, described as occurring in any particular county, he must hunt through the whole nine Annual Reports to obtain this knowledge.

In order to remove this inconvenience, the Committee have framed a compendium or abstract of the whole information in these Reports, so as to represent for each county, in alphabetical order, what is said in them regarding Boulders. This abstract will be found in Appendix I.

In addition to a geographical arrangement of the information contained in the Annual Reports, it occurred to some members of the Committee, that it would be useful to have a Summary of the most material facts found in the Reports, and of the inferences which these facts suggest, in so far as they seem to throw light on the question, by what agency Boulders could have been transported. Such a Summary has been undertaken by the Convener, and it forms Appendix No. II. This Summary consists almost entirely of the facts set forth in the Annual Reports and in Appendix I.; but the inferences from these facts involve opinions in which all persons may not agree. Therefore the Committee do not commit themselves either to the adoption or to the rejection of these opinions, though they quite allow that they are valuable as indicating points worthy of consideration.

The Committee, whilst aware that their business was to investigate the subject of Scotch Boulders, have not deemed it any departure from the objects of their appointment to advert to well authenticated cases of Boulders situated in English counties, which have been on good grounds traced to parent rocks in the south of Scotland (*Abstract*, pp. 796, 797, 838, and 852).

The bearing of this discovery on the direction of Boulder

transport, both in England and in Scotland, is very obvious, and will no doubt be noticed in the forthcoming General and Final Report of the British Association Boulder Committee.

It may here be right to remark, that the appointment of the English Boulder Committee, which took place at the Meeting of the British Association at Edinburgh in August 1871, was at the instance of Professor Archibald Geikie, who, in advocating the appointment, remarked on the importance of extending to England and Ireland the inquiry, which had already commenced in Scotland.

The Convener learns from the Rev. Mr Crosskey, Chairman of the English Boulder Committee, that his Committee intend soon to frame an Abstract of their nine Annual Reports.

These Final Reports, embracing the most interesting discoveries on this subject in England and Scotland respectively, may, it is hoped, throw new light on a subject of much geological interest.

DAVID MILNE HOME, *Convener.*

EDINBURGH, 24th June 1884.

## APPENDIX I.

*Abstract of Information in the Nine Annual Reports of the Committee.*

## ABERDEENSHIRE.

*Aberdeen, Town of.*—In excavating for foundation of house in Union Street, a boulder of syenitic granite, with hornblende crystals, found  $6 \times 5 \times 4$  feet, weighing about  $2\frac{1}{2}$  tons. The under surface of boulder covered with ruts, all parallel with longer axis, some of them 3 feet long. Longer axis pointed E. and W. No rock like that of boulder nearer than Belhelvie, 10 miles to north, or Huntly, 40 miles to N.W., or Ballater, about 40 miles W.S.W. Dr Cruickshank having, in July 1870, got notice of the boulder, made it known to late Professor Nicol, who caused it to be split, and the striated part set up in court of Marischall College (*First Report*, p. 21, and letter to Convener from Dr Cruickshank).

A syenite boulder  $5 \times 3 \times 1\frac{1}{2}$  feet, with strike parallel to longer axis, built into a wall in *King Street Road*.

In Aberdeen newspaper of November 1881, account given of granite boulder, weighing about 8 tons, at the east end of *Urquhart Road*, found in excavating a bed of sand.

Mounds and ridges of shingle and gravel, all water rolled, abound north of Aberdeen, near shore. Large boulders of trap, granite, and gneiss rest on top and surfaces of these ridges.

*Foveran.*—In a field on Drums Farm, a huge granite boulder, called “*The Grey Stone*,” measuring 54 feet in circumference, with a height of 7 feet above ground. Another block, also apparently a transported mass, measures 78 feet in circumference, and projects 6 feet out of ground. A little to the north of Drums, on one of these gravel ridges, lies a boulder,  $8 \times 5$  feet. A layer of red clay about 9 inches thick, overlies the gravel. Boulder rests on gravel, but *clay over the gravel encircles its base* (*Seventh Report*, p. 39).

*Ballater.*—Morven Hill, 2963 feet above sea, is situated a few miles north of Ballater. It stands many miles apart from any hill

of like elevation. Boulders of granite, quartzose gneiss, and laminated quartz lie on western brow of mountain and up to summit. No granite rocks occur *in situ* in Morven. Rocks there consist of greenish hornblende and white felspar (*Seventh Report*, p. 40).

*Belhelvie*.—Sienitic boulder about 8 feet in diameter, called “*Kepple Stone*,” near public school. Rocks *in situ*, near boulder, are granite (*First Report*, p. 21).

*Bourtie*.—Several greenstone boulders (supposed to be Druidical)—called “*Altar Stone*,” weighing 18 tons; “*Bell Stane*,” weighing about 20 tons; “*Wallace’s Putting Stone*,” 24 feet in girth; and other two, called “*Piper’s Stone*” and “*Maiden Stone*.”

*Boddam*.—Near the Bullers of Buchan stands the *Hare* or *Cleft Stone*, a granite boulder  $9 \times 8$  feet, which marks boundary between parishes of Cruden and Peterhead.

Another granite boulder, in a ravine,  $14 \times 8 \times 5$  feet; another  $18 \times 12 \times 5\frac{1}{2}$  feet; another  $13 \times 9 \times 5$  feet. Along the south side of Peterhead Bay, and as far as Buchan Ness, the shore strewed with blocks of granite, gneiss, trap, and sandstone; many of them composed of rocks not found nearer than 20 or 30 miles (*First Report*, p. 23, and *Second Report*, p. 20).

In Boddam Dean, a granite boulder called “*The Hanging Stone*,” 37 feet in girth and 27 feet over it. Half a mile east, another of 20 tons. Huge granite boulder, called the “*Grey Stone of Ardendraught*,” was broken up in the year 1779 to build walls of a new parish church. It was the stone on which “*All Hallow fires*” used to be lighted (*First Report*, p. 2).

*Braemar*.—There is a hill close to village named “*Cairn-a-Drochit*,” reaching an elevation of 2700 feet. Near the top of the hill, viz., about 70 yards to the north, lies a block of coarse granite 12 feet long, with many other boulders of the same kind. The rocks of the upper part of the hill consist not of granite, but of quartzose gneiss. Opinion expressed by Mr Jamieson of Ellon, that the large block, and many of the others near it, came from mountains to the north, the granite of which is identical with that of the boulders. In letter to Convener, Mr Jamieson mentions that, near shooting lodge on this hill, there is a cluster of four or five immense granite boulders touching one another (*First Report*, p. 22, and *Seventh Report*, p. 41).

*Ben Uarn More* forms the culminating peak of the great ridge

that divides the shires of Aberdeen and Perth, reaching to a height of 3587 feet. Mr Jamieson found blocks of a peculiar porphyry on the northern slope of the hill, near the top; but no such rock exists there *in situ*. The rock of the hill is quartz (*Ibid.*).

*Chapel Garioch*.—Boulder  $19 \times 15\frac{1}{2} \times 11\frac{1}{2}$  feet, weighing about 250 tons. Longer axis E. and W. The boulder differs in composition from rocks adjoining. It rests on *drift*. Legend, that thrown by Devil, from Bennachie Hill, which is situated to N.W. (*First Report*, p. 22).

*Culsalmond*.—Boulder of blue gneiss,  $6\frac{1}{2}$  feet high  $\times 5\frac{1}{2}$  feet in girth, known to archæologists as the “*Newton Stone*,”\* having on it Ogham and other very antique inscriptions (*First Report*, p. 24).

*Kemnay*.—Seven large boulders of gneiss, whilst rocks adjoining are granite. The largest weighs about 380 tons. Most of them lie on hill-sides facing W. and N.W. The gneiss hills of Bennachie and Cairnwilliam from which these boulders are supposed to have come, are situated towards W.N.W. and N.W., distant 6 or 8 miles. The valley of Don is between these hills and the boulders.

On Quarry Hill, situated not far from these boulders to north, rock striations show movement from west (*First Report*, p. 24, and *Second Report*, p. 148).

To the S.E. of the above boulders, another bluish-grey granite boulder called “*Soutar’s Stone*,” weighing about 270 tons. Height above sea about 500 feet. Lies in muddy sediment, on a hill-side facing N.W. A hill, running N. and S. for 500 yards, lies to N.W., about a quarter of a mile distant, and with ridge about 100 feet above boulder. If boulder came from N.W., it must have been carried across top of this hill (which is very improbable), or else have come round one end, and have been carried by an eddy into its present position (*Second Report*, p. 148).

Striations on rocks here show movement from W.

*New Deer*.—Many boulders from 1 cwt. to several tons in weight lie in a sort of line for more than a mile south from farm of Green of Savoch, as far as to the hill of Coldwells and Toddlehills in

\* For speculations regarding the inscriptions, see *Trans. Soc. of Scottish Antiquaries*, for years 1862 and 1882. Mentioned in last paper, that another gneiss boulder of much same size stands near, with figure of a serpent on it, barred with the Z-shaped sceptre symbol.

Added that Culsalmond parish abounds with relics of paganism.

Ellon parish. In this parish formerly, a rocking stone called “*The Muckle Stane of Auchmaliddie.*” A (so called) Druidical block formerly on Culsh Hill (Pratt’s Account of Buchan, 1858). On Whitestone, Ellon, and Dudwick Hills, chalk flints found abundantly (*First Report*, p. 25).

*Towie.*—Block of unhewn granite, reaching a height of 7 feet above the ground, on north side of river Don, near bridge. Supposed to be Druidical (*First Report*, p. 25).

*Cruden.*—Granite boulder measuring 37 feet in girth and 27 feet over it, supposed to be Druidical. Another weighs 20 tons. Another huge granite boulder, on which said, that “*All Hallow Fires*” used to be lighted (*First Report*, p. 22).

*Ellon.*—Several boulders, one  $22 \times 9\frac{1}{2} \times 8\frac{1}{2}$  feet, and another still larger, which have come from W. or W.N.W. (*First Report*, p. 24).

*Glass.*—Several large boulders differing from adjoining rocks, more than 1000 feet above sea.

1. Notes by Mr T. F. Jamieson, Ellon (from *Quarterly Journal of London Geological Society*, 7th Feb. 1866):—

(1) On coast, south of Fraserburgh, there are several localities where the rocks are smoothed and striated in such a way as to show a movement over them from  $40^{\circ}$  N. to  $60^{\circ}$  W.

(2) In the neighbourhood of Peterhead (at Invernettie Brick-work), many boulders of red and grey sandstone, and also of a tough greenish coloured stone, all which resemble rocks that occur in Caithness, but not in the adjoining parts of Aberdeenshire (*First Report*, p. 29).

(3) At *King-Edward*, “there are deep masses of unstratified pebbly mud of a dark grey colour, very hard and firm, containing stones (some of which are ice-worn and striated), and fragments of shells, which are likewise occasionally *scratched*. It is like the Caithness drift in every respect.”—“Besides this coarse stony mud, there are some beds of fine stratified sand, which often contain remains of shells in considerable abundance, most of them broken, but many of them entire.”—“There is another bed of fine dark grey silt, free from stones, containing arctic shells entire, and apparently *in situ*, with the epidermis on.” The *Tellina calcaria* occurs here of large size, with both valves connected by the ligament and shut.

## ARGYLESHERE.

*Kintyre*.—(1) At Southend, and also along east coast, south of Campbelton, the Convener saw and examined a number of boulders of a whitish-grey colour, which the schoolmaster considered to be granites, adding, that he knew of no rocks of that nature in Kintyre.

The Convener found pebbles of same rock in gravel pits at Campbelton, and was there informed that rock of same nature occurs to the north of Campbelton. Professor Nicol of Aberdeen, when he visited Kintyre, saw these boulders, and thought they had been transported from Arran, where there is rock of the same kind; in which case, they must have travelled 25 miles across the deep hollow of Kilbrennan Sound in a direction from N.E. (*Quarterly Journal of London Geological Society*, vol. viii. p. 422).

About a mile to east of Campbelton, smoothed rocks occur, dipping or sloping N.N.W.—as if smoothing agent had come from that quarter (*Sixth Report*, p. 5).

(2) Near *Kilhenzie*, a few miles west of Campbelton, a hill reaching to a height of from 500 to 600 feet, is covered with drift, and (on its western slopes) with gneiss and mica slate boulders, several weighing above 150 tons.

Old Red Sandstone rock on west coast, covered with drift; and on the drift, boulders of granite and gneiss. Diagram given in *Sixth Report*, representing these on a bank sloping down N.N.W. towards sea, at angle of 25°.

A boulder of gneiss found lying on mica schist strata, blocked at south end; its longer axis lying N. by E. and S. by W. Boulder said to have come from north (*Lithograph No. 1, Plate VIII.*).

In a fissure of the mica slate strata on the sea-shore of west coast near Tangy Burn (the fissure running N.W. and S.E.), a boulder of hard gneiss, weighing about 15 tons, has fallen into the fissure. It presses on S.W. wall of fissure, showing that the boulder had probably come from some N. or N.E. point. Fissure about 6 feet wide.

A chip of one of the granite boulders found on west coast, having been submitted to Professor Heddle, he said that it was a peculiar variety, well known in the Mourne Mountains in the N.E. of Ireland, on account of there being frequently in it crystals of topaz. In the chip from Kintyre, sent to him by Convener, the Professor found two topaz crystals.

*Loch Long.*—On ridge (about 350 feet above sea), between this Loch and Gareloch, there are several boulders of mica slate. Largest  $11 \times 6 \times 6$  feet. The rocks *in situ* are clay slate. Longer axis in most is N. by E., parallel with Loch Long valley. Two of boulders blocked at south ends.

In the Gareloch, on east beach, a little below Shandon, a gneiss boulder  $18 \times 15 \times 12$  feet (240 tons), with sharp end pointing N.W. At that end, surface is smooth—at south end, surface is rough.

In *Third Boulder Report* (p. 5), reference made to an account of the grey granite boulders seen by the late Charles Maclaren, amounting in number to several hundreds, one weighing 30 tons. Mr Maclaren inferred that these had all come from N.N.W. The opinion of Dr Robert Chambers and Sir Roderick I. Murchison also referred to.

On east side of the loch, opposite to Ardentinny, gneiss boulder called “*Jenny Meullens*,” weighing about 380 tons, lying jammed in a gorge formed by rocky banks of a rivulet (*Lithograph No. 2, Plate VIII.*). Seemed from position to have come from north (*Third Boulder Report*, p. 1).

Another gneiss boulder  $12 \times 8 \times 8$  feet, with longer axis N.W. by N. Striae on rocks adjoining run N.  $2^\circ$  or  $3^\circ$  W. The smoothed surfaces of rocks dip towards north.

On *Loch Goil*, above Carrick Castle, gneiss boulder called “*Clach Udalain*” (*i.e.*, “*Stone unstable*”), at height of 1526 feet above sea, lying on clay slate (about 300 tons) (*Lithograph No. 3, Plate VIII.*) (*Third Report*, p. 2).

*Loch Goil and Loch Long*, junction of.—“*Giant Putting Stone*,” resting on smoothed rock 450 feet above sea. Rocks smoothed only on north aspects (*Lithograph No. 4, Plate VIII.*).

*Knap Farm*.—Several boulders lying on similarly smoothed rocks (*Lithograph No. 5, Plate VIII.*).

*Glen Finnart*.—Gneiss boulder about 7 feet high, 824 feet above sea, called “*Pulag*,”—butted against a rock at its south end. Reasons given why this boulder and others of smaller size appear to have come from north.

*Firth of Clyde*.—At Dunoon, Kirn, Innellan, Toward Lighthouse, and Loch Striven, there are numerous boulders, many of large size on and near the shore, some of them with local names and legends.

They differ from adjoining rocks.

On east side of Firth, near *Gourock*, immense numbers of blocks, on or near the shore, belonging to rocks situated to the N.W. in the districts about Loch Goil, Loch Eck, Loch Fyne, and Inveraray.—("Among the rocks around Glasgow," 1881, by Dugald Bell, p. 152.)

Near Loch Glashan (400 feet above sea) smoothed and striated rocks, dipping down N.N.E. covered with boulders, apparently brought from N.E. where an opening among hills, towards Loch Awe (*Sixth Report*, p. 9) (*Lithograph No. 6, Plate VIII.*).

*East Loch Tarbert*.—About 2 miles N.W. of the town, a conical hill, whose top is 710 feet above sea, well clustered with boulders, as shown on annexed woodcut. Very summit of hill has one remark-



Boulders on Hill, East Tarbert, Kintyre.

able boulder on it, 8 feet high and 5 feet each way in width. The boulders are all *gneiss*, whilst rock of hill is *clay-slate*.

This hill separated from adjoining hills, which form a sort of amphitheatre round it, at a distance of about a mile.

The boulder has the fanciful gaelic name of *Capel Cloiche*, meaning *Stone Mare*.

Between the above-mentioned hill and the village of Tarbert, on south side of road, there is a lower hill, also conical, having two large boulders on its N.W. slope. Convener did not reach them to examine them.

On hills adjoining East Tarbert village on the south, at from 280 to 300 feet above sea, there are marks of some violent agent having

swept through the valley (now a sea loch) from westward (*Eighth Report*, pp. 4, 5).

On one of hills on north side of sea loch, and sloping down towards loch, a boulder found at height of 400 feet above sea. Boulder  $7 \times 5 \times 3\frac{1}{2}$ . Boulder apparently brought from S. or S.W. (*Ninth Report*, p. 3).

*Crinan Valley*.—Summit level between Loch Fyne and Crinan Bay, about 150 feet above sea.

At summit level, a ridge of rocks which present smoothed surfaces on *north*, but rough surfaces on *south* side of ridge. On both sides of ridge there are boulders, but ten times more on *north* than on *south* side.

Boulders are a syenitic gneiss, the rocks *in situ* a shivery clay slate; dipping steeply towards south.

Three or four boulders are butted or squeezed up against ridge on north side, apparently obstructed by ridge in their further progress southwards (*Seventh Report*, p. 4).

*Ardchattan*.—Granite boulder  $14 \times 12 \times 6$  feet. One rut on its top running whole length. Height above sea 57 feet. Nearest rock of same nature is on Ben Breac, 3 miles eastward. Near boulder, a ridge of sand and gravel running  $1\frac{1}{2}$  miles (*Reporter*, Captain White, R.E.).\*

*Loch Fyne*.—Near *Loch Gair*, a boulder  $23 \times 17 \times 12$  feet of coarse gneiss (286 tons), lying on a knoll of gravel in an amphitheatre surrounded by hills. Its longer axis N.N.E. and S.S.W.

*Inveraray*.—Boulder of porphyry, pointed out to Convener by Duke of Argyll, at height of 1000 feet above sea.

Boulder of coarse Conglomerate in same district, from 700 to 800 feet above sea, which probably came from westward, where rocks of Conglomerate are situated (*Fourth Report*, p. 10).

On summit of range of hills separating *Loch Fyne* and *Loch Awe*, about 1800 feet above sea, the rocks present a well-rounded and

\* Whilst these sheets are being printed, the Convener has had the pleasure of receiving a communication from W. Anderson Smith of Ledaig (Argyleshire), enclosing for perusal and inspection a Memoir by him entitled "*Benderloch Boulders, along with fifteen sheets of Illustrations*." Benderloch is the name of the district in Argyleshire situated between Lochs Etive and Creran, and in which the highest point is Ben Breac, 2338 feet. Mr Anderson Smith, in his letter accompanying the Memoir, mentioned that as it is intended to be read during the present session of the Glasgow Geological Society, he wishes it returned after the Convener has perused it, unless he wishes to bring it before

smooth surface. Direction of abrading forces there is from N.N.E. Remarked that, "in this case, glacier action impossible ;" and that apparently the peak had been a rocky islet, on which floating ice-bergs drifted.

"On some of the lower ridges, towards Loch Fyne, there are remarkable examples of large blocks of granite perched upon the very summits, in positions which it is impossible to suppose them to have attained, by any other means than by transportation upon ice" (Duke of Argyll, *Proceedings of Royal Society of Edinburgh*, vol. iii. p. 457).

*Loch Awe*.—(1) About a mile south of Port Sonnachan, a perched boulder of compact gneiss,  $13 \times 12 \times 6$  feet, stands on a narrow ridge of soft mica schist, in a peculiarly precarious position. Its longer axis N. and S. Its height above sea 1026 feet. Sides of hill to the ridge, so steep, that Convener could with great difficulty climb up to the ridge. There being no higher hills near, supposed that boulder could have come only by floating ice, and from north, where there is the greatest opening (*Lithograph No. 7*, Plate VIII. (*Sixth Report*, p. 8).

(2) On hills to eastward, about 900 feet above sea, the slopes facing north are well covered by boulders. The largest,  $18 \times 10 \times 10$  feet (130 tons), has its longer axis lying N. and S. (*Sixth Report*, p. 10).

*Brander, Pass of*.—On its east side two terraces, at 68 and his colleagues of the Boulder Committee, and that the Convener is free to refer to the paper in any way.

The Convener thinks very highly of Mr Anderson Smith's paper, and especially of the illustrations. But he does not feel justified in detaining it, as the meetings of the Glasgow Geological Society for the present session will probably soon terminate. The great value of Mr Anderson Smith's illustrations may be judged of even from the mere titles of a few of them.

(1) *Granite Boulder* (12 to 15 tons), a few feet from the top on northern face of a hill over Loch Creran; greatest diameter 10 feet N.W. and S.E.; smallest end N.W.

(2) *Boulder on Table land*, below the above (10 tons); N.W. and S.E.; smallest end N.W.

(3) *Black Granite Boulder* (10 tons); greatest diameter 8 feet, lying N.W. and S.E.; smallest end N.W.

(4) *Grey Granite Boulder*, over Barcaldine Gardens, 400 feet above sea,  $19 \times 12 \times 7$  feet; longest axis N.W. and S.E.

(5) *Grey Granite Boulder*, 300 feet above sea;  $13 \times 7 \times 5$  feet; longest diameter N. and S.

(6) *Ardchattan Boulder* (mentioned in this Committee's Report) is in one of the illustrations represented as partly buried in moss, and weighing about 50 tons.

120 feet respectively, above Loch Awe, with several boulders on each (*Fourth Report*, p. 9).

(3) Remarks of a general nature (p. 11) applicable to boulders at Dalmally and Tyndrum.

(4) Boulder  $24 \times 11 \times 7$  feet (136 tons), resting on a gravel knol on south bank of Loch Awe, at Kaim (west of Port Sonnachan). Boulder in a meadow surrounded by steep hills on all sides but one, viz., the West (*Sixth Report*, p. 11).

Between Port Sonnachan and Kaim, rocks smoothed and striated, seen on road side.

On the island of *Innisdraiodhnich* (Druid's Isle), in Loch Awe, a large boulder was reported to Convener by Mr Muir, the proprietor, but Convener was unable to visit the island (see notice in vol. vii. p. 226, of *Transactions of Society of Scotch Antiquaries*).

*Ardrishaig*—on Loch Gilp, a branch of Loch Fyne. On hills above town, boulders and striated rocks, suggesting transport from north; and in one case, transport through a lateral valley from N.W. (*Sixth Report*, p. 12).

On Auchendarroch lands, two large boulders seen, with N. and S. axis, lying on a hill slope facing S.E., at a height of 300 feet above the sea.

Ascending to a higher level, where hill slope faces N.N.E., several boulders found, of sizes not so great as the above.

All these appeared to have come from northern points.

*Ach-na-briach* (Field of Spots), near Loch Gilphead, visited to see sculptured cup or ring markings on smoothed rocks.

Rock surfaces evidently smoothed by natural agency. They are in different parts of field. All slope down at angle of  $10^\circ$  or  $12^\circ$  towards S.W.

One small boulder seen on west side of rocks, as if intercepted by rock in its progress eastwards. Difficult to say how or from what direction smoothings effected. May have been by heavy mantle of ice, sliding over rocks from hills to N.E.

The concentric ruts are numerous, and of various diameters and depths, some even 2 feet across. The straight rut issuing from centre and across circular ruts, generally, though not always, follows downwards slope of rock (*Ninth Report*, p. 10).

*Loch Killesport*.—A little to west of Ormsary House, on the

106 and 300 tons. Two have longer axis pointing N.W., the other with sharpest end pointing W.S.W.

About a quarter of a mile east of Ormsary House, a boulder, from which part at west end broken off. Before being broken, size was  $52 \times 36 \times 20$  feet, containing about 2770 tons;\* lying on drift at the foot of old sea-bank, whose base is about 40 feet above sea-level.

In this part of coast an immense number of other boulders of different weights up to 400 tons, some touching or lying on others. They are mostly on slopes facing westward (*Lithograph No. 8, Plate VIII.*) (*Sixth Report*, p. 14, and *Ninth Report*, p. 4).

Valley of *Auchloss*, about 2 miles to east, shows smoothed rocks. The direction of valley is E. and W.; the direction of striae W. by N.

In *Baronlongart Valley*, running E. and W. between Ormsary and Achloss, rocks ground down and smoothed, evidently from westward. A few boulders in valley.

(5) *Clach Briach Hill* (Stone Spotted Hill), about 400 feet above sea, well covered by boulders; many very large. Some so placed as to show they had probably come from N.W. Rounded on N.W. and rough on S.E. ends. Apparently all of same description of rock as "*Big Boulder*" before mentioned, a compact fine-grained gneiss. Rocks of hill, a soft schist, and on edge (*Diagrams in Ninth Report*, p. 4).

Fragments broken off S.E. ends of several large boulders, by some natural agency.

Two large boulders,  $17 \times 8 \times 8$  feet and  $18 \times 10 \times 10$ , touching one another in such a way as to show that the last which came probably came from N.W.

*Loch Sweyn*—an arm of sea 10 miles west of Lochgilphead.

(1) At Keill, on north side of Loch, at mouth, several granite and gneiss boulders lie on the shore, and on slopes facing Jura Island. Rocks *in situ*, are dark coloured Silurian.

(2) In Carig Bay, near Lochgilphead, in north Knapdale parish, a boulder is on a hill slope facing N.W. and Jura Island.

(3) At Loch Mhurrich, a boulder  $36 \times 15 \times 13$  feet (520 tons), resting on a knoll of drift, in a meadow, surrounded by low hills;

\* This boulder, first made known to Convener by Mr Campbell of Islay, who stated that it is the largest boulder he had seen or heard of in Scotland.

which are also well coated with boulders. Its longer axis, W.S.W. Its west end, 5 feet thick vertically; its east end, 12 feet thick vertically, must have come from westward, by an opening in the hills in that direction (*Sixth Report*, p. 16, and *Ninth Report*, p. 7).

(4) Numerous small lateral valleys opening on Loch Sweyn, the sides of which coated with boulders, these sides sloping down chiefly towards and facing W.N.W.

(5) *Kilmory Bay*.—Rocks smoothed and striated, with large boulders lying close at hand—their longer axis generally W.S.W. (*Seventh Report*, p. 10, and *Ninth Report*, p. 9).

The smoothed rock surfaces here dip down towards S. by E., South, S.S.E., and S.E. Where the rock slopes down S.E., the surface is not striated, only smoothed. The rock has been most severely striated on its surface sloping down S. and S. by E. Some of the striae more deeply cut at one end than at the other, viz., at their west ends, where some as much as 3 inches wide. The striating agent had therefore moved from W. by S., or from due West.

Portions of the smoothed surface were broken into small cup-shaped hollows, containing hard pebbles firmly compacted,—probably samples of the tools which effected the striations (see *Ninth Report*, p. 9, and *Lithograph No. 11*; Plate VIII.).

The hill to the east consists of a ridge running about E. and W., and rising to a height of about 600 feet. Its north flank slopes steeply down towards Loch Sweyn, and is covered by boulders in immense numbers, and some of great size. The hill slope faces down N.N.W.; but almost all the boulders lie with their longer axis pointing W.N.W.

About half a mile farther east, on a much steeper part of this hill slope, there is a cluster of huge boulders, the uppermost lying on the rest in such a way as to show it must have come from the westward (see *Ninth Report*, p. 10, and *Lithograph No. 10*; Plate VIII.).

*Taynish*.—(1) A large assemblage of boulders lying on rock of shore near Taynish House (property of Captain Campbell of Inverneil). Largest  $18 \times 11 \times 8$  feet, lies on broken edges of vertical strata. Longer axis lies W. by S.; and its narrowest end points west. There is another boulder  $19 \times 15 \times 5$  feet; its longer axis N.E. and S.W. Greatest number of boulders lie on rocky slope facing north-westerly.

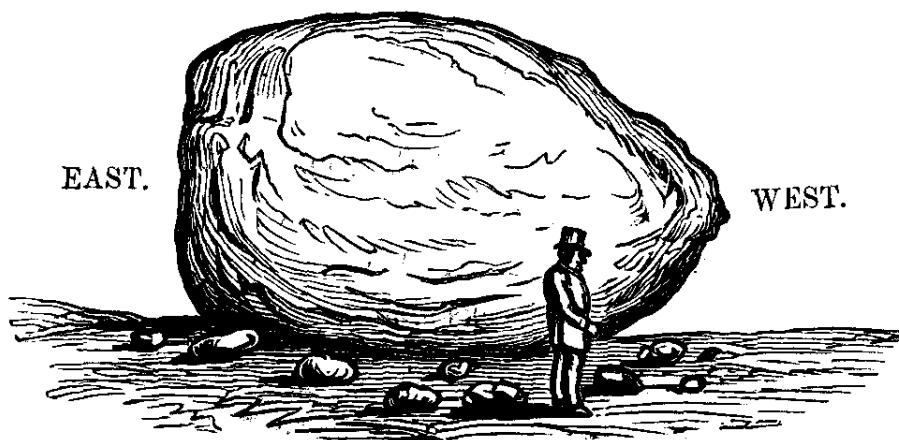
Several other large boulders near Taynish House reported, but not seen.

(2) On each side of road to Ardrishaig, many boulders observed ; —occupying chiefly north-westerly hill slopes.

(3) Near Crinan Canal at *Ballanach*, about  $\frac{1}{2}$  mile from canal, at 300 feet above sea, boulder,  $16 \times 9 \times 9$ , on north side of valley. It lies on bared rocks. Its longer axis coincides with axis of valley, viz., S.W. by S. (*Ninth Report*, p. 8).

Numbers of large boulders lie on hills to eastward, chiefly on slopes facing N.W.—(Diagram given in *Ninth Report*.)

(4) *Dana, Island of*.—On the shore of this island, forming the



Dana Boulder.

north bank of Loch Sweyn, and nearly opposite Castle Sweyn, there is on the shore a boulder weighing from 70 to 80 tons (see prefixed woodcut). Its sharpest end is towards west, and longest axis parallel with the axis of the loch (*Seventh Report*, p. 12).

On the south bank of loch here, there is a projecting mass of rock on which Castle Sweyn has been built. On the west side of this rocky mass, a number of boulders lie, as if intercepted by the rock in their progress from the west. The narrowest part of the Loch is here ; so that on this account there is the more probability of blockage having occurred at this point.

*Oban and Neighbourhood*.—(1) Grey granite boulder  $12 \times 8 \times 6$  feet at Dunolly. Nearest granite rocks are on Loch Etive, to eastward, but doubted whether of same variety. The boulder is at foot of a cliff of Conglomerate rock.

(2) A mass of Conglomerate rock above the town, well rounded. On the side facing N.W. the hard pebbles are all ground down ; on east side the pebbles of the rock are rough.

(3) *Oban*.—At south end of town, there are cliffs of old conglomerate rock, from which blocks have been carried southwards and are strewn on a meadow to a distance of from 100 to 200 yards from the cliffs (*Seventh Report*, p. 4).

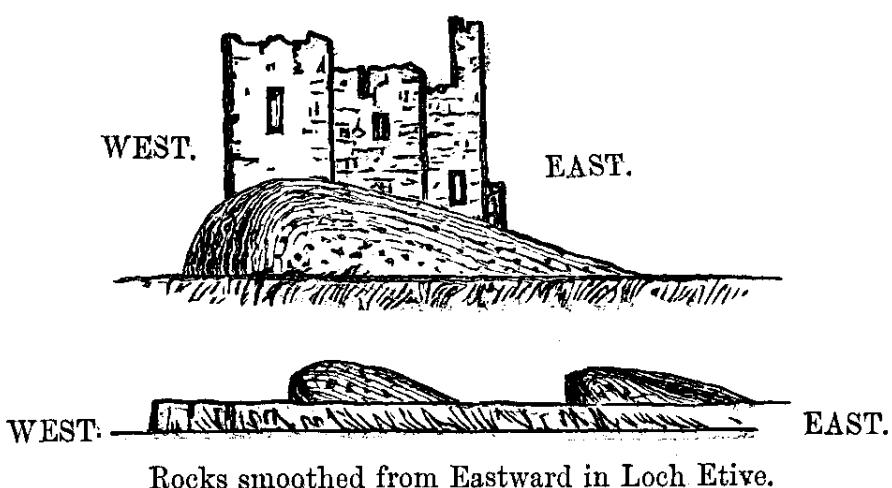
A plan given to show where these boulders situated, many being on hill slopes facing N. and N.W. These boulders are mostly all grey granite.

On the hills, near Professor Blackie's cottage, there are several large grey granite boulders on slopes facing N. and N.W.

On small island in Oban Bay, several grey granite boulders, so situated, as to show transport from north (*Seventh Report*, p. 7).

On the farm of Dunbeg, near Conual Ferry, a boulder of grey granite lying on rocks of clay-slate, in a position showing transport from N.W. (*Seventh Report*, p. 8).

At Dunstaffnage, about 5 miles N.E. of Oban, the rocks smoothed in such a way as to suggest movement over them of an agent from *eastward*, viz., down Loch Etive. Along the shore, up towards Loch Awe, there are rocks similarly smoothed, as shown on the annexed woodcuts.



Rocks smoothed from Eastward in Loch Etive.

(4) At "Lailt," a dark porphyry boulder called "*Clach-a-Currail*" (*i.e.*, *perched boulder*), from its precarious position. Differs from all the rocks in district. Remains of a granite boulder also here.

(5) *Glenlonan*.—Several boulders, at heights of from 1600 to 1700 feet, of various kinds of rocks. Boulders are on both sides of summit level, but the greater number are on slopes facing the north, and the smoothed rocks also chiefly face the north.

(6) *Loch Etive*.—At Airde Point, many boulders on slopes look-

ing up towards Loch Awe and Ben Cruachan, as if brought by glacier ; but they might also have come from north by floating ice.

Rocks on south shore of loch, above and below Connell Ferry, showing smoothings, strongly indicative of glacier from head of loch.

Angular grey granite boulder,  $11 \times 9 \times 7$  feet, above Bonawe Ferry at Innerlievern.

(7) *Kerrera, Island of*.—Numerous grey granite boulders on beach at north end of island ; so placed, as to show transport from the north. Granite boulders with red tinge, found on Ballimore farm at from 350 to 440 feet above sea ; but no granite rocks on island. Nearest place where such granite known is at Morven, about 12 miles across the sea to the north. The Mull granite said to be different.

On the farm of *Bal-na-Bak*, about 20 boulders seen by Convener, all granite except one.

(8) *Easdale*.—Many grey granite boulders lying on blue clay slate rocks. Supposed to have come from Mull Island, it being nearest place for such granite ; and no obstruction in that direction.

One clay stone boulder of a purple colour was found ;—said that rock of this character exists to the south.

(9) *Ben Cruachan* ascended to height of 2725 feet. Until contour of 1335 reached, few boulders seen. Above that, very numerous on N.W. shoulder of hill. Towards N.W. less obstruction to transport, than from any other quarter. Towards W.N.W and N.W. no hills, but those in Mull and Ardnamurchan, distant 30 to 40 miles.

Boulders are of red and grey granite. The sizes of four or five of largest given. The rocks of Cruachan, where these boulders lay, are chiefly a red granite.

Longer axis of boulders and rock striæ generally point N.W.

At heights of 334 feet and less, rocks appeared to have been smoothed from W.S.W., as if by glacier from Loch Awe. Above that height, the direction of the striæ is N.W. by N., N.N.W., and W.N.W., the last being most persistent in the highest parts of the hill. Some of these Cruachan boulders lie on beds of gravel, up to a height of 2000 feet (*Fifth Report*, p. 48).

*Lismore, Island of*.—Boulders of granite, red and grey, lie on the Limestone rocks. Old sea terrace well marked on island.

*Appin*.—On the shore of Linnhe Loch, two granite boulders, one

$20 \times 18 \times 11$  feet (292 tons), the other  $15 \times 11 \times 10$  feet (122 tons), differing from adjoining rocks, which are clay slate (*First Report*, p. 26).

*Loch Creran.*—At Fasnacloich, boulders of black granite, two of 380 and 280 tons respectively. The boulders have their sharpest ends pointing towards mouth of Loch Creran, viz., to S.W. The rocks *in situ* are different.

Chips from these boulders having been submitted by the Convener to Professor Judd (Kensington Department), he identified them as similar in composition to rocks seen by him in Skye, Mull, and Ardnamurchan. It appeared to him that the Appin boulders, before mentioned, were the same in composition as the Fasnacloich boulders.

Professor Judd stated, that these Loch Creran and Appin boulders are not granites, but “rocks of a basic composition,—a gabbro with some black mica” (*Fourth Report*, p. 11).

At mouth of loch, rocks smoothed (when facing W.N.W.) up to about 70 feet above sea. About a mile higher up loch, smoothed rocks face W.S.W. at height of 80 feet above sea.

Near sea level, smoothing seemed due to some force moving down valley. Rocks at a higher level seemed to have been smoothed by force moving from N.W.

In Glen Creran most of boulders lie on *drift*. At one place boulders form a cluster on a rocky knoll.

Statement by Mr Hall, an intelligent residenter, that a *trainée* of boulders is traceable from Glen Creran through Carroban Pass, situated on S.E. part of Glen Creran (*Fifth Report*)

#### AYRSHIRE.

*Coylton.*—Granite boulder  $11 \times 7\frac{1}{2} \times 5$  feet. Longer axis N. and S. There are four more boulders, weighing respectively 4, 8, and 12 tons, and form a line running N. and S. Legend that King Coil dined on large boulder (*First Report*, p. 28).

*Dailly.*—Granite boulder about 36 tons on Killochan estate, called “Baron’s Stone,” about 100 feet above sea. Lies on Silurian rocks; various other granite boulders south of River Girvan, on hill slopes. One on Maxwelton Farm, contains 240 cubic feet. Another on top of Barony Hill above Lannistane, 1047 feet above sea (*First Report*, p. 28).

*Doune Loch*.—Two miles south of, granite boulder called “*The Kirkstane*,”  $25 \times 20 \times 12$  feet (444 tons), so called because used as a pulpit for preaching from (*First Report*, p. 29).

*Girvan*.—Thousands of granite boulders and some whinstone boulders, for miles along the shore near Turnberry Point. Rocks *in situ* are sandstone. Nearest granite rocks are in Arran.

Along coast 4 miles south, in a ravine, two boulders of altered greywacke; one weighing 180 tons, the other 100 tons (*First Report*, p. 29).

*Kilwinning*.—On Misk Farm a pit was sunk for coal through boulder clay. Boulder of dolerite and a flint nodule found, at depth of 23 feet from surface. Flint was  $3\frac{1}{4}$  inches in diameter and  $2\frac{1}{2}$  inches thick. Dolerite was water-worn and roughly scratched. A flint nodule found on Inchlonaig, an island in Loch Lomond, in boulder clay, with arctic shells (Letter to Convener from Rev. David Robertson, Glasgow, dated 10th November 1876).\*

*Maybole*.—Granite boulder, flat and oblong, on slope of hill above River Doon, on Auchindrane, at height of 230 feet above sea, known as Wallace’s Stone, from tradition that a rude cross now carved on it represents his sword [Notes of cases from Dailly, Girvan, and Maybole, sent by Professor Geikie] (*First Report*, p. 29).

*Ardrossan*.—Near Hunterston on the shore, boulder of grey compact granite  $11 \times 6 \times 5\frac{1}{2}$  feet and  $26\frac{1}{2}$  feet in girth, opposite to great Cumbrae Island and about 12 miles from Arran (*Second Report*, p. 149).

On the shore about 2 miles to N.W. of Ardrossan, the “*Boyd-stone*” boulder of porphyry, about  $19 \times 19$  feet (about 320 tons), on property belonging to Mr Alexander. Rocks here are Old Red Sandstone. Boulder partly buried in mud of the shore, but about 9 feet in height visible.

Two other boulders on Mr Alexander’s property, one of them even larger than the foregoing,—of gneiss (*Second Report*, p. 149, *Third Report*, p. 3).

*Stinchar Valley*.—Boulder of claystone a cubic yard in size lies near hamlet of Poundland. Seemed identical in mineralogical

\* In vol. vi. part 2, of Glasgow Geological Society’s *Transactions*, pp. 186-190, notices will be found of flint nodules found on various other parts of the Ayrshire coast.

character with rock of Glassal Hill situated to N.E., and also with rock on shore to west at Bennane Head (*Sixth Report*, p. 33).

*Culmonell*.—Half a mile to north, at height of about 200 feet above sea, a dolerite boulder  $27 \times 23 \times 12$  feet (552 tons), its longer axis N. and S. It lies on till. A small boulder, apparently a fragment of large boulder, lies to the south (*Sixth Report*, p. 33).

Another boulder of dolerite, which had been  $21 \times 21 \times 10$  feet (326 tons), with longer axis N. and S.;—now rent into fragments.

*Query*.—Did boulder break by falling from a height?

*Lendalfoot*.—A little to north, an Old Red Sandstone Conglomerate boulder  $8 \times 6 \times 6$  feet. It is undistinguishable from the Conglomerate rock of Wemyss Bay, situated about 30 miles to the north (*Sixth Report*, p. 33).

*Beith*.—On Cuffs Hill, consisting of porphyry, there are on its north side many small granite blocks which must have come from the west or N.W.

(1) Mr Robert Craig of Beith, in several papers read before the Geological Society of Glasgow (*Trans.*, vol. iv. parts 1 and 2), divides the boulders in the north of Aryshire into two classes. One class consists of rocks foreign to the district, viz., Old Red Sandstone, granite, quartz, gneiss, mica of chlorite, schists, and clay slate. These he thinks were transported from mountains in the N.W., distant from 50 to 70 miles, by drift ice and marine agency. The other class he derives from rocks situated to the N.E. and at no great distance, transported by land ice.

(2) Messrs Crosskey and Robertson also sent to the Glasgow Geological Society (*Trans.*, vol. iv. part 1) an account of boulders of great size, and in large numbers, found in excavating new docks at Greenock. The great majority of the larger boulders are sandstones of the neighbourhood;—the remainder are of quartz, mica schist, &c., from the Argyleshire mountains to the N.W.

(3) Mr Robertson, in the Glasgow Geological Society's *Transactions*, 19th Jan. 1877, gives an account of large boulders, covered with *Balanus* and *Serpula*, in a bed of sandy mud 18 feet deep, containing also nodules of flint.

The conclusions he drew from the boulder being covered with marine zoophytes was, that after being so covered, they had been lifted up by shore ice and transported to their present position.

## BANFFSHIRE.

*Banff*.—Between Banff and Peterhead, beds of glacial clay, similar to that of Caithness, and probably drifted from thence (*First Report*, p. 29).

Near Peterhead, many boulders of granite and trap, one of these of a greenish colour, not known *in situ* in Aberdeenshire, but occurs in Caithness (Jamieson, *Lond. Geol. Soc. Jour.*, xxii. p. 272).

*Boyndie*.—Hypersthene boulders found along shore for some miles. Supposed to have come from rocks to S.E. (*First Report*, p. 29).

*Fordyce*.—A line of boulders through several parishes in a S. and N. direction. They are a blue whinstone. In Ordiqhull parish, so close as to touch. Height above sea 500 feet (*First Report*, p. 29).

## BERWICKSHIRE.

*Berwick*.—On *Castle Terrace*, boulder clay excavated for water pipes. Many boulders found in clay bed, of granite, gneiss, limestone, blue whinstone, greywacke, &c., all rounded. The granites showed two varieties, grey and red. Nearest granite hill is Cockburn Law, about 30 miles to N.W.;—nearest blue whinstone in rock, is about 25 miles to west (*Second Report*, p. 149).

*Berwick*.—About half a mile to north of the town, four boulders pointed out to Convener by Captain Norman, R.N., on side of a road leading to Halidon Hill. The boulders are each from half a ton to a ton in weight. Two are of fine grained granite,—one grey in colour, the other with a shade of pink.

The other two boulders are a dark porphyry;—the nearest locality for which is Lamberton Hill, situated about 2 miles to N. and N.N.W. (*Seventh Report*, p. 13).

*Burnmouth*.—Near railway station, in a gravel bed over greywacke rocks, a well rounded block of pinkish granite found by Convener.

He sent a chip to Mr Macdonald, granite worker, Aberdeen. He answered that it was a rare variety of granite. He knew of its existence *in situ*, only at Kincardine O'Neil (Deeside) and about Ballatar and Braemar, in the form of boulders, and as a rock in the Island of Uist (Hebrides) (*Second Report*, p. 149).

*Coldstream*.—A block of white chert limestone, about 4 feet square, very irregular in shape, found in a gravel bed at the Hirsel (the Earl of Home's).

The only place where rocks *in situ* of this nature found, is on the opposite, *i.e.*, the south side of the Tweed, at Carham and Nottylees, distant from Hirsel 3 or 4 miles, and bearing W. by S. (*Second Report*, p. 150).

*Duns*.—On farm of Cockburn, 2 miles N.N.W. of Duns, a boulder of mica schist, from 2 to 3 feet in length and breadth, lying at base of a steep hill facing the south. No mica schist rocks in Berwickshire, or nearer than the Grampians (*Second Report*, p. 150).

*Foulden*.—Several small boulders of coarse syenite, lying on Old Red Sandstone, composed of red felspar, black hornblende, and small flakes of mica; largest boulder is  $5 \times 3\frac{1}{2} \times 2$  feet. Sharpest end points N.W.

Nearest hill where similar rocks occur is Cockburn Law, 8 miles to N.W. (*Second Report*, p. 150).

*Greenlaw*.—At Marchmont (residence of Sir Hugh Hume Campbell) about 930 feet above sea, a blue whinstone boulder  $9\frac{1}{2} \times 5 \times 4\frac{1}{2}$  feet, with faint striæ on top, parallel with longer axis. Rocks *in situ*, Old Red Sandstone. Nearest whinstone rocks are in Gordon parish, 5 miles to west (*Second Report*, p. 150).

*Gavinton*.—Boulder clay 10 to 12 feet deep, covered by beds of gravel and sand, in some places 12 feet thick. In the clay, the boulders composed of rocks recognised as occurring *in situ* in localities W. by N., as at Kyles Hill and Dirrington,—these hills being from 3 to 6 miles distant (*Fourth Report*, p. 20).

*Ayton Parish*.—Several small boulders of grey granite, 270 feet above sea, on Whitfield farm. Nearest granite hill, Cockburn Law, 10 miles W.N.W.

Near Ayton Castle, pieces of coal found in deep bed of sand, about 200 feet above sea. Coal strata occur in Mid-Lothian on north side of Lammermuir Hills, 40 miles to N.W. (*Sixth Report*, p. 17).

*Coldingham Parish*.—On Cocklaw Farm, well rounded masses of hematite ore found, turned up by plough, at height of 500 feet above sea. Nearest place where hematite known is in East Lothian, about 30 miles to N.W.

On the same farm, blocks of white sandstone found, which is not known to be *in situ* nearer than East Lothian (*Sixth Report*, p. 17).

On the rocks near Coldingham Loch, and at St Abb's Head, the striæ on the lochs show a movement from N. by W. (Ed. *R. S. Tr.*, vol. xxvii. p. 36).

*Chirnside Parish*.—On Oldcastle Farm, numerous boulders of grey granite, from one to two tons in weight and 300 feet above sea. Nearest granite hill is Cockburn Law and Stenchel, about 8 miles to N.W. (*Sixth Report*, p. 17).

*Edrom Parish*.—At Blackadder, a boulder of blue whinstone on knoll of gravel, about 250 feet above sea. Nearest rock of same kind is at Hardens, 5 miles to N.W., which is 500 feet above sea.

*Hutton Parish*.—In Paxton brickwork, blue whinstone boulder found  $7\frac{1}{2} \times 4\frac{1}{2} \times 3$  feet, weighing about 10 tons, with *striæ* on one of its sides parallel with longer axis. Its longer axis N.W. by N., about 230 feet above sea. In that direction only there is whinstone rock *in situ*, viz., Borthwick Hill, situated 12 miles to N.N.W., about 600 feet above sea. At same brickwork, in a bed of boulder clay, small boulders of red conglomerate, greywacke, and chert found; also the brick-coloured porphyries of Kyles Hill and Dirrington, situated from 14 to 16 miles to westward. The whinstone boulder taken by Convener into Paxton Policy for preservation.

Blocks of same blue whinstone occur on adjoining lands of Broadmeadows and Sunwick.

Blocks of a very peculiar crystalline greywacke, with cavities, and of a black colour, occur in Pistol Plantations (Edrom parish). The only locality in Berwickshire for this rock is in the channel of the River Whitadder, east of Cockburn Law, at a distance of 12 miles N.W. Blocks of the same rock are found on the farms which lie between Pistol Plantations and Cockburn Law (*Sixth Report*, p. 18).

*Stitchel Parish*.—Pebbles of Old Red Sandstone lying on blue whinstone rocks at Stitchel Craggs, at 600 feet above sea. Nearest place where Red Sandstone strata known is some miles to west (*Sixth Report*, p. 18).

On west sides of those craggs, smoothed surfaces of whinstone dipping towards or facing W.N.W. (*Sixth Report*, p. 18).

At Baillie Knowe in same parish, 300 feet above sea, a whinstone hill, with similar smoothed surfaces, fronting W.N.W.

On Smailholm Craggs (3 miles west of Stitchell) at 570 feet above sea, rocks facing W.N.W. show *striæ* by an agent moving from W.S.W.

*Earlston Parish*.—Blocks of felspar porphyry, from Cowden-

knows Hill, strewed over muirs to east, resting on Old Red Sandstone strata (*Sixth Report*, p. 18).

*Hume Parish.*—Rocks on craggs there at 740 feet above sea, smoothed and striated in E. and W. directions (*Sixth Report*, p. 19).

(For other cases in Berwickshire, see paper by Mr Stevenson, in *Berw. Nat. Club. Trans.*, vol. vii. p. 20.)

*Mordington.*—A block of very coarse-grained syenite found near top of Halidon Hill, on a slope facing west, at a height of about 400 feet above sea. The only hill in Berwickshire where syenite rock occurs is the Stenchel, on east side of Cockburn Law, about 10 miles to W.N.W.

The Convener submitted a specimen of the block to the late Mr Stevenson of Duns, who was a good geologist, and well acquainted with Berwickshire rocks. He was of opinion that the block closely resembled a syenite which he had seen in Mull (*Ninth Report*, p. 11).

*Kaims.*—In different parts of this county there are numerous examples of Kaims. One on Greenlaw Muir is continuous for nearly 2 miles. They are numerous also in the lower districts, and are there more or less parallel to one another, and to the general axis of the Tweed valley. The average direction near Kelso is N.E. by N.;—in the east part of the county the average direction is E.  $10^{\circ}$  S. (Ed. *R. S. Tr.*, vol. xxvii. p. 29):

#### BUTESHIRE.

*Big Cumbrae Island.*—Many boulders of mica schist lying on Old Red Sandstone rocks of island. Largest boulder seen  $12 \times 6 \times 3$  feet, with longer axis N.N.E. lying in valley running N.N.E. at north end of island. Mica schist boulders occur also at S.W. end of island (*Second Report*, p. 151, and *Sixth Report*, p. 24).

*Little Cumbrae Island.*—On highest part of island, about 400 feet above sea, rocks *in situ* (claystone trap) sloping down towards N.W., have been smoothed by some heavy agent passing over them, from N. by W. Several boulders of Old Red Conglomerate found. The largest is about 5 feet square and rests on rock, with so small a basis that it can be rocked, known by the name of “*Bell Stane*.” Rev. Mr Lytteil suggested to Convener that name may have been originally “*Beltane*,” on account of fires lighted on it in Pagan times. Close

to this block there is another Conglomerate boulder of smaller size, with an ancient cup-shape hollow on its surface, apparently artificial, 4 inches in diameter and  $\frac{1}{2}$  inch deep. Height above sea 190 feet (*Sixth Report*, p. 25).

No Old Red or Conglomerate rocks in island. Nearest are at Toward Point and Rothesay, from 12 to 20 miles across the sea to N.W.

“*Split Boulder*,” first mentioned by Smith of Jordanhill, visited. Lies at sea-level, on rocks much smoothed and striated, forming east side of a trough, axis of which runs N.E. by N. Some of the striae are continuous for 30 yards. Striating agent must have moved from due north (*Sixth Report*, p. 25).

*Ailsa Craig*, a mass of white porphyry, reaches to a height of 1114 feet. At a height of 600 feet, on north side, there is a bed of clay mixed with sand of a red colour, derived probably from the débris of the Old Red Sandstone rocks of Arran, Big Cumbrae, Rothesay, and Toward;—all situated to the N. and N.W. Pebbles of granite and quartz said to have been seen on the Craig (*Sixth Boulder Report*, p. 23).

*Arran, Island of*.—(1). In *Brodick Bay* (East Coast), no boulders; but along coast, to north and also to south, numerous and large boulders.

*Corriegill*.—Boulder of grey granite, has longer axis and sharp end to N.W. Same kind of granite in Goatfell mountain, distant 4 miles bearing N.N.W.

Another boulder,  $12 \times 9 \times 8$  feet, half a mile to north, has its longer axis N. and S.

(2) Near *Corrie*, two large boulders of granite sit near each other on plateau or terrace, about 93 feet above sea. Largest may weigh about 620 tons. Longer axis and sharpest end point N. by W. Rock on which it lies is Carboniferous sandstone. These two boulders must have been carried,—there being no adjoining hill from which they could fall. Goatfell bears from them W. by S., and is distant about 3 miles. By a glacier they could not have been carried, as they are not in a valley, or near any valley from which a glacier could have issued (*Sixth Report*, p. 21).

(3) To the north of *Corrie*, about 2 miles, the road passes a large boulder on the sea-shore called the “*Catstane*,” whose weight is estimated at 362 tons.

Near this boulder there is a granite boulder, with a weight of about 212 tons. Its longer axis lies N. and S., the narrowest end being to the north.

(4) There is another granite boulder on the old sea-beach, at a height of 12 feet above high water. It rests on Conglomerate strata, which dip towards the south. It is blocked at south end, by a knob of Conglomerate rock, which seems to have obstructed it in its progress from the north (see Diagram in *Sixth Report*, pl. xix. fig. 5; also *Lithograph No. 9*, Plate VIII.).

Many blocks of this Conglomerate Sandstone have been carried along the shore southwards;—none found to the north.

(5) On the hills west of Corrie there are rocks with striæ on smoothed surfaces at a height of 158 feet above sea. The direction of the striæ is N.W. and S.E.

On these hills, up to 587 feet above the sea, there are many boulders,—mostly of grey granite, and a few of Conglomerate.

Between those hills and Goatfell there is a deep valley, well strewed with granite blocks. Most of them are rounded. On west side of valley, hill climbed to a height of about 1270 feet. One boulder attracted attention, being 23 feet long 9 feet wide and 12 feet high (184 tons). This, and many others, lay with longer axis N. and S. Its position showed that it had not fallen from any hill, and must have been *carried* to its present site.

(6) In crossing to *Loch Ranza*, Convener saw to the south of the high road numerous “perched” blocks on the tops and ridges of the hills at heights of from 1506 to 2000 feet above the sea. He regretted not being able to examine them. They were most numerous on hill slopes facing N.W.

The absence of boulders in Brodick Bay, whilst they abound along the shore to the north and south, invites special explanation. If a glacier descended from Goatfell, boulders should have been numerous in the bay and valley leading up from it to Goatfell. If the boulders came on floating ice from the N. or N.N.E. they would be dropped along the east shore, and on the hill slopes facing the north. But they would be deflected from Brodick Bay, by a high ridge of rocks which comes down from Goatfell to the north of Brodick Bay (*Sixth Report*, p. 22).

(7) Beds of fine clay in south end of Arran (first described by

Rev. Mr Watson) contain Arctic shells, sometimes in a broken or crushed state. This fossiliferous stratum is covered by a great thickness, of what Mr Watson calls *boulder clay*, but which Messrs Bryce and Croskey call *upper drift beds*. The upper stuff also contains broken shells (*Jamieson in paper published in Proceedings of London Geological Society of February 1866*, p. 276).

*Bute Island*.—East coast, north of Rothesay, examined, and a list of boulders found there given. They consist chiefly of schists lying on Old Red Sandstone and clay slate rocks,—and must have come from the hills to the north (*Seventh Report*, p. 14).

Along west coast, north of Ettrick Bay, there are numerous boulders, also of schists, which show by their positions that they also came from north. Several of these boulders are standing on end leaning against rocks on their east sides (*Seventh Report*, p. 16) (*Lithograph No. 12, Plate VIII.*).

*Barone Hill*, situated about 3 miles S. W. of Rothesay, at a height above the sea of about 500 feet, has at its west end a rocky gorge with remarkable striæ on sides, which indicate passage through gorge of a powerful current of some kind, hurrying through it from a northerly point, stones and rubbish. A diagram given of some of the striæ, showing that they have been incised more deeply at north ends than elsewhere, in consequence probably of the pebbles becoming blunted by friction by being squeezed against the rock.

This spot is referred to in a paper "On Glacial Drift in Scotland," by Professor Geikie, who gives it as his opinion that "the abrasion (of these Barone Hill rocks) has been done by an agent, which came up the steep northern face of that eminence, went right over its summit, and pursued its course down into the next valley beyond. The striations (the Professor adds) run from N. 15° W. to N. 20° E." (*Seventh Report*, p. 20) (*Lithograph No. 13, Plate VIII.*).

#### CAITHNESS.

*Dunnet*.—Conglomerate boulder of small size, apparently from Maiden Pap Hill, 30 miles to south. Several large boulders in parishes of Olrich and Cannesby (*First Report*, p. 29).

*Thurso*.—Near Castletown, large granite boulder. Between Wey-VOL. XII.

darle and Stonegun, several large Conglomerate boulders. Rev. Mr Joass, of Golspie, states that nearest granite and Conglomerate rocks in the county are situated in N.W. districts (*First Report*, p. 30).

*Keiss Parish*.—Conglomerate boulder  $9 \times 7 \times 5$  feet called “*Grey Stone*.” Longest axis W. by N. Differs from any rock in locality. It marked, where it stood, boundary between two parishes and two estates. It has lately been blasted into four fragments, of which three still remain (*Eighth Report*, p. 8).

Mr Jamieson of Ellon, having examined *Keiss Harbour*, states that a bed of “drift,” 40 feet thick is there, the lower half of which consists of unstratified sandy mud, containing broken shells and stones, some of which are scratched. The scratches and grooves point N.  $35^\circ$  to  $40^\circ$  W.

*Scrabster Harbour*.—Mr Jamieson reports that here the boulder clay is more than 100 feet thick. It is charged with small stones more or less rubbed and scratched. He found in it fragments of shells.

*Wick*.—Three boulders, each weighing from 20 to 30 tons. One is a Conglomerate, supposed to have come from hills 20 miles to south. But Rev. Mr Joass states that Conglomerate rock occurs to westward at less distance.

*Wick Bay*.—Mr Jamieson found here a similar bed of boulder clay, containing fragments of shells and numerous large water-worn boulders of sandstone, quartzose, mica slate, and granite, on which glacial scorings are well marked. One granite boulder was 12 feet in length (*First Report*, p. 30, and *Proceedings of London Geological Society*, 7th February 1866, p. 265).

In the same paper, Mr Jamieson states that in Caithness generally, the shells, as a rule, in the clay beds and drift, are broken. But exceptions occur. He himself found one entire valve of *Astarte Borealis*; and he saw several entire specimens in local collections.

He adds, that one of the objects he “had particularly in view was to note the direction of the glacial markings on the rocks, and to ascertain whether they could be accounted for by a movement of ice proceeding from the interior of the country towards the coast. I therefore lost no opportunity of noting the bearings of

scratches whenever I saw them." Mr Jamieson then gives the bearings at twenty localities in Caithness, from which he concludes that the movement had been from N.W. to S.E.; and he adds, that "a movement of ice from N.W. to S.E. across Caithness is totally at variance with the notion of the scratches having been caused by glacier action proceeding from the interior of the country towards the present coast." In a footnote, Mr Jamieson adds, that "the presence of marine organisms (in the Caithness drift), and the direction of the glacial striæ, which indicate a movement from the N.W., where there is now nothing but open sea for an immense distance, together with the absence of moraines, are all suggestive of *marine conditions having prevailed during the deposition of the Caithness drift.*"

In year 1828, the late Sir Roderick Murchison published a paper in *Proceedings of London Geological Society*, in which he mentions that "the highest hills in the *Brora* district afford, upon their sides and summits, distinct traces of a strong diluvial current, which has swept them free of covering matter, and deposited in the plain of Clyne, Milltown, a mass composed of the debris of the denuded hills. A large portion of the turf having been recently removed, the surface of the rock was seen to be scored with parallel lines. The direction of the markings is uniformly from N.N.W. to S.S.E."

#### DUMBARTONSHIRE.

*Luss*.—On west bank of Loch Lomond, about 150 feet above sea, in channel of a brook entering *Fruin Water*, a *mica schist* boulder  $28 \times 18 \times 7$  feet (246 tons). Longer axis E. and W., with sharp end to west. Rocks adjoining—Old Red Sandstone. Nearest mica schist hills about 5 miles to N. and W. If boulder came from that direction, it must have been carried across hills from 1000 to 2000 feet high. If it came from north, down Loch Lomond valley, it must, after coming so far, have changed its course and moved at right angles to westward to gain its present site (*Second Report*, p. 153, *Fourth Report*, p. 20).

On a moor, about half a mile to N.E. of the above boulder, there are several smaller boulders of mica schist, all with longer axis in similar direction, viz., east and west.

On west side of Loch Lomond, at *Arden*, a low valley running

up from loch, shows many small boulders,—their longer axis and sharpest ends pointing N.W. (*Fourth Report*, p. 21, *Sixth Report*, p. 6).

On east bank of Loch Lomond, nearly opposite to Arden, at about 337 feet above sea, a grey granite boulder  $5 \times 4 \times 4$  feet, much rounded—lying on Old Red Sandstone strata. Longer axis E. and W.;—it had probably crossed loch, from west (*Sixth Report*, p. 7).

In Cameron House Policy, gneiss boulder  $6\frac{1}{2} \times 5 \times 5$  feet, with longer axis N.W. and S.E.

About 3 miles to S.W. of the south end of Loch Lomond there is a hill called “*Caer-man*,” reaching to height of 720 feet above sea. Rocks on top are a coarse porphyry. The rocks on western aspects are well rounded ;—on eastern aspect, the rocks are rough. There are huge fragments on east side of top, none on west side (*Fourth Report*, p. 21).

#### DUMFRIESSHIRE.

*Kirkconnel*.—Granite boulder, 7 feet in diameter, 20 to 30 tons, 700 feet above sea. Differs from adjoining rocks. No granite rock nearer than Spango Water (*First Report*, p. 30).

*Tynron*.—Three whinstone boulders, each weighing from 20 to 30 tons, also several Conglomerate boulders ;—all have apparently come from N.W. (*First Report*, p. 30).

*Wamphray*.—Large whinstone boulder (*First Report*, p. 36).

*Moffat*.—Several large perched boulders near *Loch Skene*, at height of 1900 feet above sea—(*Mr Ralph Richardson inferred that they were “transported by a local glacier”*)—(*Seventh Report*, p. 28).

(See notes regarding these boulders, by Convener, in the *Transactions of the Edinburgh Geological Society* for May 1881.)

*Langholm*.—In Wauchope valley, and also in bed of that river, granite boulder  $16 \times 11 \times 6\frac{1}{2}$  feet, weighing from 50 to 70 tons, lying on Sandstone rocks. Many others scattered about (*W. Strachan Schoolmaster, Langholm*).

*Cairnsmore of Fleet*, a hill 2331 feet high, situated in Kirkcudbrightshire ;—composed of coarse grey granite.—“Boulders of Cairnsmore granite are scattered over the hills to the S.E. One is on the west face of the Nether Hill, at the height of 1100 feet, and 8 miles distant from its source” (*Survey of Dumfriesshire by Scotch Government Surveyors in Memoir*, No. 9, p. 39).

(*Extract from the Fourth Report of the Boulder Committee of British Association*) :—Professor Harkness mentions a boulder of Silurian Conglomerate at the village of Bothal, North Cumberland,  $20 \times 9 \times 5$  feet. It is striated on its western side. It is between 400 and 500 feet above sea-level, and, in his opinion, *was transported from Dumfriesshire*, having therefore travelled about 40 miles from N.N.W.

## ELGIN.

*Dallas*.—Many small granite boulders here, which are supposed to have come from Ross-shire (*First Report*, p. 31).

*Duffus*.—Conglomerate boulder  $21 \times 14 \times 4$  feet, longer axis N.W., on Roseisle estate (*First Report*, p. 31).

*Llanbryde, St Andrews*.—Gneiss boulder in bed of Old Spynie Loch,  $15 \times 9 \times 7$  feet, longer axis N.N.E.

*New Spynie*.—Four Conglomerate boulders lying on Old Red Sandstone rock (*First Report*, p. 31).

*Rothes*.—Six horneblende boulders lying on gneiss rocks.

*Dyke*.—Near Darnaway Castle, in the approach to, several granite and gneiss boulders from 2 to 3 tons.

A kaim  $\frac{1}{4}$  mile long, running N. and S. (*Second Report*, p. 152).

*Elgin*.—Boulder called “*Carlin’s Stone*,” on Bogton Farm, a coarse Conglomerate 230 feet above sea, with pebbles of flesh-coloured quartzite. About half a mile to N.W. another Conglomerate boulder, called “*Young Carlin’s Stone*.”

Hundreds of smaller boulders of granite, gneiss, &c., embedded in clay or sand, which seems to have been pushed or rolled, being all well rounded.

Carden Hill has been ground down and striated. Direction of striae varies between W. by N. and N.W. Numerous boulders on ridge of hill, and on both sides of it.

At several places on ridge, rocks broken up, and fragments pushed over southern slope.

At one spot on Carden Hill, the N.W. striae crossed by others from N.E.

Quarrywood Hill, composed of Sandstone rocks, has four or five large Conglomerate boulders on its N.W. slope.

*Forres.*—Conglomerate boulder on Upper Caliper Farm, about 44 tons, lies on hill-side facing Cromarty, which bears N.W. by N. 10 miles across Moray Firth. Another Conglomerate boulder on same farm, much buried in drift. These boulders contain reddish quartzite pebbles.

*Forres to Nairn.*—Extensive beds of sand and gravel, mostly stratified. Pebbles and boulders in these beds well-rounded; angular boulders chiefly on surface (*Second Report*, p. 155).

*Lossiemouth.*—On old sea margin, Conglomerate boulders of same character as those in other parishes.

In boulder clay over Limestone rocks, boulders of oolite found, which must have come from Ross or Sutherland.

Portions of an oolite boulder seen by Convener, near Duffus Schoolhouse, 125 feet above sea.

Conglomerate boulder, called “*Witch-stone*,” similar to all the others. Longer axis N.W., and sharpest end towards that quarter. Lies on bed of sand.

On Clarkely Hill, hard sandstone rock forming a surface sloping down to W. striated from N.W. Several boulders of granite and gneiss on hill (*Second Report*, p. 155).

Mr William Jolly, Inspector of Schools, Inverness, sent to the Committee valuable notes regarding the distribution and parentage of Morayshire boulders, which are given in *Fifth and Sixth Reports*.

He says—“There would seem to be two varieties of Conglomerate boulders distributed through the ‘*Laigh of Moray*.’” *One variety* is a Conglomerate, containing “a dark purplish or liver-coloured quartzite, in pieces of considerable size.” Great rocks of it occur on both banks of Loch Ness, and especially in the hill situated on the north bank called Mealfourvonie, reaching to a height of 3060 feet. This rock breaks into cubical-shaped mosses, and probably has produced the remarkable boulders in the counties of Nairn, Moray, and Banff, known as “*Culloden* or *Cumberland Stone*,” “*Tom Reoch*,” “*Clach-an-Oidhe*” or “*Stone of the Virgin*,” 20 × 15 × 9 feet, close to Geddes Public School. “*Grey Stone*” in Cawdor woods,—“*Clach-na-Calliach*,” or “*Stone of the Witch*,”—“*Clach-nan-Gillean* or *Bog’s-stone*,” and various others.

The *other variety* of Conglomerate rock, found in boulders in the

same counties, “consists of more angular components, and is entirely without the liver-coloured quartzite or porphyry;” Mr Jolly says that examples of it may be seen embedded in boulder clay at Linksfield, near Elgin, and on the crest of the hill of Roseisle.

Mr Jolly adds that the boulders of this last-named variety of Conglomerate seem to have been transported at an earlier period than those of the liver-coloured variety, being generally embedded in boulder clay or drift, whilst the boulders of the liver-coloured variety lie more on the surface of the country. It is some corroboration of this view, that there are two sets of *striæ* on the rocks, viz., from 6° S. of West, and 15° N. of West. The Conglomerate boulders from the Loch Ness Hills may have come in the first-named direction;—the other set of boulders, across the Moray Firth, from Ross-shire (*Sixth Report*, p. 48).

#### FIFESHIRE.

*Balmerino*.—Mica schist 12 × 9 × 8 feet (now destroyed) (*First Report*, p. 32).

*Craill*.—Granite boulder 10 × 8 × 6 feet, “Blue Stone of Balcomie,” close to sea, at East Neuk. Also trap boulder 12 × 8 × 8 feet (*First Report*, p. 32).

*Dunfermline*.—Whinstone boulder 7 × 15 × 6 feet “The Witch Stone.”

*Leslie*.—Kaim of drift 100 to 300 feet wide, 220 feet high, now cut through by a rivulet (*First Report*, p. 32).

*Newburgh*.—Boulder of sienitic gneiss weighing 15 tons. Legend is, that it was thrown by a giant from Perthshire, viz., from North or N.W.

*West Lomond*.—Boulders of Red Sandstone and porphyry lying on Carboniferous Limestone rocks (*First Report*, p. 32).

*Isle of May*.—Small sienitic boulders on west side of island, seen by Convener. Rocks on west side, smoothed by an agency from W.  $\frac{1}{2}$  N. No boulders or smoothings on east side of island (*Fourth Report*, p. 22).

*Bogward Den*.—Three miles west of St Andrews, a Conglomerate boulder. The nearest rock of same kind is *Drum Carro Craig*, situated some miles to N.W. (*Fourth Report*, p. 22).

*Kincraig*.—On beach, a granite boulder with girth of 23 feet and height of 4 feet lying on trap tuff. Portions of this trap tuff found in blocks 2 miles to eastward.

*Elie*.—Whinstone boulder  $8 \times 4 \times 2\frac{1}{2}$  feet, with striæ on its surface bearing N.W. Its longer axis N.W. (*Fourth Report*, p. 23).

*East Lomond Hill*, at height of 1075 feet above sea, a large number of dolerite boulders on west slope, and much rounded (*Eighth Report*, p. 28).

*Auchluisky Hill*, one of the Ochils, at 1025 feet above sea, a small red granite boulder lying on a slope facing W.N.W.

On ascending Benty Knowe, directly opposite to Auchluisky Hill to the west, another red granite boulder found.

The rocks of the Ochils here are trap, “a rotting clinkstone.”

*Bencleuch*, at a height of 2200 feet has on it two boulders, one of greywacke,—a peculiar kind, marked by nodules of white quartz, which is known by Professor Heddle to occur on the north spur of Ben Lomond, at a height of from 2230 to 2240 feet above sea. The same rock also occurs about 8 miles to the east of Ben Lomond.

The other boulder is of gneiss, laminated and convoluted, like rocks occurring in the district of Loch Earn and Glen Falloch (*Eighth Report*, p. 29).

*Ochils*.—In Alva, Silver, and Tilliecultry Glens, there used to be many boulders of granite and mica schist; but they have been all broken up for building purposes (*Eighth Report*, p. 5).

#### FORFAR.

*Airlie*.—Remarkable kaim running east from Airlie Castle 2 miles long (*First Report*, p. 32).

*Barry*.—Granite, sienitic, and gneiss boulders on shore, and on raised beaches 11 and 45 feet above shore (*First Report*, p. 32).

*Benholm*.—Huge granite boulder, now destroyed. It stood on apex of a trap knoll. In trap of this knoll are agate pebbles embedded, flattened on west side. Small hills scalloped by some agent which has passed across from west (*First Report*, p. 32).

*Carmyllie*.—Granite or gneiss boulder lying on a height. Differs from rocks *in situ*,—supposed to have come from hills 30 miles to north (*First Report*, p. 33).

*Cortachy*.—Whinstone(?) boulder,  $13 \times 10 \times 8$ . Longer axis E. and W., supposed to have come from trap situated to N.W.

Mica schist boulder within Earl of Airlie's park. Parent rock supposed to be 2 or 3 miles to N.W. (*First Report*, p. 33).

*Farnell*.—Boulder weighing about 12 tons. Supposed to have come 30 miles from N.W.

*Inverarity*.—Two grey granite boulders from 2 to 5 tons.

*Kirkden*.—Kaims of gravel and sand 440 paces long, running E. and W.

*Kirriemuir*.—Granite boulders, both red and grey. Supposed to have come from Aberdeenshire.

Several kaims of granite pebbles and sand on Airlie estate, running N.W. and S.E. (*First Report*, p. 33).

*Liff*.—Several boulders of mica schist, called “*Gows of Gowrie*.” A Druidical circle composed of boulders (*First Report*, p. 34).

*Menmuir*.—Two large granite boulders, each about 35 tons, besides others of smaller size.

*Montrose*.—On Garnock and other hills, striae on rocks point W. by N. obliquely across hill. On Sunnyside Hill, blocks of red shale derived from rocks *in situ* some miles to N.W. (*First Boulder Report*, p. 34).

*Rescobie*.—Mica slate boulder  $13 \times 7 \times 7$ , near top of Pitscandly Hill, lying on drift. Rocks *in situ* are Old Red Sandstone. Late Sir Charles Lyall was of opinion it came from Creigh Hill, about 17 miles W.N.W. Valley of Strathmore lies between boulder and parent rock. There are also several hills higher than boulder between it and parent rock (*First Boulder Report*, p. 34).

*St Vigeans*.—Gneiss boulder now destroyed. Supposed to have come from mountains situated to N.W. If so, it must have crossed several ridges of hills and valleys. Kaim in the parish full of gneiss and granite boulders.

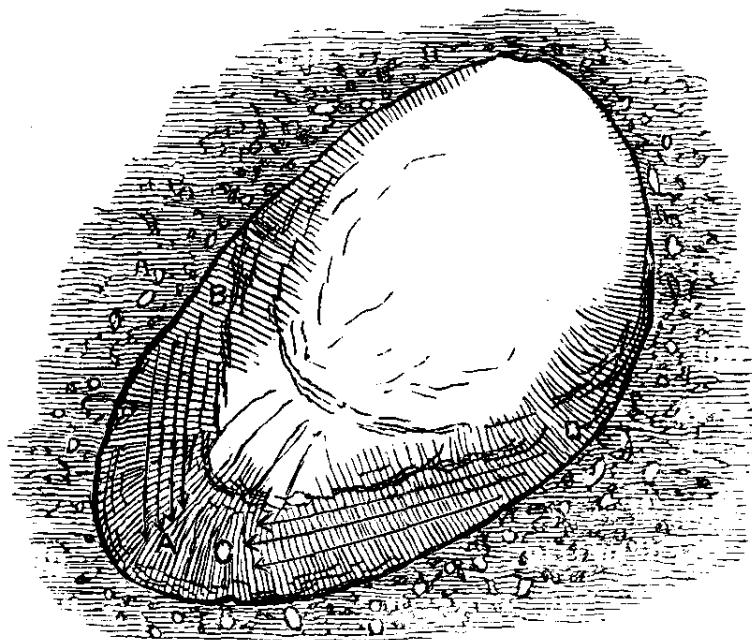
#### HADDINGTONSHIRE.

*Prestonpans*.—A large basaltic boulder on the beach, known to the fishermen by the popular name of “*Johnny Moat*,” in memory of a corpulent member of their class, who had formerly lived in the village. There being no basaltic rocks towards the east, the boulder must have come from the west (*First Report*, p. 18).

*Linton.*—(1) On Drylaw Farm, a limestone boulder  $5\frac{1}{2} \times 3\frac{1}{2} \times 3$  feet, met with in cutting a deep trench through boulder clay. The longer axis N.N.W. The N.W. end more pointed than east end, also well rounded and polished by friction. Boulder tolerably flat on upper side, but no striæ visible. On each of the two sides, meeting at N.W. end, boulder not only smoothed but striated—chiefly along side facing N.N.W.

The nearest rocks of same composition as boulder, are in Garlton Hill, about 6 miles distant, and bearing W. by N. (by compass).

If agent which smoothed and striated the sides of the boulder came, as is probable, from the westward, it seems, when it reached the boulder at A C (its west end), to have divided into two streams,—



Drylaw Boulder.

one, A B, flowing along north side E.N.E., the other, C D, along the south side S.S.E.

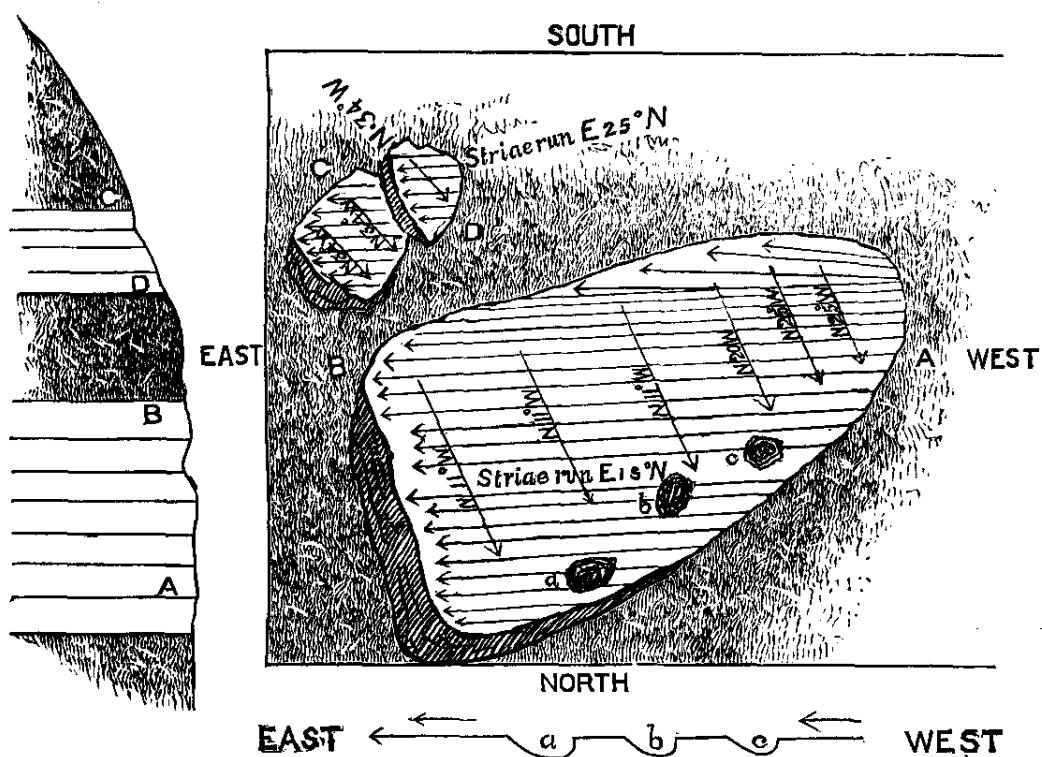
The clay in which the boulder was buried, contained blocks and pebbles, some of them, soft (such as shale, coal, &c., from the west), and others, hard (rock or greenstone, granite, &c.), quite capable of smoothing and striating the boulder, if driven and squeezed against it by some agent of sufficient weight and magnitude.

(2) In the village of Linton, several portions of porphyritic rock recently exposed, which are smoothed and striated. On one portion of rock, the surface of which is horizontal, the direction of striæ is W.N.W. and E.S.E.

On another portion, the surface of which slopes down towards north at an angle of about  $35^\circ$ , the direction of the striæ is due E. and W.

Each set of striæ might be produced by the same agent. If its normal direction was W.N.W., it would, on striking the rock which slopes down north, be deflected into an E. and W. direction.

(3) A still more remarkable case of the same kind occurs in a cutting of the North British Railway, about half a mile to the west of Linton station. The rock is on the south side of the line. The smoothed surface is about 18 feet high and 25 feet in



Striated Rock in Railway Cutting near Linton Station.

length. The surface there slopes down northwards at an angle of from N.  $11^\circ$  W. to N.  $20^\circ$  W. The striæ run across the rocky surface in a direction E.  $15^\circ$  N.—the deflection from the normal direction of the striating agent being greater here than at Linton village, on account of the larger area of the opposing surface.

*It may be added that, whilst in the lower part of the rocky surface, the striæ are horizontal, near the top of the rock they rise up towards the east at an angle of  $4^\circ$  or  $5^\circ$ . If the striating agent consisted of a mass of drift, the pebbles and blocks in the lower part would move horizontally, and produce horizontal striæ. But*

in the upper part of the mass, blocks and pebbles would not have the same weight above them to keep them down, and, in consequence of severe lateral pressure, they would have a tendency to rise.

*North Berwick Law.*—(1) An account was given by Mr David Stevenson, C.E., regarding striations on the rock of this hill. In his paper read to Edinburgh Royal Society, 1st February 1875 (vol. viii. p. 481), he states that the west side of the Law consists of exposed rock, the east side being covered by gravel, clay, and stones.

On a steeply inclined part of the hill, there is a surface of the rock, consisting of felspar porphyry, on which he found smoothings forming a sheet of about 200 feet in length, with occasional deep striae or scorings on it. He says—"The grooving of the surface is very distinctly marked, and must have been done by the passage of some dense but yielding body, which could be moulded to the different irregularities, both vertical and horizontal, on the surface of the hill. The striae must have been made by the passage of sharp-pointed bodies, harder than the felspar porphyry of the Law." "As viewed from a little distance, the scorings appear to be nearly parallel and horizontal; but on examining such as can be reached, I found, on using the clinometer, that this is by no means the case. On one patch of rock I found two striae within 18 inches of each other, the upper of which had a dip of  $4^{\circ}$ , and the lower a dip of  $20^{\circ}$ , and both markings were dipping towards the *west*, being the directions from whence the movement came, as indicated by the '*tail*' on the *eastern* side of the Law. This rise in the direction of motion may have been caused by local pressure, due to the obstruction offered to the passage of the mass by the Law."

Mr Stevenson adds, that "the rock surface discovered by him had been entirely concealed by debris, till it was removed, to allow of the rock being quarried. A similar mass of debris extends along the whole northern and southern faces of the hill, and, if removed, I have no doubt similar markings would be found along both sides."

(2) The Convener of the Committee, thinking that North Berwick Law deserved a farther examination, proceeded to it, and gave the results of his examination in a paper read before the Royal Society of Edinburgh on 7th July 1879 (vol. x. p. 261).

He found that the rock surface described by Mr Stevenson is situated on the N.W. side of the Law, and that the smoothed part slopes down towards the N. and N.W., at an angle of from  $65^{\circ}$  to  $70^{\circ}$ .

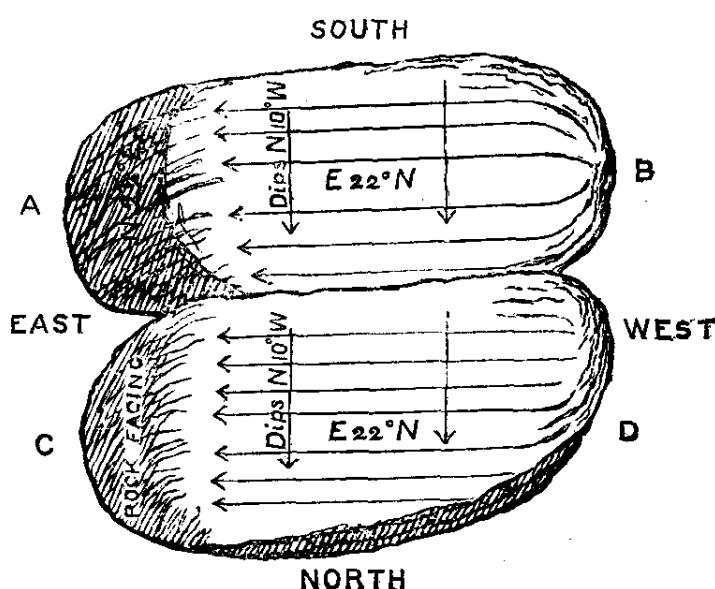
Parts of the smoothed surface face N.W., other parts face due north, and some N. by E.; but wherever the rock faced a more easterly direction, *there was no smoothing*.

The only parts of the smoothed rock surface *striated* were those fronting N.W. by N., or a few degrees on either side of that point.

Their direction is W. by S., or W.S.W.; and most of them are apparently horizontal.

Some of the ruts and striæ, especially at their west ends, are deeply incised in the rock, showing the extreme and continuous pressure which predominated there.

The particular direction in which the striating agent moved, may be inferred, by considering, that if it came in a direction *parallel*



North Berwick Law.

with the rock surface, it might grind or smooth, but would hardly produce ruts or striæ; nor would it have this effect, if it came *against* the rock surface *at right angles*. A line *parallel* with the rock surface, would be S.W., and a line *at right angles* would be about N.N.W. The intermediate point would be W.N.W.;—from which direction therefore, (the Convener inferred) the striating agent moved on and against North Berwick Law.

In the Convener's paper a diagram was given, as shown by the foregoing woodcut, of a well-marked portion of the rock, where it slopes down towards N.  $10^{\circ}$  W. The striations are very distinct, running horizontally, towards E.  $22^{\circ}$  N. But where the rock surface slopes down N.  $23^{\circ}$  E., which it does towards the east, there are no striæ, and the rock is only smoothed.

(3) On the farm of *Kingston*, 2 miles south of North Berwick, the Convener found a small boulder of red granite.

(4) A very large boulder of basalt stands on the beach, near *Tantallon Castle*, which could have come only from the westward.

#### HEBRIDES.

1. *Islay*.—(1) Near Port Askaig, on *Lossit Farm*, four or five boulders of large size. One of these  $13 \times 8 \times 8$  feet, a composite rock, extremely hard, containing crystals of quartz, augite, and hornblende; boulder resting on bed of bright yellow clay; rocks of district a slaty schist. Height above sea 300 feet.

(2) On *Arnahoo Farm*, 3 miles N. of Port Askaig and 228 feet above sea, porphyry boulder stands on summit of hill in a precarious position (pl. iii. fig. 8, in *Fourth Report*, p. 17) (*Lithograph No. 14, Plate VIII*).

This boulder must have come from a direction N. by E., as explained in Report. Mull is in that direction. Boulder is of hard porphyry, quite different from rock of hill.

(3) On *Persibus Farm*, about 3 miles S.W. of Port Askaig, four or five boulders, well rounded; all, a hard porphyritic rock, differing from any Islay rock. Their height above sea 228 feet.

Towards N. by E. an opening among hills, through which these boulders might have been carried on floating ice.

(4) On a hill, 2 miles north of *Persibus*, a boulder  $18 \times 12 \times 1$  feet, differing from adjoining rocks. Height above sea 410 feet. An igneous rock.

(5) On south of turnpike road, between *Bridgend* and *Port Helen*, a large boulder lying at north base of a hill, which probably intercepted it in its progress towards the south.

(5) On west coast, in Kilchrenan parish below old parish church, several boulders, which apparently came from N.W.

2. *Colonsay*.—Notes sent to Committee by Mr Murray of 167 West George Street, Glasgow, and Mr Donald M'Neill, farmer in Colonsay, long resident in the island. The following points are taken from these notes :—

(1) By Mr Murray.—Shores on west side of island thickly strewn with boulders, many resembling yellow Mull granite.

A large boulder on west shore, called “*Fingal's Putting Stone*.”

At Kiloran, on N.W. part of island, there are many boulders.

On several ridges sloping down towards west boulders occur, some above a ton in weight (*Seventh Report*, p. 21).

On west coast there are some granite blocks of a yellowish-red colour, different from any *rocks* seen in Colonsay.

In *Oronsay Island* there are blocks of syenite, which probably may have come from Kiloran Bay in Colonsay, distant 9 miles N.N.W., also grey granite which may have come from Colonsay.

There are fragments of red granite with large crystals;—but no *rocks* of that variety, known in Oronsay or Colonsay.

On east side of Oronsay, boulder of coarse-grained granite, *pinky* in colour, which is supposed to have come from east coast of Colonsay. There are boulders of quartzite, and nodules of chocolate red sandstone—but which cannot be referred to any rocks on either Colonsay or Oronsay (*Ninth Report*, p. 17).

3. *Mull*.—On road to Torloisk from Tobermory, Professor Duns found numerous granite boulders—for most part the reddish variety—others are grey. The largest boulder seen was gneiss. A small quartzite boulder was also seen. All of them are rounded and smooth. Four boulders lie *en trainée*, the line being N. and S.

In approaching west coast of North Mull, boulders decrease in number. The contrast is most striking, as the boulders are very numerous towards east coast. “Has ice, moving from the N.W., begun to drop its entangled boulders near the west coast, and the rate of deposit increased as it passed over the tract between *Runagal* and *Mishnish* and the S.E. of *Glen Frisa*? Be this as it may, there is no doubt as to the numerical increase of the boulders in this direction. They are all much rounded.”

Ascended *Spyon More*, 2435 feet above sea-level. Found a good many boulders scattered over the hill—all, so far as could be ascertained, granites—no granite rock occurring *in situ* in this part

of Mull. "One of the boulders lies on the very top of Spyon More. Another is met with half-way down the hill. The rocks at the summit, are well glaciated ; and a great heap of moraine-like debris rests on it" (*Ninth Report*, p. 27).

4. Iona.—On east coast of island a granite boulder  $24 \times 18 \times 6$  feet, weighing about 190 tons. Longer axis N.W. There are many boulders on E.S.E. side of island, opposite to Ross of Mull, which have led some persons to suggest that these may have been transported across the narrow arm of the sea which divides Mull from Iona. But the Duke of Argyll is quoted as thinking that the Iona granite boulders are a different variety (*First Report*, p. 27).

In Ross of Mull two varieties of granite (red and grey) extensively quarried (*Second Report*, p. 157).

About half a mile north of the large boulder above specified, there is another large red granite boulder about 12 feet square. East end rests on clay slate rocks of Iona. There is a groove (which was seen by Convener) on under surface of boulder, running N.E., indicating that it had been pushed in or from that direction (*Second Report*, p. 157).

To N.E. of Cathedral, along the shore, hundreds of granite boulders (chiefly the red variety) ;—several exceeding 20 tons.

The rocks of Iona are chiefly clay slate. Convener saw no other, and he was told there are no granite rocks.

At the south end of the island, many granite boulders (mostly red, but some also of grey variety) lying on high ground from 200 to 300 feet above sea. One of these seen by Convener, standing upon end, leaning against a rock on its S.W. side, as if it had come from a N.E. direction (*Lithograph No. 15, Plate VIII.*).

Most of the boulders in south end of Iona lie with longer axis N.E. and E.N.E.

Convener heard of a large boulder on west side of island in two fragments, which to his informant had suggested the idea of the boulder having been broken by falling from a height (*Second Report*, p. 155).

The highest hill on island is called "*Dun I.*" On the N.N.W. side of this hill there is a plateau at height of 230 feet above sea. On the plateau, where it joins the hill, there is a large red granite boulder, weighing about 400 tons, cubical in shape, and very

angular,  $22 \times 16 \times 16$  feet, its base resting on the plateau, and its top leaning against side of hill (*Lithograph No. 16, Plate IX.*).

On ascending to summit of hill (which reaches to height of 400 feet above sea) Convener found several boulders of red granite.

Mr Allan M'Donald (schoolmaster) doubts the theory that the red granite boulders on "Dun I" Hill came from the Ross of Mull; —*first*, because the rocks at Ross of Mull do not reach to so high a level as 400 feet; *second*, because, as regards the 400 ton boulder, "Dun I" Hill is situated between it and the Ross of Mull, so that transportation from Ross is hardly conceivable. Ross of Mull bears from boulder S.S.E.

The smooth faces of the rocks in Iona, front N. by E., the rough faces front south (*Second Report*, p. 156).

In a subsequent year (1878) the Convener again visited Iona, and went to look at the large boulder on "Dun I." He then observed that the boulder was composed of coarse-grained red granite—more coarse than the boulders on east side of island previously referred to. The prevailing rocks of Iona are a fine-grained gneiss, approaching in many places to clay slate.

The boulder on "Dun I" Hill seemed to indicate that it had been brought by some agent from a north-westerly point, which agent had stranded on the hill, and stuck there, till boulder dropped from it.

Captain Stewart of Coll was with Convener when latter examined the boulder. On examining the portions broken off, as also another small boulder lying below, exactly similar in composition, Captain Stewart at once exclaimed—"This is *Coll* granite."

In reference to this suggestion, it is to some extent confirmed by the fact, that the island of Coll bears about N.N.W. from Iona, and is distant about 20 miles. But the Convener, having visited Coll a few days afterwards, did not fall in with any *granite rocks* there. They were all gneiss, with only occasional veins of granite. But he did find granite *boulders* in Coll, somewhat similar in composition to the large boulder on "Dun I" (*Fifth Report*, p. 4).

A well rounded boulder of Conglomerate was found by Convener on east coast of Iona. Heard that similar blocks occur on west shore in St Columba's Bay. There are no Conglomerate *rocks* in Iona. The nearest spot is said to be Inch Kenneth Island (on west of Mull), where, according to Macculloch, it forms cliffs about 100 feet high

(*Western Islands*, vol. i. p. 515). Inch Kenneth is about 10 miles N.E. from Iona (*Second Report*, p. 155).

5. Staffa was visited by Convener. He found on it, at his first visit, several small boulders of red granite. There are no rocks of granite on the island. It consists entirely of blue trap (*Second Report*, p. 157).

In a small bay on east side of island, the Convener (on his second visit) found several small boulders of red granite, gneiss, quartzite, and limestone, none of which occur in Staffa *as rocks*.

About 20 yards from this bay, Convener found an old sea-beach 36 feet above high water mark, from the gradual breaking up of which the foregoing boulders are probably derived.

Quotation given from Dr Macculloch to show how perplexed he was to account for the occurrence on Staffa of "transported stones," which, he assumes, must have been carried by natural agency from some of the neighbouring islands (*Fifth Report*, p. 11).

6. Tiree.—(1) *Haynish Hill*, in S.W. end of island, reaches to 600 feet above sea. It consists of gneiss, in some parts passing into granite.

The hill on its west side coincides with sea-cliffs, and has on it a number of rocky knolls. Almost every knoll has on its N.W. side (*i.e.*, facing the Atlantic) boulders more or less rounded. The following are particulars of some :—

Boulder  $11 \times 8 \times 5$  feet resting on side of knoll facing W.N.W.

Boulder  $9 \times 4 \times 5$  feet resting on side of knoll facing W. by N. at height of 360 feet above sea, which is a quarter of a mile distant, with access from the sea between S. and N.N.W. points. This boulder is a coarse granite,—the knoll is gneiss.

Boulder  $8 \times 7 \times 5$  feet resting on side of knoll facing N.W. by N. at height of 365 feet above sea. Sea half a mile distant, and access from it open at any point between S.W. and due north.

Two clusters of large boulders met with, the uppermost on the cluster so posed as to show it must have come from westward. The sea is within half a mile to westward.

On this Haynish Hill boulders more numerous on sides or slopes facing W. and N.W. than on any other. On slopes facing E. and S.E. there are also boulders, but fewer in number.

(2) Passing due north, along *Big Cornish Road*, Convener found on east side of road several rocky knolls, tops of which are from 80 to

110 feet above sea. Most of these knolls present bare rock on west sides, and have boulders on those sides. On one of the knolls a boulder  $10 \times 6 \times 6$  feet, very near its top—a light coloured gneiss. Rock of knoll also gneiss, but dark coloured.

Another rocky knoll, about a mile to N.E. of last, has on it a number of large boulders called "*The Giant's Pebbles*," in reference to a legend that they were thrown by giants from Barra, an island N.W. of Tiree, and distant about 40 miles. There are here from twenty to thirty boulders of all sizes, almost all on the knoll, and none on the adjoining flat land. Suggestion offered, that knoll had intercepted the raft which carried the boulders.

(3) *Ben Gott Hill* forms a rocky ridge running N. and S. about 120 to 130 feet above sea. A very large number of boulders chiefly on its N.W. flanks. Some are on S.E. flanks, possibly pushed over ridge. On flat ground S.E. of ridge, boulders are few in number.

(4) Great beds of sand and shingle in different parts of island, showing that sea had prevailed over it at a comparatively recent period, to a height exceeding 40 feet above present sea-level.

7. *Coll.*—Visited *Bein Hoch*; hill on west side of island, reaching to 290 feet above sea. There are two boulders at top:—one near the summit which slopes down towards N.W., the other on a flat which forms summit of hill (*Lithograph No. 17, Plate IX.*).

Near foot of hill, on its N.W. side, there is a rocky plateau abutting against it, at a height of 80 feet above sea. On this low hill there is a large boulder  $16 \times 20 \times 13$  feet (308 tons).

All these boulders are a coarse granite, passing sometimes into dark coloured gneiss. Rock of hill is gneiss.

The sea (viz., Atlantic) is towards west and north, distant about half a mile.

There can hardly be no doubt, that *these boulders were brought here across the sea.*

(2) At *Grassipol* an immense accumulation of boulders in a meadow, which has a range of vertical rocks on its S.E. side (*Lithograph No. 18, Plate IX.*). These boulders seem to have been intercepted in their farther progress by the rocks on S.E.. Sea is about three-quarters of a mile distant to N.W. One of the boulders is 30 feet high.

On west side of this meadow, a rocky knoll covered by boulders,

about 18 or 20 in number—the uppermost resting on the others in such a way as to show it had come from N.W. (*Lithograph No. 19, Plate IX.*).

Near this knoll, a vein of quartz, smoothed on its edges in such a way as to show smoothing from N.W.

(3) On east side of island, near Arinagour, the boulders few in number and small. Towards the N.W. part of island, when Arniboot schoolhouse is passed, boulders increase in number and size.

(4) At S.W. end of island, there are many large granite boulders near Coll House. Convener measured one and found it  $35 \times 15 \times 8$  feet (312 tons). It was on its S.E. end, leaning on or pressing against a gneiss rock. The granite boulder is of a coarse variety, the fragments composing it being of large size. This was probably the boulder which Captain Stewart was thinking of, when he compared the large Iona boulder to Coll granite.

(5) Macculloch, in his account of the Geology of Coll, refers to a "block of *augite*" which he found at a great distance from the shore, and which he thought must "be a *transported block*," as he had seen no rock of that kind in the island. He says that it probably came from Rum Island, where that rock abounds. Rum is situated N. by E. from Coll, and distant about 20 miles.

Convener omitted to inquire for this augite block.

8. *Eigg*.—Mr M'Pherson, proprietor of the island, drew out for the Committee some valuable notes.

One large boulder rests on the Scoor ridge,—a remarkable ridge of pitchstone porphyry which runs for about 2 miles across the island in an east and west direction. It reaches, at its east end, to a height of 1300 feet above the sea—at its west end, to a height of 900 to 990 feet. It rises from a plateau which is about 400 feet above sea.

Both north and south sides of the Scoor are precipitous, almost vertical, showing a cliff on the north side of 270 feet, on the south side of 400 feet.

The boulder on this ridge is near its western extremity, and on a part of the ridge which is lower than any other part, viz., 890 feet above sea. It is close to top of ridge, and on the slope facing the north.

This boulder is said to be of granite or gneiss—a rock not existing in the island.

Many other boulders of the same kind are strewed over the island.

On N.E. part of island there is a granite boulder of a larger size than any other, and is of a darker colour. It is on the side of a hill sloping down towards S.W., at about 300 feet above sea. Hill itself is about 900 feet above sea. Mr M'Pherson says that he has seen on the shores of Loch Alsh, to the east of Skye, rocks resembling this boulder.

Chips of these Eigg boulders were procured. They were submitted to Professor Geikie. Among the chips he detected one which appeared to him to have come from the Torridon group of Old Red Sandstone, viz., the coast of the mainland to the north-east of Skye.

Professor Geikie, in his account of the Geology of Eigg, advertises to the finding of "pieces of Red Sandstone of Cambrian derivation," which (he says) make it clear that the higher grounds from which they were borne could not have lain to the S. or E. but to the N.W. or N." (*Lond. Geol. Soc. Proc.*, vol. xxvii. p. 309) (*Ninth Report*, p. 22).

9. *Canna*.—Convener told by an experienced contractor for building that he had found on the islet of *Sanda* (forming the south side of Canna harbour) blocks of a red sandstone, which he made use of for the lintels and corners of a new schoolhouse. The largest was  $6 \times 4 \times 2$  feet. These sandstones differ from the rock of the island, which is a blue slaty schist, ill-adapted for building. He knew that these sandstone rocks abound in Rum Island, as he had quarried them there.

Macculloch noticed these red sandstone blocks on Canna, which he says differ from Canna rocks; and he states that similar sandstone rocks occur in Rum and Skye (*Western Highlands*, vol. i. p. 467).

10. *Barra*.—A very large boulder of coarse gneiss approaching to granite exists here near the base of Ben Erival, on its side sloping down to north. The hill reaches to about 600 feet above sea-level. Height of boulder 28 or 26 feet, its extreme length 37 to 38 feet, and its width about 18 feet; assuming 2 tons for one cubic yard, its approximate weight would be 890 tons (*Fifth Report*, p. 12) (*Lithograph No. 20, Plate IX.*).

Convener prevailed on tenant of the hill to dig under the boulder to discover the nature of the materials forming its site. An account

is given on p. 67 of the Report, from which it appears that the materials were gravel and earth, with sea shells. The boulder was evidently not lying on rock.

The supposition of the Convener was, that when brought to its present site it fell on what was then sea-bottom. The site of the boulder is now 230 feet above sea.

A plan is given in the Report, to assist consideration of the question, from what direction the boulder probably came to its present site ;—the result of the Convener's consideration being that it must have come either from the N.W. or the N.E., there being open sea only in these two directions.

About 100 yards to the west of the "*Big Boulder*" there is a rocky isolated knoll, about 255 feet above the sea, clustered with boulders. These are lying partly on rock, partly on shelly gravel, and chiefly on the N.W. side of the knoll. On a study of the positions of the boulders on this knoll, it appeared to Convener that the uppermost boulders to get into their positions must have come from N.W. point.

About 200 yards N.E. of "*Big Boulder*" there is a boulder lying on a smoothed rock surface, which dips due north on an angle of 20°. This boulder is  $5 \times 4 \times 2$  feet. It could not have obtained and retained its position unless by having been brought from the north.

About 300 yards to S.E. of "*Big Boulder*" there is a boulder  $8 \times 6 \times 3$  feet, at height of 228 feet above sea. The boulder at its east end presses closely on rock which has prevented it moving further in an easterly direction (*Lithograph No. 21, Plate IX.*).

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

*Ben More* is a hill on Eoligarry Farm. Its west end forms a steepish sea-cliff rising to a height of 330 feet above sea. Half-way up this sea-cliff there is a boulder,  $20 \times 10 \times 5$  feet, resting on the rocky surface, which here dips W.S.W. But the rock, judging by the marks on it, has been smoothed by something passing over it

from N.W., and the boulder is *blocked at its S.E. end* by a rocky portion of the hill (as shown by *Lithograph No. 22, Plate IX.*).

At *Castle Bay* (at south end of Barra) the hills are covered with boulders, but more on their N.W. slopes than on any other.

Mr Campbell (*Paper on "Glacial Phenomena of Hebrides"*) states that he took rubbings of striæ at Castle Bay, which showed that striating agent had moved from N. by W. (magnetic).

He mentions that on the small island of *Bernera*, about 12 miles south of Barra, he got striæ at a height of 720 feet above sea, crossing the strike of the rocks from N.N.W.

On hill called *Scurrival*, whose west side rises abruptly from sea to height of 240 feet, the hard gneiss rocks show proofs of a grinding action on them from N.W. The strata are horizontal, and form blocks with their longer axis lying about N. and S. The west sides of these blocks facing sea present frequent smoothings, especially at their north ends, whilst the south ends remain rough, showing action on the blocks from N.W.

On this hill the boulders are numerous, and many of them are blocked at their S.E. ends. They are from 200 to 300 yards from the sea, and about 100 or 150 feet above sea-level. The situations and positions of these boulders combine to show that they must have come here from a north-westerly direction.

On the summit of the hill, which consists of well rounded and smoothed surfaces of gneiss, numerous boulders lie scattered, most of them on that part of the top which faces W.N.W.

11. *South Uist*.—Near south end, there is *Carshavaule Hill*, on west side of which is *Loch Dunkellie*. On east bank of loch, a gneiss rock well striated,—the striæ running N.W. by N. At a little distance to S.E., on south of Carshavaule Hill, a valley through which current might have passed, after striating the rock.

*Loch Boisdale*.—On east coast. *Kennet Hill*, situated on north side of loch, presents numerous examples on its west flanks of smoothed surfaces and of large boulders, many of them abutting on rocks at their east ends (see Diagrams in *Fifth Report*, p. 17). One of these boulders is  $19 \times 13 \times 8$  feet, 146 tons (*Lithograph No. 23, Plate IX.*).

At junction of roads from Barra and *Loch Boisdale*, where Roman Catholic and Free Churches are situated, there is a cluster of

boulders. One  $16 \times 6 \times 5$  feet, leaning on the others, must have come from N.W. to attain its position.

On hill to east of *Askernish*, and on *Mingary Hill*, there are many large boulders, chiefly on west flanks, as also striated rocks, well deserving of study (*Lithograph No. 24, Plate IX.*).

About 3 miles to north of Askernish there is a block of granite perched on the pointed summit of a rocky hill. The boulder is  $14 \times 12 \times 8$  feet (about 100 tons) (*Lithograph No. 25, Plate IX.*). There is no way in which it could have attained its position except by floating ice.

At *Jocdar*,  $1\frac{1}{2}$  miles south of ferry between Uist and Benbecula, there are smoothed rocks "literally covered by parallel striæ, ruts, and grooves," the direction of which is N.W. by W. The smoothed surface of the rocks here slopes down to westward, at an angle of about  $10^\circ$  or  $12^\circ$ . Some of the ruts are 4 or 5 feet long. One at its N.W. end measures 8 inches across and 2 inches in depth; another 12 inches across and  $1\frac{1}{2}$  inch deep. Towards the S.E. they lessen in width and depth. There can be no doubt that the striating agent here came from N.W. The height of this place is about 25 feet above the sea—the Atlantic—and  $\frac{1}{4}$  of a mile distant.

There is a similar good example of striated rocks about half a mile to the west of the above mentioned ferry (*Lithograph No. 26, Plate X.*).

On road between *Grogary* (mansion-house of Lady Gordon Cathcart) and *Loch Skipport* (on east coast) there are many striking examples of striated rocks and boulders.

*Loch Eport* is a remarkably narrow area of the sea on the east coast, which runs more than half-way across North Uist. From deck of steamboat Convener saw, on both sides of Loch, many boulders, resting chiefly on rocky knolls, and many rocks with faces smoothed on west sides.

*North Uist*.—*Loch Maddy*, a sea-loch on east coast. An hour's walk for about a mile from the shore, showed Convener that rocks here have their smoothest sides facing N.W. (*Fifth Report*, p. 22).

Professor Heddle, in a subsequent year, visited *Loch Maddy*, and reported that rocks there generally showed smoothings by some agent passing over them from the westward.

He refers also to two islets of trap rock called *Maddy More* and *Maddy Beg*, which are (as he says) "porpoise-nosed to the west, and

cliffs to the *east*," as indicating probably the direction of the agent which flowed over them.

Professor Heddle on this occasion, at Loch Maddy, met a gentleman, a member of the Glasgow Geological Society, who had just returned from Newton on the coast of North Uist. He described to the Professor a boulder he had seen there,  $13 \times 5 \times 4$  feet, and another  $9 \times 5 \times 5$  feet. The former lay with its longer axis N.N.W. He stated also that the rocks on the west shore were generally glaciated, and from points between N.W. and S.W. (*Sixth Report*, p. 34).

On *Canneum*, a rocky islet north of Loch Maddy, there are two boulders of Laurentian gneiss, weighing, the one about 15, the other about 50, tons. From the corresponding slopes of the two ends which face each other, it has been inferred that they were originally one boulder, though now about 100 feet apart from one another, and with a projecting rocky knoll between them. The reporter, Alex. Carmichael, suggested that the boulder may have fallen from a height on this rock, and been broken into two fragments (*First Report*, p. 35).

*Harris*.—(1) At *Rodil* (south end of Harris), rocks on Strondavelhill smooth on west faces, rough on east faces.

(2) At *Borve*, on west coast, a remarkable assemblage of boulders on hill about 800 feet high, sloping down to W. by N., close to shore of the Atlantic (*Lithograph No. 27, Plate IX.*). The boulders lie on and against benches of gneiss rocks, these rocks also being smoothed and ground down from westward. These boulders lie in such a way as to show they have come from westward (*Fifth Report*, p. 23).

(3) Similar appearances in *Loch Castle Bay and Valley*.

(4) About  $1\frac{1}{2}$  mile south of Tarbert, several large boulders, which probably reached their positions by coming through depressions existing in the range of hills to N.W.

(5) On hills north of Tarbert, up to height of 800 feet above sea-level, Convener saw many evidences of a N.W. current loaded with ice, which has brought boulders and smoothed the rocks (*Fifth Report*, p. 26, plate viii. fig. 28).

Professor Heddle separately visited Tarbert, and specifies certain hornblendic boulders, which he traced to a rock identical in character a few hundred yards to westward (*Sixth Report*, p. 35).

(6) At *Fincastle*, on shore west of Loch Tarbert, Convener found boulder so situated as to indicate transport from N.W.

(7) *Scalpa Island*.—Three granite boulders found by Professor Heddle (*Lithograph* No. 28, Plate IX.), one of them “*butted up*” against a knoll of gneiss rock (see plate xviii. fig. 6, in *Sixth Report*, and p. 35).

On faces of hill on Harris shore, opposite Scalpa, a great bed of granite, from which Scalpa boulders probably came.

(8) *Shiant Islands*.—On western shores Professor Heddle found several blocks of rocks foreign to the islands, and occurring *in situ* in the Long Island to the west. Some Conglomerate boulders he considered had come from Stornoway, 30 miles to north, the nearest place for Conglomerate rocks (*Sixth Report*, p. 36).

Boulders of trap on eastern shores of the islands supposed to have been pushed from rocks on west side of the islands (*Transactions of Norfolk and Norwich Naturalists' Society*, vol. iii., 27th Jan. 1880).

12. *Lewis*.—Professor Heddle examined the district between Tarbert in Harris and Stornoway on foot, a distance of 28 miles. He was struck with the general flatness of the district, especially in its northern part, considering that the rocks there come generally to the surface, and are on edge. They suggested the idea of some great abrading agent which had passed over the district (*Eighth Report*, p. 29).

(1) Near *Ardvourlie*, on Loch Seaforth, a *trainée* of boulders, forming a line E. by N. and W. by S., apparently traceable to gap in chain of hills to S.W.

Clusters of boulders seen there, so piled on one another as to show that the topmost had come from westward.

(2) At and near *Soval*, 12 miles south of Stornoway, rocks forming cliffs, smooth on sides facing west, rough on sides facing east.

On one of these cliffs facing the west there is a boulder on edge of rocky cliff, which there forms a surface sloping down towards W.N.W. at an angle of from 20° to 30°. Longer axis of boulder W.N.W. Seemed to Convener clearly to have come from westward (*Sketch in Fifth Report*, plate viii. fig. 29).

(3) *Lochs Ourn and Shiel*, on east coast. Boulders seen by Convener on hills adjoining, positions of which all indicated transport from west.

(4) *Uig*, on west coast. Rocks near road at two spots, smoothed

and striated from W.N.W. Ruts deeper at west ends than at east ends (*Fifth Report*, p. 28).

(5) *Miavig*, an arm of sea branching up from Loch Roag on *west* coast. On top of a hill called *Dramainan Voltas*, 270 feet above sea, there is an immense assemblage of boulders, chiefly on north and west slopes (*Lithograph No. 29, Plate X.*) (*Fifth Report*, p. 29).

(6) *Garry-na-hine* to *Carlowrie*. Rocks along and near road, show smooth faces towards west. At low levels they vary in their aspects, as W.;—W. by S.;—and even W.S.W. But at higher levels, viz., above 300 feet, the smoothed faces are pretty uniformly towards W.N.W. (*Fifth Report*, p. 30).

The explanation of this seemed to be that the rocks at high levels were exposed to a normal current from N.W., whilst rocks at low levels were exposed to diverging and eddying currents.

Convener examined particularly striated rocks described by Dr James Geikie (*Lond. Geol. Journal* for 1873, p. 537), who expressed an opinion that the striæ had been formed by a glacier which moved across the slope of the rocks from the S.E. The Convener, after twice examining these rocks, was of opinion that the striæ had been formed by some agent passing from the N.W., inasmuch as individual striæ were most deeply cut at their N.W. ends (see sketches in *Fifth Report*, p. 30, and plate viii. fig. 32).

Boulders seen leaning against rocks on their east sides, as if thereby stopped in their progress eastwards.

(7) *Beinn-a-Bhune*, a hill about 400 feet above sea, mentioned by Dr Geikie. Rocks seen by Convener smoothed, and boulders so situated as to show probable movement from W.N.W.

(8) *Barvas Hills*, 800 to 900 feet high, 5 miles north of Stornoway, examined by Convener, who found on them smoothed rock, and boulders indicating movement from N. and N.W.

(9) In *district* between *Barvas Hills* and *sea-coast* to north there are long lines of escars, composed chiefly of coarse gravel, with boulders lying occasionally on their ridges; these boulders in many places piled on one another, and in such a way as to show transport from N.W.

Several of these escars run for miles continuously, and reach to the north coast, following a direction generally N.W., with occasional deflections.

When viewed from top of Barvas Hills they form a striking feature, as the bright green of the grass covering them contrasts with the dark brown or black colour of the widespread muirs which they traverse.

These escars reach to a height of from 30 to 50 feet above the adjoining flat ground. At one place (about 2 miles north of Barvas Hills) an escar expands and divides into a series of knolls, on which many boulders now rest. The highest knolls have on them the greatest number of boulders. At two places the boulders form groups, piled on one another. They had formed (as was mentioned by a shepherd) hiding places in times of trouble. Most of the boulders on these escars show transport from N.W., but some indicate a transport from W.S.W.; one from N.N.E.

In this part of the island there are numerous lakelets, whose longer axis is generally parallel with the lines of escar,—a fact all the more remarkable, as the outcrops of the gneiss rocks generally form lines in the direction of N.E. and S.W. and dipping S.E.

Dr Geikie was much struck with this fact, and expressed an opinion that the formation of the escars and of these lakelets must be due to one and the same agency, viz., a glacier or ice-sheet, which came across the "*Minch*" from Ross-shire.

(10) Along coast from *Barvas*, eastward, boulders of granite, differing from any rocks near them, and alleged by a local mason seen by Convener to be same as rocks 7 or 8 miles to westward.

A great monolith here, 18 feet 9 inches high and with a girth of 16 feet, called "*Clachan Treudach*" or "*Gathering Stone*."

(11) *Dalbeag Hills*, about 9 miles west of Barvas. Smoothed rocks and boulders indicating movement from westward.

(12) At *Tolsta* (12 miles N.E. of Stornoway) a boulder  $18 \times 5 \times 4$  feet, and 358 feet above sea, called the "*Rocking Stone*." Rocked when Convener lifted it, or when he rested his weight on it, at either end of its longer axis. Its central part rests on bare smooth gneiss rock. Its longer axis points N.N.W. It is well surrounded by high hills;—but towards N.W. there is an opening in the range of hills through which boulder might have come (*Fifth Report*, p. 31).

(13) *Eye Peninsula* to east of Stornoway, where rocks are Old Red Sandstone. Boulders of gneiss occur there, which almost certainly must have come from Barvas Hills, situated about 7 miles to N.W.

(14) On *Eye Peninsula* a brickwork of boulder clay, in which, at a height of about 200 feet above sea, fragments of marine shells seen by Convener.

Dr Geikie mentions those, and states that similar shells were found by him in a deposit stretching across the north part of the Lewis, from shore to shore (*Fifth Report*, p. 36).

(15) With reference to the above-mentioned group of islands, sometimes called the Long Island, remarks of a general character may not be inappropriate.

Mr J. F. Campbell (formerly of Islay), author of *Frost and Fire*, wrote as follows to the Convener :—

“In the Long Island, from Barra Head to the Butt of Lewis, the whole country is glaciated, with boulders everywhere perched on the hills. Wherever the surface is newly exposed, the striations and smoothings are so perfect that the marks can be copied as ‘Brasses’ are copied.”

In a letter from the same gentleman to Mr Alex. Carmichael of the Inland Revenue, a native of the Hebrides, the former remarks :—“Glacial striæ occur upon fixed rocks in Tiree, Mingley, Barra, South and North Uist, and correspond with a direction from N.W. or thereabouts. The hills are ice-worn to the very tops. Transported blocks are scattered over all these islands.”

13. *Skye*.—The Convener regrets that the Committee received no report from this island ; nor had he an opportunity of visiting it himself, except at one spot, viz., *Loch Scavaig*, on the west coast, where the steamboat stops for an hour to allow passengers to see *Coriusk*. The Convener then saw and examined a large boulder (*Lithograph No. 30, Plate X.*). Its position, on a rock between the sea and the adjoining lake, is described on page 66, *Sixth Report*. The rock on which it stands slopes steeply towards W. by N., and it is in so precarious a position that it must have been very gently let down by the agent, whatever it was, which transported it.

Professor Heddle reported that in the year 1879 he walked along N.E. part of Skye from Aird Point to Portree, and partially among the hills, but saw no boulders.

He visited Stainchol Island, situated off the east coast, and found Cambrian Conglomerate blocks, similar to what he had seen on the Shiant Islands, and similar also to the rocks existing in the Lewis,

near Stornoway. On Stainchol shore the Professor found dolerite boulder containing Labradorite. He states that the parent rock is situated about fifty yards to N.N.W. (*Sixth Report*, p. 38).

Judging from what is casually said by Dr Macculloch and Principal James Forbes, regarding boulders in Skye, they must be numerous and interesting. Thus Forbes refers to boulders "*poised upon others, or fantastically balanced on the tops of elliptical domes of rocks;*" and Macculloch says that the summits (on which some of the boulders stand) are not only bare, but often very narrow, while their declivities are steep, and sometimes perpendicular. Macculloch confesses his inability to explain these phenomena.

#### INVERNESS-SHIRE.

*Loch Nevis*, on west coast. Several large boulders of coarse-grained granite seen near Inverie House, lying on slate rocks.

On road towards Gussern, several boulders of interest pointed out to Convener by late Mr James Baird, the proprietor.

At height of 360 feet above sea, and near sea-shore, rocks smoothed and striated from N.W. by W.

Two large boulders lie on side of a hill, which slopes down to the W.N.W. One of these, of elongated shape, has its longer axis N.W. and S.E.

A large boulder, consisting of two fragments, pointed out by Mr Baird, in consequence of his believing that the boulder had been broken by falling from a height, and striking on the bare rock, where these fragments now lie. The two fragments are four or five feet apart. Whilst the opposing surfaces correspond in shape, they are so weathered, as to show that the fracture was not of recent date.

At summit level between Inverie and Gussern, there is a horizontal terrace, facing the sea, and at from 400 to 500 feet above sea, with a number of boulders on it.

At Invergussern, lower part of valley blocked by a huge gravel ridge, now cut through by river, quite in the position of a terminal moraine. But, being composed of nearly horizontal beds of gravel and sand, from 40 to 50 feet deep, more probable that it is a sea deposit, and that it for some time confined a lake; for on the sides of valley horizontal water-lines occur (*Second Report*, p. 164).

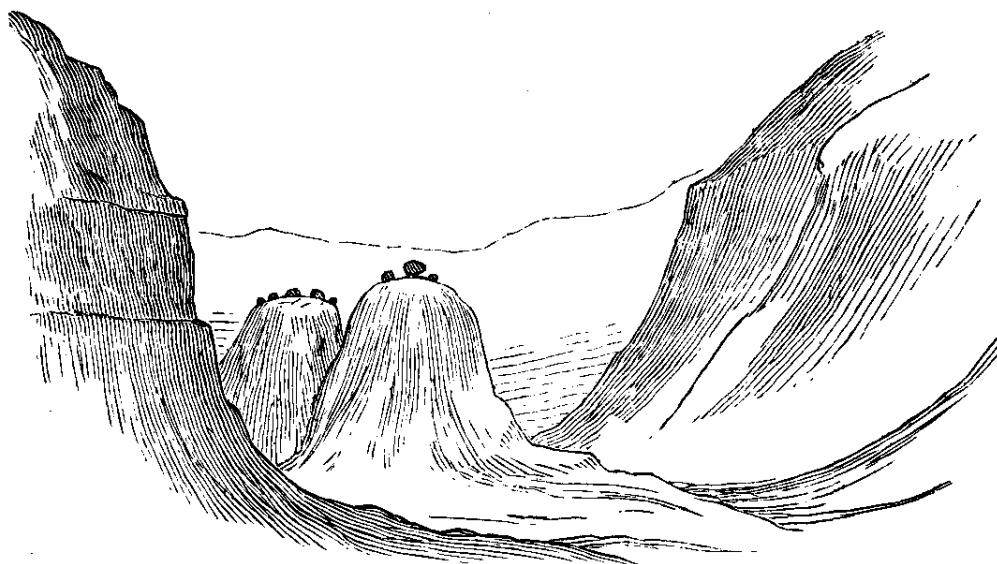
2. *Loch Corry*, near Morvern, has its rocky shores well glaciated. A large knoll of red granite, at mouth of loch, has had its W.N.W. sides rounded, and partly striated up to 150 feet. The S.E. side of knoll rough and craggy (*Eighth Report*, p. 29).

On north shore there is an angular block  $27 \times 27 \times 11$  feet, apparently moved 28 yards from a rocky cliff situated to N.W., of which it had been part. The hills on the Glen Sanda property, reaching to a height of 1800 feet and more, are glaciated to their very tops.

3. On *Loch Shiel*, several similar cases of large blocks (from 1 to 10 tons weight) apparently forced from rocky cliffs and carried eastwards.

White granite vein or dyke met with near top of hill, 2718 feet above sea, from outcrop of which, blocks detached, and carried eastward nearly one-third of a mile.

4. In *Glen Oban*, remarkable examples of rounded rock-surfaces, some more than 100 feet high; also of "perched boulders," on isolated rocky knolls, each from 300 to 400 feet high, and inaccessible, as shown in woodcut annexed.



Glen Oban, showing Perched Boulders.

5. *Mid Lochaber*.—Memoir by Rev. Professor Duns, on Surface-Geology of, and particularly on the boulders found to N. and W. of Ben Nevis. The Professor says—"Granite boulders are lying on the mica schist rocks, where the side of the mountain slopes down so steeply as to make it a puzzle to understand how they can remain in position."

The author expresses belief that the phenomena may find explanation in the recognition of two movements,—one outward from Ben Nevis as a centre, the other a force travelling from the W.N.W. or N.N.W. (*Eighth Report*, p. 21).

*Notes* on boulders, situated to the *west* of *Fort-William*, by Mr Colin Livingston, teacher of public school, Fort-William.

The author enumerates boulders and striated rocks on west side of Ben Nevis, and expresses a confident opinion that two glaciers existed, the one descending Glen Nevis, the other Glen Spean and Glen More.

He refers to immense mounds and ridges of detrital matter, (having an imperfect stratification) towards Inverlochy and Torlundy, —such as might have been produced, if it fell from some height (*Eighth Report*, pp. 23, 27).

6. Since the time when Mr Livingstone's Notes (given in the Eighth Report) were framed, he has made a further inspection of the hills to the W. and S.W. of Ben Nevis, and has communicated to Convener the following additional facts:—

*Stob Ban*, reaching a height of 3274 feet above sea, is situated west of Glen Nevis. It is composed of quartzite, which accounts for its Gaelic name of *White Pin*. Boulders of this rock are found to the eastward, on various parts of the west slopes of Ben Nevis.

Another hill of interest is “*Mulloch-Nan-Coirean*,” 3077 feet, having a rounded top of red granite. On its top there is a slab of mica slate. How it came there, Mr Livingstone says is a mystery. He admits that mica slate rock exists in large quantities towards *Sghor Challum*, a hill 1823 feet, situated to the *west*. But he sees the difficulty of conceiving that any *glacier* could have brought it.

On the same hill there are boulders of micaceous gneiss and quartz. The quartz boulders, he says, may have come from *Stob Ban*; the birthplace of the gneiss boulders is (he says) uncertain.

7. Notes on *Ben Nevis* and *Craig Dhu*, by Professor Heddle of St Andrews, were sent to Committee. He expresses an opinion that a glacier swept down Glen Nevis, even overtopping a hill of 3077 feet. He also suggested the probable existence of another vast glacier cradled in the gorges between Aonach Beg and Aonach Mor.

8. *Ben Nevis*.—Convener ascended to top, by a path leading up the N.W. side of hill. Enormous boulders of grey granite lie on N.W. slopes. A few on each side of path were measured, and gave

the following results:— $16 \times 10 \times 10$  feet (118 tons) (partially sunk in gravel);  $15 \times 7 \times 5$  feet (lying on bare rock);  $13 \times 7 \times 4$  feet; one nearly cubical, the sides being each about 4 feet square. The first three have longer axis N.W. They are from 900 to 1200 feet above sea. But there are some, up to 2000 feet above sea. Mr Doig, builder, Fort-William, who accompanied Convener, mentioned that there had been one boulder at the foot of mountain, on its N.W. side, so large as to afford materials for building the entire front wall of the Town Hospital of Fort-William.

Mr Doig stated that he considered that the boulders on west flank of the mountain were generally different from Ben Nevis rocks (*Fifth Report*, p. 65).

9. On *Treshlik Hill*, 1566 above sea, on north side of Linnhe Loch (opposite to Fort-William), Convener, under guidance of Mr Livingstone, inspected a coarse-grained granite block, 8 feet high, 52 feet below summit, on west slope of hill. This hill forms a ridge about half a mile long, running W.S.W. Rocks *in situ* are clay slate. Boulder must have been transported from some westerly point, and put down very gently, as slope exceedingly steep where boulder rests (*Lithograph No. 31, Plate X.*) (*Second Report*, p. 161).

Rocks on north and west sides of hill near top are well smoothed; rocks on S. E. side of hill are rough. The smoothed rocks are chiefly on a space along north side of hill, from 30 to 60 feet below summit. Many coarse-grained granite blocks, and water-worn pebbles, lie along north face of hill near the top.

10. *Boleskien, Abertarff, and Dores*.—Well rounded granite boulders of red and grey varieties occur over district of Stratherrick. One above ground measured  $20 \times 10 \times 7$  feet, and there seemed to be as much below. Its longer axis N. and S. Another at Fall of Foyers measured (above ground)  $12 \times 6 \times 6$  feet.

Several are *poised on tops of isolated hills*. Highest hills in this district about 2900 feet above sea. Boulders are chiefly above the level of 2350 feet. Below this level they are generally of a smaller size. Reported by Captain White, R.E. (*Second Report*, p. 137).

11. *Lochaber*.—In this district one of the most interesting hills is *Glen Dhu* 2200 feet, between Glen Roy and Glen Spean. Professor Heddle, having visited it, expressed an opinion that the large

boulders on and near the top had come from a S.S.E. direction (*Eighth Report*, p. 37).

As other geologists have visited this hill, and recorded views which contain further information, it is right to refer to them. Thus Mr Jamieson of Ellon mentions having seen several large boulders of syenitic granite on or near the top of *Craig Dhu*, a gneiss hill, at a height of 2100 feet above sea. He says—"What is remarkable is, that the largest and most angular are more numerous high up on the very brow of the hill than further down. Thus" (he says), "one  $12 \times 9 \times 6$  feet lay only 130 feet below the summit; another was a magnificent block,  $15 \times 10 \times 6$  feet" (*L. G. S. J.*, vol. xvii. p. 175).

The late Professor Nicol of Aberdeen, well known as a geologist, refers to the *Craig Dhu* boulders in these terms:—

"I found huge blocks of black granite and smaller masses of red porphyry within a few yards of the *summit* of *Craig Dhu*, a conical mountain of mica slate. One block must weigh 40 tons. They are evidently ice-borne, probably floated from the N.W." (*Lond. Geol. Soc. Proc.*, August 1869, p. 283).

The Convener visited *Craig Dhu*, and noted the following points:—(1) The boulders on the hill, in so far as not of a round shape, have their longer axis E. and W. A little above 1391 feet level, found boulder on bare rock, which here forms a flat surface, glaciated like the rest from W. by N. The boulder must have come after glaciation of rocks. Looking towards west, saw a line in that direction clearing all the hills, showing an opening for a movement from west towards and upon *Craig Dhu*. Masses of white quartz rock were found glaciated from west. A boulder near top of the hill, with longer axis W. by S. (*Edin. Roy. Soc. Trans.*, vol. xxvii. p. 641).

Mr Jamieson refers to a granite boulder on the *top* of *Bohun-tine*, a hill 2000 feet high, not far from *Craig Dhu* (*Eighth Report*, p. 639.)

Mr Jamieson, in describing smoothings and scorings of the rocks at *Loch Treig*, up to 1280 feet, states that he found "*perched boulders*" and rounded surfaces of rock much higher, and even up to the top (about 3155 feet above the sea). The gneiss, though it runs in nearly vertical stratifications, is neverthe-

less so free from any loose fragments on its surface, and the ends of the strata are often so rounded in outline as “to raise a suspicion that some *denuding agent had flowed over it*, at a period geologically recent” (*Lond. Geol. Soc. Proc.*, vol. xviii. p. 172).

The following cases of boulders were reported by the Convener :—

On the summit of the hills, at the head of *Glen Roy* (1320 feet above the sea), there are enormous granite boulders. “Some rest on bare rock, but traces of clay and gravel in their vicinity suggest that they may originally have been embedded in drift, which has been since mostly washed away from under and about them” (*Edin. Roy. Soc. Trans.*, vol. xxvii. p. 639).

The late Charles Darwin, who visited Lochaber, and wrote an instructive memoir on the “Parallel Roads” question, refers to the *Ben Erin* hills,—their height reaching to 1600 feet above the sea. He says that “on the mountains between Glen Roy and Glen Glouy, on a hillock N.N.W. of the summit of Ben Erin, I found several masses of *granite*, one of which was  $4 \times 3 \times 2$  feet, resting on the surface of the *gneiss*. This hillock seemed to be entirely composed of the latter rock, and it was separated from all other hills by a valley. On the flanks of Ben Erin, at about the same level, there were several boulders of granite.”—“With respect to these Ben Erin boulders, they are completely cut off from every granite district by valleys, the *highest point of which* is 920 feet *below a boulder*, the altitude of which I measured; that is, it would be impossible to walk from granite *in situ*, to these boulders, without ascending at least that number of feet” (Darwin, “On the Parallel Roads of Glen Roy,” *Phil. Trans. of Roy. Soc. of London*, for 1839, page 69).

Sir John Ramsden of Ardverikie (on Loch Laggan) informed Convener that on *the top of two contiguous hills*, forming part of his estate, east of Loch Laggan (one of these hills exceeding 3000 feet in height), there are large granite boulders.

Sir John Ramsden guided the Convener to the *Wester Beinin Hill* (situated on the west side of Loch Laggan) to see several *grey* granite boulders. The rocks of the hill are *red* granite. One of the boulders is on a shelf about 1516 feet above the sea, on the side of a hill sloping down to W.S.W.

Facts bearing on the *direction* of boulder transport in Lochaber have been noticed by several geologists. Thus, Mr Jamieson mentions that on the hilly ridge between Glen Spean and Glen

Gluoy the direction of the striæ at a height of 800 or 900 feet above the sea is from W.  $20^{\circ}$  N. to W.  $40^{\circ}$  N.; and as "the western sides of the rocks were most worn, the action had come from that side" (*Lond. Geol. Soc. Journ.*, 21st January 1863, p. 246).

In Glen Roy (at about 1200 feet above the sea) he found, much to his surprise, that "ice had come from the S.W. *up the glen*, and had gone out in a wide stream, towards the wide valley of the Spey," viz., eastward.

11. *Black Mount district, near Rannoch.*—Boulders of a peculiar white granite, found by Professor Heddle, forming a *trainée*. He investigated from what hills they came, and traced them to Alban-nach Hill, reaching to a height of 3425 feet above the sea, and situated about 10 miles N.W. from Loch Tulla.

Reference is made by the Professor to an enormous boulder weighing about 1900 tons, in a narrow part of a valley at Loch Dochart, where traces were seen of some very "powerful agent" which had passed through the valley eastward.

12. In the *Fourth Boulder Report* (p. 14) an account is given of the *Fassnacloich* boulders, a species of black granite. Specimens were sent to Mr Judd of London, on account of his personal knowledge of rocks in the West Highlands. His opinion was that the rock of the boulder was identical with rocks in Mull and Ardnamurchan, from which district, therefore, he supposed the boulders may probably have been transported.

On the shore of the Linnhe Loch, *at Appin*, there are two huge well-rounded boulders of the same kind of granite. Their position favours Mr Judd's suggestion, that all these boulders had been transported from the westward.

The granite boulders on the top of *Craig Dhu*, already mentioned in Lochaber, are of a dark colour. Is it possible that the mountains of Mull and Ardnamurchan could have supplied all these boulders when the sea stood 2000 feet or more above its present level? (*Fourth Report*, p. 45).

12½. *Ardgour district, on north side of Linnhe Loch.*—Professor Heddle of St Andrews, in *Seventh Report*, p. 36, states that on *Stob Choire a Chearchaill* he found a *trainée* of boulders lying along the ridge for nearly a mile, at heights varying from 2400 to 1800 feet above the sea. The direction of the *trainée* was N.N.W.

Most of these boulders consisted of syenite, with red felspar crystals

and green hornblende. Thinking that these boulders might also be found on the south side of the Linnhe Loch, he crossed, and on two hills there, viz., *Bein Bhan*, at a height of 1500 feet, and on *Beinn na Gucaig*, at a height of 2017 feet, he found boulders of the same syenite as he had found on the north side of the loch.

In the *Eighth Report* (p. 33) Professor Heddle mentions his discovery of more boulders of the same peculiar syenite, as seen by him on hills nearer Ben Nevis and on Ben Nevis itself, at an altitude of 2200 feet. This discovery led him to change his opinion as to the direction of the transport of these boulders.

13. *Loch Creran*.—The boulders there were examined by Professor Heddle. He was much puzzled to explain from what district they came. There were striæ on the rocks of the hills adjoining, at heights exceeding 2000 feet above the sea. He was inclined to think that the boulders had crossed the Linnhe Loch from Loch Sunart and Glen Tarbert.

On some of the hills of this district boulders were discovered at heights exceeding 2000 feet, which Professor Heddle was satisfied must have crossed valleys to reach their positions, and by means of floating ice (*Sixth Report*, p. 43).

14. *Glencoe District*.—On the western slopes of a hill, in the higher part of Glencoe, near Loch Tulla, boulders of a peculiar white granite were found by Professor Heddle. They were different from the adjoining rocks. He already knew that the rocks in the hills to the eastward were also different; so, in expectation of finding the parent rocks, a search towards the west was commenced. On reaching the *Aonach-Eagach* range of hills the same kind of boulders were seen, fewer in number, but larger in size. They were lying chiefly on the eastern side of the narrow ridge leading up to the summit of the nameless peak marked 2938 feet on the 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 *Meal Dearg* (3090 feet), and almost up to the summit of the western peak (3118 feet). “Their position,” adds Professor Heddle, was most peculiar. They lay on 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 boulder lay on the west slopes” (*Sixth Report*, p. 44). “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 difficult, if not impossible, to adopt for them the explanation of any local glacier" (*Sixth Report*, p. 46).

In the following year, Professor Heddle returned to the Rannoch district, to search for any farther traces of this stream of white granite boulders. To the S.E. of Loch Rannoch he found two hills, *Gea Charn* and *Creag Mhor* (2595 and 2250 feet), forming a sort of ridge running nearly N. and S., and so situated as to cross what might have been the line of stream. Two boulders found, each weighing about 7 tons, very similar in colour and composition to Loch Tulla boulders. He next proceeded to Schehallion, situated about 3 miles farther east, and found on its western slope, about 140 feet below the summit, *i.e.*, 3407 feet above the sea, a boulder of the Loch Tulla group, about three-quarters of a ton in weight.

Reference is made to other geologists who had previously found boulders on Schehallion, near its top—one being Robert Chambers, who concluded from the striations on the rocks of Schehallion, that the stream which brought the boulders had flowed from W. 30° N. (*Seventh Boulder Report*, p. 34).

Convener passed through *Glencoe Valley* thrice, the last time on foot, beginning near the upper end. He was impressed with the belief from what he saw, that *ice had passed down* the glen, smoothing the rocks along bottom, and so far up each of the sides,—and carrying blocks of these rocks for some distance *down* the valley. On the other hand, it appeared to him that blocks of rocks foreign to the valley had *come up* the valley at a subsequent period,—brought therefore, by the action of floating ice. One of these, a huge mass of Conglomerate, was resting on a terrace of *gravel*; and above the gravel there were, on the hillsides adjoining, "extensive beds of *sand*," reaching to heights exceeding 2000 feet above the sea. Besides this Conglomerate boulder, there were granite boulders in such positions as to show that *they also had come up the glen*. The Convener concluded that the glen had first been occupied by a glacier; and that at a later period the land sank to more than 2000 feet below its present level, which would allow floating ice to pass over the Glencoe Hills, and to deposit on them some of the boulders they might be carrying (*Fifth Report*, pp. 52, 53) (*Lithograph No. 33, Plate X.*).

15. *Kilmallie*.—One boulder, 12 × 10 feet, fully 2000 feet above

sea, on *summit* of a hill. Another, larger, between Loch Shiel and Loch Askaig (*First Report*, p. 38).

16. *Fort Augustus*.—About 2 miles to S.W. of the town, on Corryarrick road, a boulder of grey gneiss, on a steep bank of gravel at base of a buff-coloured felspathic rock. As the hill-slope faces N.W., boulder seemed to have come from that quarter. It happens to be exactly at same height above Loch Ness (207 feet) as boulder seen to the east of Urquhart (*Fifth Report*, p. 64).

17. *Strathglass and Glen Urquhart* (north of Loch Ness).\*—  
(1) On hill above *Affric Hotel*, on east side of river Cannich, at height of about 720 feet above sea, rock planed and striated, the striae running N. by W. coinciding with direction of valley.

At height of 970 feet above sea, a granite boulder lying on up-turned edges of gneiss rock—its position indicating that it had come from W. by N. (*Fifth Report*, p. 63).

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

(2) On public road to Urquhart, a few miles from Affric Hotel, rocks on south side of road ground down and striated, in a line about E. and W., *i.e.*, parallel with axis of main valley.

At top of hill, about 660 feet above sea, several boulders found, resting on a bed of sandy clay, and on a slope of hill facing W. by S. The west sides of boulders chiefly rounded, as if worn by friction of bodies passing over them from west.

All the rocks exposed show smoothings on sides facing west, as far up as hill reaches, viz., 927 feet above sea.

(3) Whole of Glen Urquhart indicates, by quantity of gravel and sand on both sides, that it has formerly been choked by drift, which cut through and scoured out by the river.

(4) On north bank of Loch Ness, half a mile east of Urquhart, many conglomerate boulders lie on hill sloping towards Loch Ness, from 200 feet up to 800 feet above Loch Ness. Rocks of hill here are gneiss; Mealfourvonie hill, situated some miles to west, consists of Conglomerate rock.

\* Convener made this excursion accompanied by Mr Jolly (Inverness), to ascend *Maum Saul*, a mountain reaching a height of 3880 above sea, in order to investigate the truth of a report by Ordnance surveyors, that on the west side of this mountain, at a height of 3800 feet, horizontal beds of sand and gravel had been seen by them. After the foot of the mountain was reached, bad weather prevented the ascent.

At height of 450 feet above loch, deep beds of a fine sandy clay occur.

One of the boulders is at a height of 340 feet above loch, which corresponds with a horizontal terrace on south side of loch.

18. *Glen Morriston and Glendoe, on north side of Loch Ness.*—

(1) In *Eighth Report* (p. 15) Professor Heddle describes several boulders on the hills at the head of Glen Morriston, near Clunie Inn, at great heights, and some on very steep slopes, apparently transported from westward.

(2) The Convener (*Fourth Report*, p. 23) describes a visit to Glendoe, at head of Glen Morriston, where he found several boulders of large size, at heights of from 919 feet to 1205 feet above the sea. These boulders rest on gravel and sand, and in height correspond occasionally with horizontal terraces occurring on opposite side of the valley where they occur.

In a higher part of valley, viz., about 1190 feet above sea, deep beds of sand and gravel found. Terrace seen by Ordnance surveyors at height of 1280 feet, at top of glen.

The Convener was told of a still larger boulder, about 16 feet high, at Clachnaharry, on south side of Loch Clunie, 2 or 3 miles west of Glendoe.

19. (1) In Stratherrick, a large patch of grey granite rocks occurs. They are extensively quarried, and therefore are easily recognisable. Blocks have been carried eastward, even to near Elgin. They occur also on the tops of the Conglomerate hills between Loch Kecklis and Loch Ness, at heights of from 1400 to 1500 feet (*Jolly, in Fifth Report*, p. 72).

(2) Along north bank of Loch Ness, near east end, a patch of red granite occurs, blocks of which have been recognised in the Tomnahurich gravel hill near Inverness, and even on towards Nairn and Forres (*Fifth Report*, p. 69).

Along south bank of Loch Ness, near east end, a peculiar liver-coloured Conglomerate rock occurs, blocks from which seem identical with a number of large boulders east of Inverness (*Fifth Report*, p. 71, and *Sixth Report*, p. 47).

The late George Anderson of Inverness states that in some of the drift deposits near Inverness there are pebbles and boulders "that appear to have come from very distant parts of the country. Such,"

he says, "are the white stone of Ben Nevis and of Strathconon

(Ross-shire), and the quartz rock of Foyers" (*Wernerian Trans.*, vol. iv. p. 205).

Mr Jamieson of Ellon adverts to this same drift accumulation, known as Tornain Hill, in the following terms :—" There are masses of coarse water-worn gravel rudely piled together, 200 feet thick. The stones are all water-rolled, and show no glacial striæ. The pebbles are of various kinds of metamorphic and crystalline schists, red sandstones, conglomerates, granites, and porphyries. These materials look as if derived from the rocks along the valley to the south-west" (*Proceedings of the London Geological Society*, January 11, 1865).

(3) In town of Inverness, a boulder of greenstone or black granite, called " *Clach-na-Cudaine*"—" *Stone of the tub*," now standing in High Street, with pillar on it supporting town armorial bearings. Stone had formerly stood at top of cliff above River Ness, and from time immemorial afforded a convenient rest for the tubs or pitchers in which the women brought up water for household use. When a supply of water was brought into the town by pipes, the magistrates proposed to break up the boulder, but the townspeople objected at first even to its removal. A compromise was come to by the boulder being shifted to the side of the street, opposite to the Court-House, and by the erection on it of the Town Arms (*First Report*, p. 18).

(4) At *Clachnaharry*, a boulder weighing about 100 tons, called "The Watchman's Stone," resting on a projecting part of the coast (opposite to Inverness), from which a good view can be had of Moray and Beauly Firths.

Above Clachnaharry there are smoothed rocks, with grooves running E. and W., a direction parallel with Beauly valley.

(5) *Culloden Muir*.—Here stands "The Duke of Cumberland's Stone," a Conglomerate boulder with six sides, height about 6 feet, and girth not quite 60 feet. Its longer axis W.N.W. On top of boulder traces of striæ running W. by N. Boulder lies on an extensive plateau about 450 feet above the sea. At nearly the same level a horizontal terrace is visible, looking south, on the hills to the south of the River Nairn, about two miles distant (*Second Report*, p. 158).

There are no Conglomerate rocks, except on Loch Ness, which bear W.N.W.;—or at Kilmorack (on River Beauly), which bear N.W., each place about 20 miles distant.

*Craig, Parish of*.—About half a mile S.W. of village, a mica schist boulder,  $17 \times 8 \times 9$  feet. It lies on hills sloping down N.W.

There is also a Conglomerate boulder known by name of "*Tom Riach.*" Its west side 18 feet, north side 21 feet, east side 24 feet, south side 21 feet, and height 20 feet—652 tons. Boulder rests on gneiss rock. Lower surface seems smooth, as if it had been pushed over hard materials. Boulder has by some means apparently come down the valley of the Nairn, viz., from westward (*Second Report*, p. 158).

On plateau, 4 miles south of Inverness, at about 774 feet above sea, another Conglomerate boulder, with thin stratum of Old Red Sandstone on its top. Its girth about 51 feet, height 9 feet. Longer axis N. and S. A kaim of gravel and sand, about 900 feet above sea, situated north of boulder, running E. and W., or parallel with Nairn valley, on north side of which it occurs (*Second Report*, p. 158).

(6) *Dallanossie Parish.*—Boulder (apparently coarse granite)  $30 \times 18 \times 9$  feet (360 tons), on Dallry Farm, Moy estate. Boulder split into two parts, which gives its name, viz., "*Clach Schuilt,*" or "*Cloven Stone.*" Height above sea 2090 feet (*Captain White of Ordnance Survey*).

(7) *Duntelchak Hill*, west of Inverness, about 900 feet above sea, composed of coarse Conglomerate. On N.W. side rocks are ground down and smoothed ; on S.E. side rocks rough and steep. Granite boulder,  $7 \times 4$  feet, lies on N.W. slope of hill, about 30 feet below top. Longer axis N.W., with sharp end towards that quarter. No granite rocks in this district except to west, about 10 miles distant.

(8) *Flichity Valley* (about 8 or 9 miles S.W. of Inverness), through which River Nairn flows.

An isolated hill on south side of valley, about 1620 feet above sea, well covered with boulders, which are precariously situated on account of steepness of hill-side (*Lithograph No. 32, Plate X.*). They are chiefly on west slopes.

On this hill there are horizontal terraces, with boulders on them.

At east end of Flichity valley a great embankment, which, before being cut through by River Nairn, must have been the means of forming a lake filling the valley. The cut across this embankment, through which river flows, is about 200 feet deep.

There are also in the upper part of Nairn valley many large gneiss boulders, supposed by Mr Jolly to have come from the west, several of which are split ; one at height of 2260 feet above sea-level.

At *Farr*, in Nairn valley, to the east of the embankment, and near junction with another valley which runs N.W. up to Duntelchak, there

is a remarkable assemblage of gneiss or mica slate boulders (*Lithograph No. 34, Plate X.*). They were first pointed out to the Convener by Mr Jolly. Some rest on glaciated rock surfaces, sloping down to westward, and which therefore suggest transport of the boulders from westward.

Reasons given for suggesting first a glacier, which passed down eastward, and subsequently a submergence of the land under the ocean (*Second Report*, p. 159).

(9) About 6 miles S.W. of Inverness, an extensive plain, about 645 feet above sea-level, covered with drift, on which several Conglomerate boulders occur. They probably came from Duntelchaig and other hills to westward. One is  $24 \times 21 \times 8$  feet—340 tons. Longer axis W.N.W.

On “*Craig-a-Clachan*,” at a height of about 1100 feet above sea, a large Conglomerate boulder called “*Watch Stone*”—made known to Convener by Mr Jolly. It lies on gneiss rock, and on very edge of a precipice of 100 feet vertically below it, on its N.E. side. In order to reach a site in this position it could have come in no other way than in a direction between W. by N. and W.N.W., and almost certainly on floating ice.

On the same hill there are other boulders of smaller size, whose position in like manner suggests transport from westward.

(10) Some miles farther south there is a lake bearing name of “*Loch Clachan*,” probably on account of the number of boulders on its banks and the hills adjoining. Most of these are of grey granite.

By reference to Professor Geikie’s Geological Map of Scotland, it will be seen that the nearest position for granite rocks in this district is Loch Faraline, about 15 miles westward.

One of these boulders is  $21 \times 20 \times 14$  feet (218 tons) at 983 feet above sea. Another about same size, and at about 1259 feet above sea has its sharp end towards west. The east end is broad, and butted up against a gneiss rock, which would obstruct its passage eastward. On this gneiss rock there are E. and W. striæ, which might have been made by the boulder pushing and pressing hard pebbles over the rock.

(The facts given in (9) and (10) are taken from Convener’s *Treatise on Ancient Water Lines*, pp. 86, 87.)

(11) *Craig Phaedrich Hill*, consisting of Conglomerate rock. On its N.W. slopes the rocks are bared, rounded, and smoothed, with boulders of gneiss lying on the N.W. slopes. Hardly any boulders or striated rocks are on south slopes of the hill.

On several parts of the hill, especially on its south slopes, the rocks are broken up into large cubical fragments, resembling, in shape and composition, the boulders mentioned in (5) above (*Second Report*, p. 163).

(12) In the *Ninth Report* (pp. 10–12) there is an interesting list of boulders in the neighbourhood of Inverness by Mr Wallace, High School, Inverness.

(13) *Kingussie*.—On Clunie M'Pherson's lands, two boulders of a coarse-grained granite. One is  $11 \times 9 \times 6$  feet, the other is about double the size of the former, with felspar crystals of a green colour, and mica plates about 1 inch square.\* Longer axis of both, about E. and W. Both lie on a hill-slope, facing down west. Height above sea 1035 and 1080 feet. Rocks of district are clay slate.

The nearest hill is *Craig Dhu*, situated 4 miles to north on opposite side of Spey, the rock of which is also clay slate.

Another boulder on Belville estate, 2 miles from Newtonmoor Railway Station, from 950 to 1000 feet above sea. Greatest length 14 feet, breadth at top 8 feet, height 9 feet. Longer axis S.S.W.

At *Laggan* Free Church, a well-rounded granite boulder,  $9 \times 6 \times 6$  feet, with longer axis E. and W., corresponding with directions of numerous striæ on a well-smoothed rock on which boulder lies.

Nearest hills of granite are some miles to the west.

#### KINCARDINESHIRE.

1. *Banchory-Devenick*, near Glassel Railway Station. Boulder called "Bishop's Stone"; circumference 44 feet, height above ground 8 feet, estimated weight 70 tons. Bluish granite, differing from adjoining granite rocks. An ancient stone circle of boulders about 200 yards distant.

About 2 miles to north, rocks on Hill of Farre glaciated with striæ, running E. and W.,—parallel with axis of Dee valley.

*Fettercairn*.—No boulders now in parish, of any size. Long banks of sand and gravel, running parallel with one another.

2. *Maryculter*.—Boulder  $5\frac{1}{2} \times 6 \times 6$  feet. Longer axis N. and S. Rock of boulder supposed to be same as rocks to eastward (*First Report*, p. 40).

\* The only other boulder with felspar and mica crystals, similar to those met with by Convener, is that mentioned as occurring on Treshlik Hill, p. 63.

## KIRKCUDBRIGHT.

1. *Galloway*.—Great accumulation of boulders at head of valley, at Loch Narroch. Among these are boulders of the peculiar graphic granite of Loch Enoch to the north, so that these must have been carried southwards across various ridges and valleys to places where now found.

Craiglee, remarkable for numbers of perched blocks, some of immense size; their numbers on a long ridge of hill resemble a broken-toothed saw.

Travelled blocks occur, even on summit of Merrick, highest hill in Galloway (2764 feet). A number of poised blocks, and “rocking stones” (*First Report* p. 40).

2. *Kells*.—On Craigenbay Farm, a grey whinstone boulder 17 feet long and 10 feet high, 800 feet above sea. Longer axis N. and S.

3. *Kirkbean*.—On sea-shore at Arbigland, grey granite boulder  $16 \times 9\frac{1}{2} \times 7\frac{1}{2}$  feet (about 80 tons), resting on sandstone rocks.

Criffel Hill is about 3 miles to N.N.W. Rock there, same as boulder. In all the glens between Criffel and sea-shore numerous granite boulders, generally arranged in lines parallel with glens.

4. *Penninghame*.—Granite boulders chiefly; supposed to have come from Minnigaff Hills situated to N.E. Some large boulders on watersheds between Lochs Dee and Troul.

5. *Twynholm*.—Granite boulder supposed to have come from Galloway Hills, 6 or 7 miles to westward. Several Druidical circles here.

6. *Borgue*.—Boulder of red syenitic granite; oblong in shape. Longest axis N.W. Rests on low hill of decomposed trap. South-east end vertical and rough. Girth at 3 feet above base 23 feet. No granite rocks nearer than about 10 miles, viz., a range of hills between Dalbeattie (east of boulder) and Creetown (west of boulder). Sketch of boulder given (*First Report*, p. 40).

7. *Generally*.—Large rounded fragments of granite and syenite abundantly scattered over *Stewartry*, and so arranged as to indicate that they have been dispersed by some force proceeding from N.W. (*Sixth Report*, p. 27; *Highland Society's Trans.*, vol. viii. p. 716, *Hay Cunningham*).

Professor Harkness, in the year 1870, made known to the London Geological Society his discovery of Criffel granite boulders in *Cumberland*. In his paper (published in the *Quarterly Journal for November 1870*, p. 522) he states that “this Criffel granite occurs

not only in the form of blocks on the *surface*, but also in the *boulder clays*." The Criffel granite blocks are also common in the *boulder clays* of the vale of Eden. He adds that there are also "*Eskars* in the valley, which yield blocks of Criffel granite."

In the Ninth Report of the English Boulder Committee, an account is given of the boulders found while excavating for the new docks at Maryport, on the south side of the Solway; among them were granite blocks, varying in size from pebbles to blocks of a ton. It is remarked in the Report that "the nearest granite occurs in "Kirkcudbrightshire Hills, 15 or 20 miles distant, nearly due north."

In the Fifth Report of the English Boulder Committee (*Br. Ass. Pr.* for 1877, p. 82) there is notice of a Criffel granite boulder found near Liverpool in excavating for new docks. It is added "that Mr J. Geikie and Mr Horne pronounced specimens which were sent to them to be from the outskirts of the Criffel granite area."

There is ground for believing that Criffel granite boulders occur even so far south as Lancashire. Mr Mellard Reade of Liverpool, C.E. and F.L.G.S., wrote in the course of 1882 to the Convener, that having for some years, while investigating the drift deposits near Liverpool, collected specimens from boulders, some of which were evidently derived from rocks different from any belonging to that part of England, he wished to submit these to any person known to the Convener to be well acquainted with the rocks of the S.W. of Scotland. The Convener having suggested Mr Dudgeon of Cargen, Dumfriesshire, Mr Reade transmitted the specimens to him, the result of which is explained in the following extract of a letter from Mr Reade to the Convener—

"Mr Dudgeon recognises with certainty Criffel granite, having assured himself of its identification by having seen in some of the specimens submitted to him the minerals sphene and allanite, which he is not aware occur in any other granitic district nearer than Aberdeenshire and Sutherland. He also thinks some of the granites come from veins in the Silurian rocks about 7 miles from Dumfries." \*

\* Mr M. Reade has since (Feb. 1884) read in the London Geological Society a paper narrating a visit he made to Kirkcudbrightshire, for the purpose of comparing chips from the Lancashire boulders with the supposed parent rocks. In this paper he mentions his identification not only of granite boulders with the rocks of Criffel and Cairnsmore of Fleet, but also of Liver-

## LANARKSHIRE.

*Glasgow.*—(1) Near Possil, sandstone rocks under boulder clay, striated, partly from N.W. partly from N.E., oldest apparently being from N.W., judging by length and depth of striæ. Boulders in the clay, recognised by Mr John Young of Glasgow University Museum, some from Kilpatrick Hills to N.W., and others from Campsie Hills to N.E.

(2) At Brickwork, near Garscube Road, sandstone rocks, also striated from N.W., and more deeply than at Possil.

At this place, numerous boulders of old red conglomerate, grey granite, schists, &c., supposed to be from Bonaw and Kilpatrick Hills to N.W. (*Second Report*, p. 165).

## LINLITHGOWSHIRE.

1. *Bonnington District.*—(1) On Pumpherston estate, the “*Ballengeich Boulder*,” in girth 10 or 12 feet; but now broken up into eight fragments. It is a coarse dolerite, of which no rocks nearer than Bathgate Hills, about 2 miles to N.W. Had been about 60 tons in weight. The boulder was lying on boulder clay.

Not far from this boulder there is another of quartzite, about a quarter of a ton in weight, and containing crystals of green mica, most probably transported from Highlands.

(2) On Tornain Hill, Bonnington Farm, occupied by Mr James Melvin, another dolerite boulder, known as the “*Witch's Stone*,” about same size as that at Pumpherston, and about same height above sea, viz., 431 feet. It lies on a slope which faces W.N.W. On digging below the boulder, Mr Melvin found it resting on decomposed trap. Nearest rock of same kind is on Bathgate Hills, situated 5 miles W.N.W.

There is a valley between Tornain Hill and Bathgate Hills, across which boulder had probably been transported. If a line be drawn from this boulder to Bathgate Hills, it passes close to “*Ballengeich*” boulder.

This boulder also has been broken into six fragments. Some archaeological interest attaches to boulder, as on one of its fragments there are “cup markings.”

(3) Formerly, on S.E. side of Tornain, another dolerite boulder, read he exhibited chips from these boulders and the parent rocks for comparison. In this paper there is a becoming acknowledgment that Mr Mackintosh had been the first to refer the Lancashire granite boulders to Criffel (*L. G. S. Trans.* vol. xl. p. 270).

$21 \times 5 \times 4$  feet, lying with longer axis E. and W., and at height of about 300 feet above sea. If it also came from Bathgate Hills it probably had to come by floating ice, round Tornain Hill, by valley between Tornain Hill and the Crow Hills.

(4) In channel of River Almond, below Kirkliston, a boulder of Old Red Sandstone conglomerate,  $5\frac{1}{2} \times 4\frac{1}{2} \times 4$  feet; nearest rock for which, is at Callander, about 40 miles to N.W., with several valleys and ranges of hills between.

(5) At Ratho Railway Station, rocks smoothed and striated on west sides, the direction of the striæ being W.N.W. (*Seventh Report*, pp. 23, 24).

2. *Kirkliston*.—The remarkable stone known to archæologists as the “*Catstone*,” bearing a very ancient Latin inscription, which the late Sir James Y. Simpson deciphered, is described by him as “a massive unhewn block of secondary greenstone, many large boulders of which lie in the bed of the neighbouring river.” The block is 7 feet 3 inches in length and 12 feet in circumference (*Proc. of Society of Scotch Antiquaries*, vol. iv. p. 122).

#### MIDLOTHIAN OR EDINBURGHSHIRE.

1. *Pentland Hills*.—The late Charles Maclaren was the first who described the boulders on these hills. The one of most interest is of mica slate, weighing 8 or 10 tons. The nearest spot from which it could have come is at or near Loch Vennacher or Loch Earn, about 80 miles to the N.W.

With reference to the transport of this boulder, Mr Maclaren says:—“To reach the spot where it lies, it must have passed over extensive tracts of country from 500 to 600 feet lower than this spot. Even were all Scotland converted into a *mer de glace*, like Greenland, no moving mass in the shape of a glacier could carry this boulder (and there are many such) from its native seat in Perthshire or Argyleshire to Habbie’s Howe. An iceberg from the North or West Highlands, and floating in a sea 1500 or 2000 feet above the present level of the Atlantic, is an agent capable of effecting the transportation of the stone, and offers, I think, the only conceivable solution of the problem” (*Edin. New Phil. Journal*, 1846, p. 138). Referring to this boulder, and to another, also of mica slate, on the Pentlands, weighing about three quarters of a ton, the late Professor

Nicol remarked :—"When it is considered that these masses must have been carried upwards of 40 miles in a direct line, floating ice seems the only agent to which their transportation can be ascribed" (*Lond. Geol. Soc. Journal*, vol. v. p. 23). He adds :—"Some of these Pentland Hill boulders 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" (*Sixth Report*, p. 26).

A number of rock surfaces occur on the Pentlands with striæ. Mr James Croll, of the Scotch Geological Survey, describes one of these on the very summit of Allermuir Hill, at a height of 1617 feet above the sea. On examining the striæ he says he had no "difficulty in determining that the ice which effected them came from the *west*. On the summit of the hills we found patches of boulder clay in hollow basins of the rock. Of one hundred pebbles collected from the clay, every one, with the exception of three or four composed of hard quartz, presented a flattened and ice-worn surface, and forty-four were distinctly stratified. A number of these stones must have come from the Highlands to the N.W." (*Fifth Report*, p. 82).

In like manner, Professor Geikie, in his interesting *Memoir on the Geology of the Neighbourhood of Edinburgh*, observes that "boulder clay lies along the N.W. flanks of the Pentlands, rising to a level of at least 1300 feet. When the clay has been removed, we usually find the rocks below polished, grooved, and scratched, in a direction nearly E. and W. or E.S.E. and W.S.W. The parallelism of the striations throughout the present district shows that the floating ice must have moved in a pretty uniform direction; and that it was from the *west*, is rendered clear, by the striation of the western faces of the hills, by the great depth of drift on their eastern sides, and by the fact that the transported boulders, when traceable to their parent rock, have been carried from W. to E. The drift in this district indicates a period of slow submergence, which went on until probably every hill had sunk far below the sea-level, and when ice-borne blocks from the snow-covered islets of Isla or the

Grampians, were dropped on the submarine slopes of the Pentlands" (*Memoir* No. 33, p. 127) (*Fifth Report*, p. 18).

2. *Edinburgh and Suburbs.*—The late Charles Maclaren, in his *Geology of Fife and the Lothians*, published in 1838, refers to boulders which he found on or near Arthur's Seat, the Castle Hill, and Calton Hill.

On *Arthur's Seat*, about twenty or thirty boulders are specified up to 30 tons, most of which he identified with rocks situated to the west of the boulders. Others (of sandstone) he found at much higher levels than any sandstone rocks now on the adjoining hills (p. 64, 2nd edition).

To the east of the *Castle Hill*, numerous boulders are mentioned as having been found to the eastward, which are with good reason referred to the Castle rock; but other boulders are mentioned (p. 91) as having been found on the west side of the Castle rock, which must be referred to some more distant locality.

It is right for Convener to notice a *Conglomerate boulder* standing on a stone pillar in the public gardens at the foot of the Castle rock. It was brought there as an ornament to the gardens by Mr Henderson, nurseryman, who had been entrusted by the magistrates with the arrangement of the gardens. He had found it in his own Nursery Gardens, Leith Walk. It is probably a true erratic, hailing from Callander.

On the Calton Hill, boulders are mentioned by Mr Maclaren as found there, "of the very peculiar syenitic greenstone of Corstorphine Hill" (p. 72).

In the year 1847,\* a new road (at the expense of Government), was made round Arthur's Seat, which required an excavation to be made on the S.W. side of the hill, between the main body of the hill and an outlying knoll known on account of its basaltic columns as "*Sampson's ribs*," at height of 390 feet above the sea.

The hollow between the hill and the knoll was excavated to a depth of 20 or 30 feet, in order to lessen the steepness of the road. Thereby a trough or gully, with rocky sides sloping steeply towards the axis of the gully, was disclosed. The axis of the trough was about N.W. and S.E.; its length about 120 yards; its width at the narrowest part where the road was made, about 10 yards. As the rocky sides of the gully sloped down towards the

\* The particulars here given will be found in a paper by the Convener published in the *New Edinburgh Philosophical Journal* for January 1847  
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axis, these sides would probably meet below ; but the excavation for the road did not reach that point. The gully had been filled with till, and contained numerous boulders,—almost all of which were found to be different from any of the rocks on Arthur's Seat, viz., felspar, greenstone, porphyry, limestone (both lacustrine and marine), quartz, greywacke, with fragments of shale and coal.

Many of these blocks were found in contact with both sides of the gully. The largest blocks were near the north end. The large blocks were well rounded ; the small blocks less so. One large boulder on the west side of the gully appeared to have been pressed against the rock there, and had stuck in that position, being rounded and also partially striated on its N.E. side,—an indication of the friction it had undergone, by materials forced through the gully from a N.W. direction.

The gully was not throughout of equal breadth ; at its narrowest point, the sides (when the boulder clay and drift were cleared away) were found at one place to be about 15 feet nearer one another than elsewhere. The rocks on the east side had been ground down, smoothed, and striated, some of the striæ being continuous for nearly 6 feet, and  $\frac{1}{2}$  of an inch deep.

Generally, the striæ were horizontal ; but at and near the narrowest part of the gully the striæ were seen to rise up at an angle of  $4^{\circ}$  or  $5^{\circ}$  ;—caused probably by the obstruction to the drift when being forced through the gully.

One peculiarity in the striations deserves notice, as showing the direction from which the striating agent moved. The striæ were most numerous and deepest on the east side, suggesting that the striating agent had moved in a direction from a more westerly point than N.W. The rock surfaces facing the S. and S.W. were neither striated nor smoothed.

There is another spot, on the south side of Arthur's Seat, worthy of notice, on account of the boulders there, and the position occupied by them. It is on the west side of Windy Gowl. When the new road was being made there, a thick bed of clay and sand, in stratified layers, was exposed to view. In this bed, many blocks from the overhanging rocks of the hill were found embedded. The bed of sand and clay had been *formed round these boulders*, showing

that after they fell sedimentary matter brought by water had been deposited. The largest of the blocks was round and smooth on its west side, rough and angular on its east side. Besides the blocks of stone, which were of the same nature as the rocks of Arthur's Seat, there were in this bed of sand and clay blocks foreign to Arthur's Seat (brought from the west probably), viz., red compact felspar, red syenitic porphyry, marine limestone, and clay iron-stone.

At Easter Duddingstone the excavations for the North British Railway exposed a number of large boulders embedded in the stiff blue till. Two of the boulders were of Old Red Sandstone Conglomerate—one an old porphyry, one a black basalt—rocks not existing in the immediate neighbourhood, but belonging to localities in the far west. Most of them were on their upper surfaces flat, smooth, and striated, the striæ running in directions varying between N.W. and W.N.W.

At the sea-shore, between Joppa and Magdalen Bridge, the Convener examined many large boulders sticking in the blue till, most of them flattened on their upper surfaces with striæ pointing N.N.W. Several presented smoothings and furrows on their west sides, none on their east sides. One of the boulders presented two sets of striæ—one running N.N.W., the other running W. by S., the former partly obliterated by the latter, which therefore must have been the more recent.

3. *Dalmahoy*.—Two boulders, one  $13 \times 10 \times 6$  feet, and the other  $10 \times 8 \times 5$  feet, lie at the side of the Water of Leith. The longer axis of both is E. and W. Both were covered with striæ also running E. and W. (*Sixth Report*, p. 27).

4. *Craiglockhart*.—Excavations were made in boulder clay for a hydropathic establishment. A number of boulders were seen by Convener in their original undisturbed positions. There were several of sandstone. The contractor for the building, having his attention drawn to these by the Convener, was asked if he knew any locality where there was sandstone rock of the same variety? He said that the sandstone rock quarried extensively at Hailes and at Redhall was exactly the same. On being asked to indicate the situation of these quarries, he pointed in a direction N.W. (by compass), distant about a mile.

5. *Tynecastle*, in west suburbs of Edinburgh.—A basaltic boulder examined by Convener and Mr Stevenson, C.E.,  $4\frac{1}{2} \times 4 \times 2$  feet, buried in a knoll of muddy sand, discovered on removal of the knoll. The sand contained numerous pebbles of all kinds, hard and soft, such as quartz, shale, coal. Height above sea 200 feet. Sides of boulder well rounded. Smallest end of boulder pointed westward. Both *upper* and *under* sides of boulder striated. Striae more deeply cut on under than on upper surface. The striae on under surface showed they had begun to be formed at east end of boulder, probably by the boulder having been pushed towards *east*, over hard rocks. The striae on upper surface showed that the tools which formed *them* had acted on the boulder first at west end.

6. *Granton*.—The sandstone rocks at the *Old Quarry* near the sea were covered by boulder clay, which had embedded in it many blocks derived from Linlithgow and Stirling shires. The striae on their upper surfaces all run E. and W., viz., a direction parallel with the general axis of the Firth of Forth (*Edin. New Phil. Journal* for January 1847).

At *Granton Harbour*, on the west side of, at the shore, there are two large whinstone boulders, with striae on their upper surfaces, the direction of which is W.  $3^\circ$  S. (magnetic).

7. *Leith Docks*.—In new Albert Docks excavations were made in the boulder clay, in course of which a number of large boulders were found.

They consisted mostly of blue whinstone, also some of quartz, limestone, greywacke, sandstone, and black ironstone concretions derived from beds of coal and shale. On most of the boulders there were smoothed surfaces and striae, bearing nearly the same direction, viz., points between W. and N.

Among these there were two *metallic* boulders, which, having a strange appearance, were brought to the Convener by the Inspector of Works; and to Professor Crum Brown (of Edinburgh University), the Convener submitted them for examination. One, nearly spherical, measuring  $7\frac{1}{2}$  inches in circumference, and weighing 26 oz., had been found about  $4\frac{1}{2}$  feet down in the clay bed, among the general mass of boulders. The other, more exactly spherical, measured in girth 30 inches one way and 31 inches transversely, and weighed 54 lbs. It was found 10 feet below the top of the boulder clay bed.

Professor Crum Brown having analysed both balls, reported the largest to have a specific gravity of 3·36, and to be composed of silica 52·3 per cent. and of pyrites 47·7 per cent. The smallest had a specific gravity of 4·63, and was found to consist of the pure ore of *white iron pyrites* or *marcasite*, unmixed with any other substance.

Mr Murray, of the "Challenger" Expedition, having kindly undertaken to examine the larger ball, reported that a microscopic examination revealed that it consisted "of crystalline particles of quartz and marcasite. The marcasite fills the interstices between the grains of quartz; and among the quartz there are pieces of mica."

Mr Charles Peach at the same time informed the Convener that in several districts to the west (viz., Falkirk, Slamannan, and Kilsyth) there are beds of shale and coal, containing ironstone nodules, known among the miners as "*brassy balls*," some of which contain *marcasite*. He added that "the direction of the *striæ* and *carry* of the boulders in this (the Kilsyth) district is E. or E. 5° N. Either of these sources (he remarked) could supply "*balls*" at Leith, as they are right in the direction of the "ice-flow" (*Fourth Report*, p. 29).

In consequence of the foregoing information, the Convener went to Campsie (about 8 miles N.E. from Glasgow), and in the workings of coal and shale there he obtained several ironstone balls, which, on being submitted to Professor Crum Brown, he reported contained almost exactly the same constituents as the specimens found at Leith. He added, that "deducting the coaly matter, the iron and sulphur were in the proportion in which they are generally found in marcasite, viz., iron 45·6, and sulphur 54·8. As to chemical compositions, therefore, the small metallic boulder may be considered as exactly agreeing with the nodules found in the Campsie coal strata."

With regard to the larger ball, not so purely metallic, Mr Hutchinson of Carlowrie having accidentally seen in the Convener's house, Edinburgh, the specimen excavated from the Leith boulder clay, informed the Convener that balls of the same appearance, and much larger, were found in sandstone rocks quarried at Dalmeny and Humbie. The Convener thereupon visited these quarries, and

saw several specimens of such balls, apparently concretions in the rock. Having brought one or two specimens to Edinburgh, he submitted them to Professor Crum Brown, who reported that they "consist externally of a thin shell of sandstone, and internally of a mixture of quartz and marcasite, closely resembling the substance of the large ball from Leith. The mean specific gravity of the ball was 3·49."

These facts regarding the two metallic boulders found in the Leith boulder clay, therefore afford strong presumptive evidence that they had been transported across Scotland, along with other boulders, whose parent rocks occur also in the west.

As to the mode of transport, Mr Peach, in his letter to the Convener (printed on p. 29 of *Fourth Boulder Report*), whilst allowing that the balls might have come from Kilsyth or Slamannan, in conformity with the general "direction of the *striæ* and *carry* of the boulders in this district," viz., E., or E. 5° N., suggested "*ice-flow*" as the medium of transport, but without explaining whether he meant sea ice or land ice.

With reference to this question, it is right to keep in view that the Campsie district, from which the metallic boulders are assumed to have come, is only 150 feet above the present sea-level; and that, as this district is about 30 miles distant from Leith, the gradient would not be sufficient for the movement of a glacier, even if there had been mountains at or near Campsie sufficiently high to have generated a glacier.\*

8. *Alnwick Hill, near Liberton*.—Excavations having been made in the boulder clay here, for the formation of large water reservoirs, innumerable boulders were excavated. They were chiefly whinstones, felspar, porphyries, limestones, and Old Red Sandstone—all most probably from the N.W.

Some of these boulders showed *striæ* both on the under and the upper sides, the direction of which was approximately N.W. (*Fourth Report*, p. 29).

*Inchkeith*.—The Convener visited the island, under the guidance of Colonel Mugridge, R.E., and found that the rocks consist chiefly of basalt and porphyry, intruding among coal strata. In various

\* A small map of district, given afterwards in reference to Stirlingshire boulders, may here be referred to.

places, the rocks were covered by beds of boulder-clay, gravel, and occasionally sand.

The Inspector of Works informed the Convener, that at the east end of the island, when removing a bed of shingle (about 60 feet above the sea), he had picked up out of the shingle two pebbles of *red granite*, about the size of a hen's egg. Thinking it curious to find granite there, he had laid them aside, but could not now find them.

The Convener, having been informed that there was a shingly beach at the N.W. end of the island, descended to it, and found large pebbles of granite (both red and grey), gneiss, quartz, and hard Silurian rocks.

On the highest part of the island (west of the Lighthouse) at 182 feet above the sea, the rocks on portions of the hill facing the N.W. have been planed down to even surfaces by some agency from the W. No *striæ* were distinguishable (*Sixth Report*, p. 26).

#### MORAYSHIRE.

*Dyke*.—Near west end of approach to Darnaway Castle several boulders of granite and gneiss, from 2 to 3 tons each.

*Forres*.—Conglomerate boulder,  $9\frac{1}{2} \times 8 \times 8$  feet, weighing about 44 tons. It is situated on hill side fronting Cromarty, which bears N.W. by N., from whence boulders are supposed to have come across the Moray Firth.

Convener heard of another boulder of same description in a higher part of the hill, to the eastward.

*Elgin*.—Boulder called "*Carlin's Stone*," on Bogton Farm, about 230 feet above sea; a coarse Conglomerate. About half a mile to N.W. a smaller Conglomerate boulder, called "*Young Carlin's Stone*" (*First Report*, p. 31, and *Second Report*, p. 152).

There are no Conglomerate rocks in the low-lying districts, where these boulders are situated. Wherever they have come from, they must have been *carried*.

Conglomerate rocks exist in the hills to the south, distant 5 or 6 miles. Convener was informed by Mr Martin, teacher, Elgin (well acquainted with the rocks of the district), that the Conglomerate *formations* in the hills are, in mineralogical composition, distinguishable

from the Conglomerate *boulders* in the counties of Moray, Nairn, and Banff. Two other sources were considered by him more probable—Cromarty to the N.W., and the hills near the east end of the Caledonian Canal.

Throughout the county there are hundreds of rounded boulders of granite, gneiss, and mica slate, whose shape suggests that they have been pushed or rolled over the surface. These are chiefly embedded in gravel, clay, and sand.

*Pluscardine Hill* has had lodged on its north slope a number of boulders which have apparently come from N.W. There is a gneiss boulder,  $13 \times 8 \times 6$  feet, about 46 tons, called "*Chapel Stone*," situated to west of Pluscardine Chapel; also a Syenite boulder,  $12 \times 8 \times 3$  feet, about 13 tons. The rocks *in situ* here are Old Red Sandstone.

*Carden Hill* forms a rocky sandstone range running about E. and W. Between it and Pluscardine Hill, there is a shallow valley, through which boulders may have been rafted to their present sites in an easterly direction. The two Carlin Stones might have come that way.

The rocks along ridge of Carden Hill, have been ground down by some agent which has passed over it from N.W. Many boulders of granite and gneiss lie on the ridge, most of which have longer axis N.W. by W. Some lie along ridge, on its northern edge, apparently stopped there in their farther progress; others lie on south side of ridge, as if pushed over it, and placed beyond reach of transporting agent.

Blocks of the Carden Hill sandstone rock are also there, as if broken off the ridge by the agent which passed over from north. The ridge of Carden Hill extends for about a mile, and is at a height of 400 feet above sea.

Many smoothed and striated surfaces are visible, the direction of the striae having been observed at different places as follows:—W. by N.; W.N.W.; N.W. by W., and N.W. The most frequent direction was N.W. At one spot, striae observed N. by E., and crossing the N.W. striae; the forming appearing, therefore, to have been first formed (*Second Report*, p. 154).

*Quarrywood Hill*, about 200 feet above the sea, composed of sandstone rocks. On N.W. slope there are four or five large Conglomerate boulders, about 140 feet above sea-level.

*Burgh-head.*—Rev. Dr Gordon of Birnie conducted Convener to Clarkeley Hill, on which several granite and gneiss boulders were found lying on slope of hill. One has its longer axis N.W. and S.E. Several others showed *striæ* in same direction.

On Roseile estate here, “*Hare*” or “*Witch Stone*,” a Conglomerate boulder  $21 \times 14 \times 4$  feet, with longer axis N.W.

*Inverugie Lime Quarries.*—Limestone rocks striated in an E. and W. direction. In boulder clay here, boulders of oolite found, which must have come from Ross or Sutherland shires.

*Duffus Public School.*—Convener had shown to him portion of an oolite boulder found here, 125 feet above sea.

“*Witch Stone*,” a large Conglomerate boulder, at 250 feet above sea, on hill-side sloping down to N.W. It is exactly similar to “*Carlin’s Stone*,” in respect of nodules of granite, gneiss, or purple-coloured quartz contained in it. Its longer axis is N.W. and S.E. It lies on a thick bed of sand.

*Lossiemouth.*—About  $1\frac{1}{2}$  mile west of Covesea lighthouse, a large boulder of silicated sandstone, on a hill sloping to N.W., with *striæ* on boulder running N.W. and S.E.

On old sea margin, 20 feet above present sea-level, a Conglomerate boulder, same in composition as Carlin Stone.

*New Spynie.*—Four Conglomerate boulders, lying on Old Red Sandstone rocks.

*Llanbryde, St Andrews.*—Gneiss boulder called “*Grey Stone*,”  $15 \times 9 \times 7$  feet, about 70 tons, lying in bed of old Spynie Loch.

*Rothes.*—Convener informed by Mr Martin, teacher, of six hornblende boulders, lying on gneiss rocks (*First Report*, p. 31).

Between Forres and Nairn there are extensive beds of sand and gravel, mostly in stratified beds, and containing boulders almost always rounded. The angular boulders are generally on the surface, not so embedded.

#### NAIRNSHIRE.

*Croy.*—“*Tom Riach*,” boulder of Conglomerate.—See Inverness county, under head of “Inverness and Croy” (*First Report*, p. 43) (*Lithograph No. 35, Plate X.*).

*Cawdor.*—On hill of *Urchany*, composed of granite, at levels above sea, of from 300 to 700 feet, four immense Conglomerate boulders

with popular names, described in *First Report*, p. 42 (*Lithograph No. 34, Plate X.*). There are granite rocks in hills to south, on which blocks of Old Red Sandstone lie, and in such quantities that they are gathered for the building of walls. These blocks probably came from the north, where there are rocks of the same kind (*First Report*, p. 42, and *Second Report*, p. 166) (*Lithograph No. 36, Plate X.*).

On "Piper's Hill," where rocks are Old Red Sandstone, a Conglomerate boulder, weighing about 10 tons, lies on the N.W. side of a gravel kaim. These Conglomerate boulders are all mineralogically similar, being composed of quartz, limestone, syenite, felspar, and other hard angular pebbles. Most of them are partly buried in sandy drift. The district on which they lie slopes down towards N.W., and is about 200 feet above sea, from which distant about a mile.

The longer axis of these boulders is chiefly N.W., and on that side they present smooth surfaces, whilst east side is rough and angular (see Diagram 8 in *Second Report*, and p. 166, and also *First Report*, p. 42).

Captain White of Ordnance Survey informed Convener that, having tried to find out where these boulders came from, he was of opinion that they had come from Ross-shire.

He reported also having met with granite boulders (both red and grey varieties)—the largest  $12 \times 8\frac{1}{2} \times 8$  feet, and with longest axis N.W.

A kaim of gravel and sand, with steep sides, runs on an average E. and W. through parish, but occasionally deviates slightly from this direction. Its average height above adjoining district is 30 feet (*Second Report*, p. 166).

*Ardclach*.—In Bog of Fortnightly, about 5 miles distant from the sea, and about 270 feet above it, a Conglomerate boulder with five sides, having girth of 51 feet, and 9 feet above ground. The block is scarcely rounded at its edges and corners, and therefore has probably been *carried*, not *pushed*, *rolled*, or *thrown* down, but planted gently on its site. It is smoothest on N.W. side, roughest on S.E. It is surrounded by hills on every side except towards N.W. (*First Report*, p. 42).

*Kinstearny* (about 2 miles S.E. of Nairn).—A peculiar flesh-coloured fine-grained granite rock is worked, blocks of which are stated by Mr Jolly of Inverness to have been transported eastwards

beyond Forres,—gradually lessening in size and numbers, reaching to Elgin, Lossiemouth, and even farther east. Pieces also occur on the shores of Loch Spynie (*Fifth Report*, pp. 74, 75).

Mr Wallace of Inverness mentions having found a specimen of this Kinstearny granite beside Buckie harbour, about 20 miles east of Lossiemouth (*Sixth Report*, p. 49), and he has seen many smaller specimens in the fields. Neither rock nor boulders of this peculiar granite have been found *west* of Nairn.

#### NORTHUMBERLAND.

In Chillingham Park (Earl Tankerville's seat), between Wooler and Alnwick, there is a large boulder of red porphyry, besides several small boulders of granite. The rocks there *in situ* are Carboniferous sandstones and limestones. The nearest localities for porphyry and granite are the Cheviot Hills, about 8 miles to W.N.W., which reach a height of 1800 feet above sea. Many ridges and valleys lie in the intervening district (*Fourth Report*, p. 34, and *Edin. Roy. Soc. Trans.*, vol. xvii. p. 35).

#### ORKNEY.

*Eday*.—Conglomerate boulder, about 8 tons, situated near top of hill, about 250 feet above sea, called "Giant's Stone." Legend as to it having been thrown from island of Stronsay, where there are said to be Conglomerate rocks, of which none in Eday. Longer axis points S.W. and N.E.

Patrick Neill, in his *Orkney, Visit to*, at p. 38, refers to "the great *Stone of Eday*," as "a huge flag rising about 16 feet upright in the midst of a moor."

*Frith and Stennis*.—Peebles of white sandstone lie on the hills. Rocks of island are all red sandstone.

*Sanday*.—Gneiss boulder about 14 tons. Rocks of island are Old Red Sandstone. At Stromness, 30 miles to S.W., gneiss rocks occur *in situ*. A legend that the boulder was thrown by a giant from Shetland (*First Report*, pp. 10, 44).

The late Dr Patrick Neill states that, if this boulder came from Stromness, it would have to cross several arms of the sea in a distance of 34 miles, from W.S.W. (*First Report*, p. 44, and *Second Report*, p. 167).

*Stromness*.—Two granite boulders lie on Old Red Sandstone, near Manse. Range of granite hills 6 miles long, situated to eastward (*Second Report*, p. 169).

*Walls* (in south end of group).—Lydian stone boulder, weight about 28 tons. Large numbers of granite boulders scattered over hills. The valleys show (in opinion of reporter, James Russell, teacher) both glacier and iceberg agency (*First Report*, p. 44).

In a paper on the "Glaciation of the Orkneys," by Messrs Peach and Horne of the Government Scotch Geological Survey (*London Geological Society's Journal* for November 1880), it is said that "boulders do not occur very plentifully." The only island in which boulders are mentioned as seen by them, is *Westra*, where "blocks of granite and quartzite are on the slopes of Cleat Hill; and rounded boulders of red sandstone from *Eda* occur in the southern district, as well as along the western shores." Messrs Peach and Horne state "that the only part of the Orkneys which has granite or other crystalline rocks is at *Stromness*, where they form a strip about 4 miles long by 1 in breadth." If the *Westra* boulders came from Stromness, they must have been transported about 40 miles in a N. or N.N.E. direction, across what now is occupied by several groups of islands and deep sea sounds.

If, on the other theory, the boulders of sandstone on the southern and western shores of *Westra* came from *Eda* (as suggested in the above passage), they must have been transported about 10 to 12 miles in a N.W. direction, across what is now a sea sound, in some places 25 fathoms deep.

Messrs Horne and Peach, in the memoir now referred to, referring to the beds of red boulder clay in the islands of *Eda*, *Sanday*, *Stromsa*, and *Shapinshay*, mention that in these clay beds there are boulders smoothed and striated, most of them "foreign to the islands," and in many cases, accompanied by "numerous fragments of marine shells;"—"these fragments being smoothed and striated like the stones in the boulder clay,"—"characteristics, which (they say) there can be no doubt are due to the very same cause in both cases" (pp. 656, 657).

*North Ronaldshay*.—Boulders foreign to the island mentioned (*Eighth Report*, p. 7).

In *Ninth Boulder Report* (p. 20) there is a further account of

blocks of stone, foreign to the rocks of the island, viz., Conglomerates, granite, syenite, chalk, oolite, limestone, and sandstone.

In Ronaldshay boulder clay, containing these blocks, there are fragments of *Cyprina Islandica*, *Astarte*, *Dentalium*, and other marine shells.

The *Conglomerate* boulders are supposed to have been carried from the adjacent island of *Sanday*; the blocks of *granite* and *syenite* from *Stromness* and *Pomona*, distant about 45 miles to S.W.

Messrs Horne and Peach (*Journ. of Lond. Geol. Soc.* for Nov. 1880) mention that in Stronsa Island (not far from Ronaldshay) there is a bed of clay, 20 to 30 feet thick, containing granite, gneiss, oolite, and chalk flints, &c., all foreign to the island, besides fragments of marine shells.

*Mainland*.—Mr Miller of Ben Scarth reports a valley bisecting the island, which he thinks was formerly an arm of the sea. The lochs of Stennis and Stanay now occupy it.

No large boulders; but on north exposures of hills there are small stones strewed over the surface, quite different from rocks *in situ*. The former are chiefly white freestone; the rocks Old Red Sandstones or flagstones (*Second Report*, p. 167).

Messrs Peach and Horne express an opinion that all the boulders in the Orkneys, as well as in the Shetlands, were carried or pushed across the islands by a Scandinavian ice sheet from the S.E.

Objections to that theory were suggested by the Convener, in articles which appeared in the *Geological Magazine* for 1881, and in an address by him to the Edinburgh Geological Society in May 1881.

In addition to the foregoing notes respecting Orkney boulders, it is proper to notice the researches of Messrs Peach and Horne.

In a paper, published in the *Journal of the London Geological Society* for November 1880, it is mentioned, as the result of their survey, "that the islands have been glaciated in one determinate direction, independently of their physical features. When we consider that the glaciated surfaces along the cliff tops, as well as the *roches moutonnées* on the hill-slopes, prove that the *islands must have been overflowed by ice*, we cannot resist the conclusion that the ice

movement during the primary glaciation originated beyond the limits of Orkney" (p. 654).

"From the manner in which the rock striations maintain their N.W. bend, irrespective of the physical features of the country, it is evident that the agent which produced them must have acted independently of the islands" (p. 660).

#### PEEBLESHIRE.

*Kirkurd*.—Three boulders of gneiss or trap, differing from rocks of district (*First Report*, p. 44).

*Newlands*.—Remarkable kaims (*First Report*, p. 44).

*Peebles*.—At east end of town boulder of white quartz,  $3 \times 2\frac{1}{2}$  feet, used to stand in field, to which it gave name of "White Stone Knowe,"—alluded to as a boundary stone in year 1436.

Mr Richardson, of Edinburgh Geological Society, who was the first to take public notice of the boulder, states that "the nearest beds of quartz are about 80 miles to the N.W." Height above sea 550 feet (*Fourth Report*, p. 31).

The late Professor Nicol refers "to boulders of gneiss, granite, and mica slate in Peeblesshire, which belong to rocks unknown in the hills of that county;"—and adds, "they seem to require for their transport more powerful agents than mere currents of running water" (*Sixth Report*, p. 28).

#### PERTHSHIRE.

*Aberfeldy*.—(1) On north of Tullypowrie village considerable numbers of schist boulders—rocks *in situ* being clay slate. Boulders well rounded, as if rolled. One of them called "Clach Chin'uin," or "Stone of Doom" (*First Report*, p. 45).

(2) Two miles N. of Tullypowrie, two very large boulders of mica slate at about 1500 feet above sea, shown to Convener by Mr M'Naughton, merchant.

They rest apparently on drift. Cubical in form. One found to be 71 feet in girth, and 17 feet high, weighing about 600 tons. Surrounded by hills on north and west, which overtop boulders by about 700 feet. But N.W. from boulders there is a depression in hills,

summit level of which only about 200 feet above boulders. Through this gap boulders may have come; but boulders are so cubical and sharp in angles that they must have been very gently lodged in present position. If they had fallen from any height they would have been fractured. These boulders have popular name of "*Clachan M'had*," or "*Stones of the Fox*" (*First Report*, p. 45).

(3) Above Pitnacree House, schist boulder resembling hyperssthene,  $15 \times 11\frac{1}{2} \times 4$ , differing from all rocks near it, called "*Clach Odhar*," or *Dun Stone*."

*Auchtergaven*.—Granite boulder,  $10 \times 8 \times 3$  feet, weighing about 8 tons, about 200 feet above sea, called "*Deil's Stane*." Longer axis N.E. Numerous cup markings on it. Supposed to have come from hills 30 miles to north.

*Aberfoyle*.—Arndrum Hill is a ridge of the Conglomerate rocks which cross Scotland from Dumbarton by Callander in an E.N.E. direction. On this ridge near Aberfoyle (230 feet above sea) there are six boulders of greywacke, forming a line bearing N. and S.—each about 3 cubic yards in size, and from 2 to 20 feet apart from each other. To the west of this line of boulders, four other similar boulders lie *along* the ridge, stretching to nearly top of hill, viz., to 454 feet above sea (*Ninth Report*, p. 16).

*Blairgowrie*.—Seven boulders of granite and mica schist, about 200 feet above sea. No rocks of same kind nearer than Braemar range of hills, about 30 miles to N.W.

*Callander*.—Gneiss boulder on top of Bochastle Hill, called "*Samson's Putting Stone*," resting on Conglomerate rocks. Longer axis N.E. In a very unstable position, being close to edge of a precipice, facing W.S.W., and about 330 feet above valley. About 50 feet below the above boulder there is another gneiss boulder, lying on a very steep slope of the same hill, facing westward,—from which quarter it must also have probably come (*First Report*, p. 46, and *Second Report*, p. 169) (*Lithograph No. 37, Plate X.*).

*Clunie*.—Several boulders on tops of knolls. They probably have come from Grampians, which lie to N.W. (*Second Report*, p. 170).

*Crieff*.—Two large Conglomerates, one called "*Witches' Stone*," and two of granite, one called "*Cradle Stone*," lying on the "*Knock*" Hill (*First Report*, p. 467).

*Doune* (near Kilbride).—A large Conglomerate boulder, weighing about 900 tons (*First Report*, p. 46).

The nearest Conglomerate rocks *in situ* are W.N.W. from boulder, and distant about 7 miles. The boulder in shape is angular. It lies on gravel. The boulder must have been *carried* to its site (*Estuary of the Forth*, p. 41).

*Dunblane*.—Gneiss boulder on Cromlix estate, about 4 miles south of Grampians,  $17 \times 10 \times 5$  feet. Longer axis S.W. and N.E. In *Redgorton parish*, four boulders (at west end of gravel ridge) reported to be Silurians; distant from Grampians 12 miles (*Third Report*, p. 5).

*Dunkeld*.—On Craigiebarns Hill, to N.E. of town, mica schist boulders, lying chiefly on knolls and other exposed surfaces which face N.W. at a height of about 1000 feet above River Tay.

On this hill, rocks smoothed and striated, by some agency which evidently passed over them from N.N.W.

The directions of the striæ at lower levels correspond more with axis of valley, which is about N.E.

The highest striations seem to indicate an agent which passed obliquely across the valley (*Second Report*, pp. 170, 171).

*Fortingall*.—Gneiss boulder,  $24 \times 16 \times 13$  feet, called “*Clach an Salaine*.” Height above sea, 2500 feet. Longer axis N.W. Composed of six or seven large fragments, weighing about 300 tons. Rests on coarse gritty sand. Rocks *in situ* clay slate. About 500 feet below boulder, thick beds of clay, sand, and gravel, denoting aqueous agency (*First Report*, p. 46, and *Second Report*, p. 172).

*Fowlis*.—Several granite boulders near Abercairney, lying on Old Red Sandstone. Have come most probably from N.W., in which direction, at a distance of about 20 miles, there are granite rocks. Supposed to have been used as places of worship and sepulture in ancient times (*First Report*, p. 47, and *Second Report*, p. 171).

*Killiecrankie*.—A large angular limestone boulder, half a mile north of Tenandry Manse;—believed to have come from *Ben-y-Gloe*, or some other mountain adjoining to the north.

On Fassally estate, immense beds of stratified gravel and sand (filling the valley, and cut through by mountain torrents), traced by Convener up to height of 1570 feet above sea. He was told by Rev. Mr Grant of Tenandry of there being similar beds at

a still higher level on *Ben-y-Gloe*. Boulders of granite, gneiss, quartz, porphyry seen by Convener in the Fasically drift-beds (*Second Report*, p. 172).

*Killin*.—On hill to west, about 1350 feet above Loch Tay, thick beds of gravel and sand; and therefore about 1650 feet above sea (*Second Report*, p. 173).

On *Morenish*, east of Killin, and about 1100 feet above Loch Tay, several large boulders (*Fourth Report*, p. 31), of which sketch given. These, as shown by positions, have all come from westward.

*Kilspindie*.—Seven granite boulders, from 5 to 6 tons weight. Five form a line, having a N.W. direction, all differing from the adjoining rocks (*First Report*, p. 47).

*Kirkmichael*.—*Rocking Stone*,  $7 \times 5 \times 2\frac{1}{2}$  feet, and several tall boulders near it, called “*Clachan Sleuchdaidh*,” or “*Stones of Worship*” (*First Report*, p. 47).

*Logie Almond*.—A whinstone boulder called “*Ker Stone*,” about 48 tons in weight, on north bank of River Almond, near a bog; “*Carr*” being Gaelic for “*Bog*.”

There is another boulder, a Conglomerate, resting on Old Red Sandstone, called “*Cul na Cloich*,” or “*Stone Nook*.” A stream forms a nook or angle with the drum or ridge, on which boulder stands.

Another Conglomerate boulder on Risk Farm (*First Report*, p. 47).

*Glen Dochart*.—The axis of valley is about E. and W. On its slopes facing the north, and near bottom, there are many large boulders of granite, which may have come from Ben Cruachan. They occur also on the ridges, on south side of valley;—some so placed as to show transport from westward.

At height of 1250 feet above sea, a vertical rock, well smoothed, with horizontal groovings on its west and north sides, indicative of some agent which has pressed severely on it in passing from westward (*Fourth Report*, p. 32) (*Lithograph No. 38, Plate X.*).

*Schehallion Mountain* (top of, 3560 feet above sea).—Gravel beds indicative of aqueous action, seen by Convener, up to about 3000 feet, to which height small blocks of a fine-grained grey granite seen. Side of hill with smoothest rock surfaces looks N.W. by W. No striæ seen (*Second Report*, p. 173).

Mr Jamieson of Ellon states (*Quart. Journ. Lond. Geol. Soc.* for

1865, p. 165) that *Schehallion* is marked on top, as well as on its flanks, by traces of ice passing over it from the north.

He further states, that along the *north* slopes of the great ridge of mica slate, stretching from *Schehallion* in an E. and W. direction for 10 miles, he saw many boulders of *granite* and *porphyry*, at heights exceeding 2000 feet, above the sea;—the one at the highest elevation, being a granite boulder, at an elevation of 2370 feet. On the ridge where these boulders lie there are no granite or porphyry rocks; but such rocks do occur to the northward (as in *Glen Tilt*), where, therefore, probably is the source from which the boulders came (*Seventh Report*, p. 40).

On the Perthshire Hills, between *Blair Athole* and *Dunkeld*, Mr Jamieson found ice-worn surfaces of rock on the tops of hills, at elevations of 2200 feet, as if caused by ice pressing over them from the N.W.;—and transported boulders at even greater heights.

On the highest watersheds of the *Ochils*, at altitudes of about 2000 feet, Mr Jamieson found pieces of *mica schist* full of garnets, which seemed to him to have come from the Grampian Hills to the N.W., showing that the transporting agent had overflowed the Ochil range (*Seventh Report*, p. 42).

*Pitlochry*.—On road to Straloch, a mica slate boulder, about 8 tons weight, called “*Gledstone*,” about 1800 feet above sea, lying on gravel drift; adjoining rocks are clay slate. Legend that this boulder gave name to Gladstone family, an infant having been found at boulder by shepherd, who took it to his wife to be nursed.

Near parish church of Straloch, “*Clach Mhor*” (*Great Stone*), a boulder of coarse granite, about  $24 \times 20$  feet, and weighing about 800 tons. Many other boulders of mica slate and quartzite beside it. Supposed to have come from the north, through a valley there. Adjacent rocks, clay slate (*First Report*, p. 47).

*Luib*.—Large boulders lying in a line along ridge and top of *Beinn nan Clach*. One, much rounded, on the solid rock of the very summit, 2309 feet above sea. Summit rock also much rounded. The outcrop of the strata on hill-side have been broken off by some means (*Ninth Report*, p. 13, and *Lithograph* No. 39, Plate X.).

#### KENFREWSHIRE.

*Kilbarchan*.—A porphyry boulder,  $27 \times 17 \times 12$  feet, weighing

about 300 tons, called “*Clach a Druidh*” (*Stone of Druid*). Rocks of same kind as boulder in hills to W. and N. about 2 miles distant (*First Report*, p. 48).

*Paisley*.—Mr Jamieson of Ellon describes boulders in clay beds of brickworks. Many of these boulders show glacial striæ. It is common to find *Balani* sticking on under surface of these boulders. Suggested in explanation, that after *Balani* had grown on boulders, the boulders were floated away by ice, and dropped on mud where now found. Mr Jamieson adds that “I sometimes found, on heaving up a boulder, a number of young crushed mussel shells beneath it, as if squashed by the fall of the stone.” The clay round also occasionally exhibits black stains, as if from the decay of sea-weed that had been attached to the stone” (*Lond. Geol. Soc. Proc.*, xx. p. 276 (*Seventh Report*, p. 43)).

#### ROSS AND CROMARTY.

*Glenelg* (West Coast).—On right bank of Elg, a grey granite boulder  $21 \times 18 \times 10$  feet, (280 tons)—its sharp end points N.N.W. (*Fourth Report*, pp. 3, 4).

*Glen Rossdale*.—About 8 miles from Glenelg, several boulders, which, on account of positions, seem to have come from the N.W. Ordnance surveyors reported several horizontal terraces among the hills of this glen, up to 800 feet above sea-level (*Fourth Report*, p. 49).

*Lochalsh* (West Coast).—Gneiss and quartz boulders. Longer axis of first, E. and W.;—of second, N.W. and S.E. (*First Report*, p. 49).

*Rosskeen*.—Granite boulders of large size at Ardross, Newmore, and Achnaclloch (*Second Report*, p. 175).

*Shieldag* (Loch Carron).—Boulder  $18 \times 10 \times 10$ . Longer axis E. and W.; also another. Both in precarious positions (*First Report*, p. 50).

*Applecross* (viz., on West Coast).—Three large boulders, one near shore at Rossel, called “*Clach Oiu*,” weighing about 60 tons; other two about 30 tons each, called respectively “*Clach Mhoir*” and “*Clach Bhan*;”—used as landmarks from the sea. Kaims at Ardbain and Ardrishach, each extending more than 2 miles along coast (*First Report*, p. 48).

The late Professor Nicol notes that on the tops of the Applecross Hills there are boulders of large size. He says that the direction of the rock striæ there is S.  $20^\circ$  W. (true).

*Gairloch* (West Coast).—Numerous boulders were found by

Convener along coast to north of the Gairloch Hotel, and at all heights up to the very summits of the hills, reaching to nearly 1000 feet above sea. The late Professor Nicol's description of these boulders is not inappropriate, when he says that these "hills about Loch Maree and Gairloch are strewed with innumerable fragments of red sandstone, perched, like sentinels, in the most exposed and perilous positions, on the very edge of some lofty cliff, or on the polished summit of domes of gneiss." These red sandstone boulders belong mostly to what has been termed the Cambrian formation, reddish-brown sandstone rocks, which exist along the coast towards the north, and partially also in the east coast of the Lewis. The rocks of the Gairloch Hills are generally gneiss.

*Lithograph* No. 40 (Plate X.) represents a granite boulder on the edge of a high sea-cliff facing the west, 747 feet above the sea, projecting  $2\frac{1}{2}$  feet beyond the edge of the cliff; having apparently been lodged there by some agent which, striking upon the cliff, caused the boulder to slide off upon the cliff.

*Lithograph* No. 41 (Plate X.) represents one of the hills on the coast, to the north of the Gairloch Hotel, 585 feet above the sea, with two boulders on the west side of its summit. The Convener, on ascending the hill to examine the boulders, found that the large boulder was 7 feet long by  $3\frac{1}{2}$  feet high, and that it projected 2 feet beyond the edge of the cliff. As the rock on which it rests slopes down towards N.W. at an angle of  $15^\circ$ , the Convener thought there would not be much difficulty, by means of a crowbar, in projecting it over the cliff altogether.

*Lithograph* No. 42 (Plate X.) shows the foregoing boulder, with the rock it rests on, on a larger scale. This boulder is a blue whinstone, the small boulder a red sandstone, and the rock of the hill clay slate.

*Lithograph* No. 43 (Plate X.) shows a rocky knoll, near the base of the same hill, on which a number of true erratics are clustered. The uppermost of these ( $6 \times 5 \times 3$  feet) rests on the others, in such a position as to show that it had come from the N.W.

On the hills between Gairloch and Loch Fionn, the position of the smoothed rocks, and also of boulders, seemed to indicate a movement rather from W.S.W. than from the usual direction of N.W. The deflection, the Convener thought, could be accounted for by a range of hills there, against which the transporting agent may have struck (*Fifth Report*, p. 56).

*Loch Maree*.—Rocks on road between Gairloch and Loch Maree showed striæ, in usual direction of W.N.W. and E.S.E.

Boulders are visible on all the hills. Near *Loch Maree Hotel*, at height of about 1000 feet above sea, a plateau found by Convener, well covered by boulders lying on drift.

On another hill near the hotel, about 900 feet above the sea, a well-rounded boulder was found, very near the top, on its west side, lodged in a shelf, where it pressed at its east end against the rock of the hill, as shown on *Lithograph No. 44, Plate X.*

*Achnasheen (Dingwall and Strome Ferry Railway)*.—A boulder 15 feet in girth of grey granite, on a gravel terrace, 610 feet above sea. Locality interesting, on account of the immense beds of gravel and sand which have been formed here—no doubt by the agency of the sea; and probably flattened by lacustrine waters, of which *Loch Rosque* is a remnant.

Several hills to the south ascended by Professor Heddle;—one of them, *Sgurr-na-Lapaig* (3778 feet), requiring “the hardest climb” he had ever experienced. For about 1500 feet above “*Loch Mullardoch* the slope was at an angle of 47°. At height of 1530 feet there rests on this slope a boulder 12 × 8 × 7 feet, of hard quartzy gneiss, which he says *must* have been brought there,” as it differs from the rock of the hill (*Ninth Report*, p. 16).

*Ben Wyvis* (3426 feet), near Dingwall.—Its N.W. shoulder presents whole acres of rock swept bare of soil, with rounded and polished boulders of a peculiar veined granite, identified with rocks to the westward, in the tract called *Dirriemore*. These boulders are found half way up Ben Wyvis. Similar boulders occur, strewed over the country both north (Alness and Ault Grand), and south (Strathgarve) of Ben Wyvis. In Strathgarve some of the boulders are as large as cottages (*First Report*, p. 48).

*Dirriemore*.—Mr Jolly of Inverness states that the peculiar granite of this district has been carried “eastward,” none of it “westward.” It has been carried across the Cromarty Firth, and scattered in large masses even over the Black Isle. It is plentiful over the “*Laigh of Moray*” and along the sea-shore, between Burghead and Lossiemouth (*Sixth Report*, p. 47).

Mr Wallace of Inverness also reports having seen *Dirriemore*

granite in numerous boulders in the excavations for the new harbour at *Buckie* in Banffshire (*Sixth Report*, p. 49).

*Edderton* (west of Tain).—Three large boulders of *grey* granite pointed out to Convener at about 1000 feet above sea, on side of hills sloping down towards N.N.W. Rocks on which they rest are Old Red. A horizontal terrace is site of one. The idea that they came from “*Cairn na Cunneig*” (*Hill of Pitcher*), situated 12 miles to N.W. (as suggested by Rev. Mr Joass of Golspie), is disputed, as rocks there are stated to be a *red* granite. Another idea is that they came from hills near Rogart, 10 or 12 miles to N. or N. by E., as rocks there said to be *grey* granite (*First Report*, p. 49, and *Second Report*, p. 175).

*Fannich Mountains* (situated west of Ben Wyvis).—Mr J. F. Campbell (Islay) wrote to Convener that on these hills, 2700 feet above sea, there is a boulder of grey gneiss with garnets. Its local name is “*Clach Mhor na Biachdoil*.” It is  $30 \times 10 \times 3$  feet, and there is a train of large boulders to be seen in a valley not far off. Rocks smoothed and striated. Direction of striæ, parallel with valleys (*First Report*, p. 49).

*Fodderty*.—Boulder angular in shape,  $14 \times 8 \times 5$  feet. Looked on as Druidical. There is another with an inscription, which is supposed to commemorate a battle between two clans.

*Tain*.—Granite boulder, weighing about 60 tons, lying on Old Red Sandstone, about 2 miles N. of Tain at road side. “*Sir Walter Scott*” boulder of red granite, supposed to have come from “*Cairn na Cunneig*” mountains, situated to N.W. (*First Report*, p. 50).

*Tarbet Ness*.—“*Balnabruach*” boulder, a coarse reddish granite, 33 feet in girth and 9 feet high. Longer axis E. and W. This boulder, and another near it, not so large, supposed to have come from “*Cairn na Cunneig*” hill, which visible from boulder bearing W.N.W. and distant about 30 miles. A line from boulder to this hill would cross arm of the sea, 10 or 12 miles wide, between coast at Tain and Tarbet Ness (*First Report*, p. 80, and *Second Report*, p. 175).

*Dingwall*.—Mr Morrison, teacher in the Academy, and Secretary of the Ross-shire Field Club, sent notes, of which the following is an abstract :—

On the south slope of Tulloch Hill there are three boulders of a pinkish granite, of the following dimensions :— $11 \times 7 \times 7$  feet, major

axis N.N.W., at about 550 feet above sea;— $8 \times 5 \times 5$  feet, major axis N.N.W., at about 400 feet above sea;—a flat block of mica schist  $11 \times 7 \times 2$  feet, at 620 feet above sea, major axis E. and W. On this last-mentioned boulder there are ruts and striæ running N.W., and about thirty-six artificial cup-markings.

On Drynie Farm, S.W. of last mentioned boulder, at 610 feet above sea, a mica schist boulder  $12 \times 8 \times 4$  feet, major axis N.N.W. On its surface six striations, running N. and S., with one cup-mark at south end.

On Tulloch Hill, another pinkish-coloured granite boulder 900 feet above sea,  $8 \times 6 \times 4$  feet, with major axis N.W. The prevailing rock on Tulloch Hill is bluish-grey indurated sandstone slate.

Where strata crop out on opposite side of valley their edges have been rubbed and smoothed on their north faces by some natural agency moving in a direction from N.W.

On north slope of Tulloch Hill a moor stretches up to height of about 1100 feet, on which many small boulders of same kind as above,—and to be found also all the way down to Cromarty Firth.

Mr Morrison set out on an excursion to west, with the idea of discovering the direction from which these Tulloch boulders had come. At *Ach-na-Clerach* he found “a gigantic mass of the same kind of granite as the boulders,  $25 \times 23 \times 12$  feet,—the rock on which it was resting being different from that of the boulders.

At the confluence of the rivers *Glascarnoch* and *Strathvaick* he found rock of the same variety as the Tulloch boulders, but at a lower level than Tulloch Hill. He inferred that the boulders had been carried eastwards over the south shoulder of Little Wyvis, and that “*they* probably came from Carn-Cuineag through the opening occupied by Loch Glass.”

Mr Morrison, accompanied by some geological friends, proceeded next to *Cairn Cunneag*, 2744 feet above sea. It is the highest hill in Easter Ross. Its two peaks, or *Pitcher lugs*, are pinnacles of granite. Its slopes are covered by enormous masses of granite semi-cubical in shape. An opinion was formed that most of the boulders in Easter Ross had been derived from this mountain, and its lesser neighbours *Carn-Maine*, and *Carn an Lochan*.

The saddle between the two peaks appears like a shingly beach;—rounded stones of about 10 pounds weight are packed here and

there in crevices, with longer axes of the stones lying generally in one and the same direction.

#### ROXBURGHSHIRE.

*Castleton*.—Many blocks of granite (red and grey varieties) lie on greywacke and Carboniferous rocks,—which apparently came from Dumfries and Kirkcudbright shires, 30 to 40 miles distant, crossing Esk and other rivers (*Sixth Report*, p. 28).

Rounded boulders of grey granite occur on the fields and moors near Castleton Manse, where Convener saw several from 3 to 4 feet in diameter. On east bank of River Esk, about 2 miles below Langholm, Convener saw granite boulders—both red and grey varieties—some of them very large. A number occur also in the Gill burn, which flows into the Liddell above its junction with the Esk. These granite blocks lie on the greywacke strata, as well as on the coal measures. The nearest known hill of granite is Criffel, which consists almost entirely of grey granite, situated about 20 miles W.S.W. from these boulders. The next nearest place where granite rocks occur is in Ayrshire, at Loch Doune, bearing about W. by N. from the boulders.

In a small stream north of Tofts House, and about three quarters of a mile east of Edgerstone, there were seen by Convener several angular blocks of greywacke, resting on a purplish porphyry rock. The nearest point where there are greywacke rocks *in situ* is about half a mile to west, between which, however, and these blocks, there is a porphyry hill several hundred feet high. There is no greywacke to the south or east ("Geological Account of Roxburghshire," *Trans. Edin. Roy. Soc.*, vol. xv. p. 412).

In this parish there is a remarkable kaim, composed partly of gravel, partly of sand, in horizontal beds. It runs for about half a mile; is about 200 feet wide at base, and from 50 to 60 feet high. In the gravel there are blocks and pebbles of granite (both red and grey), as well as fragments of shale and coal,—derived, no doubt, from rocks to the westward. The kaim forms nearly a straight line, the direction of which is N.E. by E. (*Trans. Edin. Roy. Soc.*, vol. xv. p. 463).

Another long ridge of sand occurs near Eckford, on the River Cayle, running E.N.E.

*Jedburgh*.—Porphyry boulder, supposed to have come from Dunion Hill, which is 2 miles to the west. Formerly a Granite boulder on this hill (seen by Convener), which must have come from Galloway or Dumfriesshire (*First Report*, p. 50).

*Nesbit*.—Near the village (about 8 miles S.W. of Kelso) a green-stone boulder, identical in composition with rocks on Penielheugh Hill, on which stands Waterloo Pillar. Boulder is on a knoll, a little to N.W. of top of knoll. Penielheugh is S.W. from boulder, and about a mile distant. Transporting agent moved, therefore, here in a N.E. direction. Hill is 774 feet above sea, and boulder 224 feet above sea. Rocks where boulder lies are Old Red Sandstone.

*Ruberslaw*.—On this hill a large boulder of greywacke found by Convener, lying on Old Red Sandstone rocks. Nearest greywacke rocks *in situ* are about 3 miles to westward. If boulder came from these greywacke rocks it must have crossed low ground 800 feet below level of boulder (*Edin. Roy. Soc. Trans.*, vol. xv. p. 454).

#### SELKIRKSHIRE.

*Galashiels*.—On the top of Meigle Hill, 1430 feet above the sea, there is a Silurian boulder  $6 \times 4\frac{1}{2} \times 3\frac{1}{2}$  feet, with its longer axis N.W. and its sharpest end pointing in that direction.

The boulder is on the east side of the apex of the hill, and 12 feet below it. It is lying on drift.

Meigle Hill is composed of Silurian rocks. It stands by itself; there being no hills of equal altitude within some miles of it.

Other boulders of a smaller size occur on the hill. They seemed to the Convener to be all erratics (*Sixth Report*, p. 30).

#### SHETLAND.

*Brassay Island*.—A number of coarse white sandstone boulders on east side of island, at heights of from 40 to 360 feet above the sea, differing from rocks *in situ*, which consist of Conglomerate and Old Red Sandstone flags. Largest boulder  $10 \times 7 \times 4$  feet. Its longer axis N.W. There are said to be distinct groovings on it, some of them 3 inches deep;—their direction E. and W. Agent which striated rocks must in that case have crossed a valley at right angles (Dr Gordon of Birnie, Reporter) (*First Report*, p. 43, and *Second Report*, p. 176).

*Foula Island*.—Situated about 20 miles from nearest other island, and with a sound between, of 50 fathoms in depth (*Second Report*, p. 177).

On this island, which has on it a hill reaching to a height of 1370 feet, several boulders were reported to the Committee.

The Rev. James Russell, in 1873 (who was then resident in Walls), visited the island, and refers to several boulders—situated in the *south* half of the island,—the *north* half he had not examined.

From the middle of the island, to south end, he reported drift as high up as 700 feet, containing much granite and gneiss, which he supposed to have come from Mainland. In the *middle* of the island there are two boulders of irregular shape, each weighing about 2 tons,—their composition he does not mention.

Mr Russell stated that at the *south end* of the island there are three boulders of gneiss and two boulders of granite, each weighing from 3 to 5 cwt., and which he supposed came from the Culswick and Delting Hills on Mainland, towards the N.E.

Messrs Peach and Horne, on the other hand, suggest that these boulders may belong to rocks *in situ* on Foula itself, inasmuch as the eastern part of the island (they say) consists of gneissose rocks, with a mass of granite in the N.E. corner (*Geol. Mag.* for August 1881, p. 372).

Messrs Peach and Horne, however, mention that they discovered in the boulder clay of Foula a block of epidotic syenite from Dunrossness;—a locality which bears S.E. from Foula, separated by sea at least 50 miles in breadth, and having a depth of 70 fathoms.

*Houssay Island*.—On a cliff 200 feet above sea there are loose blocks resting on rounded and polished rocky knolls; the knolls having been evidently polished before receiving the boulders (*First Report*, p. 43).

*Papa Stour Island* was visited by the late Dr Hibbert in the year 1822 (*Edin. Journ. Science* for 1831, vol iv. p. 86). He found in it several peculiar schists, foreign to the island, apparently derived from rocks at Hilswick Ness, situated to the N.E., and distant about 12 miles across St Magnus Bay, which has a depth of 40 fathoms.

This island was visited also by Professor Geikie, who states that he found on it many “transported blocks of gneiss, schist, and other rocks foreign to the locality” (*Nature*, vol. xvi. p. 415).

Besides the boulders pointed out by Dr Hibbert, Messrs Peach and Horne say that on *Papa Stour* they saw others of "Old Red rocks, derived from the area occupied by the rocks between Sandness and Bixiter Voe;"—places on Mainland, situated to the S.E. of *Papa Stour*, and separated from it by an arm of the sea.

*Hilswick Ness*, the south end of an isthmus, on the north side of St Magnus Bay.

Dr Hibbert refers to a transported boulder on the summit of this promontory;—describing it as "a surprising block of granite;—removed from a rock, the nearest site of which is about 2 miles north" (*Edin. Journ. Science*, vol. iv. p. 89).

Messrs Peach and Horne, who had not mentioned this boulder in their paper, adverting to Dr Hibbert's notice of it, say that "this boulder might have been derived from some of the masses of the same material, lying at a slightly greater distance to the E. and N.E. of Hilswick" (*Geol. Mag.* for August 1881, p. 372). If that view be taken, the transport must have been across an arm of the sea running N. and S. on the east side of Hilswick Ness.

*Roeness Hill*, on North Mavine, 1476 feet high.—Dr Hibbert says, this hill being "composed of *red granite*, I was struck with the immense number of boulders of a *primary greenstone*, which appear to have been removed from a site 2 or 3 miles off, and to have been brought in a southerly or south-westerly direction up a gradual ascent of 3 or 4 miles" (*Edin. Journ. Science*, vol. iv. p. 89).

Messrs Peach and Horne admit the facts as here stated. They say they "entirely support our conclusions, viz., of the boulder having been carried up hill by the Scandinavian ice-sheet, in a S.W. direction" (*Geol. Mag.* for August 1881, p. 371).

*Additional Localities*.—The Rev. Dr Gordon of Birnie visited Shetland in the year 1872, and sent to the Committee the following notes:—

(1) *Boulders*.—Near North Mavine (the extreme north of Mainland) there are large boulders between Hilswick and Ollaberry. He sent to the Committee pencil sketches of three boulders, situated in the same North Mavine district, between St Magnus Bay and Yell Sound. They are syenitic. One near Eela water is  $16 \times 12 \times 6$  feet. Another called *Crupna (bent)* is  $11 \times 8 \times 8$  feet. The third called *Bonhus*, situated between the other two, is  $8 \times 10 \times 11$  feet.

(2) *Striae* on rocks seen by Dr Gordon, at two places, about 20 miles asunder; one a mile north of the fishing huts of Stennis on N.W. shore of St Magnus Bay, on coarse Conglomerate rock. The other place was at Islebury, where there is a valley running N. and S. The *striæ* showed that striating agent had crossed valley in E. and W. direction (*Second Report*, p. 177).

*Lunnasting—Stones of Stoffas.*—Specimens from these blocks were shown to late Professor Nicol of Aberdeen, who after examination considered them to be *gneiss*, the same as the rock of the island. They are from 20 to 22 feet high, and 90 feet in girth. Height above sea 100 to 120 feet. The Professor, from the account given to him of them, thought the stones had *probably* been “*carried*,”—there being no land near them at a higher level (*Second Report*, p. 193).

The following notes were sent to Convener, by some person, evidently well acquainted with the locality, but whose name has unfortunately not been preserved :—

Four boulders, looking “like pale granite,” on the estate of *Lunna*. Nos. 1, 2, and 3 stand near each other in north part of parish, not far from sea, and at a height above sea-level of from 150 to 200 feet.

No. 1 is in height 22 feet; length, 36 feet; breadth, 25 feet, angular in shape; direction of longest axis N.W.

No. 2 is in height 19 feet; length, 34 feet; breadth, 14 feet; angular direction of longest axis N.E.

No. 3 is in height 11 feet 4 in.; length, 8 feet 7 in.; breadth, 8 feet 2 in.; direction of longest axis N.W.

Nos. 1 and 2 separated from each other by a distance of 10 or 12 feet; the intervening space *being filled* with large masses which have apparently fallen from No. 2.

Nos. 1 and 2, known as “*The stones of Stoffas*.” This word said to be a corruption of “*Stay fast*”; the legend being, that two giants were passing through Lunnaness, when some superior power arrested their farther progress by pronouncing the words, “*Stoffas!*”

No. 4 stands by itself, surrounded by deep moss, within a few yards of the highest point of a hill, about 4 miles to the south of the other three stones.

*Note by Convener.*—The stones of Stoffas are referred to by late Dr Hibbert, in his volume on Shetland. He describes them as “enormous detached masses, which do not seem to have undergone

any distant removal, since they repose on rocks of a precisely similar kind" (p. 179).

Professor Heddle of St Andrews informs Convener that he examined these stones, and thought they had been detached and wrenched off from other rocks, and moved in a direction towards E.S.E. (*Eighth Report*, p. 7).

*Fair Isle Parish.*—Rev. Mr Laurence, catechist, reported that there are no boulders above 10 tons, but that there are several small boulders of Conglomerate quite differing from any rocks in island (*Eighth Report*, p. 7).

He adds that there was one large block of sandstone which was blown up in 1880. It differed from any rocks in island, and was similar to the Eday sandstone.

The island of Eday is about 13 miles to S.S.W. of Fair Isle (*Eighth Report*, p. 8).

*North Unst.*—All over Unst the rocks show abrasion, and, in many places, deposits of drift, enclosing stones of various sizes.

Mr Peach, senior, at the request of the late Sir Roderick Murchison, examined this most northern isle of the Shetlands, and gave in a Report to the British Association in the year 1864. He stated that he "ascended the Muckle Heog Hill, reaching to a height of 500 feet; and found the W.N.W. end vertical, and polished to the depth of at least 150 feet." Professor Geikie in an article in *Nature*, of 17th September 1877, refers to the foregoing report by Mr Peach, and says "that from his own observations he can speak confidently as to the correctness of Mr Peach's determinations."

*Sumburgh Head.*—Conglomerate boulder lying on sandstone rocks (*Second Report*, p. 44).

In addition to the information in the foregoing notes, regarding boulders, it is right to refer to the information given by Messrs Peach and Horne (in their paper on the Shetlands) regarding the extent to which all the hills, even the highest, show traces of glaciation (*Jour. of Lond. Geol. Soc.* for November 1879).

They say—that "from Sumburgh Head northwards to Unst we found everywhere the clearest evidence that Shetland must have been at one time *smothered in ice*" (p. 706).

"It is apparent, on a moment's consideration, that the direction of

the striæ would have been widely different, had the island radiated *its own ice*, and had the glaciation been purely *local*" (p. 791).

"For these various reasons, we are justified in inferring that the glaciation of these outlying islets is due to the action of an ice-sheet *originating far beyond the sphere of Shetland*" (p. 792).

"The highest ground in the centre of the Mainland is likewise *ground down and striated*. The ridge which extends from Weesdale Hill (842 feet) to Scallafield (916 feet) reveals the fine lines as well the flutings of the ice-chisel" (p. 793).

#### STIRLINGSHIRE.

1. *Alloa*.—Basaltic boulder,  $13 \times 12 \times 11$  feet, called "*Hair Stone*," about 70 feet above sea. Longer axis N. and S. Assuming boulder to have come through valley or kyle, between Abbot's Craig and Damyat, it must have travelled in a direction from N.W. by W. (*First Report*, p. 50).

2. *Kilsyth and Strathblane*.—Mr Jack, of Scotch Government Geological Survey, reported two boulders,—one of mica slate, weighing about 6 tons, 1260 feet above sea, its parent rock supposed by him to be to the N., and distant 15 miles. The other boulder is Conglomerate,  $8 \times 4 \times 3$  feet, its longer axis being W.  $20^\circ$  N., its parent rock supposed by him to be also to N.W. (*First Report*, p. 51).

3. *Campsie*.—Mr John Young of the Hunterian Museum, Glasgow, accompanied Convener to an inspection of the district near Campsie, and pointed out the following objects of interest:—(1) On Craigend Moor, about 450 feet above sea, sandstone rock presented great sheets of smoothed surface, evidently ground down by severe or long-continued friction, with occasional striæ running S.E. by S. In some places there were quartz pebbles in the sandstone rock, which were ground down, showing marks of rubbing chiefly on the N.W. sides.

At four other places there were striations on rocks, pointing respectively S.E. by S. and S.E.  $\frac{1}{2}$  S., S.E. by S., S.S.E.

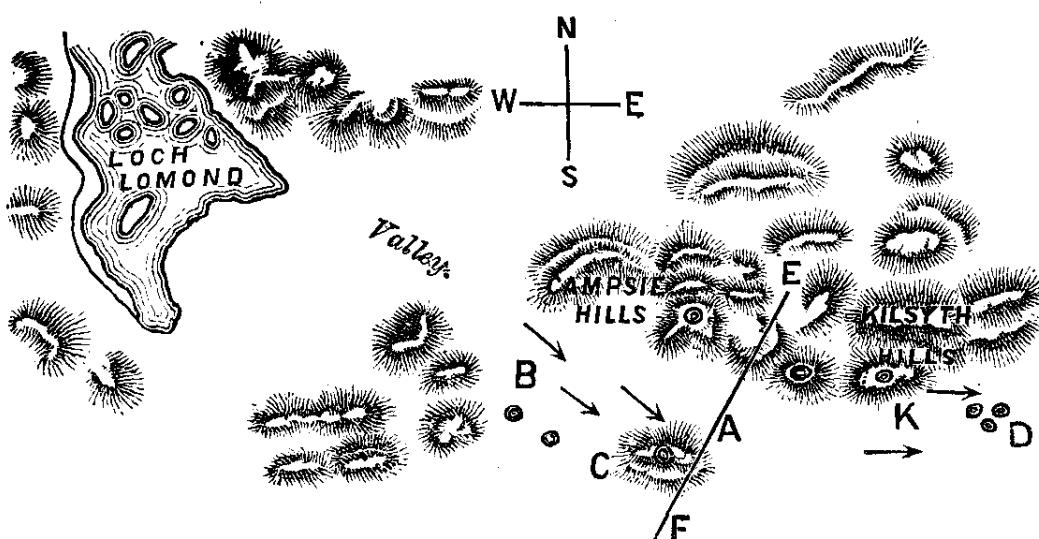
Looking from this moor towards the N.W., hills are seen about a 1000 feet high, at one place with an opening between them of about  $1\frac{1}{2}$  miles in width, through which, if there was a current, it might pass over Craigend Moor.

Several boulders were pointed out. Two were of a species of trap common in the Kilpatrick Hills, situated some miles to W.N.W. Another boulder was a grey granite, which, judging from the size of its felspar crystals, Mr Young supposed might have come from Ben Awe, a mountain situated to N.W., and distant about 30 miles. There were also several Conglomerate boulders, derived probably from the belt of that rock, which, running from Dumbarton, crosses Loch Lomond in a N.E. direction towards Aberfoyle.

The Convener at another time, when on Campsie Hills, found rocks at 800 feet above the sea, striated in a direction E. and W. On the Kilsyth Hills, a few miles further east, the rock striæ point the same way.

On *Croy Hill*, a knoll of trap rock, being the summit level between the Firths of Clyde and Forth, about 160 feet above the sea, there is an immense accumulation of boulders. Some of the boulders are of old Conglomerate, which must have come from the westward and stuck on the knoll (*Fourth Report*, p. 42).

The relative positions of these localities may be more readily understood, by referring to the annexed map.



→ → Direction of rock striæ ; B, Craigend Moor ; K, Croy Hill ; Boulders shown by black dots, •••

4. *St Ninians*.—Boulder weighing about 200 tons, at height of 1250 feet above sea, reported by Mr Jack, but no particulars given (*First Report*, p. 51).

5. *Sheriffmuir*, 3 miles from Bridge of Allan, a large boulder called "Wallace's Putting Stone" (*Fourth Report*, p. 34).

6. *Stirling and Doune districts.*—Conglomerate boulders occur at the following localities (*Sixth Report*, p. 31):—

(1) At *Kilbride*, boulder of about 900 tons (mentioned under Perthshire).

(2) On *Landrick Estate*, boulder of about 360 tons.

(3) At *Keltie Bridge*, boulder weighing about 60 tons.

(4) On *Gartincaber*, boulder weighing about 16 tons.

(5) On *North side of River Teith*, boulder weighing about 13 tons.

(6) In the *Burn of Campsie*, two boulders each weighing about 13 and 24 tons.

(7) In the district traversed by the hill road between *Doune* and *Callander*, multitudes of smaller size.

(8) At *Cornton Brickwork* (between Stirling and Bridge of Allan), small boulder found in bed of clay.

(9) On the rocks adjoining *Stirling Castle* on the north, small Conglomerate boulders, besides others of gneiss and greywacke.

(10) At *Loch Coulter* and *Gillies Hill* (places 3 miles south of Stirling), several Conglomerate boulders, besides others of mica slate and felspar porphyry.

(11) On *Plean Estate* (4 miles S.E. of Stirling), boulders of Conglomerate, gneiss, granite, greywacke, and whinstone.

(12) At *Glenbervie*, near Torwood (5 miles S.S.E. of Stirling), a Conglomerate boulder, 6 feet square, found by Convener.

(13) On *Dunmore Estate* (9 miles S.E. of Stirling), a Conglomerate boulder of about 10 tons, found by Convener.

A more particular account of the foregoing boulders may be found in "*The Estuary of the Forth*,"\* p. 41, where it will be seen, that all those which are elongated in shape, generally have their longer axis in a direction N.W. and S.E.

There can be no doubt that all these boulders had been carried from hills situated to the N.W., near Callander and Aberfoyle, as there are rocks there of the kind composing the boulders, and in no nearer district.

On the north side of *Stirling Castle* the trap rocks are traversed by narrow gorges, running about E. and W., the sides of which in many places present smoothings and striæ, especially on the south sides, indicating transport from a point a little to the north of west.

\* Edmonston & Douglas, Publishers (1871).

The striæ are generally horizontal, but occasionally are inclined slightly upwards towards the east.

A few small boulders, well rounded, occur in several of the gorges. Among them, granites and conglomerates were observed.

*Craigforth Hill*, about 2 miles west of Stirling, has smoothings on its rocks near the top (198 feet above sea), and a few striæ running in a N.W. and S.E. direction. The Convener found on it also small boulders, apparently from rocks situated at or near Aberfoyle, which bears W.  $\frac{1}{2}$  N. from Craigforth.

On or near the *Racecourse* at Stirling (situated S.W. from the Castle), about 130 to 160 feet above the sea, there are several granite boulders lying on smoothed sandstone rocks. The largest is  $7 \times 3 \times 4$  feet. It is on a rocky knoll, the smoothest part of which slopes down towards N.N.W. As the boulder, from its composition, most probably came from the hills situated to the N.W., it must have lodged on what would be the *lee* side of the knoll.

7. *Aberfoyle*.—Arndrum Hill, reaching to height of 454 feet above sea, forms part of the ridge of Conglomerate rock, which traverses country in a N.E. and S.W. direction by Callander and Loch Lomond. On this ridge Professor Heddle, at a height of 230 feet, found a line of six boulders of angular gneiss, stretching N. and S. They are from 2 to 20 feet apart, and are from three-quarters to 3 cubic yards in size.

To the west of this line, four other similar boulders lay along the summit of the ridge, and thus at right angles to the first line (*Ninth Report*, p. 16).

#### SUTHERLANDSHIRE.

*Assynt*.—Two large boulders, one at Unapool, the other at Stonechrubie, called “*Clach na Patain*” (*Stone of the Button*) (*First Report*, p. 51).

*Golspie*.—An Old Red Sandstone boulder,  $16 \times 10 \times 4$  feet, about 248 feet above sea, lying on oolitic rocks,—subangular,—with longer axis N.N.W. Three smaller boulders of Old Red Sandstone lie about 100 yards to S.E. The Old Red Sandstone formation is situated to N. and W., about 3 miles from those boulders (*First Report*, p. 51).

Rev. Mr Joass, of Golspie, refers to a large boulder of gneiss, weighing about 120 tons, called “*Clach Mhie Mhios*”; *Clach* being

Gaelic for “*Stone*,” “*Mhie*,” of a *son*, “*Mhios*,” of a *month*; this name having been given by legend, that stone was thrown from a hill 2 miles distant by a child of Fingal, when only one month old (*First Report*, p. 10).

*West and North Coasts.*—The late Robert Chambers visited the west coast of Sutherland, travelling round by Cape Wrath, and along the north coast as far as Tongue Bay; with the following results :—

1. At a height of 1700 and 1800 feet, he found striæ on the rocks of *Cuineag* and *Canish* (quartz hills in Assynt, about 30 miles north of Gairloch), running *from* about N. 60° W. with certain exceptions. One of these exceptions was at the base of *Cuineag*, where the streaks are from the direct *north*, apparently by reason of *a turn or deflection which the agent had there received at and by reason of the base of an adjoining hill*. Another exception was at the hollow dividing the mass of the hill from its loftiest top, where another system of streaking had come in from the direct *west*.

2. On a summit south from *Ben More*, fully 1500 feet high and 4 or 5 miles to the south of Cuineag, there are streakings on the quartz, observing the normal direction of this general movement, viz., from N. 60° W.

3. On the gneissic platform between *Coul More* and *Sulvean Dr* Chambers found polished surfaces striated from N.W. and from W. To the west and north of the latter mountain are markings in all respects similar. These are situations, observes Chambers, where no local glaciers could exist.

4. Streakings precisely the same as those on Cuineag and Canish exist at an elevation of at least 2000 feet on the similar quartz mountain called *Ben Eay*, south of Loch Maree, and 40 miles from Assynt;—this striation being from N.W. or thereabouts, and totally irrespective of the form of the hill.

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

6. A little farther north, at *Laxford*, a fine surface is marked with striations from the N.W., *being across the valley in which is*

occurs. At an opening in the bold "gneissic coast, which looks out upon the *Pentland Firth*, there is strong marking in a direction from N.N.W. The high desolate tract between Loch Eribol and Tongue Bay, where there is *nothing that could restrain or guide the movement of the ice*, exhibits striations from N.  $28^{\circ}$  W. Striae in nearly the same direction, viz., N.  $25^{\circ}$  W., occur 4 miles to the east of *Tongue*. On perfectly free ground, at *Armadale*, the markings point almost directly from the north. When we pass on to *Caithness* we find traces of striation, still from points between N. and N.W., which is directly transverse to a line pointing to the neighbouring hills" (*Fifth Report*, p. 62).

The late Professor Nicol observes that, "on the whole N.W. coast, from Cape Wrath southwards, numerous 'perched' boulders occur on summits and sides of hills, in most exposed situations. They are especially numerous around Loch Maree" (*First Report*, p. 51).

In another paper (*Brit. Assoc. Reports* for 1855, p. 89) the Professor states that "on the west coast of Sutherland, near Loch Laxford, enormous blocks are perched on the top of rounded bosses, or on the very verge of precipices. As the slightest impulse seems sufficient to dislodge these boulders, the manner in which they were placed in their present positions is very problematical."

It is matter of regret that no reports came to the Committee regarding the boulders on the N.W. and N. coasts of Sutherlandshire, though frequent applications for them were made. For want of reports it has been thought right to refer to the foregoing observations by Dr Chambers and Professor Nicol.

*Clyne*.—Remarkable kaims, apparently moraines, lateral and terminal, in Brora valley. At Clynnish quarry the sandstone rocks striated in a direction from W. by N. to N.W. (*First Report*, p. 51).

#### WIGTOWNSHIRE.

*Glasserton*.—Granite boulder,  $9 \times 6 \times 6$  feet, weighing about 24 tons. Longer axis N.E. and S.W. Two other boulders in a line with it. These supposed to have come from mountains to N.E., crossing an arm of the sea.

Several kaims in the parish, full of granite pebbles (*First Report*, p. 38).

*Glenluce.*—The Rev. Mr Wilson reports the finding of water-worn nodules of *flints* in beds of stratified drifts, at different places along the coast for about 6 miles. Various localities named, where flints were found by Mr Wilson in drift beds up to 200 feet above sea. He suggests that some of the drift materials probably came from Arran, and the flints from Armagh in Ireland (*Ninth Report*, p. 26).

### FARÖE ISLANDS.

Though these islands form no part of Scottish territory, they are not so far from the Hebrides, Orkney, and Shetlands, as not to warrant some notice of their glacial phenomena. Moreover, having been visited by several Scotch geologists, who reported on them to the Edinburgh Royal Society, it may be allowable to add a few notes bearing on the boulders and rock striations of these islands :—

#### I. *Erratics.*

1. The first traveller who noticed the glacial phenomena of the Faröes was the Rev. G. Landt, a Danish clergyman, whose book was translated into English in 1810.

In page 8 of his treatise he says :—

“There are sometimes to be seen in the *valleys*, *single stones*, 6, 8, or 10 feet in diameter, *in places where it is impossible they could have fallen down from the hills*. Such stones are found *also here and there*, *at a considerable height on the hills*, where there is no other eminence in the neighbourhood, from which they might have rolled down.” He adds, a little farther on, that these “stones are generally round” in shape.

2. Dr James Geikie, in his elaborate and valuable *Memoir* on the Faröe Islands, lately published in the *Edinburgh Royal Society Transactions*, vol. xxx. p. 250, says, under the head of *Erratics*, that “*large angular blocks* of basalt rock are of common occurrence. Near Thorshavn, many are of large size, measuring occasionally upwards of 20 feet across. They occupy positions which preclude the possibility of their having fallen or rolled down the hills ; and as they are now and again associated with moraine debris, I do not doubt they have been deposited during the melting of the ice-sheet” (p. 250). . . . “While perched blocks are quite absent from the

hill-tops, which give no evidence of glaciation, they are often scattered abundantly over the surface of high ground which has been glacially abraded. This is well seen upon the ridge between Gröth and Skeelfork, where isolated erratics are sprinkled about upon the *moutonnée* surface" (p. 250). In the same paper, Dr Geikie elsewhere repeats that "the *large erratics* scattered over hill-tops and hill-sides were doubtless deposited by the *mer de glace* during its final dissolution" (p. 262).

## II. *Rock Strike.*

In the year 1812 Faroe was visited by Sir George Mackenzie and Mr Allan, both Fellows of the Edinburgh Royal Society, and both of them well-versed in geological inquiries. Both of them read to the Society accounts of their visit. Sir George, in his paper, expressed much satisfaction in having induced Mr Allan to be his companion, on account of "his great experience in geological examinations" (*Edin. Roy. Soc. Trans.*, vol. vii. p. 215).

Mr Allan, in his paper, refers more than once to a "headland near the village of Eide, which (he says) presents a perpendicular front to the ocean." So much interested was he in this "headland," that he attempted to measure its height, and found it to be 1134 feet (page 242).

In a subsequent passage, he again alludes to this "headland" as a thing "of interest," on account of the "remarkable instance (it presented) of the abrasion of its surface, where the rock appears to have been worn down by the friction of heavy bodies" (p. 244).

Then remarking that generally in Faroe, where the rocks do "not consist of impracticable cliffs, they present a solid, smooth surface, always highly inclined," he goes on to say, "it would be curious to investigate whether this smoothness on the sides of the mountains could be traced to any external cause, such as that which has been observed by Sir James Hall on Corstorphine Hill and other parts of the country, indicating the passage of heavy bodies along the surface. Near Eide I observed a very remarkable example of this description. There the rock was scooped and scratched in a very wonderful degree, not only on the horizontal surface, but also on a vertical one, of 30 to 40 feet high, which had been opposed to the

current, and presented the same scooping and polished appearance with the rest of the rock, both above and below."

In the year 1855 the late Robert Chambers, also a Fellow of the Royal Society, who had previously paid much attention to glacial phenomena, visited the Faröes, and wrote an interesting account of what he saw. He explains, that being aware of Mr Allan's discovery at Eide, he went there on purpose to study the markings on the rocks. The following is his description:—"There are some small fields under cultivation. Every here and there the rocks are presented on the surface, where they are invariably seen rounded or flattened, with peculiar deep channelings, precisely like those rocks which are now generally believed to have been abraded by ice. My attention being arrested by these features, I looked narrowly for the *striæ* or scratches which ice generally leaves on surfaces over which it has passed. They presented themselves in abundance, in several places, most strikingly of all, within sea-mark on the shore of the quiet bay, *being all directed from the north, which is also* the direction of the *canaux* or channelings, and further of the passage or isthmus in which the village (of Eide) lies."

In his *Memoir on the Faroe Islands*, Dr James Geikie (p. 246) referring to the same locality of Eide, says, that "perhaps the best preserved *roches moutonnées* we anywhere observed were in Osteröe and Sandöe. It was with considerable interest that we visited the northern portion of the former island, for we felt that the evidence to be gathered there would go a long way to settle the question which we had come to solve. No difficulty was experienced in finding the locality described so long ago by Allan, and subsequently visited by Chambers but the *striæ*, instead of being '*directed from the north,*' had clearly been graved by ice coming *from quite the opposite point of the compass*. The Kodlen peninsula we found glaciated all over, the *roches moutonnées* on both sides of the isthmus being beautifully perfect, and showing *Stogs* and *Lee-seiten* in the most admirable manner. In many places the *striæ* are well seen, and long ruts and channelings, or grooves and trenches, well smoothed and ice-worn, traverse the rock surface. We traced the glaciated contour up to a height of 1302 feet, which was the summit level of the pass leading from Eide to Funding; but the

slopes facing the sound between Österöe and Stromöe seemed to be glaciated to a somewhat greater height. The direction of glaciation upon those slopes, so far as we could observe them, seemed to be in a direction corresponding with the trend of the sound, namely, from S.S.E. to N.N.W."

As any facts bearing on the smoothed and striated rocks at Eide and the Kodlen peninsula deserve attention, the following additional paragraphs in Professor Geikie's *Memoir* are quoted:—

On page 254 he states that "the soundings on the chart prove, that the long fiord which separates Stromöe from Österöe occupies the bed of two submerged valleys, with a low separating *col*, over which there is shallow water. This *col* occurs in the narrow part of the sound between Nordskaale and Öre; and the soundings show that from this point the water deepens, both towards N.W. and S.E. The fiord is shallower at its mouth near Eide, where there are  $5\frac{1}{2}$  and 9 fathoms of water, than it is at and above Haldervig, where we get depths of 18 to 30 fathoms."

On page 261 Professor Geikie states that "the long sound that separates Österöe from Stromöe brimmed with ice, which flowed in two directions. North of Nordskaale the movement was northerly; while south of the shallow part of that sound the ice held on a southerly course."

A point, apparently of some importance, is brought out in Dr Geikie's *Memoir*, viz., that many of the hills show smoothing of rocks, only up to a certain height.

Thus it is stated that "the lower part of the mountains that overlook Kolfaredel are smoothed and abraded in a S.E. direction, and we estimated the height reached by the glacial outline to be some 1500 or 1600 feet. Above that level all is rough and rugged, and destitute of the slightest trace of glacial abrasion" (p. 245).

Then, on an adjoining mountain, where there is a pass at 1243 feet above the sea, there are "*roches moutonnées*," but we saw no striæ. The glaciated outline was continued up the mountain slopes above us, for not less than 400 feet" (p. 245).

In another locality, "the *col*, we found to be 1693 feet above the sea, and the glaciation came close up to this level. But abraded rocks with the characteristic glaciated contour certainly reached 1600 feet" (p. 246).

At p. 246 it is mentioned that "the upper parts of the hills between Fundingsfiord and Andafiorf were above the limits of glaciation." . . . "Suderöe has supported a considerable mass of ice; for we traced the glaciated outline up to a height of 1040 feet. Above that level all is rough, angular, and serrated" (p. 248).

The explanation suggested by Dr Geikie of these interesting facts is, that "when the islands were enveloped in their ice-sheet, the action of frost would be confined to such ridges and hill-tops as projected above the *mer de glace*, while severe glacial abrasion would go on below" (p. 260).

Dr Geikie, in his *Memoir*, more than once takes notice of the "scarcity of moraine mounds," which, he says, "it is difficult to account for satisfactorily;"—but he offers under that head several suggestions, "the principal" being, "probably the continuous and comparatively rapid dissolution of the ice, after the snow-line had retreated several hundred feet above the sea-level" (p. 263).

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#### LIST OF LITHOGRAPHS.

##### ARGYLLSHIRE.

Plate VIII. No. 1. On west coast of Kintyre, a gneiss boulder, lying on Old Red Sandstone strata; blocked at south end, indicating probable transport from north. (*Abstract*, p. 773.)

Plate VIII. No. 2. View of a gneiss boulder jammed between rocky banks of a small stream. (*Abstract*, p. 774.)

Plate VIII. No. 3. Gneiss boulder, called "*Clach Udelain*" or "*Unstable Block*," in consequence of its precarious position. (*Abstract*, p. 774.)

Plate VIII. No. 4. "*Giant Putting Stone*," on rock smoothed from the north. Site of boulder on rock 18 x 12 inches. (*Abstract*, p. 774.)

Plate VIII. No. 5. Two boulders on similarly smoothed rock called "*The Pig's Back*," on Knap Farm. (*Abstract*, p. 774.)

Plate VIII. No. 6. *Loch Glashan*.—A boulder on Knock Farm, resting on smoothed rock, which dips N.N.E. at 30°. Longer axis of boulder and sharpest end point N. by E. (*Abstract*, p. 775.)

Plate VIII. No. 7. Three lithographs (1), (2), (3) of a boulder

perched on top of a ridge, among hills to the south of *Loch Awe*. (*Abstract*, p. 777.)

Plate VIII. No. 8. Great assemblage of boulders on south shore of *Loch Killessport*. B is boulder of 2770 tons weight. A is line of 40 feet old sea-cliff. (*Abstract*, p. 779.)

Plate VIII. No. 11. Rock smoothed and striated at Kilmory. (*Abstract*, p. 780.)

Plate VIII. No. 10. Cluster of boulders on steep hill-side, Killessport. (*Abstract*, p. 780.)

#### BUTE.

Plate VIII, No. 9. *Arran*.—On east shore of, a granite boulder (B) lying on Old Red Sandstone, and blocked at its south end. The shape of boulder shown by fig. A. (*Abstract*, p. 792.)

Plate VIII. No. 12. In *Ettrick Bay*, west coast of Bute, boulder of gneiss standing upon its thick end, against edges of slate strata, which block it on its south side. (*Abstract*, p. 793.)

Plate VIII. No. 13. *Barone Hill*.—Showing smoothing and striation of rocks on both sides of a gorge, through which striating agent had passed from north. (*Abstract*, p. 793.)

#### HEBRIDES.

Plate VIII. No. 14. *Islay Island*.—Porphyry boulder on N.E. side of summit of a steep hill. (*Abstract*, p. 806.)

Plate VIII. No. 15. *Iona*.—Granite boulder, standing on one end against clay-slate rocks. (*Abstract*, p. 808.)

Plate IX. No. 16. *Iona*.—Granite boulder of about 400 tons, on plateau 230 feet above sea, leaning on west side of Dun I Hill. (*Abstract*, p. 809.)

Plate IX. No. 17. *Coll Island*, Bein Hock hill, showing N.W. front, with two boulders on summit, A B, and one on a plateau at its base, C. (*Abstract*, p. 811.)

Plate IX. No. 18. *Coll Island*, Grassipol meadow, having a vertical wall of rocks on S.E. side, showing a great accumulation of boulders. (*Abstract*, p. 811.)

Plate IX. No. 19. *Coll Island*.—A rocky knoll covered by boulders, showing that uppermost boulder had come from N.W. (*Abstract*, p. 812.)

Plate IX. No. 20. *Barra*.—Boulder of 890 tons, 230 feet above

sea, on a terrace of drift, on north slope of Ben Erival. (*Abstract*, p. 813.)

Plate IX. No. 21. *Barra*.—Boulder 228 feet above sea, on north slope of Ben Erival, butted at its east end against rock. (*Abstract*, p. 814.)

Plate IX. No. 22. *Barra*.—Boulder on west slope of Ben More hill, on shore of Atlantic, at height of 165 feet above sea, butted by rock at its east end. (*Abstract*, p. 815.)

Plate IX. No. 23. *Loch Boisdale*.—Two boulders, A and B; A butted at its east end on rock of Kennet Hill, and B resting with its east side on A. (*Abstract*, p. 815.)

Plate IX. No. 24. *South Uist, Mingary Hill*, showing terrace on its N.W. side, with boulders of various sizes. (*Abstract*, p. 816.)

Plate IX. No. 25. *Uist*.—Askernish.—Granite boulder perched on point of a rocky knoll (two views) (1) and (2). (*Abstract*, p. 816.)

Plate X. No. 26. *South Uist, Jocdar*; rocks extensively smoothed and striated from N.W. (*Abstract*, p. 816.)

Plate IX. No. 27. *Harris*, at Borve, on shore of Atlantic; two boulders on hill-side sloping down towards sea, the uppermost having apparently come from west. (*Abstract*, p. 817.)

Plate IX. No. 28. *West Loch Tarbert*.—Scalpa Island. Granite boulder butted by rock at its east end. (*Abstract*, p. 818.)

Plate X. No. 29. *The Lewis*.—Hill top at Miavig, covered by boulders chiefly on west side. (*Abstract*, p. 819.)

Plate X. No. 30. *Skye*.—Boulder on rocky ridge, between Loch Scavaig and sea, on west coast. (*Abstract*, p. 821.)

#### INVERNESS-SHIRE.

Plate X. No. 31. *Fort William*.—Boulder on steep western side of Treshlik Hill. Two views given; upper one shows part of hill on which boulder lies; lower one shows steepness of slope. (*Abstract*, p. 825.)

Plate X. No. 32. *Flichty Valley*.—View of an isolated hill, about 1620 feet above sea, with many boulders on west side. Two views given; that on left hand, to show shape of hill and position of the boulders; the other to show steepness of hill slope. (*Abstract*, p. 834.)

Plate X. No. 33. *Glencoe*.—Boulders of gneiss, lying at foot of cliff, which faces east; supposed by Convener to have come up valley, till obstructed in farther progress by cliff. (*Abstract*, p. 830.)

Plate X. No. 34. *Farr Parish*.—Boulders on rocks smoothed, and sloping down to westward. (*Abstract*, p. 835.)

#### NAIRNSHIRE.

Plate X. No. 35. *Croy*.—"Tom Rioch"—large angular Conglomerate boulder—to show shape, notwithstanding long distance carried. (*Abstract*, p. 850.)

Plate X. No. 36. *Cawdor*.—Sketch of four other large angular Conglomerate boulders given for same reason. (*Abstract*, p. 851.)

#### PERTHSHIRE.

Plate X. No. 37. *Callander*.—Bochastle Hill. Two gneiss boulders, lying on Conglomerate rock, which forms west part of hill. The largest ( $14 \times 9 \times 9$  feet) is on very summit of hill. Its shape shown by fig. *a* in diagram; that of smaller one by fig. *b*. (*Abstract*, p. 856.)

Plate X. No. 38. *Dochart Valley*.—Rock on south side of, smoothed and rutted horizontally from west. (*Abstract*, p. 858.)

Plate X. No. 39. Boulders on ridge of hills, 2300 feet above sea, and horizontal strata broken up. (*Abstract*, p. 859.)

#### ROSS-SHIRE.

Plate X. No. 40. *Gairloch*.—Granite boulder 747 feet above sea, on edge of a high cliff, facing west; resting on schistose gneiss. It projects  $2\frac{1}{2}$  feet beyond edge of cliff. (*Abstract*, p. 861.)

Plate X. No. 41. *Gairloch*.—Hill N.E. from Gairloch Hotel, 585 feet above sea, on summit of which there are two boulders. (*Abstract*, p. 861.)

Plate X. No. 42. Shows the largest of these boulders, projecting 2 feet beyond edge of precipice, and sloping down towards N.W. at an angle of  $15^\circ$ . The smaller boulder lies on a rocky surface sloping down W.N.W. (*Abstract*, p. 861.)

Plate X. No. 43. Rocky knoll, near base of above hill, with a cluster of boulders on it, showing that uppermost boulder had come from west. (*Abstract*, p. 861.)

Plate X. No. 44. *Loch Maree*.—On hill to west of hotel, a boulder near top on west slope, butted against rock at its east end. (*Abstract*, p. 862.)

## APPENDIX II.

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### SUMMARY OF FACTS CONTAINED IN THE NINE ANNUAL REPORTS OF THE COMMITTEE, AND OF INFERENCES APPARENTLY DEDUCIBLE FROM THESE FACTS, BEARING ON THE QUESTION, BY WHAT AGENCY BOULDERS WERE TRANSPORTED TO THEIR PRESENT SITES.

#### I. *Distribution of Boulders in Scotland.*

It might be possible to extract from the Reports, approximately, the numbers of boulders in each county, so far as made known to the Committee. But these numbers would give a very incorrect idea of either the prevalence or the paucity, originally, of the boulders in different parts of Scotland,—*first*, because counties vary extremely in size; *second*, because from some counties the information sent was more copious than from others; *third*, because in some counties, where agricultural improvements have been extensive, boulders in thousands have long ago disappeared by wholesale extirpation.

In the absence of precise statistics, it may be stated generally, that there is no Scotch county where boulders do not exist, and that on all the islands, including the Hebrides, Orkney, Shetlands, and the Farœs, boulders are found.

If, however, an opinion on this point is of any value, the Convener may say, that having visited two-thirds of the Scotch counties, to inspect and search for boulders, he considers that they are in much larger numbers on the West Coast, and the hills adjoining the West Coast, than on any other district of the same extent.

## II. *Size or Weights of Boulders.*

It will be seen from the Abstract, and still more from the Annual Reports, that the dimensions of the boulders, when of considerable size, are in most cases there given. But in this Summary, it may be sufficient to refer to cases of boulders made known to the Committee exceeding 100 tons in weight.

The element of large size or weight has some bearing on the question, What could be the agency by which boulders were transported ? especially if it appears that many were transported great distances, and across valleys and hill ranges, as to fulfil these conditions the transporting agent would require to be of peculiar power and magnitude.

### EXAMPLES OF BOULDERS EXCEEDING 100 TONS IN WEIGHT.

#### 1. *On Mainland.*

*Aberdeenshire*—Chapel Garioch, boulder 250 tons (*Abstract*, p. 771).

Kemnay, two boulders, 270 and 380 tons (*Abstract*, p. 771).

*Argyleshire*—Kilhenzie, boulder 150 tons, }  
 Loch Goil,     „     300     „     } (Abstract, pp. 773, 774,  
 Loch Long,    „     380     „     } 776).  
 Loch Fyne,    „     286     „     }  
 Gareloch,     „     240     „     }  
 Loch Awe,     „     130     „     (*Abstract*, p. 777).  
 „                „     136     „     (*Abstract*, p. 778).  
 Loch Killesport, two boulders, 106 and 300 tons  
                   (*Abstract*, p. 778).

Loch Killesport, boulder 2770 tons (*Abstract*, p. 779).

„                „     520     „     (*Abstract*, p. 779).

Clach Briach     „     138     „     (*Abstract*, p. 779).

Taynish, two boulders, 108 and 116 tons (*Abstract*, p. 780).

Appin, two boulders, 124 and 292 tons (*Abstract*, p. 784).

Loch Creran, two boulders, 280 and 380 tons  
                   (*Abstract*, p. 784).

*Ayrshire*—Loch Doune, boulder, 444 tons (*Abstract*, p. 785).

Girvan, two boulders, 100 and 180 tons (*Abstract* p. 785).

Ardrossan, boulder, 320 tons (*Abstract*, p. 785).

Culmonell, two boulders, 326 and 552 tons (*Abstract*, p. 786).

*Dumbartonshire*—Loch Lomond, boulder, 246 tons (*Abstract*, p. 795).

*Inverness-shire*—Dochart, boulder (?), 1950 tons (*Abstract*, p. 828).

Ben Nevis, „ 118 „ (*Abstract*, p. 825).

Clachnaharry, boulder, 100 „ (*Abstract*, p. 833).

S.W. of Inverness, boulder, 310 tons (*Abstract*, p. 834).

Loch Clachan, boulder, 218 tons (*Abstract*, p. 835).

*Morayshire*—Craig, boulder, 652 tons (*Abstract*, p. 834).

Dallanossie, boulder, 360 tons (*Abstract*, p. 834).

*Perthshire*—Aberfeldy, boulder, 600 tons (*Abstract*, p. 855).

Doune, „ 900 „ (*Abstract*, p. 857).

Fortingall, „ 300 „ (*Abstract*, p. 857).

Pitlochry, „ 800 „ (*Abstract*, p. 859).

*Renfrewshire*—Kilbarchan, boulder (?), 300 tons (*Abstract*, p. 859).

*Ross-shire* (West Coast)—Glenelg, boulder, 280 tons (*Abstract*, p. 860).

*Stirlingshire*—St Ninians, boulder, 200 tons (*Abstract*, p. 872).

Landrick, „ 360 „ (*Abstract*, p. 873).

*Sutherlandshire*—Golspie, „ 120 „ (*Abstract*, p. 874).

## 2. *On Islands.*

In Arran—boulders respectively of 212, 362, 184, and 620 tons (*Abstract*, pp. 791, 792).

Coll Island—boulder of 308 tons (*Abstract*, p. 811).

Iona—two boulders, 400 and 190 tons (*Abstract*, pp. 808, 809).

Barra—boulder of 890 tons (*Abstract*, p. 813).

South Uist, Boisdale, boulder, 146 tons (*Abstract*, p. 815).

Shetlands—(Lunnasting), two masses of rock (supposed to have been carried some distance), respectively 1466 and 670 tons (*Abstract*, p. 869).

If cases of boulders (say) above 50 tons, had been enumerated, the number would have been at least twenty times greater.

### III. *Shapes of Boulders.*

Two classes may be specified—(1) angular and rough, (2) rounded and smooth, on the surface.

In all the Scotch counties, both of these classes exist;—with this distinction, that the second class are generally embedded in drift, whilst the first are mostly, at all events, now, on the *surface* of the district (*Abstract*, pp. 849, 850).

If, as may be assumed, the erratic blocks referred to in the Committee's Reports were originally fragments from rocks *in situ*, then it is probable that the most rounded are those which have undergone most "wear and tear" by transportation.

Boulders of both classes, have often a long and a short axis;—smooth boulders more frequently so, than others. The latter are also frequently "*Pear-shaped*," indicating that one end has probably undergone more friction than the opposite end. See, as an example, "*Dana boulder*," on p. 781 of *Abstract*.

In such cases it has also been observed that when one end is smooth and sharp-pointed, the opposite end is generally square or rough.

### IV. *Particular Markings on Boulders.*

On some Boulders there are occasionally grooves, ruts, striæ, and scratches upon their surface when smooth.

The incisions generally form lines approximately parallel with the longer axis of the boulder. They may occur on one or more of the sides, *i.e.*, along the upper, lateral, and under surfaces.

Examples of marks on the under surface will be seen by referring to the *Abstract*, p. 769 (*Aberdeen*); p. 808 (*Iona*); p. 845 (*Tynecastle*); and p. 847 (*Alnwick Hill*).

It has been thought, that from a close examination of ruts and striæ, whether on boulders or on rocks, the direction of the striating agent can be inferred by observing at which end the striæ have been most deeply cut. In multitudes of cases it has been observed, that the striæ are more deeply cut at one end, whilst towards the other end they gradually thin away and disappear. In explanation of this fact, it is suggested that hard pebbles or stones, acting as incising tools, would, in advancing along

the surface of the boulder or the rock, become blunted under severe pressure, and be at length crushed to pieces.

In the Tynecastle boulder, *striæ* were seen on both the upper and the under surface. Those on the upper surface showed incision from a *westerly* point; those on the under surface, showed incision from an *easterly* point, judging by the test before referred to. If the boulder had been pushed over sharp rocks from the westward, the ruts on the lower surface would, according to that test, show that they had begun to be formed at the *east* end. After the boulder had become fixed in position, a drift of hard shingle passing over the top from the west would produce *striæ* beginning at the *west* end.

It is evident that *striæ* could be formed less easily on the vertical or lateral sides of a boulder than on the upper or under sides, as the incising pebbles might not, in the first case, so easily continue to move in a horizontal direction. One boulder is mentioned where *striæ* were seen on both sides of the boulder—these sides meeting at, and radiating from, a point at one end, as shown in the woodcut on p. 802 of *Abstract*. The case is interesting on account of its bearing on the agency which produced the *striæ*, as it must have been such as to be capable of being separated into two currents when it reached the boulder, in which case a current would flow along each side, pushing and pressing drift on the surface of the boulder as it passed.

It is proper also to notice, as bearing on the same question, that boulders sometimes show two sets of *striæ*, the one set crossing the other obliquely, indicating a change in the direction of the striating agent, or else in the position of the boulder. The case, for example, on page 844 of *Abstract*, shows one set of *striæ* running N.N.W., and the other W. by S. (Easter Duddingstone).

As the study of striations may throw light on the nature of the transporting agent, it is right to take notice of striations on solid rocks; for if there are on *them* two sets of striations crossing one another, the cause must be ascribed either to a change of direction in the movement of the striating agent, or to the advent of another striating agent from a different quarter.

Examples of two sets of *striæ* on a rock surface will be seen in *Abstract*, p. 839 (*Glasgow*) and p. 849 (*Carden Hill*).

That the striations on rocks were produced by an agent, the same as, or similar to, that which caused striation on boulders, is evident from the multitudes of cases where there are striated boulders and striated rocks close to or near one another, the direction and appearance of the striæ on both being generally the same.

Great numbers of rock striations occur in the Hebrides, most of which are described in the *Fifth Report*. Thus (at p. 816) an account is given of smoothed rocks at Jocdar, on which there are twelve or fourteen deep ruts, some of them 4 or 5 feet in length. One measures 8 inches across and 2 inches in depth, and there are others of similar width and depth,—the ruts being in all cases deeper and wider at their west than at their east ends. In the *Lewis*, at *Uig* and *Carlowrie* (*Abstract*, p. 819), similar cases occur; also *Kilmory* (*Abstract*, p. 780), *Buteshire* (*Abstract*, p. 791).

These rock striations are found not only on surfaces more or less horizontal, but also on surfaces which *slope*, and even on surfaces which are *vertical*.

As examples take the two following cases:—

1. In *Bute*, there is a rocky defile, about 30 yards wide, at *Barone Hill* (*Abstract*, p. 793), through which boulders and drift materials have evidently passed. One side of this defile presents extensive smoothings, on which there are ruts, some of them 12 feet in length, and more deeply cut into the rock, at the end where the striating agent entered the gorge, viz., the N.W. The direction of movement is farther shown by the fact, that from that end the ruts slope *upwards* at angles of from  $20^\circ$  to  $30^\circ$ , the result, no doubt, of the force with which the materials were pushed or driven through the gorge (*Seventh Report*, p. 19).

2. Another example occurs on the west side of *Arthur's Seat*, Edinburgh, as explained in *Abstract*, p. 843. Boulders and other drift materials had passed through this gorge, which is only about 10 yards wide. A boulder sticking on one of the sides was striated on its exposed side. One of the rocky sides also presented numerous striations,—some of them 6 feet in length, and  $\frac{1}{8}$  of an inch deep. At the narrowest part of the defile, where there would be the greatest difficulty in forcing a passage, the striæ are rising up at an angle of  $4^\circ$  or  $5^\circ$  from the end where the materials had entered the defile.

## V. Particular Positions of Boulders.

Explained under the following heads :—

1. In beds of clay, gravel, and sand.
2. On the surface of the country.
  - a. Lying on flattest side.
  - b. Standing on end.
  - c. Butted against rocks or resting on other boulders.
  - d. Resting on steep slopes of hills.
  - e. Resting on ridges and tops of very high hills.

### 1. Embedded in Clay, Gravel, or Sand.

In *Aberdeenshire* a boulder of 8 tons found in a bed of sand (*Abstract*, p. 769).

In *Ayrshire*, large boulders found in a bed of sandy mud at a depth of 18 feet, the boulders being covered with *Balani* and *Serpulæ* (*Abstract*, p. 786 (3)).

In *Renfrewshire*, near Paisley, boulders in clay beds, found with *Balani*, which had grown on them (*Abstract*, p. 860).

On an island in *Loch Lomond*, a bed of boulder clay occurs containing Arctic shells.

In *Arran*, beds of boulder clay occur, with blocks and broken shells (*Abstract*, p. 793.)

In *Aberdeenshire*, thick masses of unstratified pebbly mud occur, with stones and Arctic shells, most of them broken, but some entire (*Abstract*, p. 772).

In the *Lewis*, at several places, boulder clay occurs, with boulders and fragments of sea-shells (*Abstract*, p. 821).

In *Caithness*, at Keiss, Wick Bay, and Scrabster, there are beds of boulder clay and drift, containing shells and stones, some of which are scratched; one boulder in the Wick clay bed is 12 feet in length (*Abstract*, p. 794).

In the *Orkneys*, the islands of Eda, Sanday, Stromsa, Shapinshay, and Ronaldshay present clay beds containing boulders foreign to the islands, and marine shells, most of them broken or striated, as well as the boulders (*Abstract*, p. 853).

The cases of boulders, with *Balani* and *Serpulæ* found on them, have been explained by supposing that after these fish had grown on them the boulders were lifted by floating ice and dropped elsewhere (*Abstract*, pp. 786 and 860).

## 2. *Boulders on Surface of the Country.*

(a) *Boulders lying on flattest side* occur so frequently that it is not necessary to quote cases.

(b) *A less frequent case is when boulders occur standing on end.*

This observed occasionally, when boulders embedded in clay or sandy mud (see *Estuary of Forth*, p. 99, and *Ed. Roy. Soc. Trans.*, vol. xxvii. p. 630, and *Ramsay's Physical Geology*, p. 155).

Also observed on open surface of the country; when the boulder leans against a rock, as at Iona, in the case of the large boulder at Dun I;—and of a small boulder near south end of island (*Abstract*, p. 808).

(c) *Butted against rocks, or resting on or against other boulders.* See such cases mentioned (*Abstract* pp. 773, 780, 793, 808, 810, 812, 818, 836, 861, 862).

(d) *On steep sides of hills.*

In *Abstract*, p. 825, there is notice of an isolated hill (Treshlik Hill), on an exceedingly steep side of which a large boulder rests (*Lithograph No. 31, Plate X.*).

In *Abstract*, p. 834, there is notice of another isolated hill in Flichity valley, on which there are several boulders precariously situated, because of the steepness of the hill-side (*Lithograph No. 32, Plate X.*).

In *Abstract*, p. 824, a remark by Professor Duns is referred to, with regard to some granite boulders lying on a part of Ben Nevis, where the mountain slopes down so steeply, “as to make it a puzzle to understand how they can remain in position.”

In *Abstract*, p. 856, see similar cases, on Bochastle Hill and Clunie.

In *Abstract*, p. 862, notice will be found of a large boulder resting on a slope at an angle of so much as 47°.

(e) *On tops of hills.*

In Aberdeenshire (*Ballater*), boulders of granite and gneiss are on the summit of a hill, at height of 2963 feet; there being no rocks of that nature *in situ* on the hill (*Abstract*, p. 770).

In Aberdeenshire (*Braemar*) there are boulders on tops of hills

reaching 2700 feet and 3587 feet above the sea (*Abstract*, pp. 770 and 771).

In *Inverness-shire*, at the heights of 2000, 3000, and 3155 feet, *Lochaber* (*Abstract*, pp. 824, 826, and 827);—of 3425, *Albannach* (*Abstract*, pp. 828, 829); 3407, *Schehallion* (*Abstract* p. 830).

In island of *Mull*, a boulder on the top of *Spyon More*, at a height of 2435 feet above sea (*Abstract*, p. 808).

In *Kirkcudbrightshire*, at a height of 2764 on summit of *Merrick* (*Abstract*, p. 837).

In *Glencoe* district, boulders found on summits and peaks of *Aonach* and *Eagach*, and *Meal Dearg*, at height of 3110 feet above sea. Professor Heddle remarks that “these boulders lay on a ridge not many times wider than their own bulk,” and “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” (*Abstract*, p. 830).

The following are cases where boulders are on tops of hills of less height above the sea than in the cases just mentioned; but, being higher than any other hills in the district, they present a feature similar to that just noticed by Professor Heddle. As examples of these, reference is made to boulders on *East Loch Tarbert* (*Abstract*, p. 775); *Inverary* and *Loch Awe* (*Abstract*, p. 777); *Islay Island* (*Arnahoo*) (*Abstract*, p. 806); *Forfarshire* (*Abstract*, p. 801); *Lochaber* (*Abstract*, p. 825); *Kirkcudbright* (*Abstract*, p. 837); *Midlothian* (*Abstract*, p. 840); and in *Sutherlandshire* (*Abstract*, p. 875). Similar cases of boulders perched on very precarious positions probably occur in *Skye*, judging by what is said of them by Macculloch and Forbes (*Abstract*, p. 822).

## VI. Cases where Parent Rocks of Boulders have almost certainly been ascertained.

1. In *Berwickshire*, granite, sienite, porphyry, and whinstone boulders are clearly traceable to hills situated several miles to the westward (*Abstract*, pp. 787, 788, 789, 790).

2. In *Roxburghshire* there are similar cases (*Abstract*, p. 865), in some instances the parent rocks being at least 20 miles to the westward.

3. In *Peeblesshire*, a quartz boulder, with much probability referred to beds of quartz about 80 miles to the westward (*Abstract*, p. 855).

4. In *Haddingtonshire*, *Isle of May*, and *Inchkeith* there are granite boulders which must have been carried at least 100 miles from westward (*Abstract*, pp. 801 and 802).
5. In *Midlothian* there are numerous cases of granite and other boulders, which must have been carried 50 to 80 miles from westward (*Abstract*, pp. 840, 844, and 847).
6. In *Linlithgowshire* cases are mentioned of whinstone and Conglomerate boulders carried from westward (*Abstract*, pp. 839, 840).
7. In *Aberdeenshire*, granite blocks from hills situated many miles distant to N. and N.W. (*Abstract*, p. 769 and 770).
8. In *Forfarshire*, mica schist boulder from rocks 17 miles to W.N.W. (*Abstract*, p. 801).
9. *Inverness-shire*, granite boulders at and near Loch Tulla traced to hill 10 miles to westward, also near Inverness (*Abstract*, pp. 828, 832, and 833).
10. In *Argyleshire* (Kerrera, Easdale, and Lismore), granite boulders, referred to sources situated to the north, across the sea (*Abstract*, p. 783).
11. In the *Lewis*, granite boulders from Barvas Hills, situated to N.W. (*Abstract*, 820).
12. In *Perthshire*, a Conglomerate boulder, weighing 900 tons, carried about 7 miles from westward (*Abstract*, p. 857).
13. In *Stirlingshire*, numerous cases of Conglomerate boulders in different localities, carried from 10 to 20 miles from westward (*Abstract*, p. 873).
14. In *Glencoe*, boulders which must have come down valley, viz., from S.E. (*Abstract*, p. 830).
15. In *Morayshire*, *Nairn*, *Elgin*, and *Ross-shire*, boulders of Conglomerate, and various kinds of granite, which have travelled 10 to 30 miles from westward (*Abstract*, pp. 798, 848, 851, and 852).
16. In *Buteshire (Cumbraes)*, boulders of Conglomerate from N.W. (*Abstract*, p. 791).
17. In *Kirkcudbrightshire*, Criffel granite boulders carried S.E. even to Cumberland and Lancashire (*Abstract*, pp. 796, 797, and 838).

## VII. *Special Facts indicating direction in which Transporting Agent moved.*

1. Longer axis of boulders and sharp ends of boulders generally point north-westward.

The cases showing this, which are mentioned in the Reports and Abstract, are so numerous that they need not be particularised.

Testimony to the north-westerly direction from which boulders in Scotland have been carried, is given by the following geological authorities—Professor Geikie (*Abstract*, p. 841); Sir Roderick Murchison (*Abstract*, p. 795); Charles Maclaren (*Abstract*, p. 840); Robert Chambers (*Abstract*, p. 876); J. F. Campbell (*Abstract*, p. 815); J. F. Jamieson (*Abstract*, p. 795); Professor Harkness (*Abstract*, p. 797); W. Jolly (*Abstract*, p. 799); Mr Anderson Smith (*Abstract*, p. 776); John Young (Glasgow University) (*Abstract*, p. 839); James Croll (*Abstract*, p. 841); T. Hay Cunningham (*Abstract*, p. 838).

In the *Lewis* there are kaims or escars on a very large scale,—continuous for several miles, whose north-westerly direction, and numbers of boulders lying upon them, suggest the idea that they may be due to the same agency which has transported the boulders (*Abstract*, p. 820).

2. But whilst a movement from north-westward is very general in Scotland, it is right to notice exceptional cases.

In *Loch Long* and *Loch Fyne* there has been a movement from N. or N. by E. (*Abstract*, p. 774, 775). In *Islay* (*Abstract*, p. 806). *Buteshire* (*Abstract*, p. 791).

In *Morayshire* and *Elgin* Mr Jolly points out two streams, one from  $6^{\circ}$  S. of west,—the other from  $15^{\circ}$  N. of west (*Abstract*, p. 799).

In *Perthshire* (*Dunkeld*) the direction of the striæ on the rocks at a high level is from N.N.W.,—whilst at a lower level, in the same valley, it is from N.E. (*Abstract*, p. 857). In the *Lewis* a similar case occurs;—the direction of the movement at a high level being from W.N.W.; and at a low level, in the same district, from W., or even W.S.W. (*Abstract*, p. 819). In *Assynt*, whilst the normal direction is N.  $60^{\circ}$  W., the direction changes to due north, caused (as Chambers supposes) by the interference of a hill (*Abstract*, p. 875).

So also near Gairloch, whilst the normal movement is from W.N.W., as shown by boulders and striæ, there is a locality among the hills, where the movement is shown to have been from W.S.W. (*Abstract*, p. 861).

Cases have already been noticed, where there are two sets of striæ crossing one another. Thus in *Morayshire* (*Abstract*, p. 849) the N.W. striæ are crossed by others of a later date coming from N. by E.

Near *Glasgow* there are rock surfaces presenting two sets of *striæ*, one implying a movement from the N.W. and N.E. respectively (*Abstract*, p. 838).

These different directions in the lines of *striæ* may, in some cases, indicate two separate agencies, moving independently of one another at different periods. But it is also possible that the same agent might be deflected from its normal direction by local conditions. An example of such a deflection is given by Sir James Hall, in his well-known paper on "Revolutions on the Earth's Surface" read by him in the year 1812, and printed in the 7th vol. of the *Ed. Roy. Soc. Trans.* He names a locality (p. 196), where "the rock presents furrows and scratches similar to those on Corstorphine Hill,"—but where "the action of the stream has undergone a *visible modification*, by the prominent form of some parts of the rock, in consequence of which the dressings have in some places been *turned* to the amount of  $5^{\circ}$  or  $6^{\circ}$  *out of the general direction*, which, however, they resume gradually in the course of a few yards."

In Haddingtonshire, whilst the normal direction is generally from W.N.W. on *horizontal* rock surfaces, the movement slightly changes where the striating agent struck upon, and had to pass over, a rock which *sloped*. For example, at *Linton*, on a rock surface sloping down due north, at an angle of  $35^{\circ}$ , the direction on that surface is E. and W. (*Abstract*, p. 803).

At the *railway cutting*, not far from Linton, the rock surface slopes down due north, at an angle of  $10^{\circ}$  to  $20^{\circ}$ ; and the opposing rock surface being here of considerable extent, the direction of the *striæ* is E.  $15^{\circ}$  N. (*Abstract*, p. 803).

On *North Berwick Law* the smoothed rock surface dips down N.  $10^{\circ}$  W., and the direction of the *striæ* is E.  $22^{\circ}$  N. (*Abstract*, p. 805).

3. Another set of facts, bearing on the direction in which the transporting agent has moved, is the position of individual boulders.

A very large proportion of boulders have been lodged on the *west* slopes of hills. Many are butted up against rocks, or lying on other boulders, in a way which shows that they came from the *westward*.

4. Another fact has been observed, which shows that there has been a general movement over this part of Europe from a westerly point.

Thus in describing the beds of boulder clay in the neighbourhood

of Edinburgh, the Rev. Dr Fleming cites different localities where it clearly appears that the materials composing the boulder clay, had been by some extraneous agency pushed *towards the east*; and pushed so violently, that the strata of rock covered by the boulder clay had their *edges broken off*, and carried towards the east (*Lithology of Edinburgh*, pp. 52 to 60).

In like manner, Professor Geikie says that "the mass of the boulder clay (in the basin of the Firth of Forth for instance) consists of the comminuted debris of the Carboniferous and other rocks which form the framework of the district. We can also gather that this loose fragmentary matter has *moved from west to east*. In the upper part of the basin of the Firth of Forth the coal fields are covered with *red* boulder clay, *abounding in fragments of the rocks* that lie towards the N.W., and deriving its prevalent tint from the waste of the Old Red Sandstones, and stretches up to the foot of the Highland mountains" (*Glacial drift*, p. 805).

5. If the foregoing data are sufficient to establish the general fact that the transporting and striating agent has moved in most parts of Scotland from the north-westward, the question arises, What was that agent?

In regard to boulders in Forfarshire and Aberdeenshire, it might be inferred that *they* were brought by glaciers from the Grampians and other mountainous districts there. But some of these boulders are at such heights as to suggest doubts whether any glacier could have been generated at such a level as to bring these boulders. Moreover, several of the Forfarshire boulders, if they came from the mountains to the west, must have crossed valleys and ridges of hills, which would have seriously obstructed the flow of a glacier (*Abstract*, p. 801).

In some districts, however, there is undoubtedly evidence to establish glacier action;—as in Glencoe (*Abstract*, p. 830). Professor Heddle and Mr Livingstone satisfied themselves of the existence of one or more glaciers on the west flanks of *Ben Nevis*, though Mr Livingstone sees difficulties which he cannot explain (*Abstract*, p. 824). Professor Duns seems also to recognise the probability of a Ben Nevis glacier (*Abstract*, p. 824). In *Nairn Valley* there are also appearances which suggest the agency of a local glacier (*Abstract*, p. 835). *Loch Skene* is another case (*Abstract*, p. 796).

In *Glen Etive* and *Loch Etive* there are indubitable traces of glacial action at a low level, moving from *Loch Awe* (*Abstract*, p. 782).

But in *Inverness-shire* there are boulders, reported on by Professor Heddle, which, as they must have crossed deep valleys, floating ice must be preferred for agency of transport in these cases (*Abstract*, p. 829). See also *Ruberslaw* (*Abstract*, p. 866); *Shetland* (*Abstract*, p. 869). *Forfarshire* (*Abstract*, p. 801). *Sutherland* (*Abstract*, p. 875).

That at the Boulder period floating ice of some kind existed can scarcely be doubted.

The confident testimony of Dr Chambers, Professor Nicol, and Mr Jamieson, that the positions of the boulders and the direction of the rock striations on the north-west coast are inexplicable, except on the supposition that the transporting and striating agent came there *from the sea*, scarcely leaves room for doubt (*Abstract*, p. 795).

The transport of boulders from the westward is especially interesting in those localities on the north and north-west of Scotland, where towards the west there is nothing but open sea.

Thus, on the islands of Tiree and Coll, and at Borve on the west coast of Harris, the boulders are in such positions, that to reach these positions *they must* have come across the sea.

In the Shetlands and Orkneys there are on almost every island boulders which, differing in mineral constituents from the rocks of the island, *must* have been transported *across some portion of sea*; and accordingly Messrs Peach and Horne, who have lately explored the geology and the glacial phenomena of the islands, give a decided opinion that on these islands *land glaciers* were not the transporting agent. They say that in the Orkneys "the islands must have been *overflowed* by ice;"—ice which "originated beyond the limits of Orkney" (*Abstract*, p. 855). So also of Shetland, they say that "it must have been at *one time smothered in ice*"—"originating far beyond the sphere of Shetland" (*Abstract*, p. 871).

With regard to the direction of the movement of the transporting agent in Shetland and the Orkneys, there is not the same uniformity as on the mainland of Scotland. In the island of North Unst, the northernmost island of Shetland, the direction is

from W.N.W. (*Abstract*, p. 870). On the island of Papa Stour there are blocks which apparently came across St Magnus Bay from a N.E. direction (*Abstract*, p. 867). But in other cases the boulders on the islands must have been floated from many different directions.

It is also proper to notice the fact, that in some of the islands of the Hebrides, and even on portions of the west coast of the Mainland, the positions of the boulders indicate a movement, not from W.N.W. (the normal direction for Scotland generally), but from N. or N. by E., as in Islay (*Abstract*, p. 806), in Iona (*Abstract*, p. 808). Loch Fyne (*Abstract*, p. 777); Kintyre (*Abstract*, p. 773). Buteshire (*Abstract*, p. 791).

But these exceptions do not greatly detract from the value of the generally concurring evidence, everywhere else, of a direction from W.N.W.

It is also an important circumstance that the part of Scotland where the boulders are largest, heaviest, and most numerous, is along the west coast (see p. 886). If floating ice brought boulders across the Atlantic, the first place where boulders would be discharged would be where the sea bottom rose high enough to interrupt the progress of the ice. The ice carrying the largest and heaviest boulders would most probably strike the sea bottom soonest; whilst the ice carrying smaller cargoes would flow on, till these reached the submarine rocks which now form the present inland mountains.

As bearing on the question, whether land ice or sea ice was the transporting agent, another circumstance brought out in the Reports must be kept in view. Some boulders on the tops and ridges of mountains are at heights far above what could be reached by a glacier having its birthplace in any adjoining district. Such are the boulders at heights exceeding 3000 feet; and even when at lower heights, it would be necessary, for upholding the glacier theory, to have mountains pointed out where glaciers could have been formed, and with a valley through which the glacier could have flowed in the direction of the boulder. But even if this difficulty of levels could be overcome, there is still another in explaining how a glacier could set down on the very tops of hills, or on excessively steep slopes of hills, boulders which are frequently seen in these critical positions.

Floating ice stranding on mountain tops or slopes, might, by

gradually melting, allow boulders to obtain these singular lodgments.

Of course, if the theory of floating ice be adopted, the position of boulders at heights of 3000 feet implies a sea which must have stood at that height, or more, above the present sea-level in Britain. In that supposition there is no improbability. Moreover, beds of sand, mud, and gravel (proofs of marine conditions) actually exist in several parts of Perthshire, up to a level of 1500 feet, 1600 feet, 2000 feet and more (*Abstract*, pp. 857, 858); on Ben Cruachan, up to 2000 feet (*Abstract*, p. 783); in Glencoe, up to 2000 feet (*Abstract*, p. 830); and on Schehallion, at a height of 3000 feet (*Abstract*, p. 858). The Ordnance surveyors reported drift beds at a height of even 3800 feet (*Abstract*, p. 831, footnote). Terraces on gravel and sand at 1200 feet (*Abstract*, p. 832).

In Scotland, sea-shells—and generally of an Arctic type—have been found in clay or gravel beds up to a height of about 520 feet above sea-level. In several parts of the west of England these shells occur in similar deposits up to a height of about 1200 feet, and in Ireland (near Dublin) up to a height of 1400 feet above sea-level. At the time when the sea stood at either of these heights in England and Ireland, it could not with any probability have been lower in Scotland.

Allusion has been made to deflections in the direction of the transporting agent, when it struck upon rocks, which slope towards certain points, and at different angles. These deflections can be understood and accounted for on the supposition of an oceanic current with floating ice. For by flowing over a rock, which obstructed its normal progress, the current might be deflected from its usual course. These deflections it would not be easy to explain on the theory of solid land ice moving over the country.

Another circumstance favouring the theory of an oceanic current, with floating ice, to account for the movement of boulders, and the striation of both boulders and rocks, is the presence of *marine shells*, of Arctic types, in beds of drift containing boulders. In most of the cases referred to some of the shells have been crushed, whilst others are entire and unhurt. What more probable explanation can be given of these facts, than that masses of ice floating on a sea current would, on touching the sea bottom, discharge

their cargoes of rocks and rubbish, and at the same time plough through the sea bottom, pushing forward boulders, and crushing shell fish? (See p. 891.)

It is a fact confirmatory of this view, that beds of boulder clay never show stratification, and that, moreover, in respect of colour and materials, they closely resemble hardened or compressed mud, apparently composed of the debris of rocks which had undergone disruption and friction by some extraneous agent. Boulder clay is found everywhere in Scotland,—so that there must have been one general agent instrumental in forming the deposit; and it is difficult to conceive a more probable agent than sea currents, with floating ice, grinding and grating over submarine rocks.

Another circumstance (shown in the Committee's Reports) indicates oceanic agency, viz., the uniformity all over Scotland of the direction of the *striæ* on rocks and boulders, and of the direction of the longer axis of boulders. In almost every part of Scotland there has manifestly been some agent of immense power, which has been for a long period passing over from the W.N.W. What other agent would produce these concurrent effects over a considerable portion of the earth's surface than a great oceanic current?

No such effects are likely to have been produced by an ice-sheet however gigantic, or still less by local glaciers.

The deflections from that normal direction, which are mentioned in the Reports as occurring in some localities, are not only not inconsistent with the theory of an oceanic current, but are just what might be expected, inasmuch as when currents flow over a bed which contains obstructions, eddies and deflections are produced, so that these partial deviations from the normal direction strengthen rather than weaken the theory of a great sea current.

There are also two districts crossing Scotland where the movement has been, by some special cause, deflected from the normal N.W. direction. In the low-level district between the Firths of Clyde and Forth, where the highest point is about 150 feet above the sea, the direction is about due E. and W. (*Abstract*, pp. 847 and 872). So also in the valley crossing the south of Scotland, the east part of which is occupied by the River Tweed and its tributaries, and the west part by the Rivers Liddell and Esk, the direction as shown by boulders, and by striations on rocks, is from W.S.W. in the western

districts (*Abstract*, p. 865), and N. 10° W. (*Abstract*, p. 790) in the eastern districts.

These deflections from the normal direction, both on the west coast and in the two districts across Scotland just referred to, can be explained on the theory of a N.W. oceanic current. The current, on reaching what are now the high mountains of Argyleshire, might be deflected there into a more southern direction ; and when the current reached the two valleys referred to, it might be drawn through them by the absence in them of any obstruction.

That some oceanic current has passed through the southern valley seems evident from the numbers and direction of the kaims in Roxburghshire and Berwickshire (*Abstract*, pp. 865 and 790).

The Convener (in a paper in the *Edin. Roy. Soc. Trans.*, vol. xxvii. p. 44) ascribed the formation of these kaims to *oceanic action* through a submarine channel, formed by a range of hills on each side ; and in support of his view he referred to the following passage in Professor Geikie's work on the *Great Ice Age* (p. 248), where he observes, that "when we note that strings of gravel ridges and mounds may sometimes be followed up one valley, across the dividing col, into a totally different drainage system, we cannot but conclude that ordinary river action is out of the question as an explanation of the phenomena. In the present state of our knowledge we appear to have no alternative but in such cases to admit the marine origin of such kaims."

These Berwickshire and Roxburghshire kaims present features similar to the kaims of the *Lewis* (*Abstract*, p. 819), except that the agent which formed them moved in a different direction, owing to the difference of the conditions which influenced the current in the respective localities.

6. A question may be asked, that if there existed both local glaciers and floating ice, as agencies for the transport of boulders and the striation of rocks, which of these agencies was first in operation ?

The data are too scanty to allow of this question being answered with any confidence.

In the *Abstract*, p. 831, where reference is made to *Glencoe*, and in *Abstract*, p. 835, where reference is made to *Farr*, it will be seen that an opinion is offered that glaciers existed *first*, and that submergence of the country took place *afterwards*.

7. It remains to notice what light is thrown on the subject by the Faroe Islands.

As Professor Geikie is satisfied that glaciers, or an ice sheet of some kind, existed, capable of glaciating the rocks and moving boulders, that view, entertained by an observer of so much experience and intelligence, will be at once accepted.

But the farther question arises, Whether there is evidence of there having existed *also*, at some other period, the agency of floating ice?

Professor Geikie does not admit that there is such evidence; and it has to be confessed that only one place on the islands has as yet been pointed out where such evidence is alleged to exist.

Mr Allan having drawn attention to the peninsula of Eide, as presenting rock smoothings and striations similar to those pointed out by Sir James Hall on Corstorphine Hill, Dr Robert Chambers, when he visited the Faroes forty years afterwards, went to Eide, on purpose (as he says) to study the appearances which Mr Allan had only generally described. He states that he "looked narrowly for the *striæ* or scratches;" and saw that "they presented themselves in abundance in several places;" and he says that he was satisfied that they were "all directed from the north."

Professor Geikie, in his *Memoir*, adverting to these same rocks, states, they are "perhaps the best preserved *roches moutonnées* he anywhere observed;"—but as to the direction in which the smoothing and striating agent had moved, which Dr Chambers alleged to be "from the north," Professor Geikie states that the *striæ* "had clearly been graved by ice, coming from *quite the opposite point of the compass*" (p. 246).

The Professor follows up this statement by explaining (p. 261) that "the long sound that separates Österöe from Stromöe (must have) brimmed with ice, which flowed in two directions; north of Nordskaale *the movement was northerly*, while south of the shallow part of that sound the ice held on a southerly course."

It is unfortunate that thus Professor Geikie and Dr Chambers, both of them competent and experienced observers, should have given opposite testimonies in this matter.

The question at issue being, as Professor Geikie states, one of

"considerable interest," it may be allowable to inquire whether any circumstances exist calculated to throw light upon it.

The glaciation and striæ on the rocks at Eide were by Dr Chambers ascribed to agency which came "from the north," viz., sea-ice. By Professor Geikie these were ascribed to the agency of land-ice, filling what is now the sound of Nordskaale, of which land-ice, one portion flowed north towards *Eide*, and the other portion held on a southerly course, each thus flowing in opposite directions from what had once been a *col*, or head of two separate valleys.

(1) There is one circumstance which seems to favour the view taken by Chambers, viz., that Mr Allan, when he examined the rocks, evidently considered that the agent which produced the markings, was the sea. He adopted for an explanation of these, Sir James Hall's opinion, suggested by the similar phenomena on Corstorphine Hill, viz., diluvial agency. The smoothed and striated rocks on the sea-coast at Eide forming a "headland," as Mr Allan called it, would no doubt seem to him well suited to illustrate such an agency. He accordingly takes notice of these rocks as "scooped and scratched in a very wonderful degree, not only on the horizontal surface, but also on a vertical one, of 30 to 40 feet high, *which had been opposed to the current*, and presented the same scooping and polished appearance with the rest of the rocks, both *above* and *below*."

If this be a correct view of Mr Allan's opinion, he is so far a witness corroborative of Chambers.

(2) Another circumstance bearing on the question, is the apparent difficulty of any glacier being formed which could reach the rocks at Eide, glaciated as they are, up to a height of 1302 feet (*Abstract*, p. 879).

The distance of Eide from the col (from which Professor Geikie supposes the glacier to have flowed in its northward course) is between 8 and 9 miles. At the *col* (as the map shows) the valley is exceedingly narrow, and the hills on each side apparently are not so high or so shaped as to afford good gathering ground for a large accumulation of ice. The hills there do not seem to be above 2000 feet high. Supposing ice to have filled the valley there even up to that height, and to flow towards the north, would it ever reach Eide?

There are two difficulties in the way. *First*, the map shows that between the *Col* and *Eide* the valley widens immensely, so that the glacier would almost certainly stop and break up at that place where there is both breadth and depth. *Second*, there is no *gradient* along the bottom of the valley from the *Col* to *Eide* to draw down a glacier, because, as Professor Geikie explains, the depth of water in the sound at *Eide* is much less than at places between *Eide* and the *Col* (*Abstract*, p. 880).

In these circumstances, there seems more probability that at this place the striations and smoothings were made by sea-ice than by a glacier.

(3) The mouth of the fiord is open towards the north, and when the Faröes were 1600 or 2000 feet submerged, there would be ample opportunity for floating ice to pass through the sound.

This view is to a certain extent supported by the curious circumstance, that in many parts of the Faröes the hills are glaciated everywhere *below* a pretty uniform level of 1600 feet, whilst *above* that level most of them are rough. In that northern latitude, if land-ice prevailed generally, so as to produce an ice-sheet or local glaciers, one does not see why the hills should not have been covered and glaciated to their tops.

Moreover, if it is established that to the W. and N.W. of the mainland of Scotland floating ice was brought by some north-west oceanic current, the fact that the Faröes are 2° farther north in latitude would bring them the more readily within reach of such a current.

8. The conclusion to which the facts set forth in this summary lead is, that if boulders were brought to this country by a great north-westerly oceanic current, some of these boulders now on our hills may, in mineralogical composition, be found to differ from British rocks; and in that view, it is only right to notice, that two geologists, having considerable personal knowledge of British rocks, state that boulders have been seen by them in this country, differing in mineral composition from any rocks in Great Britain with which they were acquainted. One of these authorities is the late Professor Nicol of Aberdeen University (*Abstract*, p. 841). The other is Mr James Plant of Leicester, to whom the English Boulder

Committee, in their *Second Report* (for 1874, p. 197), refer in these terms :—

Mr James Plant reports both “isolated boulders and groups of boulders, and he records one remarkable fact of especial importance, viz., that a group of boulders had been exposed in an excavation made in Leicester, 25 feet deep, composed of rocks, which Mr Plant failed to recognise as British.”

If this testimony be verified, the fact would be *in pari cases* with the case of the three plants \* found in the Hebrides and the west coast of Ireland, but unknown in any other part of Europe, whose native habitat is Boreal America, and whose transportation to our shores the late Professor Edward Forbes did not hesitate to ascribe to floating ice (*Memoirs of the Geological Survey of Great Britain*, vol. i.).

Finally, it may be asked, if the theory of an oceanic current with floating ice be adopted to account for most of the boulders in Scotland, especially those on the west and north-west coasts,—from what country could the boulders have come, and what could have produced this current?

The Committee, though not acknowledging the impossibility of suggesting an answer to this question, think that were they to venture on doing so, they would be trespassing beyond the objects of their appointment. Their proper province has been simply to collect facts bearing on boulders in Scotland, embracing their distribution, their positions, and the agencies probably concerned in their transport. To explain the source or origin of these agencies, or, in other words, to unravel the conditions of the earth's previous history, so as to account for these agencies, is a problem the solution of which must be left to others.

\* The names of these plants are *Eriocaulon septangulare*, *Neottia gemmipare*, and *Sisyrinchium anceps*.