ORDINARY MEETING.

FRIDAY, JANUARY 2ND, 1885.

HENRY HICKS, Esq., M.D., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association were accorded to the donors.

The following were elected members of the Association :—Horace T. Brown, F.G.S. ; James Howard ; C. H. Oakes ; George Patterson.

Messrs. W. V. Murray and W. H. Bartlett were elected Auditors.

The following papers were then read :—

“On some recent views concerning the geology of the North-west Highlands,” by Henry Hicks, M.D., F.G.S., during the reading of which the chair was taken by W. H. Hudleston, Esq., M.A., F.R.S., &c. ; and

“Palæolithic Man of the Thames Valley in North-west Middlesex,” by J. Allen Brown, F.R.G.S. (*Withdrawn*.)

ON SOME RECENT VIEWS CONCERNING THE GEOLOGY OF THE NORTH-WEST HIGHLANDS OF SCOTLAND.

BY HENRY HICKS, M.D., F.G.S., President.

CONTENTS :

- I.—Introduction.—*a.* Indications of the close of the Highland controversy. *b.* Origin of the controversy. *c.* Sir R. Murchison's views. *d.* Prof. Nicol's objection to Murchison's views. *e.* History of the controversy to the year 1878.
- II.—Re-opening of the controversy by the Author in 1878.—*a.* Reason for objecting to Murchison's views. *b.* Agrees in the main with Nicol's views, but differs from him on some points. *c.* Reasons why special reference should be made to papers published since 1878.
- III.—Section at Loch Maree and Auchnasheen.—*a.* Line of Section. *b.* Nicol's description. *c.* Murchison and Geikie's interpretation. *d.* Author's views of the Section in 1878, and divisions of the Series. *e.* The so-called intrusive mass in Glen Laggan. *f.* Hudleston and Bonney's views on the so-called intrusive mass. *g.* The Glen Docherty Series of the Author. *h.* The apparent unconformity in Glen Docherty. *i.* The evidence furnished by the rocks of Ben Fyn, Mulart, &c. *k.* Evidence that many of the Western and Eastern gneisses are identical. *l.* Lines mainly affected by faults, and the prevailing directions of the faults.

- IV.—Additional areas described by the Author in 1880.—*a.* States that the unaltered rocks occur in broken synclinal folds, &c. *b.* Shows that the Loch Kishorn and Loch Carron limestones and quartzites are the same repeated. *c.* Evidence of the age of the Grampian Series from conglomerates and grits in the Dunkeld Series.
- V.—Dr. Callaway's views in 1881.—*a.* Agrees with the views of Prof. Nicol in the main. *b.* On the Torridon sandstone and quartzite. *c.* Important discussion on paper at Geological Society. *d.* Remarks on Dr. Heddle's views by Hudleston, Bonney, and Hicks.
- VI.—Mr. Hudleston's views on the Assynt Sections (1882).
- VII.—Author's views on Sections in Ross and Inverness in 1883.—*a.* Points of most importance in the controversy. *b.* Areas examined. *c.* No evidence in any of the areas of a conformable upward succession. *d.* Evidences of great dislocations and of Eastern Gneiss over-riding different series of the unaltered rocks. *e.* Divisions of the Archæan rocks. *f.* Evidence from microscopical examinations of the rocks (by Prof. Bonney). *g.* Author's views as to the phenomena in the eastern areas.
- VIII.—Prof. Bonney's views. (1883).
- IX.—Prof. Lapworth on the Durness and Eriboll Areas (1883).—*a.* Evidences of an old mountain system and of great dislocations. *b.* Sub-divisions of the Palæozoic rocks of the areas into zones. *c.* The Durness-Eriboll Series newer than the Eastern Gneissic Series.
- X.—Prof. Lapworth's views in 1884.—*a.* The age and mode of formation of some of the Eastern Schists.
- XI.—Dr. Callaway's views in 1883.—*a.* Evidences of great dislocations and of the folding of the limestone and quartzite. *b.* Divisions of the Palæozoic Series into zones. *c.* On the Eastern Gneiss.
- XII.—Prof. Blake's paper (1884).
- XIII.—Views of Dr. A. Geikie, and of Messrs. Peach and Horne (1884).—*a.* The Palæozoic Series and their sub-divisions. *b.* The Durness basin and displacement of its strata by faults. *c.* Corrections of views as to a conformable upward succession. *d.* Flexures and great dislocations of the strata in Eriboll. *e.* Evidence of Archæan Gneiss in Eastern Area. *f.* Effects produced by the movements on the Silurian strata. *g.* Conclusions arrived at by Messrs. Peach and Horne. *h.* Dr. Geikie's summary.
- XIV.—General Conclusions.

I. INTRODUCTION.

a. Indications of the close of the Highland controversy.—As the 'Proceedings' of the Association contain several papers dealing with the controversy concerning the rocks of the North-West Highlands of Scotland, I have thought it desirable to call the attention of the members to views contained in an important article published in 'Nature' for November 13th, 1884, by Dr. A. Geikie, the Director-General of the Geological Survey, and in a 'Report on

the Geology of the North-West of Sutherland,' by Messrs. Peach and Horne, in the same number, which cannot fail either to change entirely the future character of the controversy, or to bring it rapidly to a satisfactory issue.

b. *Origin of the controversy.*—This controversy, commenced more than a quarter of a century since, has throughout, to a very great extent, mainly because of the positions held by the chief disputants on the one side, assumed the appearance of being one between official surveyors on the one side, and some amateurs who had been led to study the questions involved in it, on the other.

During the early part of this century geologists placed the crystalline schists of the North-West and Central Highlands of Scotland among the oldest, the so-called primitive rocks.

c. *Sir R. Murchison's views.*—Therefore, when Sir R. Murchison announced in his papers to the Geological Society in 1858 and 1860 that they were mainly of Lower Silurian age, and that he had found clear evidences in the North-West of Scotland of a regular conformable passage from fossiliferous Silurian quartzites, shales, and limestones upwards into crystalline schists, it was supposed to be one of the most important discoveries that had been made in British Geology.

These views were fully adopted by the official surveyors, including Sir A. C. Ramsay and Dr. A. Geikie, and also by the late Prof. Harkness and others who had examined the areas, and the supposed confirmatory facts brought forward by these observers seemed for the time irresistible and caused the almost universal acceptance of Murchison's conclusions.

d. *Prof. Nicol's objection to Murchison's views.*—Prof. Nicol, of Aberdeen, however, with much courage for many years stoutly contested Sir R. Murchison's views, and maintained that they were based on erroneous observations. Unfortunately, however, as might be expected, in the face of what appeared at the time overwhelming evidence in support of Murchison's conclusions, Nicol's views did not meet with much approval, and the controversy seemed for a time to have terminated in favour of the Murchisonian School.

e. *History of the controversy to the year 1878.*—The history of the controversy up to 1878 is given very fully in the interesting paper by Mr. Hudleston, in the 'Proceedings' of the Association for 1879, which deserves perusal by those interested in the Highland rocks.

II. RE-OPENING OF THE CONTROVERSY BY THE AUTHOR IN 1878.

a. *Reason for objecting to Murchison's views.*—In the year 1878, after having carefully examined some sections in Ross-shire, I ventured to re-open the controversy by calling attention to the fact that there was no evidence in that area to support the views propounded by Sir R. Murchison, but that, on the contrary, I had found it to be entirely opposed to the idea of a conformable upward succession from the fossiliferous series to the crystalline schists of the central areas.

b. *Agrees in the main with Nicol's views, but differs from him on some points.*—In my paper communicated to the Geological Society in 1878, I stated that I considered that Prof. Nicol and the older geologists were right "when they maintained that the Central Highlands contained, and were largely made up of, some of the oldest rocks in Scotland," but that they had "included with these rocks, according to my views, a series of sediments belonging to a far more recent period. On the other hand, Sir R. Murchison and Prof. Geikie, who were the first to point out the presence of some, at least, of these newer rocks, extended them into many regions occupied only by the older rocks."*

c. *Reasons why special reference should be made to papers published since 1878.*—Since I re-opened the controversy in 1878 numerous papers have appeared on the rocks of the North-West Highlands, some in support of Murchison's views, others expressing disagreement with his conclusions. It will be necessary for me to refer rather fully to the latter, to show how far the views contained in them are in agreement with, and have therefore anticipated the recently published statements of the surveyors in 'Nature.' Moreover, it may reasonably be supposed that the numerous important facts brought forward in those papers must have been to a great extent the cause of the investigations by the surveyors which have compelled them to abandon completely the views so long and strenuously maintained by Murchison, Ramsay, Geikie, and others.

III. SECTION AT LOCH MAREE AND AUCHNASHEEN.

a. *Line of Section.*—My paper in the Quarterly Journal of the Geological Society, in 1878, dealt mainly with a section extending

* 'Quart. Journ. Geol. Soc.,' Vol. xxxiv, p. 817.

along the north shore of Loch Maree, and continued as far east as the mountains to the north of Auchnasheen. A part of this section had been described by Prof. Nicol, and also by Murchison and Geikie, as offering strong evidence in support of their respective views; therefore it seemed to me a favourable point for making an unbiassed examination.

b. *Nicol's Description*.—The section as given by Nicol places the rocks in the following order: *a*, gneiss; *b*, red sandstones unconformable on *a*; *c*, quartzite conformable on *b*; *d*, limestone conformable on *c*; *s*, diorite (intrusive); then a fault; and beyond this the western gneiss, *a*, again brought up by the fault.*

c. *Murchison and Geikie's Interpretation*.—The order given in the paper by Murchison and Geikie is *a*, gneiss; *b*, Cambrian sandstones unconformable to *a*; *c* 1, quartz-rock unconformable to *b*; *c* 2, limestone; *s*, syenite, intrusive along the bedding; *d*, gneissose schists conformable to and hence higher in the succession than *c* 2, and with no fault between; the ascending order being "here, as everywhere to the north, quartz-rock, limestone, and upper flaggy or schistose beds."†

d. *Author's views of the Section in 1878 and divisions of the Series*.—The order as given in my paper‡ is the following: *a*, gneiss, hornblende-schists, mica-schists, &c.; *b*, Cambrian conglomerates, grits, sandstones, shales, &c., unconformable to *a*; *c*, sandstones and quartzites unconformable to *b*, and also in places on *a*; *c* 1, furoid beds; *c* 2, quartzites; *d*, limestone, calcareous sandstones, &c.; *e*, sandstones, calcareous grits, and blue flags; *f*, argillaceous (occasionally calcareous), quartziferous, and micaceous flaggy beds resting apparently unconformably on *a* (gneiss, hornblende-schists, mica-schists, &c.).

e. *The so-called Intrusive Mass in Glen Laggan*.—I agreed with Nicol, Murchison, and Geikie in believing that the so-called syenite in Glen Laggan was an intrusive rock, but said that it varied considerably at different points, and that it was difficult to give it everywhere a distinctive name.

f. *Hudleston and Bonney's views on the so-called Intrusive Mass*.—Further researches by Prof. Bonney§ and Mr. Hudleston|| have

* 'Quart. Journ. Geol. Soc.,' Vol. xvii, p. 85.

† 'Quart. Journ. Geol. Soc.,' Vol. xvii, p. 171.

‡ 'Quart. Journ. Geol. Soc.,' Vol. xxxiv, p. 812.

§ 'Quart. Journ. Geol. Soc.,' Vol. xxxvi, p. 93.

|| 'Proc. Geol. Assoc.,' Vol. vi, No. 2.

revealed the fact that the so-called intrusive mass is largely made up of the old gneiss floor brought up by faults, and that I was incorrect in following previous authors in classing it all as an intrusive mass.*

g. *The Glen Docherty Series.*—There are some doubts about the age of the Glen Docherty series, *f*, whether it really is newer than the limestone series, or belonging to the period between the Torridon Sandstone and Quartzite, or whether, as claimed by Nicol, it is of Pre-Cambrian age, and brought up by over-thrust faults to lie upon the limestone series?

h. *The apparent unconformity in Glen Docherty.*—The fact, however, remains that there is an apparent unconformity along the whole of Glen Docherty between these and some of the rocks forming the floor of that glen, as I pointed out in my paper, and this fact has not yet been satisfactorily accounted for unless it is, as I then suggested, the result of unconformity combined with faults.† Over-thrust faults will occasionally produce remarkable effects, but if this is the result of such causes alone the evidence has yet to be worked out.

i. *The evidence furnished by the rocks of Ben Fyn, Mulart, &c.*—Again, even if such results are proved to have been produced wholly by faults, my general conclusions remain unaffected, namely, that the rocks to the east of the glen forming Ben Fyn, Mulart, &c., are identical in character with some of the Western Archæan rocks.

k. *Evidence that many of the Western and Eastern Gneisses are identical.*—In my paper, published in the ‘Geological Magazine’ in 1880, I gave numerous facts to prove this, and they were confirmed by microscopical examinations, by Mr. T. Davies, of specimens collected by me in 1878. In that paper‡ I stated that in “walking over these mountains in all directions, I did not find a single spot where the rocks were not completely crystalline,

* That there are some intrusive rocks in Glen Laggan is certain, but the point of great importance made out by these observers is the fact that much of that formerly classed as intrusive is crushed old gneiss.

† Prof. Bonney and Mr. Hudleston (see paper by Prof. Bonney and discussion ‘Quart. Journ. Geol. Soc.’ Vol xxxvi, p. 93.), agreed in 1879 with the views of succession advocated by Murchison and Geikie; but Prof. Bonney is now inclined to regard the Glen Docherty series as of Pre-Cambrian age, and thinks it very likely that the apparently fragmental character of the rock, which has always been the great difficulty in classifying it, may prove to be the result of local crushing.

‡ Vol. vii, No. vi, p. 269.

and the vertical thickness traversed must have been very great. There was no evidence of a selective metamorphism, but all were equally affected. The mica-schists, the true gneisses, and the hornblende-rocks all equally proved that we had here no partial change due to some local cause, but a universal state of crystallization, such as could only have been induced by a wide-spreading cause. Looking at the physical as well as the petrological evidence furnished by these mountains, I have no hesitation whatever in claiming for the rocks composing them a Pre-Cambrian age, and I believe, moreover, that they can be correlated in almost every particular with the so-called fundamental rocks along the west coast, especially with those exposed about Gaerloch."

1. *Lines mainly affected by faults and the prevailing directions of the faults.*—Faults which have so greatly complicated the succession near Loch Maree, as well as in a line north and south of that area, have not apparently produced equal results in the central areas, and I ventured to suggest in my paper in 1880 that the "palæozoic contractions were accompanied with elevations and depressions along lines more or less from N.E. to S.W.;" that "such a line extending from here through the length of Ross and Sutherland is indicated by the presence of the newer deposits in the hollows so formed; and that the crust seems to have been depressed to a greater depth and to have suffered more from the pressure here than at any other point, except in the parallel line along the channel separating the Hebrides from the mainland."

"This depression, as usual, was accompanied with many fractures of the crust, generally parallel with it, and these offered numerous channels and lines of weak resistance for igneous intrusions. These faults from N.E. to S.W., combined with those at right angles to them, comprise the main systems recognisable in these areas, and have contributed mainly in producing the physical features."*

IV. ADDITIONAL AREAS DESCRIBED IN 1880.

In a paper read before the Geological Society on June 9th, 1880, I stated that, in addition to those I had previously described, I considered, after examination, that the rocks of the following districts were wholly or in part Pre-Cambrian. They are described as follows, in abstract, in the 'Proceedings.'[†]

* 'Geol. Mag.,' 1880, p. 164.

† 'Proceedings of the Geol. Soc.,' 1880, p. 101: See also 'Proceedings of the Geologists' Association,' Vol. vii., No. 1, pp. 74-85.

"1. *Glen Finnan and Loch Shiel to Caledonian Canal*.—In the former district the rocks are gneiss, generally massive, with hornblende-schists, as at Ben Fyn to the North. In Glen Finnilee is a series which the author regards as newer, and probably Pebidian. At Fassfern are quartz-rocks which the author identifies with those beneath the limestone in Glen Laggan, near Loch Maree, and probably of Silurian age. At Bannavie is a granite which the author considers to be Pre-Cambrian."

"2. *Fort William and Glen Nevis*.—In this district chloritic schists and gneiss occur, which the author regards as Pebidian. These are overlain towards the south by Silurian rocks."

"3. *Ballachulish, Glen Coe, and Black Mount*.—Chloritic schists and quartzites occur here, followed along Loch Leven unconformably by Silurian rocks. On the east of the Ardsheal peninsula there is granite which the author believes to be Pre-Cambrian. Going eastward from Ballachulish are black slates, probably of Silurian age. In Glencoe are granite, banded felsite, gneiss, and breccias. . . . Between the Black Mount and Loch Sullich are traces of a great Pre-Cambrian axis, bringing up the gneissic series; this is traceable also towards Glen Spean and Loch Laggan to the north-east. Silurian quartzites are also found along broken lines, resting on the gneiss rocks."

"4. *Tyndrum to Callander*.—South and east of the former are gneisses and silvery mica-schists. Crystalline limestones and serpentines are associated near Loch Tay, resembling those in the Pebidian series of North Wales."

"The Author states that the Silurian (and Cambrian) rocks flank the Pre-Cambrian in lines from N.E. to S.W. Thus here, as elsewhere, subsequent denudation has removed enormous masses of the more recent rocks, only leaving patches of these here and there, in folds along depressions in the old Pre-Cambrian floor."

a. *States that the unaltered rocks occur in broken synclinal folds, &c.*—In my reply in the discussion I mentioned that "the unaltered rocks occurred in broken synclinal folds in each of the areas examined, and very frequently contained fragments from the immediately underlying metamorphic rocks."

b. *Shows that the Loch Kishorn and Loch Carron Limestones and Quartzites are the same repeated*.—In the section exhibited at the meeting I also showed that the quartzites and limestones of Loch Kishorn and those in the Loch Carron valley are the same beds

repeated, and not two distinct series as shown in Dr. A. Geikie's map and section.

c. *Evidence of the age of the Grampian Series from conglomerates and grits in the Dunkeld Series.*—Another point referred to in that paper, which may prove to be of importance in connection with the succession of the rocks to the south of the Grampians, was the fact that in examining the rocks between Callander and Loch Lubnaig I had noticed in the series, named in Dr. A. Geikie's map, as composed of clay and chloritic slate, &c., bands which contained distinct fragments of the rocks immediately to the north. In some places they consist of well-rolled pebbles and grits. Specimens of these were exhibited by me at the meeting when the paper was read. The evidence which I had then obtained seemed to me to show that these conglomerates and grits formed a well-defined line of division between the underlying rocks and the purple and green slates, which appear to be on the same horizon as the Dunkeld slates. The rocks are classed in Dr. Geikie's map as of Lower Silurian age, but I believe they will prove to be of an older date. In any case, should they be shown to lie unconformably on the metamorphic rocks south of the Grampians the question as to the age of the latter will be greatly simplified.

V. DR. CALLAWAY'S VIEWS IN 1881.

In the year 1881 Dr. Callaway read a paper before the Geological Society* in which he stated that, from observations he had made at Durness and Assynt, he had arrived at the conclusion that the sections in those areas "were broken, and therefore untrustworthy, but that the relations of the several rock-groups were inconsistent with the supposition that the limestone passed below any part of the newer metamorphic series."

a. *Agrees with the views of Prof. Nicol in the main.*—Also that his observations "agreed very closely with those of Prof. Nicol."

b. *Torridon Sandstone and Quartzite.*—On Dec. 21st, 1881, Dr. Callaway read another paper† in which he maintained that in some localities the Torridon sandstone "passes up with perfect conformity into the quartzite," and he therefore objected to the Torridon Sandstone being classed as of Cambrian age.

c. *Important discussion at the Geological Society.*—The reading

* 'Quart. Journ. Geol. Soc.,' Vol. xxxvii, p. 239.

† 'Quart. Journ. Geol. Soc.' Vol. xxxviii, p. 114.

of this paper caused a discussion which markedly indicates one of the varying phases assumed by the controversy.

d. *Remarks on Dr. Heddle's views by Hudleston, Bonney, and Hicks.*—In the 'Mineralogical Magazine' for the previous August (1881), Dr. Heddle had propounded the view that the Durness limestone with fossils was not of the same composition or of the same age as the Assynt, Glen Laggan (or Logan) and other limestones which had been claimed by Murchison as passing directly under the so-called Eastern Gneiss, and in the discussion on Dr. Callaway's paper Mr. Hudleston and Prof. Bonney expressed themselves rather strongly in favour of Dr. Heddle's views. As I had previously had an opportunity of examining a series of specimens of the limestones from Durness and Assynt, as well as from the areas further south, I ventured to maintain my previously expressed views as to the identity of the limestones in those areas as well as to the unconformity between the Torridon Sandstone and the quartzite. The following passage occurs in the report of my remarks in the discussion on Dr. Callaway's paper: "In the neighbourhood of Loch Maree the Torridon Sandstone was nearly 4,000 feet thick, and the quartzite within a very short distance rested directly upon the gneiss, so that an unconformity was needed. He could not agree, however, with the views of Dr. Heddle as to the non-identity of the limestone of Durness with that of the other districts. He thought that the Torridon Sandstone represented the Lower Cambrian, and the quartzite series, which contains evidences of worm-tracks, some part of the Lower Silurian."*

VI. MR. HUDLESTON'S VIEWS ON THE ASSYNT SECTIONS (1882).

In a paper in the 'Geol. Mag.' (September, 1882), entitled, 'First Impressions of Assynt,' Mr. Hudleston gives reasons for objecting to the Murchisonian view that there is an Upper Quartzite series in that area, on this point agreeing with Nicol; but he follows Murchison and Geikie in believing that the "Dolomite" underlies the "so-called Upper Gneiss conformably, and at a moderate angle." At p. 399 he says, "It is not without feelings of regret that I cannot see my way to an Upper Quartzite, and if I have been wrong about the position of the 'Logan' rock, I still think that this monster will, in most places, have to be dealt with on the basis of a fold over of some of the lower beds. The

* 'Quart. Journ. Geol. Soc.,' Vol. xxxviii, p. 117.

sequence at Craig-a-Knockan showing the superposition of the Upper Gneiss seems to be unshaken."

VII. AUTHOR'S VIEWS ON SECTIONS IN ROSS AND INVERNESS IN 1883.

On Feb. 7th, 1883, I read a paper before the Geological Society on the 'Metamorphic and overlying rocks of Ross and Inverness,'* in which I gave the results of examinations made by me in those areas in the years 1880 and 1882. These results in the main accorded with the views expressed by me in the paper in 1878 and 1880; but much additional evidence was submitted from areas not previously referred to. Prof. Bonney also contributed lithological notes, in an appendix to the paper, which contain facts of high importance in reference to some points in the controversy. I mentioned the following points as necessary at that time to be kept constantly in mind in the inquiries:—

a. *Points of most importance in the controversy.*—“(1) Is the stratigraphical evidence as to a continuous upward succession, maintained by Murchison and Geikie, of that conclusive character that it must overthrow all petrological evidence which may seem to render this, if not impossible, yet highly improbable?”

“(2) Has this upward succession from Torridon Sandstone through the quartzite and limestone series anywhere been observed to graduate into gneiss rocks of the type such as we classify under the name Ben-Fyn series?”

“(3) Are not the flaggy micaceous rocks, such as those which we have described from the east side of Glen Logan, which probably overlie the limestone series (though there undoubtedly separated from the latter by a fault), more intimately allied in their microscopical and general characters to the Torridon series than to those of the Ben-Fyn type which they are supposed to immediately underlie?”

“(4) Are there evidences of the disturbance of the strata by faults and inversions along these lines of such a kind as would be likely to greatly interfere with, and to complicate the order of succession?”

“(5) Do the eastern metamorphic rocks show at different horizons and places that variability in the amount of alteration which is usually noticed in rocks subjected to local influences only? or do

* 'Quart. Journ. Geol. Soc.,' Vol. xxxix, p. 141.

they not rather everywhere show an identical state of alteration as if the result of some wide-spread cause, rather than due to local mechanical disturbances ? ”

b. *Areas examined.*—The main conclusions arrived at are stated in the following abstracts of the paper and of the appendix as published in the ‘*Geol. Mag.*’ for March, 1883, p. 137 :—

“ In some previous papers, sections in the neighbourhood of Loch Maree had been chiefly referred to. Those now described are to the south and south-east of that area, and occur in the neighbourhoods of Achnashellach, Strathcarron, Loch Carron, Loch Kishorn, Attadale, Strome Ferry, Loch Alsh, and in the more central areas about Loch Shiel and Loch Eil to the Caledonian Canal.”

c. *No evidence in any of the areas of a conformable upward succession.*—“ In these examinations the author paid special attention to the stratigraphical evidence, to see whether there were any indications which could in any way be relied upon to prove the theory propounded by Sir R. Murchison that in these areas fossiliferous Lower Silurian rocks dip under thousands of feet of the highly crystalline schists which form the mountains in the more central areas.”

d. *Evidences of great dislocations and of Eastern Gneiss overriding different series of the unaltered rocks.*—“ On careful examination he found that, in consequence of frequent dislocations in the strata, the newer rocks were frequently made to appear to dip under the highly crystalline series to the east, though in reality the appearance in each case was easily seen to be due to accidental causes. Evidences of dislocation along this line were most marked; and the same rocks, in consequence, were seldom found brought together.”

e. *Divisions of the Archæan Rocks.*—“ He recognised in these eastern areas at least two great groups of crystalline schists metamorphosed throughout in all the districts examined, even when regularly bedded and not disturbed or contorted; and they have representatives in the western areas among the Hebridean series, which cannot in any way be differentiated from them. These he called locally by the names, in descending order, of Ben Fyn and Loch Shiel series. The former consist, in their upper part, of silvery mica-schists and gneisses, with white felspar and quartz; in their lower part, of hornblendic rocks, with

bands of pink felspar and quartz, and of chloritic and epidotic rocks and schists. The Loch Shiel series consists chiefly of massive granitoid gneisses and hornblendic and black mica-schists."

f. *Evidences from microscopical examinations of the rocks by Prof. Bonney.*—"Thirty-three microscopical sections of the crystalline schists and the overlying rocks are described by Prof. Bonney, and he recognises amongst them three well-marked types."

g. *Author's views as to the phenomena in the eastern areas.*—"Dr. Hicks failed to find in these areas at any point the actual passage from group 1 (the unaltered rocks) to group 2 (the Ben-Fyn series); neither did the same rocks belonging to group 1 meet usually the same rocks belonging to group 2. The evidence everywhere showed clearly that the contacts between these two groups were either produced by faults or by overlapping. Group 3 (the Loch Shiel series), placed by Murchison as the highest beds in a synclinal trough, supported by the fossiliferous rocks, the author regarded as composed of the oldest rocks in a broken anticlinal. They are the most highly crystalline rocks in these areas; and the beds of group 2 are thrown off on either side in broken folds. These, again, support the rocks belonging to group 1. The author, therefore, feels perfectly satisfied that the crystalline schists belonging to groups 2 and 3, which compose the mountains in the central areas, do not repose conformably upon the Lower Silurian rocks of the north-west areas with fossils, and that these highly crystalline rocks cannot therefore be the metamorphosed equivalents of the comparatively unaltered, yet highly disturbed and crumpled, richly fossiliferous Silurian strata of the Southern Highlands, but are, like other truly crystalline schists examined by him in the British Isles, evidently of Pre-Cambrian Age."

VIII. PROF. BONNEY'S VIEWS (1883).

"In an Appendix by Prof. T. G. Bonney, F.R.S., Sec. G.S., on the 'Lithological Characters of a Series of Scotch Rocks collected by Dr. Hicks,' the author stated that he observed in the above series, as he had done in other Scotch rocks lately examined by him, three rather well-marked types:—One, where, though there is a certain amount of metamorphism among the finer constituents forming the matrix, all the larger grains, quartz, felspar and perhaps mica, are of clastic origin; a second, while preserv-

ing a bedded structure and never likely to be mistaken for an igneous rock, being indubitably of clastic origin, retains no certain trace of original fragments; while the third, the typical 'old gneiss' of the Hebridean region, seldom exhibits well-marked foliation. It is sometimes difficult to distinguish between the first and second of these; but this the author believed to be generally due to the extraordinary amount of pressure which some of these Scotch rocks have undergone, which makes it very hard to determine precisely what structures are original. Even the coarse gneiss is sometimes locally crushed into a schistose rock of comparatively modern aspect. The least altered of the above series the author considered to be the true 'newer-gneiss' series of the Highlands, but both of the others to be much older than the Torridon Sandstone."* At this time Prof. Bonney fully accepted my views as to the age of the great mass of the Highlands, and only hesitated (like myself) as to where to put the Glen Docherty series, which occupy only a very limited area.

IX. PROF. LAPWORTH ON THE DURNESS AND ERIBOLL AREAS (1883).

The 'Geological Magazine' for March, 1883, contains also two other communications bearing on the controversy, namely:— 'The Secret of the Highlands,' by Prof. C. Lapworth, at p. 120; and a letter from Dr. Callaway, 'On the Highland Problem,' at p. 139; and both of these must be looked upon as of very considerable importance in regard to the recently published views of the surveyors, as they refer directly to the sections and areas examined by the latter.

On p. 121 Prof. Lapworth makes the following statement:—

a. *Evidences of an old mountain system and of great dislocations.*—"The final results of my investigations in the Durness-Eriboll region during August last seem to me to indicate most distinctly the probable truth of the theory which has long appeared to myself to be the only possible solution of the Highland difficulty. I believe that we have in the so-called metamorphic Silurian region of the Highlands of Scotland a portion of an old mountain-system, formed of a complex of rock-formations of very different geological ages. These have been crushed and crumpled together by excessive lateral pressure, locally inverted, profoundly dislocated,

* 'Quart. Journ. Geol. Soc.,' Vol. xxxix, p. 138.

and partially metamorphosed. This mountain range, or plexus of ranges, which must have been originally of the general type of those of the Alps or Alleghanies, is of such vast geological antiquity that all its superior portions have long since been removed by denudation, so that as a general rule only its interior and most complicated portions are preserved to us."

b. *Subdivisions of the Palæozoic rocks of the areas into Zones.*—On pages 124-127 he describes several sections and sub-divides the Palæozoic rocks into numerous zones. He gives a succession in the sections east of Loch Eriboll as follows, in descending order :—

"The dark limestones (vi b.) here fringe the eastern edge of the basin. These pass downwards through the yellow band (iv a.) into the *Salterella* grit (iii), which is often very conspicuous. Next emerge the yellow and buff-tinted flaggy beds, dolomites, and shales of the *Hielem* beds (ii.), with their fucoids and worm-tracks. Rising out from below these to the east appears the *Pipe-rock* (i d.) of the Lower Quartzite, charged with its hosts of rounded Annelide tubes. Next rises to-day the massive *white Quartzite* (ii c.) so conspicuous at the opposite side of the Loch. Below follows the faintly-coloured and more flaggy quartzites of the underlying zone (ii b.), and, lastly, from beneath the whole, rises out the thin basal conglomerate itself, with its quartz-pebbles, and fragments of coloured shales. This conglomerate rests at once upon the highly crystalline or so-called igneous rock of the Sutherland gneiss upon the platform above the ridge, where a narrow island of quartzite is surrounded by the crystalline '*igneous rock*,' and is separated from it by the basal conglomerate, the visible phenomena affording very clear evidence of a distinct unconformity between the two series.

"In this locality, therefore, we have not only a complete demonstration of the identity of the so-called Lower and Upper Quartzites, but proof that the Lower Quartzite (and of necessity the whole of the fossil-bearing series) is of newer age than the '*igneous rock*' of the Sutherland gneiss."

c. *The Durness-Eriboll Series newer than the Eastern Gneissic Series.*—"The unaltered fossil-bearing Durness-Eriboll series is demonstrably *newer* than the Sutherland gneiss. If, therefore, as commonly believed, the *Sutherland*, or *Upper Gneissic Series*, is merely part and parcel of a single rock-formation which extends

over the Highlands generally, then the whole of the metamorphosed and altered rocks of the Highlands must be of 'Pre-Silurian' age."

X. PROF. LAPWORTH'S VIEWS IN 1884.

In a note communicated to the Geologists' Association in July, 1884,* Prof. Lapworth gave a summary of his views.

a. *The age and mode of formation of some of the eastern schists.*—In this note he refers to the age and mode of formation of some of the eastern schists. He stated that the so-called Upper Flaggy Gneiss of central Sutherland and Eriboll is composed of two totally distinct members—1, Arnaboll Gneiss (Archæan); 2, Sutherland schists (manufactured since Silurian times); that the process of manufacture was by crushing and shearing; and that the lines of foliation and schistosity are planes of shearing and cleavage.

XI. DR. CALLAWAY'S VIEWS, 1883.

Dr. Callaway, in his letter at page 139,† says that after spending a considerable time in examining the rocks in the Durness and Assynt areas, he had arrived at the following conclusions:—

a. *Evidences of great dislocations and of the folding of the Limestone and Quartzite.*—"1. The Eastern Gneiss has been brought over the quartzo-dolomitic group by earth-movements subsequent to the deposition of the latter, and is of Archæan age.

"2. The quartzo-dolomitic series is frequently, at its junction with the Eastern Gneiss, folded back upon itself.

"3. The 'Upper Quartzite' of Murchison is the 'Lower' Quartzite repeated by either faulting or folding, and the 'Upper Limestone' is either the Dolomite repeated by faulting or a part of the Eastern Gneiss.

"4. The 'igneous rock' of authors ('Logan Rock' of Professor Heddle) is usually the Hebridean Gneiss brought over the quartzo-dolomitic group by enormous overthrows."

b. *Divisions of the Palæozoic series into Zones.*—In a paper communicated to the Geological Society on May 9th, 1883, Dr. Callaway gives further details of the areas examined by him.‡

* Published since in Vol. viii, No. 8, p. 438.

† 'Geol. Mag.,' March, 1883.

‡ 'Quart. Journ. Geol. Soc.,' Vol. xxxix, p. 355.

He subdivides the Palæozoic series, which he calls the Assynt group, into—

C¹. Torridon Sandstone and Ben More Grit.

C². Quartzite.

C²_l. Seamy. C²_u. Annelidian.

C³. Brown flags.

C⁴. *Salterella*-grit and quartzite.

C⁵. Dolomite.

C⁵_l. Dark. C⁵_u. White.

c. *On the Eastern Gneiss*.—The Eastern Gneiss, to which he gives the name Caledonian, he says overlies the Hebridean unconformably. At page 412,* he says that “the Caledonian was faulted down to the east along a south-south-west line, and was subsequently denuded from the upcast side.”

“The Assynt series was deposited on the Hebridean; and being derived from land to the west, it thinned out eastwards, only the attenuated extension of its strata passing beyond the fault to the Caledonian.”

“The motion of the Caledonian was reversed, and it was upheaved along the old line of fault, breaking off the overlying quartzite and dolomite along the same line, parallel faults being formed near it to the west. By powerful lateral thrust from the east, the Caledonian was forced up beyond the fault, so as to double back the Assynt rocks and to overlie them for some distance. At the same time a parallel slice of Hebridean lying to the west was, in like manner, thrown over on to the quartzite and dolomite.”

“The Assynt rocks east of the great fault were denuded, leaving only a few scanty patches of quartzite.”

XII. PROF. BLAKE'S PAPER, 1884.

At the meeting of the Geologists' Association, July, 1884, Prof. Blake communicated a paper ‘On the North-West Highlands and their teachings,’ in which he objects to the Murchisonian view of the succession. This paper, and the note by Prof. Lapworth, already referred to, will appear shortly in the ‘Proceedings,’ and members will have an opportunity of referring to the detailed evidence submitted by these authors.†

* *Ibid.*

† Published since in Vol. viii, No. 8, pp. 419-442.

XIII. VIEWS OF DR. A. GEIKIE AND OF MESSRS. PEACH AND HORNE, 1884.

The most recent views to which I desire specially to call attention are, as already stated, contained in a contribution to 'Nature' of the 13th November last (1884) by Dr. A. Geikie, Director-General of the Geological Survey, and by Messrs. Peach and Horne, of the Geological Survey of Scotland. The following quotations from Messrs. Peach and Horne's report on the rocks of the Durness and Eriboll areas (pages 31-35) explain the main results arrived at:—

a. *The Palæozoic Series and their sub-divisions.*—"The highly crystalline Archæan rocks are overlain unconformably by a succession of conglomerates, grits, and sandstones, regarded by Murchison as the equivalents of the Cambrian system of Wales. . . . Between the Cambrian sandstones and the overlying quartzites at the base of the Silurian series there is a complete discordance. To the west of the Kyle of Durness, for example, the Cambrian sandstones dip to the north west, while the overlying quartzites dip to the south of east. Moreover, as the observer passes eastwards to the shores of the Kyle, the Cambrian sandstones are bed after bed transgressed by the quartzites, which eventually rest directly on the Archæan gneiss. The Silurian strata in the Durness area (A. in section) consist of a calcareous series at the top, a middle series, composed partly of calcareous and partly of arenaceous strata, and an arenaceous series at the base. . . ."

b. *The Durness basin, and displacement of its strata by faults.*—"The Silurian strata in the Durness area are arranged in the form of a basin, truncated on the east side by a fault that brings them against the Archæan gneiss, and thus disconnects them from the Eriboll area, with which they were certainly at one time united. Of the identity of these strata in the two areas there cannot be the smallest doubt. . . . A striking feature of the Durness basin is the amount of displacement of the strata by faults; indeed this feature is so characteristic of the highest limestone zones that it is difficult satisfactorily to compute their thickness. But from the base of the quartzite to the top of the calcareous series the total thickness of Silurian strata cannot be less than 2,000 feet. In Sangomore Bay, near the village of

Durine, the highest limestone zone is overlain by shattery quartzite, striped fissile schists, frilled schists, and gneiss."

c. *Corrections of views as to a conformable upward succession.*—"Though unquestionably resting upon the limestone, and sharing in the normal faulting of the district, these crystalline strata do not prove a conformable upward succession, as has been naturally enough supposed. The key to the reading of this, and of the corresponding section at Farrid Head, is to be sought in the Eriboll tract."*

d. *Flexures and great dislocations of the strata in Eriboll.*—"As the observer passes eastwards along the magnificent quartzite sections on Crag Dionard and Conamheall, south of Loch Eriboll, he cannot fail to note the numerous flexures of the strata, and especially the peculiar type of their sharp anticlinal folds. As a rule, the eastern limb of each of these folds dips at a gentle angle to the south-east, while the west limb is highly inclined, vertical, even inverted, or sometimes broken by a reversed fault, the effect of which is to bring lower over higher beds. These reversed faults (t.t.t. in section) become more numerous eastwards. They are admirably displayed, both in ground-plan and dip-section, on the shore north of Heilim, where they repeat the various zones ranging from the 'pipe-rock' to the Eilan Dubh limestone (Group II.). The strike of the reversed faults ranges on the whole with that of the strata traversed, and their hade is inclined at a higher angle than the dip of the latter, the difference generally amounting to about 10°. Inland from the coast-section, north of Heilim, to the base of Ben Arnaboll, the zones just mentioned are constantly repeated by a complicated system of reversed faults and folds, the general inclination of the strata being towards the south-east. As that hill is approached the displacement produced by these faults increases in amount; hence the observer meets with beds occupying a lower geological horizon the further east he travels. At length this intricate system of faults and folds culminates in a great dislocation, which, for convenience of description, and to distinguish it from the ordinary reversed faults, may be termed a *Thrust-plane*. By means of it a great mass of coarsely crystalline gneiss, with pegmatite veins, in places upwards of 400 feet thick, is placed above the Silurian rocks (see section). A careful examination of the mass which caps Ben Arnaboll clearly proves that it

* p. 32.

rests transgressively on all the zones of the Silurian rocks, from the lower zone of the quartzites (false-bedded grits) up to the limestone which overlies the Serpulite grit. Owing partly to its low hade, and partly to subsequent folding, the outcrop of this thrust-plane resembles that of an ordinary overlying formation cut into a sinuous line by denudation. . . ."

e. *Evidence of Archæan Gneiss in eastern area.*—"That the gneiss thus brought up on Ben Arnaboll and elsewhere is in reality the Archæan gneiss is evident for two reasons—First, its lithological characters agree with those of the typical Archæan area to the west, save in certain cases where the original features have been effaced by the crushing to be afterwards described. Near the thrust-plane this effacement is complete, but in the heart of the mass the normal characters of the Archæan rocks, including in some instances their characteristic north-west strike, are retained. . . . The occurrence of this Archæan gneiss in its present position above much younger rocks is doubtless to be ascribed to the same cause which elsewhere has resulted in foldings of the strata."*

f. *Effects produced by the movement on the Silurian strata.*—"The effects of this great movement on the Silurian strata which have been overridden by the gneiss are somewhat remarkable. The pipes, or vertical worm-tubes, in the quartzites have been flattened, drawn out, and bent over in a direction perpendicular to the strike of the thrust-plane. The false-bedded grits and quartzites present a streaky appearance resembling fluxion-structure, due to the elongation of the fragments of orthoclase felspar and the quartz grains. The fine-grained rocks, especially the compact quartzites and the Fucoid beds, are highly cleaved, the strike of the cleavage-planes being parallel with that of the thrust-plane, and this parallelism being maintained quite irrespective of any variation in the direction of dip of the strata next the gneiss.† . . ."

g. *Conclusions arrived at by Messrs. Peach and Horne.*—"This accumulated evidence points to the conclusion that in the north-west of Sutherland the rocks have been powerfully affected by one grand series of terrestrial movements, whereby new structures have been superinduced upon them. Among these changes the original characters of the rocks have been more or less com-

* p. 33.

† p. 34.

pletely effaced, and new crystalline structures have been produced.

"Although a normal upward succession from the Silurian strata into an overlying series of schists cannot be maintained in the north of Sutherland, it is nevertheless certain that the displacements and metamorphism here described are later than Lower Silurian time. It is also evident that these great changes had been completed before the time of the Lower Old Red Sandstone, the conglomerates and breccias of which rest upon, and are made up of fragments of, the crystalline schists."

"One final feature of the Durness and Eriboll area remains to be noticed. The geological structure of this region has been further complicated by the subsequent folding of the strata and by a double system of normal faults which affect the strata and thrust-planes alike. One set of normal faults trends north-north-east and south-south-west, while another, which appears to be newer, trends more or less at right angles to these. By these two systems of later dislocations the thrust-planes, with their low hade, have been intersected and shifted precisely as if they had been ordinary boundary-planes between two geological formations. Much of the difficulty, indeed, which has been from the first experienced in unravelling the complicated structure of this region may be traced to the effect of the intricate network of reversed and normal faulting. The very preservation of the Durness Basin is due to two normal step-faults, one of which lets down the quartzites more than 1,200 feet, while the other brings the whole Silurian Basin down to the sea-level."

h. *Dr. Geikie's Summary*.—Dr. Geikie states at pp. 29-30 'Nature,' November 13th, 1884: "From time to time during the summer reports had been made to me of the progress of the survey, but though from the published descriptions of that tract I was aware that its structure must be singularly complicated, and although apprised of the conclusions to which the surveyors, step by step, and almost against their will, had been driven, I was hardly prepared for the extraordinary geological structure which the ground itself presented, or for the great change necessitated in the interpretation of the sections as given by Murchison." He says also: "With every desire to follow the interpretation of my late chief, I criticised minutely each detail of the work upon the ground, but I found the evidence altogether overwhelming against the upward

succession which Murchison believed to exist in Eriboll from the base of the Silurian strata into an upper conformable series of schists and gneisses." He further states that, "Having satisfied myself that Murchison's explanation of the order of sequence could not be established in Eriboll, I was desirous to see again in the new light now obtained some of the Ross-shire sections for the description of which I am responsible. Had these sections been planned for the purpose of deception, they could not have been more skilfully devised. The parallelism of dip and strike between the Silurian strata and the overlying schists is so complete as to prove the most intimate relationship between them; and no one coming first to this ground would suspect that what appears to be normal stratigraphical sequence is not really so. . . . But the clear coast sections of Eriboll, where every dislocation is laid bare, have now taught me that I have been mistaken, for the parallelism in question is not due to conformable deposition."*

XIV. GENERAL CONCLUSIONS.

I have given very full quotations to show that the Director-General and the Surveyors evidently realize thoroughly the great changes which must necessarily follow from the publication of those views. I think I may fairly claim for those who have worked so assiduously among the older rocks in Great Britain of late years that they were amply prepared for the results announced in the recent report of the Surveyors, and also that they had in reality fully anticipated all the main facts, as may be seen by reference to the quotations in the foregoing pages. The very candid manner, however, in which the errors which have fostered controversy for so long have now been admitted by the Director-General and the Surveyors, after due and deliberate examination of the facts, is truly a matter of sincere congratulation to all concerned.

That there are minor differences between workers in this field remaining yet to be discussed is only what might be expected, but the main issues are now settled, and the results which must of necessity proceed from such an advance will doubtless be far greater than can at present be anticipated. This general agreement on some vital points in the controversy in the views of the

* These areas in Ross-shire are fully referred to in my papers of 1878, 1880, and 1883, quoted in the foregoing pages, and the results now arrived at by Dr. Geikie agree with those previously given in my papers.

Surveyors and of the amateurs who have worked among these rocks marks a most important epoch in British geological science, and will doubtless greatly tend to influence geological researches in all regions of the globe where the older rocks are found.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 6TH, 1885.

W. H. HUDLESTON, Esq., M.A., F.R.S., F.G.S., Vice-President,
in the Chair.

The following report of the General Committee for the year 1884 was read :—

The Census of the Association on December 31st, 1884, was as follows :—

Honorary Members	...	...	...	...	...	15
Ordinary Members—						
<i>a</i> Life Members (Compounded)	...	...	...	...	...	99
<i>b</i> Old Country Members (5s. Annual Subscription)...						16
<i>c</i> New Members (10s. Annual Subscription)				...	...	410
Total	...	...	...	...	...	540

During the past year 47 new members were elected.

Four members have died during the past year, viz., Mr. John Curry, Mr. Robert Hudson, F.R.S., &c., Mr. Chas Taylor, and Mr. William Tooke.

Amongst the numerous geologists of eminence who died during the past year, we have to notice two in connection with work done for the Association, Dr. Wright and Mr. Godwin-Austen.

Dr. Thomas Wright, F.R.S., F.G.S., died on the 17th November, at Cheltenham, in his 76th year. Although not a member of the Association, this well-known geologist and palæontologist has, on more than one occasion, co-operated with the excursion parties of the Association in the West of England. In May, 1872, the excursion to Bath, under the special direction of the late Charles Moore and the Rev. H. H. Winwood, was fortunate in having the presence of Dr. Wright, who contributed valuable information re-