

NO. XI.—NOTES ON GAIRLOCH, ROSS-SHIRE. By JAMES WHITE,
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GAIRLOCH is the name of a parish and of an arm of the sea in the west of Ross-shire. The parish is a large one, being about 30 miles long by 20 broad; the arm of the sea is 4 miles long by 2 broad at its entrance, and is distant from Oban about 140 miles, or eleven hours' sail. The sail from Oban to Gairloch is a popular one with the tourist, the sight-seer, the health-seeker, the archæologist, and the student of physical geology, as it presents features which call up associations of surpassing interest. It is, however, with its geological aspects that we are at present concerned.

Few geologists are unacquainted with M'Culloch's volumes descriptive of the Western Islands of Scotland, and few of them fail to appreciate the great amount of labour and care necessary for their production. Whatever imperfections they may have when viewed in the light of the present day, they are a wonderful monument of industry and painstaking for a pioneer geologist.

Then these are the waters traversed by the "Betsy," and if the Free Kirk never did any other service to the cause of geology, it deserves to be thanked for this, that it afforded Hugh Miller an opportunity of exploring regions and localities which otherwise would have been to him impracticable, and so enabled him to write some very fascinating books, which showed an enormous advance upon the then existing state of knowledge upon their various subjects.

Coming down to more recent years, Prof. J. W. Judd has read the geology and specially the petrology of these western regions with a fulness and a clearness hitherto unattained. His papers on the Secondary and on the Volcanic rocks of Scotland bulk largely in several volumes of the *Quarterly Journal of the Geological Society*, and may be said to mark a new departure in the study of the science. That on the volcanic rocks (*Q. J.*, vol. xxx.) is of special interest. The author has traced, especially in Mull, the passage of one kind of volcanic rock into another all through the various stages from tachylite to gabbro. He has shown that they have a connection, a common origin, a common descent, which it is neither fanciful nor unscientific to describe as a vital one, and so has added another and what seems to be almost the crowning

triumph to the doctrine of uniformity so closely associated with the name of Lyell. For this is really the principle which underlies and gives stability to all scientific progress. Interpret the past by the present, take your cue from nature itself, reason from what is going on around you to what has always gone on, from what is known to what is more obscure.

Then we have recently had from the pen of Dr. Archibald Geikie an apparently exhaustive sketch of the sequence of events comprised in the history of these Tertiary volcanic rocks. One quite wonders at its comprehensiveness and its mastery of detail, and how, from materials which are so very fragmentary, so complete a narrative could be constructed.

With such recollections in his mind as he is piloted through amongst these old volcanic stumps—Mull, Ardnamurchan, Rum, Skye—your geological pilgrim has something akin to those feelings of reverence which a Mahomedan may be supposed to have as he enters Mecca and sees before him in very truth those objects whose story has been told him so often and so vividly. Or like those of a Christian as he enters some venerable cathedral and gazes on its lofty proportions, its richly-stained windows and its magnificent paraphernalia of altar service seen through a “dim religious light,” and thinks of what all this is intended to conserve.

Gairloch is cut out of the rocks described by Murchison as “fundamental gneiss.” This term, however, must be understood as generally applicable to the whole formation of which those rocks form a part. At Gairloch they are not gneiss, but schists, with occasional beds of hardened sandstone, and are far less metamorphosed than those rocks with which we are so familiar on the northern shores of the Clyde.

The Torridon sandstones, which occur in low-lying masses on the north side of the loch, and appear in great force on the south, form a magnificent background to the bare dome-shaped masses of the gneiss, and overlie it with the most marked unconformability. Those quartzites, which, unconformably, cap the sandstones, form in places the basement beds of a conformable series, some of which are fossiliferous—the uppermost, the limestones, having yielded fossils of a distinctly Silurian character. These fossils have determined the age and relations of the rocks in this neighbourhood. The uppermost conformable series is described as “Silurian,” the underlying unconformable Torridon sandstones as “Cambrian,”

and the still more unconformable gneiss as "fundamental," the local names being "Hebridean" or "Lewisean," or "Laurentian," to name them in accordance with the usual geological scale, the physical breaks being recognised as forming these several divisions. By most writers these lowest "fundamental" rocks are described as "Archæan," and are excluded from the palæozoic series.

This, I presume, is in strict accordance with the present state of knowledge, as nothing to undoubtedly indicate the presence of life has hitherto been seen in them. It is obvious, however, that this is quite a provisional arrangement, there being many horizons which yield no fossils, but which overlie, and are therefore of later date than, strata which are fossiliferous, so that the absence of organic remains is not of itself sufficient evidence of their age, or to show that they have never contained any fossils; as these would in all probability be few in number, simple in character, and may very readily have been obliterated by the great changes through which those rocks have passed. At the same time it seems highly probable that sedimentation may have been carried on at a date long anterior to the appearance of living things, and under conditions in which life, as known to us, would have been impossible.

The organic world is supported from the inorganic, the plant and the animal from the mineral, but neither plants nor animals can live on stone, hard rock, or solid mineral by itself, their food being taken in a gaseous or fluid condition, and requiring to be prepared for them; so that the rocks of the first formed, the first condensed crust, must have been highly pulverised and finely divided before life could find a footing, and this could only be done by the agency of water.

Speaking generally, plants live on minerals, animals live on plants. When pushed to its lowest limit, however, the distinction between these two great kingdoms disappears, and the most arbitrary characters have to be selected to define the one from the other. The outstanding rule seems to be that the simple precedes the complex, the less precedes the more highly differentiated; and accordingly we find that what evidence there is for the existence of life in those Archæan rocks is referable to the plant rather than to the animal. An animal is more highly organized than a plant, has a greater number and a greater variety of parts, is better furnished with the means of offence and defence, and, according to this theory, would appear later in time.

Although no clearly recognisable well-defined fossils have been seen in these Archæan rocks it by no means follows that they were destitute of life. The *Lingula*, though it has persisted down to the present day, doubtless had an ancestor which was not a *Lingula*, and the *Oldhamia radiata* sprang from something which preceded it, and so with the other and more highly differentiated forms which Cambrian rocks bring to view.

The boundary of the palæozoic system is wholly unknown. Advantage is taken in this case of a well-marked physical break as a dividing line, but it is entirely arbitrary, and may at any time be thrown indefinitely backwards.

But this whole subject, which is replete with interest, is very fully discussed by Prof. Dana in his "Text-Book."

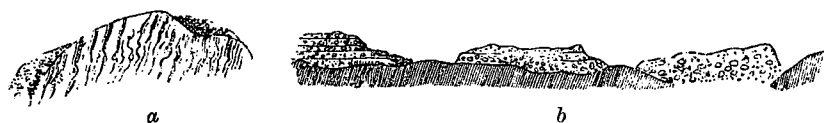
At Gairloch these rocks vary very much in their character—some are quite hard and splintery, others are softer and not far removed from an indurated shale. Beds of sandstone also occur here and there; evidently they are mechanically-formed shore deposits, and have at one time been a series of sandstones and shales such as we are familiar with among rocks of later age round Glasgow. The plane of schistosity coincides with the plane of bedding, the dip is vertical, and no means are here available for estimating their thickness. It seems, however, that further north they are thrown into a series of synclinal and anticlinal folds, from which they have been estimated to be at least 20,000 feet thick; but nowhere is the base visible. There is another feature of these rocks of unusual interest—the extremely rounded bossy forms into which they weather. Many other rocks, especially schists, take this form, but these have received it and retain it in an unusual degree. As you sail into Gairloch and gaze on their dome-like bleached and barren masses in the full glow of the afternoon sun you are at once struck with this peculiarity; nothing like it has occurred all the way, though you think you have exhausted every form of rock contour of which nature is capable. They have an almost ghastly look, innumerable knolls of a bare, dull, verdureless, ashen grey. These rocks are overlain by the sandstones, and, singular to say, in places where the junction of the two can be traced, the rounded bossy form of the gneiss is seen to persist under the sandstone. Clearly it had acquired it before the sandstone was laid down.

This rounded bossy form is by all geologists attributed to the

action of land ice. Wherever it is found, even in tropical countries which are now even farther out of the reach of such action than our own land, it is accepted as proof that "John Frost" has been there, for there is no other known agency which can produce such features. Elevation from beneath is out of the question, as these Gairloch schists stand on end; and for the same reason a puckering up of the crust by lateral pressure is out of the question. Atmospheric weathering gives us stacks and needles and other splintery forms, but a heavy mass of moving ice coming on a country which has been previously subjected to atmospheric weathering planes off the asperities which are thereby produced, and leaves instead bossy rounded forms, which may be either great or small according to the condition and character of the land at the time of its advance.

The plain inference from all this is that we have in these Gairloch schists an example of glacial action in early Cambrian times.

Dr. Archibald Geikie was the first to notice this, and to call attention to it in a paper (*Nature*, Aug. 26, 1880) which he illustrated by some drawings and a diagram of two sections; the latter I have



here reproduced. The first (*a*) occurs a little way up the hill immediately behind the Gairloch hotel, and the second (*b*) on the shore immediately to the south of the Free Church.

The Duke of Argyll in a communication to a subsequent number of *Nature* challenged the accuracy of the drawings.

Not having seen the localities of the drawings I don't discuss them, but having gone over the originals of the sections several times I can testify that they are not at all exaggerated; in fact if I had drawn them myself I would have shown the rocks as much more rounded than they are represented. I think most of you will be of opinion that these contours are not such as splintery schistose rocks standing on end would acquire from ordinary atmospheric weathering.

There are other features in the neighbourhood which point in the same direction, as, for example, the extremely rough angular character of the breccia which lies immediately on the schists.

Many blocks in it are from 3 ft. to 6 ft. long, all derived from the underlying rocks, and as sharp and angular as if they had been split off yesterday. Clearly such a mass of material was never brought together by the agency of water; it is vastly more like moraine matter which has not travelled very far.

Prof. Sir Andrew Ramsay, in his address to the British Association Meeting at Swansea, of which he was president, quotes this section of Dr. Geikie's in illustration of the subject of his address, "On the Recurrence of Certain Phenomena in Geological Time." Amongst other recurrences he finds what is to him satisfactory evidences of that of glacial phenomena, and writes:—"The general subject of palæozoic glaciers has long been familiar to me, and this account of more ancient glaciers of Cambrian age is peculiarly acceptable."

Poolewe is worth a visit were it only to see the débris of what must have been a very massive glacier, which, there is so much evidence to show, at one time swept down to the sea through the valley now designated Glen Docharty, Loch Maree, and Loch Ewe. This débris is of the most imposing character; you have boulders on the hilltops cutting the horizon in the most fantastic manner, and boulders strewn along the hillside, boulders single, boulders in groups, boulders angular, boulders rounded, boulders of sandstone, and boulders of gneiss. It seems reasonable to conclude that all this matter is the product of the latest glaciation of this valley, as these boulders appear to be local. I went up the hillside about 400 feet, and all that I saw were schists or sandstones. If those on the tops of the hills are also local, then they probably belong to the same period of glaciation, and in this case the ice must have quite filled the valley and have been sufficiently high above it to strand stones on the ridges. It would then be better described as a *mer de glace* than as local glaciers.

The stones at the bottom of the valley are all smaller and more rounded. Clearly they have suffered more attrition than those on the hillside, and have formed a moraine which has stretched across and filled the whole valley. A retiring glacier turns into a river, and these stones, as they have been acted upon by water more recently than by ice, are now just a mass of very coarse gravel. From a change of level the River Ewe now cuts through this moraine, and the sea, entering from Loch Ewe, cuts into it, so that we have along the banks of the river and at the head of the

loch a very well-marked terrace, which might be described as a Raised Beach. Nothing could be plainer or more evident, and it is worth going all the way to see. We have here the closing stages of the Ice Age clearly indicated in a rising land, retreating glaciers, and an ameliorating climate.

But all this work is of an entirely local character, limited in time, limited in space, and, although we had read twenty such localities, or all the superficial features of the county put together, we have not read the history of the Ice Age. It cannot be seen in the superficial features of the country; you must dig for it, as it is from the digging that the revelations come. What about those six distinct and separate Boulder-clays which some deep bores pass through (see *Transactions*, vol. iii., p. 133), each separation being indicative of a period when the formation and deposition of the clay was suspended and its place taken by sand or gravel or mud, materials which are in no way connected with a cold climate, and which could not by any possibility be brought together under the same climatic conditions as Boulder-clay; and these not occurring in small lenticular patches, which prove nothing either one way or another, but in wide spreading beds 60 ft. to 100 ft. thick?

We must take the maximum number of these indicated changes as the minimum number which has occurred, and so the question is at once raised, how often has this valley of the Ewe and how often have similar valleys been blocked up with this débris and then wholly or partially cleared out? Are we, after all, sure that all the material we see is the product of the *latest* glaciation? According to theory, 20,000 years would be the interval between each period of intense cold, but this is short. According to theory, 80,000 years have passed away since the last period. All the big stones you see are local schists and sandstones, the rocks which lie in the line of the passage of this glacier; but how many glaciers have passed down this glen, and have the lines of drainage which pass into it always been the same? Physiographers point out to us very clearly changes which have taken place in some of the watersheds of the country, and ice-sheds obey the same laws as watersheds. Is it a far-fetched, ill-informed thought that there may be stones amongst those hundreds which you see strewn along those hillsides, or those millions which cover the bottom of that valley, which, as to their derivation, may be widely separated

from each other both in time and locality? There are many districts which could furnish schists and sandstones; the same kinds of rocks have been forming ever since time began. The late Mr. Pratt, a well-known member of this Society, spent a large portion of his leisure time in sectioning crystalline rocks, and all his acquaintances had commissions to pick up for him specimens of them wherever they might come across them, the result being that he came in time to possess a large number of sections—over 300. As the sources of supply from rocks *in situ* became exhausted he collected specimens from the Boulder-clay and sectioned them, thus gathering another series of sections, a great many of which were of quite a different character from his first collection. These he could not possibly identify with the rocks found *in situ*, although he was in every case careful to note the locality where the parent boulders had been found.

In Dr. Croll's book on "Climate and Time" a chart is given showing the probable centres of dispersion of ice during the period of maximum glaciation, and one of these centres is in the North Highlands, where the land rises to between 3000 ft. and 4000 ft. The subsequent detailed mapping of that district by the officers of the Geological Survey has unexpectedly brought to light the fact that this was a mistake. So, as these centres of dispersion all balance and are all related to each other, if one has to be changed so must the others, leading probably to an entire reconstruction of the chart in question, and to still wider conceptions of the extent and thickness of the icy covering.

Then as to submergence. It is Dr. Croll's, and I think the general belief, that the change in the relative levels of sea and land was brought about rather by an advance of the sea, due to the displacement of the earth's centre of gravity by the great mass of ice at the pole, than to an actual sinking of the land, or at least that this was a powerful factor. Should this be correct, then, if we are to have a greater weight from a greater thickness of ice than was at one time supposed, so we must also have a greater submergence than was at one time supposed.

Such are some of the thoughts which in my own way I have had the temerity to ventilate in view of some discussions which have recently taken place in this Society and elsewhere. It seems to me that, in these matters, as generally in nature, it is impossible to draw hard and fast lines; that there is room enough for all;

that geologists cabin, crib, and confine themselves by taking too limited a view of such operations; and that if these are looked at in their true proportions much difficulty might disappear. Within its real compass we may quite well have boulders, many stranded by retreating ice, and we may also have boulders, many of which as certainly have been dropped from passing icebergs. In some cases the difference is quite easily defined, in others it is by no means evident. May they not sometimes lie side by side?

When we have a past president of the Geological Society telling us that the ice-cap in Scotland was 3000 ft., and in some places 5000 ft. thick; and another past president telling us, just the other day, that there never was an ice-cap in the country at all; when we have geologists who contend that there is no evidence whatever to show that the land was ever sufficiently submerged to allow icebergs to float over it and drop erratics on its surface; and other geologists who contend that all the glaciation which it has undergone has been due to floating and not to land ice at all, it is surely apparent that there is a vast deal of speculation going on, and that more careful and cautious and accurate observation than has hitherto been bestowed on these questions is called for.

So much for another glimpse of "our stern Scottish Highlands," a land famous in song and story, and a land of perennial and ever-increasing interest to all dabblers in physical geology.

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