EVIDENCES OF GLACIAL ACTION IN SNOWDONIA.

BY ONE OF THE COMMITTEE.

AT the first Annual Meeting of the Climbers' Club a suggestion was made that contributions to the *Journal* on Natural History and Geology might be made a feature, but so far they have not appeared. There is ample scope in the Lake District and in Wales, and, whilst the work will not be found easy, it is exceedingly interesting. There is a delightful little book by Ramsay on the "Ancient Glaciers of Wales," but, unfortunately, it has long been out of print. The observations on which this paper is based were made after reading Ramsay's work, and much of the ground covered is necessarily the same, although the details are largely different.

Before proceeding to speak of Snowdonia, it will perhaps be well to say a few words on glaciers and the effects they produce on the country. According to Professor Forbes:— "A glacier is a mass of ice, which, descending below the usual snow line, prolongs its course down the cavity of one of those vast gorges which furrow the sides of most mountain ranges." It is fed by the snow fields which lie in great stretches on the upper parts of the mountains and gradually make their way down the slopes. At its lower extremity it is gradually wasting away owing to the ice being melted by the heat of the sun. Were it not for this waste, it would continually encroach on the valley below, for it is ceaselessly moving in a downward direction. The velocity, however, is but small, varying considerably with the steepness of the slope on which the glacier lies. It may be taken to average about 500 feet per year, the greatest measured by Professor Forbes on the Mer de Glace being 876 feet, and the least 223 feet.

On the surface of the glacier are lines of rocks roughly parallel to each other. They may be confined to the sides of the glacier, or there may be some near the central portion; these are the moraines—lateral and medial. In addition to these there is a great accumulation of debris at the extremity of the glacier, called the terminal moraine. Some of the rocks thus borne down by the ice are of considerable size, and may be carried to a distance of many miles from their place of origin. Thus, one large mass in Switzerland measured over 50 feet long, 20 feet wide, and 40 feet high, and has been carried more than 60 miles.

When the ice bearing this moraine matter melts away, the debris is left behind as a lasting monument of the effect produced by the glacier. Frequently large blocks are in this way gradually lowered and left poised in apparently most insecure positions on the rock beneath; these are the perched blocks which will be spoken of as often being met with in the Welsh valleys. As the ice slowly makes its way down between the mountains, its enormous mass causes it to act on the rocks over which it passes somewhat in the manner of a huge plane, smoothing and polishing the surface with which it comes in contact. Moreover, there are frequently stones—large and small—wedged in the ice so as to be in contact with the rock, which is thus grooved and scratched; some of the markings are broad and deep, whilst others are as fine as if cut with a knife. In 1842, Professor Forbes was fortunate enough to see these groovings and striations in the actual process of formation on the glacier of La Brenva, which lies on the eastern slope of Mont Blanc. The ice was in contact with a mass of limestone; and on cutting it away the face next the rock was found set all over with sharp angular frements, some as fine as grains of sand, and others larger than cherries, all of them being of a granitic character and evidently derived from the main mass of Mont Blanc. When the face of limestone was washed, it was observed to be finely polished and furrowed in the direction in which the glacier was moving, and it was not at all difficult to determine the

markings produced by the individual angular fragments embedded in the ice. Thus, we may say there are three main evidences of glacial action to be looked for in any district where it is believed these ice streams once existed.

1. Moraine matter.
2. Rocks rounded and smoothed by the passage of the glacier.
3. Wide groovings and fine striations.

All these evidences occur plentifully in many parts of North Wales.

The district to be described is probably best approached from Aber, a little village some five miles east of Bangor. The coast at this point is spoilt by a broad expanse of mud—the Lavan sands — which stretches out towards Anglesey. Turning inland, a walk of some four or five miles leads to a lonely valley nearly a mile wide, shut in on the south by the lofty ridge of Foelfras, and containing a small tarn—Llyn-yr-afon. South of this lake, the parent rock is smoothed on the top, but presents a broken face towards the water. This is characteristic of glacier worn rocks with a somewhat steep side; for, since the ice cannot readily accommodate itself to the changes in inclination, the steep face is much less abraded than the top, and on the retreat of the ice presents a more broken appearance. Failing the presence of striations, these lee sides, as they may be called, afford evidence of the direction in which the glacier flowed. In this instance they faced towards the north—that is, down the valley. On the west side of the lake the ice-worn rocks extend to the water's edge. On reaching the northern extremity a confused pile of blocks is found stretching across the mouth of the valley to a little beyond the outflowing stream. This is without doubt the old terminal moraine; and here are several rock masses of considerable size, one measuring 12 feet by 9 feet and 12 feet high. Proceeding down the valley towards Aber, the evidences of ice action continue on both sides of the stream below the sheep pens, which are two miles from the head of the cwm; but beyond this point they become less and less distinct.

Rather more than a mile below the sheep pens a small stone bridge is crossed, a few yards from the junction of the stream from the lake with another further west. Following this westerly stream towards its source, the Aber falls are reached, the eastern of which is far the finer. From this point Carnedd Llewelyn bears almost due south, about three miles distant as the crow flies. On its west side is a little valley—Cwm Caseg —at whose mouth there are distinct traces of ice action. Under the ridge, forming its northern boundary, there is a rounded mound with a number of blocks scattered upon it, some being well perched. One of these travelled blocks measures 15 feet by 6 feet and 9 feet high. Round the little pool in Cwm Caseg there are also remains of moraine debris, but the evidence is scanty compared with that in Cwm Llafar, the next valley to the south-west. On crossing the ridge between these two cwms, rounded and grooved rocks are met with at a height of 1,700 feet above sea level, the grooves running towards N.W., or in the same direction as the valley. Many travelled blocks are strewn about on a sort of rough and uneven terrace, which reaches high up between the stream and Yr Elen. Continuing down towards Bethesda, the traces become much scarcer on the north-east side of the valley, but are still fairly plentiful on the opposite side. Turning up stream, the evidences of ice action rapidly increase. Close to the stream, on its left bank, are many rounded and polished rocks with grooves broad and narrow. The finer markings are seen to be wonderfully preserved when the turf and soil are removed, whilst the rock between them is beautifully smoothed and rounded. These groovings, like those on the opposite side of the valley, head towards N.W., the slope of the mountain at this point being N.E.—that is to say, at right angles to the ice markings. Moraine debris and rounded rocks are met with at short intervals to a height of some 1,800 feet above sea level, but beyond this they rapidly decrease. At the south corner of the valley is Carnedd Dafydd, the summit of which can be reached in about an hour and a quarter. From the cairn there is a rough and steep descent

of some 1,300 feet to the little tarn in Cwm Lloer. High up on the west side of this valley there are furrows running in a north-easterly direction—that is, down the rocks, which here slope to the north-east. This evidence might be open to objection if considered alone, but close at hand are some blocks distinctly perched on the parent rock, thus confirming the testimony of the grooves. The traces on this side of the valley are, however, far fewer than on the east. Crossing over above the lake, smoothed surfaces of rock and roches moutonnées are noticed some distance above the water's edge. In fact there is a succession of these stretching down the eastern border of the lake directly towards the mouth of the valley, with considerable accumulations of moraine matter at intervals. As might be expected, the groovings in the upper part of the cwm are not numerous, but they may be discovered with a little search. One well marked set runs about E. by S. down the valley, with an inclination of 10°, whilst the rocks at this point slope towards S.S.W. at an angle of 38°. This is a characteristic of ice groovings; that is, they run *across* the rock face in the same direction as the valley, and with a different inclination from that of the rocks. Lower down, towards the mouth of the valley, a single rock has on its surface 15 well marked furrows in a breadth of two feet, the widest being about an inch across. In addition, there are many fine scratches scattered over it, all—grooves and striations—running nearly towards the south-east. The ice-worn rocks continue to a point touched by a straight line drawn from Tryfan through the eastern extremity of Lake Ogwen, or nearly to the edge of the ridge shutting in Cwm Lloer. On quitting this ridge and proceeding closer to the stream issuing from Ffynnon y Lloer, other markings are found which stretch at short intervals from about 400 feet above Lake Ogwen to the main valley below. Before reaching the road a farm house is passed; close to it the striations run almost due S., and still nearer the road they bear S.S.W., thus shewing that the ice gradually changed its direction as it entered the new valley. Evidently the glacier here swung

round and went to join the great mass of ice which at one time filled Nant Ffrancon. The streams to-day follow much the same course; but a few hundred yards to the east they take the opposite direction, and, flowing past Bettws y Coed, enter the Conway valley. The watershed lies but a short distance from the line the old glacier took, and no doubt a few yards more to the east would have caused it to take a very different course. The little valley just described is scarcely two miles in circumference, but it is extremely rich in the evidences it affords of ice action, and apart from this is well worth a visit for its scenery.

Opposite the eastern extremity of Lake Ogwen a steep spur runs up to the summit of Tryfan, which is connected to Glyder Fach by a jagged ridge. These two form the western boundary of Cwm Tryfan, the head of which can be reached without difficulty from below. A most enjoyable climb, and one free from danger, can be had by keeping to the spur just referred to; then passing over the summit of Tryfan a rough descent is made to the bwlch, whence the head of the cwm can be reached in a few minutes. From Glyder Fach, a broad and steep sheet of screes extends to the top of the valley, and below these are ample traces of ice action, which continue to the road hundreds of feet below. In the upper part, mammillated mounds and moraine blocks are conspicuous, some of the latter being finely perched. Here, too, many of the rock surfaces are scored with broad grooves as much as seven or eight inches wide. Lower down are splendid examples of the rounding and smoothing produced by the ice as it slowly slid over its rocky bed. In many instances these rocks bear fine scratchings, as delicately traced as if drawn with the point of a needle. This is particulary well seen on those parts of the glacier bed of a slaty character, especially when the turf and soil are removed and a fresh surface exposed. The general bearing of the furrows and fine markings is about N.E., or roughly parallel to the main stream flowing down the valley, and not in the direction of the slope of the rocks which at this point is nearly S.E. On each side of the valley are terraces

on the bounding ridges, some nearly horizontal and others inclined at a high angle. On the shoulder of Tryfan, at a considerable elevation, the rocks are finely polished, and there is also a collection of moraine matter which is matched by a corresponding mass on the opposite side of the valley. It reaches to such a height that the thickness of the ice at this point could not have been less than 250 to 300 feet, and probably exceeded that amount. Lower down the valley, the groovings are a very striking feature, the widest being fully a foot across. Almost in the middle of the cwm stands a great moraine heap with a sloping side some 70 to 80 feet in height, covered with blocks of various sizes, whilst at the mouth is a belt of débris, much cut away by the water, but evidently a remnant of the terminal moraine. Some of the perched blocks are left in very prominent positions, especially on the western side. One, rather high up, on the very edge of a polished rock, is 6 feet by $5\frac{1}{2}$ feet and $4\frac{1}{4}$ feet high. It appears to be so delicately poised that a touch would send it over. Out of curiosity a friend and myself scrambled up above it and used all our strength in an attempt to dislodge it, but, as might be expected, without success. A second block on the top of a fine roche moutonnée measured 8·6 feet by 8 feet and 7·6 feet high, whilst a third was more than double the size. To get a good general view of the glaciation of this little valley, a climb should be made from the east end of Ogwen straight to the summit of Tryfan. Shortly before reaching the top a splendid view is obtained of the abraded rocks and heaps of moraine matter, which are spread out below like a map. The traces of ice action continue right down to the Holyhead road, on both sides of which there are unmistakable evidences of the rocks having been rounded and smoothed. Turning to the left at the bottom of the valley, and proceeding in the direction of Nant Ffrancon, similar evidences are found. At first the furrows run W.S.W., but just under Cwm Bochlwyd, close to the roadside, they bear due W.—exactly the same direction as the valley—and in places are eight inches in breadth.

The little glen just mentioned—Cwm Bochlwyd—can be

reached in a few minutes by following up the stream which flows from it. It is shut in on the east by Tryfan and Glyder Fach, whilst on the west there is a sharp ridge called the Gribin. A short distance north of the small tarn in the valley there is a very good example of a terminal moraine, among the blocks of which the stream finds a passage towards Lake Ogwen, more than 600 feet below. Standing near the outlet of Lake Bochlwyd, moraine heaps, more or less distinct, can be made out on all sides. One comes down from the shoulder of Tryfan almost exactly in line with the summit. Above it are several small perched blocks on the edge of a bluff which appears to have deflected the ice a little towards the south. Rounded grass-grown hummocks are to be seen to the west of the lake, but the finest and most striking mass of débris lies on the east or Glyder Fach side. Here, in the main heap, the rocks are piled up in the wildest confusion, and many are of considerable size. One block, wedged in by smaller ones, measures 12 feet by $4\frac{1}{2}$ feet and 12 feet high, whilst a second is 21 feet by $11\frac{1}{2}$ feet and $6\frac{1}{2}$ feet high. The heaps of moraine matter run right down to the water's edge, and on a clear day numbers of rocks may be seen at the bottom of the lake not far from the shore. East of these mounds, half way up the mountain slope, the rocks are rounded and smoothed, with striations on them running nearly N.W., towards the lake. These markings are at right angles to the joints, and are quite distinct from the lines of weathering. A short distance above the south end of the lake a belt of débris stretches across the valley, much cut away in places by the stream. This, no doubt, marks the position of the terminal moraine, when, on the climate becoming milder, the glacier shrank and retreated to the upper part of the valley. From the head of the lake a steep gully runs up to the col between the two Glyders. About half way up is a remarkable mass of rock, over 11 yards long, bearing dozens of well marked furrows, some upwards of 8 inches wide and $1\frac{1}{4}$ to 2 inches deep. They run up the rock at a considerable angle—about 20°—and head in the direction of Tryfan, or nearly N.E. by E. Most of the cracks

cross the grooves at an angle of 60° to 70°. Still higher up the valley is a fine roche moutonnée, with numbers of travelled blocks on it, but, as a rule, smaller than those on the main moraine heap below. Here, too, where the parent rock crops out, it is seen to be rounded, smoothed, and grooved, some of the furrows being 5 inches in width, and, as before, running in the same direction as the valley. From this point a rough scramble can be had to the col, which is some 400 feet above. In summer there is but little difficulty to be overcome; in winter, however, and often at Easter, the gully is choked with ice and snow lying at an average angle of 40°, and thus rendering an ice axe very acceptable. From the col, a short walk to the right leads to upper Cwm Idwal, which can be reached pretty easily by starting some distance beyond the Gribin, which forms its eastern boundary. The gully close to the Gribin affords a more exciting, and possibly more rapid, route. Towards the top of this little cwm is a belt of screes, followed by a stretch of grass. Here, east of the centre, is an unmistakable moraine mound, which was doubtless deposited when the Idwal glacier shrank to very small dimensions. Nearly in the centre rises a rounded and smoothed mass of rock with broad grooves and fine striae, bearing a point west of north. The grooves are as much as 3 inches wide, and can be seen several yards off, whilst the finer markings are not broader than an ordinary sewing needle. Just below, there is a sudden drop, and the moraine matter ceases, but the rounded and polished surfaces of rock can be traced right across the valley, from the Gribin on the east side to the cliff of Glyder Fawr, which lies on the west, and frowns over the south end of Lake Idwal. At one point the furrows run to the edge of a rock, which then slopes away at an angle of 60° to 65°, and so smooth that no footing can be obtained on it. The drop is 80 or 90 feet, and no doubt at one time there was an ice fall at this spot, for below it the striations are again met with running in the same direction as before. Still lower, is a mound stretching from the Gribin towards Idwal, and on it rests a block which in its largest dimensions measures 18 feet by 18 feet and 15 feet high, whilst hundreds of smaller ones lie scattered on all sides.

(To be continued.)