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EVIDENCES OF GLACIAL ACTION IN SNOWDONIA.

BY ONE OF THE COMMITTEE.

(Continued from Vol. II., No. 8, p. 161.)

THE valley which has now been reached is Cwm Idwal, which for wildness and general picturesqueness is unsurpassed by any glen in the district. It also abounds in evidences of ice action. Omitting all detailed reference for the present, it will perhaps be sufficient to say that a great mass of ice flowed from the valley and joined the Nant Ffrancon glacier. At the mouth of Cwm Idwal is a little hill surmounted by an ordnance post, a few yards below which are two well-perched masses of rock. The whole face of the parent rock has been abraded by the passage of ice, and is furrowed in a N.N.E. direction, that is towards the shoulder of Carnedd Dafydd, which stands as a sentinel at the entrance of Nant Ffrancon. At this point the stream from Lake Ogwen passes under the Holyhead road, leaps down a rocky chasm, and then flows quietly to the sea at Bangor. The valley through which it winds is Nant Ffrancon—the Valley of the Beavers—one of the most beautiful in Wales, but lacking the wildness which characterises Cwm Idwal. On the west it is bordered by a lofty ridge which sends down spurs enclosing steep and rarely visited cwms. At the northern extremity of this ridge lie the Penrhyn slate quarries, whilst on its western side are those of Llanberis. On the east the valley is shut in by a spur from Carnedd Dafydd frowning in precipices high above the road. From time to time great masses of rock, loosened by the action of the weather, fall from the cliffs and go bounding down to the stream hundreds of feet below. In spite of these

falls it is quite easy to trace the glaciation, although it is not so well marked as on the opposite side of the valley. Starting near the bridge, a few yards from the western extremity of Lake Ogwen, we find abundant traces of the rocks having been abraded by ice. In spite of the weathering the furrows can be followed without much difficulty. The direction of these groovings, however, is at first sight very puzzling, for they head nearly N.N.E. straight across the valley towards the spur from Carnedd Dafydd, which drops steeply near the outlet of Lake Ogwen. This is understood when Cwm Idwal is carefully examined. A great mass of ice came from this valley and struck some distance across the head of Nant Ffrancon. Indeed, Professor Ramsay suggests that it actually abutted on the shoulder of Braich-Du, and there are certainly evidences on this spur to justify the suggestion. Thus the furrows referred to were caused by the Idwal glacier, and not by the ice which flowed where Lake Ogwen now is. Between the stream and Braich-Du the rocks are finely rounded and also bear some scorings. In fact, from this point to Lake Idwal, it is hardly possible to find a single exposure of parent rock which does not exhibit marked evidence of being ice worn. By taking a reading of the barometer at the level of Lake Ogwen, and then following the marks of glaciation up Braich-Du, it is possible to obtain some estimate of the thickness of the ice at this point. The scrambling is rough, but presents scarcely any real difficulties. In August, 1887, I succeeded in tracing these evidences to a height of 465 feet above Lake Ogwen, when mist and a rain storm drove me down. This imperfect observation shews that the ice could not have been less than 465 feet thick at the spot where the Ogwen falls now are. On the way up some very characteristic grooves are passed. One set runs N.W. by 10° N. at a small angle *up* the rock face, which slopes at 30° in a totally different direction. Exactly at the falls the road has been cut through a finely ice worn rock, and $\frac{3}{4}$ mile towards Bangor there are others of the same character high above the road. It is, however, on the other side of the stream in Nant Ffrancon

that the most striking evidence is to be seen. Proceeding down stream, dozens of ice-carried blocks are seen, some perched on the very edge of steep little banks. Gradually the direction of the striations changes to N., then N. by W., and further on N.N.W., as the glacier from Cwm Idwal slowly swung round and adapted itself to its new quarters. Observations made under Cwm Perfedd and Cwm Bual shew that the ice here ran down Nant Ffrancon, and that the tributary glaciers from these cwms were not of sufficient size to override the one in the main valley, as was the case with the Idwal glacier. Indeed this might be expected when the size of these little valleys is considered. At the mouth of Cwm Bual, which is about 2 miles from Lake Ogwen, the old road is a considerable distance above the stream in Nant Ffrancon. On dropping to the middle of the valley, here and there rounded rocks are met with much worn by the action of the weather, but having distinct grooves on them, running N.N.W. towards Bethesda and traceable on both sides of fissures which seam the rocks. Half-a-mile further on, the direction of the striations is still the same. This is under the south border of Cwm Graianog, the edge of whose terminal moraine can be easily distinguished some 400 or 500 feet above. From it a double line of blocks stretches down to the road, easily seen from the opposite side of Nant Ffrancon. Still further towards Bethesda, where the bare rock crops out, it is finely rounded and smoothed and has grooves upon it 2 inches wide, which here, too, bear N.N.W. along the valley. About half-a-mile further the road forks, one division bending towards the stream. To the left of this branch is a rounded rock almost covered with grass. The little surface which is bare, is so much weathered that it is difficult to satisfy oneself whether the furrows have been caused by ice or not. Another, a few yards away, gives more satisfactory evidence. The top is grass grown, but the west face is exposed and has on it several grooves ranging up to 3 inches in width and running in a northerly direction, thus shewing another change in the course of the glacier as it followed the windings of the valley.

Beyond this point, which is very little south of the great slate quarries, I have no observations, but, doubtless, evidences of glaciation might be found still nearer the sea coast.

The tributary valleys are well worth examination, some of them yielding striking traces of having been ice worn. From the Ogwen falls there is no subsidiary valley on the east side of Nant Ffrancon for a distance of 3 miles, but on the west there are half a dozen in a corresponding distance. All are small and but little visited in spite of the attractions they possess for the climber, botanist, and geologist. Immediately south of the Penrhyn slate quarries is a ridge called Bronllwyd, from most points of which a fairly easy but somewhat rough descent can be made to Cwm Ceunant; or the valley can be reached with less exertion by striking up to it from Nant Ffrancon. On the north side of the centre, at an elevation of about 1,570 feet above sea level, is a distinct moraine heap running in the direction of the length of the cwm; a few yards higher is another nearly in the centre, and still higher are two others, one on each side of the valley. These mounds are partly covered with bilberry bushes mixed with short grass and a little moss, but the bare stones crop out pretty plentifully. The moraine debris extends at intervals over a distance of some 200 yards or more, and includes a number of travelled blocks which reach to the very edge of the cwm. In fact, there are some shed here and there on the slope down towards the road. The south face of Bronllwyd above the mounds in several places has been smoothed by the grinding of the ice as it slowly moved downwards. The surfaces of rock are much weathered and often covered with grey lichen; however, some striations can be seen running towards N.E. The whole of the lower slope of Carnedd-y-Filiast, between Cwm Ceunant and Cwm Graianog, is strewn with blocks, travelled and perched. In places, too, the rocks are smoothed, but have been so much weathered that it is difficult to say whether the furrows are lines of weathering or ice groovings. On crossing the shoulder and reaching the Cwm Graianog side, there are distinct striations which bear N.N.E. This

side of Carnedd-y-Filiast has an average slope of 46° to 50° , and is too steep to scale, except in a few places where advantage can be taken of fissures extending almost from top to bottom. At the head of the valley, on the south side, stands Moel Perfedd, from which stretches a great belt of serees. A descent into Cwm Graianog can be made from the col joining the two ridges which border it, but this requires some care owing to the sheets of rock from Carnedd-y-Filiast striking across the valley and ending in a series of abrupt drops, which, to say the least, are not at all inviting. A passage can be made a little to the left of the summit of Moel Perfedd, and from this point there is a fine mountain walk to the Llanberis slate quarries. Four lines of moraine debris run down Cwm Graianog, ending in a splendid terminal moraine, which stretches in a curve right across the mouth of the valley. The sweep of this can be readily seen from the opposite side of Nant Ffrancon. The rocks in this terminal moraine are piled up in a most confused manner to a height of many feet. Almost at the middle of the curve, the convex side of which is as usual directed outwards, stands a rock 9 feet by 6 feet and 6 feet high, perched on the top of others and seamed with quartz. Higher up the cwm, on the Moel Perfedd side, the water can be heard gurgling under the moraine matter, so that probably the finer debris has been washed away. This valley is unequalled by any in Snowdonia for the really perfect terminal moraine which extends across its mouth, and should certainly be visited by all interested in the geology of the district. All the cwms on this western side of Nant Ffrancon exhibit, more or less clearly, traces of having been ice worn, but particular reference will be made to only one other—Cwm Cywion. High up, on the south side of a little pool, are some finely rounded rocks with scorings as much as 7 inches in width. Contrasting with these are the fine markings on another rock close by, where 20 striations can be counted in a breadth of $2\frac{1}{2}$ inches, all heading towards N.E., in the same direction as the valley. These rounded and furrowed rocks reach up the valley almost to the foot of the cliffs of Y Garn, which forms its southern boundary.

Summing up briefly the evidences in Nant Ffrancon, and its tributary cwms, we find that it received ice from both sides, but by far the larger quantity came from the west. At the upper end of Lake Ogwen, above where Nant Ffrancon really commences, the glaciers from Cwm Tryfan and Cwm Lloer united and flowed W.S.W., turning west under Cwm Bochlywd, from which there came a reinforcement. Cwm Idwal sent out a vast mass of ice which certainly pushed its way far across the valley, even if it did not reach the other side. This tributary glacier flowed towards N.N.E., but a little further towards Bethesda the whole ice mass gradually swung round to N.N.W., as it adapted itself to the lie of the valley. From each cwm on the west side smaller glaciers flowed and joined the main one. Finally, below the mouth of Cwm Ceunant there was another swing round to the north. The traces of ice action are not confined to rounded and furrowed rocks, but embrace, likewise, travelled and perched blocks, although these are not usually of any great size, and the latter, in particular, not specially striking. Nant Ffrancon, and all the valleys bordering it, present most unmistakable signs of having once contained glaciers slowly but steadily making their way downwards, rounding, polishing, and scoring the rocks over which they passed, and carrying a great burden of moraine matter which was deposited as the climate became milder and the ice melted. Gradually these glaciers shrank, retreated to the higher recesses among the mountains, and finally disappeared under the influence of the increasing temperature. They have, however, left permanent monuments behind them, and by their aid we can recall the time when every valley was to some extent being eroded by the glaciers which held them all in an icy grip.