THE CORRIES OF THE CAIRNGORMS.

T. S. Westoll.

The charm and attraction of the Cairngorms is but little dependent on their form as mountains, for they have no claim to comparison with the serrated peaks of Arran or the Cuillins, being simply the remains of an obvious dissected composite set of high-level plateaux, the "High Plateau" and "Table-land of the Highlands" of Dr Bremner's account (*C.C.J.*, Vol. XV, p. 81). It is in the high corries that much of their power lies, and in the stark contrast between the "steep frowning glories" of their cliffs and the rolling slopes of the tops themselves. It is, in fact, a claim to interest and magnificence that is somewhat in the Chinese tradition of painting; what is not there gives form and impressiveness to the rest. Many things may draw one to the hills—the search for rare alpines, or the recapture of the "over 3,000 feet" exhilaration of high walks; the problems of geology, or the pitting of human strength and agility against the force of gravity and natural rock, snow, and ice in all their diversity; or the memory, always powerful, of the *genius loci* in his many weather-disguises, sometimes terrifying, but more often magnificent. No matter what the force of attraction may be, it is in and around the corries that most of one's satisfaction is found.

The term "corrie" is given to hollows in the upper parts of the hill-sides and mountain-sides of Scotland. Many of these corries are rather featureless depressions, often grassy or heathery, at the head-waters of streams. With these (except for a few points of interest) we have no present concern. But the great cliff-girt amphitheatres of the high hills, known as cirques, cwms, or karren, often containing wild and lonely lochs, are so spectacular that their origin has long been a matter of speculation. That they were excavated by the action of snow and ice is now a commonplace, so that it is perhaps rather interesting to note that the idea was first clearly stated by John Tyndall in 1862, and that his views did not gain wide acceptance until about fifty years ago. Indeed, even at the turn of the century, Bonney and others were still holding the view that the Alpine cirques had been eroded by running water; and Sir Archibald Geikie, in the 1901 edition of the "Scenery of Scotland," was inclined to give most credit to "small convergent torrents, aided, of course, by the powerful co-operation of the frosts that are so frequent and potent at these altitudes." A picturesque but improbable theory put forward slightly earlier invoked the action of falls and avalanches of snow and ice, which were supposed to have produced deep basins just as waterfalls may do.

All modern views of the origin of the rock-rimmed corries (cirques) are dependent upon observations on the relations of snow and ice to the hollows they occupy, and upon the fundamental fact that water expands on freezing and may then exert a very great disruptive force if in an enclosed space. But many different hypotheses have been suggested in attempts to elucidate the formation of cirques, and it may be of some interest to trace the development of thought on the matter. It will soon be clear that nothing final can be written on the subject. Scientific hypotheses are rather like climbing boots and ice-axes. They help one to reach otherwise unattainable objectives and so to see new perspectives of familiar ground and to get a glimpse of fresh territory; but boots that don't fit or are not watertight are often worse than none at all, and there is no future in the uncritical persistence, however enthusiastic, in the use of a flawed ice-axe. Conversely, of course, considerate use of inferior equipment may enable one, with care and intelligence, to explore quite difficult territory, though for a complete command of his field he will need better technique and improved equipment.

To begin with, the position and orientation of the corries, in the Cairngorms as elsewhere, is in full agreement with the basic notion that they were produced by the action of snow and ice. I have made a rather rough analysis of the rock-corries in the area covered by the inch-to-a-mile special O.S. map of the Cairngorms, to bring out the approximate average height of each rim and floor, the diameter, and the direction towards which each corrie faces. Taking every cirque into consideration, except the peculiar and aberrant Coire Bogha-cloiche, the following table expresses the main conclusions :—

Direction.	No.	Average Altitude of Rim.			Average Altitude of Floor.			Diameter.	
		Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Greatest.	Mean.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Miles.	Miles.
N.-N.E.	11	4,100	2,450	3,500	3,250	1,900	2,700	1·1	0·63
N.E.-E.	8	4,200	3,400	3,750	3,300	2,600	3,020	0·7	0·52
E.-S.E.	4	4,000	3,200	3,700	3,250	2,400	2,800	0·7	0·60
S.E.-S.*	2	4,200	4,000	4,100	3,300	3,000	3,150	0·7	0·63
S.-S.W.	0	...	...	...	...	...	...	...	...
S.W.-W.	0	...	...	...	...	...	...	...	...
W.-N.W.	0	...	...	...	...	...	...	...	...
N.W.-N.	11	3,950	3,100	3,450	3,200	2,500	2,800	1·0	0·58
* This includes Coire Sputan Dearg, which is also somewhat atypical. Without it the line would read :									
S.E.-S.	1	4,200	4,200	4,200	3,300	3,300	3,300	0·55	0·55

From this table it is clear that the greatest number of cirques face generally northwards, that is, between N.W. and E., and the largest face between N.W. and N.E.; snow-fields or ice-fields lying on slopes facing in these directions would be most sheltered from the sun, while those facing S. and W. would be exposed to the sun at the warmest time of day. Moreover, the heights of the rims and floors are significant. The highest figures for cirques facing in almost any direction are not very different, they obviously depend only on the height of the mountains; but the lowest figures in the different groups (indicating the lowest altitudes affected by the cirque-forming processes) do seem to show an interesting change, which is set out separately below. The above table includes figures for Coire Madagan Mòr near Loch an t' Seilich, which is at an unusually low altitude and outside the main massif. The figures in brackets below exclude this cirque and also Coire Sputan Dearg and those of Lochnagar.

Direction.	Lowest Average Altitude of Rim.	Lowest Approximate Altitude of Floor.
N.W.–N.	3,100	2,500
N.–N.E.	2,450 (3,000)	1,900 (2,000)
N.E.–E.	3,400	2,600
E.–S.E.	3,200	2,400
S.E.–S.	4,000 (4,200)	3,000 (3,300)
S.–N.W.	?>4,000	?>4,000

These figures seem to show that cirque formation could go on at distinctly lower levels in the Cairngorms on slopes facing N.–N.E. than on any others, and that the more a slope faces S. and S.W. the higher it must be before true cirque formation could have taken place. It is perfectly true, however, that the direction of exposure in relation to the solar radiation is not itself a complete explanation, for it fails to take into account the influence of differential precipitation of snow. Some American workers believe that the main snow-banks tend to accumulate on the slopes to leeward of the dominant snow-bearing wind. In the Eastern Grampians an interesting problem is presented by the extremely fine series of corries facing S.W. over Glen Clova, from Loch Wharral to Ben Reid, and also by the head of the Canness Glen. All these face S. or S.W., *towards* the now prevalent winds, and are bitten out of plateaux at about 2,600 feet, their floors cutting down to about 2,000 feet or even lower. They may owe their formation to eddies set up by the passage of dominant S.W. winds over Glen Clova, causing heavy precipitation on hill-slopes that might otherwise have been swept clean, but this is only one of many possibilities. In any case it is dangerous to argue from present climatic conditions, because some of the finest British corries are found in the Cuillins, where they cut down deeply even on the S.W. faces. However, a general refrigeration of climatic conditions would still allow this to be explained on the basis of dominant S.W. precipitation-winds.

Broadly speaking, one may recognise three phases in the historical development of the idea of snow-and-ice excavation of corries. In the first phase (up to *c*. 1890) various tentative hypotheses were suggested, and most weight was given to evidence of intense weathering at the margins of snow-fields. One can study this process quite well in spring and early summer at the edges of the snow-wreath that persists, often well into August, in the broad hollow S.E. of the S. top of Beinn a'Bhùird at about 3,500 feet. The daily melt-water here runs into cracks in the rock at the margins, and the usual nightly freezing slowly but surely breaks down the rock into a friable sand, which can be shifted during rainfall or by wind (often to the discomfort of the observer). Year by year the snow-wreath digs for itself a deeper and deeper hollow; the process has been called nivation and is naturally most effective where the snow lies longest. It was on the basis of such observations that Helland and, later, E. Richter, both of whom studied Norwegian cirques, invoked the intensive weathering at the margin of the *névé* (permanent snow-field) as the important agent in forming the cliffs of the amphitheatre, though both gave credit to the ice (into which the *névé* passes downward if thick enough) for at least part of the excavation of the bowl. There can be no doubt that such marginal sapping is a powerful factor in rock-weathering under snow conditions, but there are many points which cannot readily be explained on this simple theory.

The second phase was marked by the recognition of the importance of the *bergschrund* or *rimaye*, a gaping crevasse usually found near and parallel to the upper margins of a glacier or *névé* occupying a cirque in alpine conditions. Penck, the great Alpine geologist, thought that the main function of the bergschrund was to collect and remove to the base of the glacier the debris removed by sapping along the upper margin of the steep *névé* above the glacier; this material would then become embedded in the sole of the

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glacier and help to rasp away the floor of the cirque. It is, however, mainly due to American geologists and physiographers (particularly to W. D. Johnson and F. E. Matthes) that an important function of the bergschrund has come to be widely recognised. Johnson, in the eighties, allowed himself to be lowered into the bergschrund of the Mount Lyell glacier. He found a rock floor and a back wall of rock rising very steeply towards the rim of the cirque. This steep wall was much shattered, and some of the loose blocks had been wedged forward by frost action so that they were partly or wholly embedded in the front wall of ice and snow. In spring and summer the bergschrund is the scene of intense weathering, for melt-waters run over the exposed rock surfaces and usually freeze at night. This explains the shattering. Each winter the bergschrund is closed by snow and ice; the loose blocks are thus cemented to the glacier, and will be removed as the ice slowly moves away under gravity. The process of weathering is probably rapid, and the recession of the head-walls of the cirque was thus explained. A bergschrund will open again each spring, and thus moves gradually a little farther towards the original position of the head-wall. A sharply marked line of differential erosion at the base of the head-wall cliffs of an empty cirque, the so-called *schrund-linie*, is supposed on this theory to mark the level of the base of the bergschrund at the final stage. It is well shown in the accompanying photograph of Lochnagar. Here, then, was a theory that seemed to explain nearly all the known properties of cirques. But particularly within the last twenty-five years new information has been available, and this has led to modifications of the bergschrund theory.

In the third phase the bergschrund theory has been tested in a number of regions, and several observers have found it inadequate to explain all the known facts. One of the most interesting points emerged from the extraordinary mountain warfare in the Eastern Alps during the earlier "Great War." Sappers on several occasions drove tunnels through glaciers in cirques, and Klebelsberg has noted the absence of melt-waters from some at least of the bergschrund-crevasses. In the Antarctic (Priestley), the high Andes (Bowman), and elsewhere observers have noted that bergschrunds may be completely absent from some cirque *névés*. Recently much importance has been attached to the fact (emphasised also by Penck in 1905) that many cirques are immensely deep, while the bergschrund is usually assumed to be rather shallow—a figure of 150 feet is usually quoted, though I am not aware of any large body of data. Quite recently W. V. Lewis has given a short critical review of much of this recent literature and has propounded a new theory. He sets out some important points which require explanation.

1. The head-walls of several British corries show shattering right to the base, at least for parts of their circumference, and Lewis says that the depth of this shattering exceeds that of the deepest bergschrund. Sometimes, too, glacial smoothing may be found in the same corries well up the head-walls.
2. The head-wall frequently meets the glacially smoothed floor at a comparatively sharp angle, and near this point glacially smoothed knobs of rock often project through the screes at the bases of the head-walls.

To explain these points Lewis refers to observations by Priestley and by Fleming in the Antarctic and by himself in Iceland, showing that much melting may occur, even with air temperatures below 0° C., where the snow or ice is in contact with dark-coloured rocks which readily absorb radiation. This melt-water, with summer rain-water and the melted winter snows from the upper slopes, is said to pass largely down the back-wall of the cirque without traversing the glacier, or otherwise to pass largely down the bergschrund-crevasses. These melt-waters, he suggests, afford a mechanism for wetting the walls of the cirque at and below the base of the bergschrund, and thus, by alternate freezing and thawing, for deepening the corrie in the immediate neighbourhood of the head-wall, and would thus encourage the formation of an overdeepened floor meeting the head-wall at an angle.

This hypothesis is clearly a valuable one, but before it can be accepted as a sound and dependable aid to our further exploration it seems necessary that we should know far more than we do at present of two things—the thickness of snow and ice actually existing in present-day high-level cirques, and the variation in depth to be found in a large number of bergschrund-crevasses. It is in Alpine or higher-level conditions, not in the glacier-stripped Cairngorms or other British mountains, that the testing ground is to be found.

An important point emphasised by Lewis is that in regions of complex geology the cirque erosion may be controlled to a considerable degree by the distribution of hard and soft rocks. In the Cairngorms proper and on Lochnagar there is no reason to suppose that diversity of rock types is very important in this respect, but one additional factor of interest to climbers is very significant. The granites of these mountains are well jointed. There are usually two main sets of nearly vertical joints crossing nearly at right angles, and irregularly developed horizontal joints. These are collectively responsible for the effect of massive rough masonry so frequently found in the corrie cliffs. But a set of oblique joints, at about 45° to the horizontal, is frequently found in addition. Where these joints dip in the same direction as hill-slopes, erosion by frost action along joint planes is facilitated, and bare slabby surfaces result. Excellent examples are to be seen on the Devil's Point facing the Dee, and as a factor in corrie development in Coire na Ciche on Beinn a' Bhùird.

To some people, but to none who has taken the trouble to learn these mountains, the Cairngorms are rather dull because they lack serrated peaks. From the point of view of the geologist this is simply because the corrie glaciers did not stay long enough in our district to eat their way still farther into the margins of the plateaux. As they are, the Cairngorms are a fine example of what an American observer has aptly called "biscuit-board topography"; the corries are bitten out of the plateau region as one might remove pieces from the edge of a sheet of dough with a circular biscuit-cutter. But where corries, by headward plucking, encroach more and more even on to a flat plateau, some of them will almost completely reduce intervening regions. Then the walls of two corries may meet in a jagged arête complete with gendarmes, clefts, and all kinds of mountaineering improvements; three or more, encroaching from different directions, may produce triangular or quadrangular shaped peaks, growing ever steeper upwards because of the shape of the corrie walls. These, after their best-known example, are called Matterhorn peaks. The nearest approaches to this stage of development in the Cairngorms are on the Cairntoul-Braeriach mass. But what the rock-climber may deplore as the untimely wasting of the corrie glaciers is at least responsible for leaving some of the finest high-level walking that one could desire along the edges of the corries.

Useful Literature.

Two most valuable works on the glaciation and geology of the Cairngorms, by Dr Alexander Bremner:—

"The Glaciation of the Cairngorms," *The Deeside Field*, No. 4, 1929.

"The Story of the Cairngorms," *C.C.J.*, Vol. XV., pp. 81-90, 1940.

Two works which give a good survey of the history of investigation with full references:—

W. H. Hobbs, "Characteristics of Existing Glaciers." Macmillan, New York, 1911.

W. V. Lewis, "A Melt-water Hypothesis of Cirque Formation," *Geol. Mag.*, Vol. LXXV., pp. 249-265, 1938.

A magnificently illustrated book, of which Chapters VIII. and IX. deal with glaciation:—

A. K. Lobeck, "Geomorphology." McGraw-Hill, New York and London, 1939.