The Cuillin

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Highlights

The Cuillin is an outstanding area for glacial geomorphology. It is particularly noted for landforms of mountain glacier erosion, demonstrating an assemblage of classic features unmatched elsewhere in Britain. This interest is also complemented by an excellent range of moraine types formed by corrie and icefield glaciers of the Loch Lomond Readvance.

Introduction

The Cuillin site in southern Skye includes the main ridge of the Black Cuillin, extending *c.* 13 km from Gars-bheinn [NG 468 187] in the south to Sgùrr nan Gillean [NG 472 253] in the north, the slopes leading down to Glen Brittle to the west and the Bealach a'Mhàim to the north, the central trough of Loch Coruisk [NG 485 205], and to the east, Glen Sligachan (Figure 11.2)A. The Cuillin are arguably the most spectacular mountain range in Scotland. Taking the form of a semicircle concave to the south-east, the mountains rise abruptly from sea level to a maximum altitude of 993 m OD in Sgùrr Alasdair [NG 451 208]. Bitten into on all sides by corries, the central ridge to the mountains never drops below 750 m OD and is typically sharp and narrow. The individual peaks, overlooking comes on several sides, have the form of triangular pyramids and pinnacles and the spectacular glacial scenery is enhanced by the dominance of bare rock at the ground surface, there being little glacial drift within the area of the mountains (Figure 11.3). The Cuillin are of particular geomorphological interest as an outstanding example of the effects of glacial erosion, at both large and small scales, on a mountain massif (Forbes, 1846; Harker, 1901; Lewis, 1938, 1947; Haynes, 1968; Dale, 1981). They also contain evidence for two phases of glaciation during the Late Devensian: the main ice-sheet and Loch Lomond Readvance (Harker, 1901; Sissons, 1977c; Walther, 1987; Walker *et al* , 1988; Ballantyne, 1989a; Ballantyne and Benn, 1991). The lower slopes and valleys are also important for depositional landforms associated with the Loch Lomond Readvance (Donner and West, 1955; Ballantyne, 1989a; Benn, 1991).

Description

The Cuillin occur on the western side of the Skye Tertiary central igneous complex (Richey, 1961; Emeleus, 1983). The principal rock in this part of the complex is a layered gabbro and the semicircular nature of the gabbro outcrop defines the mountain range. The layering dips steeply inwards at right angles to the trend of the hills, resulting in the steep western mountain front. The gabbro is cut by many minor intrusions including cone sheets and dykes of dolerite.

The intrusions of the igneous complex reached to a shallow depth in the Earth's crust and were unroofed and eroded while igneous activity continued, as is shown by the presence of clasts derived from the intrusive rocks contained in fluvial sediments interbedded with basaltic lavas to the west. By the time of cessation of volcanic activity the mountain mass had dimensions approximately similar to those of today, although it may be anticipated that the lavas abutted against the lower flanks of the hills and the major valleys had yet to be eroded.

Extensive erosion of the western Highlands and the Inner Hebrides during the Tertiary may be inferred from the relationship of the Tertiary dykes to the valley system, the disrupted nature of the once continuous lava flows and the distribution of erosion surfaces (Godard, 1965; George, 1966; Sissons, 1967a). Thus at the onset of Pleistocene glaciation the broad outlines of the topography were unlikely to have been significantly different from today, although without those features of detail, such as corries, over-deepened valleys and stripped and polished bedrock surfaces, that can be ascribed to glacial action.

Within the area of the Cuillin there is evidence for only two glacial phases, both during the Late Devensian: one during the period of the last ice-sheet glaciation and the other during the Loch Lomond Readvance. However, it is only reasonable, given the evidence from surrounding areas in the British Isles (Bowen *et al.,* 1986), to presume that the hills have been repeatedly glaciated, perhaps from as early as 2.4 Ma BP (Shackleton *et al.,* 1984). The features of glacial erosion, which are so outstandingly developed in the Cuillin, can therefore be anticipated to have developed over a very long period.

The major features of glacial erosion centre on the main Cuillin ridge which has the form of a semicircular arete produced by the intersection of multiple corries (Figure 11.2). The floors of the corries display extensive areas of ice-moulded bedrock and rock steps, while taluses occur below the rock headwalls. At the centre of the massif there is a spectacular glacial trough with extensive areas of ice-scoured bedrock and the basin occupied by Loch Coruisk.

That the area showed evidence of glaciation was recognized at an early stage after the introduction of the glacial theory (Forbes, 1846), but despite occasional references (Geikie, 1863a, 1984; Bonney, 1871) it was not until the turn of the century that the glacial deposits and the effects of glacial erosion were discussed in detail (Harker, 1899a, 1899b, 1901; Clough and Harker, 1904). Harker (1901), in one of the first detailed systematic papers on glacial erosion, noted that the form of the valleys both in cross-profile and long profile was a direct result of glaciation. He pointed out that many of the corries 'hang' above the main valley and that this could be explained by glacial overdeepening of the main valley, or the erosion of the valley sides. Harker attributed variations in the long profiles of the corries and the valleys, including valley steps as well as rock basins, to the tendency of ice to exaggerate any pre-existing marked inequalities in the profile: increased erosion under those parts of a glacier where the ice was thicker was considered the mechanism to explain these features. The form of the ridges and the summits was attributed to the backward erosion of the corrie heads which came close to intersecting, leaving only narrow aretes and triangular, slightly concave-faced pyramids. An asymmetry was also apparent to Harker in the ridges of the Cuillin, with the northern slopes typically being steeper than the southern. A similar asymmetry was noted in the distribution of the corries, in particular among those towards the edges of the mountains, with the majority facing the north to north-east sector. These asymmetries Harker ascribed to periods of partial glaciation when the distribution of glaciers and their activity was influenced by their exposure (or lack of it) to the Sun.

In detail, Harker also noted the lack of discrimination by glacial erosion in the exploitation of small geological features in those areas where erosion was intense, the surface of dykes being planed smooth with the surrounding bedrock. This, as was evidenced by the mountain summits, was not typical of subaerial erosion. Harker thought, however, that the mechanism for the erosion of the dykes was distinct from that of the gabbro, for he recorded that there was a disproportionate amount of dyke rock in the cobble to boulder-sized material in the glacial deposits. He concluded that the dykes had been eroded by plucking and tearing away, whereas the gabbro had been ground down by debris lodged in the sole of the ice. It is of note that almost all of these observations and explanations on glacial erosion subsequently came to be accepted in standard texts (Flint, 1957; Sissons, 1967a; Andrews, 1975; Embleton and King, 1975a; Sugden and John, 1976).

W. V. Lewis also made significant contributions to the theory of glacial erosion, drawing on field examples from the Cuillin. He described the morphology of several of the Cuillin corries, noting the sharp contrast between the shattered headwalls and the ice-moulded floors, and such observations in part laid the foundations for his meltwater theory of corrie formation (Lewis, 1938). He also quoted notable examples of rock steps and roches moutonnées in support of his theories of glacial valley erosion (Lewis, 1947).

The morphology of the comes in the Cuillin has subsequently been investigated as a part of a larger study by Haynes (1968, 1969), who concluded that a large proportion of the long profiles of the corries did not fit the idealized mathematical shapes to which many other corries on the Scottish mainland closely approximated. This she attributed to the complex rock structure of the Cuillin Hills.

Dale (1981) studied the rock walls that comprise the corries and considered their development with respect to similar features in an east–west transect across the Scottish Highlands. She identified 28 individual rock walls in the Cuillin corries and demonstrated that the frequency of occurrence was among the highest measured. The size of the rock walls, as determined by both amplitude and area, was the greatest in the region studied; the average altitude of the base of the rock walls was the lowest, but this figure disguised two distinct altitudes of formation, one between 607 m and 649 m OD and the other between 470 m and 535 m OD. There was a strong northward component in the orientation of the rock walls, and even in corries that faced the west or southwest, the rock walls were best developed on their north- to north-west-facing sides. This conclusion mirrors the observations of Harker (1901) on the asymmetry of the ridges in the Cuillin Hills. Dale (1981) attributed the exceptional development of rock walls in the Cuillin to a combination of available relief, glacial history (the lack of inundation by the mainland ice-sheet) and by the mountains being particularly susceptible to glacier initiation, leading to relatively long periods of local glaciation.

Drawing on the then unpublished work of Harker, Geikie (1894) first reported that during the last glacial maximum the hills of Skye nurtured an independent ice-cap which had sufficient strength to prevent the main Scottish ice-sheet from overriding them. Harker (1901) and Clough and Harker (1904) amplified the ice-flow pattern, tracing the direction of flow of the coalescent ice-sheet and ice-cap both by the orientation of striae and by one of the earliest quantitive analyses of the erratic content of glacial drift. By such stone counts Harker (1901) traced the line of contact in Glen Sligachan between ice originating from the (granitic) Red Hills and ice from the (gabbroic) Cuillin Hills, and noted how the combined northwards ice flow was deflected to the west and then southwest by the mainland ice-sheet.

Subsequent to the period of ice-sheet glaciation, Harker (1901) recognized a distinct phase of local glaciation in which local come and valley glaciers flowed outwards from the hills. The impressive end moraine at the mouth of Coir' a'Ghrunnda [NG 445 184] (Forbes, 1846) was considered to have been formed at this time. Various other authors have agreed on the existence of later glaciation, but its extent and age have remained in dispute. Charlesworth (1956) reconstructed a small ice-field over the mountains of southern Skye, with the corries on the west of the Cuillin feeding an outlet glacier in Glen Brittle. He correlated these glaciers with his Stage M glaciation (considered to be a readvance) and depicted various retreat stages. Anderson and Dunham (1966) argued that what they termed a late-glacial readvance' extended well beyond the limits of the hills.

A more complex scheme was proposed by Birks (1973) who interpreted an extensive local glaciation prior to 12,000 BP, followed by a phase of corrie glaciation in the Cuillin during the Loch Lomond Readvance. Sissons (1977c) also inferred limited glaciation during the Loch Lomond Readvance, identifying seven corrie and one valley (Coruisk) glacier in the Cuillin. This reconstruction was not accepted by Walther (1984, 1987) who envisaged a much greater extent of ice, reaching to north of Sligachan. He proposed certain retreat stages with a final glacial episode in the corries during the early Holocene, when block moraines were formed.

The most recent reconstruction (Walker *et al.,* 1988; Ballantyne, 1989a) favoured the development of a large ice-cap over the southern mountains of Skye during the Loch Lomond Readvance with contemporaneous corrie glaciers in the western Cuillin (Figure 11.2B). These last small glaciers were similar to those identified by Sissons (1977c).

The detailed geomorphological evidence for this reconstruction is outlined in Ballantyne (1989a). Ballantyne (1989a) also reconstructed the three-dimensional form of the Loch Lomond Readvance glaciers on Skye and derived a number of palaeoclimatic inferences. The area-weighted mean equilibrium line altitude of the glaciers conforms with the overall pattern of an eastwards rise in equilibrium line altitude reconstructed for the Loch Lomond Readvance glaciers in the Inner Hebrides and Western Highlands (Sissons, 1979d, 1980b). Local variations in the reconstructed equilibrium line altitude were inferred to reflect precipitation patterns associated with southerly winds (see Sissons, 1979d, 1980b). Mean July sea-level temperature for the stadial was estimated to be about 6°C. A notable feature of Ballantyne's glacier reconstruction is the north–south asymmetry of the Cuillin ice-field. Although the southern outlet glaciers descended steeply to Loch Scavaig, the main outlets to the north in Glen Varragill and Glen Sligachan were relatively more extensive and had relatively lower surface gradients. Such asymmetry could have reflected, in part, variations in the respective glacier mass budgets, but an intriguing possibility explored by Ballantyne is that it relates to differences in the nature of the beds over which the former glaciers flowed. The glaciers on the south side of the ice-field moved over ice-scoured bedrock and their reconstructed surface profiles are typical of those predicted for rigid beds from glacier physics theory (cf. Paterson, 1981). The northern glaciers, however, were associated with extensive deposits of fluted and hummocky moraine which are believed to have formed subglacially (see below), in effect forming a deformable glacier bed. Under such conditions, the predicted ice surface profile is lower than for the rigid bed case (cf. Boulton and Jones, 1979; Nesje and Sejrup, 1988).

Particularly good examples of depositional landforms associated with the Loch Lomond Readvance glaciers include the end and lateral moraines below Coir' a'Ghrunnda in Glen Brittle and the hummocky and fluted moraine at Sligachan (Figure 11.2A) (see Donner and West, 1955; Ballantyne, 1989a; Benn, 1991; Benn *et al,* 1992). Berm (1989b) discussed aspects of the asymmetry of the end moraines in Coire na Banachdich [NG 430 218] and Coire a'Ghread-haidh [NG 430 234]. The origins of hummocky moraine are controversial and it seems probable that several landform types exist (see Coire a'Cheud-chnoic). Ballantyne (1989a) noted that large areas of moraine in Glen Varragill were fluted and streamlined, reflecting subglacial deformation comparable to that described from Coire a'Cheud-chnoic (Hodgson, 1982, 1987) and elsewhere in Torridon (Hodgson, 1986). As in the case of Coire a'Cheud-chnoic, the Sligachan and Glen Varragill areas provide potentially important evidence for further investigation of the genesis of hummocky moraine, and the different landform types, together with comparative studies of other sites and related landform assemblages, may allow not only the possibility of recognizing different styles of glaciation and deglaciation (see Eyles, 1979, 1983; Sharp, 1985; Evans, 1989), but also inputs to, and the testing of, theoretical models of glacier behaviour on deformable beds (cf. Boulton and Jones, 1979; Alley *et al.,* 1986; Boulton and Hindmarsh, 1987).

Small-scale erosional landforms are also spectacularly developed and owe their final detail of form to the Loch Lomond Readvance glaciers. Notable examples are in the corries above Glen Brittle (e.g. Coire Lagan — [NG 444 209]) and around Loch Coruisk, where the ice-moulded and striated bedrock and roches moutonnees are among the best examples of their kind in Britain (Figure 11.4). These landforms, some described by Lewis (1947) and Haynes (1969), have significant potential for detailed studies of subglacial erosional processes, as in the types of investigation reported from Snowdonia in North Wales (Gray, 1982b; Gray and Lowe, 1982; Sharp *et al.,* 1989a).

The nature of the very steep and sharp ridges and summits of the Cuillin has precluded the extensive development of periglacial features (Ballantyne, 1991b). Harker (1899b, 1901) and Clough and Harker (1904) noted the extent of rock shattering on the summit areas and the spectacular development of scree slopes, the formation of which was considered to have commenced during the period of local glaciation. Harker (1899b, 1901) also commented on the contrast in the nature of the rock surfaces of the intensely glaciated areas and on the summits, and Ballantyne (1989a) noted that this contrast relates to the upper surface of the Loch Lomond Readvance glaciers. Ballantyne (1989a) used periglacial trimlines to delimit, in part, the limits of Loch Lomond Readvance glaciers. The assignment of the local glaciation to the Loch Lomond Readvance also implies that the accumulation of the scree in the corries must have occurred in the Holocene. Aspects of scree-slope development were investigated by Statham (1976a), who concluded that the debris movement and morphological characteristics accorded with a rock-fall model of genesis. Modification of some of the taluses by snow avalanches may also have occurred (Benn, 1990). The Holocene talus accumulations may be the most outstanding features of their type in Britain (Ballantyne, 1991b).

Interpretation

The Cuillin is an area of spectacular scenery which owes its striking impact to the outstanding development of features of glacial erosion. It represents probably the single most intensive area of mountain glacier erosion in Britain. Within Scotland the Cuillin represent the classic development of corrie, arete, rock step, ice-moulded bedrock and glaciated-valley landforms typical of the zone of high-intensity glacial erosion of western Scotland (see Chapter 2), and in this respect rank ahead of even such areas as An Teallach, Rum and the mountains of North Arran, where excellent features of glacial erosion are also present. The intensity of erosion of the Cuillin contrasts markedly with that of the mountains in the central and eastern Highlands, such as the Cairngorms and Lochnagar, where more extensive elements of the pre-glacial landscape have survived and the dominant landform pattern is the equally distinctive one of selective glacial erosion. Elsewhere in Britain the area most comparable to the Cuillin is North Wales, where glacial erosion has left a strong imprint on the landscape (see Campbell and Bowen, 1989). Nevertheless, the Cuillin remain pre-eminent, particularly for the fine detail, compactness and overall impact of the geomorphology. Although the Lake District has fine landforms of glacial erosion, many classic in their own right, the overall intensity of glacial erosion there has been less.

Historically, the Cuillin have played a significant role in the study of glacial erosion, beginning with the work of Forbes (1846) and continued through that of Harker (1901), and Lewis (1938, 1947) to the recent investigations of Haynes (1968, 1969) and Dale (1981). These studies, which have provided textbook examples and laid the foundation for modern developments, have been essentially complemented by the important historical work on glacial erosion in North Wales (see Campbell and Bowen, 1989).

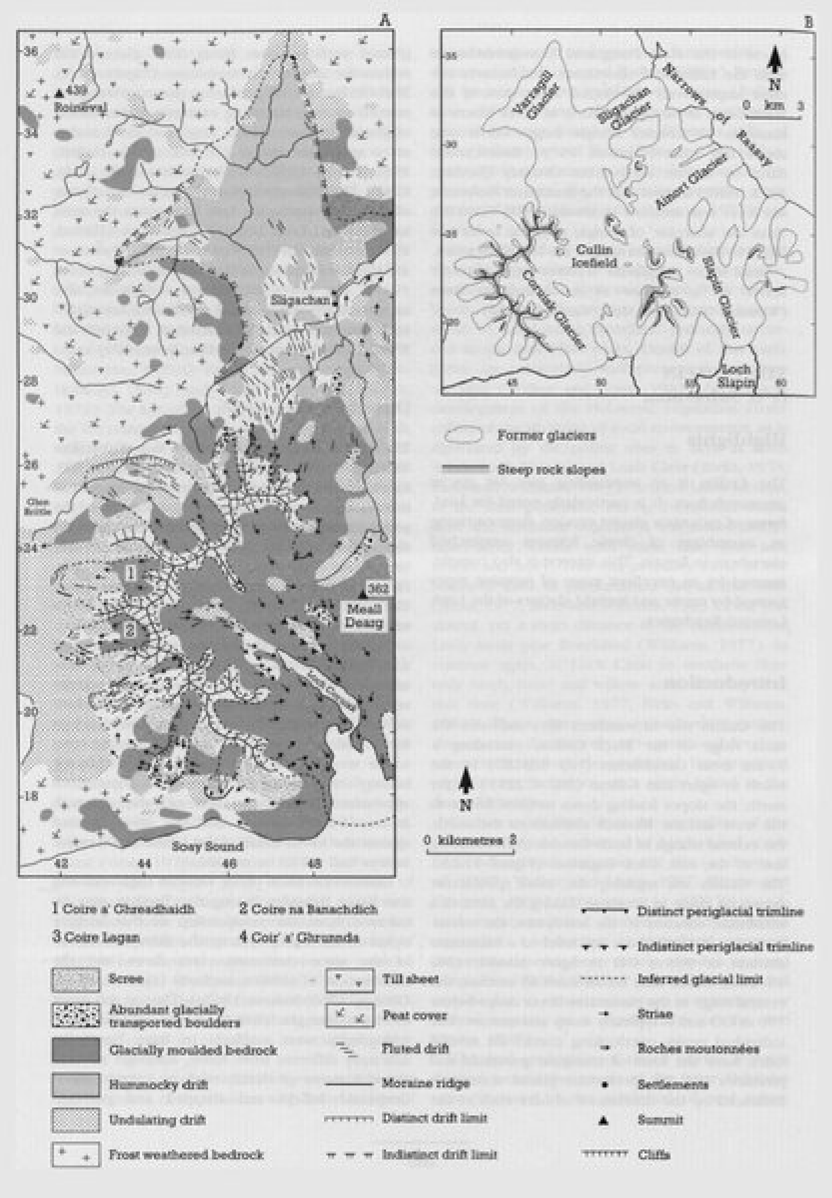
The Cuillin are also important in the evidence they provide for the development of local glaciers during the Loch Lomond Stadial. This evidence has allowed the reconstruction of a number of corrie glaciers and a central mountain ice-field, together with the associated palaeo- climatic controls. This has provided important insights into climatic conditions during the stadial and has raised questions about the nature of the glacier dynamics which have potentially wide-ranging implications (Ballantyne, 1989a): first, deformable-bed models of glacier dynamics may apply to relatively small glaciers and ice-caps as well as to large ice-sheets, and second, where such conditions pertain, they provide additional constraints on palaeoclimatic reconstructions derived from glacier–climate relationships.

Finally, the excellent assemblage of depositional landforms, particularly the fluted and hummocky moraine, has significant potential for studies of glacial sedimentation and styles of deglaciation (cf. Benn *et al.*1992), for example in comparison with the assemblages of hummocky moraine types at Coire a'Cheud-chnoic, the Cairngorms and Loch Skene.

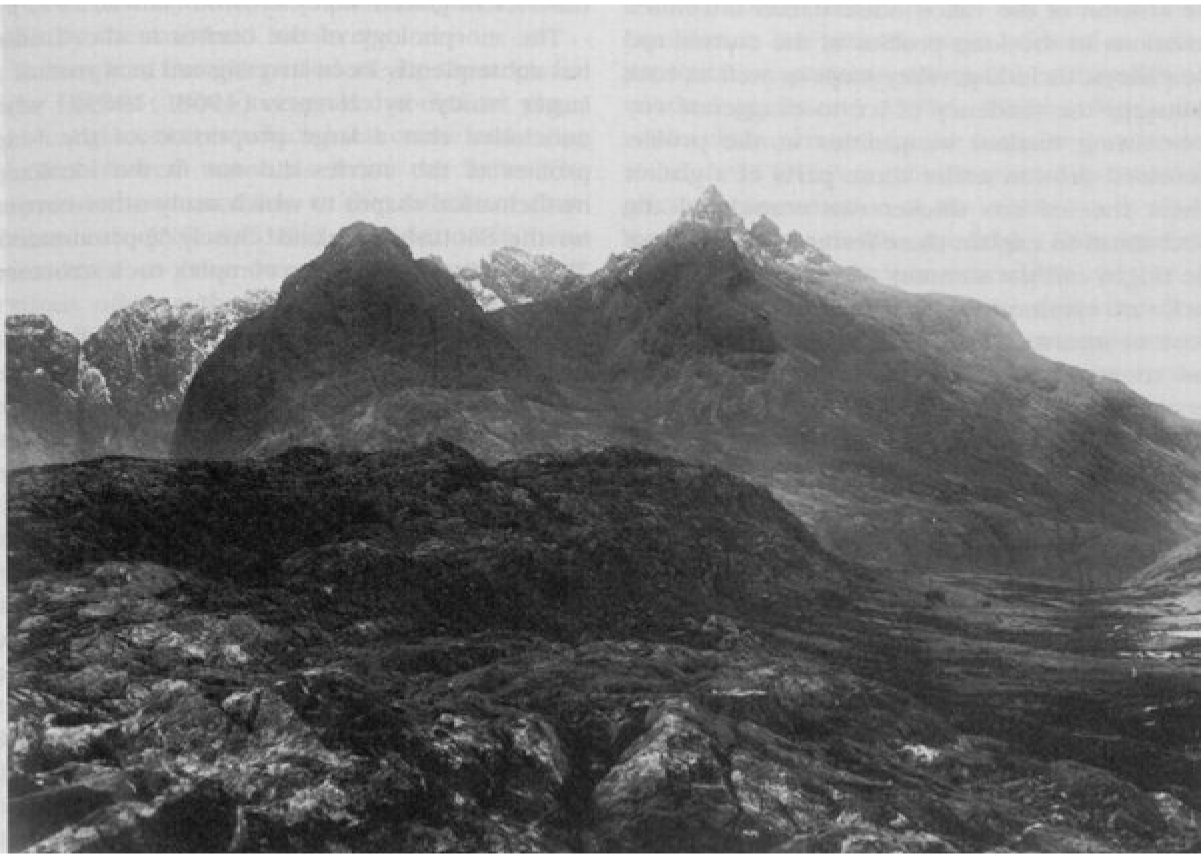
Conclusion

The Cuillin is an area of outstanding importance for glacial geomorphology. It is a classic locality for landforms of glacial erosion and has played an important part in the development of ideas in this field. The features of erosion, many among the best of their kind in Britain, are notable in spanning a range of scales, from corries and aretes to ice-moulded and striated bedrock surfaces. The area is also of great interest for a fine assemblage of morainic landforms produced by Loch Lomond Readvance glaciers (approximately 11,000–10,000 years ago).

References



(Figure 11.2) (A) Principal glacial features of the Cuillin. (B) Reconstructed Loch Lomond Readvance glaciers in central Skye (from Ballantyne, 1989a).



(Figure 11.3) Landforms of glacial and periglacial erosion are strikingly developed in the Cuillin of Skye. The serrated aspect of the main Cuillin ridge reflects intense periglacial weathering, whereas the lower slopes are heavily ice-scoured. (British Geological Survey photograph B168.)

(Figure 11.4) Detail of ice-moulded bedrock near Loch Coruisk showing glacially abraded and smoothed stoss slopes and localized joint-block removal. (Photo: D. G. Sutherland.)