Geo Factsheet

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Glaciation in Scotland:

A Case Study of Ice Erosion in the Cairngorms

Introduction

During the last 2.4 million years, Scotland experienced a succession of cooler and warmer periods - glacials and interglacials. Duly the coldest periods ice was able to accumulate in the form of ice sheets and valley glaciers. Their movement and that of the meltwater streams and rivers associated with them has had a significant impact in defining the topography of the Scottish landscape as it exists today.

Landscape of differential ice erosion

The west side of Scotland has suffered much deeper erosion and glacial scouring than the east and the effects are clearly seen in the landscape contrasts *(see Fig. 1)*. This is largely as a result of precipitation which is greatest towards the west. In eastern Scotland, over the Cairngorm and Monadhliath plateau, the ice was much thinner than in the west as snowfall was less.

The Cairngorms – setting the context

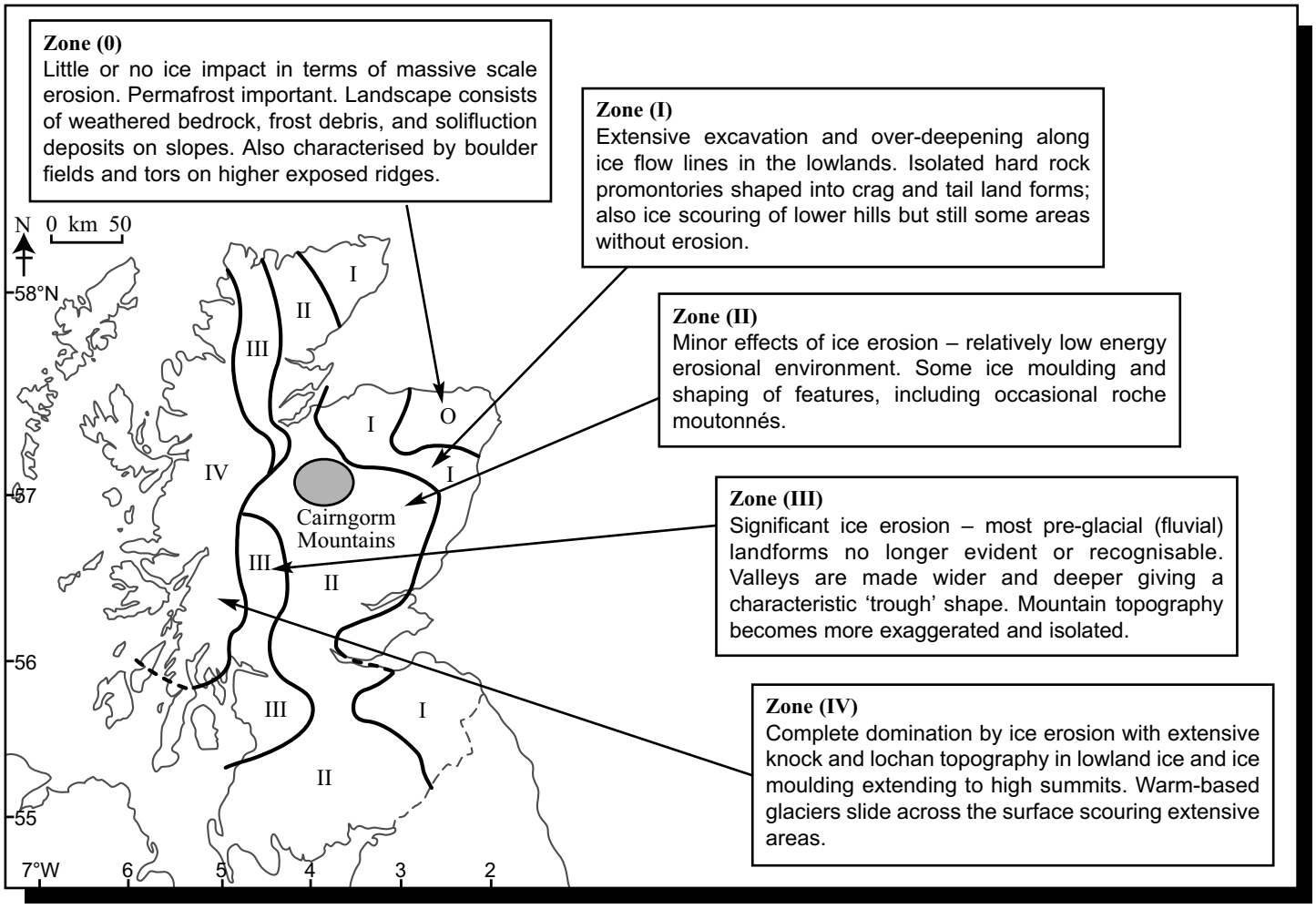
The Cairngorms is a broad granite plateau in the north eastern central part of Scotland *(see Fig. 1)*. It is the largest area of high ground in Britain, and with a severe climate, the mountains have strong 'arctic' character.

The Cairngorm granite began life over 400 million years ago when rocks melted deep within the earth's crust. Since then, weathering and erosion have removed the overlying rocks to reveal the granite mass (batholith)

The central mountain area is generally between 1070m - 1220m, with some summits rising higher than this. The ancient character of the plateau is evident in several aspects of their detailed morphology - tors of decomposed granite, sheet jointing in the granite and shallow stream valleys.

The Cairngorms were completely covered by ice during the last glaciation. This, and earlier glaciations have produced spectacular and unique glacial scenery.

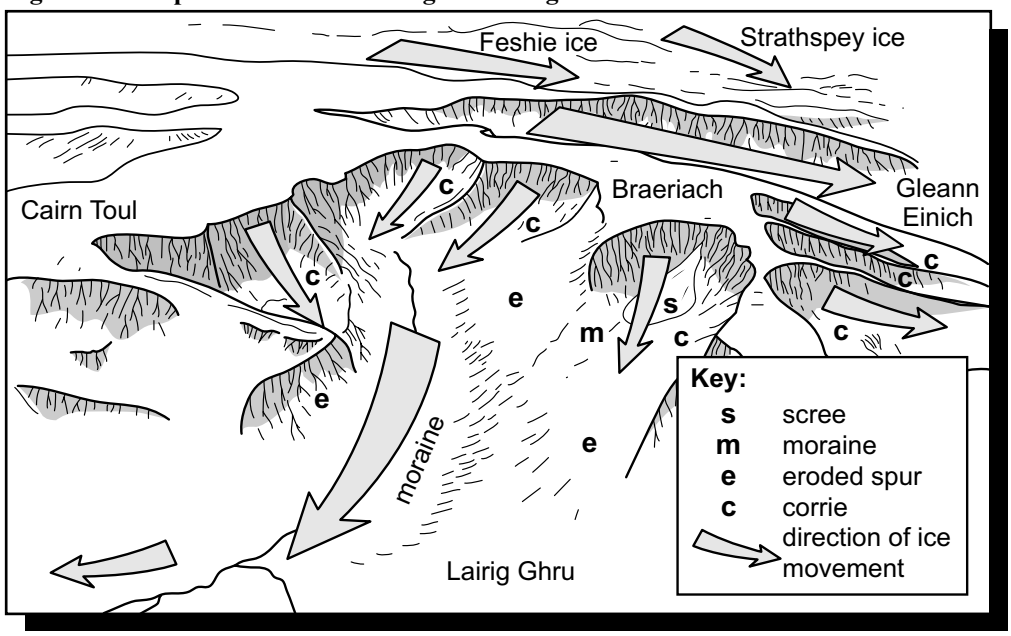
Fig. 1 Ice erosion in Scotland.



Landforms of glacial erosion

In the Cairngorms, glacial erosion has been selective and linear because it is most obvious in valley locations. In the valleys, the ice was of sufficient thickness to induce pressure melting at the base of the glaciers. Sliding was possible and abrasion, plucking and other processes of glacial erosion became active. In contrast, ice over the plateau was thin and remained frozen to its bed. One theory is that the cold-based ice moved slowly by internal deformation and creep but there was little movement over the ice-bed interface. In consequence, there was little erosion of delicate features such as tors and weathered rock on the plateau. This idea proved to be robust and it has been applied in a range of other glaciated landscapes, including Baffin Island and southern Greenland.

Fig. 2 Landscape modification during the Ice Age.

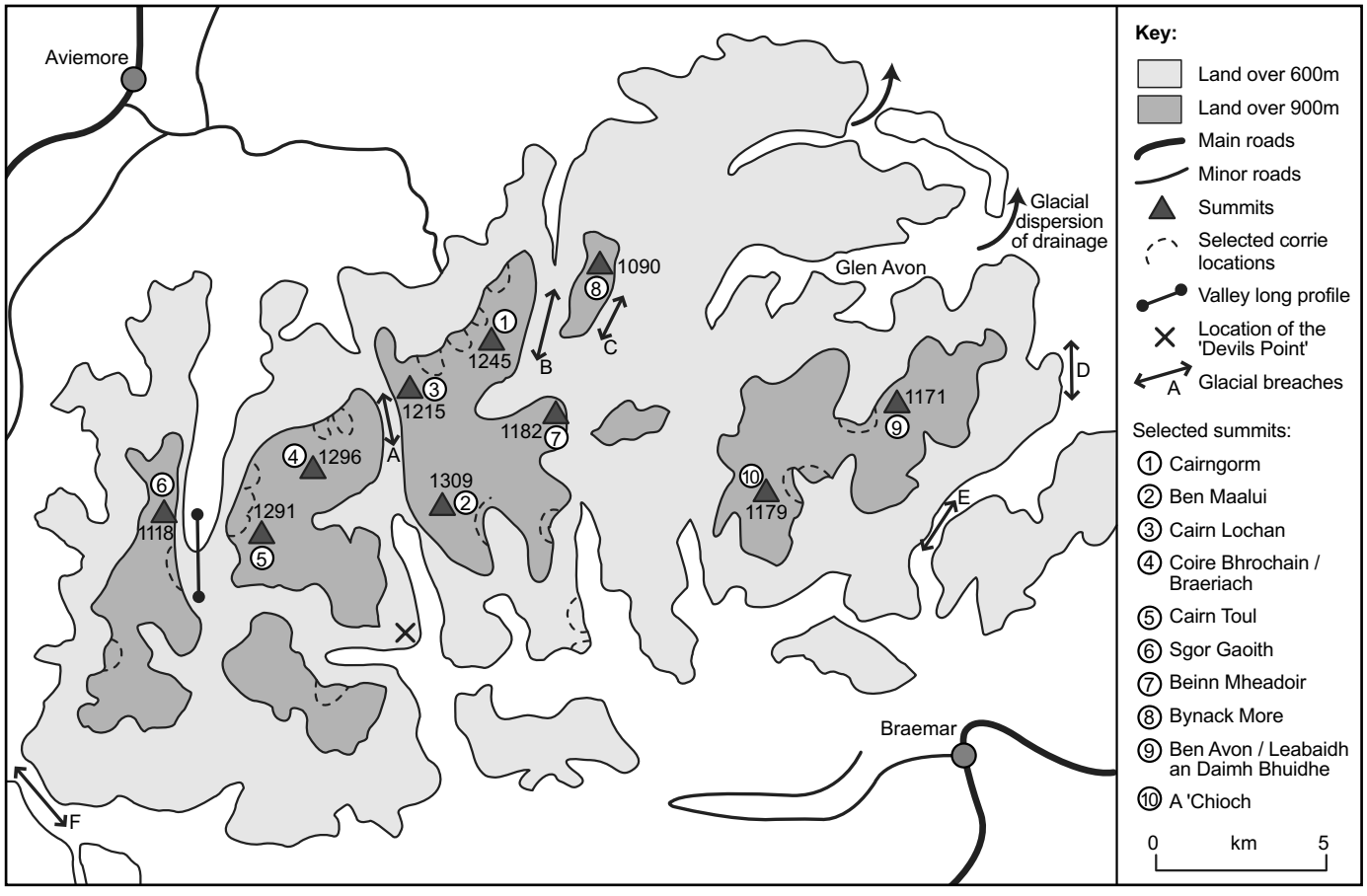


Corries

Corries are an integral part of the Cairngorm mountain scenery. They appear as a deep, shaded hollows, often with late-lying snow banks. From above the corrie headwalls appear as uniformly arcuate or even semi-circular embayments in the plateau edge. *Fig. 3* highlights the main corries in the Cairngorm region.

Corries reflect multiple phases of glaciation. The volume of moraine contained within the corries today is miniscule compared to the corrie dimensions but each phase of occupancy by ice enlarges the hollow. Using rates of corrie erosion it has been has calculated that even the largest corries in the Cairngorms could have formed with only 0.5 Myr of glacial erosion.

Fig. 3 The main corries in the Cairngorm region.



Corries (continued)

The location, size and altitude of the Cairngorm corries are closely related to the form of the pre-glacial relief.

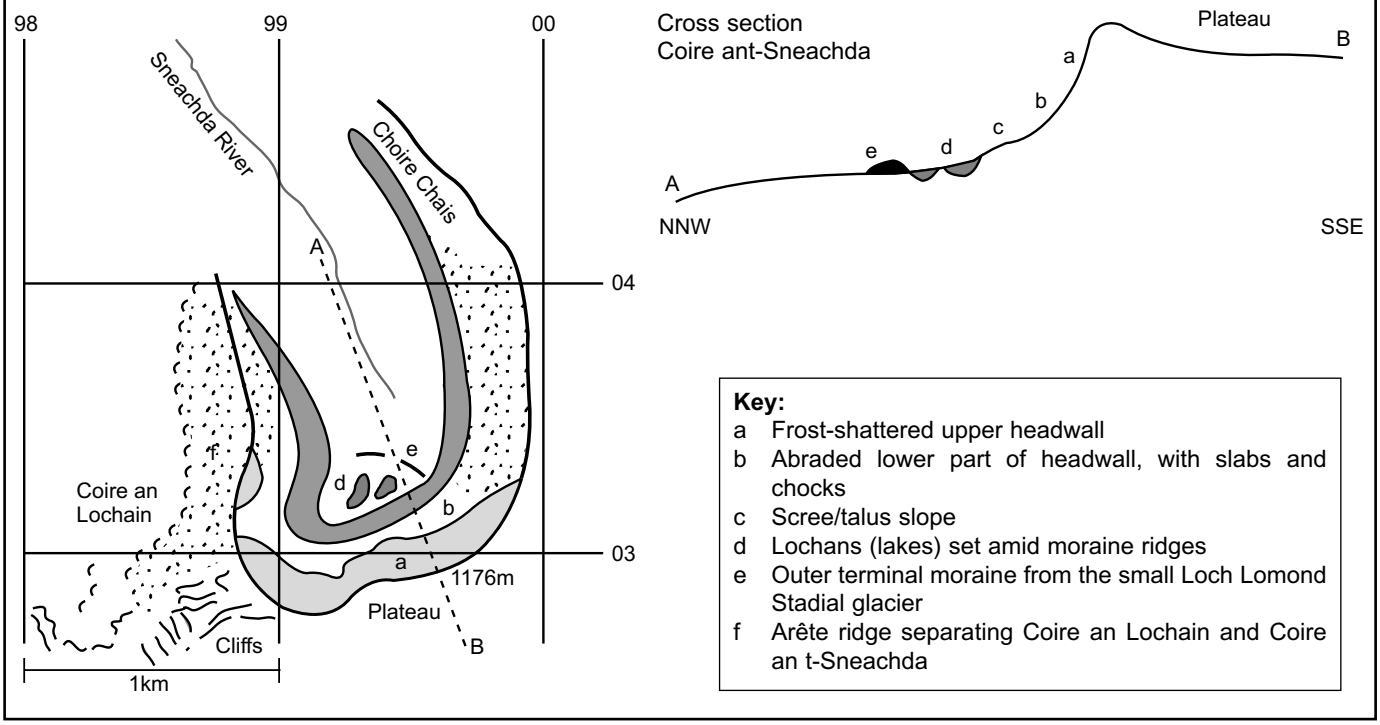
The largest corries occupy formerly large river valley heads. Aspect is also important, with almost all corries oriented within 90º of NE *(see Table 1 below)*. Corries are mostly found in the 900-1000m zone with heights of backwalls varying from about 170-270m. More speculatively, it has been observed that corries are absent from the sides of the main glacial breaches. This may imply that the corries had reached close to their present size prior to the onset of major ice sheet glaciation at around 1 Myr. Some support for this idea is provided by the fact that many corries show signs of over-riding by ice sheets.

Analysis of the corrie shows many typical features *(Fig. 4)*. The headwall (a) is a steep cliff. The structure of the granite controls the detail of the cliff face, with buttresses in areas of widely-spaced joints and gulleys and chimneys between them. This diversity also reflects glacial and periglacial activity, with intense frost-riving above the latest corrie glacier and plucking of the backwall behind the glacier. In the lower parts of the headwall (b) there is evidence of abrasion. Here there are large, steeply inclined slabs with 'chock' marks. The scree slope (c) is post-glacial and it continues to accumulate today - shown by the blocks resting on late-lying snow banks and the hazard of rockfalls. The lochans (d) are ponded behind low moraines from the last glacier to occupy Coire an t-Sneachda. These moraines are 1-3 m high and composed on large granite blocks derived from the headwall and carried on the surface of the glacier. The last glacier occupied the corrie during the Loch Lomond Stadial about 10-11,000 years before present

Table 1 Selected corrie information for the Cairngorm region.

Corrie	Grid reference	Altitude (m) (at base or lake)	Orientation	Width at widest point (m)	Approximated backwall height (m)
1 Coire Ruada	NH9500	990	NNE	500	200
2 Loch Coire an Lochain	NH9400	990	NNE	800	210
3 Coire an f - saighdeir	NN9696	920	NNE	900	260
4 Coire Odhar	NN9795	760	ENE	100	160
5 Coire an Lochain	NH9801	920	NNW	600	250
6 Coire Beanaidh	NH9501	950	NWN	600	200
7 Coire nan Clach	NN9298	940	NE	900	270
8 Coire Dhondail	NN9298	830	NE	800	170
9 An Garbh Coire	NN9298	950	ESE	900	230
10 Lochain Uaine	NO0598	960	E	500	200

Fig. 4 Fiacaill a'Choire Chais corrie and its corresponding long profile section.



Glacial Troughs

In cross-section, glacial valleys tend to have a 'parabolic', 'U' or 'trough' shape that is efficient for the evacuation of varying volumes of ice. More recently this form has been modified by glacial and fluvio-glacial deposition to give a flat or terraced floor. Postglacial processes, such as debris flows and avalanches, carry further debris to the valley floor. Perhaps the most significant changes in cross-section are a result of major rock slope failures.

The long profiles of a glacial valley are quite distinct to the graded profile of a river valley. In a glacial valley the head is steep, falling abruptly away from the plateau to an over-deepened valley section sometimes occupied by a ribbon lake, of which Loch Avon is a good example. The over-deepening is a response to the thickening of ice and rapid increase in energy through this part of the valley.

The detailed form of the valleys in both cross-section and long profile is strongly controlled by geology. Cairngorm glacial valleys tend to be relatively steep-sided and narrow, a reflection of the strength of the granite batholith.

Fig. 5

Fig. 4a Valley Cross profile from Ben Macdui (NN989990) to Lochan Uaine (NN957978).

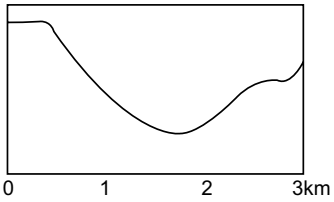
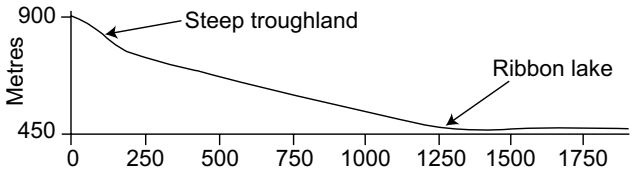


Fig. 4b Valley Long profile from Coire Odhar (NN907968) to Loch Einich (NN921016). ***Note the position of this is also located on Fig. 3.***



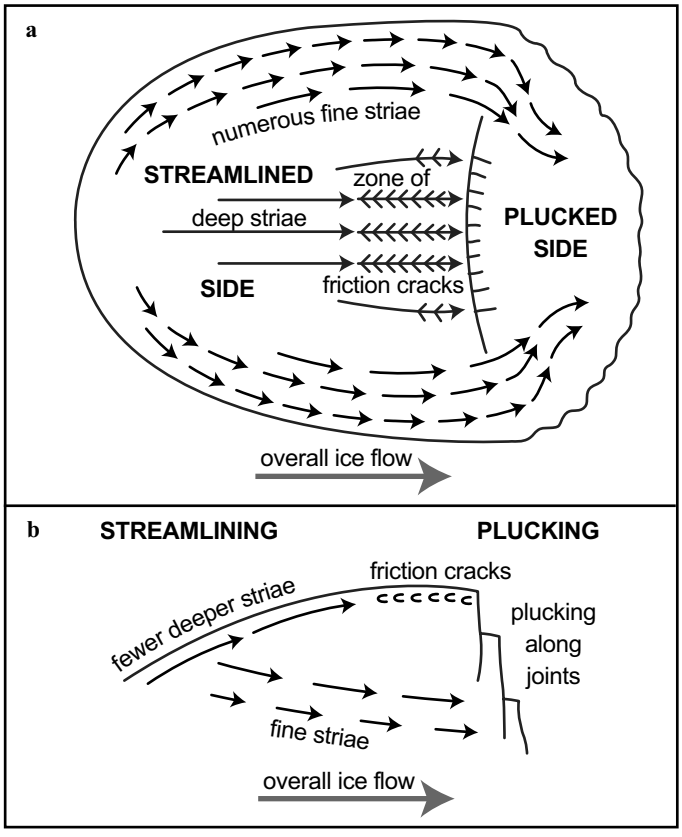
Roches moutonnées

Roches moutonnées are asymmetric bedrock bumps or hills with abraded up-ice or stoss faces and quarried / plucked down-ice faces *(see Fig. 6)*. They are developed when ice is forced to flow and deform round an obstruction.

Roches moutonnées occur widely in the Cairngorms, both on the granite and on the surrounding metamorphic country rocks. Like some other landforms of glacial erosion, roches moutonnées are usually absent from the Cairngorm plateau itself, although good examples occur at the head of Glen Avon. The roches moutonnées vary greatly in size. Ice-moulded hills in Strathspey, such as Ord Bàn, and in Glen Dee, such as Craig Leek, have a relative relief of 200-300 m. In contrast, the granite roches moutonnées in the valley of the Garbh Uisge Mhor, on the slopes of Ben Macdui, are only a few metres in height.

Roche moutonnées are generally found parallel to the direction of ice flow, although local geology can influence orientation. More significantly, large roche moutonnées have been shaped during multiple phases of glaciation. The direction of ice flow may have been similar in each phase but, in some places, it was not. The spurs of the southern Cairngorms, such as Carn Crom, show a dominance of lee-side plucking on eastern faces but also signs of plucking on southern faces. This duality may reflect two directions of ice flow; one from the Lairig Ghru and the other, more restricted in time or erosional capacity, from Glen Derry. Similarly, on Cnapan a'Mheirlich there is a scatter of metamorphic erratics which reflects a late phase of ice flow that is not related to the many phases of northeasterly flow that shaped the hill.

Fig. 6 Roches moutonnées.



Truncated spurs

Spurs are defined as blunt-ended, sloping ridges which descend the flank of a valley. Their abrupt termination is normally due to high-energy erosion by a glacier which tends to follow a straighter course than the former river.

The Devil's Point (NN976951 – see *Fig. 3*) in upper Glen Dee is perhaps the finest example of a truncated spur in the Cairngorms. The original spur protruded into the pre-glacial valley of the upper Dee and its end has been truncated by the passage of ice down the Dee valley. The glacial cliff is 400 m high.

Glacial breaches

Other remarkable features of the Cairngorms are the glacial breaches which cut through the massif across the watershed. Examples include the Lairig Ghru (A), the Saddle at the head of Strath Nethy (B), the Lairig an Loaigh (C) and its continuation to the N, Loch Builg (D), the head of the Gairn (E) and upper Glen Feshie (F). See *Fig. 3*.

In each case, the breaching has been caused by ice over-riding a pre-glacial col (gap or pass between mountain peaks). Apart from Glen Feshie, the breaches have a S-N orientation. This suggests that they were formed during periods when ice was free to flow towards the north.

Breaching appears to postdate the main period of corrie formation, as there has been no significant development of these glacial hollows on the sides of the breaches.

In some locations breaches provide excellent examples of river capture, for example where the Feshie has captured the upper Geldie. The 'pirate' river makes a spectacular 90° turn where the capture occurs, whereas the river that has been 'beheaded' has been left a sluggish misfit stream in an unusually large valley.

Further Research

Cairngorms – a landscape fashioned by geology. Scottish natural Heritage / BGS
Scotland – the creation of its natural landscape. Scottish natural Heritage / BGS
Geology and Landscapes of Scotland, Gillen, C. (2003) Terra

Useful websites

- *http://www.fettes.com/Cairngorms/* a very detailed site about the glaciation in the Cairngorms
- US Geological Survey (USGS) on glaciers and glacial hazards: *http//vulcan.wr.usgs.gov/glossary/glaciers*
- World Glacier Monitoring Service: *http://www.geo.unizh.ch/wgms*

Exam Questions

a) With reference to *Table 2*, analyse the altitude, aspect and size of corries. *(10 marks)*

b) For an upland glacial area which you have studied identify and describe three contrasting erosional landforms. *(15 marks)*

Table 2

Smallest scale → Largest scale				
Striations, grooves and chattermarks	Rock drumlin, whaleback, roche moutonnee	Crag and tail	Corrie/cirque, rock basins, arête, horn, truncated spur, hanging valley	Glacial trough, glacial breaching

Answer Guidelines

a) The text in the article gives a good starting point to describe the characteristics of the corries: Altitude 830-990m, orientation around NE, modal NNE, but orientation varies between ESE and NWN. Size of corries can be described either in terms of approximated area of hollow (simple multiplication of width and height) although this is very ballpark. Alternatively comment on range of widths (100-900m) and height (160-260m) variations. Note the command word is 'analyse' so you are expected to comment on why particular aspects / orientation, heights etc might be dominant.

b) Choice of appropriate landforms is critical for success. There are a range of features that could be chosen at various scales / sizes etc, e.g.

'Contrasting' features could be taken from anywhere along the continuum, but there is limited scope for detailed discussion of some of the micro-features. Whenever descriptions are given – be precise. For example, a description of whaleback might include

'Whalebacks are elongated smoothed bedrock bumps which lack the quarried faces of roche moutonnees. They are approximately symmetrical, often decorated with striae, friction cracks and p-forms. Whalebacks can be up to 1km in length although they are typically much smaller.'

Acknowledgements
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