Chapter 6 Landforms of glaciation

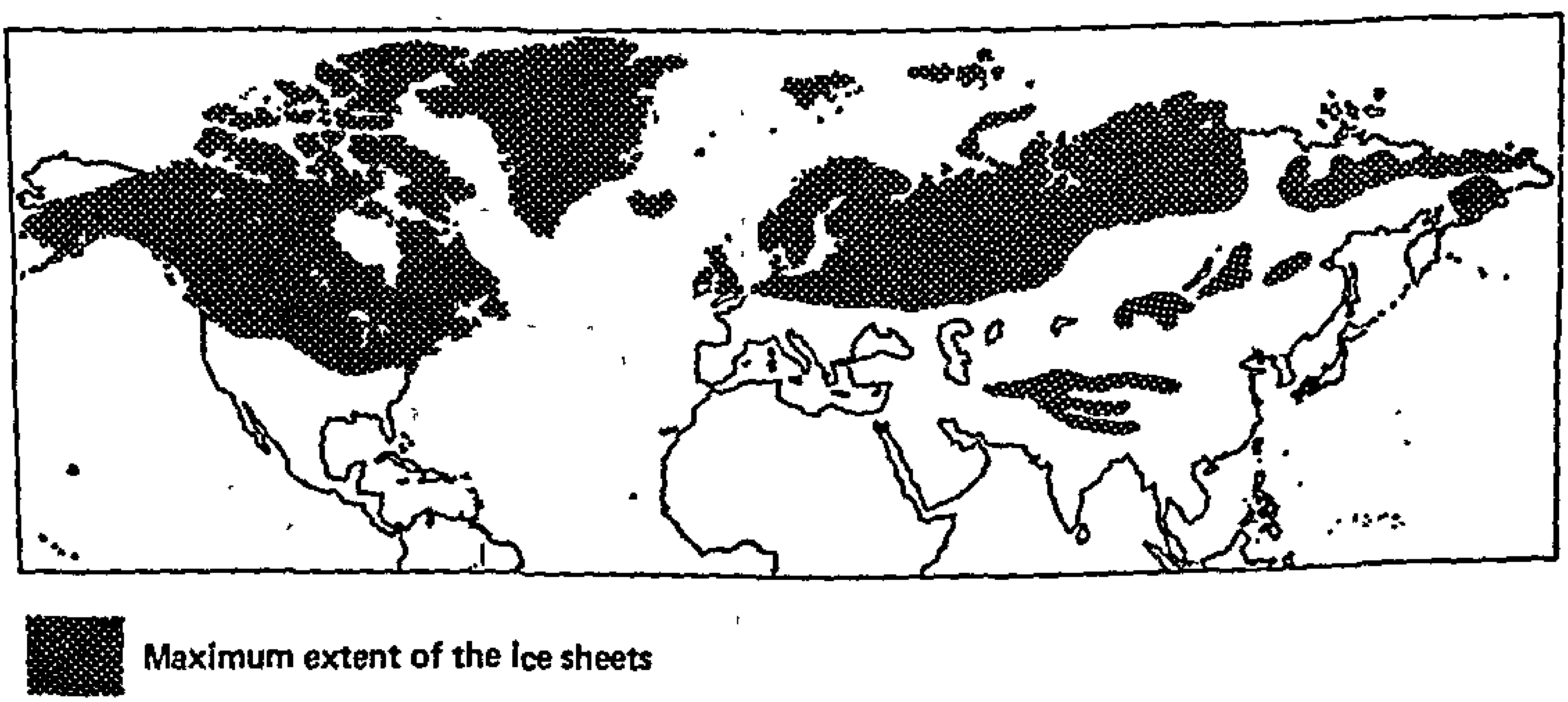
The Ice Age and Types of Ice Masses

During the Pleistocene period or the Ice Ages, about 30,000 years ago, great continental ice sheets covered much of the temperate latitudes. It is estimated that more than 12 million square miles of the northern hemisphere were buried by ice, half of which was in North America and the rest in Europe, Greenland and the high mountains of Eurasia (Fig. 46). The warmer climate that followed caused the ice sheets to retreat. Today only two major ice caps are still present, in Greenland and Antarctica. The former covers an area of 720,000 square miles while the latter is more than 5 million square miles. They are made up of compact sheets of ice, hardened and crystallised to a depth of over a mile. In Marie Byrd Land, Antarctica, the ice cap was measured and found to be more than 14,000 feet thick! Under such a collosal weight, the land sinks gradually.

From the central dome of the ice cap the ice creeps out in all directions to escape as glaciers The peaks of the loftier mountains project above the surface as nunataks. When the ice sheets reach right down to the sea they often extend outwards into the polar waters and float as ice shelves. They terminate in precipitous cliffs. When they break into individual blocks, these are called icebergs. While afloat in the sea, icebergs assume a tabular or irregular shape and only one-ninth of the mass is visible above the surface. They diminish in size when approaching warmer waters and are eventually melted, dropping the rock debris that was frozen inside them on the sea bed.

Apart from Greenland and Antarctica, glaciation is still evident on the highlands of many parts of the world, which lie above the snowline. This varies from sea level in the polar regions to 9,000 feet in the Alps and 17,000 feet at the equator, as on Mt. Kilimanjaro. Permanent snowfields are sustained by heavy winter snowfall and ineffective summer melting and evaporation. Where the slopes are gentle and the hollows are sheltered from both direct sunlight and strong winds, any snow that falls is rapidly accumulated. Part of the surface snow may melt during the day, but by nightfall it is refrozen. This process is repeated until it forms a hard, granular substance known as névé (in French) or firn (in German). Owing to gravitational forces, the neve of the upland snowfield is drawn towards the valley below. This is the beginning of the flow of the glacier—'river of ice'. It normally assumes a tongue-shape, broadest at the source but becoming narrower downhill. Though the glacier is not a liquid, under the continual pressure from the accumulated snow above, it moves. The rate of movement is greatest in the middle where there is little obstruction. The sides and the bottom are

Fig. 46 The extent of continental ice sheets in the Ice Ages



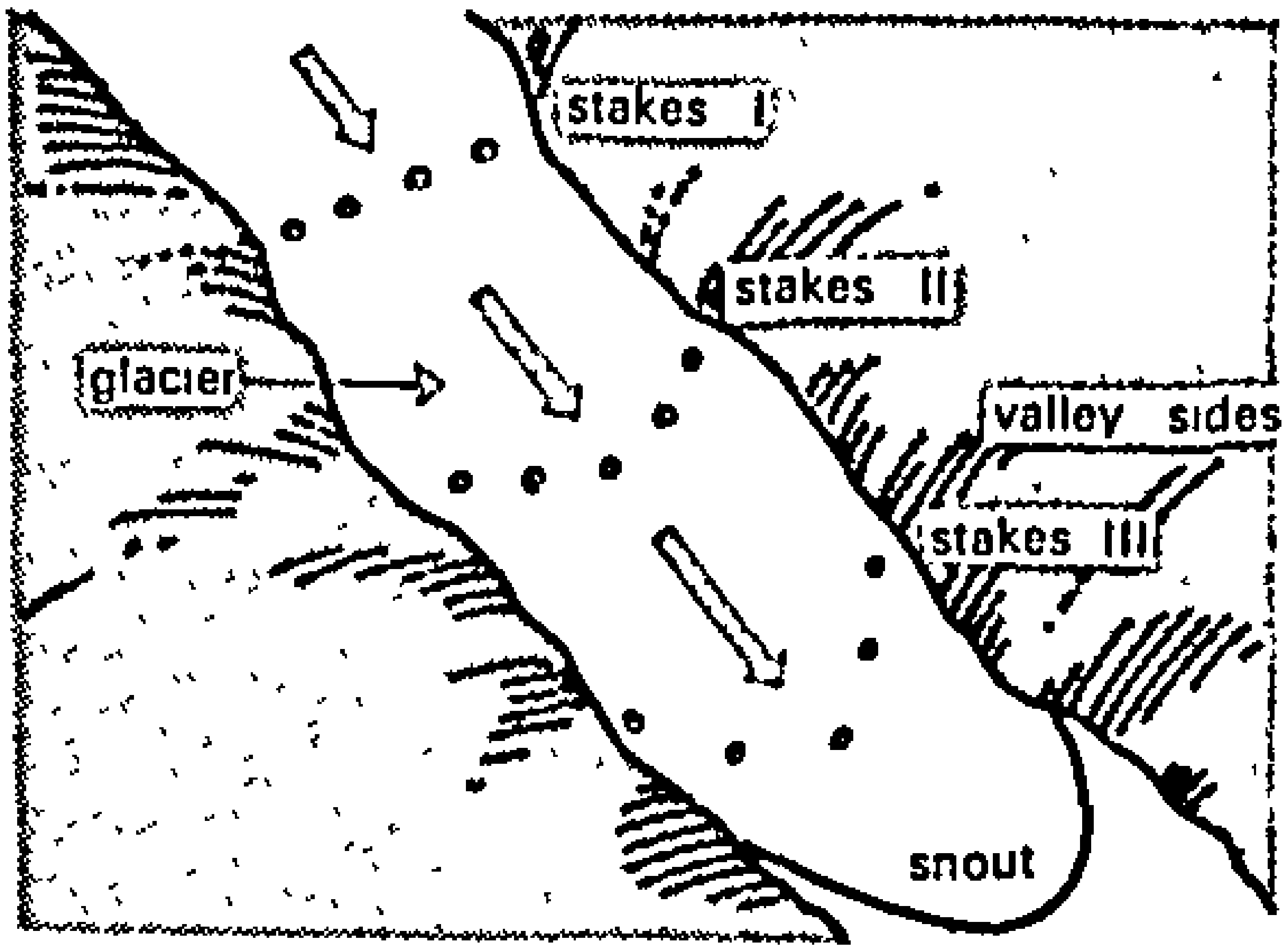


Fig 47 The different rate of glacial movement. A glacier moves faster in the centre than the sides

held back by friction with the valley side spurs and the valley floor. If a row of stakes is planted across a glacier in a straight line, they will eventually take a curved shape down the valley, showing that the glacier moves faster at the centre than the sides (Fig. 47). In the Alps the average rate of flow is about three feet a day; in Greenland it may be more than fifty feet, but in Antarctica, where there is little heat to melt the ice, glaciers move only a few inches a day! The Aletsch Glacier in the Bernese Oberland of Switzerland is 10 miles long, affording some spectacular sights to Alpine tourists. Though it is the longest glacier in Europe, it is short compared with those of Alaska and the Himalayas which measure more than five times that length!

At the foot of mountain ranges, several glaciers may converge to form an extensive ice-mass called a piedmont glacier The best known piedmont glacier is the Malaspina Glacier of Alaska which is 65 miles long and 25 miles wide, covering an area of more than 1,600 square miles. Combined glaciers of such dimensions are now rare and in most continents only valley or Alpine glaciers are seen.

Landforms of Highland Glaciation

Glaciation generally gives rise to erosional features in the highlands and depositional features on the lowlands, though these processes are not mutually exclusive because a glacier plays a combined role of *erosion, transportation and deposition* throughout its course. A glacier erodes its valley by two processes *plucking* and *abrasion*. By plucking the glacier ... joints and beds of the underlying rocks, tear... idual blocks and drags them away. By ... the glacier scratches, scrapes, polishes and scours the valley floor with the debris frozen into it. These fragments are powerful 'tools' of denudation. Large angular fragments cut deep into the underlying rocks so all glaciated floors bear evidence of striation or scratching. The finer materials smooth and polish the rock surfaces and produce finely ground rock flour. The rate of erosion is determined by several factors such as the velocity of flow, gradient of the slope, the weight of the glacier, the temperature of the ice and the geological structure of the valley.

The characteristic features of a glaciated highland are as follows.

1. Corrie, cirque or cwm. The downslope movement of a glacier from its snow-covered valley-head, and the intensive shattering of the upland slopes, tend to produce a depression where the *firn* or *névé* accumulates. The process of plucking operates on the back-wall, steepening it and the movement of the ice abrades the *floor*, deepening the depression into a a steep, horse-shoe-shaped basin called a cirque (in French). It is also known as a corrie in Scotland and a cwm in Wales (Fig. 48). There is a rocky ridge at the exit of the corrie and, when the ice eventually melts, water collects behind this barrier, to form a corrie lake or tarn

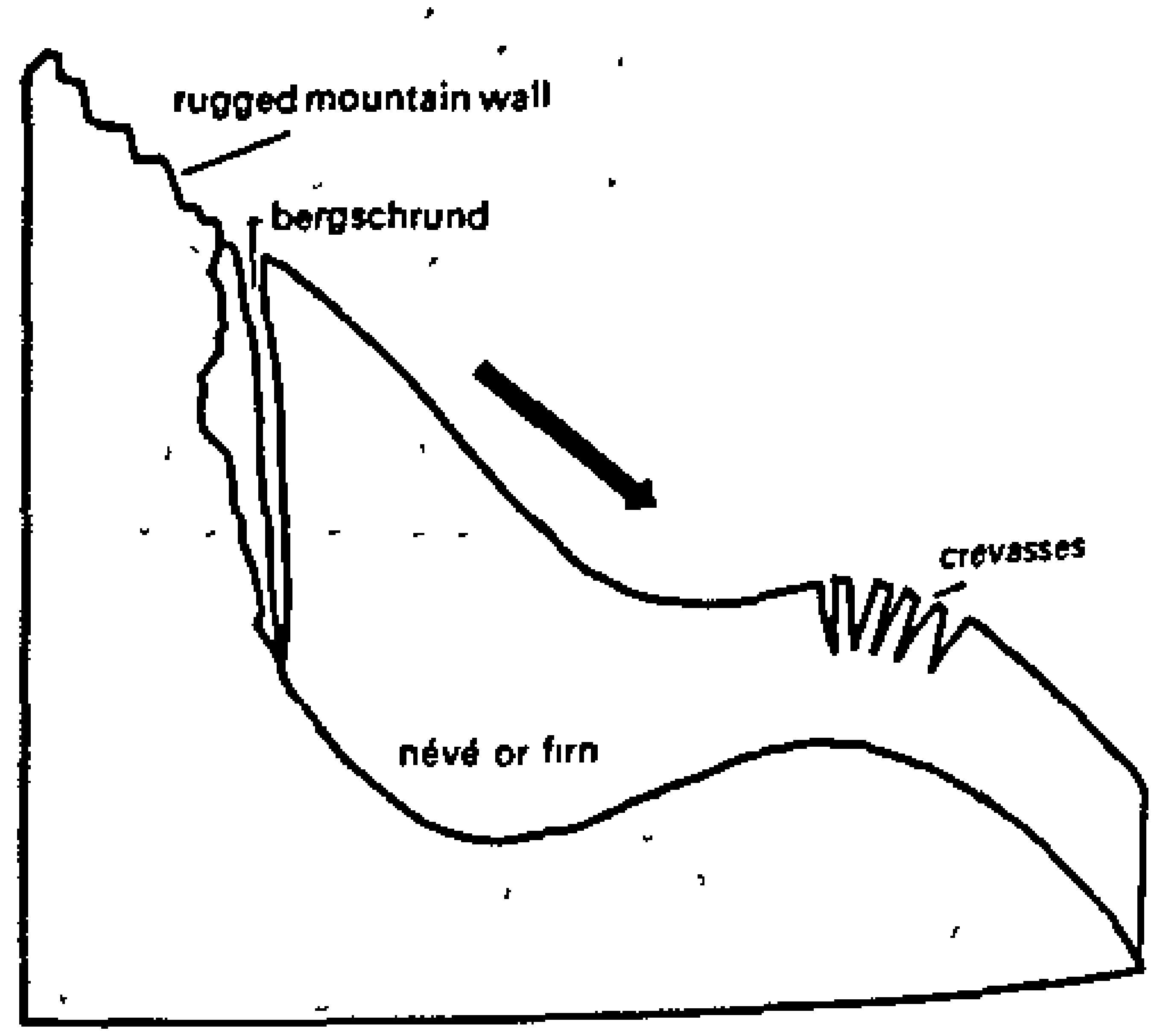


Fig. 48 Development of a corrie

2. Arêtes and pyramidal peaks. When two corries cut back on opposite sides of a mountain, knife-edged ridges are formed called aretes (a French word) A well known British example of an arête is the Striding Edge on Helvellyn in Westmorland. Where three or more cirques cut back together, their ultimate recession will form an *angular horn* or pyramidal

A glacial landscape in Switzerland *Swiss National Tourist Office*

peak. The Matterhorn of Switzerland is a classic example (Fig. 49).

3. **Bergschrund.** At the head of a glacier, where it begins to leave the snowfield of a corrie, a deep vertical crack opens up called a bergschrund (in German) or rimaye (in French). This happens in summer when, although the ice continues to move out of the corrie, there is no new snow to replace it. In some cases not one but several such cracks occur. The bergschrund presents a major obstacle to climbers. Further down where the glacier negotiates a bend or a precipitous slope, more crevasses or cracks are formed (Fig. 48).

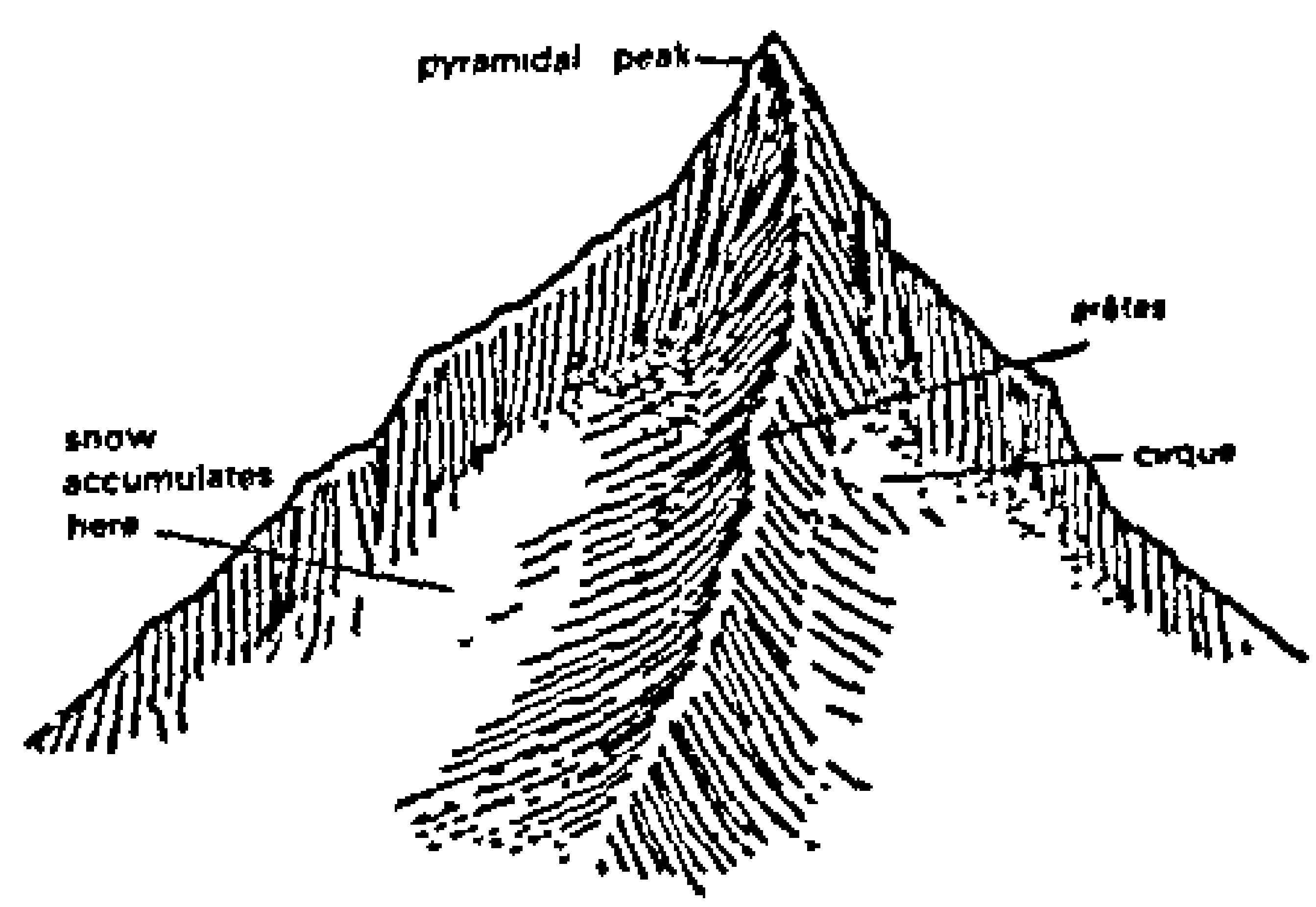


Fig 49 Cirque, arête and pyramidal peak

A U-shaped valley in Switzerland The valley sides are steep but the floor is flat. There is a ribbon lake in the valley bottom
Swiss National Tourist Office

4. U-shaped glacial trough. The glacier on its downward journey, fed by ice from several corries like tributaries that join a river, begins to wear away the sides and floor of the valley down which it moves. It scratches and grinds the bedrock, removing any rock debris and surface soil. It tends to straighten any protruding spurs on its course. The *interlocking spurs* are thus blunted to form truncated spurs and the floor of the valley is deepened (Fig. 50). A valley which has been glaciated takes a ch... ...istic U-shape, with a wide, flat floor ... sides. After the disappearance of the ic... sections of these long, narrow ... may be filled with water forming ..., such as Loch Ness and Lake Ullswater in Britain. They are sometimes referred to as *trough lakes* or *finger lakes*.

5. Hanging valleys. The main valley is eroded much more rapidly than the tributary valleys as it contains a much larger glacier. After the ice has melted a tributary valley therefore 'hangs' above the main valley so that its stream plunges down as a waterfall (Fig 50) Such tributary valleys are termed hanging valleys and may form a natural head of water for generating hydro-electric power.

6. Rock basins and rock steps. A glacier erodes and excavates the bed rock in an irregular manner The unequal excavation gives rise to many rock basins later filled by lakes in the valley trough.

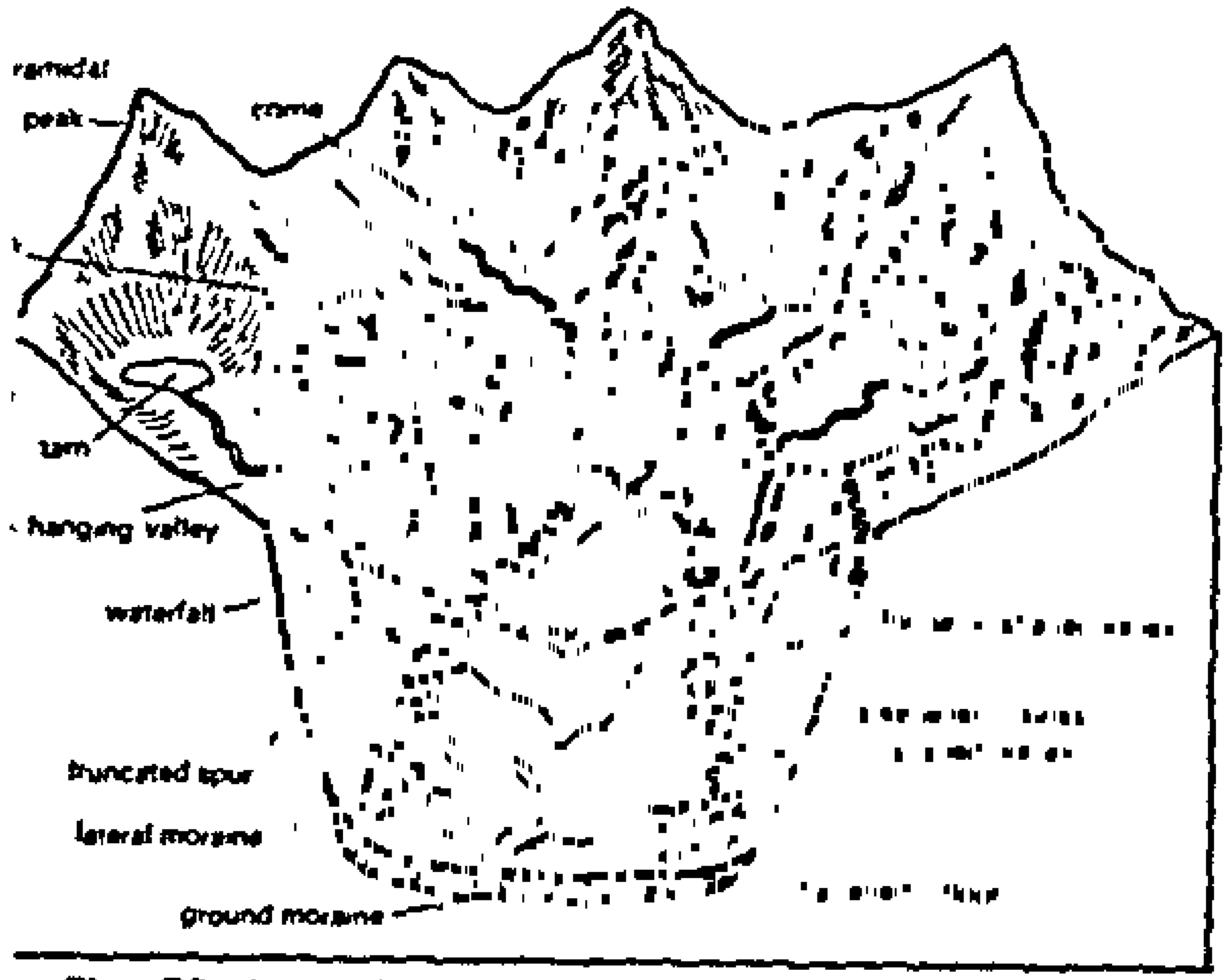


Fig. 50 A glaciated upland

Where a tributary valley joins a main valley, the additional weight of ice in the main valley cuts deeper into the valley floor at the point of convergence forming a rock step. A series of such rock steps may also be formed due to different degrees of resistance to glacial erosion of the bedrocks.

7. Moraines. Moraines are made up of the pieces of rock that are shattered b... ...bedded in ... Those the ... screes, form lateral moraines. When two glaciers converge, their inside lateral moraines unite to form a medial moraine. The rock fragments which are dragged along beneath the frozen ice are dropped when the glacier melts and spread across the floor of the valley

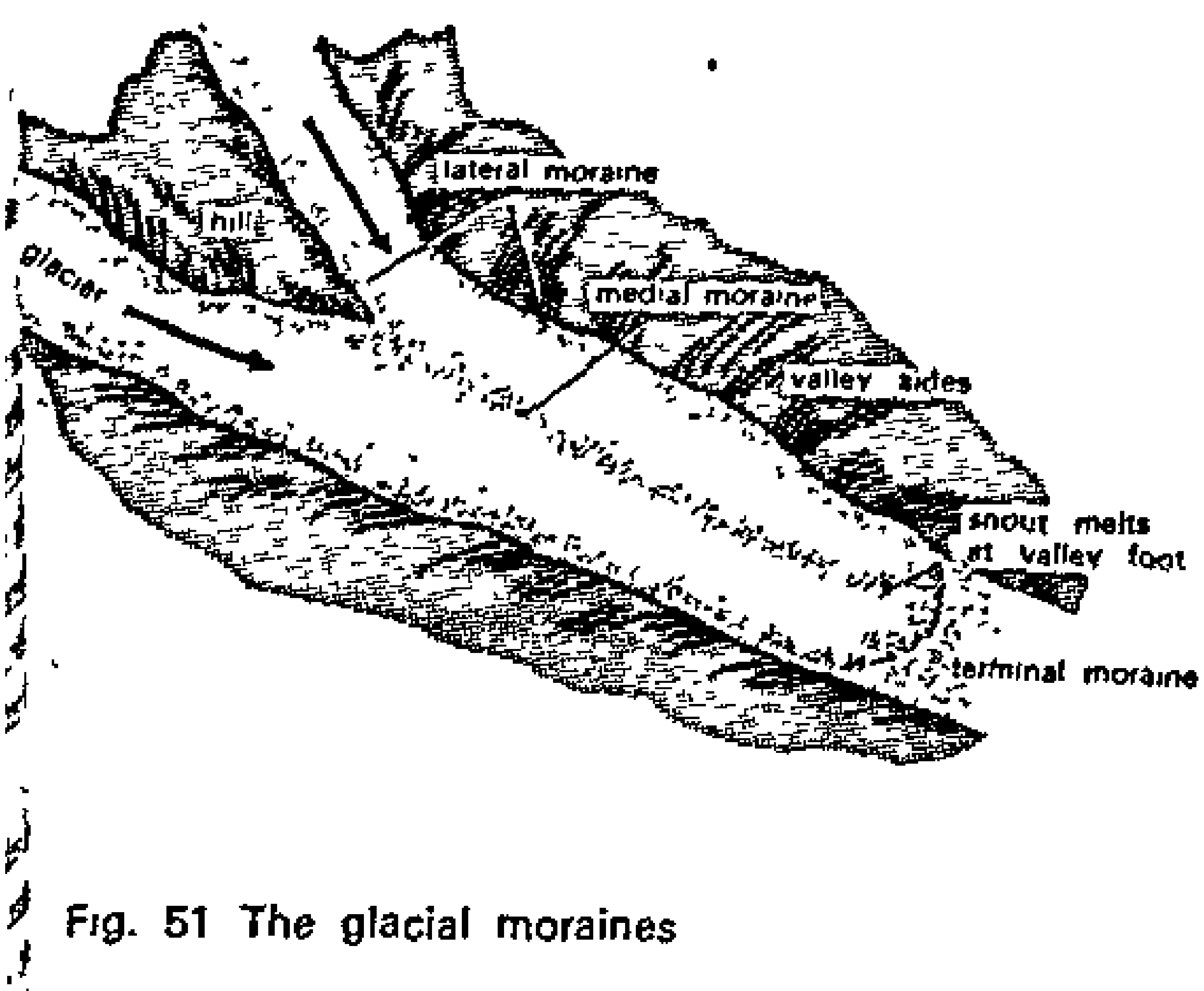


Fig. 51 The glacial moraines

as ground moraine. The glacier eventually melts on reaching the foot of the valley, and the pile of transported materials left behind at the snout is the terminal moraine or *end moraine* (Fig. 51). The deposition of the end moraines may be in several succeeding waves, as the ice may melt back by stages so that a series of recessional moraines are formed.

If the glacier flows right down to the sea it drops its load of moraine in the sea. If sections break off as icebergs, morainic material will only be dropped when they melt (Fig. 52). Where the lower end of the trough is drowned by the sea it forms a deep, steep-sided inlet called a fiord, typical of the Norwegian and south Chilean coasts.

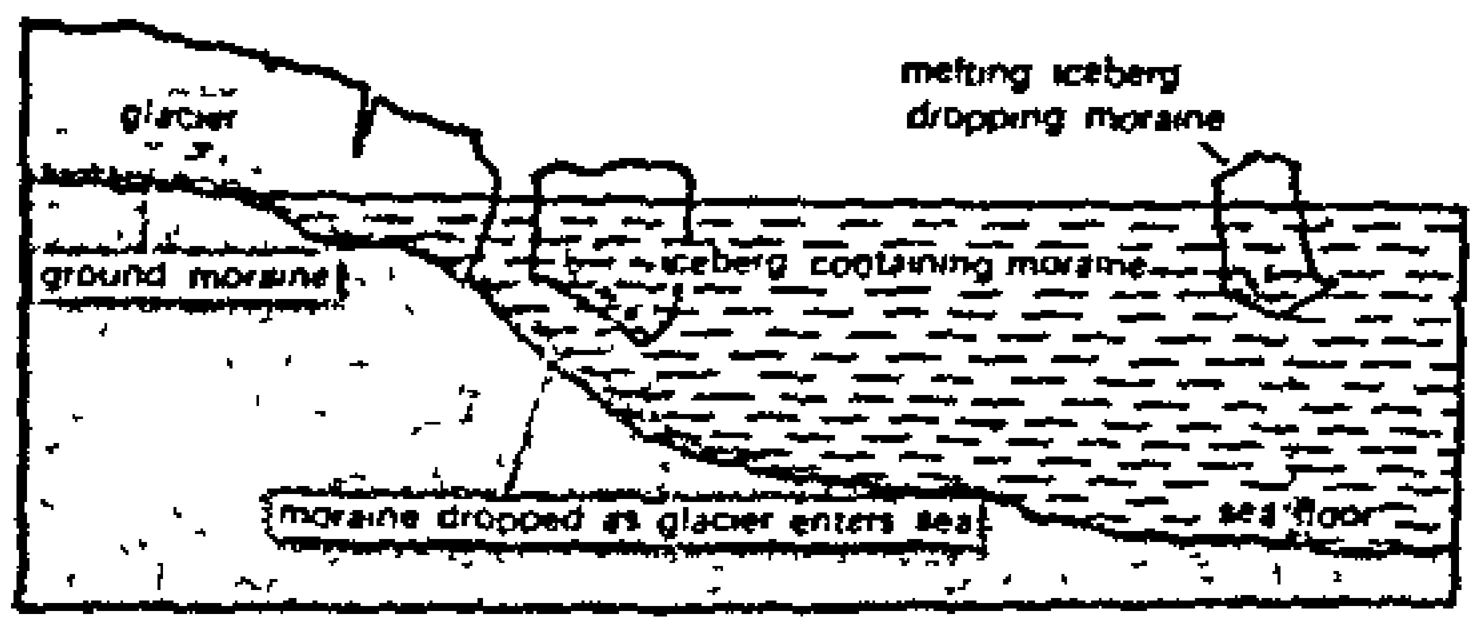


Fig. 52 A glacier ending at the sea

Landforms of Glaciated Lowlands

Landforms of glaciated lowlands are mainly *depositional* in nature, brought about by both *valley glaciers* and *continental ice sheets*. The former leaves behind the eroded materials in only restricted areas. The imprint of ice sheets on the landscape is far more widespread because they advanced through large areas during the Ice Ages, scouring and removing any surface soil and rock debris on their way. As a result, it has been estimated that almost a third of the total land surface of Europe and North America is littered with glacial and fluvio-glacial materials of all descriptions—moraines, boulder clay, tills, drifts, rock-flour, gravels and sands. Many of them are being re-eroded, resorted and redeposited elsewhere by present-day rivers.

Most of the glaciated lowlands have depositional features, but where rock masses project above the level surface, they result in striking features of erosion, such as the roche moutonnee and crag and tail:

1. Roche Moutonnee. This is a resistant residual rock hummock. The surface is striated by ice movement. Its upstream side is smoothed by abrasion and its downstream side is roughened by plucking,

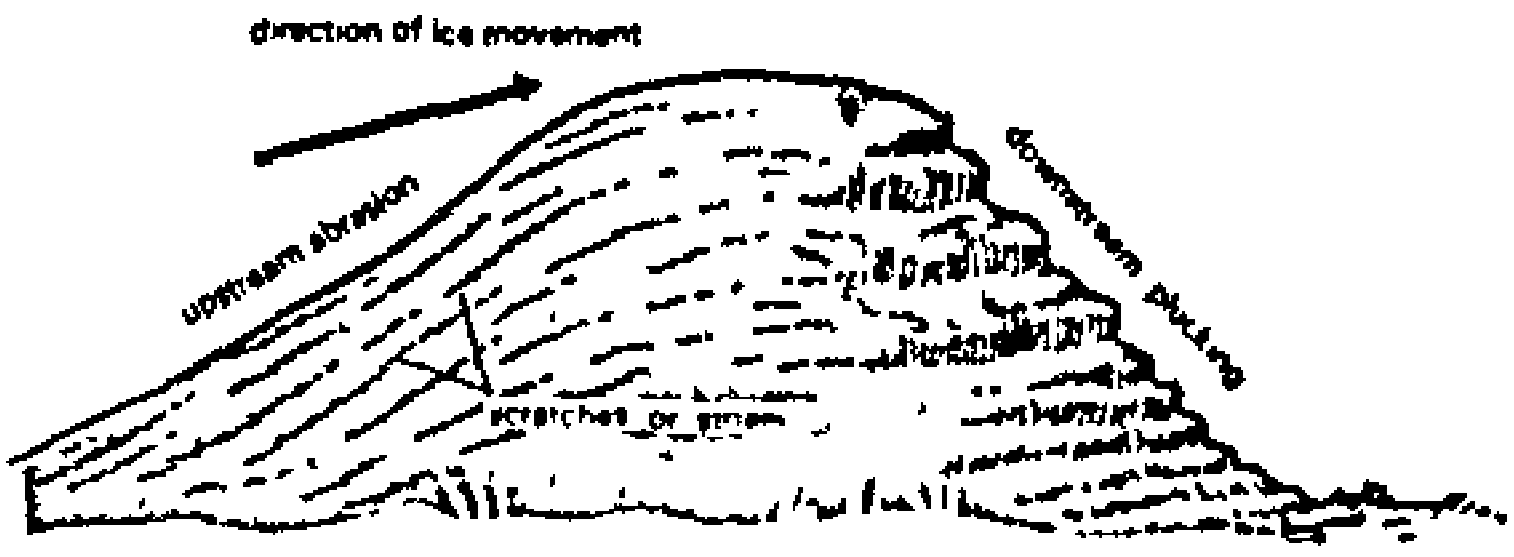


Fig. 53 Roche moutonnee

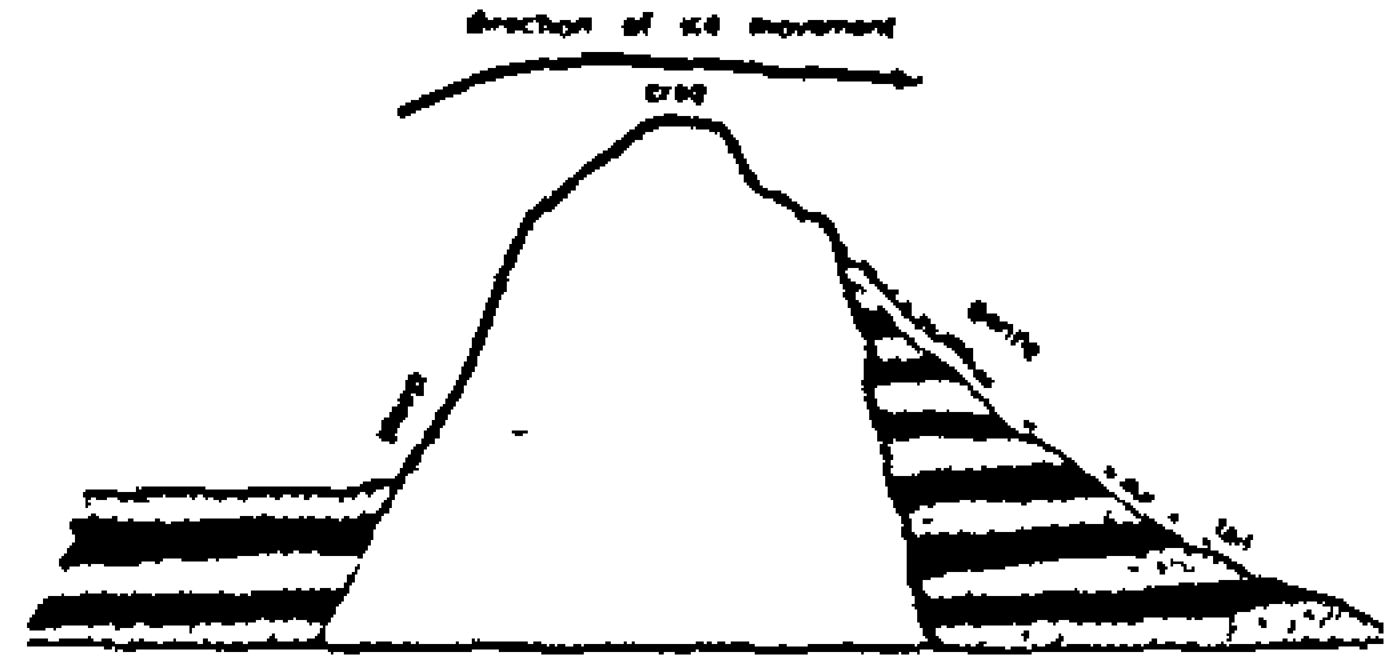


Fig. 54 Crag and tail

and is much steeper. The term roche moutonnee is used to describe such a feature because it resembles a sheepskin-wig once worn in France (Fig. 53). Roches moutonnees are found in both highland and lowland glaciated regions.

2. Crag and Tail. The crag is a mass of hard rock with a precipitous slope on the upstream side, which protects the softer leeward slope from being completely worn down by the on-coming ice. It therefore has a gentle tail, strewn with the eroded rock debris. The classic example is the *Castle Rock of Edinburgh*, Scotland. Edinburgh Castle is located on the crag and the High Street on the tail. (Fig. 54).

The remaining glaciated lowland features are of a depositional nature (Fig. 55). The following are the typical ones.

3. Boulder clay or glacial till. This is an unsorted glacial deposit comprising a range of eroded materials —boulders, angular stones, sticky clay and fine rock flour. It is spread out in sheets, not mounds, and forms gently undulating till or drift plains. The landform is rather monotonous and featureless. The degree of fertility of such glacial plains depends very much on the composition of the depositional materials. Some of the boulder clay plains such as East Anglia and the northern Mid-West of U.S.A. form rich arable lands.

4. Erratics. These are boulders of varying sizes that were transported by ice. They came with the advancing glaciers or ice sheets but when the ice melted, they were left 'stranded' in the regions of deposition. They are called erratics because they are composed of materials entirely different from those of the region in which they are f...

...found perched in precarious positions just as the ice dropped them and they are then termed perched blocks. Examples of such blocks are commonly encountered in both lowland and highland areas in ... Silurian grits are found perched on the ... Limestone of the Pennines. Their ... numbers is a hindrance to farming.

5. Drumlins. These are swarms of oval, elongat... 'whale-back' hummocks composed wholly of bould... clay, with their elongation in the direction of th... ice flow, that is on the downstream side. They ar... low hills varying from a few yards to 400 feet i... height and may be a mile or two long. They appea... a little steeper at the onset side and taper off a... the leeward end. They are arranged diagonally and so are commonly described as having a *baske... of eggs' topography.* Large numbers of them are found in County Down in Northern Ireland and the glaciated plain around the Great Lakes in North America.

6. Eskers. These are long, narrow, sinuous ridges composed of sand and gravel which mark the former sites of sub-glacial melt-water streams. They vary from a few feet to 200 feet in height and may be several miles long. In some parts of Maine, U.S.A., the outstanding eskers form a continuous ridge of 100 miles! They are very numerous in Scandinavia e.g. the Punkaharju Esker of Finland. As eskers are made up of highly porous sand and gravel, water is rapidly drained off from their crests and they may not support many trees, though in Finland they often form tree-covered ridges between lakes

7. Terminal moraines. These are made up of the

A drumlin field in northern England *J.K. St. Joseph*

coarse debris deposited at the edge of the ice-sheet, to form hummocky and hilly country such as the Baltic Heights of the North European Plain (Fig. 55).

8. **Outwash plains.** These are made up of fluvio-glacial deposits washed out from the terminal moraines by the streams and channels of the stagnant ice mass. The *melt-waters sort and re-deposit* the material in a variety of forms from the low hilly heathlands, such as the Luneburg Heath of the North European Plain, to undulating plains, where terraces, alluvial fans and deltaic deposits of the melt-water streams make up the landscape. Kames, small rounded hillocks of sand and gravel may cover part of the plain. Where the deposition takes the form of alternating ridges and depressions, the latter may contain kettle lakes and give rise to characteristic '*knob and kettle*' topography.

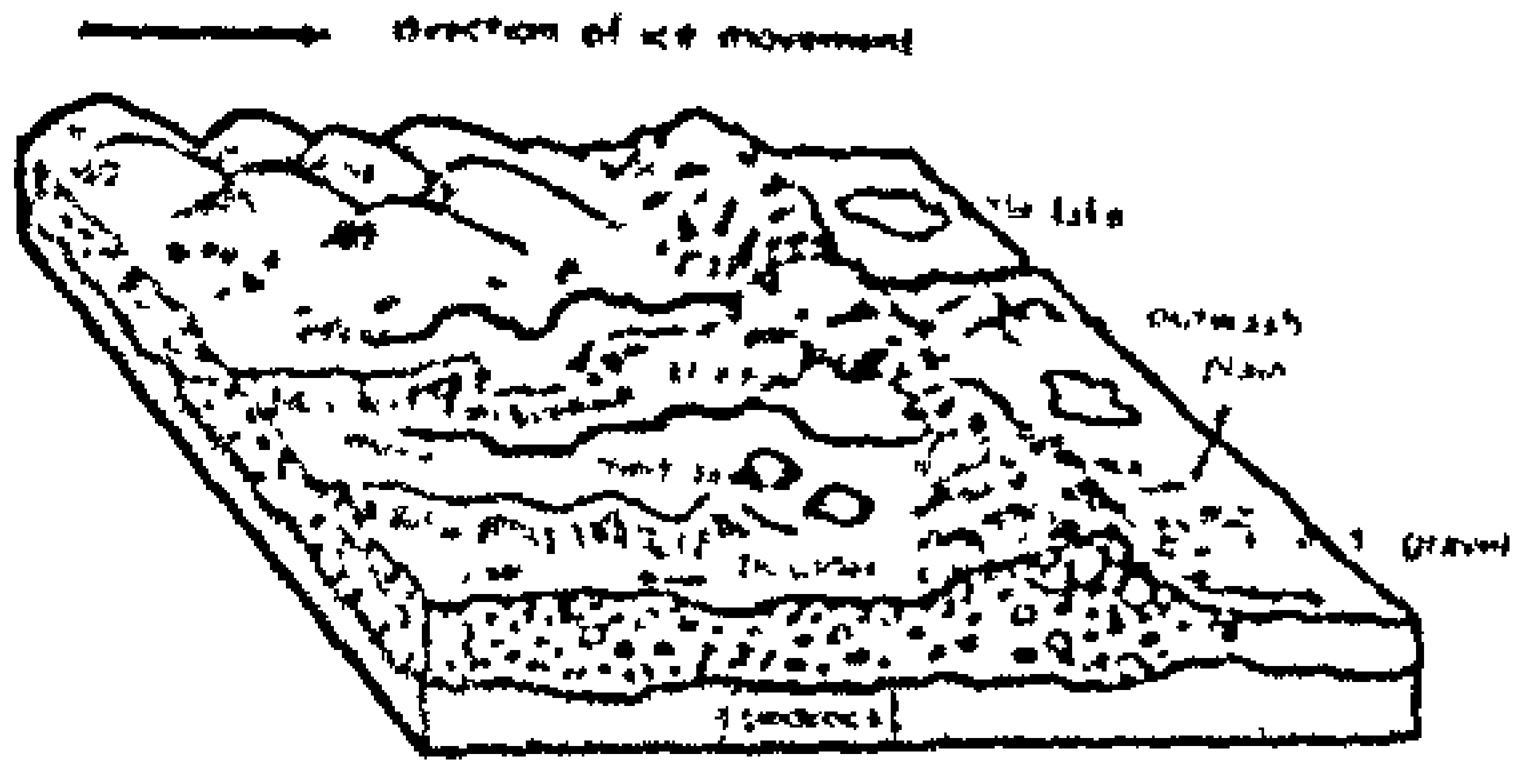


Fig 55 Glacial depositional features in the outwash plain

The Human Aspects of Glaciated Landforms

Though the Ice Ages were at their height over 10,000 years ago, the effects of glaciation on both landforms and human activities have profound influence in many parts of the world today. Their most striking impact is felt in the temperate regions of Europe and North America which were once under continental ice sheets. Further south and on the high mountains all over the world, slow-moving glaciers are still shaping the landscape in the Alps, Andes, Rockies and Himalayas. Glacial influences on Man's economic activities are both favourable and unfavourable, depending on the intensity of glaciation, the relief of the region and whether the effects are of an erosional or depositional nature.

In *hilly regions* such as the mountain slopes of Scandinavia, ice sheets and glaciers have removed most of the top soil, leaving them quite bare of vegetation. Soils that *do* exist are so *thin* that they are incapable of supporting effective agriculture. Glacial drifts in the valleys and benches or alps which were not affected by glaciers have good pastures during summer. Cattle are driven up to graze on the grass and return to the valley bottom in winter. This form of animal-migration type of farming is called transhumance. Extensive boulder clay plains such as those of East Anglia and the Mid-West of U.S.A. are some of the most fertile agricultural plains known. The loess plains of Europe and central U.S.A., with a high proportion of humus are good farming land too. On the other hand, the *sandy or gravelly* outwash plains e.g. the heath-covered *geest* of northern Germany, the *marshy boulder clay* deposits of central Ireland, the *barren* ice-scoured surfaces of the Canadian and Baltic Shields are infertile. The presence of numerous erratics and perched blocks in parts of Britain and in Alberta, Canada, many of them of gigantic size obstruct farming and the use of machines. Morainic deposits may dam, or glaciers may hollow out, lakes which greatly inconvenience large scale farming or land development. But when the lakes are eliminated, the old glacial lake beds with their rich alluvium support heavy cropping.

Large lakes formed by former glaciation, e.g. the Great Lakes of North America, make excellent waterways. They may also cut deep overflow channels while draining off, making natural routeways across a mountainous terrain e.g. the Hudson-Mohawk Gap that links the interior with the Atlantic seaboard of U.S.A. On the other hand in regions where drumlins are dominant, the drainage is either poor or much confused.

Terminal and recessional moraines comprise coarse materials of little use to man but fluvio-glacial deposits are not without their economic significance. In the outwash plains, eskers and kames have been excavated to provide sands and gravels for *highway* and *building construction*. The purest sands are extracted to make *moulds* for metal castings. The lake basins of glaciated mountains provide natural reservoirs. In countries like Scandinavia, Switzerland and Canada where there is little available coal, streams and waterfalls that plunge down from hanging valleys or other glaciated uplands are being harnessed to provide hydro-electric power. This has helped to develop many of the chemical and metallurgical industries. With the magnificent scenery provided by the glaciated mountains e.g. the French, Italian and Swiss Alps, large numbers of tourists are attracted to them annually. Skiing, mountain climbing and sight-seeing are all popular with Alpine tourists.

QUESTIONS AND EXERCISES

1. Choose any *three* of the following glacial features: corrie, arete, erratic, hanging valley, kettle lake, nunatak. For each of them:

(a) Describe its physical appearance.

(b) Account for its mode of formation.

(c) Locate and name an area where an example could be seen.

2. (a) Distinguish between valley glaciers and continental ice sheets.

(b) Explain why glaciation in the uplands produced erosional features while that of the lowlands produced mainly depositional features.

3. The following lowland glacial features are all, in fact, small ridges, but are quite different in their process of formation:

(a) State which of them are of erosional or depositional nature

(b) Pick out their distinctive differences in both appearance and formation.

roche moutonnee, drumlin, esker, crag and tail, kames.

4. Briefly explain any *three* of the following

(a) Glaciated valleys assume a characteristic U-shaped.

(b) The middle of a glacier moves faster than the sides.

(c) In glaciated lowlands, eskers, kames and other morainic deposits are extensively quarried.

(d) Glacial soils vary greatly in their fertility.

(e) Erratics and perched blocks are the best indicators of the source and direction of ice movement.

5. With the aid of diagrams, attempt to explain the difference between any *three* of the following pairs of terms connected with glaciation.

(a) Valley glacier and piedmont glacier

(b) Bergschrund and crevasses

(c) Corrie lake and ribbon lake

(d) Interlocking spurs and truncated spurs

(e) Terminal moraine and recessional moraine.