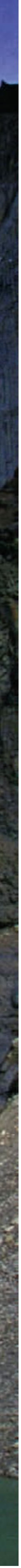


10 Shaping the landscape

The effects of glacial erosion and deposition are abundantly clear in many of the world's most beautiful mountain regions. Although now devoid of glaciers, regions such as the greater part of the Rocky Mountains of the USA or the uplands of the British Isles provide a rich legacy of glacial phenomena. Sharp peaks and steep-sided, flat-bottomed valleys are typical manifestations of the erosive capability of glaciers, while deposition from glacier ice has produced a variety of heaps of sand, gravel and mixed sediments. Even more abundant glacial deposits are found in the lowland regions bordering mountain ranges, or on the plains that underlie the outer limits of the last great ice sheets.

Glacial erosional landforms

The effects of erosion can be seen on all scales – from small outcrops of bedrock to the world's highest peaks, and to the vast areas of scoured low rocky country of the Canadian Shield. The distinctive imprint left by glaciers permits us to recognize the effects of glaciation in areas that have not been covered by ice for many thousands or even millions of years.

Small-scale features

On the smallest scale of centimetres to metres, glacial erosion is represented by striated, polished and grooved rock surfaces, features which are the result of debris-laden ice at the base of the glacier sliding over a slab of rock. Associated with them are smaller features such as **chattermarks** and **crescentic gouges** which are the result of a repeated juddering of an ice-embedded stone on the rock surface. In addition, the glacier can 'pluck' at the bedrock, creating a jagged rock-face, especially downstream of a bump in the bed.

The dramatic granite peaks of the Torres del Paine tower above a moraine-dammed lake and the person standing amongst the huge blocks that make up the moraine. A glacier filled the whole lake basin less than 200 years ago, and the only remnants occur on the intermediate bench above the lake and as a debris-covered calving mass at the foot of the cliff to the right.

http://dx.doi.org/10.1017/CBO9780511807602.011

Crescent-shaped chattermarks and striations on bedrock of gabbro, Isle of Skye, Scotland. These features are the result of the juddering effect of debris-bearing ice as it slides over the bedrock. Ice flow was from top to the bottom of the picture.

Other features, eroded with the help of subglacial meltwater under pressure, take the form of small, irregular, smooth hollows in bedrock, known as plastically moulded forms or **p-forms**. Such features form by a combination of erosion by sediment-laden meltwater, wet slurry-like glacial sediment and direct glacial abrasion. Discrete channel forms, cut into solid bedrock, are referred to as **Nye channels** after the British physicist who first defined numerically how they formed.

Intermediate-scale features

The smaller features are often mirrored on a scale of tens to hundreds of metres. For example, large **grooves** in areas of scoured low relief, that are many times longer than they are wide, resemble striations in form. Other larger features include rocky knolls that are convex and smooth but striated on their upstream side, and irregular and plucked on the slope facing downstream. These knolls, which are known as **roches moutonnées** after a wavy French wig popular in the eighteenth century, are common at the bottom and

Roches moutonnées were used widely in Scandinavia by bronze age people. The smooth rock surfaces were an ideal base for petroglyphs often showing people, boats and animals. This spectacular scene is near the south shore of Lake Mälaren (close to Sundbyholm) was created much later during the early eleventh century. Locally known as 'Sigurdsristning', it shows the fight of Sigurd against the dragon.

The combination of glacial abrasion (producing striae) and subglacial meltwater under high pressure gives rise to channel-like structures (called Nye channels) cut in the bedrock, as at the margin of Glacier de Tsanfleron, Switzerland. View away from glacier across limestone bedrock to the ranges in the Valais Alps (Weisshorn, right of centre).

Small-scale features of glacial erosion are striations (fine scratches) resulting from the abrasive characteristics of debris-laden ice sliding over bedrock. The whaleback form shown here is a roche moutonnée on the island of Sandham in the Stockholm archipelago. It is abraded on the upstream side to the left and was plucked by ice on the right.

The erosion of a mountain from all sides by glaciers produces a 'horn' with steep arêtes rising to a sharp peak. Ama Dablam 6856 metres) viewed from the Khumbu Valley is one of the world's finest horns.

along the flanks of glaciated valleys. A large fine example is the Lembert Dome in Yosemite National Park, California. Sometimes deposition occurs in the lee of a rock outcrop, and the result is a **crag-and-tail** feature, such as the classic example of Edinburgh and the Royal Mile in Scotland. These large-scale landforms are described as follows.

The Lembert Dome in Yosemite National Park, California is an exceptionally large roche moutonnée. It clearly demonstrates ice flow from right to left, the abraded slope providing an easy walk to the top, while the plucked craggy slope to the left is a challenging rock climb.

Below. A sunset over the Cordillera Huayhuash in Peru brings out the intricate detail of the arête on Nevado Jirishanca (6019 metres).

A series of cirques on the north flank of the Glyderau range in Snowdonia, Wales, viewed from Tryfan. The centre left peak is Y Garn (943 metres), and the tarn below is Llyn Idwal. It was in the cirque containing this tarn that Charles Darwin recognized evidence of glaciation for the first time in Wales, in 1842.

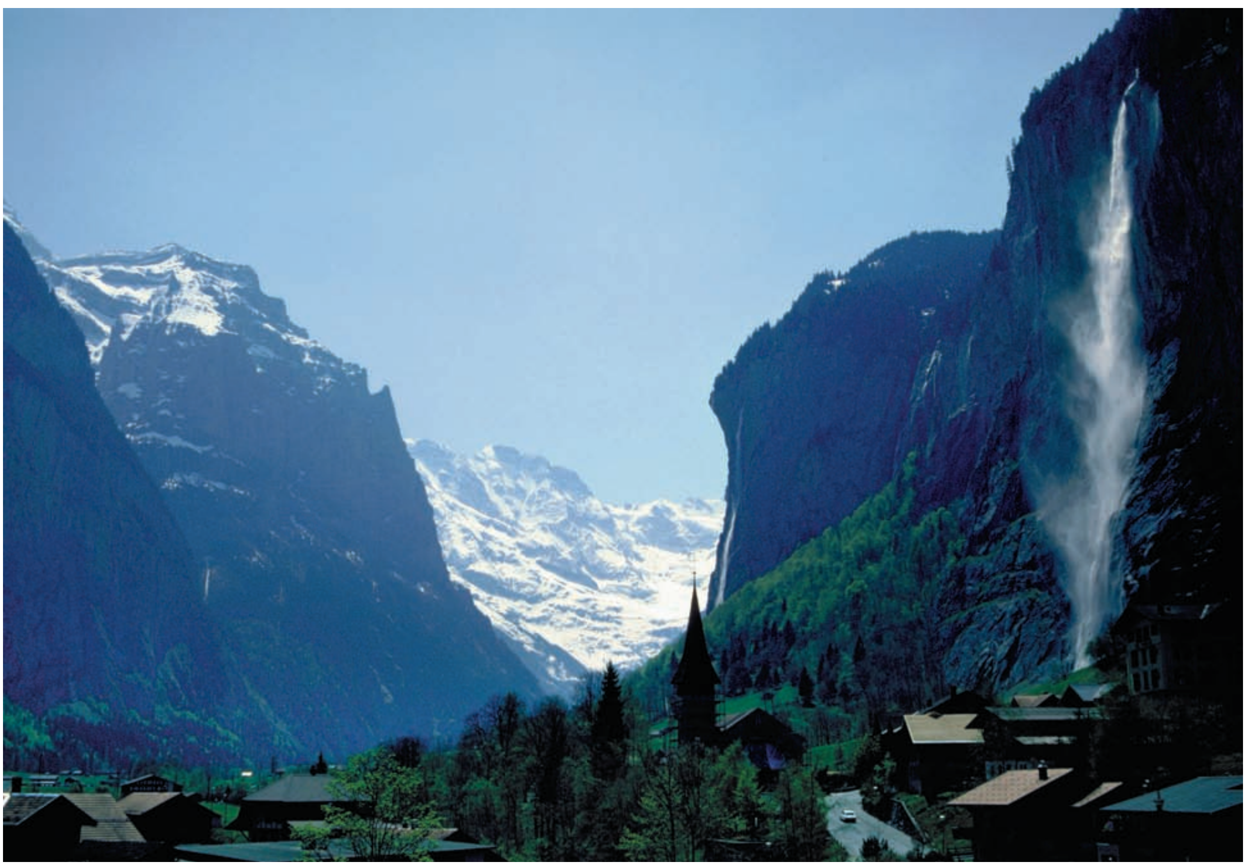
Large-scale features

The larger-scale landforms in mountain regions are the most impressive features of glacial activity, as in the glacial erosional landscapes of the Scottish Highlands, the English Lake District and Snowdonia in Wales; parts of the Rocky Mountains and Sierra Nevada in North America; the Pyrenees, much of Scandinavia, and the Alps in continental Europe; and the Urals and ranges in Siberia and Japan in Asia. In low latitudes, abundant forms occur in the Himalayan and associated mountains, and even near the summits of the highest mountains of Africa and New Guinea. Straddling both hemispheres, the Andes also have large-scale glacial landforms, as do New Zealand's Southern Alps and the Tasmanian highlands in Australia.

Cirques, arêtes and horns

In mountain areas without extreme contrasts of height, rocky hollows can often be found that have been excavated out of the higher parts of the mountains by small glaciers that have eroded

backwards and downwards. These hollows are known internationally as **cirques** (from the French), although terms like **corrie** (Scottish) and **cwm** (Welsh) are also widely used in Britain. Cirques typically measure a few kilometres in length and width, and about half to a third of their length in height. However some, such as the Walcott Cirque in Antarctica, measure tens of kilometres in length. But whether it is a large one, a moderate-sized one like the Western Cwm on Mount Everest, or a small one such as is found in the English Lake District, the length-to-height ratio is much the same. All cirques have a steep, commonly near-vertical headwall, and many have an over-deepened basin containing a small lake or **tarn**. In the steepest alpine terrain, however, headwall and downward erosion has normally not been sufficient to create such lakes and the cirque floors slope outwards.



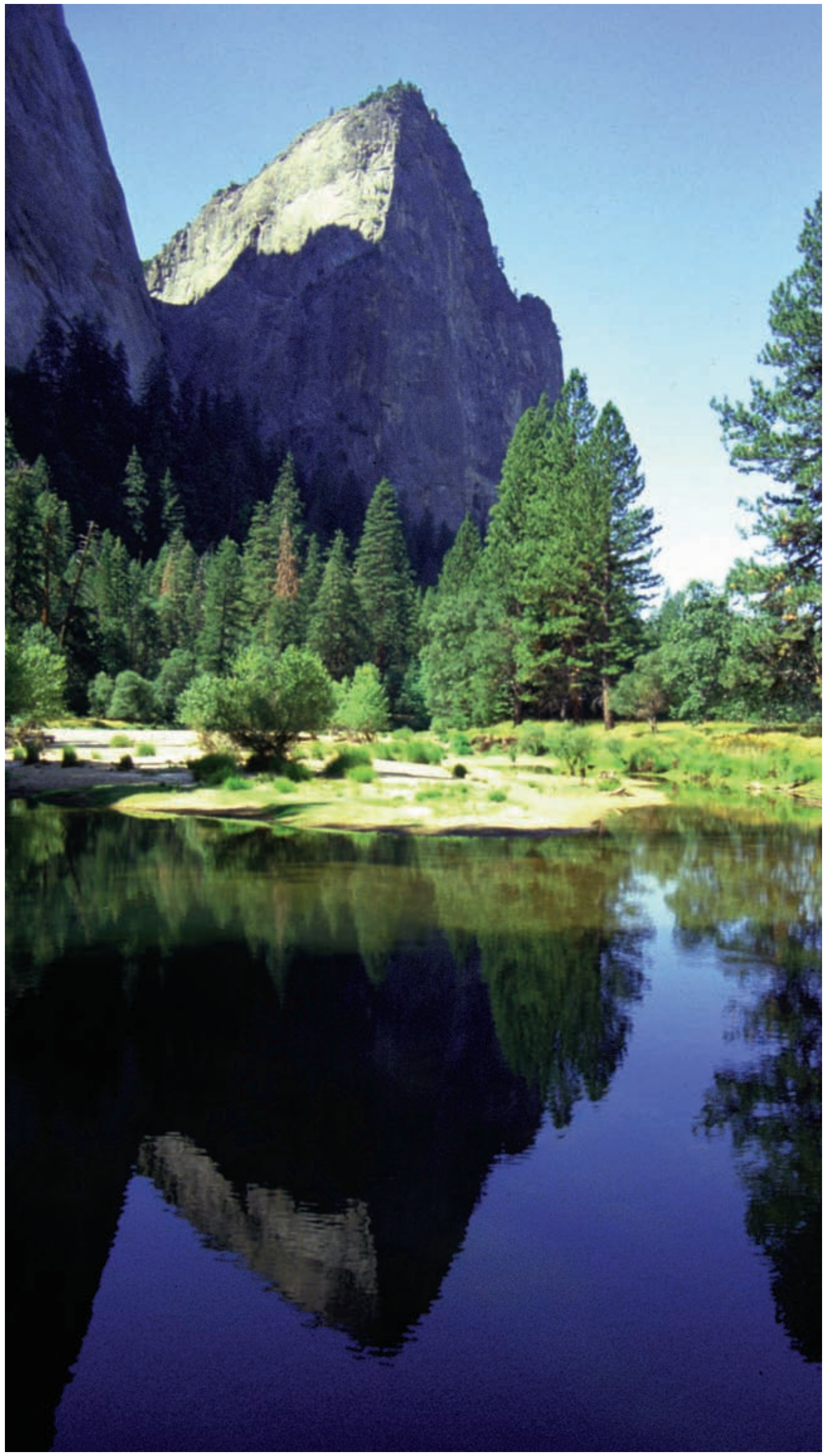
Lauterbrunnental in the Berner Oberland of Switzerland. This valley is often regarded as a typical glaciated valley, in having a near U-shaped form in cross-section. True U-shapes such as this are relatively rare, however. The extremely steep valley sides result in numerous high waterfalls, such as Staubbachfall seen here above the village of Lauterbrunnen.

If cirques on opposite sides of a mountain erode backwards sufficiently they may meet and a steep-sided rock ridge, known as an **arête** (from the French) or **Grat** (German), develops. In Britain arêtes such as Crib Goch in Wales, Striding Edge in the Lake District, Aonach Eagach and the Cuillin Ridge in Scotland provide popular scrambling or climbing routes, and in the Alps or western Cordillera of North America, they provide aesthetically pleasing and challenging routes to the summits. Many of the first ascents of Alpine peaks, such as the Matterhorn and Weisshorn, were made by way of arêtes.

Where three or more cirque glaciers have eroded backwards to the extent that the highest ground is no longer immune from erosion, a sharp, pointed peak or **horn** is produced, with a series of arêtes between each pair of glaciers rising steeply up to the summit. The best known is the Matterhorn on the Swiss-Italian border. Other well-known and well-formed horns are Ama Dablam in Nepal,

Glencoe in the Grampian Highlands of Scotland is one of the finest glaciated valleys in Britain. This view down-valley from 'The Study' illustrates the parabolic curved cross-section that is more typical of glaciated valleys than a U-shape. The crags on the left are known as the Three Sisters, and represent spurs truncated by the valley glacier.

Opposite. Near-vertical walls, eroded by glaciers, are characteristic of some glaciated valleys. El Capitan in Yosemite Valley, California is a wall of granite, and represents one of the most famous climbing grounds in North America.



Glaciated valleys over-deepened below sea level are described as fjords. Spectacular examples, exceeding over 100 kilometres in length, are a feature of the coastline of East Greenland. Kejser Franz Josef Fjord is one of the longest, and is bounded by mountains approaching 2000 metres high, whilst the waters of the fjord are over 1000 metres deep in places.

Opposite. Mitre Peak (1692 metres) is a horn located in the inner reaches of Milford Sound, a popular tourist destination in Fiordland National Park, New Zealand. This view seawards also illustrates a hanging valley to the left of the peak.

Mount Assiniboine in the Canadian Rockies, Mount Aspiring in New Zealand's Southern Alps and K2 in the Karakorum Mountains of Pakistan. In Britain, one of the best examples is Cir Mhor on the Isle of Arran.

Glaciated valleys

Glaciated valleys that were formerly occupied by the principal glaciers descending from the higher mountains have a characteristic form. In cross-section they are often described as U-shaped, but only rarely are their sides truly vertical, and the term 'parabolic' is more appropriate. Lauterbrunnental in the Berner Oberland of Switzerland and the Yosemite Valley in California are excellent examples of valleys that can truly be regarded as U-shaped, the vertical walls providing rock climbers with extremely challenging ascent routes. In contrast, the more typical parabolic form is exemplified by Glencoe

Areal scouring is the product of powerful glacial erosion over relatively wide areas of subdued relief. Irregularities in bedrock structure give rise to the intricate detail of hillocks and lakes in the landscape. This example of areal scouring shows ancient crystalline rocks (with black dykes) in the Vestfold Hills of East Antarctica, looking towards the ice sheet from near the coast.

in the Grampian Highlands of Scotland, as well as by the many other glaciated valleys through the British Isles.

In many glaciated valleys enhanced erosion has created a series of rock basins, filled by lakes that are formed when a tributary glacier joins the main one. Later these lakes will be partly or totally filled with sediment. Many glacial valleys have a stepped longitudinal profile, or a series of rock barriers called **riegels** (a term derived from the German) that extend part or the whole way across the valley.

The level to which a valley glacier has eroded is clearly marked by a change in slope, as well as by the preservation of spurs above the glacier level. Up as far as the erosion level, the side of a glaciated valley normally consists of a single clean sweep, the spurs that would have existed in preglacial times having been truncated. Above the erosion level, the preglacial forms and deeply weathered bedrock may survive. Some tributary glaciers may not have had the erosive

One of the best known glacial meltwater channels in Britain is Newtondale, cut by overflow from ice-dammed Lake Pickering during the last glaciation. It carries a small stream that is out of proportion to the size of the valley. The North York Moors Railway, which uses steam locomotives to carry tourists, follows this route.

power to cut down to the level of the main valley, and hanging valleys result, often with fine waterfalls plunging from them. In other cases, valley glaciers may have spilled over the low saddles or cols of the bounding ridges into another valley, resulting in **breached watersheds**.

Fjords

Fjords are flooded over-deepened glaciated valleys, formed because valley glaciers erode deeply in their middle reaches and, if extending into the sea, to a depth well below sea level. The term 'fjord' is of Norwegian origin (spelt 'fiord' in North America), and it is Norway that has one of the finest fjord coastlines in the world. Almost its entire coast is indented with fjords, the longest and deepest being Sognefjord (200 kilometres long and 1300 metres deep). Many other moderate- to high-latitude countries have fjords too. Those in western Scotland are known as **sea lochs**, but are small by world standards. In contrast, Greenland, where fjords are still being formed, has the world's longest, with the combined Nordvestfjord and Scoresby Sund on the east coast measuring 350 kilometres in length. In the Americas well-developed fjord coastlines occur in southern Alaska, British Columbia and southern Chile, many of them still under the influence of glaciers. The islands of the High-Arctic have many smaller fjords, while on the other side of the world south-western New Zealand has a well-developed fjord coastline as impressive as any, and the Antarctic Peninsula has many fjords that are filled by glaciers. The sub-Antarctic island of South Georgia has numerous short fjords still occupied by glaciers.

Like glaciated valleys, fjords may comprise several rock basins, but the simplest of them are deepest at their heads and become gradually shallower towards the sea. Many fjords have a shallow or even partly exposed sill at their seaward limits, and some have near-vertical rock walls. Like valleys, they have U-shaped or parabolic cross-sections and, with time, they too become filled by sediment. **Hanging valleys** and waterfalls are common features along the flanks of fjords.

Scoured bedrock of low relief

Erratic boulders, such as this north of Zug on the Swiss Plateau transported by the ice age Reussgletscher, were first used by scientists such as Louis Agassiz in the early nineteenth Century to hypothesize that glaciers were once much more extensive.

The vast areas of the gently undulating Canadian Shield, parts of the Baltic Shield and the margins of the Greenland and Antarctic ice sheets contain large-scale glacial erosional landforms of a scenically less dramatic nature. The hard crystalline Precambrian rock that underlies these regions bears evidence of erosion along the structural grain of the bedrock, with long linear erosional forms. In many cases elongated lakes or boggy hollows were eroded out parallel to the bedrock structure. Such areas are regarded as having undergone **areal scouring**. Parts of northwest Scotland show the same landscape attributes, except that the scouring process is incomplete. Here, isolated sandstone peaks stand proud above the heavily scoured ancient crystalline rocks with their little knolls and small lakes; this is called **knock-and-lochan topography**.

Meltwater channels

A variety of channel-like forms, typically tens of kilometres long and a kilometre or two wide, are a feature of glacial landscapes formed towards the end of the last glaciation when meltwater was abundant. Some channels have the typical downhill profile of any normal river valley, and are viewed as **overspill channels**, where glacial lakes have escaped over a low point in a barrier. A good example in Britain is the overspill from former Lake Pickering in Yorkshire. Other meltwater channels have 'up-and-over' profiles that must have formed sub-glacially. In such situations water is under pressure and is able to flow uphill if there is a sufficient head of water. Northern England and Wales are well endowed with such features, but networks and individual channels may be found in almost any glaciated landscape.

Glacial depositional landforms

It is, perhaps, appropriate to start this section with a quotation from the *Bible*, as this underpinned much of the early thinking about how the extensive unconsolidated deposits of Europe were formed.

The lower slopes of Val d'Hèrens in Canton Valais, Switzerland are draped with thick deposits of 'till' – sediment released directly from a glacier. Near the village of Euseigne erosion of the till has left these well-consolidated pinnacles, capped by boulders, through which engineers have driven the main road up the valley.

Till exposed in a roadside quarry above the north shore of Loch Torridon in the Northwest Highlands of Scotland. The texture is clearly visible with large boulders ranging down to clay-size material. The reddish colour is from the ancient sandstones that are a feature of this region.

Towards the end of seven days the waters of the flood came upon the earth. In the year when Noah was six hundred years old, on the seventeenth day of the second month, on that very day, all the springs of the great abyss broke through, the windows of the sky were opened, and rain fell on the earth for forty days and forty nights. . . . More and more the waters increased over the earth until they covered all the high mountains everywhere under heaven. The waters increased and the mountains were covered to a depth of fifteen cubits. Every living creature that moves on the earth perished, birds, cattle, wild animals, all reptiles, and all mankind . . . only Noah and his company in the ark survived

(Genesis 7: 10–12, 20–21, 23).

This was the explanation widely held in the early nineteenth century to explain the distribution over northern Europe of so-called **drift** deposits – unconsolidated sediments which we now know to be of glacial and glaciofluvial origin. At the time controversy raged as to whether or not the *Bible* should be taken literally, and this particularly affected geologists. It was recognized that many large blocks of rock, now called **erratics**, scattered over much of northern Europe had been transported great distances, for example from the

Although the deposits released by a glacier (till) have a wide mixture of particle sizes, meltwater streams rework and sort this sediment, producing sand and gravel. This example of sand at Banc-y-Warren near Cardigan, Wales shows faults that were generated as ice around the deposit melted. Such deposits are a valuable resource for the construction industry.

Glaciers carry large amounts of mud that is also removed by meltwater streams, and then collects in hollows. When it dries out, 'desiccation cracks' form, as here near Kongsvegen in northwest Spitsbergen. The polar bear footprints (about 30 centimetres in diameter) give the scale. We met the culprit about half an hour later.

Scandinavian mountains all the way to Denmark. The influence of glaciers was not then known, and the geologists of the day could only conceive that the blocks were moved during catastrophic floods. Thus Noah's Flood was the widely accepted explanation for these deposits, which were given the name *Diluvium* (the Latin word for flood or deluge).

In fact, the idea that glaciers could be responsible for transporting large boulders was already gaining currency, following the work of Swiss naturalists, notably Louis Agassiz in the Alps in the late eighteenth and early nineteenth centuries, but the widespread acceptance and application of the theory only grew very slowly.

Glacial and meltwater deposits are the components of a wide range of interesting landforms, which, although less dramatic than erosional ones, are nevertheless distinctive features of the environment. The rolling countryside with fertile fields and wooded knolls, so characteristic of the lowlands of central and northern Europe and the northern Mid-West of the USA, are dominated by such features. Yet, although best developed in the lowland areas that once were covered by continental ice sheets, depositional landforms are also present in highland areas where glacial erosion was dominant.

When glaciers advance they push large amounts of debris before them. Then, as they recede, large ridges or moraines of loose debris are left behind. In this example, lateral moraines join with a terminal moraine to enclose a lake in front of Imja Glacier in the Khumbu Himal, Nepal. Rapid recession has exposed a steep unstable inner face that occasionally collapses into the lake, whilst fine sand and silt is caught up in the wind and redeposited elsewhere. The collapse of such moraines is of concern in high mountain regions, because of the potential for lake-outburst floods.

Moraines

The most easily identifiable of depositional landforms are **moraines**, since they are commonly long, sharp-crested ridges or ridge complexes, made up of a mixture of till and other deposits pushed up during glacial advances. In a valley setting, the furthest advance of a glacier is marked by a **terminal moraine**, normally arcuate in form, reflecting the original shape of the glacier snout. Such features usually range from a few to 50 or more metres in height but, because powerful streams normally accompany glacier recession, only remnants may remain. In lowland areas the advances of ice sheets created even larger ridge complexes that can sometimes be traced for hundreds of kilometres, which were breached in places by huge streams issuing from the receding ice. Lakes frequently formed behind these terminal moraine complexes, the Great Lakes of North America and Zürichsee in Switzerland being prominent examples.

Twelve-thousand-year-old hummocky moraines in Coire a' Cheud Cnoic (Corrie of a hundred hills), Glen Torridon, northwest Scotland are amongst the best preserved glacial depositional features in Great Britain. Ice flow was from top right to mid-left. The small white cottage in front of the moraines gives the scale.

The clean white snout of Matanuska Glacier in Alaska contrasts strongly with the grey debris in front of it, most of which was released from the base of the glacier. Remnants of glacier become buried by debris and, as the ice slowly melts, small hollows called kettle holes form, filling with ponds. Vegetation is rapidly taking hold on the mineral-rich sediment in the proglacial area of this glacier and will soon become dense forest.

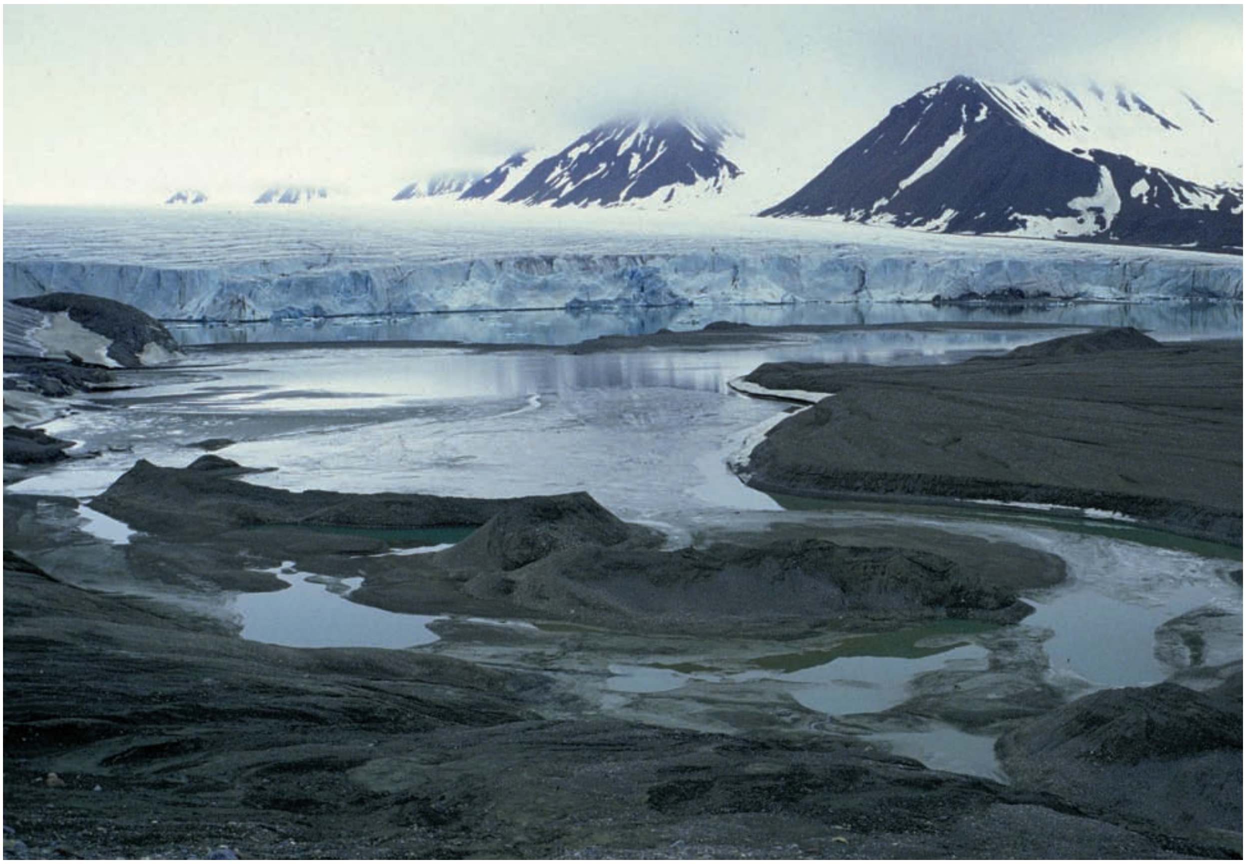
In some areas terminal moraines are not simply dumped at the ice margin, but are the product of deformation (notably thrusting), both at the ice margin and beyond. Propagation of deformation from a glacier into the forefield means that the terminal moraine may actually form a few hundred metres from the ice front.

Lateral moraines are evident along the sides of the valleys, but these have a much poorer chance of surviving; hill-slope movement and subsequent rock-falls combine to obliterate them. However, in areas of recent recession, unstable ridges dating back to the 'Little Ice Age' of around 1650–1850 are still very much in evidence high above the present glacier tongue and down-valley of the glacier's snout. The ridge commonly stands out from the valley sides, creating a so-called **ablation valley**, with its own stream and ponds, between the ridge and the valley side, well above the floor of the main valley. A steep face of bouldery till, held temporarily together by the clay in the deposit, is a feature formed on the glacier-facing side of such moraines, and today rainwater creates a furrowed pattern down them, making scrambling up or down them surprisingly difficult and dangerous. In contrast, the side of the moraine nearer the hillside tends to be well covered, plant growth having been possible even when the ice was in position. Once the ice has gone, these ridges collapse rapidly.

Where a valley opens out, lateral moraines may leave the valley sides and merge with terminal moraines. Between the moraines and the receding ice margin, an assemblage of hillocks and hollows, filled with water, is present. This zone includes **hummocky moraines** that traditionally have been regarded as the product of ice stagnation. Some hummocky moraines show alignment parallel to the ice margin and are the product of active recession and deformation, notably by thrusting, in the ice. Hummocky moraines of fresh-looking appearance are found in those parts of upland Britain that were affected by the last pulse of glaciation about 10 000 years ago. Other examples were associated with the recession of the Laurentide Ice Sheet, with well-known examples associated with the Des Moines lobe in the American Mid-West.

Each of the above types of moraine when first formed may have a core of ice, and the volume of debris may be small; dark wet patches of unstable debris are clear indications of an ice core. These ice-cored moraines may survive for many decades or even centuries, especially in the Polar Regions.

There are other types of moraine up to a few metres high associated with existing glaciers, but they rarely survive for more than a few decades. Small **annual push moraines** may form as a glacier advances a few metres in winter when ablation largely ceases, and a whole series of such parallel ridges may develop if the longer-term trend is one of recession. Sometimes, ice movement across a plain of till may



Meltwater commonly flows in channels beneath glaciers. They cut upwards into the ice, and then may become clogged with fluvial sediment. When the ice recedes an upstanding, sinuous, flat-topped ridge of sand and gravel may be left behind. This example is at the tidewater glacier of Comfortlessbreen in northwest Spitsbergen.

generate **fluted moraine** – long, straight, parallel, smoothly rounded ridges parallel to the ice-flow direction, which may be exposed if the ice front recedes steadily without *in situ* stagnation.

A special set of moraines is associated with surge-type glaciers that periodically advance catastrophically, as described in Chapter 5. Debris may be thrust up from the glacier bed during a surge to form curving ridges a few metres high parallel to the snout. At the end of the surge wholesale stagnation of ice occurs, creating a hummocky and pitted morainic topography on which the thrust ridges have been let down. Discriminating between non-surge and surge-type moraines is, in fact, an important way of assessing whether a particular glacier advance was the result of either climatic change or periodic instability of the ice mass.

If a glacier or ice sheet rides over a plain of till or heaps of moraines, the material becomes quite gooey and is easily moulded into new shapes or eroded. One product of this process is the generation of 'drumlins', streamlined hillocks of till, sometimes draped over bedrock knolls. A drumlin is shaped like an inverted spoon, with the steep slope in the upstream direction, and is orientated parallel to the ice-flow direction. They reach 100 metres or more in length and are up to 50 metres high, often covering large areas in a type of landscape known as basket-of-eggs topography. The Eden Valley of north-west England is a good example, and extensive drumlin fields also occur in New England in the USA and in Northern Ireland.

Although glacial transport is best demonstrated by the above landforms, isolated erratics are also good indicators of the former extent of ice and the directions of flow. Large blocks that fell on a glacier surface, or boulders in the bed of a glacier may end up hundreds of kilometres from their place of origin.

In some cases, moraines may contain valuable minerals, and even if the moraine itself is uneconomic, by reconstructing flow paths back to the source rocks it is possible to locate viable mineral reserves. This method of mineral location has been used most widely in Canada and Finland.

Glacial meltwater as an agent of deposition

Meltwater within, at the side, or beyond the limits of a glacier also creates landforms. Wide fluctuations in discharge between summer and winter create unstable 'braided' stream-channel systems, where the streams modify, sort and redistribute glacial debris creating **outwash plains**, both beyond the terminal moraine system and directly in front of the receding glacier. Such systems normally extend across the entire width of a flat-bottomed valley, as can be seen in some fine examples in New Zealand and Alaska. In lowland areas these plains may be many tens of kilometres wide. They are sometimes known as **sandar** (singular **sandur**), a term from Iceland where they extend along much of the south coast, in the strip of land between the ice cap of Vatnajökull and the sea.

Tasman River with Mount Cook in the background is a typical braided river, in this case emanating from the Mueller and Hooker glaciers to the left and the Tasman Glacier to the right. Braided rivers are characterized by massive variations in discharge, so channel switching is common, and vegetation has difficulty becoming established.

Glacial outwash deposits often bury remnants of dead glacier ice. As the ice slowly melts, steep-sided, water-filled hollows, known as kettles or **kettle holes** (a term of Celtic origin), develop. Beneath the glacier a stream cuts a channel upwards into the ice, and may eventually become choked with debris. As the ice melts, long, narrow ridges of sand and gravel may be left standing above the general level of the outwash plain, in features known as **eskers** (another Celtic term). Varying in height from a few to tens of metres, they wind for hundreds of metres across the landscape. In Finland, which is particularly noted for them, they provide convenient flat-topped ridges on which roads have been built through lake-studded country.

Stream deposits frequently accumulate adjacent to the ice, which are left as isolated hillocks when the ice melts. The term **kame** (an old Scottish word) is used to describe ice-contact meltwater deposits formed in this way parallel to the ice front, and **kame terraces** are formed at the side of a glacier, especially where a tributary stream enters the main valley. As the ice melts, a level, gently sloping platform is left, perched on the hillside. In addition to stream deposits, a kame and kame terrace may also be composed of lake sediments.

Apart from their character as distinctive elements of a glacially influenced landscape, outwash, esker and kame deposits provide much of the sand and gravel needed for road and building construction around the temperate regions of the world, especially in Europe and North America.

Offshore depositional features

Many glaciers and ice sheets during the Ice Age advanced across high- and mid-latitude continental shelves. By using sophisticated geophysical techniques such as seismic profiling and side-scan sonar, scientists have identified many of the same depositional features on the sea floor, much as they occur on land; flutes and moraines are examples. In addition, there are large-scale depositional forms known as **trough-mouth fans**, formed where large amounts of sediment have been delivered to the edge of the continental shelf by ice streams and dumped over the edge. Trough-mouth fans are well-studied off the coast of Norway, on the western edge of the Barents Shelf and in Prydz Bay in Antarctica. Some of them measure more than 100 kilometres across.

Glacial landscapes are the product not just of glacial erosion and deposition, but also of associated processes such as running water, wind and mass movement. It is no wonder then that for the scientist to understand the processes responsible for such landscapes, considerable detailed research is necessary. This chapter thus provides only the briefest of summaries of the components of the glacial landscape.