

GLACIAL LANDFORMS |

Structure

7.1 Introduction	Sediment Transport
Expected Learning Outcomes	Depositional Landforms
7.2 Glacier and its Surface Features	7.7 Periglacial Landforms
7.3 Causes of Glaciation	7.8 Quaternary Glaciation
7.4 Formation of Glaciers	7.9 Summary
7.5 Types of Glaciers	7.10 Activity
On the Basis of Distribution with Respect to	7.11 Terminal Questions
Altitude and Latitude	7.12 References
On the Basis of Temperature Profile	7.13 Further/ Suggested Readings
On the Basis of Presence or Absence of Debris	7.14 Answers
7.6 Glacial landforms	
Movement of Glaciers	
Erosional Landforms	

7.1 INTRODUCTION

You have read about geological work of glaciers in Unit 8 of BGYCT -131 and learnt about types and morphology, erosional processes, glacial transport, deposition and erosional and depositional landforms developed by glacial activities. You know that glacier is a mass of ice and snow that moves under the influence of gravity and results in the creation of erosional and depositional landforms. In Unit 5 you have read about landforms developed by the tectonic and volcanic activities. We have also discussed about river channels, river profiles, river grading and morphometry and some fluvial landforms in Unit 6. In this unit, we will discuss glacier and its surface features, causes of glaciation, formation and types of glaciers, and erosional and depositional landforms developed by glaciers. We will also discuss about significant features of Periglacial landforms and also Quaternary glaciation.

Expected Learning Outcomes

After reading this unit you will be able to:

- ❖ explain causes, formation and types of glaciers;
- ❖ explain the movement of glaciers and sediment transport;
- ❖ describe the erosional and depositional features developed by glacial activities;
- ❖ recognise the main features of Periglacial landforms; and
- ❖ discuss the Quaternary glaciation.

Instruction: You are advised to study **Unit 8 Geological Works of Glaciers and Oceans** of the **Course BGYCT-131** before reading this unit.

7.2 GLACIER AND ITS SURFACE FEATRUES

We know that **glacier** is a mass of ice and snow that moves down the slope of a hill/ mountain or spreads outward on a land surface or continent (Fig. 7.1). According to an estimate, approximately 11% of the Earth's land surface is covered by glaciers and they hold about 75% of the fresh water.

Study of landforms created/ formed by the glacier by way of erosion or deposition of rocks/sediments falls under **glacier geomorphology**, whereas study of the physics / dynamics of glacier snow and ice that change constantly with change in temperature and pressure falls under **glaciology**.



Fig. 7.1: A view of the Durung Drung Glacier, Penzi La, Zaskar, J & K.

You have studied about morphology of glaciers in the Course BGYCT-131 and are now familiar with the terms bergschrund and crevasse. The crevasse or crack is a significant feature on the surface of glacier body which is developed as a consequence of differential movement of the body. The crack or crevasse

in an arc shape developed at the head of glacier body separating the cirques of glacier from the valley walls is known as **bergschrand**. You have also learnt about different types of crevasse, i.e. **longitudinal** (which is more or less parallel to the length of glacier body), **transverse crevasse** (which is more or less transverse to glacier body), and **chevron crevasse** (running more or less in zig-zag form). The crevasse also develops in the front/ snout and on the sides / lateral margins of a glacier, which are known as **radial** and **marginal** crevasse, respectively (Fig. 7.2). **Splaying crevasses** are a pattern of crevasses. They develop when ice flow decelerates downslope and where the glacier bed flattens or rises, and where the valley widens, on the inside of a bend, and at the snout.

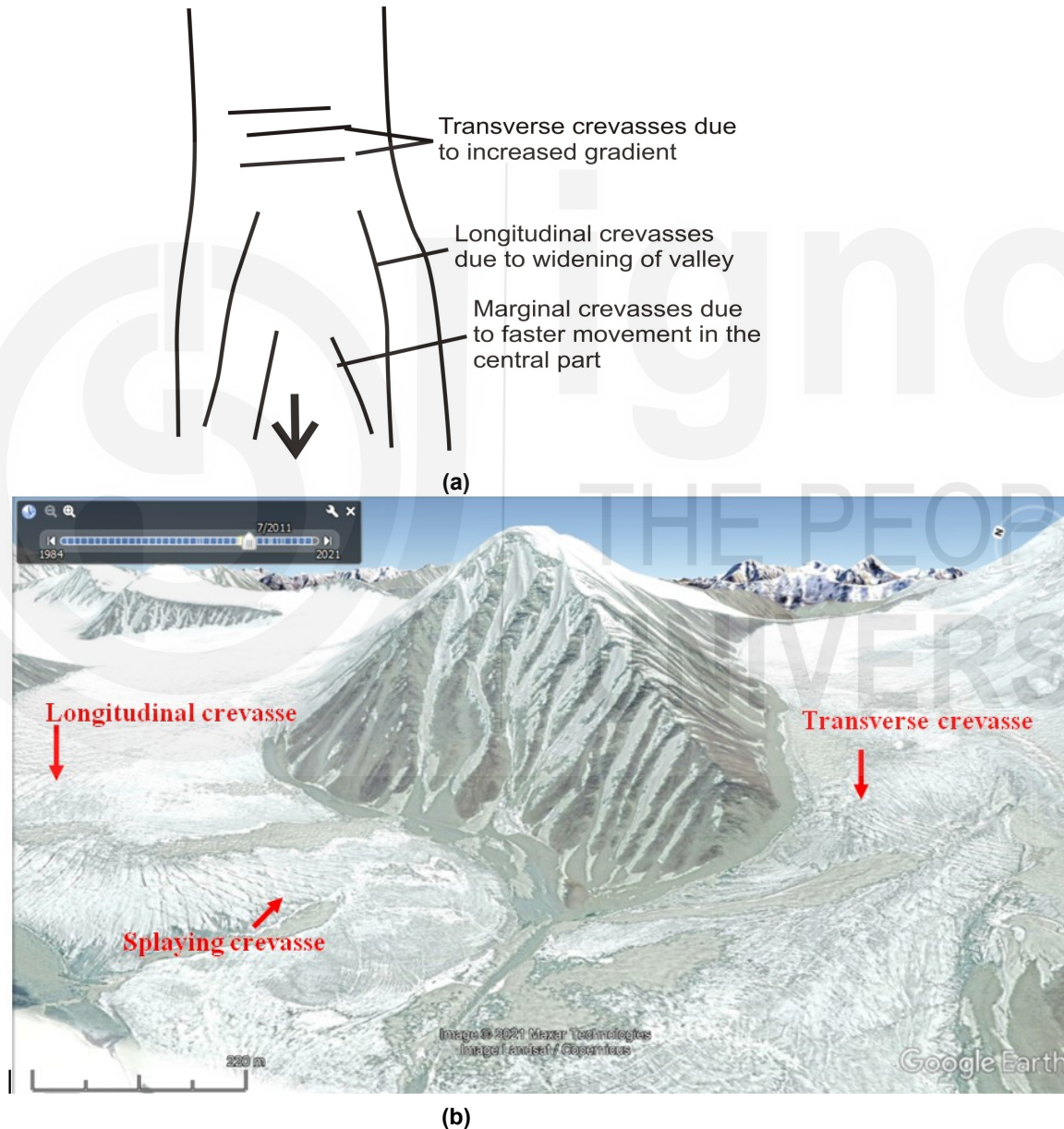


Fig. 7.2: a) Sketch of crevasses; and b) Panoramic view of a glacier valley, Rongdo basin, Eastern Karakoram India. Note the glacial features and landforms annotated with red arrows showing types of crevasses formed on the surface of glaciers due to differential movement. (Courtesy: Anayat Ahmad Quarshi; Source Google Earth Pro July 2017 scene)

The end or terminal part of a glacier body is known as **snout** (Fig. 7.3) which can be of various shapes and sizes. The snout can be broad occupying the entire width of the valley in case of large sized glacier such as Siachen glacier (Fig. 7.3). The snout that resembles an arc convex shape and wide than rest of the body of glacier is termed as **lobe shaped snout**.



(a)



(b)

Fig. 7.3: a) Snout of a glacier in Rongdo basin eastern Karakoram, India. Also seen is development of a glacial lake; and b) Broad snout of Siachen glacier, Nubra Valley, Ladakh, J & K, India

Most of the cases, a cave is formed in the ice/snow in the snout of a glacier and melt water flows out in the form of river, known as **ice cave** (Fig. 7.4). River Ganga is the best example of river (melt water) flowing out of Gaumukh (ice cave) from Gangotri glacier and Durung Drung glacier (Fig. 7.4).



Fig. 7.4: A glacier cave located on Durung Drung Glacier, Zaskar, J & K, India.

7.3 CAUSES OF GLACIATION

The Earth's surface was covered by glaciers in the geological past as compared to the present. The more recent glaciation period ended about 10,000 years ago. The northern part of North America and the high altitude mountain ranges are the regions where the erosional and depositional landform processes of glaciers are noticed.

In order to know the causes of glaciation it is important to study the global climate changes as they are interlinked. Let us discuss the reasons for climate fluctuations and its relation to causes of glaciation.

- Over a long period of variation in climate for tens of millions of years on a particular continent is most possibly caused by drifting of continents. If the continent drifts towards poles it results in glaciation on the continent and conversely if the continent drifts towards equator it becomes warmer.
- Short-term variations such as the atmospheric and astronomical factors also play an important role in controlling the solar radiation reaching the Earth surface that influences the glaciation.
- The fluctuations in output energy sourced from the sun may influence glaciation.
- The large amount of dust released from volcanic eruptions may enhance the atmosphere solar reflectance and result in global cooling due to drop in temperatures.

7.4 FORMATION OF GLACIERS

In the previous section, we have learnt about the causes of glaciation. Let us now study how glaciers form.

Formation of a glacier begins with snowfall. The fresh snow is almost 90 percent air. With subsequent snowfall, the snow overburden builds up and snowflakes are packed up into a grain that becomes coarser and larger. The conversion of snow to glacier ice is dependent on temperature conditions. One

of the necessary conditions for formation of a glacier is that summer temperatures should be low enough to disallow all the snow to melt.

The snow that has survived the summer and is in the process of transforming into solid glacier ice is called **firn**. The firn turns into solid glacier ice through a metamorphic process (compression) wherein interconnecting air passages between grains are completely sealed and air bubbles are compressed. As a consequence firn becomes denser than snow. Due to the overlying weight, the accumulated ice and snow over a period of time, begin to slide/ move down the slope of a mountain or spread outward on the land surface and assumes the name **glacier**. The layers of snow that have changed to glacier ice by compression are distinct alternate of fine-grained and coarse-grained ice.

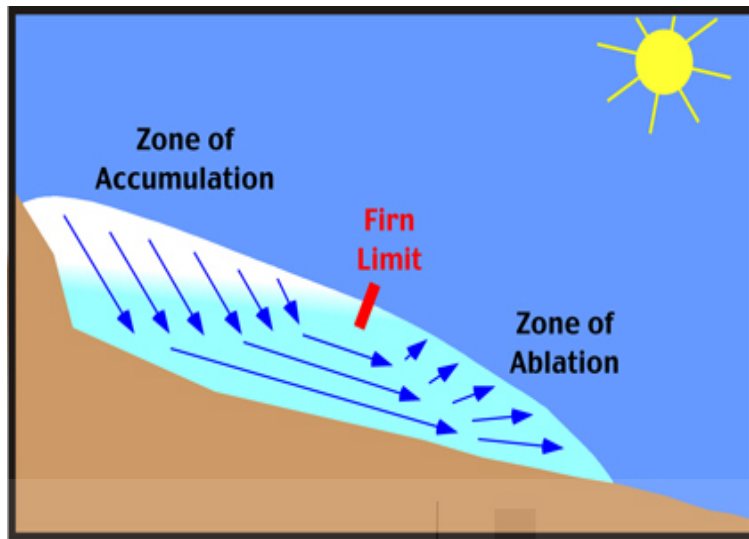
Glacier is formed over a substantial period of time only after the fresh snow gradually converts into ice through **firn/névé**. Firn, the left over snow of last/previous year is partially compacted and re-crystallised to form névé. The regular accumulation of snow on the hill/mountain gradually compresses the underlying bed/ beds of snow. The overload of snow, in the process of compressing the underlying snow bed/s, squeezes out the air trapped within snow and makes it compact to form firn/névé. This process further leads to the diagenesis of underlying snow bed/s causing compaction and crystallisation of the snow, termed as ice.

Ice has a regular crystalline structure consisting of a single oxygen atom covalently bonded to two hydrogen atoms (H-O-H). The ice frozen at atmospheric pressure is approximately 8.3% less dense than liquid water. The density of ice is 0.9167 g/cm^3 and water has a density of 0.9998 g/cm^3 at 0°C .

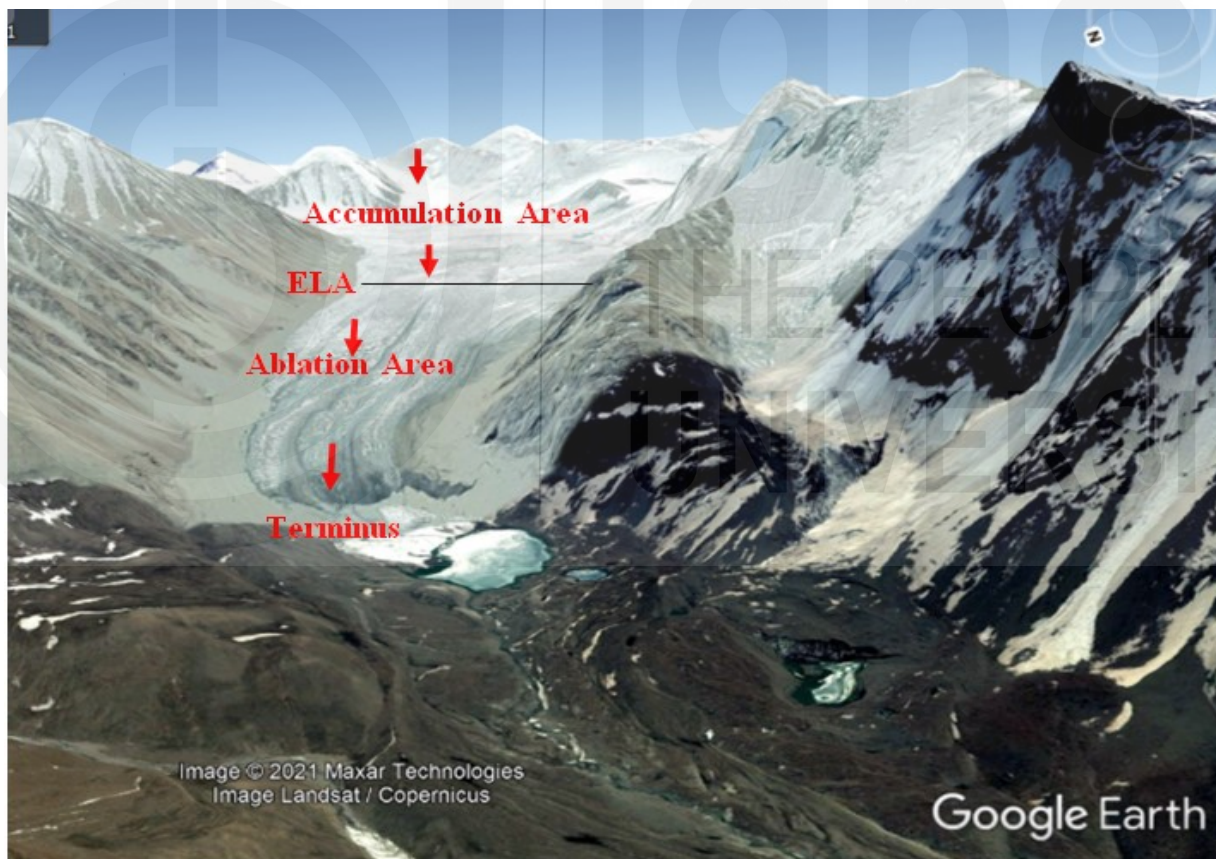
Glacier/ice forms an important part of the water cycle and holds significance in understanding the global climate during the geological history of the Earth. The part of the Earth, that is in frozen form, whether on land or oceans, is collectively called as **cryosphere**. The glacier/ snowpacks are an important source of fresh water for rivers.

The glacier body is divided into two major zones namely, the accumulation zone and the ablation zone. **Accumulation zone** is a part of a glacier body where the snow accumulates to transform into ice, whereas **ablation zone** is the one where snowfall largely is under constant melting (Fig. 7.5). As a consequence, the accumulation grows in thickness/ area and the ablation zone loses thickness/area over a period of time. The increase or decrease in thickness/area of the zones determines health of a glacier. In cases, where the thickness/area of the accumulation zone increases over time, the glacier is said to have attained positive mass balance. This indicates healthy state of the glacier. However, when the accumulation area of a glacier decreases, the glacier is said to have negative mass balance and this indicates the unhealthy state of glaciers. This gaining/losing mass of a glacier can be used as a proxy to understand climatic conditions of a region. The zone that lies between the area of accumulation and ablation, is known as the **equilibrium line** where the glacier body neither gains nor loses thickness/area. The Equilibrium Line is a factor of increase or decrease in the area of accumulation/ablation zones. With increase in the accumulation zone and decrease in the ablation zone, the equilibrium line shifts downwards. With decrease in the accumulation area, the

equilibrium line shifts upwards. The equilibrium line, therefore, is known as **equilibrium line altitude (ELA)** (Fig. 7.5).



(a)



(b)

Fig. 7.5: a) Schematic showing accumulation and ablation zones of a glacier; and b) Panoramic view of a glacier valley in Rongdo basin, Eastern Karakoram India. Different zones and features have been annotated with red arrows. (Courtesy: Anayat Ahmad Quarshi, Source: Google Earth Pro)

7.5 TYPES OF GLACIERS

Glaciers are classified based on various parameters. Let us now learn about different types of glaciers.

7.5.1 On the Basis of Distribution with Respect to Altitude and Latitude

The classification of types of a glacier is based on its distribution with respect to altitude and latitude.

- a) **Alpine or mountain or valley glacier:** The glaciers exist at the altitudes in mountain regions of the world irrespective of the latitudes. These are also known as **Alpine or mountain or valley glaciers** (Fig. 7.6).



Fig. 7.6: View of a valley glacier.

The most commonly occurring glacier of Mountain/Alpine/Valley glacier is the **longitudinal glacier**. This type of glacier occupies, from cirque to snout, the valley in the mountain and is fed by tributary glaciers that are transverse to the longitudinal profile of the valley. The tributary glacier is, therefore, known as a **transverse glacier**.

In some cases, the glacier withdraws completely to higher reaches of the mountain to occupy the troughs and hollows. The remnant of a valley glacier in a degenerated form is known as **niche glacier**. The glacier that may have been the feeding/ tributary glacier of the main glacier in the past and is presently disconnected from valley / main glacier and exists at an elevation higher than main/ valley glacier is known as a **hanging glacier** (Fig. 7.7). The glacier occurring on steep slopes of the valley that spreads out on a relatively flat slope with lobe shaped snout is called **piedmont glacier** (Fig. 7.8).

- b) **Continental or polar glaciers:** The mountain range extensively covered with snow/ice enveloping several peaks can be the source for several glaciers to flow out from the extensive cover of snow and ice known as ice field. The glaciers also exist from vast ice fields that cover large continents

such as Antarctica and Greenland, known as **continental glaciers**. The continental glacier is present at certain latitudes, polar in this case. The continental glacier, therefore, is also known as a **polar glacier**.



Fig. 7.7: Hanging glaciers located in the Chugach Mountains, near Cordova Peak, Chugach National Forest, Alaska. (Source: <https://pubs.usgs.gov/of/2004/1216/glaciertypes/glaciertypes.html>)



Fig. 7.8: A view of a piedmont glacier.

7.5.2 On the Basis of Temperature Profile

The glaciers can also be classified based upon the temperature profile. The glaciers that are presumably cold, meaning that the temperature gradient of a glacier is well below the pressure-melting point, is known as a **cold glacier**. The cold glaciers do not form a thin film of water because of pressure-melting at

the base known as **regelation slip**. As a consequence, there is very little or no movement in cold glaciers because of the dry base of the glacier. On the other hand, the glacier with a wet base, as a result of the presence of regelation slip at the base, is known as a **warm/ temperate glacier**. The warm glacier has movement/slippage.

7.5.3 On the Basis of Presence or Absence of Debris

Glaciers are also classified on the basis of presence or absence of debris on the surface of the glacier body. The glacier that is covered with debris is known as a **dark/dirty/debris-covered glacier** whereas the glacier devoid of any debris on the surface is known as a **clean glacier**. Most of the glaciers in the Himalaya are dirty/dark glaciers.

The snout/front of a glacier in some cases very rapidly advances, due to the rapid transfer of mass (snow/ice) from accumulation to ablation zone, and retreats causing fluctuation in the snout movement within a short duration of time. A glacier with such character is known as a **surge glacier**. A group of surging glaciers is present in Karakoram Himalaya, Ladakh (Fig. 7.9).

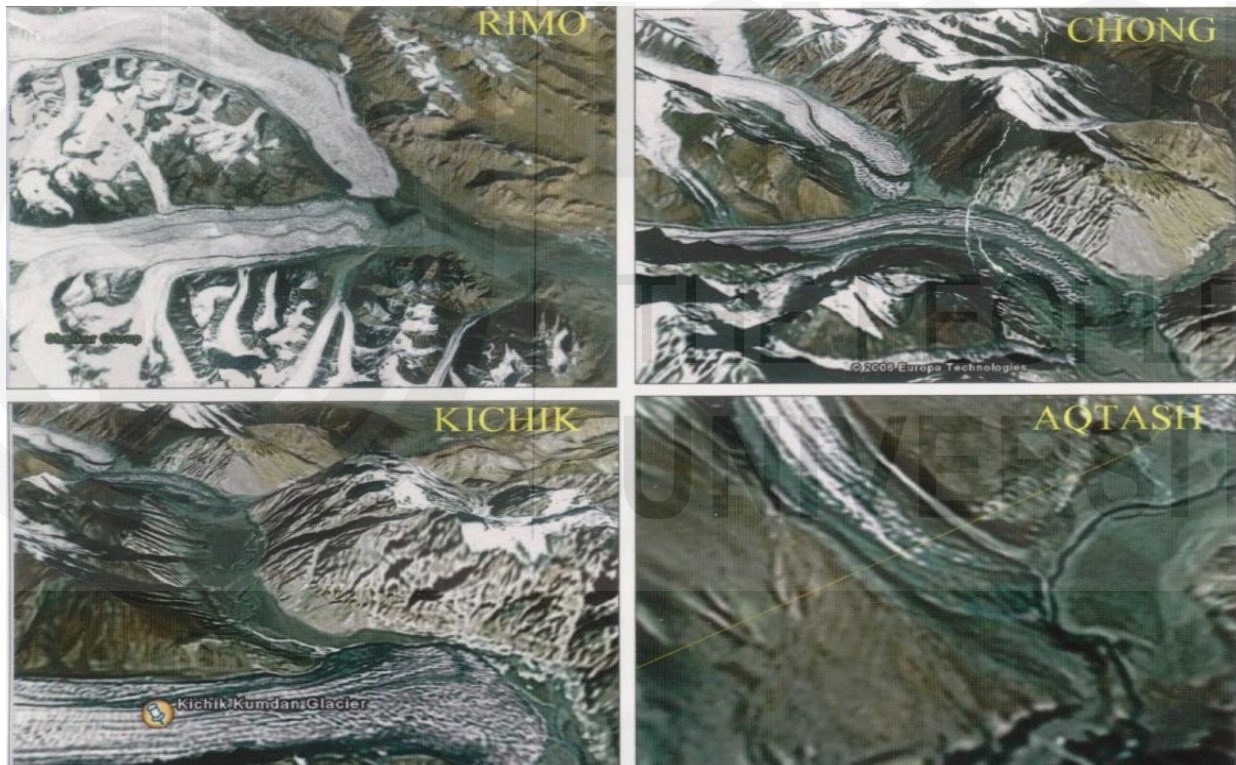


Fig. 7.9: Satellite pictures of the group of surging glaciers (Rimo, Chong, Kichik and Aqtash) in Nubra Valley, Karakorum Himalaya, India. (Source: Google Earth)

The glacier with a snout of much larger width than the glacier body is termed as **expanded foot snout**. The expanded foot snout occupies wide open space available in foot of the valley and is a result of rapid transfer of mass (snow/ice) from accumulation to ablation zone of the glacier. Such type of snout is mostly observed in **surging glacier**. A **narrow or needle shaped snout** is observed in a glacier which is rapidly and constantly advancing.

SAQ 1

- a) Define glacier.
- b) What are the necessary conditions required for the formation of glacier?
- c) Define cryosphere. What are the main sources of fresh water to rivers?
- d) Differentiate between a dirty glacier and a clean glacier.

7.6 EROSIONAL AND DEPOSITIONAL FEATURES

Glaciation activity results in the development of erosional features in the highland areas and the depositional features in the low elevated regions. Let us discuss these erosional and depositional features in some detail.

7.6.1 Movement of Glaciers

Before learning about the erosional landforms, let us first learn about movement of glaciers.

Glaciers move from higher to lower elevation by the action of gravitational force developed by virtue of their own weight. Movement develops due to the activity of one or three processes that act collectively. These processes are:

- 1) **Internal Deformation:** This type of movement occurs both in polar as well as temperate glaciers. It is also known as **creep** that mainly occurs due to the sliding of ice crystals past each other. The upper parts of the glaciers are fragile when the rate of deformation is high in the basal part because of development of high pressure. Thus the upper parts may develop cracks known as **crevasses**.
- 2) **Basal Sliding:** Thin layer of water created at the base of the glacier due to melt water lessens friction by loosening the surface and letting the glacier to move across the surface. This phenomenon doesn't happen in Polar glaciers as the glaciers are normally frozen to the surface and the temperatures are too low to allow the process to occur.
- 3) **Bed Deformation:** This type of deformation is noticed when soft beds or weak rocks are noticed below the glacier that initiates the movement of the glacier.

7.6.2 Erosional Landforms

Erosion by a glacier is mostly done because of the extreme fluctuation in temperature leading to freezing and thawing conditions. The water released, however little, from the melting of glacier enters into the cracks, joints and other weak zones of the rock during the day. It freezes during the night due to a fall in temperature. The frozen water in the cracks/joints expands to act as thaw and opens/ widens the cracks/joints/ weak zones. The phenomenon over a period of time results in weakening of rock along the cracks/joints/weak zones to disintegrate huge blocks due to frost shattering (Fig. 7.10) that are plucked by the moving glacier and transported down.

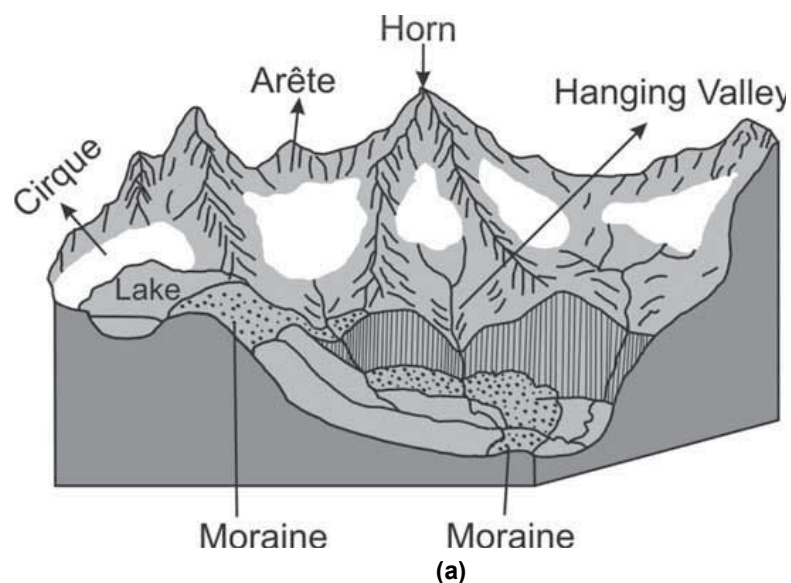


Fig. 7.10: *In situ* breaking of rock due to frost shattering

Let us now learn about erosional landforms.

Cirque, arêtes and horn: As you have learnt in the Course BGYCT-131, the most noticeable erosional landform is cirque. The **cirque** is an amphitheatre like depression at the head of a valley glacier from which the glacier emanates (Fig. 7.11a&b). The depression grows larger in size over time due to the ongoing freezing and thawing process. Deglaciation of cirque results in complete melting of glacier leading to formation of a lake in the cirque called as **tarn-lake**. Sometimes, a series of cirque occur along the longitudinal profile known as **staircase cirques**. The intersection of two adjacent cirques produces a “U” shaped notch called **col**.

The ridge separating the two adjacent cirques is sharp and saw-tooth edged called as **arêtes** (Fig. 7.11a). The triangulated faceted peak developed as a consequence of the erosion by three or more than three adjacent cirques is called a **glacier horn** (Fig. 7.11-13).





(b)

Fig. 7.11: a) Schematic showing some of the erosional landforms in a glacial landscape; and b) A cirque with degenerated glacier remains and arête separating two adjacent cirques.



Fig. 7.12: Photograph showing features of a glacial landscape (such as U shape valley and horn) developed by glacier in the Rongdo basin eastern Karakoram, Ladakh, India. (Courtesy: Anayat Ahmad Quarshi)

Icefall: A ridge-like feature, developed at the head of cirque where the glacier debouches out of the cirque is known as **icefall**. The icefall is formed in response to the underlying topography.



Fig. 7.13: A photograph showing horn.

Striations: The rock fragments and coarse sediments plucked by the glacier from underlying bedrock, while moving down the valley slope, sticks to the bottom or **sole** of the glacier. This material erodes the rock surface over which the glacier moves to leave the marks in the form of grooves and thin fine lines known as **striations**. The striations are conspicuous glacial feature to identify the direction of movement of a glacier in the areas which are free of glaciers present day.

Roche moutonnée: The glacier body in the valley overrides the large rock outcrop. This movement of glacier smoothens the surface of the rock outcrop with the upstream side rounded and polished and the downstream side eroded. The rock outcrops exhibiting this feature are called **roche moutonnée** (Fig. 7.14).

Whaleback and glacier pavement: Constant erosion and polishing of rock outcrop surface by the moving glacier body leads to the development of polished oval-shaped small hillock with length greater than the breadth, called **whaleback**. The polished bedrock surface, without any striations, is produced by the overlying weight of the glacier and is known as **glacier pavement**.

Hanging valley: The main valley of the glacier deepens to the extent that the tributary valley carrying the glacier hangs much above the main valley. Such tributary valley is called **hanging valley** (Fig. 7.11a). There can also be a situation where the tributary valley glacier is situated at a level much lower than the main valley glacier. The tributary valley glacier, in such cases, is generally dry and the main valley is occupied by a glacier. The tributary valley is known as **dry valley**.

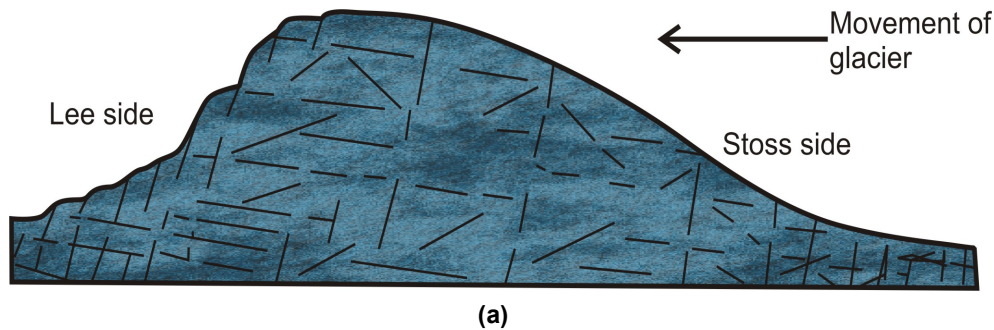


Fig. 7.14: a) Sketch of a Roche moutonnée resembling sheep's back; and b) Roche moutonnée with striation, Machoi Glacier, Zoji La, Dras, J & K. Mr. V.K. Raina, Deputy Director General (Retd.) Geological Survey of India, a renowned glaciologist is seen in the picture.

7.6.3 Sediment Transport

Rock bodies that are eroded by prevailing glaciers ice yield detritus with a varied grain size, ranging from huge boulders to fine grained clay sized particles. The glaciers transport the produced material in thoroughly mixed form to far of distances by carrying them on its surface or by embedding them within it. The sediment transported by a glacier is different from other transporting agents such as water and air. However, certain amount of debris is entrained with the basal ice.

A greater amount of debris is possibly transported by water from underneath wet-base glaciers. Erosion, entrainment and transport form a continuous series that finishes only when the debris reaches to an ending destination.

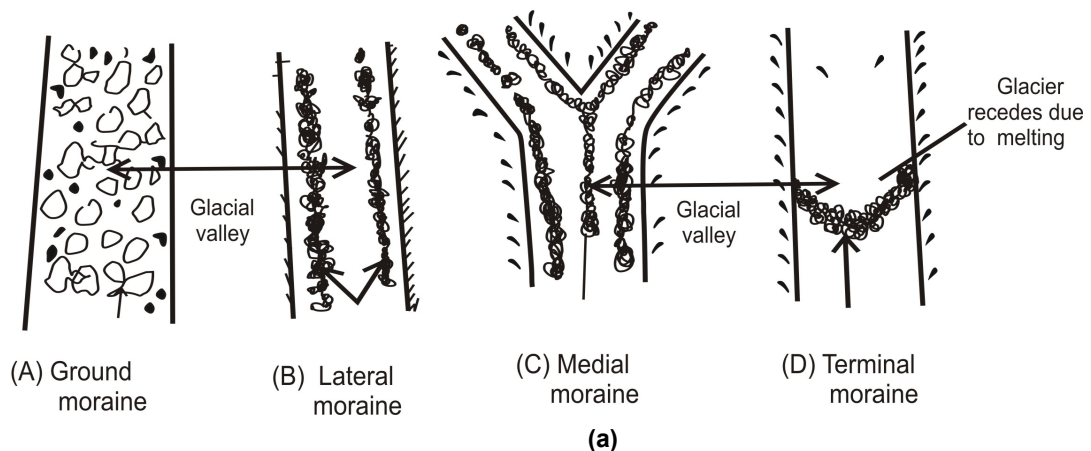
7.6.4 Depositional Landforms

We have learnt that glaciers generate enormous amount of sediments (boulders) due to their erosive power. The sediments or glacial deposit is called drift. These sediments are carried by ice and later deposited by either ice or meltwater or by combination of both. The deposition takes place either in the valley floor (underneath between the bed rock and the ice), or at the sides or at

its terminus. Thickness of the deposits may vary from few meters to hundreds of meters. Glacial deposition develops some forms, about which we shall learn here.

Moraine: The glacier body itself is not a geomorphic agent to deposit the sediments it carries. The rock fragments and sediments eroded and plucked by the glacier are carried on the margins and bottom of the glacier. The glacier body being solid in itself does not carry any sediment and rock fragment within the body of the glacier. The rock fragments and sediment that are carried on the margins of the glacier are called **moraines** (Fig. 7.11a & 14). The one which is along the longitudinal margin is called a **lateral moraine** (Fig. 7.15a). The lateral moraine situated on the left margin of the downstream direction of glacier body is called **left lateral moraine** and the one situated on the right margin is called as **right lateral moraine** (Fig. 7.15a). The moraine that is in front or carried with a snout is called **end or terminal moraine** (Fig. 7.15), and the one which is at the bottom or sole of the glacier is called a **ground moraine**. The glacier in the process of shrinking or retreat gradually leaves behind the moraines along the length of and front of the glacier body. The gradual retreat and shrinking of a glacier can lead to the development of moraines in step-form within the valley, exhibiting the actual extent of a glacier in the past.

The moraines are elongated ridges which comprise assorted sediments either parallel or across the glacier body. Many times the rock fragments and loose sediments as a consequence of rock avalanches in higher reaches accumulate on top of the glacier surface known as **supra-glacial material/sediment**. With complete melting of glacier, the supra-glacial sediment merges with the ground moraine and is sometimes indistinguishable. The thickness of supra-glacial sediment determines the surface melting of a glacier. The thick cover of supra-glacial material/ sediment, also called as **debris-cover**, usually being dark in colour, absorbs solar radiation and transfers heat to surface of the glacier buried under the supra-glacial material/ debris cover. Higher the thickness of supra-glacial material/debris, less is the transfer of heat to the glacier surface leading to less melting of surface of the glacier. Sometimes, two glaciers merge with each other. Due to this merging, the lateral moraines of left and right margins of the two glaciers merge with each other and the moraine thus appears to be trapped within the body of glacier called as **medial moraine** (Fig. 7.15a).





(b)

Fig. 7.15: a) Sketch of types of moraine deposits; and b) Lateral and terminal/end moraine of past glaciations near Leh, Ladakh (J&K). (Courtesy: Anayat Ahmad Quarshi).

Outwash plains: They are planar landforms containing proglacial stream deposits. The outflow of excessive melt water from fast retreating glacier carries with it rock debris and fine sediment in excess. The sediment load (both as a bed and suspended) is deposited downstream of the retreating glacier in the plains known as **outwash plains** (Fig. 7.16). The streams (varying in width from few meters to hundreds of meters) are generally braided because high sediment load coupled with varying discharge and lack of vegetation result in channel instability. These streams continually evolve and may form very extensive outwash plains. Such an extensive outwash plain is called **sandur**. With distance from snout, influence of glacier reduces. Grain size of the sediments also reduces to gravel and sand. Due to sorting and abrasion during transport, roundness of grains increases.

Till: The assorted dumps of sediments deposited by the glacier during the last Ice Age and found in the regions that are presently completely devoid of any glacier are called as **till**. Tills occur as elongated ridges spread over tens or hundreds of kilometres.

Kames or kame terraces: Regions covered with glacial drift are often present as more or less flat-topped, steep-sided and irregular elevations. It is believed that they form due to pouring of sediments by glacial streams from high level or sedimentation between the valley walls and the tongues of glaciers. **Kames** are conical hills of stratified drift up to 50 m high. Many form when a stream deposits sediment in a depression on a glacier's surface; as the ice melts, the deposit is lowered to the land surface. Kames also form in cavities within or beneath stagnant ice. The irregularly formed terraces downstream of snout by

the melt water of glacier is called **kame terrace**. The kame terrace is made up of stratified gravel and sand brought by the melt water.

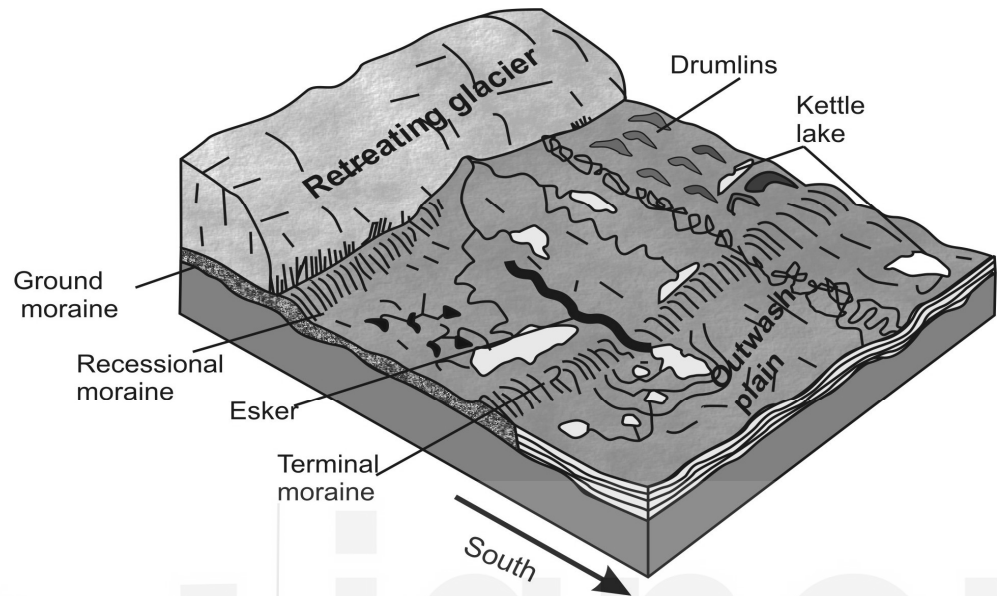


Fig. 7.16: Erosional and depositional features developed by glacier.

Esker and englacial tunnel: The sinuous ridge of elongated stratified sediments exhibiting bedding is called **esker** (Fig. 7.16). Esker is formed within the tunnels developed at the base of the glacier body called as **englacial tunnel**.

Erratic: Erratics are the rock fragments which are carried by a glacier or floating ice and deposited at a distance from the outcrop from where they were derived (Fig. 7.17a). The term *erratic* is used to represent them because their lithology is different from the surrounding rocks and sediments, where they are found. Size of the erratic may vary from few centimeters to tens of meters. These are used as a tool to reconstruct history of dynamics of glaciers and ice flow.

Drumlin: The oval-shaped rounded hill with a longer axis aligned to the glacier flow direction is known as **drumlin** (Fig. 7.16 & 17b). It has a steep or blunt face on upstream and is gentle in the downstream direction of glacier movement.

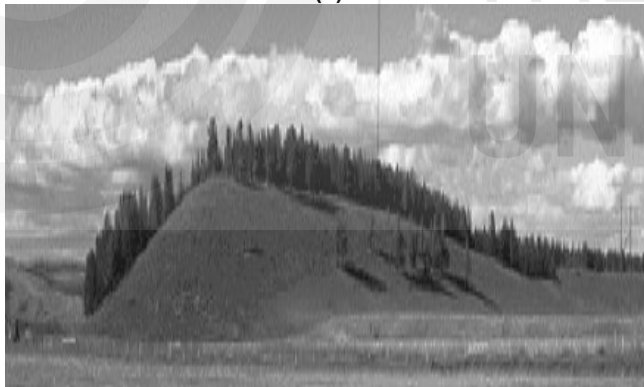
Crevasse-filled ridges: The isolated ridges lying close to or in front of the snout of a glacier comprising assorted sediments with the dominance of gravels and ranging 10 to 15 meters high are called **crevasse-filled ridges**.

Lakes and glacial varves: Various types of lakes are formed in glaciated terrain by one or the other way and are collectively called as **glacier lakes** (Fig. 7.3a). There are depressions left behind after partially-buried ice blocks melt and many of the depressions are filled with water. Such lakes are then called **kettle lakes**. The lake that is formed due to the damming of course of a river/stream by an advancing glacier transverse to the river/stream is called **glacier dammed lake**. Surging glaciers in Shyok valley, Ladakh are the good examples of forming glacier dammed lakes due to surging. Such type of lake can also develop as a result of the blockade, of accumulated melt water in a

depression, by main or tributary glacier. The **moraine-dammed lake** is formed as a result of the blockade of melt water/ river/ stream by a moraine (lateral or terminal) of the retreating glacier. Water of the lake passes under the loose sediments of a moraine.



(a)



(b)

Fig. 7.17: Photographs showing: a) erratic boulders transported by glaciers from the adjacent areas and deposited on granite outcrop on the right bank of Shyok river basin, eastern Karakoram, Ladakh, India; and b) Drumlin.
(Source: for a - Anayat Ahmad Quarshi)

The depression formed on the valley floor, due to scouring by moving glacier, accumulates water from degenerating glacier to give rise to a **sub-glacial trough lake**. The accumulation of water in pre-existing landform, such as cirque, gives rise to **ice scoured trough lake**. The deposition of fine sediments in quiet lake waters in glaciated mountains leads to the finely laminated deposits known as **glacial varve** (Fig. 7.18).

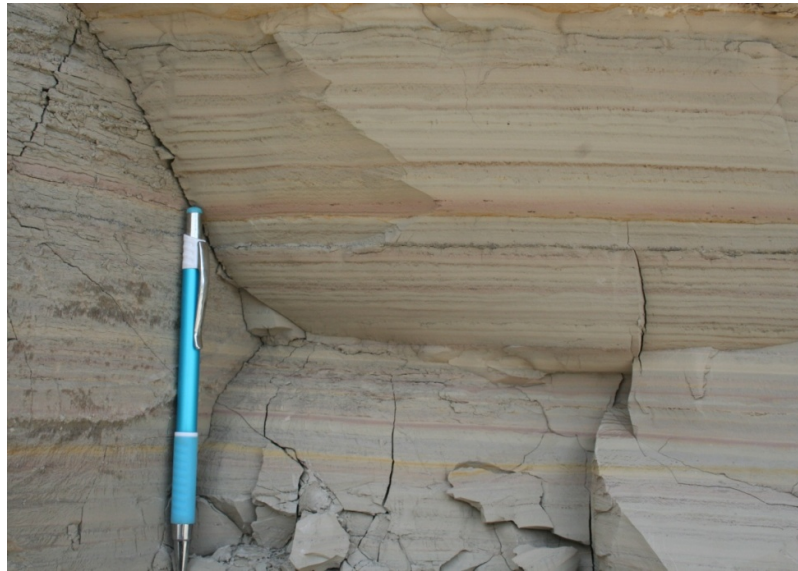


Fig. 7.18: Varve deposits at Leh, Ladakh, J&K, India

7.7 PERIGLACIAL LANDFORMS

We have read about erosional and depositional features formed by glacial process. We will now study periglacial landforms.

The word *periglacial* refers to wide-ranging cold areas with non-glacial settings irrespective of their vicinity to a glacier. It covers regions of high latitudes and below the latitudinal and altitudinal tree lines. Periglacial regions experience intense frost during winter season and without any snowfall during summer months. A wide range of landforms are developed in periglacial environments with the incidence of ice in the soil. Let us discuss the landforms developed in periglacial environments in some detail.

Ice and sand wedges: Ice wedges are vertical masses (V-shaped) of ice that penetrate the ground down up to the permafrost layer. They are generally formed by thaw and freeze in permafrost environment. Sand wedges are formed when thawing accompanied by erosion of an ice wedge results in formation of empty cracks that are filled with sand or loess.

Frost mounds: These are the multifarious landforms formed by freezing water supported with hydraulic or hydrostatic water pressure.

Pingos: Pingos are huge, persistent, generally circular to elliptical in plan and conical shaped ice-cored mounds that are generally formed in certain low-lying fine-grained sedimentary environments (Fig. 7.19). Their height may vary from about 3 to 70 m. While young pingos may vertically grow at the rate of around 20 cm per year, old pingos may take thousands of years to evolve. They are common in central Alaska and coastal Greenland and also in deltaic and estuarine areas in the north of Siberia.

Bugors: They are small mounds that are short-lived and usually occur in the active layer. Active layer is the surface layer that freezes and melts according to seasons.

Palsa and Peat plateaux: Palsas are conical or dome shaped low peat mounds with a height ranging from 1-10m and a diameter of 10-50m. **Peat plateaux** are generally larger in size which are formed by coalescence of palsas.

String bags: They are formed by alterations of thin, string like strips or ridges of peat which may contain ice for certain part of a year.



Fig. 7.19: Sketch of pings occurring in a low lying area.

Thermokarst: Thermokarst is an irregular landscape comprising of hills and depressions when permafrost melts.

Patterned Ground: Patterned ground results when a variety of regular geometric patterns are prominently spread over ground surface in a periglacial zone. The main geometric patterns include circles, polygons, nets, and stripes that may occur in sorted or non-sorted forms.

Periglacial Slopes: Periglacial slopes are slopes similar to the slopes found in other climatic regions. However, they are different from them in certain conditions like frost action, absence of vegetation and covered frozen surface.

7.8 QUATERNARY GLACIATION

The planet Earth since its evolution has experienced glaciations at various intervals. The glaciations varying from continental glaciations to ice caps or Alpine glaciers, have been prominently deciphered from the geological records of the Earth. The glaciation of geologically old time period, pre-Quaternary (>2 Ma), have been the result of geographical positions of various continents at higher palaeo-latitudes. Extensive glaciations, known as Huronian glaciation, occurred during Late Precambrian (~ 2000 to 2500 Ma). Glaciation also occurred during Palaeozoic (570 to 230 Ma) during Permo-Carboniferous time period all across the Gondwana landmass.

The glaciations occurring during geologically younger time period have been a consequence of subsequent drift of continents and mountain building. The development of glaciation of younger time period initiated from late Tertiary. The tectonic uplift of Tibetan Plateau during late Tertiary with building up of

Indian Summer Monsoon (ISM) circulation led to the glaciation in Himalaya. The Antarctic ice sheet development is believed to be during past 5 to 10 Ma (Million Years). The Greenland glaciation is considered to be a result of intensification of glaciation during 3.5 to 3 Ma.

Quaternary glaciation is also called as Pleistocene glaciation and referred to as ice age because of continuous existence of permanent ice sheet. The Quaternary glacial period is a comprehensive cycle of several glacial and interglacial. The glacial cycles represent cold climate conditions that led to the expansion of glaciers, whereas interglacial cycle represents warm climate conditions that affected the glaciers. The number of glacial and interglacial cycles during Quaternary period is debatable. According to isotope stages, the scientists have estimated between 30 and 50 glacial-interglacial cycles during past about 2.5Ma.

The main activities that had been noticed during the Quaternary glaciation period are the land erosion and deposition in larger parts of the continents; changes in the river system; formation of new lakes; sea level changes; isostatic variations in Earth's crust; unusual changes in winds and occurrence of floods.

We will now study in brief about glaciation in the Himalaya.

Glaciation in the Himalaya

We know that the Himalaya mountain chain formed due to northward movement of Indian plate and its collision with the Eurasian plate. The Tethys sea existing between the two continental plates was narrowed with the movement of the plates around 30 million years ago. Wedging of Indian plate under Tibet began around 20Ma. It resulted in formation of Tibetan Plateau about 8Ma. The climate became cold and arid and subsequently the current strong monsoon system came into existence. Further wedging resulted in two huge thrust movements i.e. Main Central Thrust (MCT) and later Main Boundary Fault (MBF) in south of the MCT. The later is still continuing. Siwaliks, the lowest and southernmost range of hills formed from the sediments eroded from the northern ranges deposited and later these deposited sediments were folded and uplifted. During Pleistocene extensive glaciation happened when mountains were being formed and drainage systems getting established. So, the Himalayan glaciation is linked to erosion of the mountain slopes, formation of the drainage system and transportation of the enormous quantities of sediments eroded. Due to the geological history, there are variations in the lithology, structures, relief and slopes of the mountains and also in the amount and period of precipitation received. Due to combination of these factors, nature of glaciers at different regions within the Himalaya is varying. As indicated by the glacial geomorphological features, glaciers were much larger during the Pleistocene. According to a study, length of majority of the current Himalayan glaciers range between 1 and 5 km and concentrations of glaciers tend to occur near the higher parts of the Himalaya. However, there are several valley glaciers, which are longer than 50 km such as Siachen (72 km) and Biafo (62 km) glaciers.

SAQ 2

- a) The process of deglaciation of cirque that results in complete melting of the glacier and formation of lake in the cirque is known as _____.
- b) The polished bedrock surface, without any striations, is produced by the _____ weight of glacier is called as _____.
- c) The moraine that is found at the edge of a glacier is known as _____ moraine.
- d) The type of movement that occurs both in polar as well as temperate glaciers is termed as _____.
- e) _____ are the V-shaped vertical masses of ice that penetrate the ground down up to the permafrost layer.

7.9 SUMMARY

Let us sum up what we have learnt in this unit. We have learnt that:

- The Earth's surface was covered by glaciers in the past as compared to the present and glaciation period ended about 10,000 years ago. The causes of glaciation can be identified by studying the climatic fluctuations.
- The formation of glacier begins with the successive snow falls and the snow overburden builds up resulting in the formation of glaciers. The conversion of snow to glacier depends on temperature where summer temperatures must be low such that the snow does not melt.
- The classification of types of glacier is based on the distribution with respect to altitude and latitude. The glaciers that exist at the altitudes of mountain regions are known as Alpine or mountain or valley glaciers. And the glaciers that exist covering large continents are known as continental glaciers.
- Glacial activity results in the formation of erosional features in the highland areas and depositional features in the low elevated regions. The glacial erosion mostly occurs because of the extreme fluctuation in temperature and results in the formation of erosional landforms. The excessive melt water from retreating glacier helps in the formation of depositional landforms.
- Glaciers move from higher to lower elevation by virtue of gravitational force. The glacier movement takes place by one or three process that act collectively. They are i) internal deformation ii) basal Sliding iii) bed deformation.
- The sediment transported by a glacier is different from other transporting agents such as water and air. A greater amount of debris is possibly transported by water from underneath wet-base of glaciers. Erosion, entrainment and transport form a continuous series that ends when the debris reaches to an absolute destination.
- Periglacial covers regions of high latitudes and below the latitudinal and altitudinal tree lines and experience intense frost during winter and with no

snowfall during summer period. Wide-ranging landforms are developed in periglacial settings with the prevalence of ice in the soil.

- The glaciations varying from continental glaciations to Alpine glaciers had been prominently noticed from the geological records. Quaternary glaciation is also known as Pleistocene glaciation is referred as a period of comprehensive cycle of several glacial and interglacial conditions.

7.10 ACTIVITY

- 1) Refer to the Fig. 7.20, then mark and label the regions covered with Alpine and continental glaciers in the below given world map.
- 2) Learners residing in high altitude areas can visit nearby areas and try to identify glacial landforms and make a list of them. Those living in other areas may try to find out if there is any rock record in their areas showing glaciation event in geological past.



Fig. 7.20: A blank map of the world

7.11 TERMINAL QUESTIONS

- a) Briefly discuss the causes of glaciation.
- b) Explain the formation of glaciers.
- c) Describe erosional landforms with neat diagrams
- d) How are Periglacial landforms developed? Elucidate any two landforms.

7.12 REFERENCES

- Hugget, R. J. (2006). Fundamentals of Geomorphology. 2nd Edition. Taylor and Francis, Delhi. 458p.

- <https://www.tutor2u.net/geography/reference/glacial-landscapes-periglacial-landforms>

7.13 FURTHER/SUGGESTED READINGS

- Raina, V.K. and Srivastava, D. (2008) Glacier Atlas of India, Geological Society of India, Bangalore.
- Nesje, A. and Dahl, S.O. (2000) Glaciers and Environmental Changes, Oxford University Press, New York.
- Singh, S. (1999) Geomorphology, Prayag Pustak Bhawan, Allahabad.

7.14 ANSWERS

Self Assessment Questions 1

- a) Glacier is known as a mass of ice and snow that moves down the slope of a hill/ mountain or spreads outward on a land surface or continent.
- b) The necessary conditions required for the formation of glacier is that summer temperatures should be low enough to prohibit snow to melt.
- c) The part of earth, that is in frozen form, whether on land or oceans, is collectively called as cryosphere. The main sources of fresh water to rivers are the glacier/ snowpacks.
- d) The glacier that is covered with debris is known as dark/dirty / debris-covered glacier whereas the glacier devoid of any debris on the surface is known as clean glacier.

Self Assessment Questions 2

- a) Tarn-lake
- b) Overlying; glacier pavement
- c) End or terminal
- d) Internal deformation
- e) Ice wedges

Terminal Questions

- 1) Refer to section 7.3.
- 2) Refer to section 7.4.
- 3) Refer to subsection 7.6.2.
- 4) Refer to section 7.8.