

E-content module

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Unit-3

3.3 Glaciers:Types; Erosional and Depositional Features Produced By Glaciers. Glaciation Through Geological Ages.

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What are Glaciers?

A slow moving mass of ice in high mountain valleys and in colder Polar regions is called Glacier. To form glacier, ice must be at least six hundreds of a square mile in size and more than 164 feet in thickness. Glaciers develop in regions where a lot of snow falls during winter than it melts in summer. The extremely low temperatures in these regions allow huge amounts of snow to pile up and transform into ice.

Ice sheet

An ice sheet is a big, uncontrolled ice mass that flows downhill in all direction. These ice sheets are enormous continental masses of glacial ice and snow expanding over 50,000 sq. km. These are found now only in Antarctica and Greenland, The ice sheet on Antarctica is over 4.7 km thick in some areas, covering nearly all of the land features.

Ice-cap

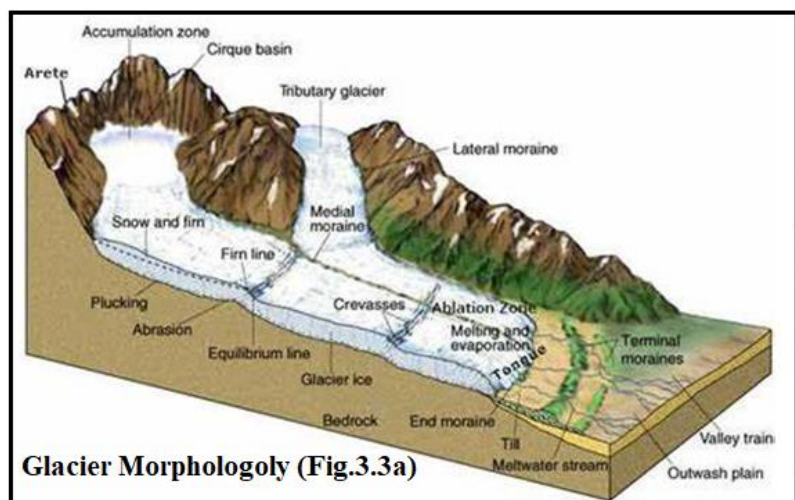
An ice-cap is a domed shaped, unrestricted glacial mass which is capable of flowing in any direction. It can cover up an entire island or mountain range. In dimension it is smaller than ice-sheet and when area goes beyond 50,000 square kms, it becomes an ice sheet.

The movement of glacier is caused by gravity when weight of the overlying layers of ice and snow push down on the lower layers of the **glacier**. This weight also **causes** grains of ice to partially melt and refreeze. Morphology of glacier is shown in **Fig.3.3a**.

On the basis of their stage of development, size, shape and the relationship between the supply and flow areas, glaciers have been distinguished in different types, these are as:

Alpine glaciers

They are bowl shaped and form high up in the mountains and look like mountain ranges. The largest mountain glaciers are found in Arctic Canada, Alaska, the Andes in South America, and the Himalaya in Asia.



Valley glaciers/ Mountain type glaciers

These are large alpine glaciers that are confined to steep-walled pre-existing valleys in mountain areas and are fed by snow fields. They carry along rock debris they accumulate on the way or those that fall into them. The downhill movement of valley glaciers causes massive erosion, shaping the valley in U shape. Valley glaciers differ in their characteristics and are further distinguished as i) simple glaciers, which are isolated glaciers consisting of simple flow without any tributaries. ii) Complex or polysynthetic glaciers, contains of a number of coalescing glaciers resembling with river tributaries.

Piedmont Glacier

These are also known as Intermediate type of glaciers. They are intermediate in form as well as origin between the valley glacier and the continental ice-sheets. A piedmont glacier comes about when a huge Alpine glacier slides to the bottom of the mountain range. While at the bottom of the mountain range, it can spread to become bigger than its valley source. Several glaciers unite at the base of a mountain range forming an extensive and comparatively thick sheet of ice covering the low-lying ground. Such an ice sheet is called a piedmont glacier. The Malaspina glacier of Alaska is the best known example of piedmont glaciers. These glaciers are much larger in dimension than the valley glaciers. Their rate of movement is quite slow. They are also called plateau glaciers that combine the characteristics of both continental ice-sheets and valley glaciers. Such glaciers are common in Scandinavia (Norway).

Cirque glacier

A Cirque is an amphitheatre-like valley carved out by glacial erosion. These accumulate the ice and forms the Cirque glaciers. They are bowl in shape on the mountain. The majority of Cirque glaciers are relatively small, less than one km across. As they fall downhill, they mix up with other glaciers to become a broader valley glacier.

Continental ice-sheets

These are the largest forms of accumulation of ice covering large areas of the landmass including cliffs of mountains. These glaciers are of enormous size and immensely thick ice-sheet may reach even thousands of metres. The surface of the ice-sheets has a plain-convex shape which is not controlled by the bottom relief. The movement of the ice in ice sheet is in many directions from points of high pressure within the ice-sheet towards the margin. The movement is very

slow which takes place at the bottom, while the top of the ice-sheet remains almost stationary.

Glaciers of the continental type are formed in polar regions and are located almost at sea-level. At present, the Antarctica ice-sheet is the biggest continental type of glacier covers 13 million square kilometres. In Greenland the ice-sheet covers almost the whole of the continent. The complete ice-sheet does not reach the sea. The ice which enters the sea tends to float upon the water and its marginal part is buoyed up. It is easily broken by the waves giving rise to separated ice-mass which is known as **Icebergs**. These icebergs are large pieces of ice floating on the sea.

Erosion by Glacier

This movement of the glaciers causes erosion on the land underlying the glacier known as glacial erosion. It causes curving and shaping of the land beneath a moving glacier. Glaciated **valleys** are formed when a **glacier** travels across and down a slope, carving the **valley** by the action of scouring. There are two main types of glacial erosion:

1) Abrasion

The glacial ice carries with them rock material of different sizes which rubs the floor and sides of valley rocks like sand paper. The glacier rubs the rock, leaving behind long scratches that form in the direction of the glacial movement called glacial **Striations**. The occurrence of these scratch marks is a positive indication that a glacier once covered the land.

2) Plucking

This is defined as the erosion and transport of large chunks of rocks. As the glacier moves over the land, water melts below the glacier and seeps into the cracks within the underlying bedrock. This water freezes and melts causing the weakening of rock and breaks it in to pieces. The resulting pieces of rocks then become ready to get plucked from their rocky base and easily get carried alongside the moving glacier. Plucking removes rocks and changes the landscap,

Crevasses : Crevasses are the deep cracks, or fractures, found in an ice sheet or glacier. These crevasses results by the movement of glaciers. When two semi-rigid pieces of ice above a plastic substrate have different rates of movement generates shear stress. The crevasses have vertical or near-vertical walls, which can then melt and create seracs, arches, and other ice formations. Crevasse size often depends upon the amount of liquid water present in the glacier. A crevasse

may be as deep as 40 metres, as wide as 20 metres, and up to several hundred metres long (Fig.3.3b).

Types of crevasses

i). Longitudinal crevasses form parallel to flow, where the glacier width is expanding. They develop in areas of valley widens or bends. They are typically concave down and form an angle greater than 45° with the margin.



Crevasses (Fig.3.3b)

ii). Splashing crevasses result from shear stress from the margin of the glacier and longitudinal compressing stress from lateral extension. They extend from the glacier's margin and are concave up with respect to glacier flow, making an angle less than 45° with the margin.

iii). Transverse crevasses are the most common crevasse type. They form in a zone of longitudinal extension where the principal stresses are parallel to the direction of glacier flow. These crevasses stretch across the glacier transverse to the flow direction, or cross-glacier. They generally form where a valley becomes steeper.

Erosional Features of Glacier

1. Cirque

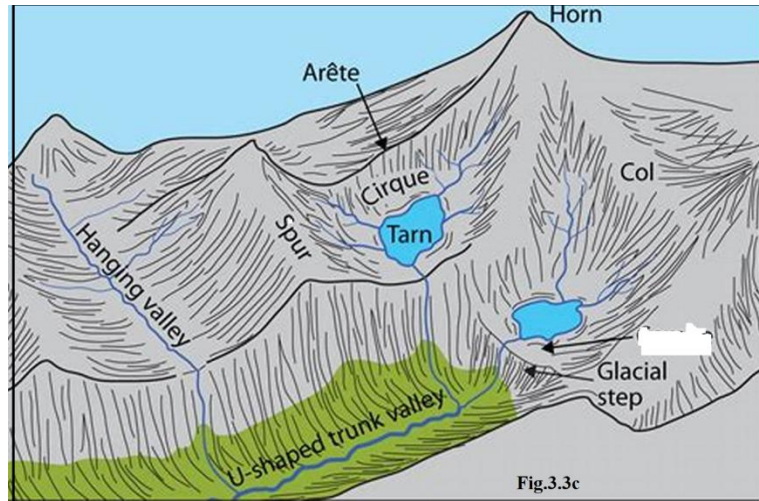
A cirque, also known as a corrie, is a valley created by the glacial erosion. The shape of such valley is like an amphitheater and looks like a large cup from above. The floor of the valley is like a bowl and is a place where large amounts of debris and rock particles are deposited.

2. Cirque Stairway

These are series of cirques arranged one above the other at different elevations. Germany's Black Forest has the best-known example of cirque stairway.

3. U-shaped valleys, trough valleys/ glacial troughs:

These are formed by the process of glaciation and are characteristic of mountain glaciation (**Fig.3.3c**). They have U shape, with steep, straight sides and a flat or rounded bottom. Glaciated valleys are formed when a glacier travels across and down a slope, carving the valley by the action of scouring. When the ice recedes, the valley have with small boulders that were transported within the ice, called glacial till or glacial erratic. U-shaped valley is in Leh valley, Ladakh, NW Indian Himalaya. The glacier is visible at the head of the valley which is the last remnants of the extensive valley glacier which carved this valley.



4. Hanging Valley

These valleys have a broad, flattened bottom and steep sides (**Fig.3.3c**). The glaciers that are tributary to the main glacier most of the time carve out V-shaped valleys. When the main and the tributary glaciers flow at the same level, the shallower valleys created by the tributary glacier hang above the valley carved out by the main glacier. This feature is known as hanging valley.

5. Fjord

A fjord is a long, narrow inlet with steep sides or cliffs, created by a glacier. When glaciers are formed in pre- U shaped valleys of the glacier, it over deepened U-shaped valley that ends abruptly at a valley or trough end. Such valleys are fjords when flooded by the ocean. Most fjords are deeper than the adjacent sea. There are many fjords on the coasts of Alaska, Antarctica, British Columbia, Chile, Denmark and Greenland.

Examples of U-valleys are found in mountainous regions like the Andes, Alps, Ladakh (Leh) in Himalaya, Rocky Mountains and New Zealand.

6. Arête

This is a narrow ridge between two valleys. Glacial movements often erode two parallel U-shaped valleys or two glacial cirques headwords resulting in a ridge in between them. This is known as an arête (**Fig.3.3c**).

7. Glacial Striations

The glacier carries sand grains and rock particles with them which scratches the bedrock when the glacier moves leaves stains or striations which are parallel to sub-parallel marking, gouges and scratches. After the glacier has receded, these marks on the bedrock become visible.

8. Glacial Horn/Pyramidal Peak

When more than one glacier divulge from a common point by eroding cirques, a sharply pointed and angular ridge appears between the cirques. This is known as the glacial Horn (**Fig.3.3c**). A pyramidal peak, is an **angular, sharply pointed mountain peak** which results from the cirque erosion due to multiple glaciers diverging from a central point.

9. Nunatak:

When glacier recedes by the melting a rocky outcrop becomes apparent in the ice field or a jagged and angular structure made of rock and surrounded by glaciers becomes visible (**Fig.3.3d**). This is called a Nunatak. Since this landform has no flat surface, ice does not accumulate on it, which makes them easily identifiable. A good example of the pyramidal peak is Queen Louise Land of Greenland.



Nunatak (fig.3.3d)

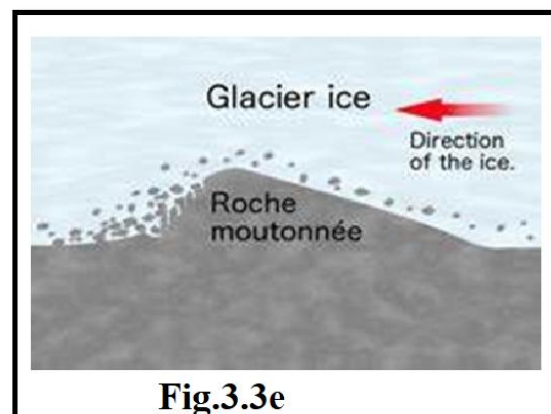


Fig.3.3e

10. Rôche Moutonnée

It is also known as the sheep rock, a *rôche Moutonnée* is formed due to glacial movement on the bedrock. It creates a rounded knob shaped mountain with a gentle upstream slope with polished and striated surface. The downward slope is jagged, steep and has an irregular surface. It is also an outcome of glacial scouring. The ridge between these two slopes remains perpendicular to the direction of glacial movement (**Fig.3.3e**)

10. Trim Line

When a glacier moves over a terrain, it leaves debris and sands on the bedrock, which makes the land less fertile or poorly vegetated. The land opposite this terrain becomes more vegetated, and a line appears between these two landforms as a distinguishing mark. This is known as the trim line. One side of the line has more vegetation than the other side of it, and thus, the line is often very distinct and recognizable.

Depositional Features of Glaciers

Glaciers deposited their sediment when they melt. They drop and leave behind material that was frozen in their ice. These deposits are mixture of particles and rocks of different size and angular in shape called glacial till.

Aqueo-glacial **deposits** are formed inside and along the periphery of glaciers from **sorted** moraines material that has been re-deposited by melt-waters.

1. Outwash Fan

When the braided streams of a flowing glacier deposit sediments on a flat plain, the large quantities of water that flowed from the melting ice deposited various kinds of materials, the most important of which is called glacial outwash. They consist of layers of sand and other fine sediments, which are especially good for agriculture.

2. Kame deposits

A kame is a glacial landform, an irregularly shaped hill or mound. It is composed of sand, gravel and till that accumulates in a depression on a retreating glacier, Kames are formed by melt-water which deposited more or less washed material at irregular places in and along melting ice. At places the *material* is very well washed and stratified; at others it is more poorly washed,

with inclusions of till masses. Kame gravels tend to be variable and range from fine to coarse grained and even to cobble and boulder.

3. Kame Terrace

A kame terrace is formed when the glaciers deposit sediments on the sides of a glacial valley. These are flat-topped mound or hil(**Fig.3.3f**) composed of sorted sand and gravel deposited by melt-water in a former glacial lake. These are frequently found along the side of a glacial valley and are stratified deposits of melt-water streams flowing between the ice and the adjacent valley side. These kame terraces tend to look like long, flat benches, with many pits on the surface made by kettles.

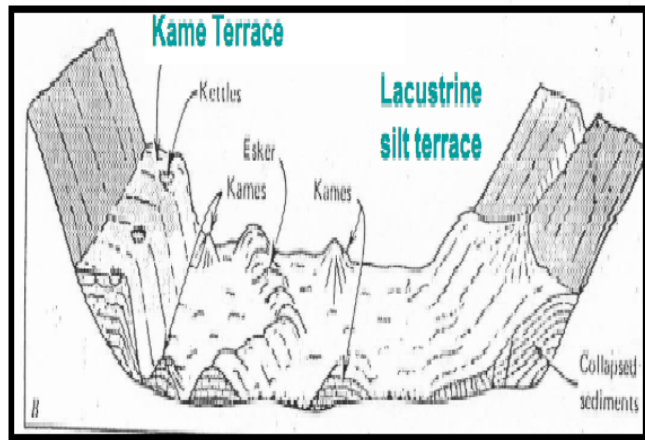


Fig.3.3f

4. Drumlins

Drumlins are elongated hills of glacial deposits that can be 1 to 2 km long, less than 50 m high and between 300 to 600 metres wide (**Fig.3.3g**). The long axis of the drumlin indicates the direction in which the glacier was moving. The drumlin are deposited when the glacier became overloaded with sediment. Drumlins occur in various shapes and sizes, including symmetrical, spindle, parabolic forms, and transverse asymmetrical forms; their long axis is parallel to the direction of movement of the formative flow at the time of formation. Drumlins may comprise layers of clay, silt, sand, gravel and boulders in various proportions.

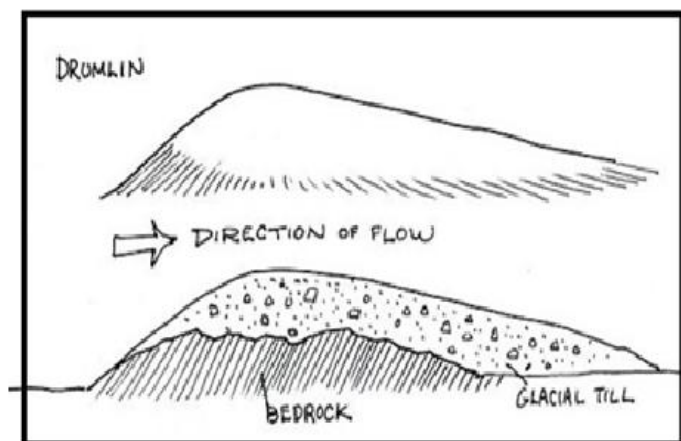


Fig.3.3g

5. Erratics

The glacial sediments are carried within the glacial ice these deposits are mixed, unsorted and angular. They are unusual shapes, unusually large and of a rock type uncommon to the area they have been deposited.

6. Kettle hole

A kettle hole is formed by blocks of ice that are separated from the main and then get buried in the outwash sediment (**Fig.3.3h**). On melting of these ice blocks, they leave behind depressions that fill with water to become kettle hole lakes. Many kettles have been infilled with sediments, especially peat, during the Holocene.



Fig.3.3h

7 Esker

Esker are fluvial-glacial deposits which are long, narrow, ridge composed of stratified sand and gravel deposited by a subglacial or englacial meltwater stream. Eskers range in size from a few meters to a many miles (**Fig.3.3i**). They occur in form of unbroken or as detached segments. The sediment is sorted according to grain size, and cross-laminations that show only one flow direction commonly occur. Areas of eskers are found in Maine, U.S.; Canada and Ireland



Fig.3.3i

8. Moraine

A moraine is a glacially formed accumulation of unconsolidated glacial debris that occurs in both currently and formerly glaciated regions on Earth. Moraines may be composed of debris ranging in size from silt-sized glacial flour to large boulders. The debris is typically sub-angular to rounded in shape. Moraines may be on the glacier's surface or deposited as piles or sheets of debris where the glacier has melted. Moraine may also form by the accumulation of sand and gravel deposits from glacial streams originating from the ice margin.

Types of Moraines

There are number of basis for the classification of the moraines these are their origin, location with respect to a glacier or former glacier, and their shape. The various types of glaciers are (**Fig.3.3J**);

a). Lateral moraines

Lateral moraines are parallel ridges of debris deposited along the sides of a glacier. The unconsolidated debris can be deposited on top of the glacier. Lateral moraines stand high because they protect the ice under them to melt or sublime less than the uncovered parts of the glacier. Multiple lateral moraines may develop as the glacier advances and retreats.

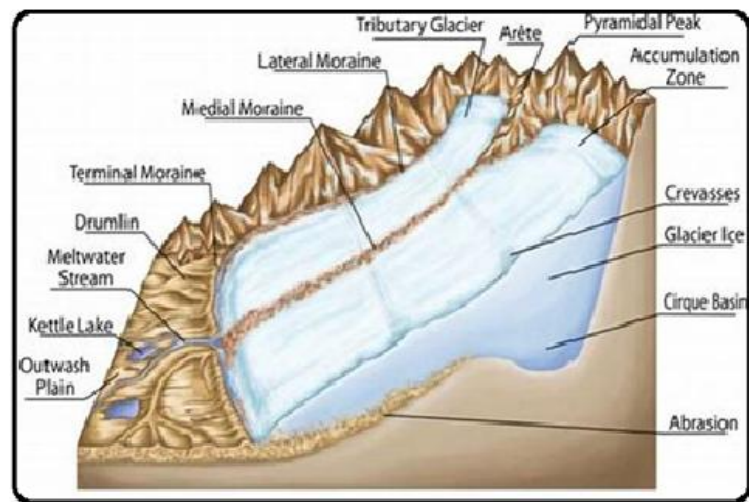


Fig.3.3j

b). Medial moraines/ Ground moraines

Ground moraines areas covered by tills with irregular topography. They form no ridges often forming gently rolling hills or plains. They are accumulated at the base of the ice and also deposited as the glacier retreats. In alpine glaciers, ground moraines are often found between the two lateral moraines

c). End moraines/ Terminal moraines

These are ridges of unconsolidated debris deposited at the snout or end of the glacier. Glaciers carry debris from the top of the glacier to the bottom where it deposits it in end moraines. End moraine size and shape are determined by whether the glacier is advancing, receding or at equilibrium. There are two types of end moraines: **terminal and recessional**. Terminal moraines mark the maximum advance of the glacier.

Recessional moraines are series of transverse ridges running across a valley behind a terminal moraine. They form perpendicular to the lateral moraines that they reside between and are composed of unconsolidated debris deposited by the glacier

A **medial moraine** is a ridge of moraine that runs down the center of a valley floor. It forms when two glaciers meet and the debris on the edges of the adjacent valley sides join and are carried on top of the enlarged glacier. As the glacier melts or retreats, the debris is deposited and a ridge down the middle of the valley floor is created.

9. Tills

Tills are unsorted material deposited directly by glacial ice which shows no stratification and are composed of clay and/or boulders of intermediate sizes. The rock fragments are usually angular and sharp rather than rounded.

There are two types of till these are ;

Basal tills (primary deposits): These are laid down directly by glacier action.

Ablation tills (secondary deposits): These tills are reworked by fluvial transport, erosion, etc.

Till is deposited at the terminal moraine, along the lateral and medial moraines and in the ground moraine of a glacier. As a glacier melts, especially a continental glacier, large amounts of till are washed away and deposited as outwash in sandurs by the rivers flowing from the glacier, and as varves (annual layers) in any proglacial lakes which may form.

When tills get indurated or lithified by subsequent burial into solid rock, it is known as the sedimentary rock tillite. Ancient tillites on opposite sides of the south Atlantic Ocean provided early evidence for continental drift. The same tillites also provide some support to the Precambrian Snowball Earth glaciation event hypothesis.

Glaciation Through Geological Ages

Ice covered 30% of total land area during the most recent ice age.

The largest concentration of ice today is the Antarctic ice sheet, up to 4,200 meters thick in some areas, and in the Greenland ice sheet.

In 4.6 billion years of Earth history record shows current and previous two major glacial periods. The second ice age, is estimated to have occurred from 850 to 635 Ma (million years) ago, in the late Proterozoic Age and it has been suggested that it produced a second "Snowball Earth" in which the earth iced over completely.

A minor series of glaciations occurred from 460 Ma to 430 Ma. There were extensive glaciations from 350 to 250 Ma. The current ice age, called the Quaternary glaciation, has seen more or less extensive glaciation on 40,000 and later, 100,000 year cycles.

There are five known ice ages in the Earth's history, Quaternary Ice Age during the present time. Within ice ages, there exist periods of more severe glacial conditions called glacial periods separated by interglacial periods.

The Earth is currently in an interglacial period of the Quaternary Ice Age, with the last glacial period of the Quaternary having ended approximately 10,000 years ago with the start of the Holocene epoch.

The glacial and interglacial periods of the Quaternary Ice Age were named after characteristic geological features, and these names varied from region to region. The marine record preserves all the past glaciations; the land-based evidence is less complete because successive glaciations may wipe out evidence of their predecessors. There are five Pleistocene glacial/interglacial cycles recorded in marine sediments during the last half million years, but only three classic interglacials were originally recognized on land during that period these are Gunz, Mindel, Riss and Würm.

The last glacial period was the most recent glacial period within the current ice age, occurring in the Pleistocene epoch, which began about 70,000 and ended about 12,500 years ago.

The total volume of land ice, sea level, and global temperature has fluctuated initially on 41,000- and more recently on 100,000-year time scales, as evidenced most clearly by ice cores for the past 800,000 years and marine sediment cores for the earlier period.

The last glacial period is the best-known part of the current ice age, and has been intensively studied in North America, northern Eurasia, the Himalaya and other formerly glaciated regions around the world.

Greenland glaciation: In Northwest Greenland, ice coverage attained a very early maximum in the last glacial period around 114,000. After this early maximum, the ice coverage was similar to today until the end of the last glacial period. Towards the end glaciers readvanced once more before retreating to their present extent. According to ice core data the Greenland climate was dry during the last glacial period, precipitation reaching perhaps only 20% of today's value.

Antarctica glaciation: During the last glacial period Antarctica was covered by a massive ice sheet, much like it is today. The ice covered all land areas and extended into the ocean onto the middle and outer continental shelf.

Causes of Glaciation: The cause of glaciation may be related to several simultaneously occurring factors, such as astronomical cycles, atmospheric composition, plate tectonics, and ocean currents.

Astronomical Cycles: The role of Earth's orbital changes in controlling climate earth. The changes in the Earth's orbital eccentricity cause the climatic cycles known as Milankovitch cycles. Changes in the orbital eccentricity of Earth occur on a cycle of about 100,000 years. The inclination, or tilt, of Earth's axis varies periodically between 22° and 24.5°.

Atmospheric composition: Glacial and interglacial cycles of the late Pleistocene epoch, as represented by atmospheric CO₂, measured from ice core samples going back 650,000 years. Decreases in atmospheric CO₂, an important greenhouse gas, started the long-term cooling trend that causes glaciation. Mesozoic CO₂ levels also play an important role in the transitions between interglacials and glacials. High CO₂ contents correspond to warm interglacial periods, and low CO₂ to glacial periods.

Plate tectonics and ocean currents: The long-term temperature drop may be related to the positions of the continents, relative to the poles. This relation can control the circulation of the oceans and the atmosphere, affecting how ocean currents carry heat to high latitude. Equatorial waters flowed into the polar regions, warming them with water from the more temperate latitudes.

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