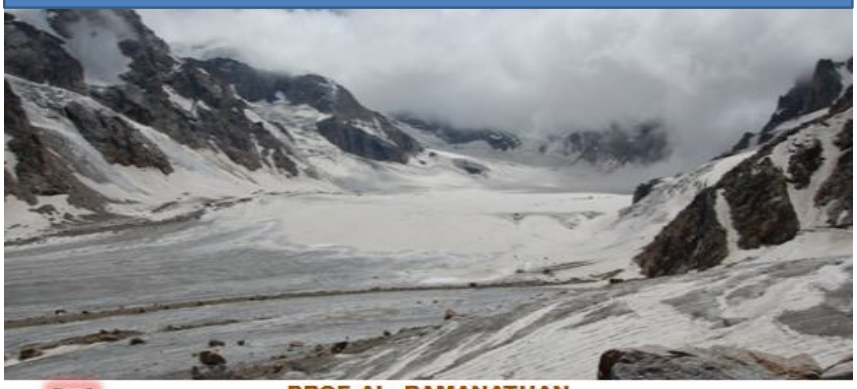
26/08/2014

GLACIER PROCESSES AND LANDFORMS



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2nd Indo-Swiss Capacity Building Programme on Himalayan Glaciology
JNU, New Delhi

Glaciers- definitions

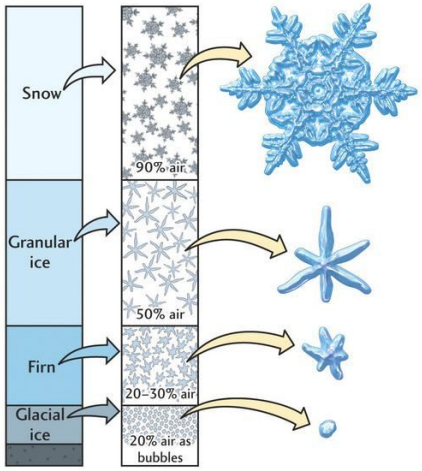
❖ When snow accumulates to a great thickness, it can turn into flowing glacial ice

❖ alpine glaciers form in high mountains, while ice sheets form on continental interiors at high latitudes

Most authors define glacier as a large mass of ice which persists throughout the year, and moves slowly down-slope by its own weight.

Glacial Ice Formation

- Recent snow exposed to freezing and thawing, plus metamorphosis
- Granular ice neve' forms
- Neve' buried, pressure of snow and ice above changes it to firn
- Under pressure firn changes to into glacial ice



Formation and control

How it forms?

❖ More specifically, glaciers must have an area where snow accumulates (snowfall, wind drifting, and avalanching) in excess of ablation

Accumulation

- Snowfall
- Rainfall
- Superimposed ice
- Regelation ice

Ablation

- Surface melt
- Basal and englacial melt
- Evaporation
- Sublimation
- Calving
- Avalanching

CONTROLS INFLUENCING GLACIER FORMATION AND HEALTH

Climatic Condition

- Precipitation
- Temperature
- Insolation
- Wind
- Humidity

Physical Condition

- Elevation
- Latitude
- Aspect
- Slope
- Accumulation characters
- Geothermal heat

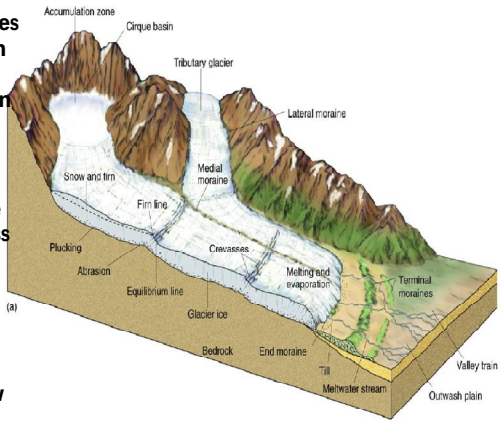
Source: Karpilo, R.D., Jr., (2009); Glacier monitoring techniques

Anatomy of Glaciers:

Accumulation Zone:
The accumulation zone is the area where snowfall accumulates and exceeds the losses from melting, evaporation, and sublimation and there is net accumulation of snow, which subsequently turns into firn and then glacier ice.

Ablation Zone:
Or *ablation area* refers to the low-altitude area of a glacier or ice sheet with a net loss in ice mass due to melting, sublimation, evaporation ice calving, and any other ablation.

Equilibrium Line Altitude (ELA):
The equilibrium line altitude (ELA) or snow line separates the ablation zone from the higher-altitude accumulation zone.



Types of Glaciers

Types of Glacier:

1. **Ice sheets (continental glaciers)** -- cover large areas of land
2. **Valley (alpine) glaciers** -- form at mountain tops and flow down valleys

How do glaciers move?

Glaciers must be thick enough so that they flow downslope.

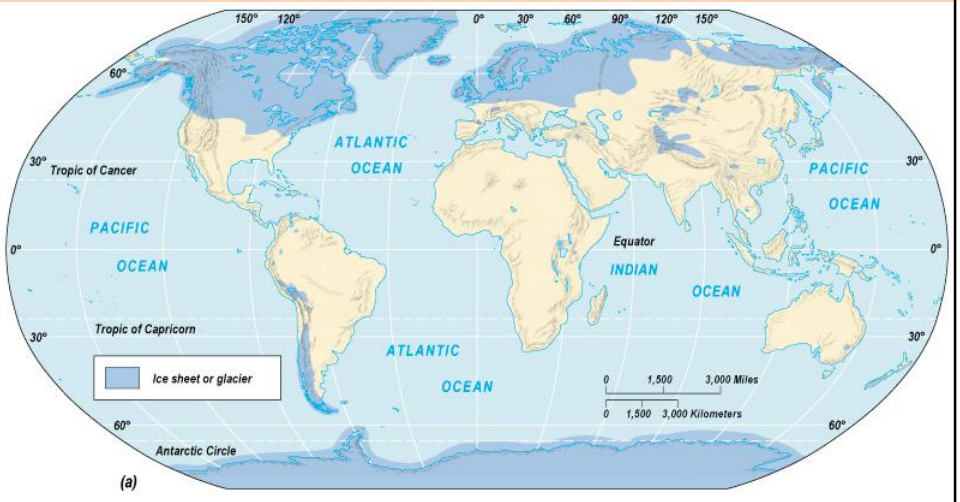
Flow is by basal slip or plastic flow.

Basal slip -- ice moves over a thin layer of meltwater

Plastic flow -- ice deforms internally and flows like plastic

When glacier reaches critical mass (>20m thick)

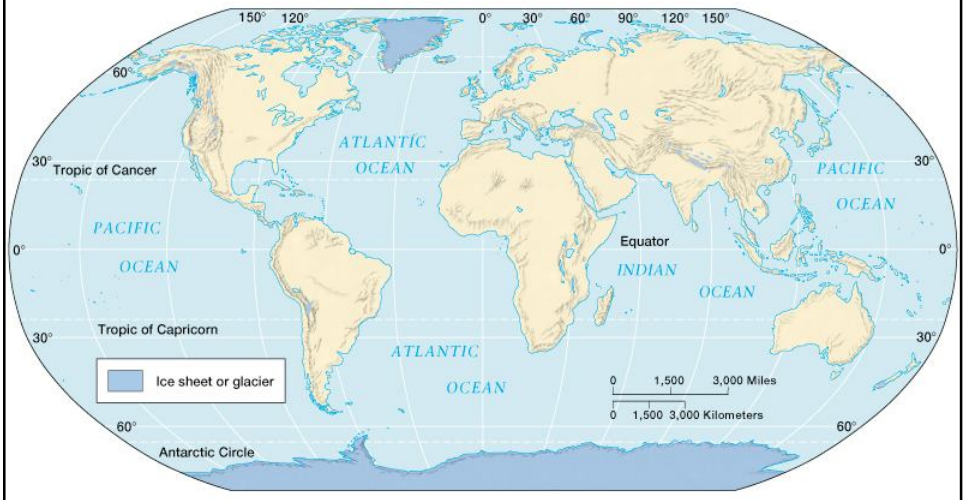
Glaciation



Maximum Extent of Pleistocene Glaciation - 1/3 of land surface

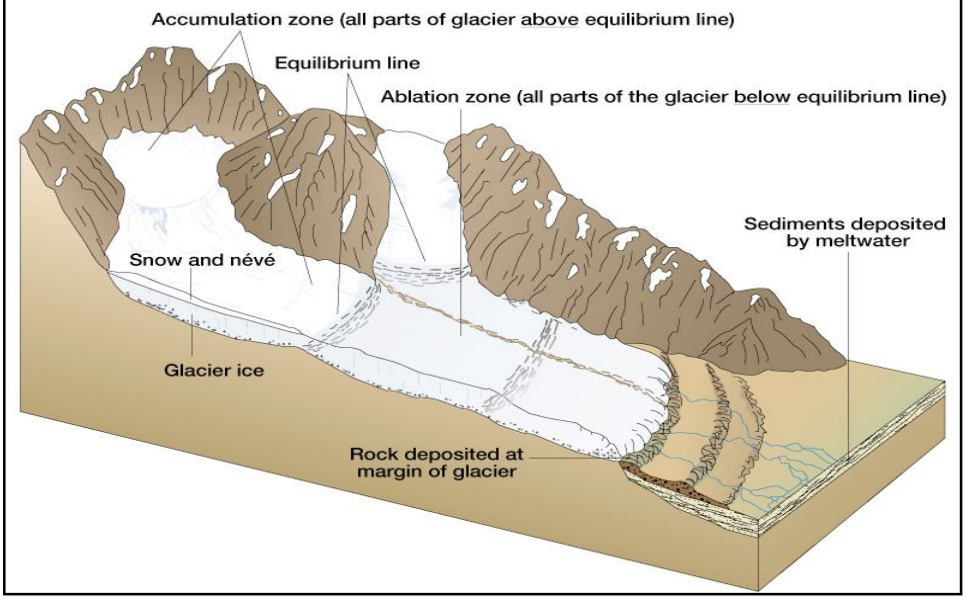
Most recent glacial maximum peaked 18,000 years ago and is considered to have ended 10,000 B.P.

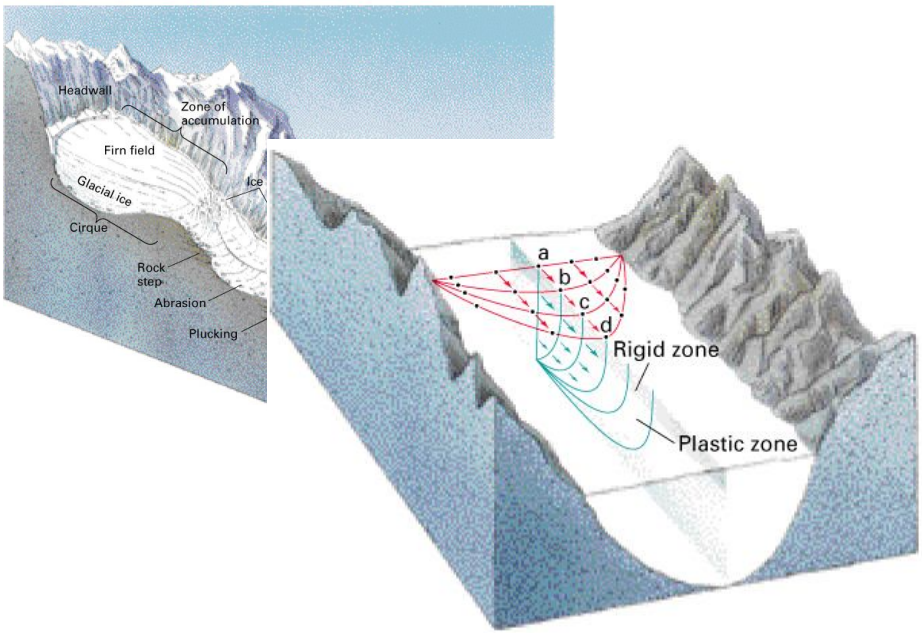
Glaciation

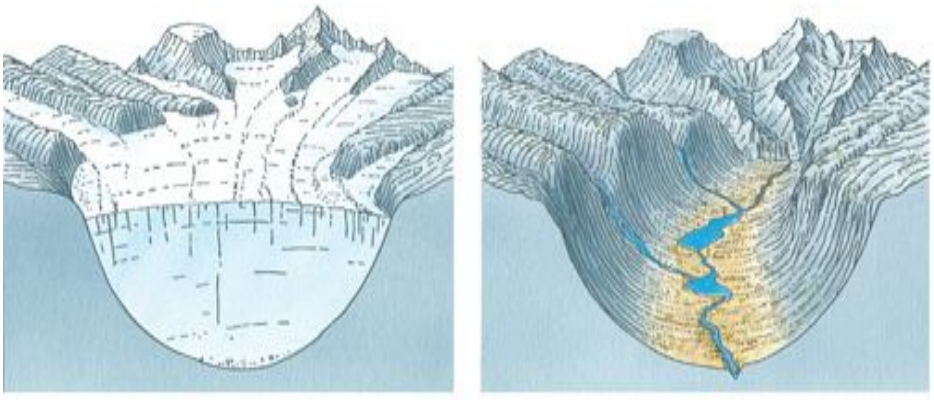


Current Extent of Glaciation - about 10% of land surface

Terminologies







during glaciation

after glaciation

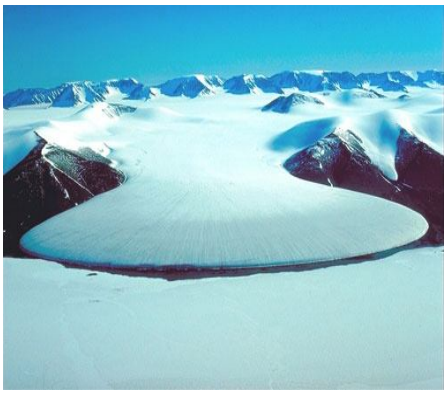
Different Types of Glaciers

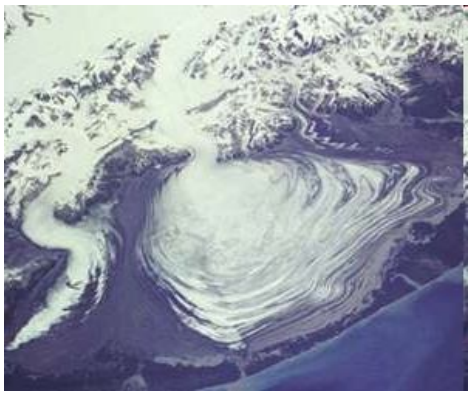
Valley Glaciers

photograph of the upper part of the Bucher Glacier, an outlet glacier of the Juneau Icefield, Coast Mountains, Tongass National Forest, Alaska.

Piedmont glacier

Piedmont glaciers are large, gently sloping ice mounds. Also known as lakes of ice, piedmont glaciers form when a valley glacier reaches the lowlands or plain at the foot of a mountain and spreads out. These are common in Alaska, Greenland, Iceland, and Antarctica.





Cirque Glacier

Cirque Glaciers are named for the bowl-like hollows they occupy, which are called cirques (semicircular basin at head of valley formed by plucking of bedrock by glacier moving down hill). Typically, they are found high on mountainsides and tend to be wide rather than long.

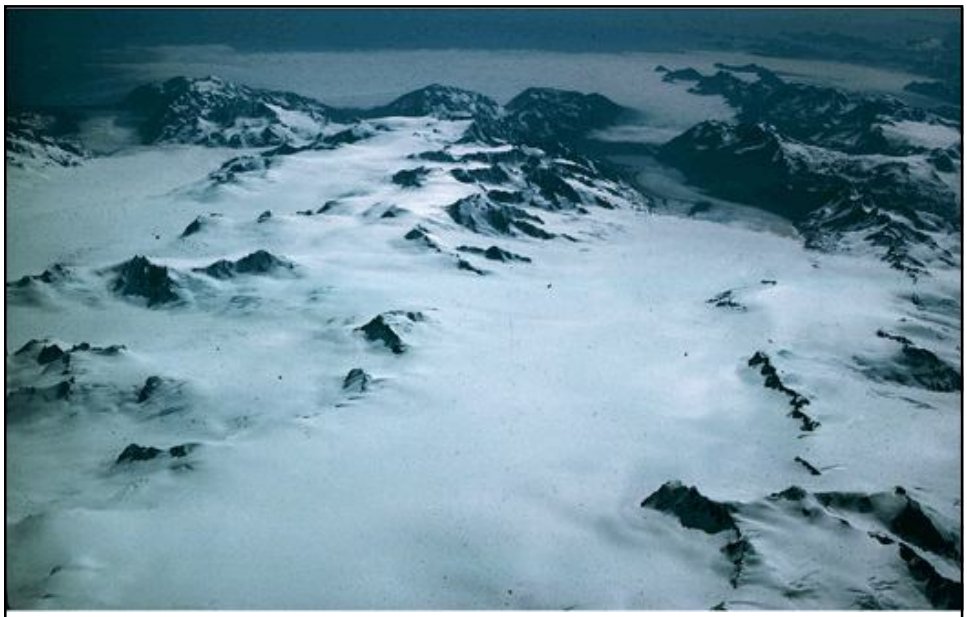
Hanging Glaciers

Also called ice aprons, these glaciers cling to steep mountainsides. Like cirque glaciers, they are wider than they are long. Hanging glaciers are common in the Alps, Himalayas where they often cause avalanches due to the steep inclines they occupy

Hanging glacier located in the Chugach Mountains, near Cordova Peak, Chugach National Forest, Alaska.

Ice Field

- A continuous accumulation of snow and glacier ice that completely fills a mountain basin or covers a low-relief mountain plateau to a substantial depth. When the thickness become great enough, tongues of ice overflow the basins or plateaus as *Valley Glaciers*.



photograph of the Harding Ice Field, Kenai Fjords National Park, Kenai Mountains, Alaska.

Reconstituted Glacier

- A glacier formed below the terminus of a hanging glacier by the accumulation, and reconstitution by pressure melting (regelation), of ice blocks that have fallen and/or avalanched from the terminus of the hanging glacier. Also called *Glacier Remanié*.

photograph of the reconstituted Ogive Glacier, located on the shore of Northwestern Fjord, Kenai Fjords National Park, Kenai Mountains, Alaska.

Rock Glacier

- A glacier-like landform that often heads in a cirque and consists of a valley-filling accumulation of angular rock blocks. Rock glaciers have little or no visible ice at the surface. Ice may fill the spaces between rock blocks. Some rock glaciers move, although very slowly.

unnamed rock glacier with multiple flow lobes, located in the Metal Creek drainage on the north side of the Chugach Mountains, Alaska.

Calving Glacier

- A glacier with a terminus that ends in a body of water (river, lake, ocean) into which it calves icebergs.

Photograph of the calving terminus of Tyndall Glacier, located at the head of Taan Fiord, Icy Bay, Wrangell - St. Elias National Park, Alaska.

Temperate Glacier

- A glacier with a or temperature-regime in which liquid water coexists with frozen water (glacier ice) during part or even all of the year.

photograph showing the stream and pond covered-surface of the Taku Glacier, Juneau Icefield, Tongas National Forest, Coast Mountains, Alaska.

Continental Glacier

Continental glaciers are glaciers that cover continent-sized land masses under thousands of feet of ice. These glaciers are also called ice sheets. The south polar continent of Antarctica is almost completely covered by ice sheets. Except along its margins, Greenland is covered by an ice sheet that is up to 1 3/4 miles thick near the center.

Tide Water Glacier

A glacier with a terminus that ends in a body of water influenced by tides, such as the ocean or a large lake. Typically, tidewater glaciers calve ice to produce icebergs.

photograph of the tidewater terminus of the calving Chenega Glacier, located at sea level in western Prince William Sound, Kenai Mountains, Alaska.

Continental Glaciers

an enormous ice sheet, or more accurately several ice sheets acting in concert. An ice field is the smallest of the three.

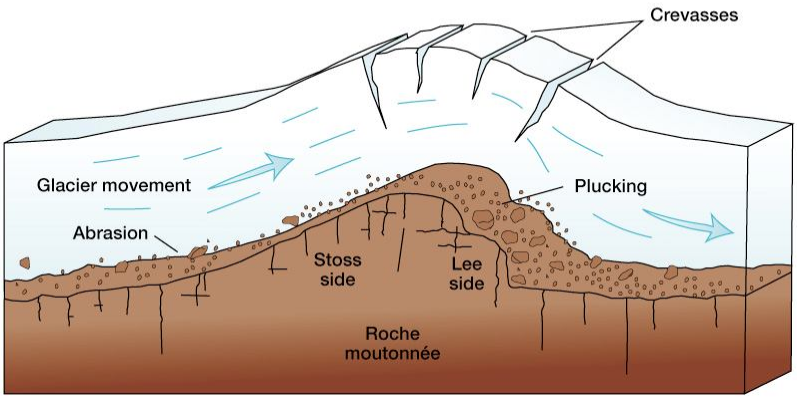
Glacial Processes

1. **Erosion:** Erosion is possible due to presence of till combination of all sizes of sediments (pebbles to boulders) carried within glacier and eventually deposited.

2. **Transportation & Deposition**

3. **Glaciofluvial**

Erosion



Transportation & Deposition

- Debris within glacier = transported
- Debris ahead or to sides of glacier = deposited
- Moraines form when till gets pushed into linear piles by the movement of a glacier.

Glaciofluvial

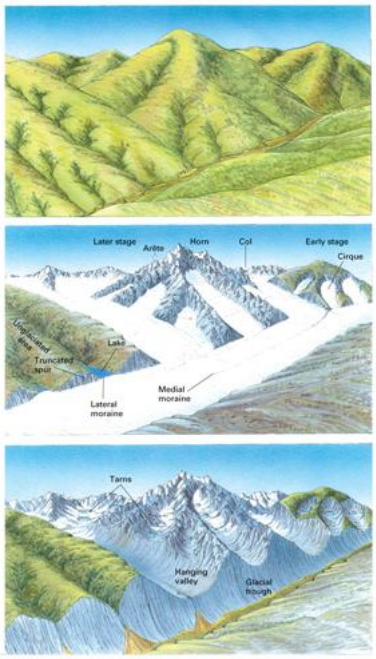
- Meltwaters can deposit materials far away from the glacier
- Braided streams are formed – think of all that till moving inside the glacier, and what happens to it as it is carried by melt waters.
- Erosional Features: Cirques
- Bowl-shaped depression (amphitheatre) area where snow first accumulates and modifies into glacial ice

Major landforms produced by alpine glaciers

(a) before glaciation sets in, the region has smoothly rounded divides and narrow, V-shaped stream valleys

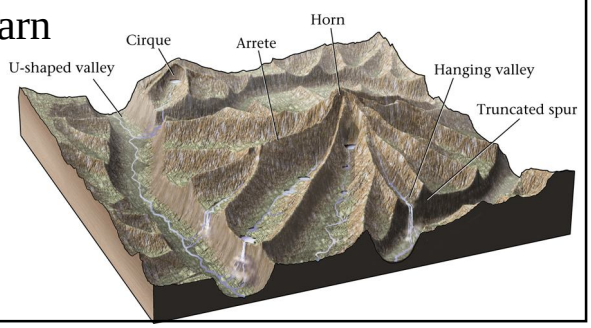
(b) after glaciation has been in progress for thousands of years, new erosional forms are developed

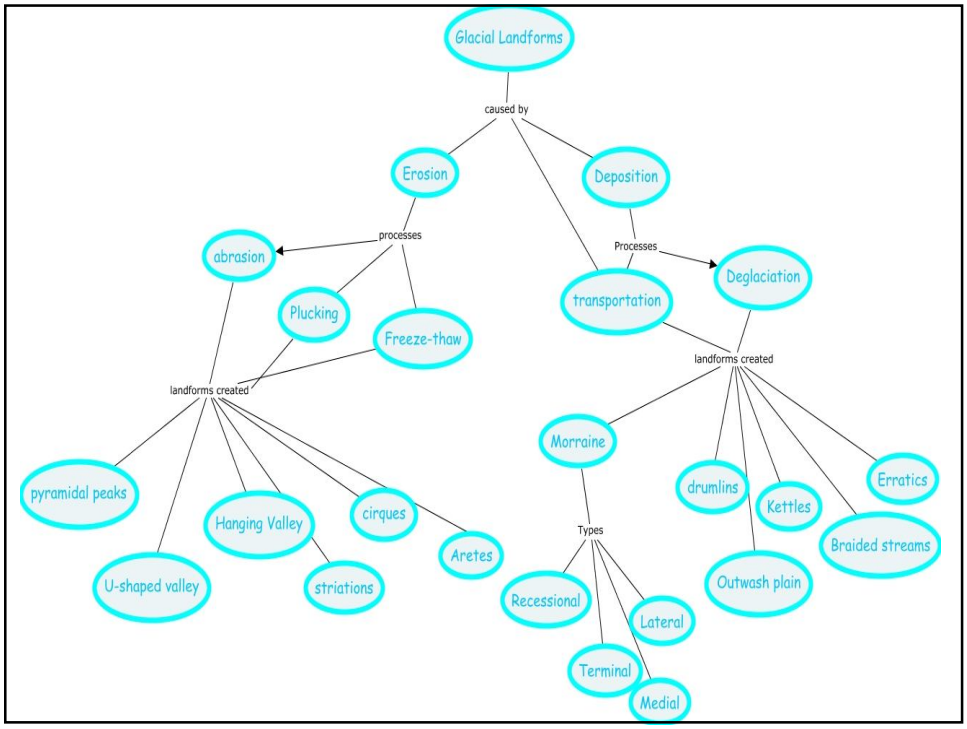
(c) with the disappearance of the ice, a system of glacial troughs (U-shaped valleys) is exposed

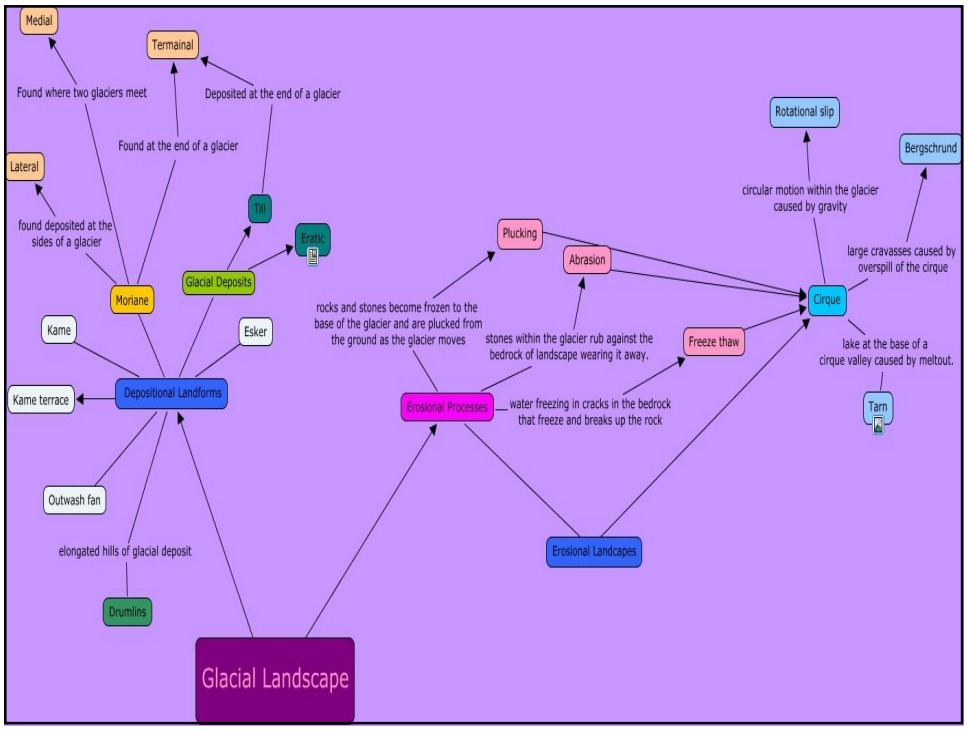


Erosional Landforms Created by Alpine Glaciation

- Cirque
- V & U shaped Valleys
- Fjord
- Erratics
- Truncated Spurs
- Arête
- Col
- Horn
- Bergschrund
- Tarn
- Paternoster Lake
- Hanging Valley




Glacial Landforms
caused by
Erosion
Deposition
processes
Processes
abrasion
Plucking
Freeze-thaw
transportation
Deglaciation
landforms created
landforms created
pyramidal peaks
Hanging Valley
cirques
Aretes
U-shaped valley
striations
Morraine
drumlins
Kettles
Erratics
Braided streams
Outwash plain
Types
Recessional
Lateral
Terminal
Medial


Medial
Termainal
Found where two glaciers meet
Deposited at the end of a glacier
Found at the end of a glacier
Lateral
found deposited at the sides of a glacier
Till
Eratic
Moriane
Glacial Deposits
Kame
Esker
Kame terrace
Depositional Landforms
Outwash fan
elongated hills of glacial deposit
Drumlins
Glacial Landscape
Plucking
Abrasion
rocks and stones become frozen to the base of the glacier and are plucked from the ground as the glacier moves
stones within the glacier rub against the bedrock of landscape wearing it away.
Freeze thaw
Erosional Processes
water freezing in cracks in the bedrock that freeze and breaks up the rock
Erosional Landcapes
Rotational slip
Bergschrund
circular motion within the glacier caused by gravity
large cravasses caused by overspill of the cirque
Cirque
lake at the base of a cirque valley caused by meltout.
Tarn

Cirques

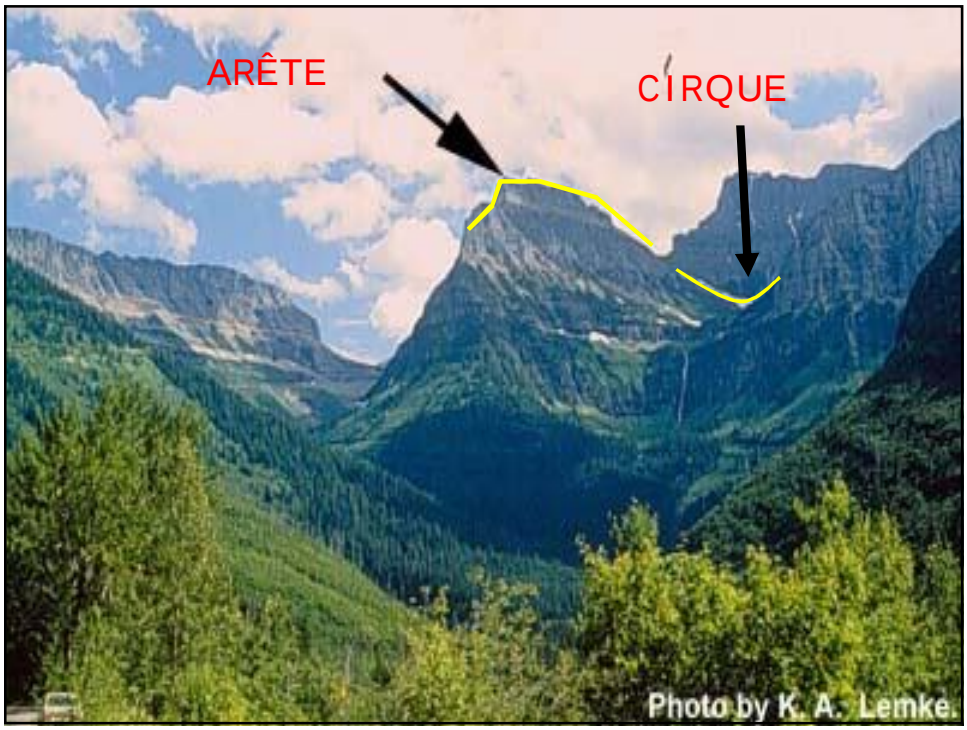
- curved depressions formed at the head of glacial valleys

bowl-shaped rock cavity, where alpine glaciers form and then retreat to and persist; commonly have small lakes called **tarns**

Arêtes

ARÊTES: steep-sided, sharp-edged bedrock ridge formed by two glaciers eroding away on opposite sides of a ridge


Arête - a knife shaped ridge between two corries.


ARÊTE
CIRQUE
Photo by K. A. Lemke.

Horn

A pyramidal, sharp-pointed peak that results when several cirques glaciers gorge an individual mountain summit from all sides

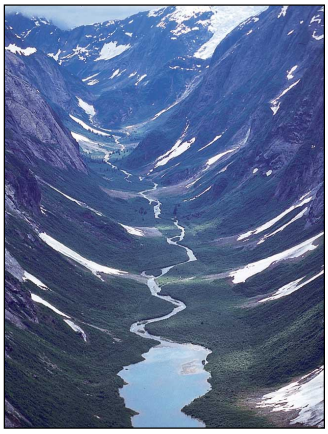
Hanging & U shaped valleys

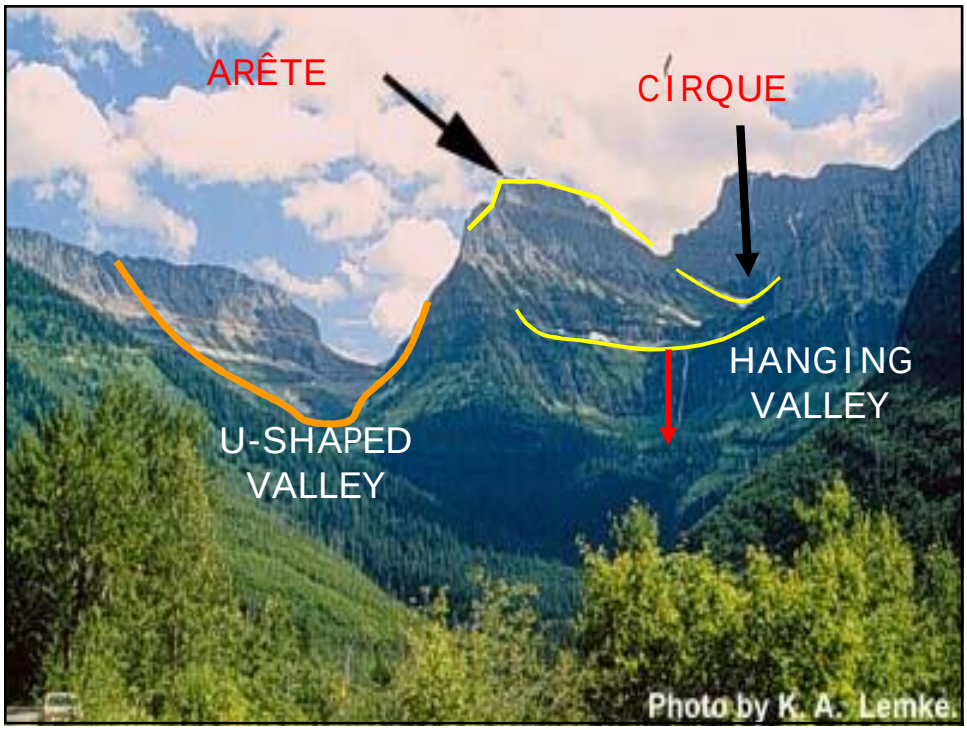
- valley produced by side glaciers entering main valley glacier. After retreat, or melting, the hanging valley floor will be above the main valley

HANGING VALLEY: valley eroded by a small tributary glacier; floor is at a higher elevation that valley it feeds into…

U-SHAPED VALLEY: a glacially eroded valley; also called a *glacial trough…*

small tributary valley above the floor of the main valley (due to differential erosion)






Chhota Shigri


Patsio glacier

Supraglacial lake

- Supraglacial Lake formed on the Ice surface once the surface melt water is dammed by the debris

A **supraglacial lake** is any pond of liquid water on the top of a glacier. Although these pools are ephemeral, they may reach kilometers in diameter and be several meters deep.

Depositional Landforms Created by Alpine Glaciation

- **Glacial Drift:** A general term for all glacial deposits both sorted and unsorted.
- **Stratified Drift:** Sediments deposited by glacial meltwater that are sorted by size.
- **Tills:** Unstratified and unsorted debris from ice deposits.
- **Moraines:** lateral, medial etc.

EROSIONAL FEATURES

- **Bergschrund**

These form when a crevasse or wide crack opens along the headwall of a glacier; most visible in the summer when covering snow is gone.

EROSIONAL FEATURES

- **Tarn**

A small mountain lake especially one that collects in a cirque basin behind risers of rock material or in an ice gouged depression.

EROSIONAL FEATURES

- **Paternoster Lake**

One of a series of small, circular lake formed in individual rock basins aligned down the course of a glaciated valley

Hanging Valley

Valleys carved by tributary glaciers that are left standing high above the primary valley floor.

Fjord

A drowned glaciated valley or glacial trough along a seacoast

Erratics

An unique rock carried by a glacial formation that deviates in size and or type relative to the native area.

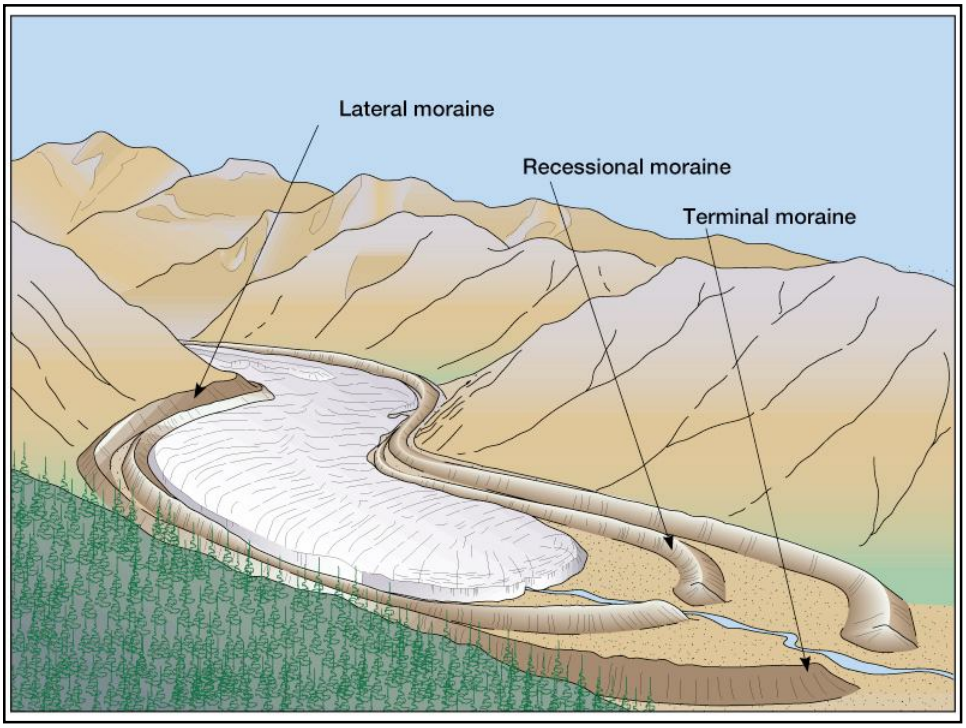
Truncated Spurs

Occur where a glacier carves its way though rock, cutting off the edges of interlocking spurs

Moraines

- *Moraines* are linear features deposited at bottom or along sides of glaciers. After all the ice of glacier recedes piles of sediment are deposited. The material may range in size from blocks or boulders to sand and clay, is unstratified when dropped by the glacier, and shows no sorting or bedding. Several kinds of moraines are recognized, depending on how they are deposited by the glacier; these include

  Lateral Moraine: pile up along the sides
  Medial moraine: material within the glacier (two come together)
  End moraine: occurs at the ice front
  Ground moraine: blanket" of till left by melting glacier



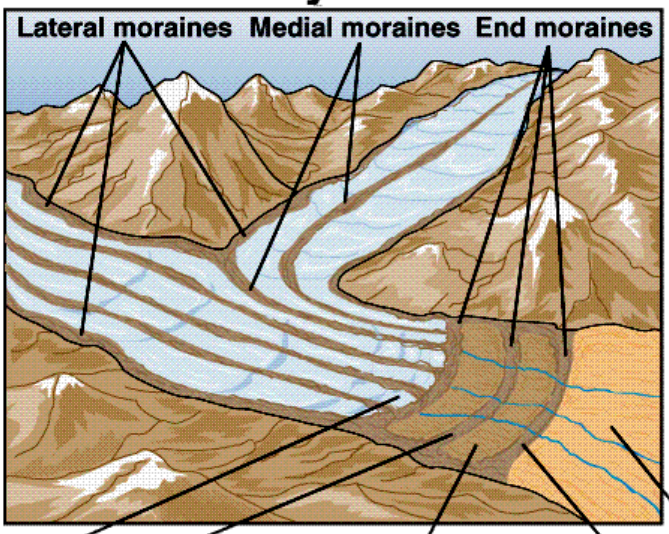
Lateral moraines are elongate, low mounds of till that form along the sides of a valley glacier. The lateral moraine are formed along valley sides below the equilibrium line. They are most prominent where the valley is not too restrictive. Debris may be from within the glacier due to lateral flow or may be mass-wasted

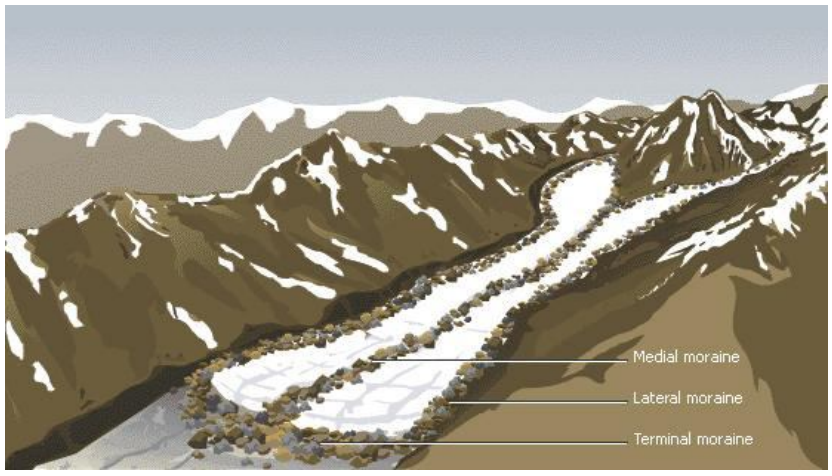
Medial moraines form when tributary glaciers come together and adjacent lateral moraines get trapped between the two flowing ice streams. Medial moraines form from the merger of two valley glaciers and their lateral moraines. Traced downglacier, medial moraines often merge with a cover of ablation till resting on the ice. Medial moraines are rarely preserved when the ice melts

End moraines are ridges of till piled up along the front end of a glacier. The end moraine marks the outermost advance of the glacier during a particular glacial stage. There can be only one terminal moraine.

Recessional moraines Successive end moraines left behind by a retreating glacier are called. Recessional moraines mark the stabilized ice margin during a period of punctuated recession of the glacier

Moraines Associated with Valley Glaciers



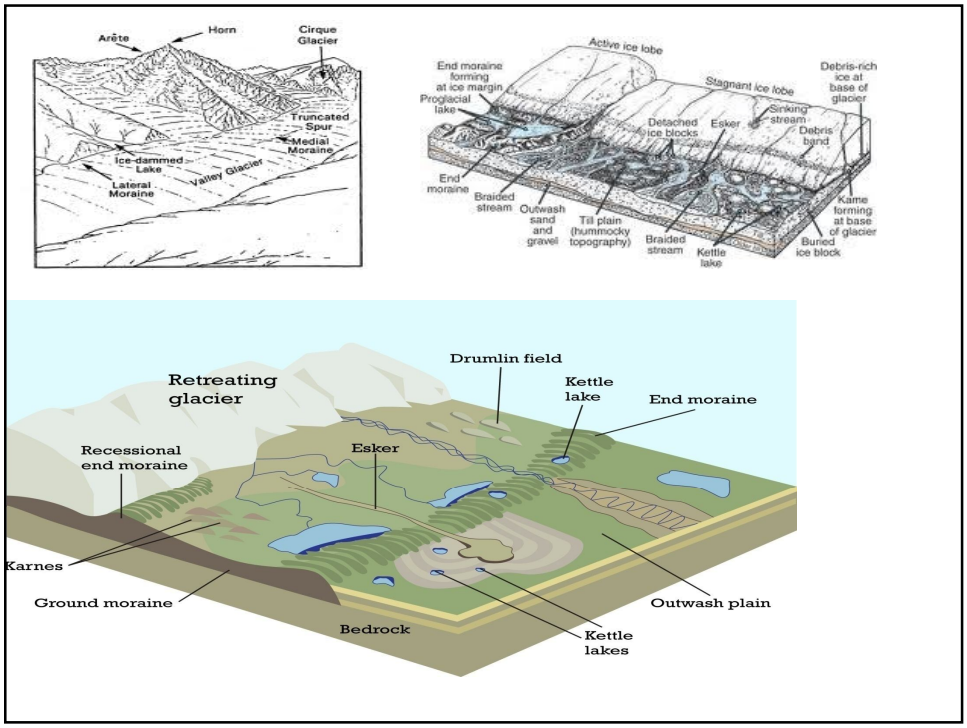


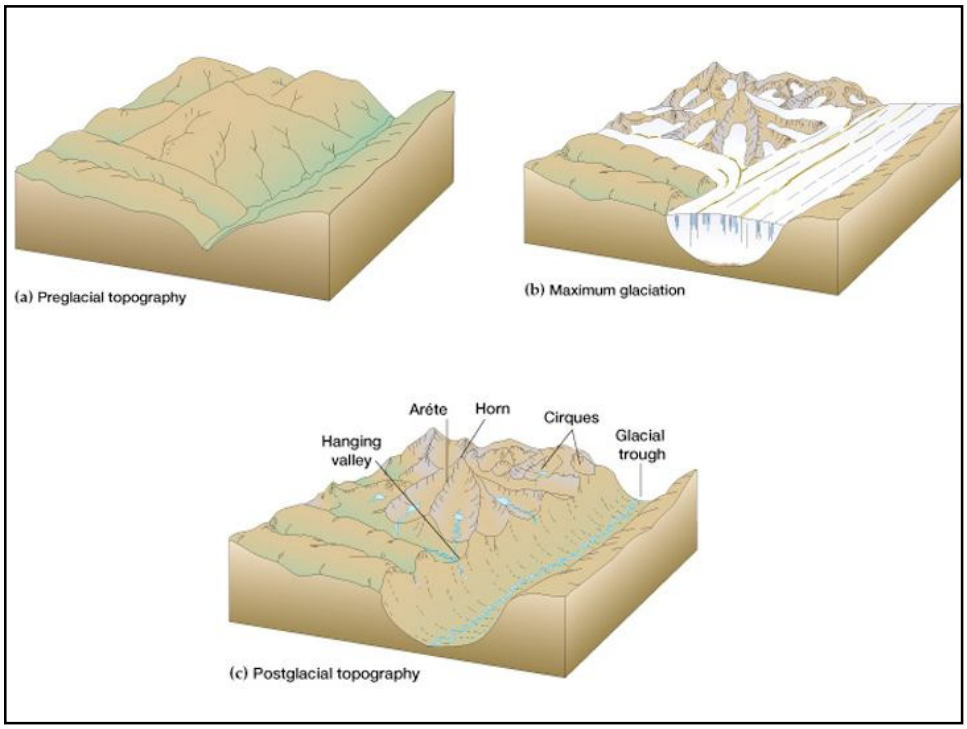
Lateral Moraines: A deposition of sediments along both sides of a glacier.

Medial Moraine: A deposition of sediments between two lateral moraines.

Terminal Moraine: Eroded debris that is dropped at the glacier's farthest extent.

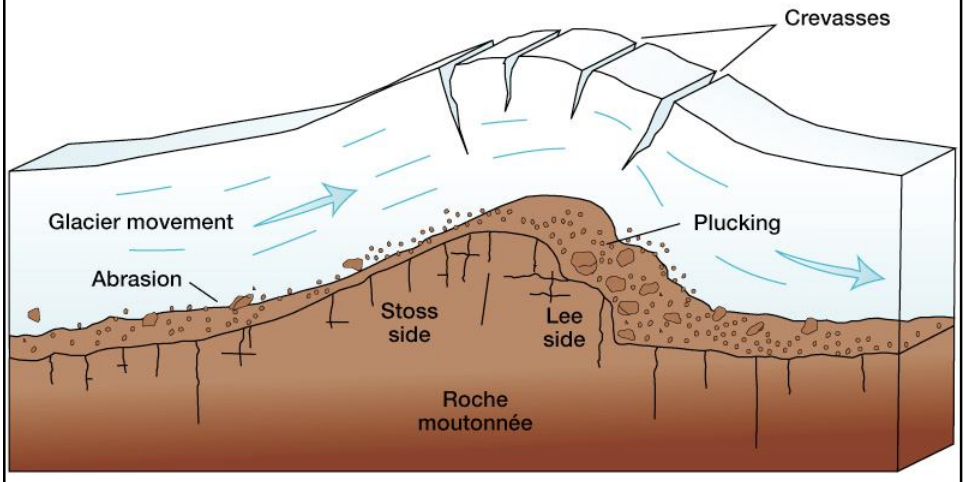
Medial and Lateral Moraines


Arête
Horn
Cirque Glacier
Truncated Spur
Medial Moraine
Ice-dammed Lake
Valley Glacier
Lateral Moraine
Active ice lobe
End moraine forming at ice margin
Proglacial lake
Stagnant ice lobe
Debris-rich ice at base of glacier
Sinking stream
Debris band
Detached ice blocks
Esker
End moraine
Braided stream
Outwash sand and gravel
Till plain (hummocky topography)
Braided stream
Kettle lake
Kame forming at base of glacier
Buried ice block
Retreating glacier
Drumlin field
Kettle lake
End moraine
Recessional end moraine
Esker
Karnes
Ground moraine
Bedrock
Outwash plain
Kettle lakes

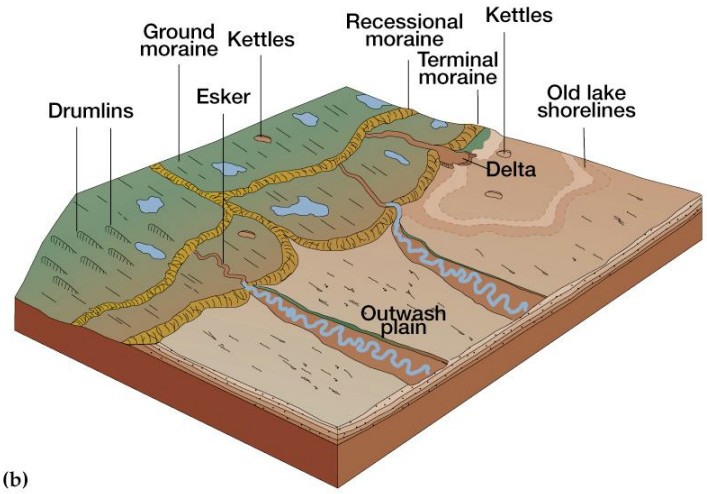

(a) Preglacial topography
(b) Maximum glaciation
Aréte
Horn
Cirques
Hanging valley
Glacial trough
(c) Postglacial topography

Crevasses: *is a crack in an ice sheet or glacier*

- Near the top of the glacier, the ice can fracture due to stresses associated with flow. These fractures are called crevasses. In the lower parts of the glacier, the ice flows like a fluid; this region is called the zone of plastic flow. At the very base of the glacier, the ice slips over the surface (a process called basal slip). Typical flow speeds for glaciers are a few mm to a couple meters per day. However, occasionally glacial surges occur; during these times, glaciers can move up 6 km/year. Many crevasses form during glacial surges.



Continental Glaciers or Ice Sheets



Depositional Landforms Created by Continental Glaciation

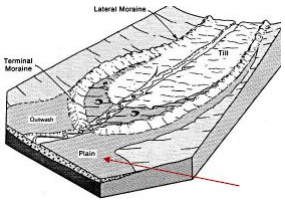
- **Till Plain:**
- **• Outwash Plain:**
- **• Esker:**
- **• Kettle:**
- **• Kame:**
- **• Roche Mountonnée:**
- **• Drumlin:**

Till Plain

Forms behind a end moraine; it features unstratified coarse till, has low and rolling relief, and has a deranged drainage pattern.

Outwash Plains

Are Glacial stream deposits of stratified drift from melt-water, braided, and overloaded. They occur beyond a glacial morainal deposit



DEPOSITIONAL FEATURES

- **Eskers**

A sinuously curving, narrow deposit of coarse gravel that forms along a melt-water stream channel, developing in a tunnel beneath a glacier.

Eskers

KETTLE

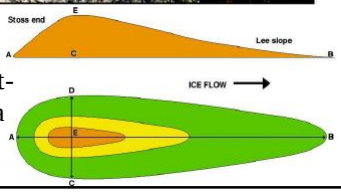
Forms when an isolated block of ice persists in a round moraine, an outwash plain or valley floor after a glacier retreats; as the block finally melts, it leaves behind a steep sided hole that frequently fills with water.

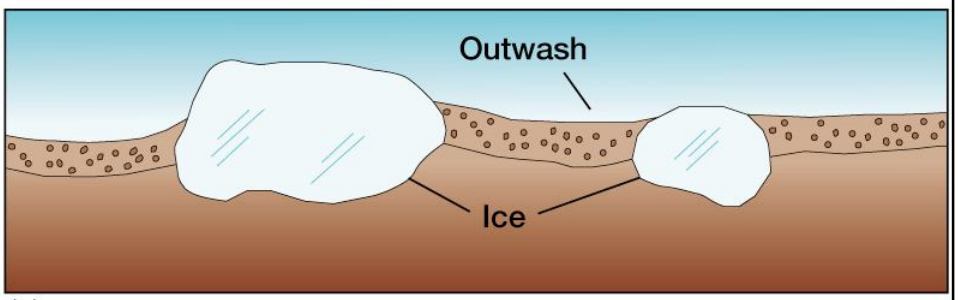
Kame

A depositional feature of glaciation; a small hill of poorly sorted sand and gravel that accumulates in crevasses or in ice caused indentations in the surface.

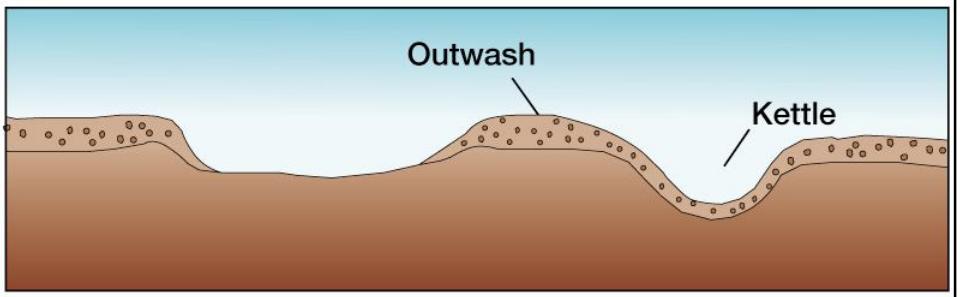
Drumlin

Composed of till (unstratified, unsorted) and is streamline in the direction of continental ice movement- blunt end upstream and tapered end downstream with a rounded summit

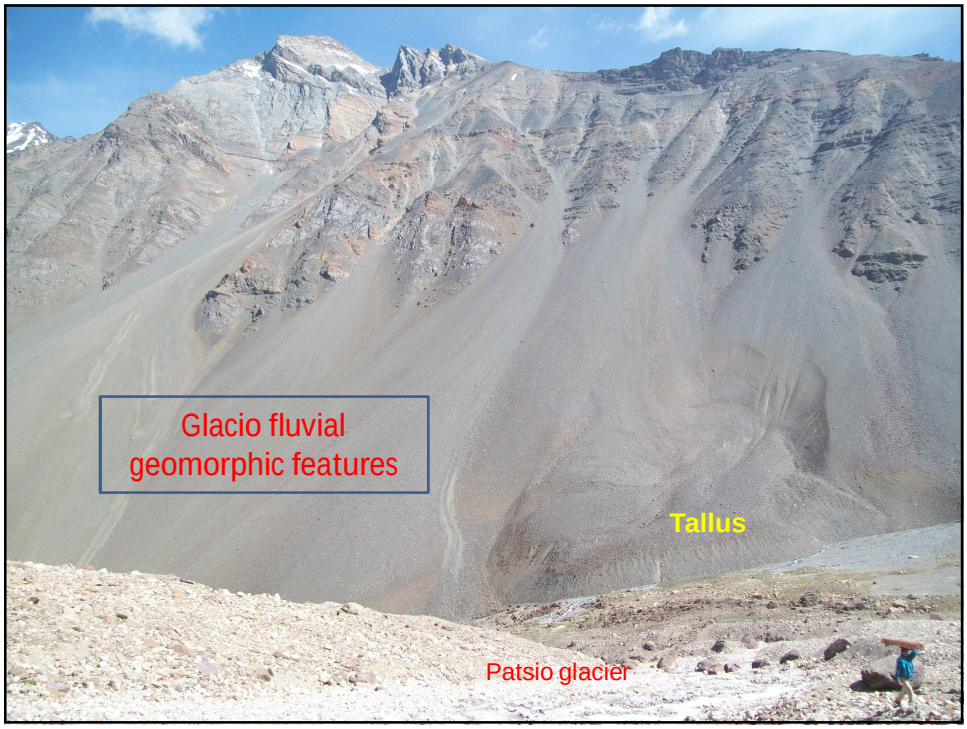




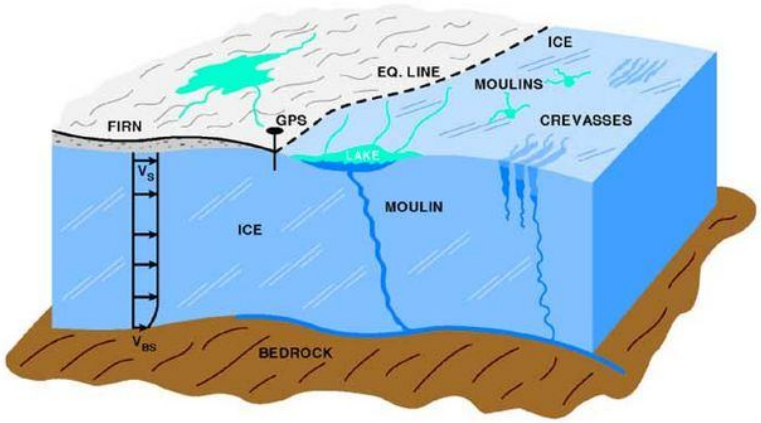
(a)

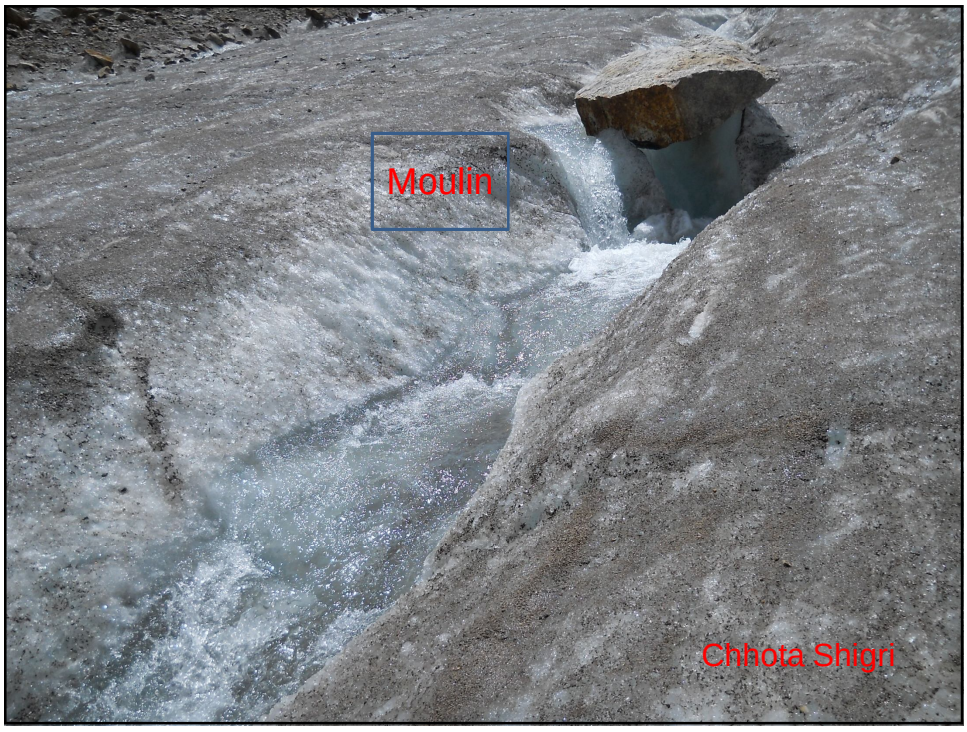


(b)



Moulin glacier well or cave



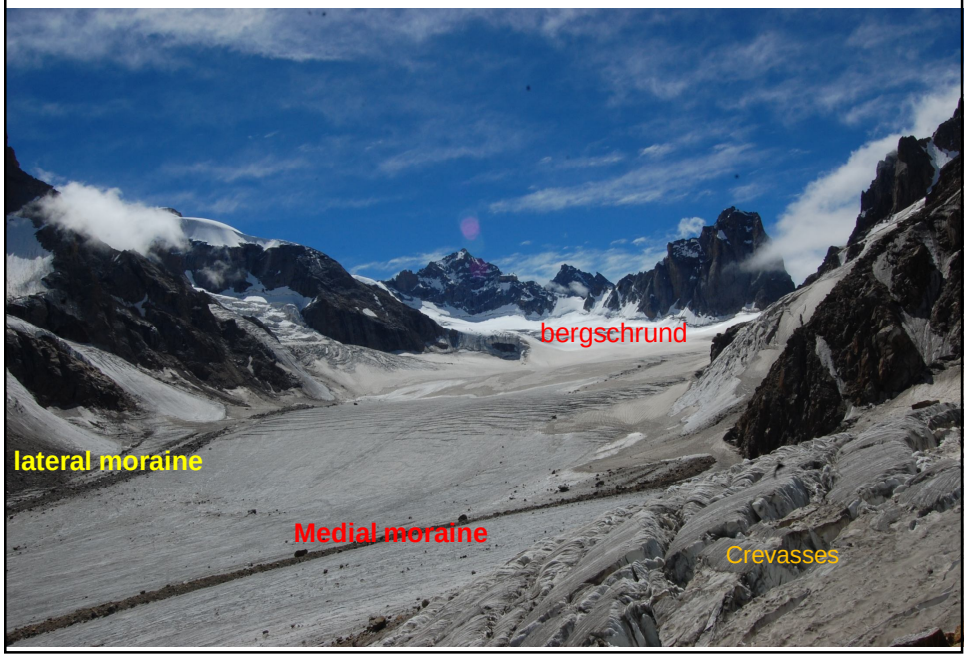

Moulin
Chhota Shigri


Supra glacial lakes


Tributary glacier
Medial Moraines

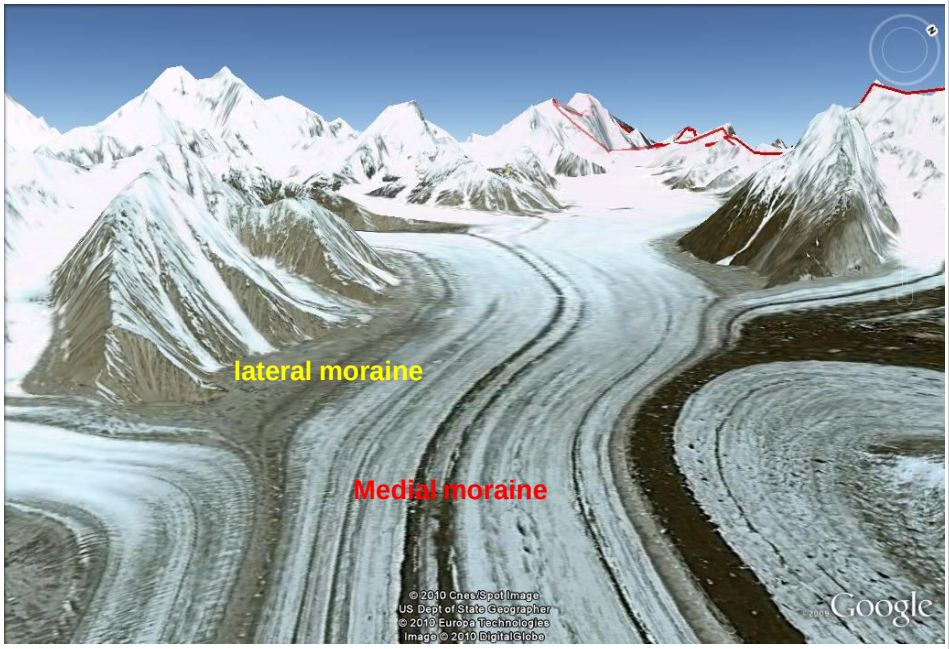

Glacial
boundaries

Chhota Shigri glacier



Bara Shigri glacier largest glacier in Himachal Pradesh

Siachen glacier one of the world's longest mountain glacier




Thank you
Namaste
Supra glacial lake on Chhota Shigri glacier (May, 2012)