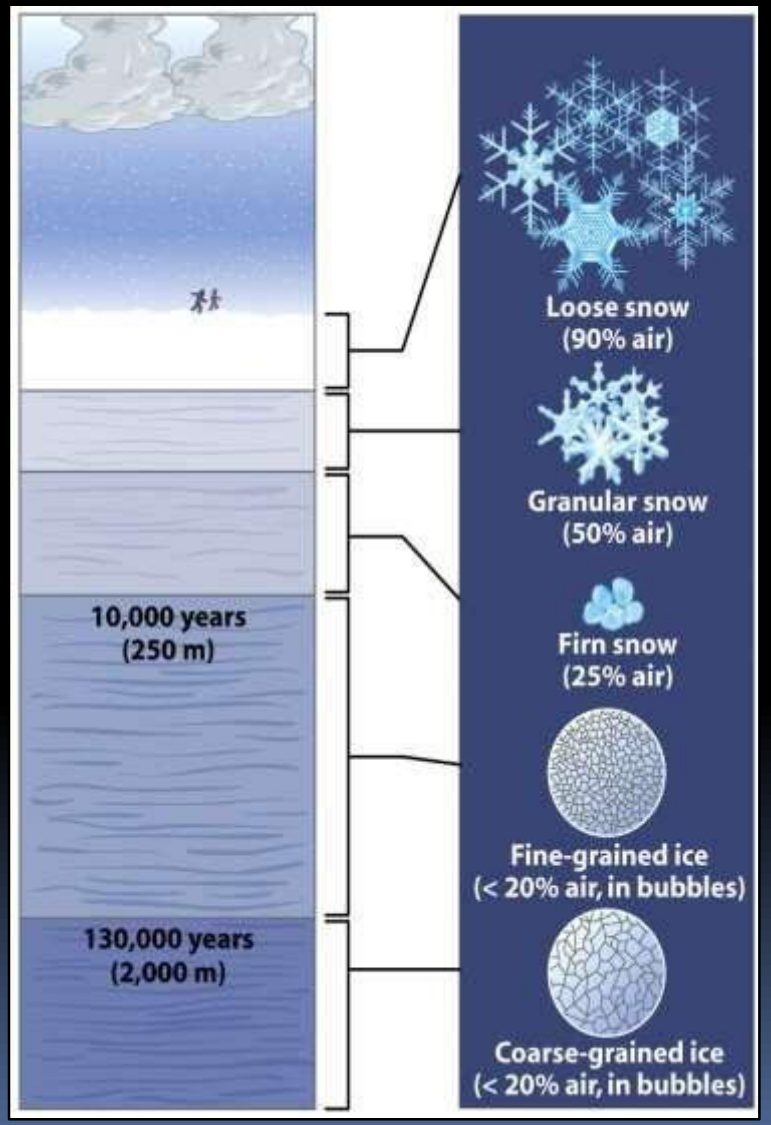
Ice: The Water Mineral

1. **Ice is solid water (H_2O).**
2. **Forms when water cools below the freezing point.**
3. **Natural ice is a mineral; it grows in hexagonal forms.**

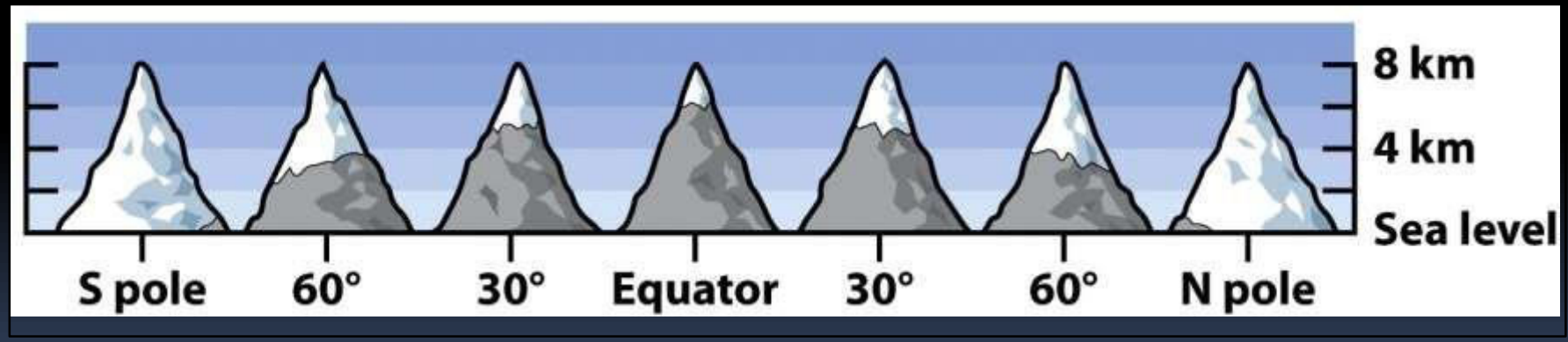
Formation of Glacial Ice

- Snow is transformed into ice.
  - Delicate flakes accumulate.
  - Snow is buried by later falls.
  - Compression expels air.
  - Burial pressure causes melting and recrystallization.
  - Snow turns into granular firn.
  - Over time, firn melds into interlocking crystals of ice.



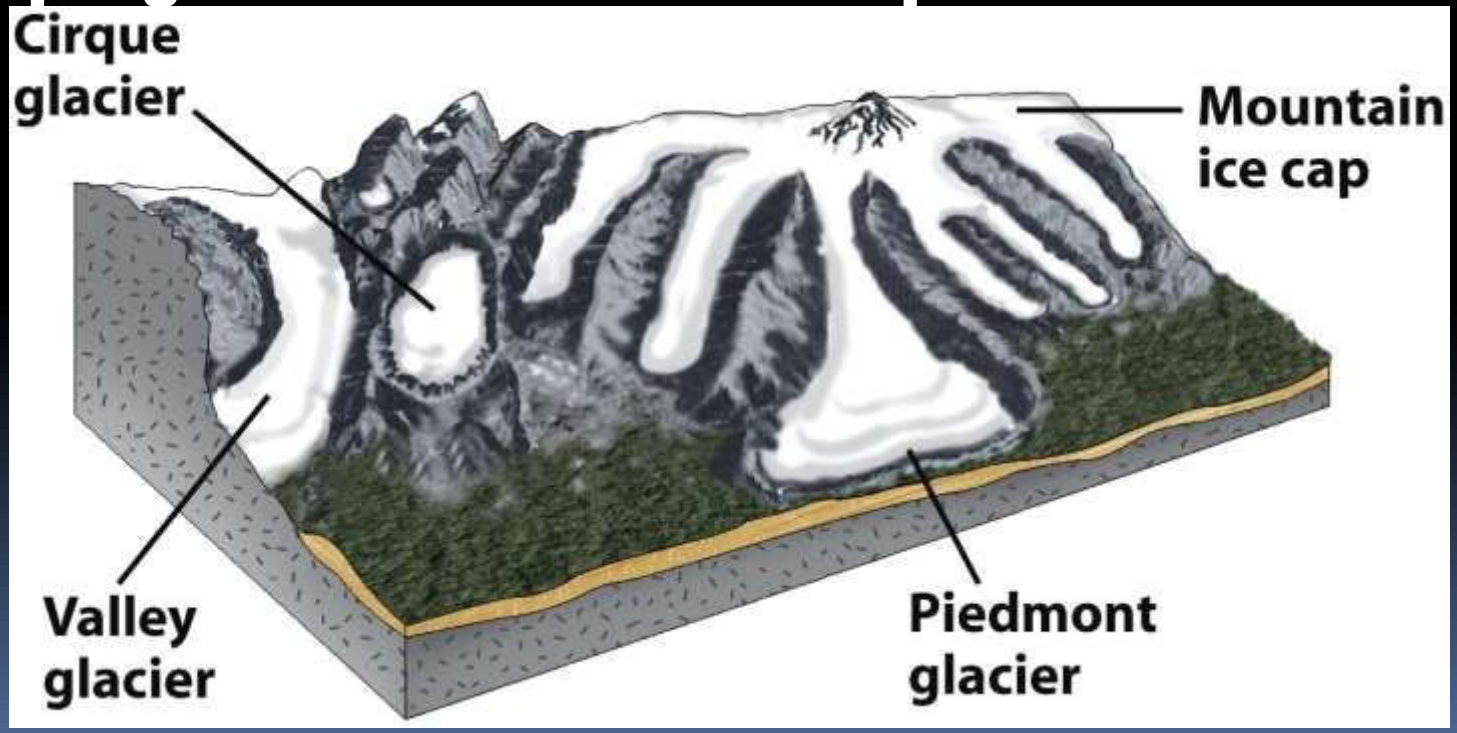
Forming a Glacier

- **Glacier-sustaining elevation is controlled by latitude.**
  - **In polar regions, glaciers form at sea level.**
  - **In equatorial regions, glaciers form above 5 km elevation.**
- **This elevation is marked by the "snow line."**



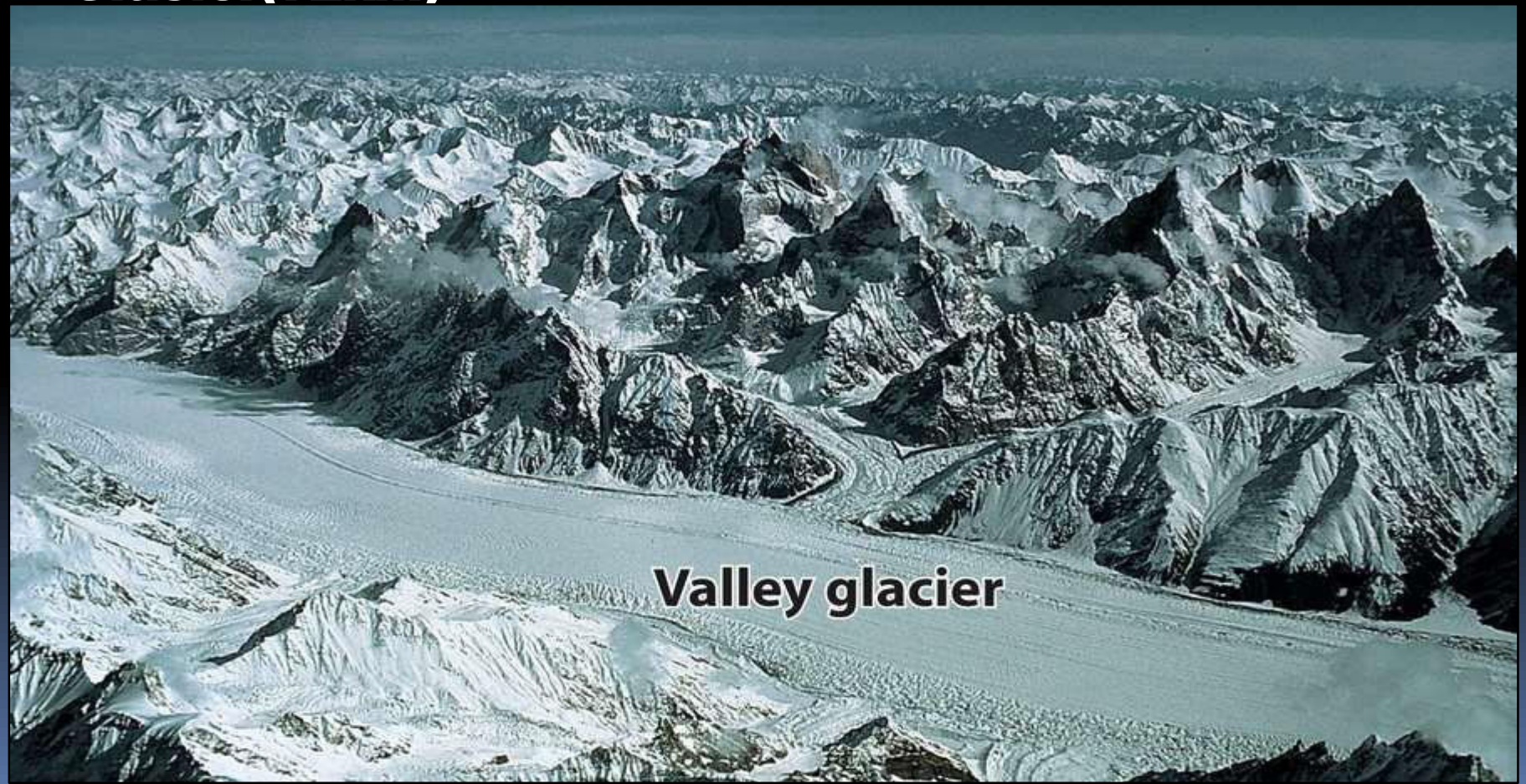
Mountain Glaciers

- **Flow from high to low elevation in mountain settings.**
- **Include a variety of types.**
  - **Ice caps cover tall mountain peaks.**
  - **Cirque glaciers fill mountain top bowls.**



Mountain Glaciers

- **Include a variety of types.**
  - **Valley glaciers flow like rivers down valleys.**
  - **E.g. Gangotri Glacier(25km), Siachen Glacier(72km)**

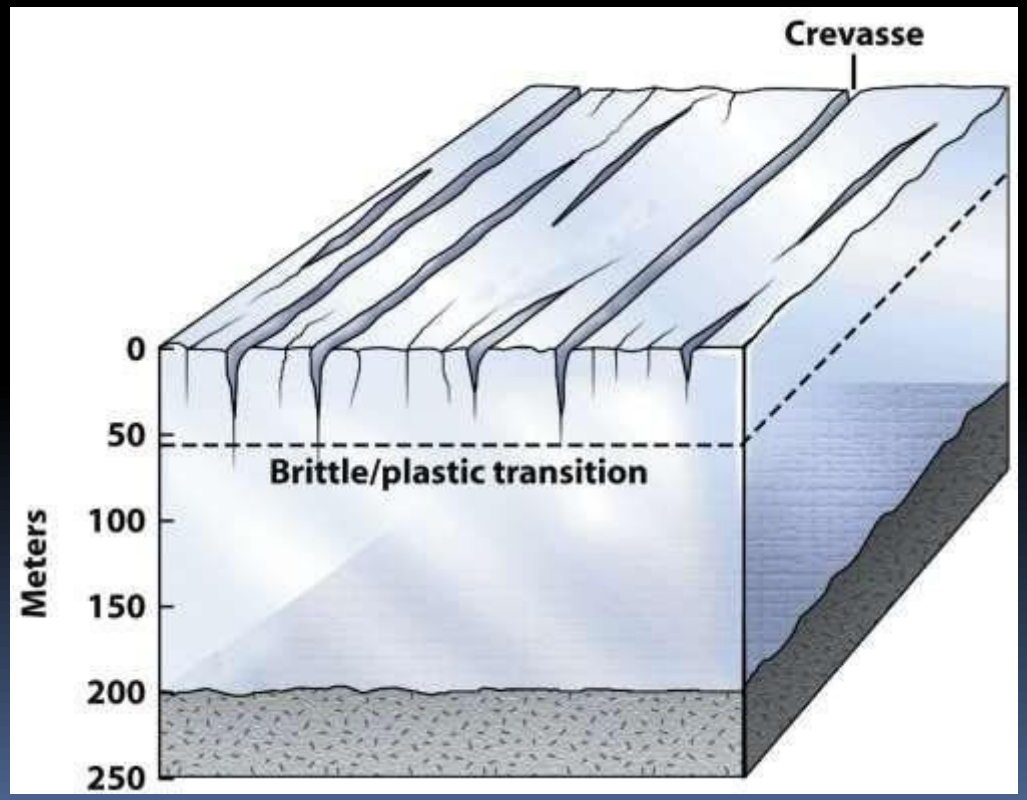


Mountain Glaciers

- **Include a variety of types.**
  - **Piedmont glaciers spread out at the end of a valley.**

Movement of Glacial Ice

- **Two types of mechanical behavior.**
  - **Brittle – Uppermost 60 m.**
    - **Tension initiates cracking of the ice.**
    - **Crevasses may open and close with movement.**
  - **Plastic – Lower than 60 m.**
    - **Ductile flow occurs in deeper ice.**
    - **Ice flow heals cracks.**

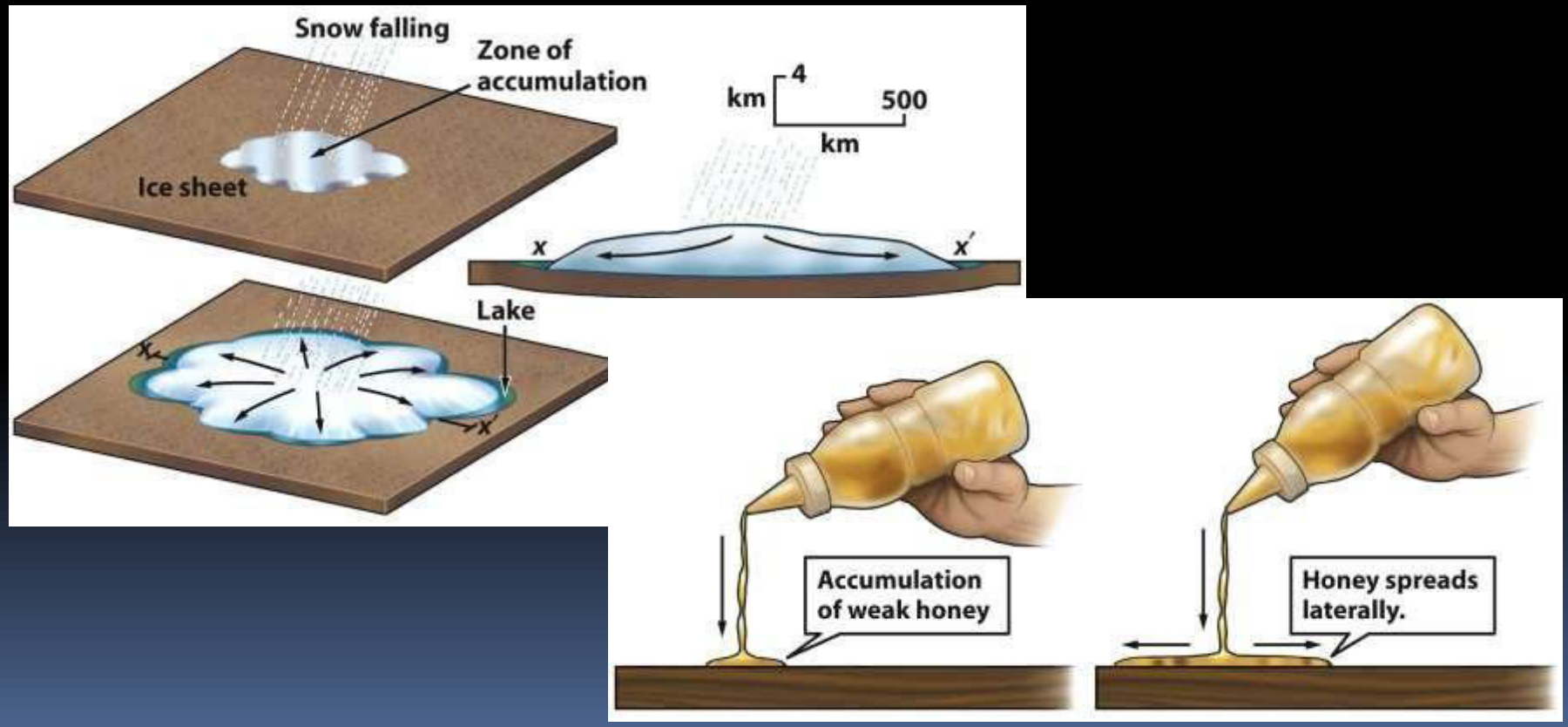


- Ice flows downhill via gravity.

MOVEMENT OF GLACIAL ICE

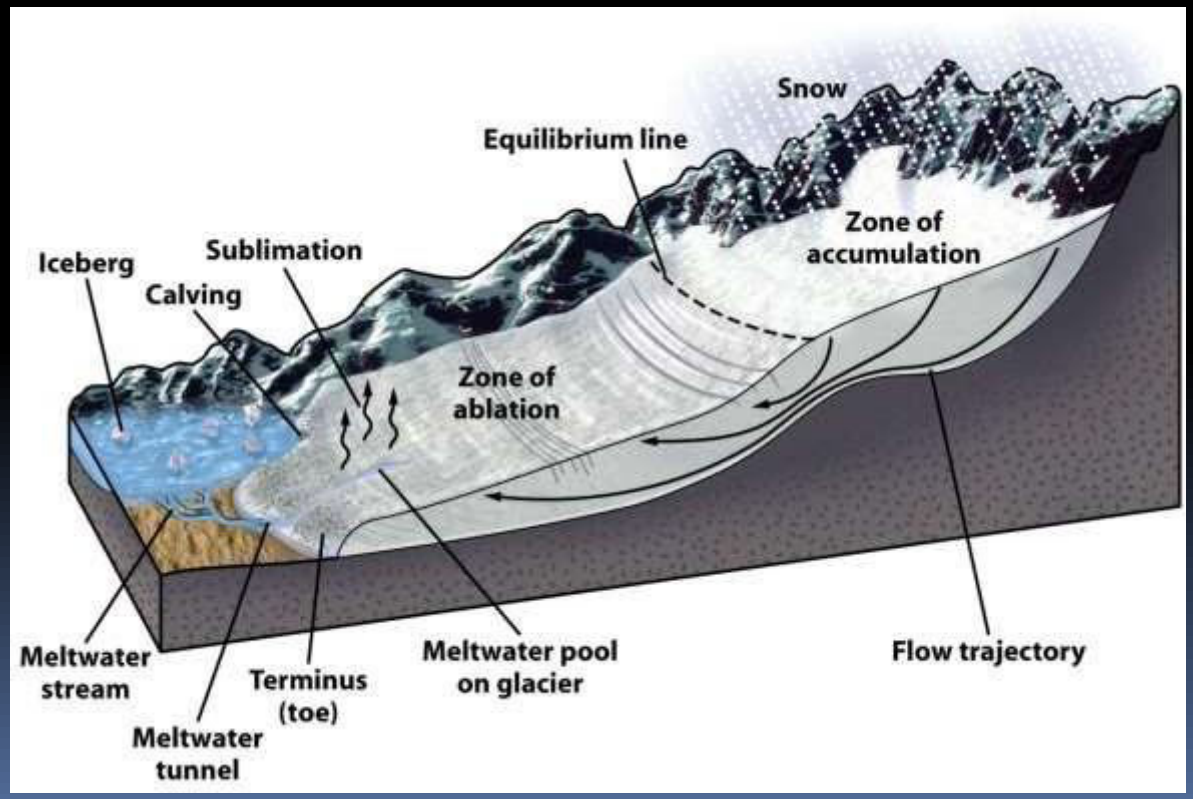
Movement of Glacial Ice

- **Ice flows downhill via gravity.**
  - **Ice flows away from the thickest part of continental glaciers.**
    - **Analogous to honey flowing away from thickest zone.**



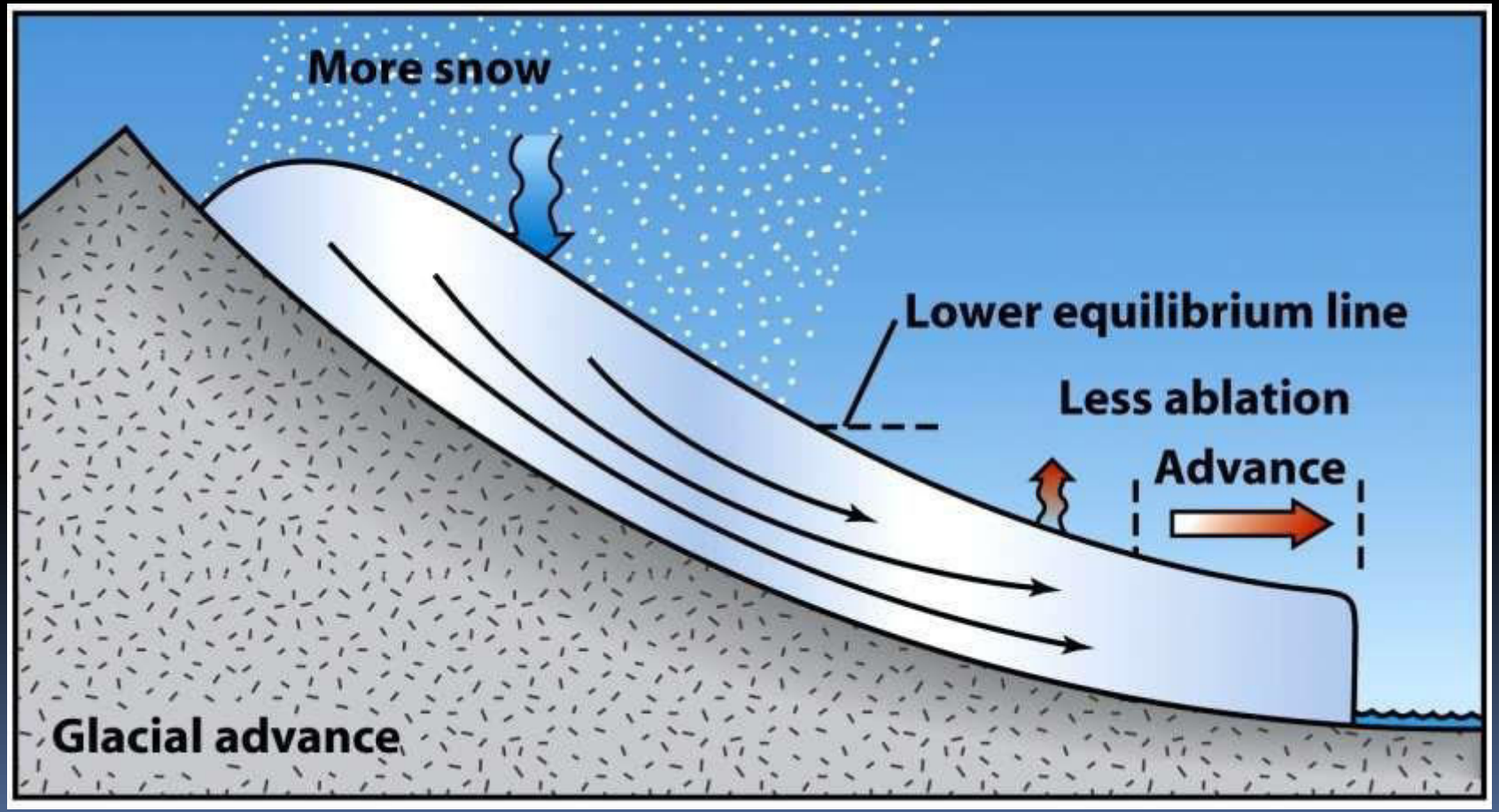
Glacial Advance and Retreat

- **Zone of accumulation – Area of net snow addition.**
  - **Colder temperatures prevent melting.**
  - **Snow remains across the summer months.**
- **Zone of ablation – Area of net ice loss.**
- **Zones join at the equilibrium line.**



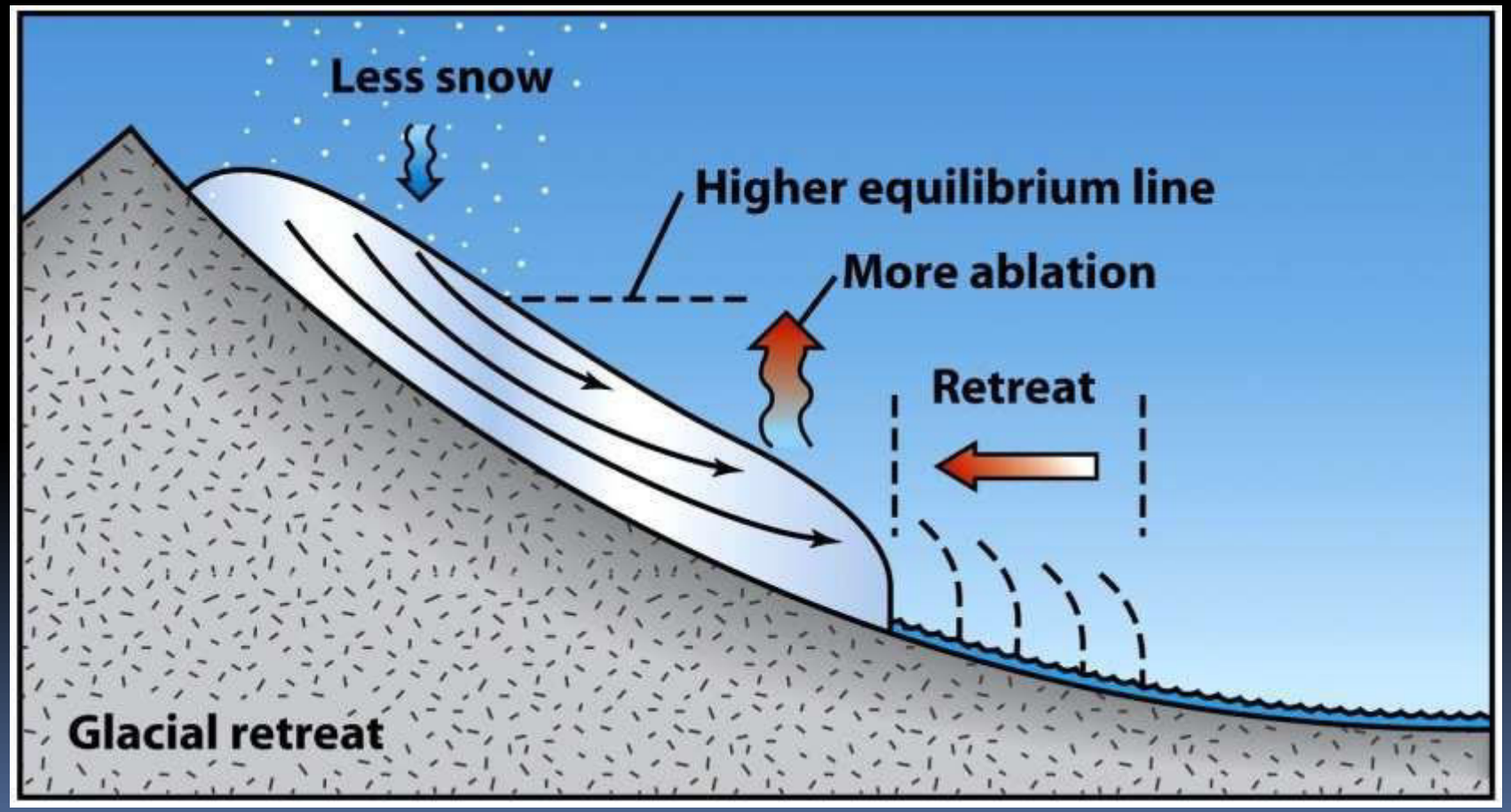
Glacial Advance and Retreat

- **Toe position.**
  - **If accumulation > ablation, the glacial toe advances.**



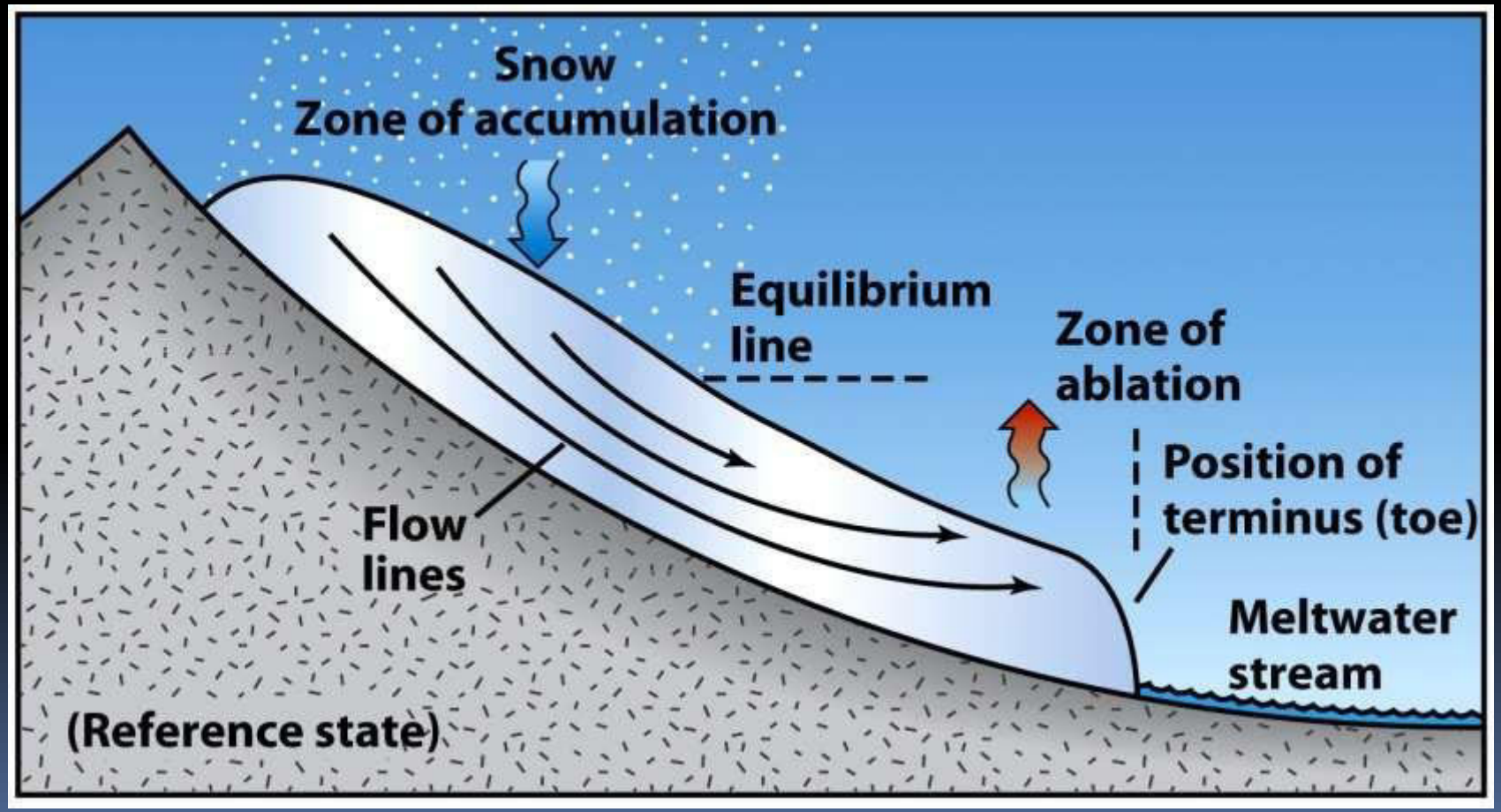
Glacial Advance and Retreat

- **Toe position.**
  - **If accumulation < ablation, the toe will retreat upslope.**



Glacial Advance and Retreat

- **Toe position.**
  - = **accumulation = ablation the toe stays in the same place.**

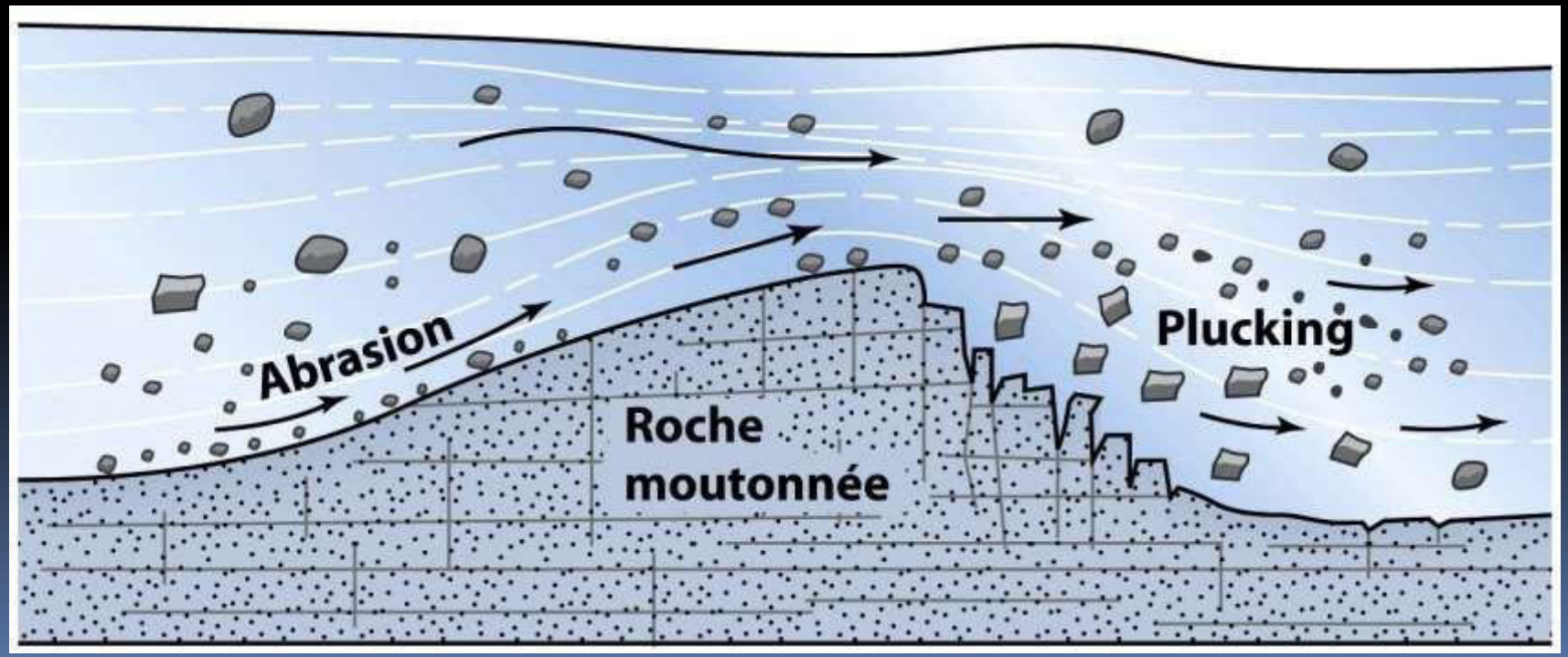


Glacial Effects

- **Glaciers are important forces of landscape change.**
  - **Erosion.**
  - **Transport.**
  - **Deposition.**

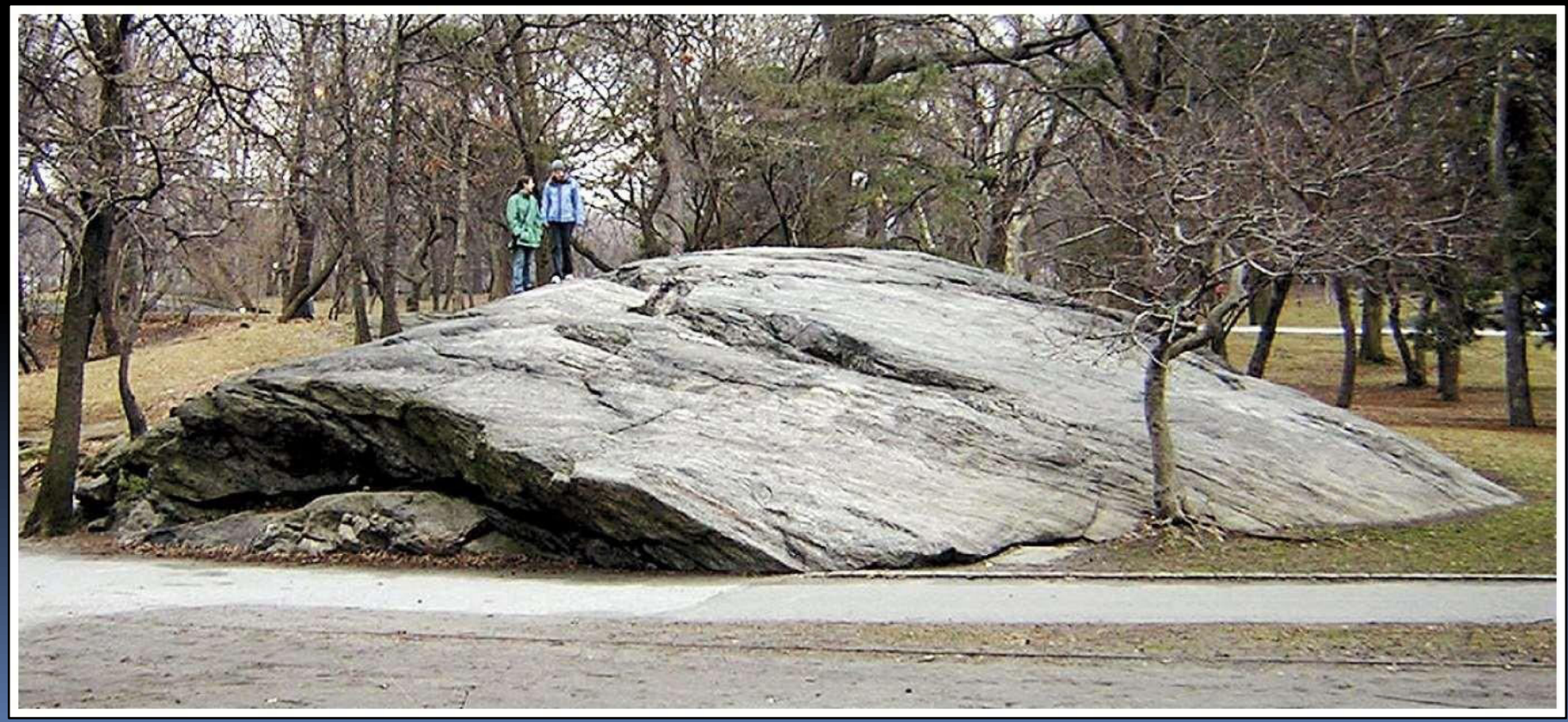
Glacial Erosion

- **Glaciers erode substrates in several ways.**
  - **Plucking – Ice breaks off and removes bedrock fragments.**
    - **Ice melts by pressure against the up-ice side of an obstruction.**
    - **Entering cracks in bedrock, this water re-freezes to the ice.**
    - **Glacial movement plucks away bedrock chunks.**



Glacial Erosion

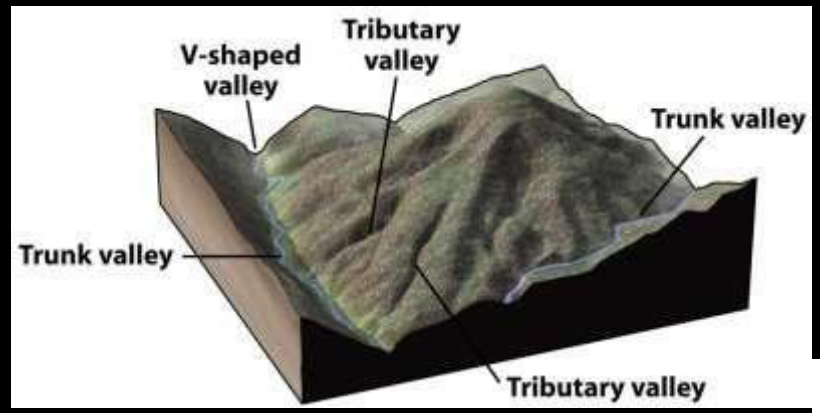
- **Glacial abrasion – A “sandpaper” effect on substrate.**
  - **Substrate is pulverized to fine “rock flour.”**
  - **Sand in moving ice abrades and polishes bedrock.**

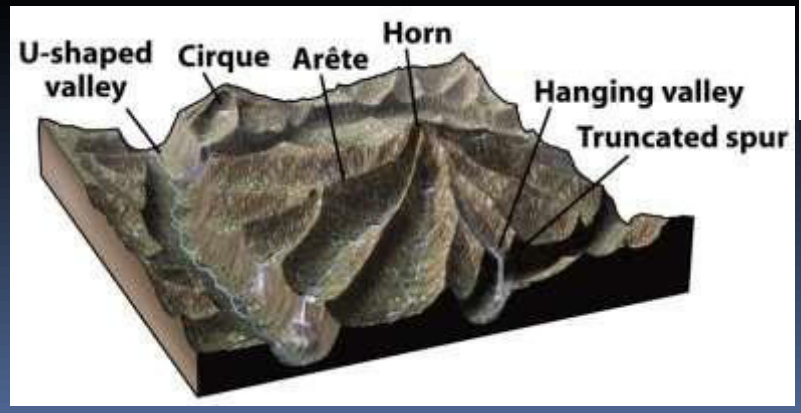


Glacial Erosion

< **Erosional features of glaciated valleys.**

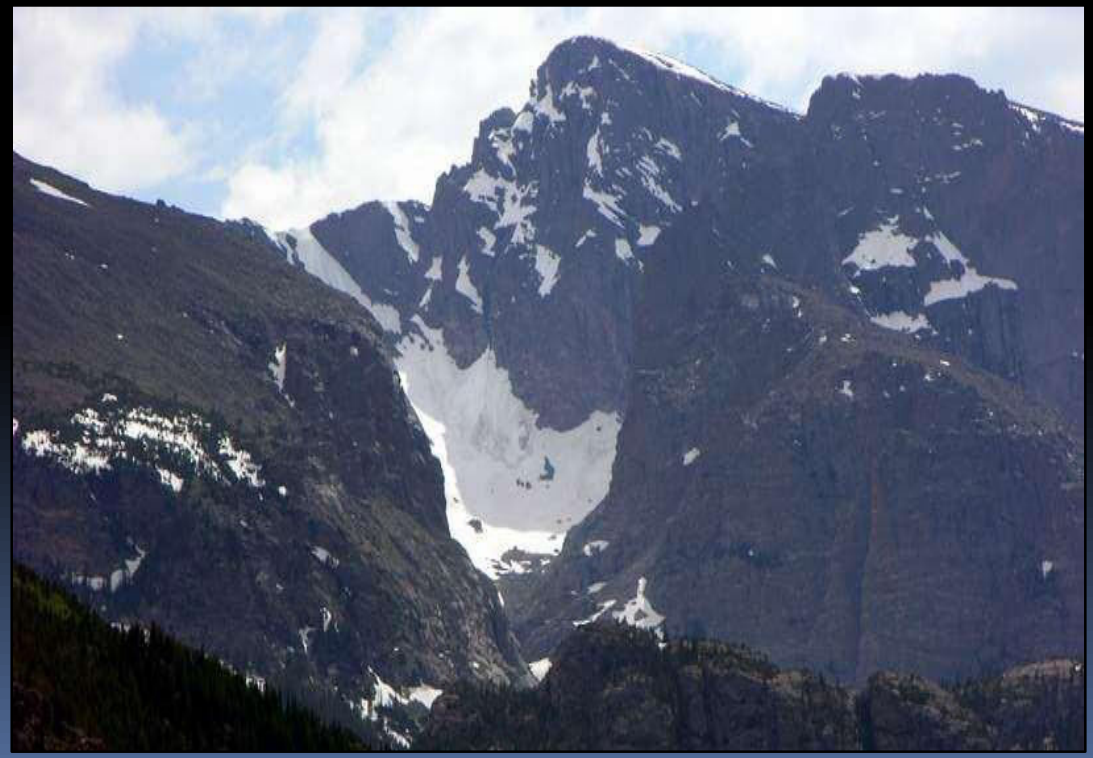
- = **Cirques.**
- = **Tarns.**
- = **Aretes.**
- = **Horns.**
- = **U-shaped valleys.**
- = **Hanging valleys.**
- = **Roche moutonnée.**
- = **Fjords.**





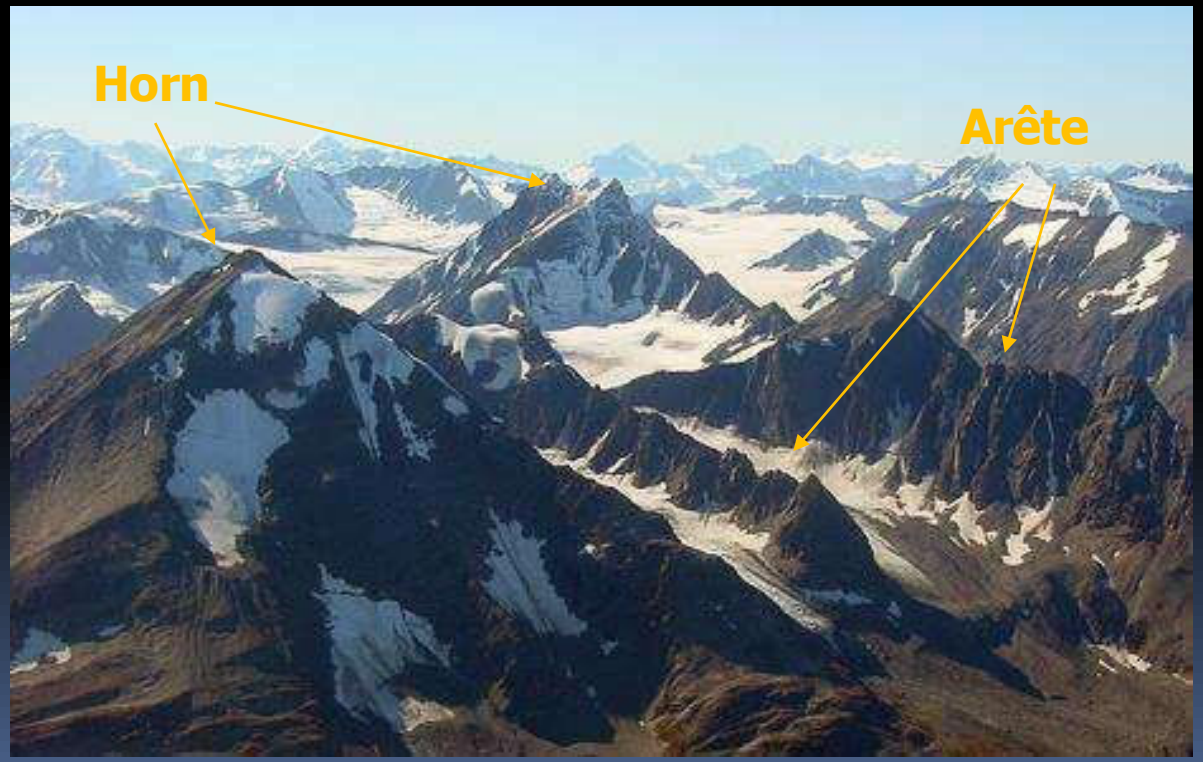
Glacial Erosion

- **Cirque – Bowl-shaped basin high on a mountain.**
  - **Forms at the uppermost portion of a glacial valley.**
  - **Freeze-thaw mass wasting into the cirque headwall.**
  - **After ice melts, the cirque is often filled with a tarn lake.**



Glacial Erosion

- **Arête – A “knife-edge” ridge.**
  - **Formed by 2 cirques that have eroded toward one another.**



Glacial Erosion

- **Horn – A pointed mountain peak.**
  - **Formed by 3 or more cirques that coalesce.**
  - **e.g. karakoram range, Nanda devi, Mt. Kailash**

Glacial Erosion

- **U-shaped valleys.**
  - **Glacial erosion creates a distinctive trough.**
  - **Unlike V-shaped fluvial valleys.**

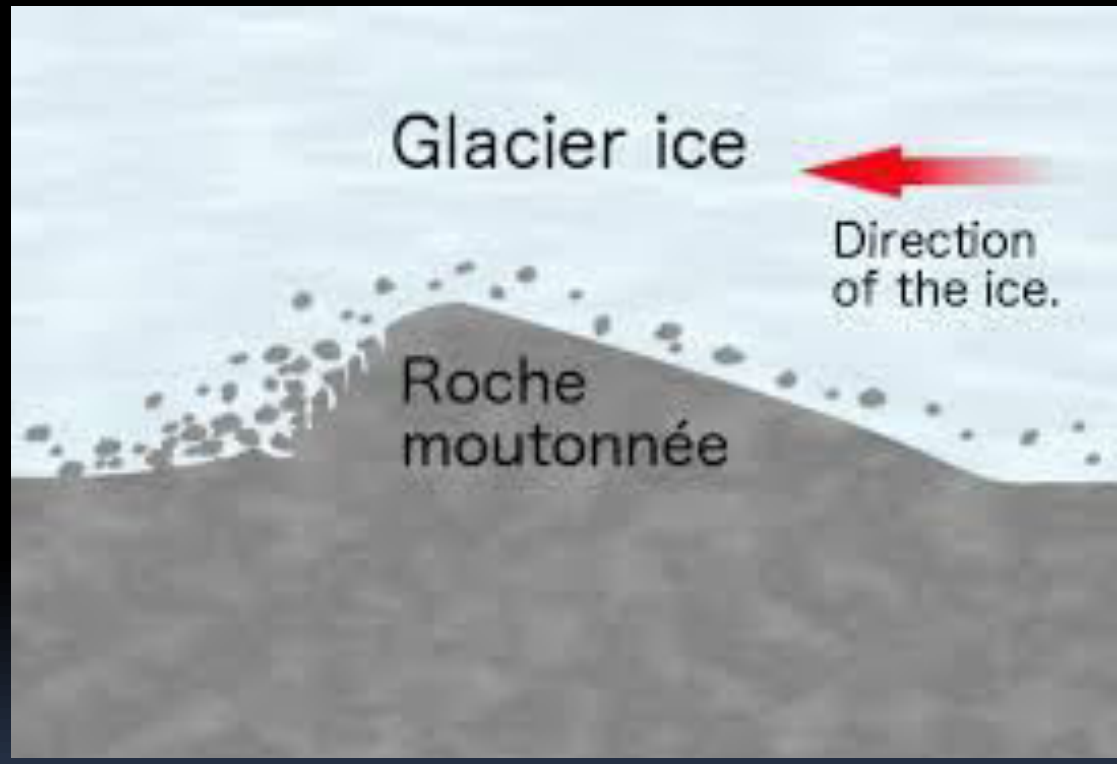
Glacial Erosion

- **Hanging valleys.**
  - **The intersection of a tributary glacier with a trunk glacier.**
  - **Trunk glacier incises deeper into bedrock.**
  - **Troughs have different elevations.**
  - **A waterfall results.**

Roche moutonnée

- A roche moutonnée is a rock formation created by the passing of a glacier. The passage of glacier ice over underlying bedrock often results in asymmetric erosional forms as a result of abrasion on the "stoss" side of the rock and plucking on the "lee" side.

Glacial Erosion



Glacial Erosion

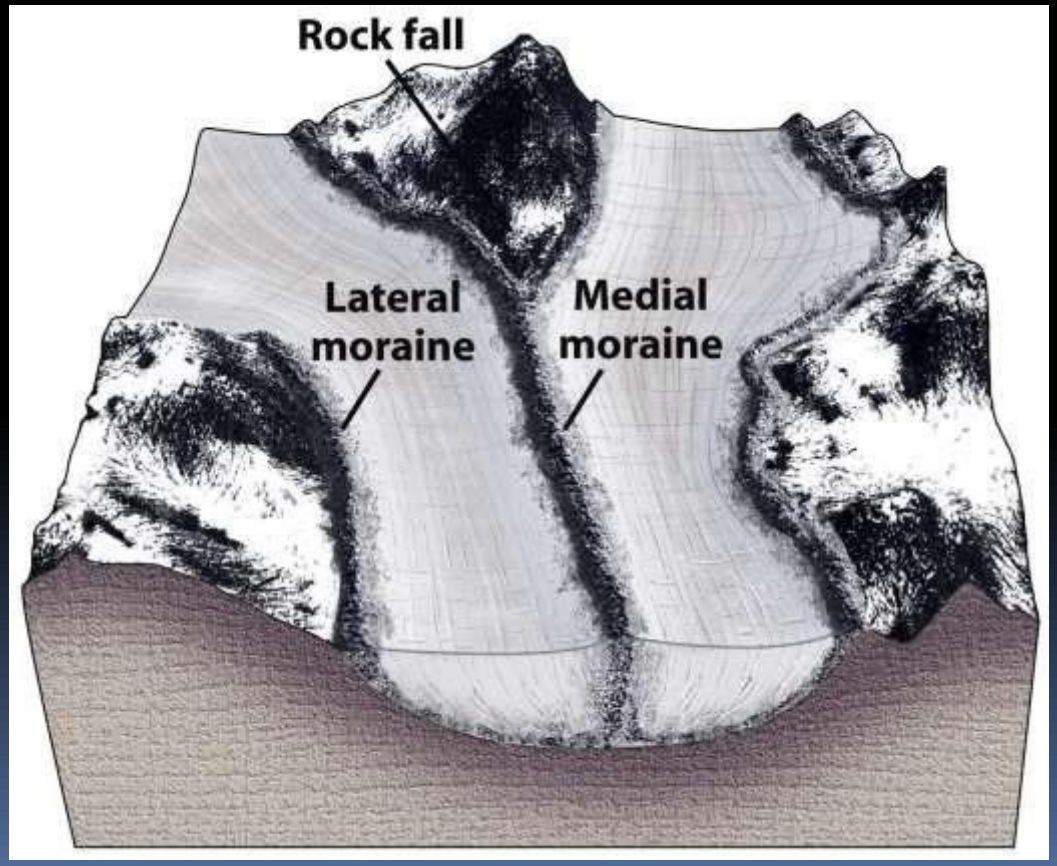
- **Fjords.**
  - **U-shaped glacial troughs flooded by the sea.**

Glacial Sediment Transport

- Glaciers carry sediment of all sizes – lots of it!
  - Some sediment falls onto the ice from adjacent cliffs.
  - Some sediment is entrained from erosion of the substrate.
- When glacial ice melts, this material is dropped.

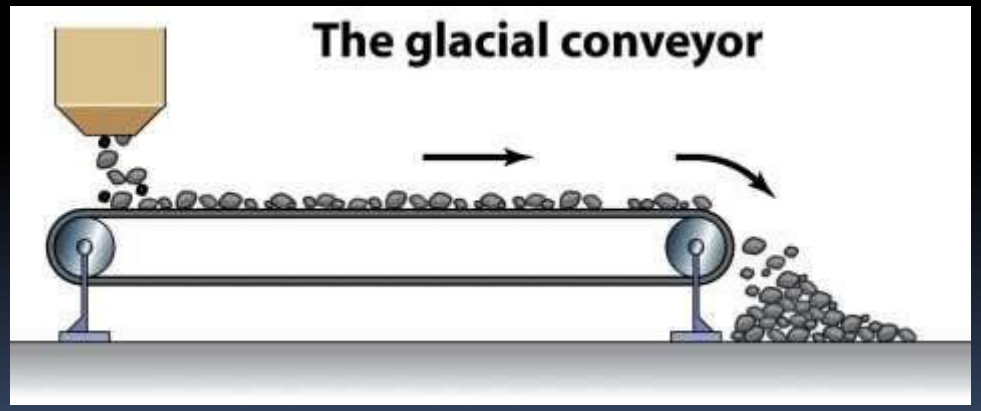
Glacial Sediment Transport

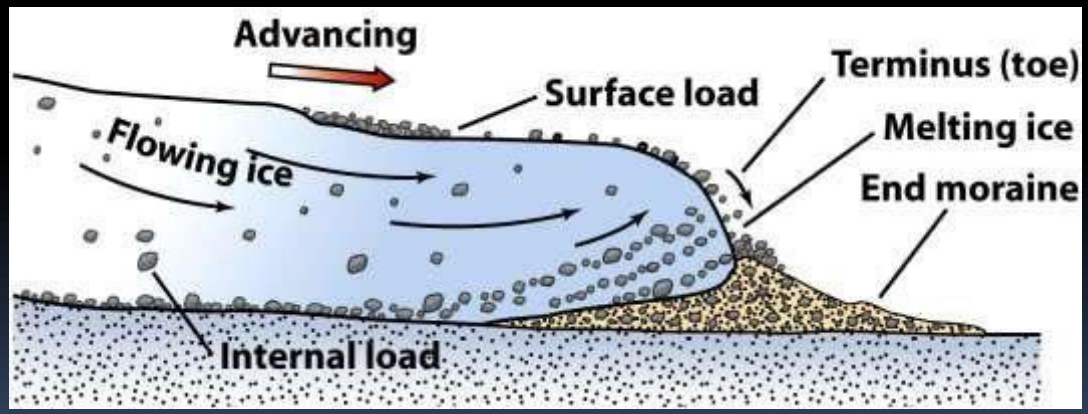
- **Moraines – Unsorted debris dumped by a glacier.**
  - **Lateral – Forms along the flank of a valley glacier.**
  - **Medial – Mid-ice moraine from merging lateral moraines.**



Glacial Sediment Transport

- **Glaciers act as large-scale conveyor belts.**
  - **They pick up, transport, and deposit sediment.**
  - **Sediment transport is always in one direction (downhill).**
  - **Debris at the toe of a glacier is called an end moraine.**





Glacial Deposition

- Many types of sediment derive from glaciation.
- Called glacial drift, these include...
  - Glacial till.
  - Erratics.
  - Glacial marine sediments.
  - Glacial outwash.
  - Glacial lake-bed sediment.
  - Loess.
- Stratified drift is water-sorted; unstratified drift isn't.

Glacial Deposition

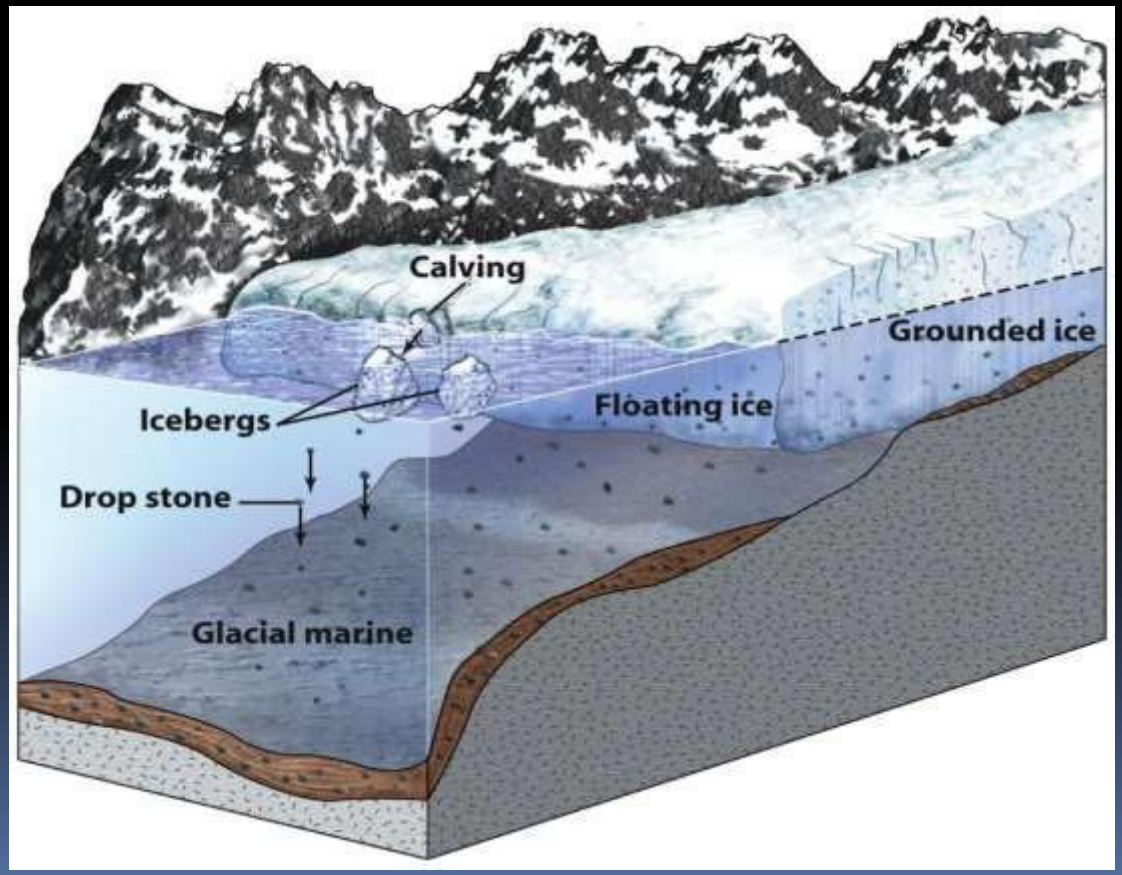
- **Glacial till – Sediment dropped by glacial ice.**
  - **Consists of all grain sizes.**
  - **Also called "boulder clay."**
  - **Unmodified by water, hence:**
    - **Unsorted.**
    - **Unstratified.**
  - **Accumulates…**
    - **Beneath glacial ice.**
    - **At the toe of a glacier.**
    - **Along glacial flanks.**

Glacial Deposition

- **Erratics – Boulders dropped by glacial ice.**
  - **These rocks are different than the underlying bedrock.**
  - **Often, they have been carried long distances in ice.**

Glacial Deposition

- **Glacial marine – Sediments from an oceanic glacier.**
  - **Calving icebergs raft sediments away from the ice.**
  - **Melting bergs drop stones into bottom muds.**
  - **Drop stones…**
    - **Differ from ambient sediment.**
    - **Indicate glaciation.**



Glacial Deposition

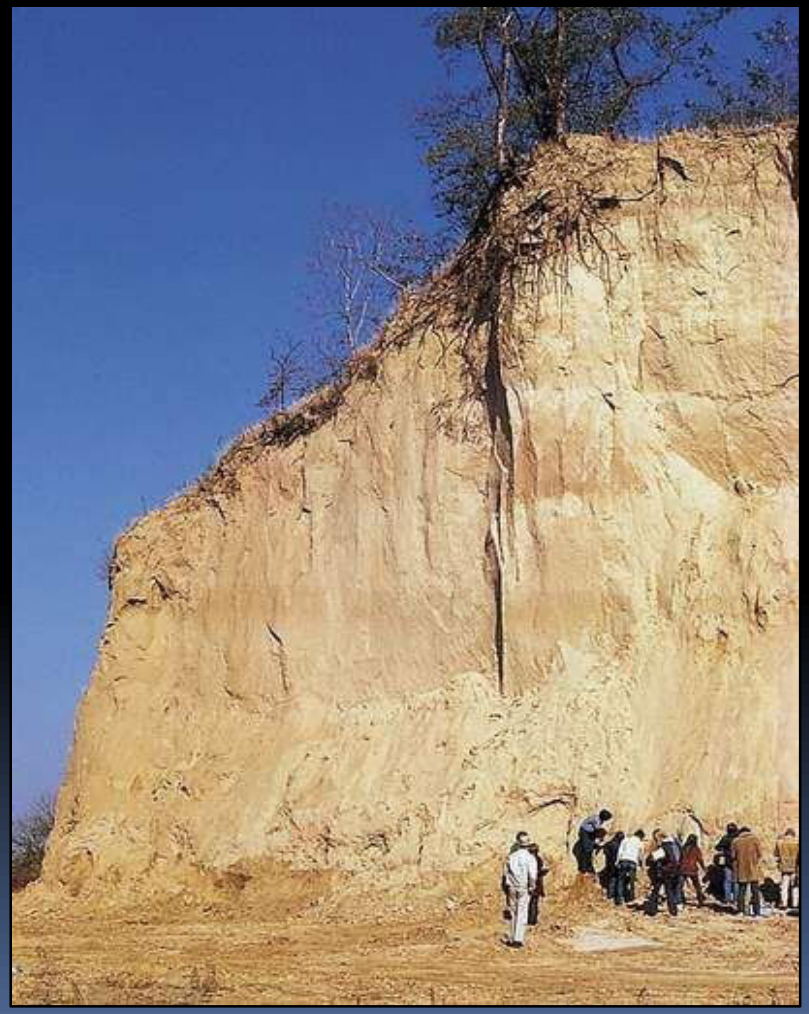
- **Glacial outwash – Sediment transported in meltwater.**
  - **Muds removed.**
  - **Size graded and stratified.**
  - **Abraded and rounded.**
- **Outwash dominated by sand and gravel.**

Glacial Deposition

- **Glacial lake-bed sediment.**
  - **Lakes are abundant in glaciated landscapes.**
  - **Fine rock flour settles out of suspension in deep lakes.**
  - **Muds display seasonal varve couplets.**
    - **Finest silt and clay from frozen winter months.**
    - **Coarser silt and sand from summer months.**

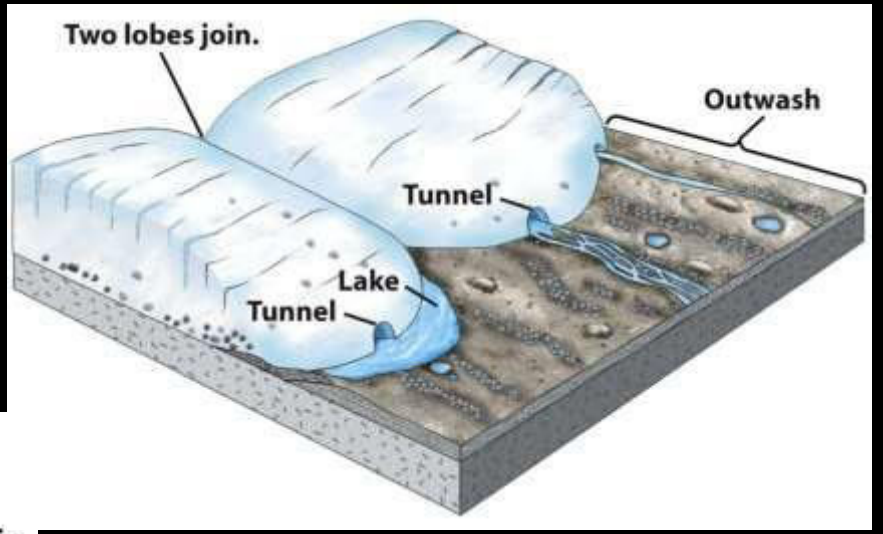
Glacial Deposition

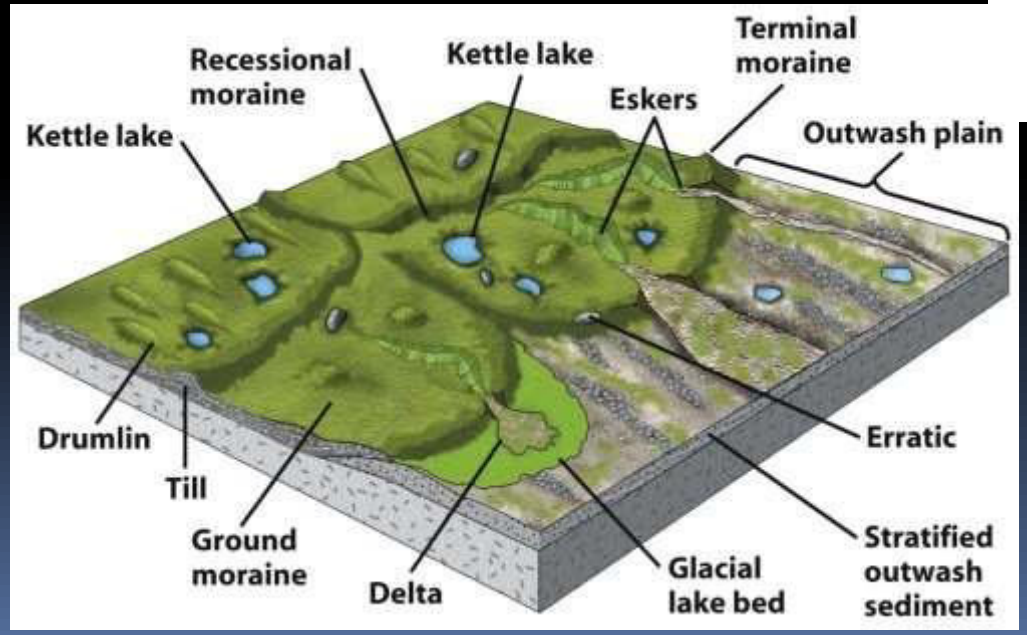
- **Loess – Wind-transported silt. Pronounced "luss."**
  - **Glaciers produce abundant amounts of fine sediment.**
  - **Strong winds off ice blows the rock flour away.**
  - **This sediment settles out near glaciated areas as loess deposits.**



Depositional Landforms

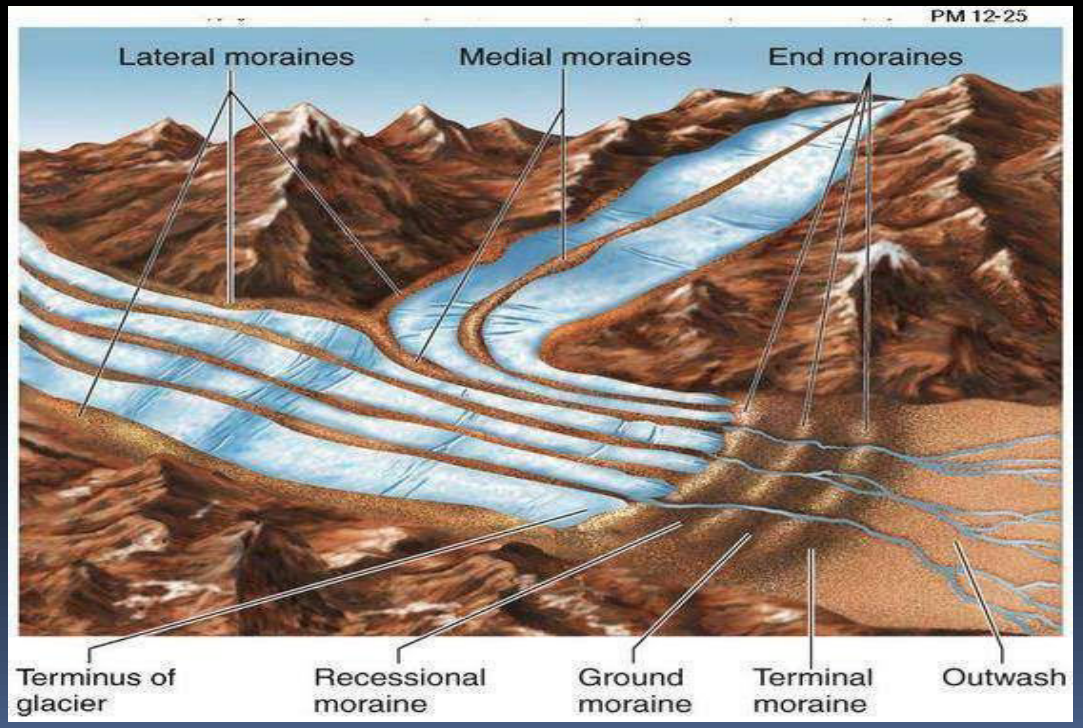
- **Glacial sediments create distinctive landforms.**
  - **End moraines and terminal moraines.**
  - **Recessional moraines.**
  - **Drumlins.**
  - **Ground moraine.**
  - **Kettle lakes.**
  - **Eskers.**

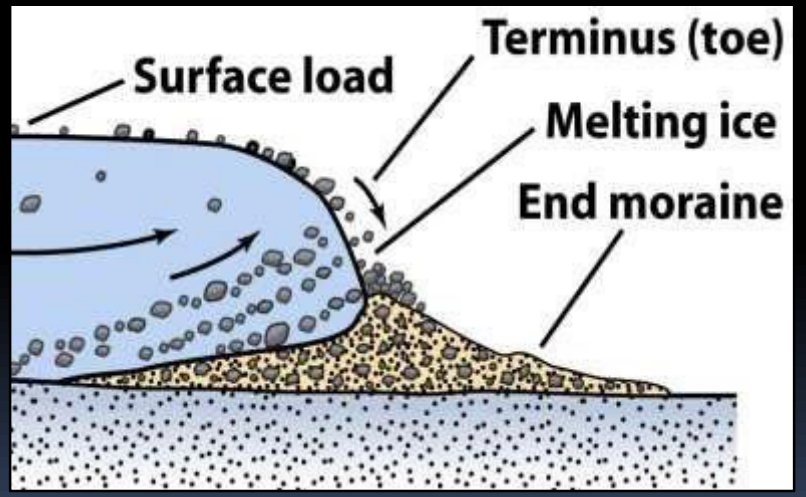




Depositional Landforms

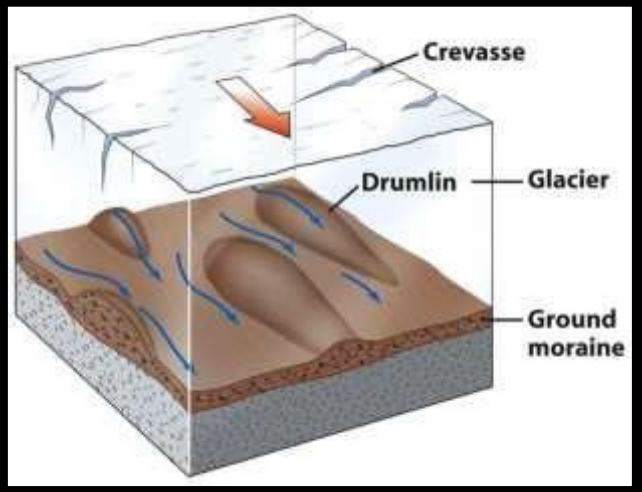
- End moraines form at the stable toe of a glacier.
- Terminal moraines form at the farthest edge of flow.
- Recessional moraines form as retreating ice stalls.

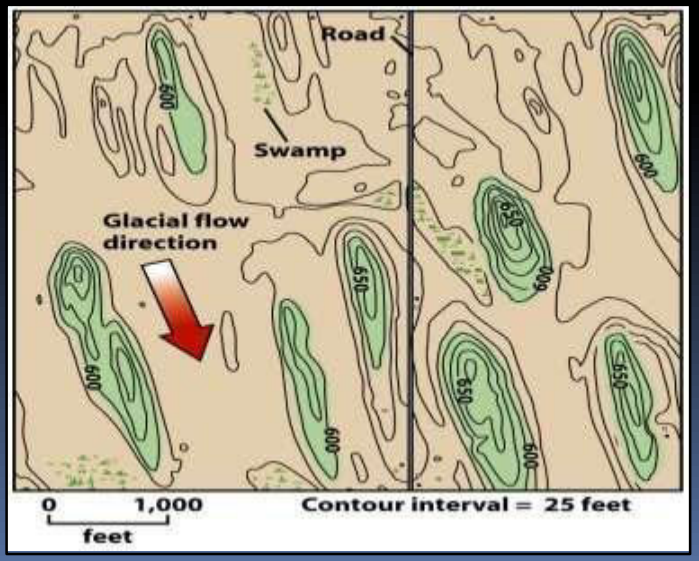




Depositional Landforms

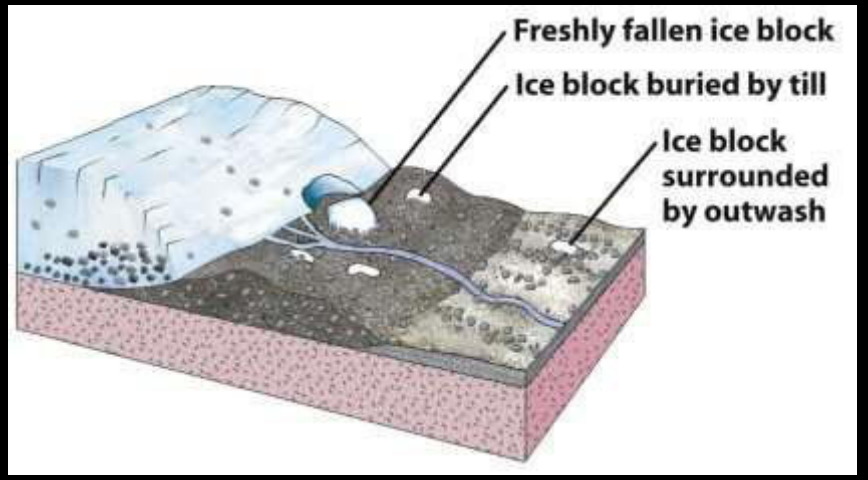
- **Drumlins – Long aligned hills of molded lodgment till.**
  - **Asymmetric form – Steep up-ice; tapered down-ice.**
  - **Common as swarms aligned parallel to ice flow direction.**

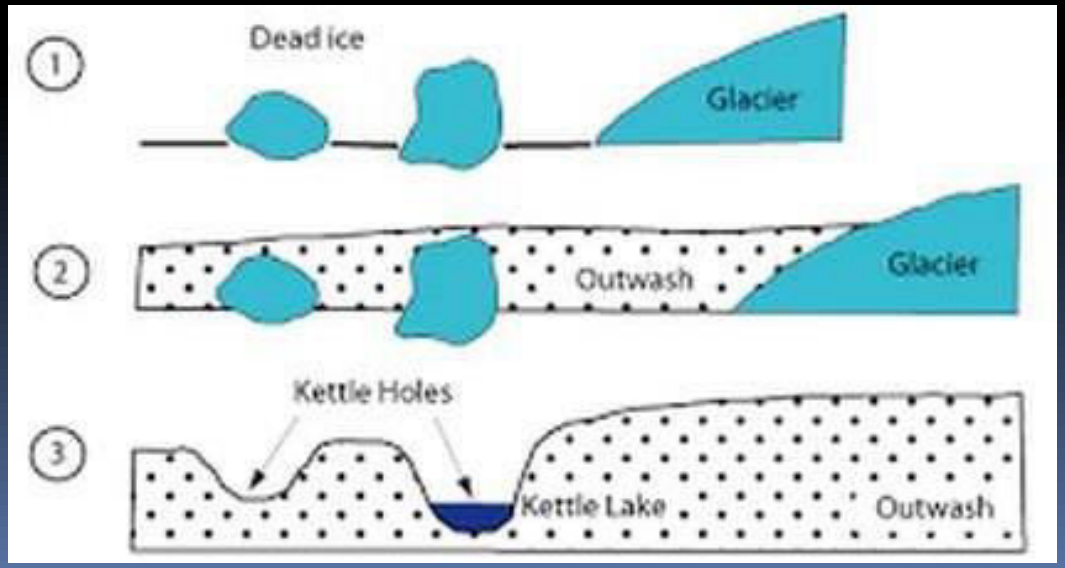


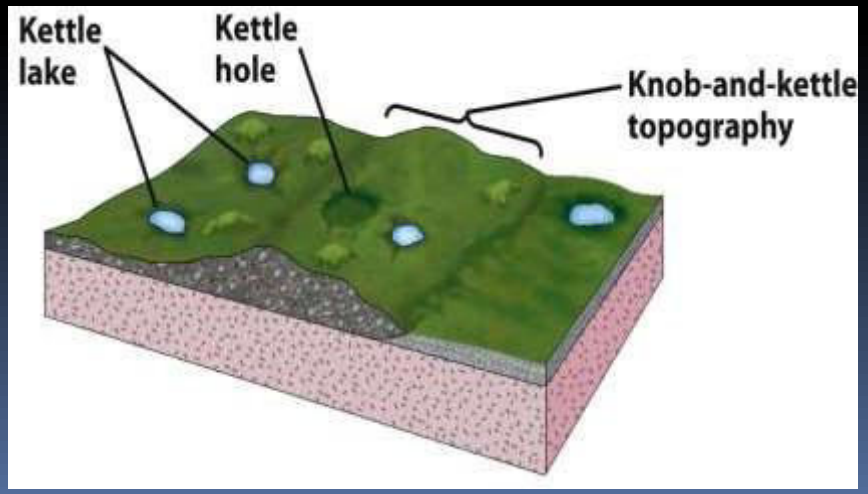


Depositional Landforms

- **Kettles**
  - = Small depressions in the landscape, often filled with water post glaciation
  - = Large blocks of ice are left by a retreating glacier
  - = Outwash sediments deposited around the blocks,
  - = Ice block melts, only a void or kettle remains.
  - = Subsidence and melting can deepen the kettle.
  - = Kettles lakes are sourced by rainfall or snowmelt.

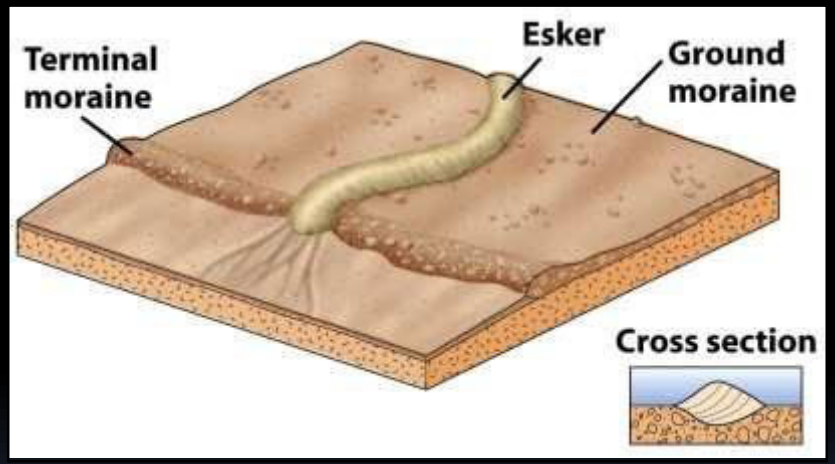






Depositional Landforms

- Eskers are long, sinuous ridges of sand and gravel.
- They form as meltwater channels within or below ice.
- Channel sediment is released when the ice melts.



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