Lecture 10 – Glaciers and glaciation

Outline

- Importance of ice to people!
- Basics of glaciers – formation, classification, mechanisms of movement
- Glacial landscapes – erosion and deposition by glaciers and the features that result
- Periglacial environments and features

Importance of ice to climate and society

What happens to snow

- Snow can sublimate (turn from solid to gas) even at temperatures below 0 ^{o}C when exposed to sunlight, especially in dry and windy conditions

- When temperatures rise e.g. in spring, snow melts to form water

- Snow that does not melt or sublimate (turn into water vapor) can build up to form glaciers and ice sheets

Birth of a glaciers and land ice

1. more snow accumulates each winter than melts each summer: snow depth gradually increases

2. pressure recrystallizes deep snow into denser ice with less air space

3. Eventually ice and snow become so thick that the pull of gravity causes the frozen mass to move:

a glacier is formed

Birth of a glaciers and land ice

Air bubbles start to close off

Air bubbles sealed and isolated from the atmosphere

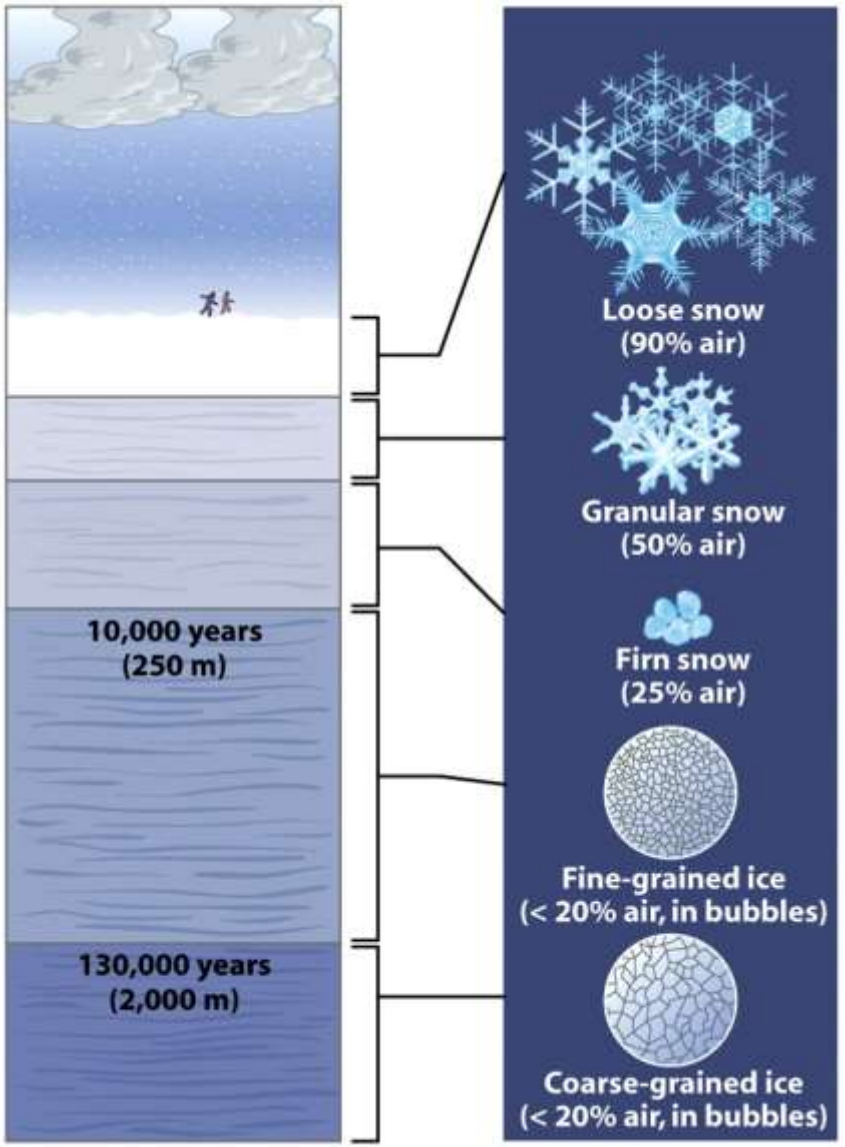


Figure 22-8 Earth: Portrait of a Planet 3/e

Are the air bubbles in snow younger or older than the isotope records in the surrounding ice?

a) Older
b) Same
c) Younger

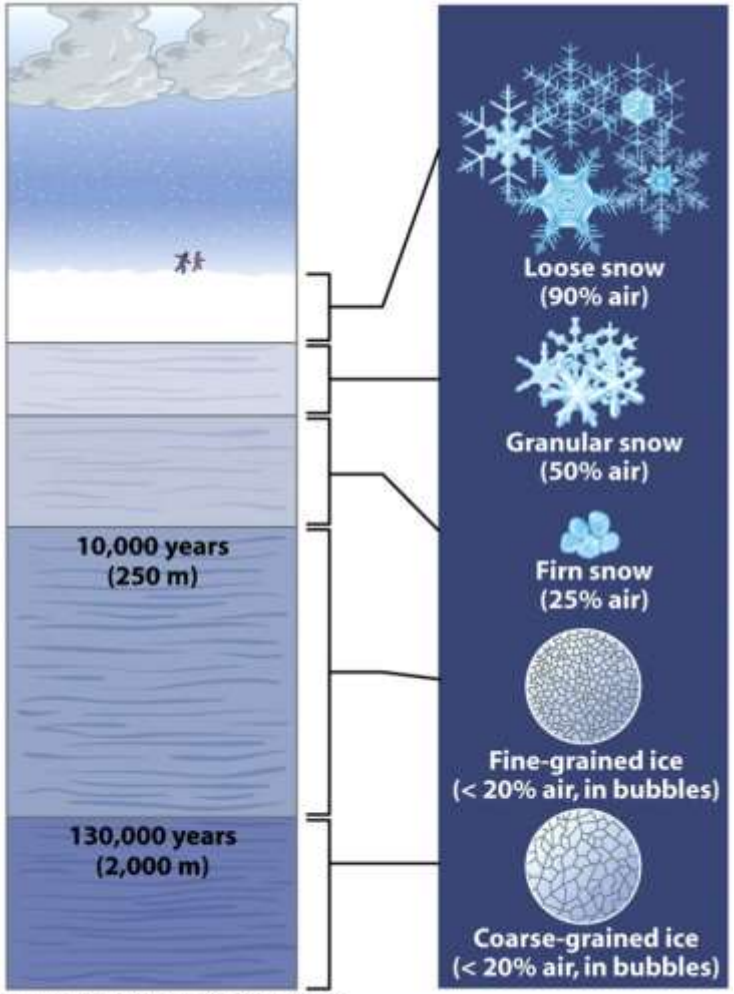


Figure 22-8 Earth: Portrait of a Planet 3/e

What is a glacier?

"a permanent body of ice, consisting largely of recrystallized snow, that shows evidence of slow downslope or outward movement due to its own weight"

Classified based on **shape** and **base temperature**

Glaciers: Types based on shape

Alpine glaciers – glaciers in mountains that flow down valleys

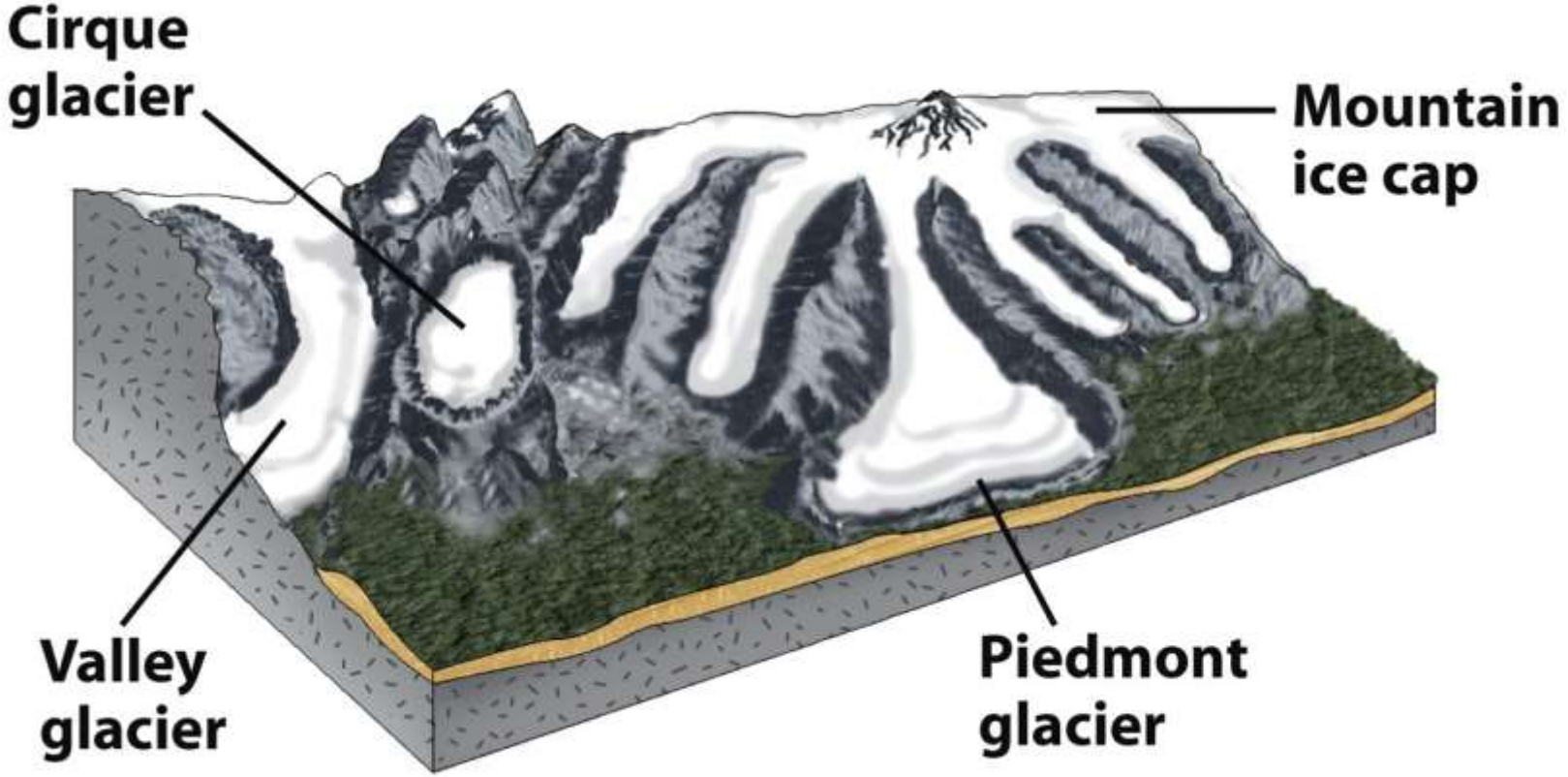


Figure 22-4a Earth: Portrait of a Planet 3/e

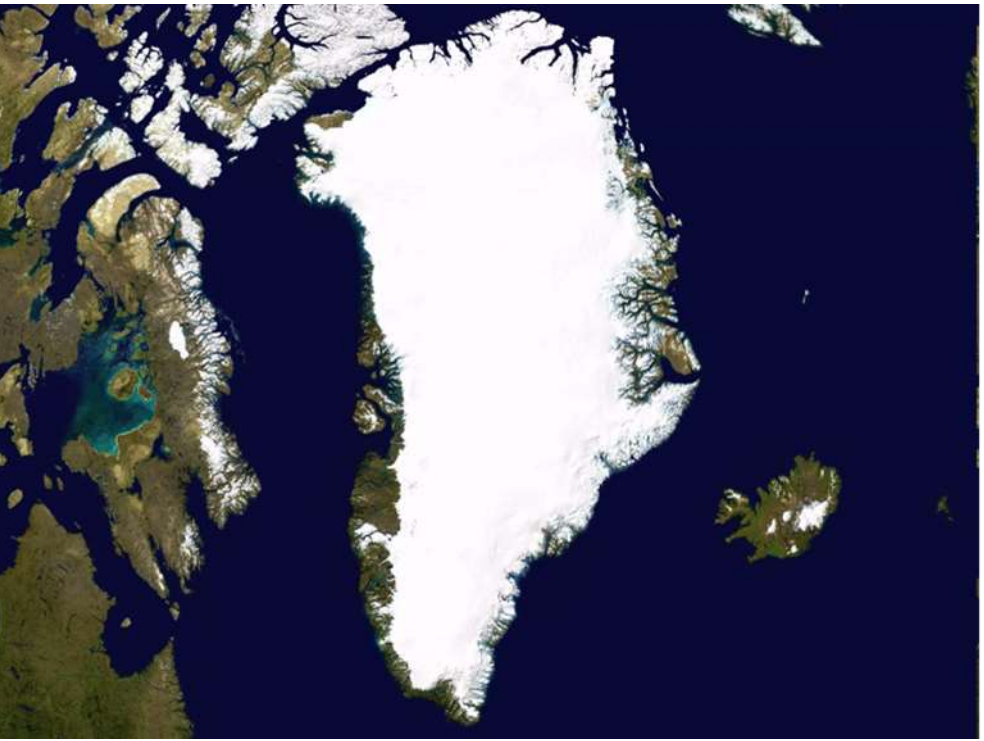
Glaciers: Types based on shape

Alpine glaciers - glaciers in mountains that flow down valleys
Tidewater glaciers – when a valley glacier reaches the sea

Glaciers: Types based on shape

Continental glaciers

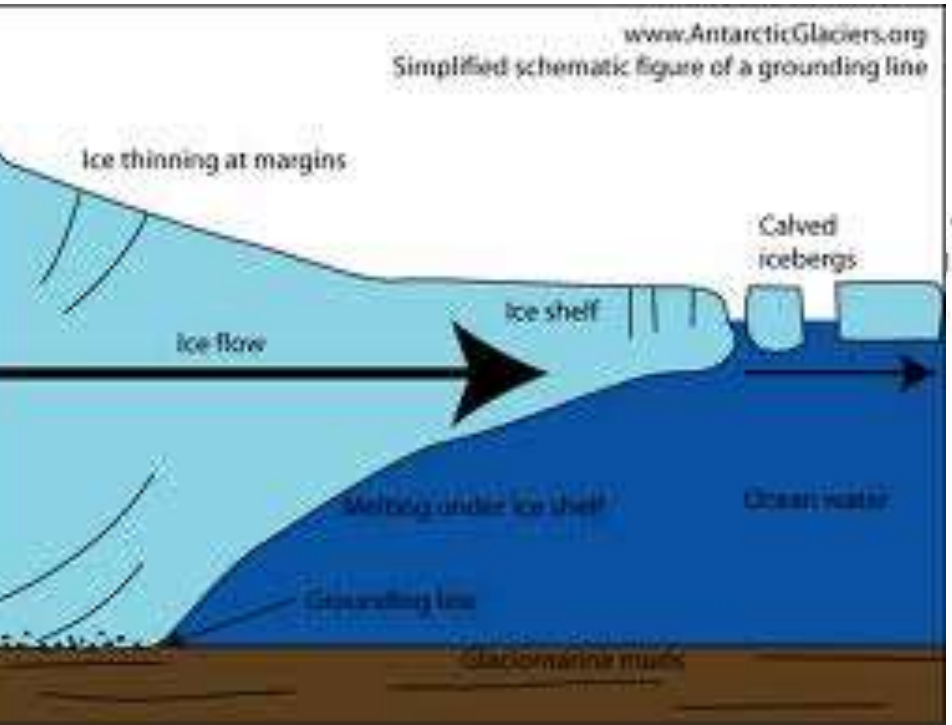
1. **Ice sheets –** only found in Antarctica and Greenland today, continental sized masses of ice covering >50,000 km^2 , also extremely thick (up to 4km in Antarctica) covering almost all land features

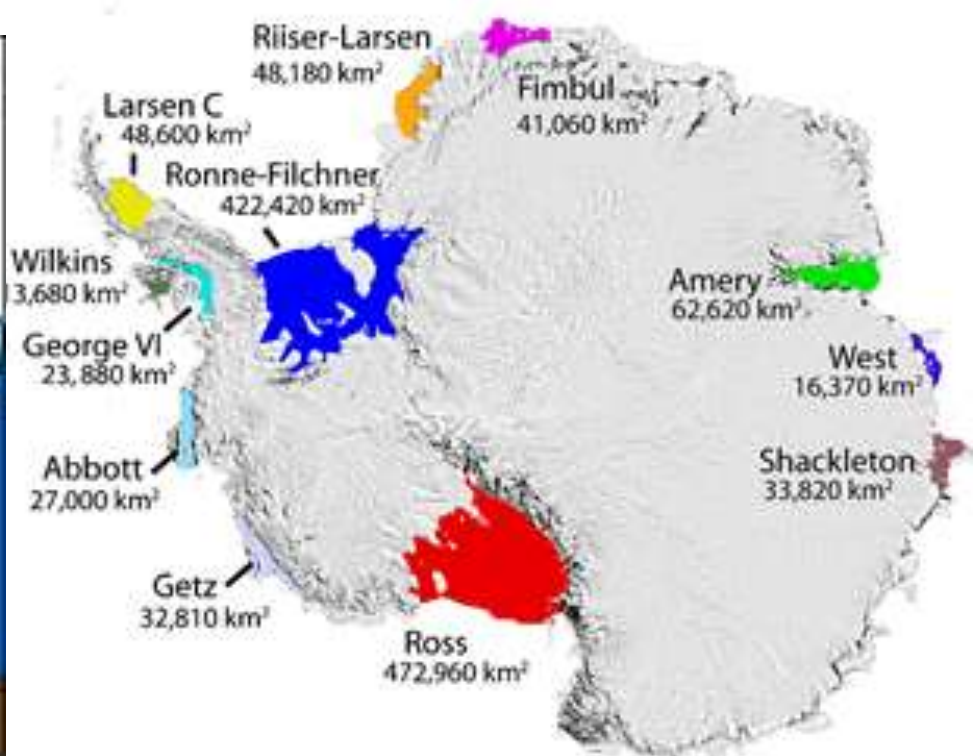


Glaciers: Types based on shape

Continental glaciers

2. Ice shelves – only found around Greenland and Antarctica today, occur where ice sheets extend over the sea and float on water, between 250m to 2.5km thick

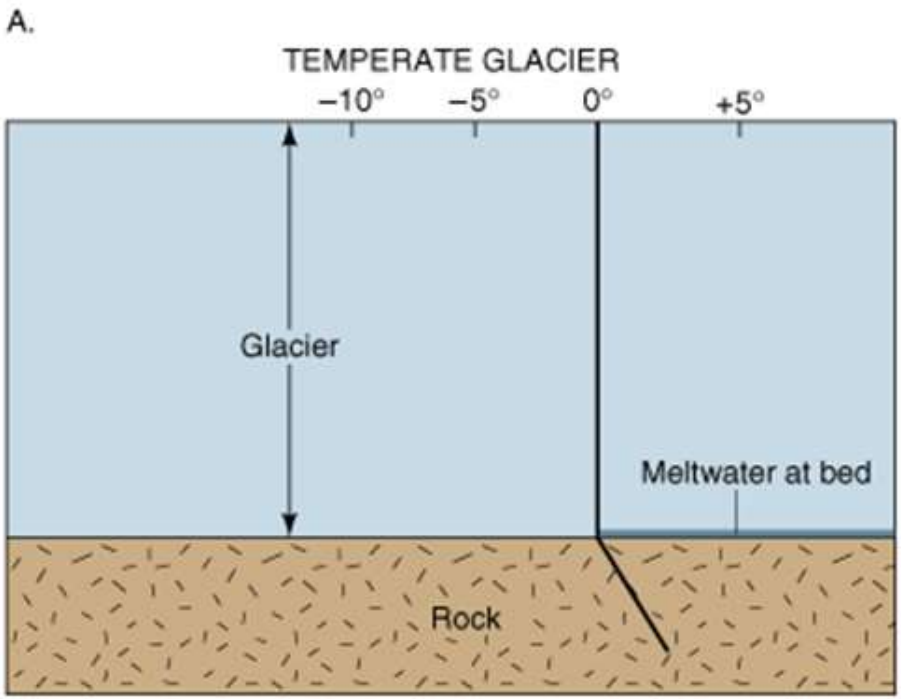


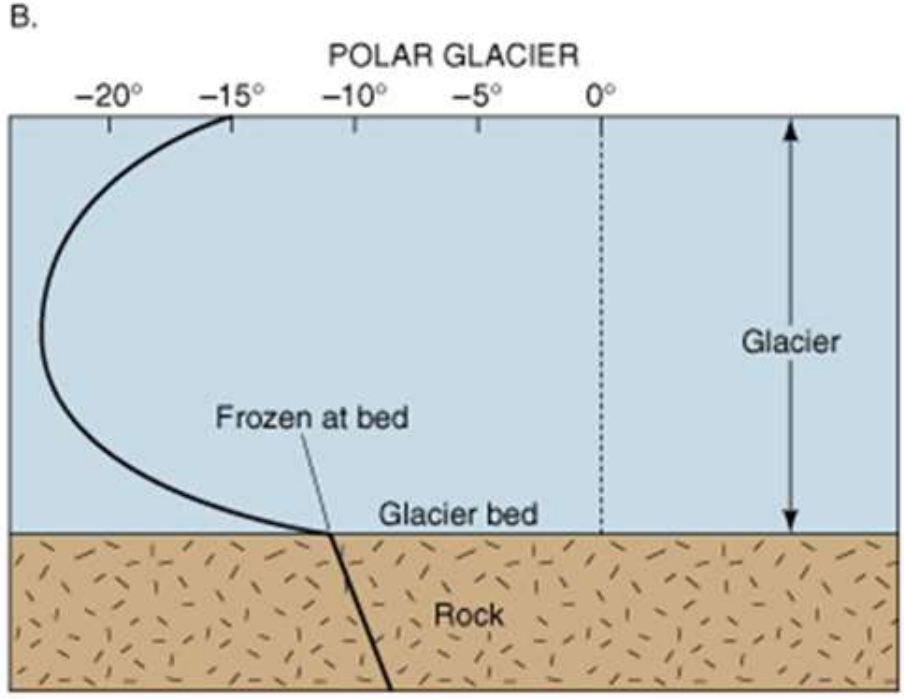


Glaciers: Types based on base temperature

- **Temperate glaciers** = where atmospheric temperatures high enough for the glacial ice to be at or near its melting temperature

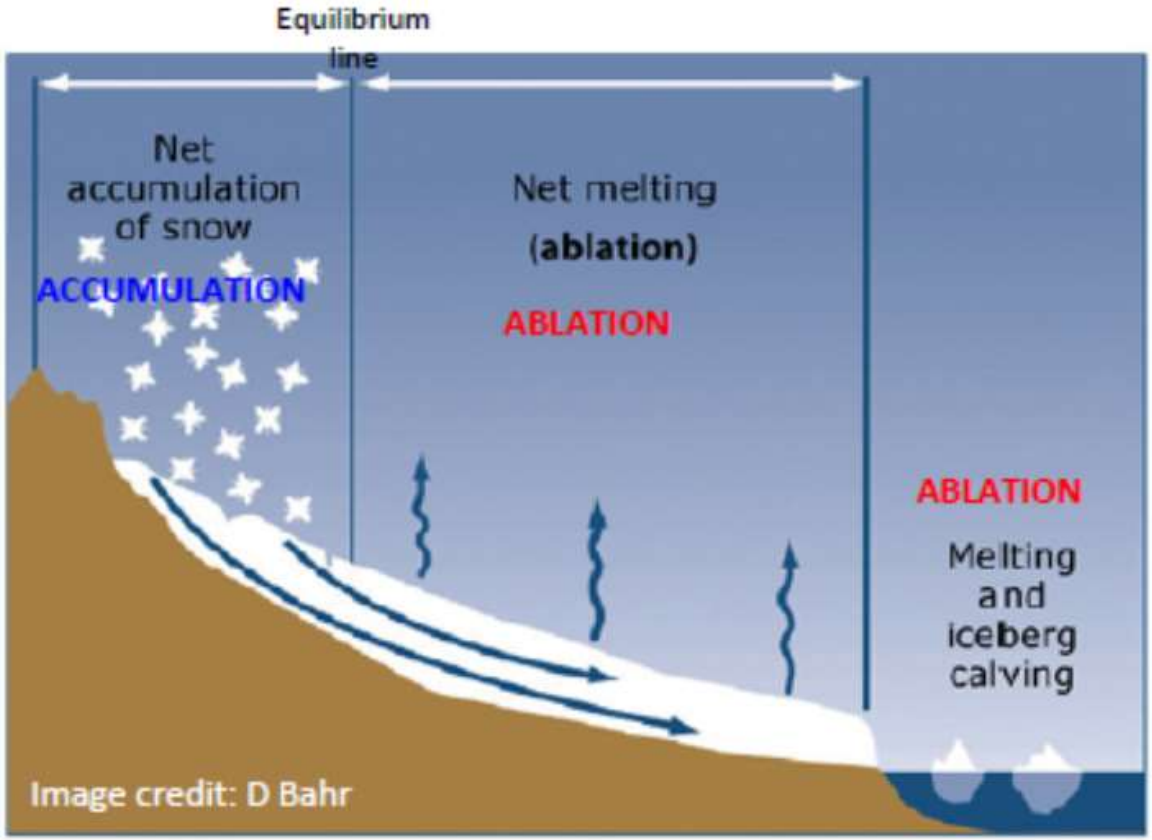
- **Polar glaciers** = where atmospheric temperatures are so low all year that the glacial ice stays well below its melting temperature





What controls a glacier's size and mass?

- A "river" of ice (and debris) flowing under its own weigh due to gravity
- Accumulation is the addition of ice to the glacier
- Ablation is the loss of ice from the glacier



What is a glacier?

"a permanent body of ice, consisting largely of recrystallized snow, that shows evidence of slow downslope or outward movement due to its own weight"

http://extremeicesurvey.org/

https://www.youtube.com/watch?v=89sOW-FzoII

How does a glacier move?

- Glacier ice deforms as a visco-plastic material
- Plastic because pressure has to be large enough to cause flow (and it will break/snap if there is too much force)
- Viscous because behaves like a fluid once it is flowing
- Two types of glacier motion:
  - Basal sliding
  - Internal deformation

Glacier Dynamics: Basal Sliding

- Process where the whole thickness of ice slides over the bedrock on a thin layer of water

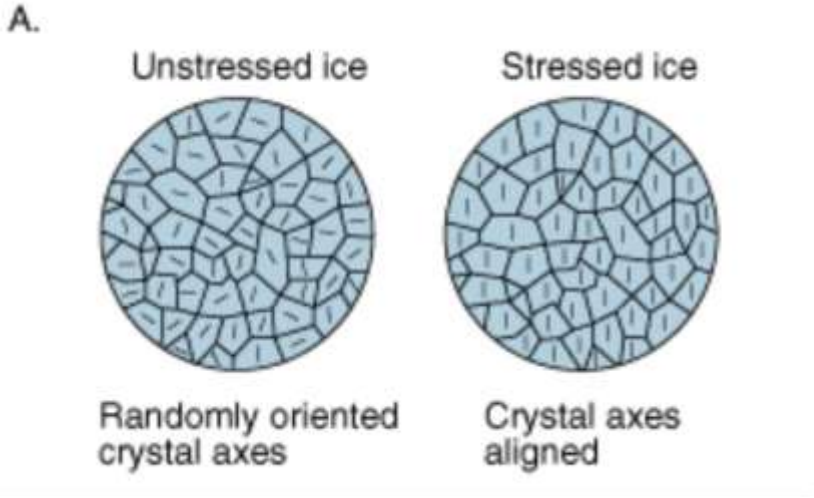
Glacier Dynamics: Basal Sliding

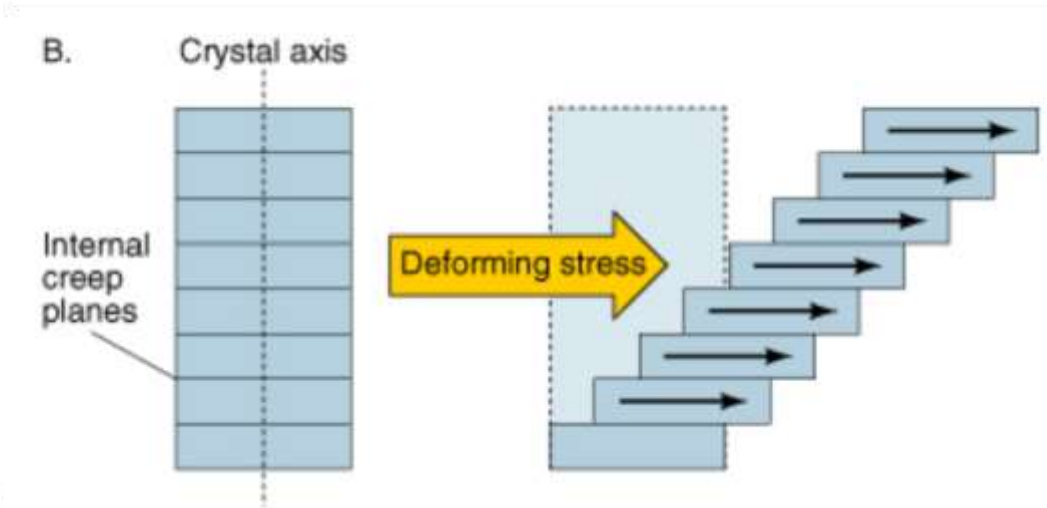
- Process where the whole thickness of ice slides over the bedrock on a thin layer of water
- Most important in temperate glaciers where the base is close to 0 °C. (Will not occur if base is frozen.)

https://www.youtube.com/watch?v=njTjfJcAsBg

Glacier Dynamics: Internal Deformation

- Process where the, under huge pressure, the ice crystals rearrange themselves in layers parallel to the surface of the glacier and begin to glide over one another
- Most important in polar glaciers where the whole glacier, including the base, is under 0 °C but will also occur in temperate glaciers





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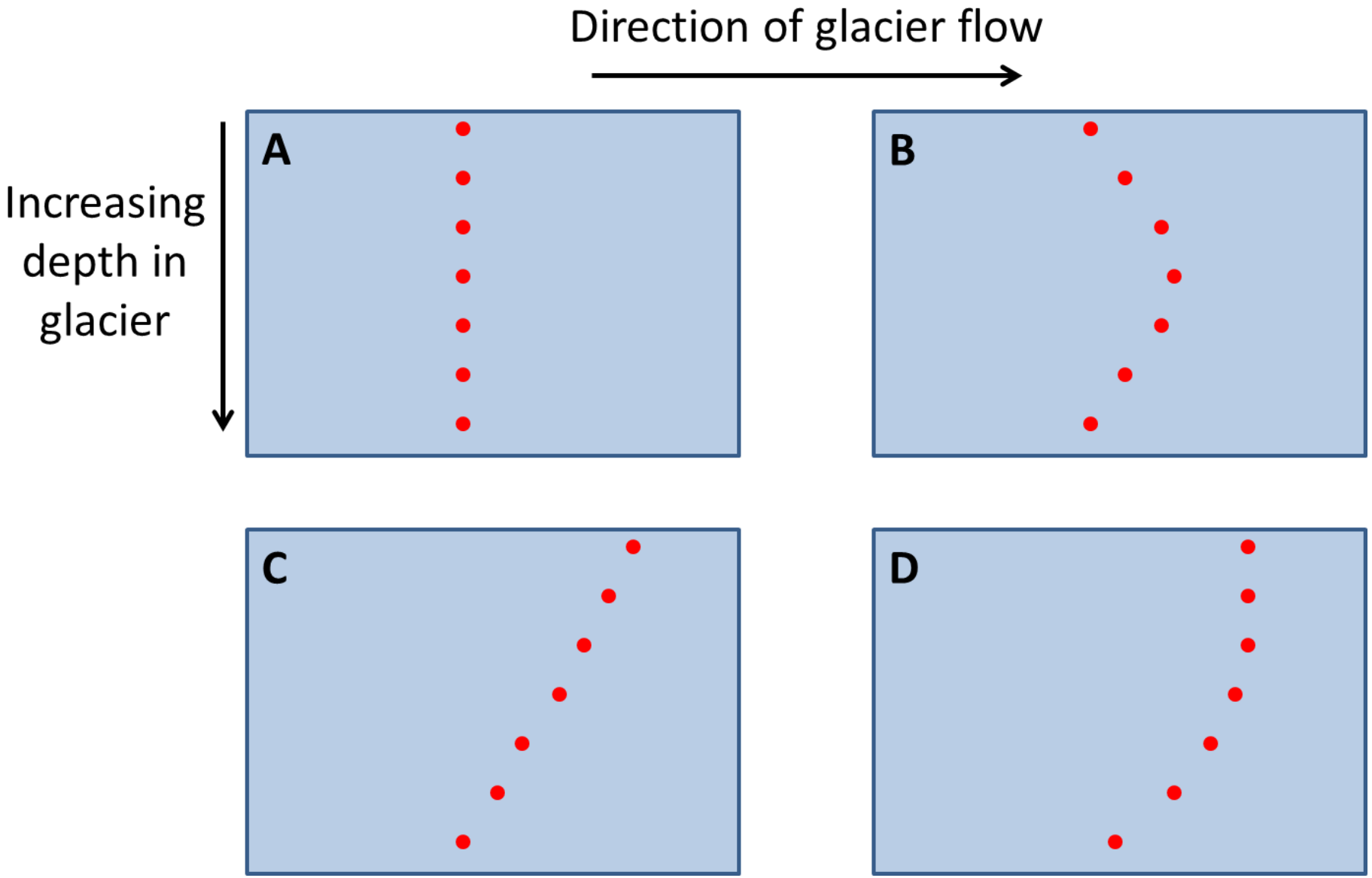
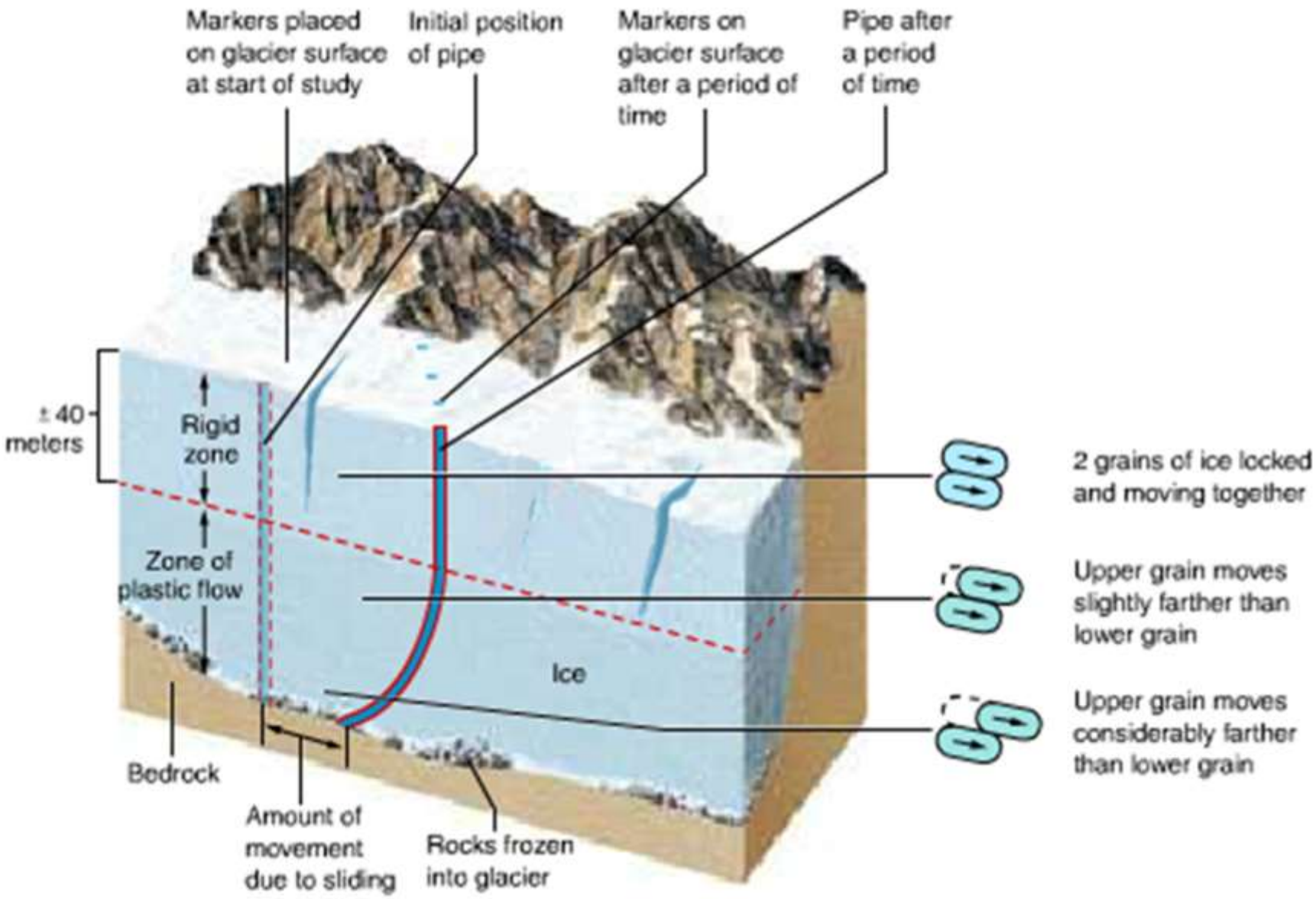

Direction of glacier flow
Increasing depth in glacier
A
B
C
D

How does a glacier move



Moving ice

- Moving ice has enormous power
- Sculpt and carve away rock beneath
- Transport sediment away and deposit it elsewhere
- Pattern of glacials and interglacials has shaped much of the landscape around the world

Question – Which of these is NOT a glacial landscape?

Glacial Landscapes: Erosion

- Glacial erosion produces some of our most dramatic landscapes - deep, steep-sided valleys and jagged, knife-edged ridges and pointed spires

Glacial Landscapes: Erosion

- Rock fragments embedded in glacial ice act like sandpaper on underlying bedrock
- The moving ice abrades and polishes substrates, producing a fine pulverized “rock flour”
- Larger rocks gouge lines in bedrock called “striations”

https://www.youtube.com/watch?v=Gbfu2-Z_iDI

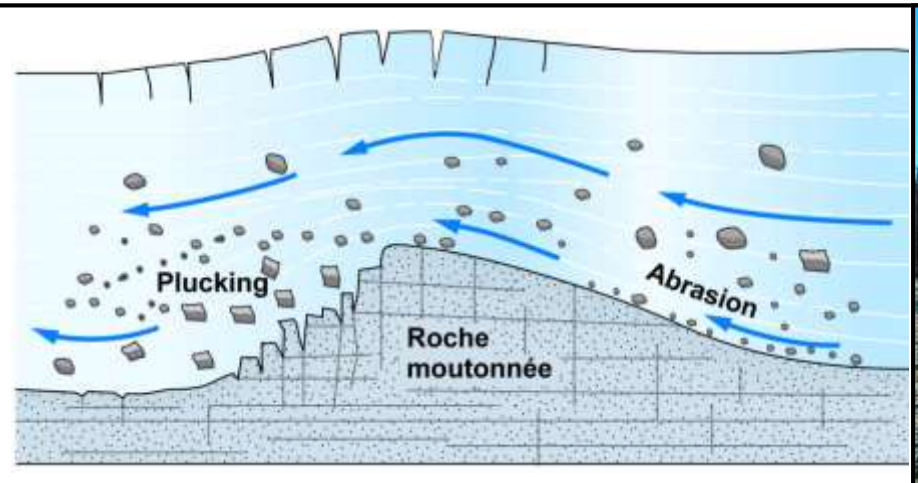
https://www.youtube.com/watch?v=njTjfJcAsBg

Glacial Landscapes: Erosion

- Polished mountains in Wyoming

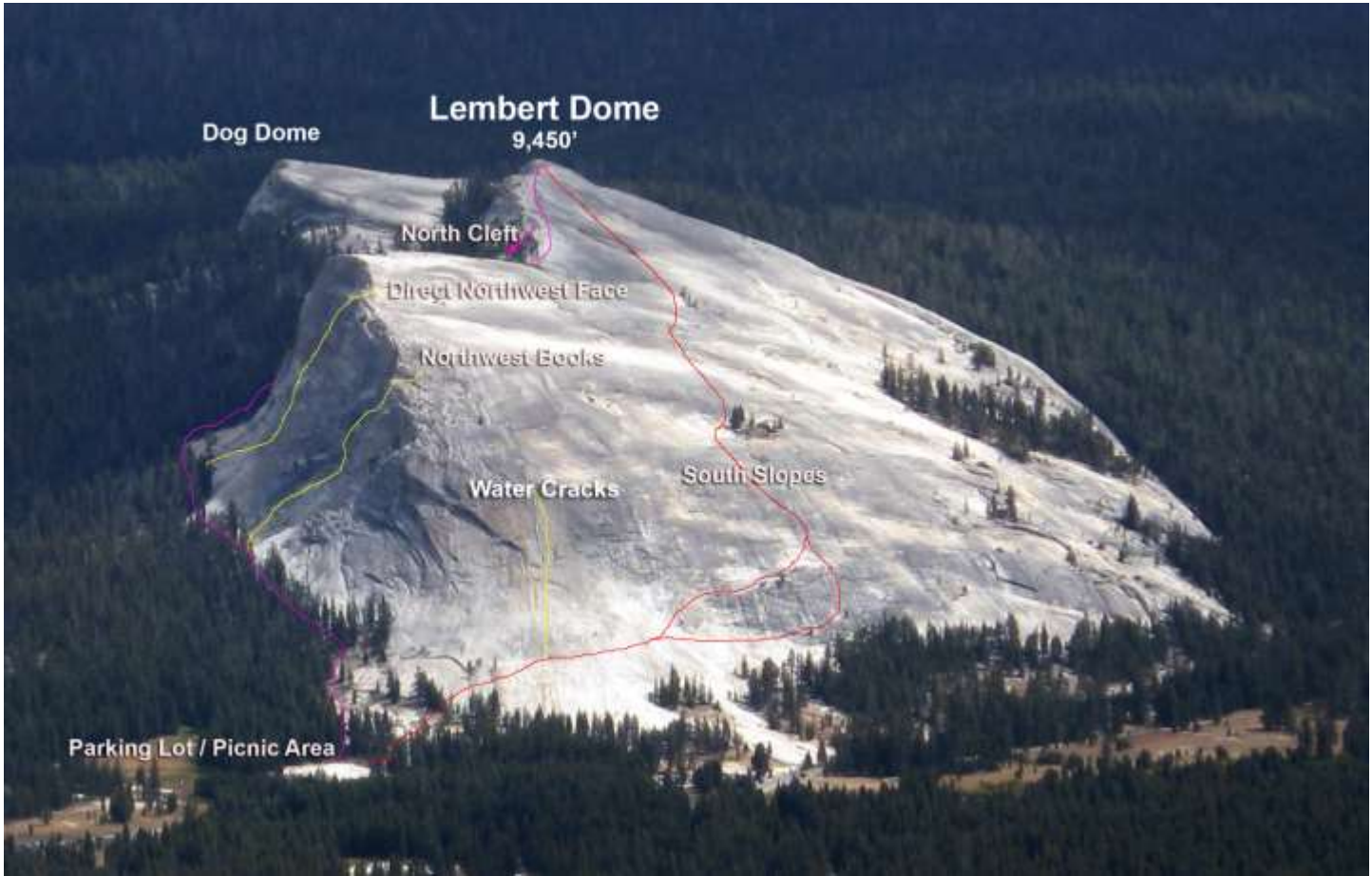
Glacial Landscapes: Erosion

- Glacial ice picks up rock fragments and incorporates them into the internal flow
- Roche moutonnee are asymmetric bedrock hills shaped by ice



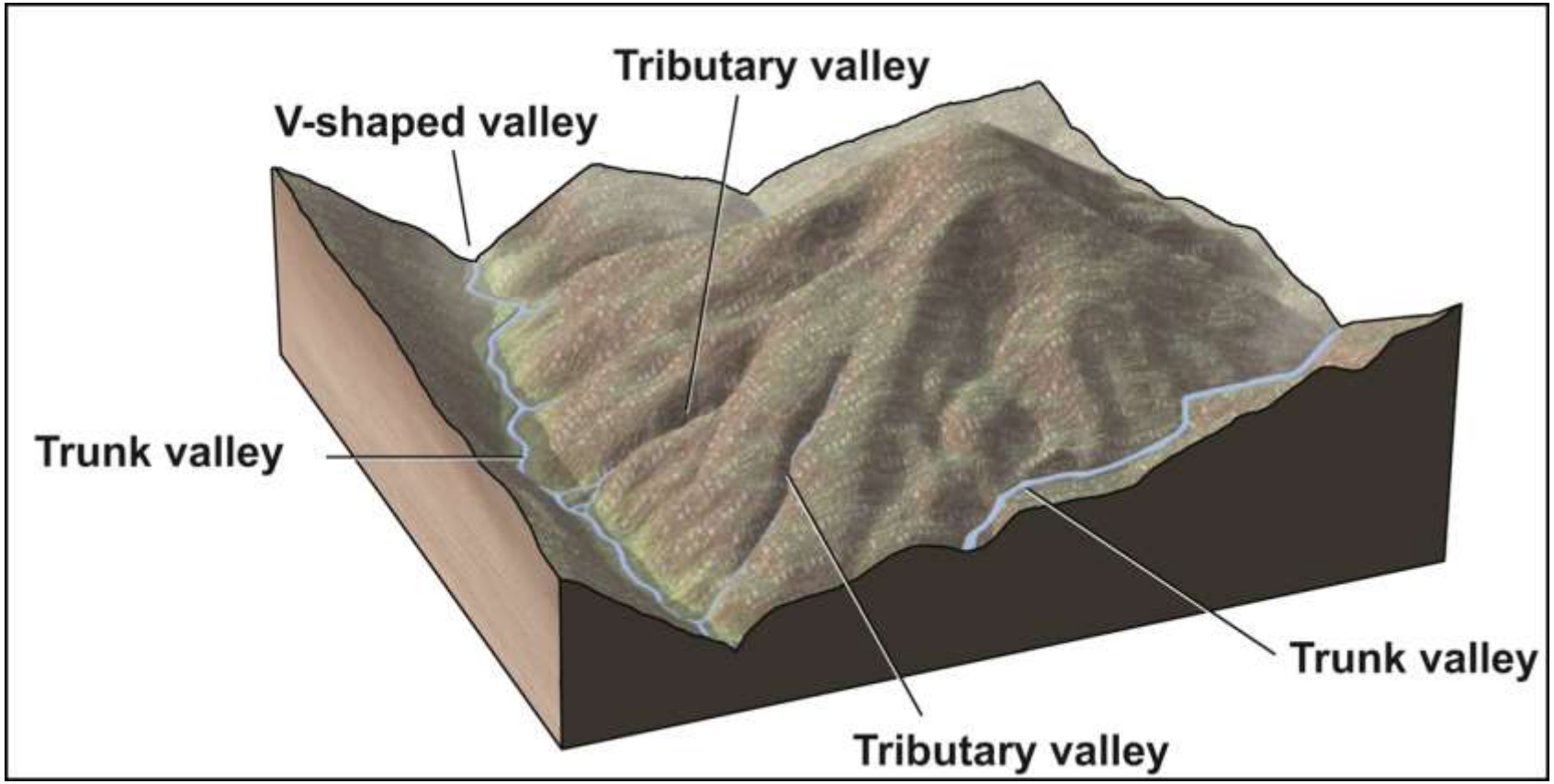
Which way did the glacier flow?

a) Left to right
b) Right to left



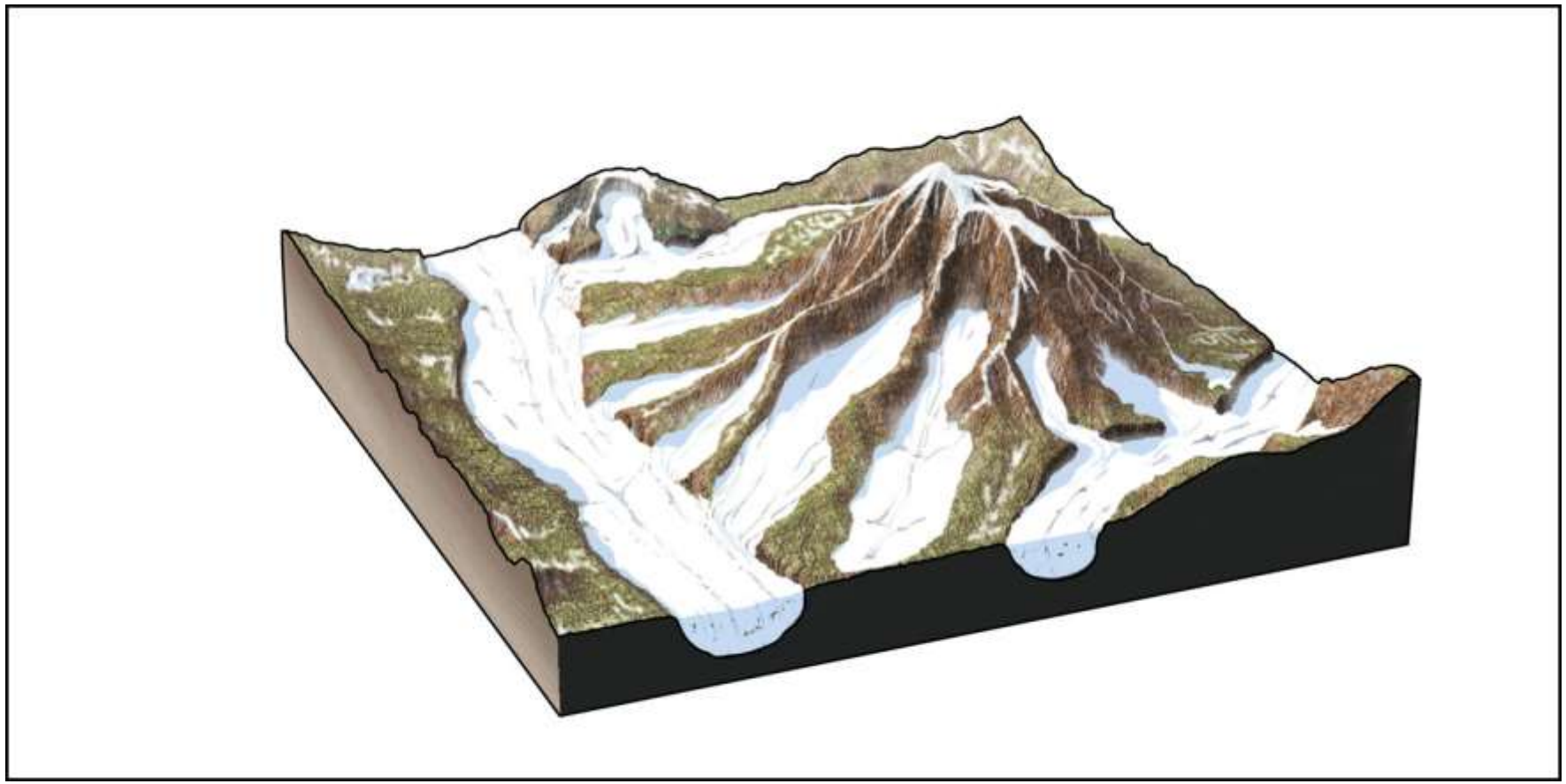
Glacial Landscapes: Erosion

- Before glaciation, valleys are V-shaped, and tributary mouths are the same elevation as the trunk stream



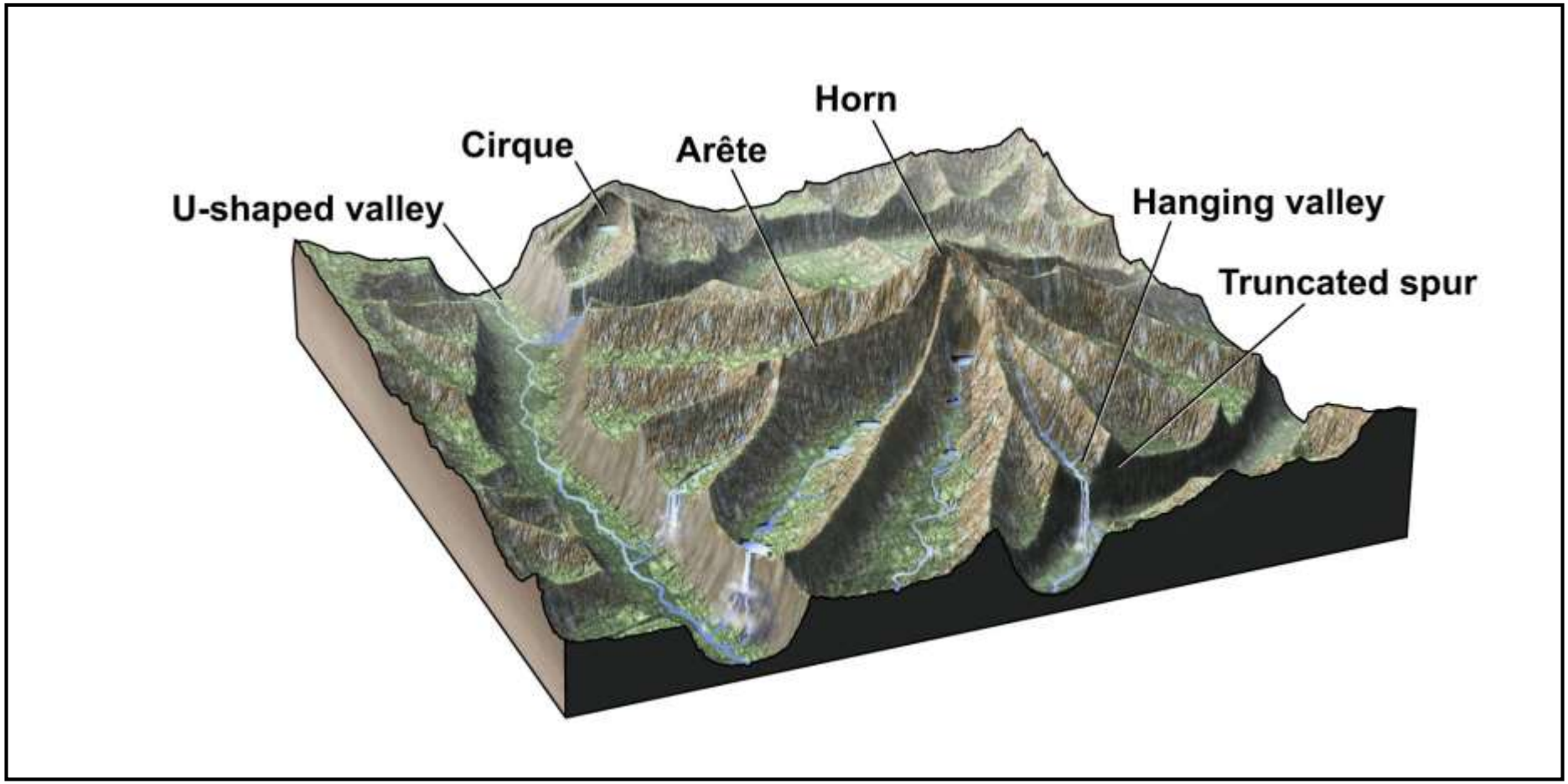
Glacial Landscapes: Erosion

- During glaciation, the valleys fill with ice and are aggressively eroded and oversteepened



Glacial Landscapes: Erosion

- After glaciation, the landscape is transformed, containing U-shaped valleys, hanging valleys, cirques, arêtes, horns



Glacial Landscapes: Erosion

- A horn is a pointed mountain peak formed by three or more cirques that coalesce

Glacial Landscapes: Erosion

- A cirque is a bowl-shaped basin formed at the uppermost portion of a glacial valley. After the ice melts, a cirque is often filled with a tarn lake.

Glacial Landscapes: Erosion

- A hanging valley results from the intersection of a tributary glacier with a larger valley glacier

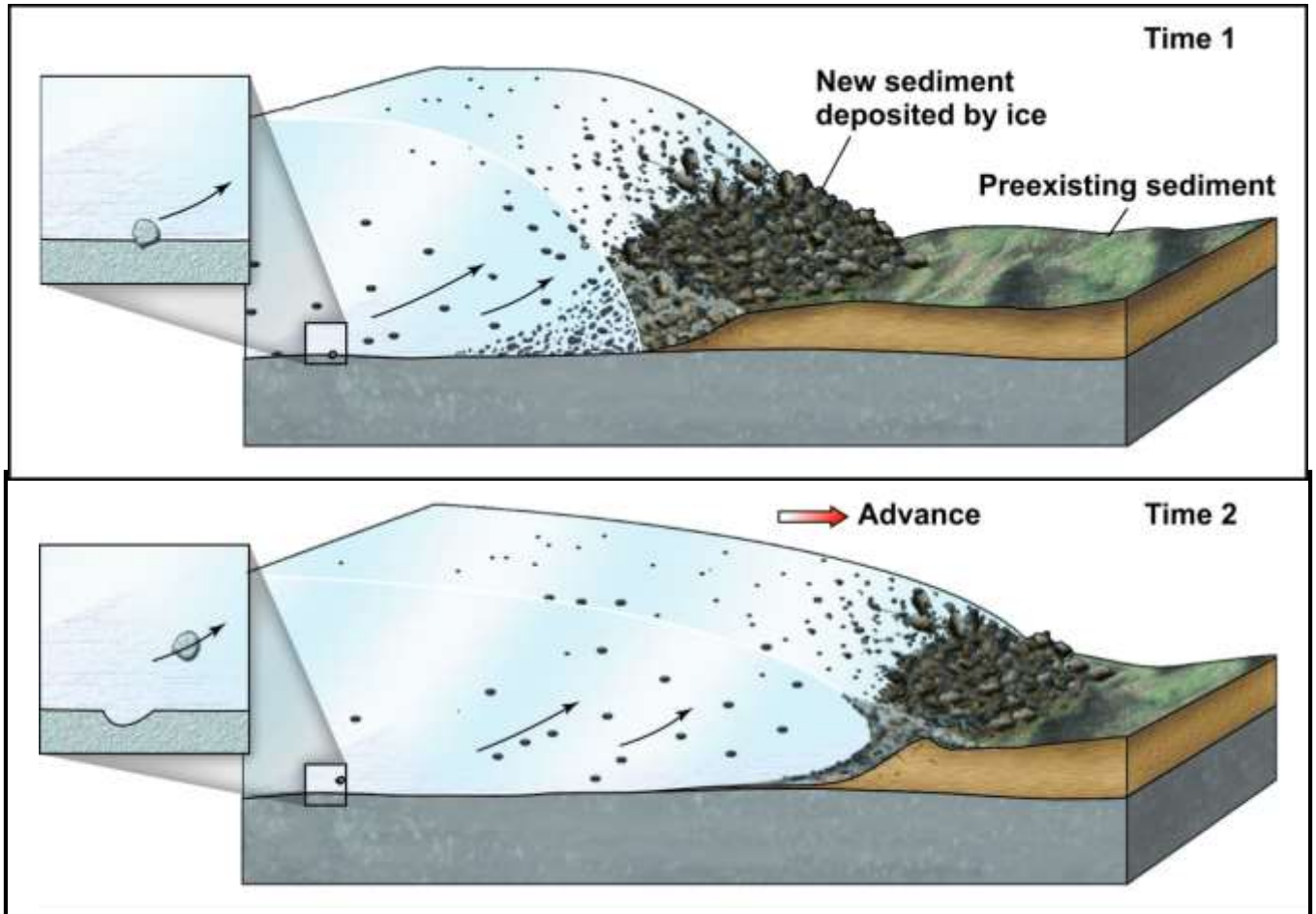
Glacial Landscapes: Erosion

- Fjords are U-shaped glacial troughs that have become flooded by the sea


Yosemite Valley

Glacial Landscapes: Transport

- Glacial ice picks up rock fragments and incorporates them into the internal flow – plucking – which deepens valleys
- Fragments move in the ice until they are dumped at the toe of the glacier.

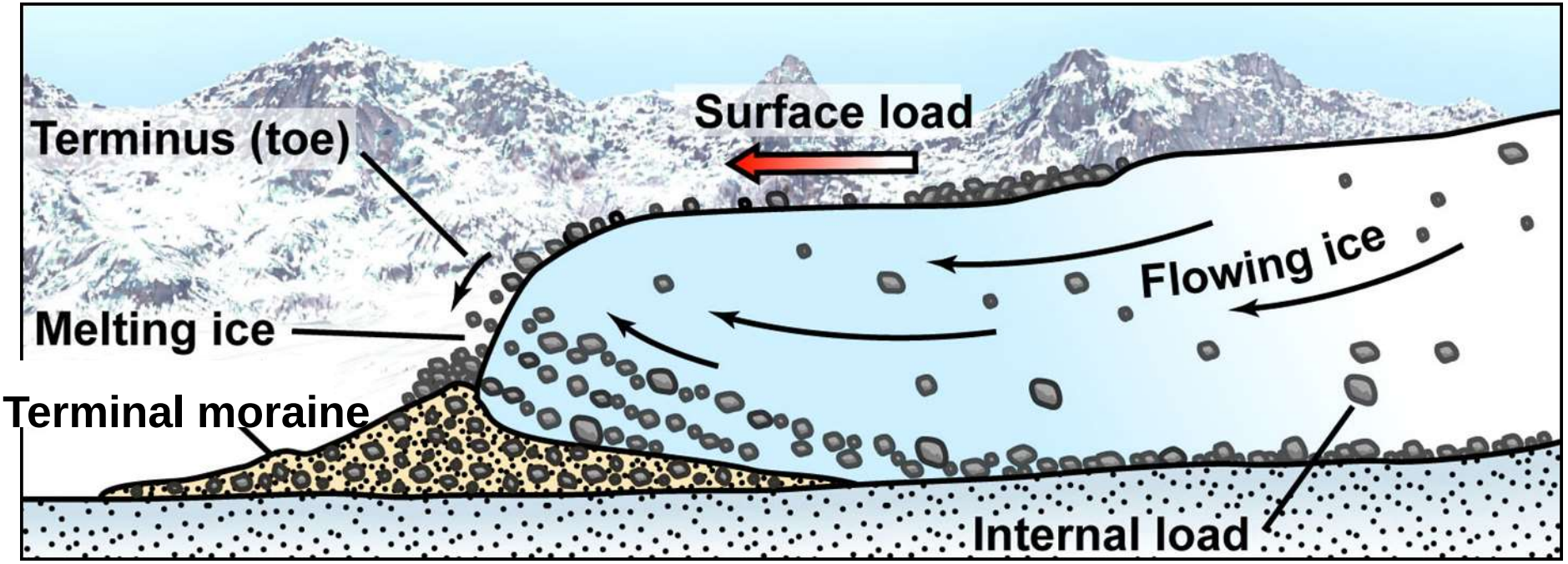


Glacial Landscapes: Transport

- Glacial ice also carries rock fragments that fall onto the glacier
- Fragments move in the ice until they are dumped at the toe of the glacier

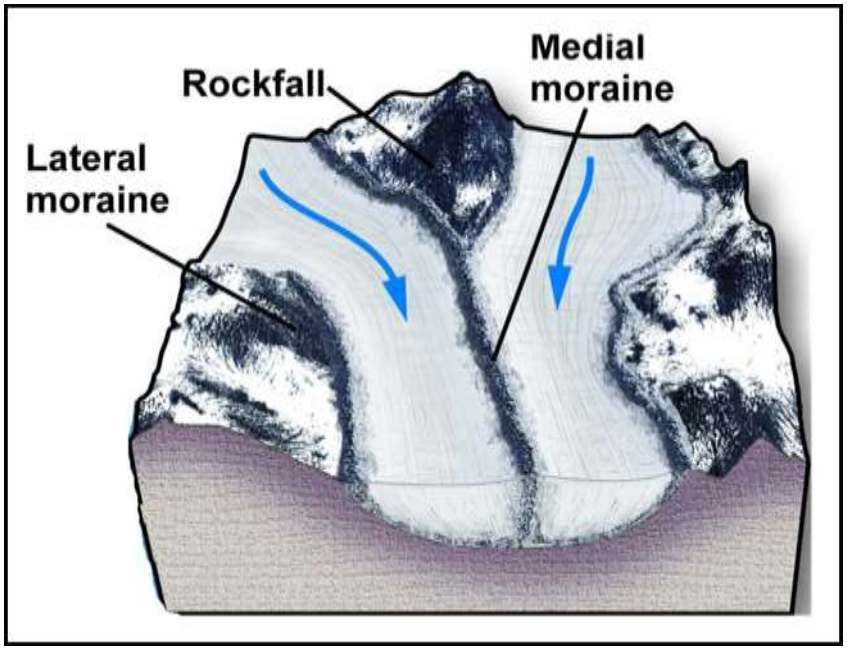
Glacial Landscapes: Deposition

- Rock and sediment are deposited at front of glacier
- Called a terminal moraine
- What would the characteristics of this sediment be?



Glacial Landscapes: Deposition

- Rock and sediment also build up at edges and in the center of the glacier
- Called lateral and medial moraines



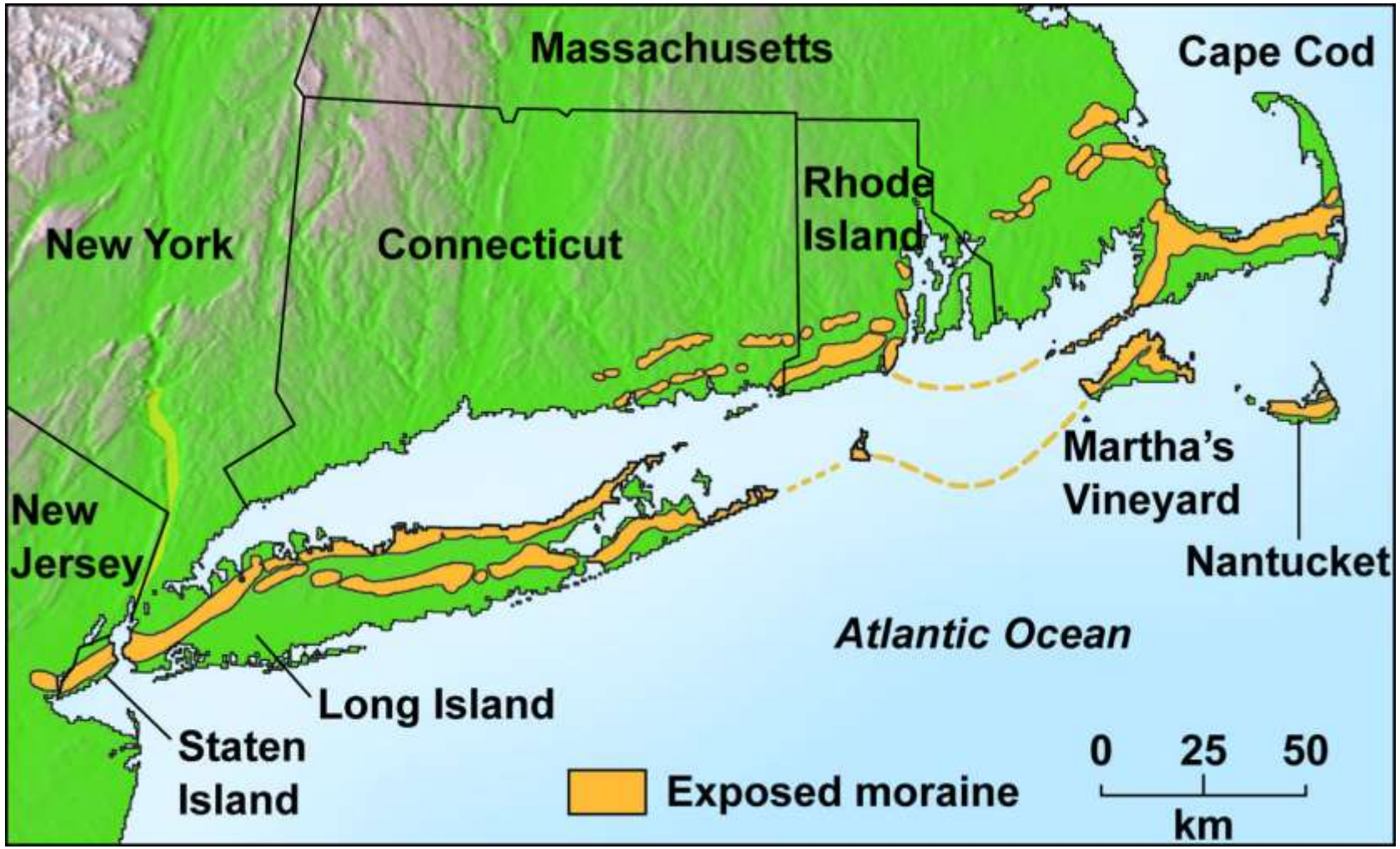
Moraine left by retreating glacier – Mt. Cook, New Zealand

Glacial Landscapes: Deposition

- Lakes often form by melt water pooling behind moraines as glaciers retreat

Glacial Landscapes: Deposition

- Moraines mark the furthest extent of glaciers

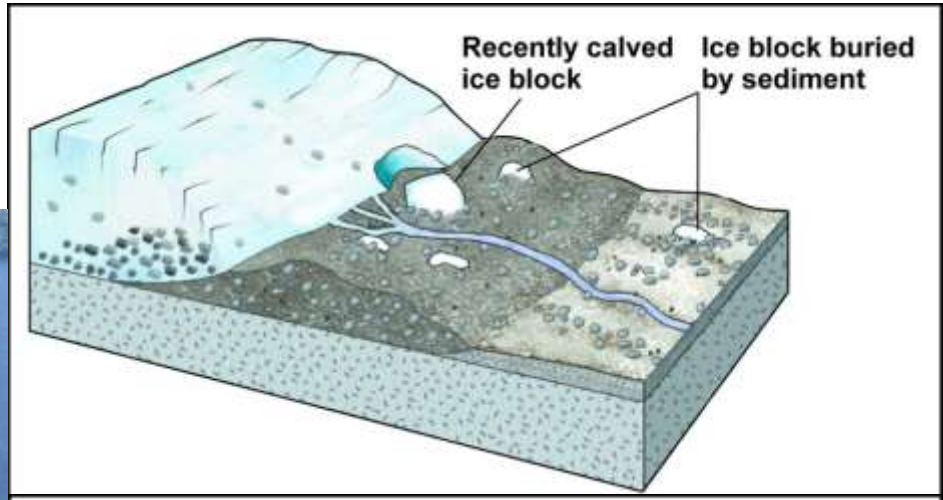


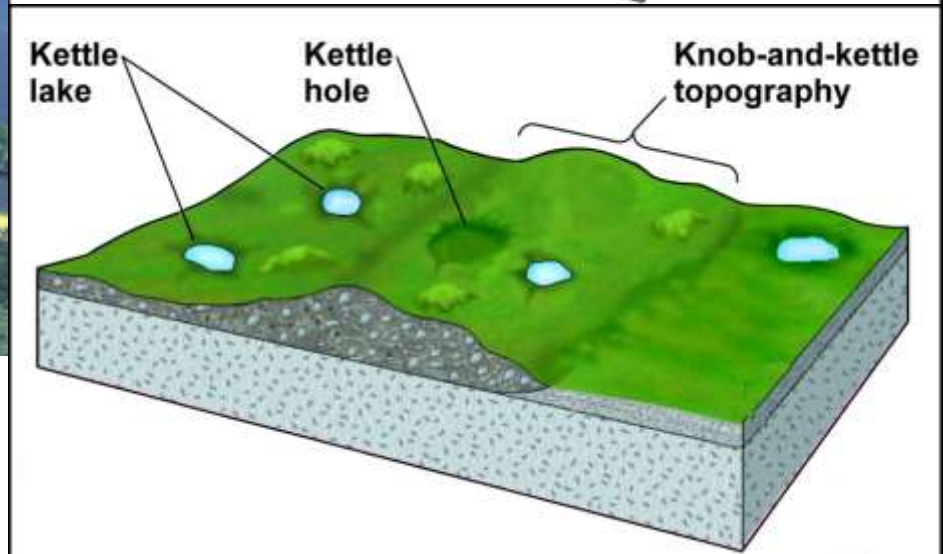
Glacial Landscapes: Deposition

- Erratic boulders
- VERY large boulders that have travelled a long way
- Could only have been deposited by ice

Glacial Landscapes: Deposition

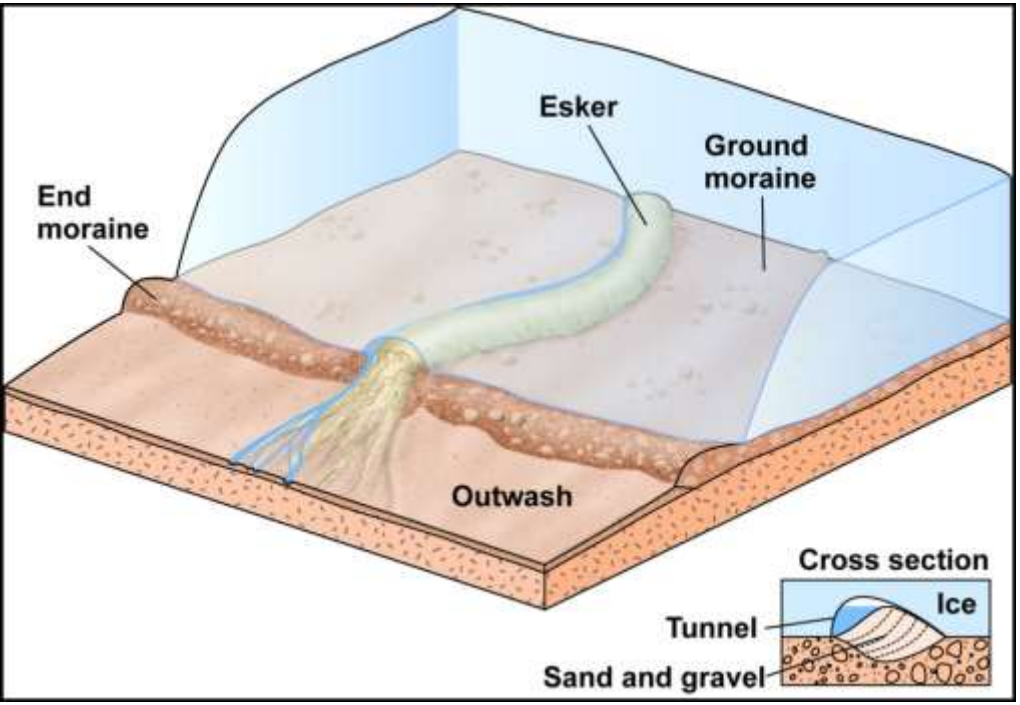
- Ice blocks calve off of glaciers and become buried in sediment. When the ice melts, a kettle forms.





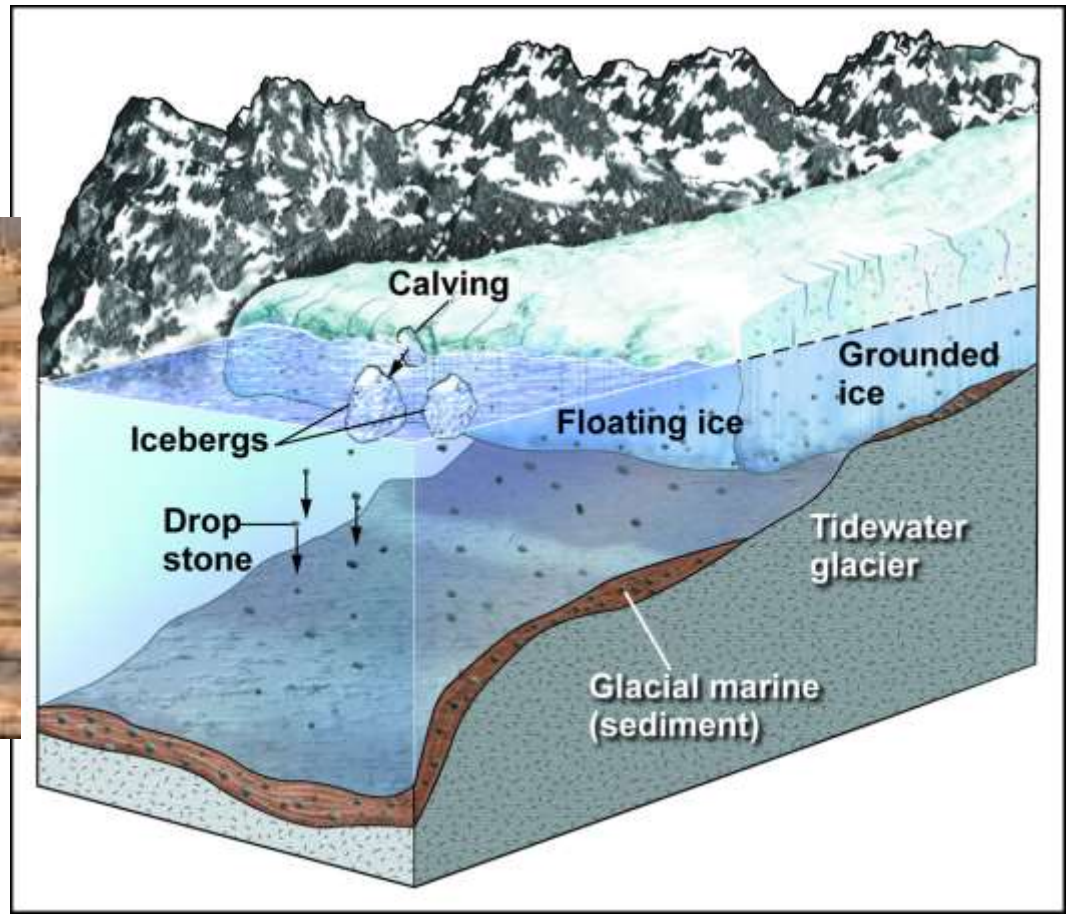
Glacial Landscapes: Deposition

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



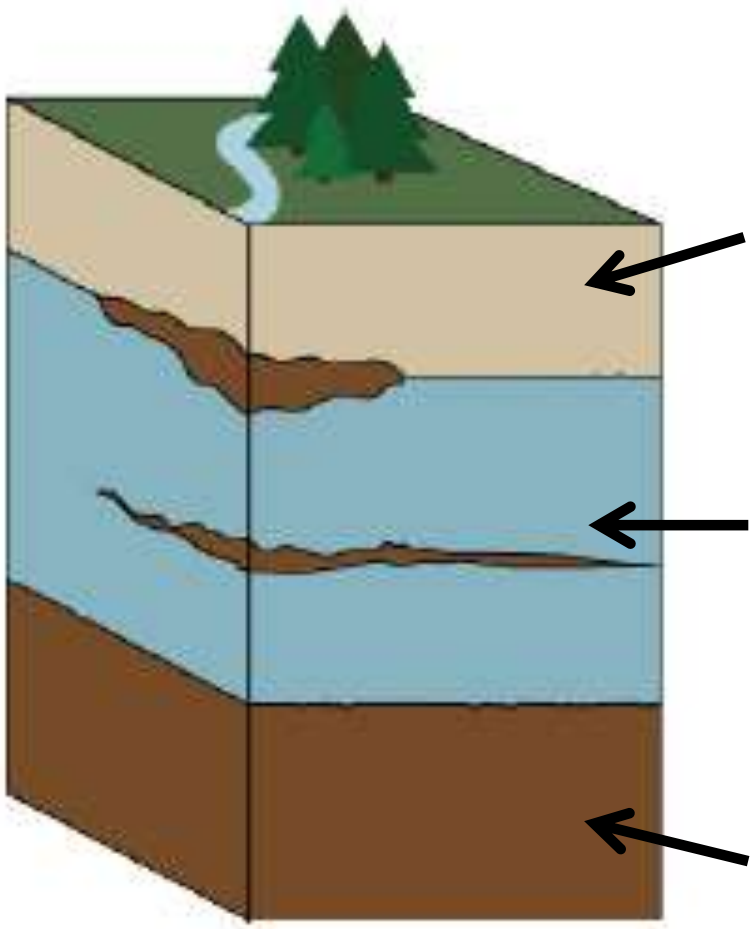
Glacial Landscapes: Deposition

- Dropstones are large rock fragments that are incorporated into ice that calves to form icebergs
- When the icebergs travel far offshore and melt the dropstones fall into the ocean sediment



How many glacial features can you name in this photo?

Periglacial environments: Permafrost



Active layer: layer of ground above permafrost that thaws in the summer and freezes in winter (0-3m)

Permafrost: soil and/or rock that has been below 0 °C for more than 2 years, may or may not contain ice (1-1400m)

Talik: thawed permafrost


Active Layer
Permafrost

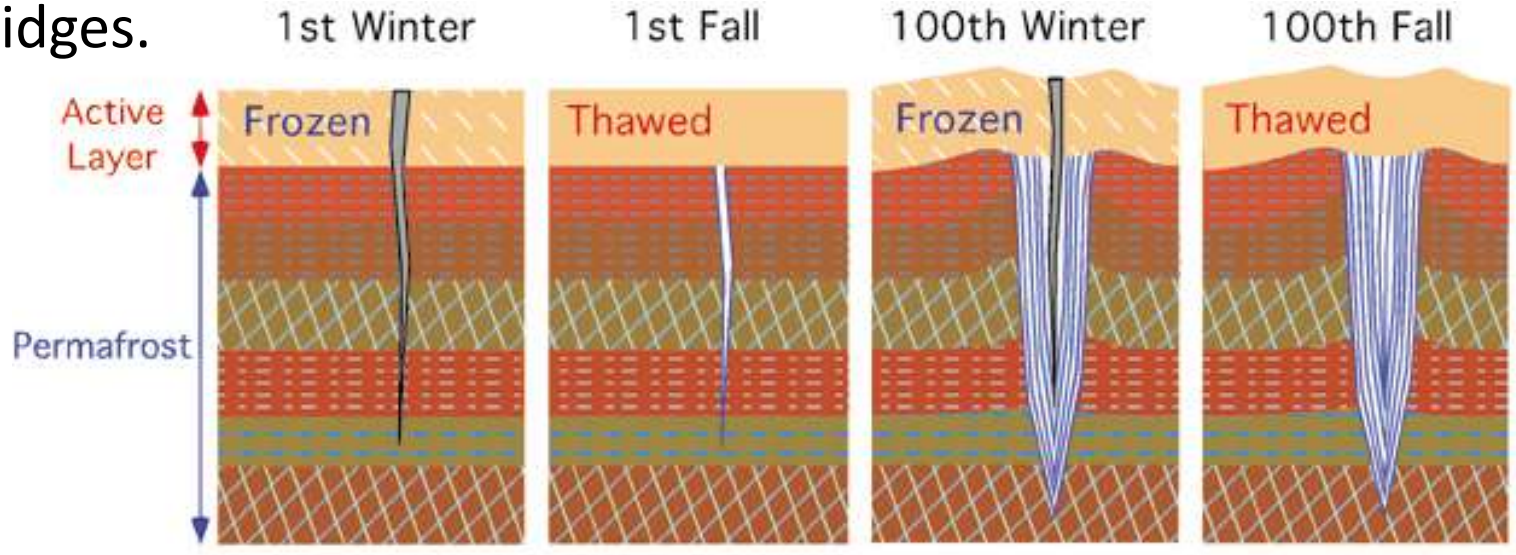
Periglacial environments

Ice wedges and patterned ground

Thermokarst lakes

Periglacial environments: Ice wedges

- Cold temperatures in winter causes soil to contract so cracks form.
- During warm summer days water seeps into the crack and freezes when cooled by permafrost.
- The freezing water pushes the crack apart and during the next winter the soil contracts again too, also pulling the crack apart and the cycle begins again.
- The soil in the active layer above these wedges get pushed upwards forming ridges.

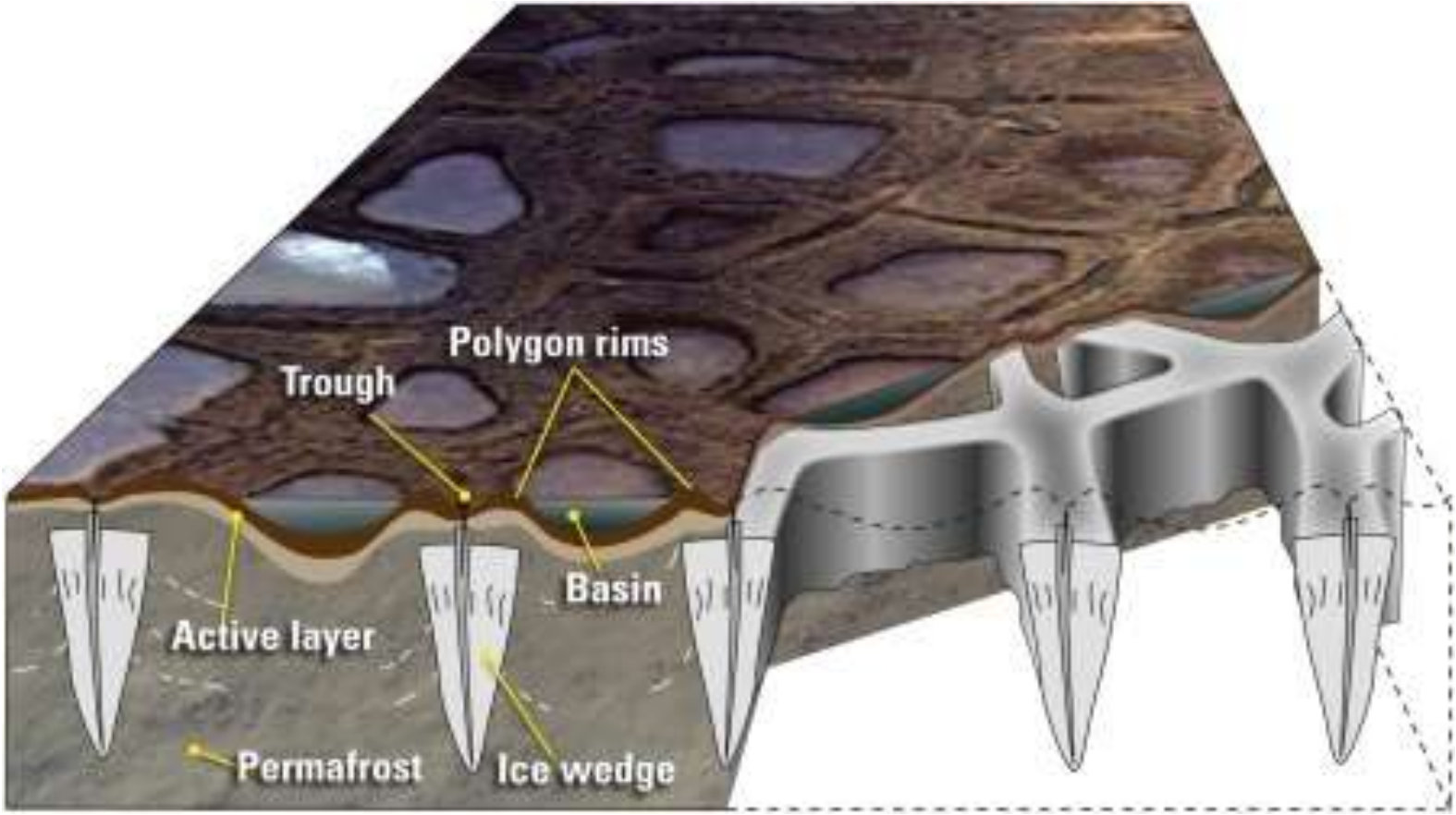


Periglacial environments: Ice wedges

(b)

Periglacial environments: Patterned ground

Ice wedges can build up to form a network of ice visible on the surface as polygons or ‘patterned ground’



Periglacial environments: Patterned ground

Periglacial environments: Patterned ground

Group question

- Permafrost will be:

a) Permeable
b) Impermeable

Periglacial environments: Thermokarst Lakes

- Shallow freshwater lakes formed in a depression by melt water from thawing permafrost
- Eventually lake drains leaving behind a marshy area

Importance of permafrost?