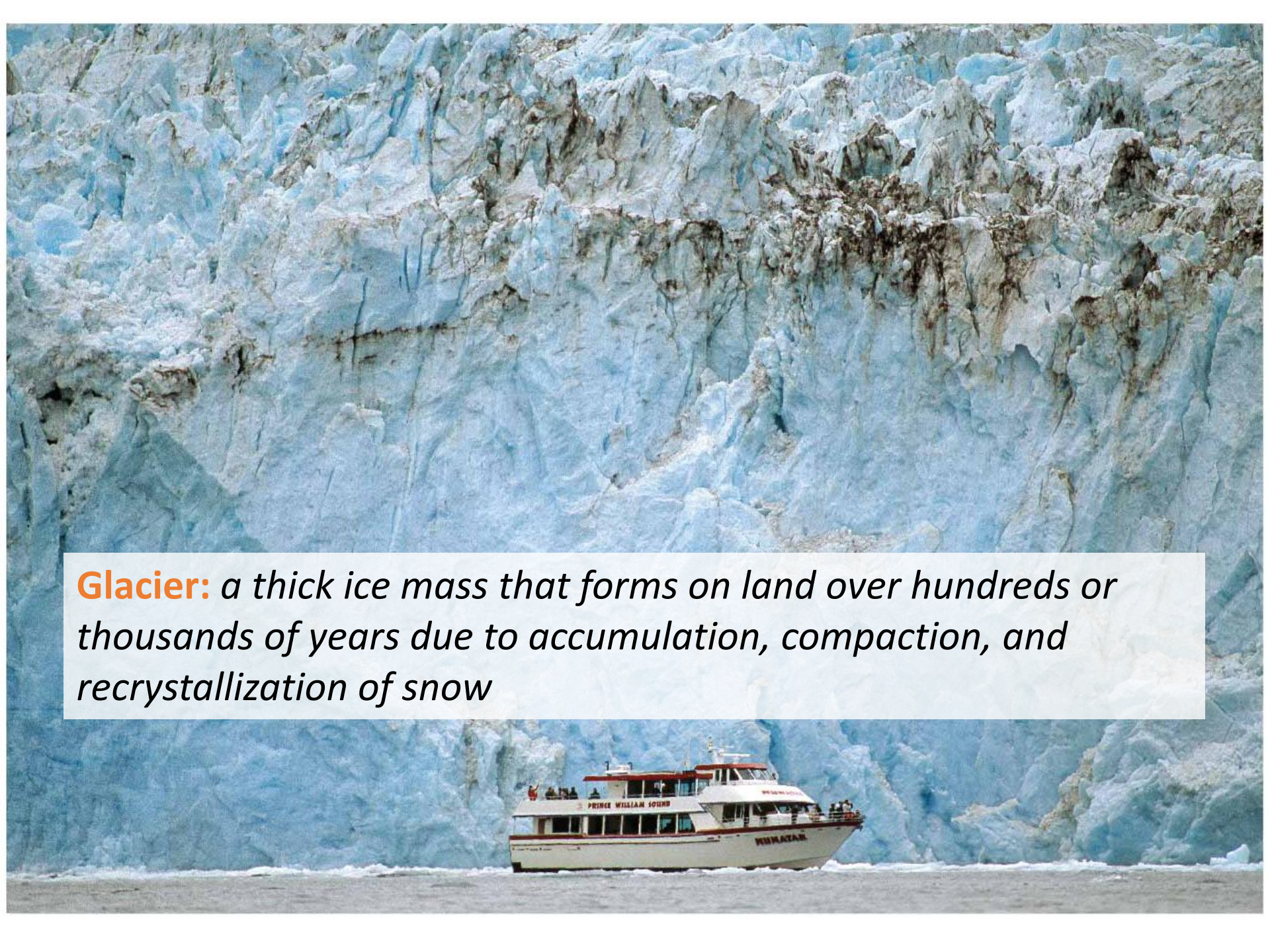


# Glaciers & Glaciation





A photograph of a massive, blue glacier wall. The glacier is composed of jagged, layered ice with visible brown sediment streaks. In the foreground, a white boat with a red stripe is on the water. The boat has "PRINCE WILLIAM SOUND" written on its side and "KIMMATAK" on the bow. The water is dark and calm.

**Glacier:** *a thick ice mass that forms on land over hundreds or thousands of years due to accumulation, compaction, and recrystallization of snow*



# Types of Glaciers

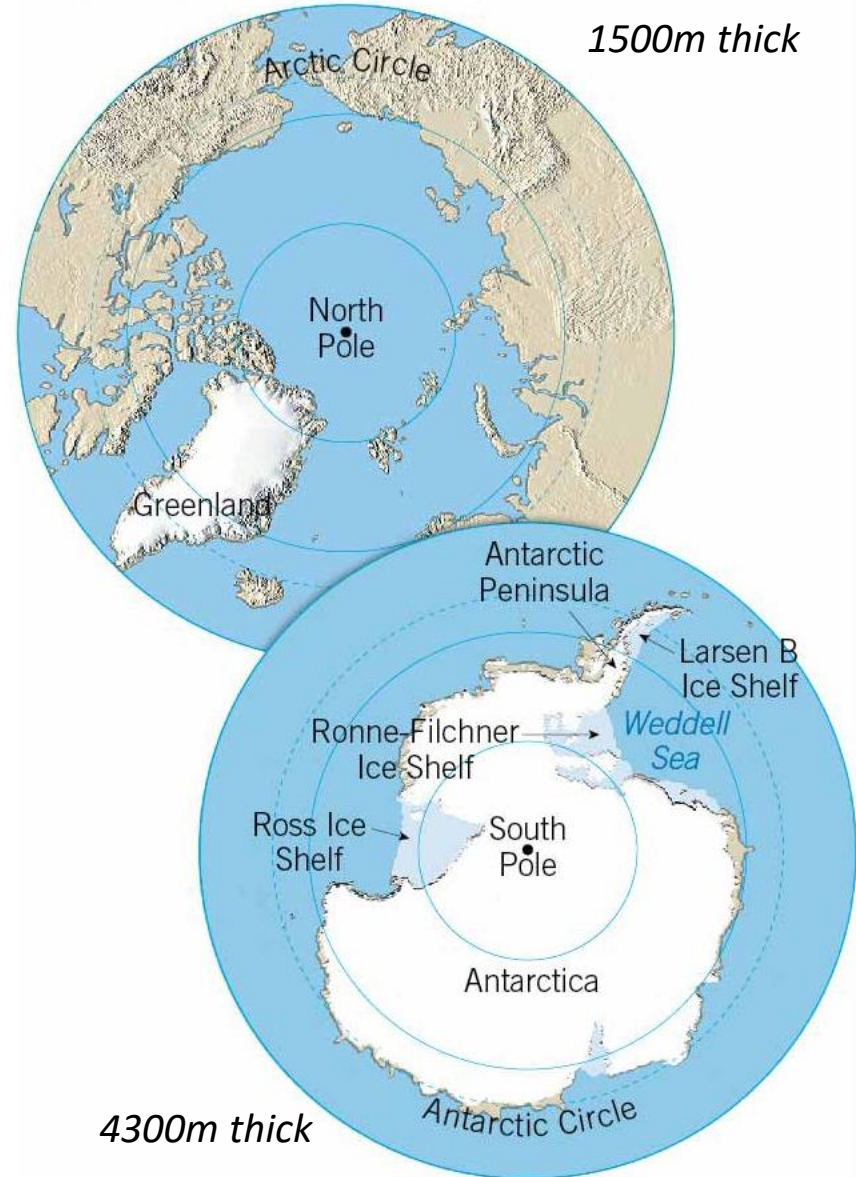
**Valley (Alpine):** glaciers in high altitude valleys that were originally occupied by streams

**Ice Sheets:** massive (continent-scale) accumulations of ice

**Ice Shelves:** portions of the coast along Antarctica where ice flows onto the adjacent ocean (ice sheet over ocean)

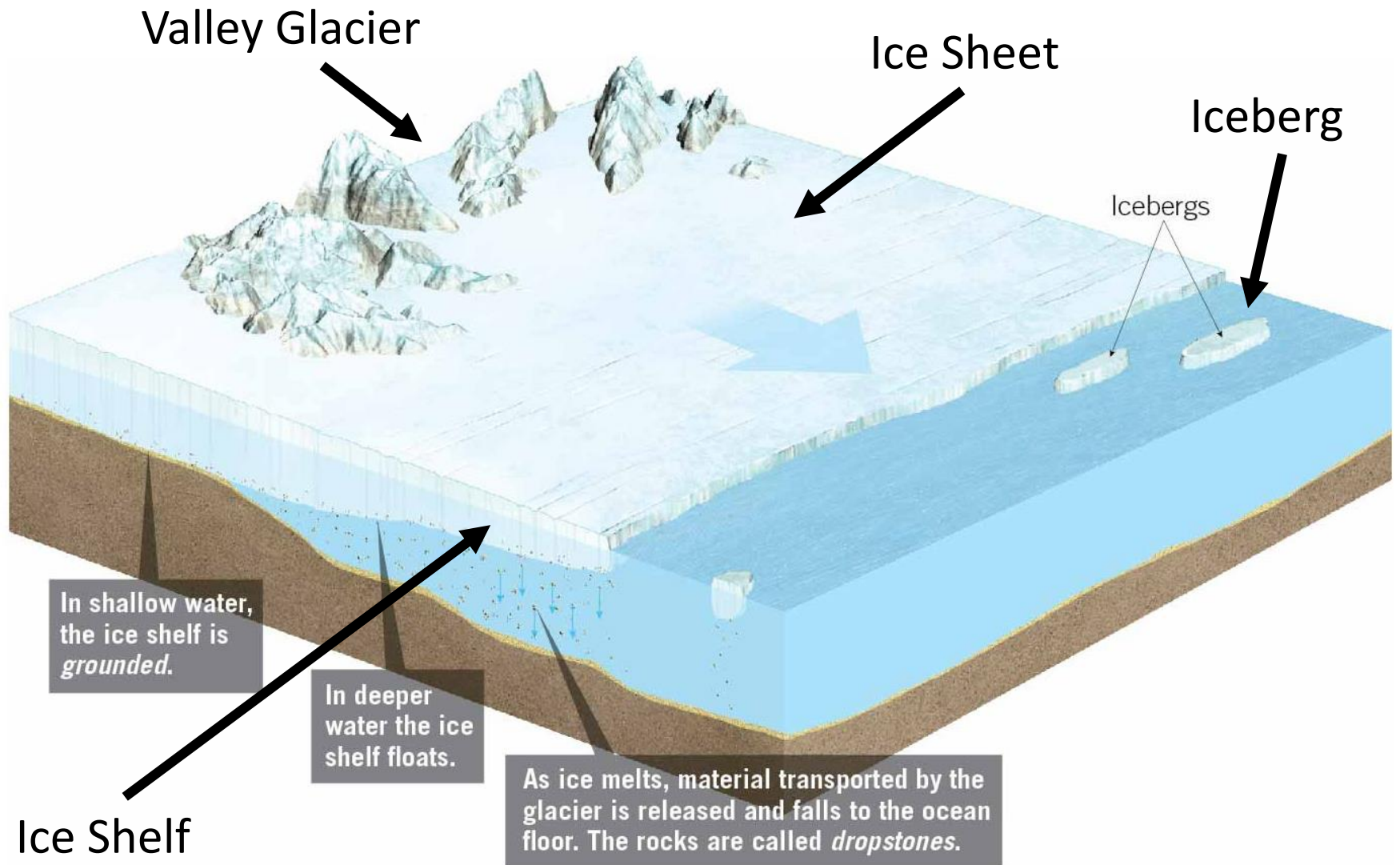


Greenland's ice sheet occupies 1.7 million square kilometers (663,000 square miles), about 80 percent of the island.



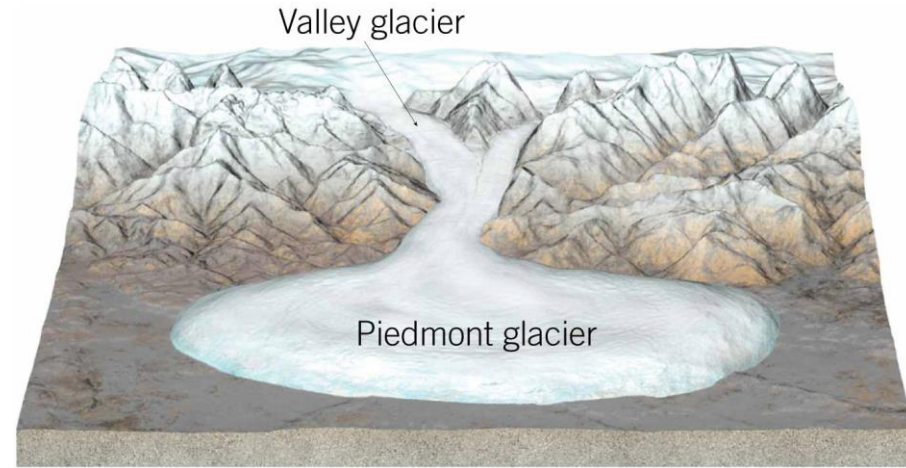
The area of the Antarctic Ice Sheet is almost 14 million square kilometers (5,460,000 square miles). Ice shelves occupy an additional 1.4 million square kilometers (546,000 square miles).

# Types of Glaciers





# Types of Glaciers



When a valley glacier is no longer confined, it spreads out to become a piedmont glacier.



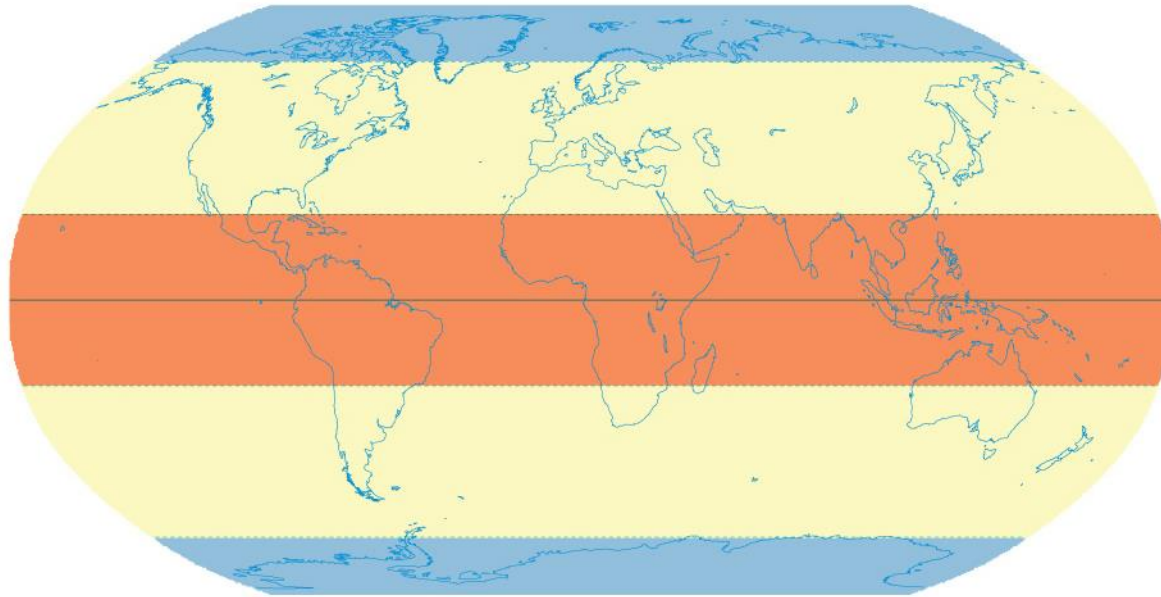
Vatnajökull  
ice cap

Ice caps completely bury the underlying terrain but are much smaller than ice sheets.

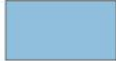
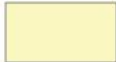





# Formation & Movement of Glacial Ice



## Climatic bands

-  Polar regions
-  Temperate zones
-  The tropics

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*Glaciers form in the high-latitude **polar regions** because temperatures remain low throughout the year so any snow that falls will not easily melt*



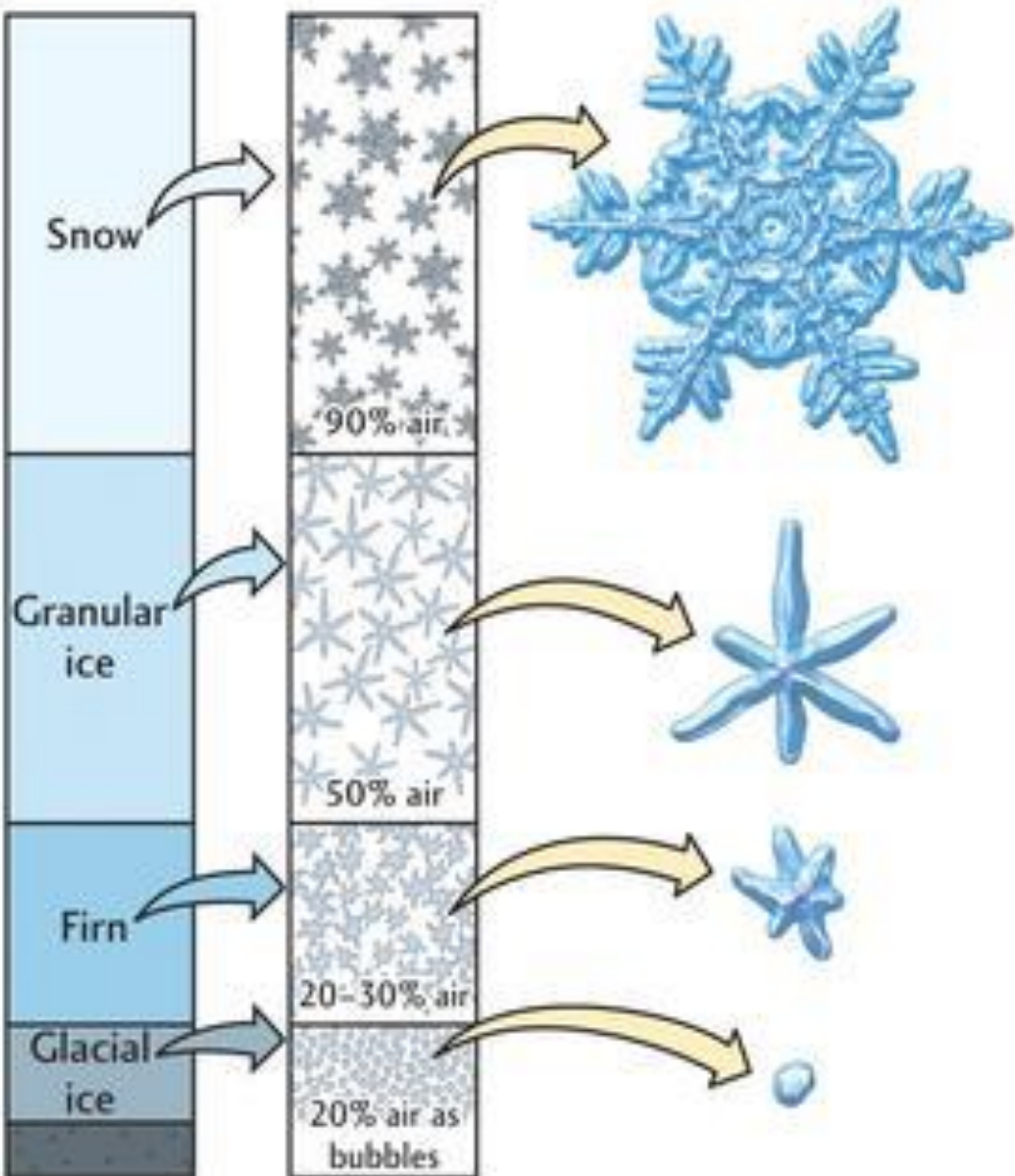
# Formation & Movement of Glacial Ice



*Glaciers can form in **high altitudes**, at the top of mountains, at any latitude because temperatures remain low throughout the year  
Form above the **snowline***



# Formation & Movement of Glacial Ice



*Glacial ice forms due to extreme **compaction** (due to gravity) of snow*

*Compaction causes recrystallization and reduction of air*



# Formation & Movement of Glacial Ice

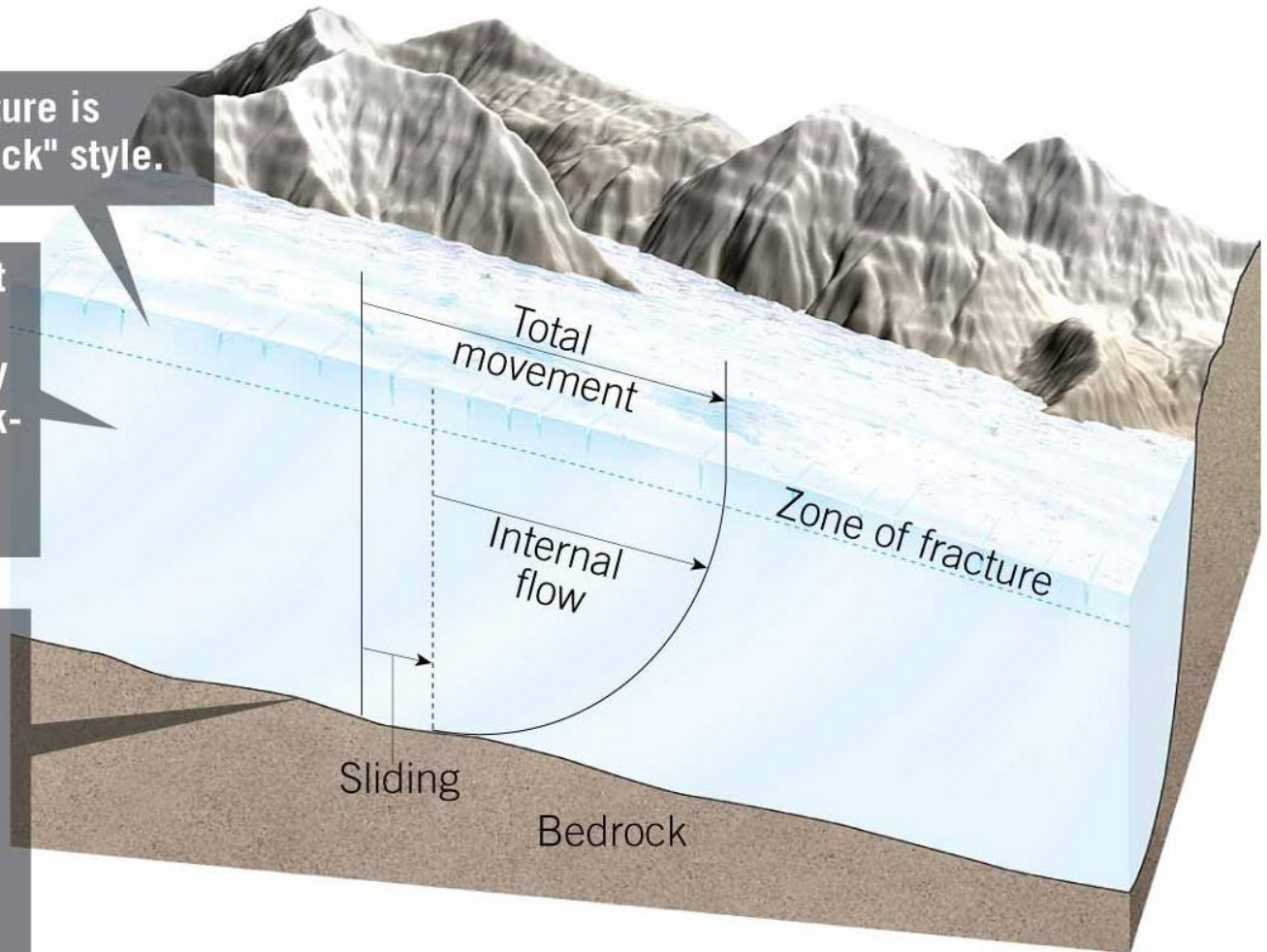
Glacial movement is called **flow**

Portions of a glacier flow differently

Ice in the zone of fracture is carried along "piggyback" style.

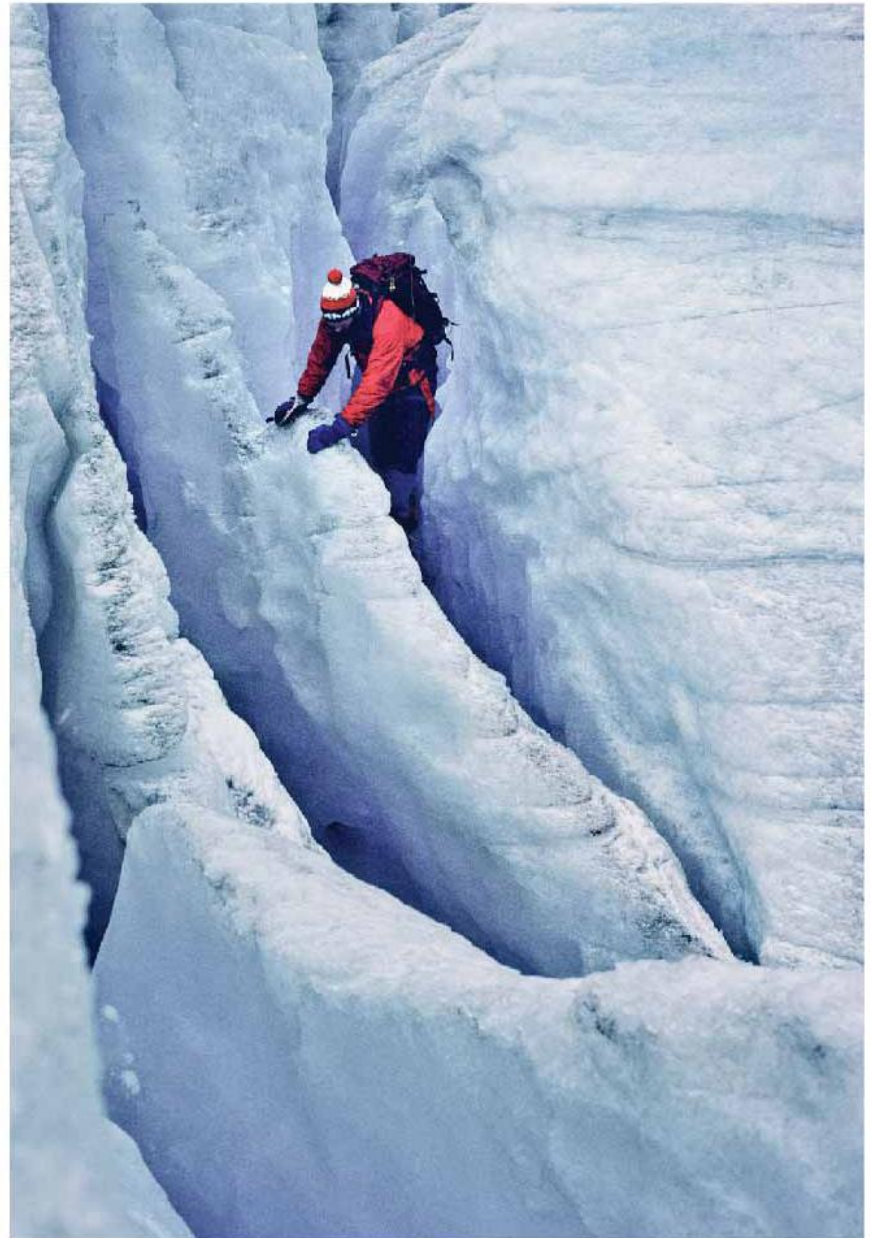
Below a depth of about 50 meters (160 feet), ice behaves plastically (deforms without breaking) and gradually flows.

Basal slip occurs episodically. Ice in contact with the valley floor remains fixed as stress builds to the point that the glacier lurches forward.



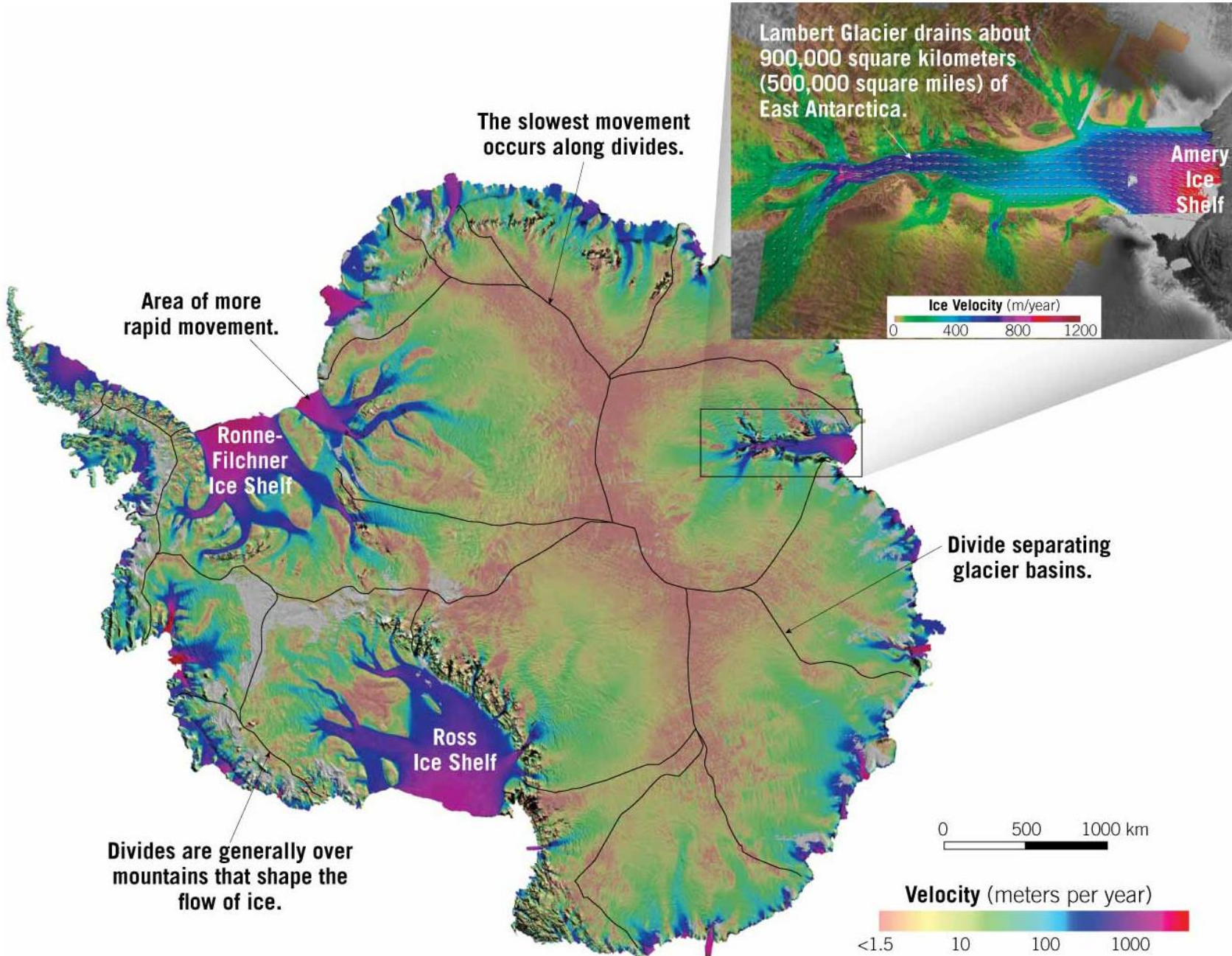


# Formation & Movement of Glacial Ice





# Formation & Movement of Glacial Ice

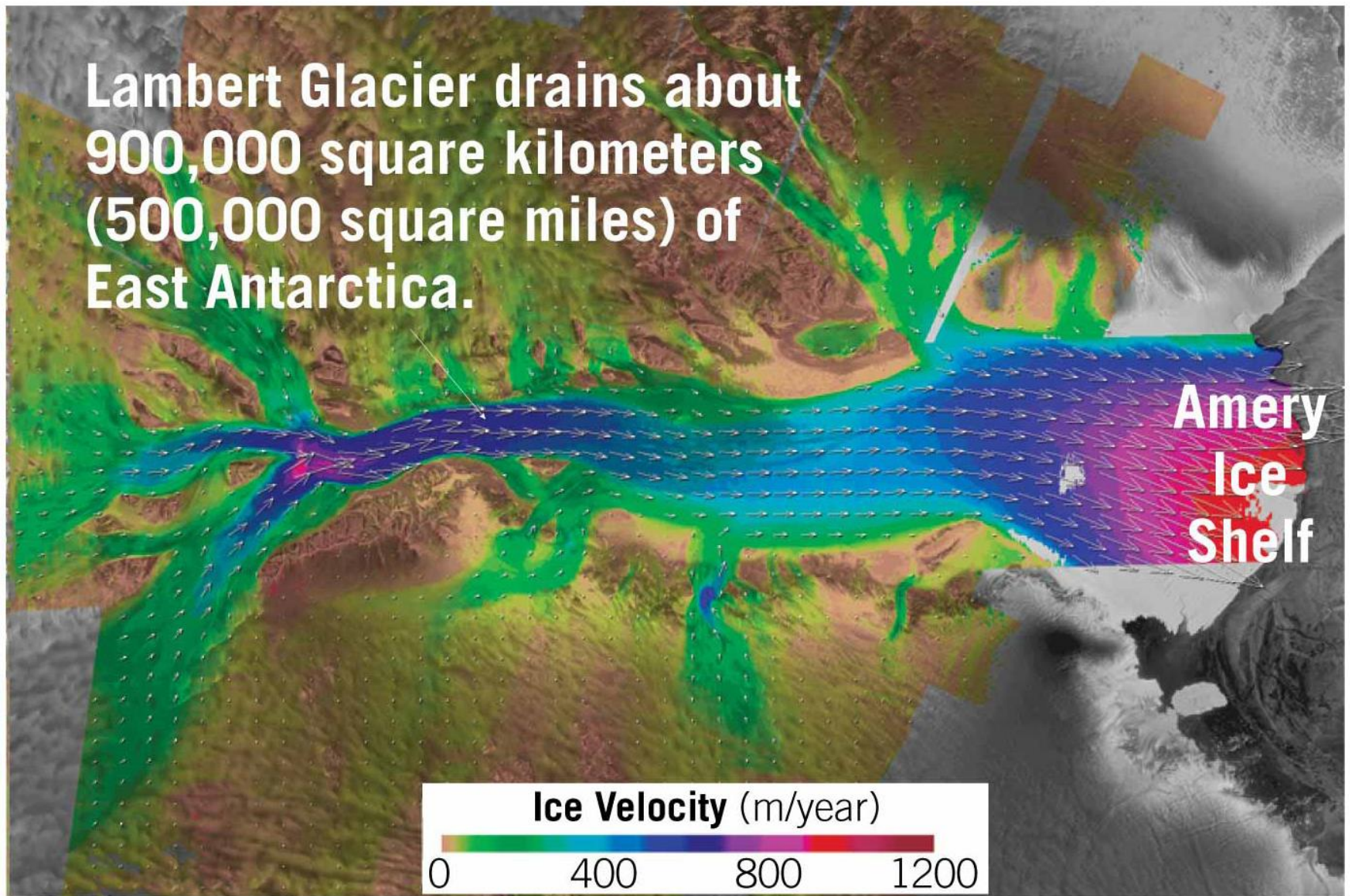
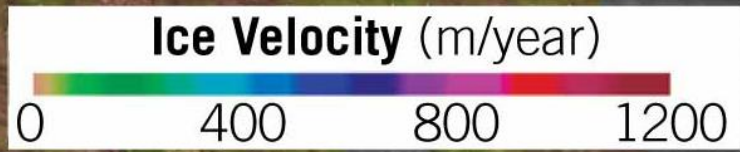




# Formation & Movement of Glacial Ice

Lambert Glacier drains about 900,000 square kilometers (500,000 square miles) of East Antarctica.

Amery Ice Shelf



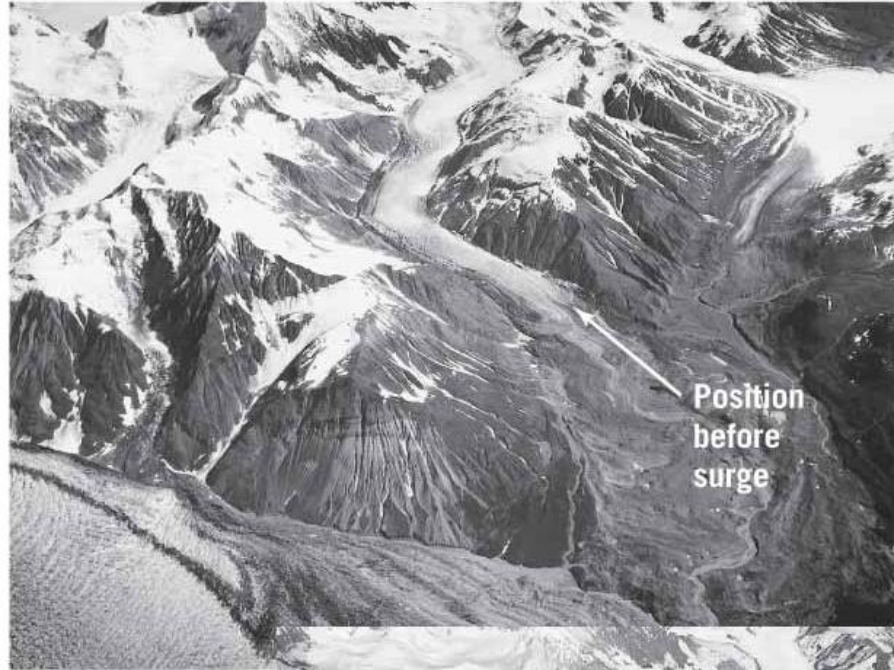


# Formation & Movement of Glacial Ice

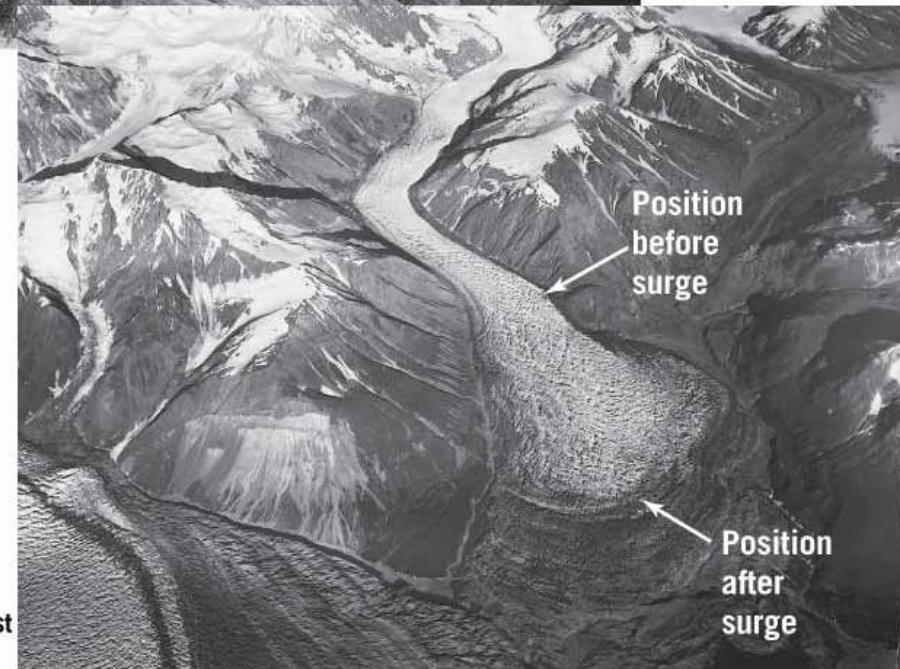
*Periods of rapid glacial movement are called surges*

*Flow rate during a surge can be up to 100 times faster than normal*

*Likely due to increased basal sliding*



August  
1964



August  
1965



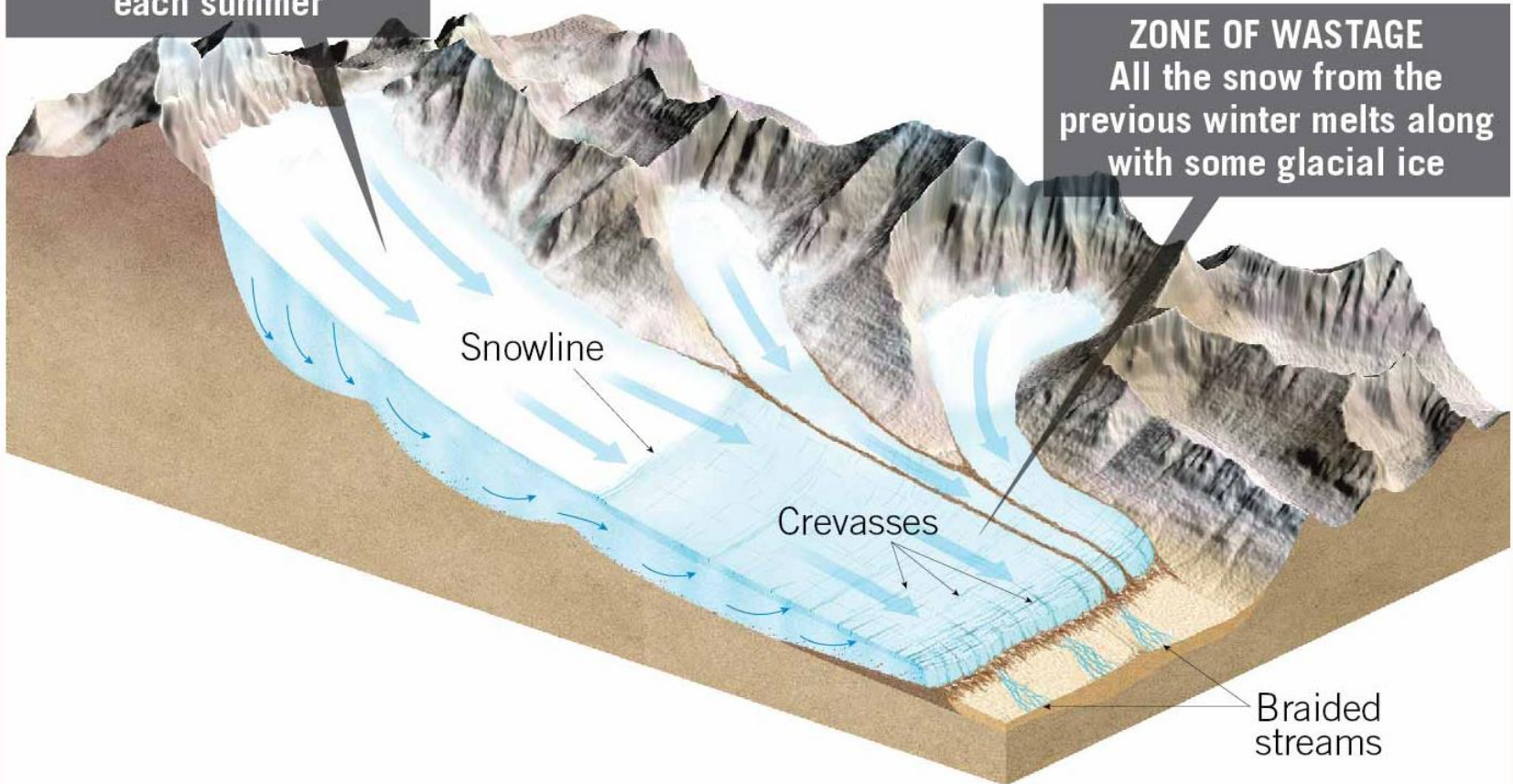
# Formation & Movement of Glacial Ice

**Glacial Budget:** *the balance between accumulation at the upper end and loss at the lower end*

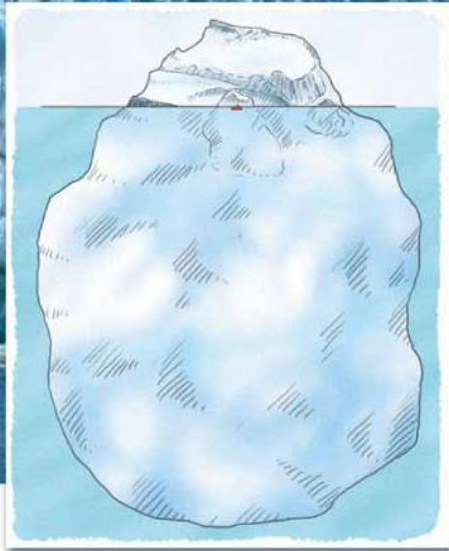
**Ablation:** *when the budget is negative (i.e., the glacier is shrinking)*

**ZONE OF ACCUMULATION**  
More snow falls each winter than melts each summer

**ZONE OF WASTAGE**  
All the snow from the previous winter melts along with some glacial ice



# Formation & Movement of Glacial Ice



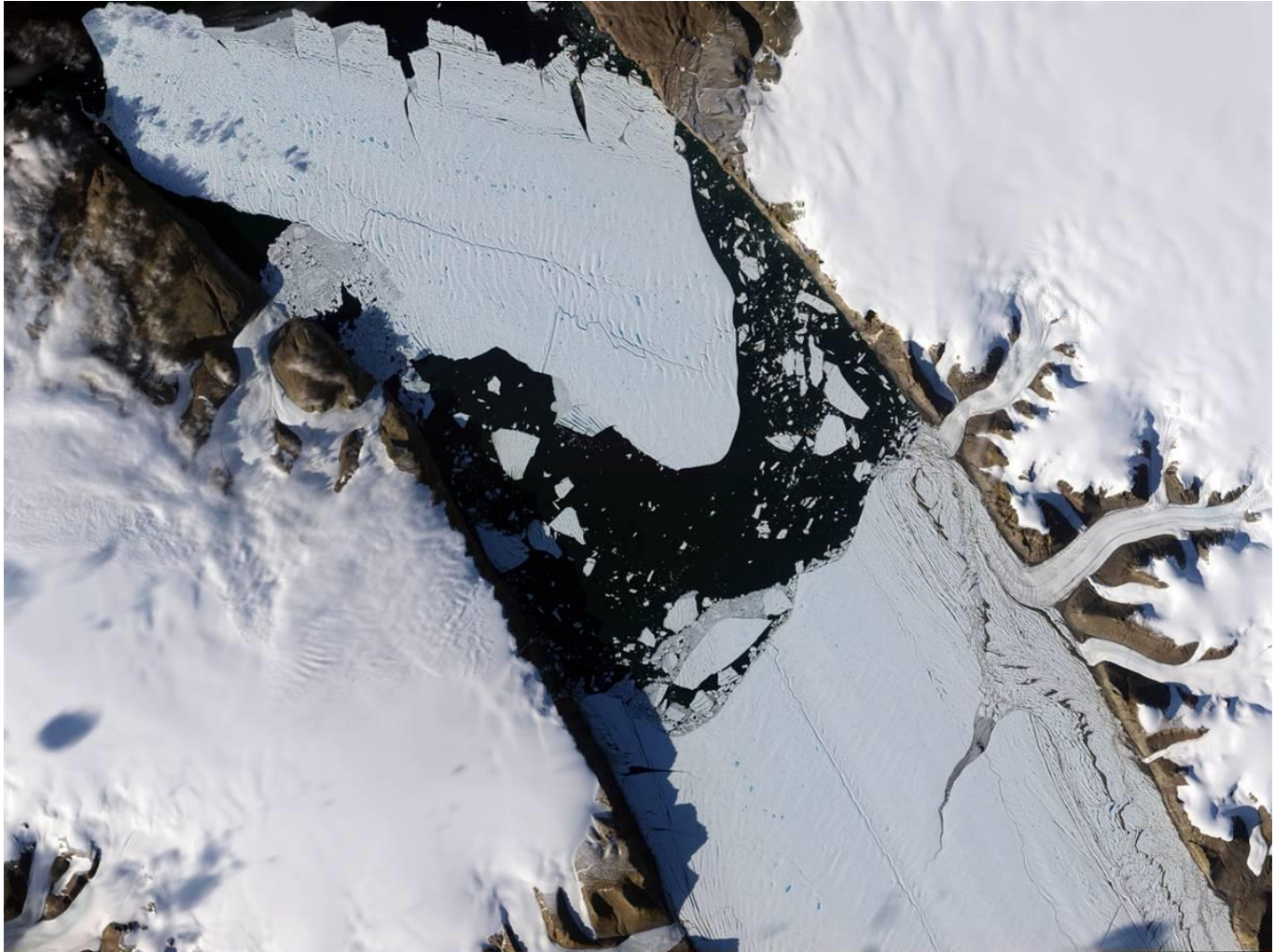
**Icebergs form when large masses calve from the front of a glacier after it reaches a water body.**

**Only about 20 percent or less of an iceberg protrudes above the waterline.**



# Ice tongue calving

Petermann Glacier, Greenland



# Iceberg off the coast

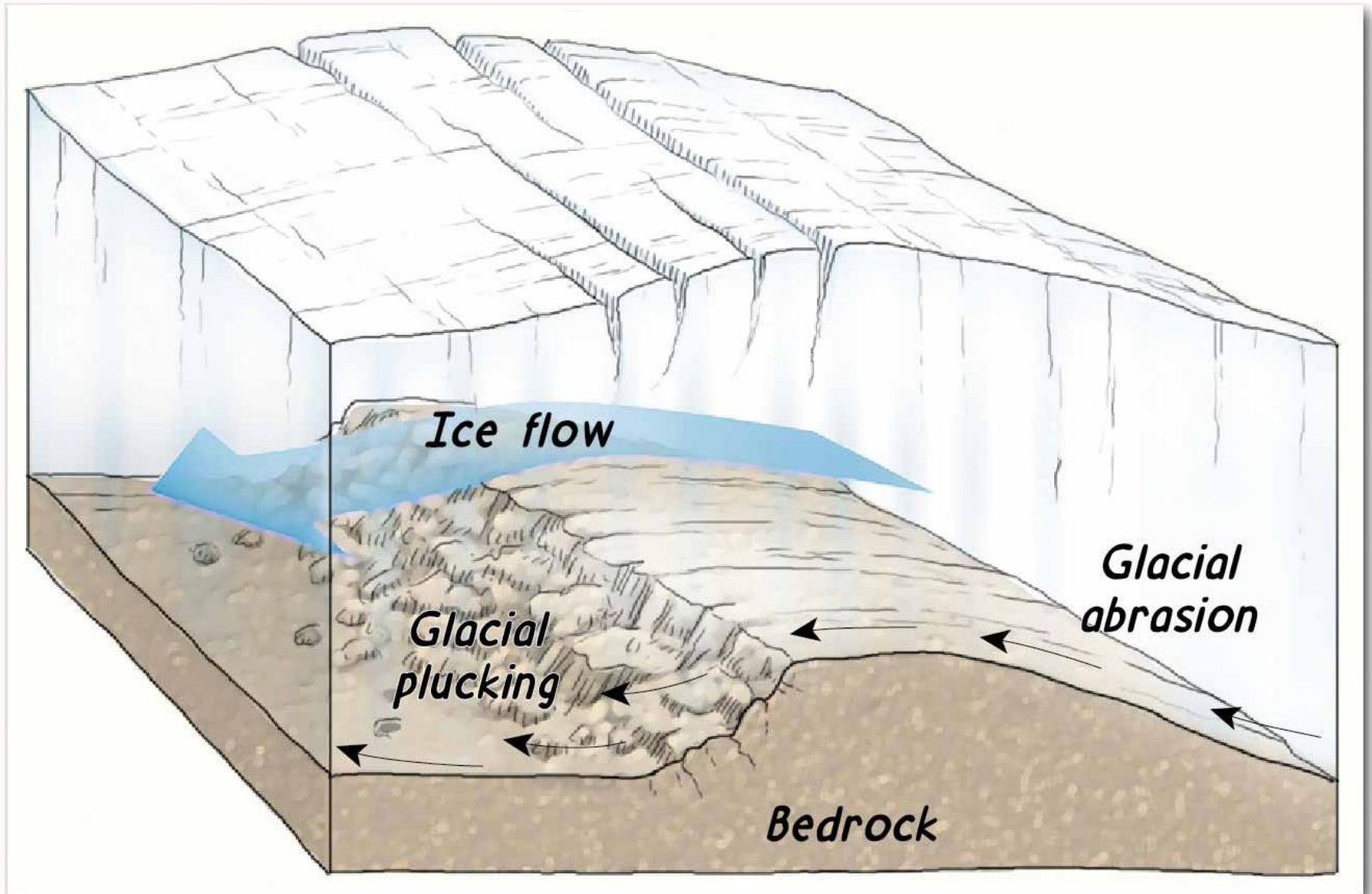




# Glacial Erosion



# Glacial Erosion



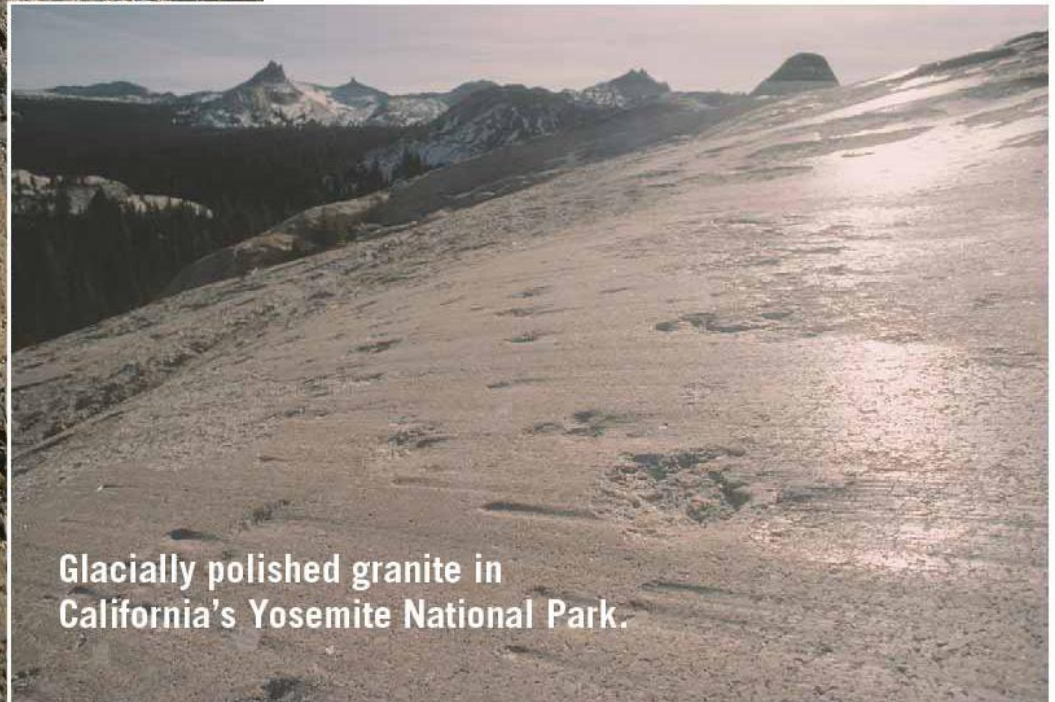
*Geologist's Sketch*



# Glacial Erosion



**Striations:** long scratches and grooves cut by rock fragments dragged by the base of the glacier (**abrasion**)



Glacial abrasion created the scratches and grooves in this bedrock.

Glacially polished granite in California's Yosemite National Park.

A.

B.



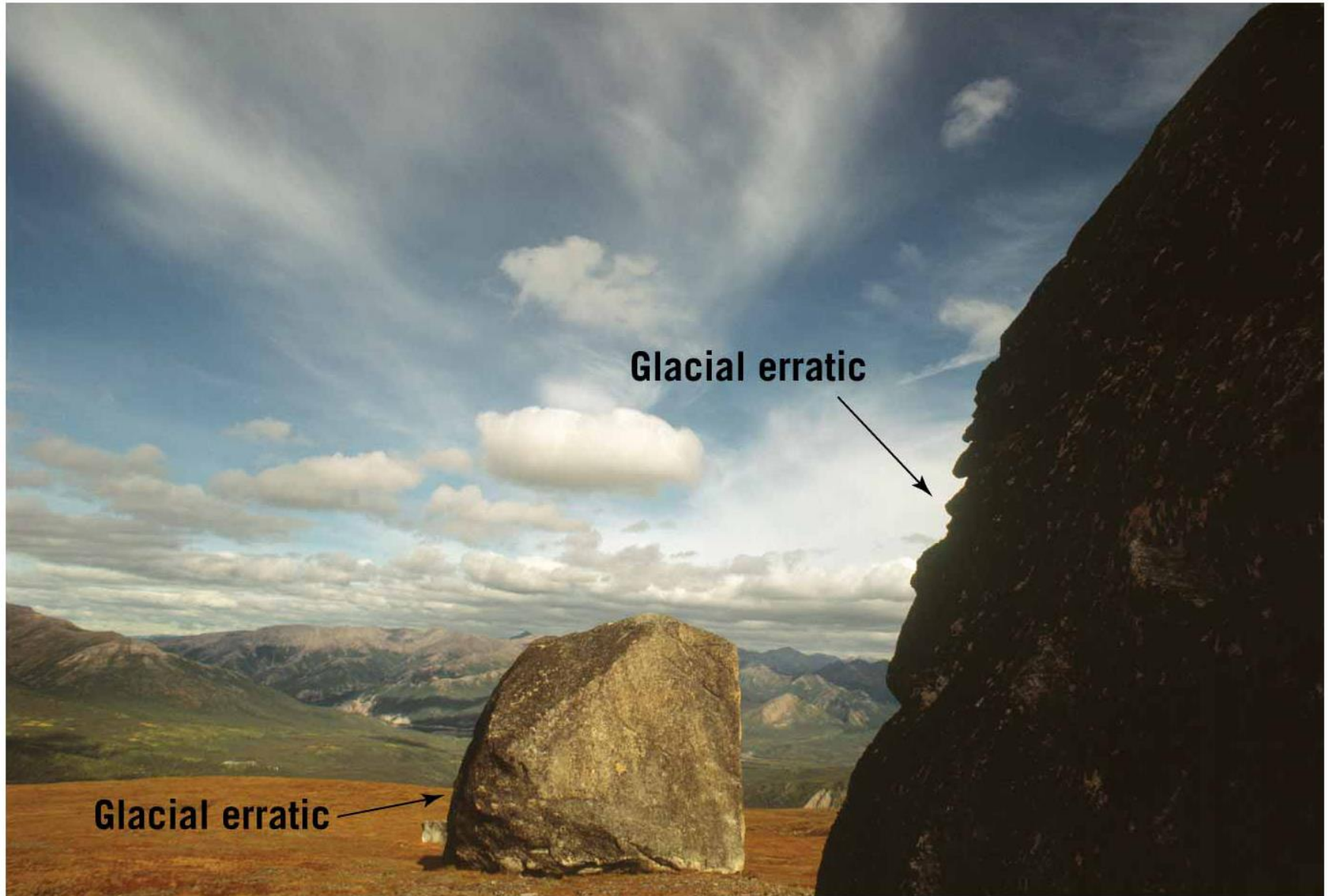
# Glacial Erosion

**Rock Flour:** *pulverized rock visible in the streams and lakes at the toe of glaciers*



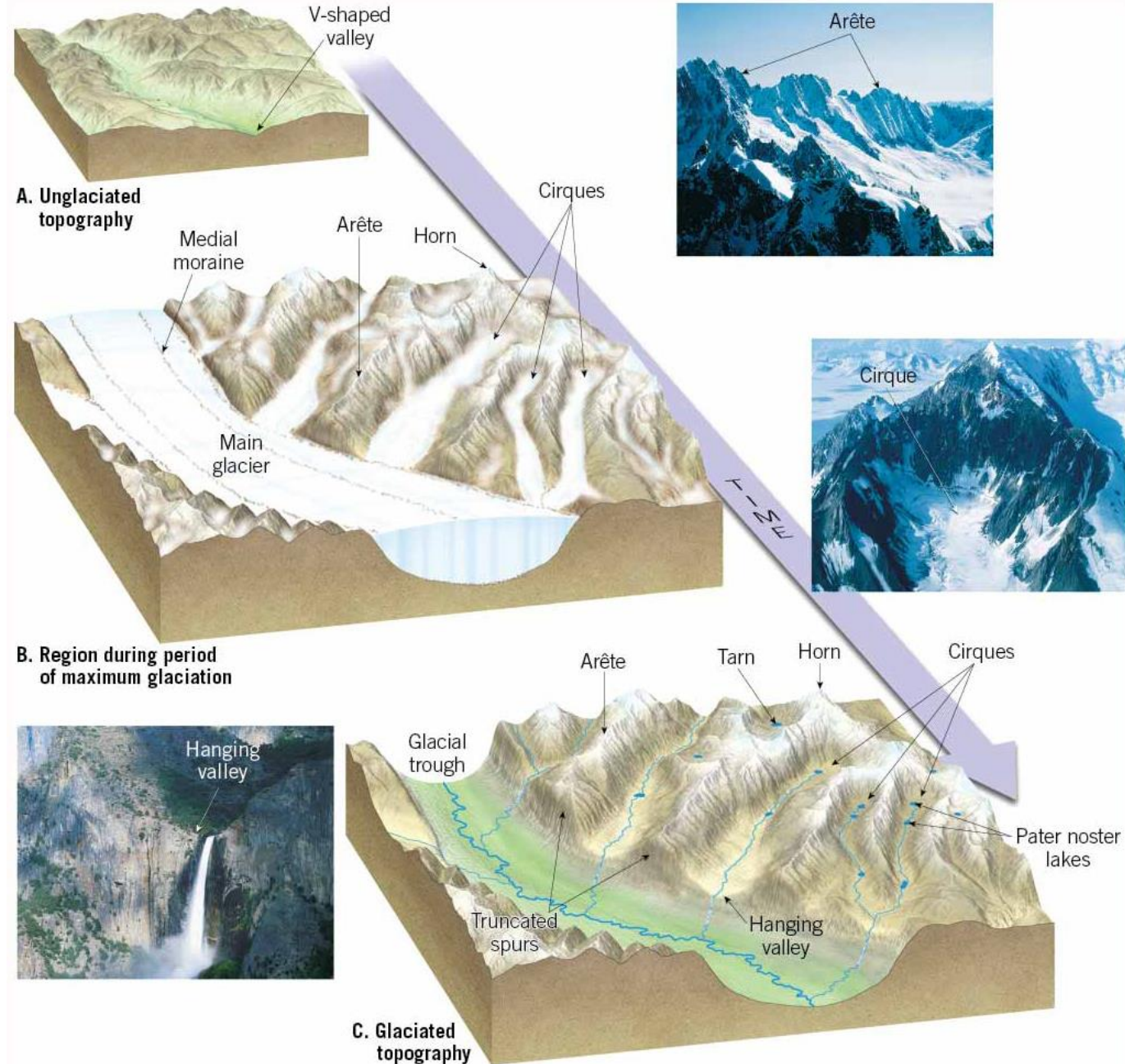


# Glacial Erosion



# Landforms Created by Glacial Erosion

- *Moraine*
- *Medial moraine*
- *Arête*
- *Horn*
- *Cirque*
- *Tarn*
- *Glacial trough*
- *Truncated spur*
- *Hanging valley*
- *Pater noster lake*







# Tarn

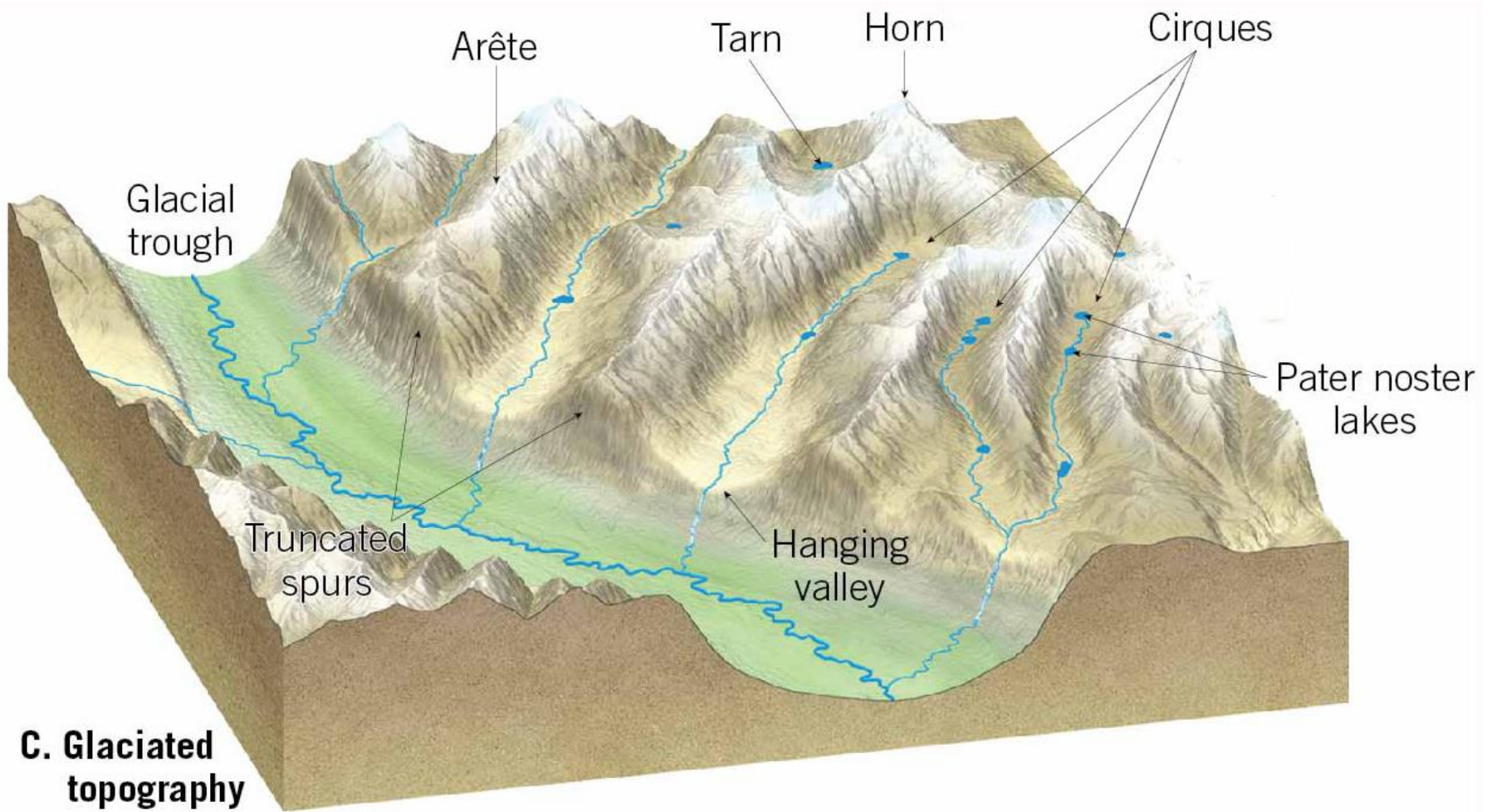




# Landforms Created by Glacial Erosion



**A. Unglaci-  
ated  
topography**





# Erosional Features

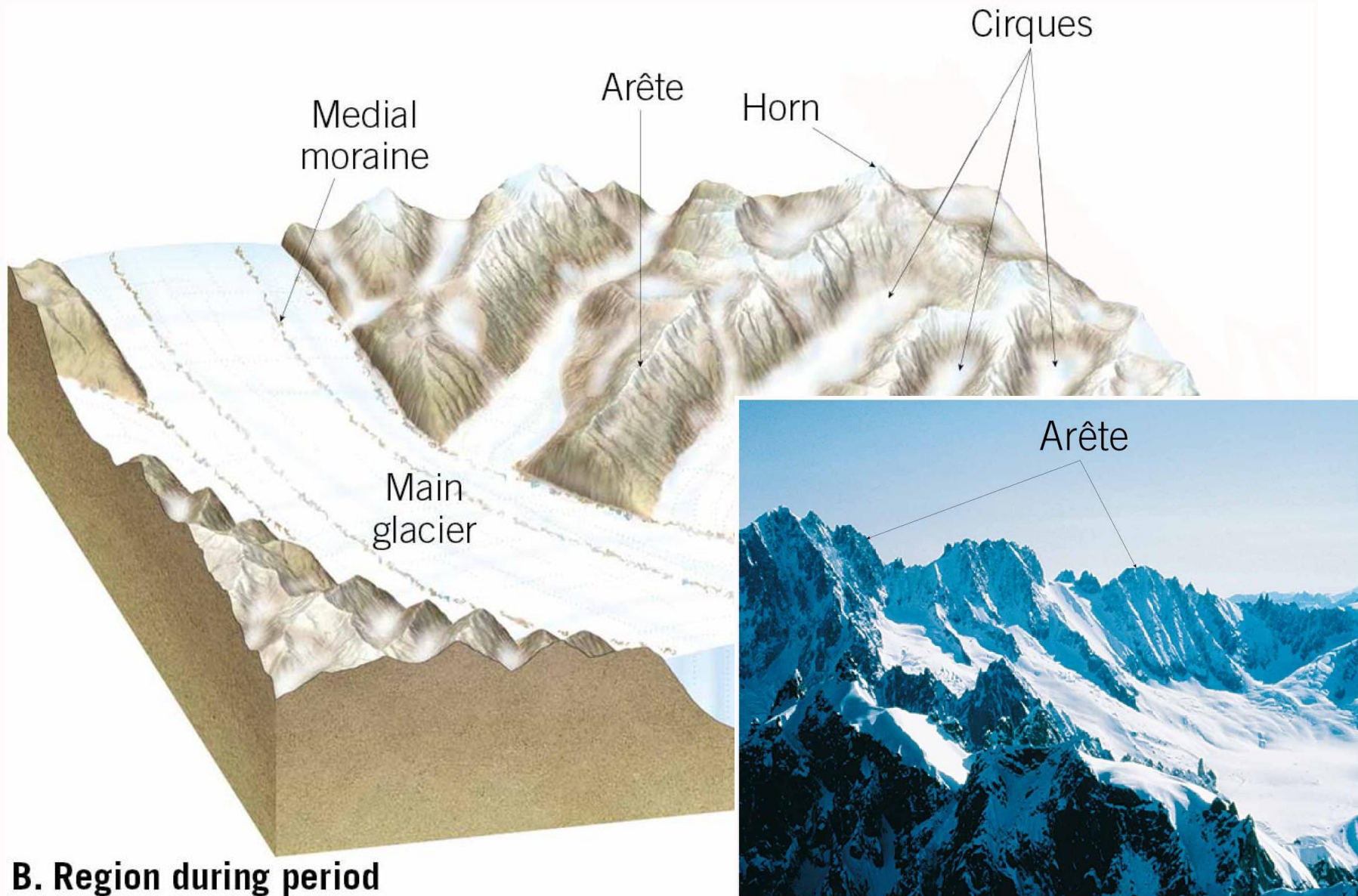
## U-Shaped Valleys

Yosemite, CA (below)





# Landforms Created by Glacial Erosion



**B. Region during period of maximum glaciation**



# Erosional Features

## Hanging Valleys

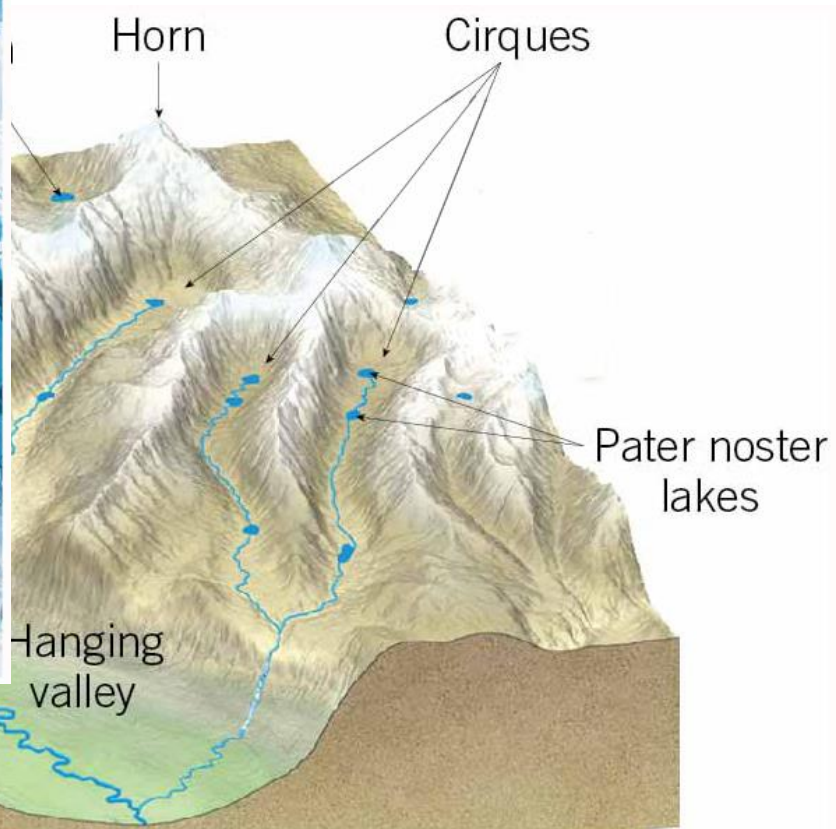
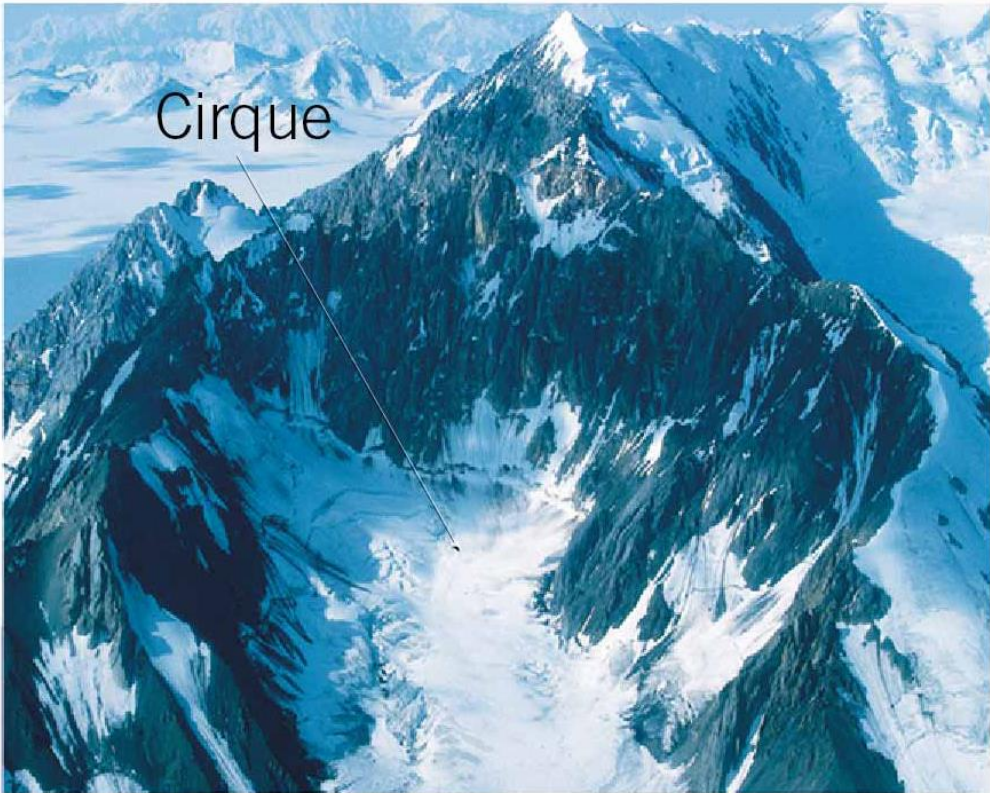
Bridal Veil Falls, Yosemite Nat'l Park, California



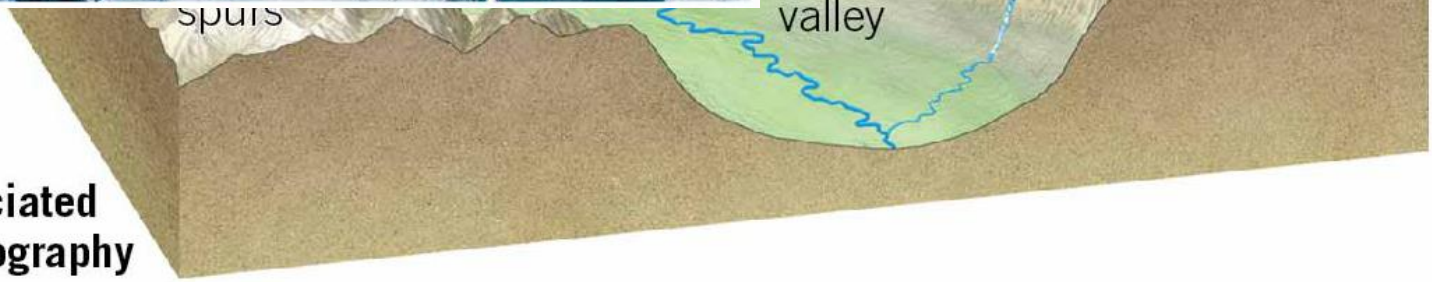
Photo: J.A. Thomas, 1987. USGS Photographic Library, photo

post00008. < <http://libraryphoto.cr.usgs.gov/> > Accessed July 2010.

# Landforms Created by Glacial Erosion



**C. Glaciated topography**





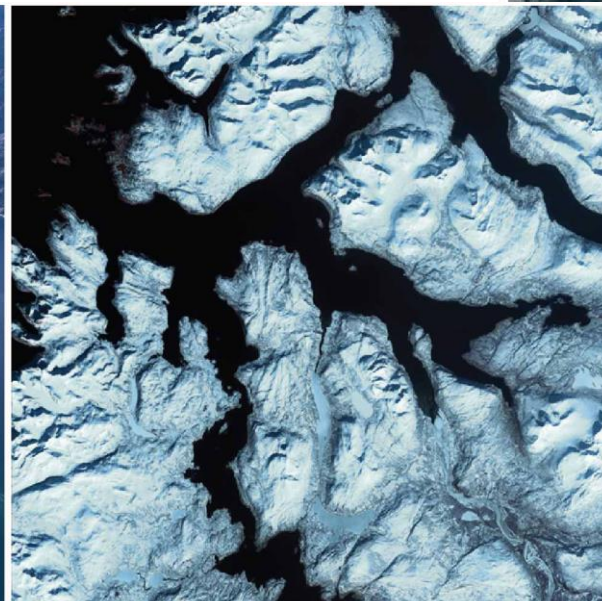
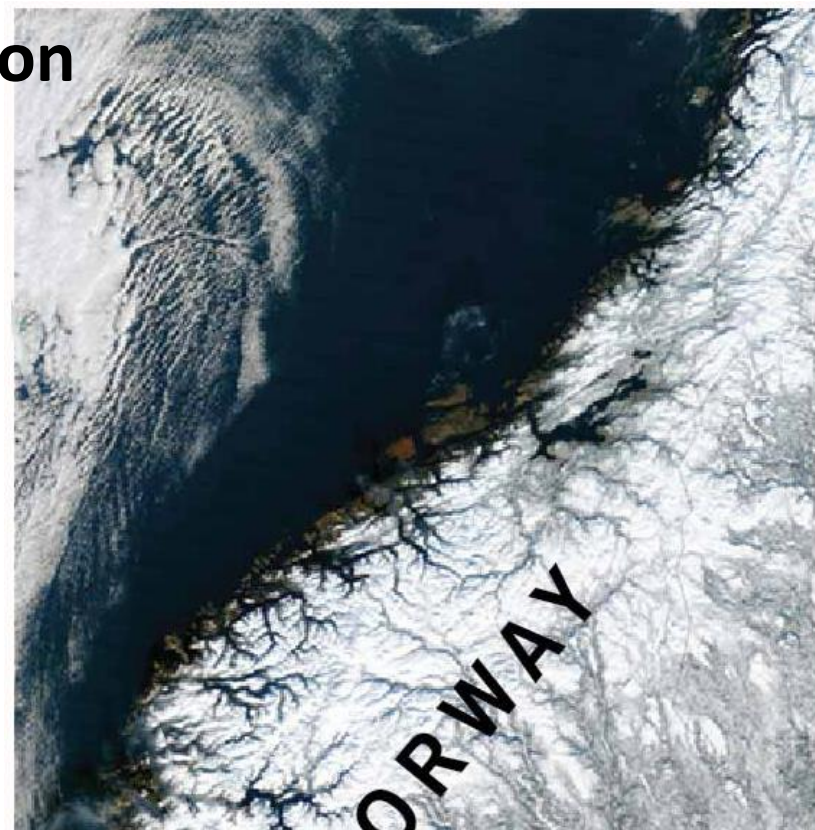
# The Matterhorn in the Swiss Alps



# Landforms Created by Glacial Erosion

**Fjords:** *deep, steep-sided ocean inlets that are drowned glacial troughs*

*Form from a combination of sea level rise and **glacial rebound***



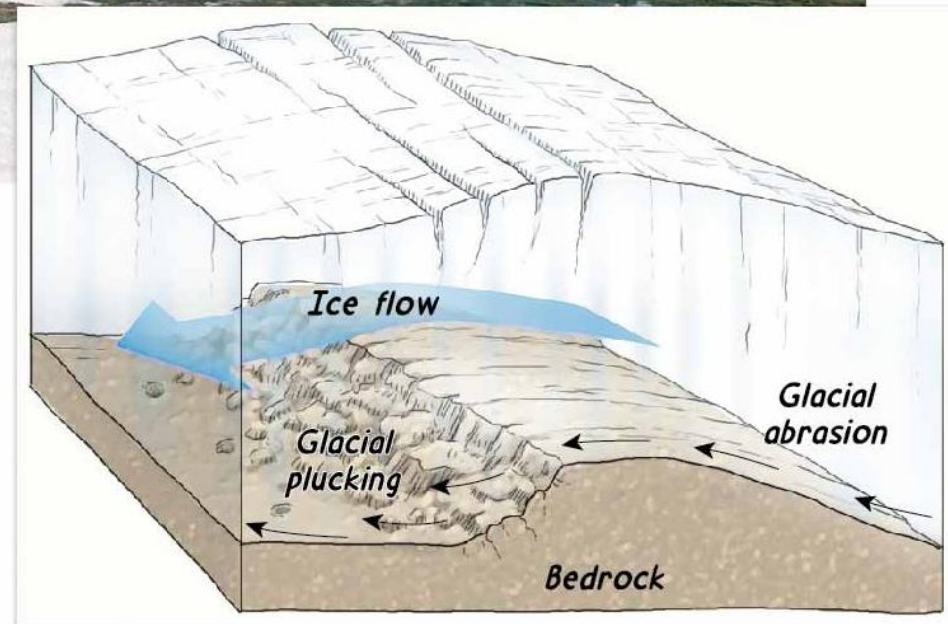


# Landforms Created by Glacial Erosion



## Roche Moutonnée:

*asymmetrical knob of bedrock formed by glacial abrasion and plucking*

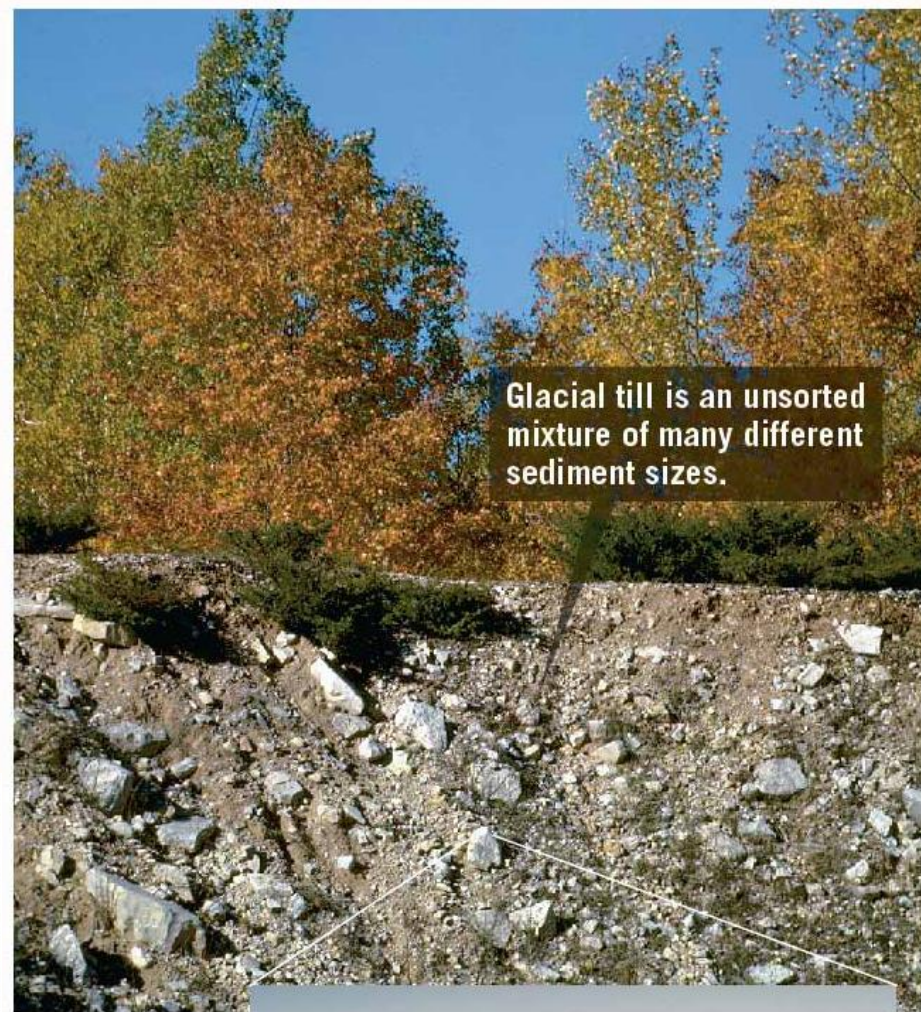


**Geologist's Sketch**

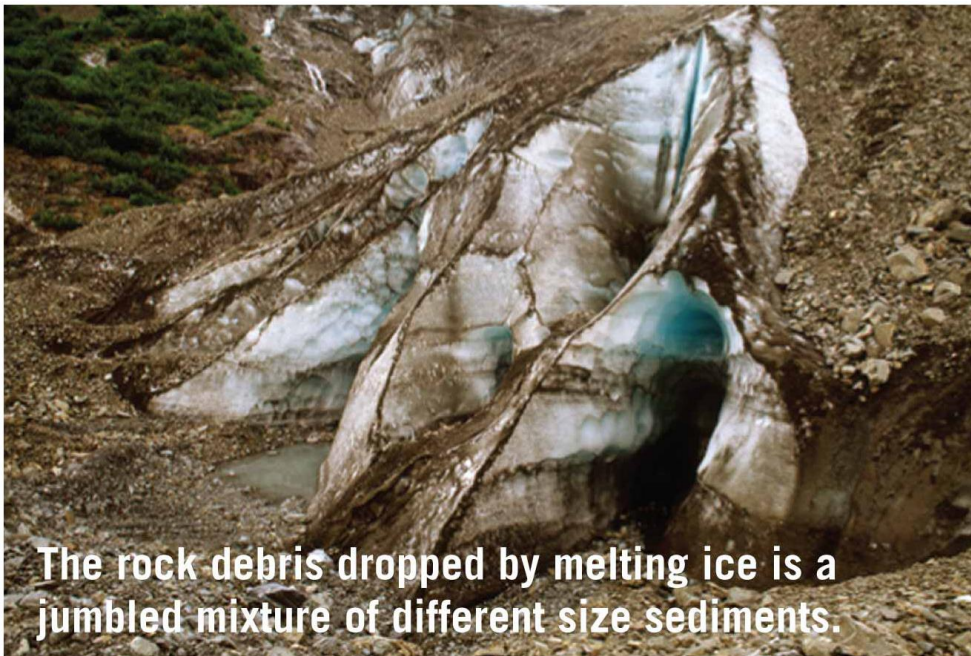


# Glacial Deposits

*Glaciers can transport a vast amount of debris because ice has a much higher carrying capacity than water*

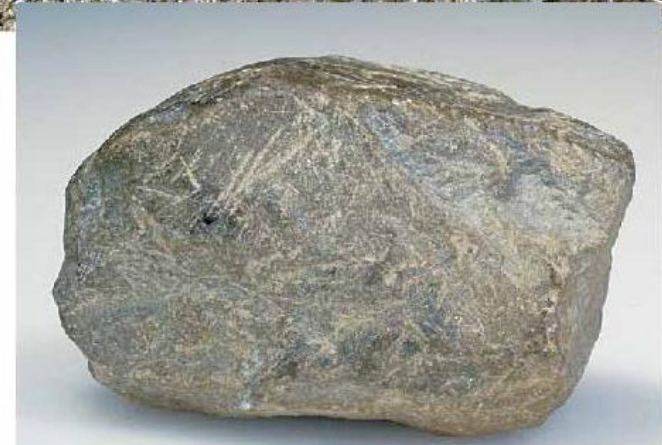


Glacial till is an unsorted mixture of many different sediment sizes.



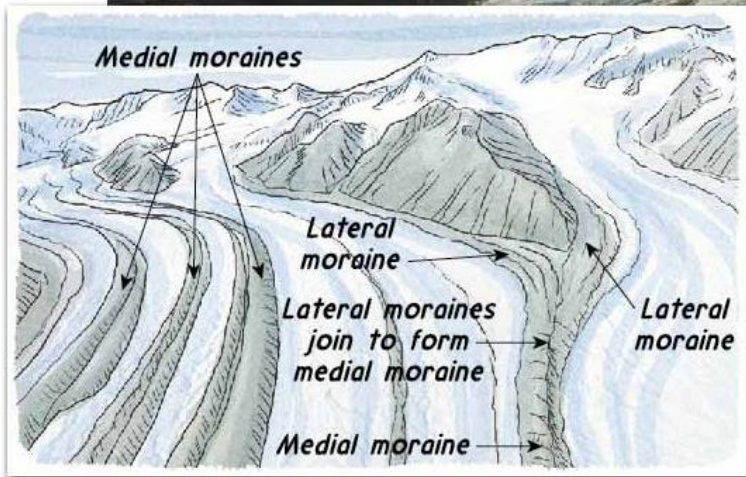
The rock debris dropped by melting ice is a jumbled mixture of different size sediments.

A close examination of glacial till often reveals cobbles that have been scratched as they were dragged along by the ice.





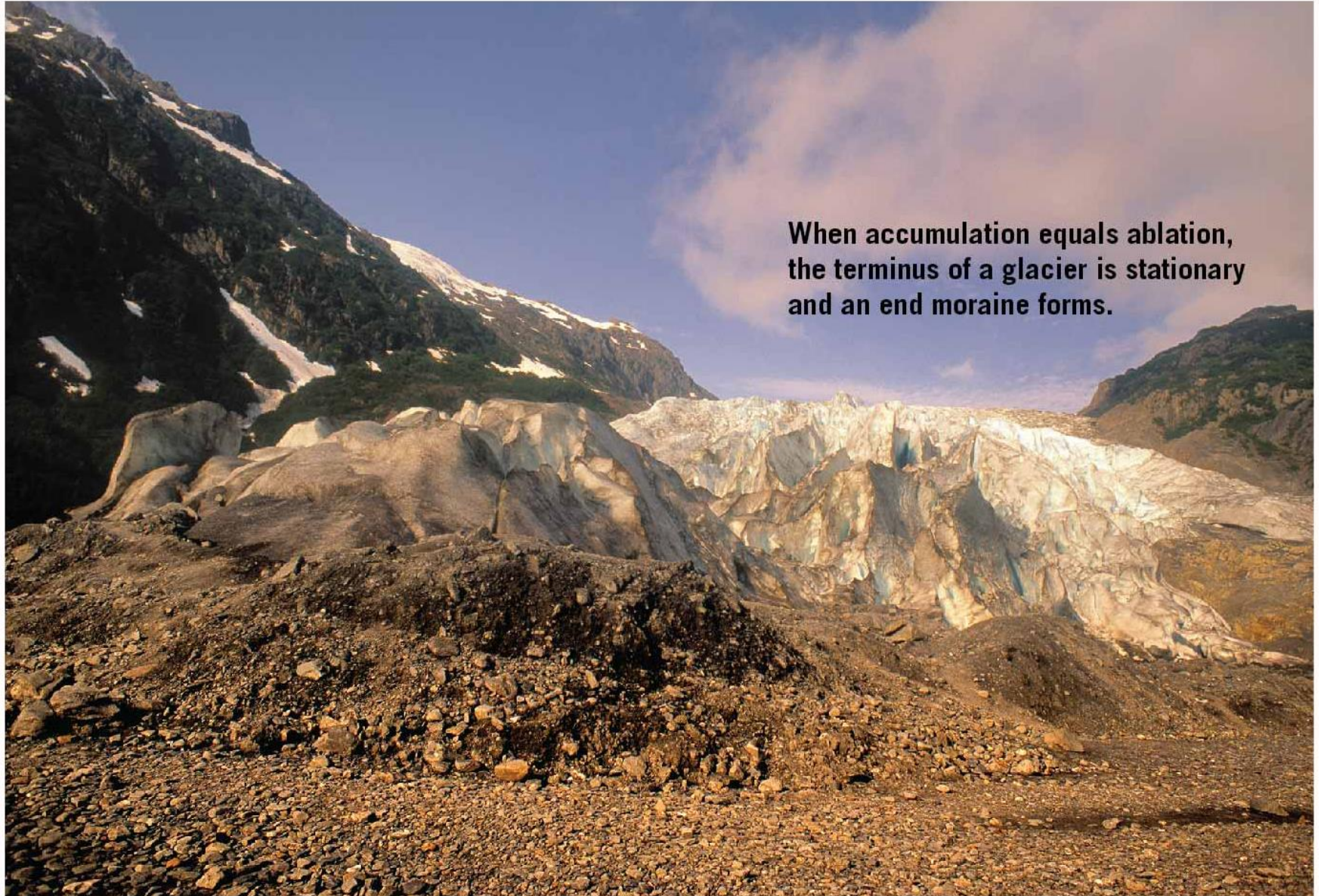
# Landforms Made of Till – *lateral & medial moraines*



***Geologist's Sketch***



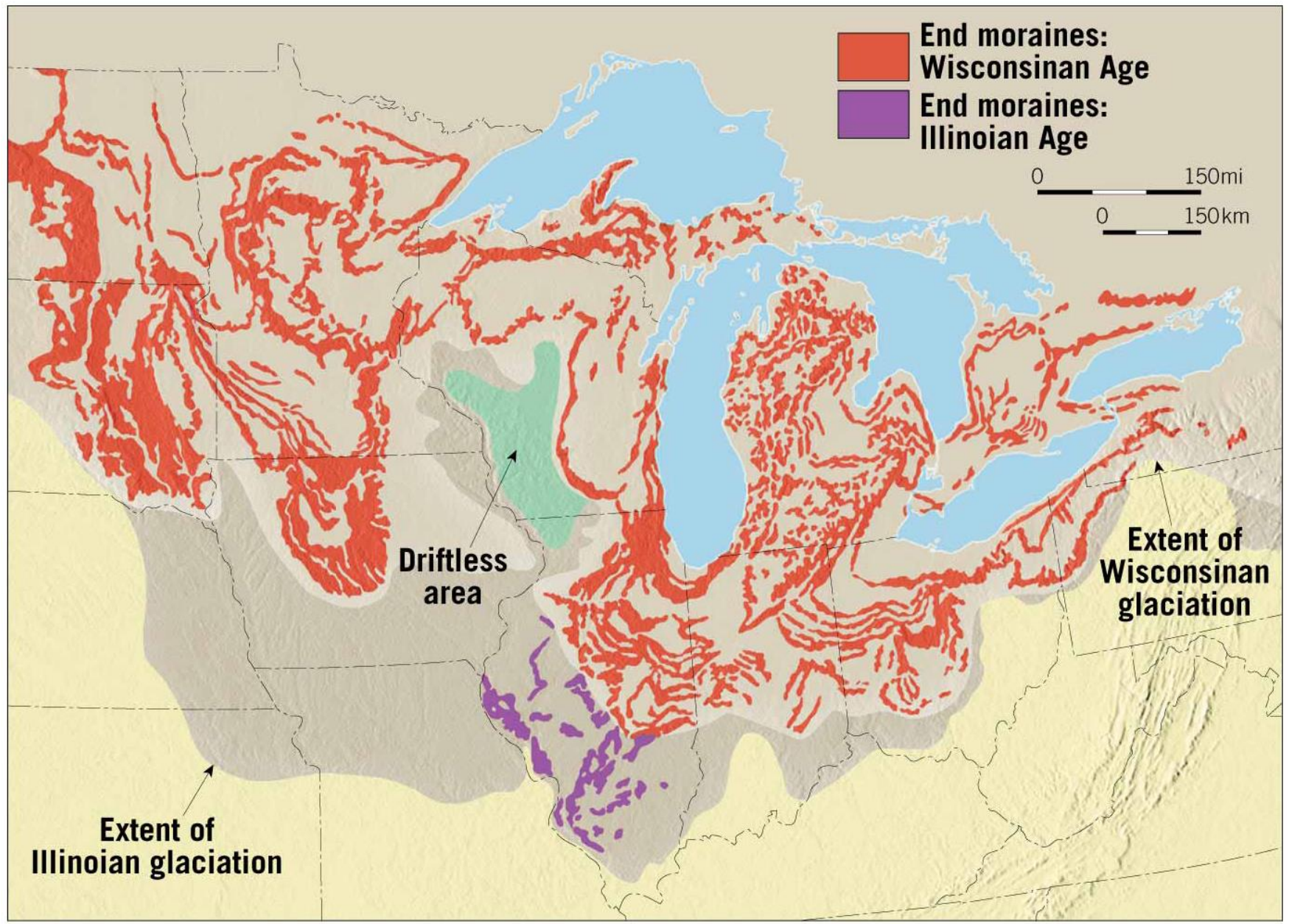
# Landforms Made of Till – *end moraines*



**When accumulation equals ablation, the terminus of a glacier is stationary and an end moraine forms.**

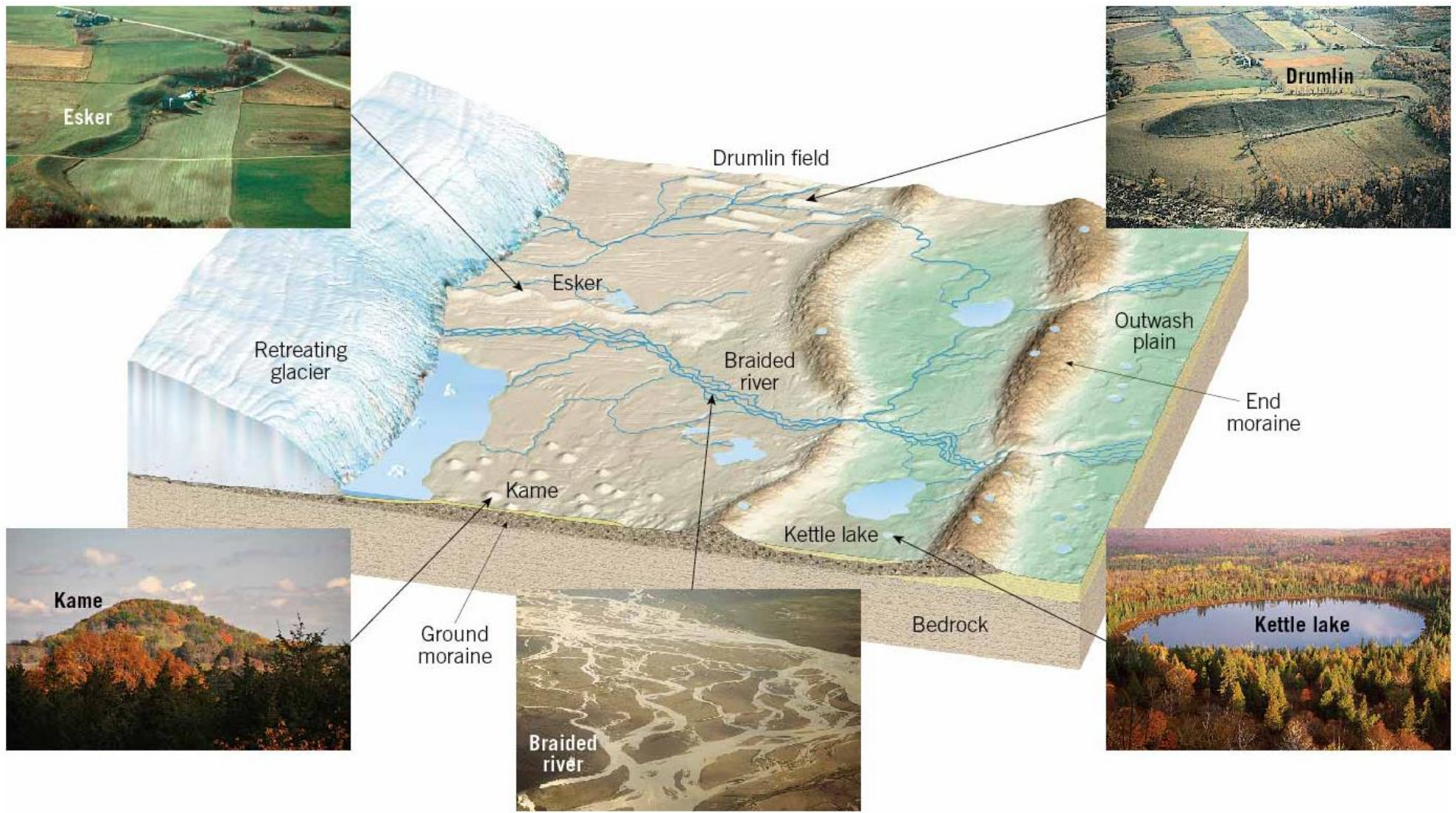


# Landforms Made of Till – *terminal and recessional moraines*





# Landforms Made of Till – *other landforms*

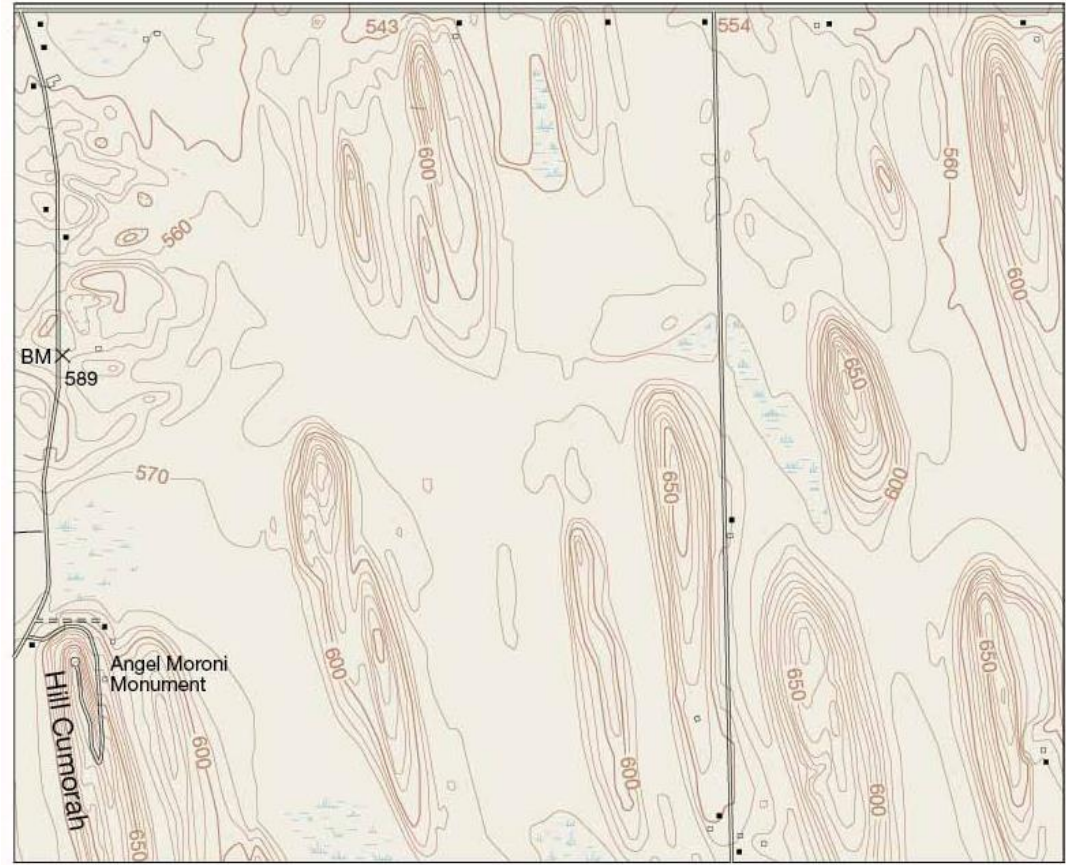
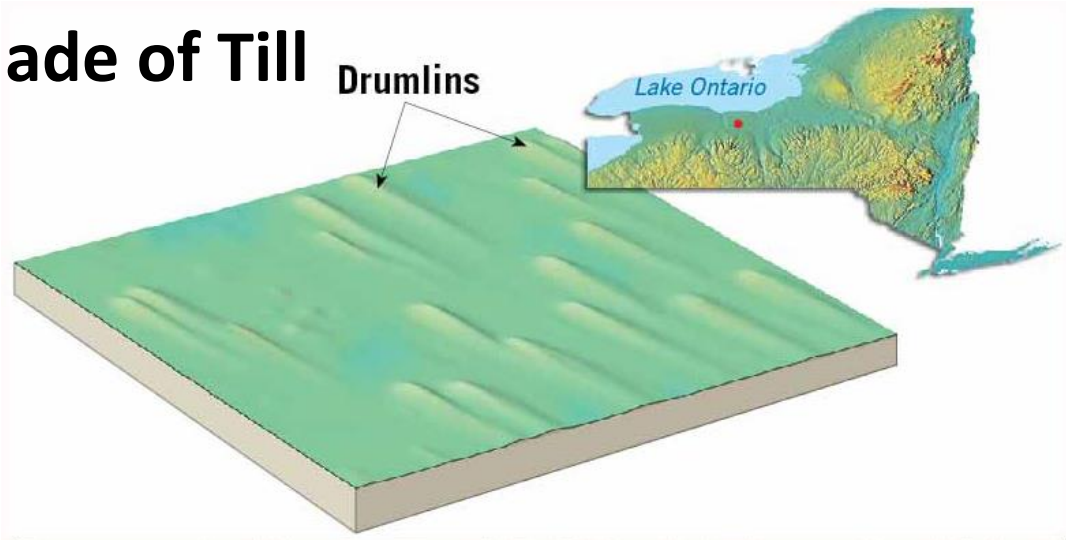




# Landforms Made of Till

## *Drumlins*

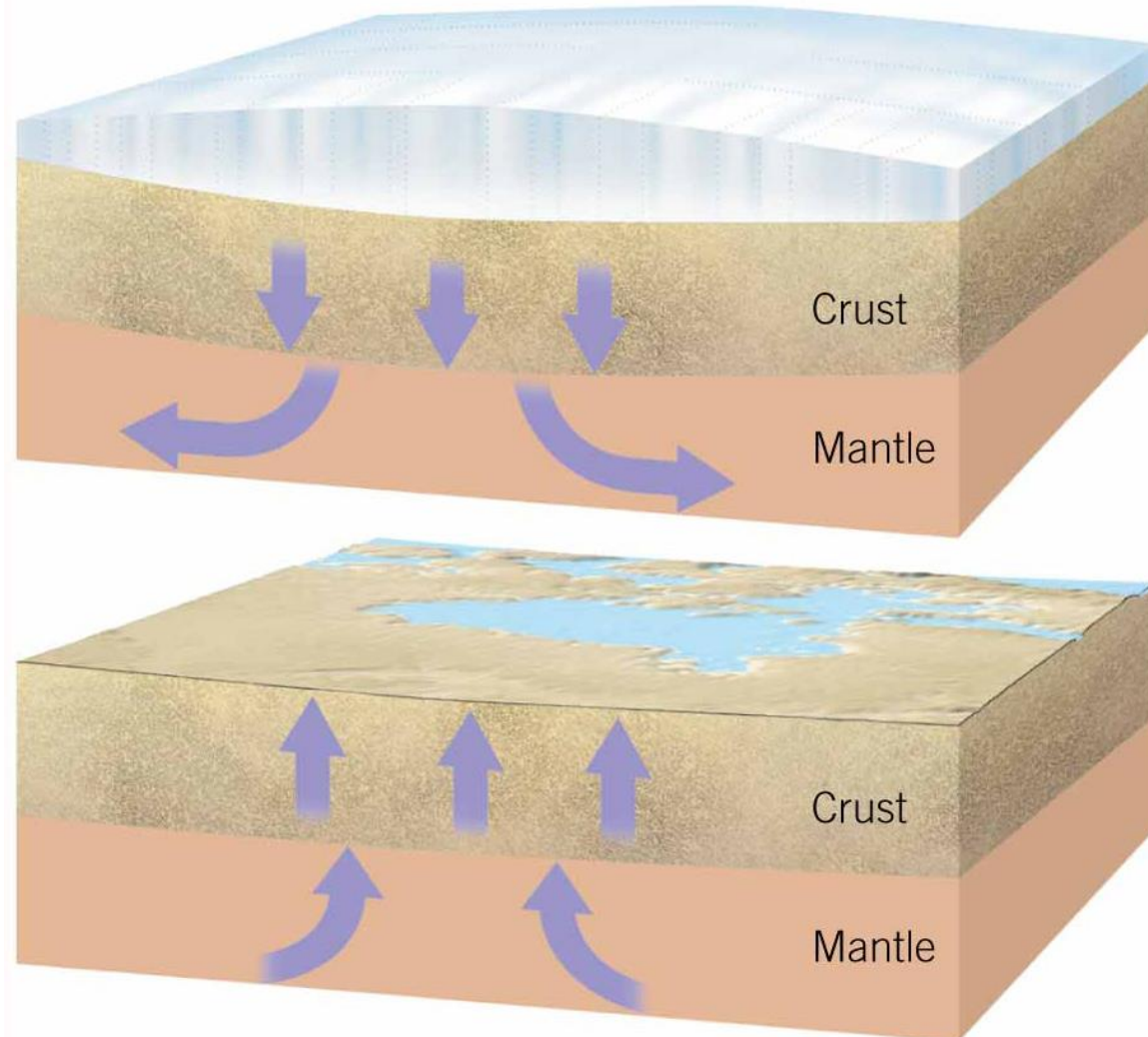
Drumlins



# Other Effects of Ice Age Glaciers

## *Crustal subsidence & rebound*

In northern Canada and Scandinavia, where the greatest accumulation of glacial ice occurred, the added weight caused downwarping of the crust.



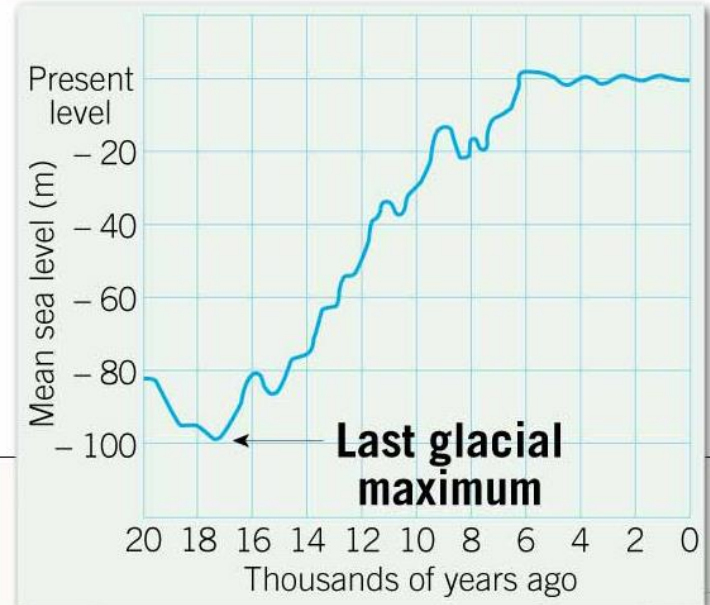
Ever since the ice melted, there has been gradual uplift or rebound of the crust.



# Other Effects of Ice Age Glaciers

## *Sea Level Rise*

During the Last Glacial Maximum, about 18,000 years ago, sea level was nearly 100 meters (330 feet) lower than it is today.



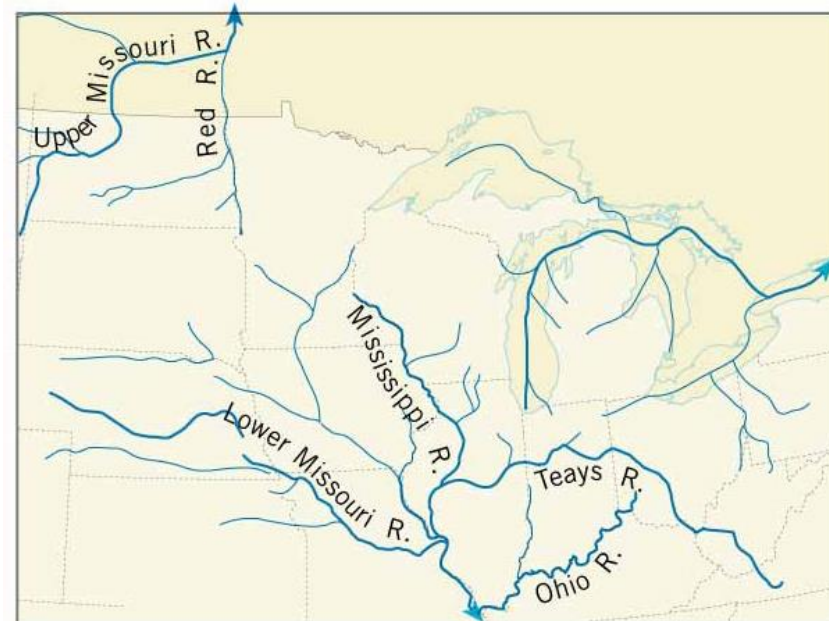
During the Last Glacial Maximum, the shoreline extended out onto the present day continental shelf.

# Other Effects of Ice Age Glaciers

***Changes to River Systems:***  
*A major glaciation can shift the direction rivers flow*



**A.** This map shows the Great Lakes and the familiar present-day pattern of rivers. Quaternary ice sheets played a major role in creating this pattern



**B.** Reconstruction of drainage systems prior to the Ice Age. The pattern was very different from today, and the Great Lakes did not exist.

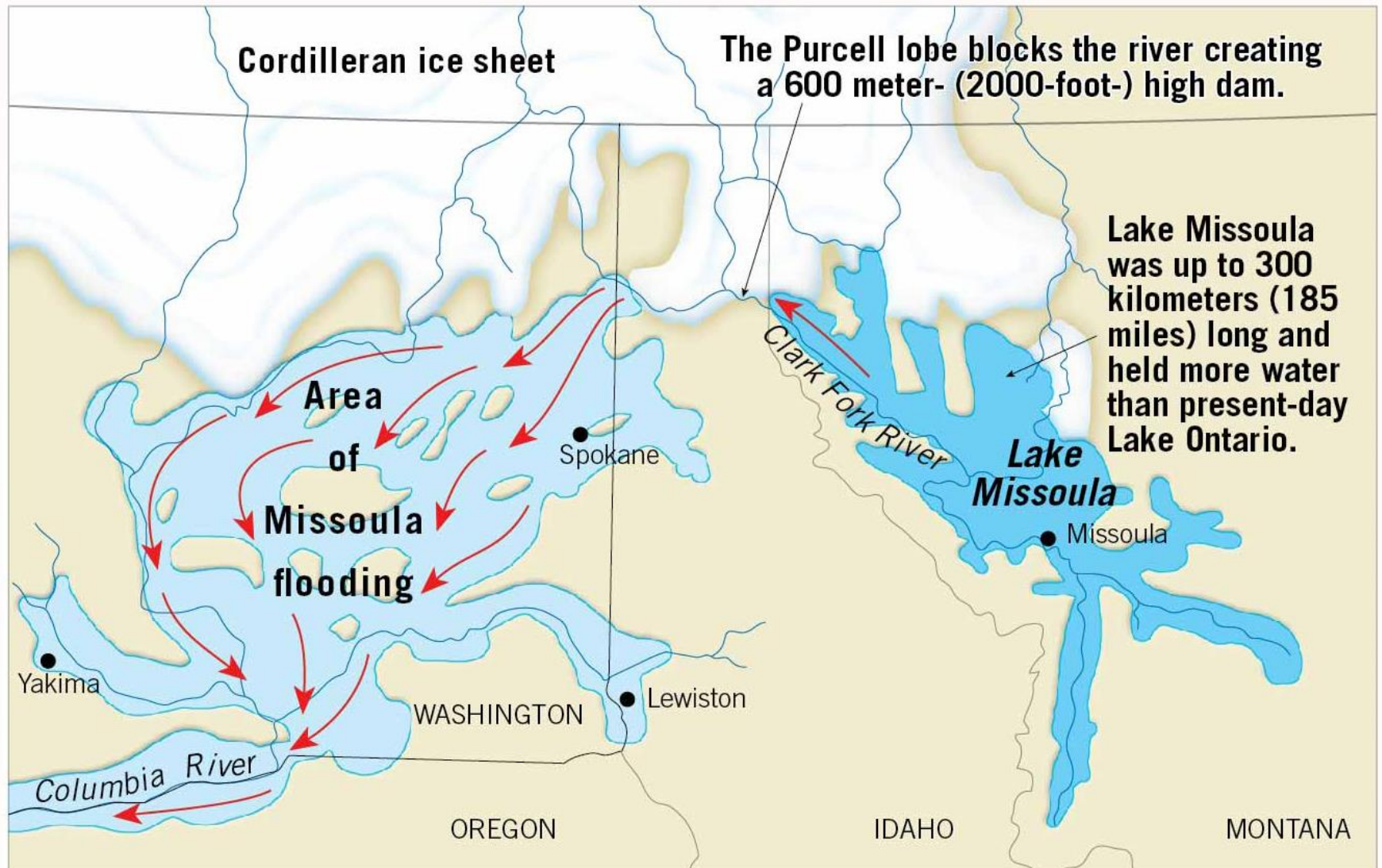


# Other Effects of Ice Age Glaciers

## Proglacial Lakes:

*Major lakes or bodies of water that form during a glaciation*





**This prehistoric proglacial lake in western Montana periodically broke through the ice dam that created it. This resulted in huge floods (megafloods) that shaped the landscape of eastern Washington State.**





**The towering mass of rushing water from each megaflood stripped away layers of sediment and soil and cut deep canyons (coulees) into the underlying layers of basalt to create the Channeled Scablands.**



