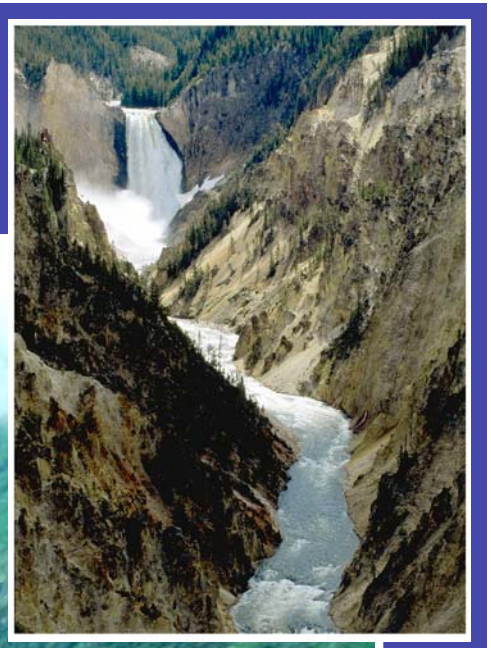
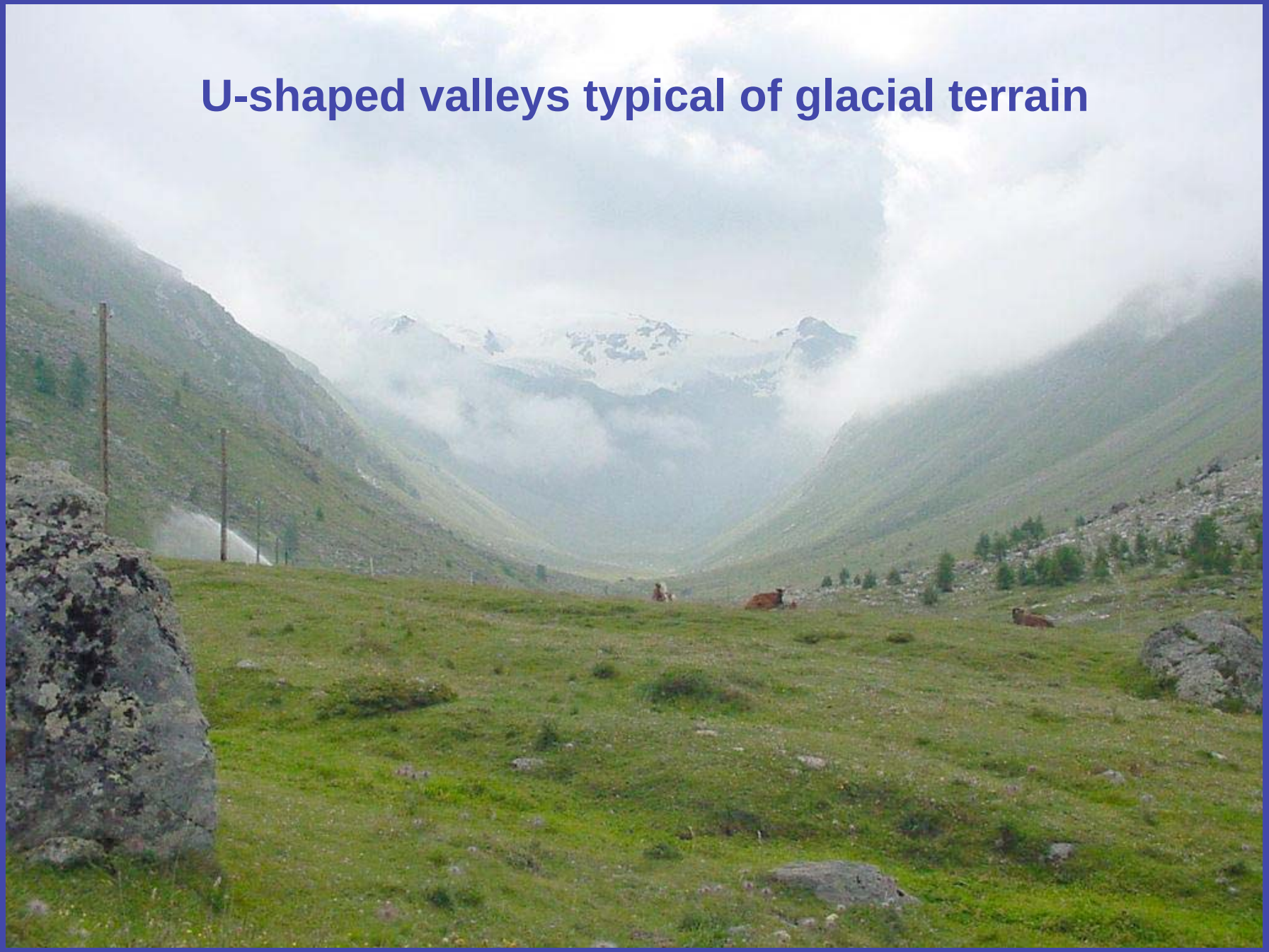
Did this stream create this valley?



What's different about these two valleys?



U-shaped valleys typical of glacial terrain





Glacial valley formation

1) Ice mass fills pre-existing stream valley

2) Erodes deep U-shape



3) Remnant valley has small stream or lakes at base



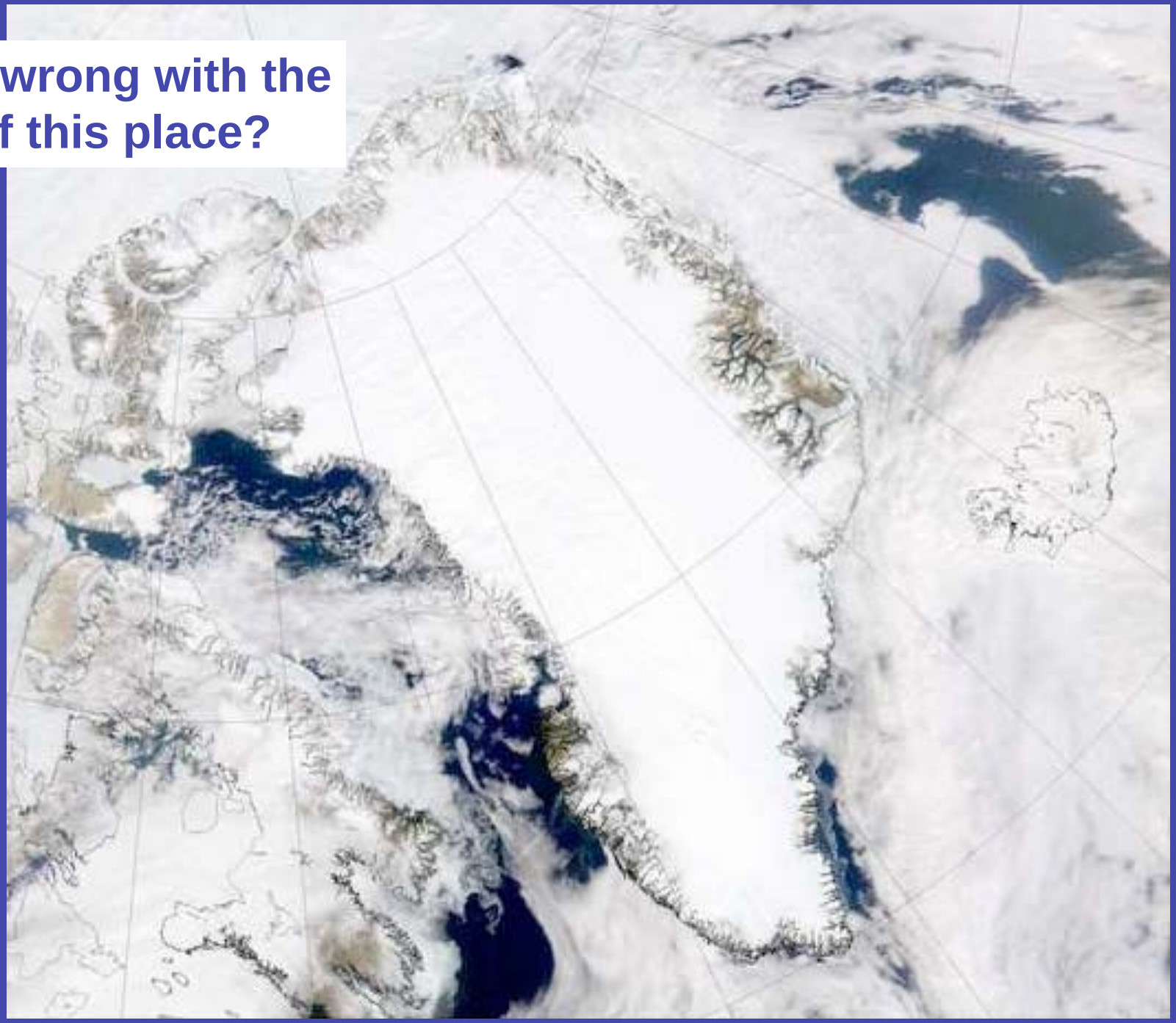
Glaciers are the most voluminous part of the hydrosphere after oceans

Why is this important today?



How are these two glacial settings different?

What's wrong with the name of this place?



Greenland is 80% ice covered, 11% of world's ice



Ice sheet 1,500-3,000m thick 0.7 million square miles



84% of world's ice is in Antarctica



Up to 4,300m thick
13.6 million square miles

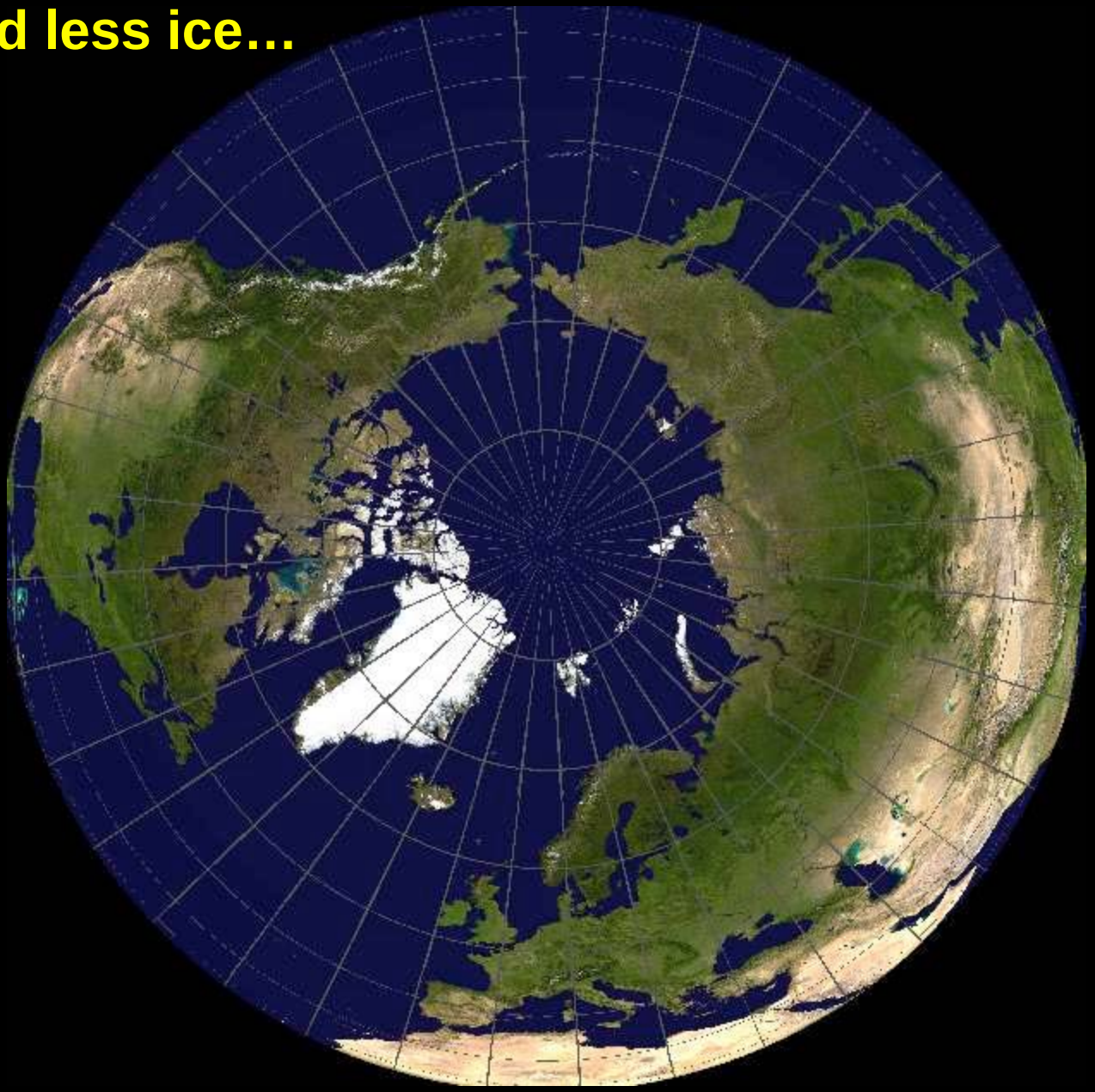


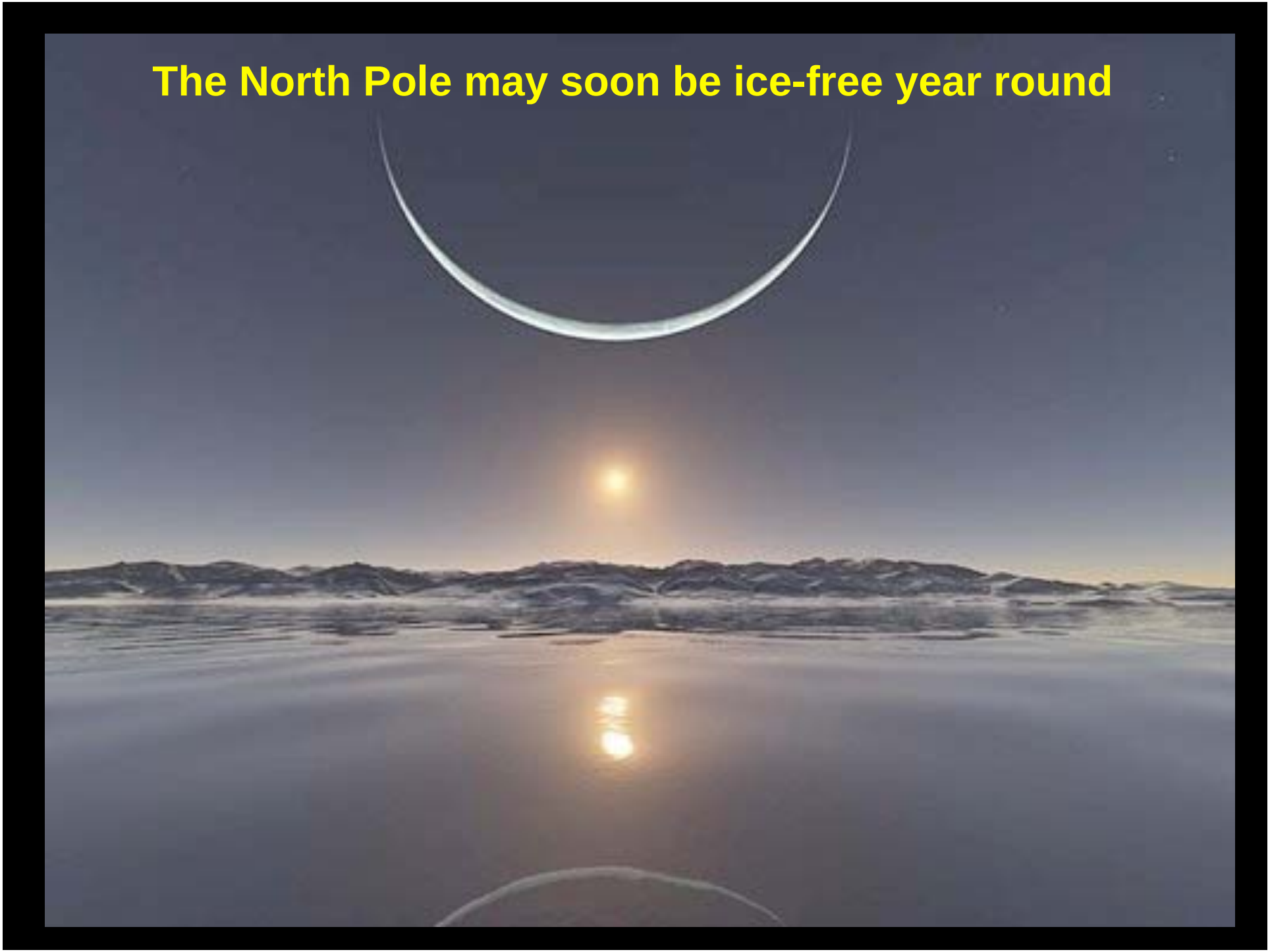
Antarctica/Greenland = 10% of Earth's surface
95% of Earth's ice

5% of Earth's ice in alpine glaciers, sea ice

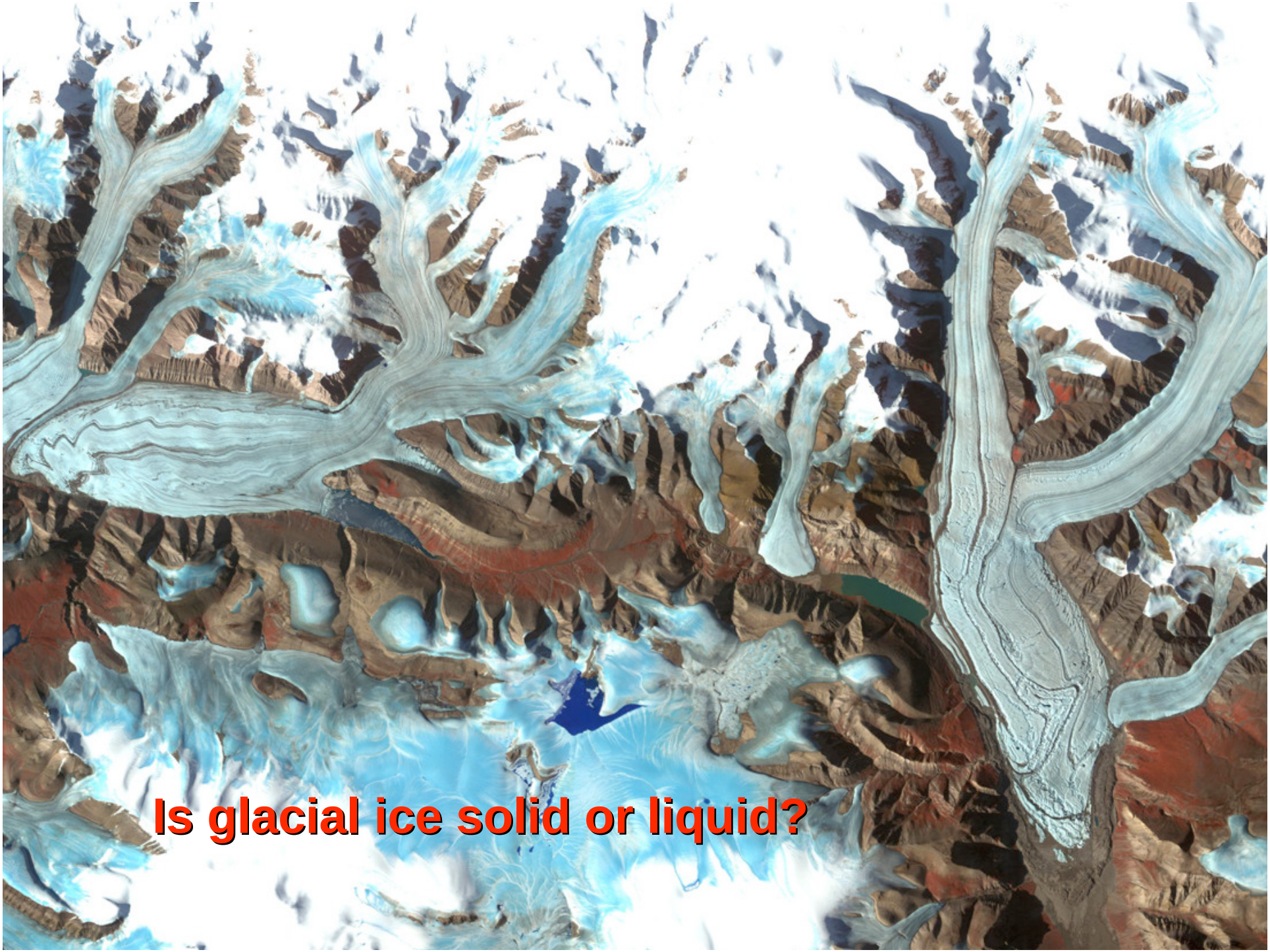
What’s at the North Pole?

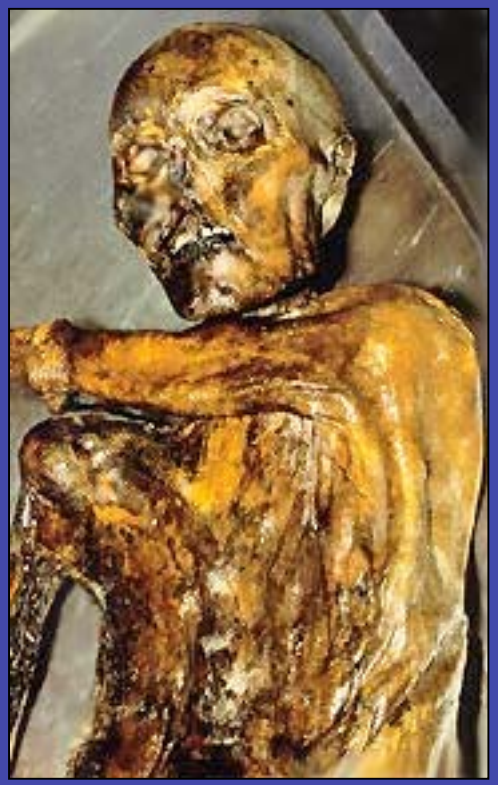
Less and less ice…




The North Pole may soon be ice-free year round


How will Hawaii fare?
Seattle
San Francisco
Phoenix
Memphis
Houston
Orlando
Charleston
New York
Coastline if present ice sheets melt
Coastline 18,000 years ago
Isostatic rebound


Is glacial ice solid or liquid?





Who is this guy?





Ötzal Alps - Italy

Ötzi the Ice Man

- Fell into a glacial crevasse 3300 BC
- Found by tourists at base of glacier 1991



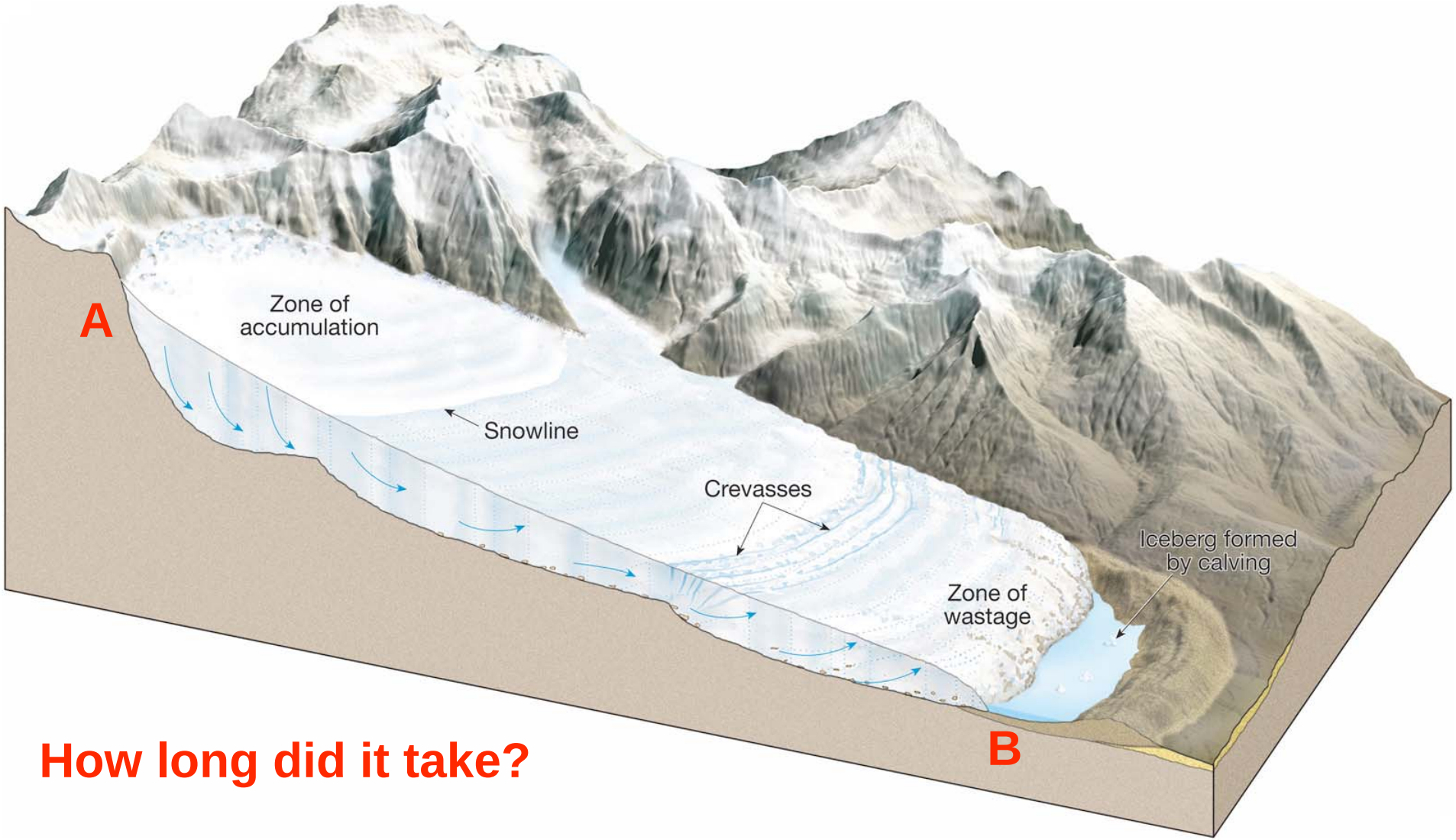




A bergshrund is a large crevasse at the top of a glacier



How did Ötzi get from point A to point B?



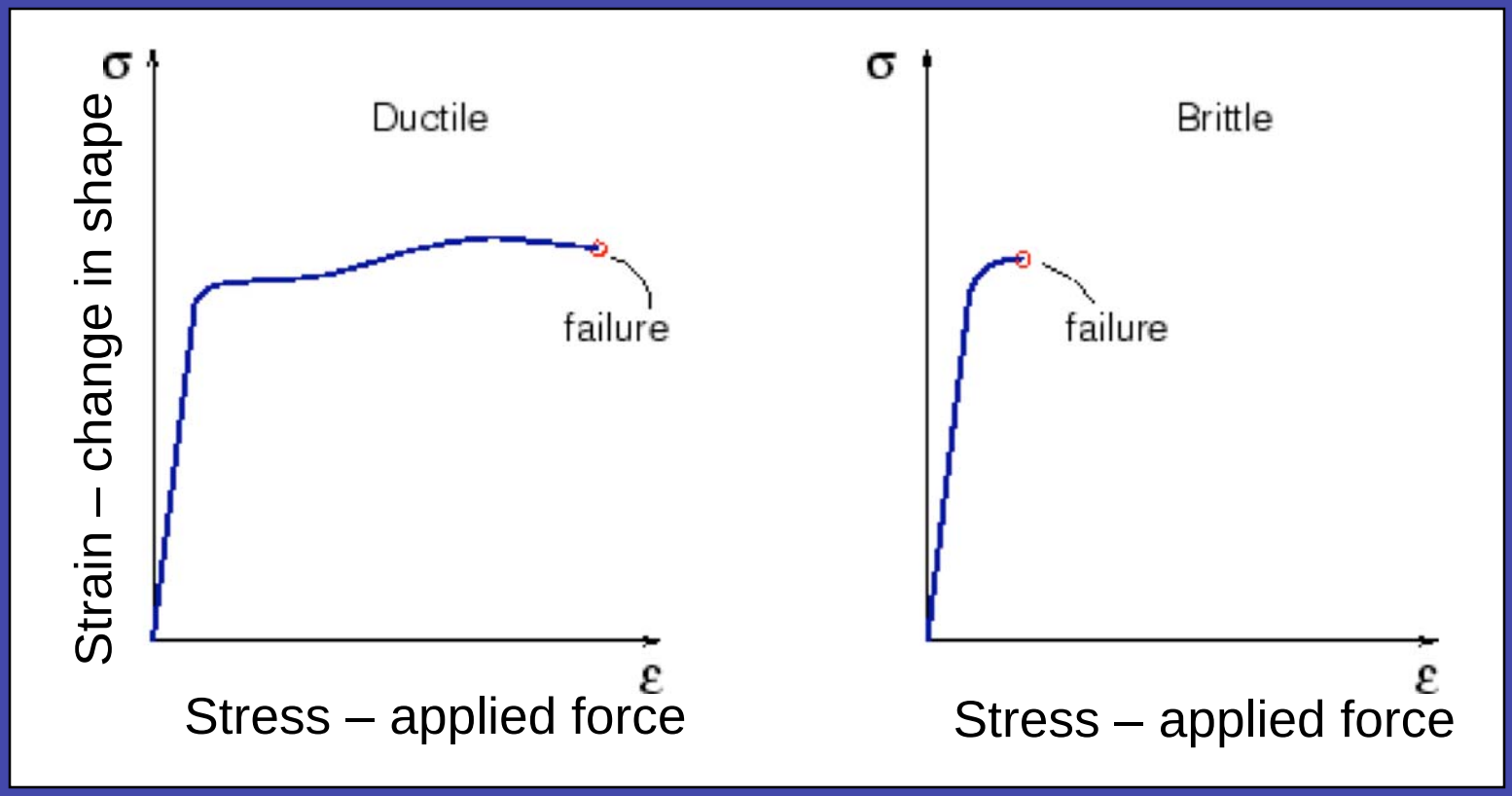
How long did it take?

What is mass balance of glacier?

Ice is solid form of water, but it flows under stress



Is glacial ice deformation brittle or ductile?

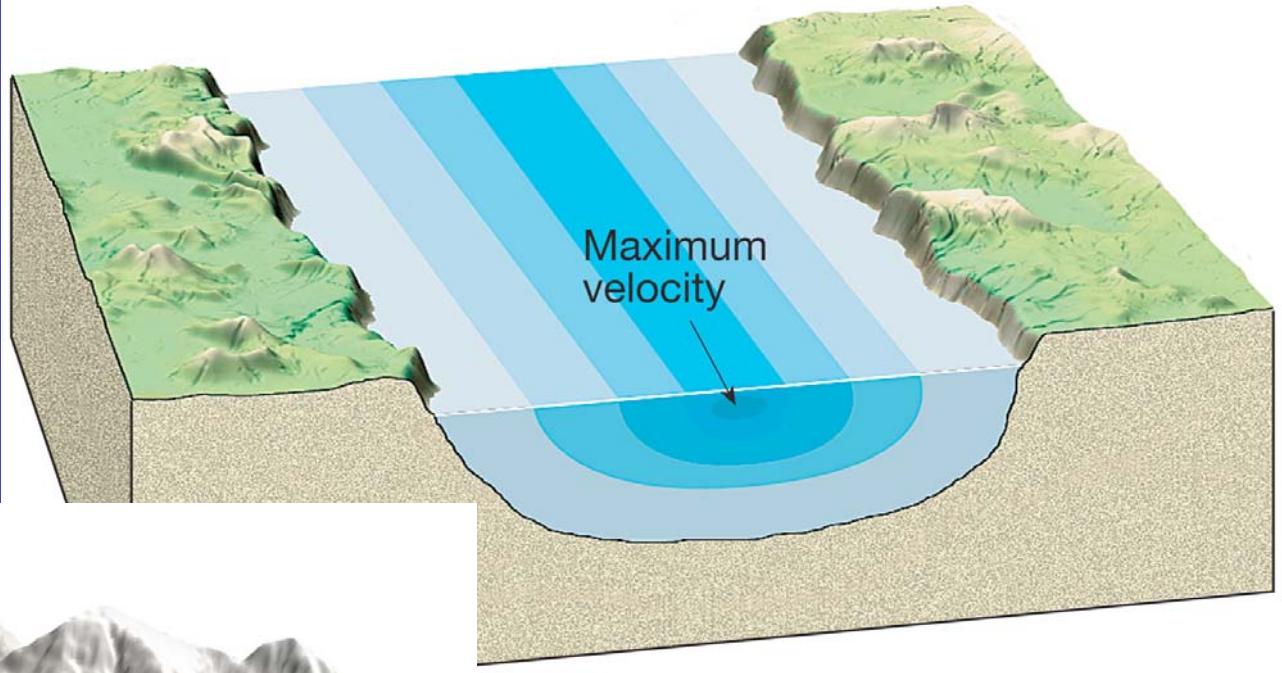


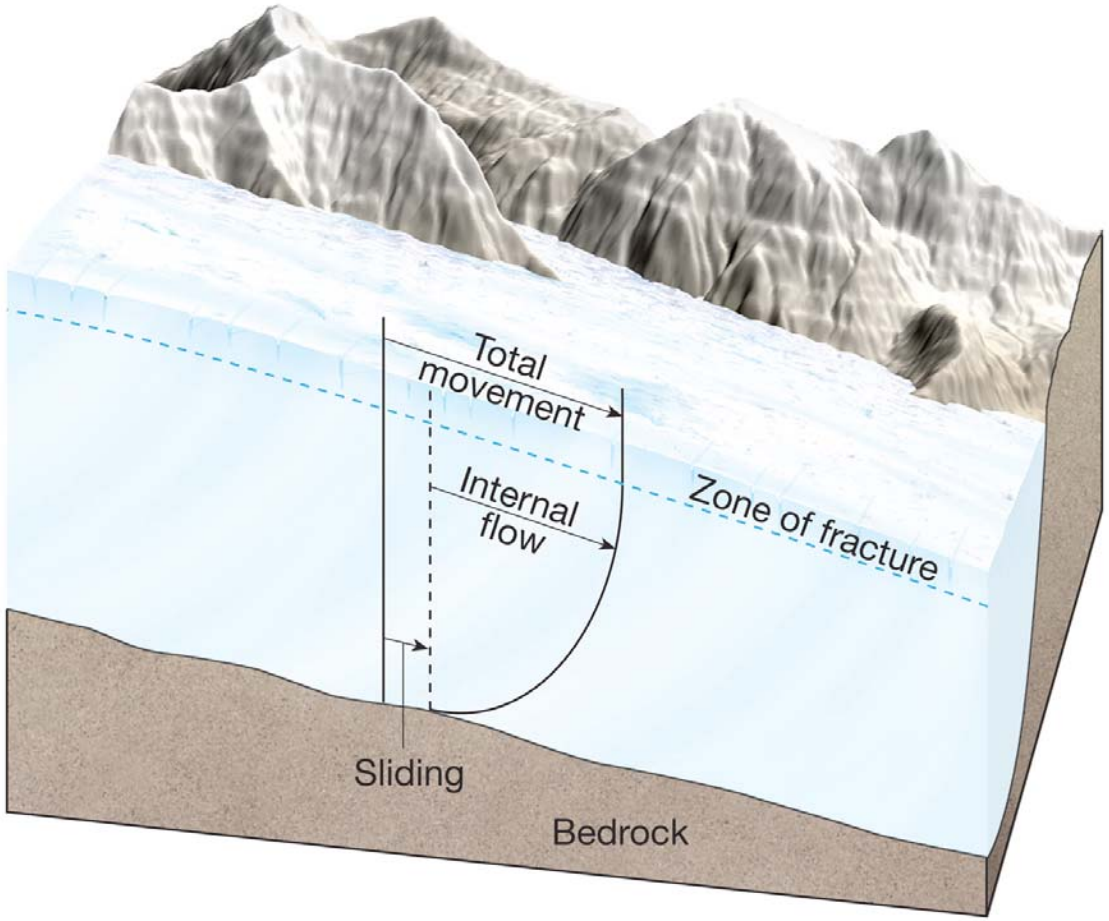
What is the applied force?

Where is the fastest-flowing ice in this glacier?



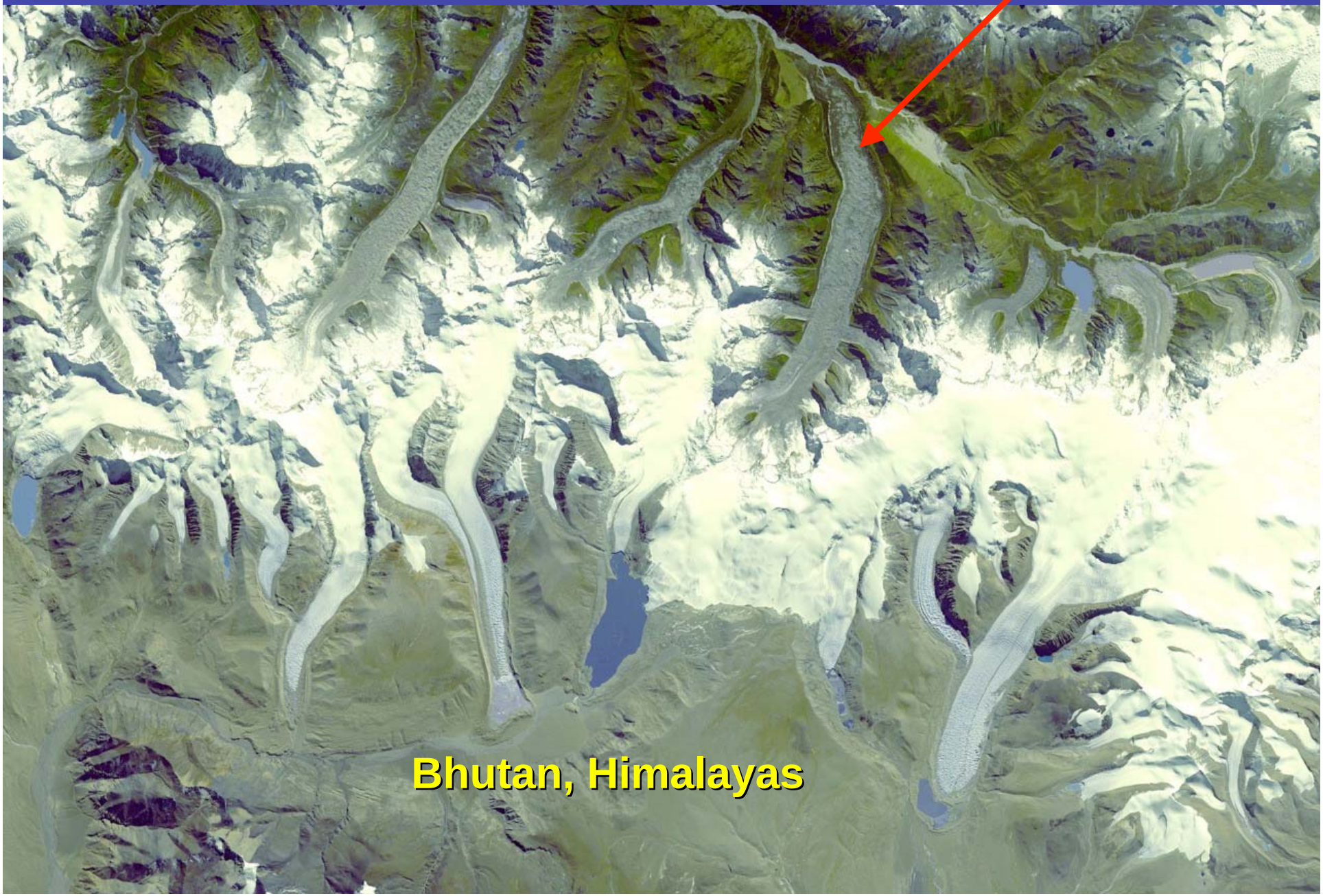
Ice flow dynamics resemble stream flow dynamics



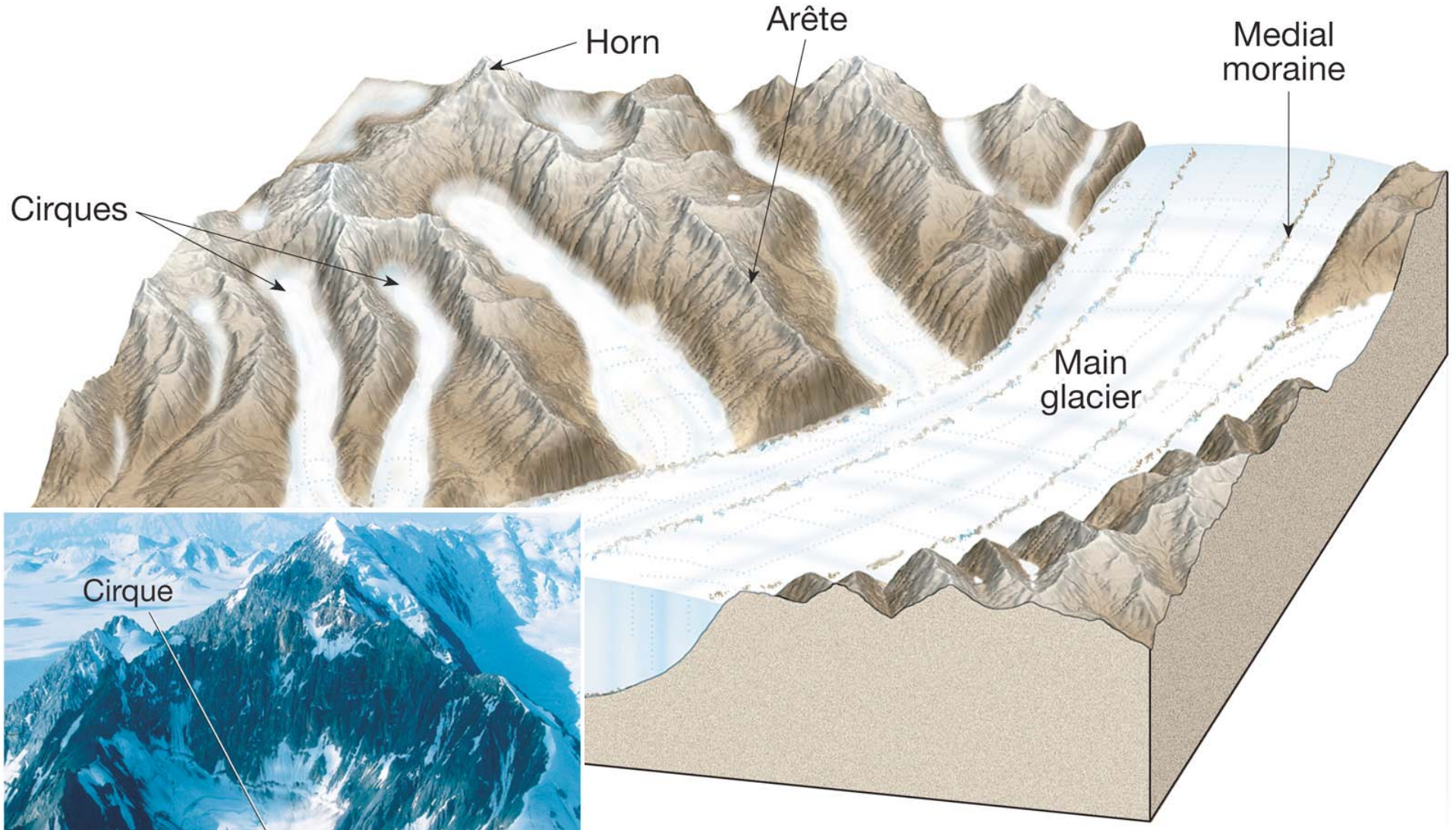


Zone of <u>maximum velocity</u> farthest removed from frictional contact with substrate

Where is the ice accumulation area for this glacier?

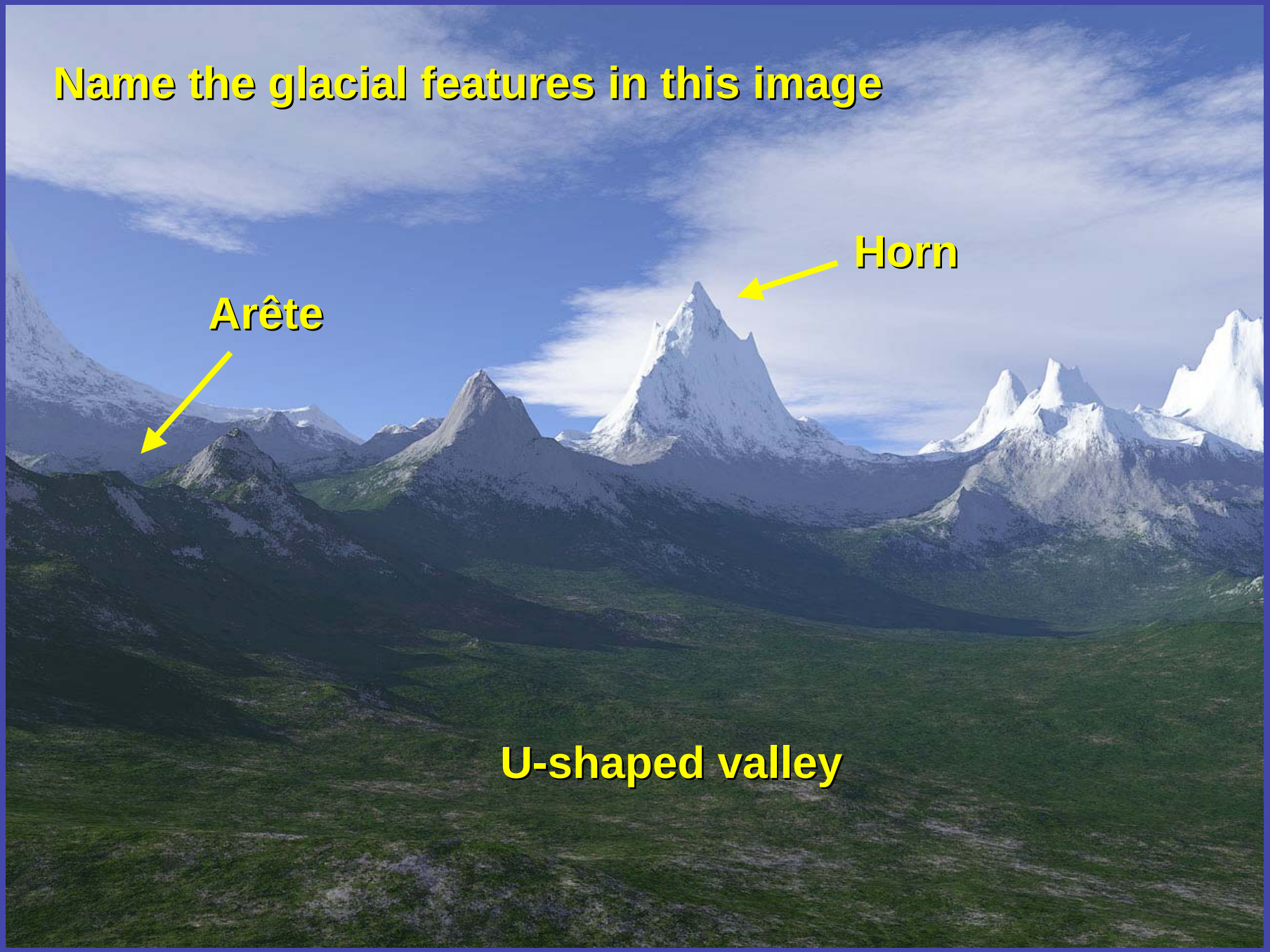


Distinctive features of alpine glaciers



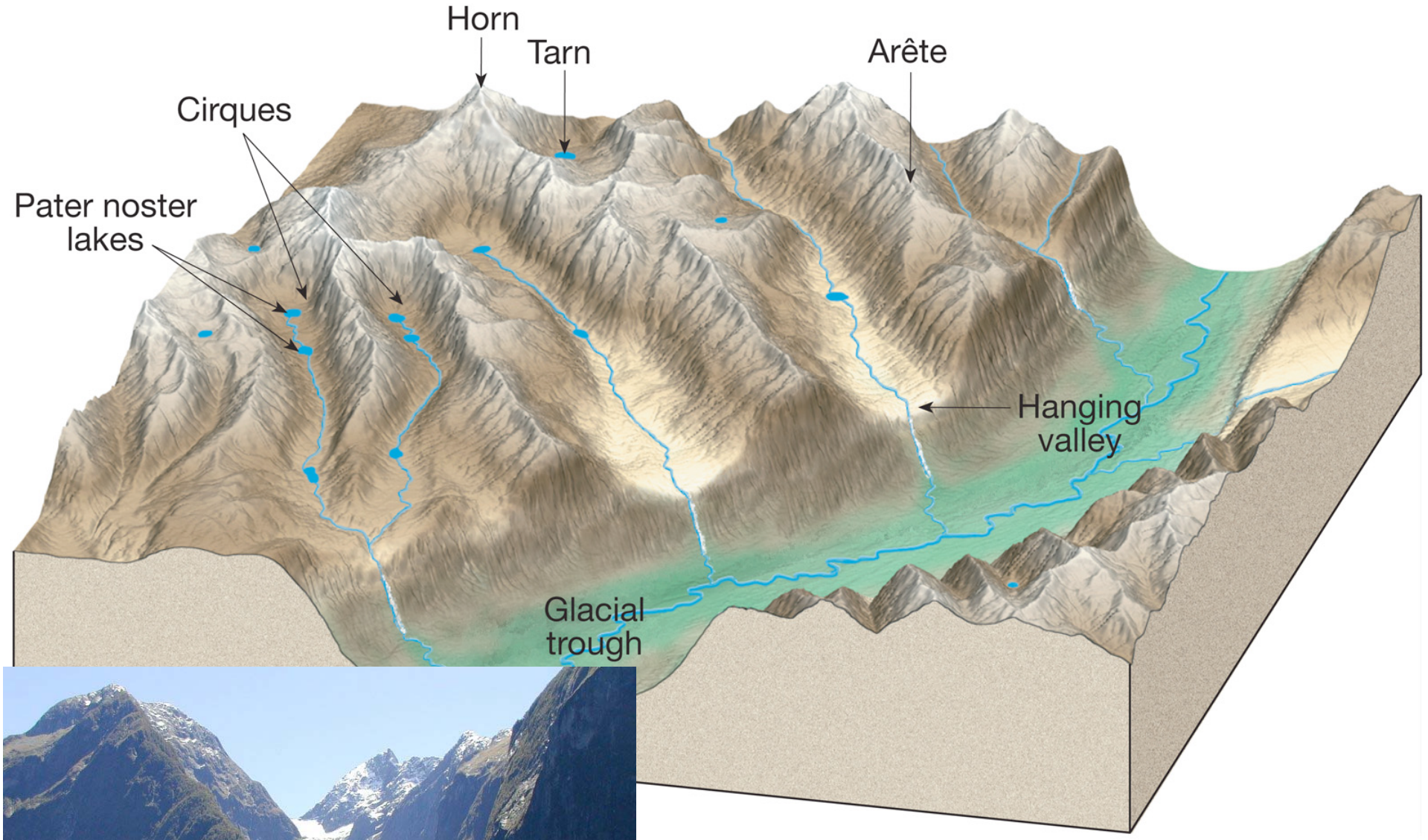
Cirque is created by head of alpine glacier

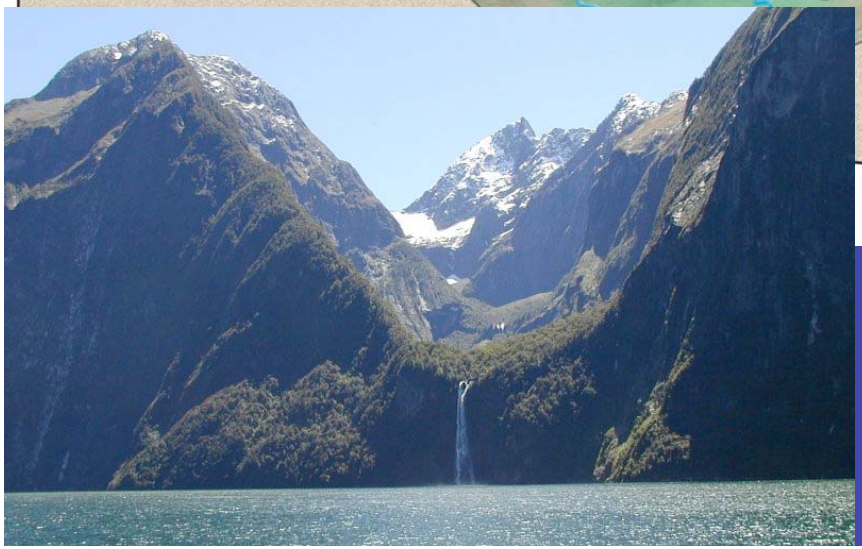

Name the glacial features in this image


Name the glacial features in this image
Horn
Arête
U-shaped valley

What has happened here?







Hanging valley left when ice retreats



Milford Sound New Zealand – glacial fjord

Distinctive remnants of alpine glaciers

1. Cirques

2. Horns

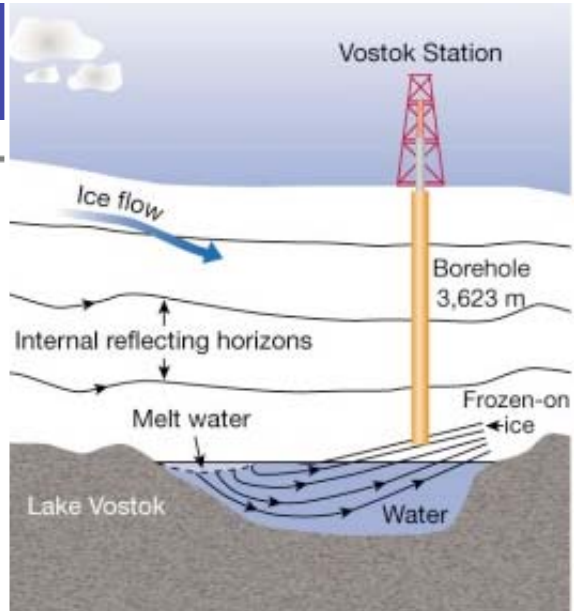
3. Arêtes

4. U-shaped valleys

5. Hanging valleys

6. Fjords

Vostok Antarctica Ice Core



When were Ice Ages?

Δ Temperature (°C)

4
2
0
-2
-4
-6
-8

CO_2 (ppmv)

260
240
220
200

Dust (ppm)

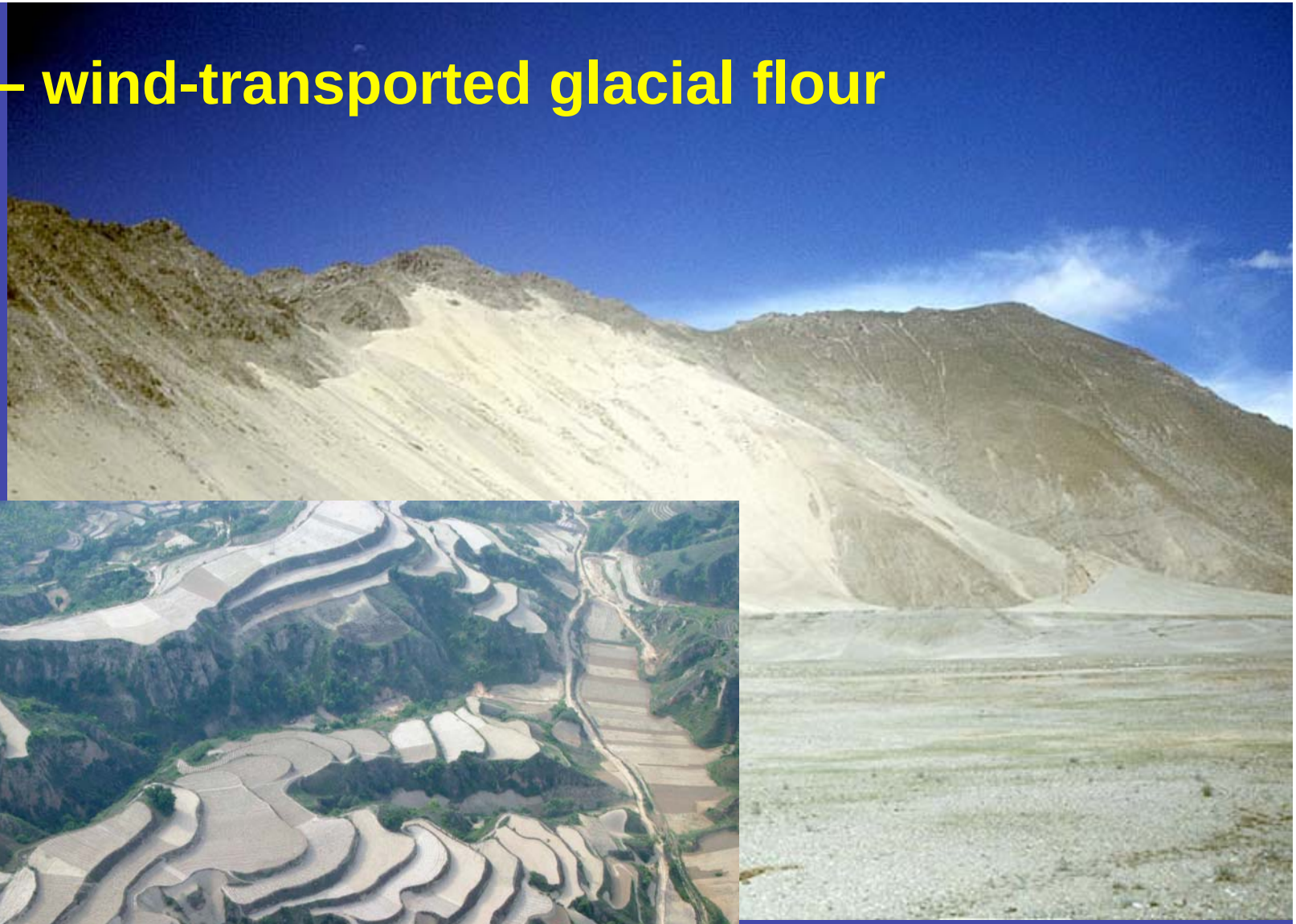
1.5
1.2
0.9
0.6
0.3

0 50 100 150 200 250 300 350 400

Thousands of Years Ago

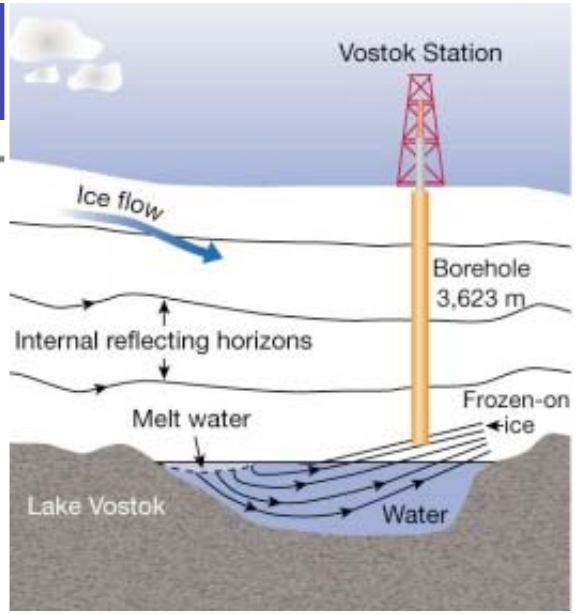
Loess – wind-transported glacial flour





High dust volumes during ice ages

Vostok Antarctica Ice Core



When were Ice Ages?

Δ Temperature (°C)

4
2
0
-2
-4
-6
-8

CO_2 (ppmv)

260
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Dust (ppm)

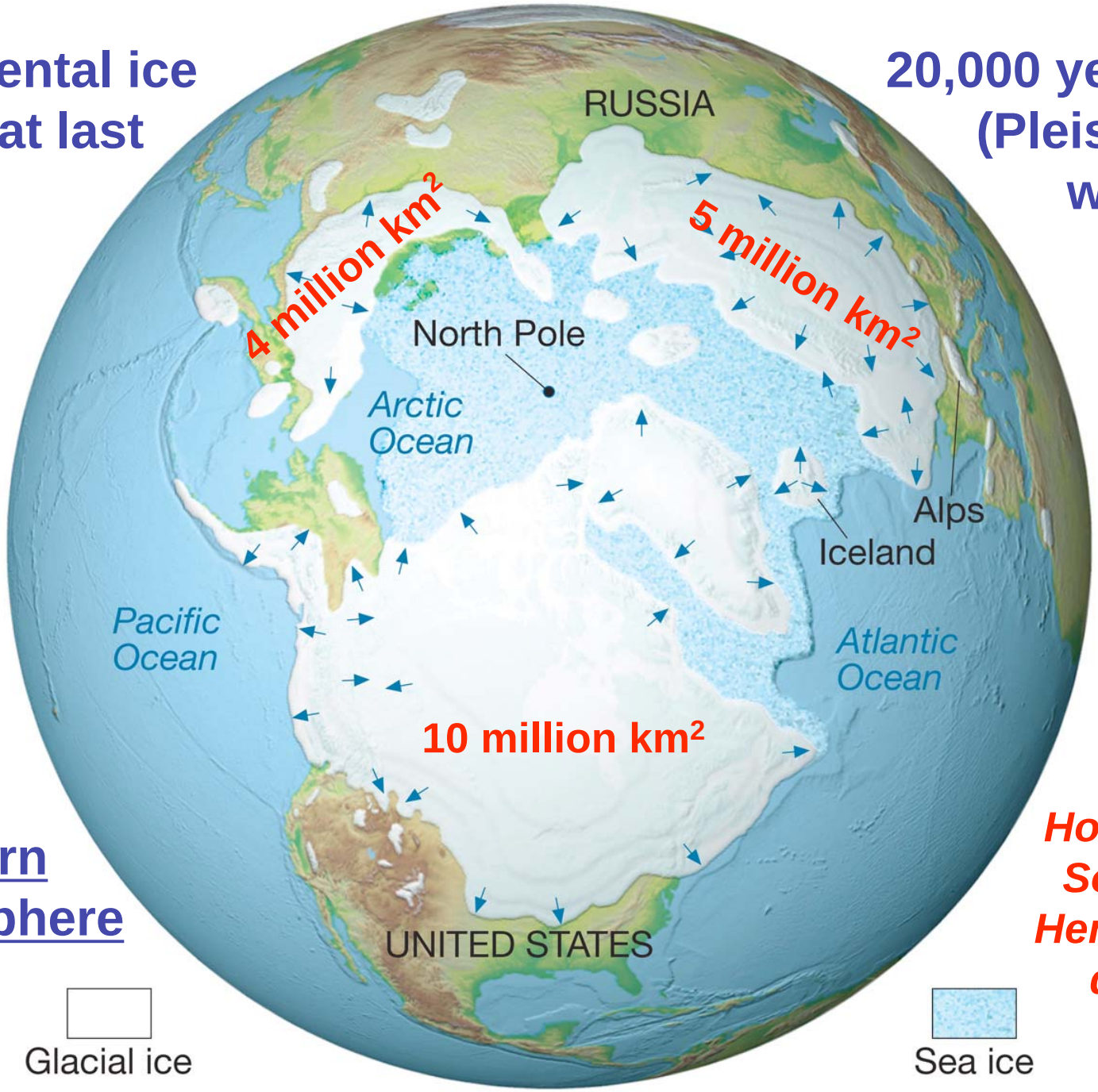
1.5
1.2
0.9
0.6
0.3

0 50 100 150 200 250 300 350 400

Thousands of Years Ago

Continental ice extent at last glacial max

20,000 years ago (Pleistocene) was peak ice



Northern Hemisphere

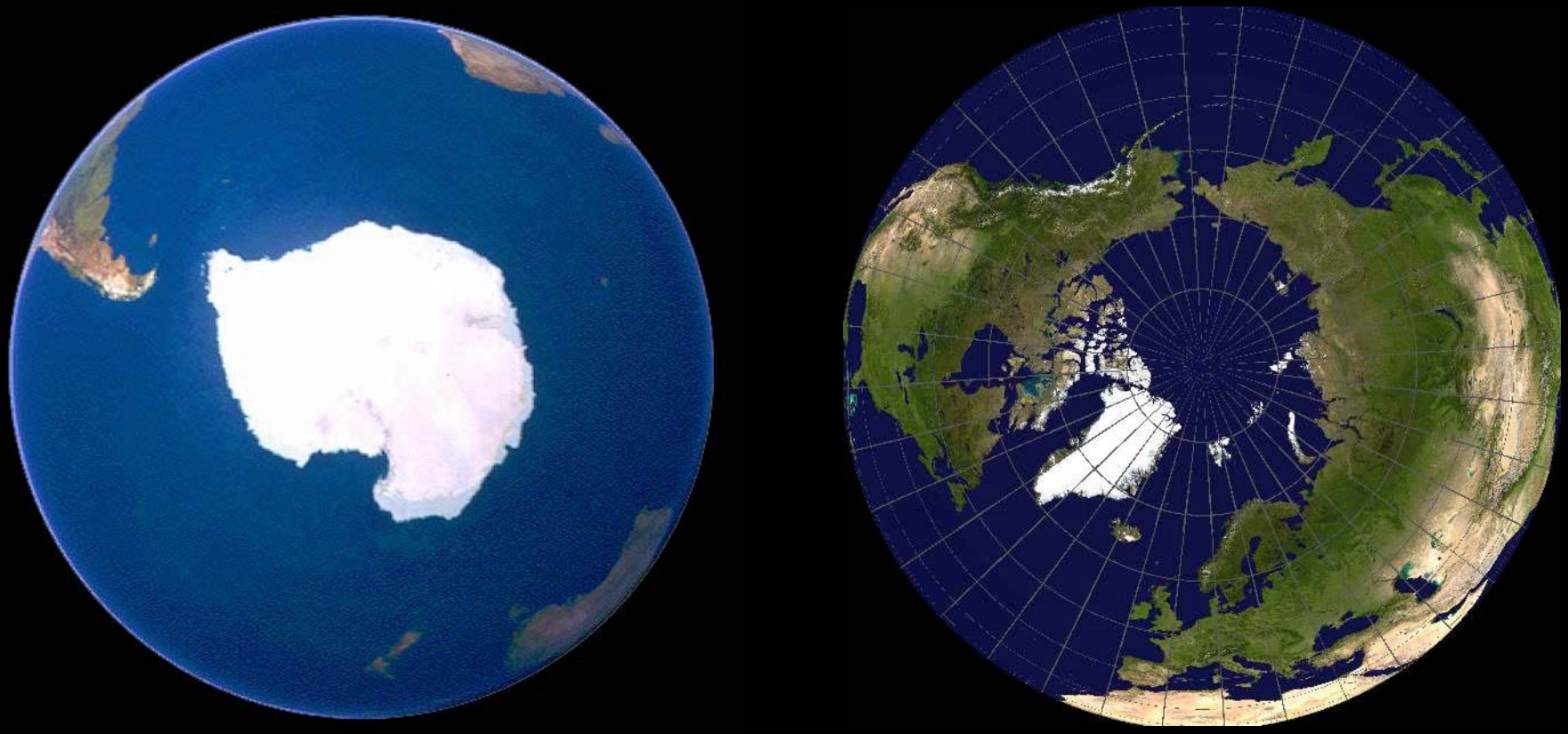
How would Southern Hemisphere differ?

Continental configuration makes it….



…Harder to expand ice volume

Arctic is “mediterranean” ocean



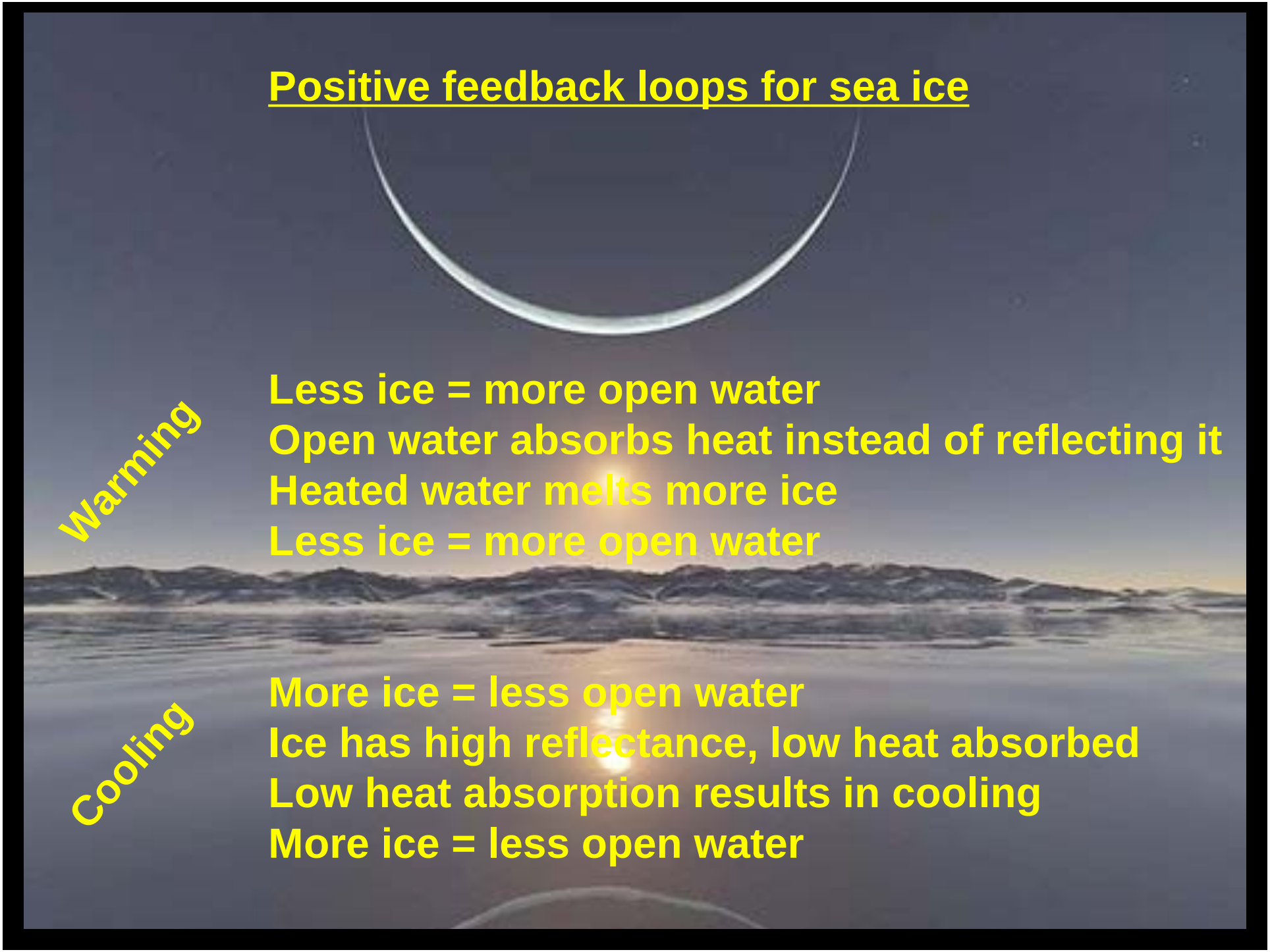
More sea ice can accumulate at North Pole

Albedo - measure of surface reflectance (of sunlight)



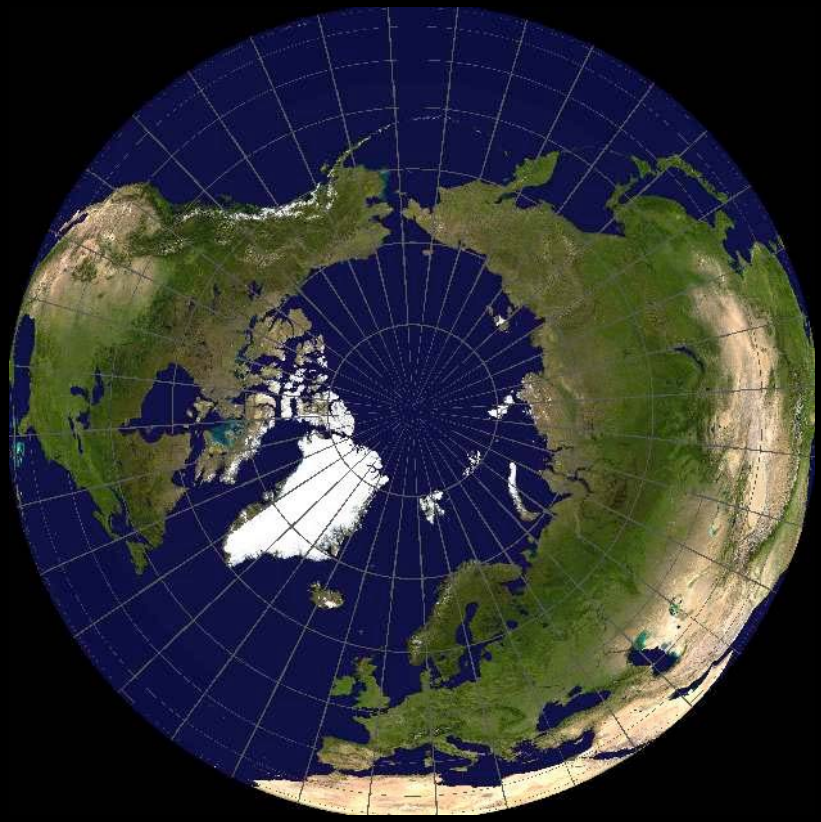


Which is more reflective - water or ice?


Positive feedback loops for sea ice
Warming
Less ice = more open water
Open water absorbs heat instead of reflecting it
Heated water melts more ice
Less ice = more open water
Cooling
More ice = less open water
Ice has high reflectance, low heat absorbed
Low heat absorption results in cooling
More ice = less open water

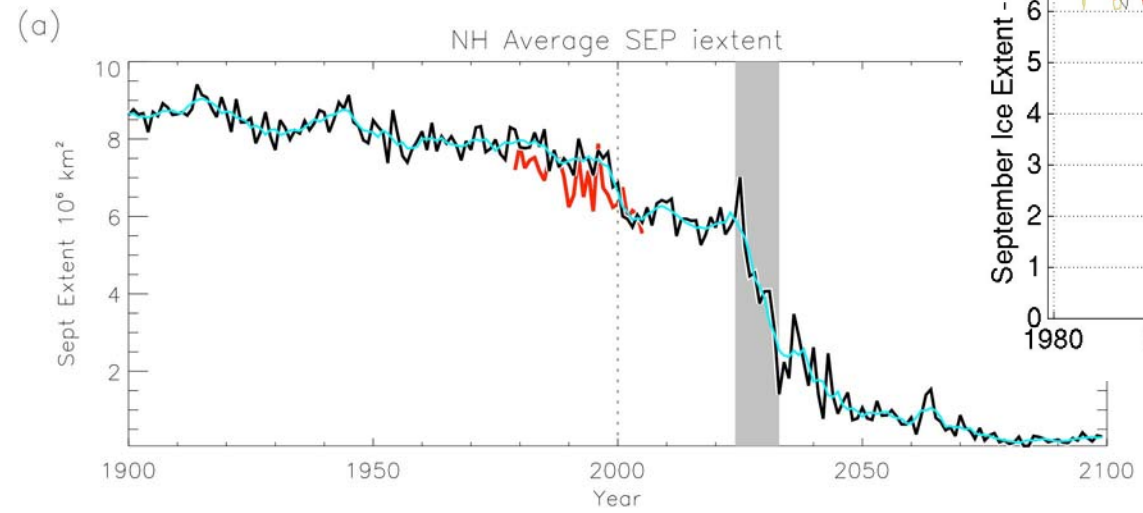
Which pole is more dynamic?

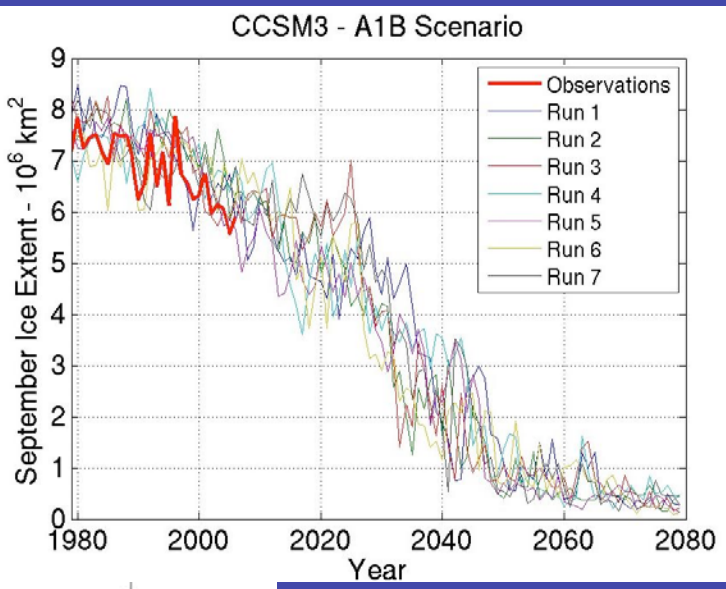


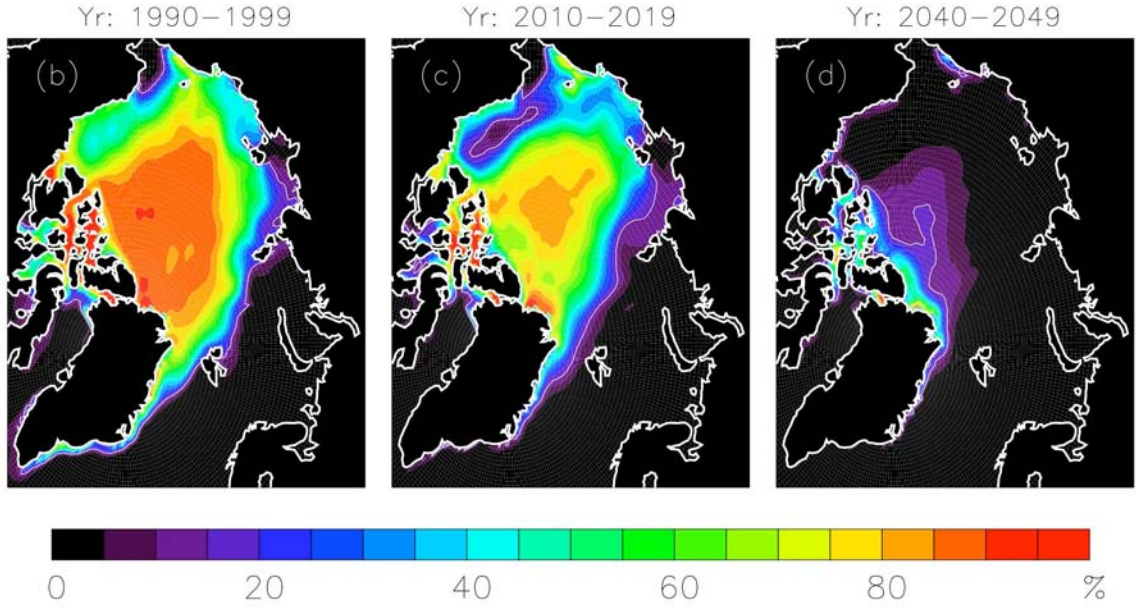


Which pole is more susceptible to climate change?

Climate models predict no summer sea ice in Arctic by 2060







Holland, Bitz Tremblay

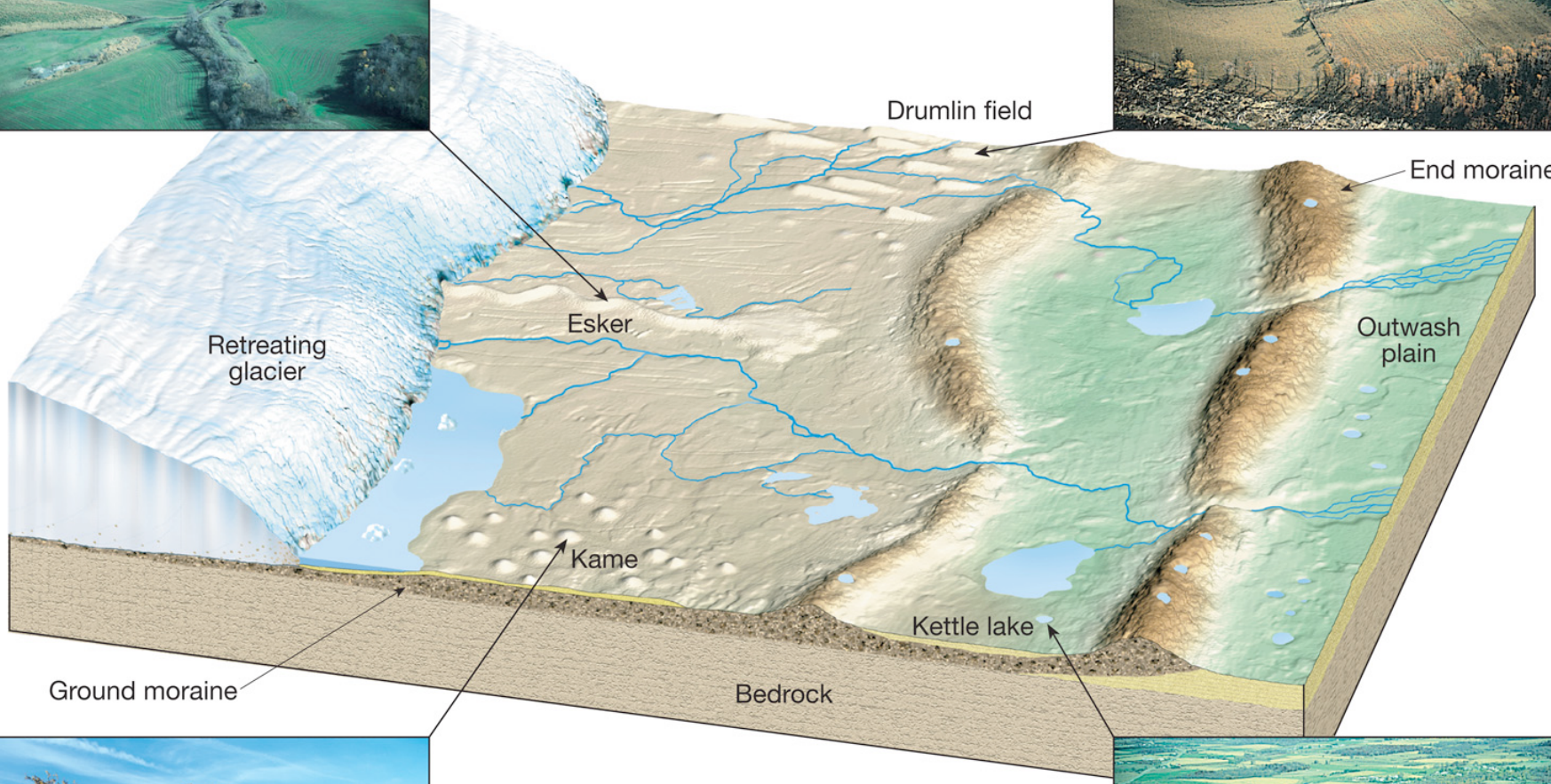
Community Climate System Model Version 3

GRL, 12/06

Features left by continental glaciers



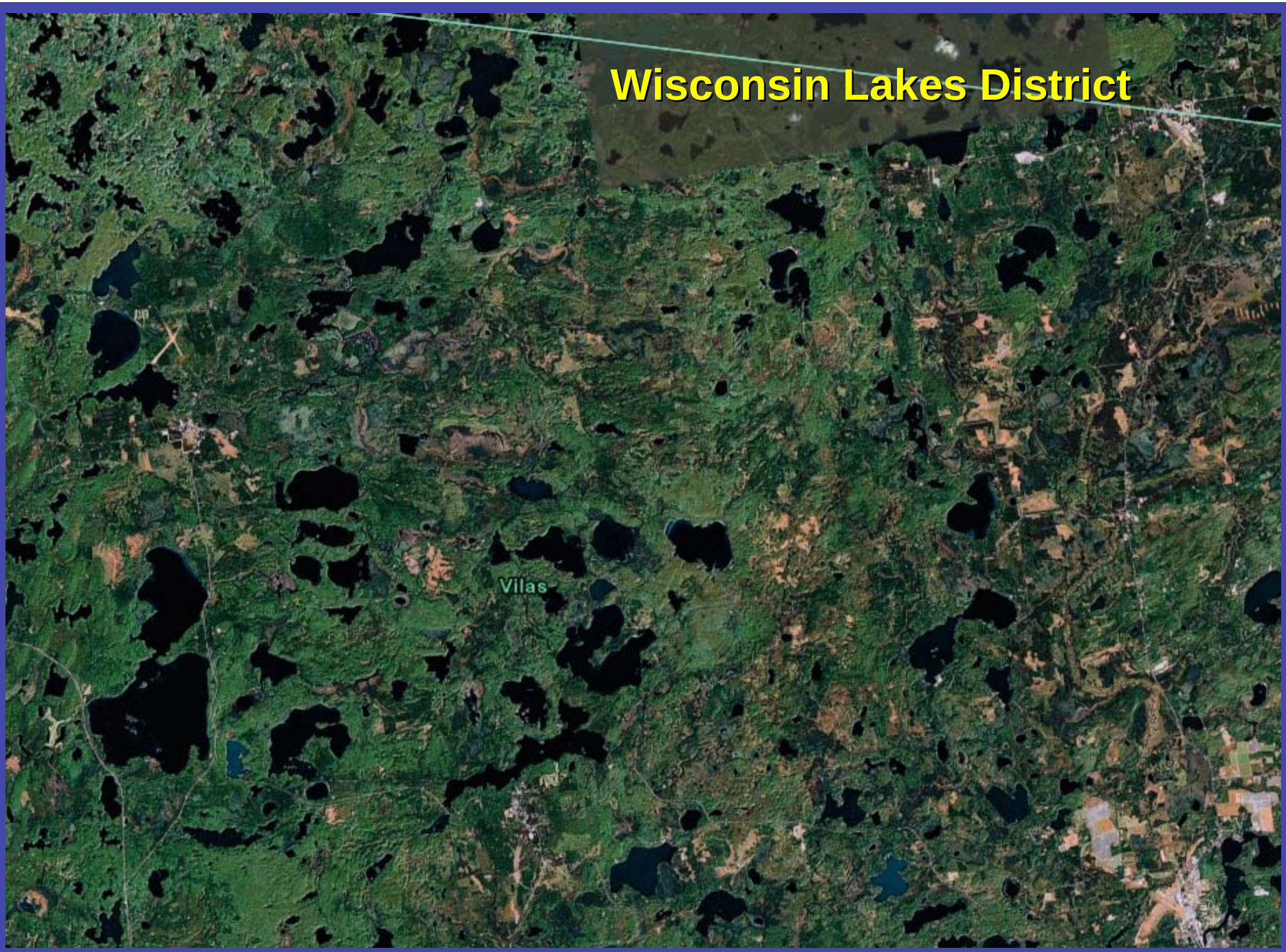








Canada, U.S. Northeast and Midwest


Wisconsin Lakes District
Vilas



Chunk of glacial ice buried in debris melts

Kettle lake is remnant water from ice chunk



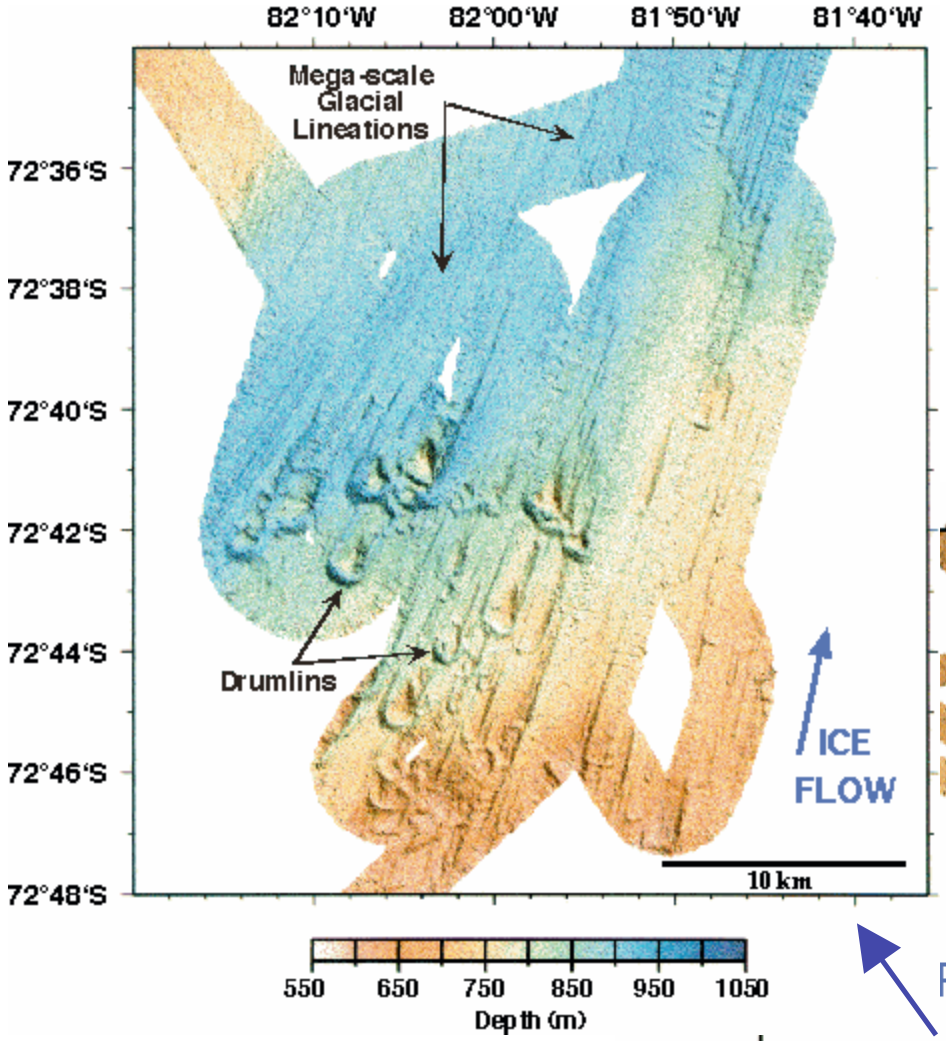


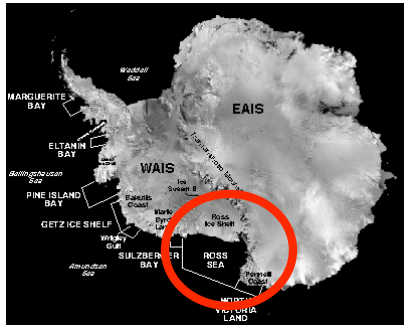
What can glacial striations tell you about flow dynamics?

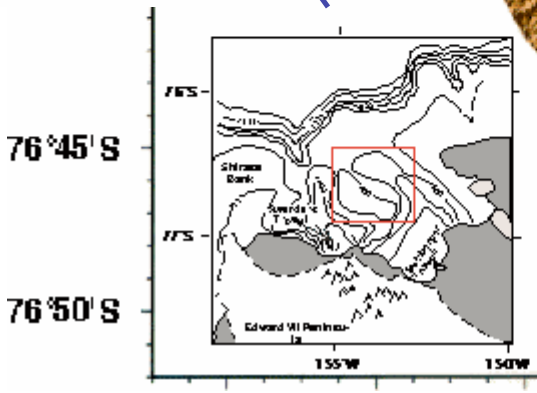


Glacial striations/lineations are also mapped on the modern seafloor

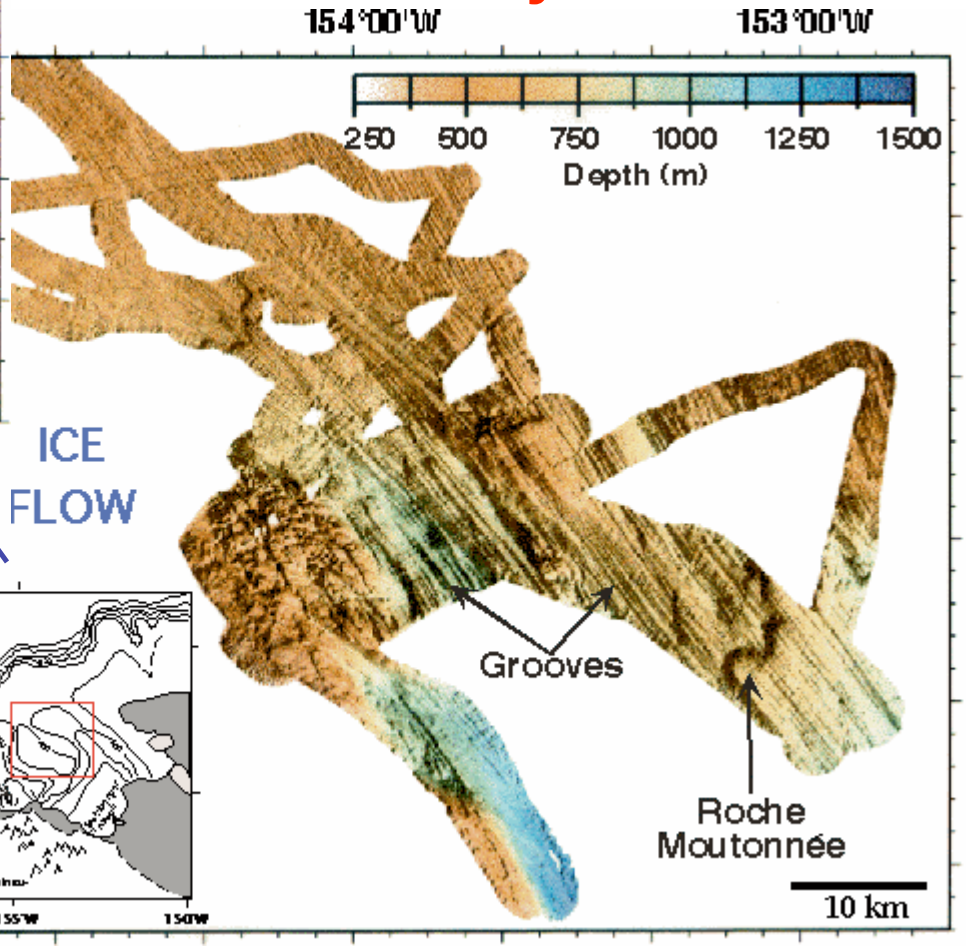
Why are they under water today?







ICE FLOW



Which direction were these glaciers flowing?



Which direction were these glaciers flowing?

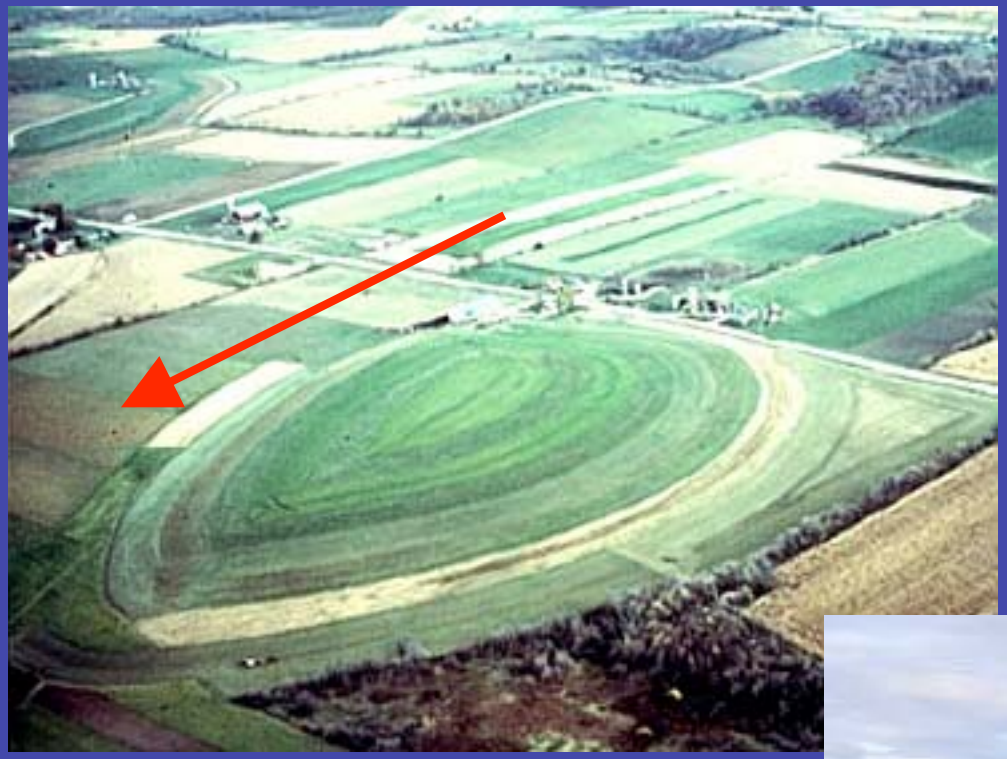


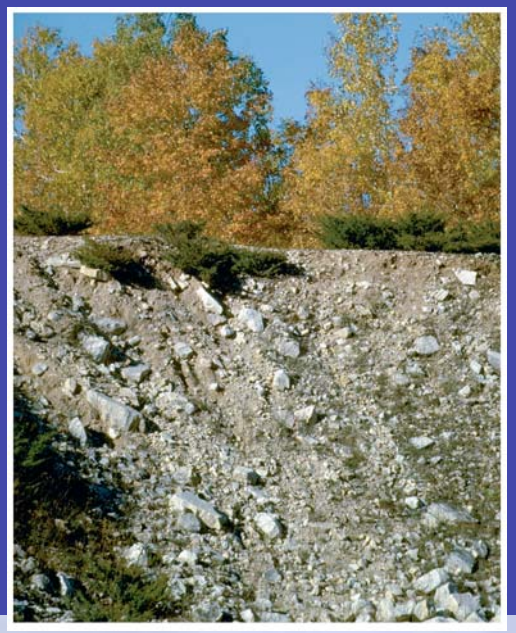


What was ice flow direction?



How can you tell?





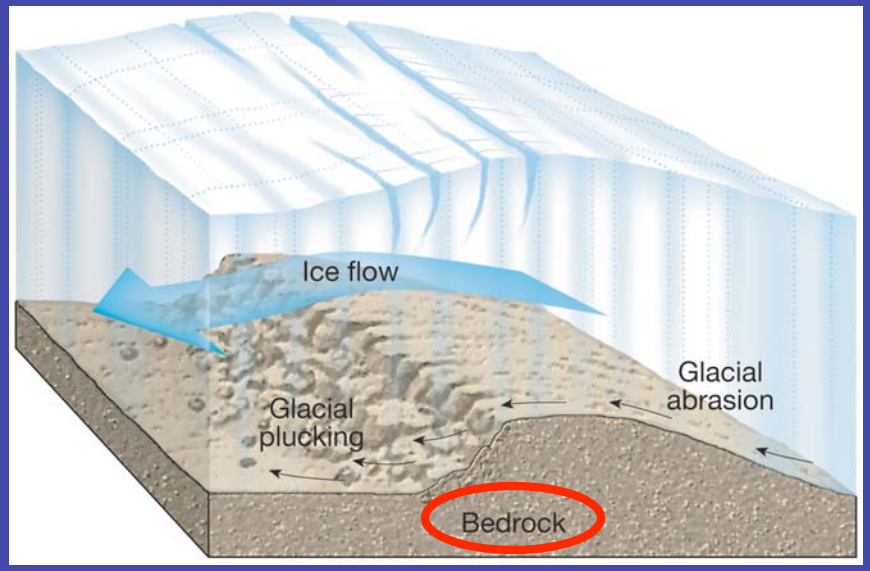
Drumlins formed from glacial “till”



Drumlin formation

Upstream slope is steep

Downstream slope is gentle



Roche moutonnée formation

(French for "rock that looks like a sheep")

Upstream abraded slope is gentle

Downstream slope is plucked steep



How did this rock get here?




Glacial erratics are too big to have been
transported by streamflow



What process has produced these features?



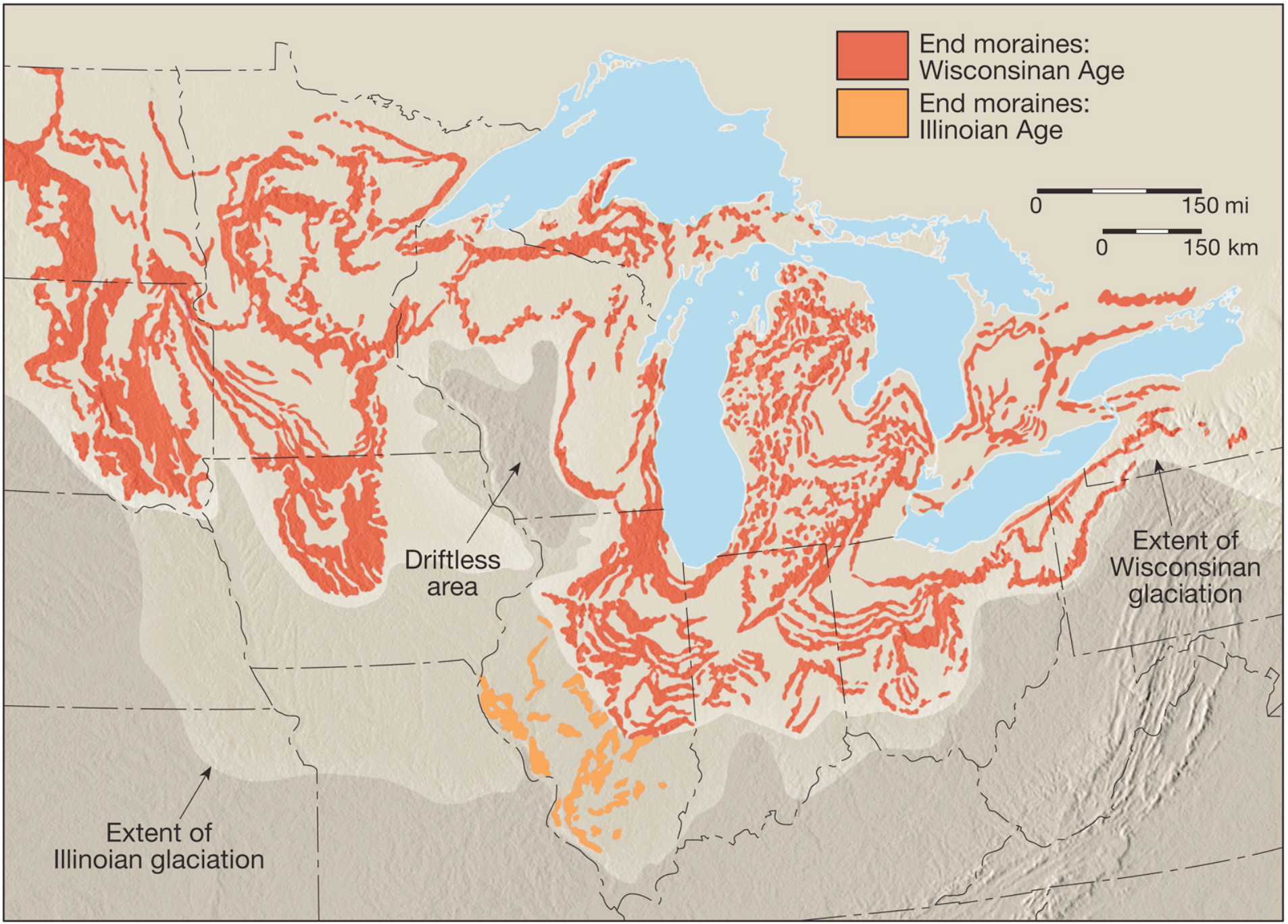
Form along margins of glaciers



Marginal moraines

How are moraines useful to us?




End moraines:
Wisconsinan Age
End moraines:
Illinoian Age
0
150 mi
0
150 km
Driftless
area
Extent of
Wisconsinan
glaciation
Extent of
Illinoian glaciation

Distinctive remnants of continental glaciers

1. Kettle Lakes

2. Striations/Lineations

3. Drumlins/Roches moutonnées

4. Erratics

5. Moraines