

## Earth's Changing Landscape Systems

### Glacial and Periglacial Landscapes

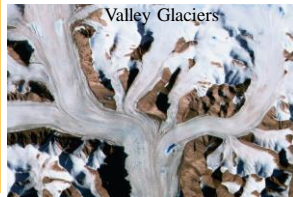
## Glaciers

- Glaciers are large masses of ice, resting on land or floating in the sea:
  - Cover ~11% of Earth's land area today
- Glaciers move slowly in stream-like patterns
- Two types:
  - Alpine Glaciers are restricted to mountains
  - Continental Glaciers cover entire continents (e.g. Greenland and Antarctica)



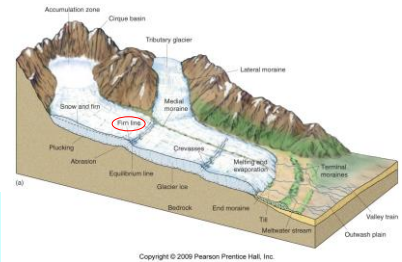
## Alpine Glaciers

- Glaciers in mountain ranges are termed 'alpine glaciers'
- A cirque is a bowl-shaped depression at the head of the valley that accumulates snow that feeds the glacier
- The accumulated snow then flows downslope as a valley glacier:
  - Valley glaciers range in length from 100m to over 100 km
  - Erode bedrock while flowing slowly downhill
  - Transport and deposit sediment



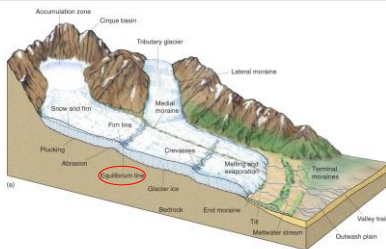
## Glacial Mass Balance

**Firn:** Compact, granular texture acquired by snow turning into ice



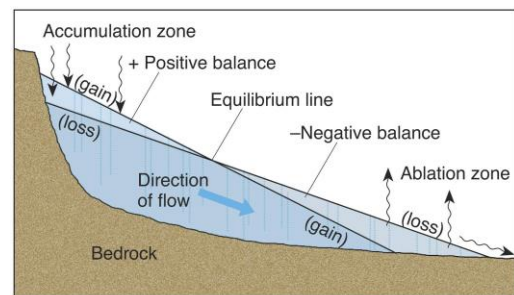
- A glacier is an open system:
  - Inputs: Snow and other moisture
  - Outputs: Ice, meltwater and water vapor
- On the upper end, snowfall feeds the glacier in the accumulation zone:
  - Accumulation zone ends downslope at the firn line

## Glacial Mass Balance



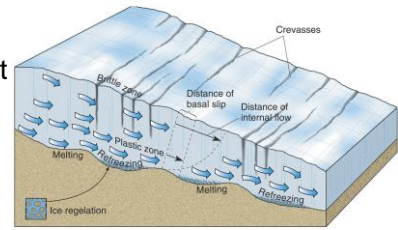
- Further downslope below the firn line, the glacier is wasted via ablation involving several processes:
  - Melting on the surface, internally, and at the base
  - Ice removal by deflation (wind)
  - Calving (breaking off) of ice blocks
  - Sublimation (moisture transfer from ice and snow directly to vapor)
- Equilibrium line is where accumulation gain balances ablation loss

## Mass Balance



## Glacial Advance Retreat

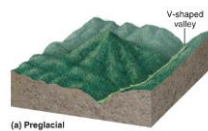
### Glacial Movement



- Glaciers flow at rates ranging from almost nothing to 1-2 km/year:
  - Depends on rate of snow accumulation
- A flowing glacier can develop crevasses within the upper brittle zone
- A glacier can lurch forward in a surge:
  - Possibly caused by build-up of water pressure underneath
- A passing glacier can pluck and remove rock material via erosion:
  - Embedded rocks can scour the landscape through abrasion as the glacier moves downslope

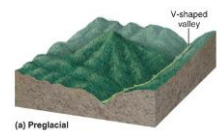
### Erosional Landforms Created By Alpine Glaciation

Glacial erosion can convert a V-shaped stream valley...



### Erosional Landforms Created By Alpine Glaciation

Glacial erosion can convert a V-shaped stream valley into a U-shaped glacial valley



### Erosional Landforms Created By Alpine Glaciation

A fjord forms when a glacial trough intersects a large body of water and water flows inland



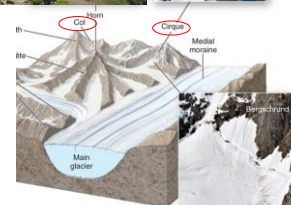
Norwegian fjord

### Erosional Landforms Created By Alpine Glaciation

Col



Two cirques eroding back-to-back can create a saddle-like ridge in between called a 'col'



### Erosional Landforms Created By Alpine Glaciation

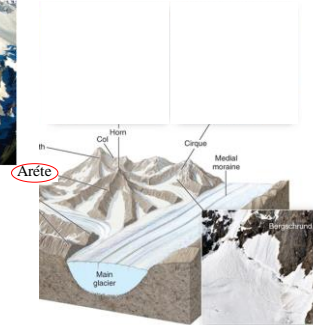
A horn is a sharp-crested feature that forms when several converging cirques erode a mountain summit from all sides



### Erosional Landforms Created By Alpine Glaciation

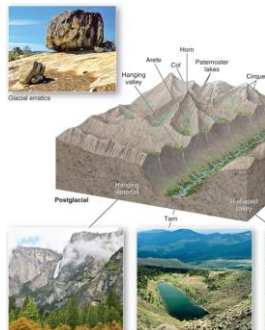


Arêtes Are Jagged Ridges Between Valley Glaciers



### Postglacial Meltwater Features Resulting From Alpine Glaciation

- Hanging waterfalls
- Mountain lakes:
  - Tarn: small mountain lake
  - Paternoster lakes are a series of circular lakes within a glacial valley



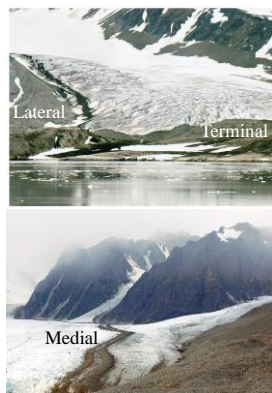
### Depositional Landforms Created By Alpine Glaciation

- Glacial drift consists of unsorted and sorted glacial deposits (rocks & sediment):
  - Till is an unstratified (non-layered) and unsorted mixture of different particle sizes

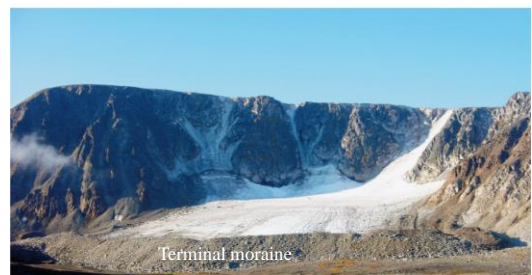


### Depositional Landforms Created By Alpine Glaciation

- Moraines are ridge-like features of accumulated glacial sediment:
  - Lateral moraine forms alongside of a glacier
  - Lateral moraines from two adjacent glaciers may merge to form a medial moraine
  - Terminal moraine marks the glacier's furthest extent



### Terminal Moraine

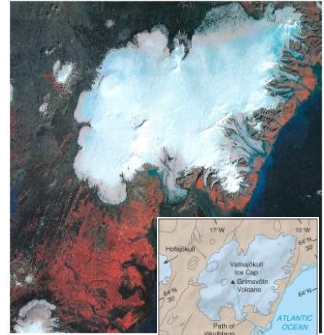




## Glacial Processes

### Continuous Ice Cover

An ice cap is a roughly circular feature that covers an area less than 50,000 km<sup>2</sup>



Vatnajökull  
Ice Cap, SE Iceland



An ice field exhibits an elongated pattern with ridges and peaks visible above the buried terrain

### Continental Glaciers

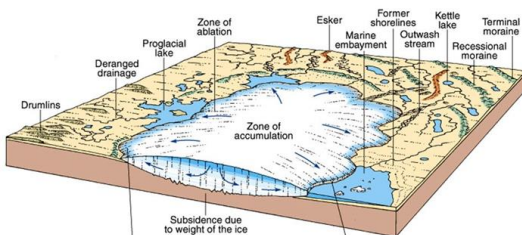


- A continental glacier is a continuous mass of ice on continents:
  - Blankets 80% of Greenland and 90% of Antarctica
- Underlying crust is isostatically depressed due to the enormous weight of the ice:
  - Crust depressed more than 2,000 m below sea level in Greenland and Antarctica



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### Radial Flow Pattern And Depositional Features Of Continental Glaciers

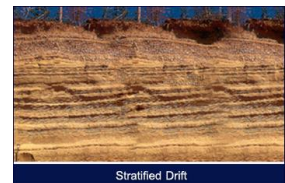


### Depositional Features Of Continental Glaciers

- Glacial drift consists of unsorted and sorted glacial deposits (rocks & sediment):
  - Till is unstratified (non-layered) and unsorted
  - Stratified (layered) drift is deposited ahead of the glacier by glacial meltwater



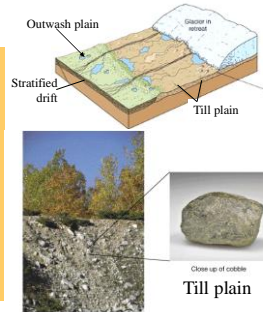
Glacial Till



Stratified Drift

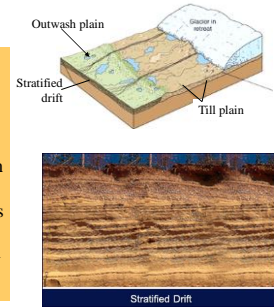
## Erosional and Depositional Features of Continental Glaciation

- Most erosional and depositional features of continental glaciers are associated with glacial retreat:
  - Till plain forms behind an end moraine



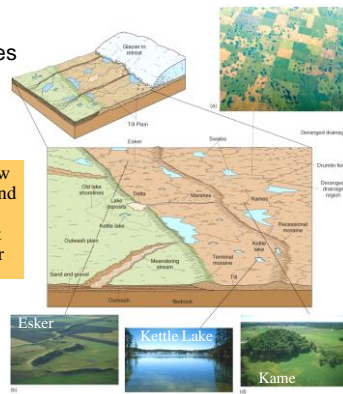
## Erosional and Depositional Features of Continental Glaciation

- Most erosional and depositional features of continental glaciers are associated with glacial retreat:
  - Till plain forms behind an end moraine
  - Stratified (layered) drift is deposited by glacial meltwater on the outwash plain ahead of the glacier



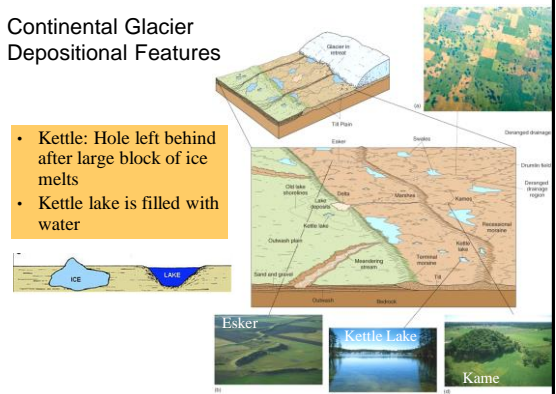
## Continental Glacier Depositional Features

- Esker: Sinuous, narrow ridge of coarse sand and gravel deposited by meltwater stream that flowed beneath glacier



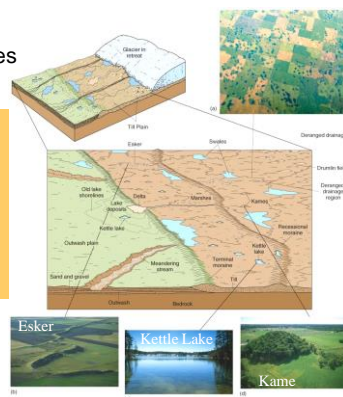
## Continental Glacier Depositional Features

- Kettle: Hole left behind after large block of ice melts
- Kettle lake is filled with water



## Continental Glacier Depositional Features

- Kame: Small hill or knob of poorly-sorted sand and gravel



## Continental Glacier Depositional Features

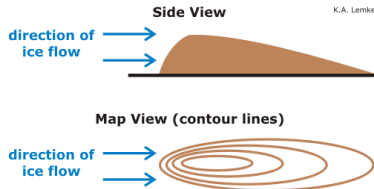
- Kame: Small hill or knob of poorly-sorted sand and gravel
- Drumlin: Elongated deposit of till streamlined in the direction of glacial ice movement



## Drumlin Formation



K.A. Lemke



(a) Topographic map south of Williamsport, near Marion, New York, featuring numerous drumlins (7.5-minute series quadrangle map, originally produced at a 1:24,000 scale, 10-ft contour interval).

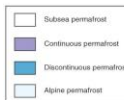
## Drumlin Field



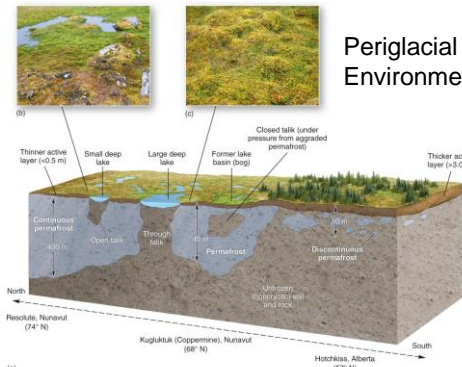
(b) Aerial view of drumlin swarm: drumlins with vegetation cover are most visible.

## Periglacial Landscapes

- Located in subarctic and polar climates (tundra)
- Affected by frost weathering and freeze-thaw shattering of rock:
  - Some are associated with near-permanent ice
  - Others occur at high elevation and are seasonally snow-free
- Permafrost occurs where soil or rock remain below freezing for at least two years but are not covered by glaciers



## Periglacial Environments



## Frost Action



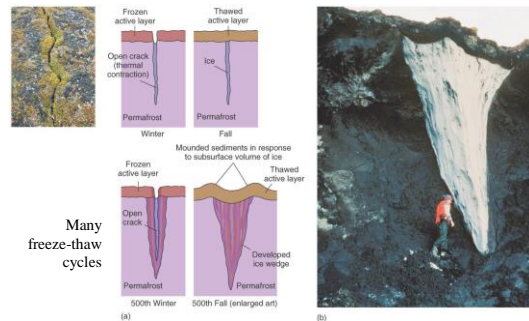
(b) Earth



(d) Mars

- The freezing of water in soil and rock initiates frost action:
  - The expansion of freezing water fractures rock and disrupts soil
- Saturated soil and rocks are subjected to large displacements when freezing:
  - Vertical movement is called frost heaving
  - Horizontal motion is called frost thrusting

## Ice Wedge



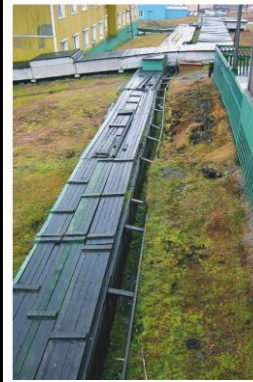
Many freeze-thaw cycles



## Permafrost Melting



## Permafrost Structures



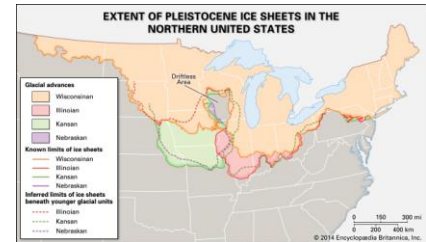
Pipeline  
1.2 m diameter  
Average height  
1.5 to 3.0 m

Proper construction in periglacial environments requires raising of buildings and pipes above ground

## The Pleistocene Ice Age

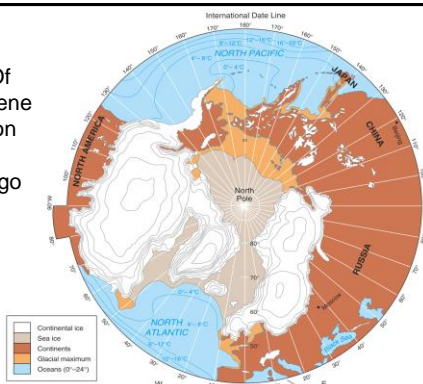
The Last Two Million Years

### Pleistocene Chronology



- During the early 20th century, four major glacial advances were recognized and mapped in North America:
  - Wisconsin (maximum ~18,000 years ago)
  - Illinoian (ended ~130,000 years ago)
  - Kansan
  - Nebraskan (~2 m.y)
- Three to five glacial episodes were recognized in Europe

### Extent Of Pleistocene Glaciation ~18,000 Years Ago

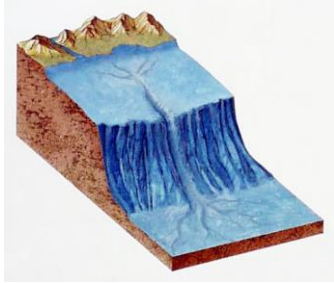


## Diverse Effects of Last Ice Age

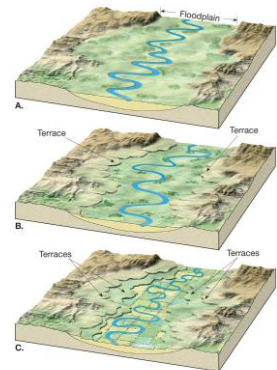
- Changes in oceanic circulation patterns
- Temperate climatic belts shifted to lower latitudes
- Sahara and western North America were wet and fertile
- Glaciers locked up abundant water on continents, lowering global sea level:
  - Coral reefs stood high and dry
  - Continental shelves and land bridges exposed
  - Rivers flowed across the exposed shelves, cutting canyons
  - On land, downcutting rivers formed terraces

## Submarine Canyons

Lower sea level exposed continental shelves, allowing rivers to flow across and carve submarine canyons that later became submerged when sea level rose again



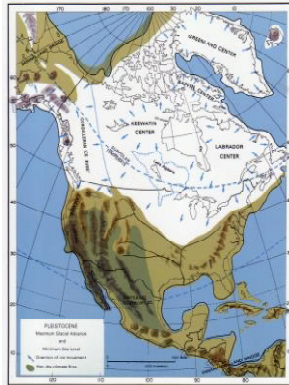
Sea Level Drop Lowered Base Level, Causing Streams To Down-cut And Form Terraces



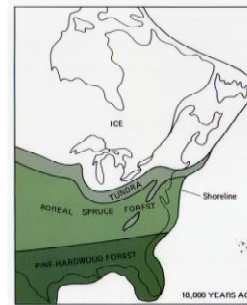
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**Wisconsin Glaciation (~18,000 years ago):**

- Glaciers flowed from several major ice centers in Canada and Greenland
- Low-stand of sea level exposed continental shelves
- Bering Land Bridge permitted migration of animals and early humans between Asia and North America



## Effects of Climate Change on Plant Communities

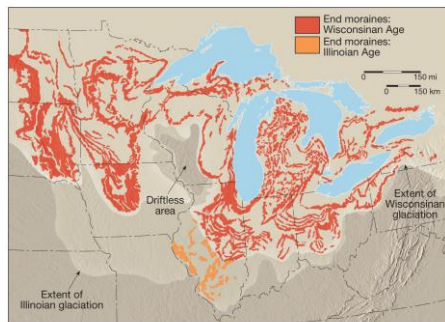


18,000 years ago



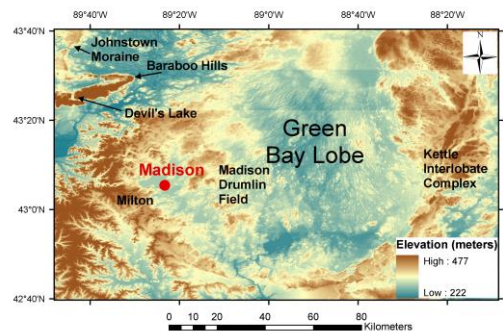
Present

## Extent of Glacial Landforms in the Great Lakes Region



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## Digital Elevation Model Of The Green Bay Lobe, South-Central Wisconsin





## End Moraines of Long Island, Cape Cod and Nantucket



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