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Franz Joseph Glacier and Outwash Plain, New Zealand

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## The Impact of Glaciers on the Landscape

- Extent of Glaciations
  - Glacial ice coverage of the land surface
    - Past –  $\approx 1/3$  (i.e. maximum extent)
    - Today –  $\approx 1/10$
    - Slow moving “rivers of ice”
- Direct Impacts
  - Glacial topography and meltwater are the bases for many of the world’s lakes and river channels e.g. the Great Lakes
  - Glaciers sculpted the awesome alpine vistas (e.g. in Switzerland)
  - Glacial deposits are parent material for soils
  - Glaciers still cover sizeable areas of Earth’s land surface

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## Glaciations Past and Present

- Pleistocene Glaciations
  - Time period
    - Roughly the last 2 million years
  - End of Pleistocene Epoch
    - ca. 10,000 yrs. ago
    - **Holocene epoch** then began (interglacial/post-glacial)
    - And we are still in this Holocene period
  - Extent (shown in Animation and next slides)

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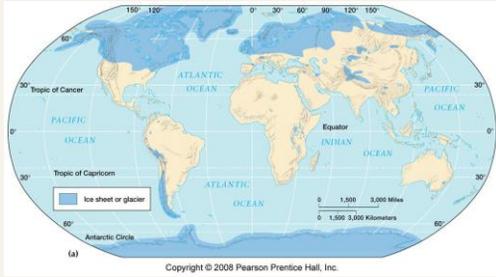
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## Pleistocene Glaciations



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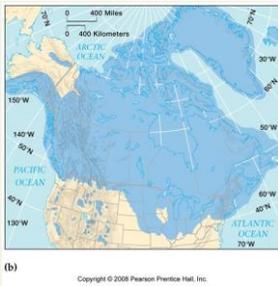
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## Pleistocene Glaciations



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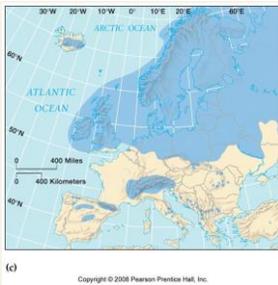
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## Pleistocene Glaciations



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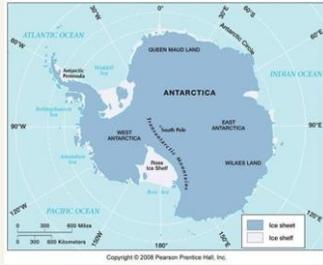
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## Contemporary Glaciation (today)

- Two-thirds of the world's fresh water is frozen
- Antarctic Ice Cap
  - West Antarctica
  - East Antarctica



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## Greenland Ice Cap



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## North American Glaciers



(a)

(b)

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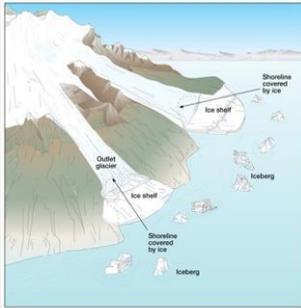
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## Types of Glaciers

- Continental Ice Sheets
  - Found in non-mountainous areas
  - Antarctica and Greenland Ice Sheets where you have:
    - Outlet glaciers
    - Ice shelves
    - Iceberg formation



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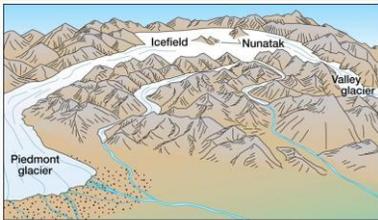
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## Types of Glaciers

- Mountain Glaciers
  - Highland Icefields (accumulates in unconfined sheets, quite broad)



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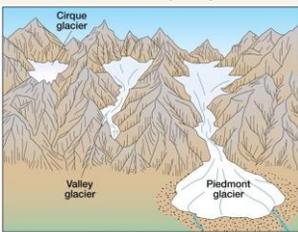
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## Types of Glaciers

- Alpine Glacier (develops high up as 'individual glaciers')
  - Cirques are the "bowls" they originate in



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## Large Glaciers

- Tributary alpine glaciers have joined to form a very large glacier in foreground.



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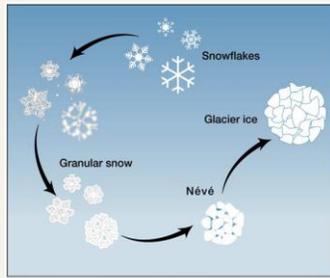
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## Glacier Formation and Movement

- Changing snow to ice
  - Compression and Coalescence



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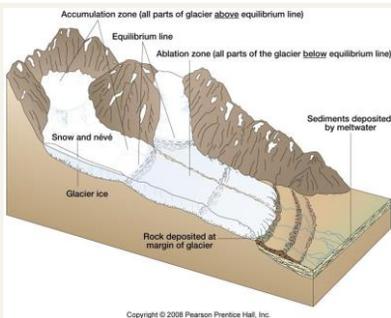
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## Zones of net accumulation & net ablation



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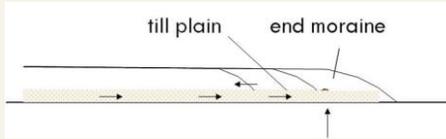
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## Mass (ice) balance

- Ice inputs (zone of accumulation) vs. ice outputs (zone of ablation)
  - 3 conditions and landform development
    - Inputs > outputs – advancing glacier
    - Inputs = outputs – stationary glacier
    - Inputs < outputs – retreating glacier




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## The Effects of Glaciers

- Erosion by Glaciers
  - Glacial Plucking




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## Glacial Abrasion

- Grooves and striations caused by glacial abrasion near Cuzco, Peru.




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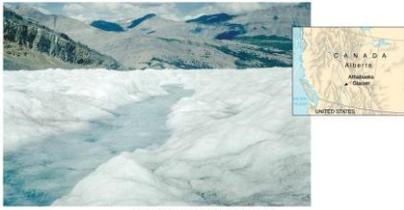
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### Sub-glacial meltwater transport

- ❑ Meltwater from top of ice flows into crevasses and tubes and ends up beneath glacier.
- ❑ Subglacial streams form, they carry debris beneath the ice



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## Deposition by Glaciers

- **Till** is debris deposited directly by ice
  - Unsorted/unstratified **drift**; heterogeneous collection of debris of all sizes, which could range in size from boulders to glacial flour.



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## Deposition by Glaciers

- Glacial erratic, example of till. This is a huge boulder resting on a completely different type of bedrock, and was brought by glaciers.



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## Glacial Deposits

- ❑ Glaciofluvial deposits – debris deposited by melt water

- ❑ Stratified drift (layered deposits)



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## Continental Ice Sheets

- ❑ Development and Flow

- ❑ Origin of Pleistocene Ice Sheets

- Northern Hemisphere: Subpolar and midlatitude locations
    - Antarctica

- ❑ Erosion by Ice Sheets

- ❑ Ice Excavations (extensive plucking action)

- Hudson Bay basin
    - Great Lakes basins
    - Finger Lakes

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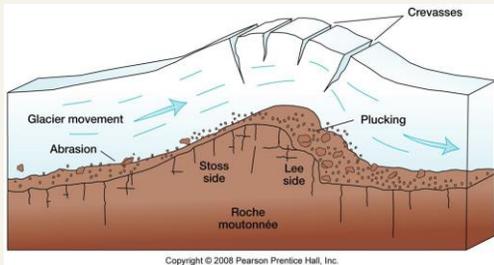
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## Continental Ice Sheets



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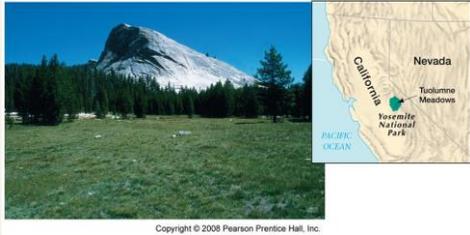
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## Lembert Dome, a roche moutonnée

□ Can you tell which **direction** the glacier moved **from**?



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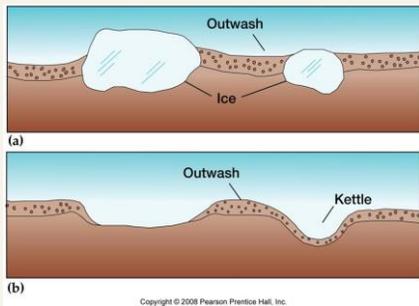
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## Deposition by Ice Sheets

□ Kettle



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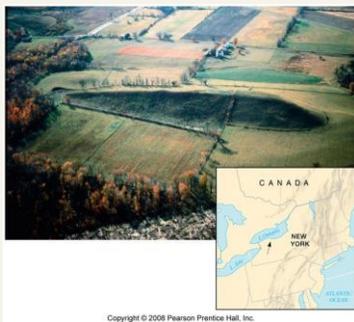
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## Deposition by Ice Sheets

□ Drumlin



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## Deposition by Ice Sheets

- Eskers (glaciofluvial debris/ gravel)



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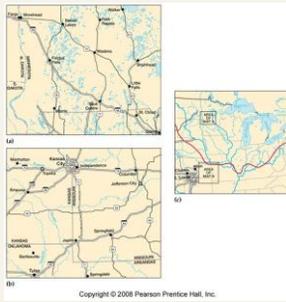
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## Deposition by Ice Sheets

- Lakes
  - Deranged drainage



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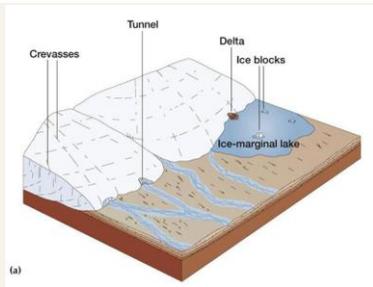
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## Deposits associated with icesheets



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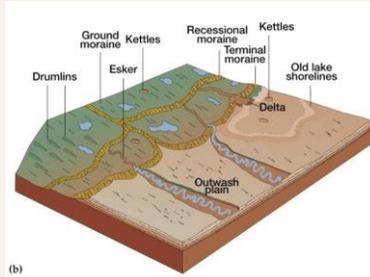
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## Deposits associated with icesheets



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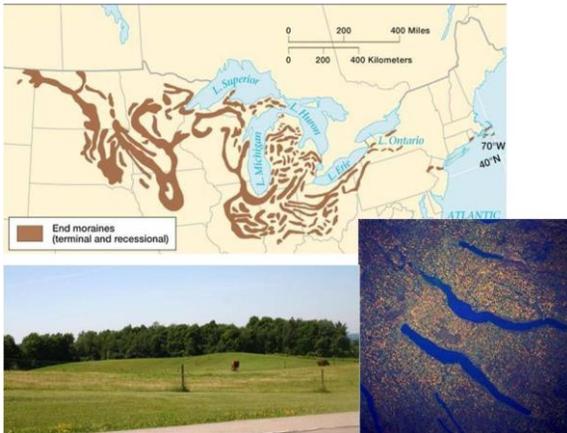
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## Mountain Glaciers

- Development: long-term, high-elevation snowfall, above the equilibrium line
- Example of Highland Icefield and valley glaciers (below)



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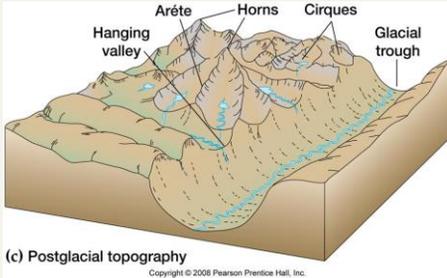
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## Erosion by Mountain Glaciers

□ Erosion dominates upper portion of the valley



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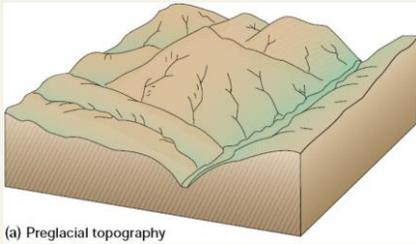
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## Development of the erosional landscape



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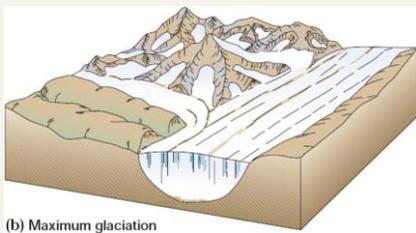
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## Development of the erosional landscape



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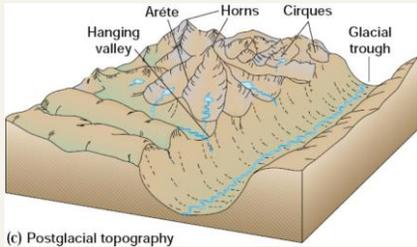
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## Development of the erosional landscape



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## Cirque

- Cirque
  - Upper end (head) of a glaciated valley.
  - The signature feature of alpine glacial topography



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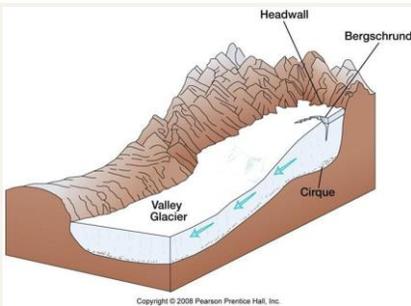
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## Cirque



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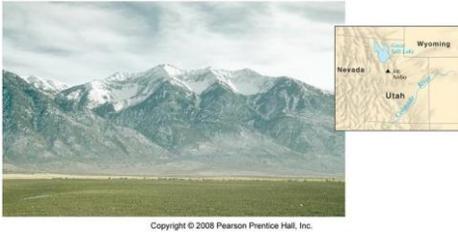
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## Cirques

- Three small cirques on Mount Nebo in Central Utah. The cirque glaciers never grew out of their basins.



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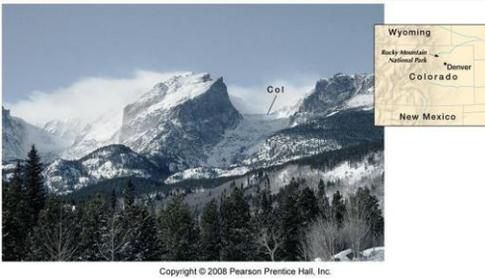
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## Col



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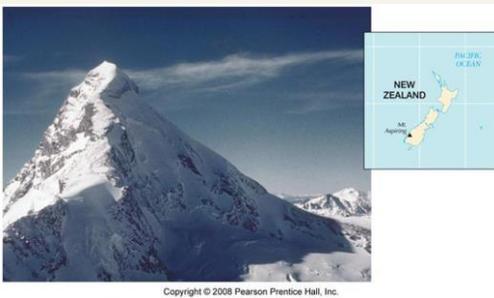
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## Horn



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## Glacial trough

- Hollyford Valley



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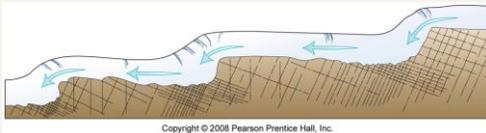
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## Glacial trough

- Longitudinal cross section of a glacial trough showing sequence of glacial steps (glacial stairway).



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## Hanging Valley and Waterfall

- Bridalveil Creek, occupies a hanging valley.



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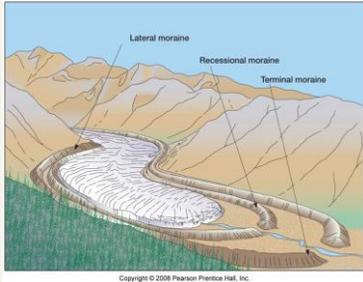
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## Deposition by Mountain Glaciers

### □ Moraines (principal features)



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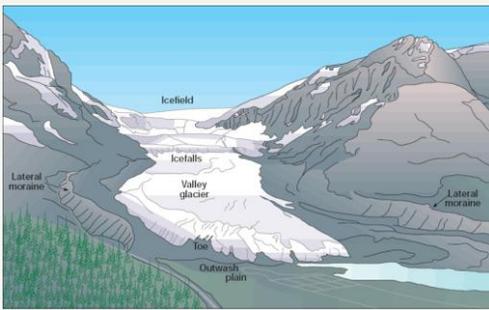
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## Lateral moraine and nearby features



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## Lateral moraine and nearby features



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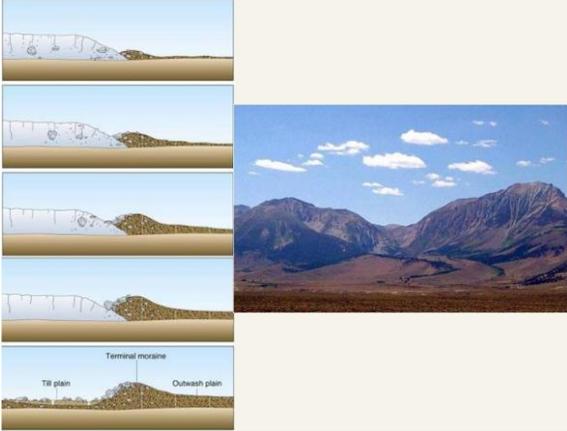
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### Deposition by Glaciers - Moraines



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### Lateral moraines



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## Medial moraine

- Dark strip of debris running down the middle of the glacier is a medial moraine.



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## End (terminal) moraine

- Nellie Juan Glacier and terminal moraine, Prince William Sound, AK.



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## Fjords



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## The Periglacial Environment

- Periglacial – ‘perimeter of glaciation’
  - 20% of world's land area
    - High latitudes and high elevations
  - Usually areas covered by ice during Pleistocene epoch
  - Non-glacial landscape features
    - Permafrost
    - Patterned ground

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## The Periglacial Environment

- Polygonal ground patterns, near Prudhoe Bay, AK



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## Proglacial lakes

- Channeled scablands of Washington formed by periodic discharges from an ice sheet-dammed Lake Missoula, a pro-glacial lake during the Pleistocene.



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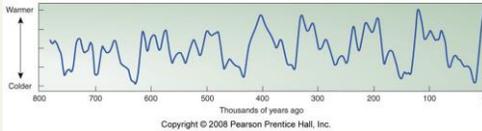
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## Causes of the Pleistocene

### Explanations:

- Cyclical variation in Earth-Sun relations
  - Seem to explain cycles of glaciations and deglaciations involving tens of thousands to hundreds of thousands of years.
  - Shorter cycles are more difficult to explain.




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## Causes of the Pleistocene

### Other possible factors

- Variability of solar output
- Variations in amount of atmospheric CO<sub>2</sub>
- Changes in position of continents, configuration of ocean basins and ocean circulation patterns
- Changes in atmospheric circulation due to increased elevation of continental mass after a period of tectonic upheaval
- **Reductions in insolation due to volcanic eruptions**

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## Causes of the Pleistocene

### Are We Still in an Ice Age?

- Is our climate merely an interglacial warming period?
- If we are in an interglacial period, will human-induced global warming slow down the return of another glacial period?

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