Essentials of Geology, 11e

Glaciers and Glaciation
Chapter 11

Instructor – Jennifer Barson
Spokane Falls Community College
Geology 101

Stanley Hatfield
Southwestern Illinois

Jennifer Cole
Northeastern Universi

Glaciers

- Glaciers are parts of two basic cycles
  - Hydrologic cycle
  - Rock cycle
- Glacier – a thick mass of ice that orig-inates on land from the accumulation, compaction, and recrystallization of snow

Glaciers

- Types of glaciers
  - Valley (alpine) glaciers
    - Exist in mountainous areas
    - Flows down a valley from an accumulation center at its head
  - Ice sheets (continental)
    - Exist on a larger scale than valley glaciers
    - Two major ice sheets on Earth are over Greenland and Antarctica
    - Ice flows out in all directions from one or more snow accumulation centers

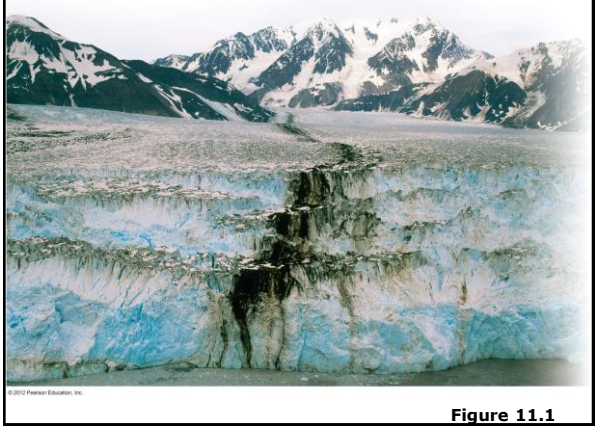


Figure 11.1

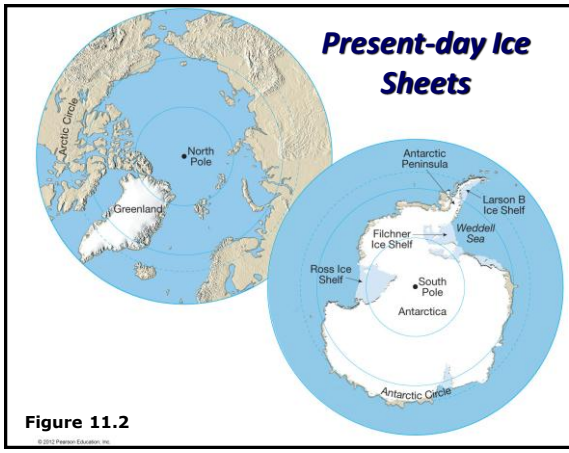


Figure 11.2

Glaciers

- What if the ice on Earth melted?
  - Slightly more than 2 percent of the world's water is tied up in glaciers
  - Antarctic ice sheet
    - Eighty percent of the world's ice
    - Covers almost one and one-half times the area of the United States
  - If melted, sea level would rise 60 to 70 meters (180-210 feet)

Glaciers

Figure 11.6

Formation of Glacial Ice

- Glaciers form in areas where more snow falls in winter than melts during the summer
- Steps in the formation of glacial ice
  - Air infiltrates snow
  - Snowflakes become smaller, thicker, and more spherical
  - Air is forced out

Formation of Glacial Ice

- Steps in the formation of glacial ice
  - Snow is recrystallized into a much denser mass of small grains called firn
  - Once the thickness of the ice and snow exceeds 50 meters, firn fuses into a solid mass of interlocking ice crystals – glacial ice

Movement of Glacial Ice

- Movement is referred to as flow
  - Two basic types
    - Plastic flow
      - Occurs within the ice
      - Under pressure, ice behaves as a plastic material
    - Basal slip
      - Entire ice mass slipping along the ground
      - Most glaciers are thought to move by this process

Movement of Glacial Ice

- Zone of fracture
  - Occurs in the uppermost 50 meters
  - Tension causes crevasses to form in brittle ice
- Rates of glacial movement:
  - Average velocities vary considerably from one glacier to another
  - Some glaciers exhibit extremely rapid movements called surges

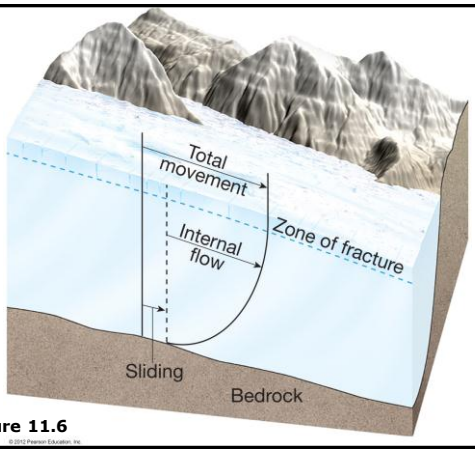
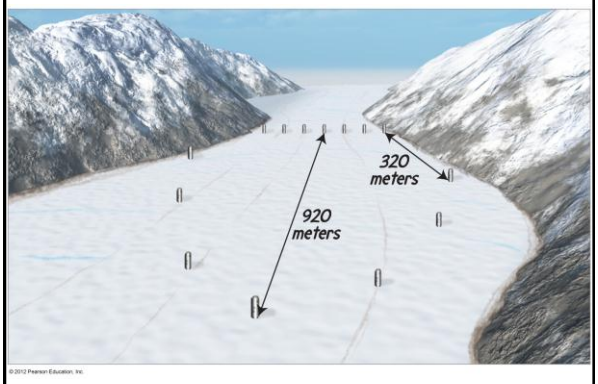


Figure 11.6



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Movement of Glacial Ice

- Budget of a glacier
  - Zone of accumulation – the area where a glacier forms from snowfall
  - Elevation of the snowline varies greatly

Movement of Glacial Ice

- Budget of a glacier
  - Zone of wastage – the area where there is a net loss to the glacier due to
    - Melting – warm temperatures
    - Calving – the breaking off of large pieces of ice (icebergs where the glacier has reached a body of water)

Movement of Glacial Ice

- Budget of a glacier
  - Balance, or lack of balance, between accumulation at the upper end of the glacier, and loss at the lower end is referred to as the glacial budget
    - If accumulation exceeds loss (ablation), the glacial front advances
    - If ablation increases and/or accumulation decreases, the ice front will retreat

The Glacial Budget

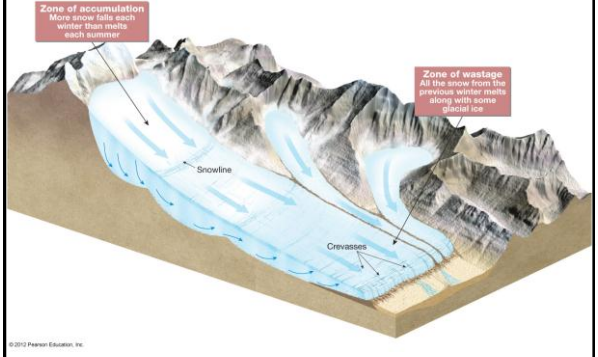


Figure 11.10

Glacial Erosion

Glaciers are capable of great erosion and sediment transport

- Glaciers erode land in two ways:
  - Plucking – lifting of rocks
  - Abrasion – Rocks within the ice acting like sandpaper, smooth the surface below
    - Abrasion produces
      - Rock flour (pulverized rock)
      - Glacial striations (grooves in the bedrock)

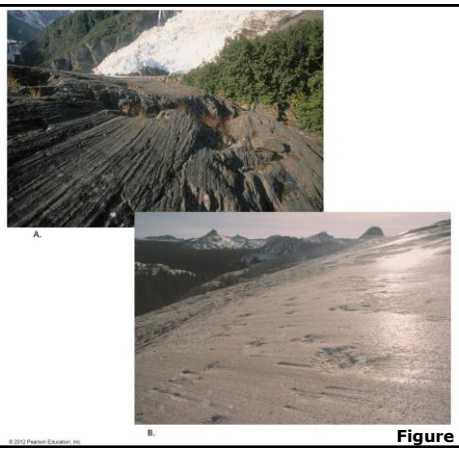


Figure 11.16

Glacial Erosion

- **Landforms created by glacial *erosion***
  - **Erosional features of glaciated valleys**
    - **Glacial trough**
    - **Hanging valleys**
    - **Pater noster lakes**
    - **Cirques**
    - **Tarns**
    - **Truncated spur**
    - **Fiords**
    - **Arêtes**
    - **Cols**
    - **Horns**

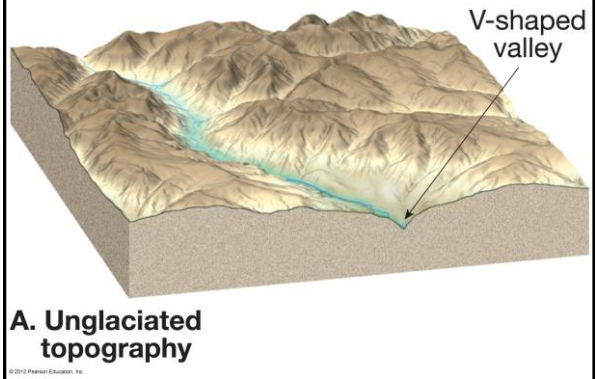


Figure 11.17 A

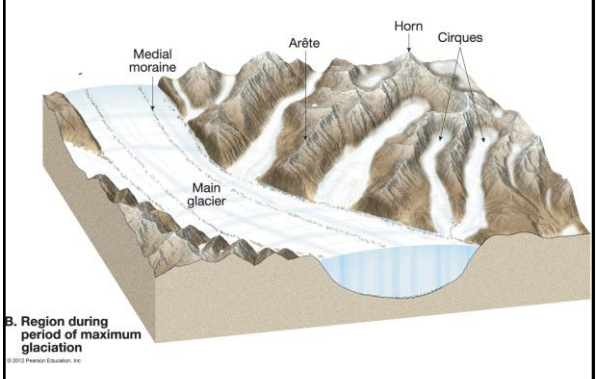


Figure 11.17 B

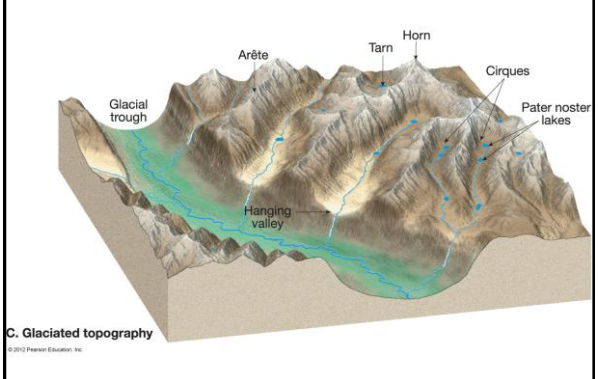


Figure 11.7 C

The Matterhorn in the Swiss Alps

Figure 11.20

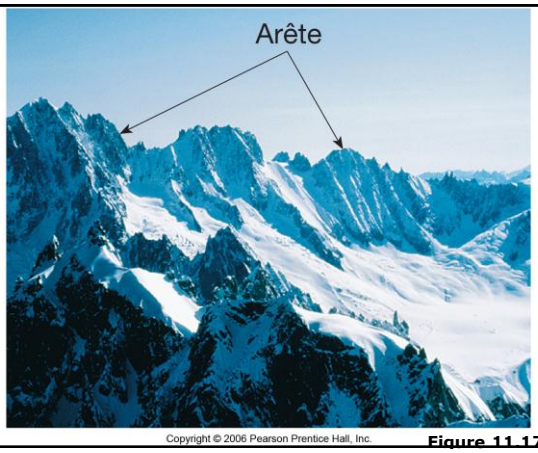
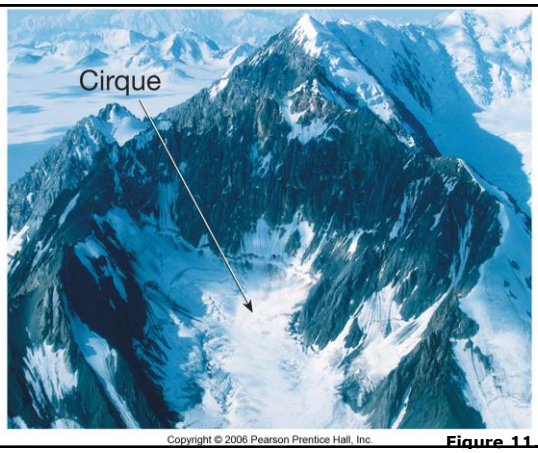


Figure 11.17



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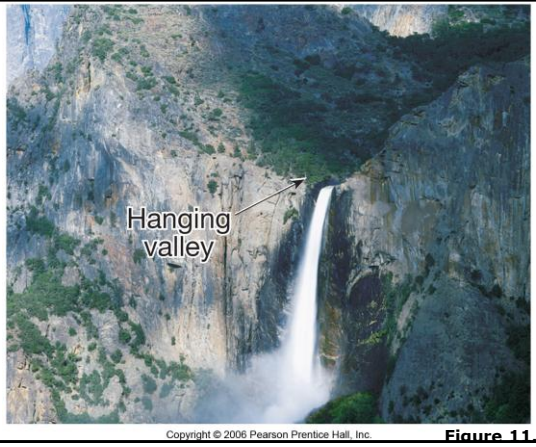
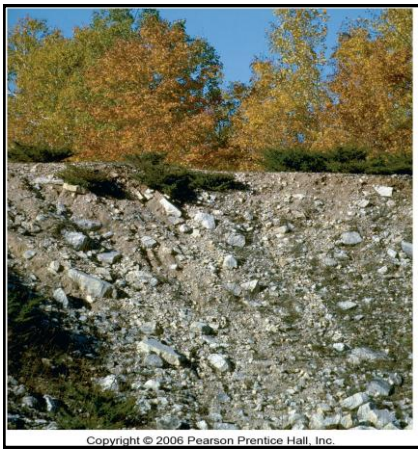


Figure 11.17

Glacial Deposits

- **Glacial drift** – **refers to all sediments *deposited* from glacial origin**
  - **Types of glacial drift**
    - **Till – material that is deposited directly by the ice**
    - **Stratified drift – sediments laid down by glacial meltwater**
    - **Glacial erratics – boulders of rock different than the bedrock that are found in till or lying free on the surface**



Glacial Till is Typically Unstratified and Unsorted

Figure 11.18

Glacial Deposits

- Landforms made of ***till***
  - **Moraines**
    - Layers or ridges of till
  - Moraines produced by alpine glaciers
    - Lateral moraine
    - Medial moraine
    - Other types of moraines
      - End moraine – terminal or recessional
      - Ground moraine

A.

B.

Figure 11.24

Glacial Deposits

- Landforms made of ***till***
  - **Drumlins**
    - Smooth, elongated, parallel hills
    - Steep side faces the direction from which the ice advanced
    - Occur in clusters called **drumlin fields**
    - Formation not fully understood

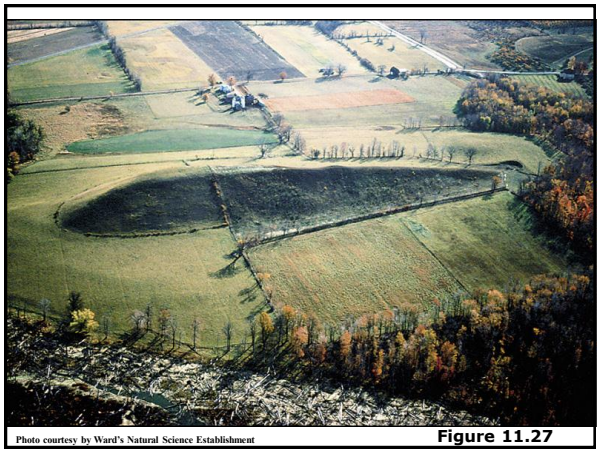


Photo courtesy by Ward's Natural Science Establishment

Figure 11.27

Glacial Deposits

- Landforms made of ***stratified drift***
  - **Outwash plains** (with ice sheets) and **valley trains** (when in a valley)
    - Broad ramp-like surface composed of stratified drift deposited by meltwater leaving a glacier
    - Located adjacent to the downstream edge of most end moraines
    - Often pockmarked with depressions called **kettles** (lakes)

Glacial Deposits

- Landforms made of ***stratified drift***
  - **Ice-contact deposits**
    - Deposited by meltwater flowing over, within, and at the base of motionless ice
    - Features include
      - Kames
      - Kame terraces
      - Eskers

Glacial Erosion

- **Landforms** created by ***erosion or deposition*** from an active ice sheet
  - Drumlin
  - End, terminal, recessional moraine
  - Kettle lake
  - Esker
  - Roche moutonnee
  - Outwash plains and ground moraine
  - Kames

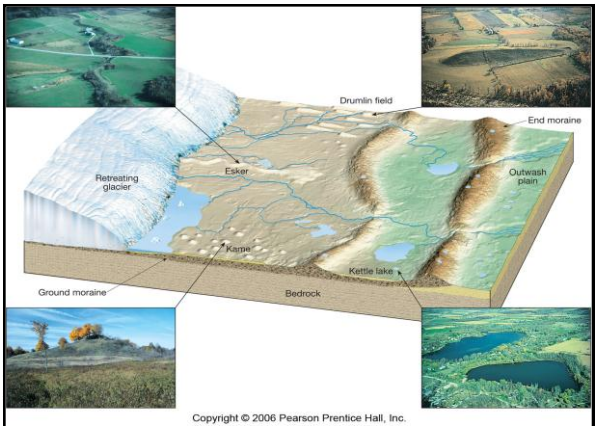


Figure 11.27

Glaciers of the Past

- **Ice Age**
  - **Four** major stages recognized in North America
    - Nebraskan
    - Kansan
    - Illinoian
    - Wisconsinan
  - Ice covered 30% of Earth's land area

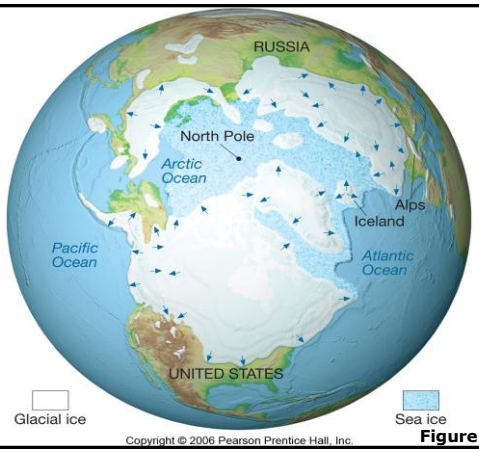


Figure 11.32

Glaciers of the Past

- Ice Age
  - The most recent Ice Age began between two million and three million years ago
  - Most of the major glacial stages occurred during a division of geologic time called the Pleistocene epoch
  - ~ 20 glacial/interglacial cycles

Glaciers of the Past

- Indirect effects of Ice Age glaciers
  - Forces migration of animals and plants
  - Changes in stream courses
  - Rebounding upward of the crust in former centers of ice accumulation
  - Worldwide change in sea level
  - Climatic changes

Coastline Changes Due to Glaciation

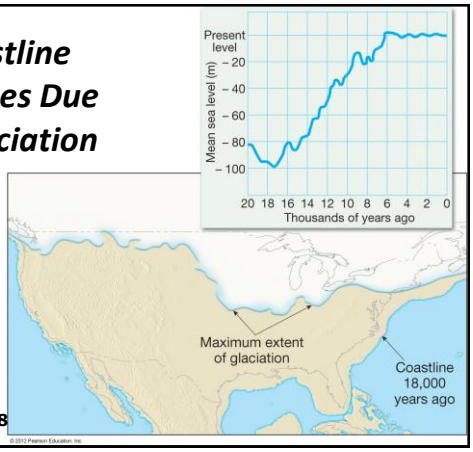


Figure 11.28

Causes of Glaciation

- Some possible causes of glaciation
  - Plate tectonics
    - Continents were arranged differently in the past
    - Changes in oceanic circulation
  - Variations in Earth's orbit
    - The Milankovitch hypothesis (or theory)

Causes of Glaciation

- Some possible causes of glaciation
  - Milankovitch hypothesis
    - Shape (eccentricity) of Earth's orbit varies
    - Angle of Earth's axis (obliquity) changes
    - Earth's axis wobbles (precession)
    - Changes in climate over the past several hundred thousand years are closely associated with variations in the geometry of Earth's orbit
  - Other factors may also be involved

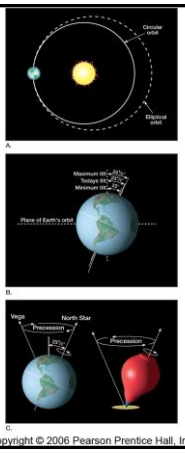


Figure 11.34