Glaciers

Earth 10th Edition – Chapter 18

Glaciers: summary in haiku form

Ten thousand years thence
big glaciers began to melt -
called "global warming."

Glaciers

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

Glaciers

- Types of glaciers
  - Valley (alpine) glacier
    - Exists in mountainous areas
    - Flows down a valley from an accumulation center at its head
  - Ice sheet
    - Exists on a larger scale than valley glaciers
    - Two major ice sheets on Earth are over Greenland and Antarctica

Present-day Ice Sheets

Glaciers

- Types of glaciers
  - Ice sheet
    - Often called continental ice sheets
    - Ice flows out in all directions from one or more snow accumulation centers
  - Other types of glaciers
    - Ice caps
    - Outlet glaciers
    - Piedmont glaciers
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  -
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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
    - Nearly two-thirds of Earth's fresh water
    - Covers almost one and one-half times the area of the United States
    - If melted, sea level would rise 60 to 70 meters

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

16 ***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

17 **Transformation of snow to glacial ice**

18 ***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

19 ***Movement of glacial ice***

- Movement is referred to as flow
  - *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

20 **Glaciers move by basal sliding and internal flow**

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22 ***Movement of glacial ice***

- Rates of glacial movement
  - Rates of up to several meters per day
  - Some glaciers exhibit extremely rapid movements called *surges*
- Budget of a glacier
  - *Zone of accumulation* – the area where a glacier forms
  - Elevation of the snowline varies greatly

23 ***The Glacial Budget***

24 ***Glacial Processes and Budget***

25 ***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*
    - *Calving* – the breaking off of large pieces of ice (icebergs where the glacier has reached the sea)

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27 ***Movement of glacial ice***

- Budget of a glacier
  - Balance, or lack of balance, between accumulation and wastage
    - If accumulation exceeds loss (called ablation), the glacial *front* advances
    - If ablation increases and/or accumulation decreases, the ice *front* will retreat

28 ***Flowing of Ice Within a Glacier***

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The glacial budget

Glacial erosion

- Glaciers are capable of great erosion and sediment transport
- Glaciers erode the land primarily in two ways
  - *Plucking*
    - lifting of rocks
  - *Abrasion*
    - Rocks within the ice acting like sandpaper to smooth and polish the surface below

Glacial erosion

- Glacial erosion
  - Glacial abrasion produces
    - *Rock flour* (pulverized rock)
    - *Glacial striations* (grooves in the bedrock)
- Landforms created by glacial erosion
  - Erosional features of glaciated valleys
    - *Glacial trough*
    - *Truncated spurs*
    - *Hanging valleys*

Glacial erosion

- Landforms created by glacial erosion
  - Erosional features of glaciated valleys
    - *Pater noster lakes*
    - *Cirques*
    - *Tarns*
    - *Fiords*
    - *Arêtes*
    - *Horns*

The Matterhorn

Glacial deposits

- *Glacial drift* – refers to all sediments of glacial origin
  - Types of glacial drift
    - *Till* – material that is deposited directly by the ice
    - *Stratified drift* – sediments laid down by glacial meltwater

Glacial till is typically unstratified and unsorted

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*
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54 **Glacial depositional features**

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56 ***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

57 **A drumlin in upstate New York**

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60 ***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*

61 ***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

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64 ***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

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67 **Maximum extent of ice during the Ice Age**

68 ***Glaciers of the past***

- *Ice Age*
  - The 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

69 ***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

70 **Crustal rebound following the removal of glacial ice**

71 ***Causes of glaciation***

- Any successful theory must account for:
  - What causes the onset of glacial conditions?
  - What caused the alternation of glacial and interglacial stages that have been documented for the Pleistocene epoch?

72 ***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*

73 ***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?

74 ***Orbital Variations***

75 **End of Chapter 18**