

1 **Glaciers**

Earth 9th Edition – Chapter 18

2 **Glaciers: summary in haiku form**

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

3 **Key Concepts**

- Glaciers and types of glaciers.
- Formation and movement of glacial ice.
- Erosion by glaciers.
- Landforms produced by glacial erosion.
- Landforms produced by deposition of glacial sediment.
- Glaciers and "Ice Ages."

4 **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

5 **Glaciers**

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

6

7 **Glaciers**

- Types of glaciers
 - ☒ Ice sheets
 - ◆ 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

8

9

10

11 **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

12

13

14

- 15 **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**
- 21
- 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 ***Glacial Processes and Budget***
- 24 **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)
- 25 **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 (called ablation), the glacial front advances
 - ◆ If ablation increases and/or accumulation decreases, the ice front will retreat
- 26 ***Flowing of Ice Within a Glacier***
- 27

28

29

30

31

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

32

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

33

34

35

36

37

Glacial erosion

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

38

39

40

41

42

43

44

45

46

47

48

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

49

50

51

52

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


53  **Glacial depositional features**

54  **Glacial deposits**

- 55  ● 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

56  **A drumlin in upstate New York**


57  **Glacial deposits**

- 58  ● 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

60  **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

61  **Glaciers of the past**

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

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

65  **Glaciers of the past**

- 66  ● 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

68  **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

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

70  **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

71  **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

72  **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 are probably also involved

73  **End of Chapter 18**