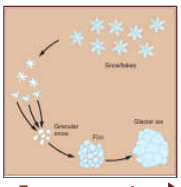
Chapter Outlines

NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

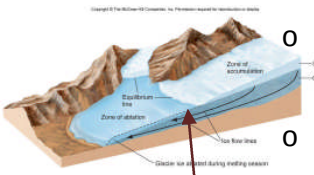
Glaciers

Glaciers are thick, sprawling masses of ice that form on land during cooler climatic periods. Currently 75% of the world's fresh water is locked up in glaciers. Glaciers begin to grow when more snow accumulates during the winter than is lost through melting during the summer. The older snow compacts, recrystallizes, and turns to ice from the increasing weight of the new snow above it. When a glacier reaches a sufficient size and mass, the force of gravity begins to move it downslope. The most recent glacial period covered most of Canada and the northern 1/3 of the U.S. under ice. This glaciation ended about 10,000 years ago.



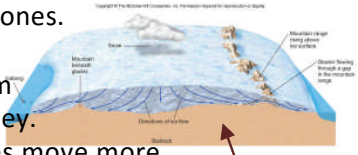
From snow to glacial ice by compaction

- **Glaciation** is the movement of an ice sheet over a land surface. Past glaciation on Earth was first recognized in the early 1800's by the Swiss scientist Louis Agassiz. Two types of glaciation are:
  - **Continental glaciation** covers a broad section of a continental land mass, such as Antarctica.
  - **Alpine glaciation** is usually restricted to deep valleys in high mountainous terrain.
- **How Glaciers Develop**
  - Snow accumulates & turns first into **firn,** then into **glacial ice** under the pressure from overlying layers of snow. The increased weight compacts the snowflakes. The greater the overlying weight, the greater the amount of compaction and **recrystallization** that leads to the development of thick slabs of glacial ice.
  - **Wasting and calving.** When glacial ice reaches its point of farthest advance, it is wasted, or **ablated**, through either melting or calving *(pieces break from the glacial face and plunge into the water of an ocean or lake as icebergs).*
  - A glacier's **budget** is defined as the difference between ice gained and ice lost. When a glacier gains more volume from new snowfall than it loses from melting, it has a **positive budget,** and the **terminus** *(front)* advances downslope**.** A glacier with a **negative budget** loses more volume than it gains and its terminus recedes upslope**.**
  - The upper elevations of a glacier are called the **zone of accumulation.** The lower portion of the glacier where the ice is lost is called the **zone of ablation** *(wastage).* The **equilibrium line** *(snow line)* is the irregular changing boundary between these two zones.

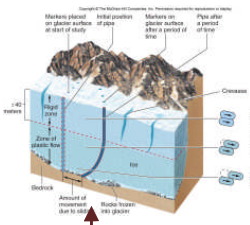


Equilibrium line (also snow line)

- **Glacier Movement** *(driven by gravity)*
  - A **continental ice sheet** moves downslope in a number of directions from a central area of higher altitude and is not restricted to a channel or valley.
  - Some **valley glaciers** can move 15 meters a day. The ice on steeper slopes move more quickly than the ice on the more gentle slopes farther down the valley.
  - **Basal sliding** is glacial sliding over the base due to meltwater acting as a lubricant.
  - **Plastic flow** causes glacial ice buried within underneath more than about 50 meters of overlying ice to move like a slow-moving plastic stream. The central and upper ice move quickest. Ice less than 50 meters deep ***(zone of fracture)*** is brittle and can contain numerous crevasses.



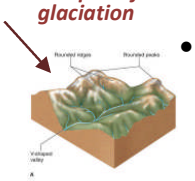
Continental glacier



Cross section view of a valley (alpine) glacier

- **Glacial Erosion**
  - Basal sliding erodes the rock surface underlying a glacier by grinding, plucking, and transporting bedrock. Basal abrasion erodes, striates, and polishes the underlying rock surface and produces abundant fine rock powder known as rock flour.
  - Alpine glaciers also erode the walls of a valley.

Landscape before glaciation

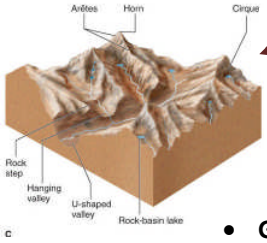


Period of glaciation

- **Glacial Erosional Landforms…**striking glacial features are associated with alpine glaciation.
  - Alpine glaciers form **U-shaped valleys** called **glacial troughs**.
  - The ice also erodes away the ends of ridges creating **truncated spurs.** The valleys of tributaries can also be truncated thereby forming **hanging valleys** that are higher than the main valley and often marked by waterfalls *(Yosemite Falls).*
  - The mass of ice at the top of a glacial valley forms a steep, circular hollow called a **cirque.**
  - A **horn** is a sharply defined peak.

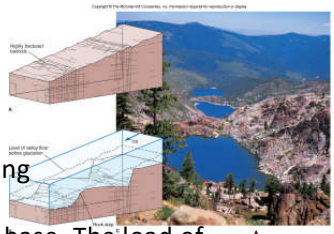
Cirque

Horns



Landscape after glaciation

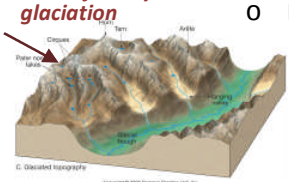
- The lake formed in a cirque is a **tarn**.
- A steep 'sharp' ridge called an **arête** commonly extends downward from a horn to separate two adjacent glacial valleys.
- An advancing glacier may scour out a series of depressions in the underlying bedrock, which later fill with water and become **rock-basin lakes.**

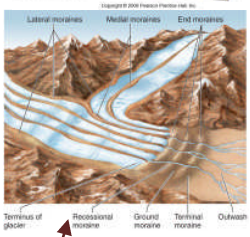


Rock-basin lakes or Paternoster lakes

- **Glacial Deposits and features.** An advancing ice sheet carries rock/sediment at its base. The load of alpine glaciers comes also from rocks that have fallen onto the glacier from the valley walls.
  - **Moraines** are glacial deposits of **till** that are left behind when a glacier ends or recedes.
    - **Lateral moraines** consist of rock debris/sediment that have worked loose from the walls beside a valley glacier and have built up in ridges along the sides of the glacier.
    - **Medial moraines** are long ridges of till that result when lateral moraines join as two tributary glaciers merge.
    - An **end moraine** can build up at the front of the glacier. Two kinds are recognized: terminal and recessional moraines. A **terminal moraine** is the ridge of till that marks the farthest advance of the glacier before it started to recede. A **recessional moraine** is one that develops periodically at the front of intermittently receding glacier.
    - A thin, widespread layer of till deposited across the surface as an ice sheet melts is called a **ground moraine.**
  - Ground moraine material can sometimes be reshaped by subsequent glaciers into streamlined hills called **drumlins**.

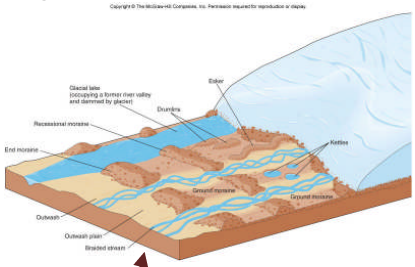
Features of valley glaciation





Examples of moraines

  - The sediments deposited by glacial meltwater are called **outwash.** Outwash deposits can be braided, sorted, and layered. The broad front of outwash associated with an ice sheet is called an **outwash plain.**
  - **Kames** are steep-sided mounds of stratified till which were deposited by meltwater in depressions or openings in the ice.
  - **Kettles** are depressions left by the melting of large blocks of ice that had become buried during glaciation.
  - **Eskers** are long, winding ridges of outwash that were deposited in streams flowing through ice caves and tunnels at the base of the glacier.
  - A **varve** is sediment representing a single year's deposition in a glacial lake.



Terminal, recessional moraines, & outwash plain

- Other features resulting from glaciation
  - A **fjord** is a steep-walled fingerlike coastal inlet that was carved by glacial action during lowered sea level and later flooded by the rising sea as glaciers melted.
  - **Pluvial lakes** formed during the wetter climates which existed during and after glacial retreat.
  - Most of the soil and sedimentary rocks were scraped off underlying crystalline rock in northern and eastern Canada, and lake basins were gouged out of the bedrock…forming the '**Canadian shield**'.
  - Extensive sets of recessional moraines were left behind by retreating ice sheets in the upper Midwestern US and Canada.

A fjord

- Indirect effects of current and past glaciations
  - Great Salt Lake is remnant of much larger pluvial **Lake Bonneville.**
  - Huge floods emanated as ice-dammed lakes drained catastrophically.
  - Sea level was significantly lowered by large amount of water locked-up in ice sheets.
  - Meteorites that fall onto continental ice sheets like Antarctica are easily found were the ice ablates.
- **Glaciers in the Past**
  - The earliest known glaciation occurred about 2.3 billion years ago and is recognized in Ontario, Canada, from older tills that have lithified into a rock called **tillite.**
  - Other major periods of glaciation occurred about 600 million and 300 million years ago.
  - There is some evidence that the entire Earth was covered under ice during a portion of the Paleozoic. It is nicknamed **"snowball Earth".** This hypothesis is not widely accepted.
  - Glaciation has occurred more frequently in the last 20 million years. The estimated worldwide t° difference between the Pleistocene and today is only about 5 degrees centigrade.

'Hypothetical' Snowball Earth

- Geologists do not understand completely why ice ages occur. Possible causes include variations in the earth's orbit and inclination to the sun, atmospheric changes, large volcanic eruptions, changes in continental positions, changes in ocean currents, or movements in the Antarctic ice sheet. Climatic variations in the past 100,000 years coincide with periodic variations in the amount of solar energy received by the earth. In the mid 1900's, many Earth scientists were hypothesizing that Earth was entering another period of glaciation…that hypothesis is no longer being considered.