EENS 1110	Physical Geology
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Glaciers and Glaciation

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Glaciers constitute much of the Earth that makes up the cryosphere, the part of the Earth that remains below the freezing point of water. Most glacial ice today is found in the polar regions, above the Arctic and Antarctic Circles. While glaciers are of relatively minor importance today, covering only about 10% of the surface, evidence exists that the Earth's climate has undergone fluctuations in the past, and that the amount of the Earth's surface covered by glaciers has been as much as 30% in the past. In fact, much of the topography in the northern part of North America, as well as in the high mountain regions of the west, owe their form to erosional and depositional processes of glaciers. The latest glaciation ended only 10,000 years ago. The Earth has experienced numerous glaciations, the most recent during the Pleistocene Epoch between 1.8 million years ago and 11,000 years ago. Other episodes occurred in the Permian, Ordovician, and Late Precambrian.

Definition of a glacier

A glacier is a permanent (on a human time scale, because nothing on the Earth is really permanent) body of ice, consisting largely of recrystallized snow, that shows evidence of downslope or outward movement due to the pull of gravity.

Types of Glaciers

(note: images of these features are shown in your textbook and will be shown in class.)

Mountain Glaciers - Relatively small glaciers which occur at higher elevations in mountainous regions.

- Smallest of these occupy hollows or bowl-shaped depressions on sides of mountains (***cirque glaciers***).
- As cirque glaciers grow larger they may spread into valleys and flow down the valleys as ***valley glaciers***. Paths these valley glaciers take are controlled by existing topography.
- If a valley glacier extends down to sea level, it may carve a narrow valley into the coastline. These are called ***fjord glaciers***, and the narrow valleys they carve and later become filled with seawater after the ice has melted are ***fjords***.
- If a valley glacier extends down a valley and then covers a gentle slope beyond the mountain range, it is called a ***piedmont glacier***.
- If all of the valleys in a mountain range become filled with glaciers, and the glaciers cover then entire mountain range, they are called ***ice caps***.

Ice Sheets (Continental glaciers) - are the largest types of glaciers on Earth. They cover large areas of the land surface, including mountain areas. Modern ice sheets cover Greenland and Antarctica. These two ice sheets comprise about 95% of all glacial ice currently on Earth. They have an estimated volume of about 24 million km^3. If melted, they contain enough water to raise sea level about 66m (216 ft.). This would cause serious problems for coastal cities (L.A., NY, Washington DC, New Orleans, Miami, SF etc). The Greenland ice sheet is in some places over 3000 m (9800 ft) thick and the weight of ice has depressed much of the crust of Greenland below sea level. Antarctica is covered by two large ice sheets that meet in the central part along the Transantarctic Mountains. These are the only truly polar ice sheet on earth (North Pole lies in an ocean covered by thin layer of ice).

Ice Shelves - Ice shelves are sheets of ice floating on water and attached to land. They usually occupy coastal embayments, may extend hundreds of km from land and reach thicknesses of 1000 m.

Glaciers can also be classified by their internal temperature.

- ***Temperate glaciers*** - Ice in a temperate glacier is at a temperature near its melting point.

- ***Polar glaciers*** - Ice in a polar glacier always maintains a temperature well below its melting point.

The Formation of Glacial Ice

Three conditions are necessary to form a glacier: (1) Cold local climate (polar latitudes or high elevation). (2) snow must be abundant; more snow must fall than melts, and (3) snow must not be removed by avalanches or wind.

Glaciers can only form at latitudes or elevations above the ***snowline***, which is the elevation above which snow can form and remain present year round. The snowline, at present, lies at sea level in polar latitudes and rises up to 6000 m in tropical areas. Glaciers form in these areas if the snow becomes compacted, forcing out the air between the snowflakes. As compaction occurs, the weight of the overlying snow causes the snow to recrystallize and increase its grain-size, until it increases its density and becomes a solid block of ice. A glacier is actually a metamorphic rock.

Changes in Glacier Size

A glacier can change its size by ***Accumulation***, which occurs by addition of snowfall, compaction and recrystallization, and ***Ablation***, the loss of mass resulting from melting, usually at lower altitude, where temperatures may rise above freezing point in summer. Thus, depending on the balance between accumulation and ablation during a full season, the glacier can advance or retreat (see figure 22.9 in your text book).

Movement of Glaciers

Glaciers move to lower elevations under the force of gravity by two different processes:

- Internal Flow - called creep, results from deformation of the ice crystal structure - the crystals slide over each other like deck of cards. This type of movement is the only type that occurs in polar glaciers, but it also occurs in temperate glaciers.

- Basal sliding - meltwater at base of glacier reduces friction by lubricating the surface and allowing the glacier to slide across its bed. Polar glaciers are usually frozen to their bed and are thus too cold for this mechanism to occur.

The upper portions of glaciers are brittle, when the lower portion deforms by internal flow, the upper portions may fracture to form large cracks called **crevasses**. Crevasses occur where the lower portion of a glacier flows over sudden change in topography (see figure 22.6 in your text).

The velocity of glacial ice changes throughout the glacier. The velocity is low next to the base of the glacier and where it is contact with valley walls. The velocity increases toward the center and upper parts of the glacier (see figure 22.8 in your text).

Glaciation

Glaciation: is the modification of the land surface by the action of glaciers. Glaciations have occurred so recently in N. America and Europe, that weathering, mass wasting, and stream erosion have not had time to alter the landscape. Thus, evidence of glacial erosion and deposition are still present. Since glaciers move, they can pick up and transport rocks and thus erode. Since they transport material and can melt, they can also deposit material. Glaciated landscapes are the result of both glacial erosion and glacial deposition.

Glacial Erosion - Glaciers erode in several ways.:

- Abrasion – Rock fragments carried by the glacier scrape against rock causing abrasion, like sandpaper.

- Plucking – Ice breaks off and removes bedrock fragments

- Ice melts by pressure against the up-ice side of an obstruction. Entering cracks in bedrock, this water re-freezes to the ice. Glacial movement plucks away bedrock chunks (see figure 22.13 and 22.14 in your text).

Small scale erosional features (note: most of this material will be presented as slides in class)

- Glacial striations - long parallel scratches and grooves that are produced at the bottom of temperate glaciers by rocks embedded in the ice scraping against the rock underlying the glacier (see figure 22.12 in your text).

- Glacial polish - rock that has a smooth surface produced as a result of fined grained material embedded in the glacier acting like sandpaper on the underlying surface (see figure 22.12 in your text).

Landforms produced by mountain glaciers (see figure 22.15 in your text)

- ***Cirques*** - bowl shaped depressions that occur at the heads of mountain glaciers that result form a combination of frost wedging, glacial plucking, and abrasion. Sometimes small lakes, called ***tarns*** occur in the bottom of cirque.
- ***Glacial Valleys*** - Valleys that once contained glacial ice become eroded into a "U" shape in cross section. Stream erosion, on the other hand, produces valleys that are "V" shaped in cross section.
- ***Arêtes*** - If two adjacent valleys are filled with glacial ice, the ridges between the valleys