

## Glaciation: A “Cool” Topic for Dynamic Planet

- I Definition of glaciers: areas of snow and ice that have accumulated over many years and have at some time flowed
- II. Types of glaciers
  - A. Mountain (or cirque): fill bowl-like depressions that may be a few square kilometers
  - B. Valley glaciers: flow through valleys and may be enlarged by cirque glaciers
  - C. Piedmont glaciers: valley glaciers that flow out of the valley and onto the adjacent plain
  - D. Icefields: massive collections of glaciers
  - E. Ice sheets: largest accumulations of glaciers
  - F. Rock glaciers
- III Formation of glaciers
  - A. Latitude
  - B. Elevation: each 1000-foot change in elevation causes a 3° change in temperature
  - C. Slant of rays from the sun: glaciers have a better chance of surviving on the sides facing away from the sun
  - D. Prevailing wind direction: Snow is blown from the windward to the leeward sides of mountains. Prevailing Westerlies in the U.S. blow from west to east.
- IV. Glacial history
  - A. When glaciers advance from polar regions toward the equator
  - B. Quaternary Period: Past 1.6 million years
    - 1. Pleistocene Epoch: from the beginning of the Quaternary Period to the end of the last glaciation
    - 2. Holocene Epoch: 10,000 years ago to present
  - C. Interglacial Periods: ~ 20,000 years in length according to ice core studies
- V. Mechanisms responsible for formation and maintenance of glaciers: a change of ~ 6° below present world temperatures can mean a return to a glacial period
  - A. Solar variability: a change in the amount of energy produced by the sun
  - B. Insolation: amount of the sun’s energy that strikes Earth’s surface
    - 1. Eccentricity. Earth’s orbital path around the sun
    - 2. Obliquity. Variation in the tilt of Earth’s axis over a 41,000 year cycle
    - 3. Precession. Wobble of Earth’s axis
  - C. Dust
    - 1. Particles from Earth’s surface carried into the atmosphere
    - 2. Dust particles reflect incoming solar ultraviolet rays causing Earth’s surface to cool
    - 3. Includes wind-eroded dust, volcanic particles (dust and gas), forest fires

- D. Gases that absorb heat and raise the temperature of the atmosphere
  - 1. Water vapor
  - 2. Carbon dioxide
  - 3. Methane
- E. Ocean current circulation: the North Atlantic Deep Water Current is one long, continuous ocean current that takes ~ 1000 years to complete
- F. Sea ice
  - 1. Reflects incoming solar radiation
  - 2. Blocks ocean water from sinking, thus preventing thermohaline circulation of ocean currents
- G. Atmospheric circulation: when ice sheets advance toward the equator, the convection cell circulation patterns change to exaggerate glacial conditions

#### VI. Crystal structure of ice

- A. Ice is a mineral
  - 1. Definite crystal structure
  - 2. Definite chemical composition
  - 3. Naturally occurring
  - 4. Inorganic
- B. Crystal structure of a snowflake is a hexagonal molecule
- C. The cooler the temperature, the less delicate and more blocky the snowflake
- D. As snow accumulates, the shape of each crystal begins to change as it is compressed, melted, and crystallized
- E. Density
  - 1. Snowflakes ~  $0.1 \text{ g/cm}^3$
  - 2. Firn (German term for last year's snow) ~  $0.6 \text{ g/cm}^3$
  - 3. Glacial ice ~  $0.9 \text{ g/cm}^3$
  - 4. Density of fresh water for comparison ~  $1.0 \text{ g/cm}^3$

#### VII. Movement of glaciers

- A. Flow mechanisms
  - 1. Slope of the bedrock surface: steepness of the land surface
  - 2. Internal deformation: the ice crystals are flattened by the overlying pressure and lie parallel to the base of the glacier (like playing cards). Ice crystals slide along the platy flat surface of each successive ice crystal beneath them.
  - 3. Basal meltwater and water that percolate downward from the surface to form a lubricating layer
- B. Downwasting: when melting exceeds forward flow

C. Types of movement

1. Compressional flow areas: where the glacier is constantly pushed from behind
  2. Extensional flow areas: ice responds slowly to change and cannot flow fast enough to continually stay compressed. Ice pulls apart in the extensional flow areas to form crevasses.
  3. Crevasses are formed because the surface ice cannot deform and therefore crack to accommodate the plastic flow of deeper ice.
- D. Most glaciers move ~ 0.5 meters per day. They may occasionally surge forward at speeds of 10's or 100's of meters per day.
- E. Glaciers never move backward, however, they may stall if the proper conditions for flow are not met.

VIII. Parts of a glacier

- A. Head: uphill top end
- B. Terminus: downhill end
- C. Terminal moraine: furthest forward movement of the glacier
- D. Snowline: area between summer melting and accumulation area where snow lasts from season to season
- E. Firn: year-old snow found in the accumulation area
- F. Superglacial streams: streams on the surface of glaciers that carry surface melt water
- G. Equilibrium Line Altitude (ELA): average position of the firn line.
- H. Superglacial debris: a large amount of dust and rocky material scattered over the surface of a glacier
- I. Moraine: piles of rock material that have eroded from the valley walls and pushed to the front and sides of a glacier
- J. Moulin: a hole or tunnel exposed on the glacial surface through which meltwater flows

IX. Glacial-created features

- A. Kettle ponds: formed when large blocks of ice deposited along with rocky debris melt and leave depressions which fill with water
- B. Esker: a long, serpentine hill of gravel and sand accumulated in internal glacier water tubes and exposed after a glacier has completely ablated
- C. Suncups: small, rounded depressions, from 1 centimeter to 30 centimeters in diameter and equally deep, in the surface of a glacier. Caused by uneven reflection of light, or albedo – the percent of sunlight reflected by a surface
- D. Digenic ice mounds and pedestals: icy surfaces covered by rocky materials melts faster than ice surfaces covered by rocky material
- E. Glacial lakes: form from glacial meltwater below the terminus

X. Climate records

- A. Our present atmosphere contains all the same gases, soluble ions, and dusts as in earlier times but possibly in different concentrations
- B. Ice cores contain information about atmospheric conditions throughout the past 450,000 years
- C. Sea level change: reallocation of water from the oceans to glaciers may cause a 300 foot drop in ocean waters
- D. How current climate trends compare to the past
- E. Annual layers represent one year's growth and are still distinguishable even after the layers have been compressed and transformed into glacial ice

XI. Glacial geology: a study of the effect of glaciation on the landscape

A. Erosional

- 1. Subglacial debris grinds against the bedrock abrading or eroding bits of rock
- 2. Subglacial material erodes striations or grooves up to a few centimeters deep and up to 10's of meters long
- 3. Rock flour: glacial rocks grind into "flour" and are carried in streams
- 4. Frost wedging: when ice pushes from the sides and breaks off pieces of rock
- 5. Plucking: pieces of rock along joints or other features in the bedrock are wedged by frost and lifted or plucked from the surface
- 6. Horns: small cirque glaciers erode the tops of mountains and form horns (Matterhorn)
- 7. Erosional processes are responsible for creating classic "U" shaped valleys.

B. Depositional

- 1. Ice rafted debris: rock material carried away by ice and meltwater
- 2. Erratic: rocks transported through glacial actions and placed into areas of differing rock types
- 3. Kame terraces: debris deposited between glaciers and valley walls form conical, hilly deposits
- 4. Till: deposits formed underneath glaciers plastered down by moving ice as it drags debris across the land surface.
- 5. Eskers: supraglacial material from the surface of a glacier carried through a Moulin and into the glacier's plumbing system forming long, snake-like ridges
- 6. Drumlins: material accumulates under a glacier, is covered with till, and then reshaped into an elongated ridge. These features indicate the relative direction of the flow of the glaciers at the time they were formed.

Visit <http://www.otherworlds-edu.com> to review TASA's Earth's Dynamic Surface CD that includes a subtopic on glaciers.