Valley and Piedmont Glaciers

- Malaspina Glacier, Alaska
Cycle of valley glacier erosion

- U-Shaped Valley with tarns
- Hanging Valley
- Arete
- Cirque, Horn
- Fiord

- Lateral moraine
- Lateral and Medial Moraine
- Moraine deposit

http://jesse.usra.edu/articles/iceagemodule/iceagemodule-paper.html
Continental Glacial deposits

Pleistocene Ice Maximum

Bering land bridge

http://www.atmos.washington.edu/~dennis/Our_Changing_Climate.html

Upper Midwest

End Moraines

Coastal moraines of New England

Upper Midwest Drainage—after glaciation

Upper Midwest drainage before glaciation

• Deranged drainage after ice melts

Pluvial Lakes of Southwest
Past Glacial Ages

- **Pliocene-Pleistocene**
  - Ice in Antarctica starting about 40 m.y.a.
  - Widespread N. Hemisphere ice about 3 mya
  - Advances every 40,000 to 100,000 years

- **Karoo Ice Ages**
  - 260 to 350 mya
  - Lasted 90 million years
  - Wegener’s evidence of continental movement

- **Andean-Saharan Ice Ages**
  - 430 to 460 mya
  - Lasted 30 million years

- **Cryogenian**
  - 630 to 850 mya
  - Lasted 200 million years
  - Periods of all Earth covered with glacier

- **Huronian**
  - Over 2 billion years ago
  - Lasted 300 to 400 million years

**Causes**

- Land mass configuration
  - High latitude land mass—Antarctica
  - High elevation in westerlies—Andes, Cascades
- Coincidence of astronomical variations of Earth in relation to Sun
  - Orbit shape: eccentricity
  - Axial tilt amount: obliquity
  - Tilt direction superimposed on orbit shape: progression of the equinox
- CO₂ levels—may be effect and not cause

**Documentation**

- Drift
- Loess and marine deposits
- Oxygen isotope ratio in shells
- Air trapped in ice—CO₂ levels

**Elliptical orbit**

**Axial Tilt variation**
- **Precession of axial tilt**
  - Milankovitch cycles
  - Link to a lovely explanation of these cycles: http://skepticsplay.blogspot.com/2008/12/axial-tilt-milankovitch-cycles.html

- **Northern hemisphere insolation differences due to Milankovitch cycles**

- **Oxygen isotope fractionation**
  - Temperature record from O-18

- **Positive Climate Feedback Loops**
  - Ice albedo decreases temperature, increases ice. Reduced ice increases temperature

- **Ice-albedo feedback loop**

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Positive Climate Feedback Loops

- Ice albedo decreases temperature, increases ice. Reduced ice increases temperature.
- Glacial periods result in larger arid areas, increasing delivery of iron nutrients to sea, increasing algae productivity, lowering CO$_2$ levels, and temperature.
- Lowering sea level will expose reefs to weathering. Reaction consumes CO$_2$, lowering temperature. Rising sea level has opposite effect: reef preserved, does not consume CO$_2$.

Negative Climate Feedback Loop

- Forest die out during glacial ages, reducing mechanism to remove CO$_2$ from atmosphere, increasing CO$_2$, allowing temperature to increase.