Glaciers and Ice Ages

Slides from lectures preceding Ice Age exercise

Eileen Herrstrom

herrstro@illinois.edu

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What Are Glaciers?

- **Def: sheets of ice on land that last for 1000s of years**
  - **The ice flows:**
    - **From higher elevation to lower, or**
    - **From thicker ice to thinner**

Transantarctic Mountains protrude through the ice.

https://commons.wikimedia.org/wiki/File:Mountain_(30724588702).jpg

One Type of Glacier

- ***Alpine glaciers (or mountain glaciers, or valley glaciers)***
  - **Ice flows downhill**
    - **Rockies, Cascades, Sierras, Alps, Andes, Himalayas**

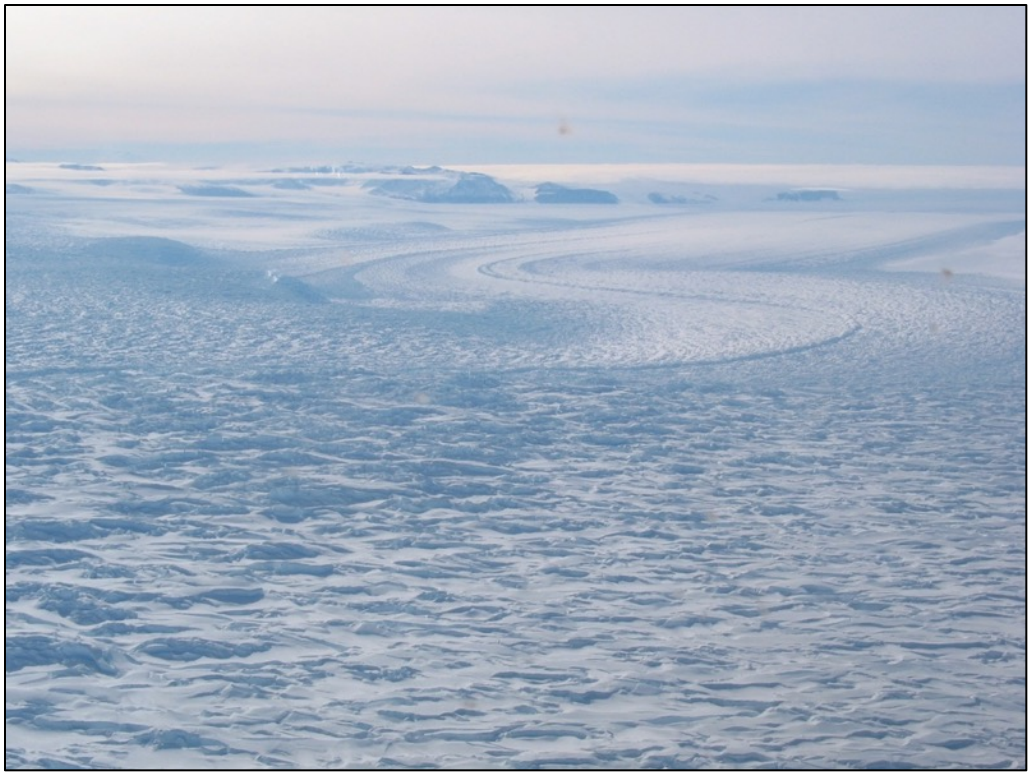
Aletsch is the largest glacier in the Alps.

https://commons.wikimedia.org/wiki/File:Grosser_Aletschgletscher_3178.JPG

Another Type of Glacier

- *Continental glaciers*
  - Cover large areas (10% of land today)
  - Ice flows outward
    - Antarctica
    - Greenland

Antarctic ice sheet



https://commons.wikimedia.org/wiki/File:David_Cauldron.jpg

Advance & Retreat of Ice

- **Depends on *glacial budget* = gains vs. losses**
  - **Gains = winter accumulation**
  - **Losses**
    - **Summer melting**
    - **Icebergs breaking off (*calving*)**
    - **Sublimation (*solid → vapor*)**

An iceberg is calving from a glacier.

https://commons.wikimedia.org/wiki/File:Fall_(7283079102).jpg

Glacial Budgets

Description of Budget	Gains vs. Losses	Volume Change	Movement of Ice Edge	Alpine Glaciers	Continental Glaciers
Positive	G > L	Increases	Margin advances	Spread to lower elevations	Spread out over more land
Neutral	G = L	Constant	Margin is stationary	No elevation change	No area change
Negative	G < L	Decreases	Margin retreats	Shrink to higher elevations	Shrink to cover less land

- **Glacial retreat does not mean ice flows back uphill!**
  - **Ice movement is <u>always</u> down or outward.**

Deposition by Ice

- **Debris carried by ice is dropped at margins when ice melts**
  - ***Till* = mixture of grain sizes (clay to boulders)**
  - **Till may contain *erratics*: rocks ≠ local bedrock**
  - **A mound of till is a *moraine*.**

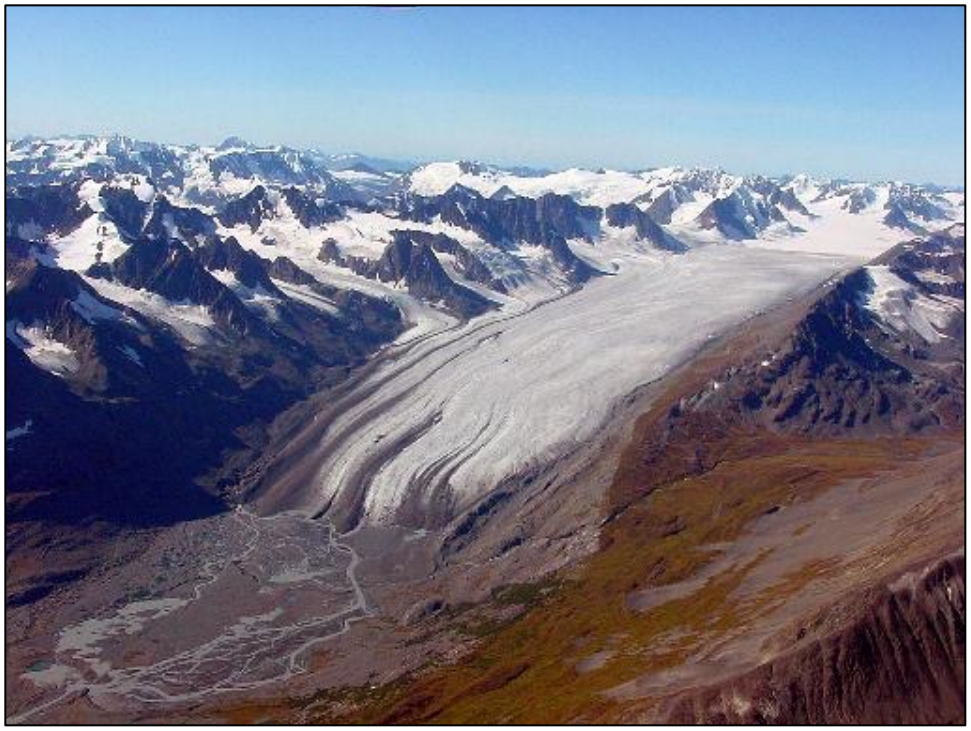
Closeup view of till with small erratics.

https://commons.wikimedia.org/wiki/File:Geschiebelehm_hg.jpg

Deposition by Meltwater

- **Glacial streams carry lots of sediment**
  - **It is considered glacial sediment, because it was once frozen in ice**
  - **But it is actually deposited by water**
    - ***Outwash*: sand & gravel**

Outwash is deposited in lower left corner.



http://www.earthscienceworld.org/images/index.html, Photo ID: iam8vi

Deposition by Wind

- **When outwash dries, wind picks up fine grains**
  - **It is still called glacial sediment, because it was once frozen in ice**
  - **But it is actually deposited by wind**
    - ***Loess*: deposits of wind-blown rock powder**

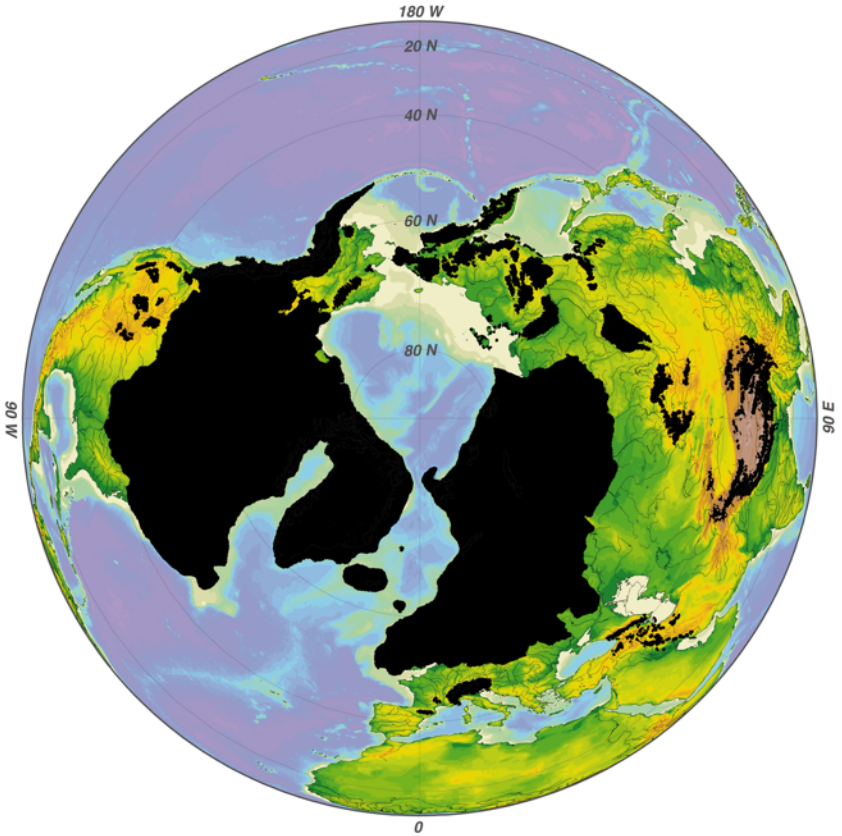
Loess can form near-vertical cuts and cliff faces.

Wikimedia.

The Ice Age

- **Pleistocene** Epoch of the Quaternary Period of the Cenozoic Era
  - 2,800,000 - 10,000 years ago
  - 5°C cooler (3-8°F)
  - 25% of land was covered by continental glaciers

Black represents ice.



https://commons.wikimedia.org/wiki/File:Iceage_north-glacial_hg.png

Glacial Cycles

- **Repeated advances & retreats in the Ice Age**
- **How do we know?**
  - **Depositional features: cross-cutting moraines, multiple layers of till**
  - **Composition of clasts in till: erratics in IL match rocks in Canada**

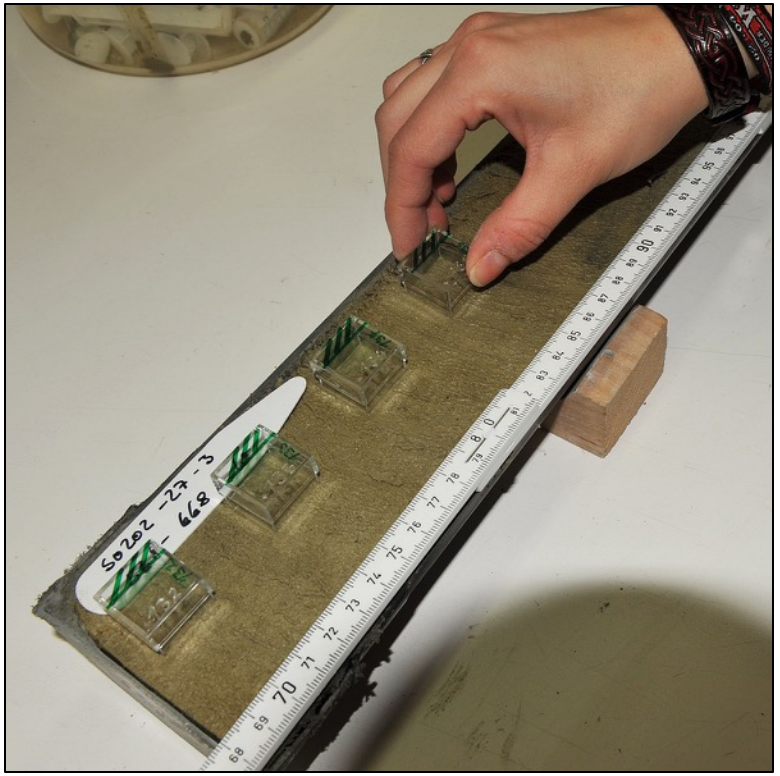
Two layers of till separated by outwash.

http://www.earthscienceworld.org/images/index.html, Photo ID: hflssn

More About Glacial Cycles

- Early 1900s: 4 advances / interglacial times
- Now, ~20 cycles recognized (~100,000 yrs long)
- How do we know?
  - Deep-sea sediments
  - Ice cores (from Greenland & Antarctica)
  - Both give a continuous record of temperature

Sampling a sediment core.



https://commons.wikimedia.org/wiki/File:Paleomagnetic-posi_hg.jpg

Older Ice Ages

- **Based on sedimentary rocks:**
  - ***Tillite*** **= lithified glacial till (large clasts in sandstone and mudstone)**
  - **Glacial striations**
  - **Best if combined**

Striated clast in tillite.

https://doi.org/10.1016/j.sedgeo.2019.03.003

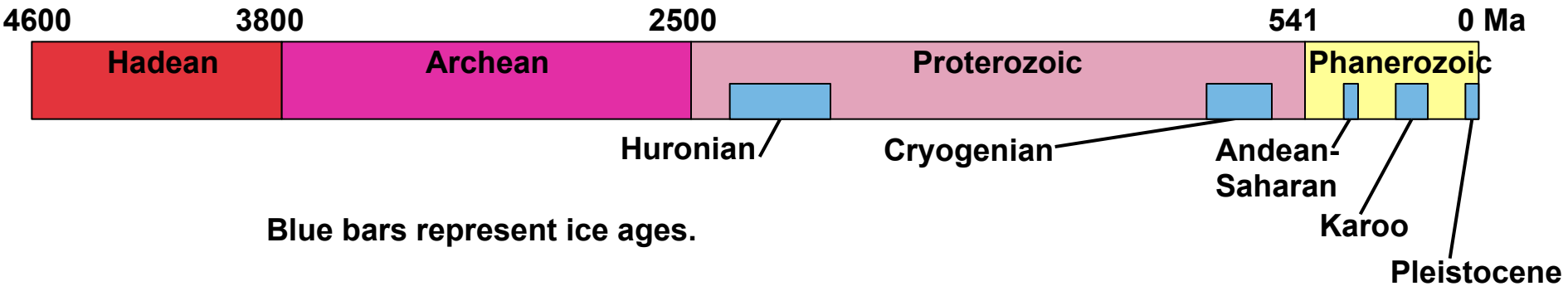
What Causes Ice Ages?

- **Explanation must include:**
  - **Onset of glaciation**

    time scale = millions of years

  - **Cycles of glacials & interglacials**

    time scale = thousands of years

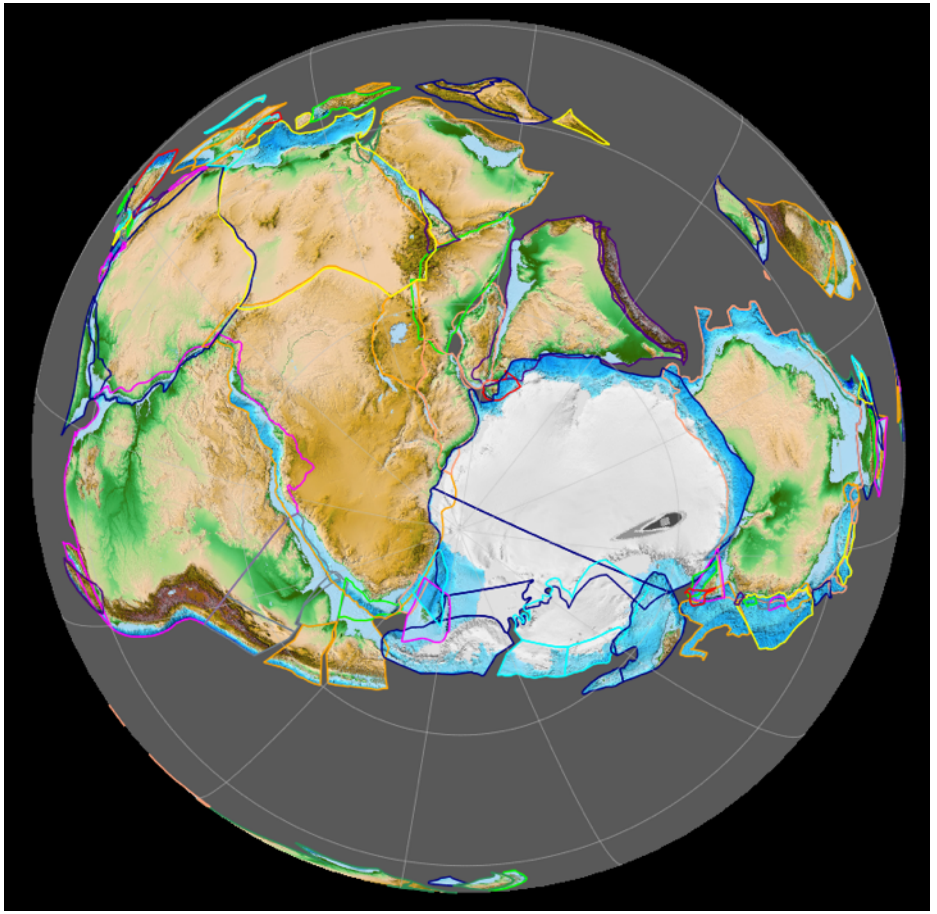


Onset of Ice Ages

- **Need continents near N & S Poles**
  - **Due to moving tectonic plates**
  - **Plate movements are slow:**

√ **o 1,000,000s of yrs**

Gondwana (420 Ma; view centered on South Pole). Glacial evidence found in SA, AF, IN, AU, AN.

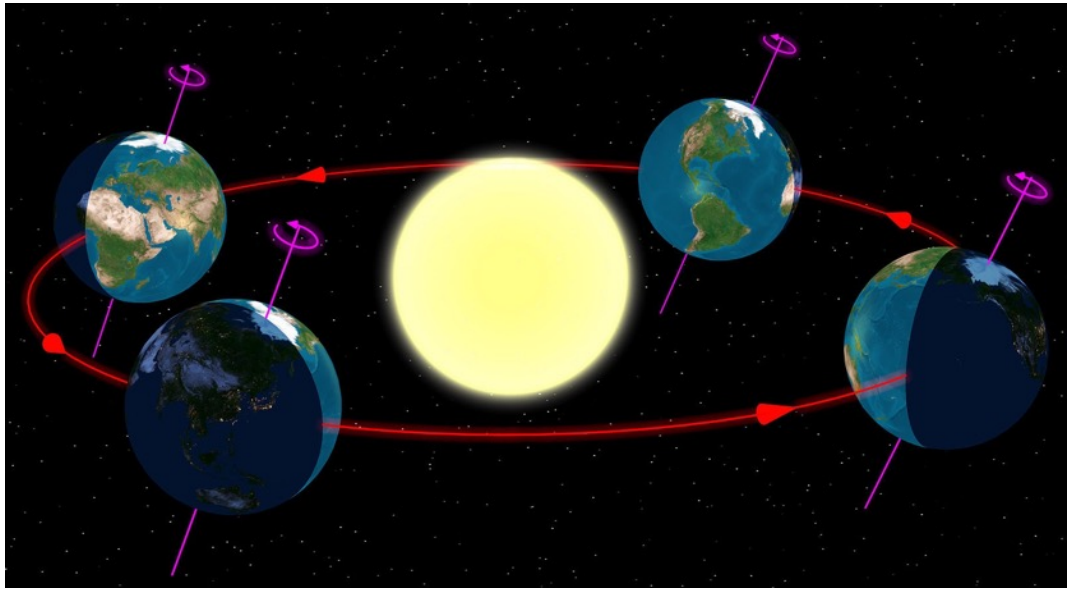


https://commons.wikimedia.org/wiki/File:Gondwana_420_Ma.png

Glacial Cycles

- **Due to changes in Earth's orbit around Sun**
  - **Affects seasons: wetter winters, cooler summers**
  - **Proposed in the 1920s**
  - √ **23,000-yr to 100,000-yr cycles**

Seaons change with orbit shape, axis tilt, and axis direction.



https://commons.wikimedia.org/wiki/File:North_season.jpg

Teaching Notes and Tips

This exercise is divided into three complementary sections. The exercise may be completed in one extended laboratory period, or individual sections may be assigned as separate, shorter activities or as homework.

Note that the Excel workbook file includes three worksheets that contain the key. The workbook given to students should have only the Insolation, Hydrogen and Oxygen worksheets.

In Part I, students would ideally handle physical samples of glacial sediments (till, erratics, outwash, and loess). Note that if the instructor uses physical samples, then some answers may need to be changed to match the specimens. Alternatively, the instructor may provide the sample images illustrated in the Glacial Samples file (PDF) either in electronic form or as hard copy.

Because computer software changes so rapidly, the instructions for accomplishing certain tasks with Excel might differ from those given in the student instructions. Thus, the instructor should be aware of possible difficulties using Excel.