Geog 1000 - Lecture 34

Periglacial Environments and Paleoclimatology

http://scholar.ulethbridge.ca/chasmer/classes/

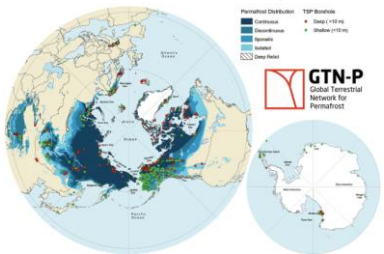
Today's Lecture (Pgs 422-434)

1. Exam questions from last week, and today
2. Extent of Periglacial and Global Permafrost
3. Factors affecting periglacial location
4. Periglacial processes
5. Periglacial Landscapes
6. Pingo development example
7. Permafrost types, importance in a changing climate
8. Example of permafrost change
9. Paleoclimatology and past climates

Extent of Periglacial = Global Permafrost

Permafrost: Soil and/or rock where temperatures remain below 0 degrees C for 2 or more years.

Periglacial: Landscapes that have near permanent ice cover.
→ Many different processes: permafrost, frost action, ground ice.

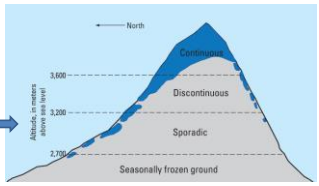


Northern hemisphere permafrost regions ~ 23 million km²

Factors affecting periglacial location

Latitude: Periglacial located in higher latitudes, especially in northern hemisphere

Altitude: Mountainous environments, edges of glaciers.

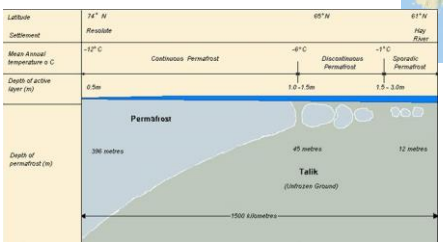


Ocean Currents: Cold currents reduce temperatures

Continentality: Extreme temperature variations = deeper freeze/thaw cycles

Factors affecting periglacial location

Example of Latitude: Permafrost transect line from Hay River to Resolute



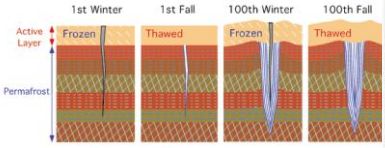
Periglacial Processes

Periglacial environments: Originally, edges of glaciers

Now, geomorphological term: landforms created due to freezing water.

A range of processes & landforms including:

- Ice wedges → Crack in ground from ice

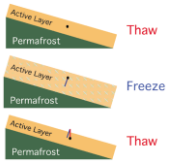


Causes formation of patterned ground →

Periglacial Processes

Solifluction (Gelifluction) → slow mass movement of melt water (from ice) and debris

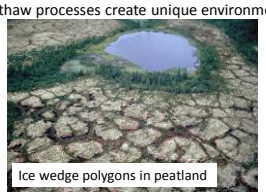
Frost Creep → movement of debris through frost-heave and settling



Periglacial Landscapes

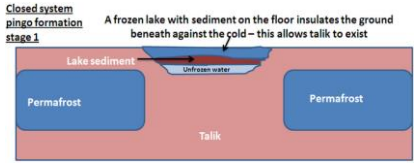
Geomorphology → Freeze and thaw processes create unique environments:


Frost Creep


Ice wedge polygons in peatland

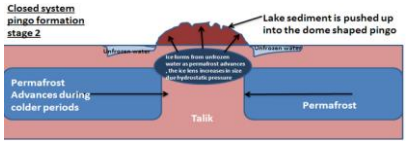

Palsas (low permafrost mounds)

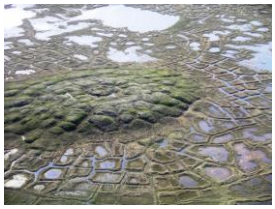
Pingo Development: Stage 1



Source: www.coolgeography.co.uk

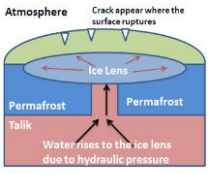
Pingo Development: Stage 2





Source: www.coolgeography.co.uk

Pingo Development: Stage 3



The formation of an open system pingo stage 3

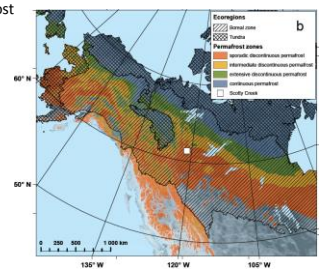
Eventual collapse

Permafrost Types

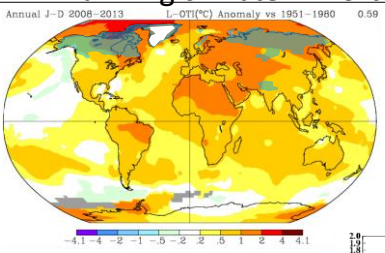
Continuous permafrost: Annual average temperatures = -7°C.
→ Found under all surfaces except deep lakes, rivers.
→ Averages 400 m, but may exceed 1000 m in depth.

Discontinuous permafrost: Sporadic patches of permafrost – become more dense poleward; less dense south of -1°C isotherm
→ Warmer areas have little permafrost

→ Susceptible to climate change…

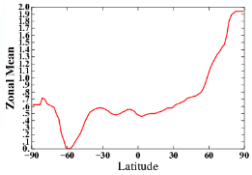


A warming climate in Northern Canada



Source Data:
Land → GISS
Ocean → NCDC/ER v. 3b

data.giss.nasa.gov



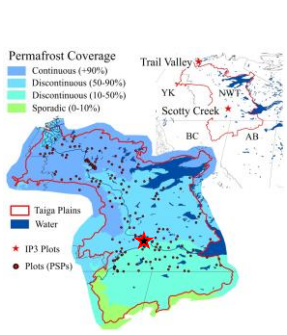
Canada's Discontinuous Permafrost Zone…

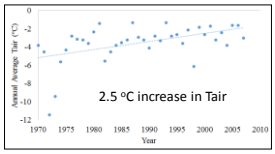
→Contains vast areas of peatlands (1/3 global soil C pool).

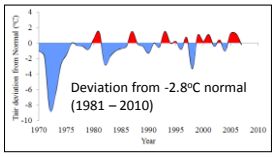
Permafrost thaw has significant implications for:

→Carbon cycling
→Water resources
→Northern climate
→Northern infrastructure

Fort Simpson, NWT: Discontinuous Permafrost

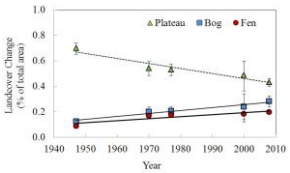






Snow-free period has increased by 14 days

Thawing permafrost plateaus

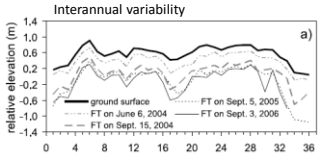


Total change in land cover area 1947 – 2008

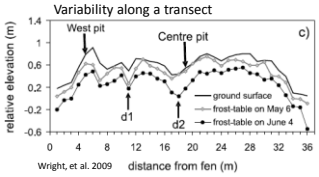
Plateau Areas ↓ 27%
Bog ↑ 16%
Fen ↑ 11%

Changes in depth to frost table

Interannual variability



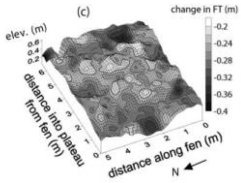
Variability along a transect



Frost table → Seasonally thawed soil layer

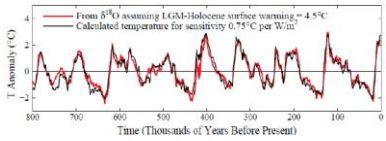
Increasing temperatures increase depth to frost table.

Increasing depth to frost table over time = plateau thaw



Paleoclimatology

Examining changes in the climate over past Earth history



→ Use "proxy" methods: Sources of climate data to determine past climate and changes.

→ Proxies can go back decades, centuries, millenia, or millions of years.

Paleoclimate Proxies

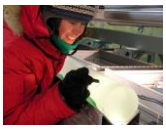
Historical Records

Example newspaper entry from the Charleston Courier, Dec. 1859.

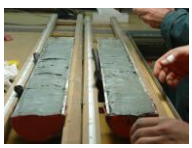
Coral reef: calcium carbonate, oxygen, past air temperature

Fossilized ocean microbes: Foram and diatom shells (calcium carbonate or silicon dioxide) = water chemistry during life

Ice cores: contain ancient gases, oxygen from past climate (up to 500,000 years)



Tree rings: width = fluctuations in precipitation & air temperature

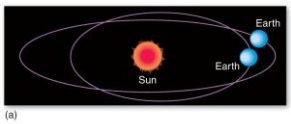


Ocean sediment cores: contain sediments, pollen, microbes → environmental conditions (up to 2,000,000 years)

Causes of Climate Variation: Astronomical

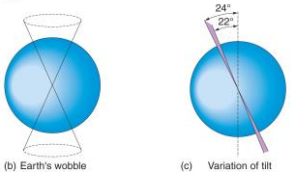
Orbital Variations: Tilt, eccentricity → *Milankovitch Cycles*

→ Orbital variations: 17.7 million kms every ~100,000 years



→ Axis 'wobble' or *precession* → roundness of the wobble on axis

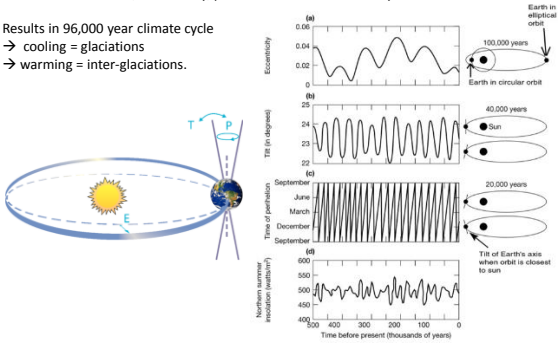
→ Axis tilt: Varies between 21.5° and 24.5°
→ Every 41,000 years.



Causes of Climate Variation: Astronomical

Orbital Variations: Tilt, eccentricity, precession → Milankovitch Cycles

Results in 96,000 year climate cycle
→ cooling = glaciations
→ warming = inter-glaciations.



Causes of Climate Variation: Solar Energy?

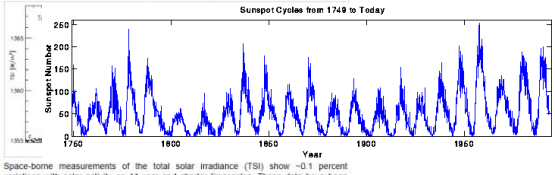
Textbook: No evidence that solar radiation output varies significantly

NASA: 11-year sunspot activity → Solar irradiance much higher during solar maximum

→ Global temperature increases by 0.1°C during solar maximum.

What does this mean?

Average air temperature → increased by 0.6°C over past century
→ solar heatinɑ = 25% of this change



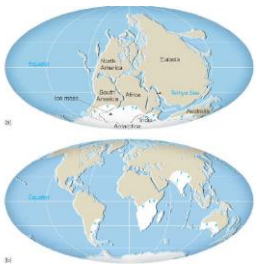
Space-borne measurements of the total solar irradiance (TSI) show ~0.1 percent variations with solar activity on 11-year and shorter timescales. These data have been corrected for calibration offsets between the various instruments used to measure TSI. SOURCE: Courtesy of Greg Kopp, University of Colorado.

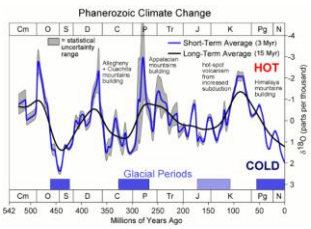
Causes of Climate Variation: Plate tectonics

Major glaciations → Some landmasses moved to higher latitudes.

→ Evidence of past glacial activity in Africa, India, Australia from movement of Gondwana, north.

Also mountain building = land above snow line.

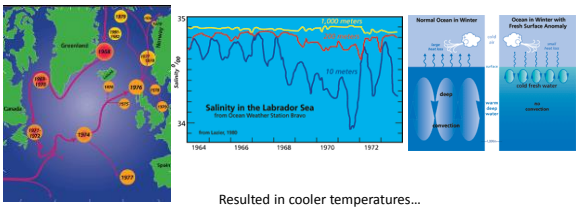




Causes of Climate Variation: Ocean currents

Changes in ocean currents, salinity, surface temperatures, rates of upwelling/downwelling

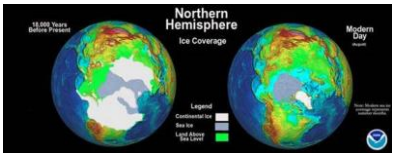
Example: Great Salinity Anomaly 1968 to 1982 → Pulse of fresher water
(Source: Woods Hole Oceanographic Institute)



Resulted in cooler temperatures…

Past Climates and Glaciations

North American Ice Sheet Retreat from Last Glacial Maximum:



What Triggers Ice Ages?

Pre-Cambrian (600 million years ago) → ice ages occurrence ~every 200 million years

During Cenozoic period (70 million years ago through today) → decreasing deep water temperature; increased ice sheets.

Present ice age → glacial advance & retreat occurred > 20 times → likely due to position of Earth, solar cycles, ocean circulation, atmospheric composition

52 – 57 million years ago → warm earth, trees in the Arctic and Antarctic

Past Climates and Glaciations

We are still within third major cooling period → began 3 million years ago!

52-36 million years ago → surface Tair dropped by 5-8 deg C
36-20 million years ago → surface temperature again dropped by 12 deg C.

→ Climate change over very long periods: plate tectonics.

→ Also, CO_2 in the atmosphere + water, methane trap solar radiation = warming.

Significant amount of C into atmosphere due to:

1. Degassing from metamorphic rocks
2. Weathering of organic C
3. Weathering of silicates
4. Burial of organic C

Reading for Wednesday:

Global climate change: Chapter 7; Pgs 240 - 248