AQA Geography A-Level

3.1.4: Glacial Systems and Landscapes

Essential Notes

Glacial systems and processes

Processes

Accumulation: The **addition of mass** (precipitation, usually snow) to the glacier. Mainly occurs at high altitudes at the source of the glacier.

Ablation: The **loss of mass** from the glacier. This includes meltwater, avalanches, sublimation, evaporation and calving.

Glacial budget: The **mass balance** of a glacier, i.e the **difference between accumulation and ablation**.

- A **positive** glacial budget shows **accumulation exceeds ablation**, so the glacier is **advancing**.
- A **negative** glacial budget shows **ablation exceeds accumulation**, to the glacier is **retreating**.

System features:

Glaciers are natural systems, meaning there are certain features that glaciers contain.

Inputs: **Additions** to the glacier (**accumulation**). Precipitation such as snow or hail are inputs to the glacier, as well as avalanches from other areas entering the system.

Outputs: Things that **leave** the glacier system, usually in the form of meltwater. All **ablation** processes are outputs.

Energy: Glaciers all have varying amounts of energy dependent on their **mass**, their **environment**, their **composition** and other factors. Glacial energy is usually in the form of **kinetic** energy as the glacier moves. This energy allows erosion to occur.

Stores: Also known as components. Stores are the **mass** that glaciers **hold**. This can be ice or sediment stored within the glacier.

Flows: Flows occur in glaciers through the **transfer** of **mass** or **energy**. There are flows in mass and energy from ice on the glacier to meltwater leaving the glacier. The glacier also moves through flows, such as compressional flow.

Dynamic Equilibrium: Equilibrium refers to a **state of balance**. This balance is **dynamic** when the processes causing the balance are **continual** (always occuring). For example, even if the glacier is constantly gaining inputs and losing outputs, if the amount of these are the same, the mass of the glacier does not change and the glacier is at dynamic equilibrium.

Feedback Loops: A feedback loop is a type of **chain reaction**, where one process leads to another process, leading to another process, and so on. There are two types of feedback loops: positive and negative.

In positive feedback, a process occurs, which causes another process to occur, which starts a chain reaction that **heightens** the first process.

Temperatures rise → Permafrost melts ↓

Greenhouse effect ← CO_2 released ↑

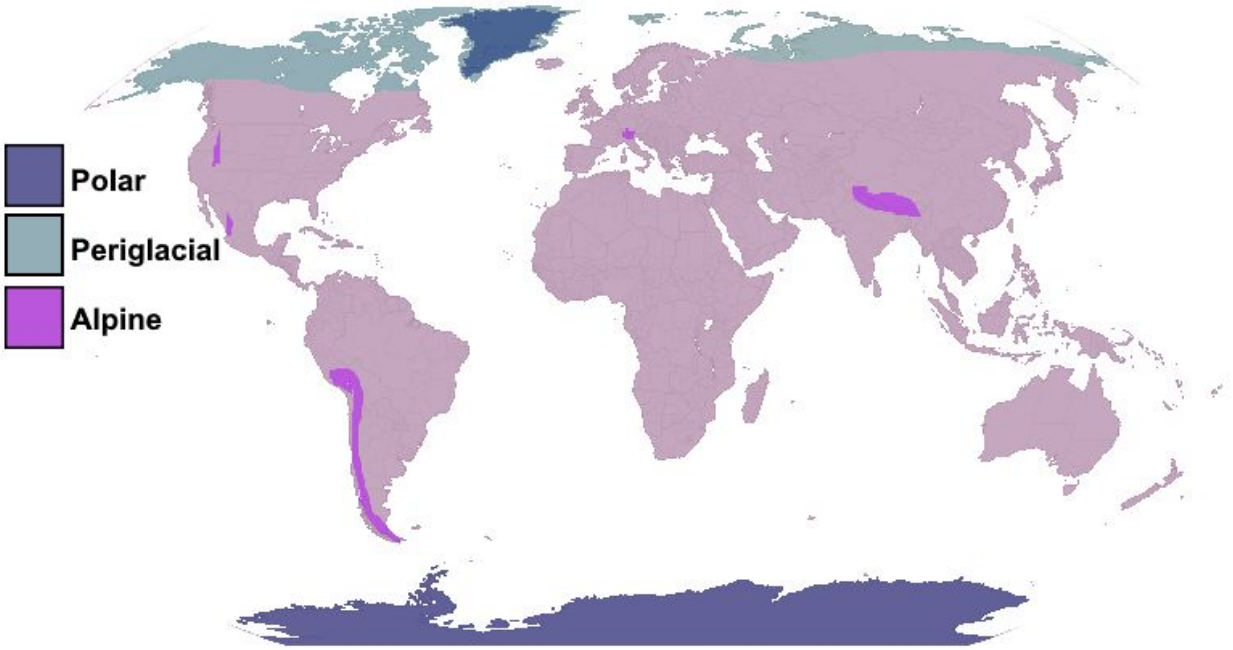
In negative feedback, the process that occurs is **counteracted** by an opposing process, causing the effects to cancel each other out and **nothing to change**.

Temperatures rise ↓ Permafrost melts ↓ More plants to take in CO_2 ↑ Greenhouse effect lessens ↑ Temperatures fall

Cold environments: nature and distribution

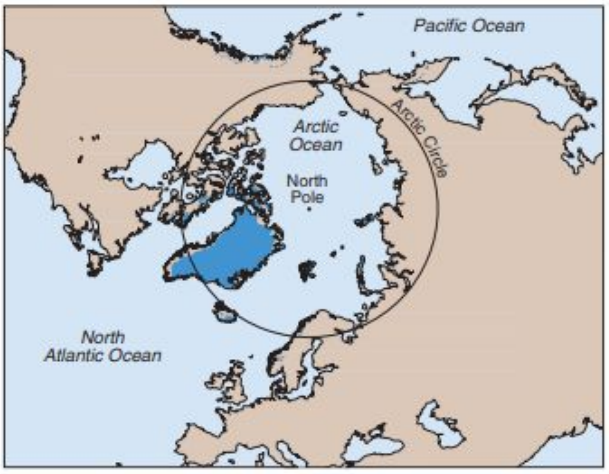
There are 4 main types of cold environment:

- **Polar** - areas at the **poles** (high **latitudes**) of the Earth. Polar regions lie within the Arctic Circle and the Antarctic Circle, and they are **consistently below freezing temperatures** and receive **little rainfall**.
- **Alpine** - areas of low temperatures in high **altitude**, **mountainous** regions. Alpine areas usually have fluctuating temperatures - Alpine summers can be above 0°C and wildlife is prevalent.
- **Glacial** - areas that **glaciers can be found in**. These areas must be cold enough consistently to facilitate glacial growth. Glacial environments can be in polar and alpine regions.
- **Periglacial** - areas found on the **edge** of colder environments, such as polar. These areas have permafrost (permanently frozen ground). Permafrost can be **continuous**, **discontinuous** or **sporadic**.

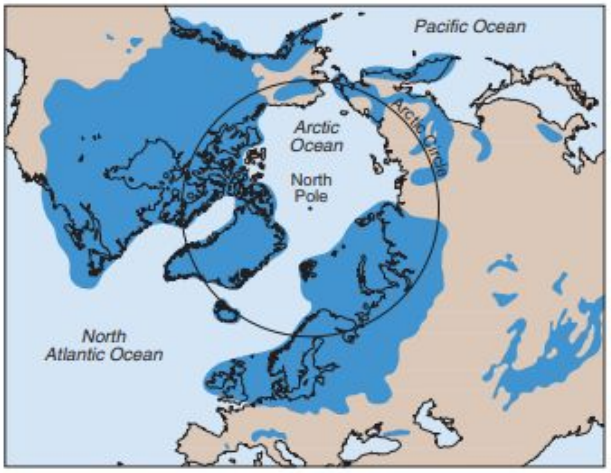


Pleistocene era - The most recent ice age. The period spanned from around 2.5 million years ago to 11,700 years ago. The most recent period of glacial advance was around 21,000 years ago, which is when the majority of glaciers were advancing.

Present distribution of ice sheets.



Last glacial maximum distribution of ice sheets.



Source: http://www.open.edu/openlearn/ocw/pluginfile.php/614637/mod_resource/content/1/e500_11_sci_sk1_05t.pdf

Characteristics of cold environments

Climate, soils and vegetation

Cold environments have characteristic features that are dependent on other features. Climate, soils, and vegetation interact with one another.

Due to the **cold climate** with **little precipitation**, polar and periglacial environments especially have **slow nutrient cycles**, meaning the soil is usually **deprived of nutrients**.

The cold, harsh climate with little rainfall also means only **highly adapted vegetation can grow**, such as mosses and lichen.These plants decompose slowly.

This **lack of nutrient rich vegetation** from the harsh climate causes the **soil to be low in nutrients**. The nutrient deprived, frozen soil also means that **little can grow**.

Types of Glacier: Warm based

Environment: Alpine
Climate: Fluctuating, warmer temperatures

Features: Lots of meltwater
Processes: High erosion from basal sliding, internal deformation also present

WARM BASED	Summer	Winter
Surface Temperature	≈5°c (above freezing)	≈-10°c. Large range between seasons.
Base Temperature	Just below 0°c (melting as it reaches PMP*)	Below 0°c. Less meltwater but still present.

Types of Glacier: Cold based

Environment: Polar
Climate: Consistently dry and cold

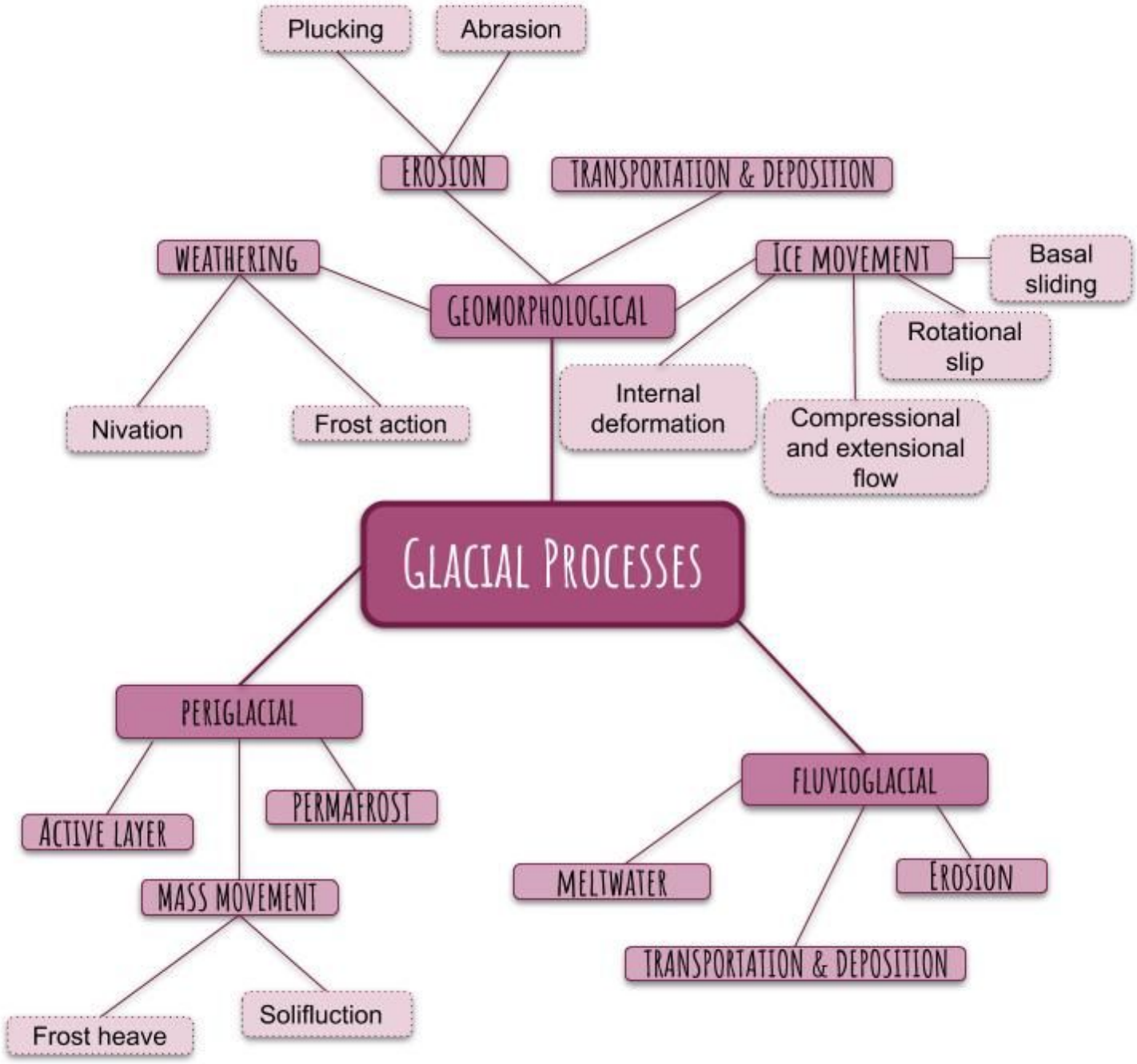
Features: Very little meltwater
Processes: Internal deformation only, very little basal sliding

COLD BASED	Summer	Winter
Surface Temperature	≈ -15°c or colder.	≈ -20 to -30°c. Sometimes colder.
Base Temperature	≈ -10°c or colder. Way below PMP*.	≈ -10°c or colder. Little change compared to summer.

***Pressure melting point (PMP):** The temperature at which ice melts under pressure. Deeper = more mass weighing down on base = more pressure on base = more friction = lower pressure melting point (so ice melts before 0°C).

Development of Glaciated Landscapes

Glaciated landscapes are shaped by **processes** that create **landforms**. The three main type of processes that create landforms are **geomorphological** (topography/rocks), **periglacial**, and **fluvioglacial** (water). These processes create glaciated, periglacial, and fluvioglacial landscapes.



Erosion

- **Plucking:** Rocks attached to bedrock or sides become **frozen** to the glacier. When the glacier moves, the rocks are pulled (**plucked**) from the landscape, leaving a jagged surface.
- **Abrasion:** A **sandpapering** effect caused by small rocks embedded within the glacier rubbing on bedrock. Usually leaves a smooth surface with scratches called **striations**.

Weathering

- **Frost Action:** Water gets into the cracks of rocks, freezes and then **expands** by around 10%. This repeated action puts pressure on a rock, eventually causing it to shatter and **break off**.
- **Nivation:** Common in periglacial environments due to the **fluctuating** temperatures. Nivation is a collective term for processes involving **snow and ice** that cause erosion.

Ice Movement

- **Internal Deformation:** The deformation of **layers of ice** or **individual ice crystals** caused by the pressure from the weight of the ice. This causes **some layers** to move **faster** than others, so different parts of the glacier can be further advanced.
- **Compressional Flow:** When ice hits a shallower gradient, friction causes the ice to slow down, **build up** and compress. This causes ice to get thicker.
- **Extensional Flow:** When ice meets a steep downhill gradient (usually when going over a hill), gravity forces the ice to **increase in velocity**. Friction causes the ice to thin out and extend, causing **crevasses**.
- **Rotational Slip:** Compressed ice becomes **trapped** in a hollow, but **gravity** causes it to continue to move **downwards**. Meltwater assists in moving the glacier in a rotational movement, causing it to continually **erode** the hollow.
- **Basal Sliding:** Glacier sliding over the bedrock. This is due to **meltwater** providing **lubrication** for the glacier to move.

Periglacial Processes

- **Active Layer:** The top layer of permafrost that **thaws in the summer**.
- **Frost Heave:** Water underneath rocks or ground freezes, **expands**, and thus forces the mass **upwards**.
- **Solifluction:** Mass movement of soil that becomes **waterlogged** when water is trapped between the active layer and the frozen permafrost. Waterlogged soil **flows** easily when gravity acts upon it (usually on a gradient).

Development of Landforms

Different **landforms** are created in certain cold environments. The table below shows which landforms arise from different environments.

		PROCESS		
		Geomorphological	**Fluvioglacial**	**Periglacial**
LANDFORM	**Erosion**	Corries	Meltwater channels	Patterned ground
		Arêtes	Kames	Ice wedges
		Glacial troughs	Eskers	Pingos
		Hanging valleys	Outwash plains	Blockfields
		Truncated spurs		Solifluction lobes
		Roches moutonnées		Terracettes
	Deposition	Drumlins		Thermokarst
		Erratics		
		Moraines		
		Till plains		

Geomorphological Landforms and Glaciated Landscapes

Erosional

Corries

Red Tarn, The Lake District
(Source:http://www.living-art.org.uk/Members/Daz_Hill/Helvellyn,_Swirral_Edge_&_Red_Tarn/)

Deep hollows caused when a small glacier develops in a depression. Through **rotational slip** and **erosion** of the back wall, the hollow is deepend into a corrie. Water can fill corries to make **tarns** (lakes).

Arêtes

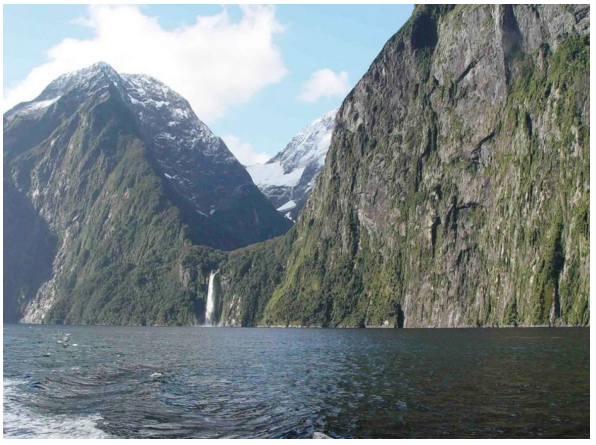
Striding Edge (Helvellyn), The Lake District (Source:https://where2walk.co.uk/lake_district/classic_circuits/helvellyn-by-the-edges/#jp-carousel-31175)

A **knife-edged ridge** formed between two corries. Erosion (abrasion and plucking) of the steep back wall leaves the edge remaining.

Glacial Troughs

Glen Geusachan, The Cairngorms
(Source:https://www.flickr.com/photos/28183399@N03/3720916604)

Hanging Valleys



Fiordland National Park, New Zealand
(Source:http://www.lobster.co.nz/the-source/gallery/image-22/)

A **u-shaped valley** formed by a glacier **bulldozing** and eroding through a river (v-shaped) valley. This leaves smooth but steep **truncated spurs** on the valley sides and a wide, flat valley floor.

A smaller **u-shaped valley** caused by a **tributary glacier**. The smaller glacier does not have enough **energy** to erode to the valley floor, leaving a hanging valley. **Waterfalls** often form here.

Roches moutonnées

Myot Hill, Falkirk, Scotland
(Source:https://www.geograph.org.uk/photo/164736)

A mound of rock shaped by a glacier flowing over it and eroding it. The glacier would be moving right to left in the picture. The glacier hits a large, hard rock. It **abrades** one side as it moves onto the rock, and **plucks** the other going over it.

Depositional

Drumlins

Eureka Drumlin Field, Montana
(Source:http://jupiter.plymouth.edu/~sci_ed/Turski/Courses/Earth_Science/Images/4.drumlin.jpg)

Erratics

Norber Erratics, Yorkshire Dales
(Source:https://www.tripadvisor.co.uk/Attraction_Review-g503988-d4932501-Reviews-Norber_Erratics)

When a glacier hits an **obstacle** that cannot be eroded, deposition from underneath the glacier **builds up** behind the obstacle. The glacier moves over the large mound and then drags excess deposition over the other side. This causes a **tear drop** shape with a long, **tapered** edge.

A large **boulder** that is of a **different rock type** to surrounding rock. Theoretically, this boulder would have been **broken off** by weathering and erosion, then **transported** by a glacier and **deposited** when it has been moved to a different location. The glacier deposits when it **loses energy**.

Moraines

Wrangell-St. Elias, Alaska
(Source:https://www.nps.gov/articles/lateralmedialmoraines.htm)

Deposits of eroded material that is transported with the glacier. There are different types of moraine:

Lateral: material deposited on the **sides** of a glacier, leaving a ridge when the ice melts.

Medial: formed from two lateral moraines meeting in the **middle** of a glacier and depositing material.

Ground: carried **under** the glacier and abraded between the glacier and valley floor.

Recessional: Forms at the **end** of a glacier when a **retreating** glacier stays stationary for a sufficient time. Usually shows smaller, seasonal retreats.

Terminal: Material deposited at the **snout** of a glacier on the valley floor.

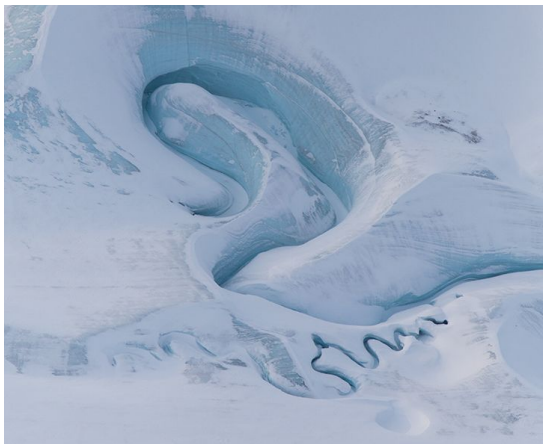
Till Plains

Saskatchewan Glacier, Alberta
(Source:http://www.albertawow.com/hikes/Saskatchewan_Glacier/Saskatchewan_Glacier.htm)

Till is **unsorted** glacial material formed through **erosion** and **weathering**. Till plains form when an ice sheet detaches from the main glacier and melts, causing all of the till **on top of** and **within** the glacier to **deposit** on the valley floor.

Fluvioglacial Landforms and Fluvioglacial Landscapes

Meltwater Channels



Ellesmere Island, Canada
(Source:https://earthobservatory.nasa.gov/images/90004/meltwater-channels-on-ellesmere-island)

Streams of meltwater (melted glacier) formed by higher temperatures. Channels can flow within, in front of, and around the glacier. Due to the pressure from the glacier, they are **highly erosive**. If meltwater channels lose energy, they **deposit** sorted material in small islands, creating **braided channels**.

Kames

Kirriemuir,Scotland (Source:https://upload.wikimedia.org/wikipedia/commons/6/62/Kame_below_Wester_Pearsie_-_geograph.org.uk_-_605724.jpg)

Meltwater transports and deposits eroded material on a retreating glacier. Material collects **within a depression** on top of the glacier. When the glacier melts completely, the material is left on the valley floor. This leaves a mound of (usually fine) material.

Eskers

The Kippet Hills Esker, Aberdeenshire
(Source:http://earthwise.bgs.ac.uk/images/3/30/P219697.jpg)

Outwash Plains

Rendu Glacier, Alaska
(Source:http://www.geo.mtu.edu/KeweenawGeoheritage/Glaciers/Outwash.html)

A long, winding **ridge** of glacial deposition. An esker is a mould of glacial **meltwater channels**. Material is deposited when the subglacial meltwater channel loses energy. Due to the high **hydrostatic pressure**, the mound builds up and retains its shape.

When a glacier recedes, a large amount of meltwater is released due to the higher temperatures melting the ice. The meltwater loses energy as it is under less pressure, so it **deposits** the material in front of the glacier. The deposits can create **alluvial fans**.

Periglacial Landforms and Periglacial Landscapes

Patterned Ground

Stone Rings, Svalbard
(Source:https://commons.wikimedia.org/wiki/File:Permafrost_stone-rings_hg.jpg)

In **permafrost** under the **active layer**, **frost heave** causes stones around the ice lens to be **shunted** upwards. Fine sediment fills the space to stop larger rocks. Polygons on flat surfaces, or stripes on steeper inclines.

Ice Wedges

Banks Island, Canada
(Source:https://www.researchgate.net/publication/286392120_Ice-wedge_growth_and_casting_in_a_Late_Pleistocene)

Water infiltrates small cracks in the permafrost and expands on freezing (**frost action**). Water then fills the expanded ground. The process repeats and leaves a large ice wedge.

Pingos

Blockfields

Pingo National Landmark, Canada
(Source:http://www-personal.umich.edu/~kpetaine/visuals/album/NLand/Pingo/)

Ground is forced upwards through **frost heave** of an **ice lens**, leaving a mound. The mound can be an **open** or **closed** pingo.

Broad Crag, The Lake District
(Source:http://www.summiteer.co.uk/2013/Aug13/ScafellP22/SP22.html)

A rock-strewn landscape caused by extensive **frost action** of the landscape.

Solifluction Lobes

Seward Peninsula, Alaska
(Source:http://www.adfg.alaska.gov/index.cfm?adfg=viewinglocations.nomecouncil34to53)

When the active layer thaws and **solifluction** occurs, tongue-shaped lobes of soil fall down a slope.

Terracettes

Kingston near Lewes, The South Downs
(Source:http://www.geograph.org.uk/photo/1822067)

Formation of terracettes is not wholly known. However, in periglacial environments, **frost heave** causes soil to push upwards. It then falls downhill, which is thought to cause the steps, similar to **creep**.

Thermokarst

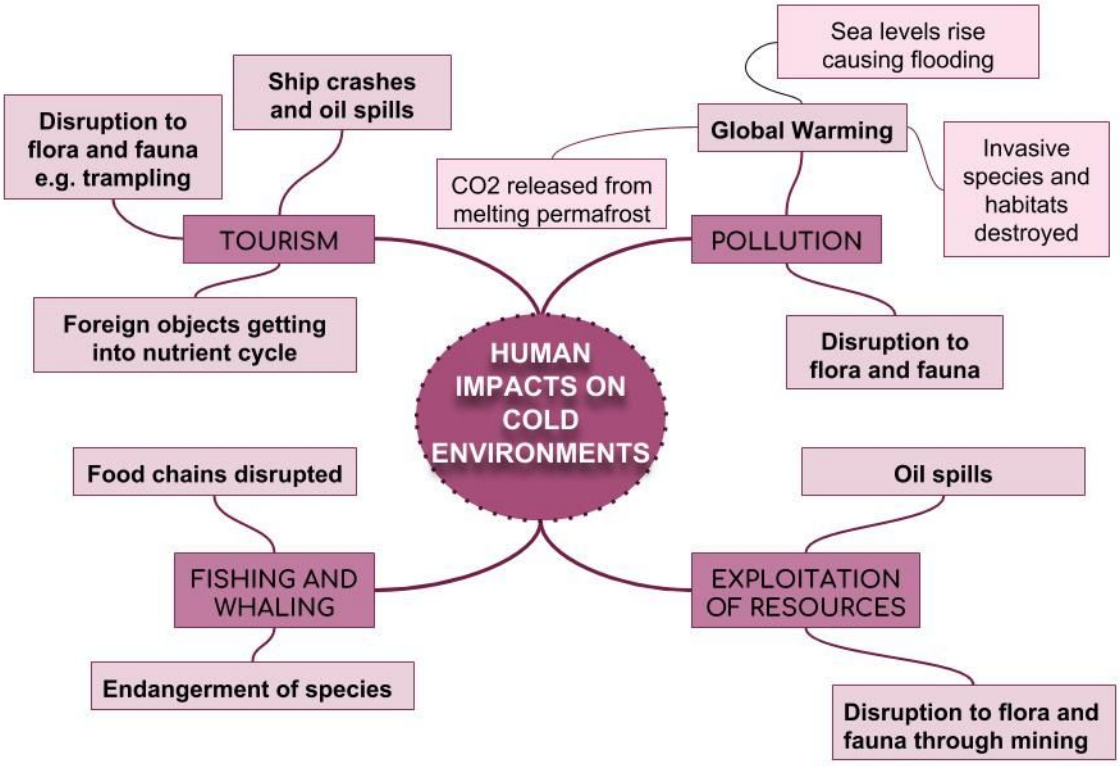
Hudson Bay Lowlands, Canada
(Source:http://www.ougseurope.org/index.php?id=39)

Marshy, **boggy** wetlands caused when **permafrost melts**.

Environmental Fragility and Human Impacts on Cold Environments

Environmental Fragility: The concept of an environment being **vulnerable and at risk**, as it lacks the **ability to be resilient** and **adapt** to **changes**.

Cold Environments are sometimes classed as environmentally fragile because they are **highly adapted** and have a **slow nutrient cycle**, meaning small changes can have large impacts.



Management of Cold Environments

Current	Future
Government Agreements and Treaties for Conservation (e.g. Antarctic Treaty)	Further developments into renewable energy that will lesson CO2 emissions
Government Agreements and Treaties for climate change (e.g. The Paris Agreement)	Possible need to have further protection of oil exploitation as finite resources run out
Charity campaigning (e.g. Greenpeace)	Stricter policies for reduced pollution
Sustainable Tourism	Flooding mitigation if sea levels rise
Sustainable 'green' energy	