

Periglacial processes, features & landscape development

3.1.4.3/4 Glacial Systems and landscapes

What you need to know
Where periglacial landscapes are found and what their key characteristics are
The range of processes operating in a periglacial landscape
How a range of periglacial landforms develop and what their characteristics are
The relationship between process, time, landforms and landscapes in periglacial settings

Introduction

A periglacial environment used to refer to places which were near to or at the edge of ice sheets and glaciers. However, this has now been changed and refers to areas with **permafrost** that also experience a seasonal change in temperature, occasionally rising above 0 degrees Celsius. But they are characterised by permanently low temperatures.

Location of periglacial areas

Due to periglacial environments now referring to places with permafrost as well as edges of glaciers, this can account for one third of the Earth's surface. Far northern and southern hemisphere regions are classed as containing periglacial areas, particularly in the countries of Canada, USA (Alaska) and Russia.

Permafrost is where the soil, rock and moisture content below the surface remains permanently frozen throughout the entire year. It can be subdivided into the following:

- **Continuous** (unbroken stretches of permafrost)
- **extensive discontinuous** (predominantly permafrost with localised melts)
- **sporadic discontinuous** (largely thawed ground with permafrost zones)
- **isolated** (discrete pockets of permafrost)
- **subsea** (permafrost occupying sea bed)

Whilst permafrost is not needed in the development of all periglacial landforms, most periglacial regions have permafrost beneath them and it can influence the processes that create the landforms. Many locations within extensive discontinuous and sporadic discontinuous permafrost will thaw in the summer months. The surface layer that seasonally thaws is known as the **active layer**.

Periglacial processes

Periglacial environments are characterised by the large amount of angular rock which lies strewn across the land surface. The angular shape of the material suggests that rock fracturing is responsible for its creation and regular freeze thaw processes are at work. Extensive areas of angular rock are called **felsenmeer**. The temperature is critical in developing this landscape: between -4 and -15 degrees Celsius.

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Periglacial ground surfaces are influenced by ground ice, which is why the permafrost is an important feature in many periglacial areas. The most common type of ground ice is **pore ice**, which develops in the spaces between particles of soil. **Needle ice** is also important and are slices of ice that penetrate down through the soil. Needle ice is particularly important as it loosens soil particles, making them available for erosion and mass movement. Needle ice encourages the process of **frost creep**, which is where soil particles on a slope show a dominant movement downhill under the force of gravity. Particles are dislodged and elevated by the expansion of freezing ground and when the ground thaws the particles drop back down even further on the downslope side.

Frost heave also occurs, whereby the ground freezes and pushes material upwards with ice expansion, creating indentations on the ground. This continual process can result in loosened material on the surface.

As well as the mass movement process of frost creep, other types include solifluction, gelifluction and rockfalls.

- **Solifluction** – slow downslope flow of saturated soil, often forming lobes of movement and terracettes.
- **Gelifluction** – a periglacial category of solifluction where the downslope sliding movement of seasonally thawed and saturated soil material is facilitated by an impermeable layer of permafrost beneath.
- **Rockfalls** – frost shattering loosens materials on steep rock faces and it falls under the force of gravity.

Processes of erosion also take place in periglacial areas. **Nivation** is the name for a group of processes which carve out depressions in the ground. Snow builds up in a sheltered/shaded natural shallow depression and even in the warmer summer months, the snow doesn't melt as often, even in warmer months, temperatures don't exceed 0 degrees Celsius. During the winter, further snow falls and pressure turns the snow into neve/firn ice. Freeze thaw weathering occurs at the edge and along the bottom of the depression, creating loose material. The weathered material is then removed from the bottom of the feature by gelifluction.

Eolian erosion is a result of strong winds which are characteristics of periglacial regions. Winds often move large amounts of loose, unconsolidated particles and sediments. With very little vegetation to bind and protect surfaces combined with drying air conditions, there is much exposure of fine, loose material that has been deposited in outwash plains. The amount moved can vary across the year. More material is wind-blown during the summer months as the melting of snow and ice allows for looser drier material to be available on the ground. Deposits of wind-blown, fine, soil particles can lead to the accumulation of **loess soils** many hundreds of kilometres from their source.

Fluvial erosion also takes place but is seasonal. During winter months when most water is stored as snow and ice, streams are non-existent, whereas in the summer months' rivers will appear. The differences in seasonal discharge is vast. The concentration of the discharge in a short time period creates some particular features. These short-lived streams tend to have poorly developed

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shallow braided channels. When discharge is suddenly reduced, large quantities of gravel and boulders are left on the landscape where the flow was taking place. Another characteristic of periglacial streams is that their channels can be braided with deep pools. Braided channels develop when a stream passes over a network of ice wedges and the river flow divides into several interlinking river channels. Heat from the flowing water causes the ice wedges to melt, producing the pools.

Landforms

There are a range of landforms that develop in a periglacial environment.

- **Patterned ground:** Patterned ground is a term given to the ground which has surface material distributed across it in a pattern. The examples of patterned ground include stripes, circles, polygons, ovals and garlands.

Circles, ovals, garlands and polygons are found on flat ground. They are formed when ice lenses grow in the soil and the constant ice expansion and thawing make the ground surface uneven. This occurs as a result of frost heave. The ice lens pushes material up to the surface and fine sediments fill in the gaps left by the stones so the stones don't fall back down during the summer melt. When the stones reach the surface, the larger stones roll down to the side of the uneven ground and the finer material stays in the middle. This leaves stone circles, garlands, ovals or polygons. Where the gradient of the land is steeper, stripes will form instead, due to the impact of gravity on the process.

- **Ice wedges:** Ice wedges are vertical masses of ice that penetrate down to 10 metres from the surface in some cases. They are formed as a result of the large amount of ground ice present and following significant temperature fluctuations. During the summer, meltwater will enter a ground crack and then freeze when the temperature drops. This causes an expansion of around 9% which fractures the surrounding material and makes the wedge deeper and wider. In the intense cold of winter, the surrounding soil contracts, creating the gap between the developing ice wedge and adjacent soil into which more water can infill. This process of thaw and freeze will continue to occur over time and the ice wedge will continue to widen and deepen.
- **Blockfields:** Blockfields are extensive areas of angular rock that have been created by regular freeze-thaw activity fragmenting exposed rock in situ. The material is left strewn across the level ground with blocks representing more homogenous lithology and the gaps where the bedrock had more weaknesses and/or joints. Large areas of these blocks are called **Felsenmeer**. Where this occurs on rock faces on a gradient, **scree** will be left at the bottom of the slope where **talus** accumulates.
- **Pingos:** Pingos are hills with an ice core. They are between 3 to 70 metres in height and have a diameter between 30 to 1000 metres. Most pingos are circular in shape. Smaller pingos tend to have a curved surface, whereas larger ones usually have exposed ice at their top and the melting of this exposed ice can form a crater.

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Sometimes the craters can be filled with water forming a lake. The ice in the centre of the pingo accumulates because of hydrostatic pressure or groundwater flow.

The development of a pingo begins with a lake occurring where there is no permafrost beneath it in an area of discontinuous permafrost. The lake gradually fills in with sediment and permafrost extends under the lake, isolating the remaining water in the lake's sediments. Continued freezing of the old lake sediments generates an expanding ice core that exerts upward pressure towards the surface. The overlying weight of this core and permafrost layers press down on ground water even further below the surface, which rises up, through the permafrost gap to meet – and freeze to – the ice core. This migrating pore water then begins to expand the segregated mass of ice at the core of the developing pingo, causing the surface 'hill' to rise even more.

Artesian pingos develop when water is channelled to a particular location at the lowest elevation, where it freezes just below the ground surface and grows.

- **Solifluction lobes:** Solifluction lobes are created when the saturated active layer of soil is thawed, usually during the summer months. The gradient of the ground is important too as these lobes will only form on slopes. Winter freeze-thaw weathering loosens material while summer thaw melts the ice content and then it will flow down the hill. When the gradient changes again and flattens out, the material flow slows and is deposited in a tongue shape.
- **Terracettes:** Terracettes are a series of small ridges in the ground, underneath vegetation, on a sloped piece of land. They are formed when the active layer thaws and gravity allows material to slump down underneath the vegetation. Frost creep is an integral process in the formation of terracettes and can make them larger, as material is lifted by the ice and then dropped.
- **Thermokarst** is an irregular land surface consisting of hills and hollows formed when permafrost thaws.

The relationship between process, time, landforms and landscapes in periglacial landscapes

There are features in Britain that are actively developing that may have commenced in much colder conditions as the last glaciation ended. Scree slopes on the Lake District fells above Wastwater are largely composed of freeze-thaw talus shattered, it has been proposed, thousands of years ago when periglacial conditions characterised northern Britain as the ice retreated. However, they are still added to each winter as sub-zero temperatures cause the same process to be activated, although at a much reduced rate than can account for their present volume and size under current climate conditions.

Other periglacial features are relic features from 10 000 years ago, including the sand deposits of the Breckland in Norfolk, which are thought to be aolian deposition that accumulated as the last ice sheets retreated leaving periglacial conditions for a while.

Canada's periglacial landscape

Specification topic: Periglacial processes, features and landscape development 3.1.4.3 & 4

Case study: Canada

A periglacial environment describes conditions near, or at the edge, of ice sheets and glaciers. However, this term has now been changed and refers to areas with permafrost, areas where freeze-thaw is a dominant process and areas which have a seasonal change in temperature, including increases above 0 degrees Celsius. More than 50% of Canada is covered by some form of permafrost, from continuous permafrost in the far north and around the majority of Hudson Bay, to – as you move south – extensive discontinuous-, sporadic discontinuous- (middle belt of Canada), to isolated patches- (eastern Canada particularly) of permafrost. The approximate southern third of Canada is largely permafrost-free other than in the Rocky Mountains in British Columbia and western Alberta.

Features and landscape development

Patterned ground is a term given to terrain which has material distributed across it in a pattern. The examples of patterned ground include stripes, circles, polygons, ovals and garlands. Circles, ovals, garlands and polygons are likely to be found on flat ground. They are formed when ice lenses grow in the soil and the constant growth and thaw will make the ground surface uneven. The lens pushes material up to the surface and fine sediments fill in the gaps left by the stones so the stones don't fall back down. When the stones reach the surface, the larger stones roll down to the side of the uneven ground and the finer material stays in the middle. This leaves stone circles, garlands, ovals or polygons. Where the gradient of the land is steeper stone stripes will form instead. These are found in the North West Territories in Canada.

Ice wedges are vertical masses of ice that extend down to 10 metres from the surface in some cases. During the early summer, meltwater will enter a winter-formed ground-contraction crack and then freeze when the temperature drops. This causes an expansion of around 9% which compresses the surrounding material and makes the ice wedge deeper and wider. This ongoing process creates larger ice wedges as time goes on. Examples of these can be found across northern Canada.

Ice wedges can develop polygon shapes tens of metres wide in peatland to produce another form of patterned ground. In the permafrost peatlands of the Hudson Bay Lowlands which consist, largely, of dry sphagnum massive ice wedges occur in brown polygons extending down 2-3 m. from the surface. The contraction of the peat in winter into regular polygon shapes creates the cracks in which ice wedges develop.

Blockfields are areas of angular rock that have been created by regular freeze-thaw activity and the material is left strewn across the ground. Extensive areas of these blocks are called Felsenmeer. These are found in northern Manitoba.

Canada's periglacial landscape

Pingos are ice-cored hills with a height between 3 to 70 metres and a diameter between 30 to 1000 metres. Most pingos are circular in shape. Smaller pingos tend to have a curved top whereas larger ones usually have exposed ice at their top and the melting of this ice can form a crater. Sometimes the craters are filled with water forming a lake. The ice in the centre of the pingo is thought to accumulate because of cryostatic pressure and groundwater flow. The development of a cryostatic pingo begins with a lake with no permafrost beneath it. The lake then fills in with sediment and permafrost isolates the remaining water in the lake's sediments. Continued freezing of the old lake sediments generates enough pressure to move pore water upwards towards the surface. This pore water then begins to freeze to form a segregated mass of ice at the core of the developing pingo. Artesian pingos develop when a supply of water is channelled to a particular location where it freezes just below the ground surface. Examples of pingos are to be found on Prince Patrick Island, Northwest Territories, Canada. They are up to over 100 m. across and still retain their sediment covers but it is expected that as they continue to grow internally, the sediment cover will be ruptured to expose the ice core. However, scientists studying the pingos are still unsure where the free water is coming from and how it is being transferred through frozen ground material to enable the features to continue to grow. The largest pingos are dated at less than 10 000 years old with many of the smaller ones just a few centuries old. These young ones can grow vertically by as much as 1.5 m. each year.

Solifluction lobes are created when the active layer of soil is saturated with fluid water and poorly drained, resulting – even on shallow gradients - with previously weathered and loosened material flowing slowly downhill. After extended periods of persistent melting these conditions can arise. Where the gradient changes again and flattens out, the material is deposited in a tongue shape. These lobes can be seen in the Yukon Territory in Canada. Gelifluction is a form of solifluction restricted to periglacial environments where the impermeable sub-surface layer over which the active layer flows, is permafrost.

Terracettes are ridges in the ground, underneath vegetation, on a sloped piece of land. They are formed when the active layer thaws and gravity allows material to slump down underneath the vegetation.

Thermokarst is an irregular land surface consisting of hills and hollows formed when permafrost thaws. Both terracettes and thermokarst are found across central and northern Canada.

Exam style questions

1. Describe the various processes that operate in periglacial regions (6)
2. Describe the common landforms found in periglacial regions (6)
3. Analyse the links between climate, process and landform which lead to the formation of periglacial landscapes. (9 marks)

Canada's periglacial landscape

1. Describe the various processes that operate in periglacial regions (6)

For a 6-mark response, the candidate should be focusing in on 3 processes minimum. A clear description of how they work should be given. The processes that may be developed the best are:

- Solifluction/gelifluction
- Freeze thaw weathering
- Frost creep

2. Describe the common landforms found in periglacial regions (6)

Again, 3 landforms should be described. Here, it is important for the candidate to recognise that the examiner is not looking for an explanation of how they are formed but a description of their characteristics. The focus of the answer should be on the material, the location and the size.

An example of this would be solifluction lobes. A description of them would be that they are found extending in material surges down a slope. Each one is a mound of active material, generally less than a metre high, which is shaped like a tongue. The end nearest the uphill section is flat and the material is spread out whereas the material at the point where the gradient flattens, bulges out. Polygons, ice wedges and pingos are equally valid to describe.

3. Analyse the links between climate, process and landform which lead to the formation of periglacial landscapes. (9 marks)

AO1 – Knowledge and understanding of the climate, physical processes, environments and landforms where periglacial landscapes develop.

AO2 – Analyses the links and interconnections between climate (and therefore geographical location), process and landforms which contributes to the development of the landscapes.

To achieve level 3, the key focus is the analysis of links. Candidates should start their response by outlining Canada's location and its ice coverage during the Pleistocene. Awareness of the country's latitude linked to ice coverage is needed in order to discuss the relic periglacial features that would have been created during the ice age, on the fringes of ice sheets. More important however, is to link latitude with the fact that Canada has large amounts of permafrost which leads to current periglacial processes occurring. The landscape, therefore, has a combination of relic and active periglacial features.

Explain the formation of 3 landforms, clearly linking the processes to the climatic conditions and how the climate enables the processes to occur and therefore the landforms to be created.

Example – ice wedges are formed when water enters the winter contraction-cracks in the ground and freezes against the permafrost. Water enters the cracks during the milder summer months and then freezes and expands in the winter months, enlarging the wedges. Seasonal variation of temperature either side of freezing point is key, together with the intensity of prolonged cold to contract the ground.

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Q1	<i>True or False?</i>	
A	Permafrost refers to permanently frozen ground.	
B	Periglacial areas don't experience temperatures above zero degrees Celsius.	
C	Fluvial erosion is caused by water.	
D	Eolian erosion is caused by the glacier.	
E	Periglacial areas account for 15% of the earth's land surface.	

Q2	Match the correct term to the correct process	
A	Downslope movement of thawed/unfrozen material over permafrost.	
B	Enlargement of a depression in the ground, mainly as a result of alternate freezing and thawing.	
C	Alternate sub-zero and above-zero conditions of water penetrating rocks in situ, leading to the rock being fragmented through weathering.	
D	The slow downslope flow of saturated soil.	
E	Where particles are elevated when the ground freezes and then when the ground melts the particles drop and move downslope.	
Select from: Solifluction Gelifluction Frost creep Nivation Freeze thaw weathering		

Q3	One sentence is incorrect in each of the explanations below. Identify the wrong one.	
A	Ice wedges are ice masses which extend down into the earth. They can grow to up to ten metres deep in some cases. They occur when during the winter months, water enters the wedge and freezes. This alternate freezing and melting process causes the wedge to expand and over time which will make the wedge wider and deeper.	
B	Solifluction lobes are created when the active layer of soil freezes and previously weathered and loosened material flows slowly down the hill. When the gradient changes again and flattens out, the material is deposited in a tongue shape. They are composed of soil, sand, clay and peat.	
C	Terracettes are ridges in the ground. They form when the land is flat. The active layer thaws and this allows material to move in a series of successive waves of material.	
D	Blockfields are areas of smoothed rock that have been created by regular freeze-thaw activity and the material is left strewn across the ground over a large area. The landscape is uneven and largely rocky. It is the breaking up of exposed bedrock by intensive periglacial weathering.	
E	Patterned ground is formed when ice grows in the soil and as it pushes up to the surface it moves material to make a pattern. When the stones reach the surface, the finer material moves down to the side of the uneven ground and the larger stones stay in the middle. This leaves stone circles, garlands, ovals or polygons or stripes on steeper ground.	

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Q4	<i>Decide whether the terms relate to a periglacial process or feature</i>	
	<i>Periglacial process</i>	<i>Periglacial feature</i>
	Terracettes	eolian erosion
	Nivation	Solifluction lobe
	Thermokarst	Pingo
		Permafrost
		Gelifluction
		Fluvial erosion

Q5	<i>Consider the climate change implications for people living in periglacial environments</i>
A	What are some of the future negative implications?
B	What are some of the future positive implications?

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ANSWERS

Q1	<i>True or False?</i>	
A	Permafrost refers to permanently frozen ground.	True
B	Periglacial areas don't experience temperatures above zero degrees Celsius. <i>Do</i>	False
C	Fluvial erosion is caused by water.	True
D	Eolian erosion is caused by the glacier. <i>Wind-blown material erosion</i>	False
E	Periglacial areas account for 15% of the earth's land surface. <i>About 25%</i>	False

Q2	Match the correct term to the correct process	
A	Downslope movement of thawed/unfrozen material over permafrost.	Gelifluction
B	Enlargement of a depression in the ground, mainly as a result of alternate freezing and thawing.	Nivation
C	Alternate sub-zero and above-zero conditions of water penetrating rocks in situ, leading to the rock being fragmented through weathering.	Freeze thaw weathering
D	The slow downslope flow of saturated soil.	Solifluction
E	Where particles are elevated when the ground freezes and then when the ground melts the particles drop and move downslope.	Frost creep
Select from: Solifluction Gelifluction Frost creep Nivation Freeze thaw weathering		

Q3	One sentence is incorrect in each of the explanations below. Identify the wrong one.	
A	Ice wedges are ice masses which extend down into the earth. They can grow to up to ten metres deep in some cases. They occur when during the winter months, water enters the wedge and freezes. This alternate freezing and melting process causes the wedge to expand and over time which will make the wedge wider and deeper.	This usually occurs during the summer months when higher daytime temperatures cause the ice to melt and water will enter the wedge. Night temperatures which are lower will then cause freezing to take place. Winter cold will cause further ground contraction around the wedge.
B	Solifluction lobes are created when the active layer of soil freezes and previously weathered and loosened material flows slowly down the hill. When the gradient changes again and flattens out, the material is deposited in a tongue shape. They are composed of soil, sand, clay and peat.	The material can only flow downhill when the active layer thaws.
C	Terracettes are ridges in the ground. They form when the land is flat. The active layer thaws and this allows material to move in a series of successive waves of material.	Material will only move in the active layer when the land is on a gradient as gravitational force is needed to aid the flow.
D	Blockfields are areas of smoothed rock that have been created by regular freeze-thaw activity. The material is left strewn across the ground over a large area. The landscape is uneven and largely rocky. It is the breaking up of exposed bedrock by intensive periglacial weathering.	As blockfields are formed by freeze-thaw action they are not smooth but angular fragments.
E	Patterned ground is formed when ice grows in the soil and as it pushes up to the surface it moves material to make a pattern. When the stones reach the surface, the finer material moves down to the side of the uneven ground and the larger stones stay in the middle. This leaves stone circles, garlands, ovals or polygons or stripes on steeped ground.	The larger stones move to the side to form the shape of the patterned ground. The finer material stays in the middle.

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ANSWERS**

Q4	<i>Decide whether the terms relate to a periglacial process or feature</i>	
	<i>Periglacial process</i>	<i>Periglacial feature</i>
	eolian erosion	Terracettes
	Nivation	Permafrost
	Gelifluction	Solifluction lobe
	Fluvial erosion	Thermokarst
		Pingo
	Terracettes	eolian erosion
	Nivation	Solifluction lobe
	Thermokarst	Pingo
		Permafrost
		Gelifluction
		Fluvial erosion

Q5	<i>Consider the climate change implications for people living in periglacial environments</i>
A	<p>What are some of the future negative implications?</p> <ul style="list-style-type: none"> • Climate change will cause permafrost coverage to reduce (potential problems for people who live in these areas and use summer meltwater) • Climate change which will warm the earth and melt some permafrost. This will lead to increased landslides and unsafe infrastructure, with possible subsidence. • Release of methane into the atmosphere when permafrost melts resulting in a positive feedback loop of climate change leading to even faster warming of the area • More rapid erosion of river banks and coastlines as permafrost melts.
B	<p>What are some of the future positive implications?</p> <ul style="list-style-type: none"> • Meltwater may increase which can provide additional water supply in the short term. • Human adaptation for living in permafrost areas – insulated floorings and having pipes above ground ensure people can live in this harsh landscape. • Extension of forests into previously non-forested regions expands economic potential. • Easier accessibility – benefiting local transport or incoming economic investment