SL IB Geography

Your notes

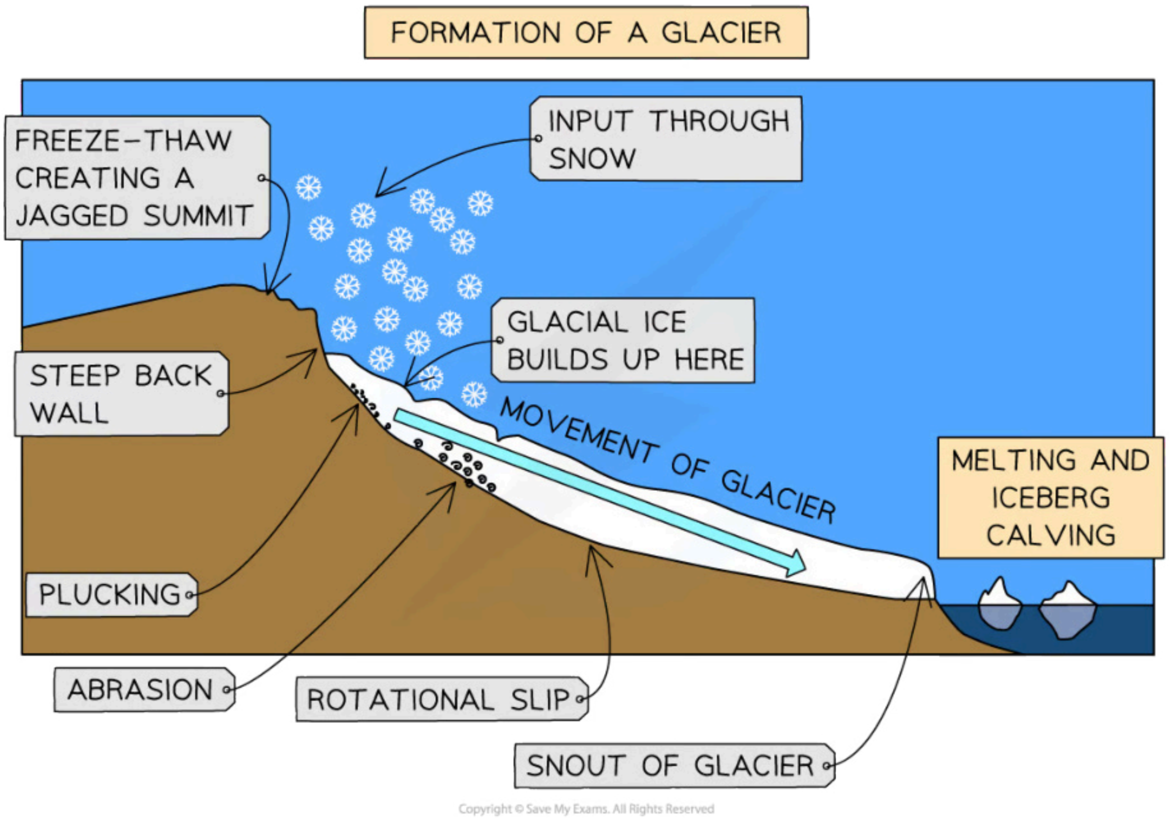
6.2 Physical Processes & Landscapes in Extreme Environments

Contents

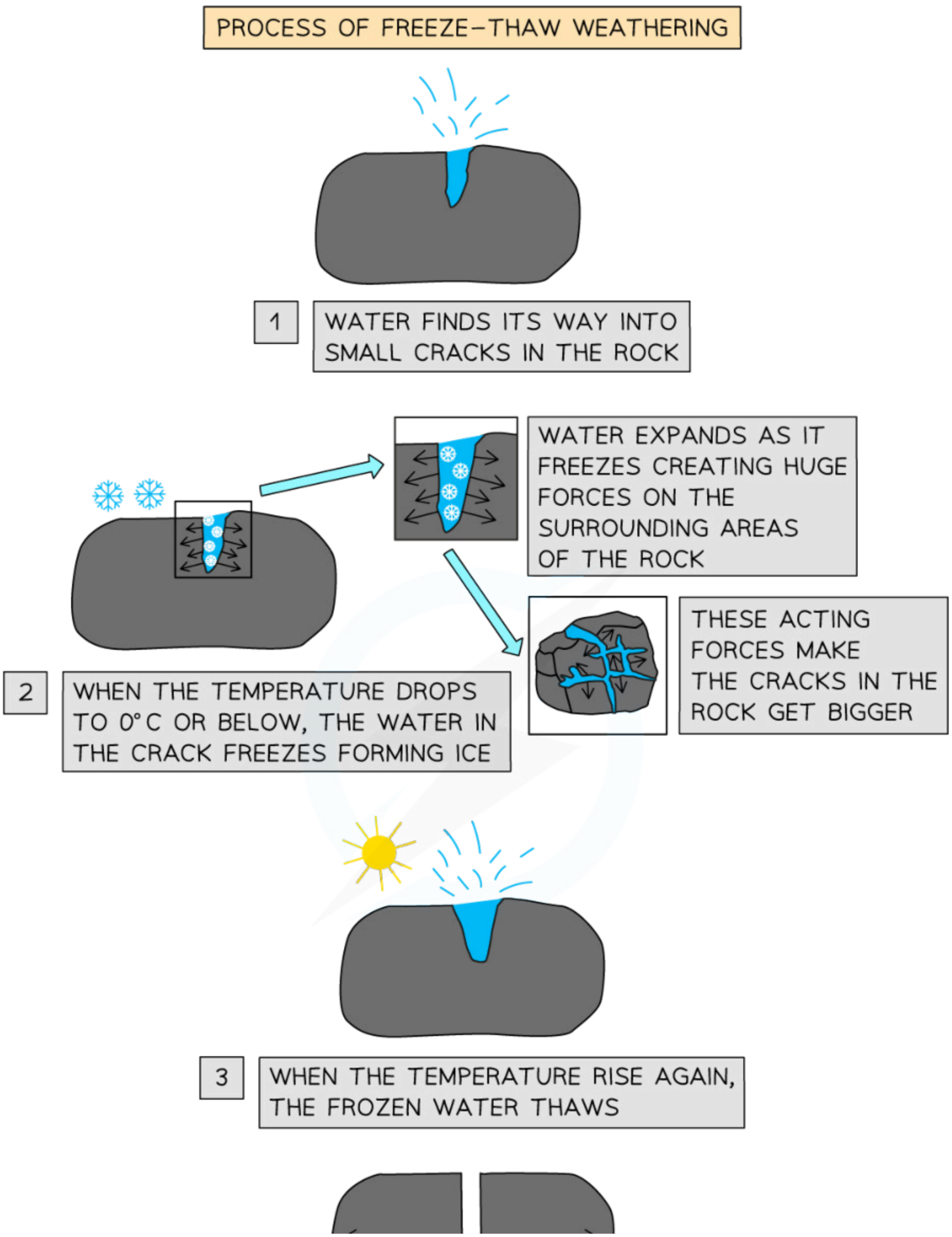
6.2.1 Glacial Processes

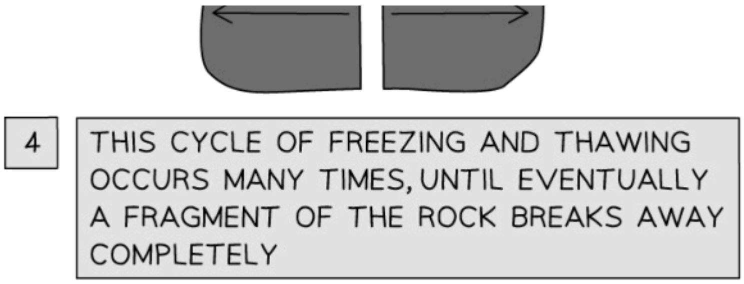
Your notes

Glacial Erosion



- Glaciers create distinct landforms through weathering, erosion, transportation and deposition
- Freeze-thaw weathering happens when rocks contain cracks and temperatures regularly dip below the freezing point
- Any water in the cracks will freeze as the temperature drops, which will expand as it freezes, exerting pressure on the crack
- Repeated freezing and thawing of water will eventually break the rock apart


PROCESS OF FREEZE–THAW WEATHERING
1
WATER FINDS ITS WAY INTO SMALL CRACKS IN THE ROCK
WATER EXPANDS AS IT FREEZES CREATING HUGE FORCES ON THE SURROUNDING AREAS OF THE ROCK
THESE ACTING FORCES MAKE THE CRACKS IN THE ROCK GET BIGGER
2
WHEN THE TEMPERATURE DROPS TO 0°C OR BELOW, THE WATER IN THE CRACK FREEZES FORMING ICE
3
WHEN THE TEMPERATURE RISE AGAIN, THE FROZEN WATER THAWS

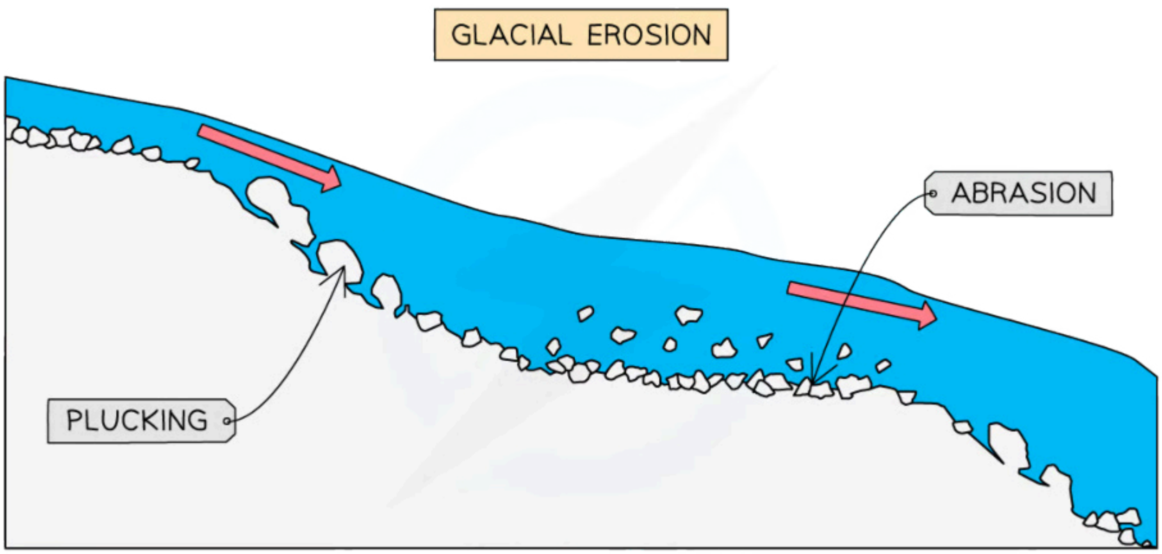


Your notes

Exam Tip

- Do remember to tell the examiner that the process of freeze-thaw is a cycle and happens over a long time
- Practice using a sketch to help you with the process

- After glaciers break down the rock through freeze-thaw action, **erosion continues** the process by plucking and abrasion
- **Plucking:**
  - As a glacier moves through a valley, pressure is exerted on the sides and bottom of the valley
  - This generates friction and heat, causing the edges of the glacier to melt a bit
  - This meltwater freezes around rocks and stones under the glacier
  - As the glacier moves forward, it 'plucks' this ice, pulling the rock away
- **Abrasion:**
  - Abrasion occurs as bits of rocks, stones and boulders stuck in the ice, grind against the rock below the glacier, wearing it away and leaving scratch marks called **striations** across the rock
- It is the weight of the ice in a glacier which forces it to advance downhill, eroding the landscape as moves
- Ice advances in a circular motion called rotational slip, which hollows and deepens the landscape


GLACIAL EROSION
ABRASION
PLUCKING
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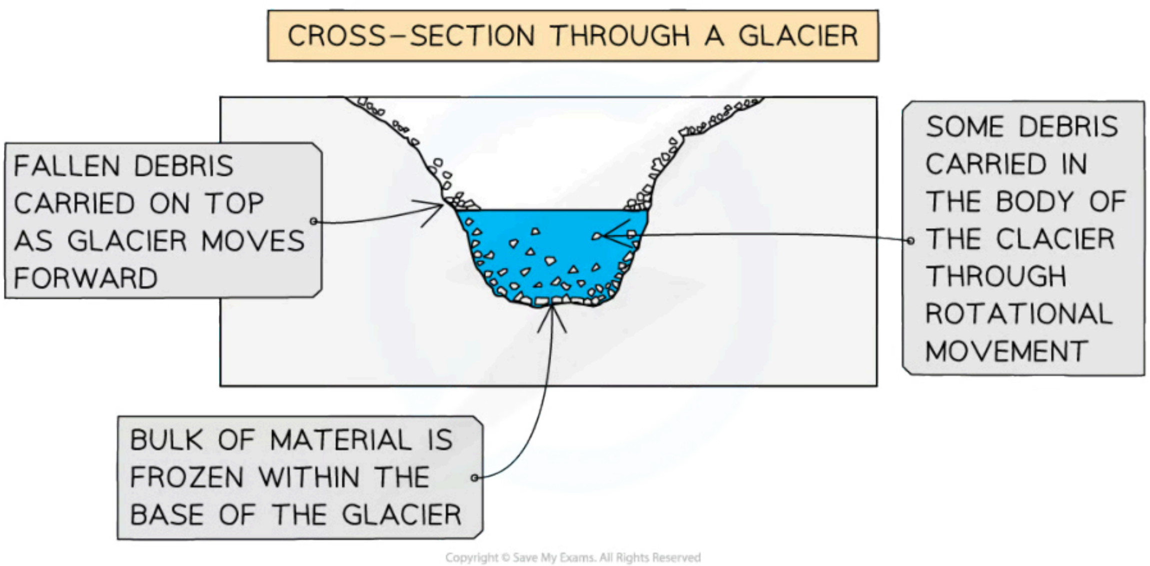
Your notes

Glacial Transportation

Your notes

- Glaciers **move under gravity very slowly**
- Glaciers **transport** material such as clay, rock, and sand in the body, base and surface of the glacier over **long distances**
- The front of a glacier is called the '**snout**' and acts as a bulldozer pushing loose rocks and debris downhill by the sheer force of the moving ice
- **Rotational slip** is the circular motion of the ice in a hollow
- Due to the **weight** of the ice, **friction** at the base of the glacier melts the ice and the glacier will move on a film of **meltwater**
- Any material carried or moved by the glacier is called **glacial till**



Glacial Deposition

Your notes

- During the warmer summer months, glaciers begin to melt, and **glacial till** is deposited on the valley floor or sides of a moving glacier
- Till is unsorted, irregular debris ranging from clay to boulders of any size and shape
- Meltwater will also flow out of the glacier's snout forming **meltwater rivers**
- These rivers carry large amounts of glacial till, which will undergo further erosion through attrition to become **outwash**
- This finer till **is sorted** and when the energy of the river reduces, the **outwash** is deposited in **layers** further down the valley on the **outwash plain**

Glacial till

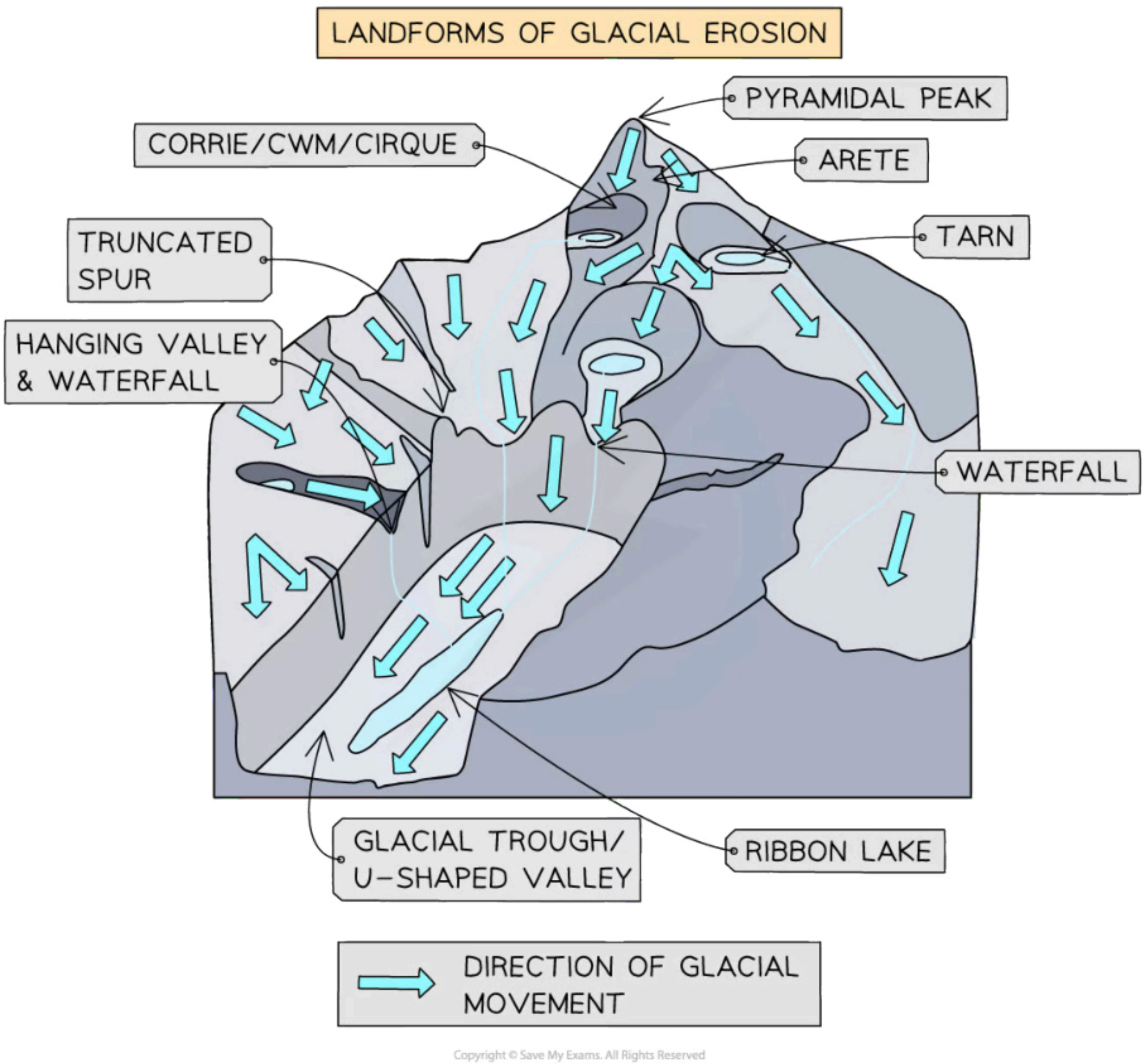
Glacial outwash plain

6.2.2 Glacial Landforms

Your notes

Erosional Landforms

- As a glacier moves it erodes everything in its way
- Glacial erosion creates different features as it flows downhill:
  - **Pyramidal peak**
  - **Arête**
  - **Corrie/cwm/cirque**
  - **Tarn**
  - **Truncated spur**
  - **Hanging valley**
  - **Ribbon lake**
  - **Glacial trough/U-shaped valley**



Your notes

- **Pyramidal peak**
  - As the name suggests, this is a three-sided, pointed mountain peak
  - Formed when three or more back-to-back glaciers carve away at the top of a mountain
  - This creates a sharply pointed mountain summit
  - Examples include Snowdon in Wales and Buachaille Etive Mòr, Glencoe, Scotland
- **Arête**
  - Arêtes are knife-edge, steep-sided ridges
  - Formed when two glaciers flow back-to-back
  - As each glacier erodes either side of the ridge, the edges become steeper and the ridge narrower
  - This gives the arête it's a jagged profile

- Examples include Crib Goch in Wales, and Striding Edge in Lake District, England
- **Corrie/cwm/cirque**
  - Corrie, cwm and cirques are all the same feature and are formed in hollows where snow can accumulate, usually on a north facing slope
  - In Wales corries are called cwms and in France, they are called cirques
  - Formed when the glacial ice moves through gravity, rotational slip, and sheer mass of the ice
  - Ice freezes on the back wall of the hollow and as the ice moves, it plucks the rock out, which steepens the back wall
  - Freeze-thaw, plucking and abrasion further erode the hollow into a rounded, steep-sided 'armchair' shape with a lip at the bottom end
  - Examples include Helvellyn Corrie in the Lake District and Cwm Idwal in Snowdonia
- **Tarn**
  - Tarn lake or corrie loch is a mountain pool or lake in a corrie after the glacier has melted
  - Because of the corrie lip at the bottom end, the meltwater is held in place and a circular body of water is formed
  - Examples include Red Tarn, Helvellyn in the Lake District and Cadair Idris in Snowdonia
- **Truncated spur**
  - Truncated spurs are past interlocking spur edges of past river action that have been cut-off forming cliff-like edges on the valley side
  - Found between hanging valleys and are an inverted 'V' shape
  - formed when the lower valley glacier cuts off previous ridges or spurs as it passes by
  - An example is Nant Ffrancon Valley in Snowdonia
- **Hanging valley**
  - These are small tributary glaciers found 'hanging' above the main valley floor
  - When melting occurs, there are waterfalls onto the valley floor
  - An example is Cwm Dyli in Snowdonia
- **Ribbon lake**
  - As a glacier flows, it travels over hard and soft rock
  - Softer rock is less resistant to erosion, so a glacier will carve a deeper trough over this type of rock
  - When the glacier has melted, water collects in these deeper areas
  - This creates a long, thin lake called a ribbon lake
  - Examples include Lake Windermere in the Lake District and Llyn Ogwen in Snowdonia
  - The areas of harder rock left behind are called rock steps
- **Glacial trough/U-shaped valley**
  - Glacial troughs are steep-sided valleys with a flat floor
  - They start as V-shaped river valleys but due to the size and weight of the glacial ice, it changes to a U shape as the glacier erodes the sides and bottom, making the valley deeper and wider
  - Examples are found all over the UK, but Nant Ffrancon and Nant Gwynant in Snowdonia are good examples

Your notes

Your notes

Exam Tip

When explaining the formation of landforms of any kind (fluvial, coastal, glacial etc.) you should use labelled or preferably annotated diagrams to support your answer.

A well annotated diagram showing the stages of formation will gain you full marks and a labelled diagram will gain you credit.

Diagrams do not need to be flawless but a solid representation of the feature and follow the geographical rules:

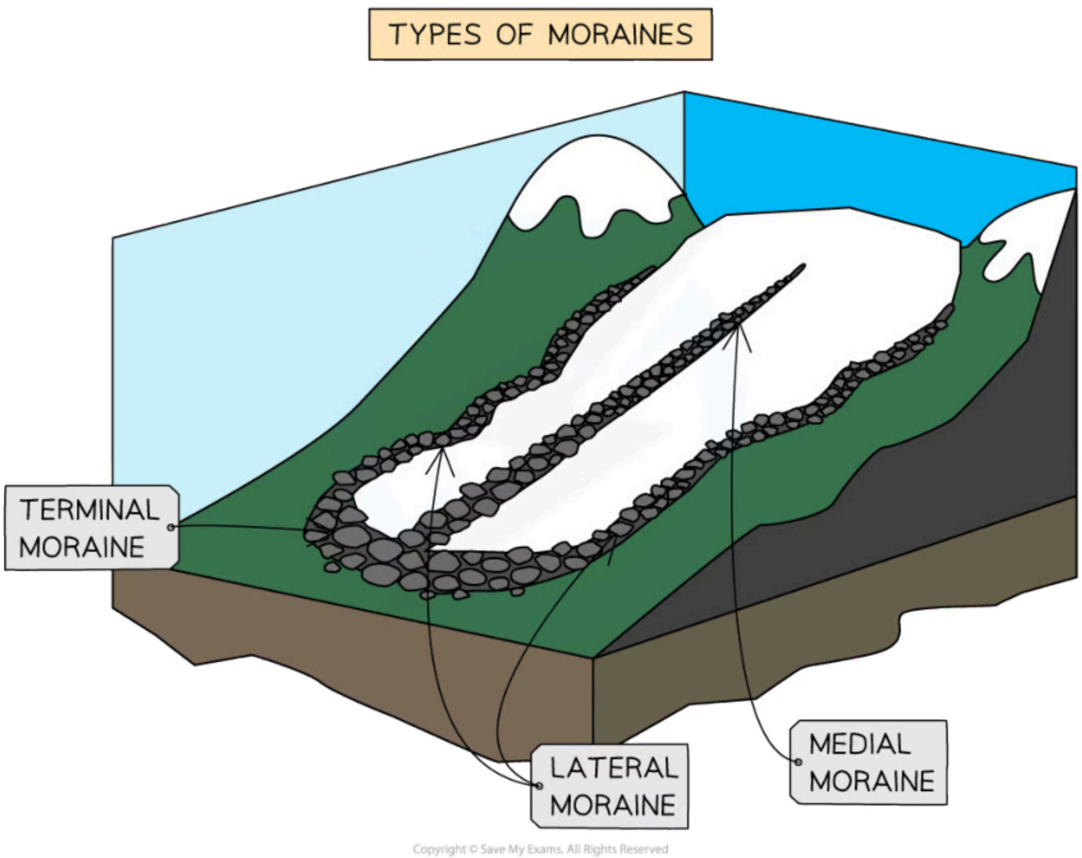
- In a box, drawn in pencil and labelled/annotated in pen
- Arrows drawn with a ruler, in pencil and points to the feature (not the writing) and **never cross**
- Shade in colour to highlight features
- Labelling should ideally be around the outside, but can be on the feature
- If annotating, you can use numbers on the sketch and write below the diagram in sequence

Your notes

Depositional Landforms

Moraines

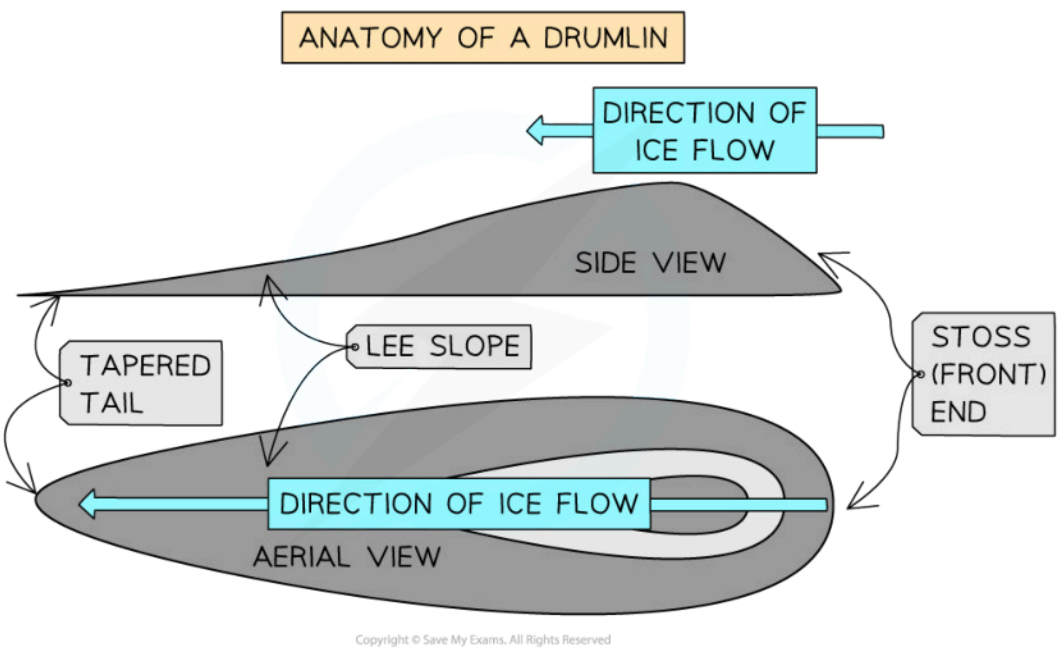
- Unsorted glacial till that is deposited in mounds are called **moraines**
- There are four types of moraines:
  - **Terminal:** Material deposited at the snout of the glacier
  - **Lateral:** Material is deposited along both sides of the glacier
  - **Medial:** Ridge of deposited material in the middle where two glaciers meet and continue to flow downhill together
  - **Ground:** Material dragged under the base of the glacier and deposited over a wide area on the valley floor



Drumlins

- Drumlins are **elongated**, **egg-shaped hills** made of glacial **till**

- They form beneath the glacier when the glacier meets an obstruction and material is deposited as ground moraine
- The moving ice then follows the direction of the flow of ice to shape the moraine
- The largest ones can be over 1km in length, 0.5km wide and 50m high
- Multiple drumlins are known as **swarms or baskets of eggs**
- As the material is deposited, it builds up to have a round, blunt and steep **front** (**stoss**) end
- The flow of ice over the top of the drumlin drags the material along and down, creating the **lee** slope
- The lee is gently sloped, elongated and has a tapered tail
- Examples include The Drumlin Field below Cam Fell in the Yorkshire Dales and Conway Valley, North Wales



Erratics

- Erratics are random rocks of different sizes and types from the area where they are found
- There is no pattern to their deposition, and they look completely out of place on the landscape
- Glaciers pick up large rocks and carry them hundreds, sometimes thousands, of kilometres from where they originate
- Erratics are carried deep in the ice and do not erode as much as rocks at the edges of the glacier
- An example is the **Great Stone of Fourstones**, (Big Stone)' on the moors of Tatham Fells, England

Your notes

The Great Stone of Fourstones – erratics are random rocks that vary in size!

6.2.3 Periglacial Processes & Landforms in Cold Environments

Your notes

Periglacial Processes

- A periglacial landscape is characterised by permanently frozen ground, or **permafrost** and is defined as:

'An area where soil and rock has not risen above 0°C for at least 2 consecutive years'

- The **major process** that contributes to the production of a periglacial landscape is:
  - **Freeze-thaw**
    - The action of freeze-thaw weathering (frost shattering) results in rough, angular, broken rocks
    - At the foot of a slope, these rocks are known as scree
    - Periglacial regions are also characterised by blockfields or felsenmeer, caused by the quick freeze-thaw action of temperatures ranging between -5°C to -14°C
- This leads to vast plains of permafrost with low-growing marsh vegetation and exposed rocks

Comparison of Glacial and Periglacial Areas

Action	Periglacial	Glacial
Altered by ice	Within the ground	Above ground
Landforms created through	Freeze/thaw weathering and mass movement	Erosion and deposition
Found	Outer margins of cold environments	High altitudes and latitudes

Your notes

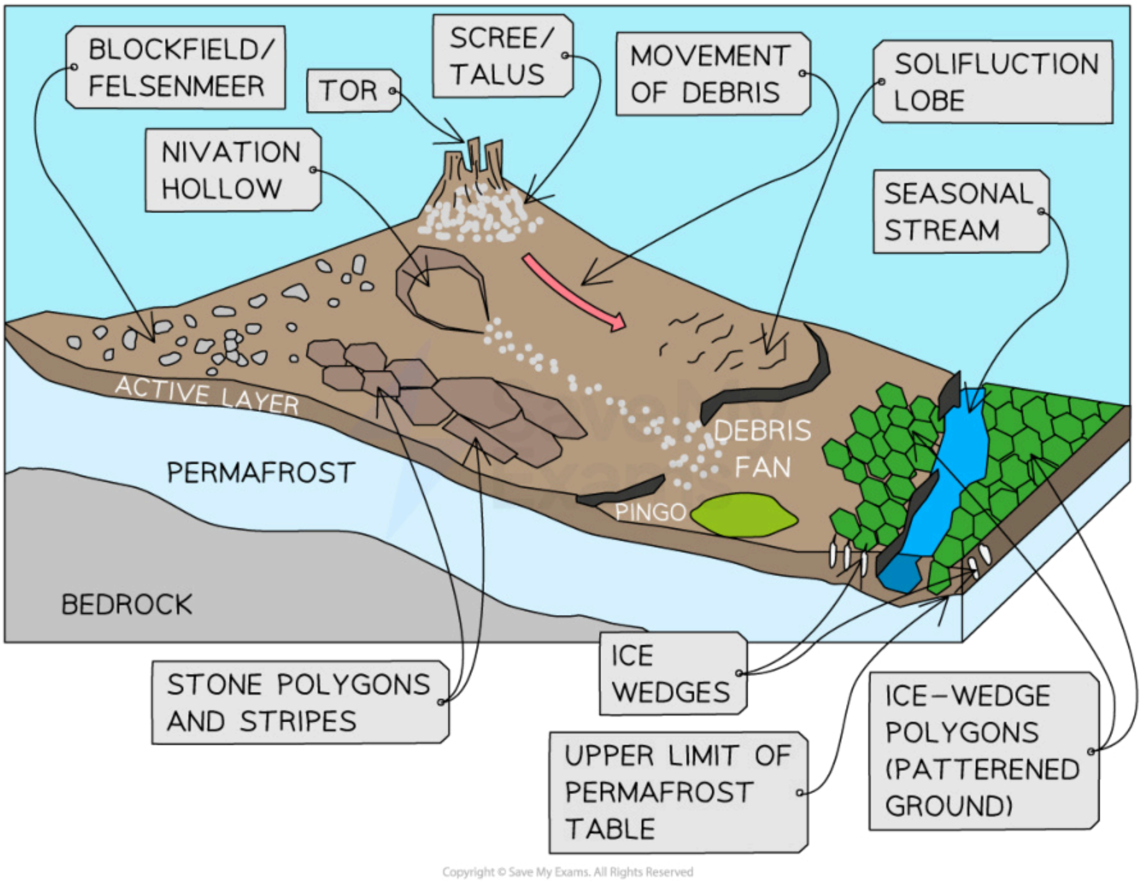


Image showing main features of a typical periglacial landscape

Exam Tip

- It is important to differentiate between glaciated and periglacial landscapes
- Remember that periglacial regions are dominated with permafrost and a seasonally changing active layer

Other periglacial processes

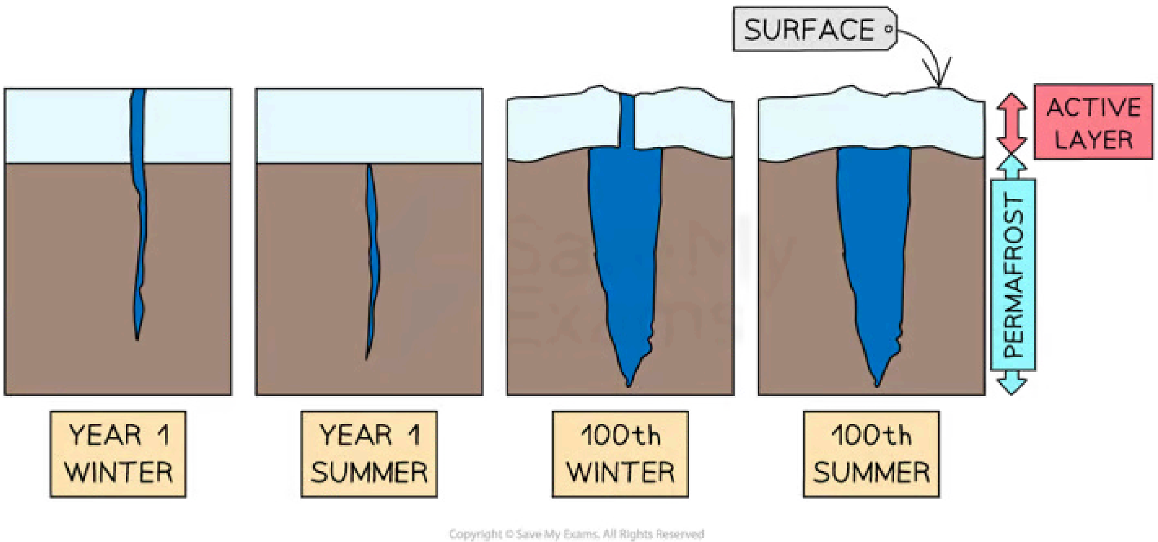
- **Solifluction**
  - This is a form of **mass movement**
  - There are two types of solifluction:
    - Fast
    - Slow

- **Fast**
  - When an active layer on a slope becomes **heavily waterlogged** due to melting, gravity acts to pull it downhill
  - This flow of material is called solifluction and produces characteristic lobes on the sides of the slopes
  - The steeper the slope, the faster and further the material will travel, and the larger the lobe will be
  - Movement can be up to 10 cm/yr
- **Slow**
  - **Also known as solifluction or soil/frost creep, it** occurs when water in the soil expands as it freezes
  - This **expansion** forces soil particles to **rise perpendicular** to the ground (**frost heave**)
  - As the ground **thaws**, the particles are **dropped vertically** downward (due to gravity)
  - With each repeated cycle, soil particles gradually '**creep**' downslope at a rate of a few cm/yr

Frost action

- **Frost-action** periglacial processes include:
  - **Ground ice**
    - The most common form of ground ice is pore ice
    - It develops in the pore spaces between soil and rock particles, where meltwater has accumulated and frozen
    - Needle ice are thin slivers of ice and can be several cm long
    - Found mostly in moist soil where temperatures drop below freezing at night
    - Needle ice helps with loosening material for erosion and moving soil particles in soil creep
  - **Frost contraction and ice wedging**
    - As temperatures drop, the active layer freezes and contracts
    - Crack begin to form in the permafrost as a result
    - When the active layer thaws, meltwater will fill the cracks
    - The cold of the permafrost freezes the water in the crack, forming ice-wedges
    - Continued melting and thawing can enlarge the crack to sizes of 3m wide and 10m deep

Your notes



Ice wedge formation over time

- **Frost heave**
  - When ground ice forces soil or small stones to the surface, frost heave occurs
  - Freezing occurs from the surface downwards, which helps ice crystals form either within the soil pores or as ice needles
  - As the ground ice expands, these crystals force soil and stones to the surface

Exam Tip

Always remember that these processes are not one off occurrences. They are cyclical and take a number of years to complete the cycle.

Your notes

Periglacial Landforms

- Typical landforms found within a periglacial landscape are:
  - **Permafrost**
  - **Solifluction lobes and terracettes**
  - **Ice wedges and ice lenses**
  - **Patterned ground**
  - **Blockfields/felsenmeer**
  - **Thermokarsts**
  - **Pingos**

Permafrost

- Most permafrost water stays frozen as ground ice
- Seasonal melting at the surface produces the active layer of between 2cm and 5 metres in depth
- However, meltwater cannot drain through the impermeable permafrost below and sits on the surface as **thaw lakes**
- Thaw lakes are common in these poorly drained areas and as the water continues to absorb solar radiation, so the depth and size of these lakes increase in size
- **Permafrost can be subdivided into:**
  - **Continuous**: large, unbroken stretches of permafrost, that reach depths of up 1 500 metres—the largest areas are located in Canada, Alaska and Siberia
  - **Discontinuous:** mostly permafrost, with some small, localised unfrozen ground (talik)
  - **Sporadic:** where small patches of frozen ground occur in talik (unfrozen ground)

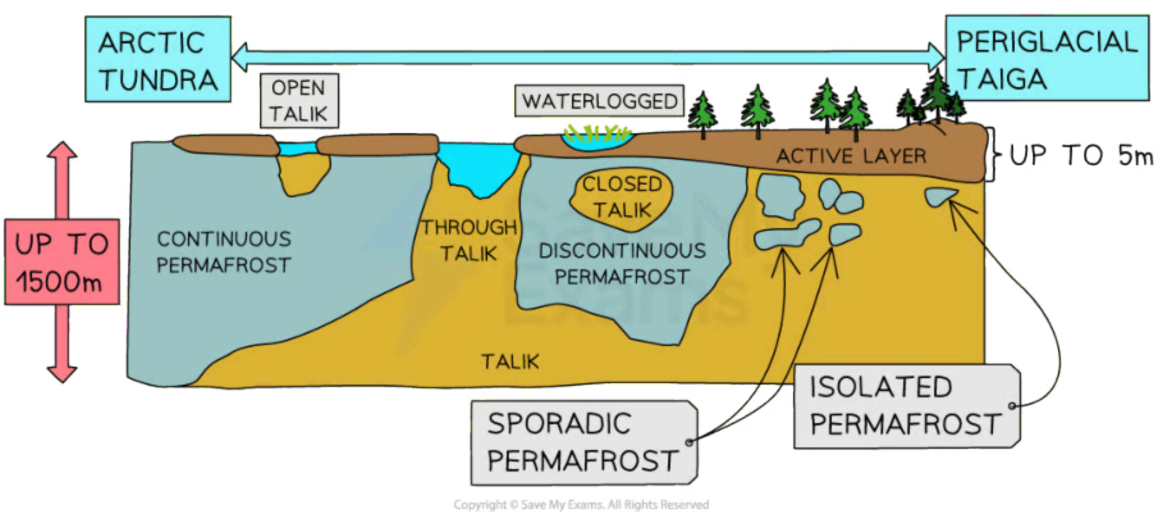


Image showing types of permafrost found in periglacial areas

Your notes

- Areas of unfrozen ground within the permafrost is known as **talik**
- Talik can be:
  - **Open:** a small area of unfrozen ground exposed to the surface
  - **Through:** a large mass of unfrozen ground beneath a small open area
  - **Closed:** unfrozen ground completely surrounded by permafrost

Blockfields or felsenmeer

- The periglacial landscape is littered with **angular rocks across its surface**
- Quickly weathered through freeze-thaw processes, these areas are called **felsenmeer,** meaning 'field of rocks' in German
- In mountainous/alpine regions, extensive freeze-thaw weathering of the bedrock leaves broken, angular fragments of rock strewn across the landscape
- These areas are subject to intensive, repeated cycles of freezing and thawing

Solifluction lobes and terracettes

- Solifluction is the downward movement of rock and soil under gravity, resulting in lobed-shaped features called **solifluction lobes**
- Occurs during the summer melt period, when the permafrost's active layer becomes saturated with meltwater and 'slips' downslope
- Terracettes are formed when saturated soil freezes and expands, which forces the soil to shift (heave) upwards towards the surface
- During the spring/summer melt, the soil dries and collapses back vertically
- Each cycle of frost heave and thaw moves the soil downslope, slowly forming a terraced environment

Ice wedges and ice lenses

- Ice wedges form when cracks in the surface fill with summer meltwater and freeze during the winter
- Temperatures have to remain low for cracks to form initially but also to prevent evaporation of water during the melt phase
- Continued freezing and thawing cycles increase the size of the ice wedges each year
- Ice lenses begin to form when moisture in the soil pools and freezes
- Ice lenses grow with subsequent thawing and refreezing, forming a lens-shaped block of ice
- As ice lenses increase in size, they cause soil heave, patterned ground and pingos

Your notes

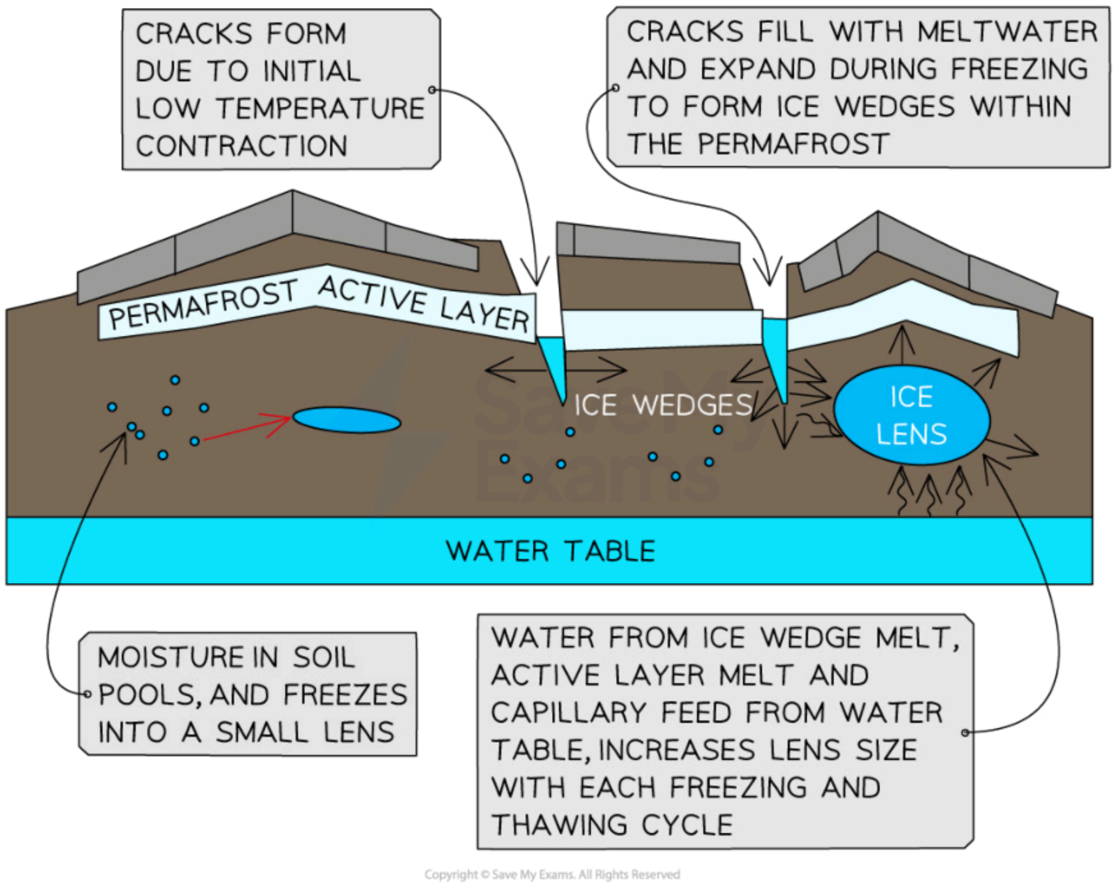


Image showing the formation of an ice lens and wedge.

- **Note** that lenses form when moisture within the soil pool freezes
- Ice wedges initially form when temperatures are low enough for the surface to contract and crack
- Meltwater fills these cracks and subsequently freezes, expanding the crack
- Further cycles of melting provide water to the forming wedges and lenses, helping them to grow and expand to further 'heave' the ground upwards

Patterned ground

- The **ordered pattern** is created through the **sorting of sediment, stones and ice wedges**
- Shapes include **polygons, circles, and stripes**
- The repeated **freezing, heaving and thawing of the active layer** produces the pattern
- Initially freezing sorts material from the rock, and when thawing occurs, redistributes the rock particles into a system of shapes

- **Frost heave then pushes larger stones to the surface**, which due to its uplift, moves the stones sideways
- Smaller particles are removed via meltwater or wind, which leaves the larger material lying on top of ice wedges, which in turn, marks the polygon pattern
- The **sloping ground and gravity**, force rocks to move downhill forming **elongated stone stripes** instead of polygons or circles

Your notes

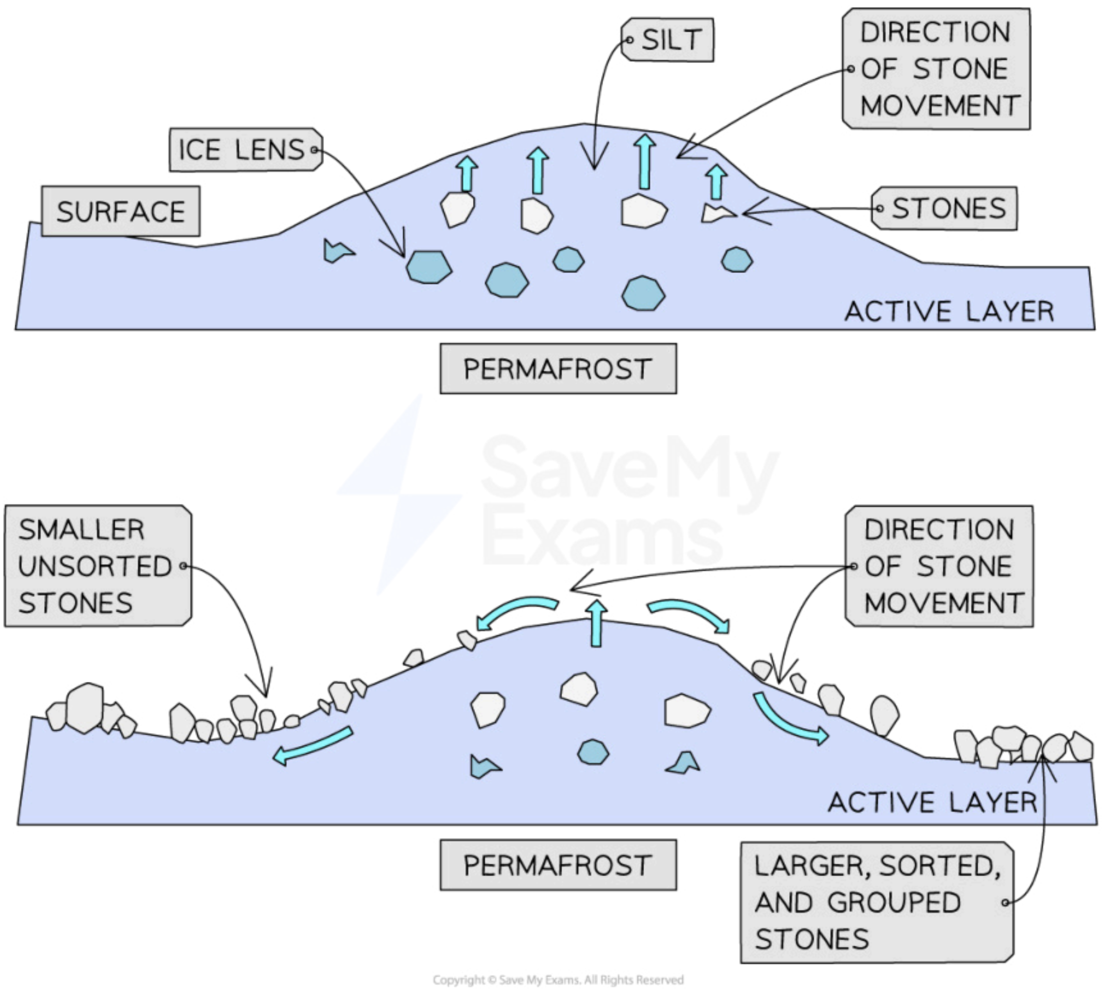


Image showing formation of stone patterned ground. Ice wedges form the outer demarcation line of polygon patterned ground, where lighter material is removed by meltwater, leaving the heavier stones behind at the point of the ice wedge during summer melt.

Thermokarsts

- Thermokarsts result from melted ground ice settling unevenly to form marshy ground of hummocks and hollows
- Found mostly in the flat, lowland plains of the Arctic

Pingos

- Found in the Arctic and sub-Arctic region
- These landforms can reach heights of up to 90m
- They have a core of ice and are surrounded on the outside by green vegetation
- There are two forms of pingos:
  - **Closed** system
  - **Open** system
- **Closed-system**
  - Form in areas of continuous permafrost with a lake on the surface
  - Lake sediments act as an insulator to the ground beneath, which remains unfrozen, and the permafrost layer
  - Liquid water is contained in this unfrozen ground/talik
  - When the lake retreats, the ground is no longer insulated and the residual water freezes into a core/lens
  - As the permafrost advances, it squeezes the talik and pushes the ice lens and lake sediments towards the surface
  - During the summer the ice lens may melt and collapse, leaving a hollow, called an **ognip**, that fills with water
- **Open-system**
  - Form in areas of discontinuous permafrost
  - Groundwater is forced through gaps in the permafrost
  - Water rises, accumulates and freezes in the active layer of permafrost, to form an ice lens
  - As the groundwater continues to feed the ice lens, the surface domes to form a pingo

Your notes

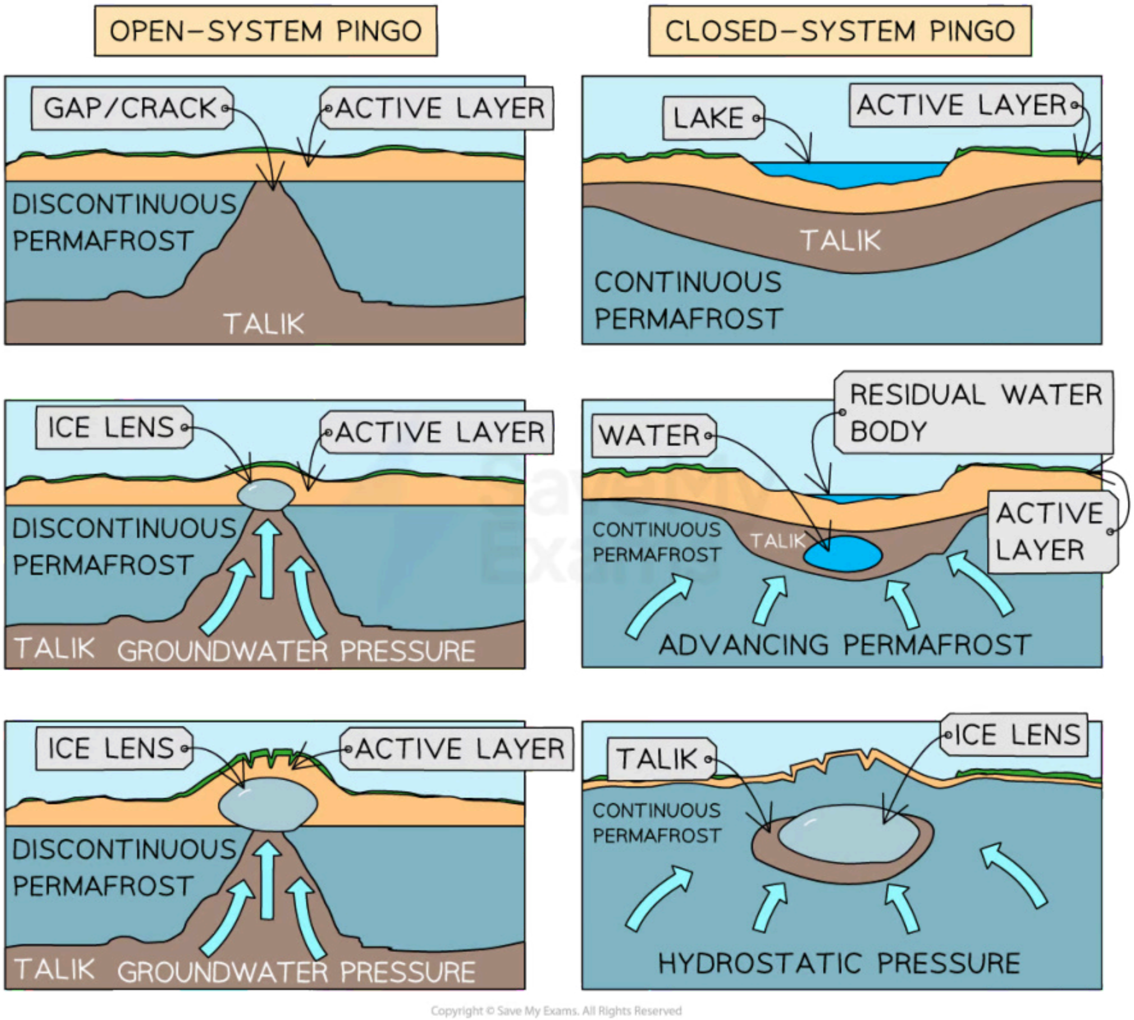


Image showing formation of the open and closed pingo system. Note the importance of ice lens/block formation.

Exam Tip

Make sure you can draw and annotate simple sketches of periglacial landforms to help you explain their characteristics and formation in the exam.

Always give an indication of any timescale involved in their formation or changes.

Remember that processes in cold environments take a long time to happen due to the temperatures involved.

6.2.4 Processes in Hot Arid Environments

Your notes

Physical & Chemical Weathering in Hot Arid Environments

- Overall, weathering rates are **slow** in hot arid and semi-arid environments
- Rock breakdown is **mainly** through **physical** weathering

Physical weathering

- The **main** forms of mechanical or physical weathering in hot deserts are:
  - **Thermal fracture**
  - **Pressure exfoliation**

Thermal disintegration

- Also called **thermal fracturing, thermal exfoliation** or **onion skin weathering**
- Caused by **extreme** diurnal temperature
- During the day, rocks absorb insolation and **expand**
- At night heat is **released** and the rock contracts
- This process continues (cyclical process 1 in the diagram below) until eventually, fractures form along the surface
- These fractured pieces expose the rock beneath and the process continues (cyclical process 2)
- Thermal expansion and contraction occur at **different rates** on **different parts** of the rock

Your notes

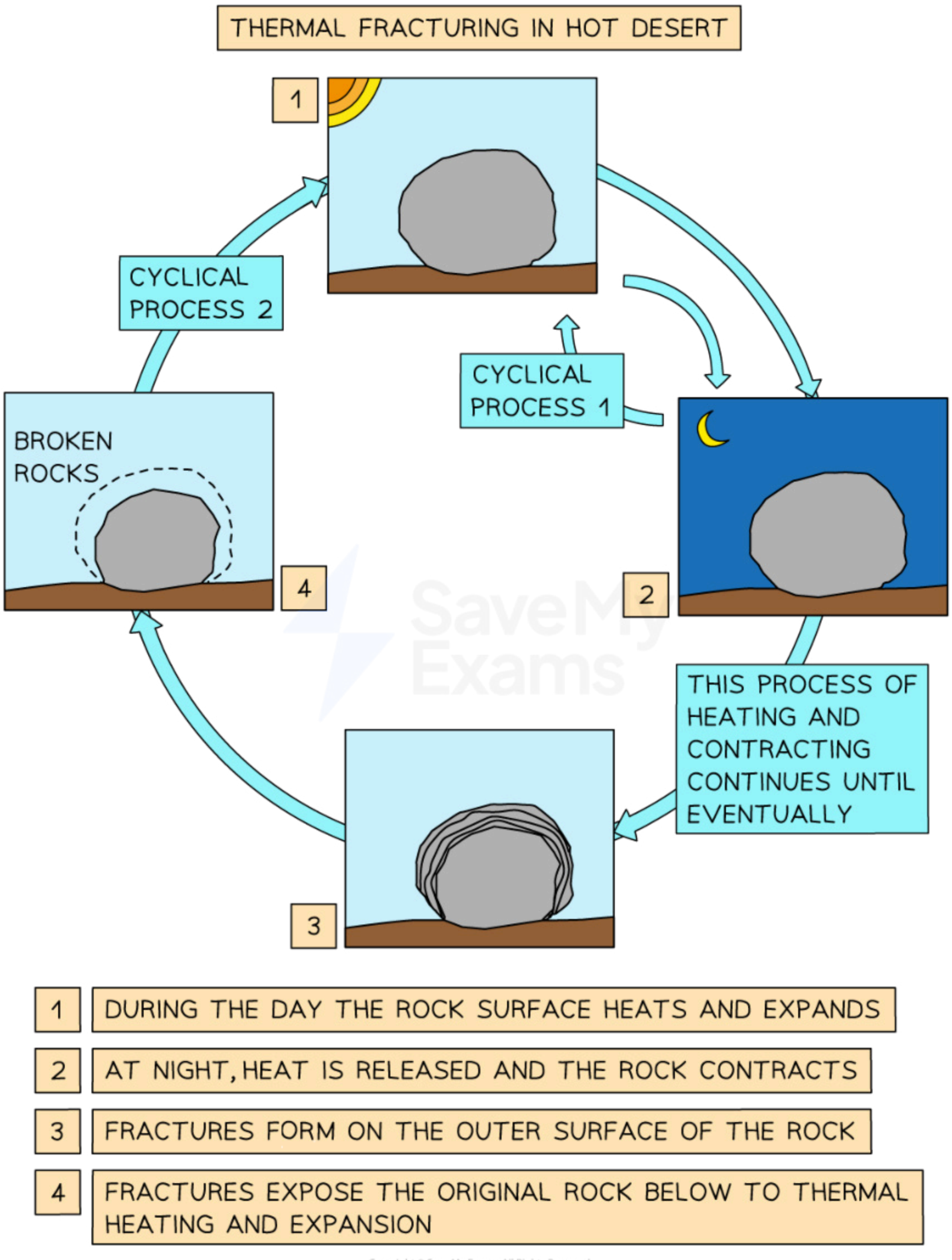

THERMAL FRACTURING IN HOT DESERT
1
CYCLICAL PROCESS 2
CYCLICAL PROCESS 1
BROKEN ROCKS
4
2
THIS PROCESS OF HEATING AND CONTRACTING CONTINUES UNTIL EVENTUALLY
3
1 DURING THE DAY THE ROCK SURFACE HEATS AND EXPANDS
2 AT NIGHT, HEAT IS RELEASED AND THE ROCK CONTRACTS
3 FRACTURES FORM ON THE OUTER SURFACE OF THE ROCK
4 FRACTURES EXPOSE THE ORIGINAL ROCK BELOW TO THERMAL HEATING AND EXPANSION
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Image of cyclical thermal fracturing in hot deserts

Your notes

Exam Tip

Always remember to tell the examiner that weathering is cyclical and takes time. It doesn't happen in an instant!

Pressure exfoliation

- Also known as **pressure-release exfoliation**
- This is where overburden is removed through weathering and erosion and the rock beneath is gradually exposed
- The removal of the weight of the overburden releases the pressure on the rock beneath and the outer layer splits/fractures apart
- Once fractures develop, water enters and chemical weathering takes place, leading to the **formation of new low-density minerals**
- This enhances the fractures and encourages slabs of rock to detach from the rock surface

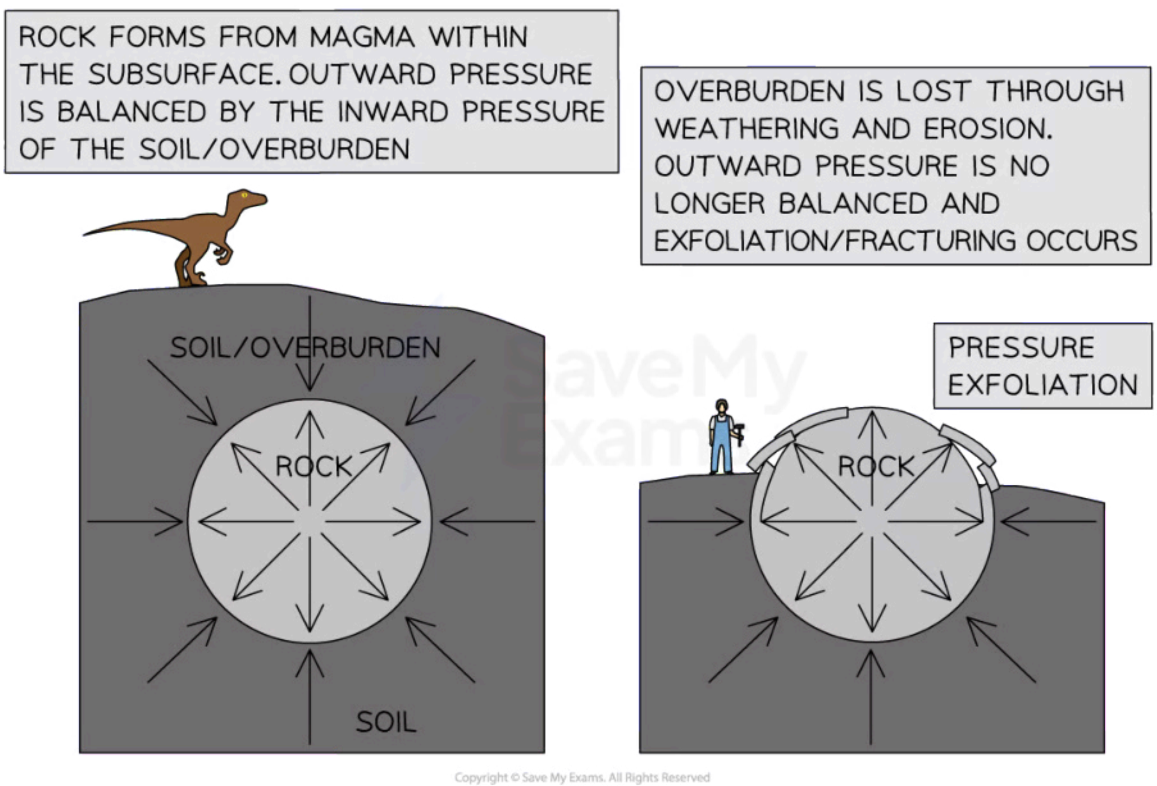


Image showing pressure release exfoliation over time

Your notes

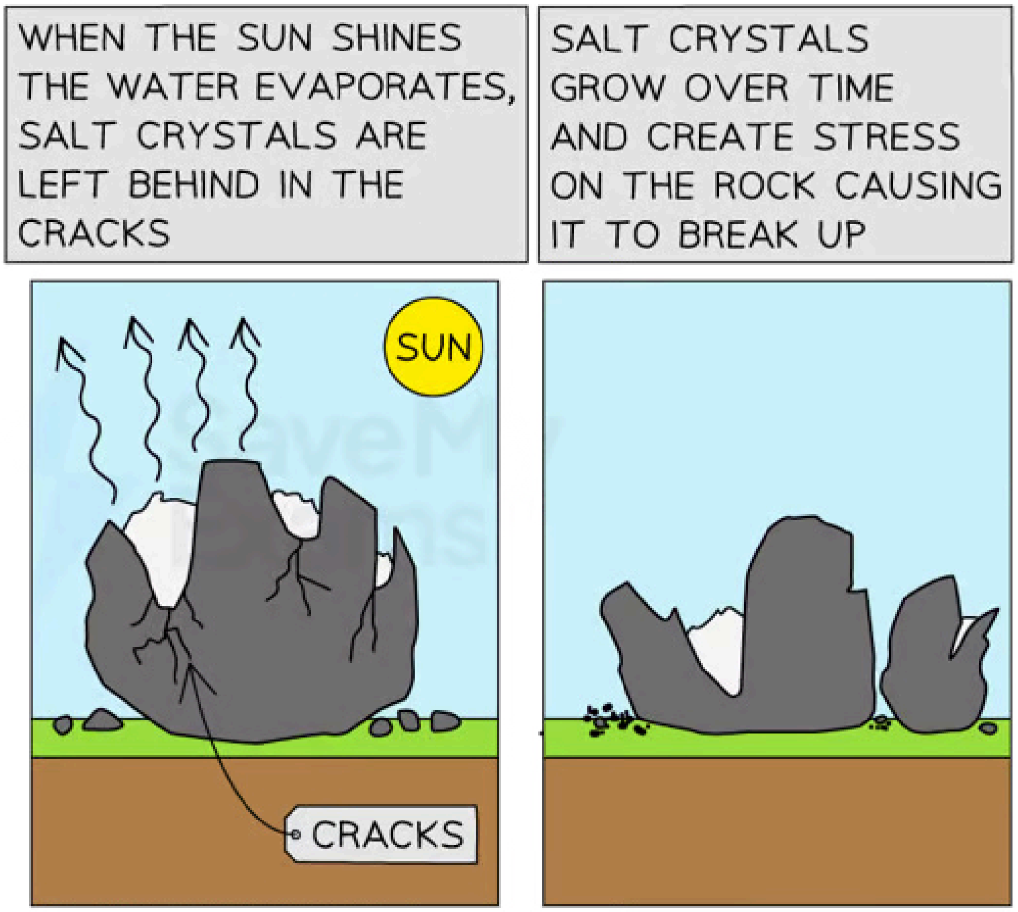
Chemical weathering

- Rates of chemical weathering are **low** due to a lack of water
- Chemical weathering depends on rock type and includes:
  - Crystal growth
  - Granular and block disintegration
  - Hydration

Crystal growth

- Crystal growth is the **major** cause of chemical weathering, especially in porous, **sedimentary** rock such as sandstone
- Coastal, fog-bound deserts are particularly prone to this type of weathering
- High temperatures draw salty groundwater to the surface, where it evaporates, leaving behind salt crystals
- Salt crystals grow between pores and joints, leading to **granular** and **block disintegration**

Your notes



Salt crystallisation is where salty/saline water is drawn into the pores of a rock to evaporate and expand, exerting pressure on the rock

Granular disintegration

- Found in rocks of **different coloured minerals**
- Darker minerals absorb more heat than lighter ones
- The rock will break down into grains to produce sand-sized material

Block disintegration

- Well-jointed and bedded limestone breaks into blocks along the natural weaknesses

Hydration

- The **minerals** in rocks **expand** when they absorb water, putting the surrounding rocks under more stress
- This build up of stress causes the rock to snap along its joints

Exam Tip

When you are describing the different types of weathering, make sure you link them to specific rock types. Not all rocks weather in the same manner.

Your notes

Erosion, Transportation & Deposition in Hot Arid Environments

Your notes

- **Wind and water** are the main agents of erosion, transportation and deposition

Wind action

- Winds in hot, arid environments are usually:
  - Strong (over 20 kilometres per hour)
  - Turbulent
  - Come from a mostly constant direction
  - Blow for a long time
- Friction slows down surface wind speed
  - The rougher the ground, the more the wind speed is reduced
- Transportation is greater where there is:
  - A lack of vegetation
  - Sediment is dry loose and small
- Deposition is mostly as sand dunes
- The shape and size depend on:
  - The supply of sediment
  - The direction of wind
  - Type of ground surface
  - Presence of vegetation
- Wind erodes in three ways:
  - **Deflation**
  - **Abrasion**
  - **Attrition**

Deflation

- The wind removes fine sediments and lowers the desert floor
- This leaves behind coarser gravels, forming a slag-type deposit of duricrust from the exposed bedrock
- This hardened desert floor, known as **desert pavement**, limits any future deflation and forms the features of a 'reg' desert
- Strong wind eddies can further hollow out the desert surface to form **deflation hollows (blowouts)**
- These deflation hollows are usually small but can extend several square kilometres

Deflation of the desert floor

Your notes

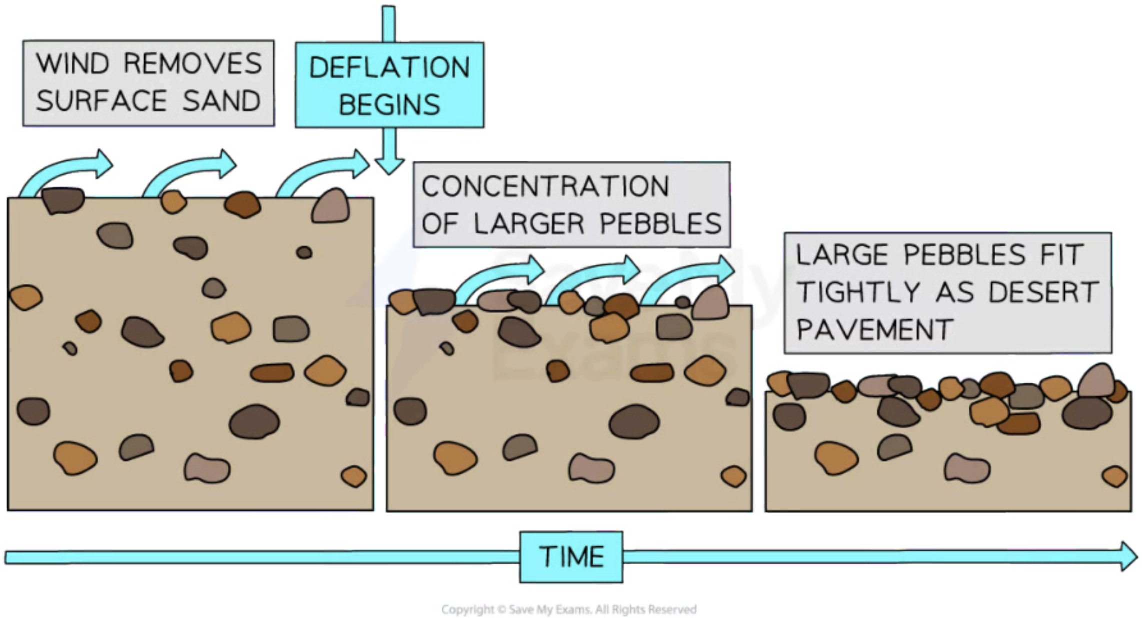


Image showing the formation stages of a desert pavement through deflation

Formation of deflation hollows

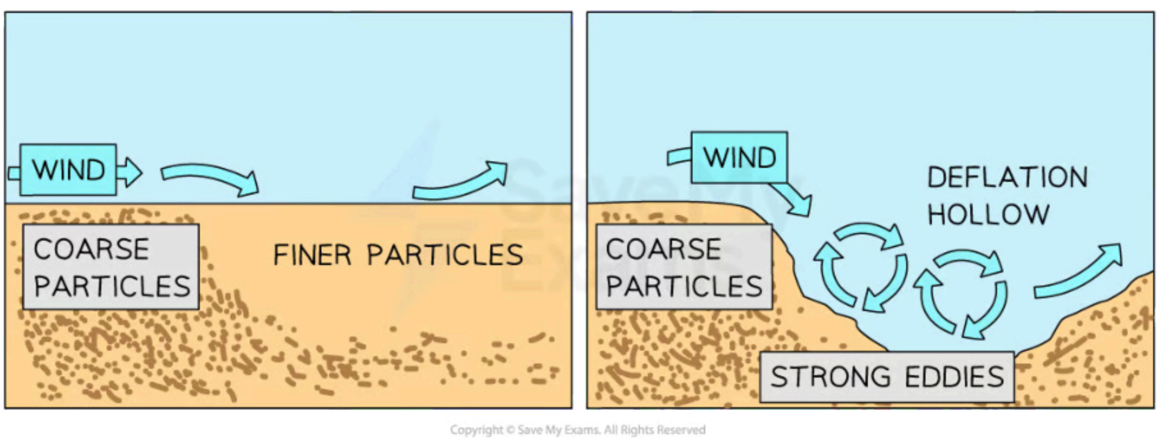


Image showing how deflation hollows form

Abrasion

- Wind laden with sand carves and sculpts rock (sandblasting), usually within a metre of the desert floor
- The strength, duration and direction of the wind will dictate the rate and intensity of the abrasion

- The geology of the rock also factors into the rate of abrasion, with sandstone and limestone being the easiest to erode

Abrasion in deserts

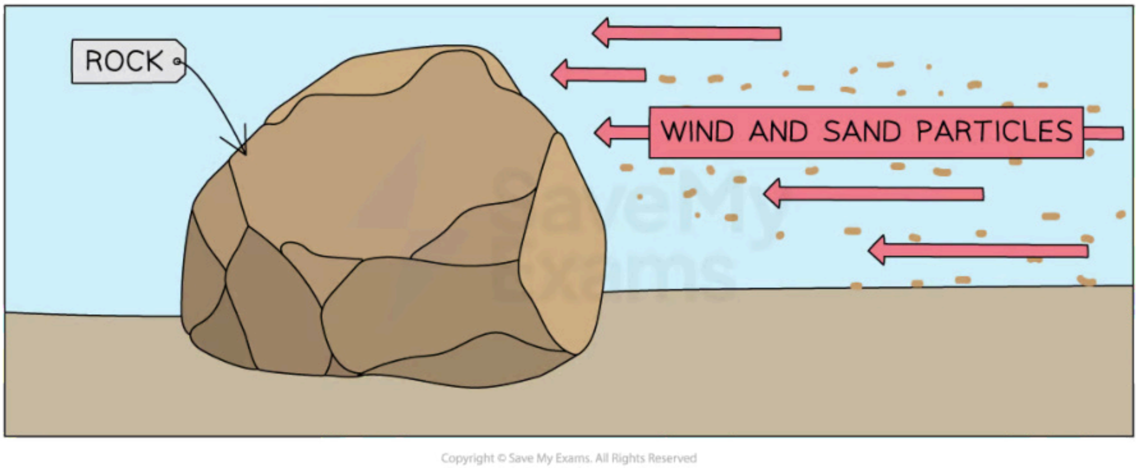


Image showing how wind abrades rocks in the desert

Attrition

- Attrition happens during transportation
- The wind picks up small pebbles.
- These pebbles are too heavy to be carried far so attrition happens within 0.5 m of the desert floor
- As they move, the pebbles collide with each other, and bits of rock are broken
- The wind picks up these smaller fragments and carries them along the desert floor, crashing into one another and break into even smaller pieces.
- Eventually, these particles become part of the abrasion process

Attrition in deserts

Your notes

Your notes

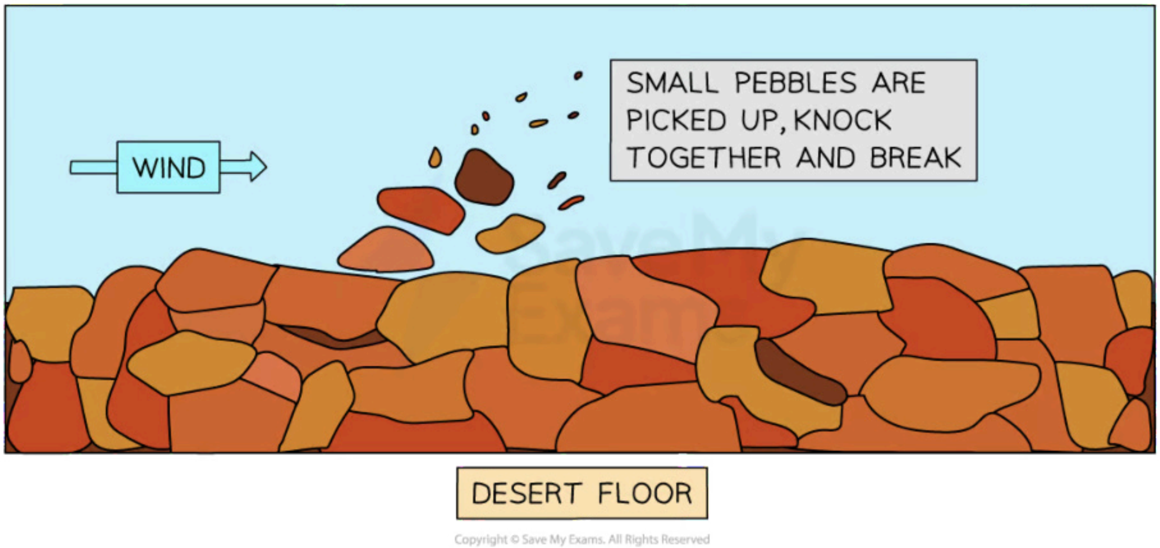


Image showing how desert attrition occurs

Wind transportation in hot, arid environments

- Wind transports sand particles away from an area in 3 ways:
  - **Creep** occurs when sand grains (>0.25 mm) slide and roll across the surface
    - Small changes in air pressure result in a lift of no more than 2 mm
  - **Saltation** occurs when the wind is strong enough to bounce particles close to the ground
    - Material moved by saltation may move around and push bigger particles that are too heavy to lift.
    - The steady bombardment moves small rocks and pebbles across the desert's surface
    - The wind can not carry the particles very far because they are too heavy, and they only rise 10 cm above the desert floor
  - **Suspension** occurs when high-speed winds carry small dust particles (fine silt and clay) of less than 0.15 mm high into the atmosphere
    - This process is the main cause of dust storms
    - These dust particles can travel for thousands of kilometres
      - Saharan dust has been found in the Amazon basin, the Himalayas, the UK, Japan, and other regions

Transportation of sediment in deserts

Your notes

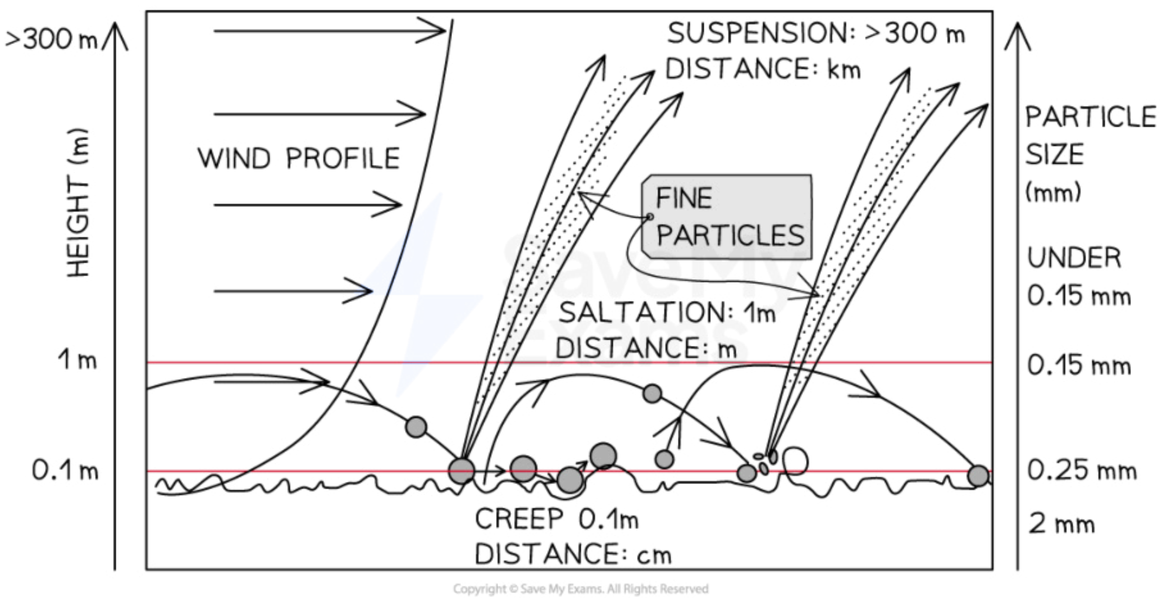


Image showing how material is transported along the desert surface

Wind deposition

- Deposition will only happen when the **wind speed falls** below a certain level
- This depends on how big the particle is and how strong the wind is
- The wind can then shape the object that has been dropped
- Only 30% of all deserts are covered in wind-blown sands and are called **'erg' deserts**
- Some of the most unique landscapes on Earth are sand seas, also known as great erg deserts
  - The Great Sand Dunes National Park in Colorado, USA, has over 600 km^2 of different types of sand dunes

Your notes

Worked example

State the role of wind in the process of transportation in hot deserts. [4 marks]

Suggested answer:

- Wind transportation is the major cause of erosion in deserts [1].
- Traction, or creep, happens when sediments are blown along the desert floor [1].
- Saltation is the bouncing movement of sediments, usually in stronger winds, and involves smaller pieces than those involved in creep [1].
- Suspended particles stay airborne because they are the smallest and usually form dust storms [1]

Water action in hot, arid environments

- The **impact** of water is **significant** in shaping desert landscapes
- Rainfall is sporadic; however, rare, substantial, and intense flash floods generate considerable runoff
- Due to convectional mountain storms, these **flash floods** flow as water sheets or are held within the channel
- Although short-lived, **huge** amounts of **sediment** are **washed** down from the mountains and **deposited** on **alluvial lowland plains**
- There is not much vegetation to soak up water, so soil levels are low
- This limits plant roots disturbing the soil, making it dense and hard
- Rain is able to hit the surface hard, moving small particles around and covering soil pores, which slows the rate of infiltration even further
- Because of this low rate of infiltration, slopes of less than 2° have a lot of horizontal flow

Erosion

- Hydraulic action
- Abrasion
- Corrosion
- Attrition

Transportation

- Traction
- Saltation
- Suspension
- Solution

Deposition

- This takes place when velocity drops
- Usually occurs:

Your notes

- On the inside of meander bends
- Where streams and channels flow out of the mountain edges onto flat desert plains

Sheetwash processes

- Studies show that surface flow is most likely to happen within 10 minutes of the rain starting
- **First**, there is **sheet flooding**, in which water flows widely over land and is not limited to channels.
- **Second**, water from all sources gathers in deep, **steep-sided wadis or arroyos**
- It happens about once a year on average along the semi-arid edges of the Sahara and once every ten years in the very dry interiors
- The fact that floods do not happen very often compared to the number of wadis indicates that they were built when storms were more frequent; they are a relict feature

Other water processes

- Splash erosion
- Rill erosion
- Gully erosion
- Bank erosion

Exam Tip

Remember that it rains infrequently in deserts, and the influence of water in shaping desert landscapes is often overlooked. You need to know that water's effectiveness in erosion, is due to factors such as vegetation cover, slopes, the permeability of surfaces, and rainfall amounts.
Also, many desert landforms may be relict features, formed during wetter climatic periods.

6.2.5 Landforms in Hot Arid Environments

Your notes

Hot Arid Wind Landforms

- Each desert landscape is unique due to past and present interactions of rocks and processes operating on them
- **Wind and water action** are the most **important** processes, although weathering, mass movement and vegetation also play a role

Wind landforms of erosion

- The wind is responsible for the formation of a number of distinct landforms, including:
  - Deflation hollows and desert pavements
  - Ventifacts
  - Yardangs and zeugens
  - Rock pedestals

Ventifacts

- Ventifacts are faceted cobbles and pebbles that have undergone erosion and shaping by wind-blown sediment
- **Formed in the direction of the prevailing winds**
- There are sharp edges separating the leeward side from the windward side

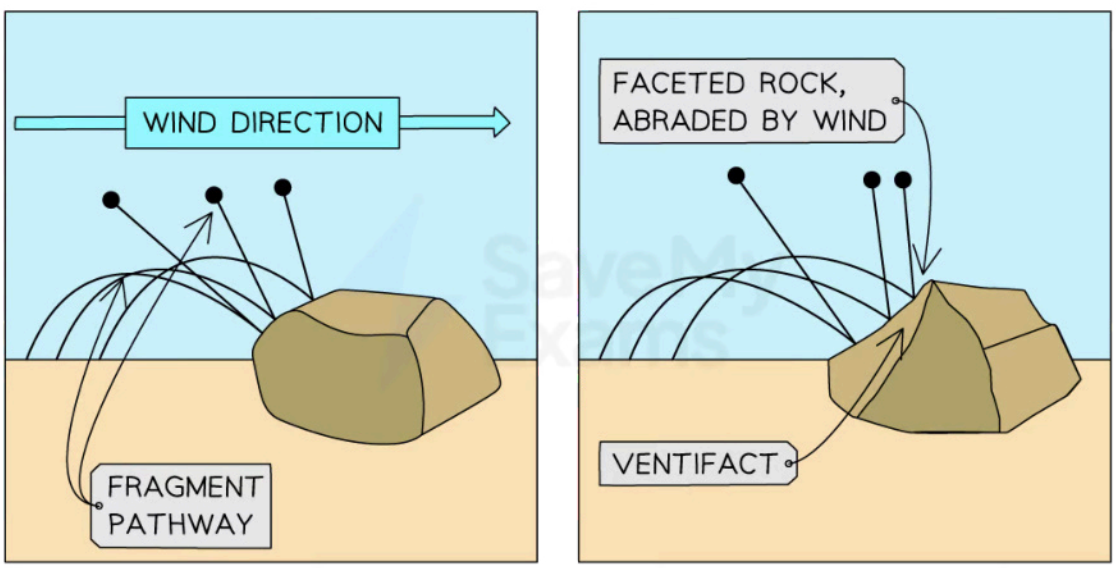


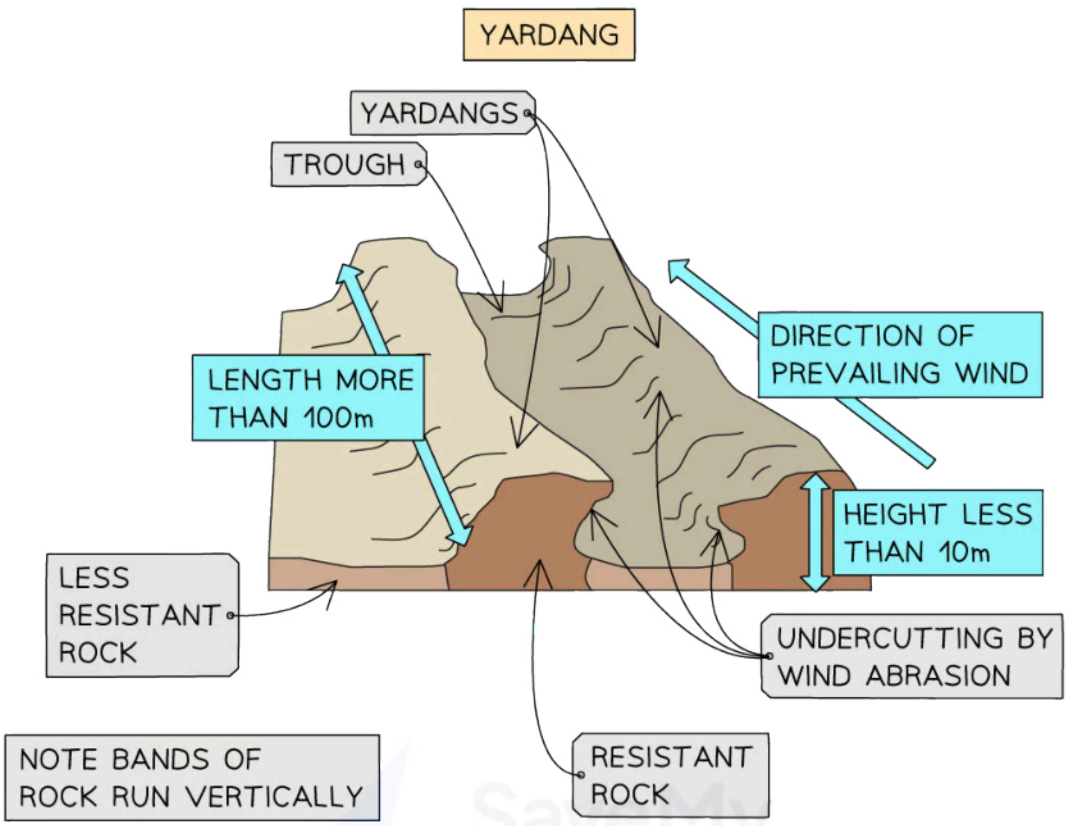
Diagram showing the formation of a ventifact

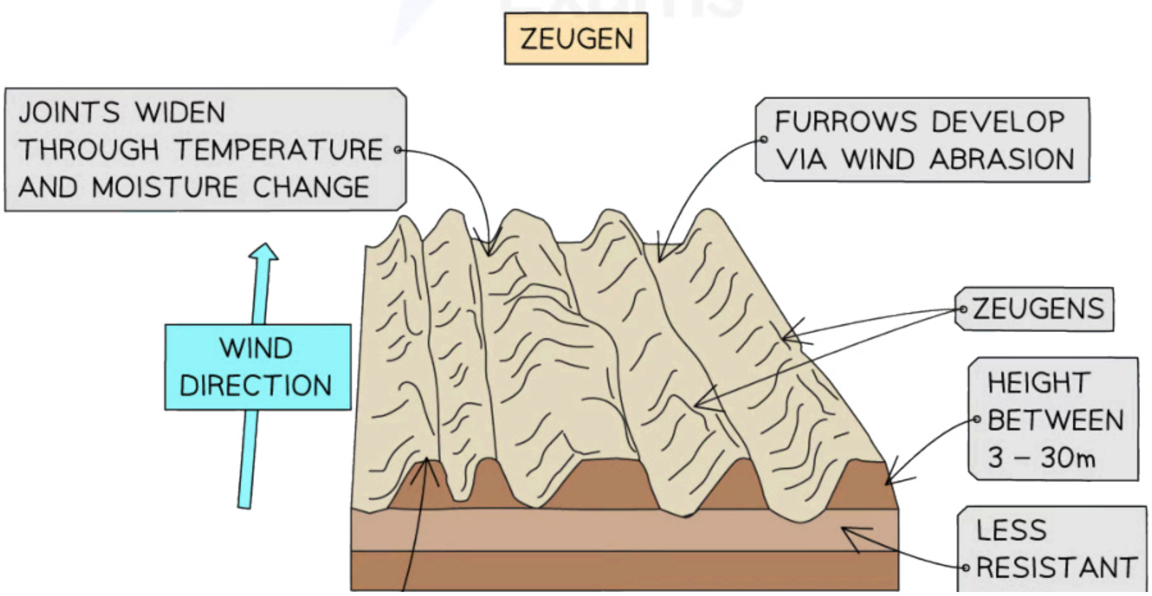
Yardangs

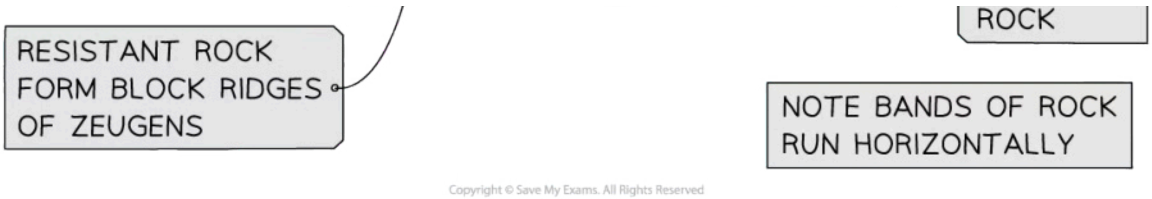
- Yardangs look like an upturned boat
- They are **elongated, streamlined ridges**, that are **less than 10 m high** and **more than 100 m long**
- They are formed where **vertical layers of resistant and less resistant rock** are **aligned to the direction of the prevailing wind**
- Abrasion causes the less resistant rock to erode, leaving behind vertical yardangs of resistant rock and creating deep troughs.
- People are not 100% sure about their formation yet, but due to their alignment with the prevailing winds and the abrasion from sand erosion at their bases, this suggests that wind plays a part in their formation

Your notes

Your notes


YARDANG
YARDANGS
TROUGH
LENGTH MORE THAN 100m
DIRECTION OF PREVAILING WIND
HEIGHT LESS THAN 10m
LESS RESISTANT ROCK
UNDERCUTTING BY WIND ABRASION
NOTE BANDS OF ROCK RUN VERTICALLY
RESISTANT ROCK


ZEUGEN
JOINTS WIDEN THROUGH TEMPERATURE AND MOISTURE CHANGE
FURROWS DEVELOP VIA WIND ABRASION
ZEUGENS
WIND DIRECTION
HEIGHT BETWEEN 3 – 30m
LESS RESISTANT



Yardangs and zeugens form in the same way, but the layers of resistant and less resistant rock lie differently

Zeugens

- Zeugens **form in the same way as yardangs**, **but** the layers of resistant and less resistant **rock lie horizontally**
- The resulting ridges can be anything from **3 to 30 metres high**
- **Joints** in the resistant rock **widen** through **weathering**
- **Abrasion deepens** the **furrows** down into the less resistant rock beneath
- **Undercutting** of the furrows may also occur to give them a **pedestal**-**like shape** with a **flat cap rock** which **protects** the underlying, less resistant rock
- As the **primary process** is **abrasion**, which is **concentrated** within 2 **m** of the desert floor, zeugens often have an **eroded, narrower base**

Pedestal rocks

- Pedestal rocks are also called '**mushroom rocks**'
- Thought to be the **final remains of a zeugen,** they are again primarily formed as a result of **aeolian abrasion**
- It can also be found in areas where isolated rock peaks are exposed to the surface
- Made of **alternating, horizontal bands of sedimentary rock**
- Winds carrying **fine sand particles** act as an **abrasive** and start **cutting and polishing** the exposed rock
- **Abrasion works up to a maximum height of 2m**
- The softer, least resistant rock is eroded faster than the case hardened **upper cap**
- Effectively creating a mushroom-like structure
- **Continued erosion** leads to the eventual **collapse of the pedestal**

Your notes

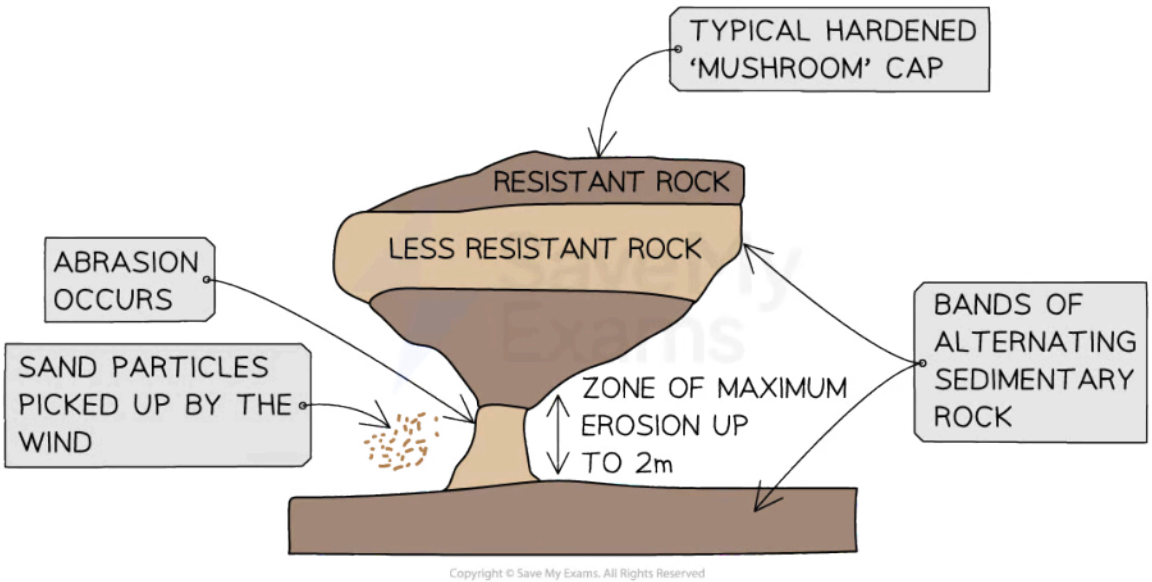


Image showing the formation of a pedestal 'mushroom' rock

Exam Tip

You may have to describe the formation of a landform. Refer to shape, size, geology and field relationship (the position of the landform in relation to the landscape). Make sure you are able to draw a labelled diagram of the landform to support your description.

Wind landforms of deposition

- Wind-deposited material occurs as:
  - **Sand sheets**
  - **Ripples**
  - **Dunes and sand seas**

Sand sheets

- These are flat areas of sand with sand grains that are too large to saltate (bounce)
- 45% of all depositional surfaces are of this type, e.g. Selima in South Egypt

Sand ripples

- These are **small landforms formed by the wind**
- They consist of **crests and troughs** and develop at **right angles to the wind**
- The main **difference** between a **ripple** and a **dune** is size, with **dunes** being **taller** than about **10 cm**

Sand dunes

Your notes

- The wind eventually blows sand into a **network of troughs, crests and ripples** that are **perpendicular** to the **wind** direction
- They are the consequence of **saltation**
- They become a **dune** when the **crest** is about **30 cm high** and the **slip-face's angle of repose is 34°**
- Dunes grow as sand particles move up the gentle, **windward slope** by the **processes of saltation and surface creep**
- The sand particles continually fall over the **crest** of the dune, onto the steeper, **slightly concaved, leeward slope/slip face**
- The **top** of the slip face **is steep** because it is made of **fine-grained sand and it is kept steep by wind eddies**
- The **bottom** of the slip face is **gentle,** contains **coarse-grained sand** and may have further sand ripples
- A sand dune can **move** up to **30 metres a year** and can be **several metres high**
  - The Duna Federico Kirbus, Argentina is the highest dune in the world, measuring 1234 metres in height (2845 metres above sea level)
  - The Big Dipper, Merthyr Mawr, Wales, is home to the tallest dune in the UK and the second-largest in Europe, measuring around 61m

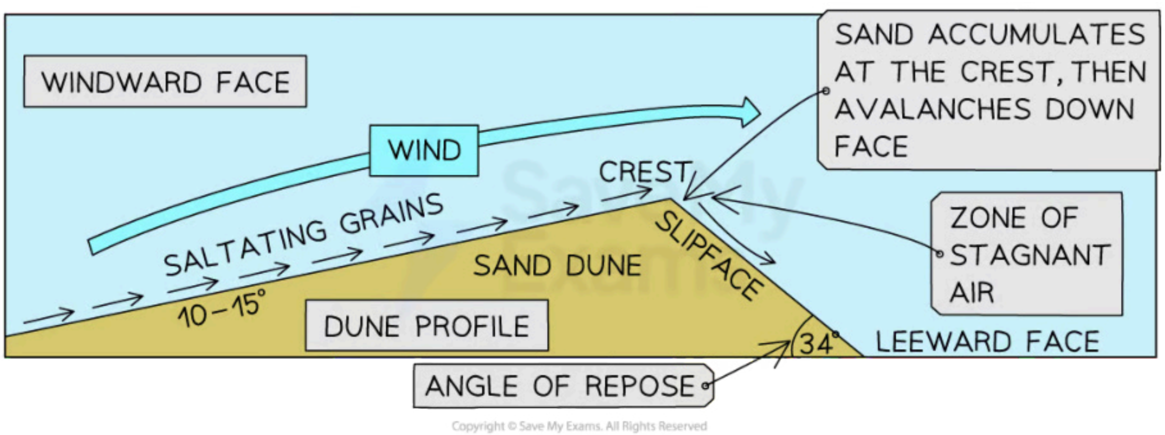


Image showing how a sand dune is formed, dependent on wind and loose sand.

Types of sand dunes

- There are many types of sand dunes but the two most common are:
  - **Barchan dunes**
  - **Seif or longitudinal dunes**

Barchan dunes

- These are the typical **crescent-shaped** dunes
- Found in isolation in deserts where there is a **limited supply of sand but a very dominant wind direction**
- Barchan dunes **form at right angles to the prevailing wind in one direction**

- They have wind-pushed horns that curve in the direction of the slip face

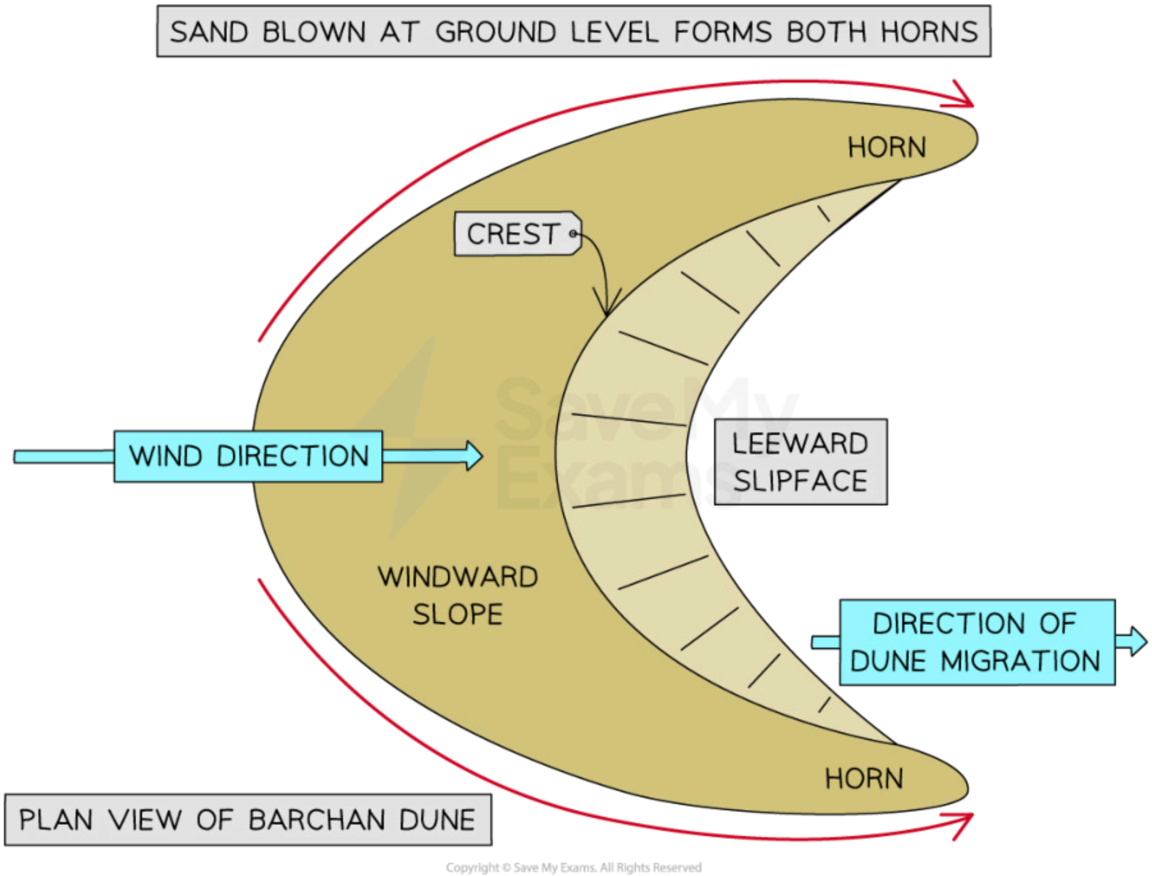


Diagram showing the characteristic features and formation of barchan dunes

Seif or longitudinal dunes

- These are **elongated**, **linear** sand dunes
- Most often **found in extensive areas of sand** known as **sand seas**
- They can **stretch** for **several hundred metres**
- Formed from **two dominant prevailing winds** in **two different directions**
- One blows in one direction for part of the year
- The second blows from the other direction for the remainder of the year
- Seif dunes **form parallel to the wind direction** and may develop from barchan dunes

Your notes

Your notes

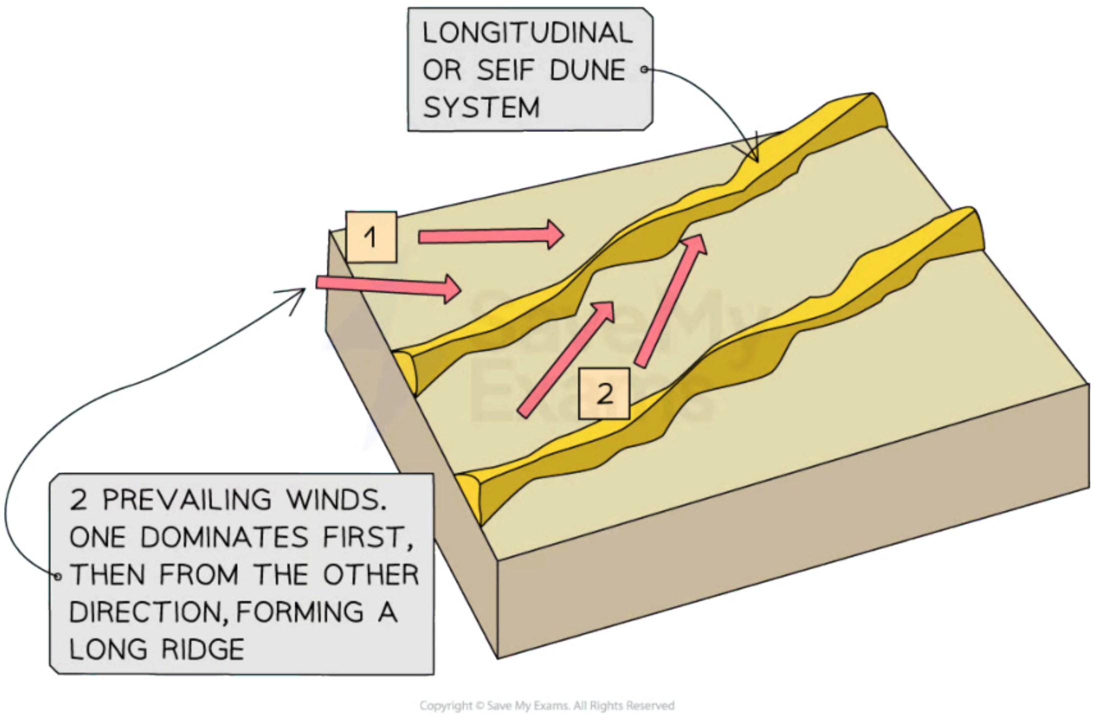


Diagram showing the formation of seif dunes

Your notes

Hot Arid Water Landforms

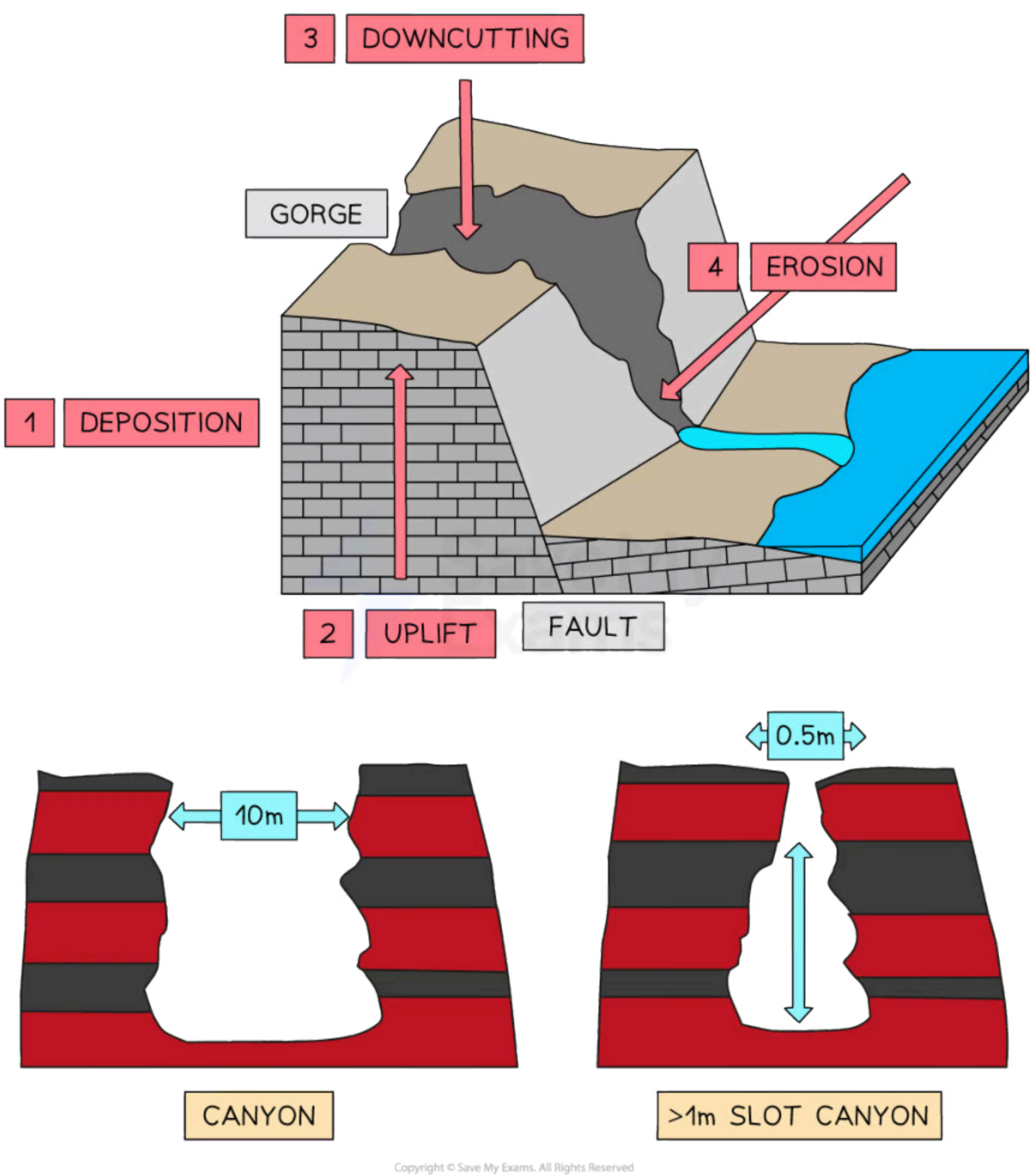
- Despite low rainfall, temporary streams and rivers are powerful land-forming agents
- High-intensity rainfall and lack of plant cover mean that runoff is rapid, creating erosional landforms such as canyons
- Streams and rivers carry high sediment loads, creating depositional landforms such as alluvial fans
- Some of these landforms are still being actively formed (e.g. wadis), whilst others are being gradually removed through weathering, mass movement and erosion (e.g. mesas)

Canyons

- Canyons are deep gorges that usually have a river running through them
- Canyons are formed over millions of years when water rushes through any kind of rock, but especially sandstone and limestone (the Colorado river has cut down vertically to form the Grand Canyon)
- Formed through: **D U D E**
  - **D**: **deposition,** deposition of sediment from rivers builds up layers of sedimentary rock
  - **U: uplift,** the newly formed rock layers undergo uplift, where they rise up and form large plateaus
  - **D: downcutting,** hydraulic action deepens the channel of a stream or valley by removing material from the stream's bed or the valley's floor
  - **E**: **erosion** (not wind), erosion wears away at the sides of the plateaus and forms steeper gradients
- **Slot canyons** are narrow types of canyons that are deep rather than wide
- A special combination of flash flood water and rock is needed for a slot canyon to form, which makes them rare
- They form when a crack is covered by a flash flood waters pooling in a natural wash/wadi/gully
  - The water seeps into the crack, bringing with it rocks, sediment, and other debris that erode small areas from the inside edges of the crack
  - **Rain, flood, repeat**
  - Slot canyons are usually formed in sandstone
- Found anywhere in the world, but are concentrated in the southwestern U.S. and Australia
  - Petra in Jordan, made famous in the Indiana Jones film 'Last Crusade', is entered via the 1.2 km (3/4 mile) Siq slot canyon
  - In some places, this canyon narrows to less than 0.5 m across
  - Unlike most slot canyons, Siq was formed through tectonic uplift, splitting the mountain apart, but flash floods have subsequently smoothed the canyon walls

Formation of a canyon

Your notes

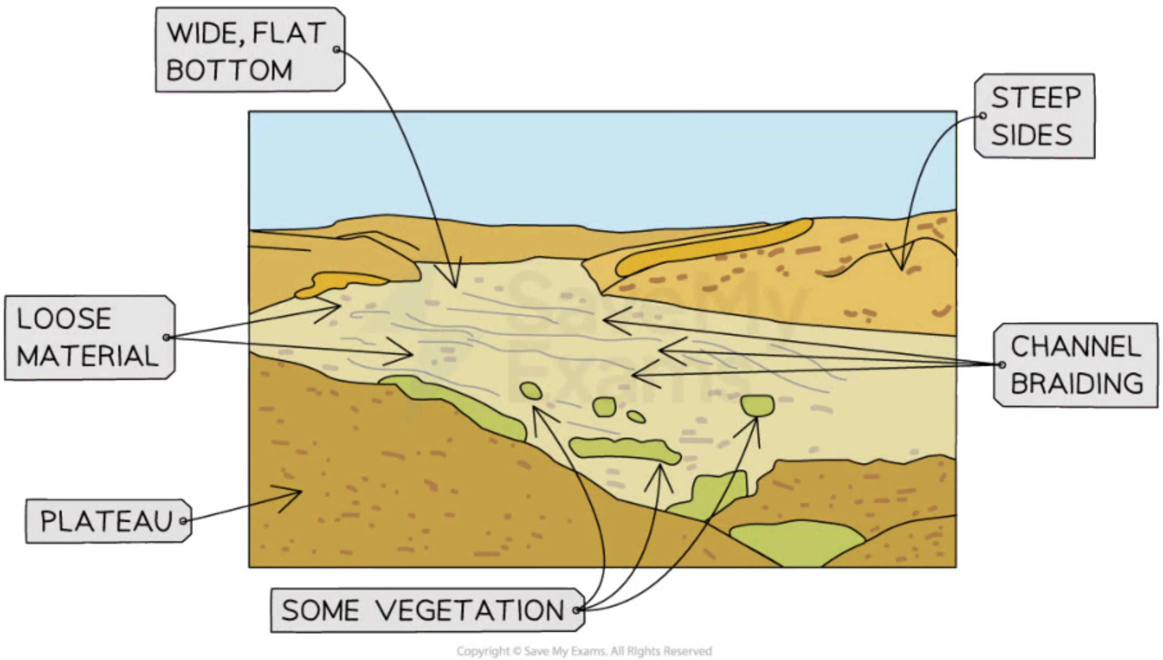


(Slot) canyons have taken a long time to form and are still being formed

Wadis

Your notes

- Wadis are channels that were **once part of a constant drainage system but** now receive run-off from torrential storms
- Water wears away **deep trench systems** called wadis or arroyos
- Wadis can be found in **lowland areas** or as a **valley or gully that is cut into a plateau**
- Normally, wadis are **dry stream channels**, but **quickly fill** after rain and flash floods, which make these channels dangerous
- Wadis come in a range of sizes and shapes, but they usually have steep sides and a flat channel floor
- Wadis have **thick sediment layers, loose debris** from flash floods and **may contain vegetation**



Wadis can vary in shape and size but have similar characteristics

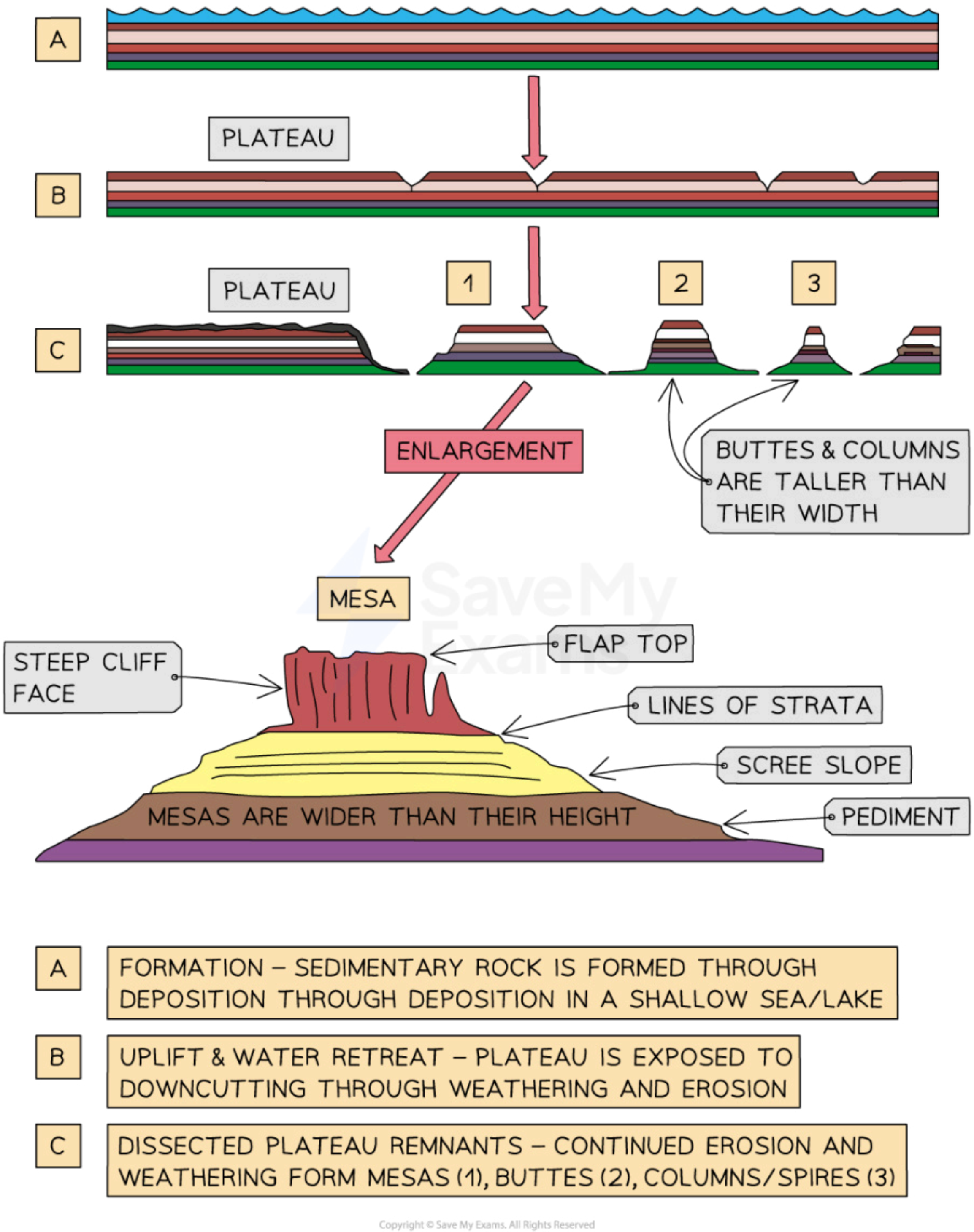
Plateau

- Plateaus, also called high plains or tablelands, are **flat-topped, elevated, sedimentary rock landform** that are wider than they are tall
- **Many processes** form plateaus, including **tectonics, lava outflows, and erosion by past river and glacial action**
- **Plateaus can be considered a relict feature (old feature)**
  - The Colorado Plateau or the Colorado Plateau Province is the largest plateau in America
  - It covers an area of 336,700 km^2, covering northern Arizona, western Colorado, north-western New Mexico, along with southern and eastern Utah

Mesas and buttes

- **Formed in flat-lying sedimentary layers,** with **flat tops, steep eroded sides, and scree slopes,** they are wider than taller
- Mesas **can occur in groups** but are more **often isolated**
- Mesas are **remnant** parts of a larger sedimentary table-top **plateau**
- **Buttes** (pronounced 'beaut') are **remnant mesas** that have undergone further weathering and erosion and **are taller than they are wide**

Your notes


A
B
PLATEAU
PLATEAU
C
1
2
3
ENLARGEMENT
BUTTES & COLUMNS ARE TALLER THAN THEIR WIDTH
MESA
STEEP CLIFF FACE
FLAP TOP
LINES OF STRATA
SCREE SLOPE
PEDIMENT
MESAS ARE WIDER THAN THEIR HEIGHT
A
FORMATION – SEDIMENTARY ROCK IS FORMED THROUGH DEPOSITION THROUGH DEPOSITION IN A SHALLOW SEA/LAKE
B
UPLIFT & WATER RETREAT – PLATEAU IS EXPOSED TO DOWNCUTTING THROUGH WEATHERING AND EROSION
C
DISSECTED PLATEAU REMNANTS – CONTINUED EROSION AND WEATHERING FORM MESAS (1), BUTTES (2), COLUMNS/SPIRES (3)
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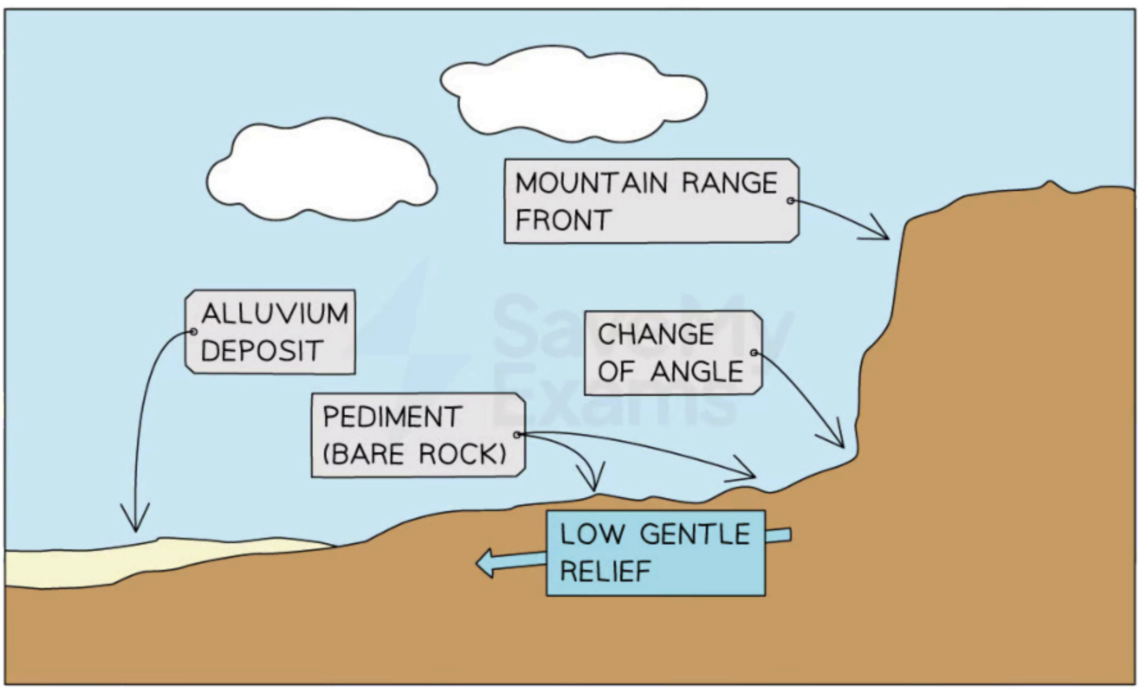
Your notes

Plateaus take millions of years to form; mesas are wide and buttes are taller than they are wide

Pediments

- A pediment **forms at the foot of a steep slope** or cliff of a **receding mountain range** by running water
- They have **gentle, eroded slopes**, or plains, with a **low relief** of between 2° and 7°
- They **mark** the **angle of change** between the **cliff face and the pediment plain**
- Alluvium, which comes from upland areas, typically covers a pediment, and sheet-washing removes the sediment to leave a smooth rock surface

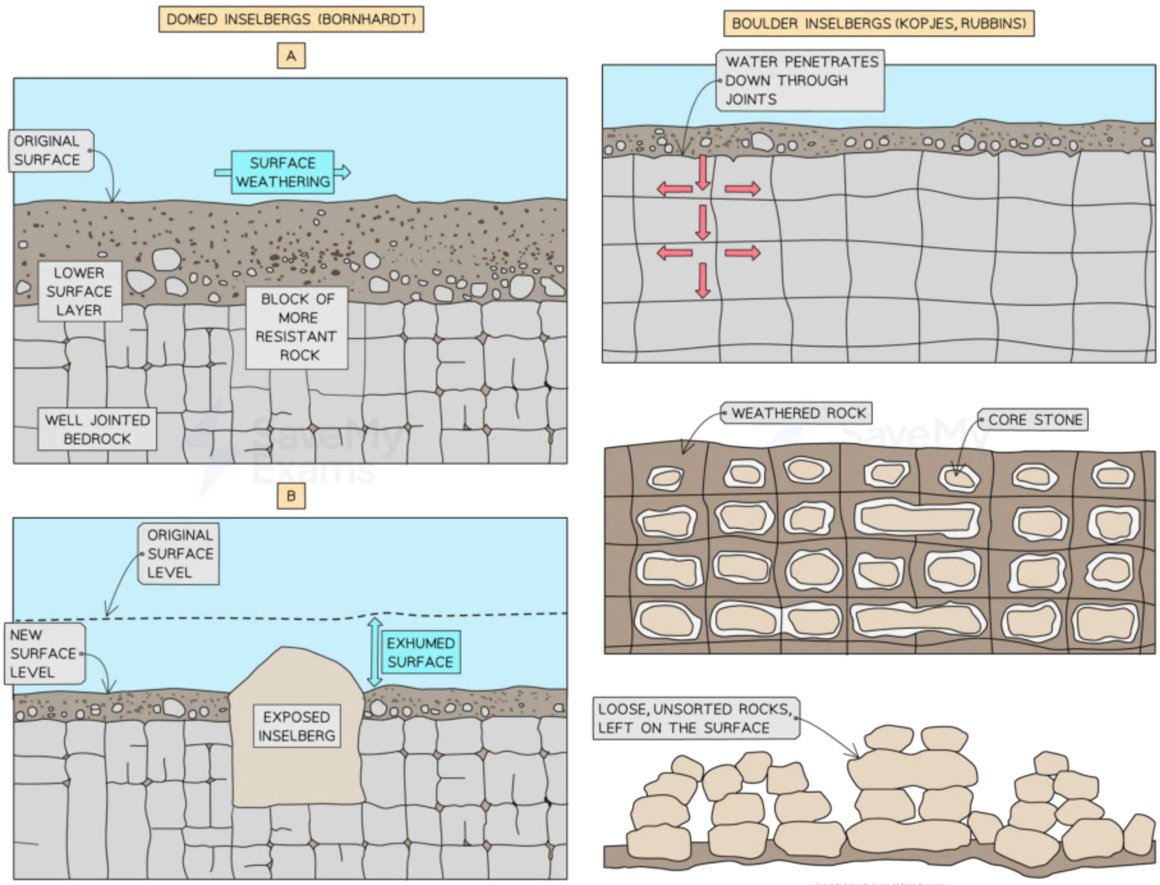


Much of the alluvial material on a pediment is in transit, moving during episodic storm events or blown by wind

Inselbergs

- **Inselbergs rise abruptly out of desert landscapes and are known as 'island mountains'**
- Inselbergs are usually formed from a granite intrusion (pluton), but can also be large sandstone deposits
- Water (and wind) attack the original surface, leaving a round-topped inselbergs **(through exhumation/uncovering)**

- The exposed inselberg has a deep-seated 'decay' origin where subsurface weathering has begun rounding the edges
- Or the rock may have extensive **subsurface chemical weathering** that has broken the inselberg into boulders
- There are **two major forms**:
  - **Domed** inselbergs (bornhardts), e.g. Uluru, Australia
  - **Boulder** inselbergs (kopjes, rubbins), e.g. Matopos, Zimbabwe



The formation of inselbergs begin underground through chemical weathering, which changes to erosion as the rock is exposed

Depositional water landforms

- Hot, arid water landforms consist of:
  - Alluvial fans
  - Bajadas
  - Playas

Your notes

- Salt pans

Alluvial fans

- In areas with flash flooding, rocks are washed out through a wadi, or canyon and land in an alluvial fan at the edges of mountain ranges
- Due to a sudden loss of energy, rivers leave their mountain channels and join a plain, leaving behind cones of sediment
- Sediment is sorted in size from largest to smallest
- A bajada can be made when several fans come together
- Alluvial fans can extend for several kilometres and reach a depth of 300m

Bajadas

- A bajada is the blending of many alluvial fans and are common in dry climates
- Bajadas can be narrow, from the flow of two or three streams of water, or they can be wide, where dozens of alluvial fans converge
- Bajadas and large alluvial fans are sources of groundwater

Playas

- Playa lakes form in low areas of deserts following intense precipitation
- They are shallow, often saline, and short-lived, lasting from a few hours to several months
- When the water of a playa lake evaporates, the dry lake bed is referred to as a playa or salt pan
- Playas contain mud-cracks and salt deposits; some are thick enough to mine

Salt pans

- A salt pan is a small bowl or depression in the ground where salt water evaporates and the salt is left behind
- Seawater pools turn into salt pans when they dry up faster than they can be filled up by rain
- As the water evaporates, it leaves behind the minerals precipitated from the salt ions dissolved in the water
- Salt is typically the most abundant of these minerals, accumulating over many thousands of years and giving the surface its hard-white crust

Your notes