Arid landform development
3.1.2.3 Hot desert systems and landscapes

What you need to know
Origin and development of landforms of mid and low latitude deserts – formed by aeolian and water processes
The relationship between process, time, landforms and landscapes in mid and low latitude desert settings

Origin and development of landforms of mid and low latitude deserts
The huge scale of deserts, the lack of surface vegetation cloaking the landscape and the removal of fine sediments by the action of wind and water can produce spectacular desert landforms.

Aeolian (wind) erosional features

- ***Deflation hollows:*** Surface depressions, known as deflation hollows, have formed in some of the world's largest deserts by the erosional process of deflation. Dew collects in low-lying basins, providing an input of moisture. The surface material is then broken down by chemical weathering and transported away on the wind. Some of the deflation hollows in the Sahara Desert are hundreds of kilometres wide. The largest is the Qattara Depression in Egypt which, at its deepest point, is 134 metres below sea level. The American Mid-West Dust Bowl of the 1930s was formed as a consequence of deflation, following a severe drought that made the soil dry, friable and prone to wind erosion. In the example of erosion in the American Mid-West, the **dynamic equilibrium** (the tendency towards a natural state of balance) was upset by an extreme event, in this case drought, but it could easily be a storm or floods. Human activity can also cause disruption to the dynamic equilibrium, such as by modifying the drainage basin

- ***Desert pavements:*** Covering huge areas, desert pavements or 'reg' are flat, stony surfaces that resemble a cobbled street. Any silt-sized or sand-sized particles have been blown and transported elsewhere. The desert surface represents all the particles that are too large to be lifted by the wind and can be a measure of wind strength (the larger the dominant sediment left behind – the stronger the wind).

- ***Ventifacts:*** Individual rocks and boulders are often the focus for wind erosion. Sand in suspension causes abrasion and pitting on the side facing the prevailing wind. Abrasion can completely smooth one side of a rock and produce irregular sandblasted shapes.

- ***Yardangs:*** Extensive ridges of rock known as yardangs, separated by grooves (troughs) can form in alignment to the prevailing wind direction. These ridges are usually three to four times longer than they are wide. Strong winds blowing in one direction and carrying sand in suspension erode the desert surface by abrasion. Softer rocks erode faster than harder rocks, so ridges of more resistant rocks remain upstanding. In parts of the Saharan, Arabian and Atacama Deserts, yardangs are large enough to be visible on satellite imagery.

- ***Zeugen:*** this is another landform sculpted by wind erosion. They are long tabular (block-shaped) masses of resistant rock separated by trenches and are formed in areas

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where more resistant rock overlies less resistant rocks. The overlying rocks are weathered and the wind cuts vertically through the cap exposing the underlying softer rock, which is then eroded more rapidly. Zeugens can be anywhere between five and 30 metres in height.

- ***Rock pedestals:*** These mushroom-shaped rocks form as a result of sand blasting. Sand particles skip across the desert surface blown by strong winds and abrade anything in their path. Sand blasting is most effective within the first 1.5 metres of the ground surface and this means that there is significant undercutting of the base of vertical rocks. Continued erosion of the 'stalk' can lead to the eventual collapse of the pedestal. Spectacular rock pedestals are seen in Utah, USA and the White Desert in Egypt.

Aeolian depositional features

When sand grains transported by saltation are deposited, they form sand dunes as the wind slows down. Wind can slow for a number of reasons, but it is usually vegetation, rocks or other sand dunes creating an obstacle. Sand dunes form in a number of shapes and layouts dependent upon a number of factors:

- The direction and speed of the wind
- The quantity of sand being transported
- The nature of the desert surface
- The presence of vegetation

- ***Erg****:* A large area of sand dunes is known as an erg (sand sea). These features can stretch for hundreds of kilometres and cover approximately one quarter of all arid regions. Ergs are mainly confined to the Arabian and Sahara Deserts. Sand seas are an apt name for a large area of sand dunes due to the way that sand dunes appear like a slow-moving wave as they migrate with the wind. Five basic dune shapes have been recognised: crescentic, linear, star, dome and parabolic.

- ***Barchan dunes:*** The barchan is a crescent-shaped dune that can reach 30m high and is moved by the wind. Saltation and surface creep take place on the gentle upwind-facing slope of the dune (stoss face) as the wind pushes material upslope. Sediment then continually avalanches over the ridge and down the steeper lee (slip face) of the sand dune, moving the entire sand dune forward at a rate of up to 30m/yr. Swirling wind currents (eddies) help to keep the lee slope steep. The horns (edges of the dune) move faster than the centre of the dune as there is less sand to move. The barchan dune below is actually on Mars!

- ***Seif dunes:*** these are longitudinal dunes (named after an Arab curved sword) that are long ridges of sand which form parallel to the prevailing wind. They are much larger and more common than barchan dunes. Seif (linear) dunes can reach 200m in height and over 100km in length. They form from linked barchan dunes when a temporary – but repeated - change in wind direction occurs. This causes one of the horns or 'arms' of a barchan dune to elongate and merge with its neighbouring dune to form a series of connected dunes. These dunes are dominant in South East Libya and South West Algeria.

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Image of a Martian barchan dune taken by the Mars Reconnaissance Orbiter: NASA/JPL/Uni of Arizona

Water (fluvial) landforms

Although storms are infrequent in desert areas, torrential rain can be very erosive altering the landscape dramatically, bringing sediment down from desert mountains, reshaping river beds and depositing debris in alluvial fans, bahadas and chotts. These are classed as fluvial processes and landforms as distinct from aeolian or 'windblown' processes and features.

Erosional features

- ***Inselbergs:*** Meaning 'island hill' (German), inselbergs are isolated steep-sided hills including mesas and buttes that are remnants of the erosion process upon extensive desert surfaces leaving masses of more resistant rock as legacy features in a lowered plain. Mesas are plateau-like mountains and buttes are isolated pillar-like formations. There is great debate about the conditions under which inselbergs form. Many geomorphologists now believe that they are relict uplands of past climatic conditions when rainfall was higher and had much more power to erode the softer rock surrounding inselbergs, by water erosion. Uluru (Ayers Rock) is an inselberg in Australia.

- ***Wadis:*** Dry river valleys known as wadis are dry for most of the year and only fill with water flowing in ephemeral streams after torrential rain. Wadis can develop into deep ravines and gorges if they are repeatedly eroded by fast-flowing torrents of water.

Depositional features

The main depositional features created by flowing water in desert landscapes can be found within intermountain basins or desert pediment.

- ***Pediments:*** these are gentle sloping terrain located at the foot of desert mountain ranges with a low slope angle (between 1° and 7°) consisting either of solid base rock, depositional accretions, or a mixture of the two. They represent the junction between a zone of steep slopes and erosional processes (uplands) and flat, depositional lowlands. They are formed by the abrasion of rock by the sediment carried in sheet floods and are usually covered in a thin layer of sediment representing the remains of the last flood.

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- ***Alluvial fans:*** these are delta-like depositional landforms that develop where an ephemeral stream runs over a break of slope to a shallower gradient, causing energy loss and the consequential deposition of the sediment carried. The deposited sediment spreads out into a fan shape, the heaviest being dropped first. Alluvial fans can be anywhere from 20 km in length and 300 m in thickness. The pediment often forms the break in slope upon which the deposition of discrete (individual) alluvial fans takes place.

- ***Bahadas (Bajadas – Spanish for 'slope'):*** Where a number of parallel wadis converge at a mountain front in close proximity, a number of alluvial fans coalesce with those adjacent on either side, forming a bahada/bajada. These bahadas can cover up mountain pediments, or form at the foot of them where the gradient becomes almost flat.

- ***Chotts:*** Chotts (North Africa), sabkhahs (Arabian Peninsula) and playas (North America) or pan (Australia) are all names for salt lakes or their evaporated deposits. These features are very common in deserts and have a number of common characteristics:
    - They feature at the low points of the desert landscape
    - They are usually very flat
    - They have no outlet to the sea
    - Ephemeral water collects in them after heavy rain
    - Evaporation leads to the formation of salt pans or thick crusts of salt and other evaporate deposits
    - Vegetation is sparse due to the salt left behind after evaporation of the ephemeral water

- Chott Ech Chergui a large endorheic salt lake in Saïda Province, Algeria and although vegetation is sparse it has been designated a Ramsar wetland of international importance for a number of threatened and vulnerable animal and plant species.

The relationship between process, time, landforms and landscapes in mid and low latitude desert settings: characteristic desert landscapes.

Many of our present-day deserts were once much wetter, fertile grasslands and forests in the past. Some of the evidence for this includes stores of groundwater under the Sahara, old soil horizons and relict landforms such as mesas and buttes in Utah, USA. 8,000 years ago the northern hemisphere had a wetter climate, monsoons intensified and the Sahara experienced humid conditions. During the Holocene Climate Optimum (9000-4000 BC), Lake 'Mega-Chad' was hundreds of kilometres wide with people settled on its shores. In Sudan, Wadi Howar, a once mighty river, sustained fish and crocodiles as well as agriculture and human settlement and in south-east Algeria, rock paintings show savannah animals such as elephants and zebus (cattle).

It is thought that the drying of Sahara from savannah to desert began around 5,500 years ago and was caused by a shift in the Earth's orbit. This means the current desert landscape is an accumulation of a time-series of landforms and landscapes, some of which were formed under past climatic conditions but are still evident, some that have been developing over recent millennia (thousands of years) but are persistent, some over the last century, and others that are quite short-lived features but that are in existence during contemporary conditions.

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The Kavir Desert and the development of hot desert landforms

Specification topic: Arid landscape and landform development 3.1.2.3

Case study: The Kavir Desert, Iran.

The Kavir Desert (Dasht-e Kavir literally 'desert of saltmarsh'), also known as the Great Salt Desert, is located on the Iranian plateau in a basin southeast of the Elburz Mountains and Tehran. It is the largest desert in Iran, approximately 800 km wide by 320 km in length and stretches from the Alborz mountain range in the north-west to the Dasht-e Lut desert in the south-east. The main features of the desert are hamadas (pebbly steppes), kavirs (salt deserts) and sand dunes.

Salt deposits

Tens of millions of years ago this area was covered in a saline ocean called the Paratethys Sea, which dried up and left a layer of salt over six kilometres thick. In more recent times layers of mud buried this salt. As salt has a lower density than mud, it pushed through the mud and formed salt domes or diapirs. These domes have also been squeezed and folded by recent tectonic uplift and the tops of these domes have been worn away by wind and rain, leaving the layers exposed in cross-section. Namak Lake has a surface area of about 1800 km^2, but water only covers 1 km^2 and is one metre at its deepest. The rest of it is dry and the salt has formed into salt polygons (hexagonal to octagonal shapes). The underlying mud and salt layer finds its way to the surface under high pressure and temperatures and the polygons form. The lake is a remnant of a large saline ocean, which left Lake Urmia and the Caspian Sea as relict features further to the north.

Salt marshes and crusts

The desert is incredibly arid and high evaporation rates have resulted in the formation of many salt lakes. Salt crusts (duricrust) have formed over the salt marshes and they can be particularly dangerous if people try to travel across them. The largest of the salt marshes is Kavir Buzurg and it is over 320 km in length. With hazardous salt marshes, fault lines that run through this area and extremely hot temperatures few people settle here. Although a few animal herders called the Yazd, live around the oases of Mesr, Farahzad and Amirabad.

Although the temperatures regularly reach 50°C, frequent heavy storms cause many erosional landforms in the sedimentary rocks of the flat hilltops. This results in the formation of shallow, wide wadis, where ephemeral streams occasionally flow, in between the saltmarshes.

Sand dunes

In the northern part of the desert lie sand dunes and shifting sands. Barchan dunes in single and complex forms can be found around Maranjab caravanserai and may reach heights of

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5.8 metres. Within the Kavir national park region, sword-shaped seif dunes have formed alongside spectacular wind-blown ripple marks. Sand dunes mostly consist of particles of quartz, feldspar and some other minerals. In between dunes where the water table is high and plants are able to grow, sand gets trapped in the vegetation and low hills grow. These nebkhas are around 1.8 – 3.0 metres in height

Desert pavements

These are formed by the wind erosion of sand and silt, leaving behind angular pebble-sized rocks on the slopes of Siah Kuh (Black Mountain). Sometimes they have shiny, glossy, opaque and other smooth surfaces according to how hard they are.

Exam style questions

1. **Account for the wide range of landforms found in mid and low latitude deserts. (6 marks)**

2. **Examine the relationship between process, time, landforms and landscapes in mid and low latitude deserts. (20 marks)**

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The Kavir Desert and the development of hot desert landforms

1. **Account for the wide range of landforms found in mid and low latitude deserts. (6 marks)**

Responses should cover a number of different processes and the resultant landforms/landscapes. Every desert landform or landscape does not need to be covered, but enough included to show a breadth of understanding about chemical and mechanical weathering processes as well as wind (abrasion and deflation) and water erosion.

- There are a wide range of landscapes in mid and low latitude deserts. Responses could include a discussion about any of the following - desert uplands and mountains, desert plateaus, stony deserts, desert floodplains/wadis, desert lake basins and sandy deserts

- There are a wide range of landforms in mid and low latitude deserts because of the wide range of processes (water and wind erosion, weathering, transportation and deposition) that take place across a number of different landscapes.

- Origin and development of landforms can include aeolian features such as deflation hollows, desert pavements, ventifacts, yardangs, zeugen, barchans and seif dunes and water features such as wadis, bahadas, pediments, playas, inselbergs.

- There are a wide range of processes which shape the desert including weathering, wind and water erosion.

- In addition, the climate, soils and vegetation all influence the physical processes taking place in a desert and help shape the landscape and landforms.

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The Kavir Desert and the development of hot desert landforms

2. **Examine the relationship between process, time, landforms and landscapes in mid and low latitude deserts. (20 marks)**

There are complex relationships between process, time, landforms and landscapes. Responses should develop some of the inter-relationships (links between two or more phenomena, such that changing one leads to change in the other) between process, time, landforms and landscapes in mid and low latitude deserts. Answers should include the following:

- The concepts of landform and landscape and how related landforms combine to form characteristic landscapes. This can include sand dunes and other sand features developed under contemporary conditions.

- Where landform and landscape features are not related they were probably formed under different conditions for example finding salt domes next to desert pavements.

- The relationship between landforms, landscapes and location (mid and low latitude) should link to high-pressure systems, low rainfall and the formation of desert landforms. However, as the landscape is a palimpsest (superimposition of features developed at different phases over a given timescale) of past landforms and current processes, there is often a mixture of landforms formed in recent arid conditions and those of the past. Past conditions could be warmer, wetter (giving rise to fossil aquifer reserves of water) or it could have even been a coastal or marine environment.

- Certain relict landforms could have only formed under different climatic conditions. For example, salt domes of over 6 km must have developed when sea levels were rising and falling and the area was underwater. Salt marshes would have taken millions of years to form and would have required conditions to be warm, so that evaporation could make the water highly saline for the salt to be deposited.

- Based on the present-day climate data, there is a link of desert pediments to ancient humid phases, which provided high-energy runoff for the formation of these landforms and were associated with erosional features under more humid and colder climate during the last glacial period.

- Folding is evidence of tectonic uplift, and significant ancient earth movement were required to tilt rock strata to a vertical orientation for yardangs to be currently developing still.

- Deep ravines and wadis are often evidence of a past environment that was wetter and experienced more rainfall where rivers flowed for longer and had more erosive power.

- Desert plains and aeolian dunes are the related products of contemporary climate, such as smaller barchan sand dunes, having been eroded and transported more recently.

- Different past conditions would have given rise to different processes, which would have resulted in distinctive landforms for the time. These may now be relict features.

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Hot Deserts: Arid landscape and landform development *3.1.2.3*

Q1	***True or False?***	
A	Desert pavements (reg) are flat, stony surfaces made of stones too heavy to lift	
B	Yardangs are formed where more resistant rock overlies less resistant rocks.	
C	Rock pedestals are sand blasted landforms, with wide stalks supporting them.	
D	The slope on the leeward side of a barchan dune is the steepest side	
E	Seif dunes can be over 200m high and form at right angles to the prevailing wind	

Q2	**Match the correct term to the correct erosional landform**	
A	Isolated steep-sided relict hills that rise up from pediments e.g. Uluru, Australia	
B	Plateau-like mountain where the flat surface is wider than the mountain is tall	
C	Isolated pillar-like hills, taller in height than the surface is wide	
D	Dry river valleys for most of the year, only filling with water after torrential rain	
E	Gentle sloping desert plains at the foot of mountain ranges	

Select from: **Mesas** **Wadis** **Pediments** **Buttes** **Inselberg**

Q3	**Allocate the correct description alternative to the most appropriate sand dune type**
Barchan dunes	***Seif dunes***

Travel at a rate of up to 10m per year/ Travel at a rate of up to 30m per year

Linear in shape/Crescent shaped ***Can reach 30m in height/ Can reach 200m in height***

Horn shaped ends / Tuning fork shaped

Can reach 100km in length/ Can reach 400m in length

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Q4	***Comparing two distinctive desert landscapes, how might each of the variables affect the development of the named features***
The development of chotts	Hotter than usual temperature:
	Unusually wet year:
The formation of alluvial fans	Frequent rainfall:
	Large amount of stream sediment:

Q5	***Explain all the ways a previously wetter climate may still be influencing key features in a contemporary desert landscape***
A previously wetter climate may still be influencing key features in a contemporary desert landscape including:	

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Hot Deserts: Arid landscape and landform development *3.1.2.3*
ANSWERS

Q1	***True or False?***	
A	Desert pavements (reg) are flat, stony surfaces made of stones too heavy to lift	**True**
B	Yardangs are formed where more resistant rock overlies less resistant rocks. ***Vertical alternate layers of rock along which wind erodes softer bands faster***	**False**
C	Rock pedestals are sand blasted landforms, with wide stalks supporting them. ***Narrow stalks are reduced due to aeolian abrasion with wider platforms above***	**False**
D	The slope on the leeward side of a barchan dune is the steepest side	**True**
E	Seif dunes can be over 200m high and form at right angles to the prevailing wind ***Form parallel to the prevailing wind but where alternative wind direction occurs***	**False**

Q2	**Match the correct term to the correct erosional landform**	
A	Isolated steep-sided relict hills that rise up from pediments e.g. Uluru, Australia	**Inselberg**
B	Plateau-like mountain where the flat surface is wider than the mountain is tall	**Mesas**
C	Isolated pillar-like hills, taller in height than the surface is wide	**Buttes**
D	Dry river valleys for most of the year, only filling with water after torrential rain	**Wadis**
E	Gentle sloping desert plains at the foot of mountain ranges	**Pediments**

Select from: **Mesas** **Wadis** **Pediments** **Buttes** **Inselberg**

Q3	**Allocate the correct description alternative to the most appropriate sand dune type**
Barchan dunes	***Seif dunes***
Crescent shaped	*Linear in shape*
Can reach 30m in height	*Can reach 200m in height*
Can reach 400m in length	*Can reach 100km in length*
Travel at a rate of up to 30m per year	*Travel at a rate of up to 10m per year*
Horn shaped ends	*Tuning fork shaped*

Travel at a rate of up to 10m per year/ Travel at a rate of up to 30m per year

Linear in shape/Crescent shaped ***Can reach 30m in height/ Can reach 200m in height***

Horn shaped ends / Tuning fork shaped

Can reach 100km in length/ Can reach 400m in length

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Hot Deserts: Arid landscape and landform development *3.1.2.3*
ANSWERS

Q4	***Comparing two distinctive desert landscapes, how might each of the variables affect the development of the named features***
The development of chotts	Hotter than usual temperature: • Faster than usual evaporation, causing the rapid formation of salts and a thick crust on the lake surface. • Ephemeral water is available for shorter periods of time.
	Unusually wet year: • Salt lakes expand in size, as there is no outlet to the sea. • Vegetation has more water available and so grows more than usual. • There are more salts to be deposited, as there is more water available.
The formation of alluvial fans	Frequent rainfall: • Frequent rainfall will transport more sediment and deposit it on the alluvial fan making the fan larger. • Larger streams will carry larger material.
	Large amount of stream sediment: • More sediment will be deposited at the top of the alluvial fan, as there may not be enough energy to continue to carry the sediment. • Greater chance that individual alluvial fans will coalesce into a bahada (bajada)

Q5	***Explain all the ways a previously wetter climate may still be influencing key features in a contemporary desert landscape***

A previously wetter climate may still be influencing key features in a contemporary desert landscape including:

- Deeper ravines and wadis than current water flows can account for, through water erosion cutting downwards
- Wider ravines, formed on the edge of the plateau
- Relict features such as inselberg, mesa and butte formations that were left remaining after rapid surface lowering under wetter conditions.
- Bigger alluvial fans as more sediment was transported by more powerful rivers
- Steeper pediments, as there was more sediment available to erode the surface by abrasion
- Large salt deposits exist as a result of the drying up of an inland sea, formed under wetter conditions
- More extensive chotts/playas exist than current temporary lake volumes can account for.

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