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APRIL 2009
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Desert Landforms

A desert is classified as an area receiving less than 250 mm of rainfall a year, or one where evaporation exceeds precipitation. In many desert areas the average annual total is far less than this figure, and in some cases rainfall may not even be an annual occurrence.

Deserts cover 11,500,000 square miles (29,7885,000 sq km) of the Earth's land surface, 25% of the total surface area. Deserts possess unique land forms as a result of their location and the agents of erosion acting within them.

Deserts vary greatly in appearance. These dry or arid environments display many characteristic surface features, quite apart from sand dunes, including mountains, plateaus and plains.

Deserts can be categorised in three ways:

- **Hammada**: barren rocky highlands. The world's largest hammada is the Hammada du Draa, which occupies 70% of the NW Sahara between between Morocco, Algeria and the Western Sahara.
- **Reg**: a vast stony plain, a transition zone between the hammada and erg desert.
- **Erg**: sand seas formed by the accumulation of dunes covering approximately 25% of the total desert landscape. In the Arabian Desert they occupy 30% of the desert landscape, while in desert parts of the USA, dunes occupy only 1% of the total area.

Desert locations

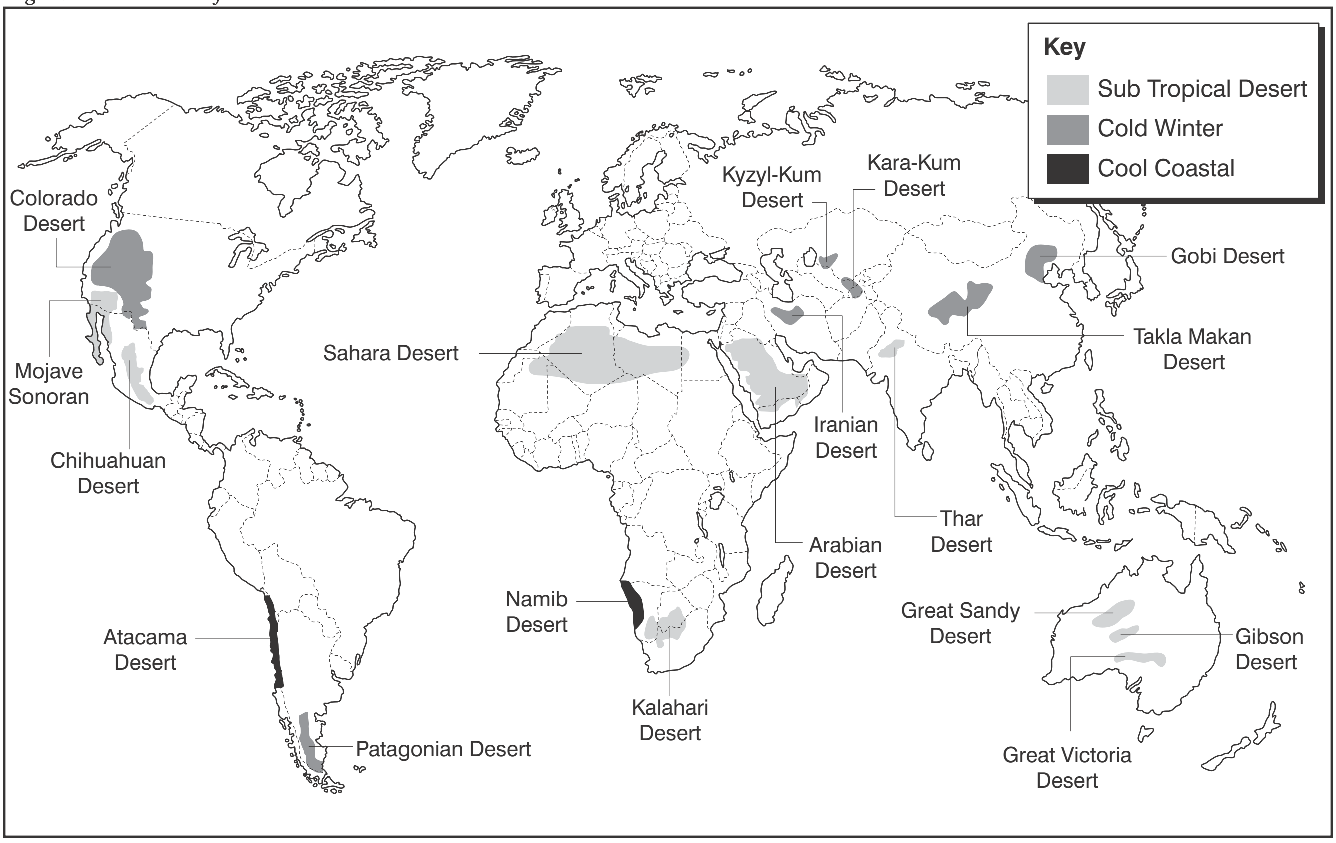
Deserts occur on all continents except Europe, but it is believed that the south of Spain is now so dry as to be classified as a desert area. The lack of rainfall associated with deserts is due to their location. Sub-tropical deserts such as the Sahara and the Arabian desert are located at approximately 30 degrees north or south of the Equator. In other cases deserts occur to the lee of mountain ranges. This is the case with the mid-latitude deserts such as the Great Basin Desert of the USA, while in the case of the Gobi Desert of Mongolia, sheer distance from the ocean has created a desert climate. Coastal deserts such as the Namib and Atacama deserts occur where cold ocean currents lie adjacent to hot coastal regions, meaning rainfall falls over the ocean before it reaches the land.

Agents of weathering and erosion in a desert

The traditional assumption has been that mechanical weathering is the dominant process in desert landscapes. However, recent studies suggest that water is also an important agent of erosion, even though the quantities present in

Figure 2: A mushroom rock, Timma National Park, Israel

Figure 1: Location of the world's deserts



desert areas may be low. This means that chemical weathering has a role to play in producing the distinctive landforms found in deserts.

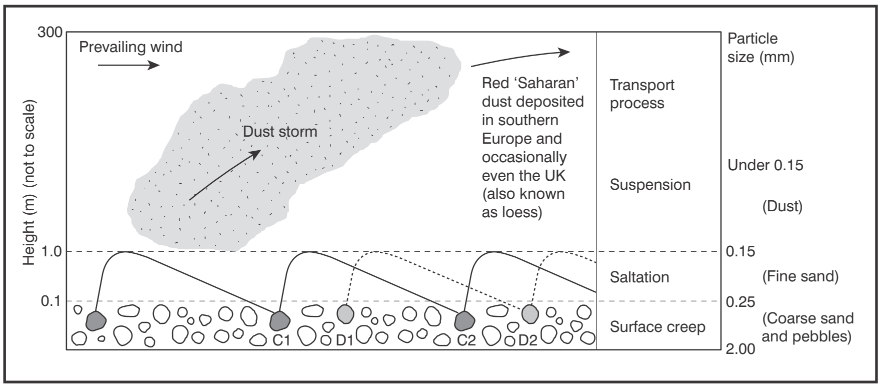
1. Mechanical weathering
The diurnal temperature range experienced in deserts is up to 40°C. The direct heating of the sun on the surface layers of the desert contrasts to low night temperature, and this puts severe strain upon the rock surface. Rocks are composed of differing minerals which react differently to these extreme changes of temperature, leading to stress fractures occuring. The surface layers peel, in a process known as exfoliation. Aided by the wind this can produce features often referred to as 'mushroom rocks', where exfoliation has caused the rock to peel and the wind has abraded the lower base of the rock.

Work by the geomorphologists Griggs (1936) and Goudie (1974) has cast doubt on the mechanics of this process. They stress the importance of water in the process of exfoliation. Deposition of dew at night increases chilling and the contraction of rock surfaces.

Salt weathering is a second form of mechanical weathering. Salts percolate upwards by capillary action and form crystals which expand with further evaporation. This expansion can lead to the crystals breaking away from the main body of the rock. Rainfall may cause the crystals to hydrate, or swell, or change their structure. Such accumulations produce a naturally cemented **duricrust**. Other desert surfaces may develop a **desert varnish** comprised of iron and manganese oxides giving the rocks a dark, glazed appearance.

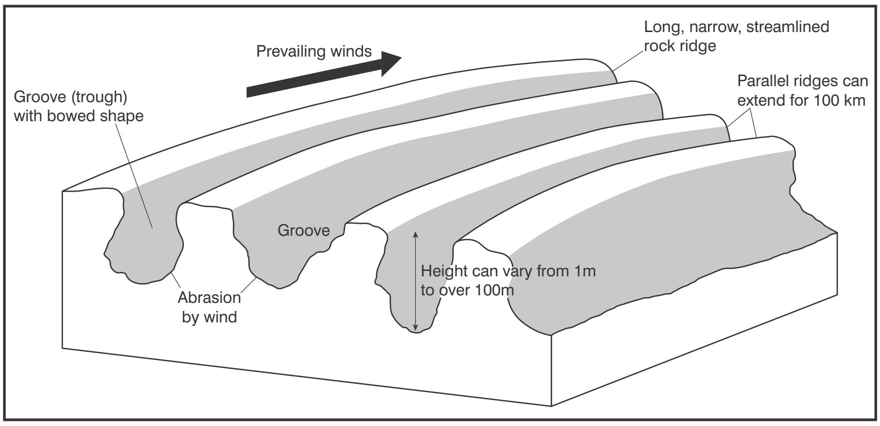
2. Wind as an agent of erosion and transportation
Wind, a common occurence in deserts, is most effective as an agent of erosion when the particles it can transport are under 0.15 mm in diameter and there is a relatively constant or dominant wind direction. These combined forces can then lift the material and erode the base of isolated rocks by the process of abrasion where the transported materials 'sand blast' the base of the obstacles giving them the characteristic mushroom shape (Figure 2). This action is most effective within one metre of the ground surface.

Figure 3: Processes of wind transportation



Source: D. Waugh (2000) *Geography, An Integrated Approach* (3rd edn), Nelson Thornes, p. 167.

Figure 4: The appearance and formation of yardangs



Source: D. Waugh (2000) *Geography, An Integrated Approach* (2nd edn), Nelson Thornes, Fig 7.11, p. 168.

The lack of moisture to bind or hold rock particles together and the resultant ability of individual grains of sand to be carried enables the process of **saltation** to occur, whereby loose sediment particles are transported in a series of short 'jumps'. The particles of sand or sediment on landing dislodge other similar grains which are then carried by the wind and so the process continues. Dependent upon the strength of the wind, particles will 'jump' different distances or be transported in the air (suspension) for longer distances (Figure 3).

In deserts, the wind erodes in two different ways: **deflation** and **abrasion**.

Deflation refers to the action of the wind on the desert floor, where the sedimentary rocks containing pebbles have been naturally cemented together with sand and silt. These are progressively removed by the wind, leaving behind the typical reg desert strewn with pebbles. This action lowers the level of the land surface and produces a desert pavement comprising of coarse stones which have settled and appear to interlock like a cobblestone pavement.
The process of deflation can also produce a **deflation hollow** where the concentrated action of the wind, often aided by dew, may further loosen the silt and sand and cause a continued lowering of the landscape. This can be seen in the Qattara Depression in Egypt, which now lies 134 metres below sea level.

At its smallest scale, abrasion produces highly polished, flat or faceted surfaces on individual pebbles. These are called **ventifacts** or **dreikanter**. Similarly, rock outcrops can be sand-blasted by wind action and the effect is to make the outcrop more rounded and polished.

If such a rock outcrop is eventually moulded by wind action to lie parallel to the dominant wind direction, **yardangs** are produced. These elongated features are typically three or more times longer then they are wide and are common features of the reg desert due to their composition of hardened deposits of silt and sand. As the wind cuts down into the bed rock it produces parallel ridges, which in time erode into seperate hills that take on a

Figure 5: Wadi Rum, the largest wadi in Jordan

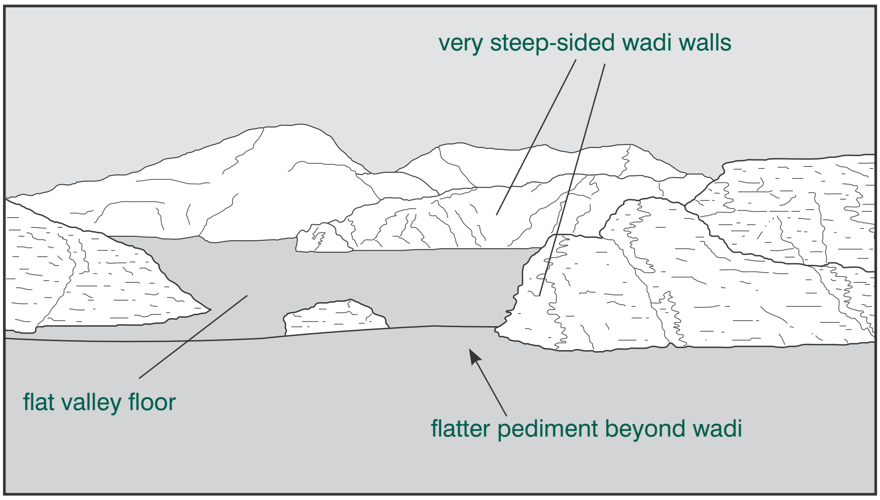
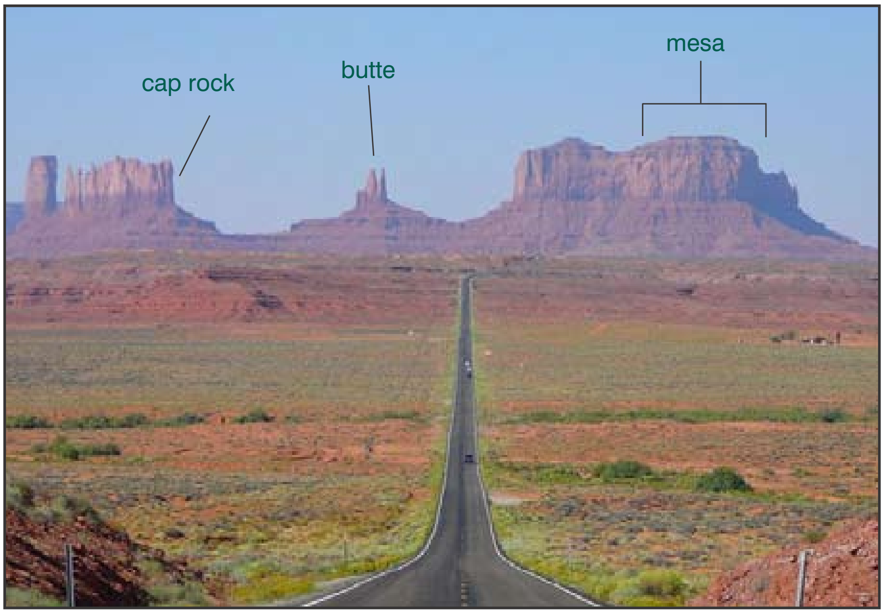


Figure 6: Mesas and Buttes in Monument Valley, Utah-Arizona border, USA



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unique shape. Yardangs vary in size and have been divided into three categories: mega-yardangs, meso-yardangs and micro-yardangs. These vary in size, from many kilometres in length and hundreds of metres in height, to a few metres long and 10 to 15 metres high, to those of only a few centimetres in size, respectively. With the mega-yardang, the wind action can produce a 'field of yardangs' of similar size, and these are referred to as a 'fleet of yardangs', owing to their resemblance to an upside-down fleet of ships. Yardangs can be found in most deserts, but the largest concentration of mega-yardangs is found in the Tibesti Mountains of the central Sahara.

3. Water as an agent of erosion.
Water is of major significance in desert areas. Although infrequent, when rainfall occurs it often takes the form of very heavy and violent convection storms which produce vast quantities of water, having the ability to transform the landscape while the water remains on the desert surface. Initially it is difficult for the water to penetrate the surface of the desert as it has become baked by the intense heat of the sun, so run-off is significant. This run-off leads to erosion, transport and later deposition of material on the surface of the desert floor. The most common landform produced is a **wadi** (Figure 5).

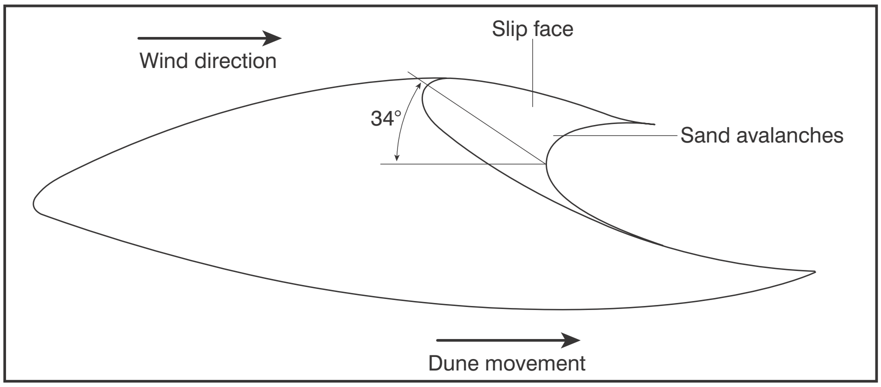
A wadi is a steep-sided valley containing an ephemeral (occasional) stream. After a torrential storm the wadi rapidly fills with water, creating a flash flood. This powerful flow has the ability to lift ground debris from the dry river bed, which then further erodes the wadi. Once the flow of water leaves the restriction of the wadi walls, it spreads out on to the **pediment**, or plain area lying beyond the wadi itself. Material that had earlier been rolled by traction or carried in suspension will then be deposited as poorly sorted gravel and sands and an **alluvial fan** will develop.

4. Impact of geology
The landscape of the high land on either side of the wadi is dominated by bare rock and debris slopes. The rock outcrops are subject to mechanical weathering and surface run-off when rainfall occurs. The resultant features are dependent upon the nature of the geology of the area. In North Africa, the upland areas are composed of granite and the eroded remnants of the high mountain range are referred to as **inselbergs**.

In the South West of the USA, **mesas** and **buttes** have been formed in the horizontal layers of sedimentary strata. The top layer of the mesa and butte, called the cap rock, comprises a hard layer which is relatively resistant to erosion. This resistance is due to it being baked by the heat and aridity of the environment or, as in certain areas of Monument Valley, the cap rock is a horizontal band of lava which has extruded from vertical fissures which scar the landscape.

A mesa is an isolated, flat-topped hill that has steep sides, while a butte is the same but smaller. A mesa can be categorised as having a surface area of less than 10 sq km and a butte a surface area of less than 11,000 sq m. They both originated as part of the same plateau, but once the upper horizontal band was fractured, fluvial action produced wadi-shaped gullies and once the water has disappeared from the landscape, mechanical agents of weathering took over to create the mesas and buttes. This lowered the surrounding landscape. The upper sides of the mesas and buttes are steep as material is weathered from them, but nearer to the base of the slope where the eroded debris has accumulated, there is a distinct change of slope. The base of the mesas and buttes are protected by the accumulation of this material.

Figure 7: Simplified sketch of a barchan sand dune



5. Wind as an agent of deposition
Sandy deserts form the final stage in the desert cycle and are mobile landforms composed of fine grains of material that were previously solid rock and have been broken down by the agents of erosion and weathering operating within the whole of the desert environment. The processes of saltation and surface creep move this material and once it is deposited sand dunes develop.

Sand dunes were first studied by R.A. Bagnold in the 1920s. He worked largely in North Africa. He concluded that sand dunes occur where there is a steady wind to transport the material and where there are obstacles such as rocks, boulders or vegetation on the ground surface. Initially sand begins to accumulate on the downwind side of the obstacle, due to the the grains of sand being deposited here as wind speed falls. This initial accumulation then grows and develops into identifiable features such as the **barchan** sand sune (Figure 7).

Barchans are crescent-shaped features which can measure between 9 and 30 metres in height and up to 370 metres in width at the base when measured perpendicular to the wind. Horns develop downwind – there is less sand at the side of the dune than in its centre.They are asymetrical in cross-section, with a gentle slope facing towards the wind, and a much steeper slip face facing away from the wind. The processes of saltation and soil creep transport the grains of sand up and over the dune. The finer particles are more readily moved. Material at the top of the crescent will avalanche down the slip face of the dune. As the wind blows over the barchan, eddying occurs and the fine grains will be deposited at the base of the crescent, producing a basal apron containing unsorted and unconsolidated material. This process continues – it appears as if the barchan itself is moving across the desert, but it is the individual grains of sand which are continuously being transported in line with the prevailing wind direction over the barchan itself. The migration of the barchan can vary from one to 100 metres a year, depending upon the wind speed and its consistency. Barchans are found where there are limited amounts of sand moving across a hard rock surface, and are characteristic of open, inland desert regions such as Turkmenistan in Central Asia.

Seif dunes, in contrast, are linear features. They rely in particular on the Trade Winds with their constant direction enabling the parallel dunes with slip faces on either side to develop. They can extend for up to 100 km and have a height of 200 metres. They appear to be fixed features of the landscape, as movement is not as obvious as it is with the barchan dune.

Other dune types are found where wind direction is variable. Star dunes occur where there is an abundant supply of sand and variable wind directions. Linear dunes are present where sand is limited and there are converging winds.

Conclusion

Desert landforms vary dramatically both in appearance and in process. Weathering and erosion are both important; weathering is primarily mechanical, but chemical weathering also occurs. Wind is probably the chief erosive force, with water playing a part from time to time in different locations. Desert landforms are distinctive and dramatic, and of huge interest.

Focus Questions

1. What are the differences between a hammada, a reg and an erg desert?

2. (a) What forms of weathering are found in desert areas?
   (b) What types of erosion are found in desert areas?
   (c) What is the key difference between erosion and weathering?

3. Explain how either wadis or mesas and buttes are formed.

4. Make a copy of any of the figures in this unit. Use the detail in the text to add labels, to produce a well annotated diagram.

5. Reseach the differences between reversing, parabolic, dome, transverse sand dunes, and also barchanoid ridges.