1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Arid Topography (Action of Winds) – Part 5
Module Id	kegy_10705
Pre-requisites	Basic knowledge about the landforms developed by the action of glacier
Objectives	After reading this lesson, learners will be able to: • Acquire the knowledge and understanding of action of winds in the arid regions. • Understand the aid topography and its formation. • Understand the concept of erosion, transportation and deposition activity of the wind in the desert. • Understand the landforms formed by the erosional and depositional activity of the wind in the desert.
Keywords	Arid Topography, Aeolian Process, Pediments, Pediplains, Blowouts, Inselbergs, Mushroom Rocks, Demoiselles, Zeugen, Yardangs, Playas, Sand Dunes, Barchans, Seif, Loess.

2. Development Team

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Wind is an important geomorphic agent but it is as much affective process of erosion as rivers and sea waves. Wind is a comparatively minor agent of geomorphic change because of the low density of air as compared to rocks and water. Aeolian processes are generally associated with desert areas but one should keep in mind that deserts (defined as barren, desolate and plant less areas) are of two types viz; hot and warm deserts and cold deserts. Aeolian processes are not active in cold deserts because the surfaces are always covered with permanent ice sheets. Wind action is particularly important in arid regions where lack of vegetation and presence of extensive bare rock and sandy soil surfaces make wind erosion, transportation and deposition possible. Aeolian processes are responsible for only relatively small topographical features of the desert. Winds are active in those arid and semi-arid environments where the ground surface is covered with loose and friable geo-materials. About one-third of the land surface area of the earth is characterized by arid and semi-arid environments wherein extremely arid, arid and semi-arid areas account for 4%, 15% and 14.6% respectively.

Wind is one of the two dominant agents in hot deserts. The desert floors get heated up too much and too quickly because of being dry and barren. The heated floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up eddies, whirlwinds, updrafts and downdrafts. Winds also move along the desert floors with great speed and the obstructions in their path create turbulence. Of course, there are storm winds which are very destructive. Winds cause deflation, abrasion and impact. Deflation includes lifting and removal of dust and smaller particles from the surface of rocks. In the transportation process sand and silt act as effective tools to abrade the land surface. The impact is simply sheer force of momentum which occurs when sand is blown into or against a rock surface. It is similar to sandblasting operation. The wind action creates a number of interesting erosional and depositional features in the deserts.

In fact, many features of deserts owe their formation to mass wasting and running water as sheet floods. Though rain is scarce in deserts, it comes down torrentially in a short period of time. The desert rocks devoid of vegetation, exposed to mechanical and chemical weathering processes due to drastic diurnal temperature changes, decay faster and the torrential rains help in removing the weathered materials easily. That means, the weathered debris in deserts is moved by not only wind but also by rain/sheet wash. The wind moves fine materials and general mass erosion isaccomplished mainly through sheet floods or wash. Stream channels in desert areas are broad, smooth and indefinite and flow for a brief time after rains.

Aeolian landforms are features of the Earth's surface produced by either the erosive or constructive action of the wind. In Aeolian processes, wind transports and deposits particles of sediment. Aeolian features form in areas where wind is the primary source of erosion. The particles deposited are of sand, silt and clay size. The particles are entrained in by one of four processes. Creep occurs when a particle rolls or slides across the surface. Lift occurs when a particle rises off the surface due to the Bernoulli Effect. If the airflow isturbulent, larger particles are transported by a process known as saltation. Finally, impact transport occur which one particle strikes another causing the second particle to move.

DO YOU KNOW

The Sahara Desert extends from the Atlantic to the Red Sea, a distance of almost 5000 km, and covers an area of about 7.5 million km^2 (about one quarter of the size of Africa); it is the largest tropical desert in the world. There are two other deserts in Africa, both south of equator- the Kalahari Desert, which is semi arid (5,00,000 km^2), and the Namib Desert, which is arid.

There is insufficient rainfall and comes in most irregularly, very erratic. High temperature and high rate of evaporation are the chief causes of aridity. Under this condition weathering is a very effective process. It is mainly mechanical weathering which is prevailing. Days are mainly hot and nights are cooling. Arid lands are commonly supposed to exhibit morphological characteristics quite different from those of more humid regions.

Wind erosion is largely controlled and determined by:

(i) Wind velocity,
(ii) Nature and amount of sands, dusts and pebbles (tools of erosion),
(iii) Composition of rocks,
(iv) Nature of vegetation, and
(v) Humidity, rainfall amount and temperature

It may be mentioned that wind erosion generally takes place above the ground and thus wind velocity plays a major role in determining the degree of aeolian erosion. The quantity and size of materials lifted and moved by wind determined the degree of wind abrasion. Wind erosion in believed to be effective only upto 180 cm above the ground surface. Maximum wind erosion occurs at a short distance above the ground, say at a height of 20-25 cm.

Types of Desert

About a fifth of the world's land is made up of desert, some rocky, others stony and the rest sandy. Deserts that are absolutely barren and were nothing grows at all are rare and they are better known as 'true desert'. The largest arid and semi-arid deserts occur between 15^0N and 45^0N and 15^0S and 30^0S, and most of these are located on the western sides of the continents, in the trade wind belt where the winds are offshore. Such winds are dry, having lost most of their moisture in their journey across the eastern part of the continents.

The combined action and effect of wind and water has given rise to four distinctive types of desert.

a) **Erg or Sandy Desert**

It is an undulating plain of and produced by wind deposition called erg in Sahara and *koume* in Turkestan. The largest erg is *Rub al Khali* in Arabia. The sand sea of Egypt and Libya is a good example of an erg.

b) **Reg or Stony Desert**

The surface is covered with boulders, gravel and angular pebble which have been produced by diurnal temperature change called *reg* in Algeria and *serir* in Libya and Egypt.

c) **Hamada or Rocky Desert**

This consist of extensive areas of bare rocks from which all fine materials have been removed by deflation, while abrasion polishes and smooths the rock surface. The best known rocky deserts are those of the Sahara Desert e.g., the Hamada el Homra, in Libya, which covers an area of almost 20,000 square miles.

d) **Badlands**

The term 'badlands' was first given to an arid area in South Dakota, USA where the hills were badly eroded by occasional rain-storms into gullies and ravines. This type of desert develops in semi-desert regions mainly as a result of water erosion produced by torrential rain storms. Deserts with similar features are now referred to as badlands e.g., The Painted Desert of Arizona.

The Mechanism of Arid Erosion

Features produced by either erosion or deposition occur in a desert and all of these are formed mainly by action of weathering, wind and water. Although wind erosion is effective in the deserts, transport and deposition are far more significant. Arid landforms are the result of many combined factors, one reacting upon the other. Wind perform erosion in three distinct ways.

1) **Deflation**

The process of removing, lifting and blowing away dry and loose particles of sands and dusts by winds is called deflation (derived from Latin words '*deflatus*', which means blowing away). Long continued deflation removes most of loose materials deflation removes most of loose materials and thus either depressions or hollows known as 'blow out' are formed on and bedrock are the exposure of the rocky surface beneath the sandy cover. Deflation also attacks rock surface mainly of sandstones detaches small fragments and helps in forming depressions in rock surfaces but the process of depression formation through deflation in bedrock surfaces is exceedingly slow. Since deflation removes only the fine particles (mainly sands), larger particles such as gravels are left over the surface.

Deflation has possibly been responsible for the formation of pedestal rocks, which consists of residual masses of weak rock capped with harder rocks, found in the intermount basins of South and Eastern California. But in the sandy deserts deflation hollows or blow outs of variations sizes are known to form and sometimes large hollow may be produced. Several such depressions are known to exist in the desert lying West of Nile Valley of these the most well known is Quattara Depression in Western Egyptian Sahara which has been excavated to nearly 134m below sea level. (Since deflation removes mostly fine particles larger particles such as gravels are left over the surface. Thus, accumulation of gravels over thousands of years forms desert pavements which protect the rock below from further wind erosion.

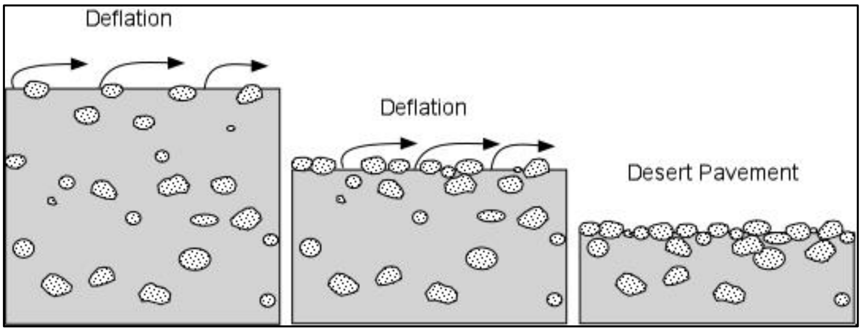


Fig 1: The process of deflation (Source: http://earthsci.org/education/teacher/basicgeol/windes/windes.html

2) **Abrasion**

Abrasion is the work of wind charged with sand particles wind armed with entrained sand grains as tools of erosion attacks the rocks and erodes them through the mechanisms of abrasion, fluting, growing, pitting and polishing. The combined effects of these mechanisms are collectively called abrasion or sandblasting. Wind abrasion a sand blasting is minimum at ground level because wind velocity is retarded by friction. Similarly, wind ceases to become an erosive agent beyond the height of 182cm from the ground level, because normal wind cannot lift and carry particles of average size. Thus, maximum abrasion occurs at the height between 20-25cm from the ground surface. Abrasion undoubtedly cuts the upstanding objects from all sides because its direction. It may be thus, stated that wind abrasion decrease drastically with increasing height from the ground and becomes inactive beyond 182 cm height, except during strong gales and storms.

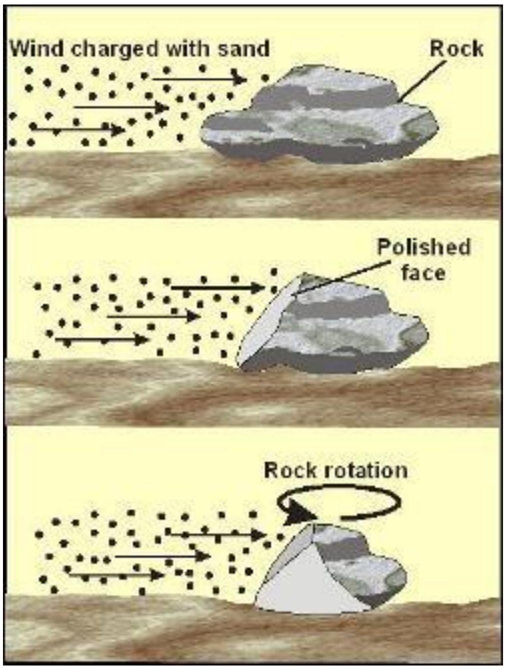


Fig 2: The process of Abrasion

Source: http://www.cms.fu-berlin.de/geo/fb/e-learning/geolearning/en/mountain_building/weathering/Erosion/index.html

3) **Attrition**

It involves mechanical tear and wear of the particles suffered by themselves while they are being transported by wind through the processes of saltation and surface creep. Saltation involves the movement of sands and gravels through the mechanisms of bouncing, jumping, and hoping by turbulent air flow.

Saltation grains (saltation is derived from Latin, word '*saltare*' which means '*to leap*') frequently rise to a height of 50 cm over a sand bed and upto 5 meter over pebbly surface.

Thus by mutual friction and forceful contact rocks break down further and there is a gradual reduction in their size and ultimately they are converted into sand and dust particles, which cover large part of the desert. This process of gradual reduction in the size of rock particles by mutual impact in called attribution.

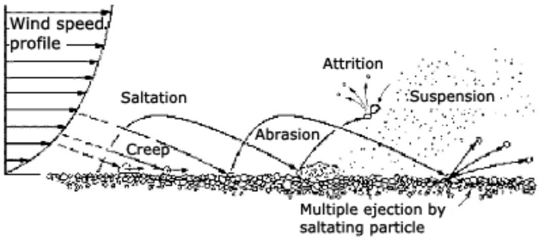


Fig 3: The process of Attrition (Source: http://www.environment.nsw.gov.au/soildegradation/winder.htm)

1. **Landforms Formed by Winds**

In the combined processes of abrasion, deflation and attrition, a wealth of characteristics desert landforms emerge.

Wind Erosional Features

Long- continued erosional works through the mechanism of abrasion or sand blasting, deflation and attrition produces some characteristics landforms in desert areas. They are as follows:

1. Deflation Hollows (Blow outs)
2. Desert Pavements
3. Ventififacts, driekanter and zweikanter
4. Rock Pedestal
5. Zeugens
6. Yardangs

Wind Depositional Features

Depositional landforms resulting from wind action are essentially related to its mechanism in transport. Due to this deposition of sand by the wind, the wind produces certain landforms features.

Deposition in arid regions takes two forms:

1. Sand Deposition
2. Clay deposition

Landforms due to mechanical disintegration of rocks and water action

1. Wadi
2. Alluvial fan
3. Bajada
4. Bolson
5. Pediment

Did You Know

The Great Indian Desert, also called as Thar Desert is vast arid land like a sea of sand in the northwestern part of India. Its world 9th largest desert covering an area of about 1500000 Sq Km in Rajasthan and parts of Haryana and Punjab and in the south its is extended up to Gujarat.

For additional information on Indian Desert and landforms click on the following weblink: (Geological Survey of India, document)

http://www.portal.gsi.gov.in/gsiDoc/pub/sanddunes_rajasthan.pdf

Erosional Landforms

Pediments and Pediplains

Landscape evolution in deserts is primarily concerned with the formation and extension of pediments. Gently inclined rocky floors close to the mountains at their foot with or without a thin cover of debris are called pediments. Such rocky floors form through the erosion of mountain front through a combination of lateral erosion by streams and sheet flooding. Erosion starts along the steep margins of the landmass or the steep sides of the tectonically controlled steep incision features over the landmass. Once, pediments are formed with a steep wash slope followed by cliff or free face above it, the steep wash slope and free face retreat backwards. This method of erosion is termed as parallel retreat of slopes through back wasting. So, through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving an inselberg which is a remnant of the mountain. That’s how the high relief in desert areas is reduced to low featureless plains called pediplains.


Pediments

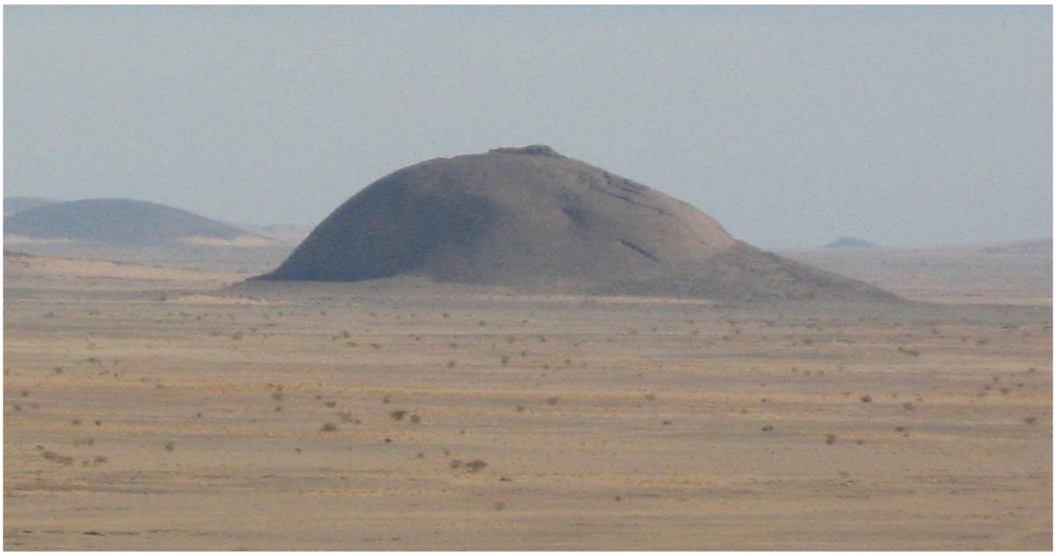

Pediplains

Deflation basins

Deflation basins, called blowouts, are hollows formed by the removal of particles by wind. Blowouts are generally small, but may be up to several kilometers in diameter. Commonly found in coastal settings and arid margins, blowouts tend to form when wind erodes into patches of bare sand on stabilized vegetative dunes. Generally, blowouts don't form on actively flowing dunes due to the fact that they need to be bound by some extent, such as plant roots. These depressions usually start on the higher parts of the stabilized dunes on the account that desiccation and disturbances are more considerable which allows for greater surface drag and sediment entrainment when sand is bare. Most of the time, exposures become quickly re-vegetative before they could become blowouts and expand; however, when the opportunities are given, wind erosion can lower the exposure surface and create a tunneling affect, which increases the wind speed. The depression may continue until it hits a non-erodible substrate or morphology limits it. The eroded substances climbs the steep slopes of the depression and become deposited on the downwind side of the blowout which can form a dune that covers vegetation and lead to a larger area of depression; a process that helps create parabolic dunes.

Inselbergs

An **inselberg** or **monadnock** is an isolated rock hill, knob, ridge, or small mountain that rises abruptly from a gently sloping or virtually level surrounding plain. If the inselberg is dome-shaped and formed from granite or gneiss, it can also be called a bornhardt, though not all bornhardts are inselbergs. The word *inselberg* is German for "island mountain"; the name was coined by geologist Wilhelm Bornhardt (1864–1946) in 1900 to describe the abundance of such features found in southern Africa.



An Inselberg in Western Sahara

Mushroom Rocks

A **mushroom rock**, also called **rock pedestal** or a **pedestal rock**, is a naturally occurring rock whose shape, as its name implies, resembles a mushroom. Usually found in desert areas, these rocks form over thousands of years when wind erosion of an isolated rocky outcrop progresses at a different rate at its bottom to that at its top. Abrasion by wind-borne grains of sand is most prevalent within the first 3 ft of the ground, causing the bases of outcrops to erode more rapidly than their tops. Running water can have the same effect. An example of this type of mushroom rock is the one in Timna Park, Israel.

Occasionally, the chemical composition of the rocks can be an important factor; if the upper part of the rock is more resistant to erosion and weathering, it erodes more slowly than the base. Its formation has also been attributed to chemical weathering at the base of the rock due to the collection of dew near the surface.

A mushroom rock may ultimately form from an originally flat area of hard rock overlying soft rock, similar to the pattern of rocks that form awaterfall. Weathering of the exposed hard rock layer eventually exposes the lower rock to erosion from wind, water, salt intrusion, etc., depending on local conditions. The layer of softer rock is more readily eroded, leading to the formation of a depression or blowout. The overlying harder rocks are resistant to this process, and may ultimately end up as isolated mushroom rocks standing above the new, lower plain.

The nature of wind erosion is that it concentrates a few feet over the ground - wind speeds increase with height, but sediment load reduces. This means that the combination of highest sediment loads and fastest wind speed exist a few feet over the ground - leading to the characteristic narrowing of the support pedestal at this height.

Demoiselles

These are rock pillars which stand as resistant rocks above soft rocks as a result of differential erosion of hard and soft rocks.

Zeugen

Zeugen is a flat-topped rock masses resembling a capped inkpot, it stand on softer rock pedestals like mudstone, shale, etc. Zeugens are formed in desert areas characterized by a high range of temperature. The alternate freeze and thaw of moisture results in expansion and contraction which ultimately disintegrates rocks along the joints.

Yardangs

A **yardang** is a streamlined protuberance carved from bedrock or any consolidated or semi-consolidated material by the dual action of wind abrasion by dust and sand, and deflation which is the removal of loose material by wind turbulence. Yardangs become elongated features typically three or more times longer than wide and when viewed from above, resemble the hull of a boat. Facing the wind is a steep, blunt face that gradually gets lower and narrower toward the lee end. Yardangs are formed by wind erosion, typically of an originally flat surface formed from areas of harder and softer material. The soft material is eroded and removed by the wind, and the harder material remains. The resulting pattern of yardangs is therefore a combination of the original rock distribution, and the fluid mechanics of the air flow and resulting pattern of erosion.

Yardangs come in a large range of sizes, and are divided into three different categories: mega-yardangs, meso-yardangs, and micro-yardangs. Mega-yardangs can be several kilometers long and hundreds of meters high and are found in arid regions with strong winds; meso-yardangs are generally a few meters high and 10 to 15 meters long and are commonly found carved in semi-consolidated playa sediments and other soft granular materials; and micro-yardangs are only a few centimeters high.

A large concentration of mega-yardangs is found near the Tibesti Mountains in the central Sahara. There is a famous yardang at Hole in the Rock in Papago Park in Phoenix, Arizona, a rock formation with a roughly circular hole in it. Another yardang in Arizona is Window Rock, near the town of Window Rock. It is a 60-meter sandstone hill with a very large circular hole in the middle of it. Some geologists have suggested that the [Great Sphinx](#) of [Egypt](#) is an augmented yardang. Pictures from Mars show that the yardang ridges occur on a massive scale there; some individual ridges are tens of kilometers long with intervening valleys nearly 1 km wide. Yardangs on [Mars](#) are typically found in the [Amazonis](#) region but the best ones are found in the equatorial region. Yardangs on Mars demonstrate that much of the eolian erosion is recent since they are sculpted in young geologic units.

Playas

Plains are by far the most prominent landforms in the deserts. In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin. In times of sufficient water, this plain is covered up by a shallow water body. Such types of shallow lakes are called as *playas* where water is retained only for short duration due to evaporation and quite often the playas contain good deposition of salts. The playa plain covered up by salts is called *alkali flats*.

Depositional Landforms

Wind is a good sorting agent. Depending upon the velocity of wind, different sizes of grains aremoved along the floors by rolling or saltation and carried in suspension and in this process of transportation itself, the materials get sorted. When the wind slows or begins to die down, depending upon sizes of grains and their critical velocities, the grains will begin to settle. So, in depositional landforms made by wind, good sorting of grains can be found. Since wind is there everywhere and wherever there is good source of sand and with constant wind directions, depositional features in arid regions can develop anywhere.

Sand Dunes

Heaps or mounds of sands are generally called sand dunes or simply dunes. Though sand dunes are significant depositional features of desert areas but they are also formed in all those areas where sands are available in profusion and wind is capable of transporting and depositing them in suitable areas. This dunes are also formed in coastal areas (riverine dunes) etc. There is a wide range of variation in the shape, size, structure, length and height in different types of dunes. On an average, their height ranges between a few meters and 20 meters but sometimes they are several hundred meters in height and 5-6 km in length. The wind ward slope is generally gentle (5^0-15^0) while reward slope in steep (20^0–30^0).

Formation of sand dunes begins with the accumulation of sands in the form of low sand mounds due to obstructions (eg. trees, bushes grasses, rocks, hills etc.) Formation of sand dunes requires (i) abundance of sands (ii) high velocity winds, so that huge quantity of sands may be blown and transported to form dunes (iii) obstacles of trees, bushes, etc boulders, wall etc. (iv) suitable places for accumulation of sand. Dunes are generally formed in groups and, such dune areas are called dune complex, dune colony and dune chain (Table.1).

Dunes get fixed on the land due to the roots of the plant. They are affected by a number of factors.

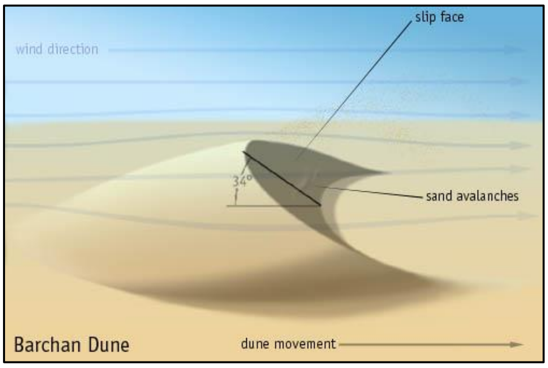
(a) Size of particles of sand-coarser or fine.
(b) Velocity and direction of winds.
(c) Topography of the surface and creates obstruction and soil gets started depositing
(d) Presence of natural vegetation.

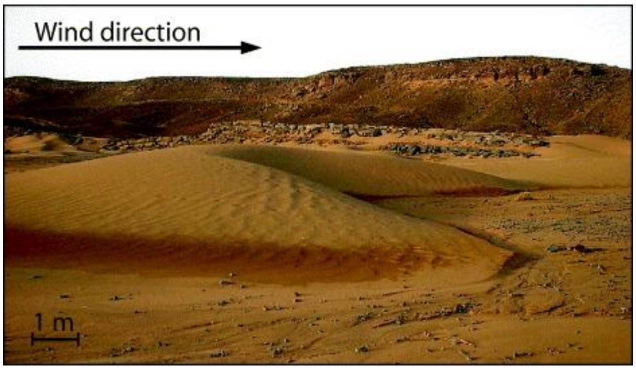
Some of the forms are discussed below.

Barchan Dunes

Barchan dunes have a crescentic shape with two horns. The windward side in convex while the leeward is concave and steep. This face maintains an angle of about 35^0 sides as concave ends of each ridge are curved in the direction, the winds is blowing and they develop horns. Such barchans are quite common in Turkestan. When these barchans get coalesced together, they appear like sinuous strings; these are the elementary forms of dunes and result from a combination of moderate sand supply and moderate wind velocity. Barchans do not need any obstruction to develop. The maximum height of barchans in about 30 meter (100 ft) and their maximum width and length about 400 meter (1300 ft). The Barchan is formed when the wind is nearly unidirectional; it is oriented with the horns downward. An additional evidence for the association of barchans with unidirectional winds is provided by Kharga Oasis, one of the only deserts stations with wind records; at this locally the winds are almost unidirectional and the barchans is the only form of dune present.

Transverse dunes are transformed into barchans when sand supply becomes more limited downward. They are formed in groups when there is ample supply of sand. Isolated barchans are formed when the supply of sands is inadequate. A barchans dune will tend to form a mound of sand, as the wind, will be felt more on the windward slope of a mound of sand, they will tend to sand, they will tend to accumulate on the crest, for the effect on; it is felt less here. Accumulation at the top of the lee slope leads to the steepening of that slope and hence to a decrease of the wind effect on it. The steeping of the lee slope by accumulation at the top goes on until the angle of rest of the material is exceeded, when shearing takes place along a slightly less steep surface. The flanks of the original mound of sand advance more rapidly are inversely proportional to the height of the slip face. In this way the crescentic Barchan form is developed. The rate of migration is very fast. The can move upto 25 ft. a year.





Barchan Dunes Source

(Source: http://en.wikipedia.org/wiki/Barchan,
http://iopscience.iop.org/1367-2630/11/2/023014/fulltext/)

Do You Know

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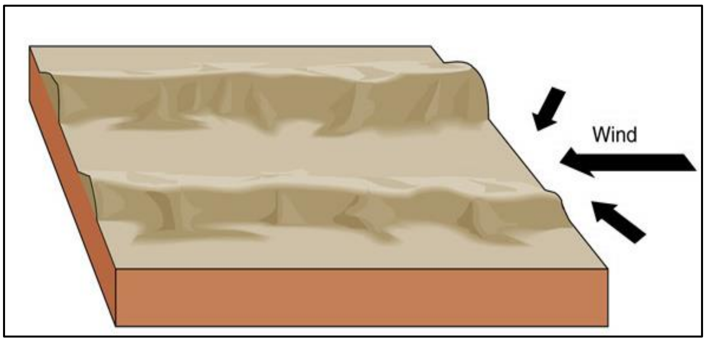
For additional information on Indian Desert and landforms click on the following weblink: (Geological Survey of India, document)
http://www.portal.gsi.gov.in/gsiDoc/pub/sanddunes_rajasthan.pdf

Longitudinal Dunes

Longitudinal Dunes are formed parallel to the wind movement. In other words, these dunes are formed by a modification in the shape of the transverse dunes. They are huge aeolian landforms extending hundreds of kilometers in length with average width of a kilometer or more and average height of several hundred meters. Wind ward slope of these dunes is gentle while the leeward slope is steep. These dunes are formed in the inner parts of the great deserts where high velocity winds are constant in direction or they change their direction seasonally. Thus, longitudinal dunes are generally formed in the heart of trade wind deserts. Great systems of longitudinal sand dunes are found in Australia, Libyan, Saharan, South African, Thar desert (India).

If the wind is faster and moves violently, it carves out a channel through the minor hollows and concavities on the leeward. The sand is trailed out along them and the transverse dunes are divided into two separate ridges parallel to the prevalent wind direction. They remain nearly fixed in their positions. In the Egyptians desert many seifs are about 100 meter high but in southern Iran they rise to more than 200 meter. Longitudinal dunes are separated by *reg* or *hammada*- sand-free bare surfaces. The corridors so formed are called *caravans*.



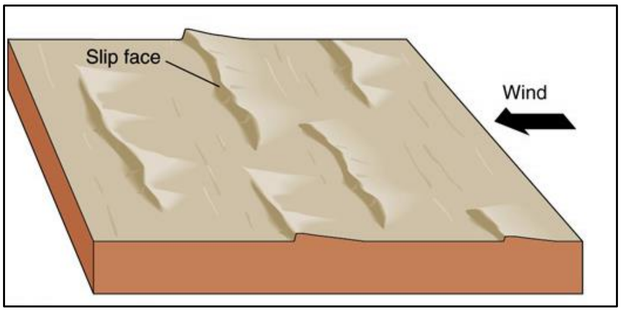
Longitudinal sand dunes or Seifs

(Source:http://geog-leics.blogspot.in/2012/08/desert-depositional-features.html, http://www.panoramio.com/photo/8638127)

Transverse Dunes

Transverse Dunes are dunes deposited transverse to the prevailing wind direction. They are formed due to ineffective winds blowing along the coast and margin of the desert. They are not very common depositional features in extensive deserts. They appear as wave-like features. Their shape is asymmetrical and the gentler slope is on the windward side. On the leeward side there is usually a hollow or a concavity. They are big sized but small multitudes of them. They can't be formed by less sand. They are found in extensive desert areas for eg. Sahara, Kalahari or Australian desert.

The entire area where transverse dunes are formed may be called as '*sand sea*', because it resembles a storm tossed sea suddenly frozen to immobility. Deep depressions lie between the dune ridges. Transverse dune belts also form adjacent to beaches that supply abundant sand and have strong on shore winds.



Transverse Dunes

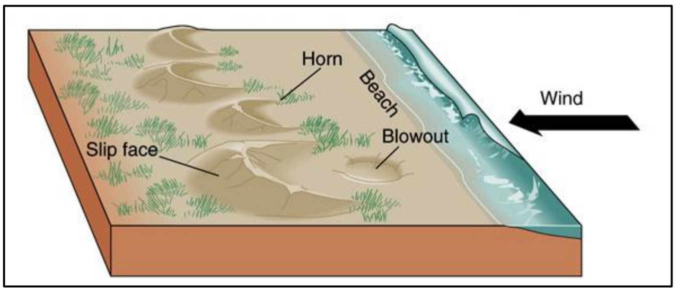
(Source:http://www.comphys.ethz.ch/hans/dunes.html,
http://geog-leics.blogspot.in/2012/08/desert-depositional-features.html)

Parabolic Dunes

They generally develop in coastal areas and in partially stabilized sandy terrains. They are usually 'U' shaped having convex nose which migrates longer and narrower than barchans but are always associated with 'blowout'. Their gentler windward rides have scooped out hollows formed by the removal of sands. These hollows have point tapering to the windward direction. Some shrubs are also found growing on them. They surface of all these types of dunes in marked by ripples. They look much like Barchan, but accumulation of sand and formation is opposite to Barchan. In this case a horse-sheo kind of plan is there. In the middle of the horse-shoe there is a deflation hollow. The inner sides are steep and they move very fast and seldom remain fixed. They go on wandering with the prevailing winds till they reach the outer edge of vegetation. They generally occur in groups. When the wind is strong and the sand is plentiful in supply, the dunes often rise to the height of a few 100 ft. Their length may also be in several 100 ft. or they may extend over area of a few kilometers.

In some cases the dune ridge migrates downward drawing the parabola into a long, narrow form with parallel sides resembling a hair pin in outline. Hair dunes stabilized by vegetation.

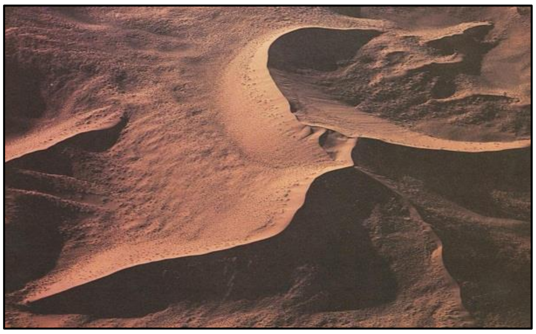
Other forms are: ***Star dunes*** have a high central peak, radically extending three or four arms. ***Reversing dunes*** are formed when winds blow from opposite direction and are balanced in strength and duration. When the longitudinal dunes migrate, the coarser sands are left behind to form ***whaleback dunes***. Very large whaleback dunes are known as *draas*.



Parabolic dunes

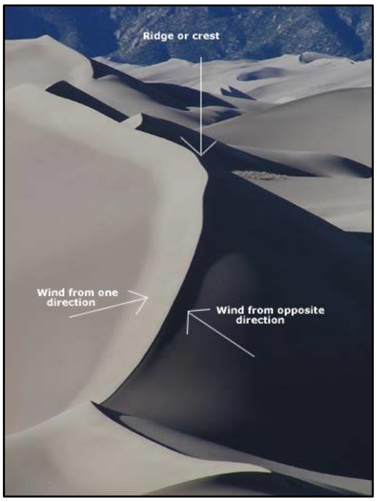
(Source:

http://www.comphys.ethz.ch/hans/dunes.html,http://pbisotopes.ess.sunysb.edu/reports/dunes/



Star shaped dunes

(Source: http://commons.wikimedia.org/wiki/File:Star-dune.jpg)



Reverse Dunes

(Source: http://www.calvin.edu/academic/geology/coastaldunes/dunes/reversingdunes.htm)

Nearly all types are dunes can be observed in India. Thar Desert or Great Indian Desert (western part of Rajasthan) is characterized by long longitudinal dunes; coastal dunes are found along Malabar Coast, Orissa coast, Kutch, Tinnevelli coasts etc. Transverse dunes are the characteristics of the riverine banks of the Ganga, the Kosi, the Krishna, the Godavari rivers etc.

Types of Dunes	Description	Supply of Sand	Wind Direction and Speed	Vegetation Cover	Speed of Dune Movement
Barchan	individual dunes, crescent shape with horns pointing downwind	Limited	constant direction, right angles to dunes	none	highly mobile
Barchanoid Ridges	asymmetrical, oriented at right angles to wind, rows of barchans forming parallel ridges	Limited	constant direction, right angles to dunes	none	mobile
Transverse	orientated at right angle to wind but lacking barchanoid structure, resemble ocean waves.	Abundant (thick) sand cover	steady winds (trades) constant direction but with reducing speeds, right angles to dunes	vegetation stabilizes sand	sand checked by barriers, limited mobility
Dome	dome shaped (height restricted wind)	Appreciable amounts of coarse sand	strong winds limit height of dune	none	virtually no movement
Self (Linear)	longitudional, parallels dune with slip faces on either side, can extend for many kilometers	Large	persistent steady winds with slight seasonal or diurnal change in direction	none	regular (even) surface, virtually no movement
Parabolic	hair-pin shaped with noses pointing downwind, a type of blow out (eroded) dune where middle section has moved forward may occur in clusters	Limited	constant direction	where present, can anchor sand	highly mobile by blow outs in nose of dune
Star	complex dune with a star (starfish) shape.	Limited	effective winds blow from several directions	none	virtually no movement
Reversing	undulating haphazard shape	Limited	winds of equal strengths and duration from opposite direction	none	virtually no movement

Loess

Loess is an Aeolian sediment formed by the accumulation of wind-blown silt, typically in the 20–50 micrometer size range, twenty percent or less clay and the balance equal parts sand and silt that are loosely cemented by calcium carbonate. It is usually homogeneous and highly porous and is traversed by vertical capillaries that permit the sediment to fracture and form vertical bluffs.

Loess is homogeneous, porous, friable, pale yellow or buff, slightly coherent, typically non-stratified and often calcareous. Loess grains are angular with little polishing or rounding and composed of crystals of quartz, feldspar, mica and other minerals. Loess can be described as a rich, dust-like soil.

Loess near Hunyuan, Shanxi province, China

Loess deposits may become very thick; more than a hundred meters in areas of and tens of meters in parts of the Midwestern United States. It generally occurs as a blanket deposit that covers areas of hundreds of square kilometers and tens of meters thick.

Loess often stands in either steep or vertical faces. Because the grains are angular, loess will often stand in banks for many years without slumping. This soil has a characteristic called vertical cleavage which makes it easily excavated to form cave dwellings, a popular method of making human habitations in some parts of China. Loess will erode very readily.

Conclusion

- Arid region lies mostly between 15^0N and 45^0N and 15^0S and 30^0S, and most of these are located on the western sides of the continents, in the trade wind belt where the winds are offshore.
- The main deserts landscapes are erg (sandy); reg (stony); hammada (rock platform) and badlands (restricted to semi-arid region).

- Wind is the most important agent of erosion along with the intermittent rainfall and running water.
- Wind transport and deposition are the main agents of denudation in deserts; together they produce features such as barchans and seifs.
- Mechanical weathering is more important than chemical weathering in arid regions, so little soil is formed.
- Wind erosion is mostly by deflation and abrasion.
- Wind erosion forms deflation hollow, deserts pavement, einkanter, zweikenter, drickanter, rock pedestral, Zeugens, yardangs, stone lattice and incelbergs.
- Wind transports sand by saltation and surface creep. Silt and dust size particles are carried in suspension.
- Windblown sand commonly accumulates in dunes that migrate as sand is transported up the windward slope and accumulates in the relatively guest areas.
- A variety of sand dunes result from variation in sand supply, wind direction and velocity. The most significant one include: transverse dunes, barchans dunes, longitudinal dunes, parabolic dunes.
- Nearly all types are sand dunes can be observed in India.