CE/SC 10110-20110: Planet Earth

Deserts

Earth

Portrait of a Planet
Fifth Edition

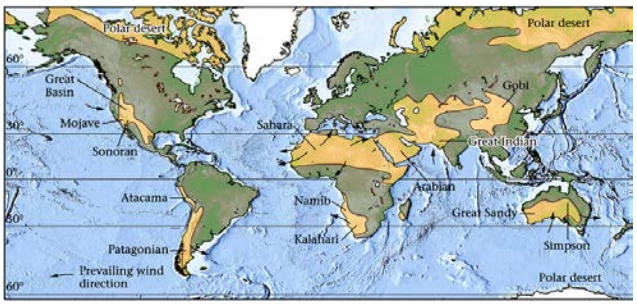
Chapter 21

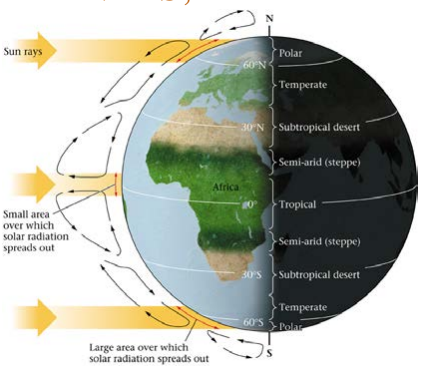
Definition of a Desert

Area with less than 25 cm of ***precipitation*** annually.

It is **NOT** defined by temperature - it is defined by ardity.

Distribution: Zones of high pressure at ~30°N & S, as well as 90°N & S. Also leeward sides of mountains.





Deserts have no permanent surface water,<15% vegetation cover.

Arid nature produced by high and low temperatures as well as orographic lifting.

Little chemical weathering - bare bedrock, wind blown sand, cobbles, and salt precipitation.

Definition of a Desert

Desert land surfaces often include:

- Exposed bedrock
- Accumulated clasts
- Unweathered sediment
- Precipitated salt
- Windblown sand

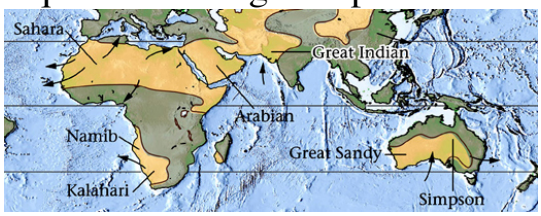
Mirages, which look like distant water, result from light interacting with heated air just above the ground surface.

Each desert has unique characteristics of landscape and vegetation. Geologists group deserts into one of five classes.

Types of Deserts

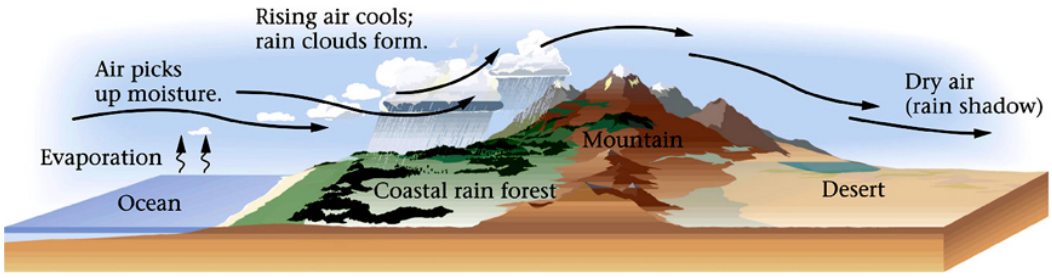
Five Categories:

Subtropical Deserts: (Sahara, Arabian, Kalahari, Australian) form where convection cells diverge. Has very little water, which has condensed out after rising at the equator. Dense air mass moves to the equator with high evaporation rates as sinking dense air heats up.



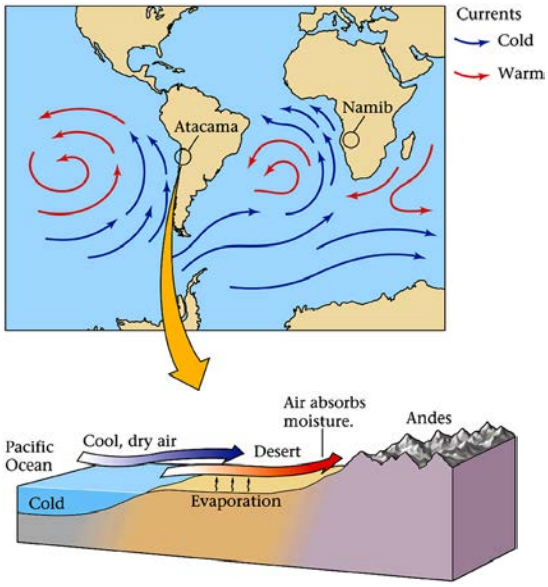
Found from 20° to 30° N and S latitude across geologic time.

Rain Shadow Deserts: (Washington State, east of the Cascades)



Types of Deserts

Coastal Deserts: formed along cold coastal currents. The cold Humboldt current flows from Antarctica to southern Chile. Sucks the heat (and moisture) out of the air. Atacama Desert had no rain from 1570-1971.



Cool air over cold ocean water holds little moisture. This air absorbs moisture when it interacts with land.

Types of Deserts

Continental Interior Deserts: Long way from oceans (e.g., central Asia), air has to rise from ocean and drops moisture close to the coast.

Deserts of the Polar Regions: air has moved north and cooled by cold oceans (reduced moisture). Now it rises, expands and rises further. Above 66º N and S latitude there is very little moisture in the air due to cold temperatures. Air circulation carries air to the polar regions, but it is so cold, the air can't hold any moisture.

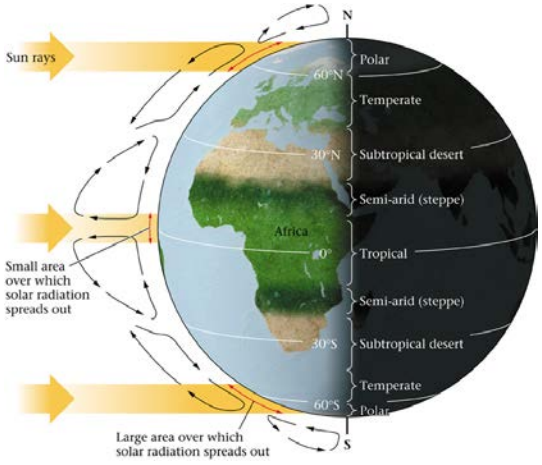


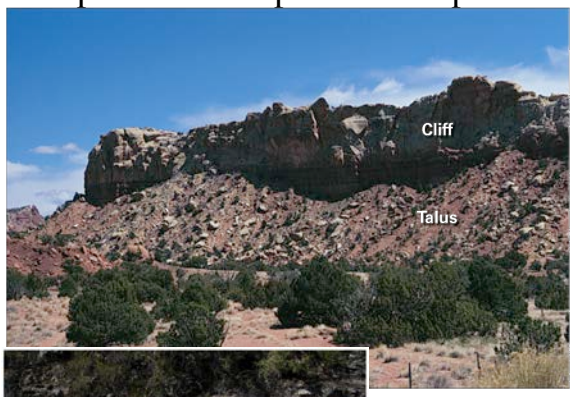
Plate tectonics plays important role in distribution of deserts on the continents.

Weathering & Erosion in Deserts

Weathering

Physical weathering occurs along joints - expansion and contraction due to temperature changes. Lack of soil allows these blocks to build up (**as TALUS**) at the bottom of slopes and keeps bedrock exposed on slopes.

Chemical weathering does occur, but slowly. Dew and some rain percolates in cracks and fractures and leaches material out of the rock, reducing its integrity. Amount of water is not enough to flush it out of the system. Deposits material lower down - if calcite has been dissolved "calcrete" is deposited because it cements loose grains together.



Weathering & Erosion in Deserts

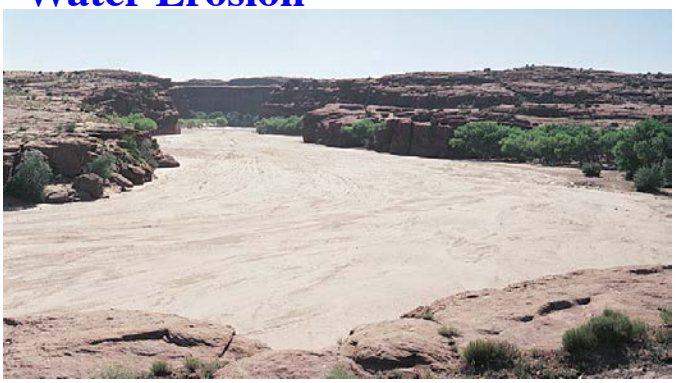
Weathering

Desert Varnish: wind-borne dust settles on rocks. When dew precipitates, bacteria metabolize these particles and deposit Fe- and Mn-oxides. Takes a long time to form, but Native Americans made use of it for artwork (petroglyphs).

Weathering & Erosion in Deserts

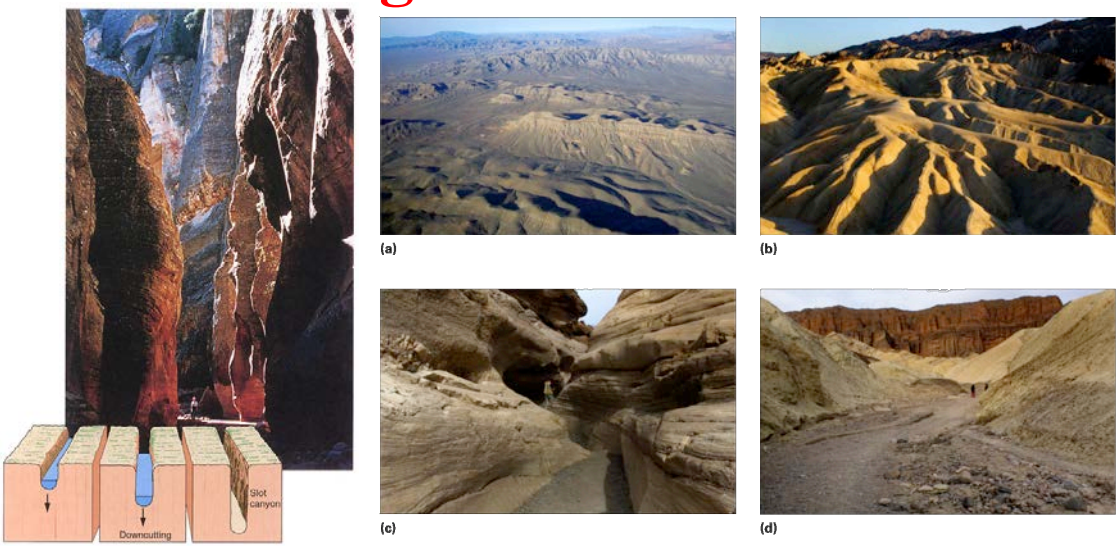
Lack of vegetation means variations in bedrock color stands out (e.g., Painted Desert, N. Arizona - variations in the amount of Fe and/or the amount of oxidation).

Water Erosion



Deserts get most of their rain all at once. Lack of vegetation means loose material is easily moved. Streams are ephemeral. Deep channels with steep sides are carved, called **Dry Washes** or **Arroyos** in the US - **Wadis** in the Middle East. Flash floods are common.

Weathering & Erosion in Deserts



Though rare, water is the dominant force shaping landscapes. Desert landscapes reveal dry drainages. Sediment erodes quickly when torrential rains generate dangerous flash floods characterized by rapid flow of thick, muddy, and viscous water. Flash floods quickly infiltrate dry streambeds.

Weathering & Erosion in Deserts

Wind Erosion

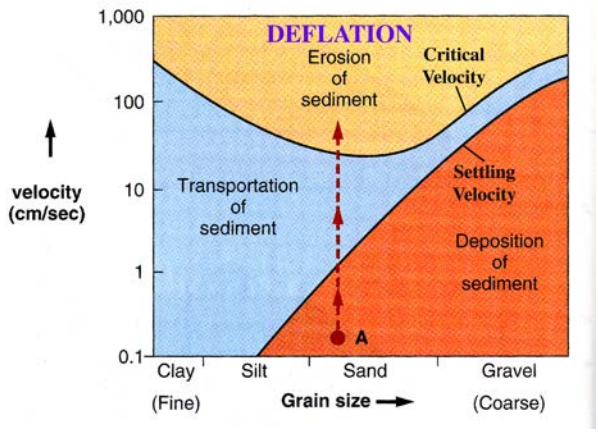
Can carry sediments long distances, including uphill.

Initial movement = deflation – requires dry grains that are not restricted by vegetation (**or water**).

Deflation = the sorting out, lifting, and removal of loose dry, fine-grained particles by turbulent eddy action of a fluid.

Critical Velocity = velocity of fluid flow at which flow changes from laminar to turbulent. In comparison, water can move larger material with lower velocity. Why?

Settling Velocity: the rate at which suspended solids subside and are deposited.



Weathering & Erosion in Deserts

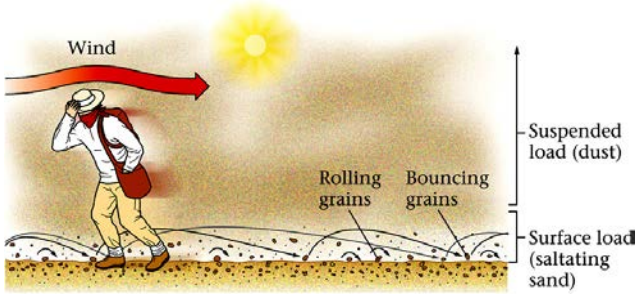
Wind Erosion

Depends upon grain size and wind velocity.

Grains >0.2 mm:

Traction (rolling, bouncing along ground).

Saltation (jumping) to about 5' above the ground (sand storms).



Grains <0.2 mm:

Suspended (dust storms).

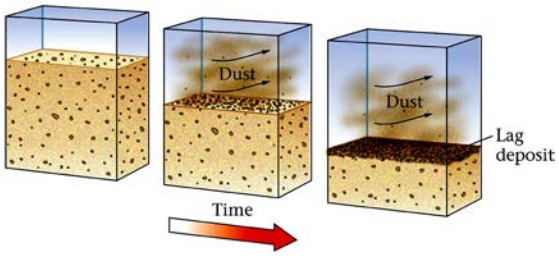
All three make up the **surface load** of the wind.

Lag Deposit: coarse material left behind by wind.

Weathering & Erosion in Deserts

Desert Pavement

Mosaic of tightly fitting stones above a finer fraction that form a relatively smooth surface.



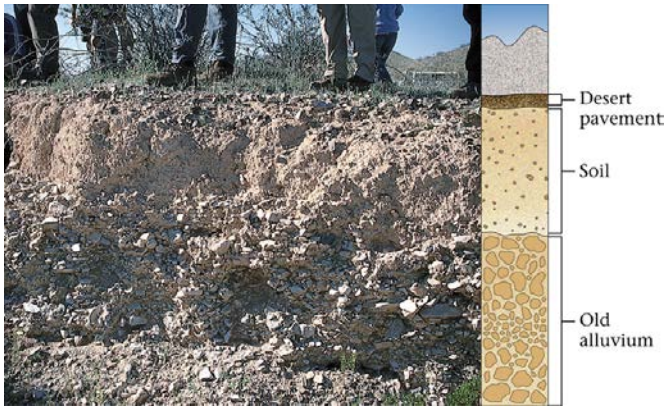
Theories of formation:

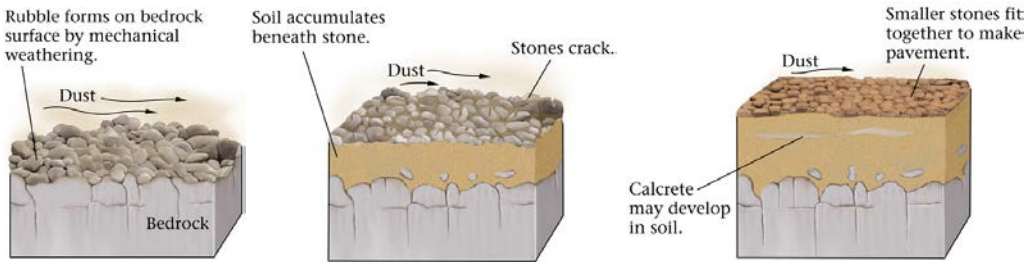
1) They are a lag deposit.
2) They are a product of sheetwash erosion.
3) Wetting of soils causes clays to expand pushing larger stones upward. Drying shrinks the clays and the stones settle down fitting together tightly.

Weathering & Erosion in Deserts

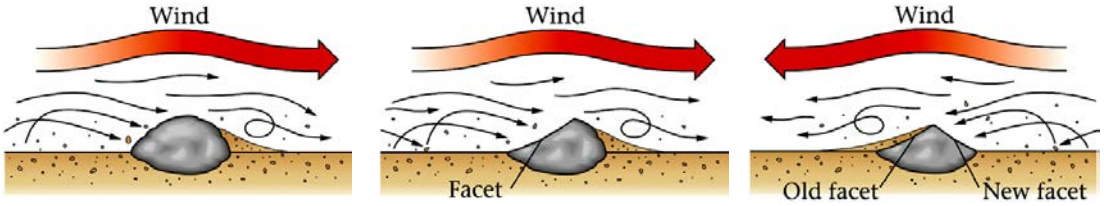
4) Bubbles formed by bacteria metabolism gradually buoy stones upward.

5) Wind blown fine sediment is deposited between the stones and washes down. The stones were never buried, but this is a way to increase the thickness of the finer layer beneath them.





Ventifacts



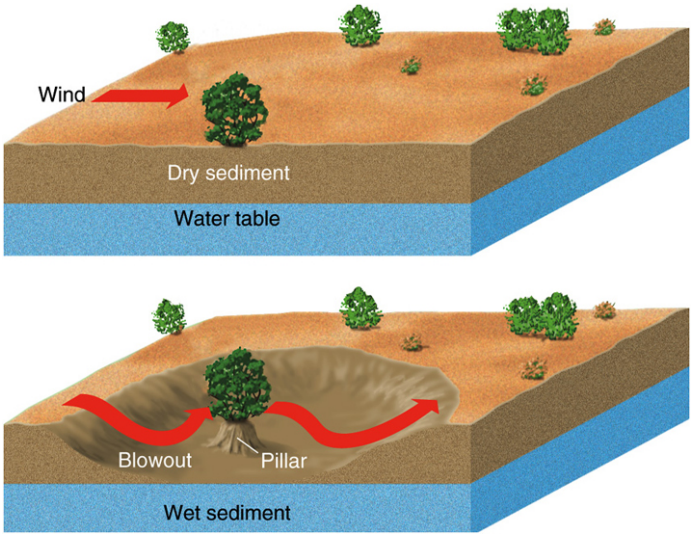
Yardangs

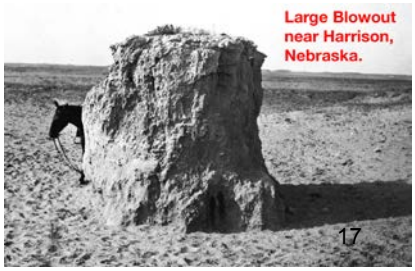
Perched rocks. Pedestal formed by sand blasting (abrasion).

Deflation

Process of lowering the land surface.

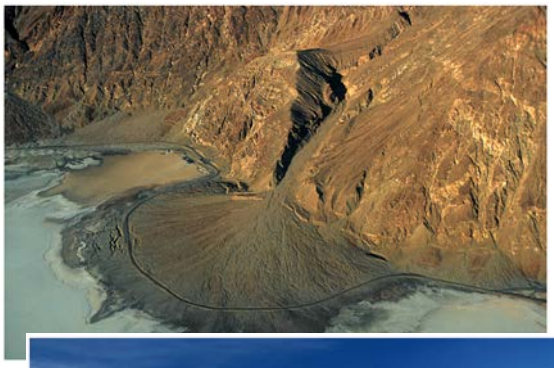
Blowout: depression scooped out by deflation. Erosion stops when the water table is reached.





Development of Landforms in Basin & Range Topography

Alluvial Fan: deposit of sediment at the mouth of a valley.

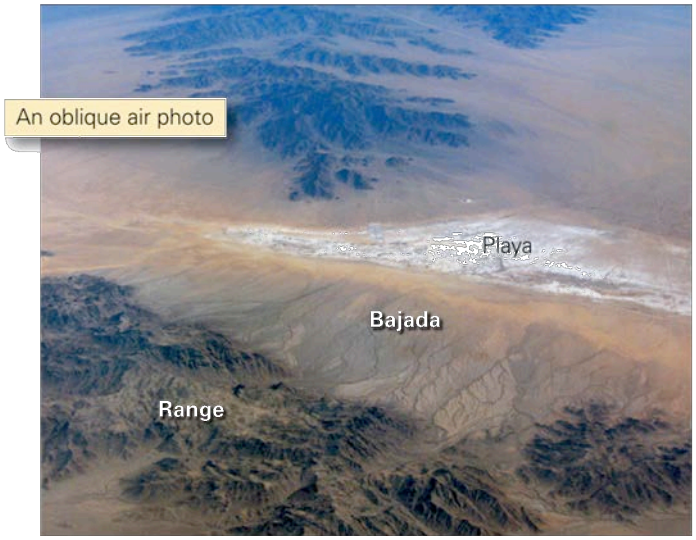


Talus Slope: deposit of weathered material along a steep slope.

Development of Landforms in Basin & Range Topography

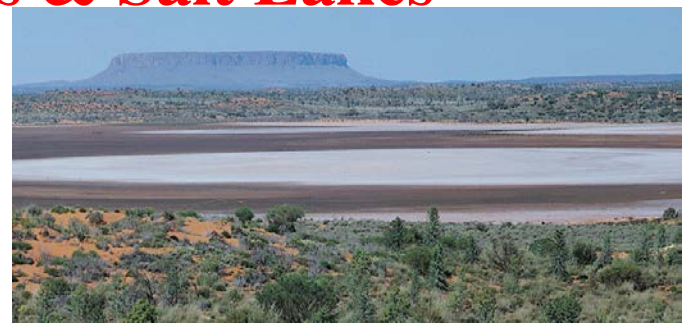
Alluvial Fan: deposit of sediment at the mouth of a valley.
Bajada: wedge of sediment along a mountain front formed by calescence of alluvial fans.
Pediment: bedrock surfaces that extend out from the mountain front to the alluvium-filled valleys. Formed by sheetwash.

Pediment + Bajada = PIEDMONT



Playas & Salt Lakes

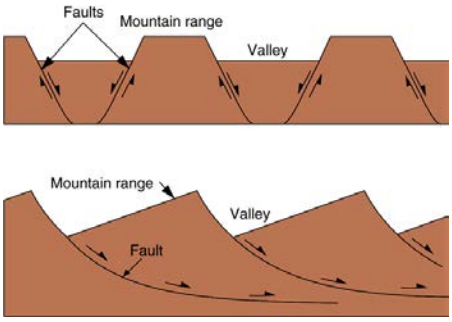
Playas: remnants of temporary lakes. Salt encrusted clay deposits. Very flat! Salts include halite, gypsum, borax, etc.

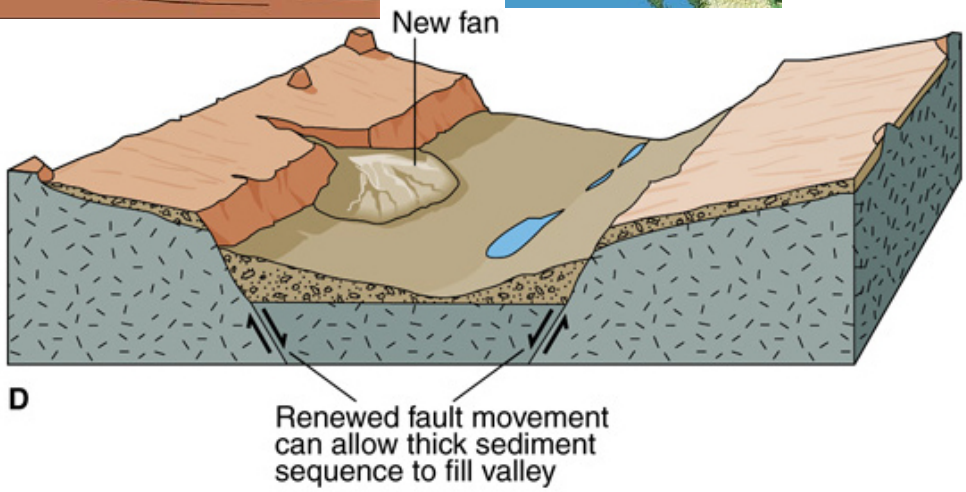


When it does rain, the surface becomes slippery - rocks can be blown over the surface.

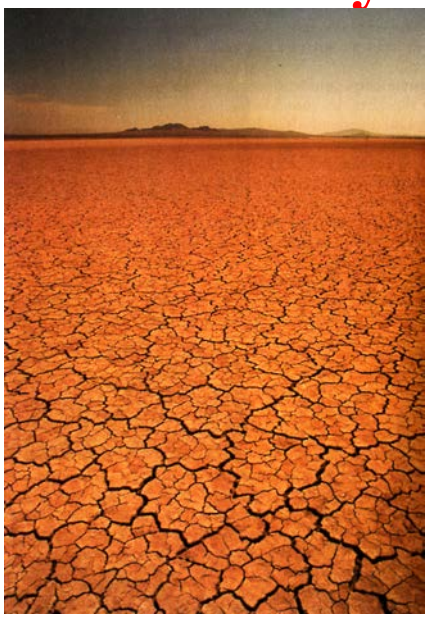
If there is sufficient water flowing into a desert basin, a salt lake may form due to great evaporation concentrating the dissolved ions. The Great Salt Lake in Utah is the remnant of a much larger lake - Lake Bonneville.

Development of Landforms in Basin & Range Topography

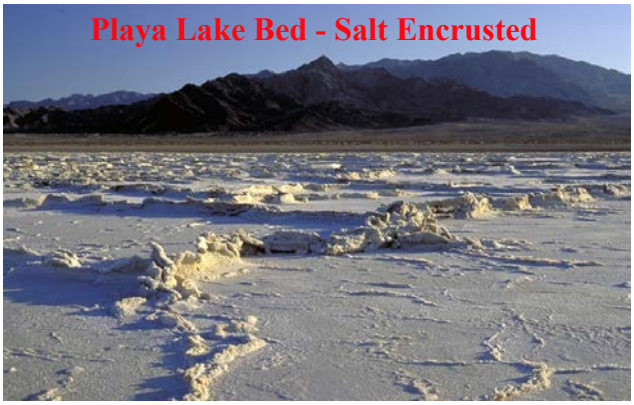




Playas & Salt Lakes



Mud-cracked playa surface

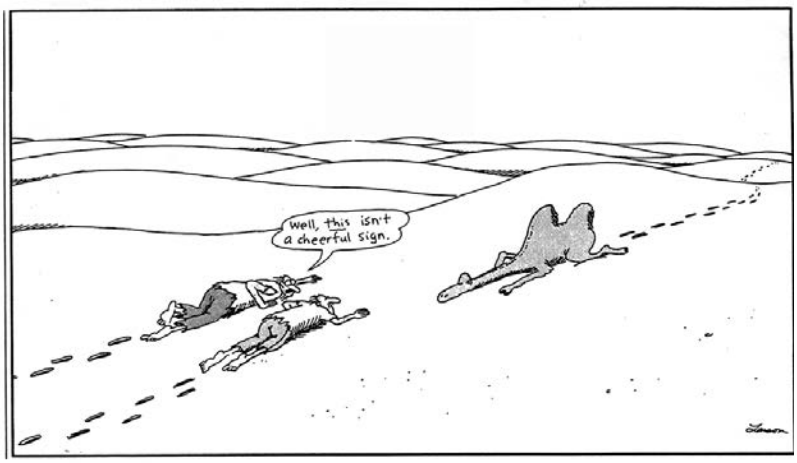


EOLIAN LANDSCAPES

Recognition of eolian features in the geologic record is key in understanding paleoclimatology.

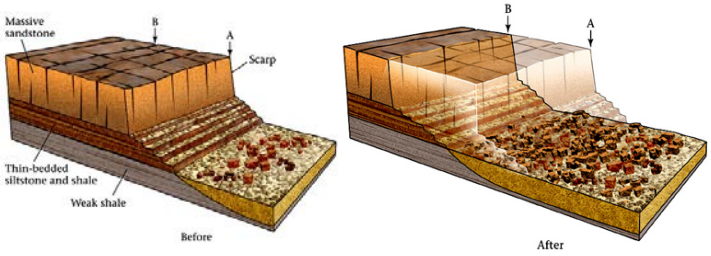
Look for:

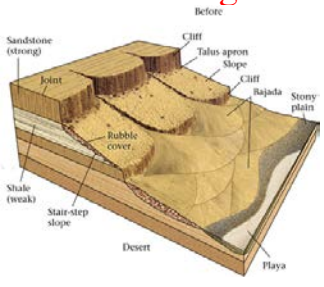
1) Dune-scale cross-bedding;
2) Sediments are extremely well sorted;
3) Sediment grain composition dominated by quartz;
5) Frosted quartz grains due to abrasion and chemical etching;
6) Terrestrial fossils.



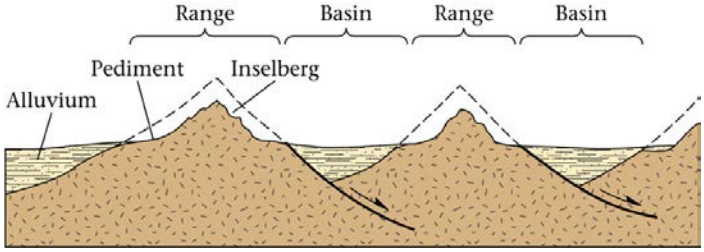
EOLIAN LANDSCAPES

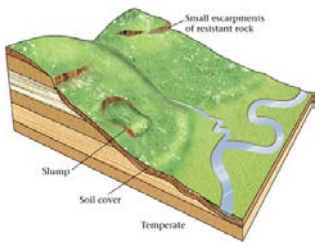
Cliff Retreat: due to joints being weakened through weathering and lack of vegetation to smooth out the slope. Older = more irregular.



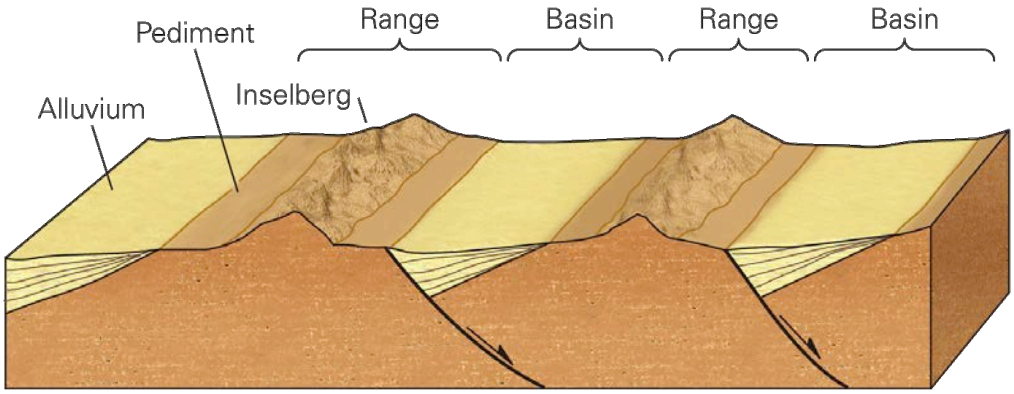


Cliff retreat on all sides produces "islands of rocks" or ***inselbergs*** – pointed hills.





Desert Landscapes: Inselbergs



EOLIAN LANDSCAPES

Rock Features of the Southwest

Plateaus: broad, flat-topped areas elevated above the surrounding land and bounded, at least in part, by cliffs.

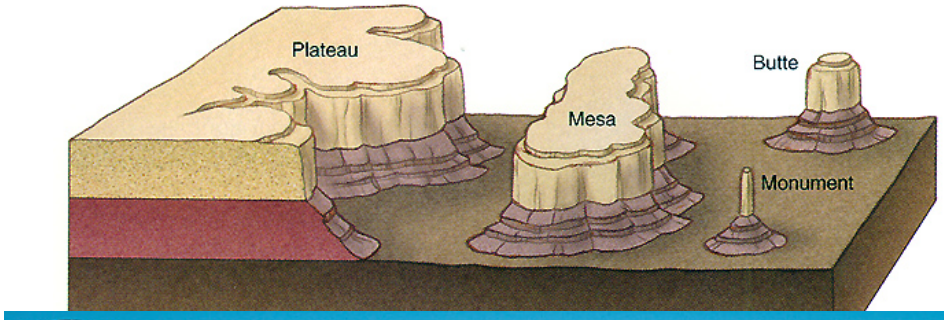
Mesa: broad, flat-topped hill bounded by cliffs and capped with a resistant rock layer - wider than it is high.

Butte: narrow hill of resistant rock with a flat top and very steep sides - about as wide as it is high.

Monument/Chimney: pillar-like spire of resistant rock with a flat top and steep sides, much taller than it is wide.

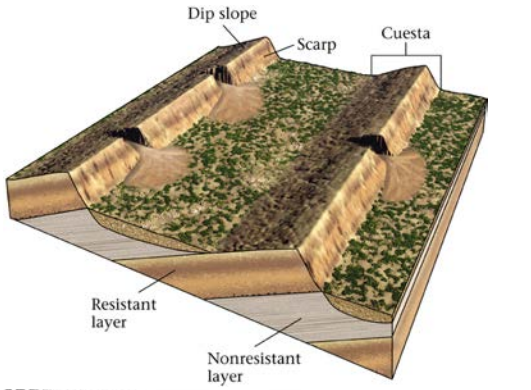
Plateau > Mesa > Butte > Monument/Chimney

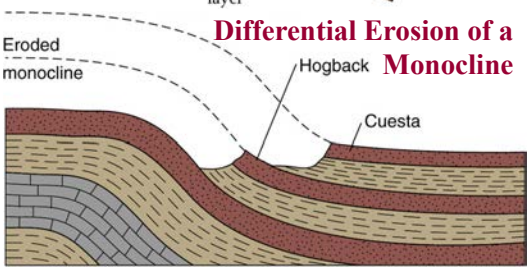
Apart from climate, what is the main control on the development of these features?



EOLIAN LANDSCAPES

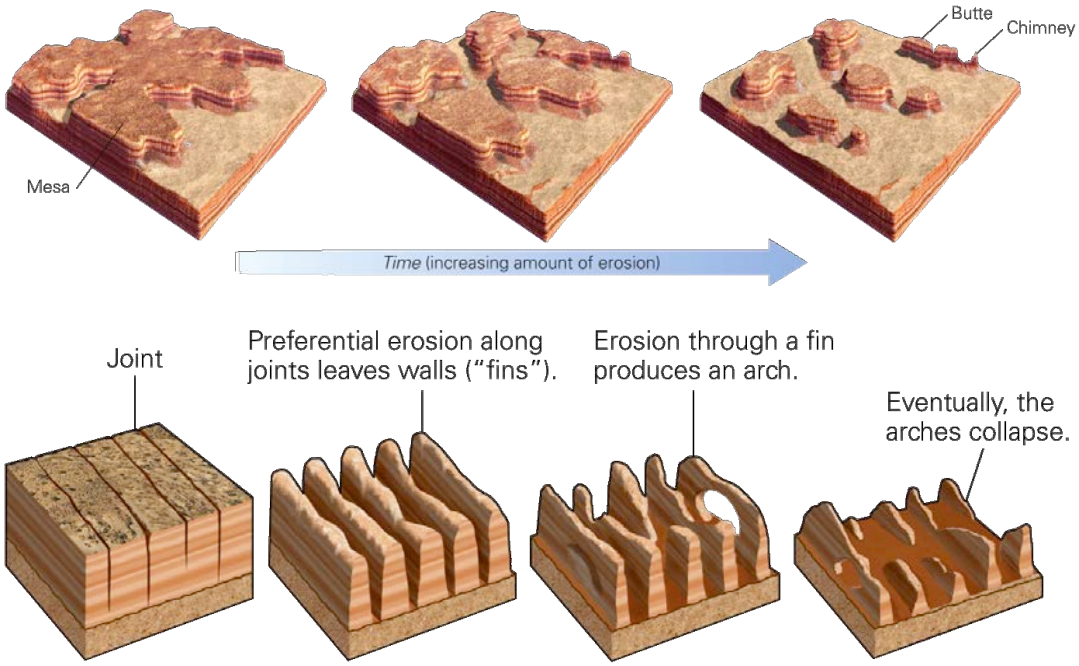
Cuesta: Asymmetric ridge developed due to gently dipping strata;
Hogback: Symmetric risge developed due to steeply dipping strata.





Differential Erosion of a Monocline

Landscape Evolution



Eolian Deposits

LOESS: silt-size, extensively well-sorted sediments, unstratified, cohesion strong due to fine grain size. Can reach >100 m thick (e.g., Gobi Desert).

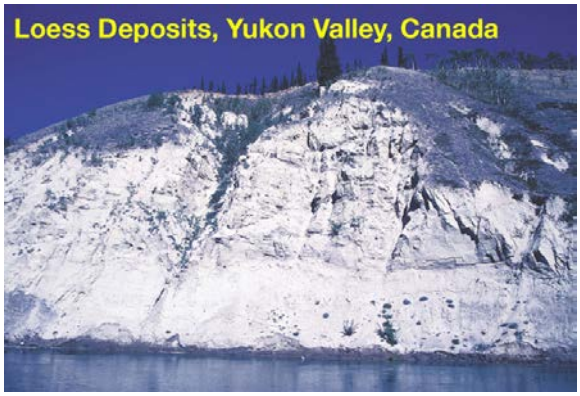
Figure 13.20
Vertical road cuts in loess, Vicksburg, Mississippi.

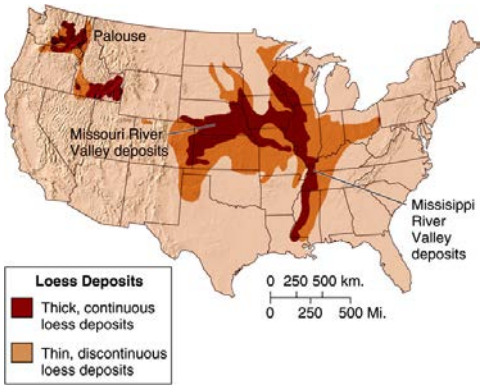
FIGURE 13.20
Vertical scarps in loess deposits from western Iowa.

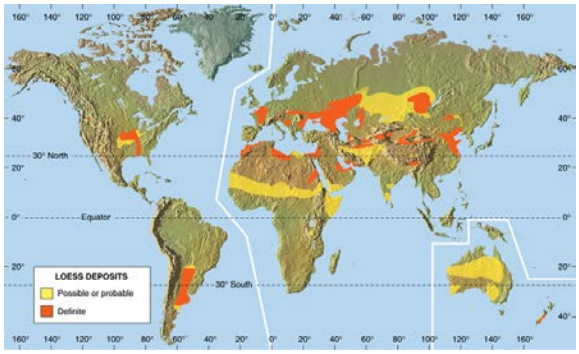
Definition: diameter of particles between 4.0 and 62.5 μm. Clay is <4.0 μm.

What is the glacial equivalent of loess?

Eolian Deposits



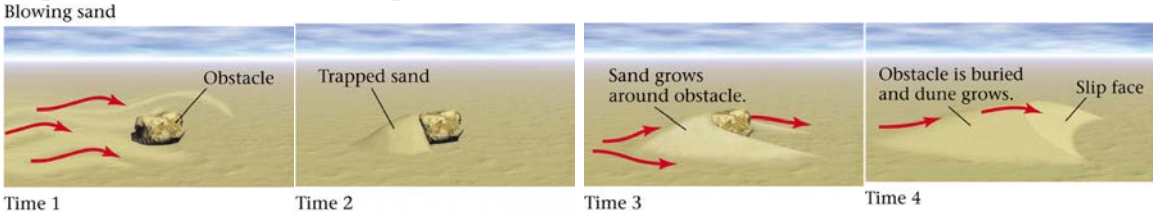




Dune Formation & Migration

Dunes are typically a few meters high, but can be 200 m by 100 km!

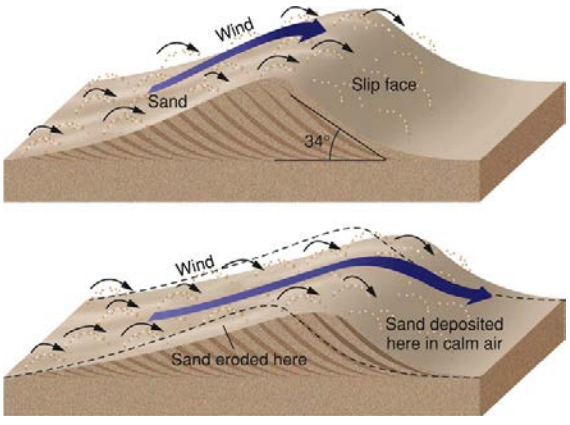
Formation: movement of sand is retarded by an obstacle (wind shadow) & low pressure eddies result in deposition.

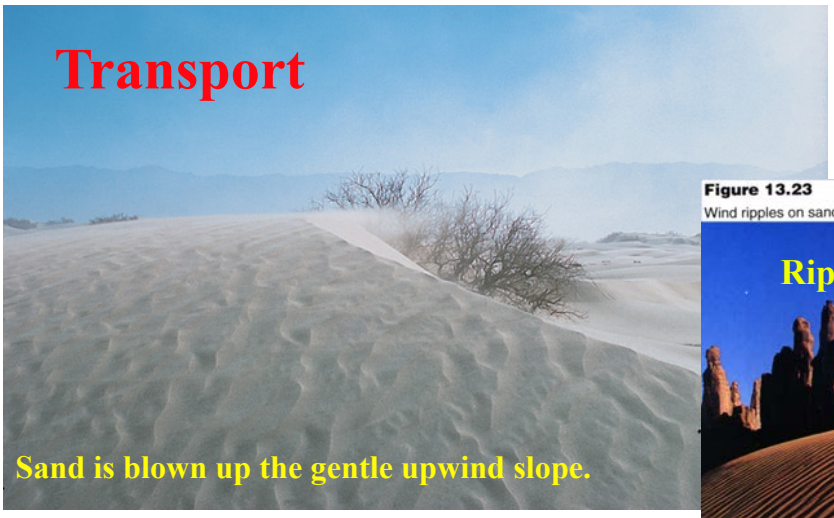


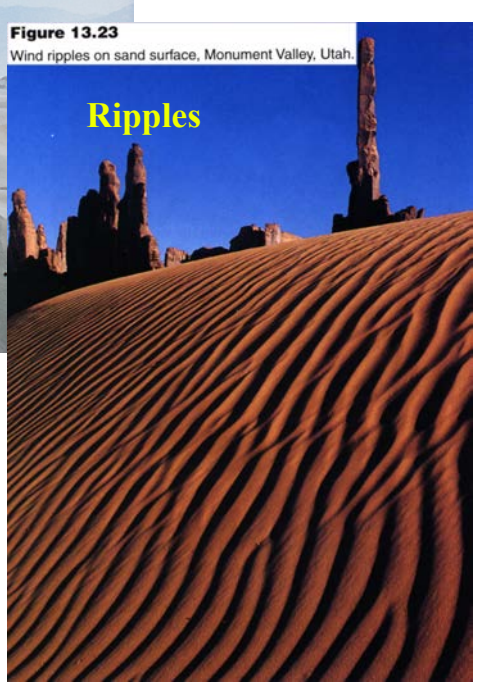
Gentle slope windward; steep slip-face ~34° leeward.

Migration: can be >15 miles/year, but this depends upon wind velocity, persistence, obstacles. Migration produces cross bedding.

What is the transportation process depicted in these diagrams?







Dune shape is dependent upon:

(i) Velocity and persistence of wind;

(ii) Abundance of sand;

(iii) Vegetation.

Sand Dunes

1) Irregular: Beach Dunes – hummocky, variable onshore/ offshore winds, vegetation present.

Can produce "star" dunes if wind direction is variable.

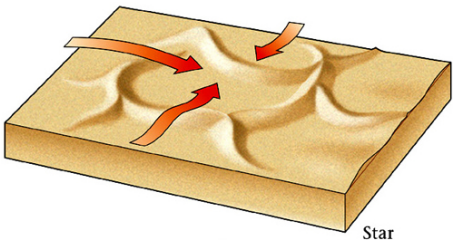
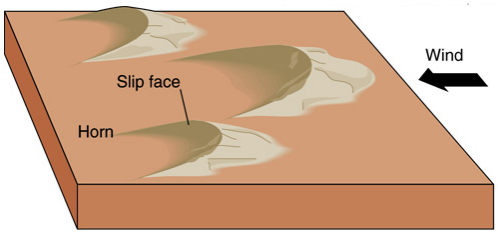


Figure 13.21
Coastal dunes formed from beach sand blowing inland, Pismo Beach, California.

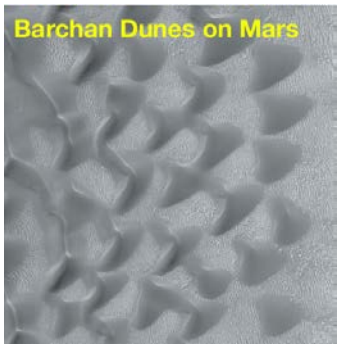
Sand Dunes

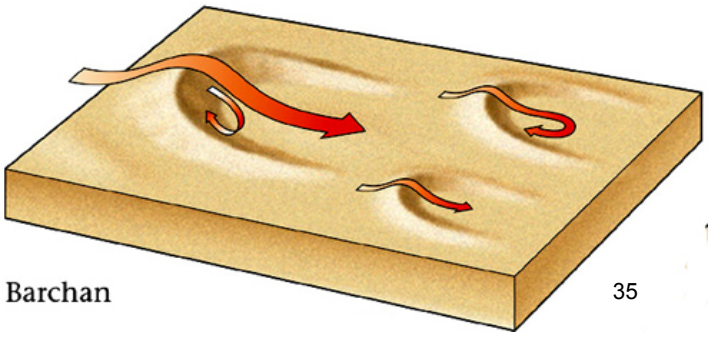
2) Crescentric:

Barchan Dunes – horns point downwind, bows into wind; gentle slope into the wind, steep slip face on the inside of the arc; limited sand.



A Barchans



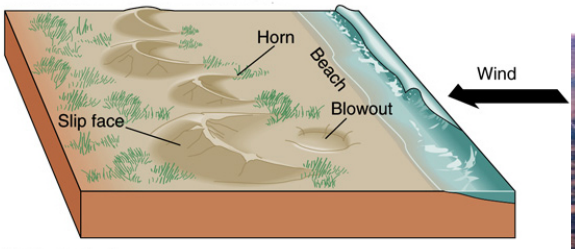


Barchan

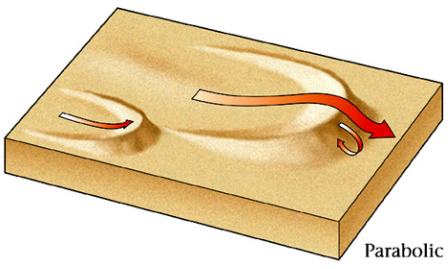
Sand Dunes

2) Crescentric:

Parabolic Dunes – horns point upwind, bows downwind; shallow slope into wind; steep slip face on outside of the arc; forms around a blowout or deflation hollow; abundant sand.



C Parabolic dunes

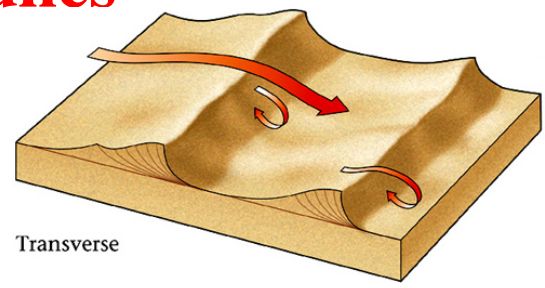


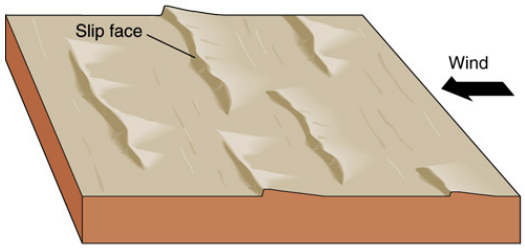
Parabolic

Sand Dunes

3) Elongate:

Transverse Dunes – perpendicular to wind, steep slip face; abundant sand.





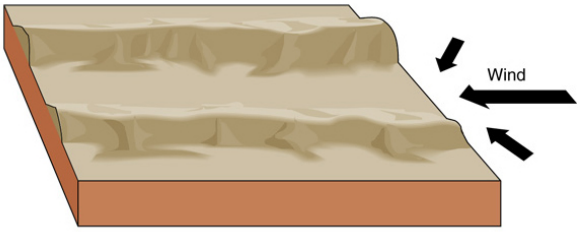
B Transverse dunes

FIGURE 13.26
Transverse dunes in the Great Sand Dunes National Monument, Colorado. Wind blows from left to right.

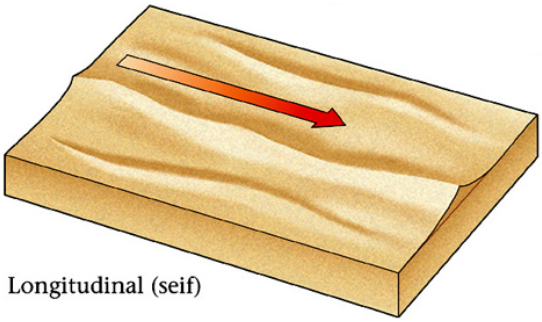
Sand Dunes

3) Elongate:

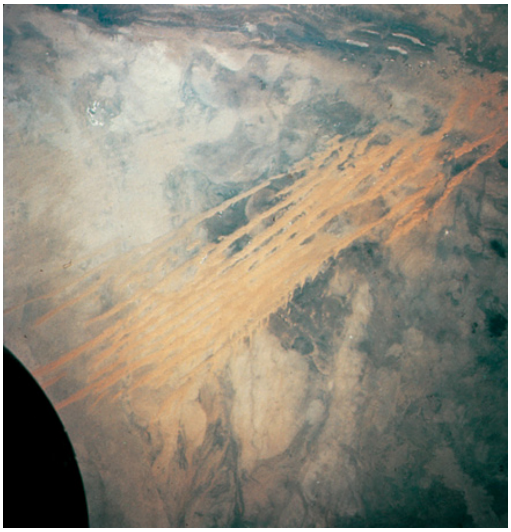
Longitudinal or Seif Dunes– parallel to wind; limited sand.



D Longitudinal dunes (seifs)

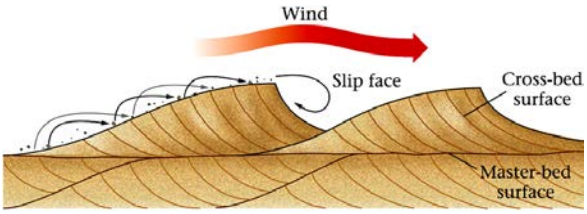


Longitudinal (seif)



Sand Dunes

Fossil Sand Dunes



Environmental Aspects of Wind

Unprotected fields – soil blown away during dry periods (e.g., dust bowl of the thirties – dust storm in Colorado drops 166,000 tons of dust on Kansas. Dust clouds up to 12,000 feet. Dust blocks out sun in New York city.

Changing climates cause desert encroachment on cities = desert-ification; caused by overuse of land.

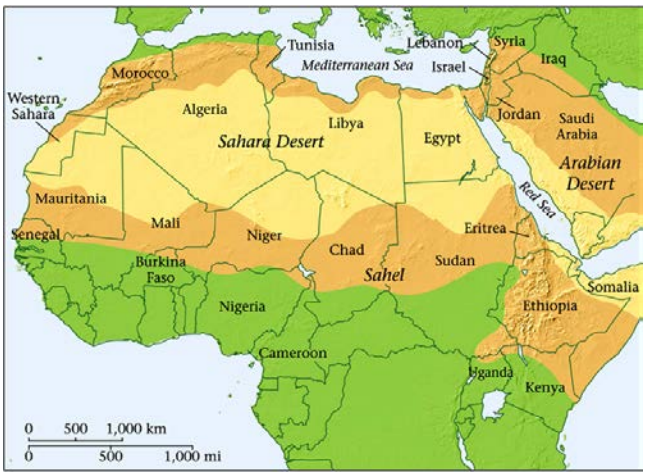
Violent storms especially in tropics.

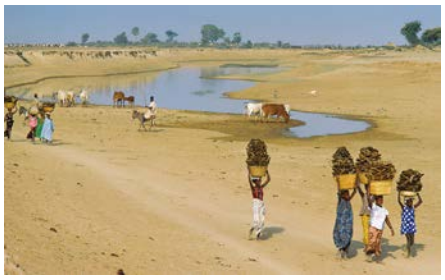
Wind power.

Desertification

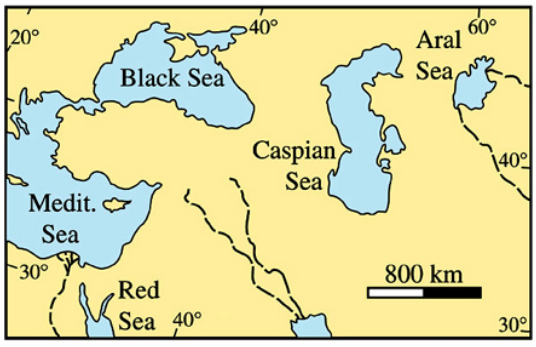
Expansion of Deserts.

Caused by: overgrazing, overpopulation, water diversions.
Too many people = over farming and increased water use.
Diversion of water for agriculture upstream.
Climate change - drought.



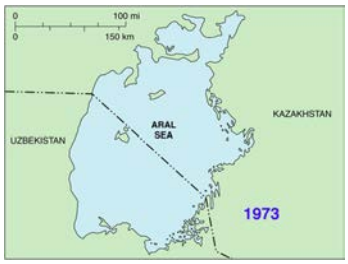


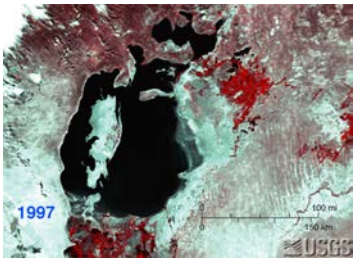
The Aral Sea

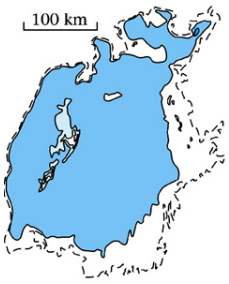


Location Map

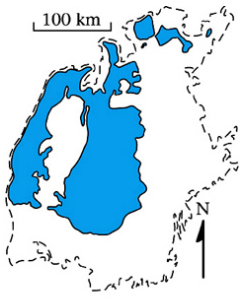
1957







1984



2000

Desertification

Fishing boats engulfed in a sea of sand. Aral "Sea".

Summary

Definition: Based on aridity, not temperature. Found where atmospheric convection cells diverge/converge.

5 Desert Types: Subtropical Deserts; Rain Shadow Deserts; Coastal Deserts; Continental Interior Deserts; Polar Deserts.

Weathering: Physical Weathering; Chemical Weathering (slow) - leaching and "calcrete" formation. Desert Varnish.

Water Erosion: Water - Dry Washes/Arroyos/Wadis; Slot Canyons.

Wind Erosion: Deflation; Critical Velocity; Settling Velocity; Traction; Saltation; Suspended Load; Surface Load; Lag Deposit; Desert Pavement; Ventifacts, Yardangs; Blowouts.

Landscape Development: Alluvial Fan; Bajada; Pediment; Piedmont; Talus Slope; Playa Lake; Salt Lake; Recognizing Fossil Deserts; Cliff Retreat; Inselbergs; Plateaus, Mesas, Butte, Monument/Chimney; Cuesta; Hogsback.

Eolian Deposits: Loess; Dand Dunes.

Sand Dunes: Formation; Migration; Irregular/Star; Barchan; Parabolic; Transverse; Longitudinal/Seif; Fossil Dunes.

Desertification: Land Overuse; Wind; Unprotected Fields; Climate Change; Diversion of Water; Aral Sea; Lake Chad.