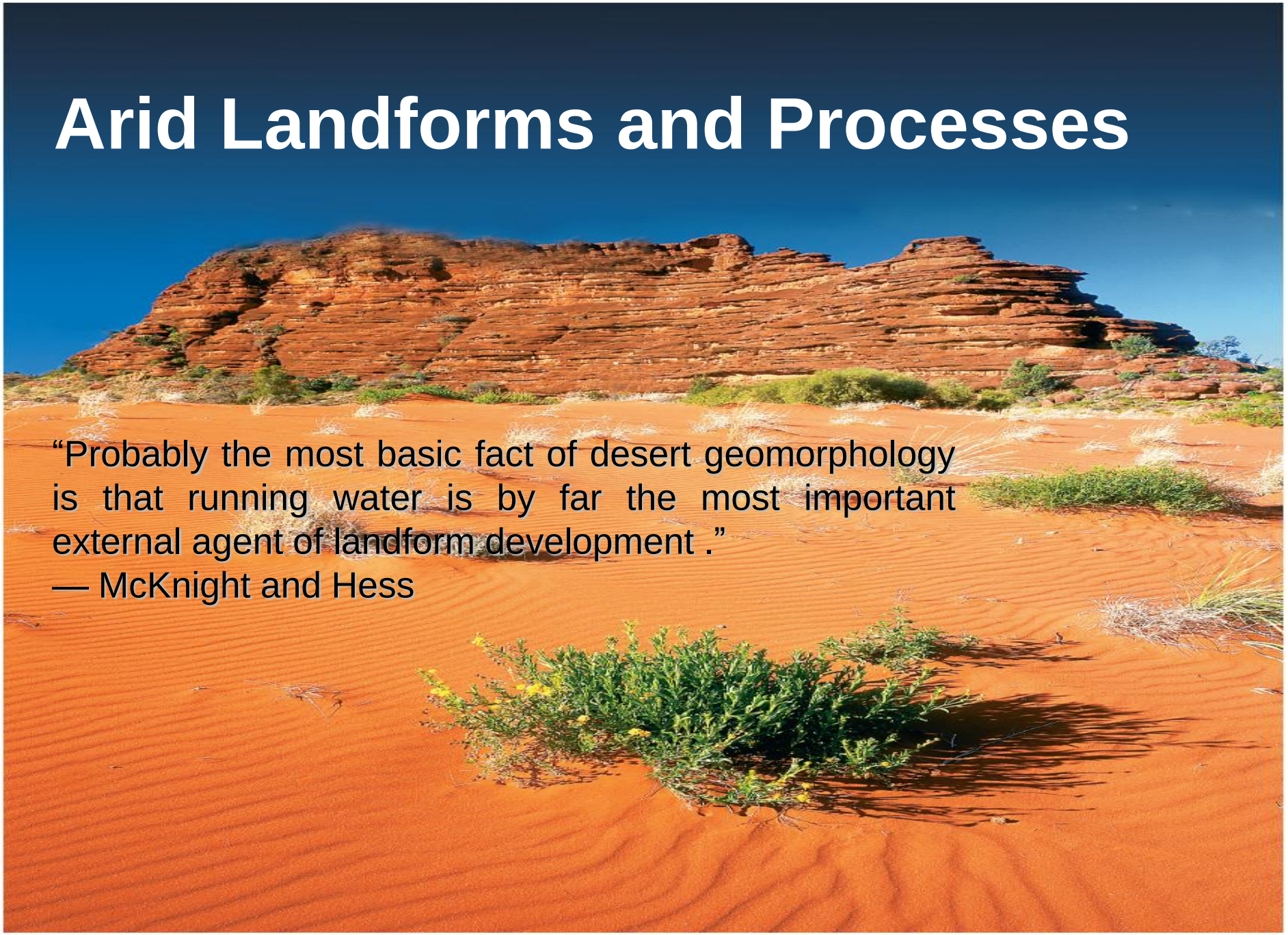
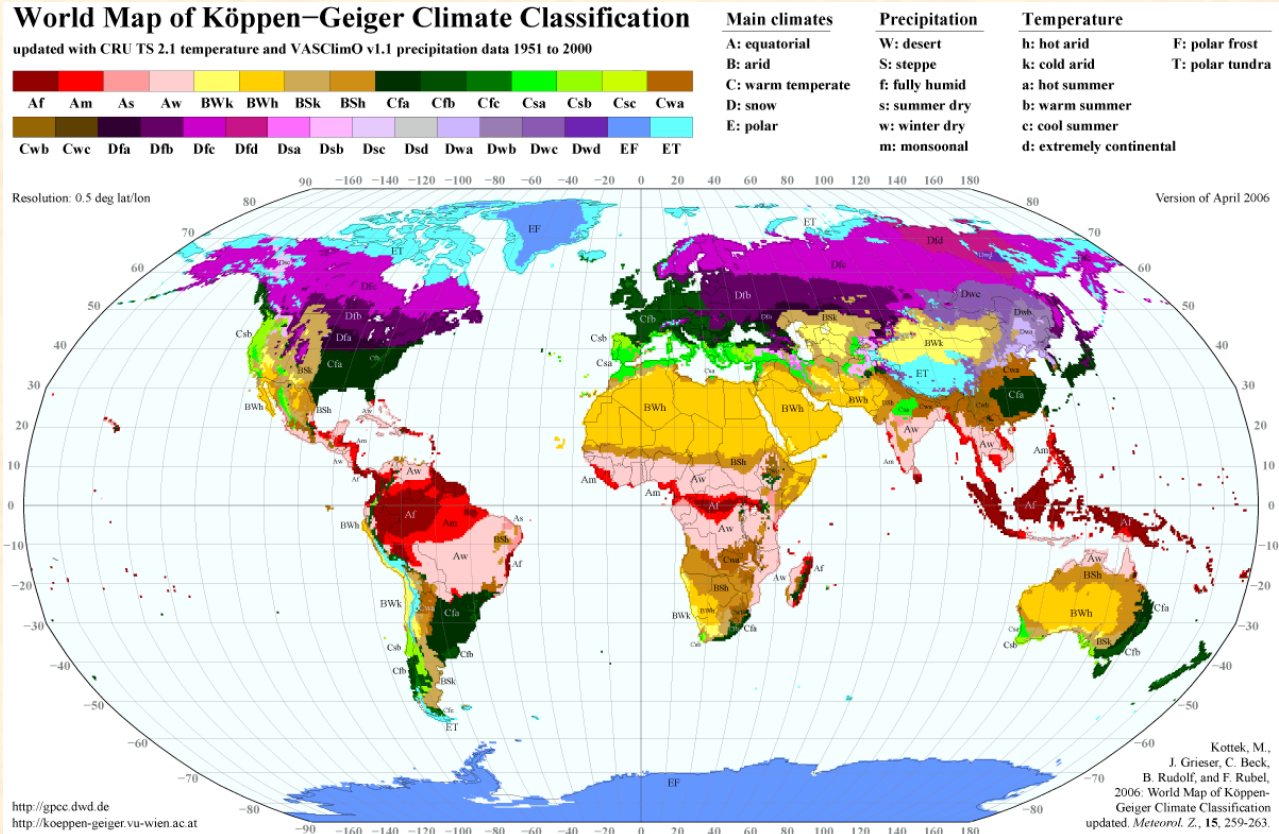
Arid Landforms and Processes



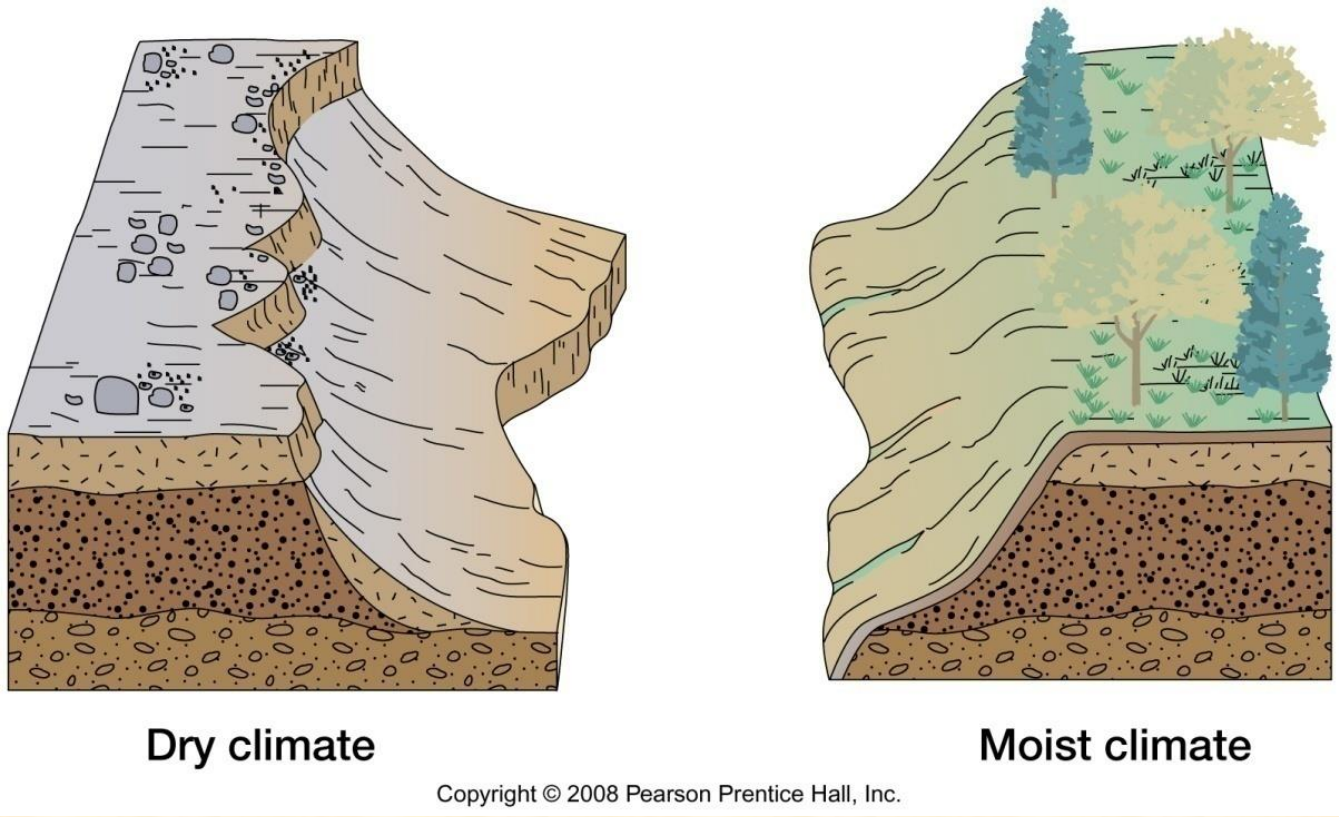
"Probably the most basic fact of desert geomorphology is that running water is by far the most important external agent of landform development ."
— McKnight and Hess

The Topography of Arid Lands

- A Specialized Environment
- Importance of Fluvial Processes
- Characteristic Desert Surfaces—Ergs, Regs, and Hamadas
- Aeolian Processes
- Two Characteristic Landform Assemblages in U.S. Deserts
  - Basin & Range
  - Mesa & Scarp

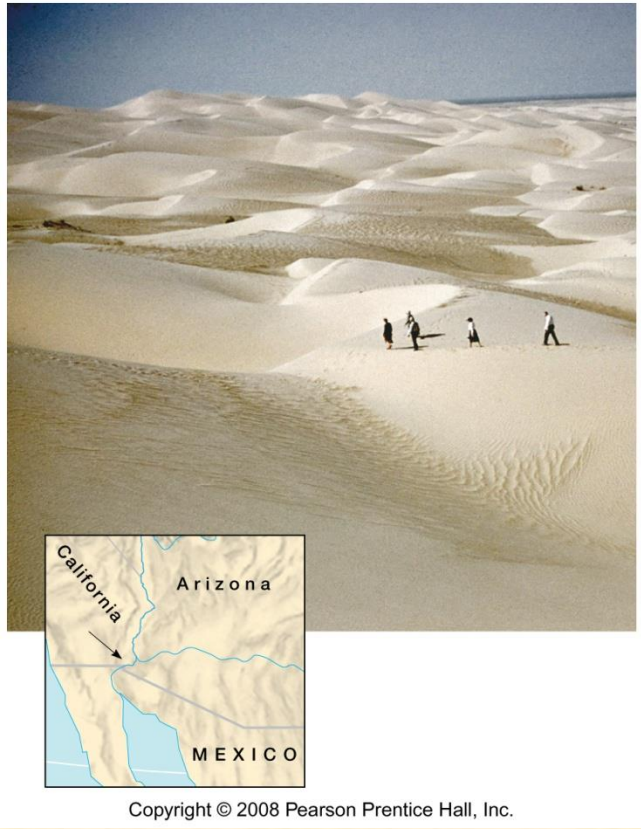


- **Special Conditions in Deserts**
  - Mechanical weathering dominates, e.g. **salt wedging**
  - Soil and regolith are thin, leading to rocky terrain



Special Conditions in Deserts

- **Impermeable surfaces** predominate e.g. **caprocks** (bedrock) and **hardpans** (hardened soil).
- **Rain** ends up as run-off. Never gets into groundwater, were plants can draw it up later.
- **Sand & Wind** – but not *all* deserts have sand or have landforms shaped mainly by wind.
- **Fluvial deposition**: rainfall occurs as intense convective thunderstorms, brief flooding.
- **Interior drainage** that does not lead to the sea.
- **Vegetation** cover is minimal.



Running Water in Waterless Regions

- Significance of Running Water
  - **Aeolian** (wind) processes is less significant
  - Sparse vegetation leads to overland flow erosion, and hence large volumes of sediment moved within a short time.

- Surface Water in Deserts
  - **Exotic Streams**: fed by sources *outside* the desert. E.g. the Nile travels 2,000 miles thru the Sahara, without additional tributaries

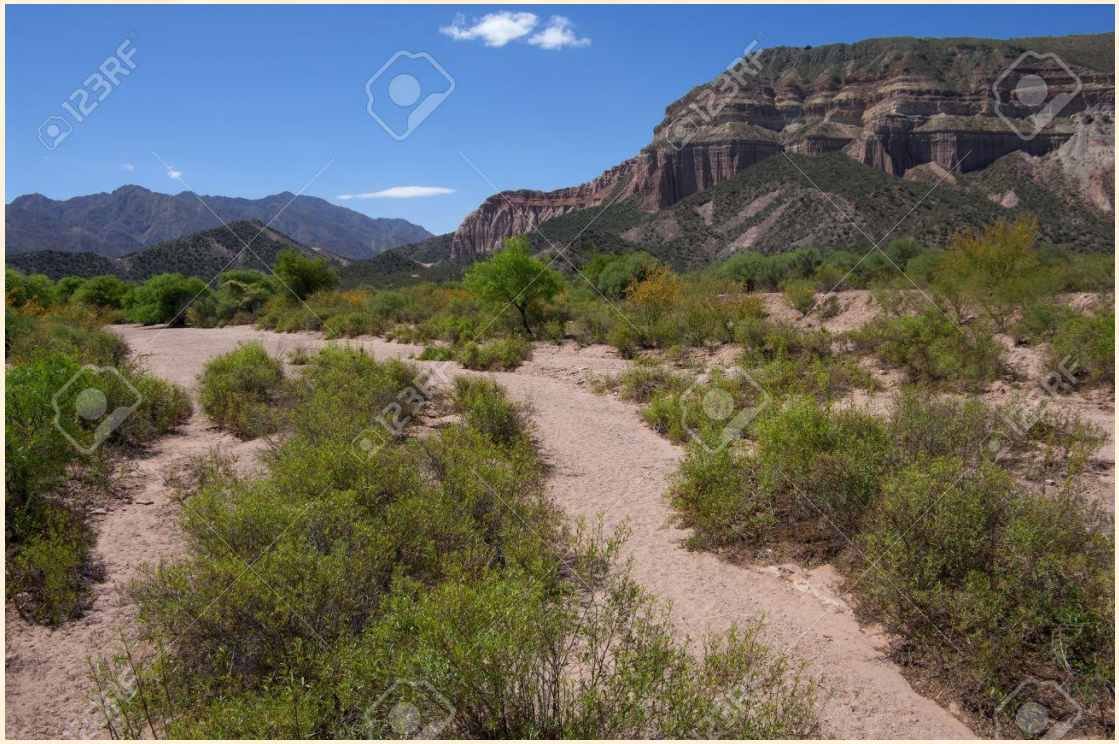
- **Ephemeral Streams**
- **Desert Lakes**
  - **Playas** (dry lake beds), or **Salinas**
  - Playa lakes tend to be temporary. Permanent playa lakes are mostly salty e.g. Great Salt Lake, UT.

Dry lake bed (playa) in central Nevada.

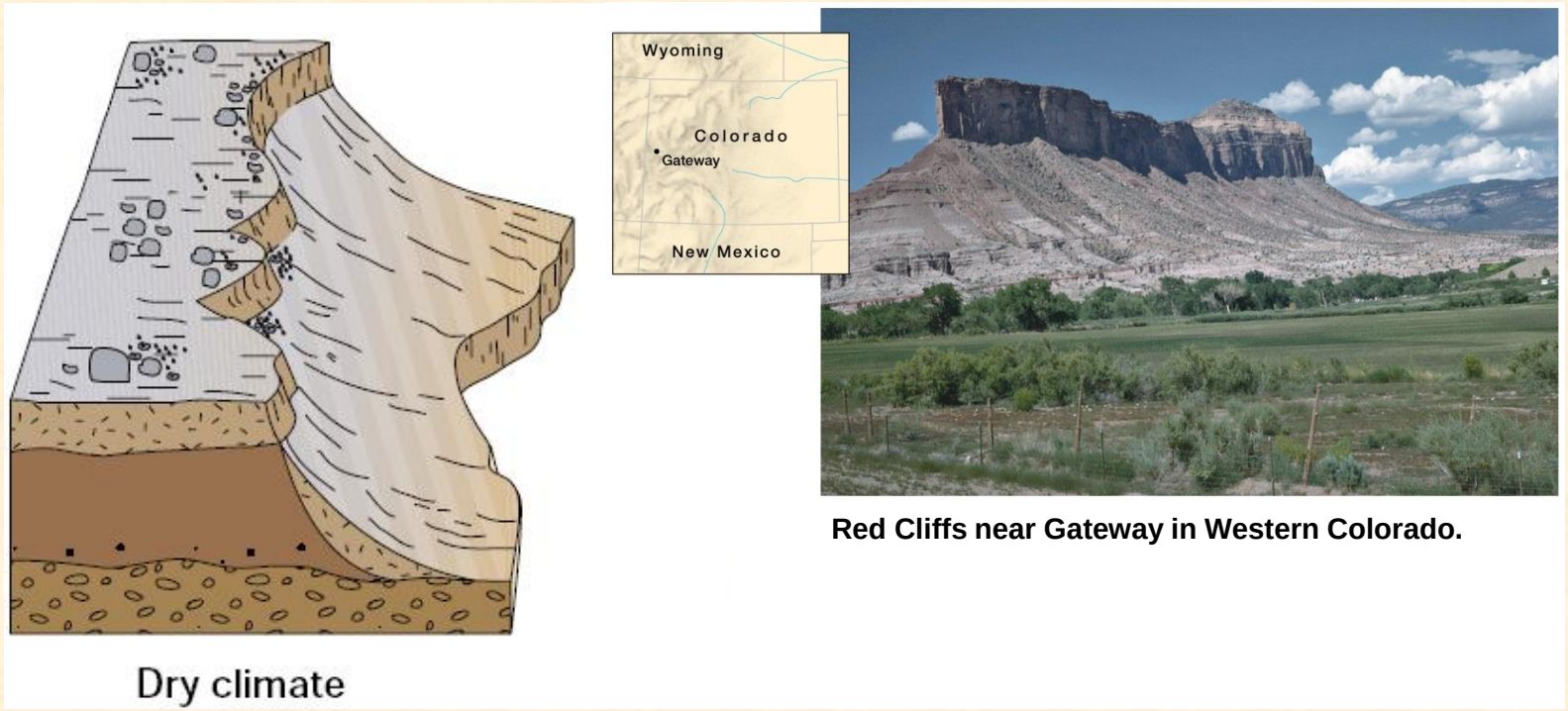
– Desert Stream Channels

- **Wadi** (in Arabic)
- Mojave Desert, near Baker, CA.

- Flat, sandy bottoms, steep side slopes
- **US:** arroyos, gullies, washes, coulees
- **South Africa:** donga
- **India:** nullah



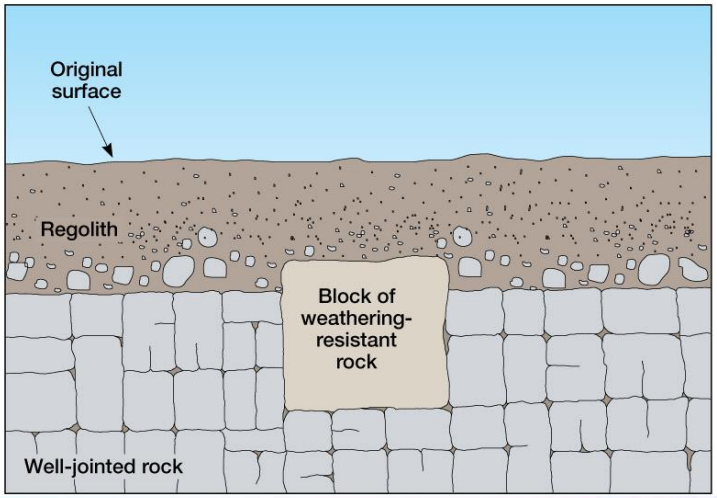
- **Fluvial Erosion in Arid Lands**
  - Differential Erosion (common in sedimentary layers)
    - Differential hardness of rock layers

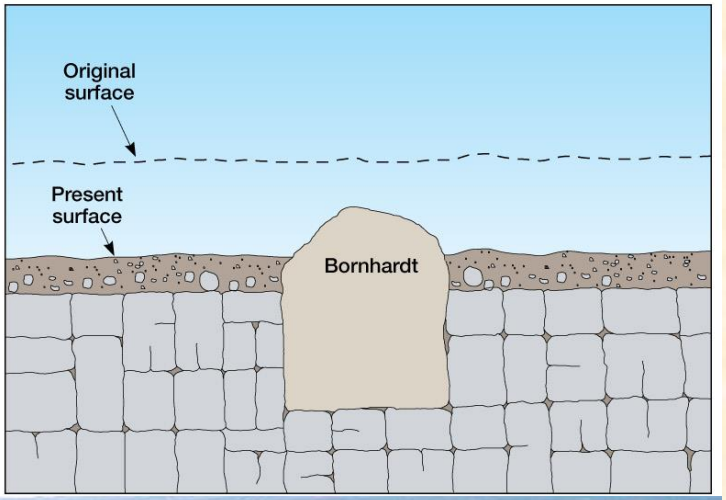


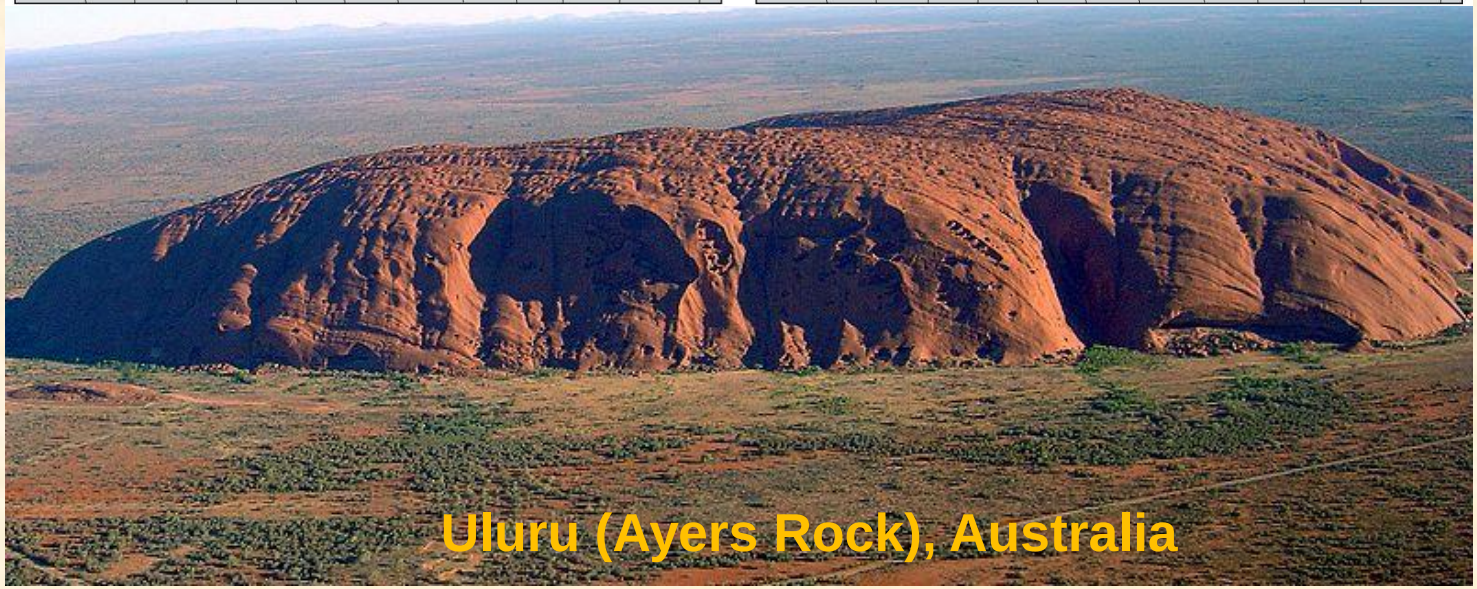
Red Cliffs near Gateway in Western Colorado.

Residual Erosional Surfaces

- **Inselbergs** (“island mountains”)
  - **Bornhardts** (resistant rocks that are round).

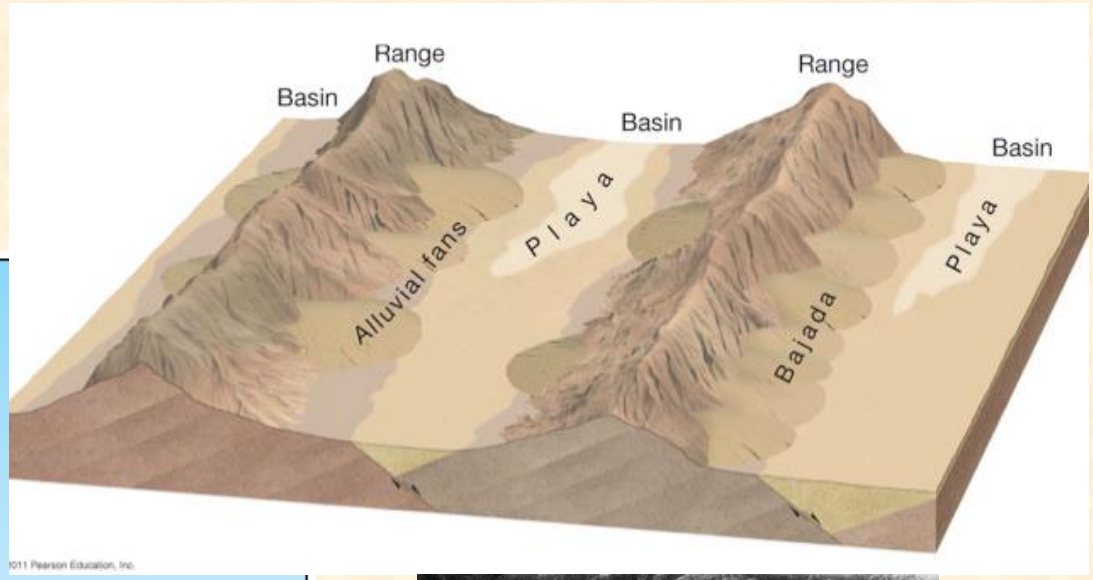


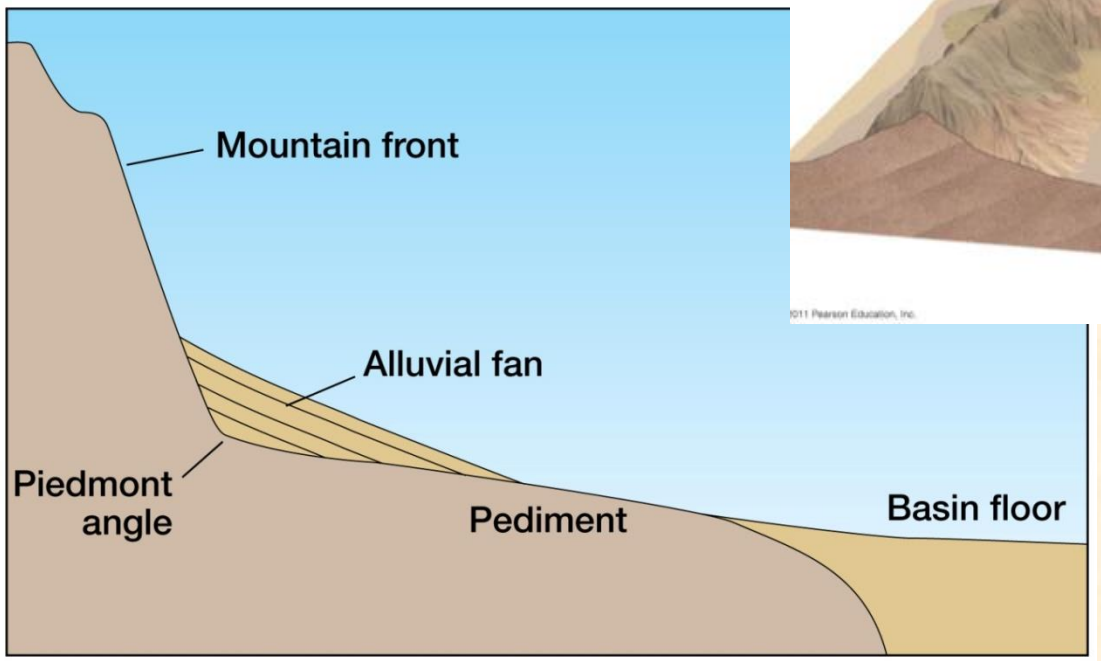




Uluru (Ayers Rock), Australia

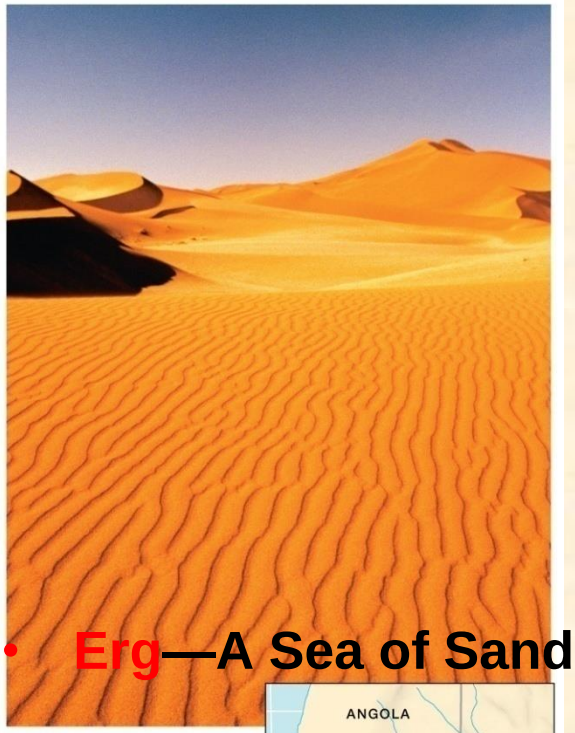
- **Fluvial Deposition in Arid Lands**
  - These depositional features are more obvious than erosional features, and they occur in ephemeral stream channels
  - **Piedmont zone**. This is any zone at the foot of a mountain range where you find:
    - **Talus accumulations and alluvial fans**

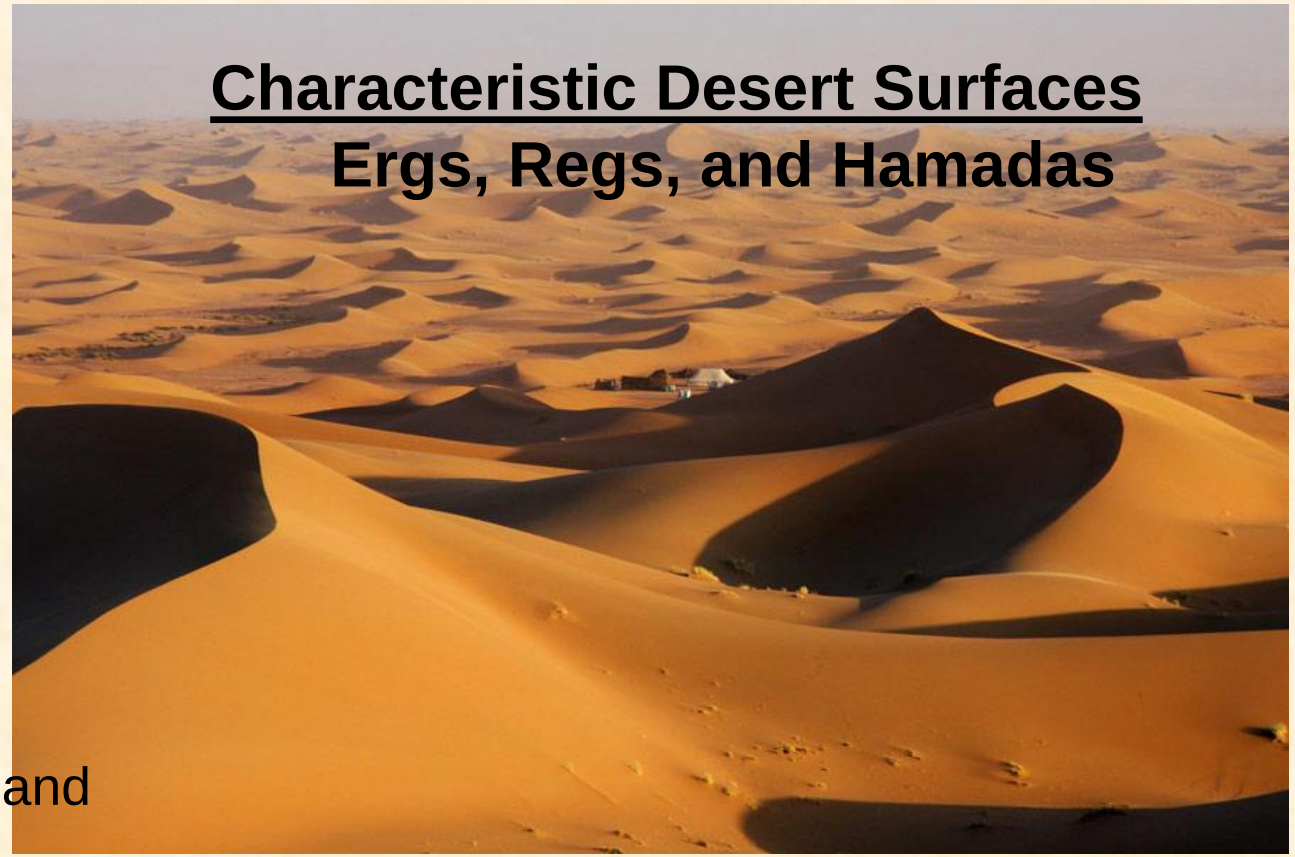




Characteristic Desert Surfaces

Ergs, Regs, and Hamadas





- **Erg—A Sea of Sand**
  - 'Erg' – Arabic for sand
  - Found in the deserts of Arabia, the Sahara and Namibia.

  - The Arabian desert is the sandiest of all deserts; and even then, only a *third* of it is covered in sand. Moreover, most of that sand is not 'true erg'.
  - "Relict ergs" (covered with vegetation) are found in Western Nebraska. The "Sand Hills" on Hwy 2.

- **Reg—Stony Desert**

  'Reg' – Arabic for "stone"

  – Desert pavement

  – Called 'gibber plains' in Australia

- **Hamada—Barren Bedrock**

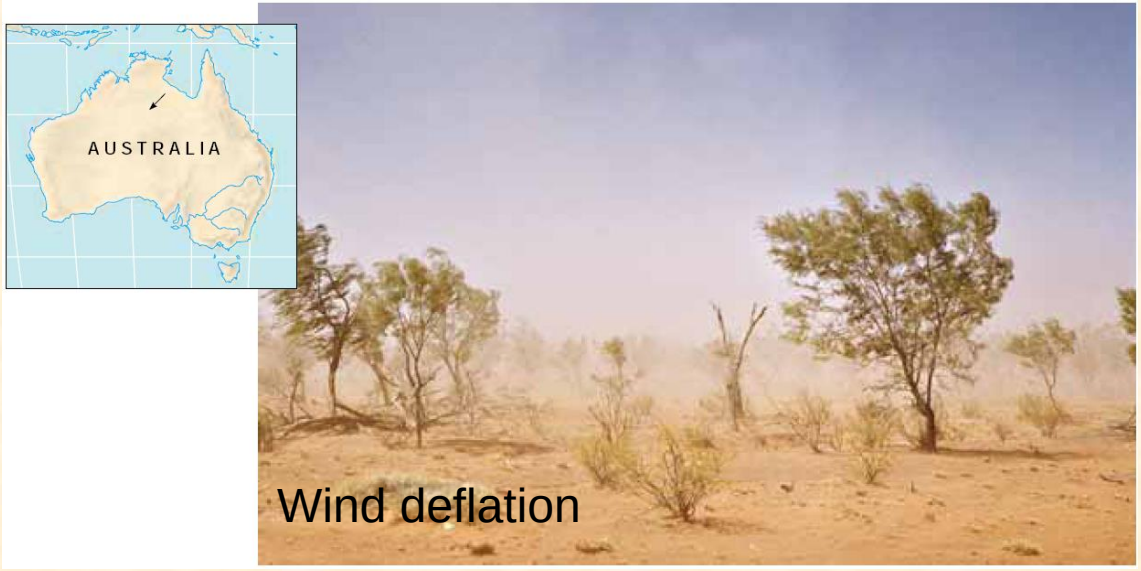
  'Hamada' – Arabic for "rock"

  – Comprises of exposed bedrock or cemented sedimentary material

Aeolian Processes

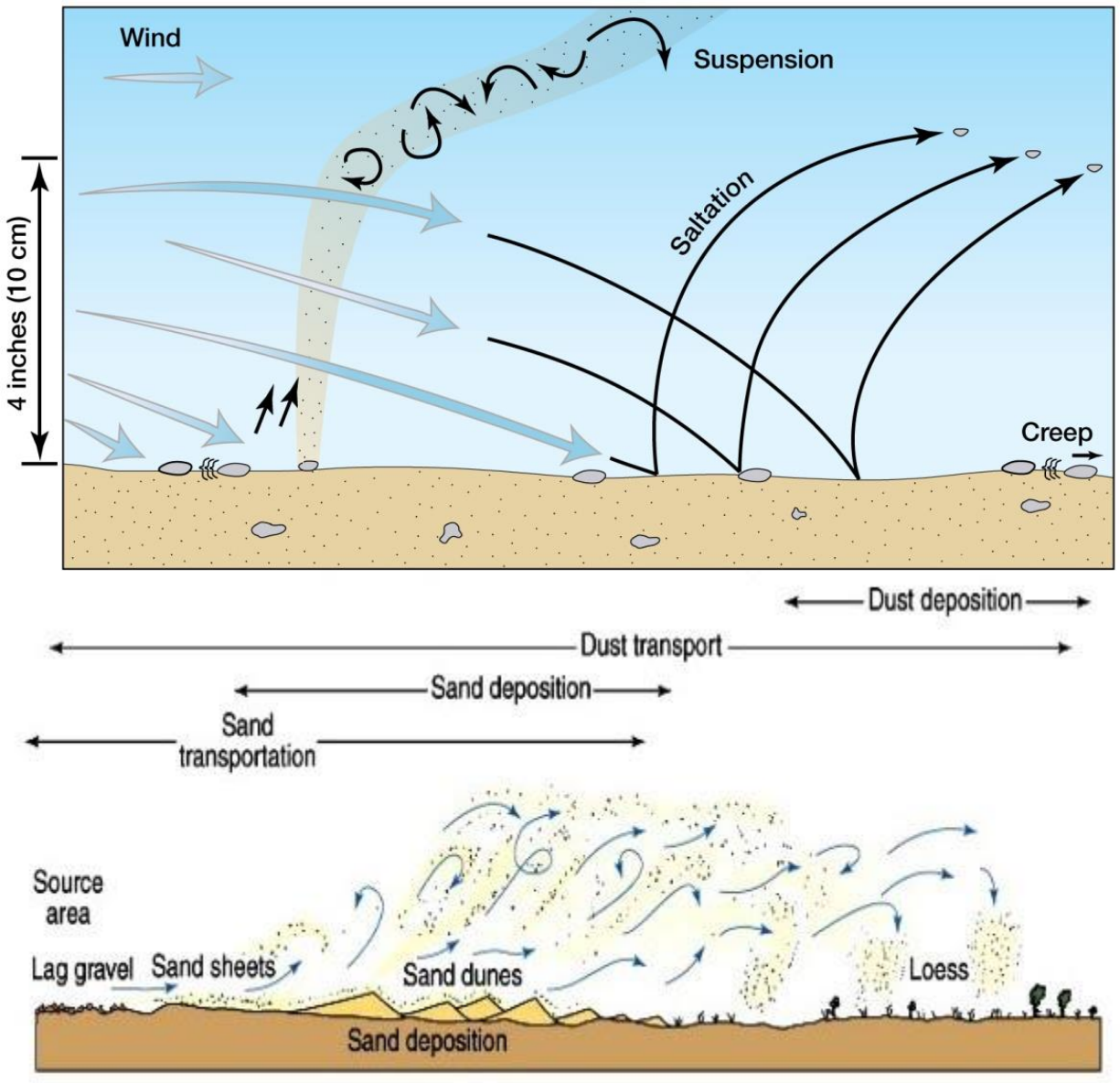
- Wind Erosion
  - **Abrasion** – wearing away of rock by airborne sand and dust particles
  - **Deflation** – shifting of loose particles

Sand-blasted rock, or **ventifact**



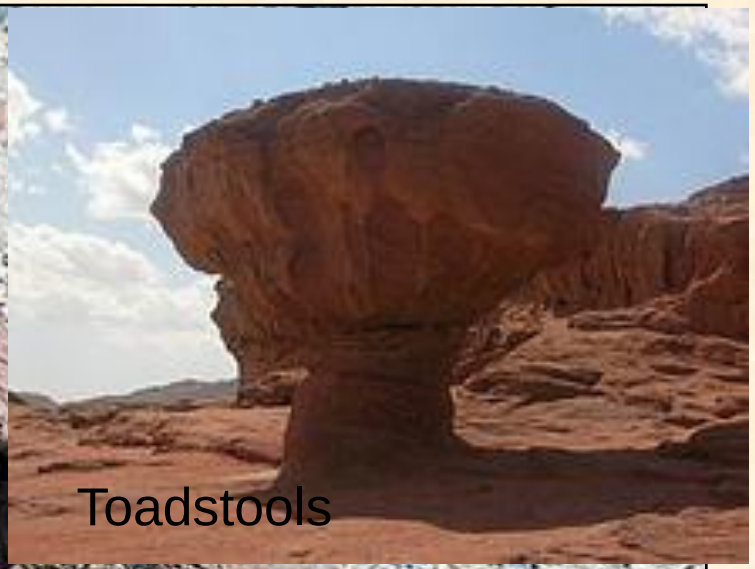
Wind deflation

- **Aeolian Transportation**
  - Suspension, saltation, traction and creep (bed load).

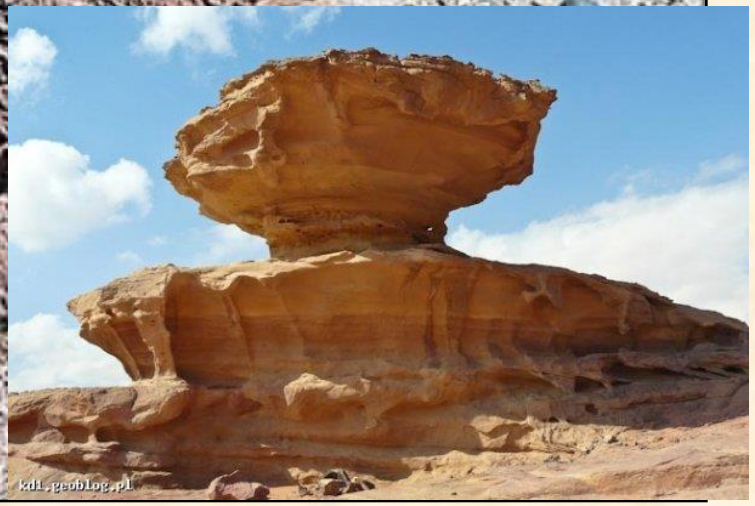


Erosional Landforms - Ventifacts

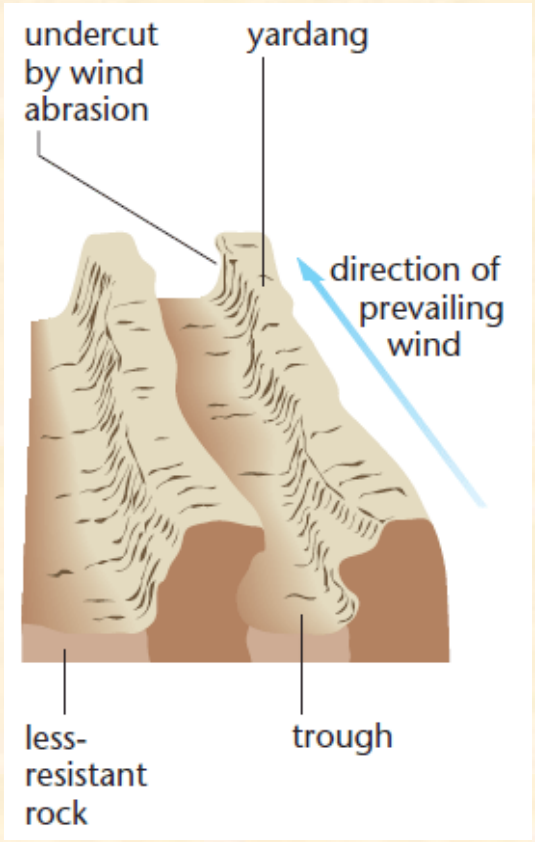
Wind eroded (sand blasted) surfaces

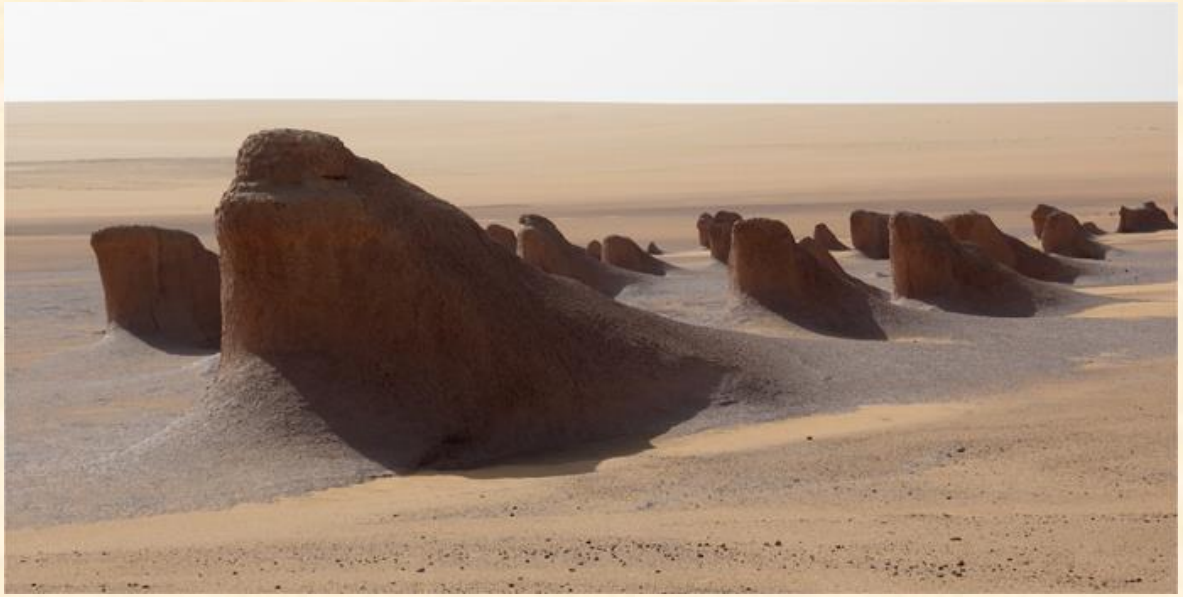


Toadstools



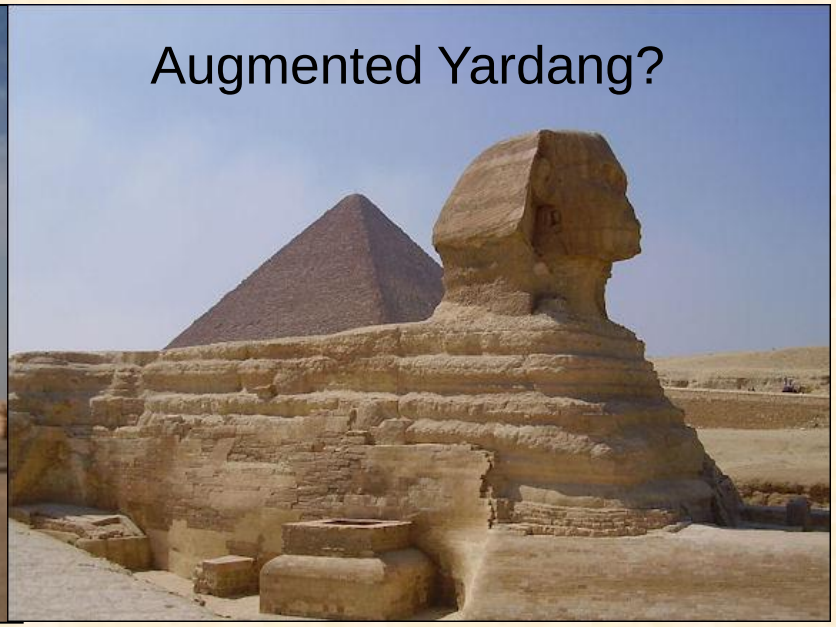
Erosional Landform - Yardangs





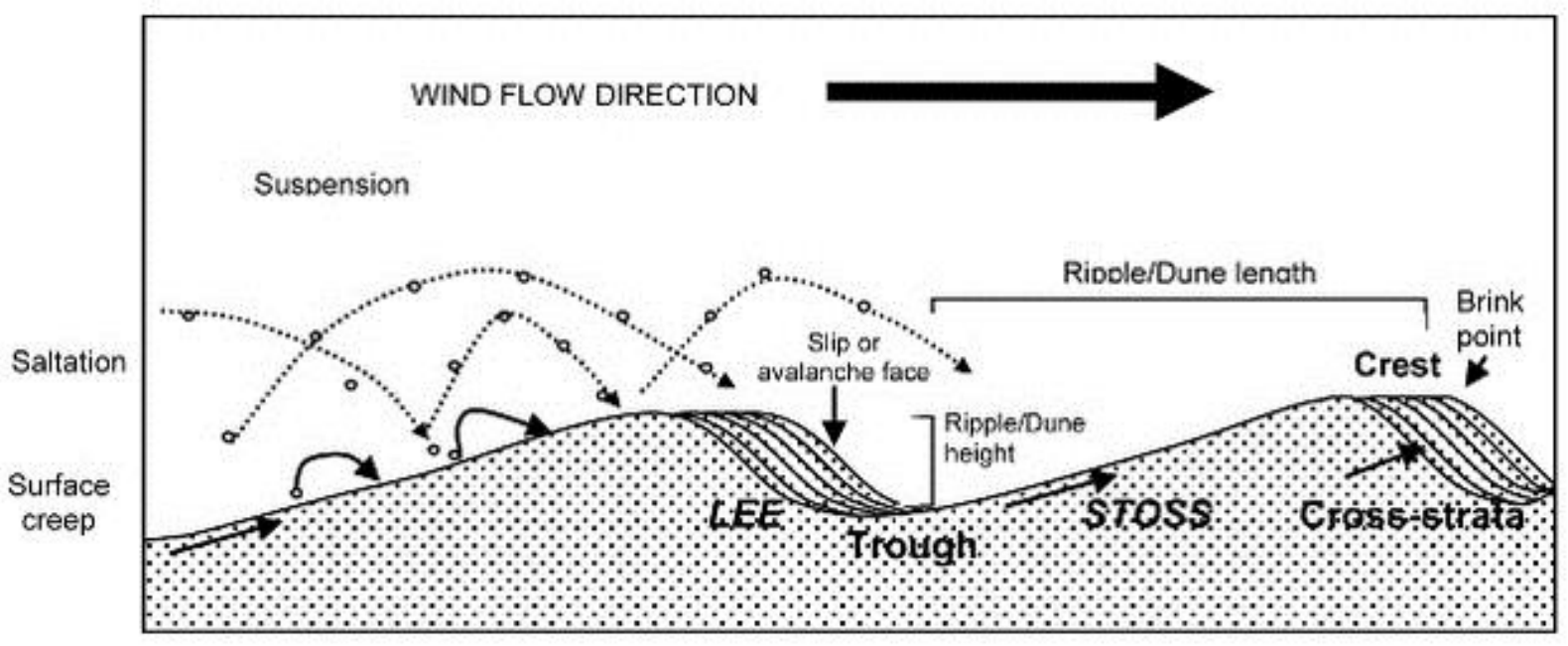
Yardang

- Elongate ridge or remnant rock feature sculpted by abrasive wind erosion.
- Strong, steady, prevailing winds come from a single direction.
- Mega-yardangs, several kilometers wide and hundreds of meters high,
- Meso-yardangs are only a few meters high and 10-15 meters long
- Micro-yardangs may only be a few centimeters in size.

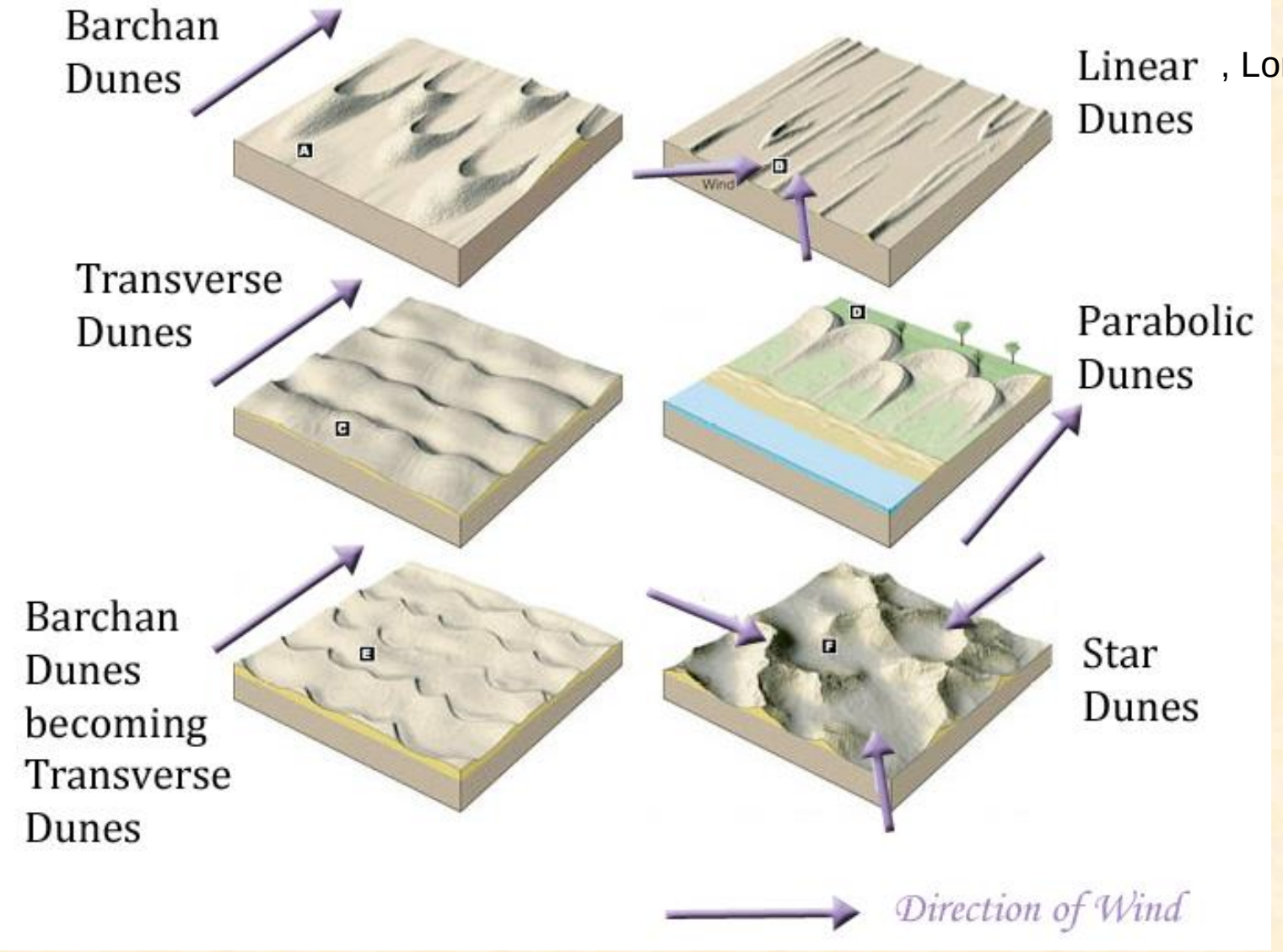


- **Aeolian Deposition and Landforms**

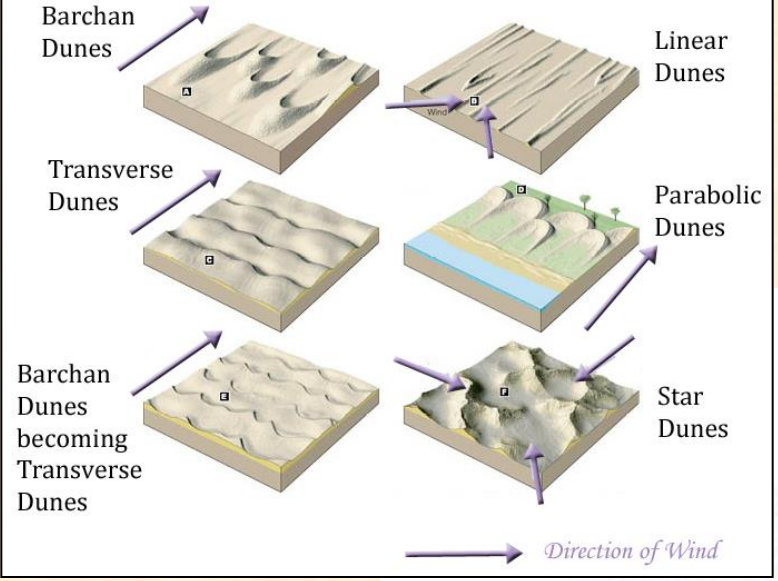
  - Desert Sand Dunes
    - Accumulations (hills) of loose wind-born sand
    - Vegetation and Dune Stabilization
    - Dune migration
    - Size, shape, and orientation of dunes are determined by available sand, vegetation and wind



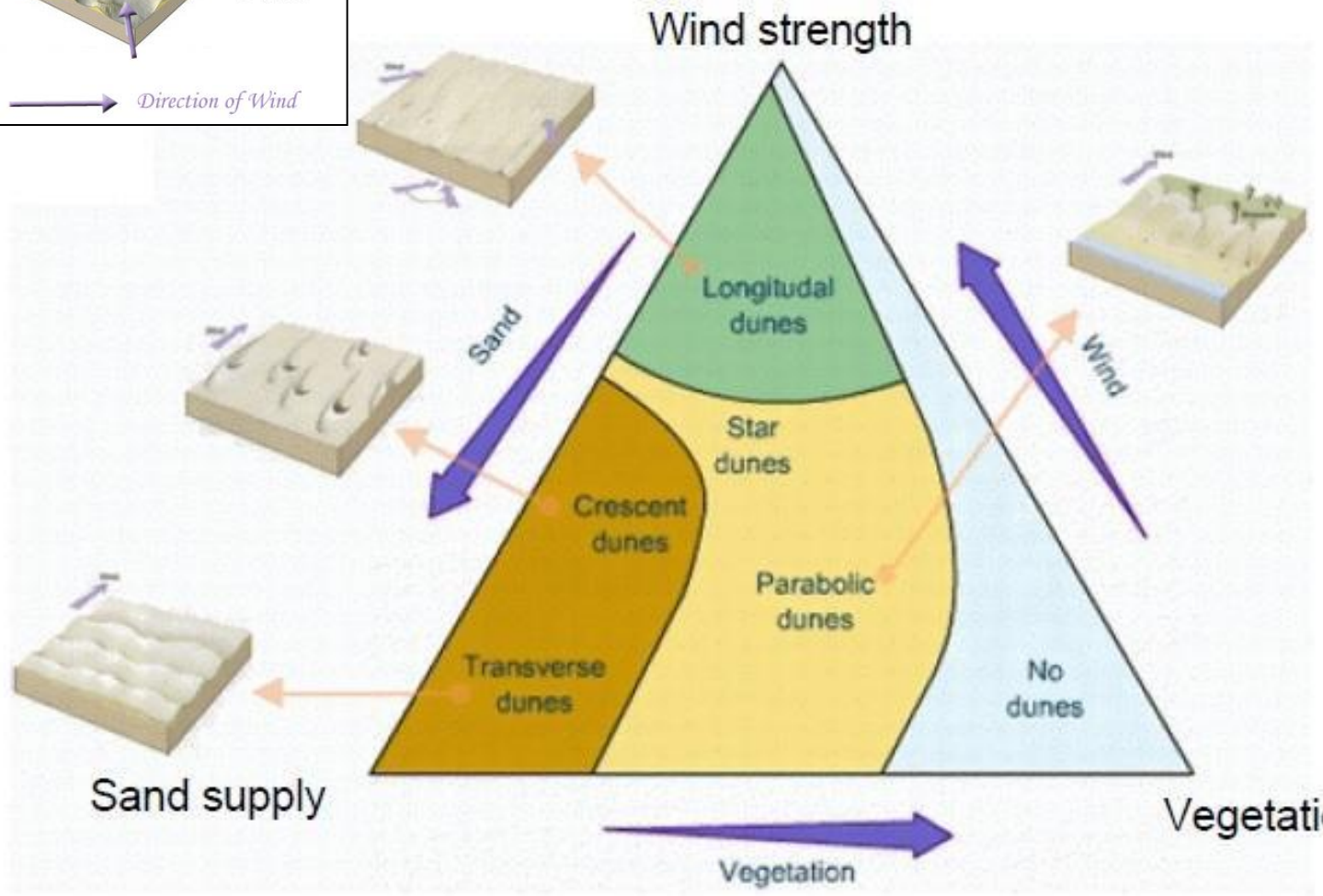
– Types of Sand Dunes



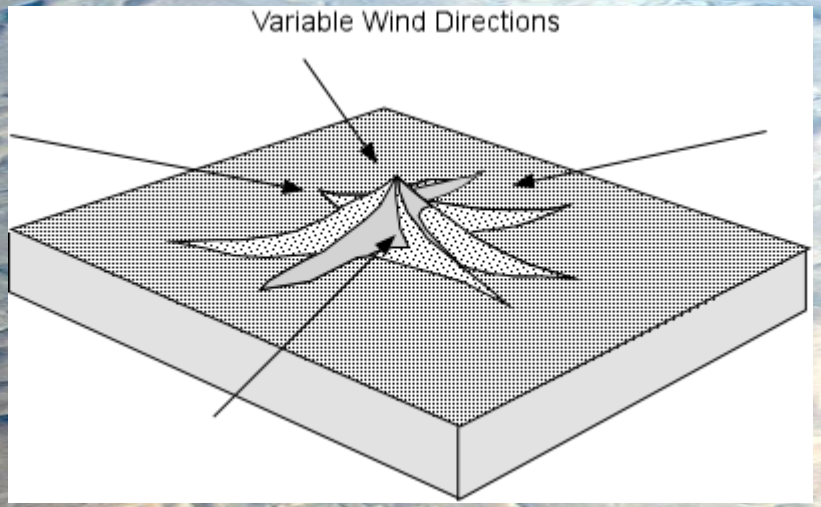
, Longitudinal, Seif

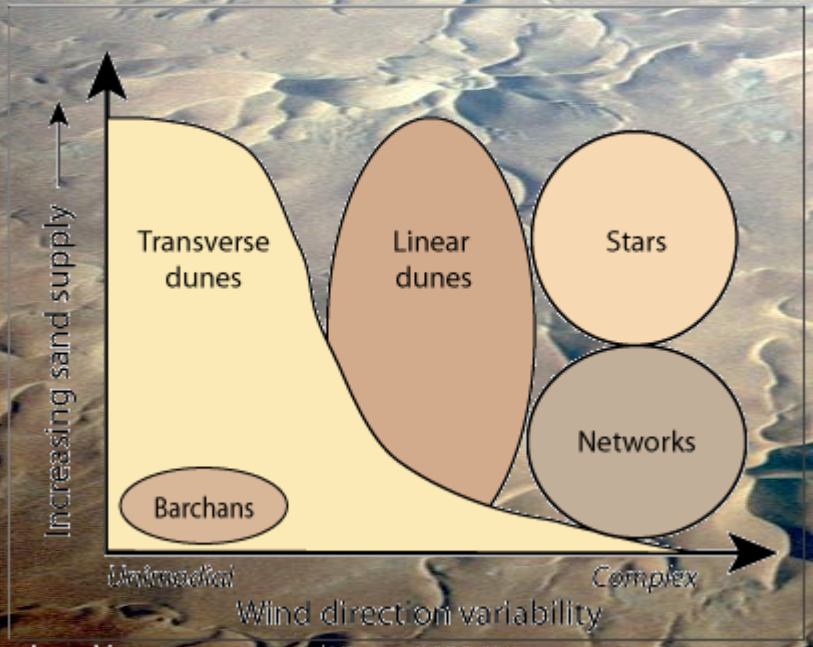

Barchan Dunes
Linear Dunes
Transverse Dunes
Parabolic Dunes
Barchan Dunes becoming Transverse Dunes
Star Dunes
Direction of Wind

Dune forms


Wind strength
Longitudal dunes
Star dunes
Crescent dunes
Parabolic dunes
Transverse dunes
No dunes
Sand
Wind
Sand supply
Vegetation
Vegetation

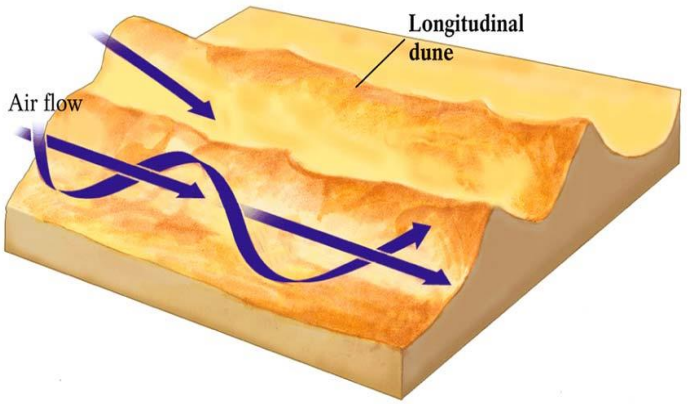
Star Dunes



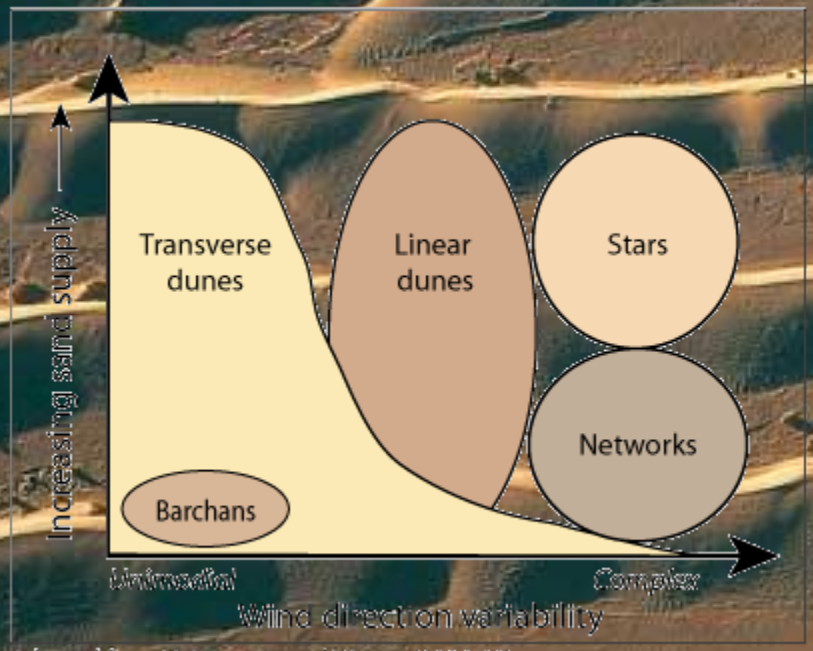


Adapted from Livingstone and Warren (1996, 80)

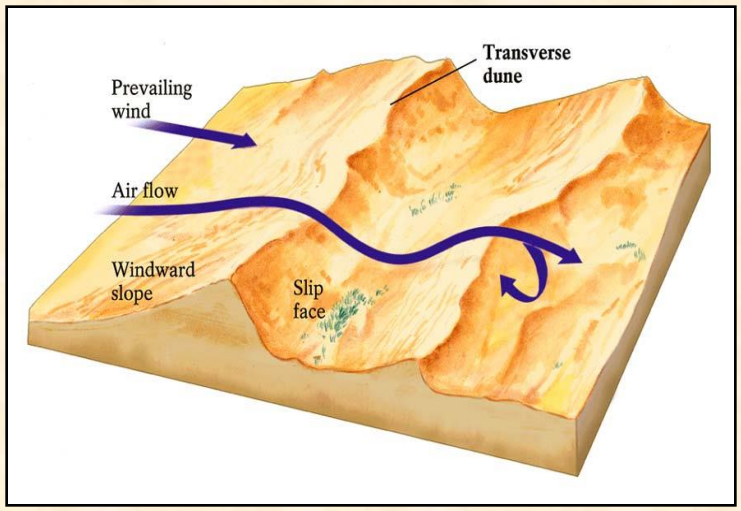
Longitudinal, Sief Dunes



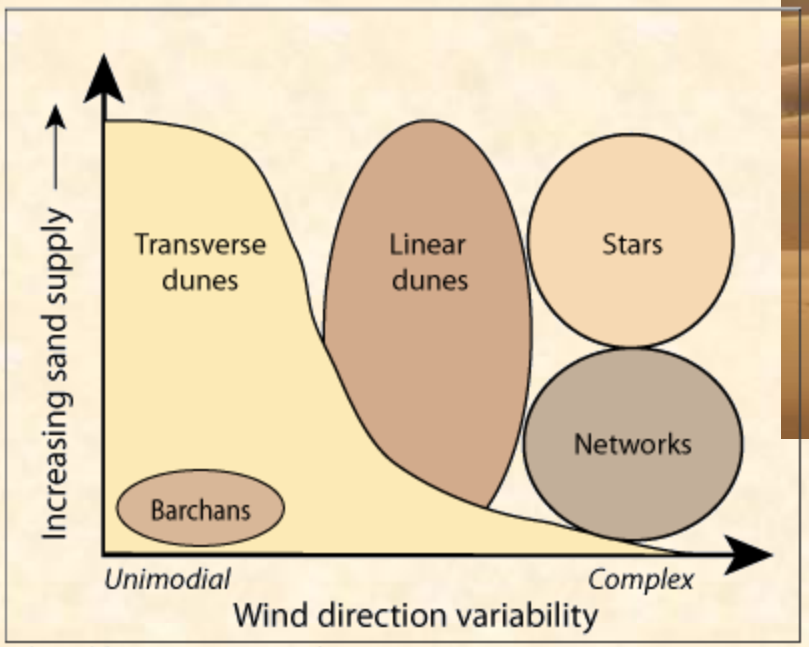
Constant wind direction
No vegetation



Transverse Dunes

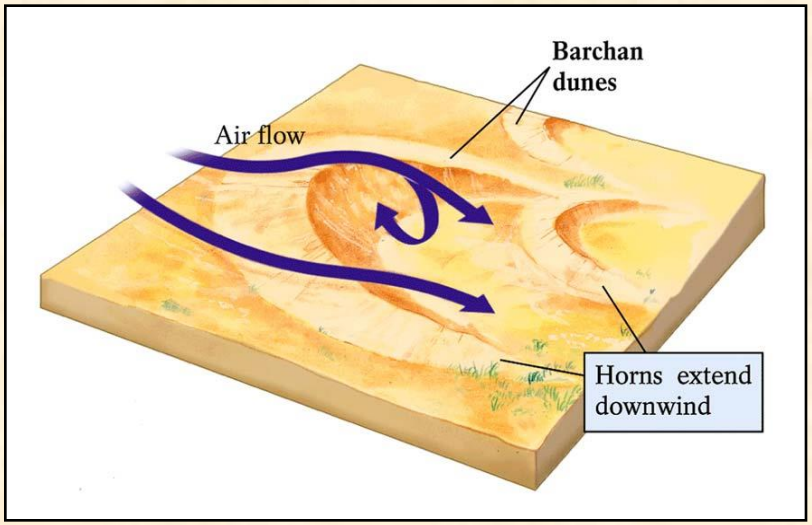


- Massive volumes of sand
- Low consistent winds

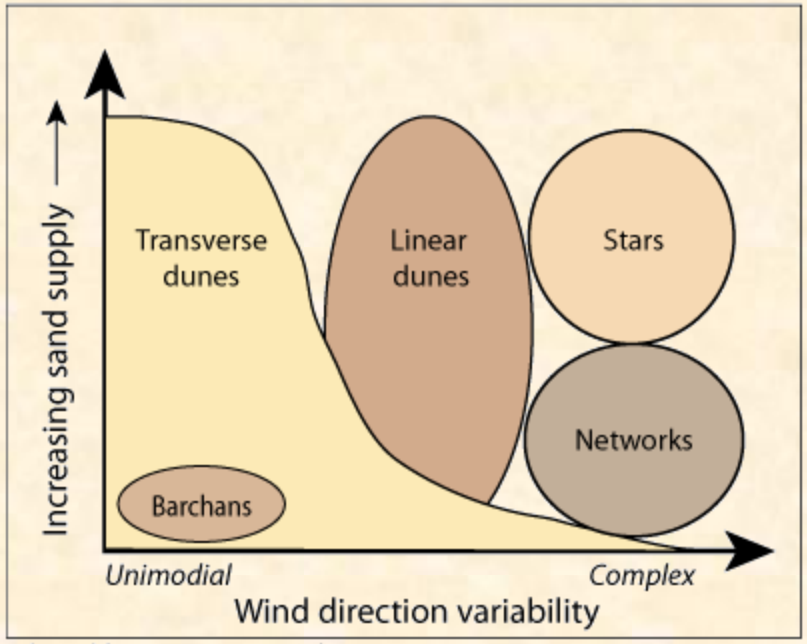


Adapted from Livingstone and Warren (1996, 80)

Barchan Dunes



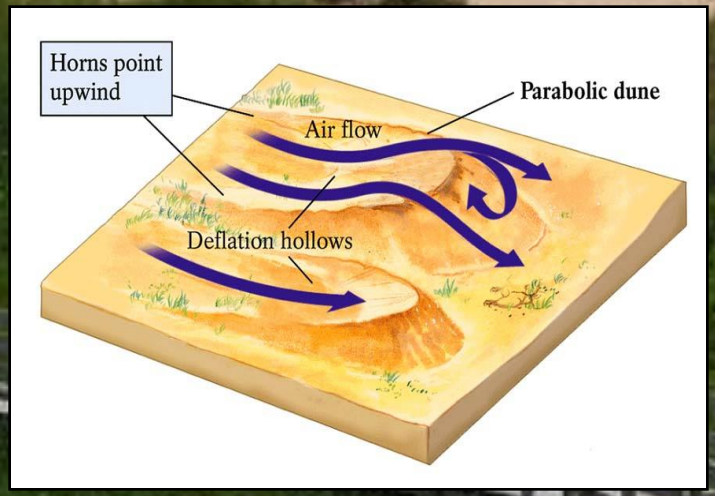
- Isolated Dunes
- Low sand supply
- Migrating across rock



Adapted from Livingstone and Warren (1996, 80)

Parabolic Dunes

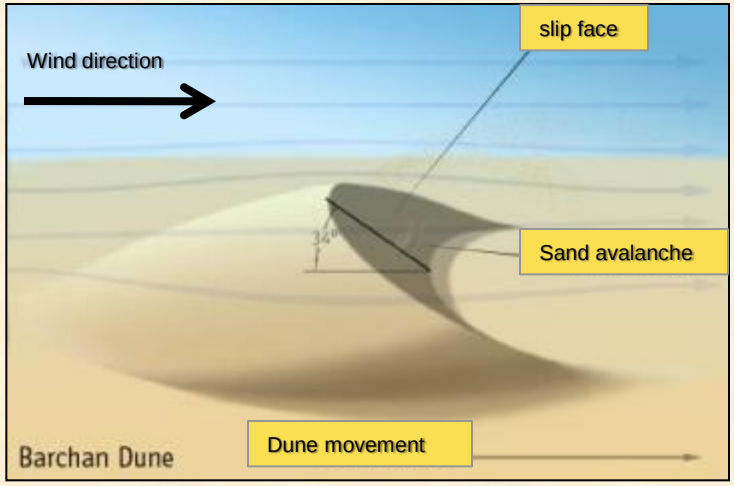
- Stabilized “horns" point upwind



Dunes

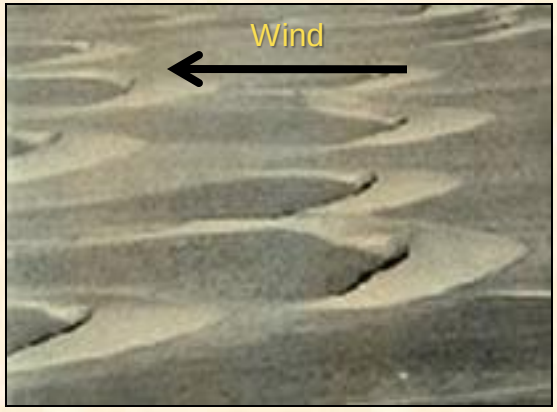
- **Barchan dunes** are solitary, crescent shaped dunes with their tips pointing downwind. They form where sand source is limited, wind direction is constant, and the ground is void of vegetation. They can reach heights of **30 meters** and spread nearly **300 meters**.

- **Transverse dunes** are a series of long ridges that are parallel to one another, and are perpendicular to the prevailing wind. They form in areas where the prevailing winds are steady, there is an abundant supply of sand, and vegetation is sparse. They can reach heights of **200 meters** and may extend for **100's of kilometers**.



http://www.nps.gov/archive/grsa/resources/images/lgformat/barchan.jpg

Barchan Dunes



John McCauley, USGS

Transverse Dunes

John McCauley, USGS

Dunes

- Longitudinal dunes, Seifs are long ridges of sand that form parallel to the prevailing wind, moderate supply of sand, range in size **5-10 meters** tall to **100 meters** in height and width.

- Star dunes are complex dunes with a central mound surrounded by radiating points. Star dunes can reach heights of **90 meters** and extend outward for over twice their height.

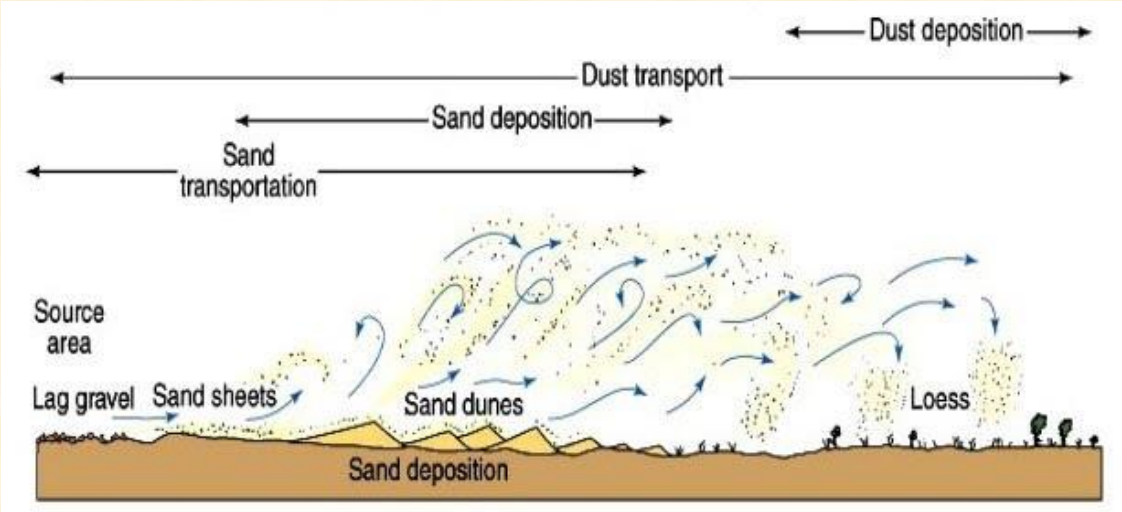
- Parabolic dunes form as blow outs where the sand has carved out the sediments and deposited it onto the leeward side. Form inland from coastal shorelines from sands on the beach.

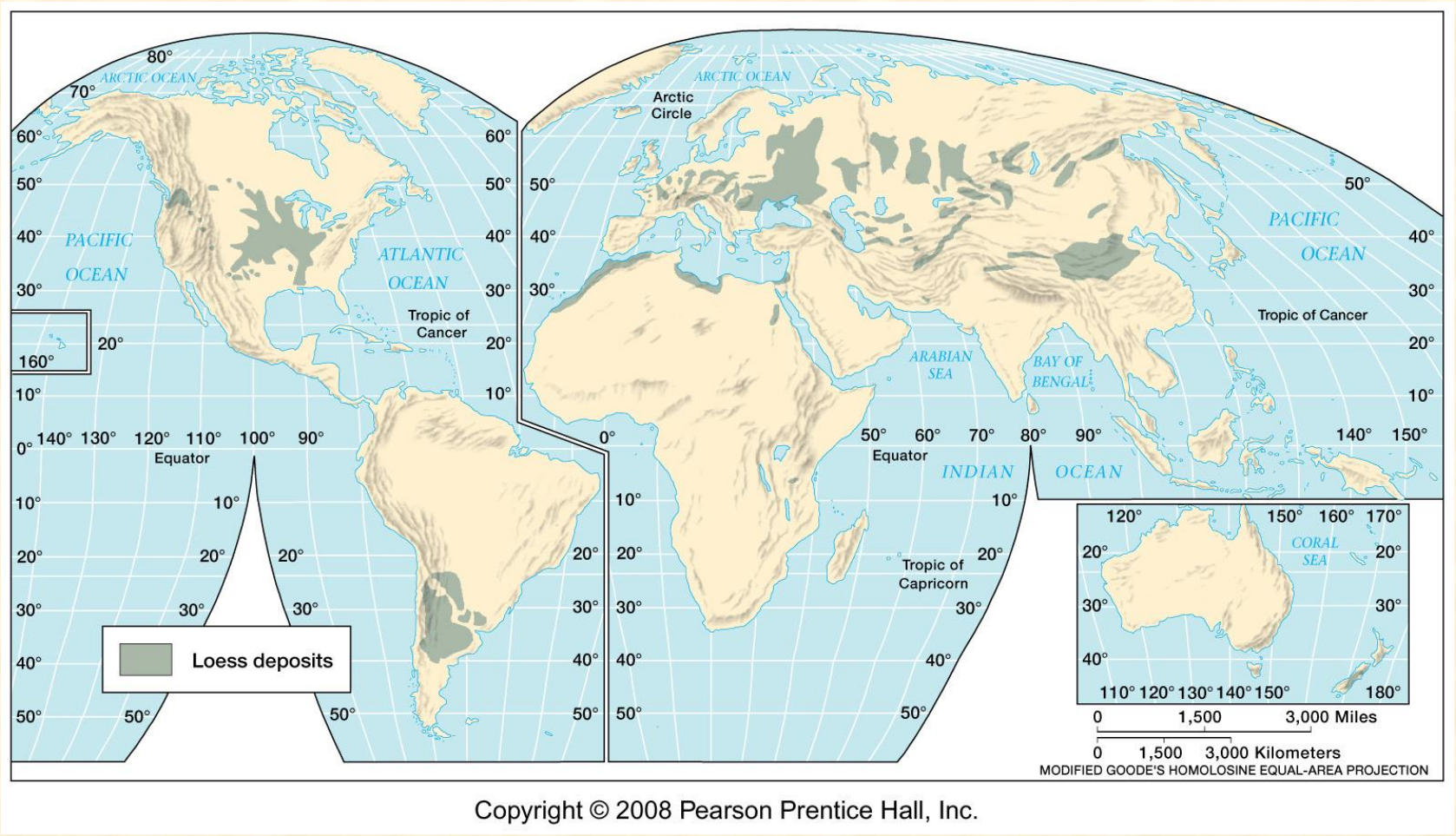
http://en.wikipedia.org/wiki/Image:Dune_7_in_the_Namib_Desert.jpeg

Photo: www.googleearth.com Eve, Montana

Loess

- Loess deposits are regionally extensive accumulations of windblown silt resulting from thousands of dust storms.
- Loess deposits are generally coarsest and thickest close to their source, and they decrease in thickness and grain size with increasing distance from their source.
- Loess is not stratified, and deposits range from 30 to >100 meters thick.





- The most extensive loess deposit occurs in western and northern China, sediments were blown from the **deserts of Central Asia**.

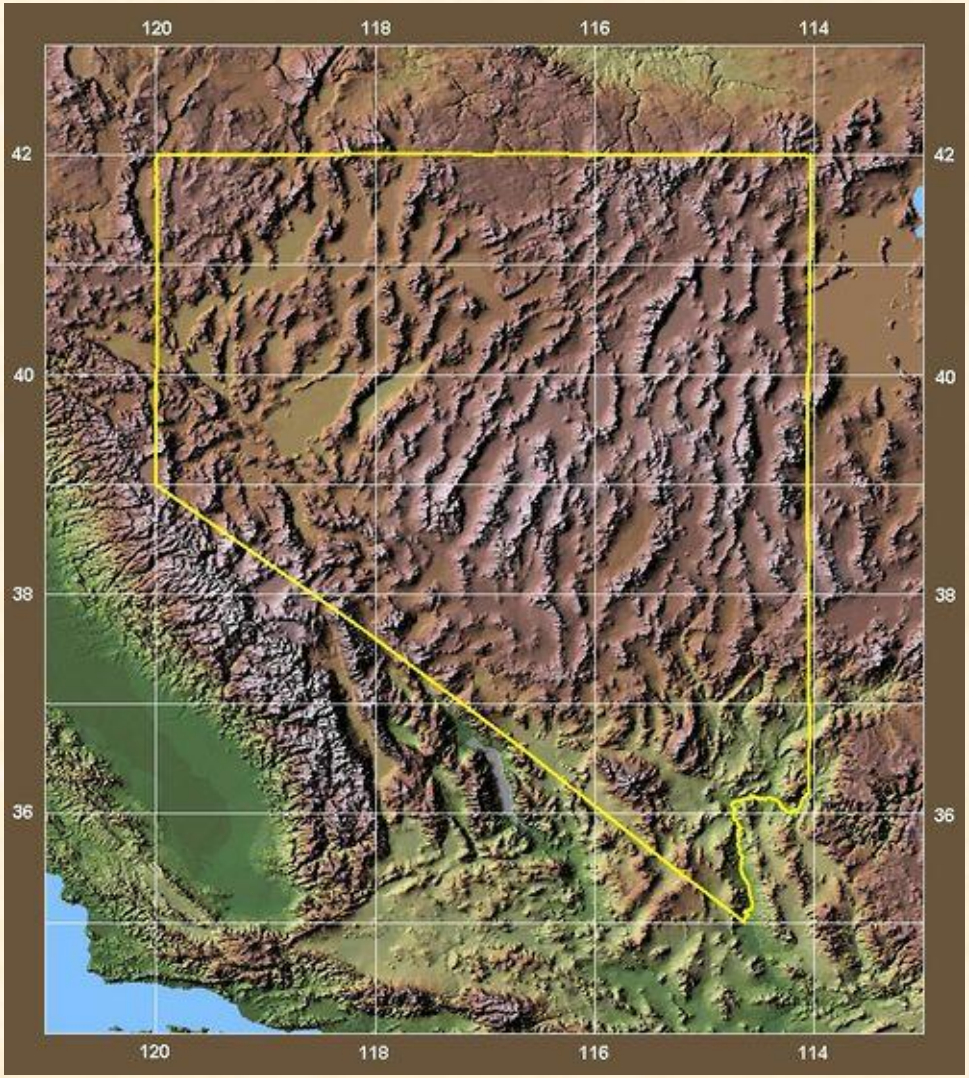
- US loess deposits occur in South Dakota, North Dakota, Nebraska, Iowa, Missouri, **Mississippi**, and Illinois. Deposits were sourced from glacial sediments.

Two Characteristic Desert Landform Assemblages in U.S. Deserts

- **Basin-and-Range Terrain**
  - Horst – Graben
  - Half Graben
  - Block faulting
  - Rain Shadow system lee of the Siera-Nevadas

- **Mesa-and-Scarp Terrain**
  - Horizontal sedimentary strata
  - Differential weathering

Horst and Graben: Basin and Range

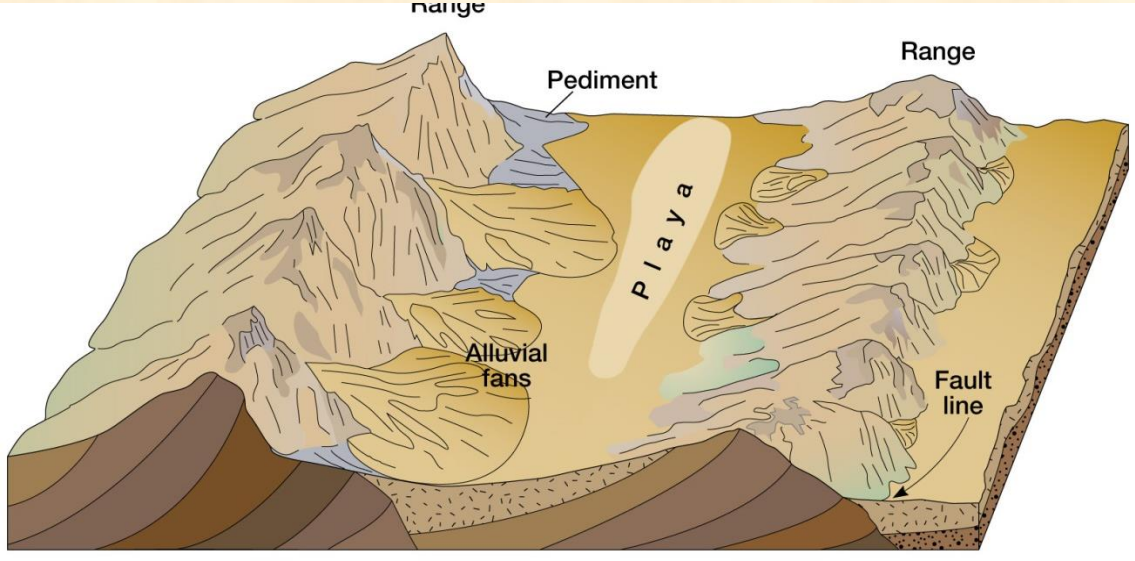


- Some horsts may tilt slightly producing asymmetric, tilted terrane or mountain ranges.

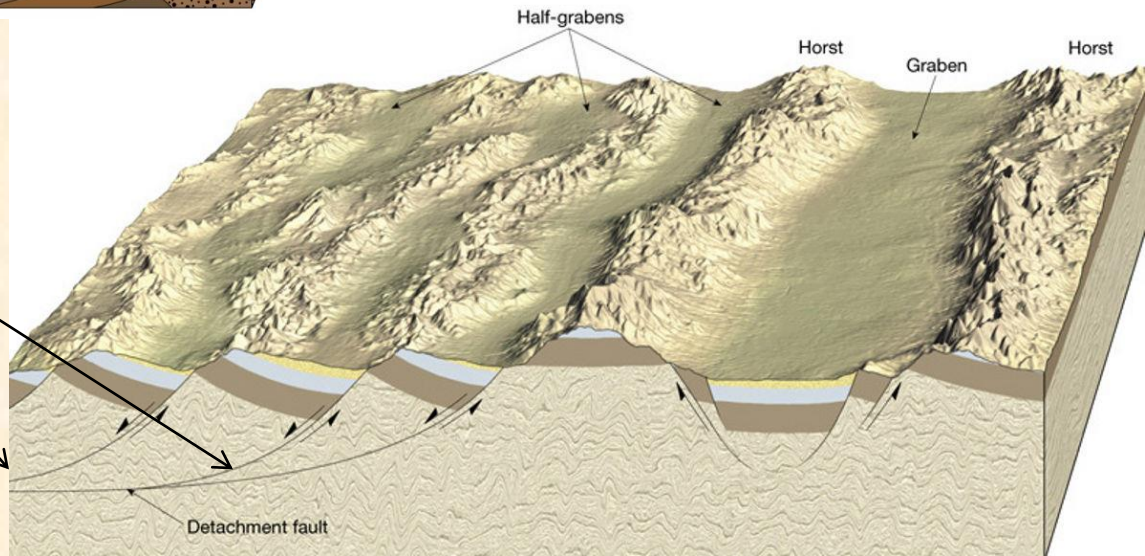
- In the Western United States, horst and graben fault sequences are described as "**Basin and Range**" topography.

Basin and Range topography, Nevada.

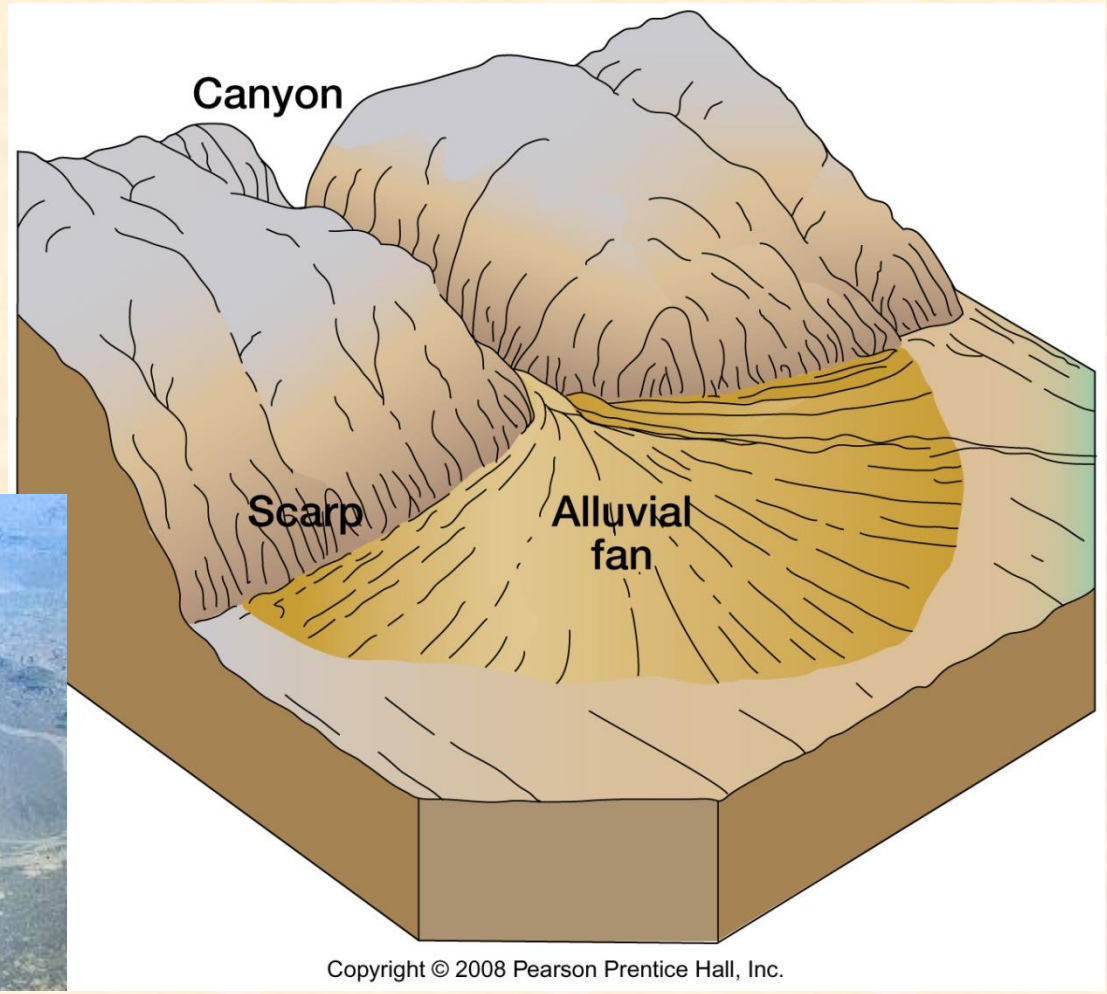
- **Basin-and-Range Terrain**
  - Ranges: long, narrow and parallel
    - gullies, wine-glass canyons, ephemeral streams



Fault Slices

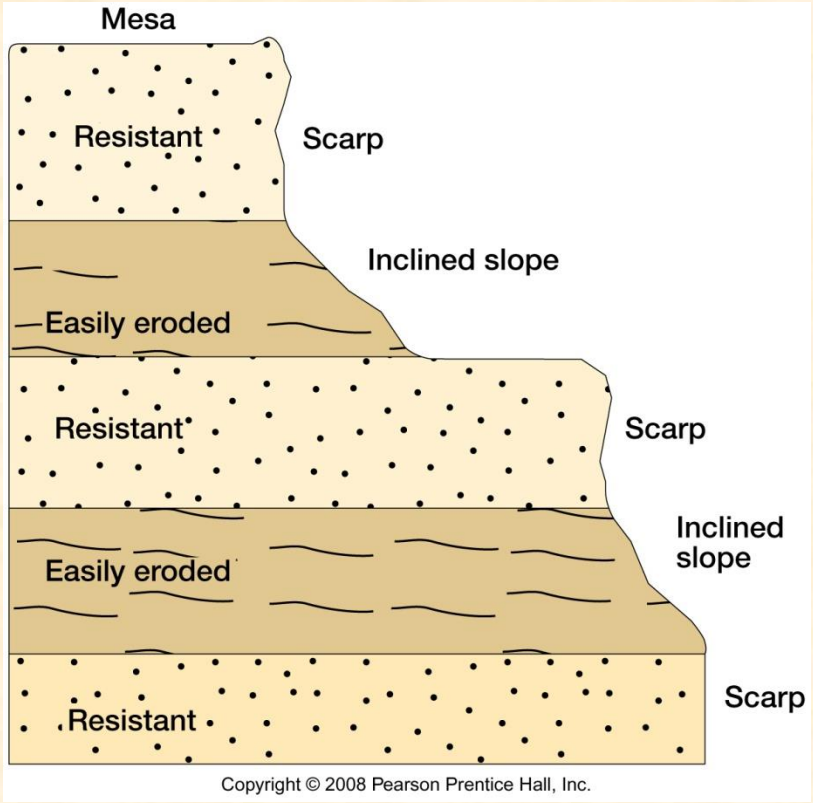


- **Basin-and-Range Terrain**
  - Piedmont Zone: region where the range intersect with the basin, characterized by fluvial deposition
    - Alluvial fans
    - Bajadas



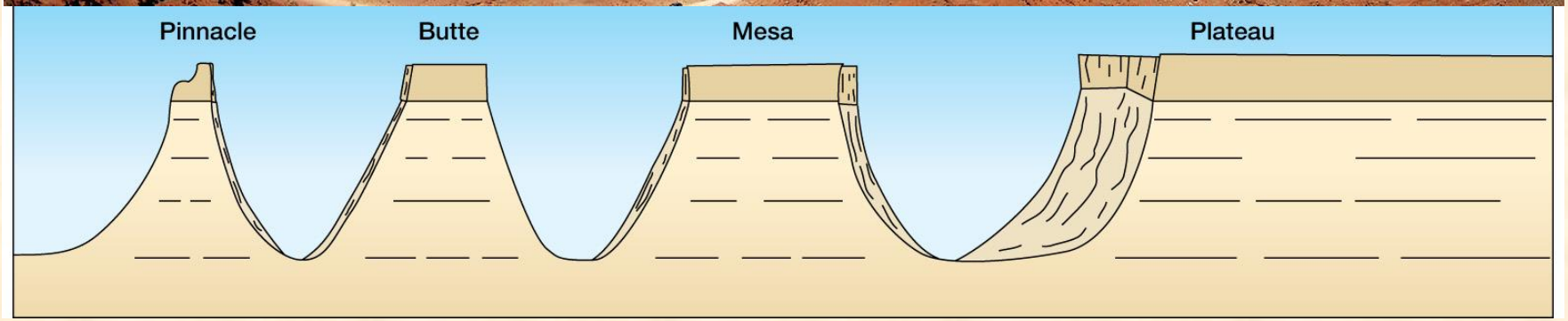
- **Basin-and-Range Terrain**
  - Basin: broad, flat internal region between ranges
    - Interior drainage, no connection to the sea
    - Playas (dry lake beds), ephemeral, order days
    - Salina: playas with high salt content
    - Salt pans, salt flats

- **Mesa-and-Scarp Terrain**
  - Sedimentary strata
  - ‘Mesa’ broad, flat region
  - Slopes have multiple scarps.
  - ‘Scarp’: escarpment
  - Differential weathering
    - resistant rocks = ‘scarps’
    - softer rock gentler slopes



– Residual landforms

- Flat-topped summits in horizontal sedimentary strata
- Hard cap rock; if they are bounded on one or more sides by a prominent escarpment, they're called **plateaus**.
- Plateaus are "tablelands" (bigger than **Mesas**)
- **Buttes** are just eroded remnants of mesas
- **Pinnacles** are the smallest remnants



– Residual landforms

Arches and Natural Bridges

- weathering
- fluvial erosion

Arches

http://www.nps.gov/arch/photosmultimedia/index.htm