Chapter 13

Deserts

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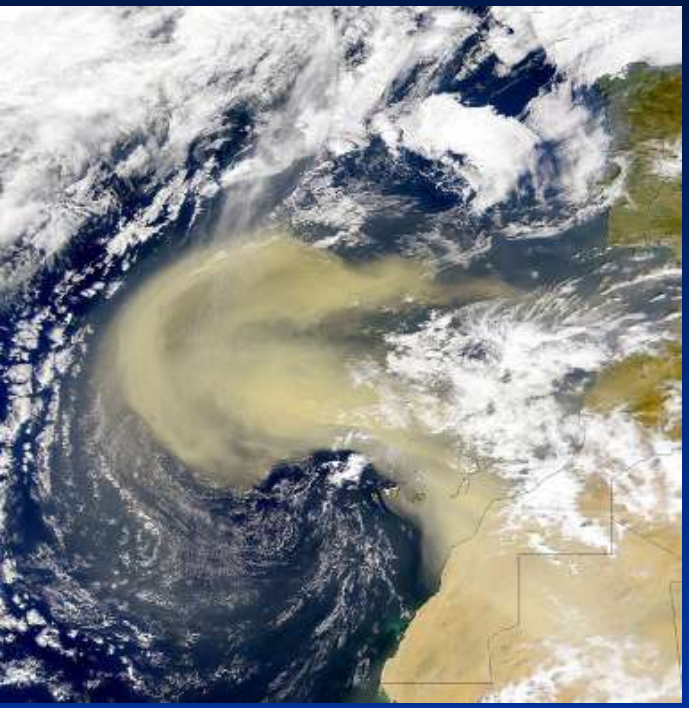
Desert

- Region with low precipitation
  - Usually less than 25 cm of rain per year
- Distribution
  - most related to descending air
  - Belts at 30 degrees North & South latitude
  - Rain shadow of mountains
  - Great distance from oceans
  - Tropical coasts next to cold ocean currents
  - Polar deserts

Dust Storms and Whirlwinds



Sand and dust storm originating from North Africa

Dust storm in Southwest U.S.

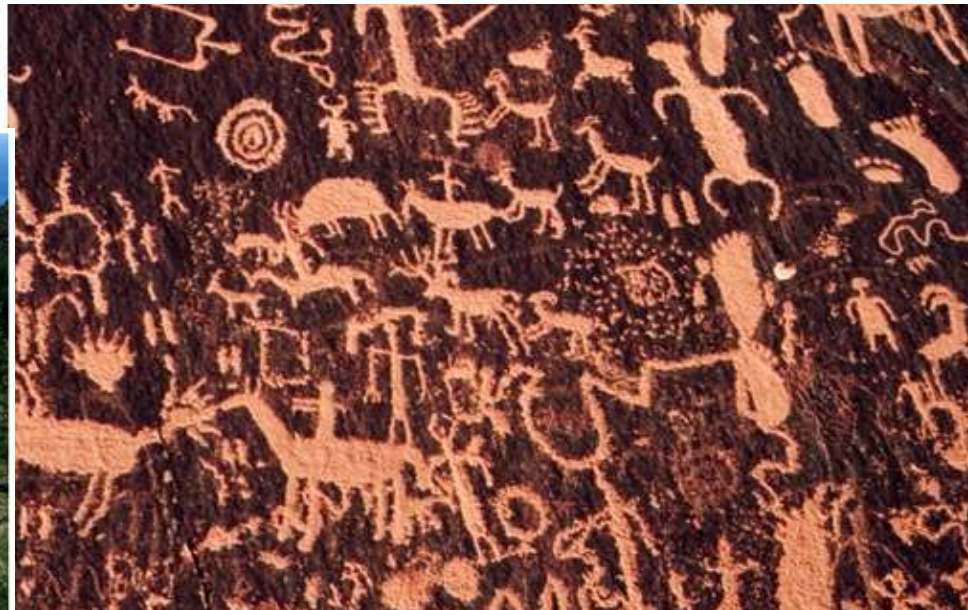
Whirlwind in Peru

Deserts

- A *desert* is any region with an arid climate that receives less than 25 cm of precipitation per year
- In spite of low rainfall, *running water* is the predominant force shaping most desert landscapes
  - Rare and often violent *flash flood* events produce most of the water erosion in deserts

Desert weathering

- Chemical (oxidation)
  - Fe, Mn oxides
- Mechanical
  - thermally induced
  - mass wasting
  - intermittent water transport



Characteristics of Deserts

- Streambeds flow *intermittently*, typically during/after heavy rains
  - Most of the time, desert streambeds are dry
  - Most deserts lack *through-flowing streams*
  - Many desert regions have *internal drainage*, such that streams drain into landlocked basins that slowly fill with sediments

Characteristics of Deserts

- Streambeds flow *intermittently*, typically during/after heavy rains
  - Most rain in desert regions comes from occasional, often violent, thunderstorms, producing *flash floods*
- Desert *washes* or *arroyos* are commonly steep-sided, with flat floors covered by loose sediments - a result of rare but highly erosive flash flood events

Some characteristics of deserts

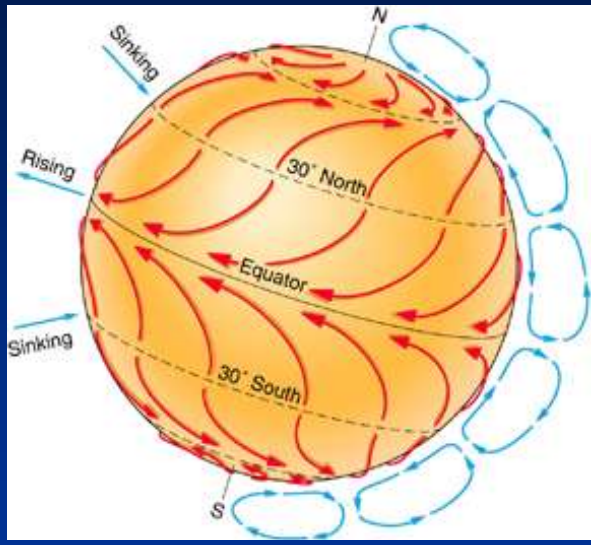
- Stream channels normally dry
  - covered with sand & gravel
  - Narrow canyons with vertical walls
- Resistance of rocks to weathering
  - Desert topography typically steep and angular

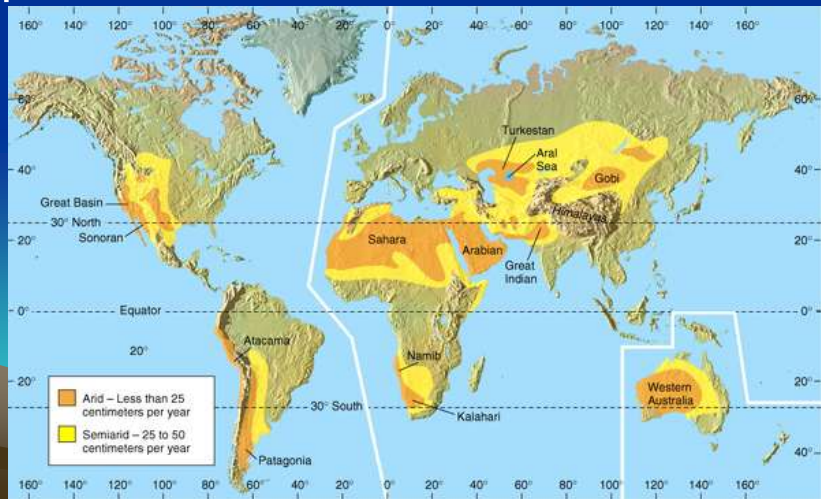
Some characteristics of deserts

- Lack of through-flowing streams
- Internal drainage
- Local base levels
- Desert thunderstorms
  - Flash floods
    - Mudflows

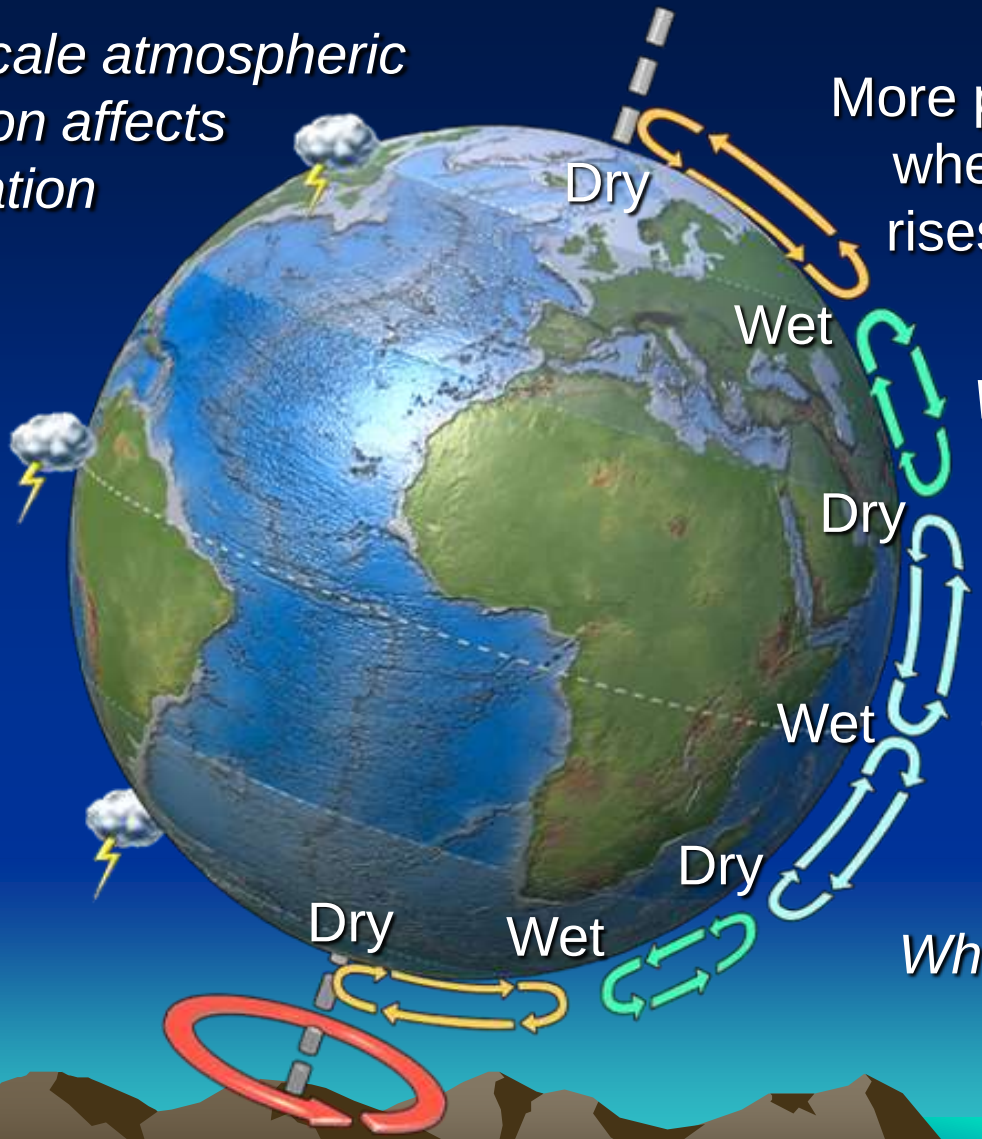
Distribution of Deserts

- Deserts can be found anywhere that the atmosphere (air) is usually *dry*
- Most deserts are associated with areas where *air is descending*
  - On a global scale, hot, moist air rises in the tropics, rains out most of its moisture, and descends back to Earth near 30° north and south latitude





Large-scale atmospheric circulation affects precipitation



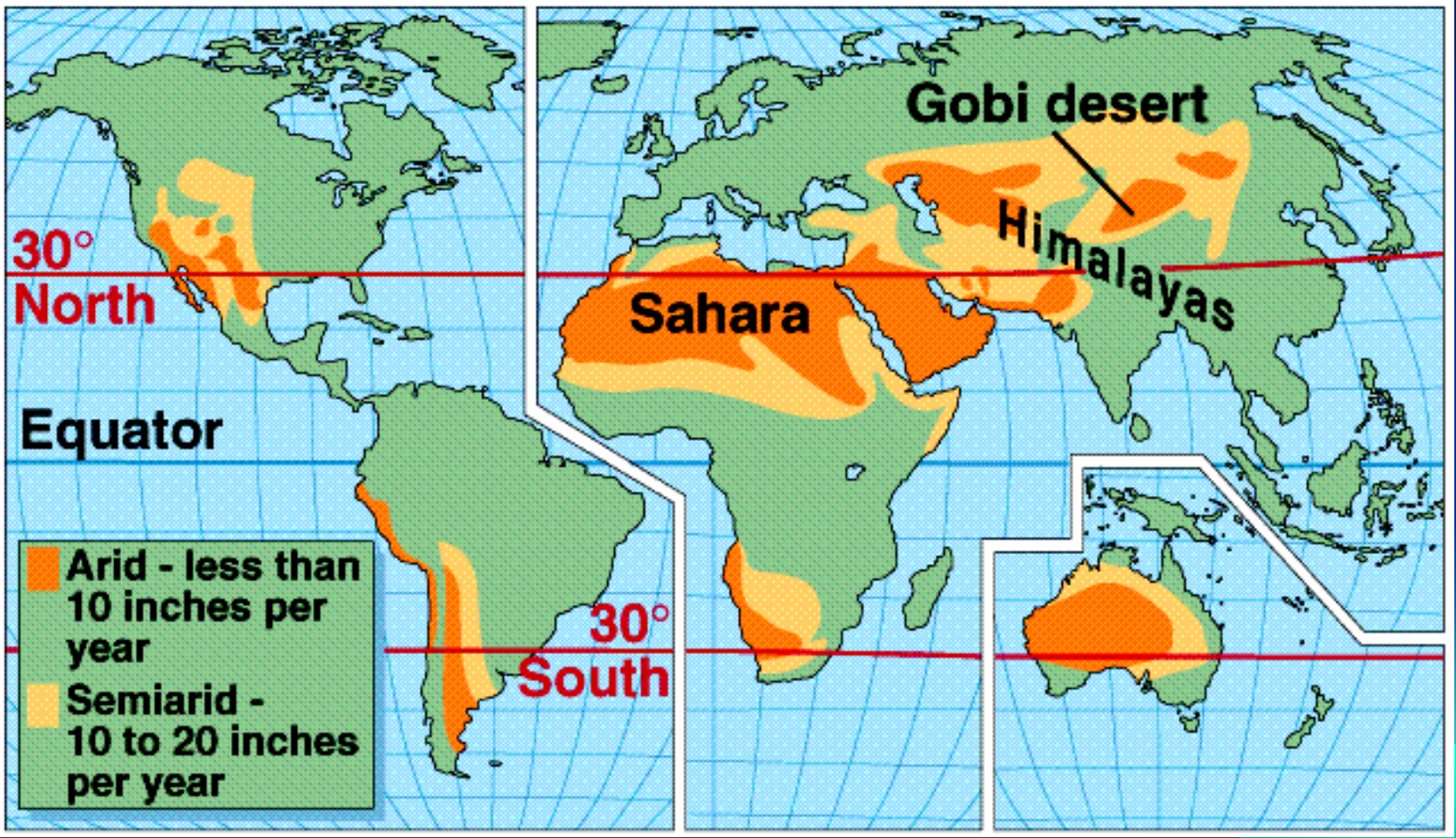
More precipitation where warm air rises and cools:

Where does this occur?

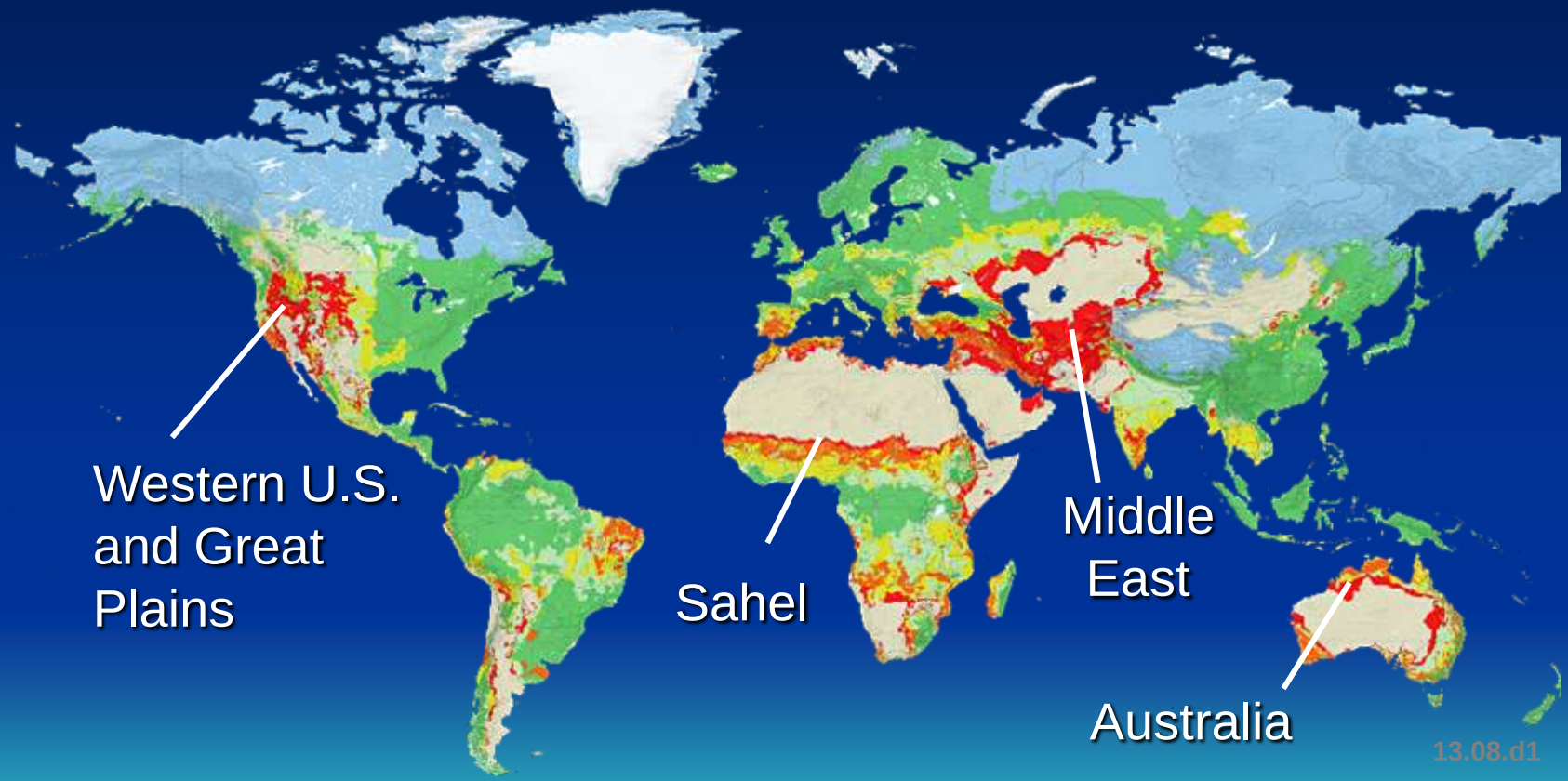
Tends to be dry where air descends:

Where does this occur?

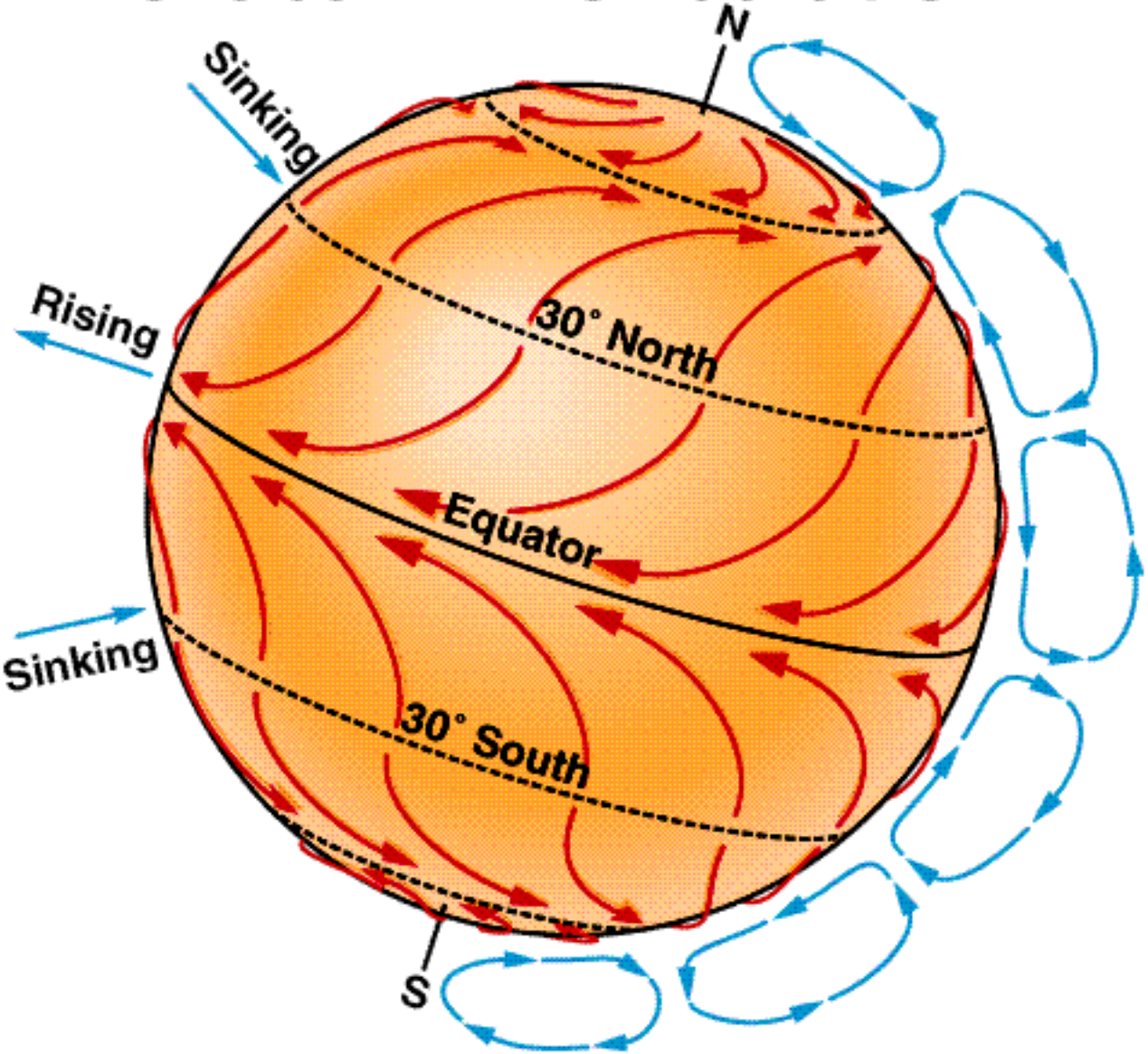
World Distribution of Nonpolar Deserts



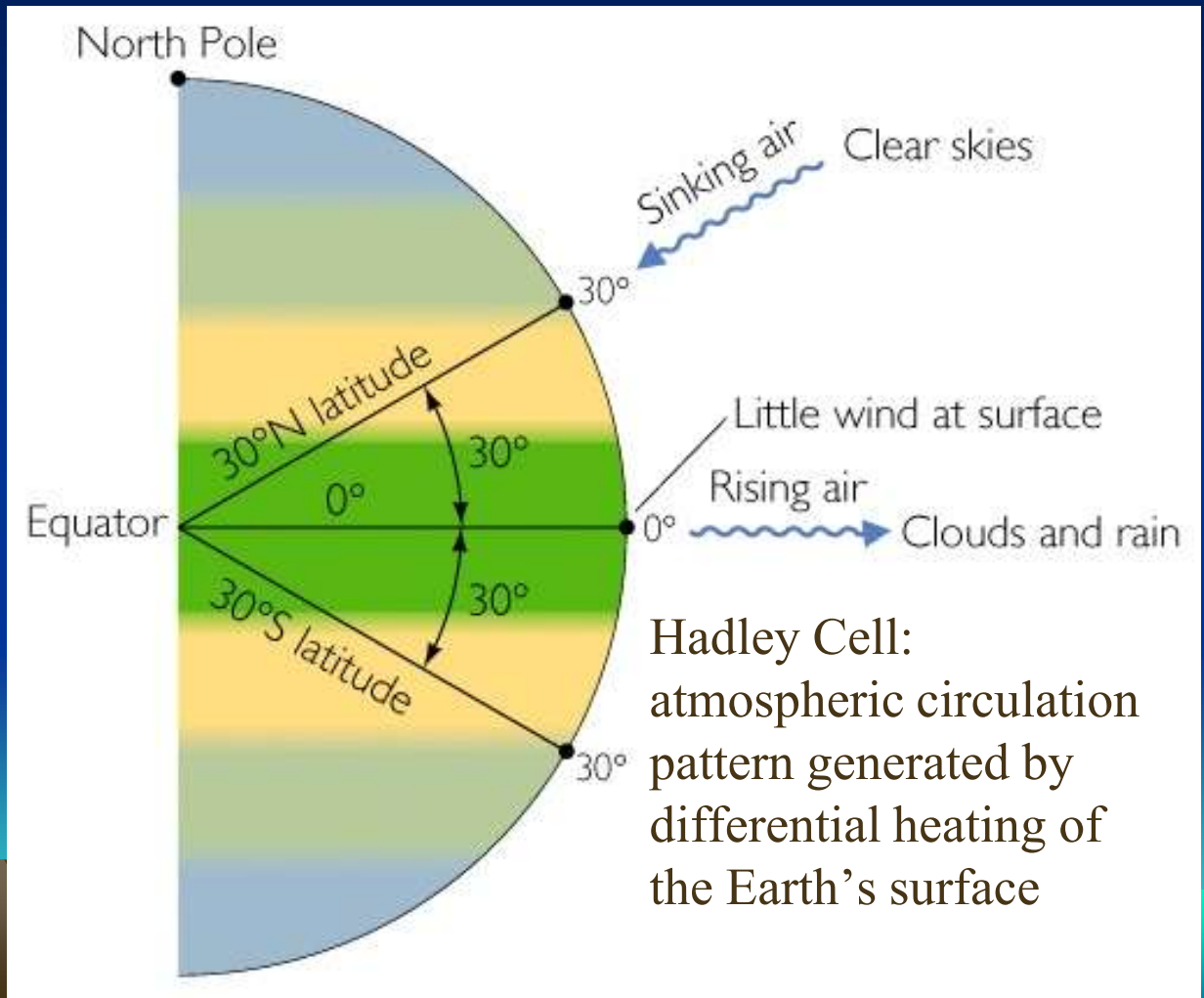
Observe areas at risk for desertification



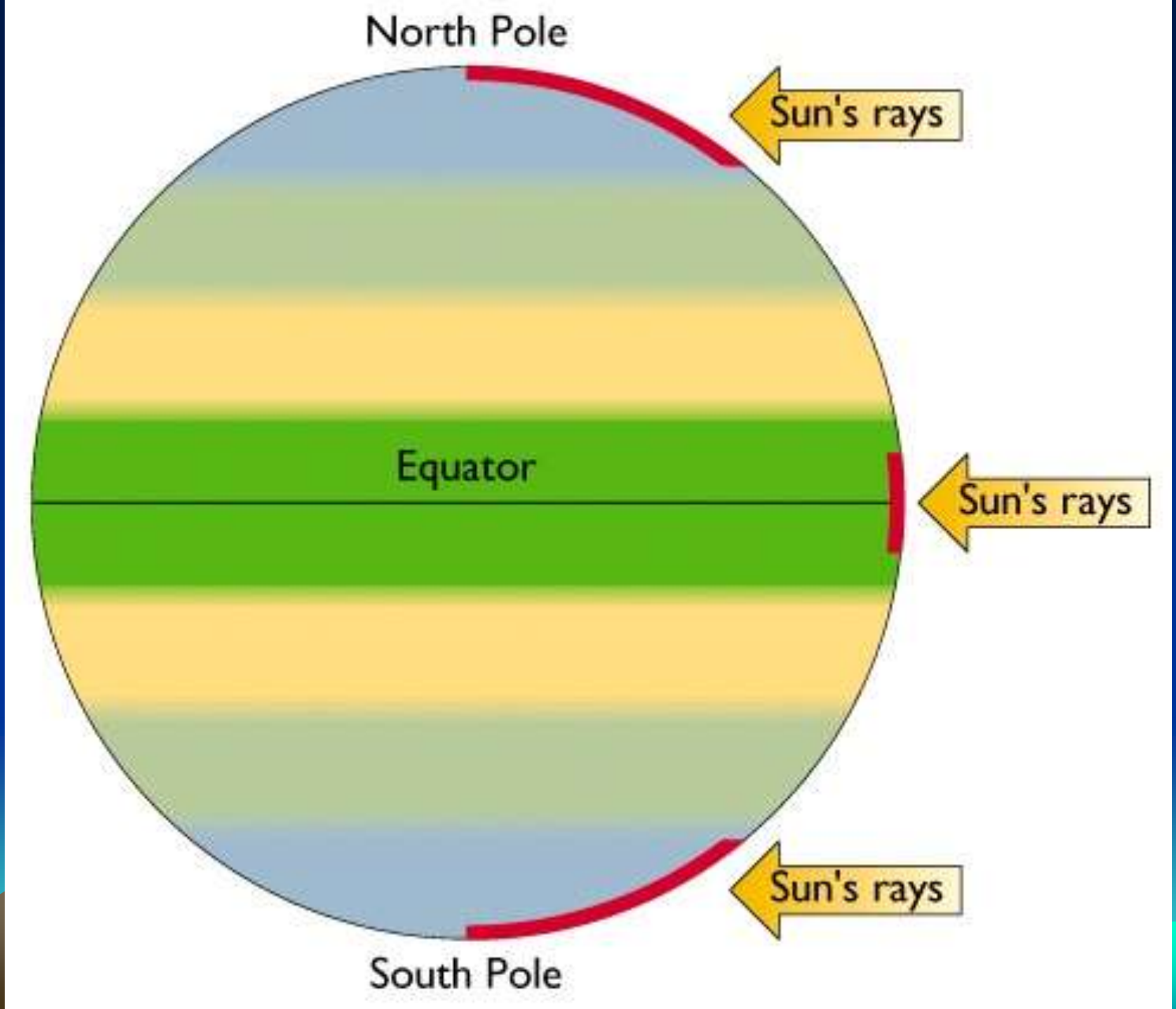
Global Air Circulation

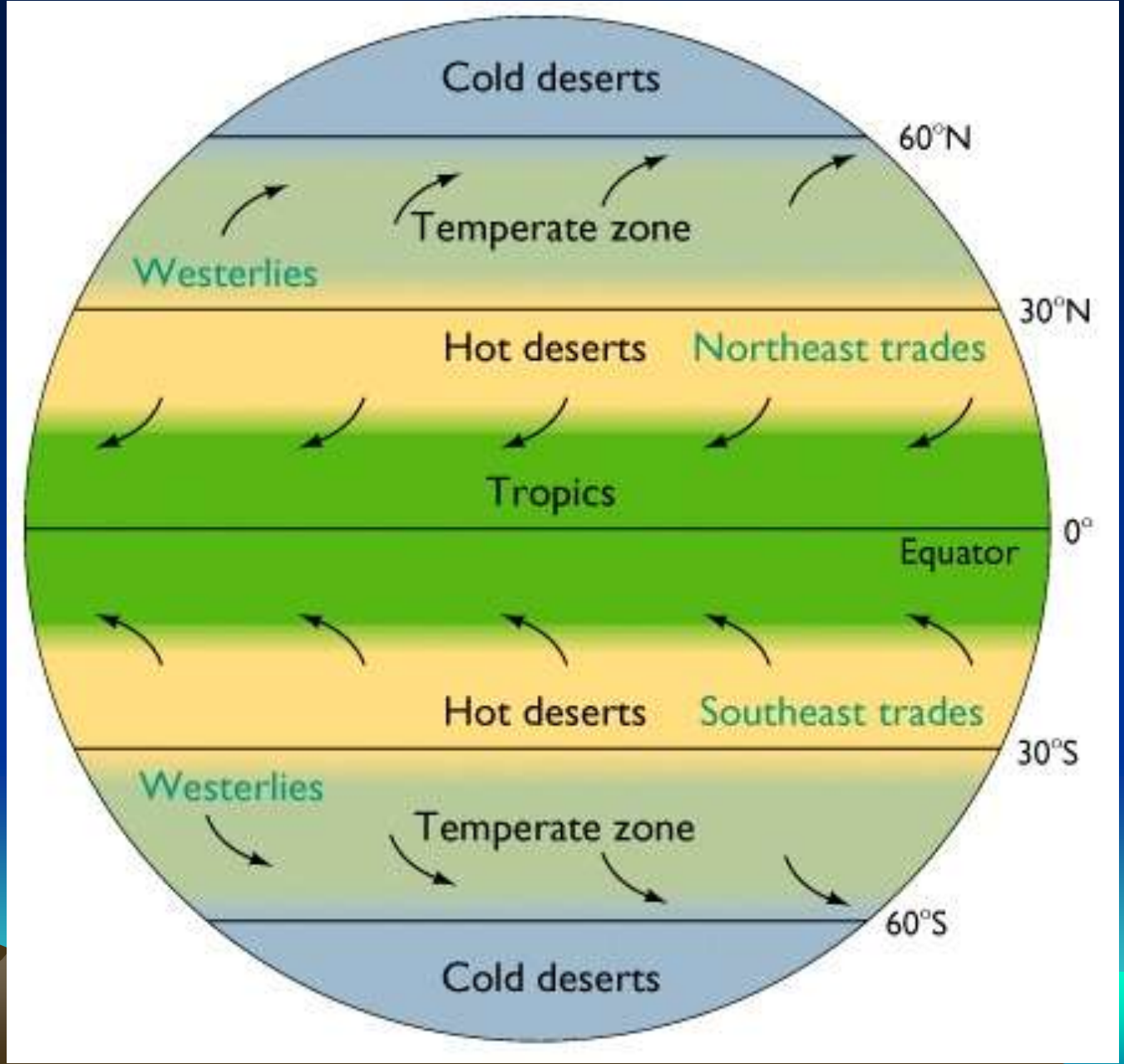


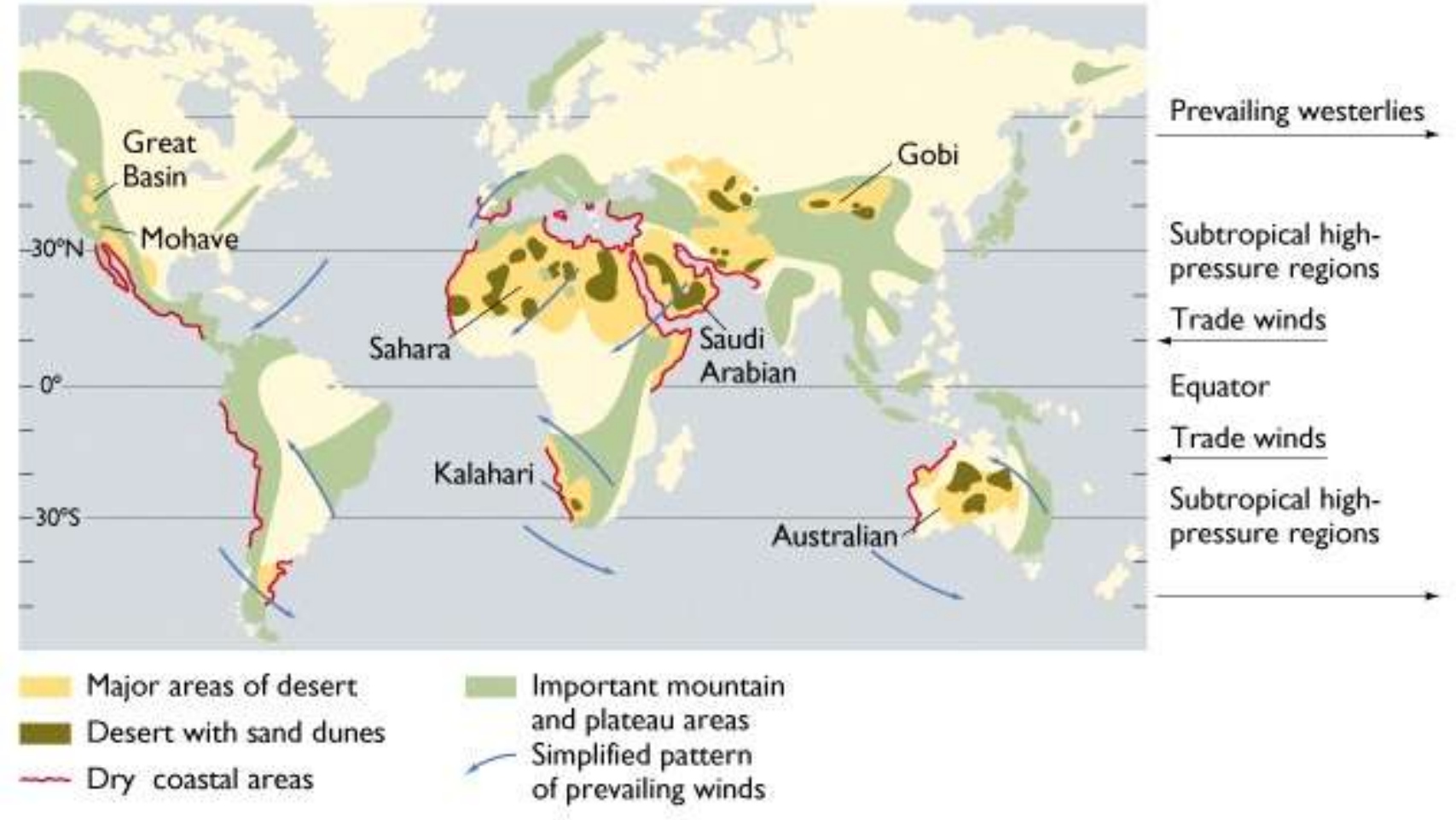
Rising and sinking air: results in arid and wet zones



Hadley Cell: atmospheric circulation pattern generated by differential heating of the Earth's surface


North Pole
Sun's rays
Equator
Sun's rays
Sun's rays
South Pole


Cold deserts
60°N
Temperate zone
Westerlies
30°N
Hot deserts
Northeast trades
Tropics
0°
Equator
Hot deserts
Southeast trades
30°S
Westerlies
Temperate zone
60°S
Cold deserts


Great Basin
Mohave
30°N
0°
30°S
Sahara
Gobi
Saudi Arabian
Kalahari
Australian
Prevailing westerlies
Subtropical high-pressure regions
Trade winds
Equator
Trade winds
Subtropical high-pressure regions
Major areas of desert
Desert with sand dunes
Dry coastal areas
Important mountain and plateau areas
Simplified pattern of prevailing winds

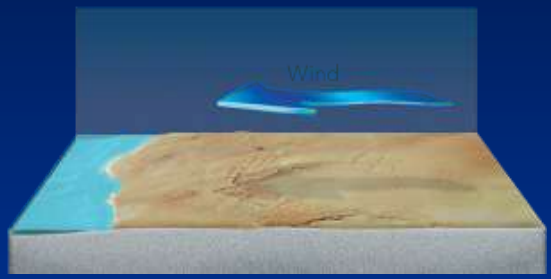
Locations of Deserts

- Warmest areas favored if rainfall is not high
  - Especially +/- 30 degrees from equator, but out of tropics
- Also form in midlatitudes
  - Where rainfall is low because of orographic effects or great travel distances from sources of moisture (central Asia today)
- Implications for paleoclimates
  - Deserts favored by supercontinents, e.g., Pangaea (around Paleozoic-Mesozoic boundary)

Settings of Deserts and Other Arid Lands

Subtropical deserts: descending air and high pressure

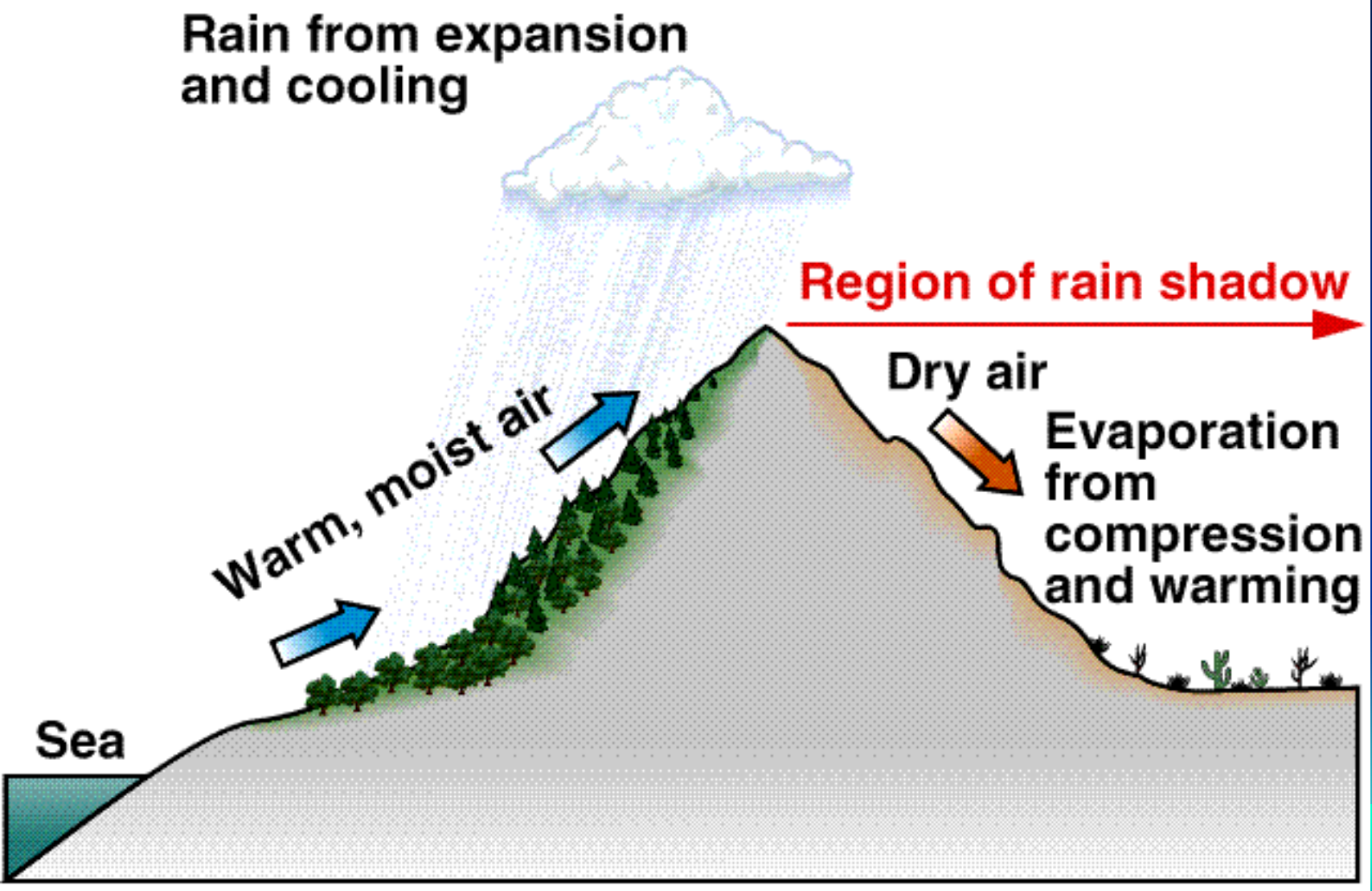
Rain shadow desert



Continental desert

13.08.c

Rain Shadow



Wind Action

- *Wind* can be an important agent of *erosion and transportation* of fine sediments in desert regions
- Large daily temperature and pressure differences lead to strong winds in desert regions
  - Loose, dry, fine sediments are easily moved by vigorous desert winds (often >100 kph)
  - Large *dust storms* may occur if fine-grained sediments are readily available
  - Like volcanic ash, dust can be transported 1000s of km away by atmospheric winds

Wind Action

- Strong in desert because:
  - Low humidity
  - Great temperature ranges
  - More effective because of lack of vegetation
- Effective erosion in deserts because sediment is dry

Wind Erosion and Transportation

- Dust storms
- Sand
  - Moves along ground- saltation
  - Sandstorms
  - Sandblasting up to 1 meter
    - Ventifact
- Deflation
  - Blowout

Wind Action

- *Wind* can keep dust in suspension, but larger sand grains move by hopping along the ground (*saltation*)
- Sand grains moving in high-speed winds can effectively sand-blast rocks into erosional forms called *ventifacts*
  - Sandblasting of man-made objects, like power poles, can be problematic

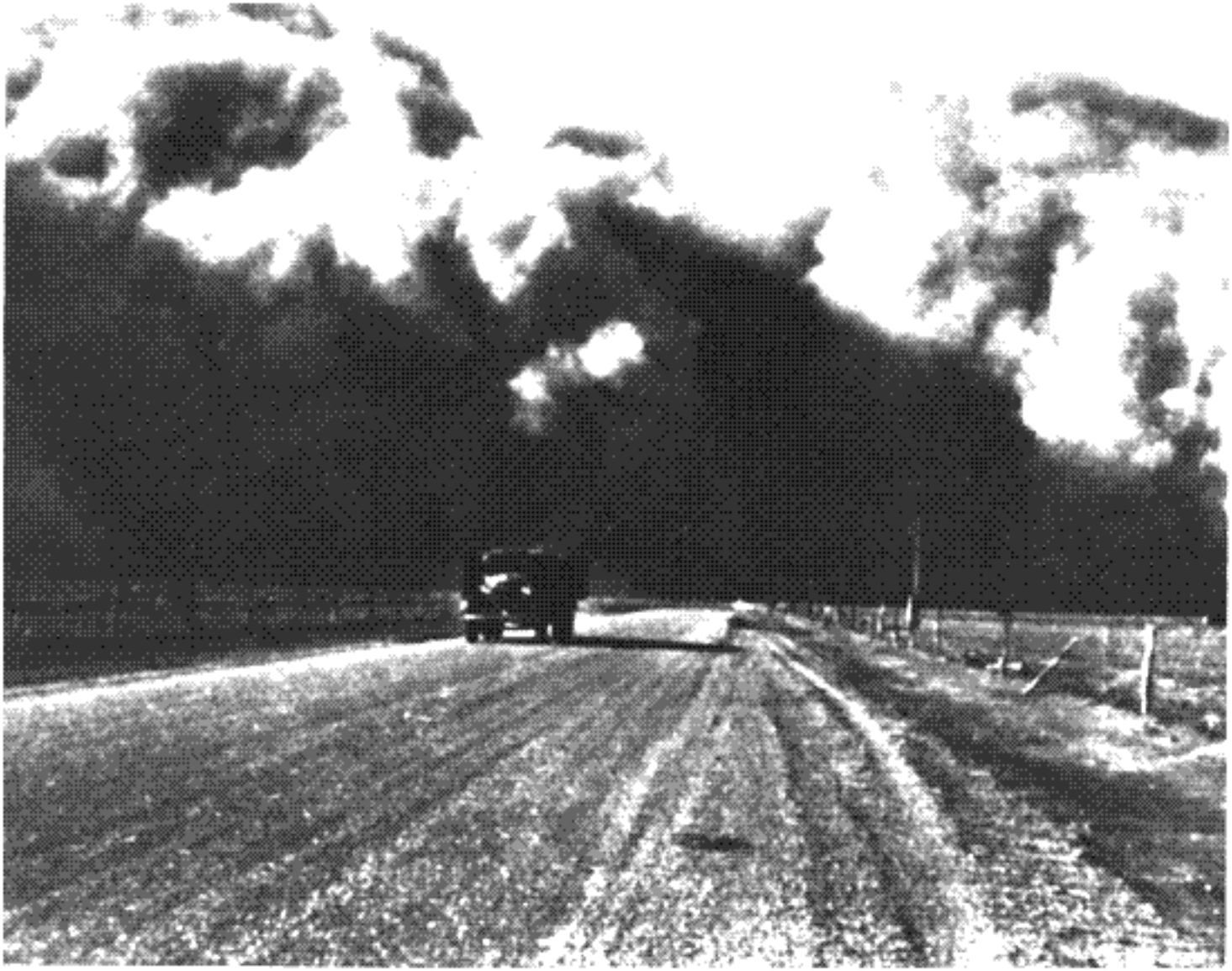
Wind Erosion in Death Valley, CA

A

Wind Erosion

A

Dust Storm

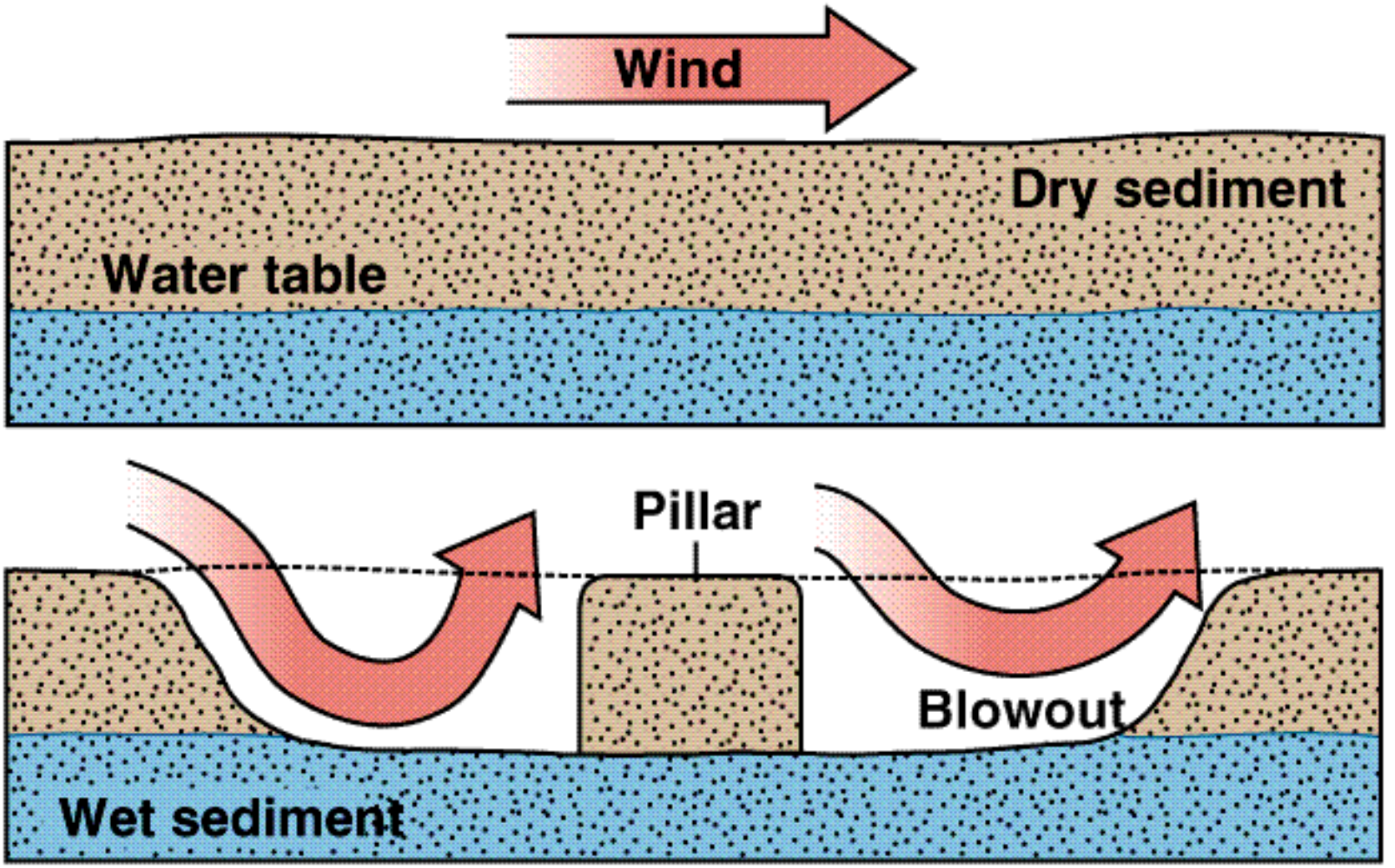


B

Abrasion Resistant Material

B

Deflation Forms Blowouts



Large Blowout

Features the Develop Over Time in Deserts

Pediment

Desert pavement

Caliche

Desert varnish

Natural stains

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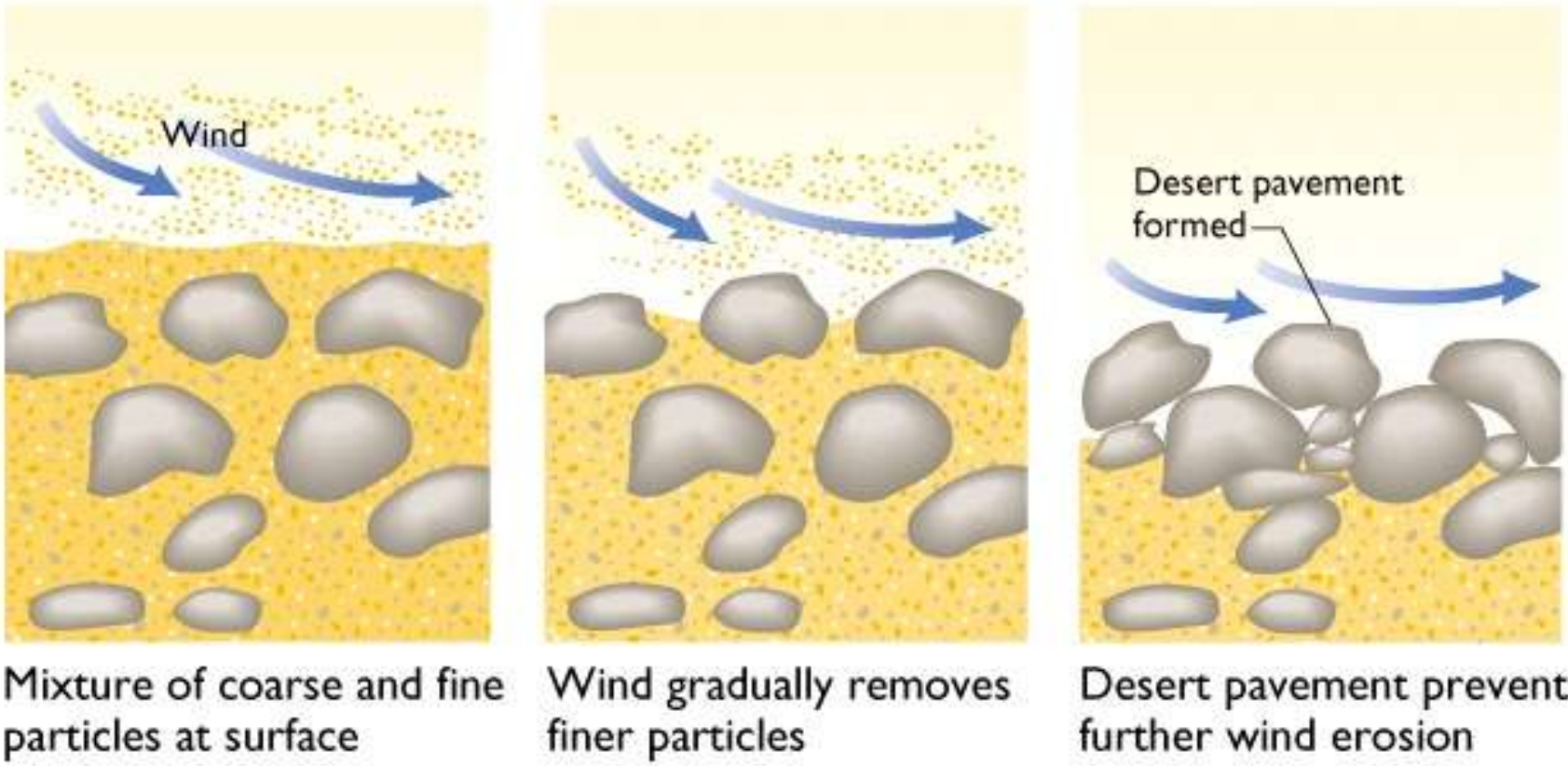
Ventifacts Eroded by Blowing Sand

Lag surfaces (desert pavement)

Ventifacts: wind-faceted pebbles

Desert Pavement

Removal of fine-grained fraction by wind



Eolian sands

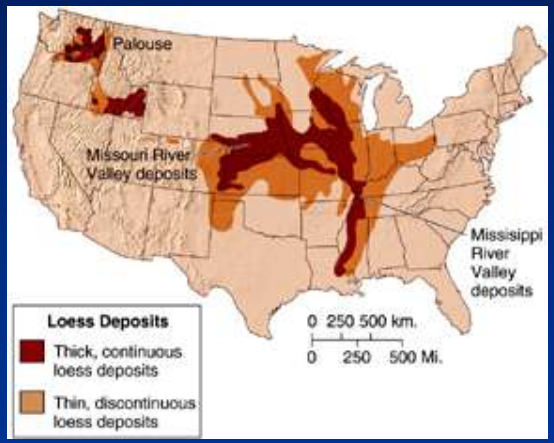
Typically fine, very well sorted, frosted (“sand blasted”)

Wind Deposition

- Loess
- Sand Dunes
  - Well-sorted, well-rounded sand grains
  - *Slip face*
    - Angle of repose
  - Wind ripples

Wind Deposition - Loess

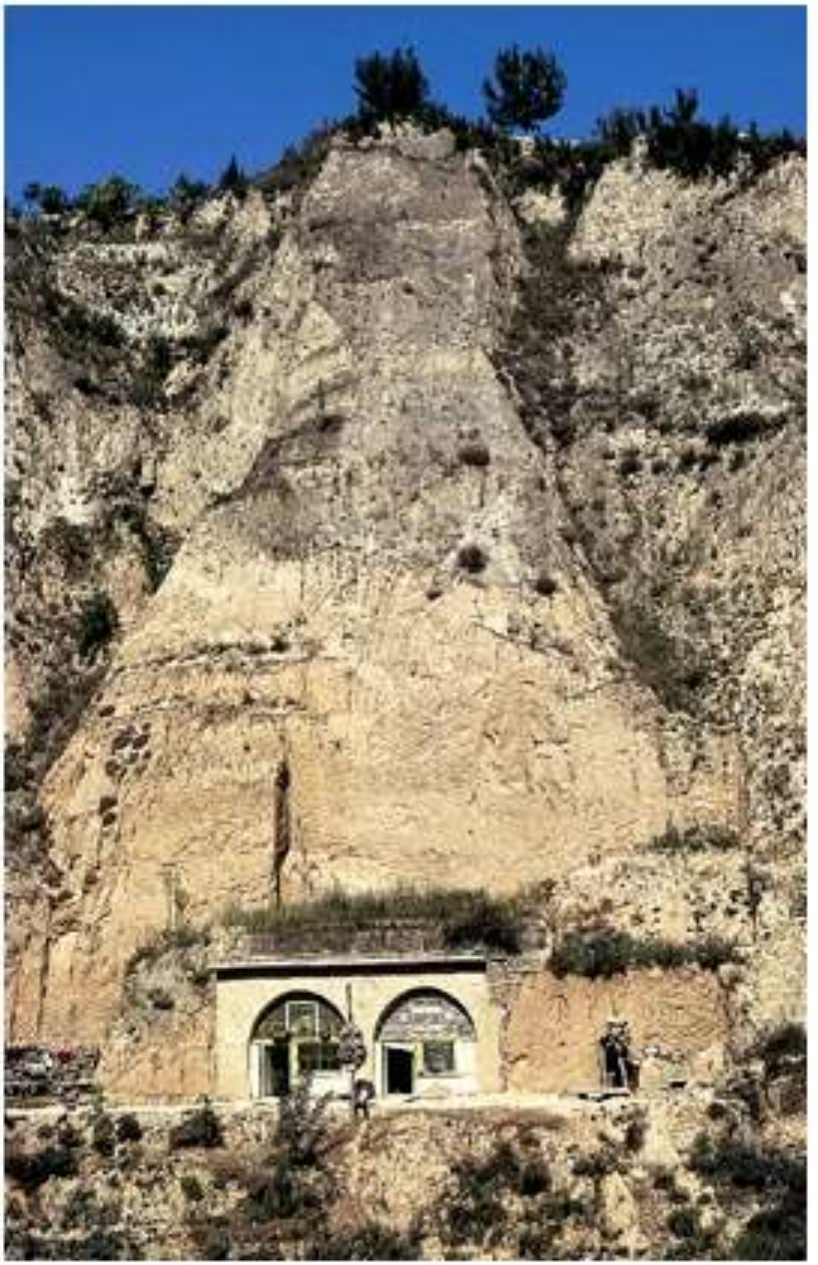
- Wind can deposit thick layers of silt and clay-sized sediments to form *loess* deposits
  - Sediment sources for loess deposits include glacial outwash plains and desert playas
- Thick loess deposits exist in China, and in the central plains, mid-western and northwestern regions of the United States
  - Loess typically forms soils that are very fertile, yet easily eroded



Eroded loess deposits in Nebraska

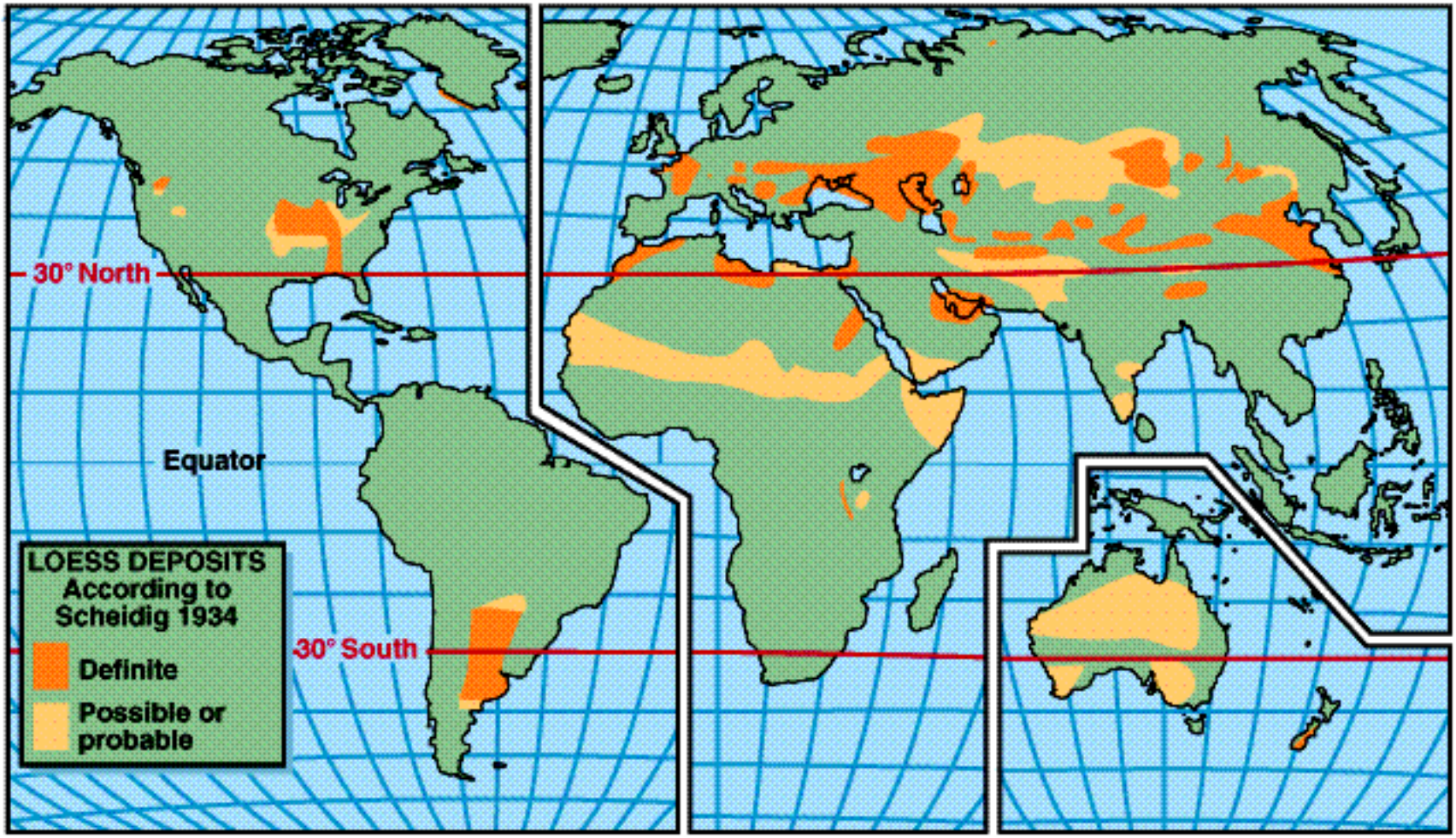
Loess

- Accumulations of wind-blown silt and dust
- Especially abundant in the Pleistocene (ice ages) — why?



Vertical Road Cuts in Loess

Major Loess-Covered Areas

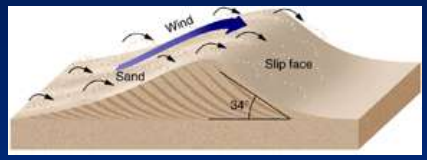


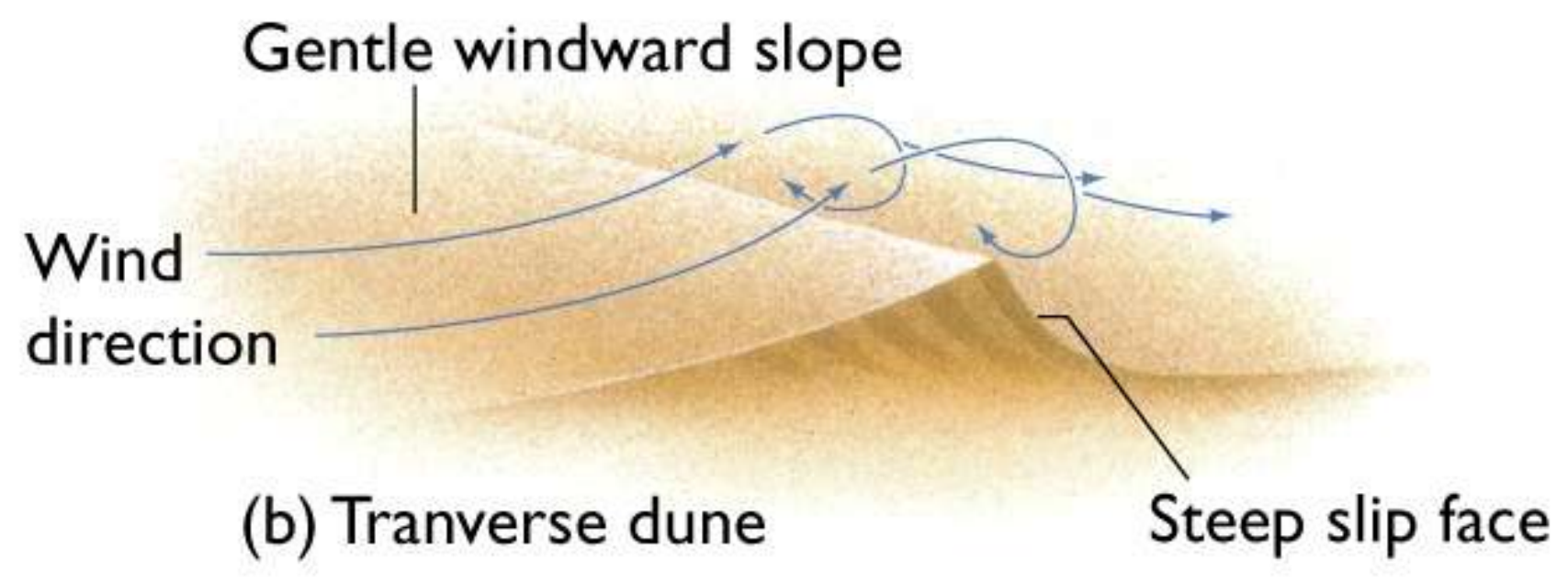
Wind Deposition

- Types of dunes
  - Barchan
  - Transverse dune
  - Star dunes
  - Parabolic dune
  - Longitudinal dune

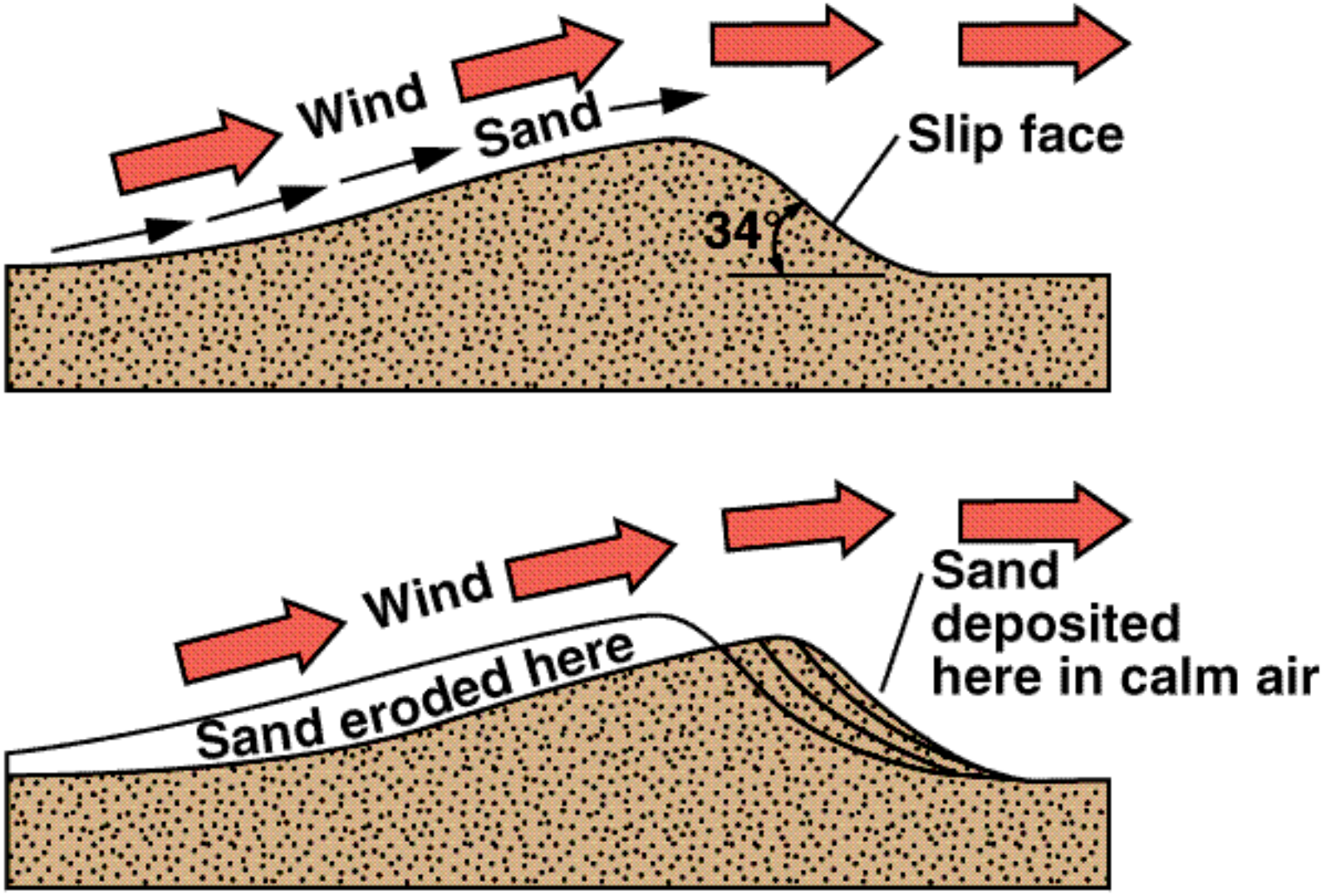
Wind Deposition - Sand Dunes

- *Sand dunes* are mounds of loose sand piled up by the wind
  - Most likely to develop in areas with large sand supply and winds that generally blow in the same direction
  - Small patches of dunes are common in desert valleys of the southwestern U.S., but huge sand seas exist in the Sahara and Arabian deserts
  - Dunes may also form just inland of beaches along the coasts of seas and large lakes
  - Most coastal dunes are composed primarily of quartz grains, but inland dunes may contain feldspar, gypsum and rock fragments
  - Carbonate sand dunes can form on or near tropical beaches



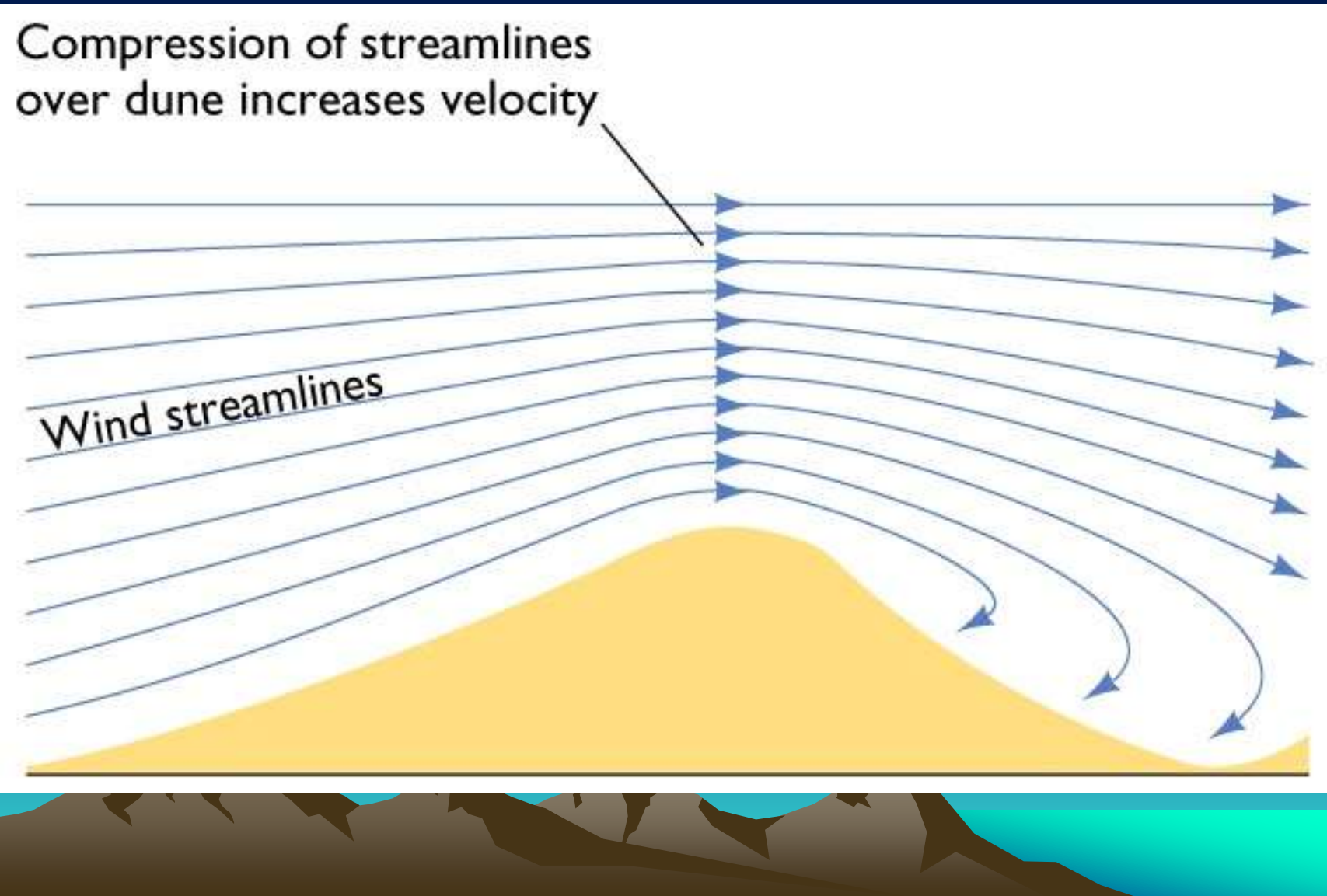

Gentle windward slope
Wind direction
(b) Tranverse dune
Steep slip face

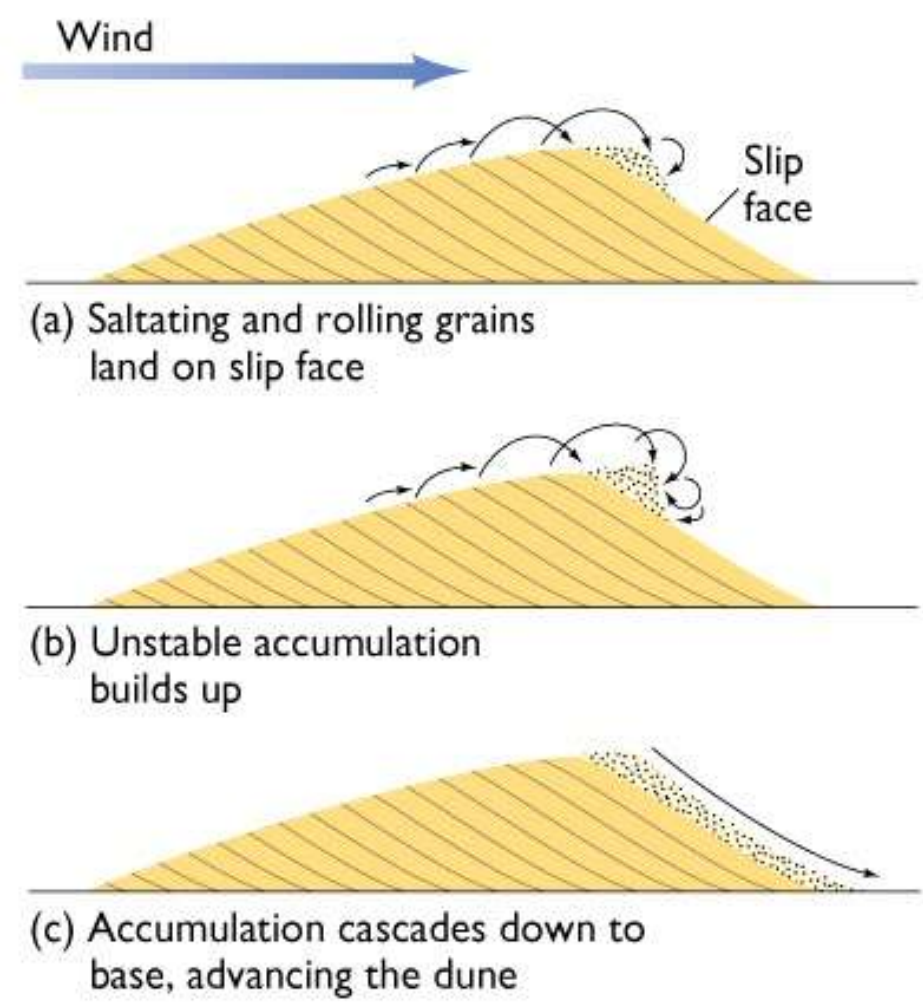
Sand Dune Formation

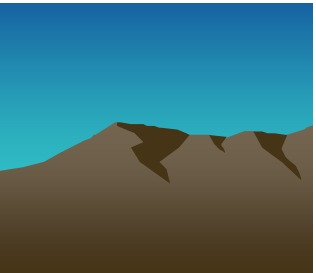


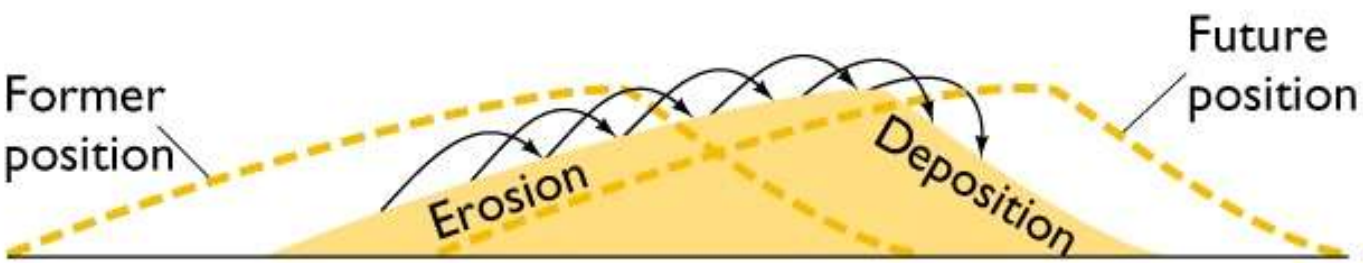
A

Winds Settle Sand in Slip Force


Compression of streamlines
over dune increases velocity
Wind streamlines

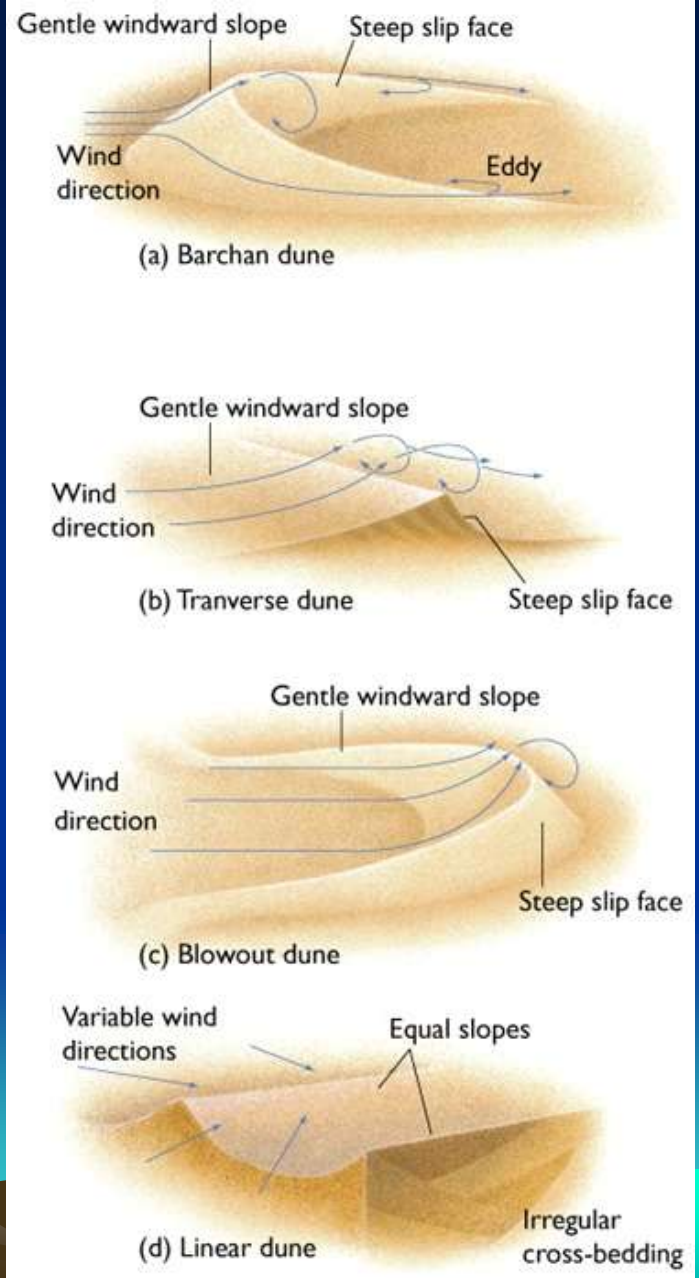

Wind
Slip face
(a) Saltating and rolling grains land on slip face
(b) Unstable accumulation builds up
(c) Accumulation cascades down to base, advancing the dune




Former position
Erosion
Deposition
Future position

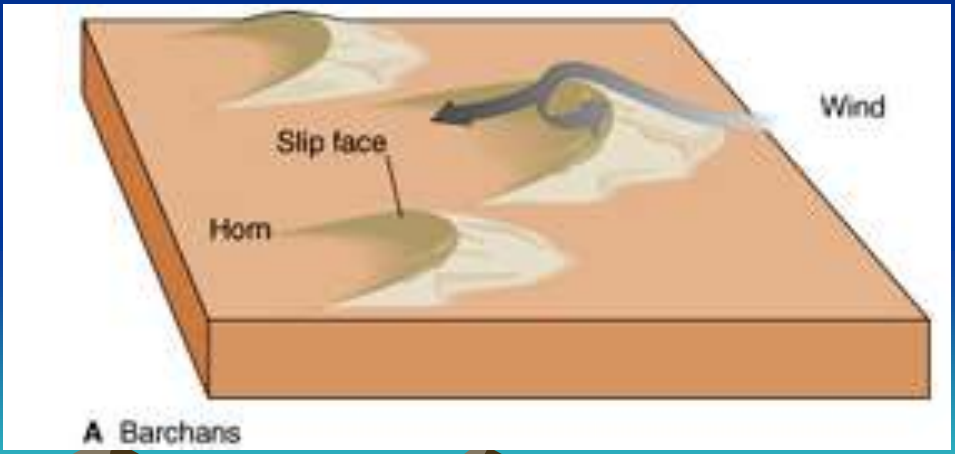
Several types of sand dunes

- Defined by shape
- Types vary with sediment supply and wind direction
- Steepest side is always downwind

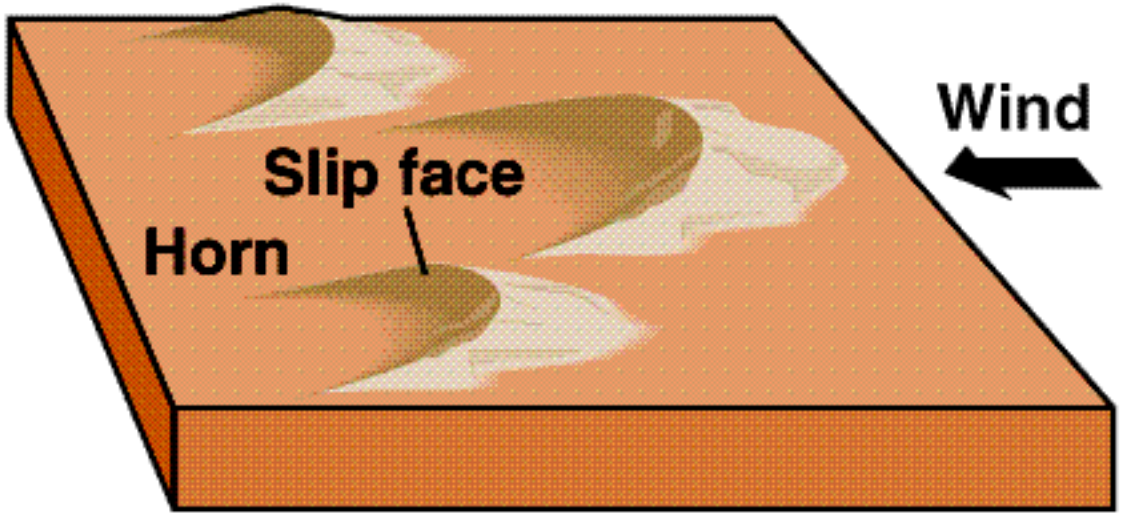


Types of Sand Dunes

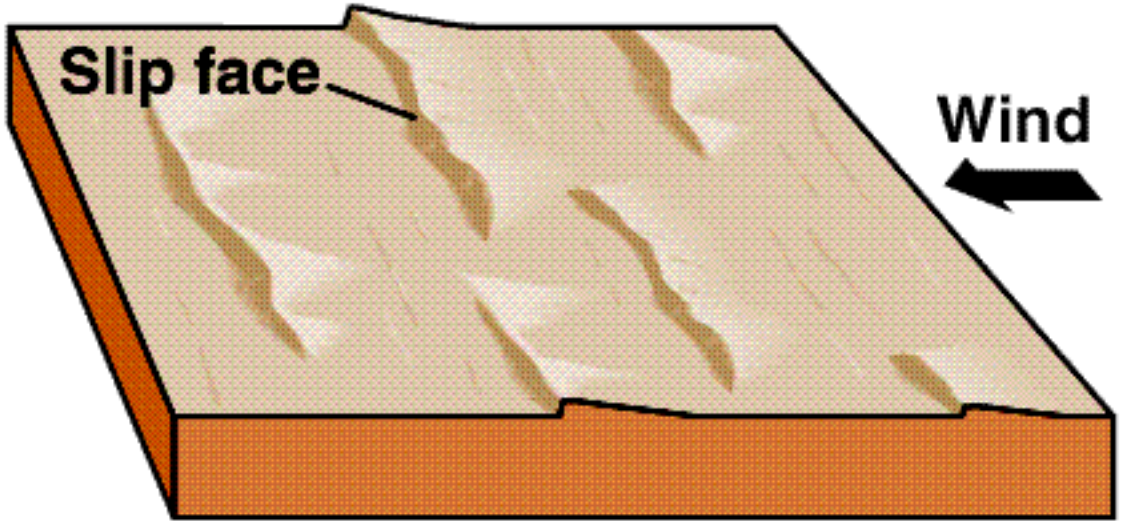
- Different types of sand dunes form depending on the *dominant wind direction(s),* the *amount of available sand,* and arrangement of any existing *vegetation cover*



Types of Sand Dunes



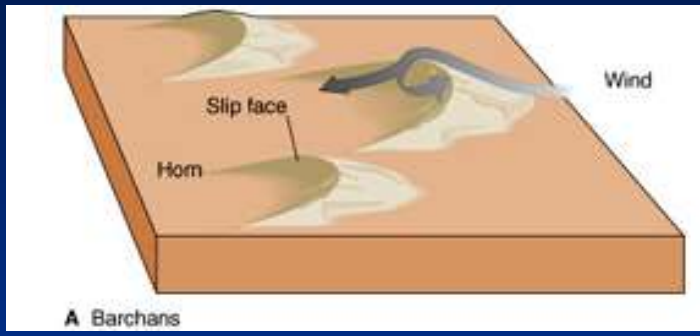
A Barchans

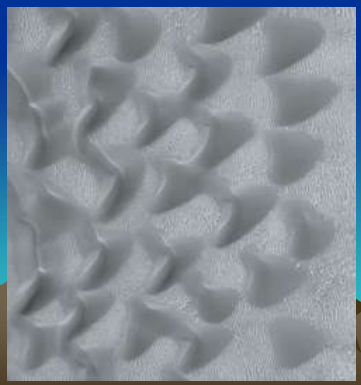


B Transverse dunes

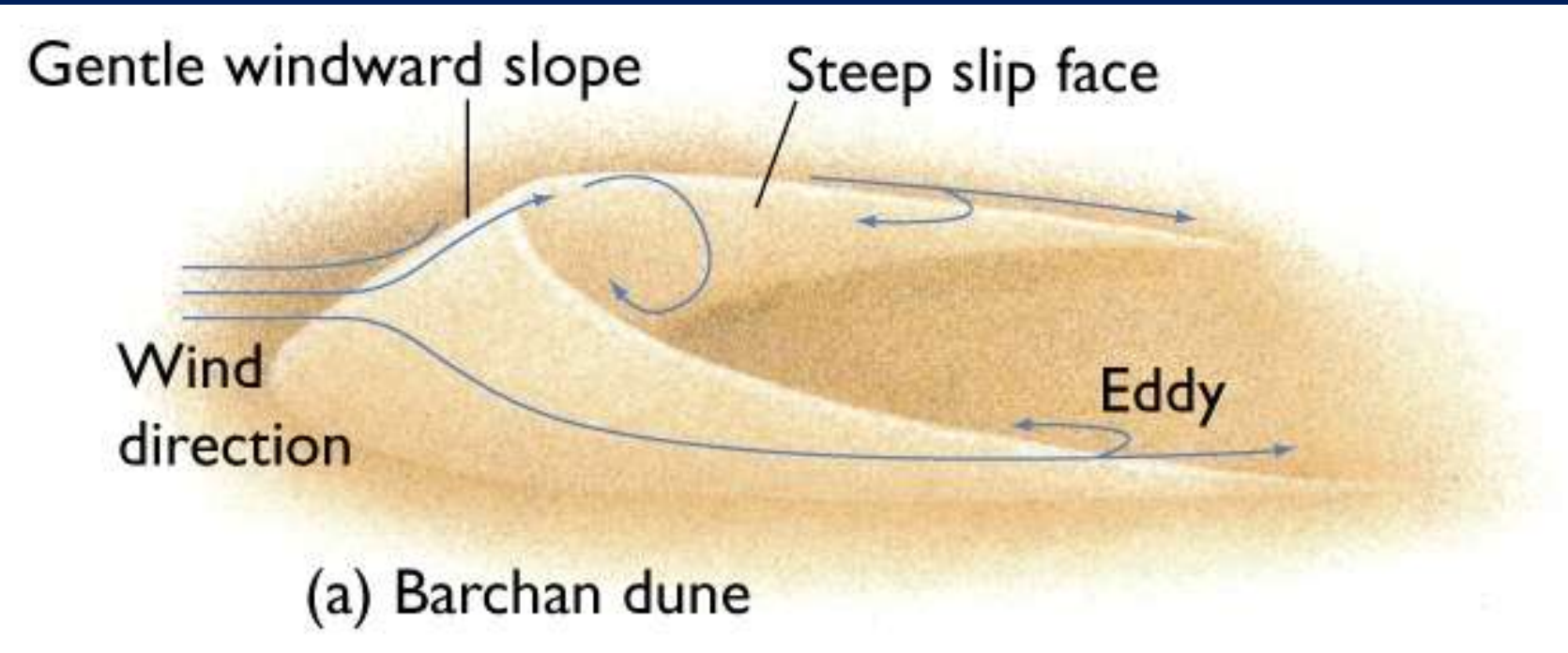
Barchan Sand Dunes

- *Barchan* dunes are crescent-shaped, with horns that point downwind and a steep slip face on the concave side
- Barchans form in areas with one dominant wind direction and a limited sand supply
- Barchan dunes also exist on Mars





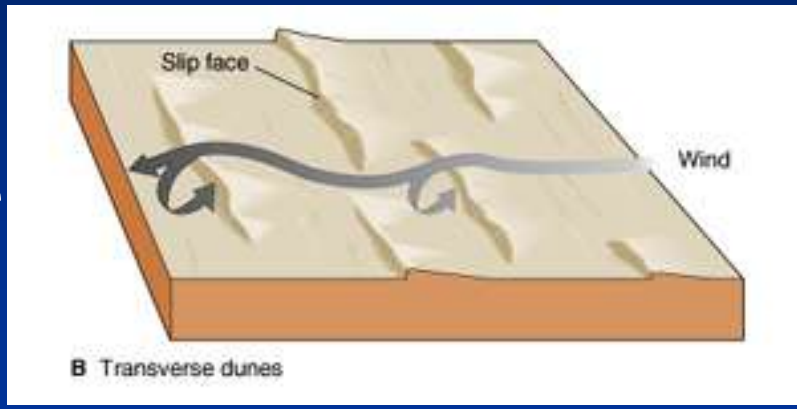
Barchan dunes on Mars



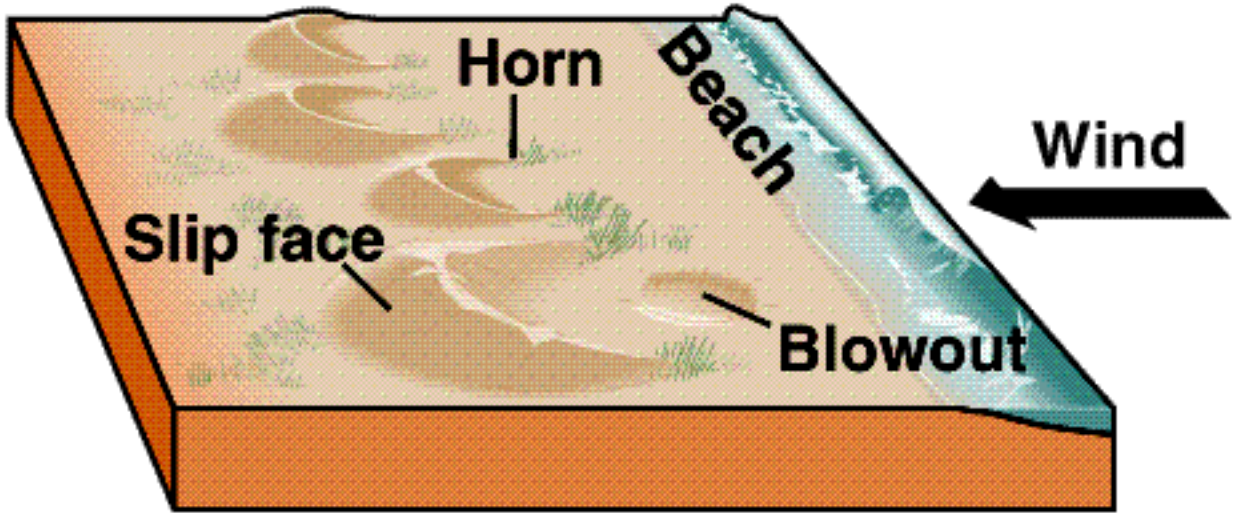
(a) Barchan dune

Transverse Sand Dunes

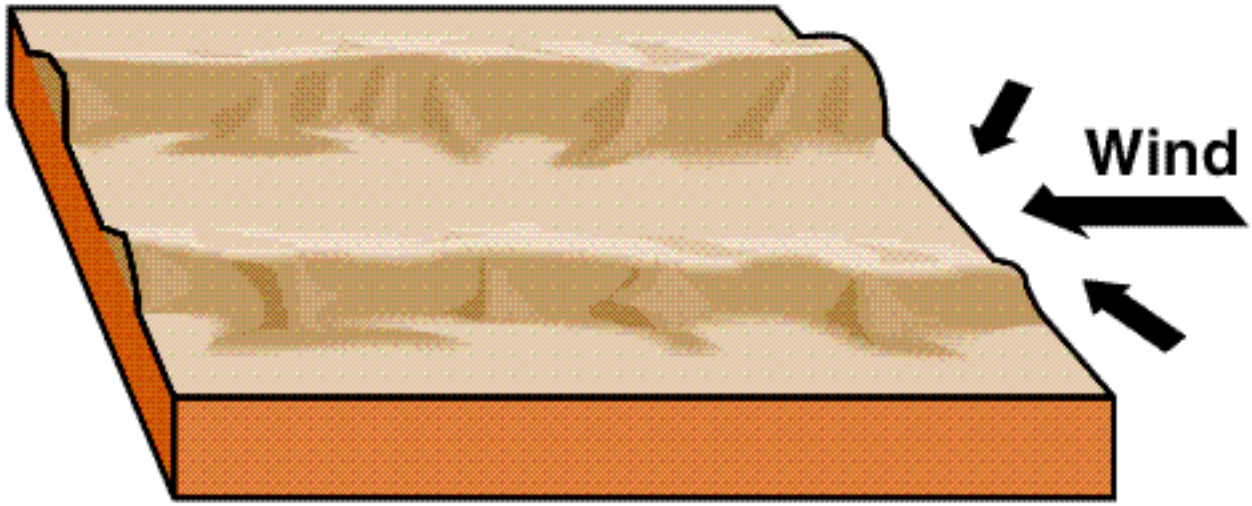
- *Transverse dunes* form in areas with large sand supply and one dominant wind direction
  - Relatively straight, elongate dunes



Types of Sand Dunes

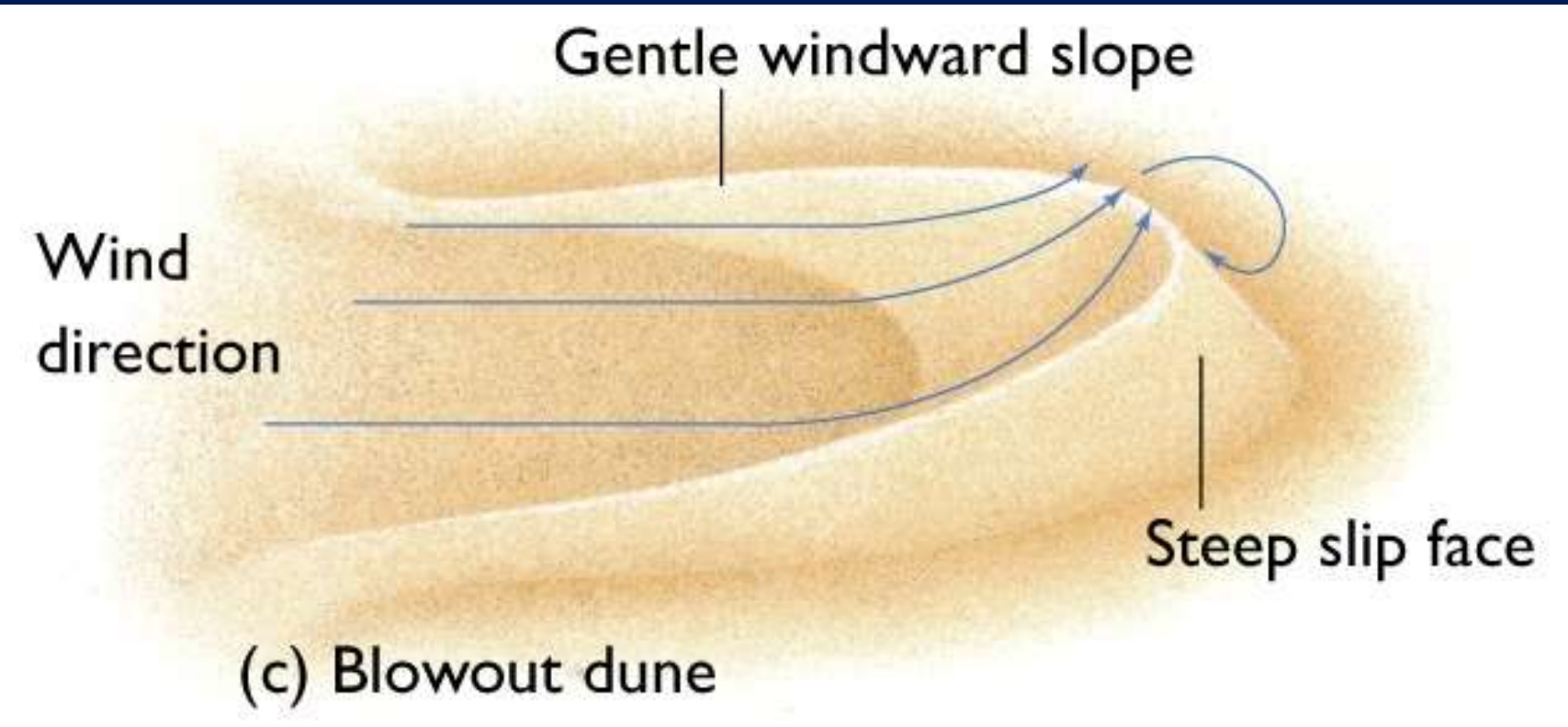


C Parabolic dunes



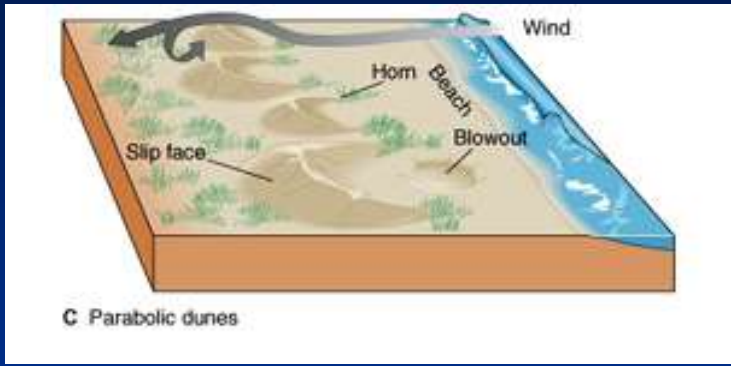
D Longitudinal dunes (seifs)

Parabolic or blowout dune

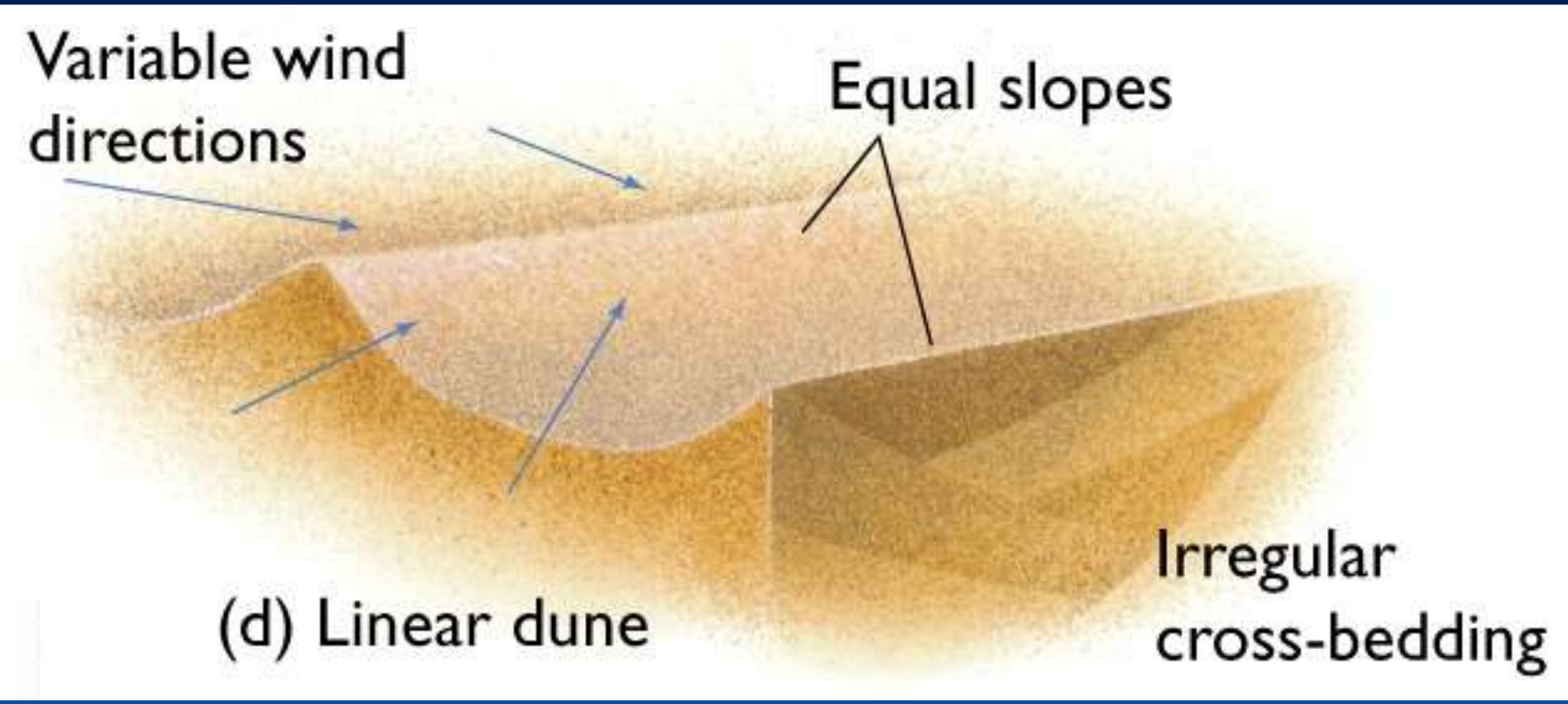


Parabolic Sand Dunes

- *Parabolic dunes* form around *blowouts* in areas with abundant sand, and have horns that point upwind which are typically anchored by vegetation
  - Deeply curved, look similar to barchans, but are convex in the *downwind* direction
  - Steepest side is downwind

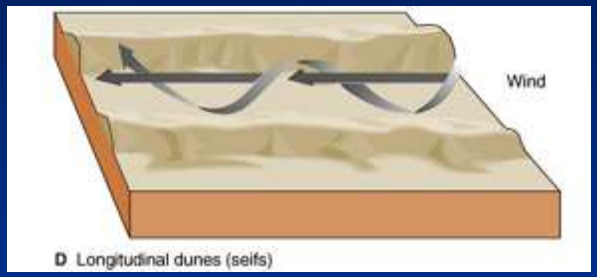


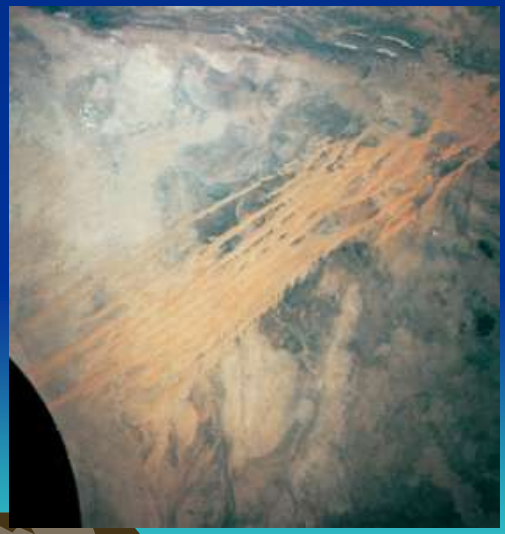
Longitudinal dune



Longitudinal Sand Dunes

- *Longitudinal dunes* form in areas with large sand supply, parallel to the prevailing wind direction
  - Extremely long, high, straight and regularly spaced
  - Crosswinds may play part in their development
  - Area between parallel dunes is swept clean of sand by winds
  - Formation mechanism still not fully understood





Longitudinal Dunes in Sahara Desert

Namibia coastal desert

Nambia

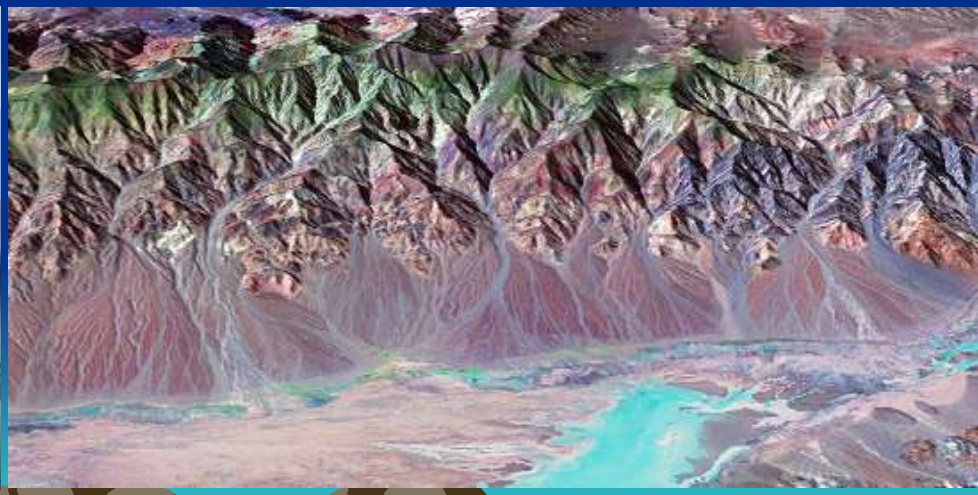
Landscape Features Characteristic of Deserts

Alluvial fans

Desert washes

Playas

Dunes

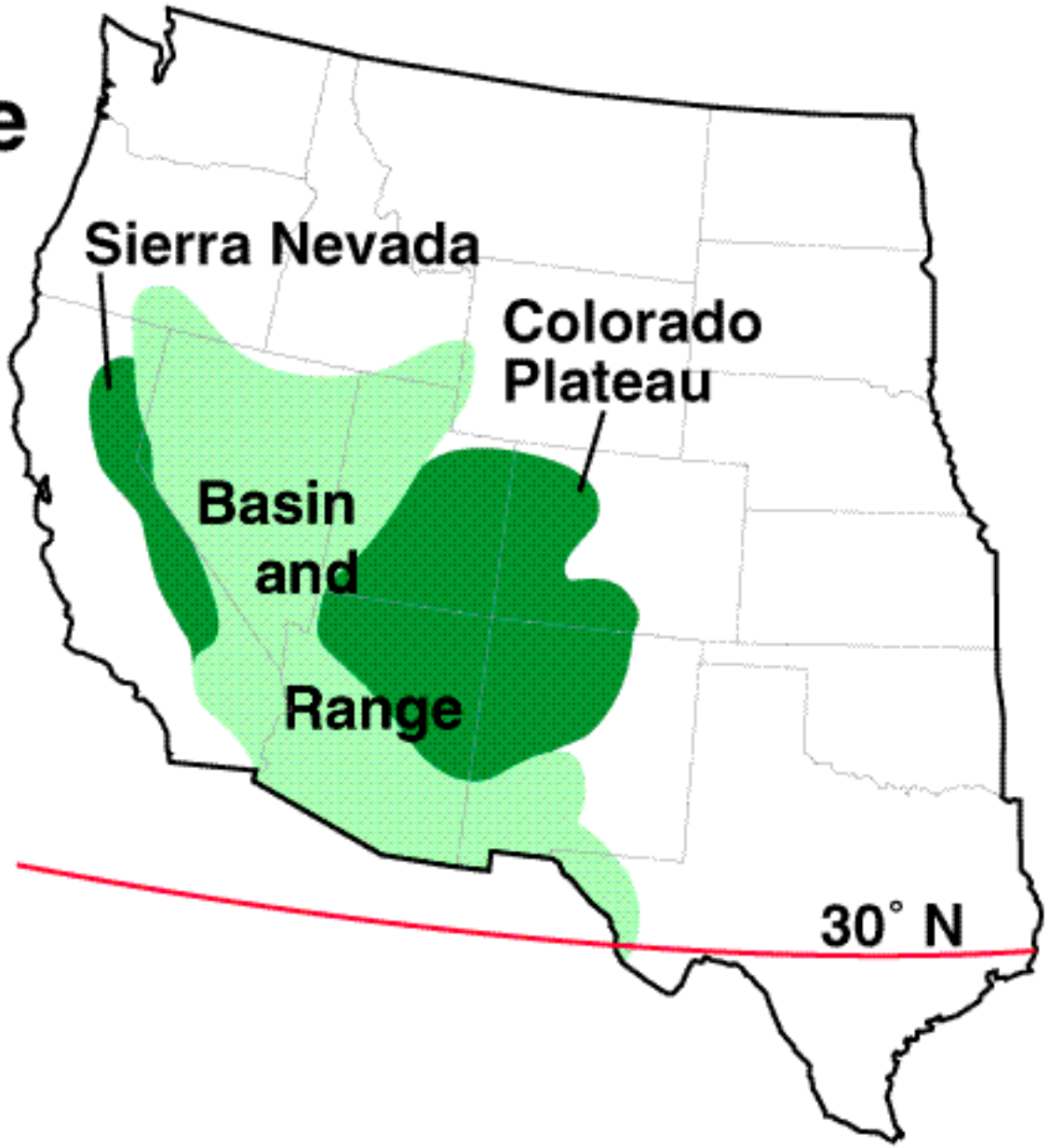


Satellite image: fans, washes, playas

Desert Landforms of the Southwestern United States

- Two distinct landscapes in the desert southwest: the *Colorado Plateau* and the *Basin and Range* province
- Colorado Plateau is marked by flat-lying sedimentary rocks that are heavily eroded (due to their large elevation above sea level) into *plateaus*, *mesas* and *buttes*

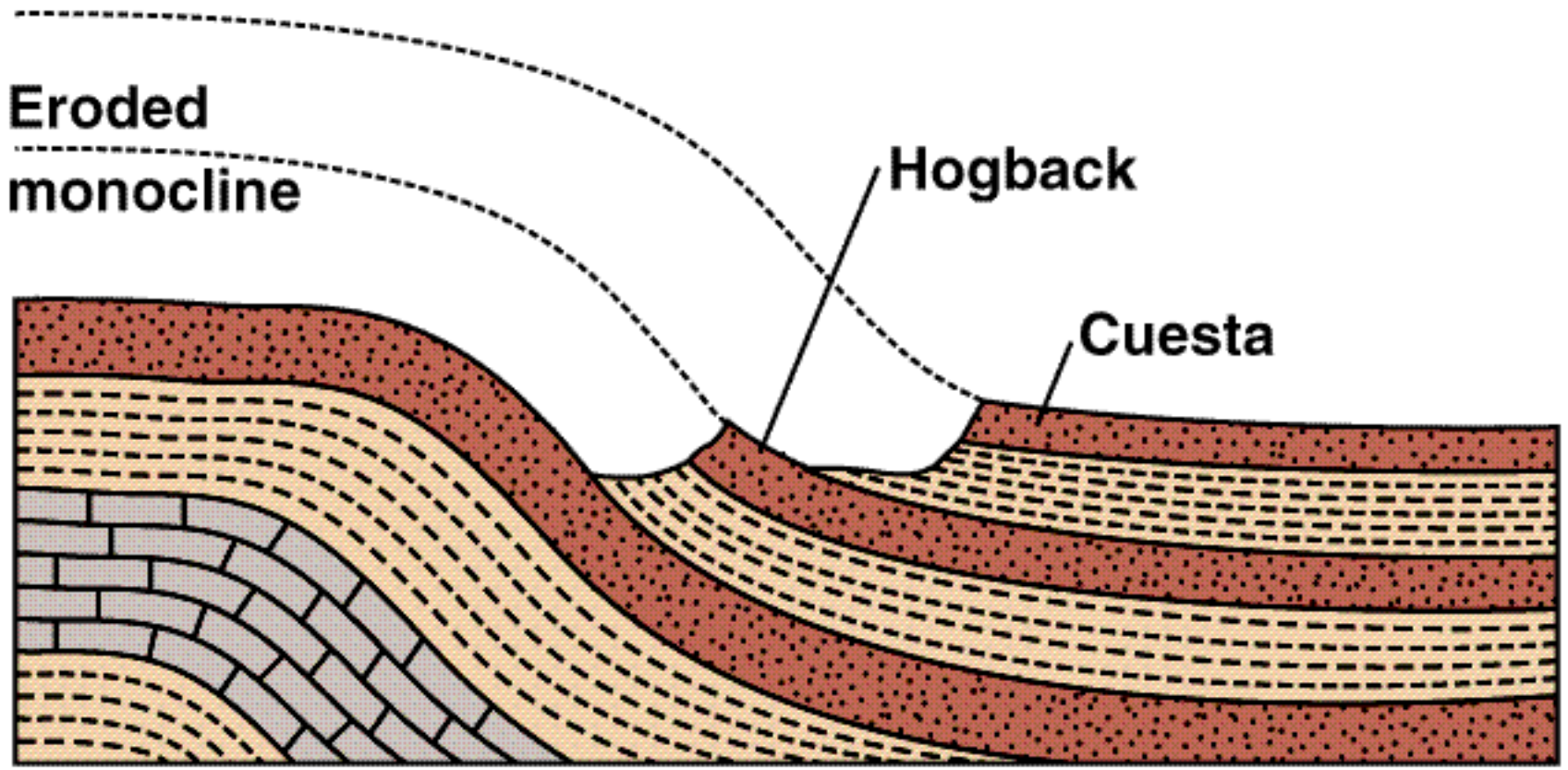
Plateau and Basin Range



Desert Features in S.W. United States

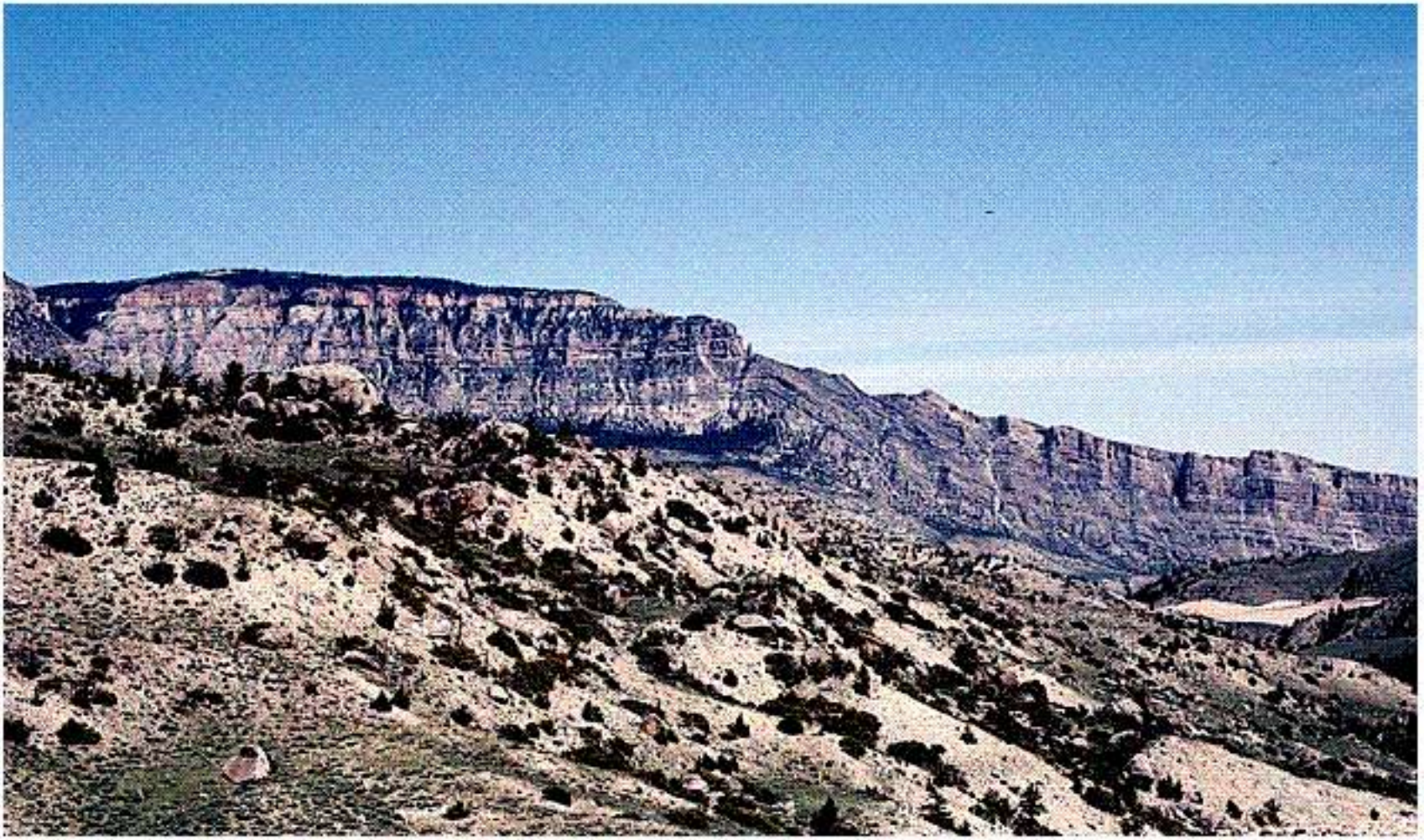
- Colorado Plateau
  - Mostly flat-lying sedimentary beds
  - Plateaus, mesas, buttes
  - Monoclines
    - Hogback; cuesta

Monocline Folds



A

Monocline Folds

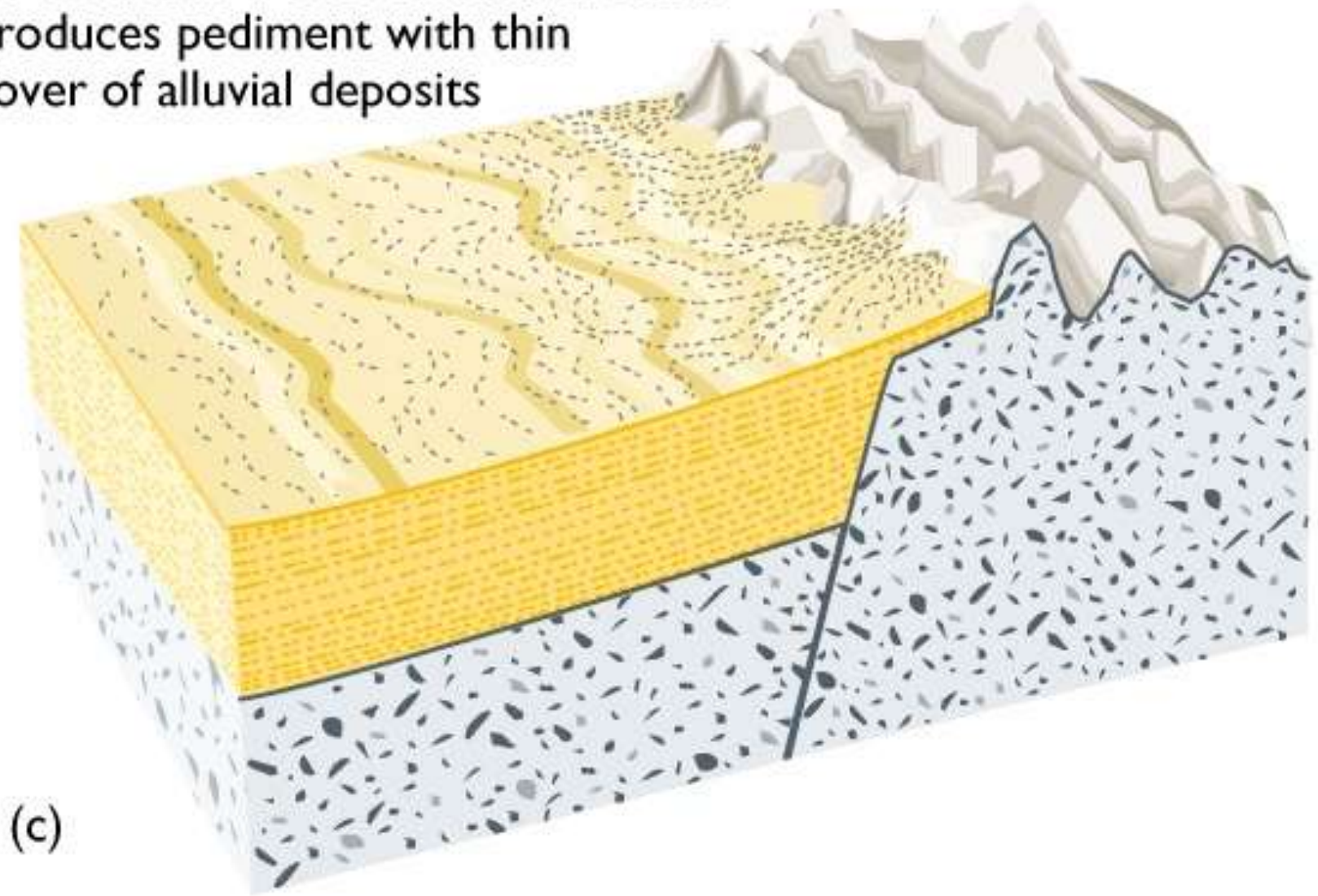


Desert Features in S.W. United States

- Basin and Range Province
  - Mountains & valleys bounded by faults
  - Alluvial fans; bajada
  - Playa lake; playa
  - Pediment
  - Parallel retreat of slope

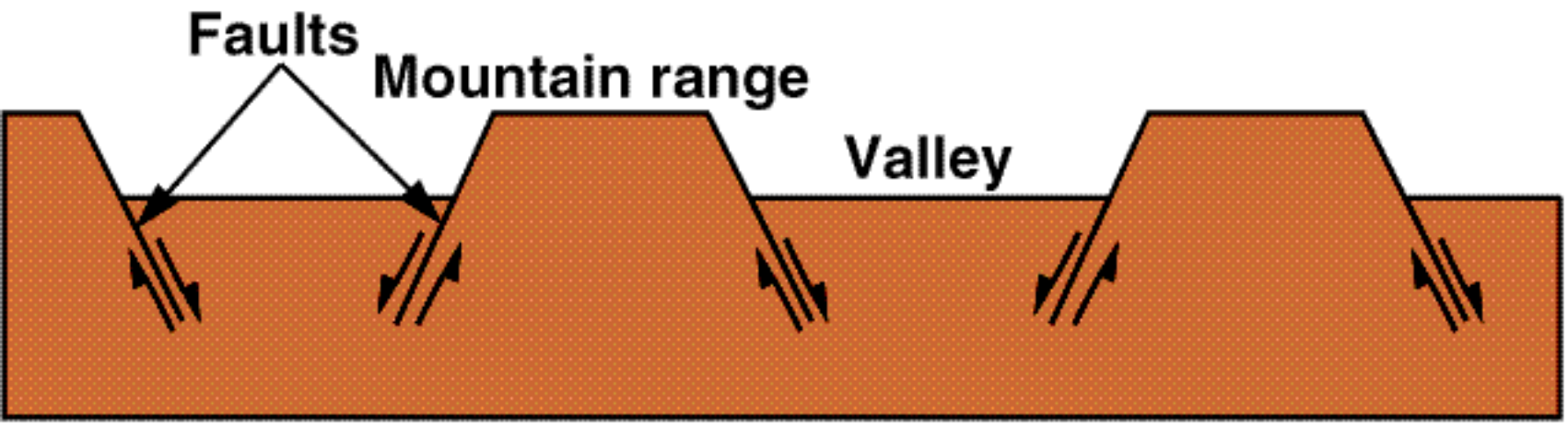
Basin and Range Topography

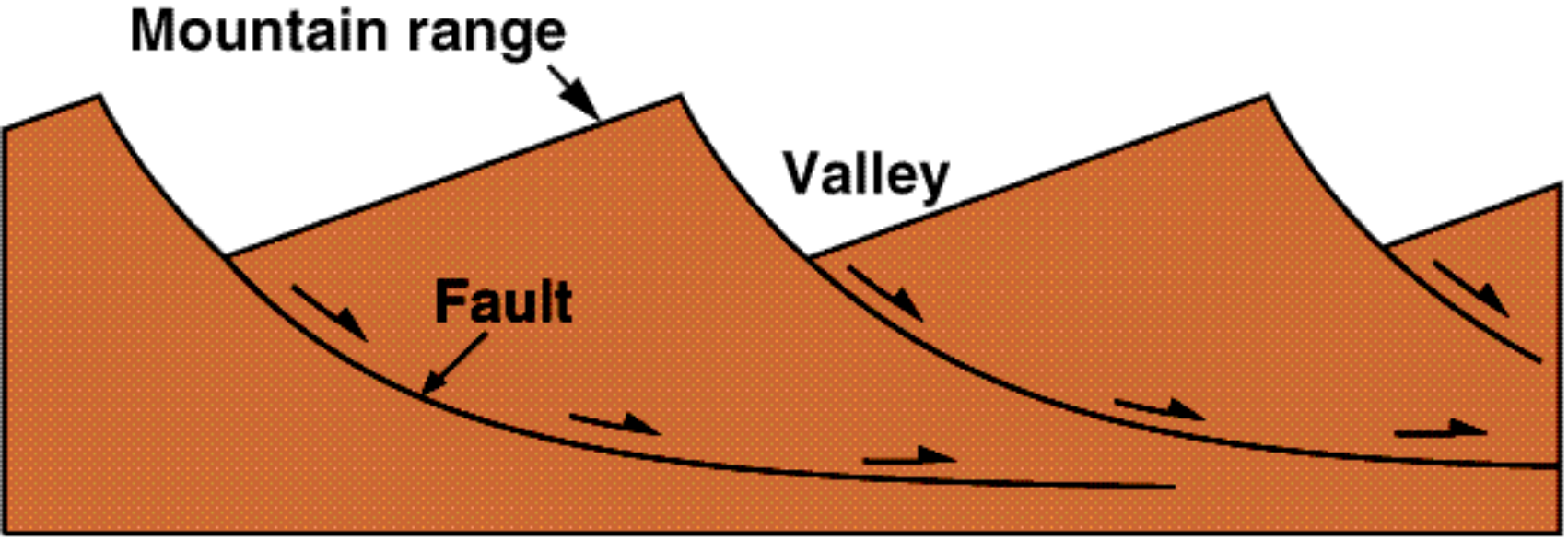
As mountain front retreats, erosion produces pediment with thin cover of alluvial deposits



(c)

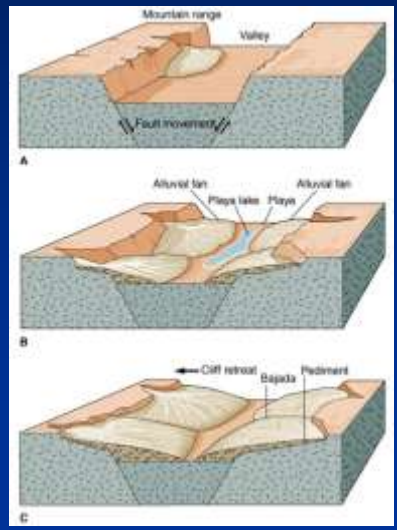
Origins of Mountains and Valleys



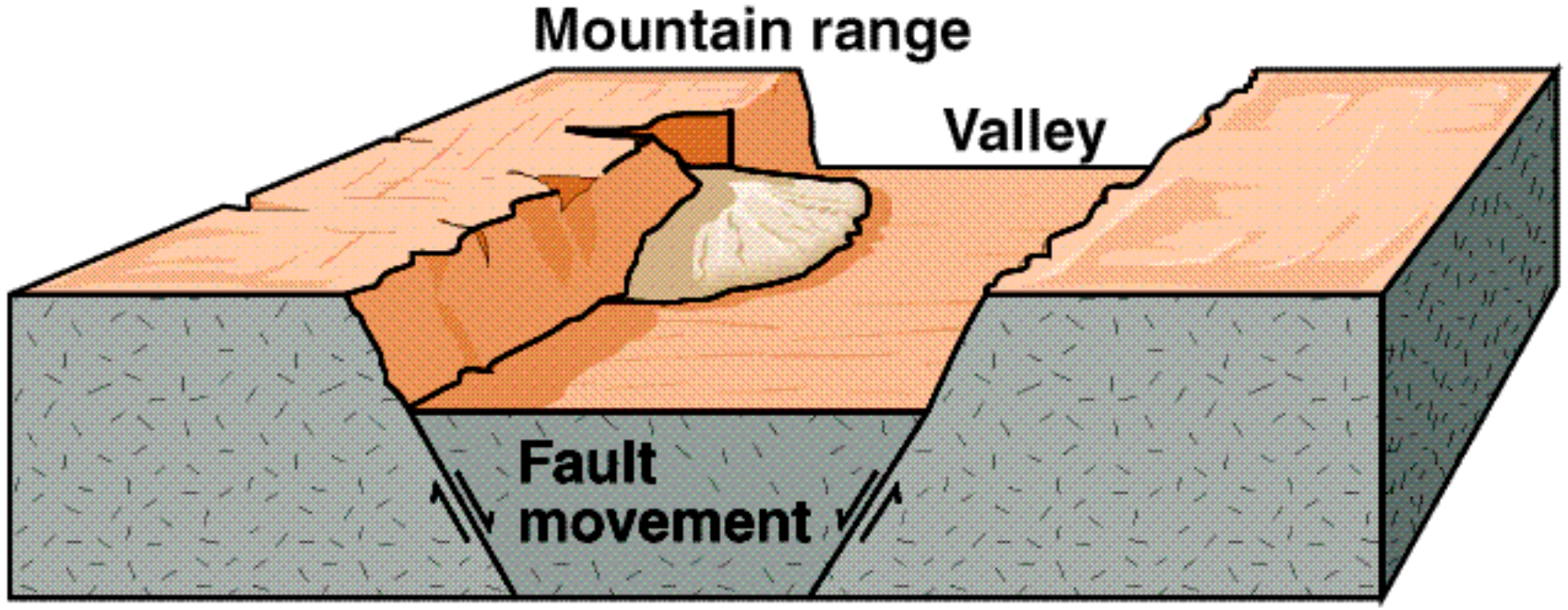


Desert Landforms of the Southwestern United States

- Basin and Range province has rugged, linear, *fault*-bounded mountain ranges separated by flat valley floors
- Steep mountain ranges erode to form narrow canyons that carry much sediment down to desert valley floors during heavy rains
  - Sediment gets deposited into *alluvial fans*, sloping piles that fan outward from the mouths of mountain canyons
  - Alluvial fans may overlap to form a bajada
  - Finest sediments travel to center of basin where water ponds and evaporates in *playas*

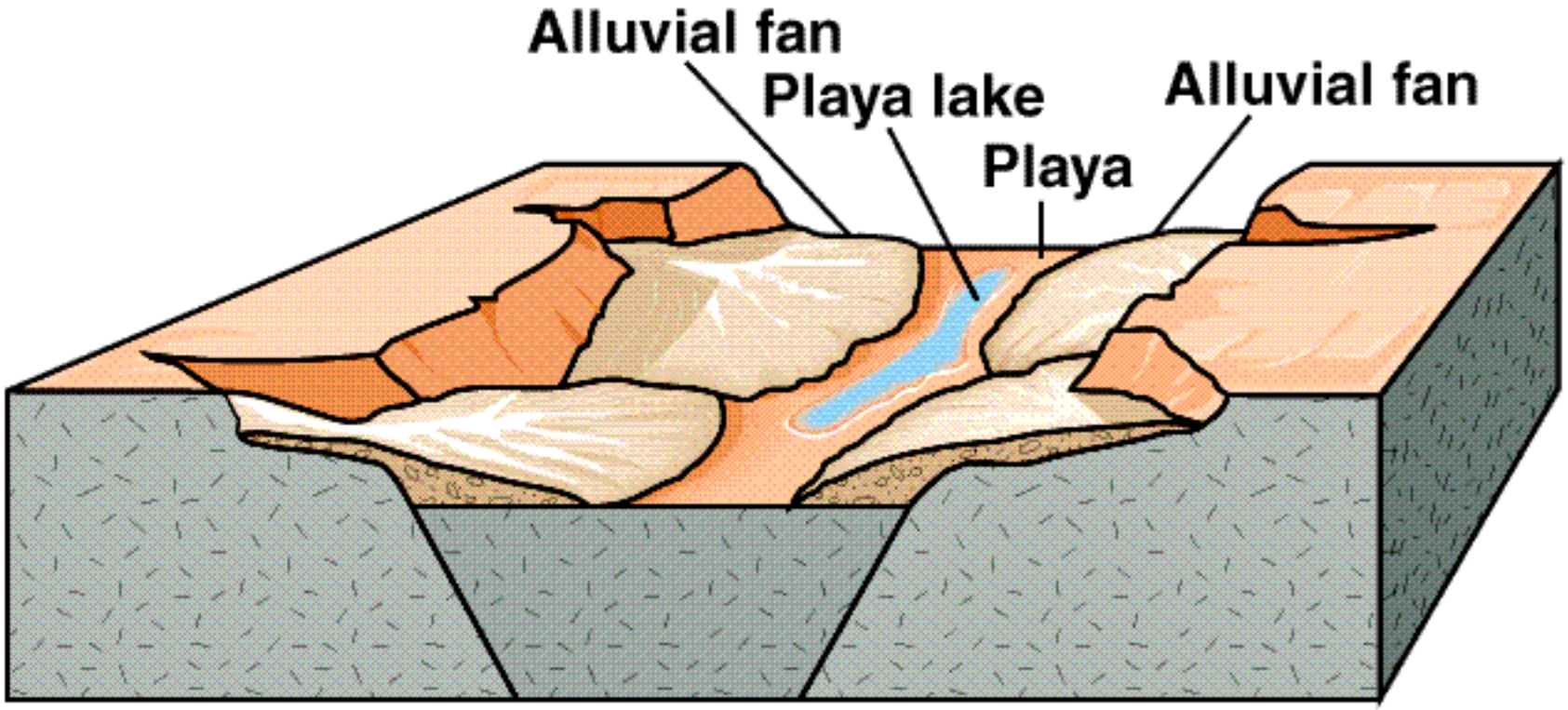


Basin and Range Topography



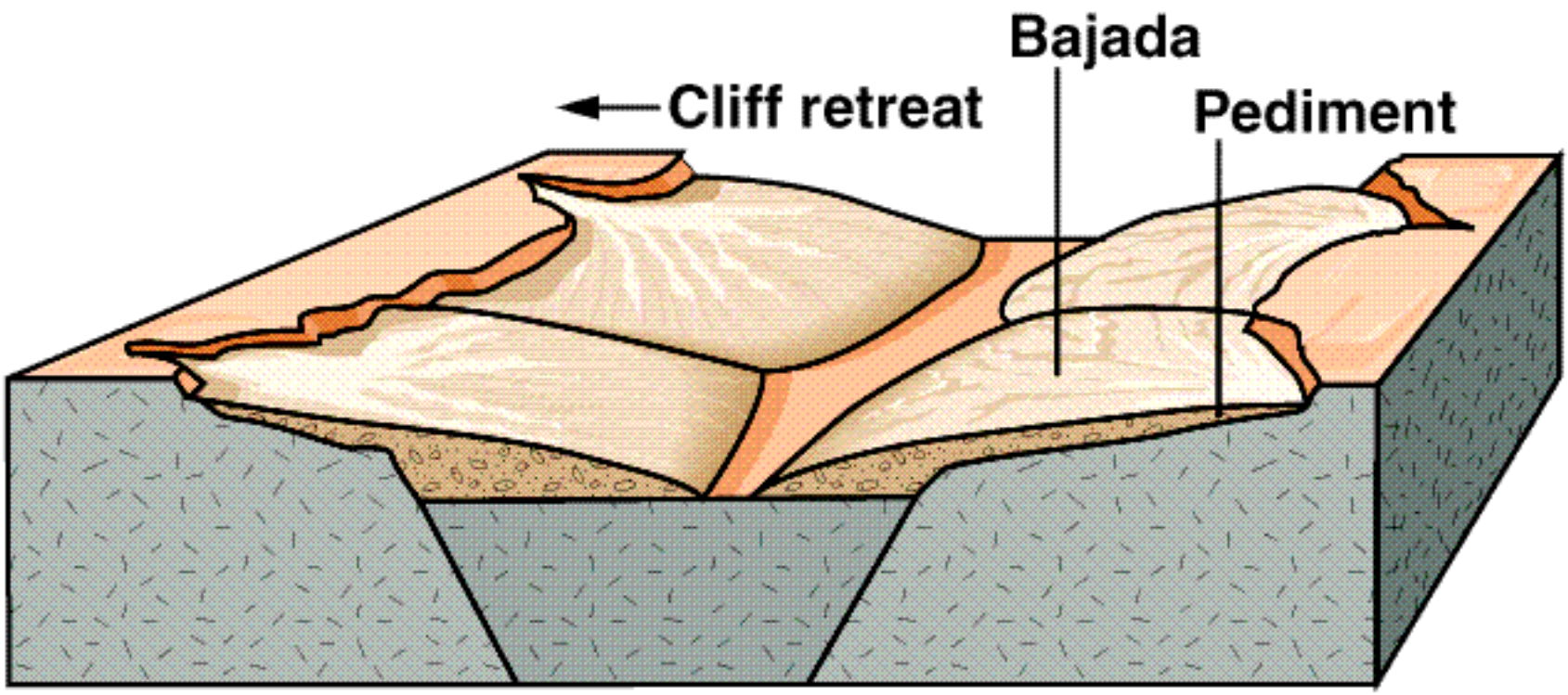
A

Basin and Range Topography



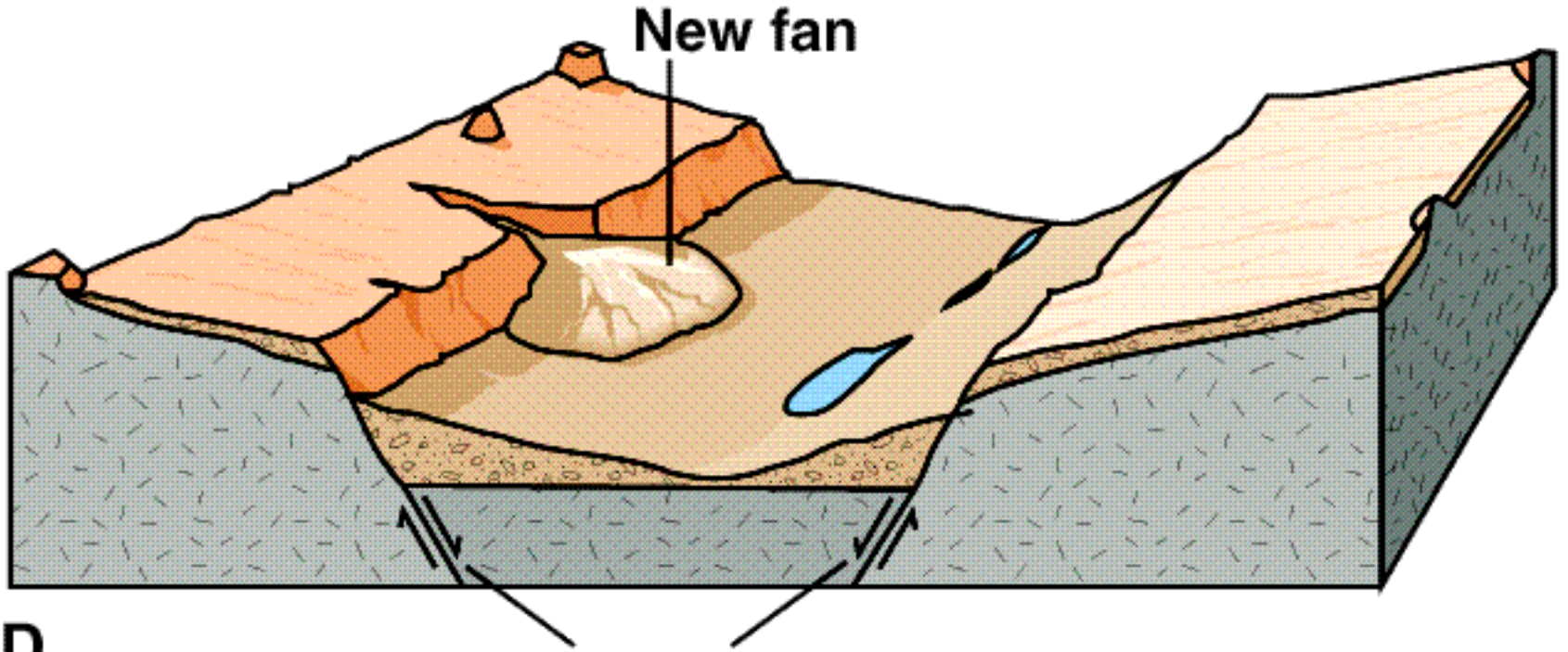
B

Basin and Range Topography



C

Basin and Range Topography

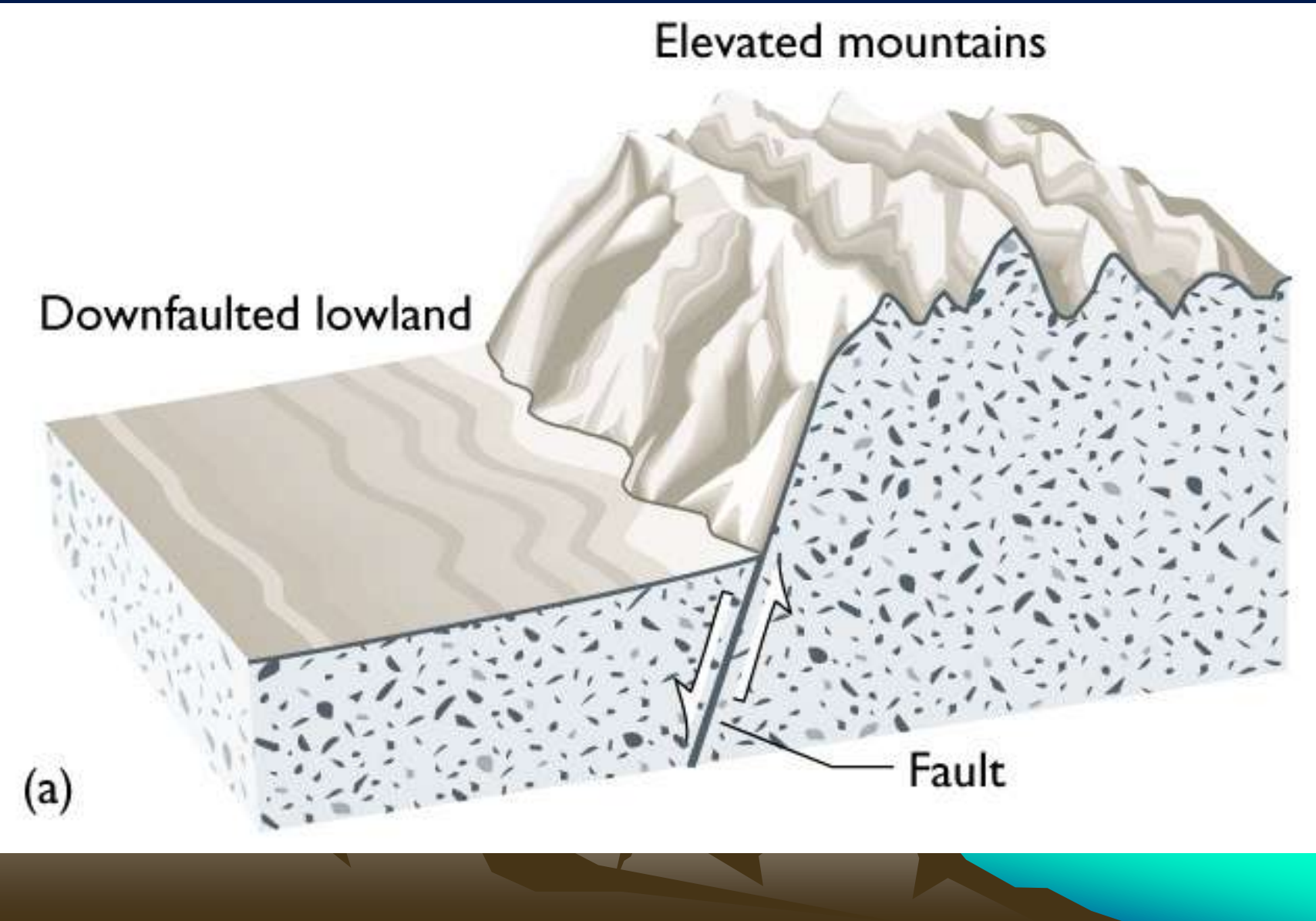


D

Renewed fault movement can allow thick sediment sequence to fill valley

Basin and Range Topography

Southwestern U.S. Desert


Elevated mountains
Downfaulted lowland
Fault
(a)

Sites Where Wind-Blown Material Is Deposited

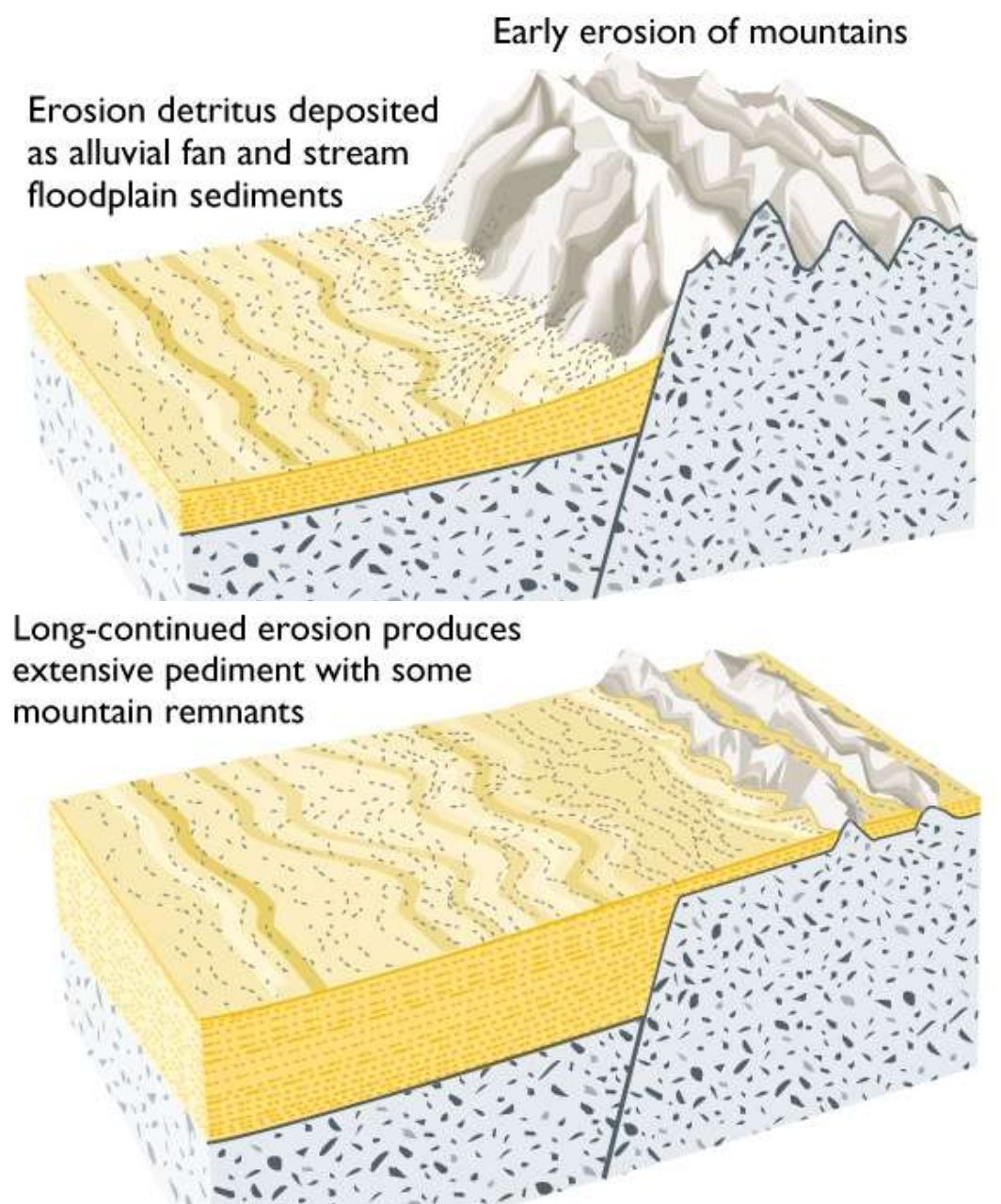
Sand Dunes

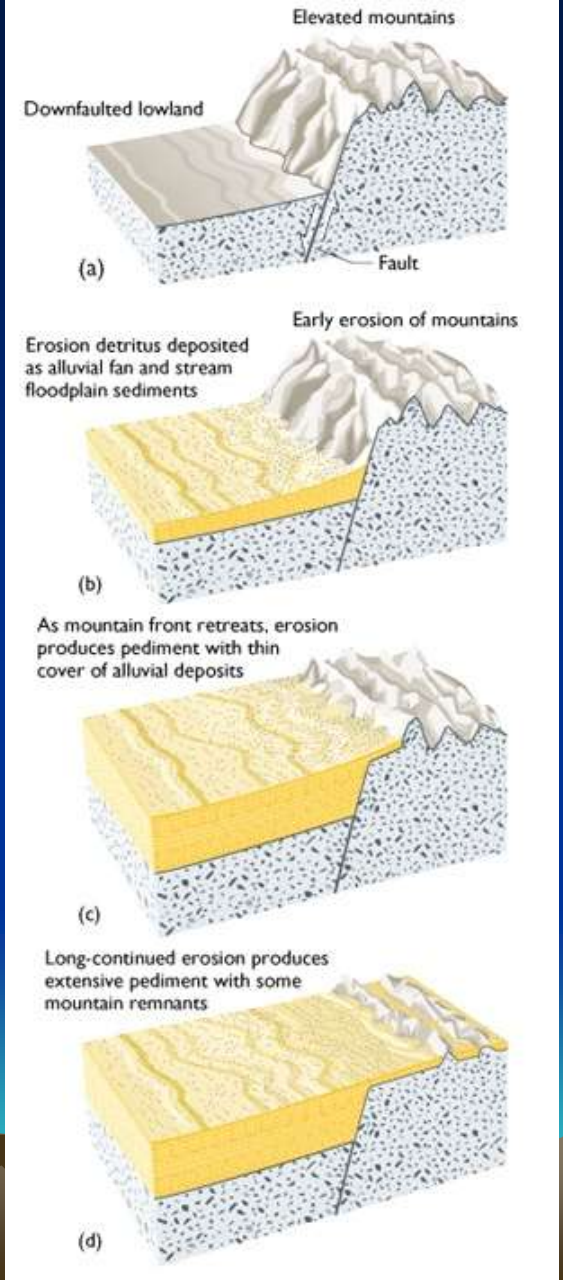
13.02.c

Loess: Windblown Silt

Erosion / deposition

- Formation of *pediments* (erosional surface across bedrock or older gravels) & valley fill (alluvial fans to playas)




Elevated mountains
Downfaulted lowland
Fault
(a)
Early erosion of mountains
Erosion detritus deposited as alluvial fan and stream floodplain sediments
(b)
As mountain front retreats, erosion produces pediment with thin cover of alluvial deposits
(c)
Long-continued erosion produces extensive pediment with some mountain remnants
(d)

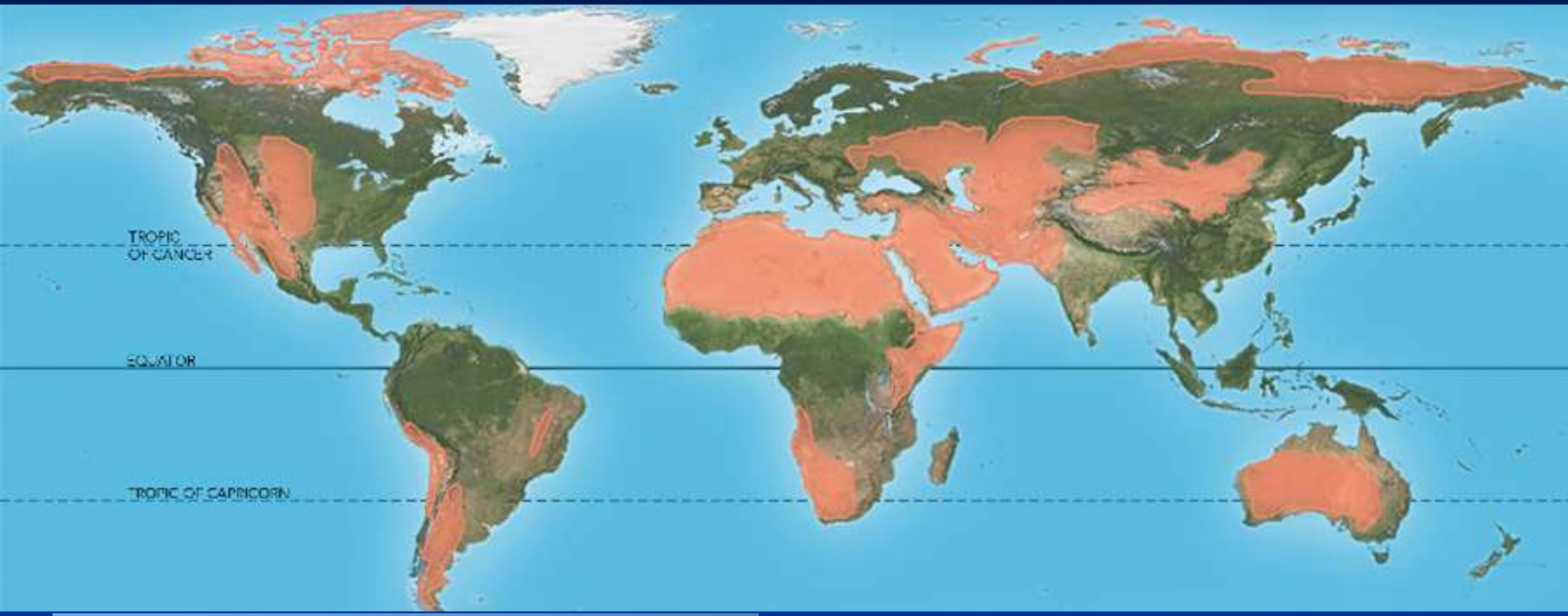
Inselberg

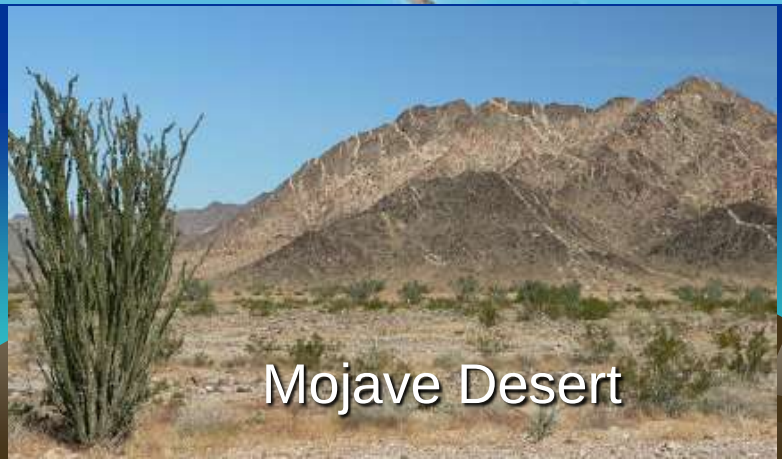
= island of rock in sea of sand

is German for "island mountain"

: A **monadnock** or **inselberg** is an isolated hill, knob, ridge, or small mountain that rises abruptly from a gently sloping or virtually level surrounding plain. In southern Africa a similar formation of granite boulders is known as a **koppie** or **kopje** (from Dutch/Afrikaans).

Observe locations of deserts and other arid lands




Mojave Desert

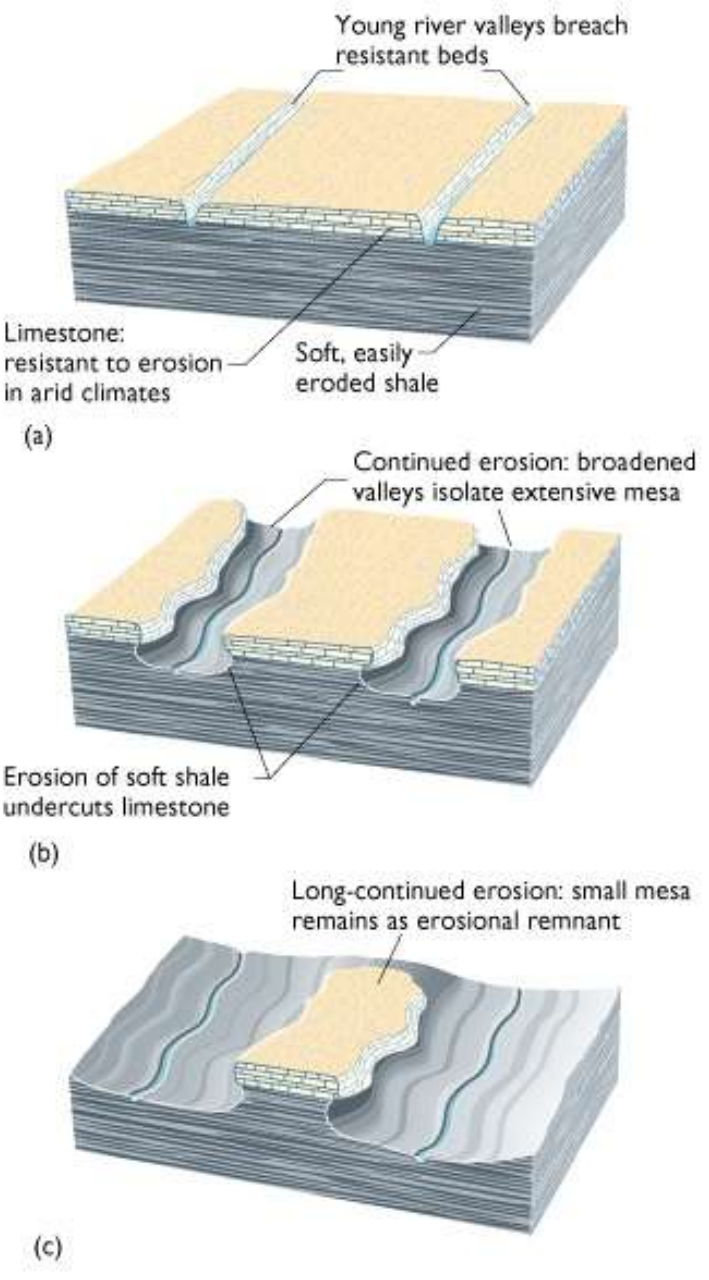

Sonoran Desert

13.08.a

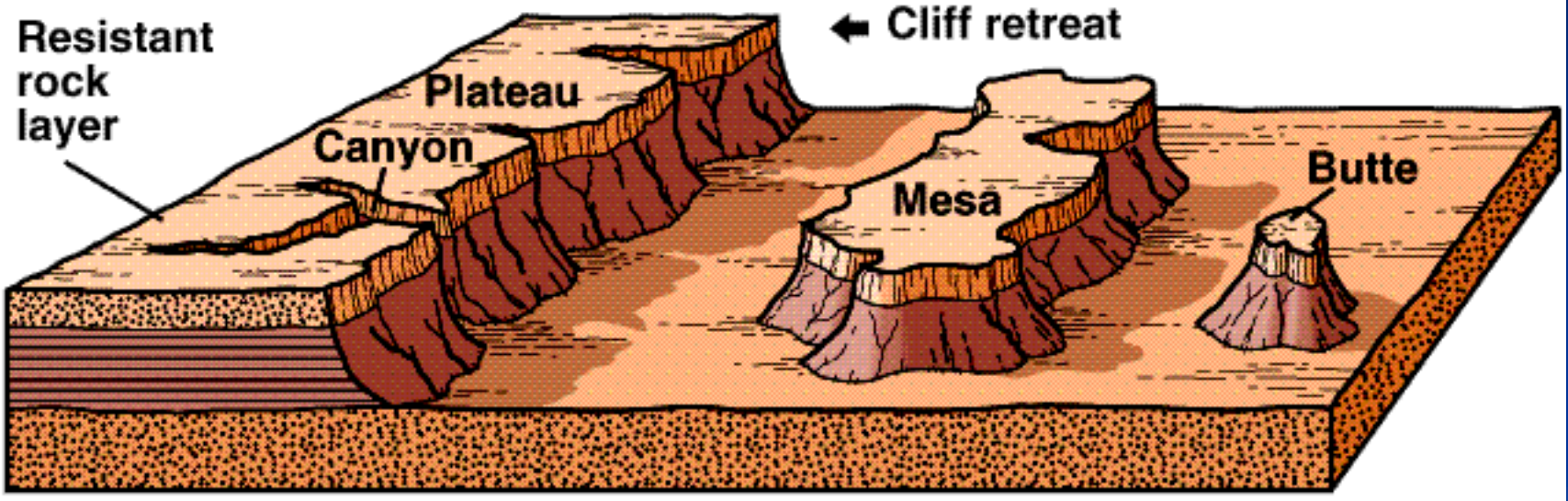
Trekkopje, Namibia

Landscape development

- Erosional features
  - mesas / plateaus
  - pediments
- Depositional features
  - alluvial fans
  - playas (dry lakes)



Erosional Retreat of a Cliff



A

Mesas and Buttes in Arizona Desert

Erosion by wind — deflation / sandblasting

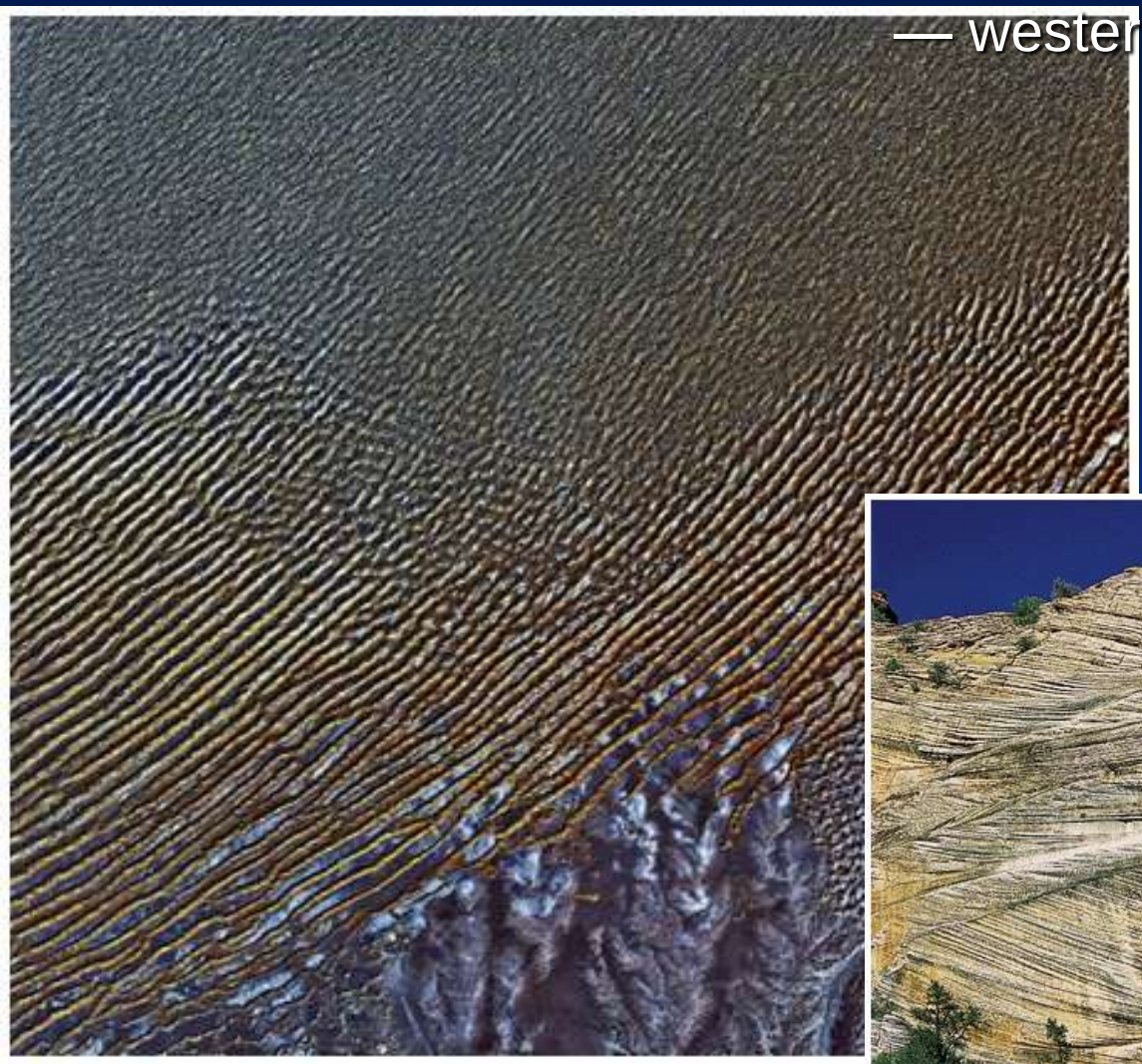
Bedrock erosion — yardangs

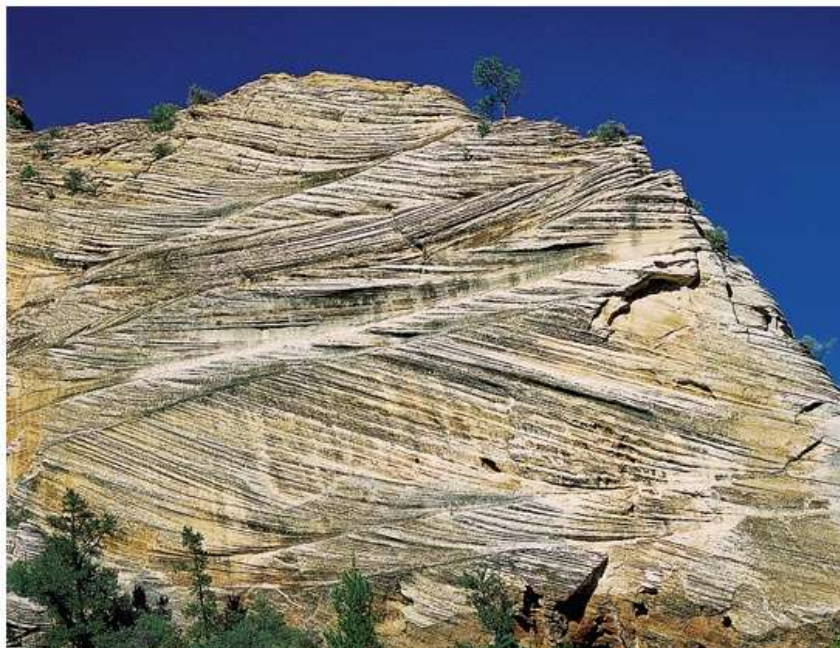
Depositional features (wind)

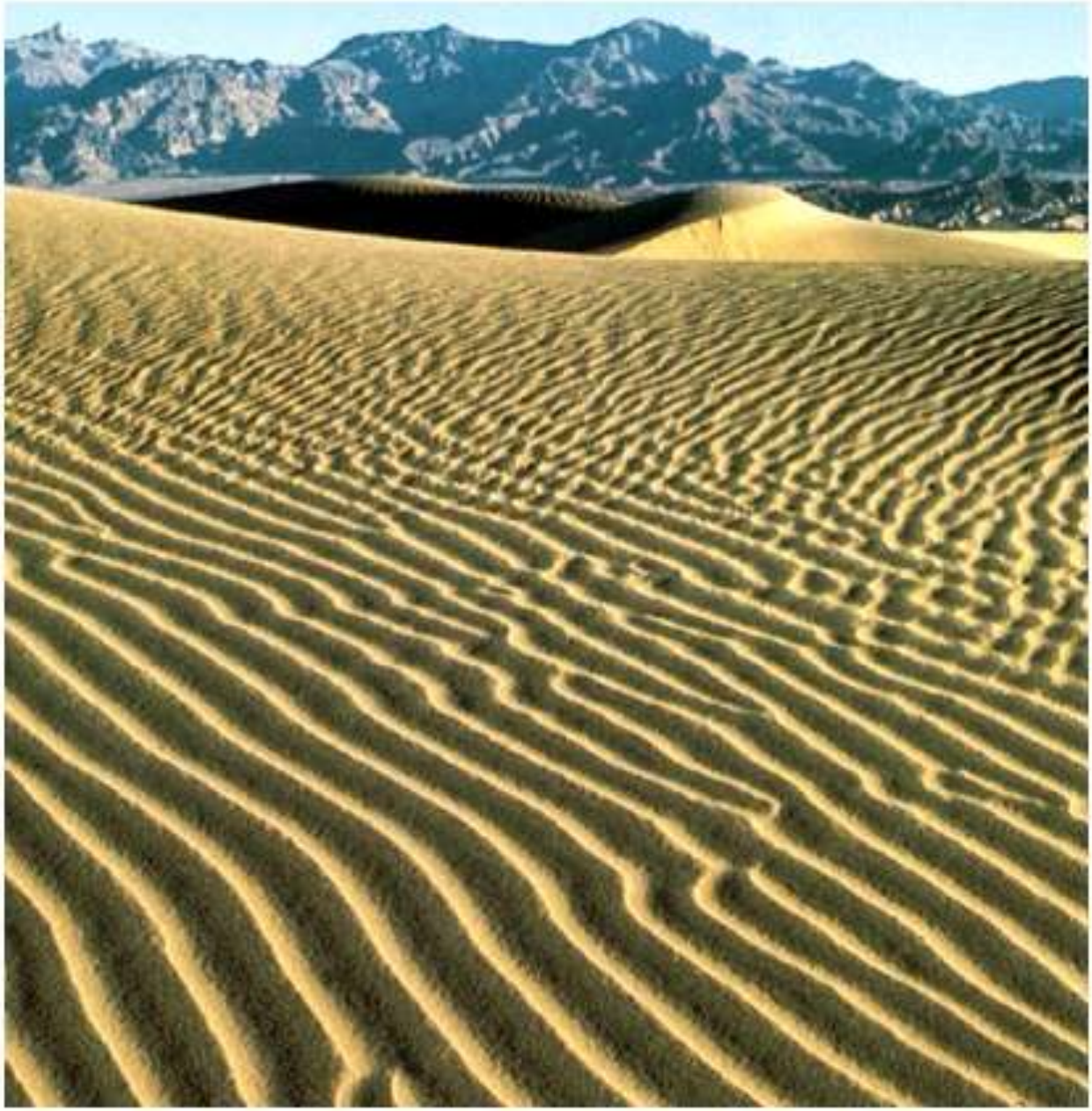
- Sand — dunes, ergs (= sand seas)
- Silt/dust — loess
- Wind-related features in non-deserts
  - Coastal dunes
- Contrast water-related features in deserts
  - Alluvial fans
  - Braided streams
  - Playas (dry lakes)
- Not all wind features are in deserts!

Sand seas (“ergs”)

— western US in Jurassic

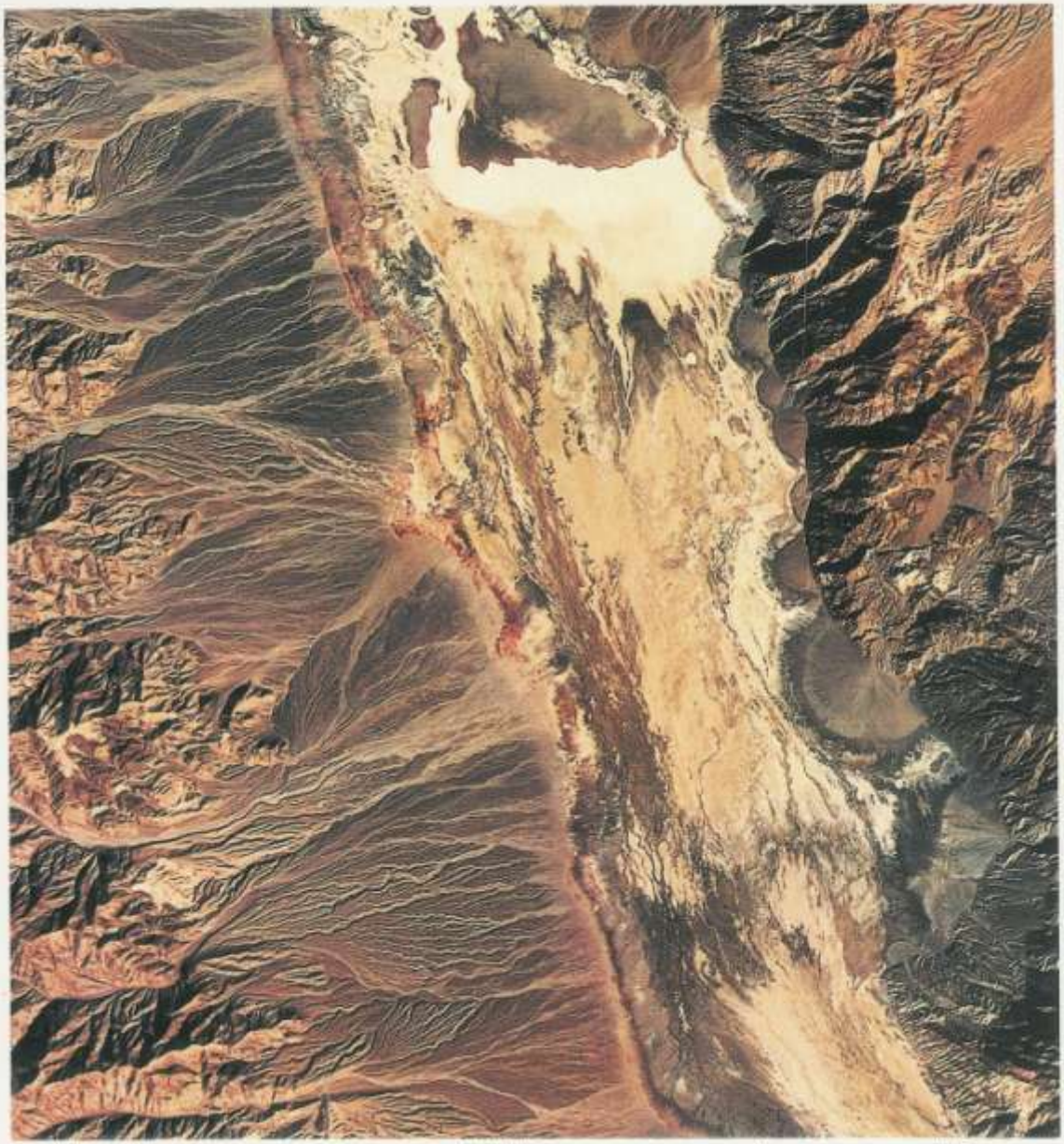






Playas — dry lakes and evaporites

- Accumulation of dissolved load in closed basins



(Earth Satellite Corporation)

Landsat image

0 30 miles

Significance for water and other issues

- Water qualilty / availability
  - Variable salinity (function of hydrology and history)
- Resources
  - Evaporitic minerals (borax, Li, salt)
  - Sand and aggregate

Badwater area, Death Valley, California