Deserts and Landforms

Source of Sand

Several studies have revealed that the sources of dune sands are complex and diverse.

The sands were derived from local upwind dune field from river sediments weathering materials of underlying rock and beach sands or flat sediments

Wind erosion and transportation

- Wind can erode only finer particles such as clay silt and sand.

- Deserts typically have strong winds which can erode loose dry sediments causing sand storms/dust storms.

Work of Winds

- Erosion by Wind
  - Deflation- wind removes finer particles from the surface
  - Desert pavement- layer of pebbles left behind after deflation
  - Abrasion- sand blasting
  - Ventifacts- wind-shaped stones with sharp-edge faces
  - Yardangs- streamlined desert ridges

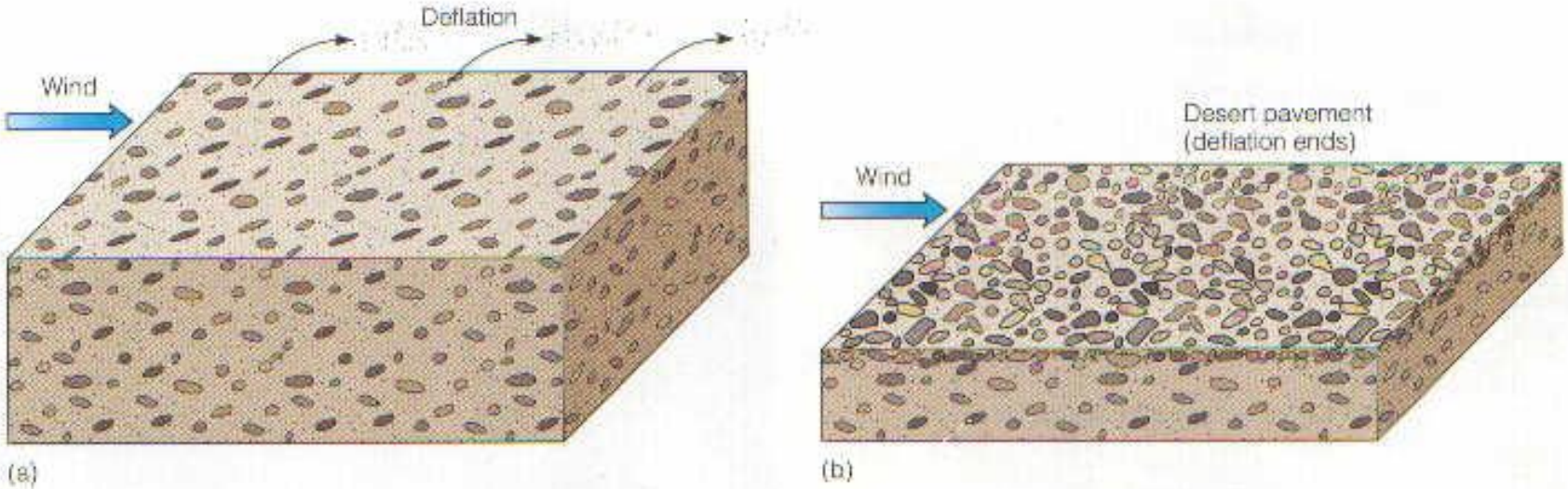
A

U.S. Department of Agriculture, Soil Conservation Service

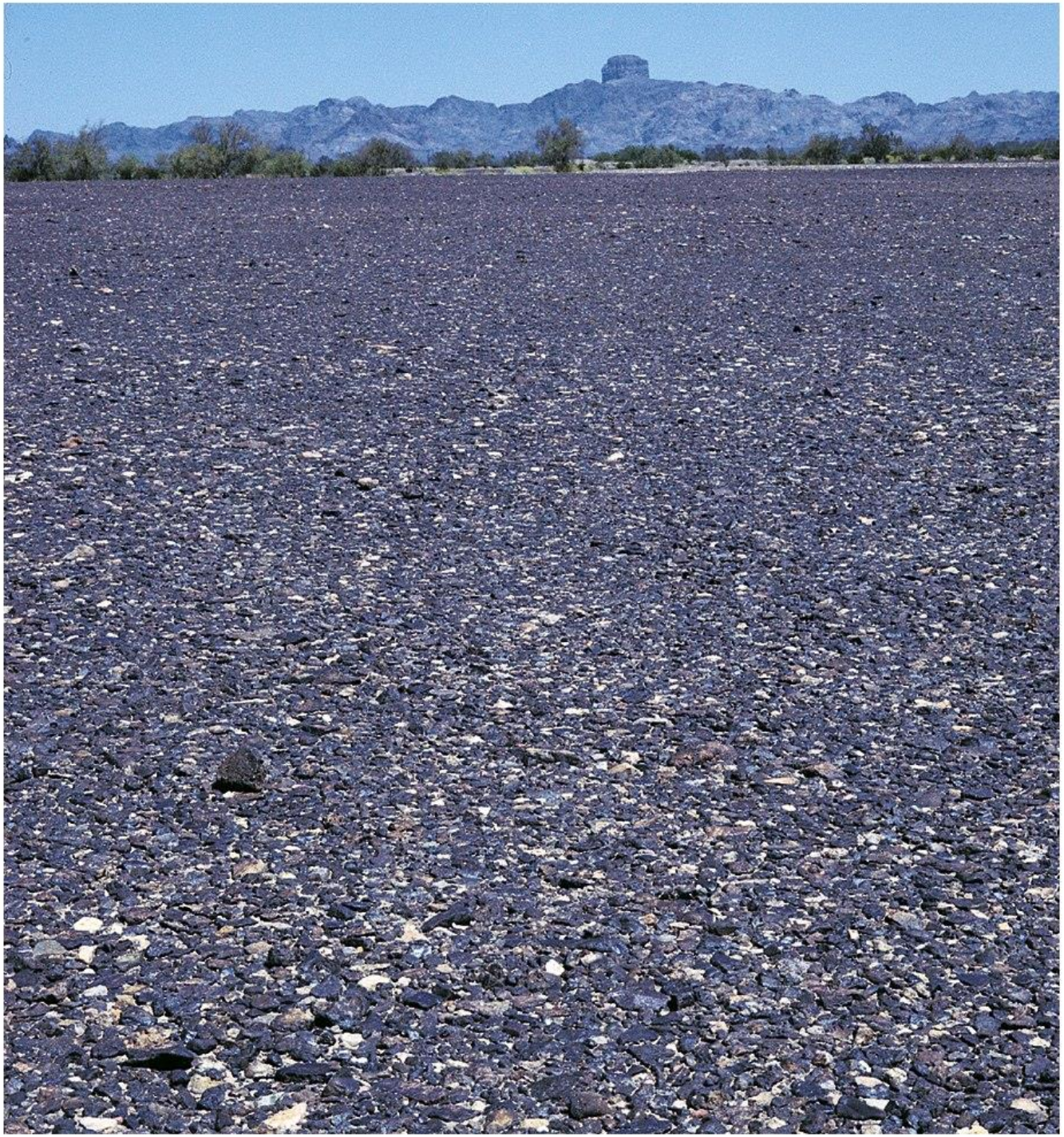
- **Effects of wind action are strong only close to the ground (upto one meter from the ground surface).**

Erosional features

- **Desert pavement: Thin surface layer of closely-packed pebbles.**

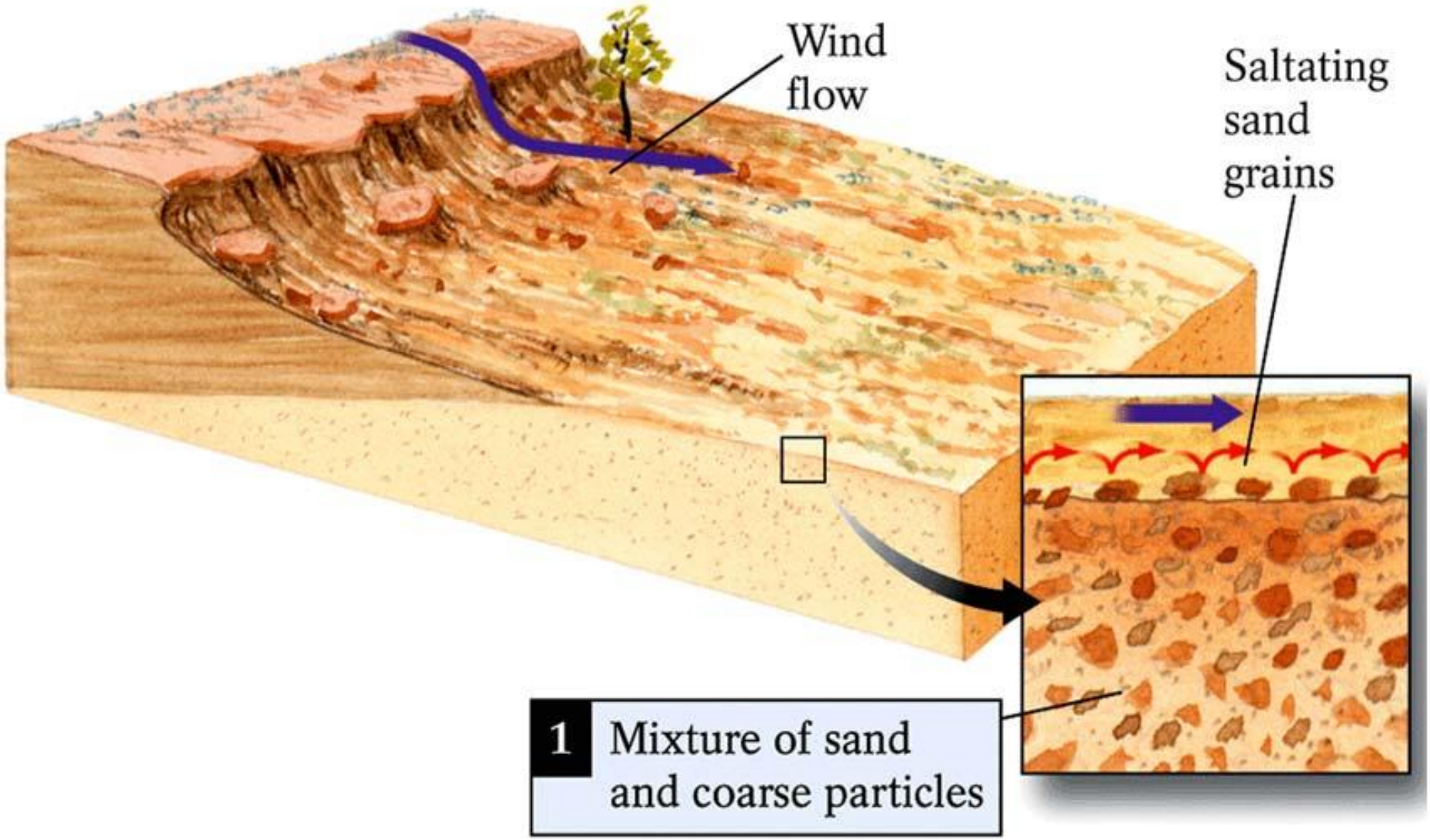


▶ FIGURE 18-8 (*a*) Desert pavement forms when deflation removes fine-grained material from the ground surface leaving larger-sized particles. (*b*) As deflation continues and more material is removed, the larger particles are concentrated and form a desert pavement, which protects the underlying material from additional deflation.

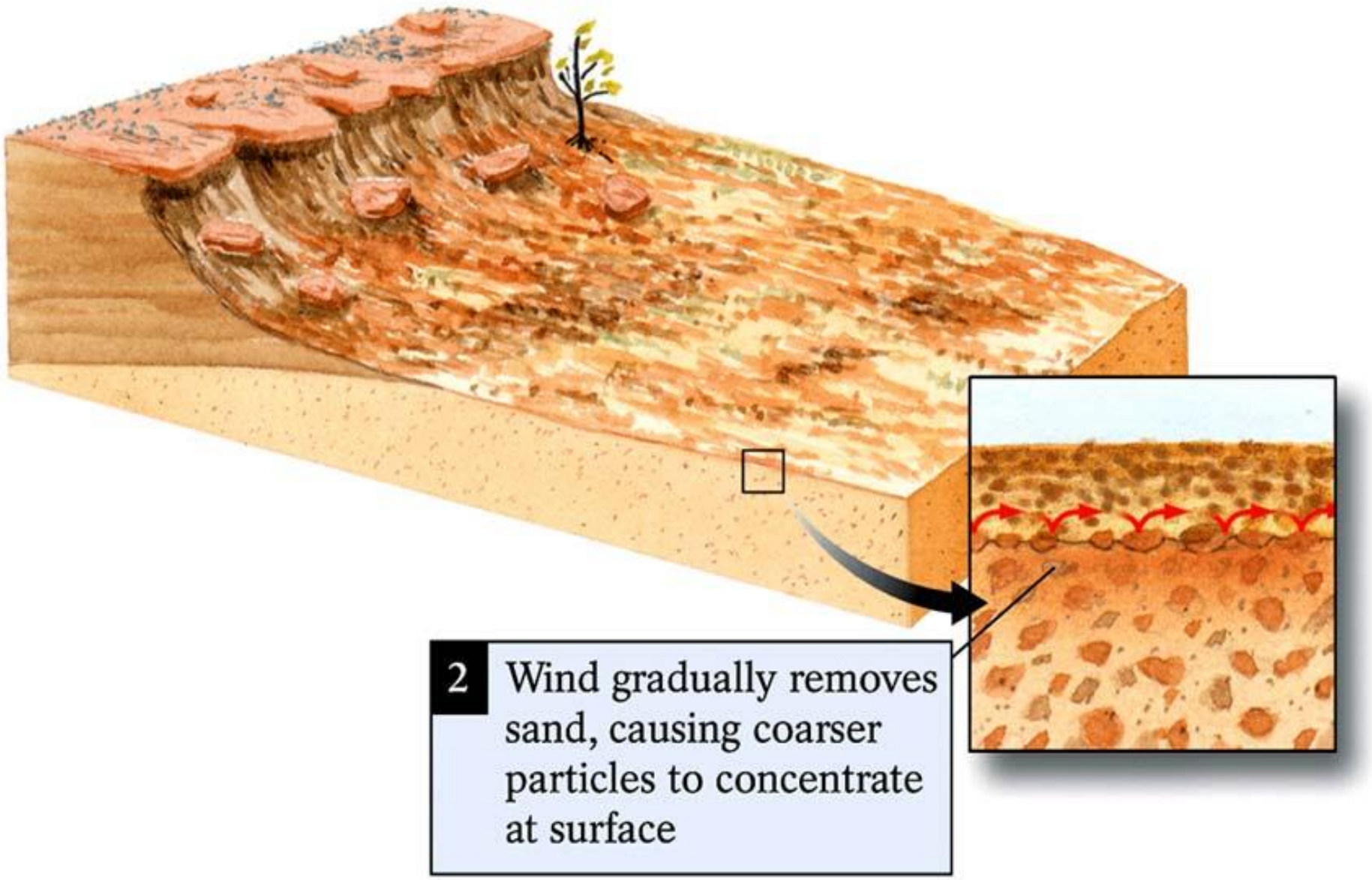


Desert Pavement in the Sonoran Desert, Arizona

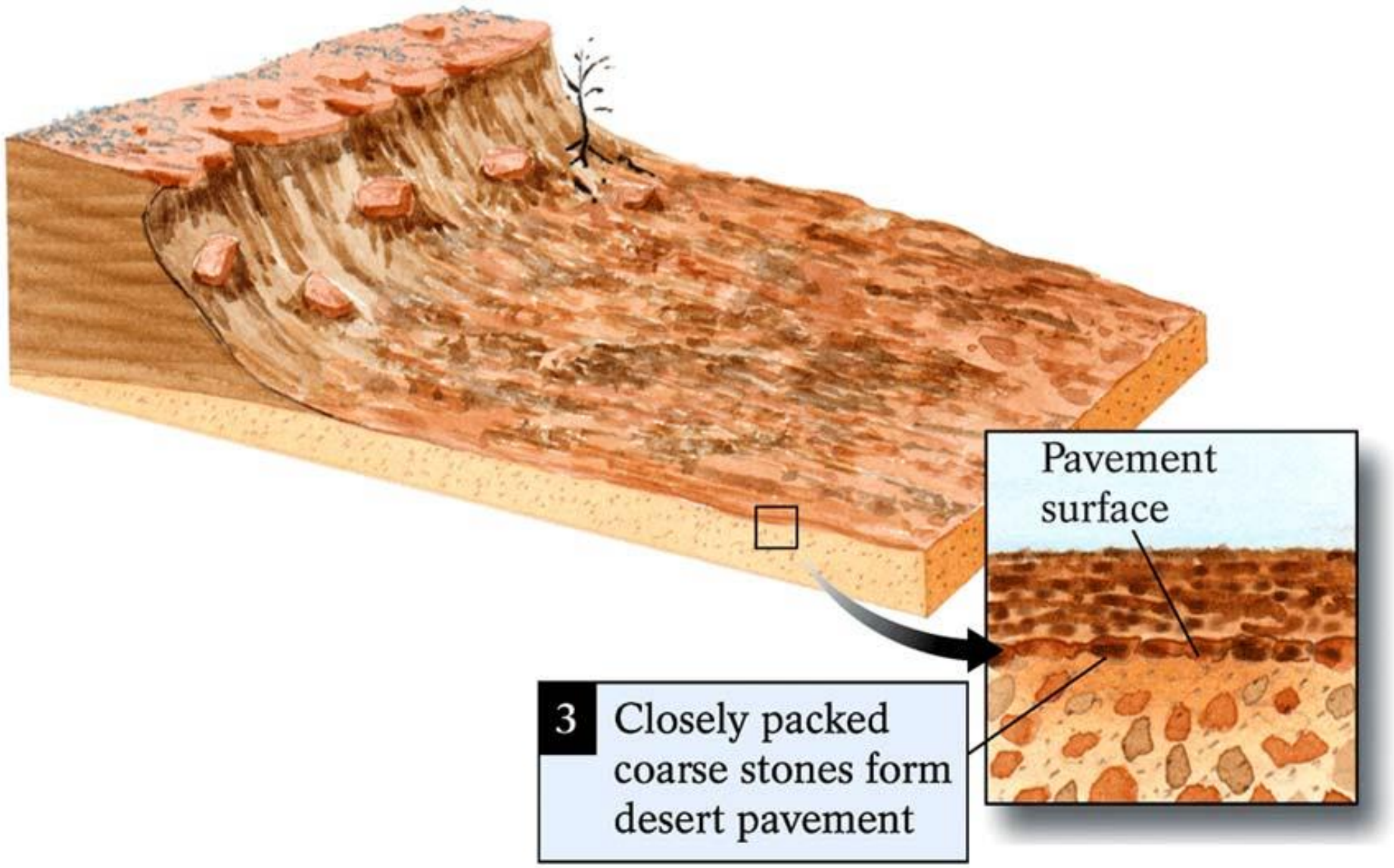
Desert Pavements



Desert Pavements (cont'd)



Desert Pavements (cont'd)

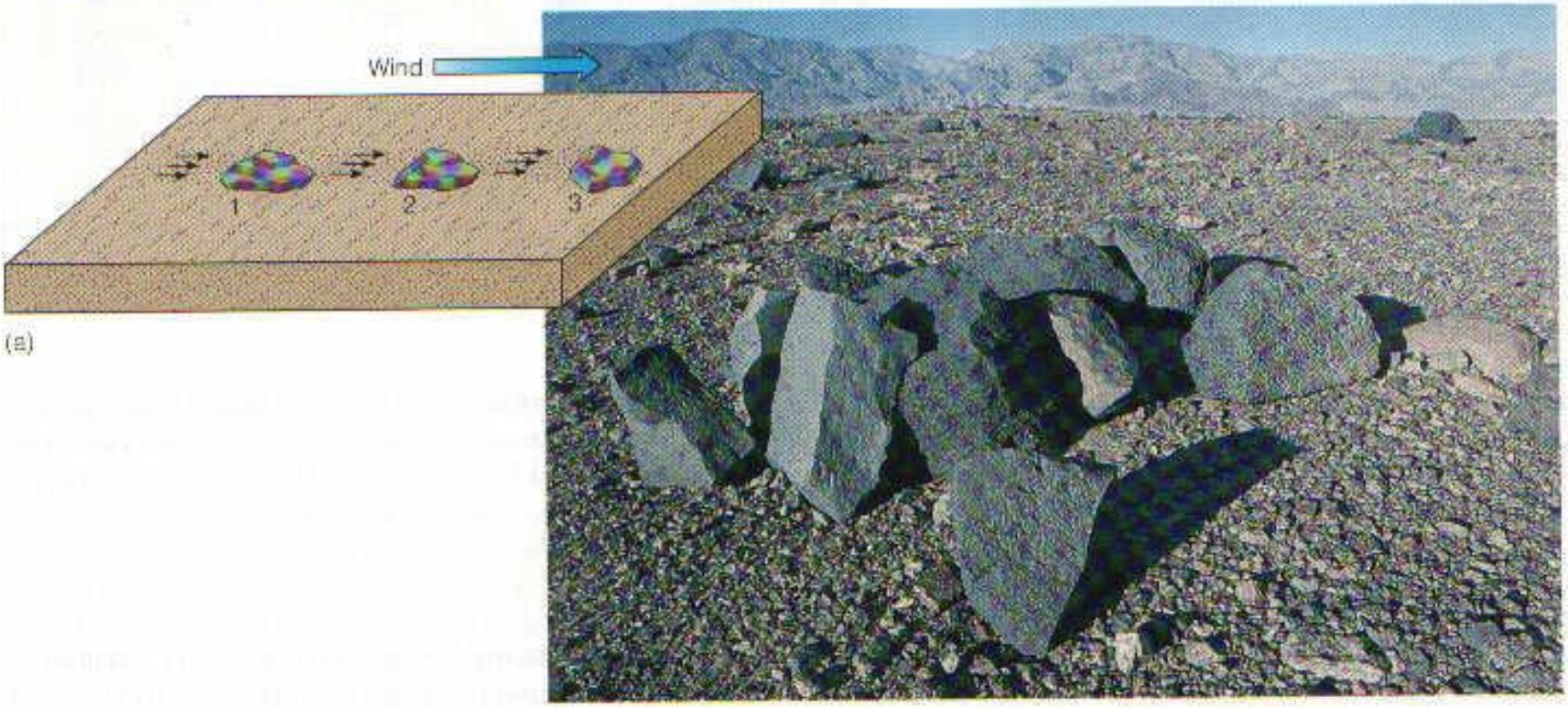


Desert Pavements (cont'd) –

These make good landing strips

Source: Martin Miller

- Ventifacts: Rock fragments with flat, wind-abraded surfaces.

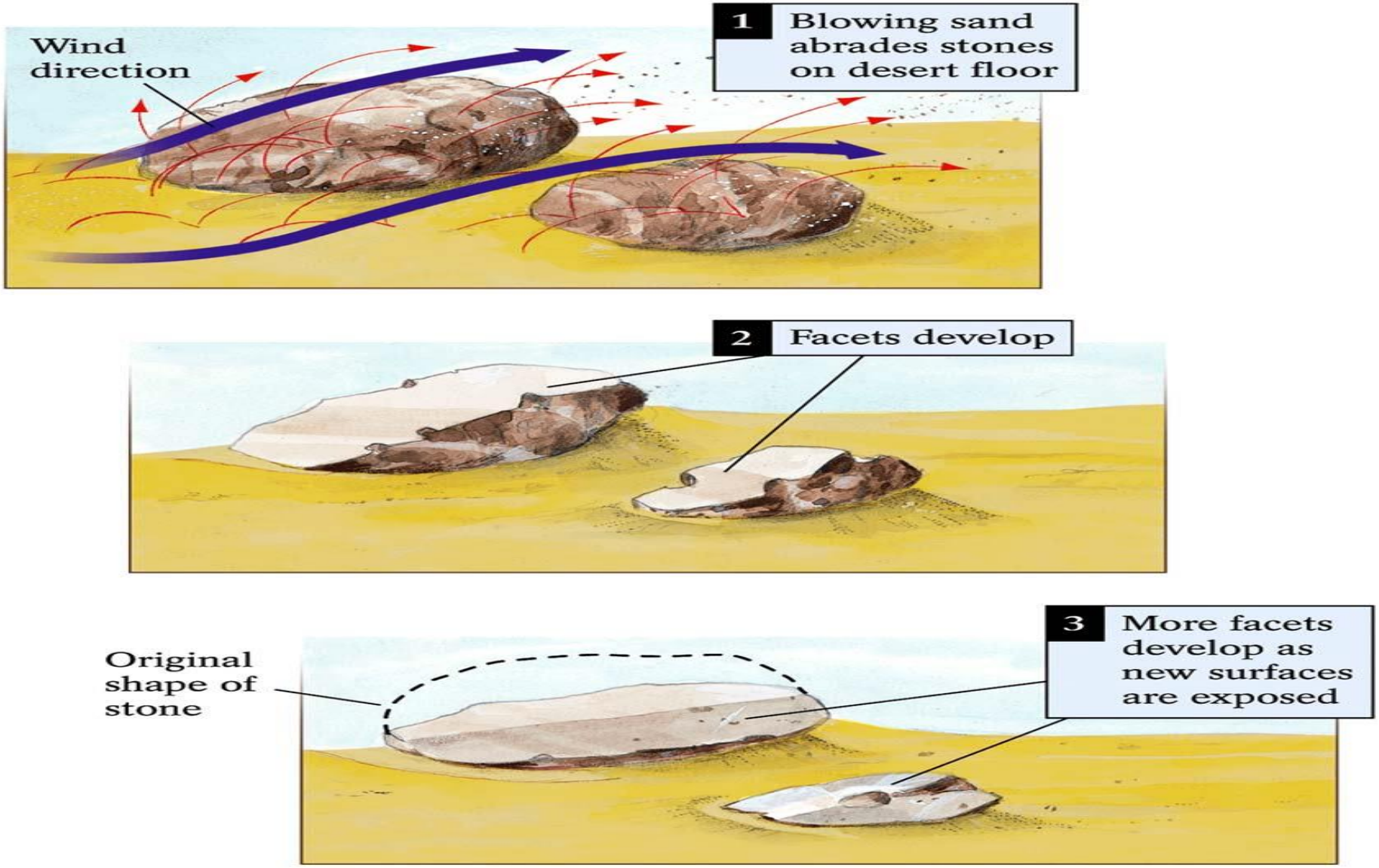


(a)

(b)

Photo by David McGeary

Origin of Ventifacts

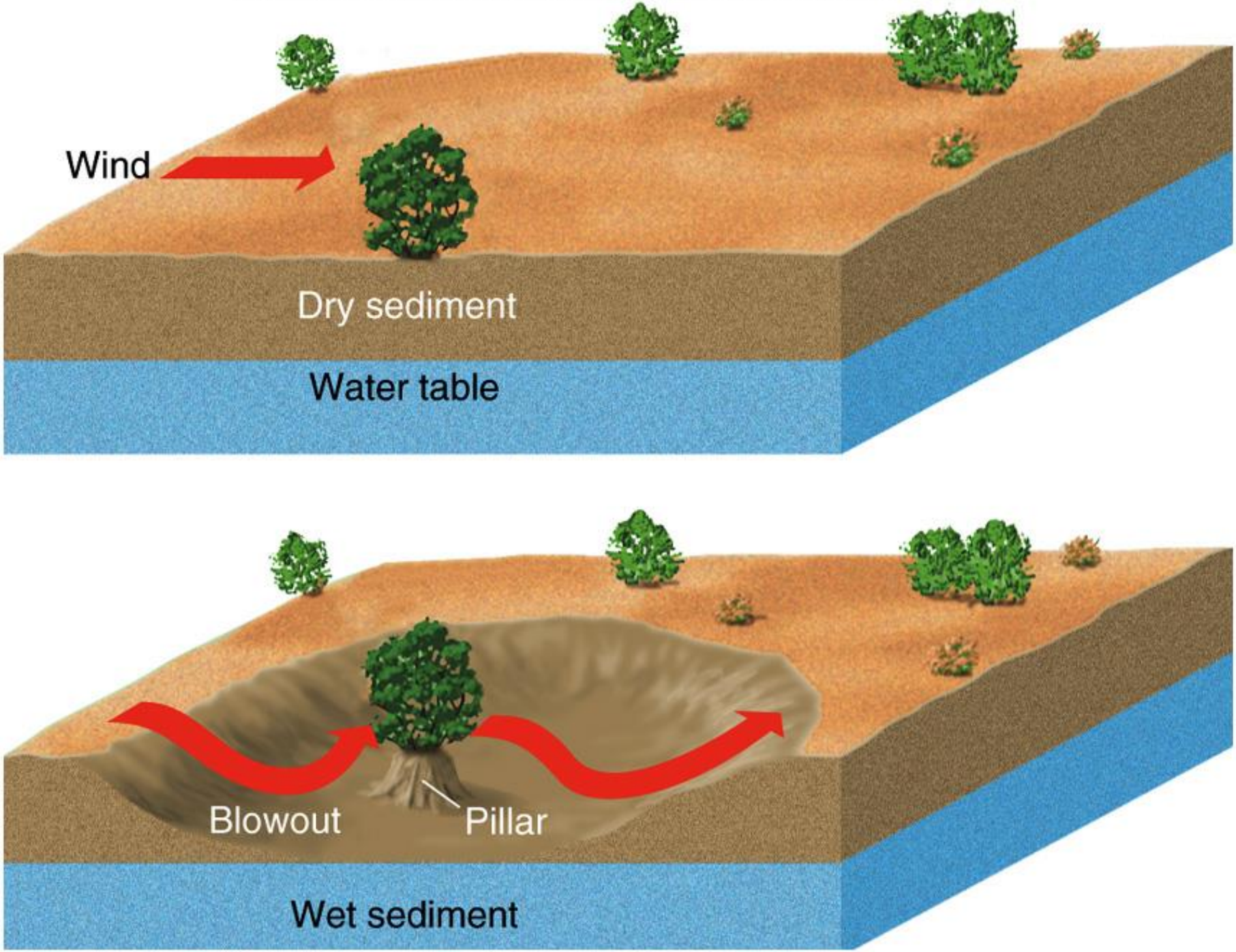


Origin of Ventifacts (cont'd)

Wind

Yardangs , White Desert, Egypt

- Blowout: Depression on the land surface caused by wind erosion.

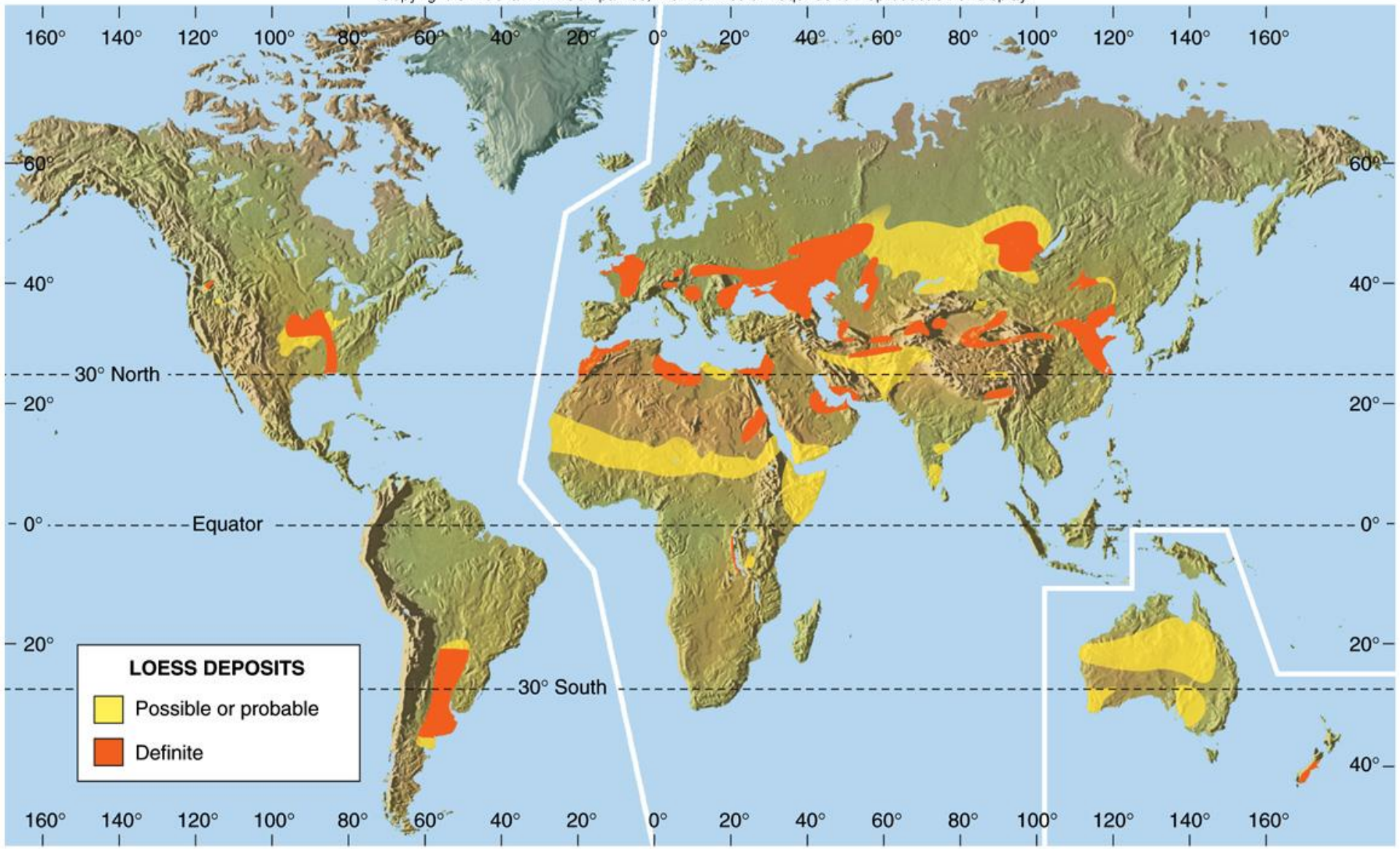


Blowout Caused by Deflation

Wind Deposition

- Loess
- Sand dunes

- **Loess: deposit of wind-blown silt and clay consisting of quartz, feldspar and clay minerals.**
- **Weakly cemented by calcite.**
- **A desert or glacial outwash is needed as source material.**



Sand dunes

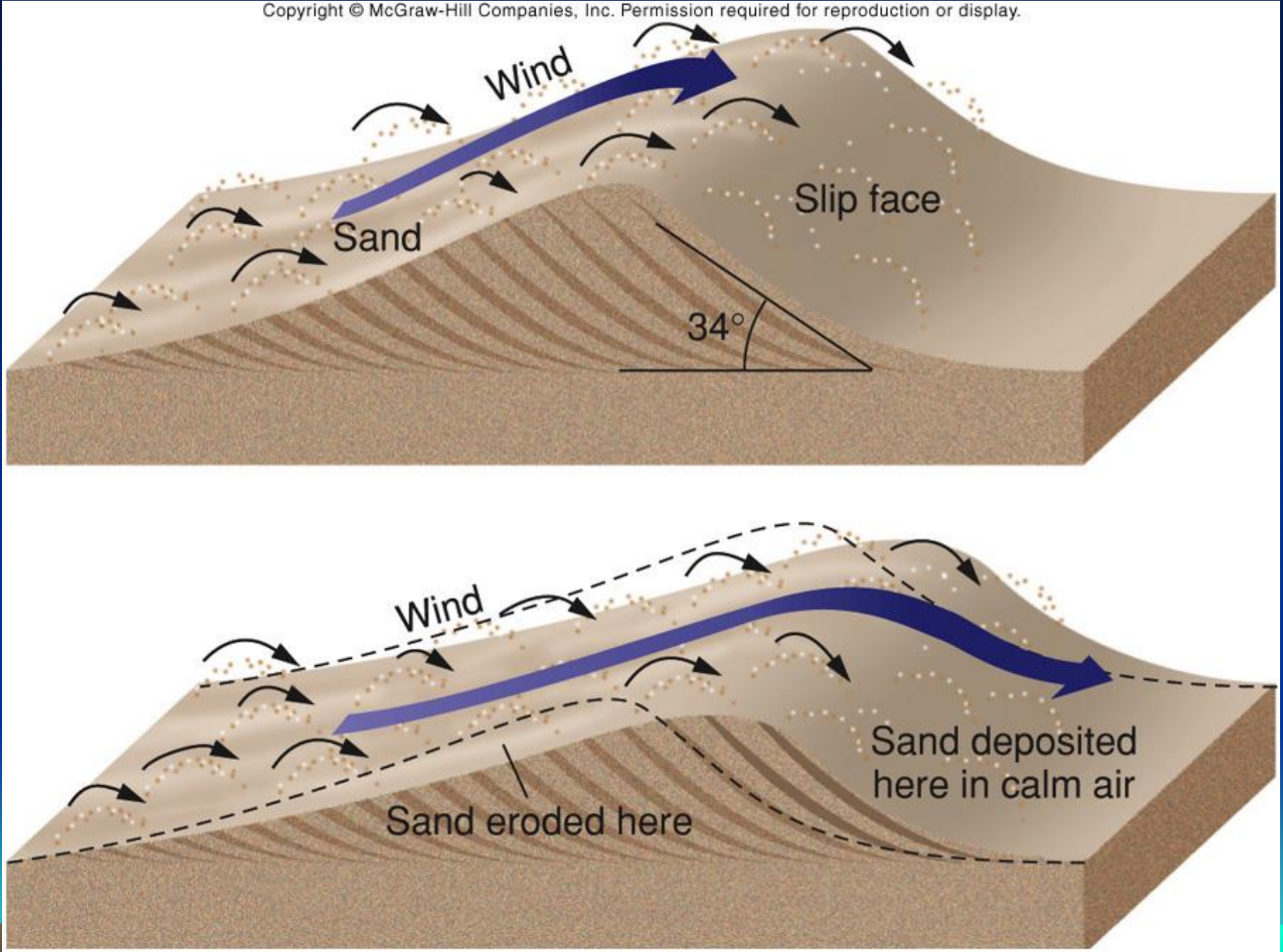
- Mounds of loose sand grains heaped up by the wind.
- Composition of sand depends on;
  - Sand source
  - Chemical weathering
- Quartz, feldspar and calcite are generally more abundant.
- Well sorted and rounded.

B

Photo by David McGeary

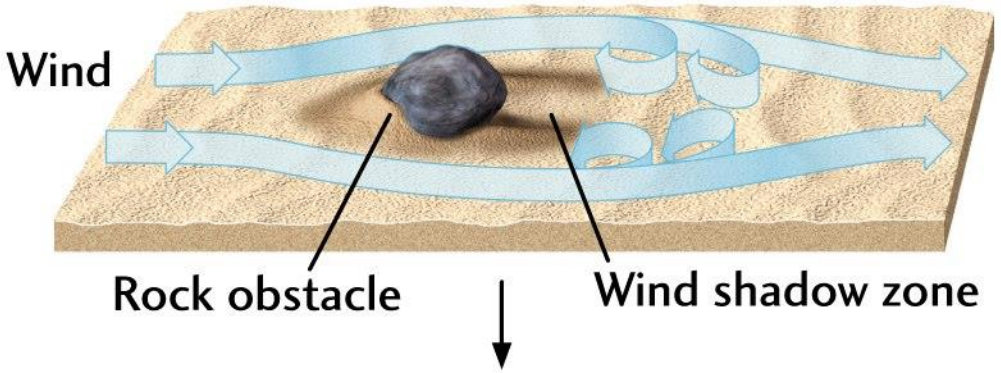
How a dune forms?

- A sand dune forms with a gentle upwind slope and a steeper slip face on the downwind side.
- Sand eroded from the upwind side is deposited on the slip face, forming cross-beds.

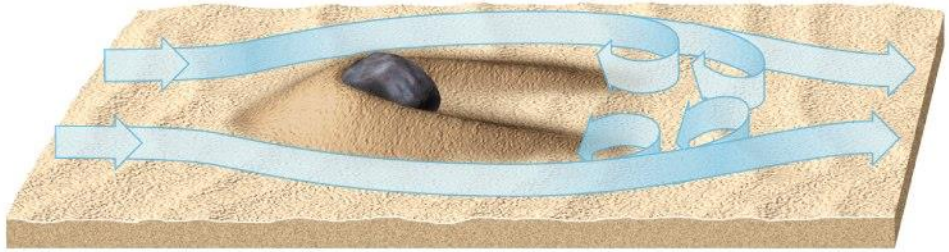


A

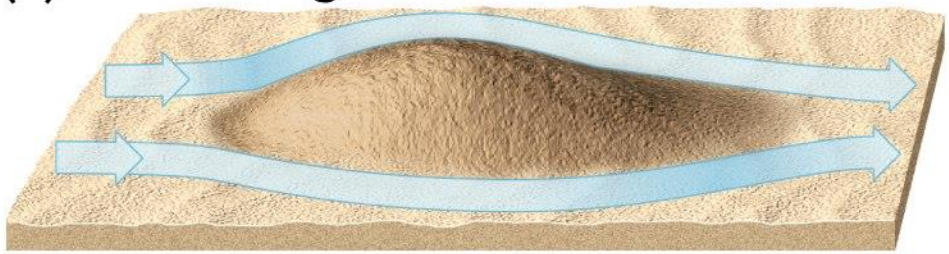
(a) Early stage: small sand drifts form in wind shadow



(b) Middle stage: large but separated drifts form in wind shadow



(c) Final stage: drifts coalesce into dune

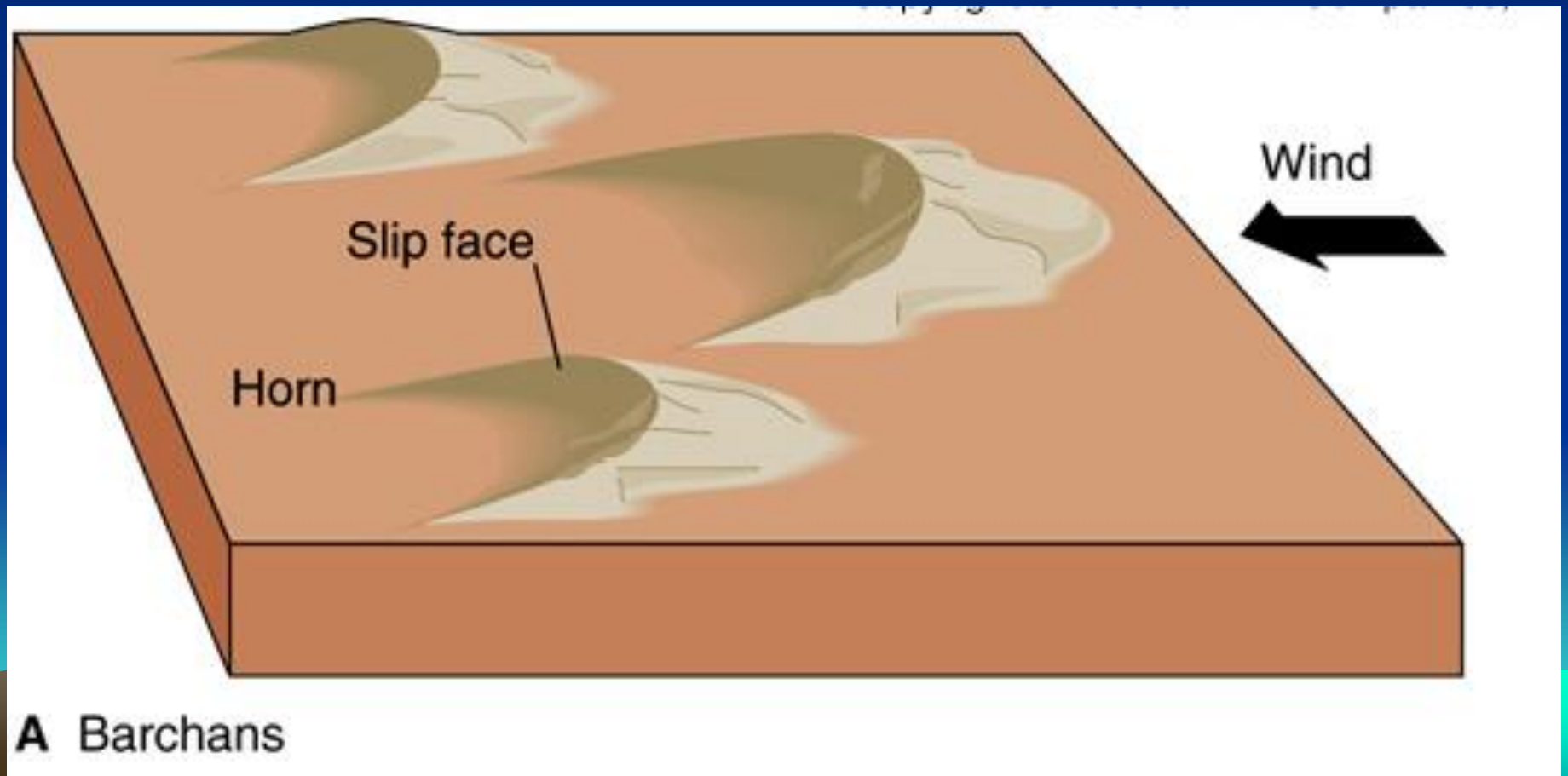


Types of Dunes

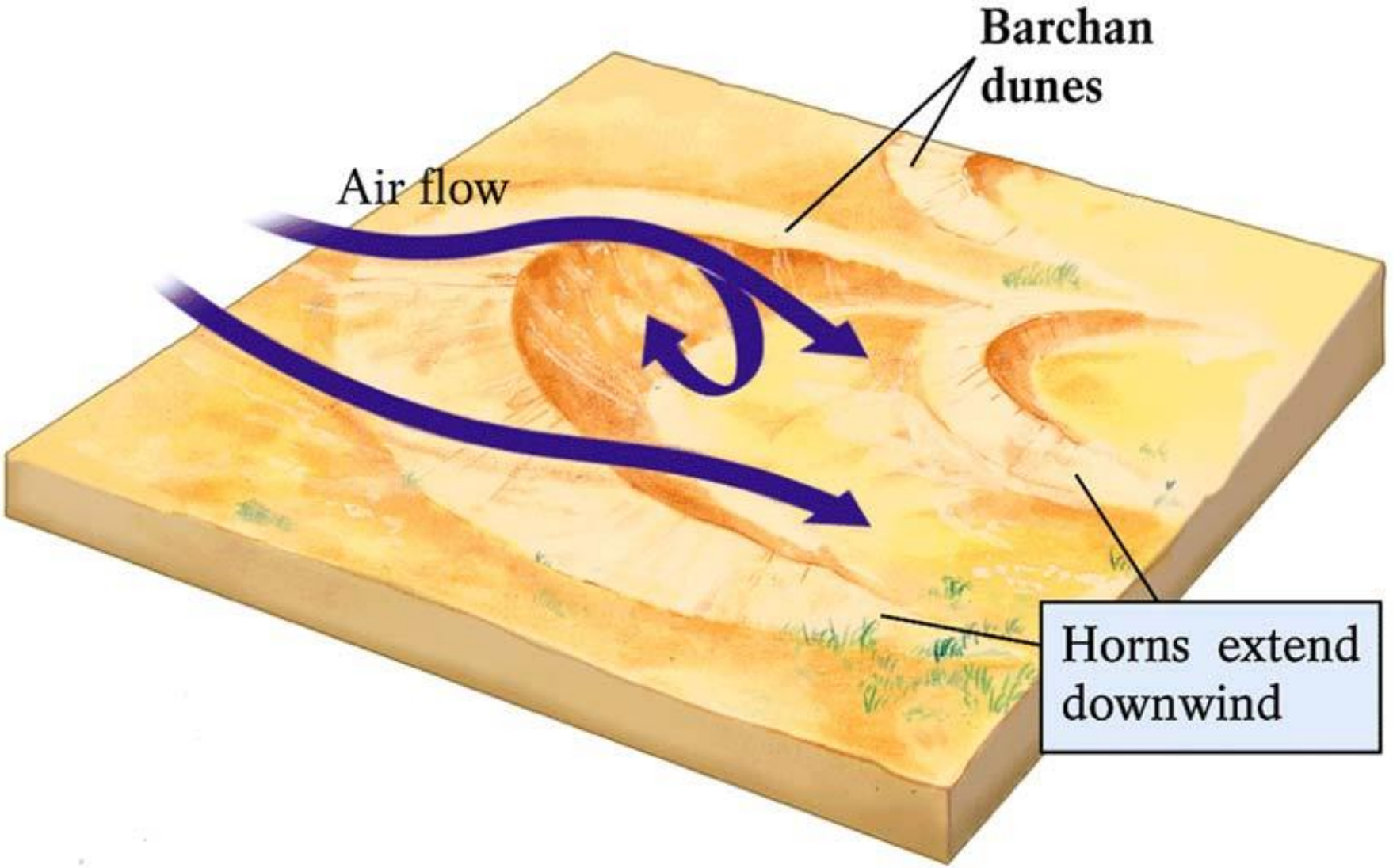
- Factors controlling dune type:
  - Wind velocity and direction
  - Sand supply
  - Vegetation cover

- 5 types of dunes:
  - Barchan
  - Transverse
  - Parabolic
  - Longitudinal
  - Star

Barchan: crescent shaped dune convex in the upwind direction.

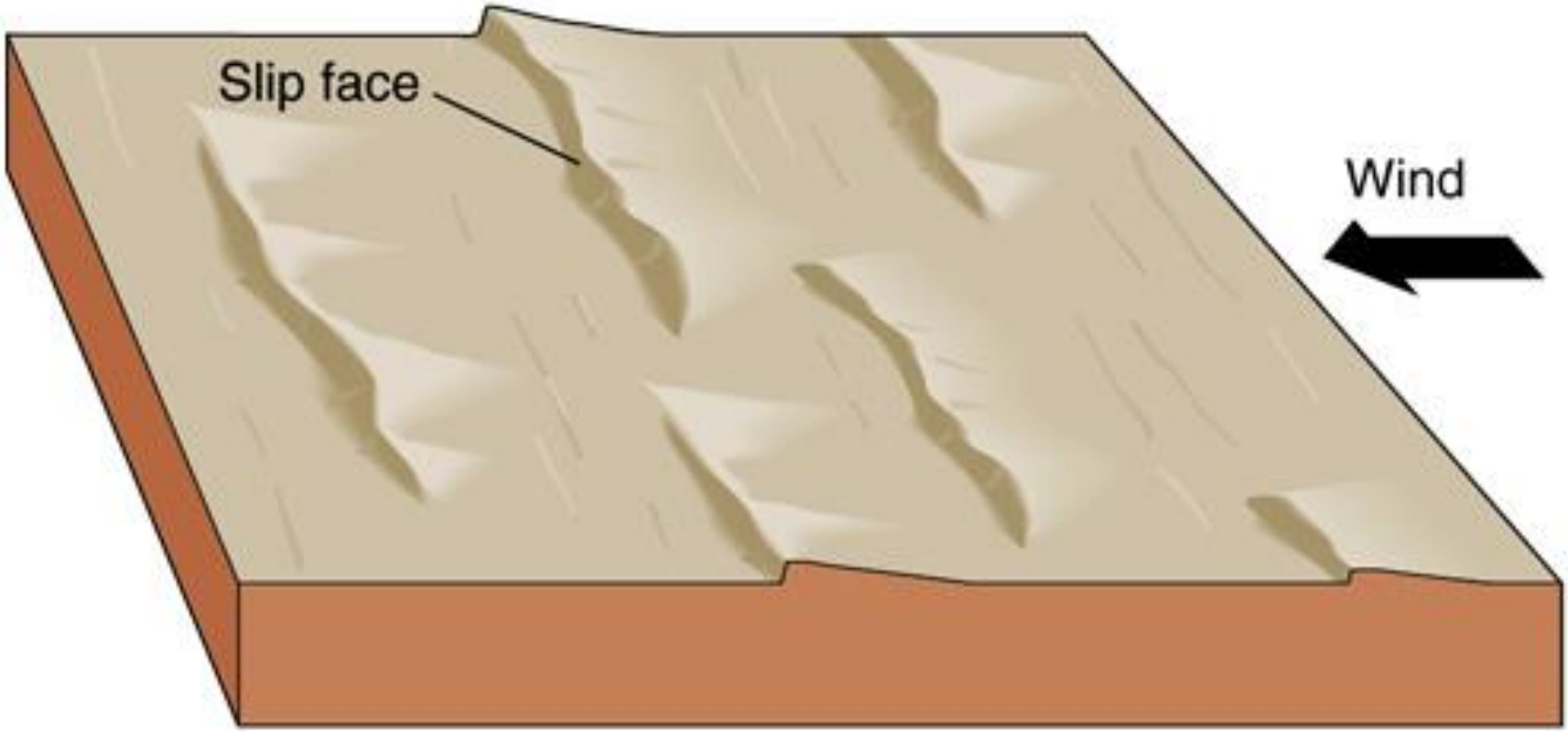


Barchan Dunes



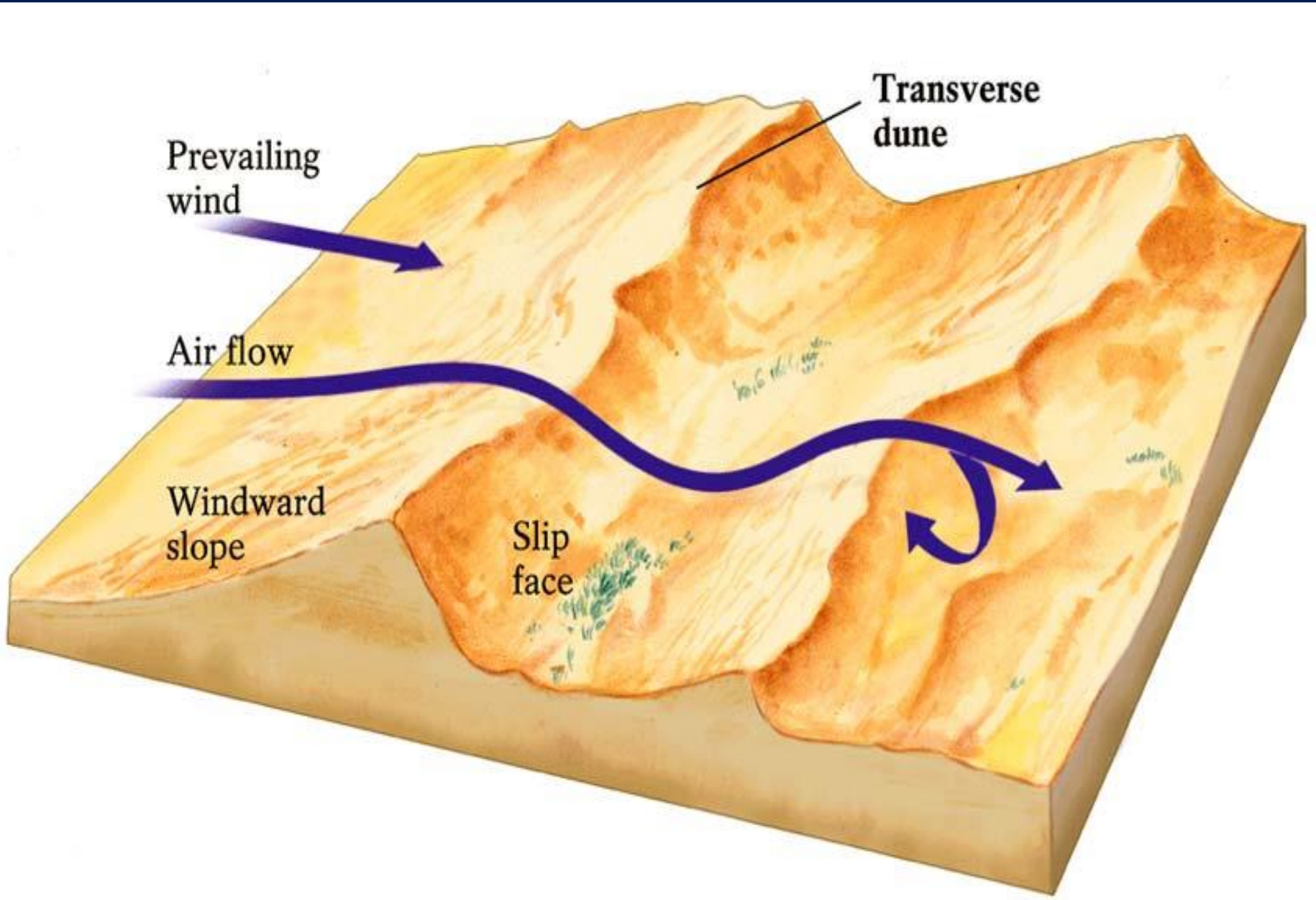
Barchan Dunes in Baja California

Transverse: relatively straight, elongate dune oriented perpendicular to the wind direction.



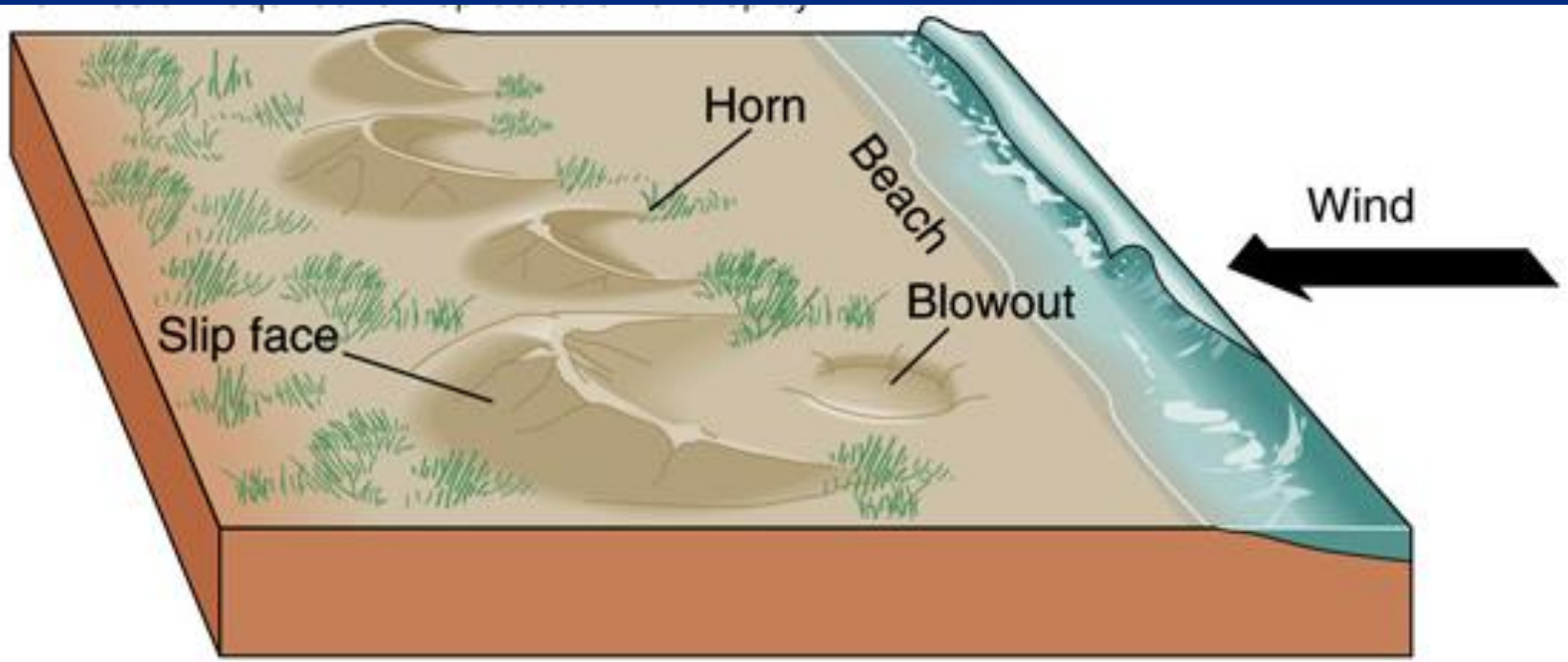
B Transverse dunes

Transverse Dunes



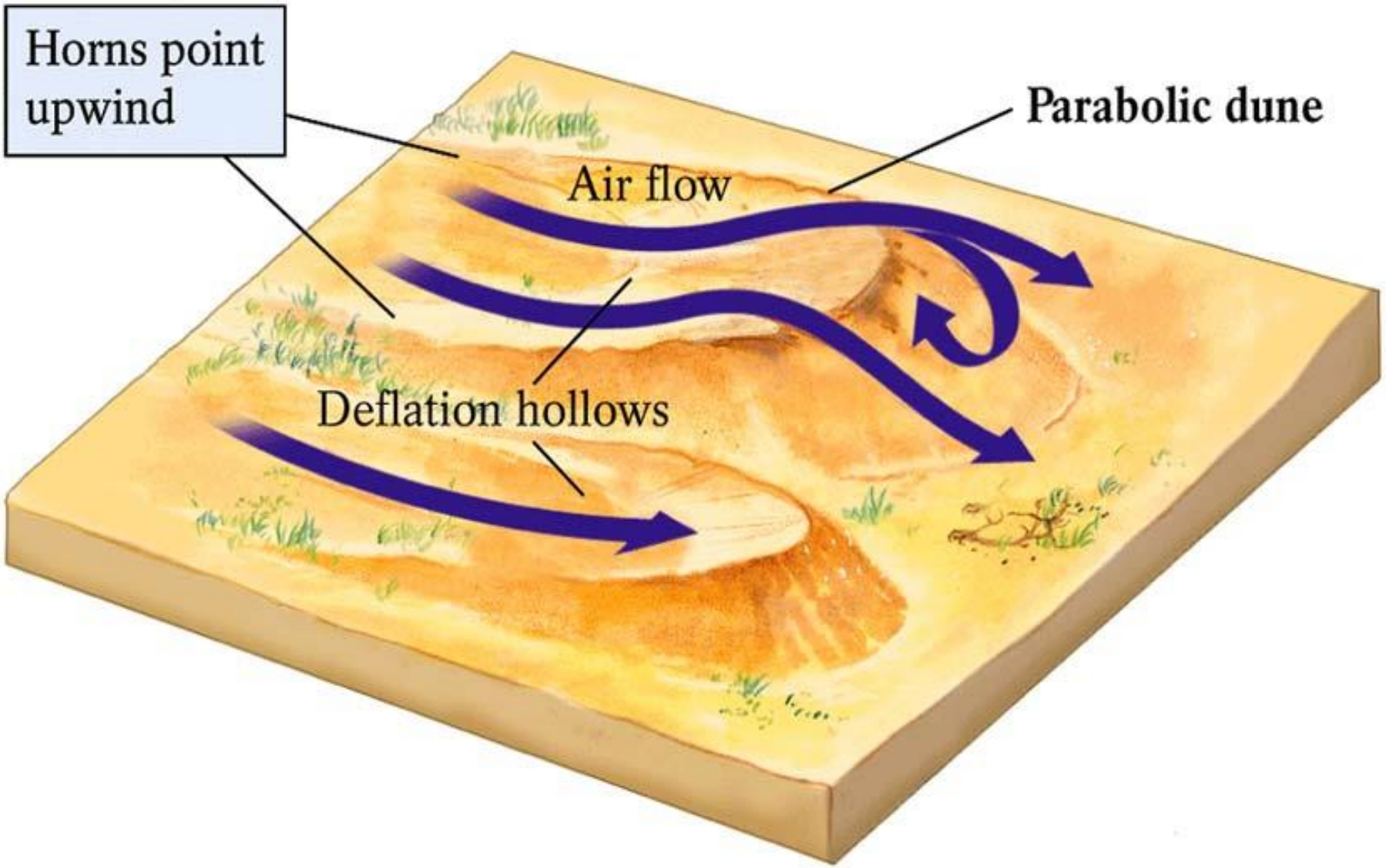
Transverse Dunes

Parabolic: similar to a barchan dune except that it is convex in the downwind direction.

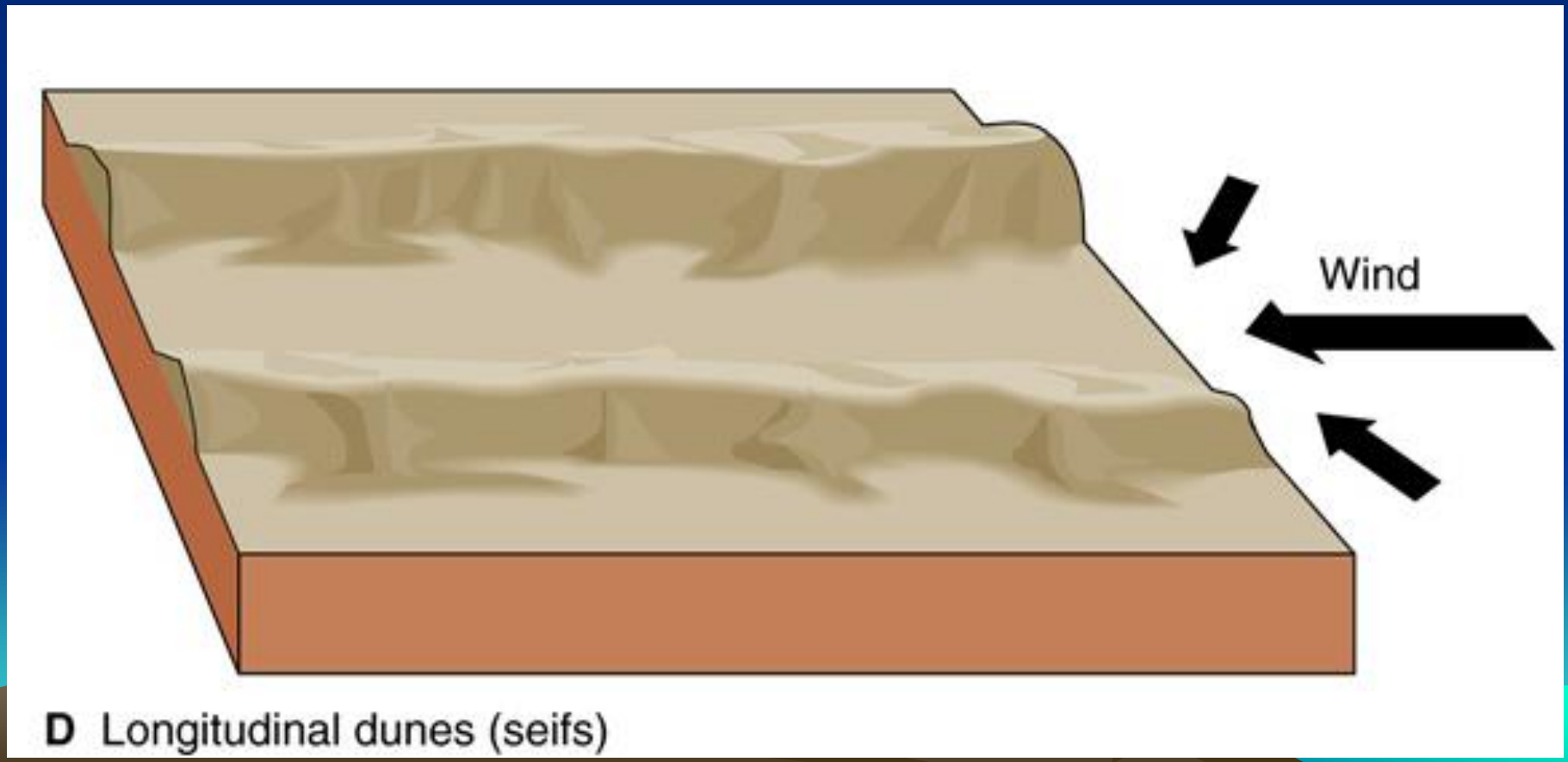


C Parabolic dunes

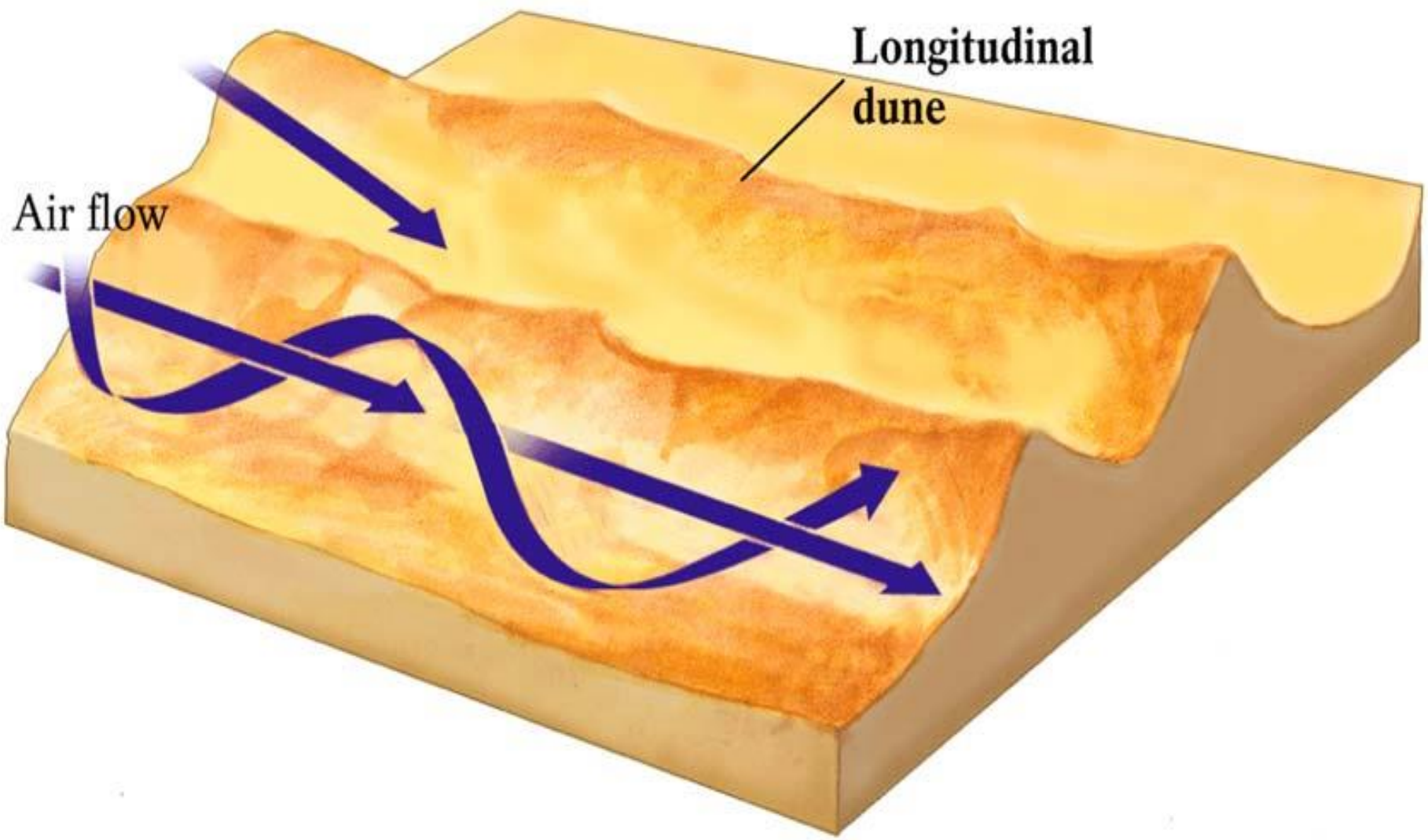
Parabolic Dunes



longitudinal: symmetrical ridge that forms parallel to the wind direction.



Longitudinal Dunes



Longitudinal Dunes

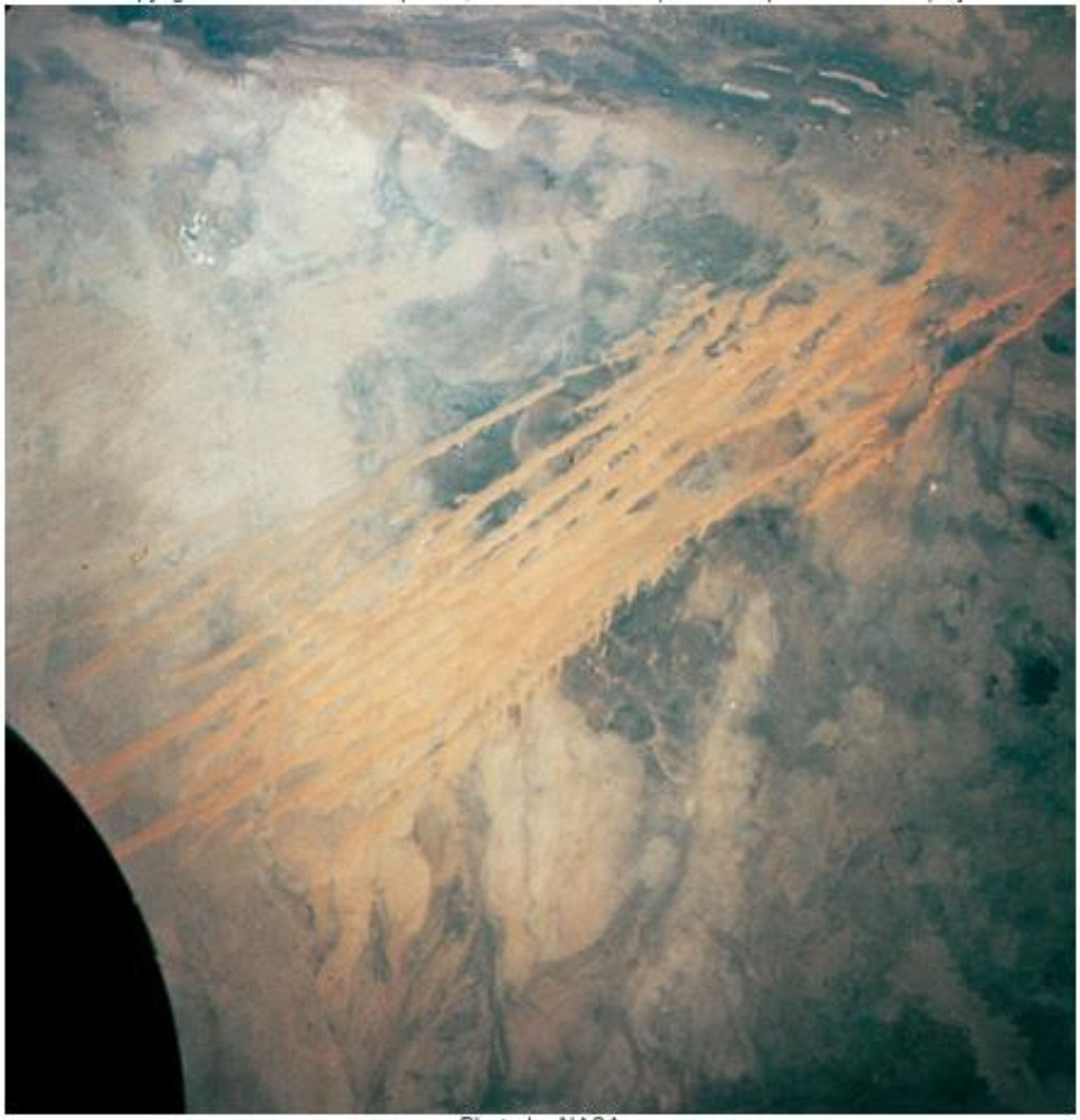
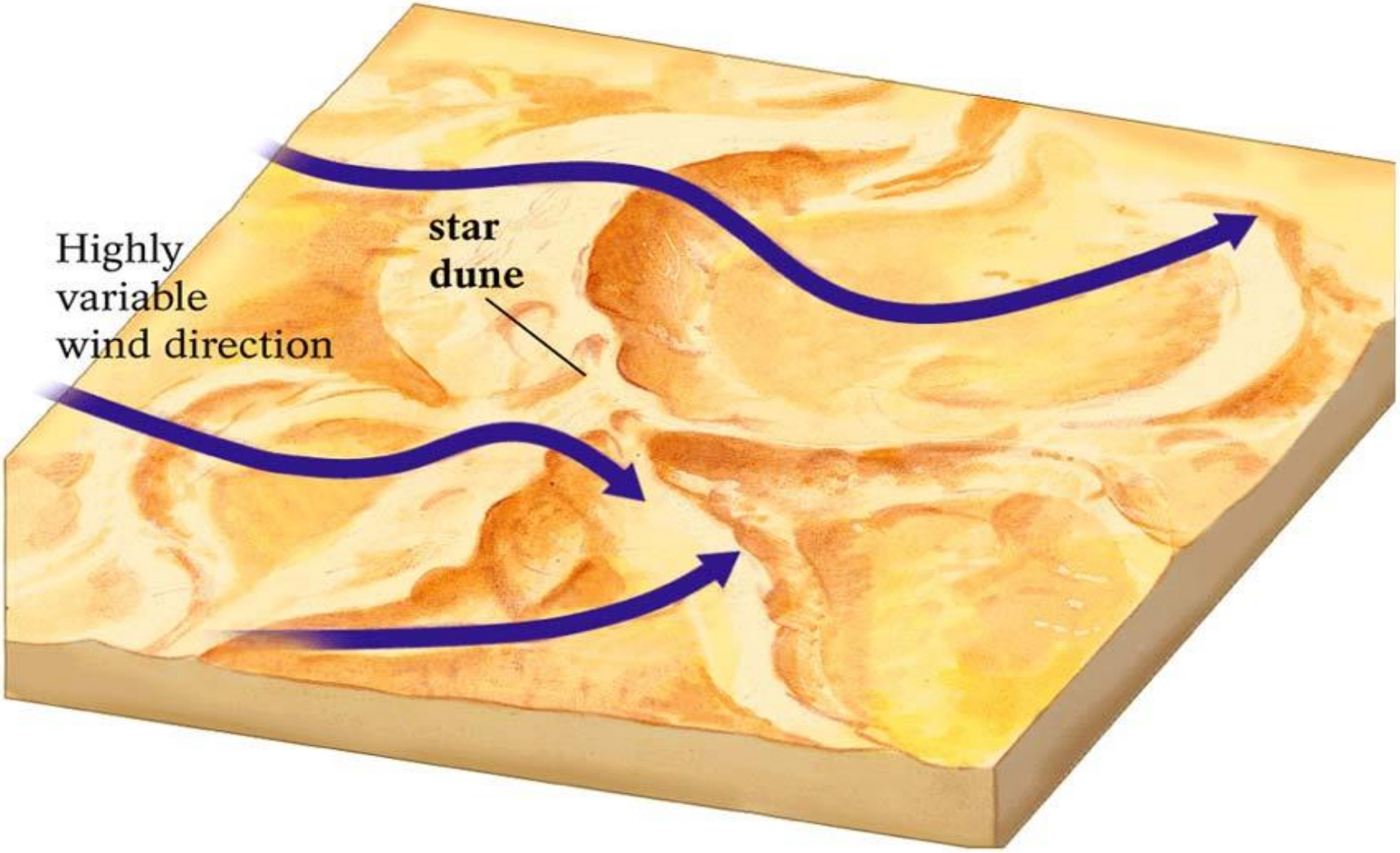


Photo by NASA

Star Dunes



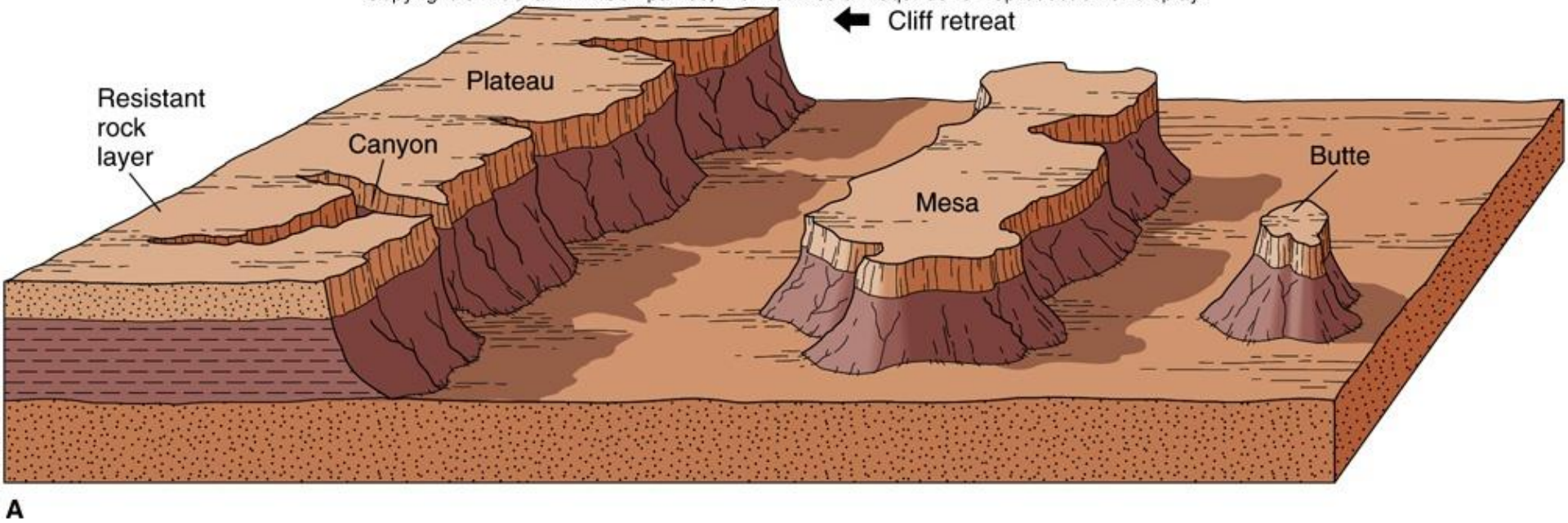
Star Dunes

Associated Features

- Plateaus: broad, flat-topped areas elevated above the surrounding land and partly bounded by cliffs.

Mesa: broad flat-topped hill bounded by cliffs from all sides.

Butte: narrow hill of resistant rock with a flat top and very steep sides.



A

B

Photo by David McGeary

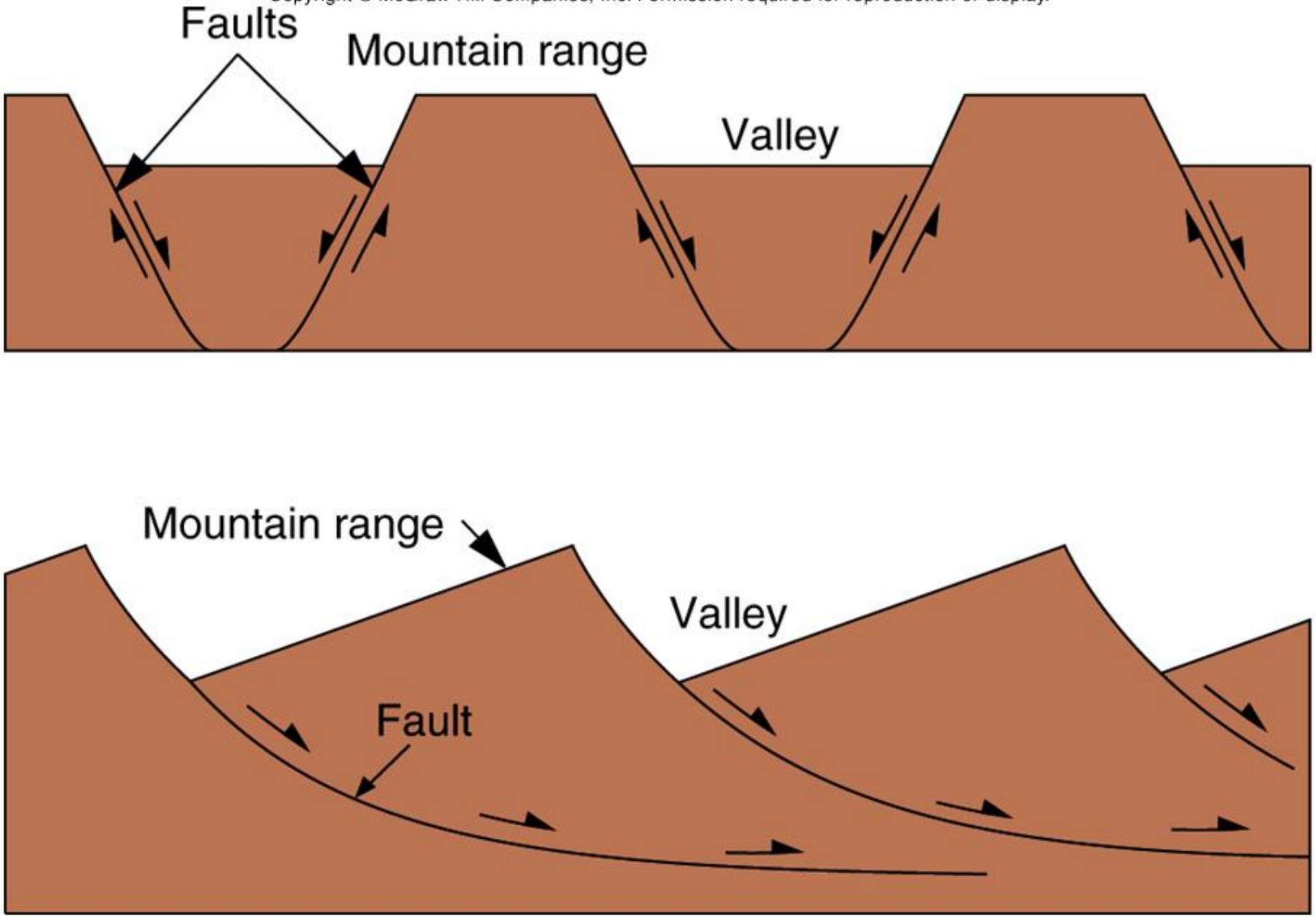
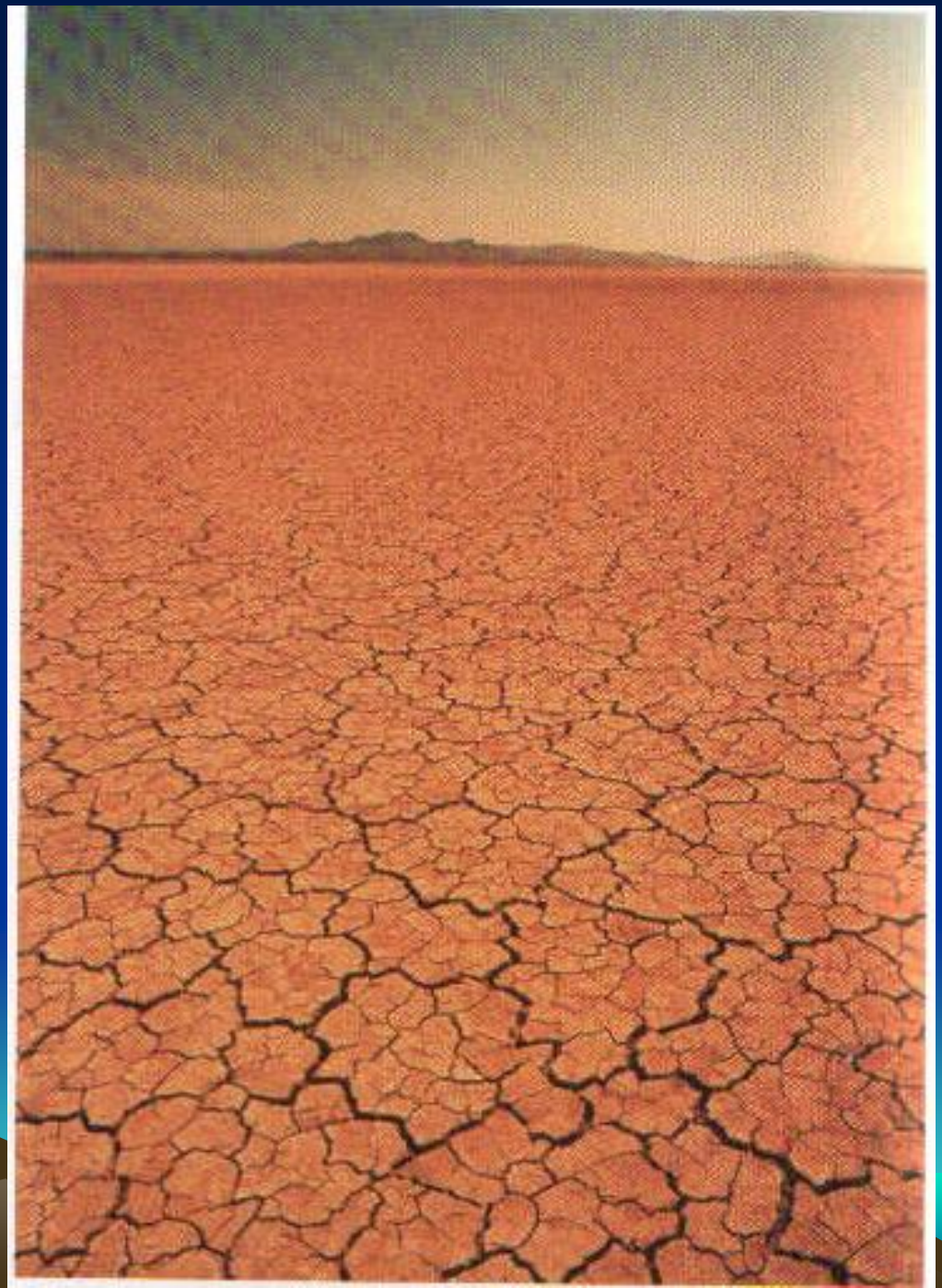


Photo by David McGeary

- Runoff water in the valley may collect at the floor forming a Playa lake.
- Mud cracks develop when a playa lake dries.

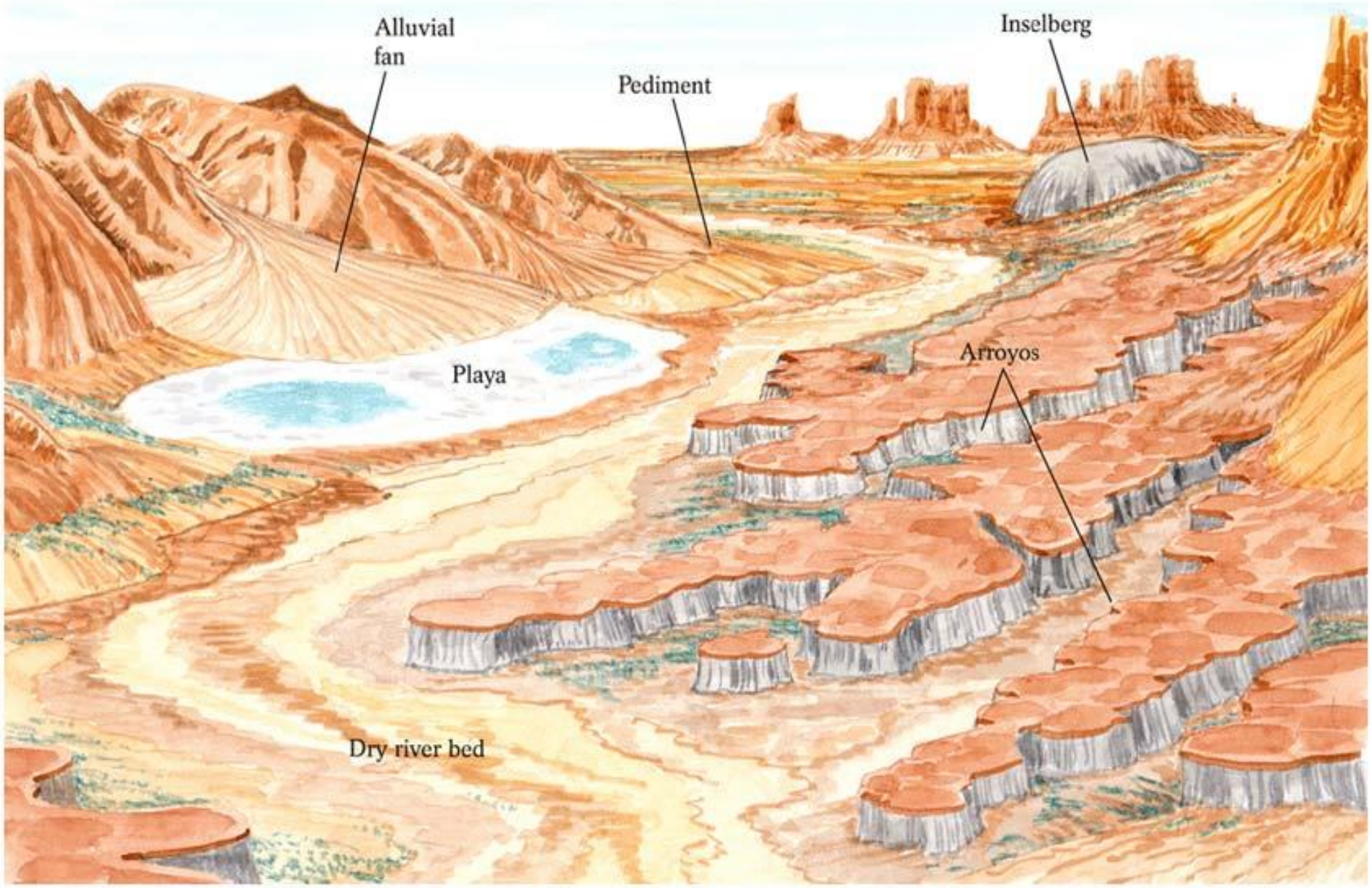


- When individual alluvial fans join with on another, they form a Bajada.

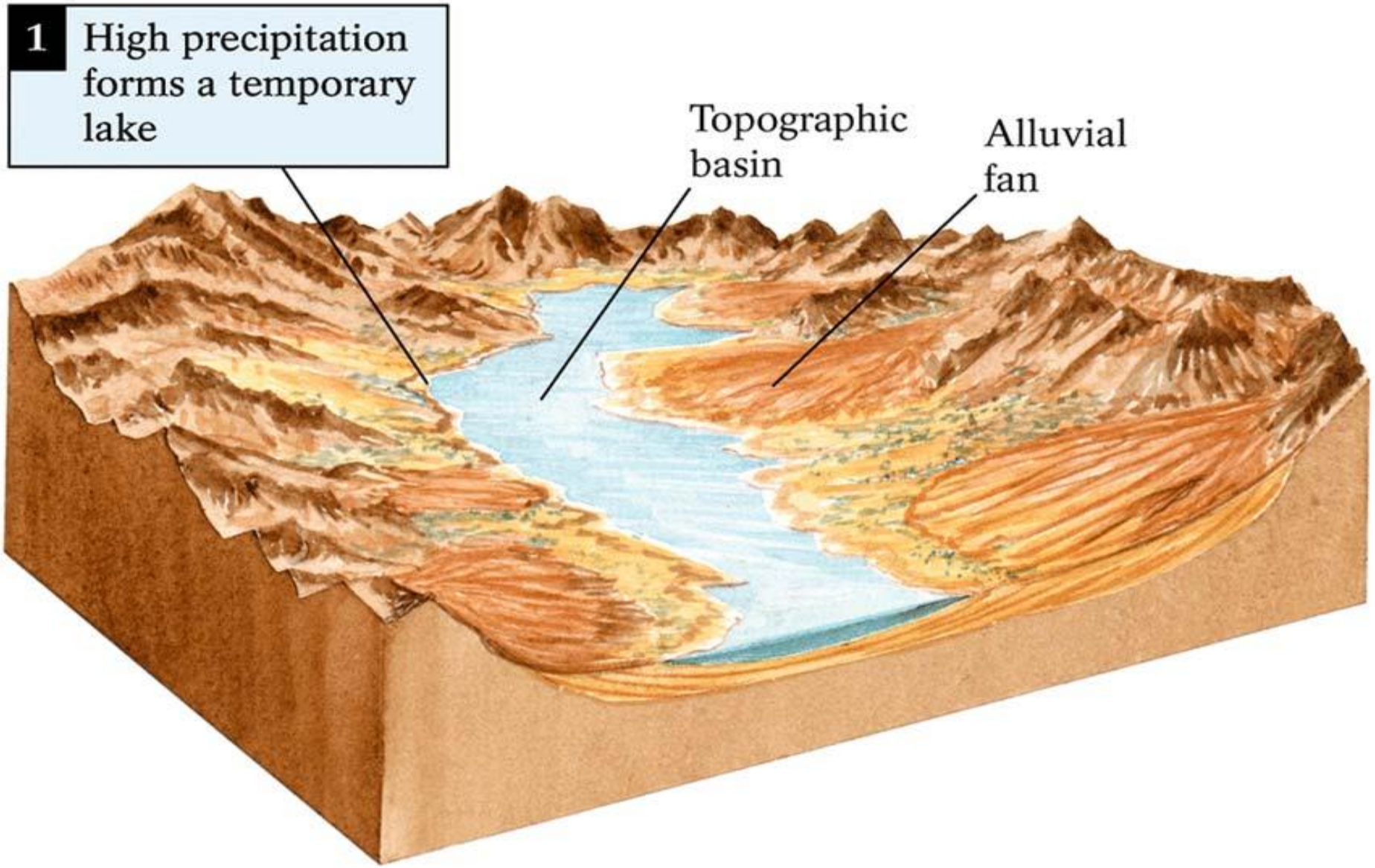
Shield and Platform Desert

- The Shield and platform dominate areas of relative tectonic stability.
- They are principally associated with stable plainlands of southafrica.
- These areas are dominated by erosional surfaces that are often cut-across the basement.

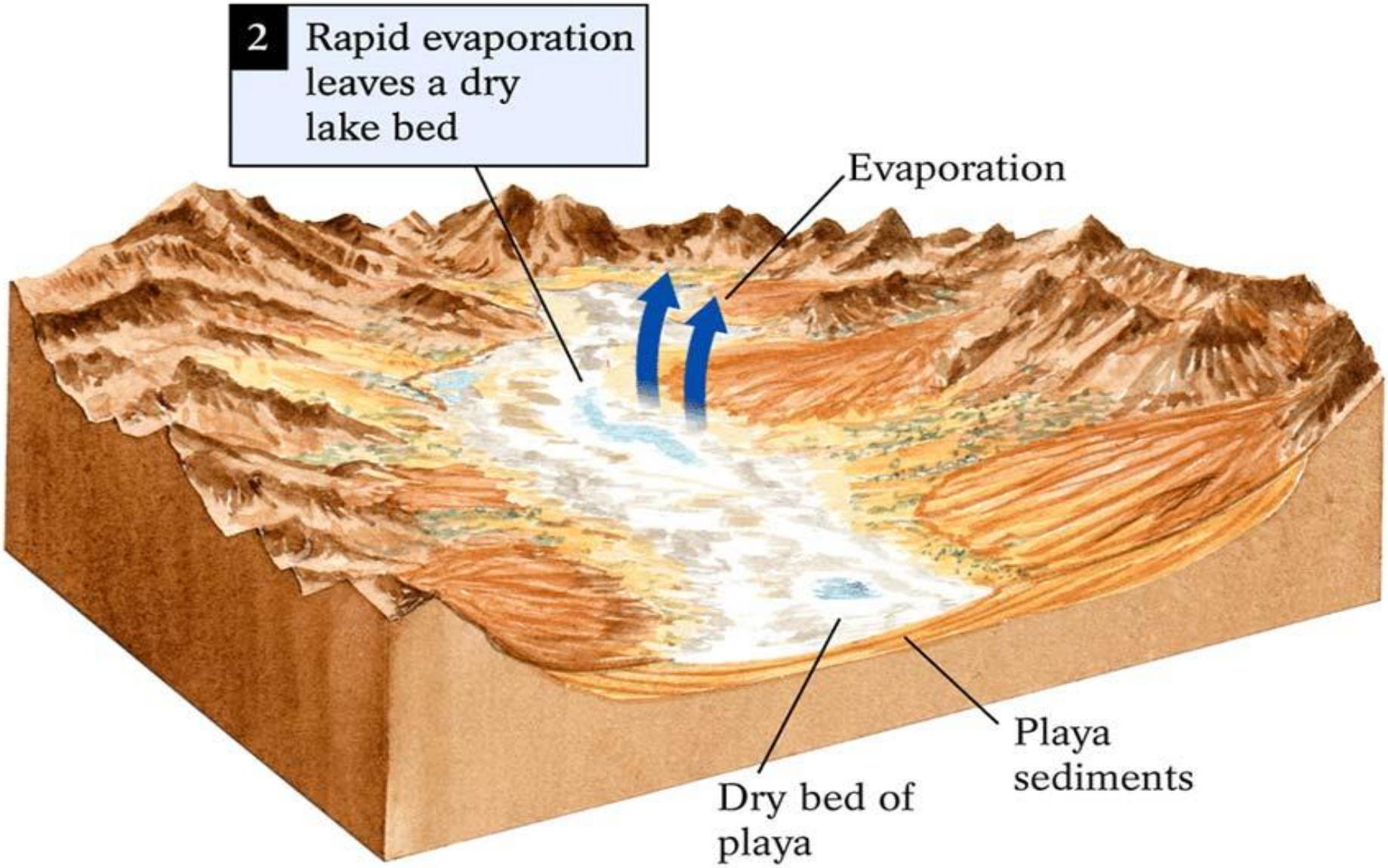
Desert Landforms Produced By Water



Playas


1 High precipitation forms a temporary lake
Topographic basin
Alluvial fan

Playas (cont'd)



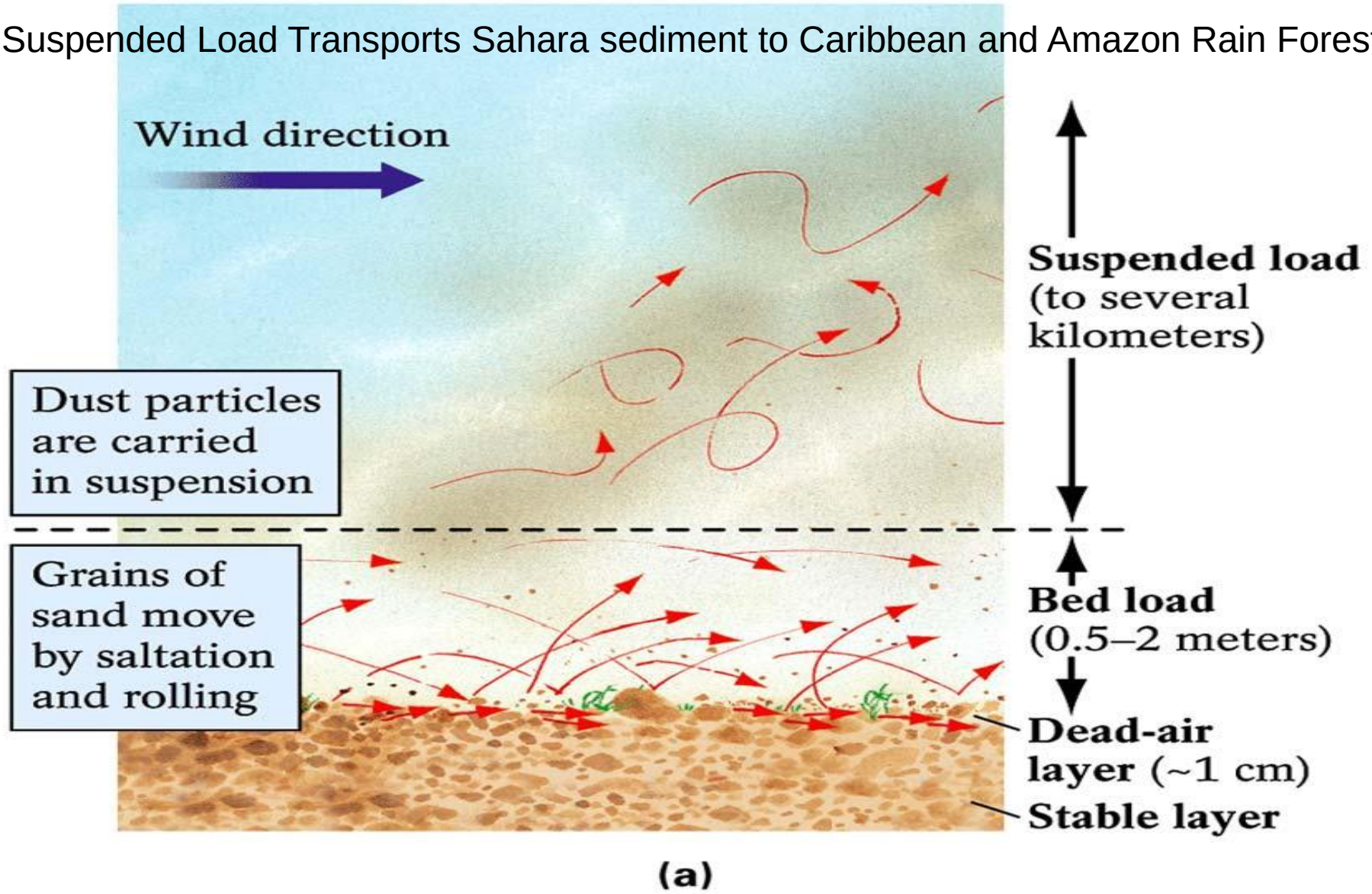
Playas (cont'd) –
A Playa in Death Valley, California

Transport By Wind

- No dissolved load
- Suspended Load- most consist of dust (silt, clay, pollen, bacteria, salt crystals, etc.)
- Bed Load- sediments moved along or near the ground
  - Rolling or saltation- bed loads lifted off the ground momentarily due to force of collision with other grains

Transport of Wind-Borne Sediment

Suspended Load Transports Sahara sediment to Caribbean and Amazon Rain Forest

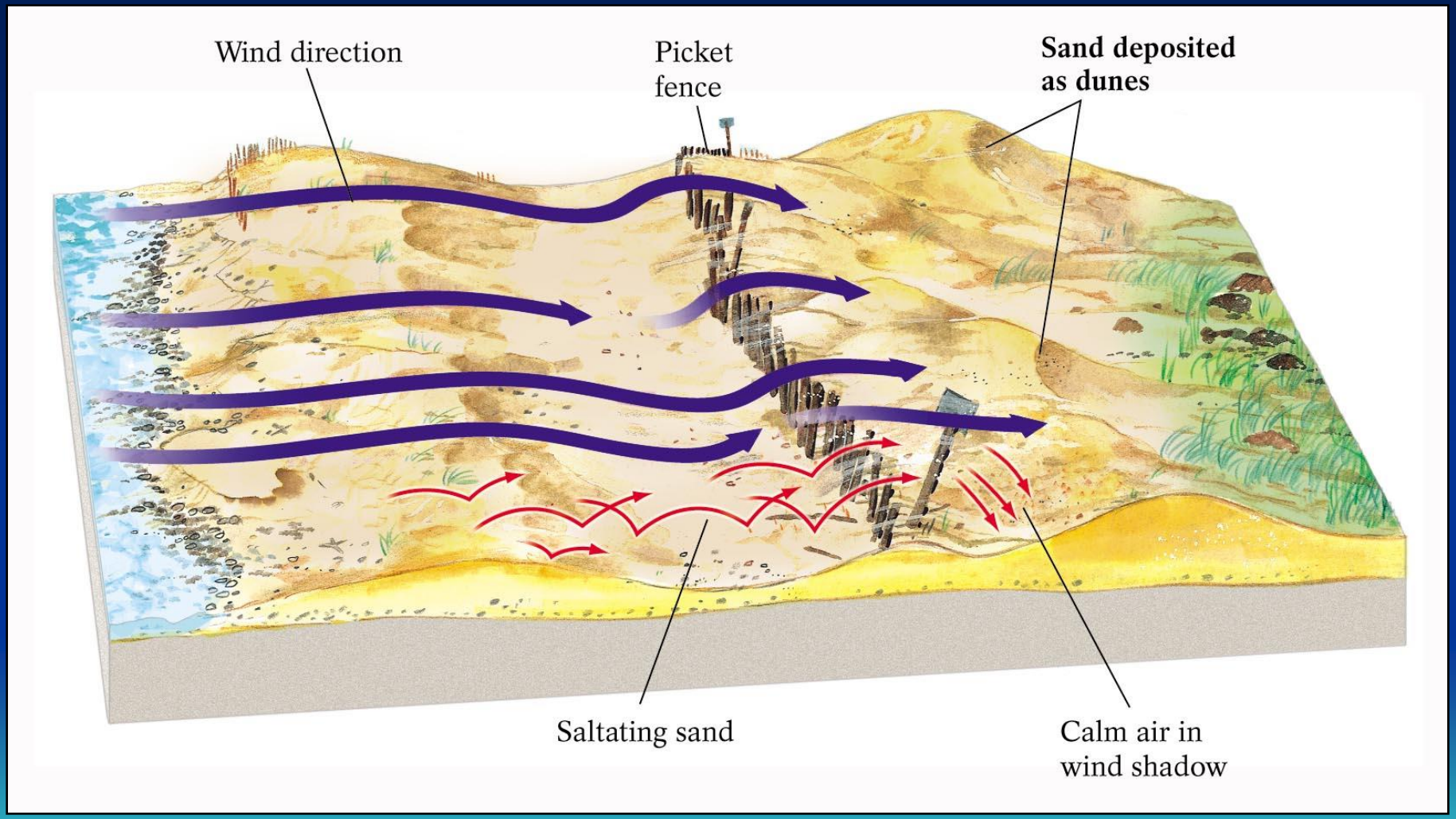


Deposition of Dunes

- Reduced wind velocity results in sediments deposition

- Dunes are hills of loose wind-born sand
  - **Size, shape, and orientation of dune are determined by** available sand, vegetation, and wind

Beach Sand Dunes

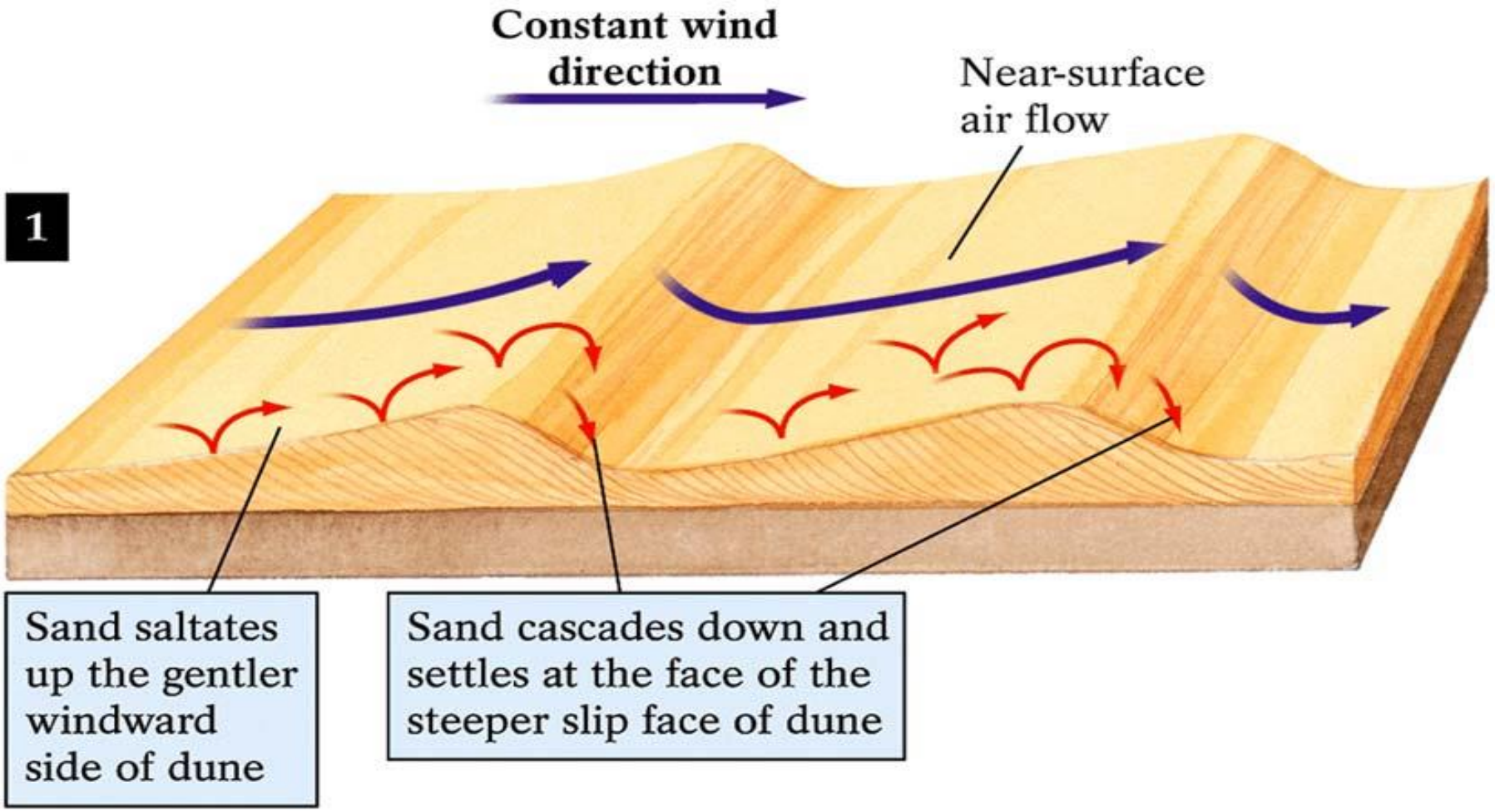


Deposition of Wind's Bed Load

Rain – Shadow Desert in Lee Of Mountains

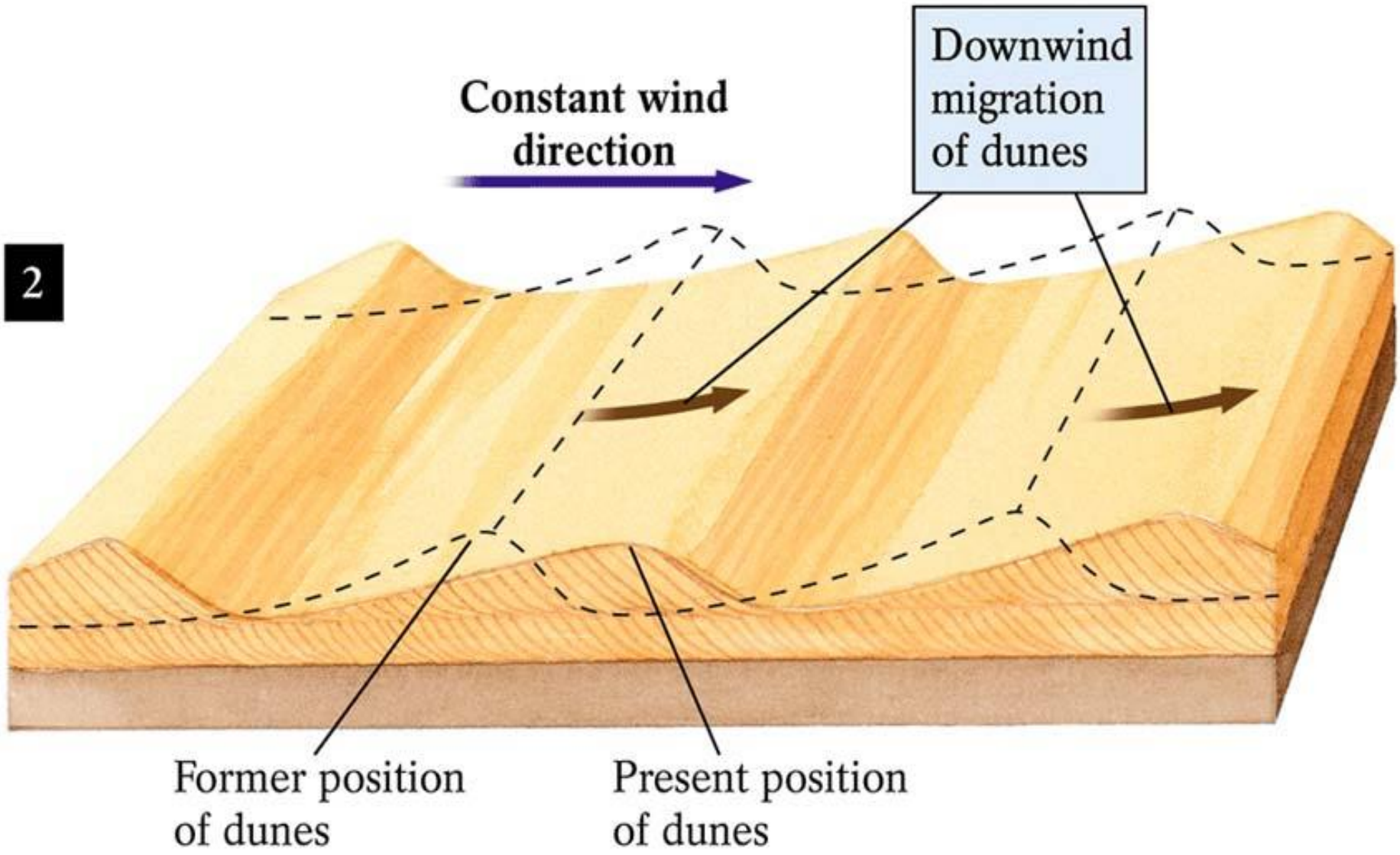
Large Scale Dunes (Gobi Desert)

Dune Migration



Just like ripples in a stream

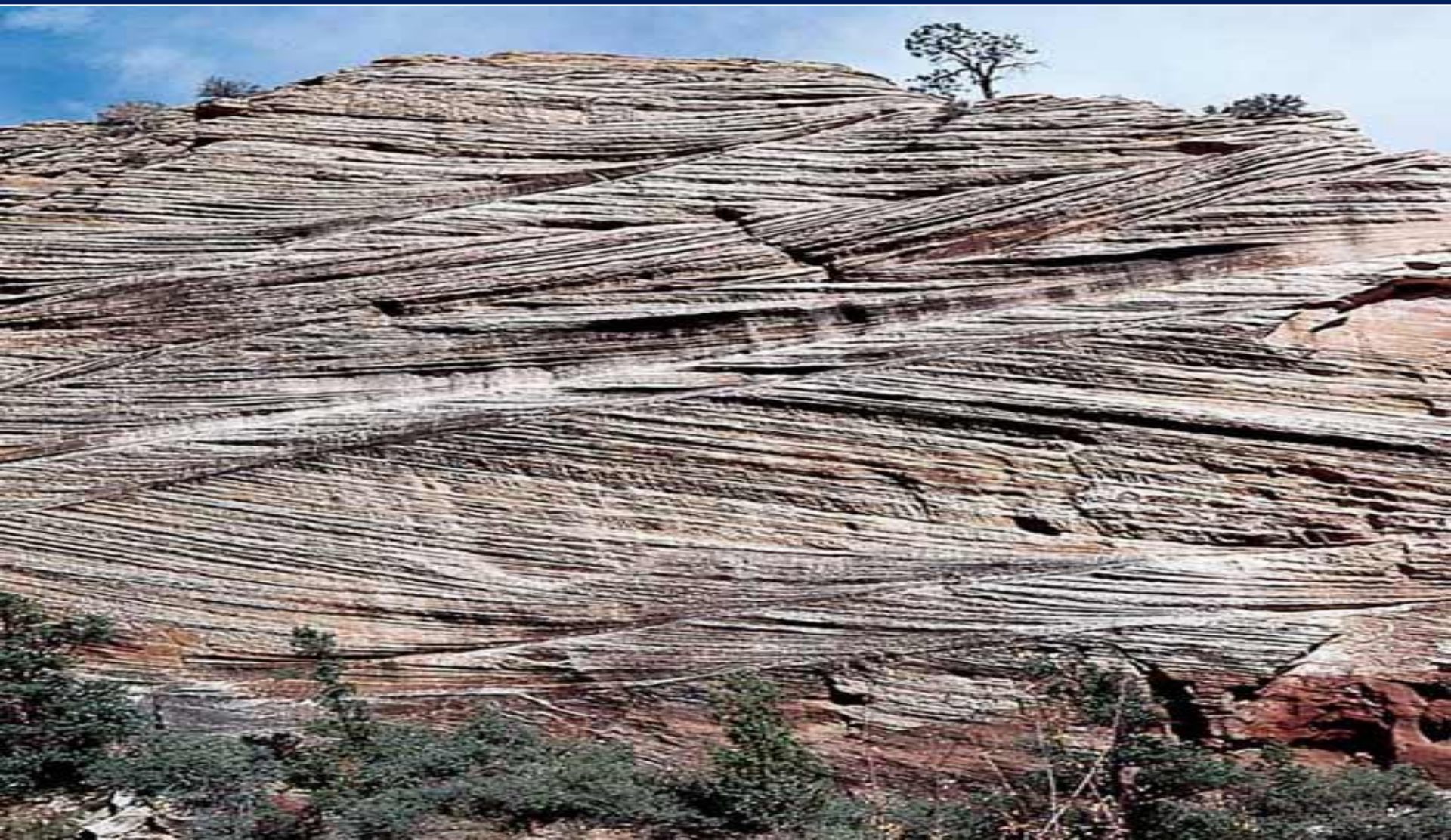
Dune Migration (cont'd)



Deposition and Dune Types

- Dune Types
  - Transverse- ridges that are perpendicular to prevailing wind direction
  - Longitudinal- ridges that are parallel to prevailing wind direction
  - Barchans- crescent-shaped with horns pointing downwind
  - Horseshoe (Parabolic)- crescent-shaped with horns pointing upwind
  - Star- winds from three or more directions

Lithified Sand Dunes (Jurassic Navajo Sandstone)



Loess

- Loess formed by windblown deposits of glacial outwash silt

Loess from the Columbia River Basin

Palaeo Aeolian Deposits

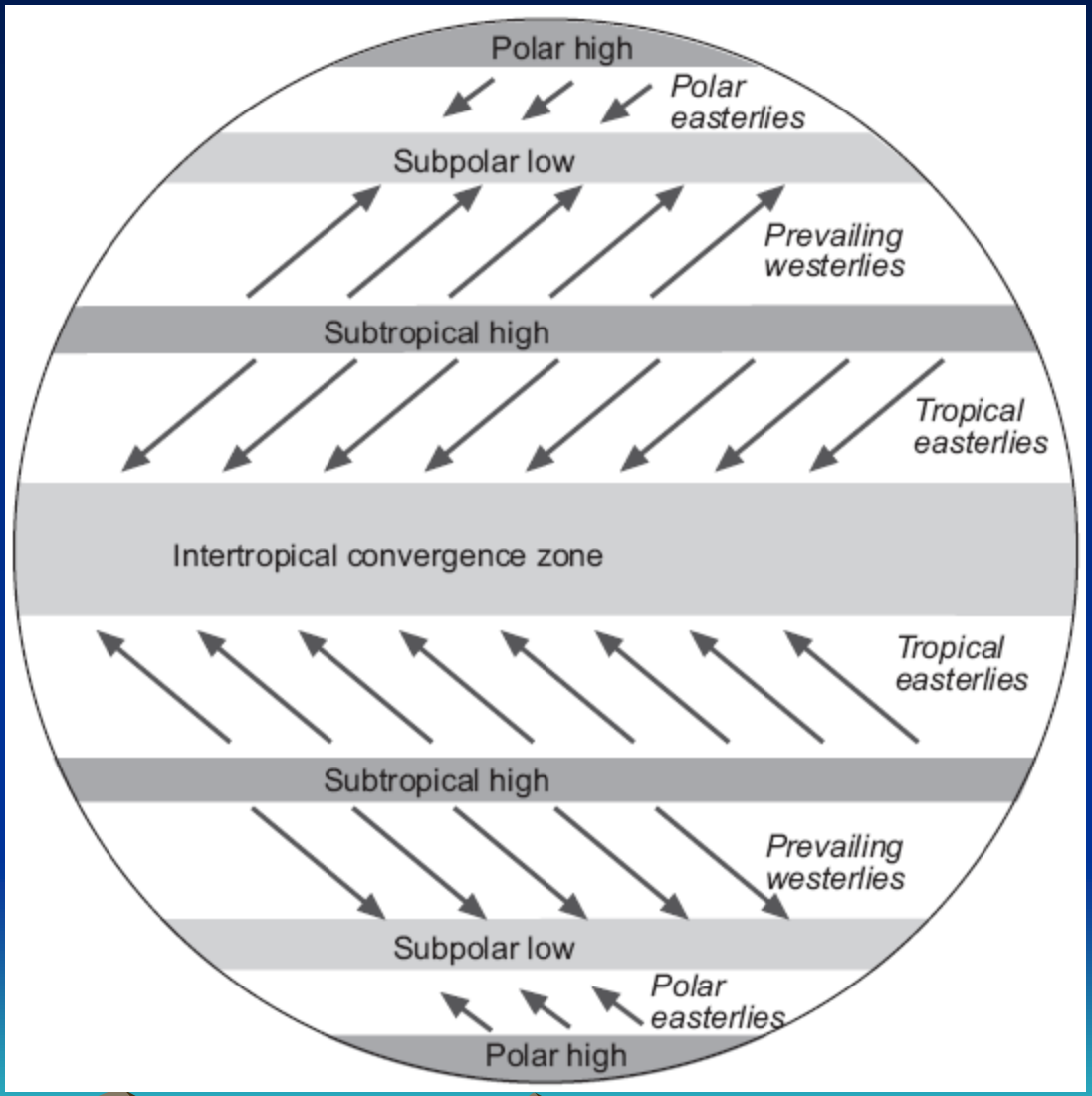
- Many evidence for episodes of dune formation, or reactivation of old dunes, over the past 10,000 years.
- The region of multiple sand dunes and Aeolian deposits is currently stabilized by vegetation indicates the palaeo deposits
- Analyses of sediments within sand dunes (stratigraphic records) and the shapes of the dunes (geomorphic records) provide information about multiple past droughts, which resulted in the removal of vegetation, and the movement and accumulation of Aeolian sand.
- Accumulations of aeolian sediment and formation of dunes occurs when there is adequate sediment supply, when winds exceed the speed needed to move particles of sand, and when there is a lack of stabilizing vegetation or landforms.

The combination of integrated geomorphic and stratigraphic studies and advances in dating techniques has lead to an enhanced understanding of the timing and location of Holocene (the last 10,000 years) aeolian activity.

Recognition of these features provides important palaeoenvironmental information that can be used in subsurface exploration because aeolian sandstones are good hydrocarbon reservoirs and aquifers.

AEOLIAN TRANSPORT

The term aeolian (or eolian) is used to describe the processes of transport of fine sediment up to sand size by the wind, and aeolian environments are those in which the deposits are made up mainly of wind-blown material.



The distribution of high- and low-pressure belts at different latitudes creates wind patterns that are deflected by the Coriolis force.

CHARACTERISTICS OF WIND-BLOWN PARTICLES

Texture of aeolian particles

When two grains collide in the air, one or both of the grains may be damaged in the process.

The most vulnerable parts of a grain are angular edges, which will tend to get chipped off, and with multiple impacts the grains gradually become more rounded as more of the edges are smoothed off.

Inspection using a hand lens reveals another feature, the grain surfaces will have a dull, matt appearance that under high magnification is a frosting of the rounded surface.

CHARACTERISTICS OF WIND-BLOWN PARTICLES

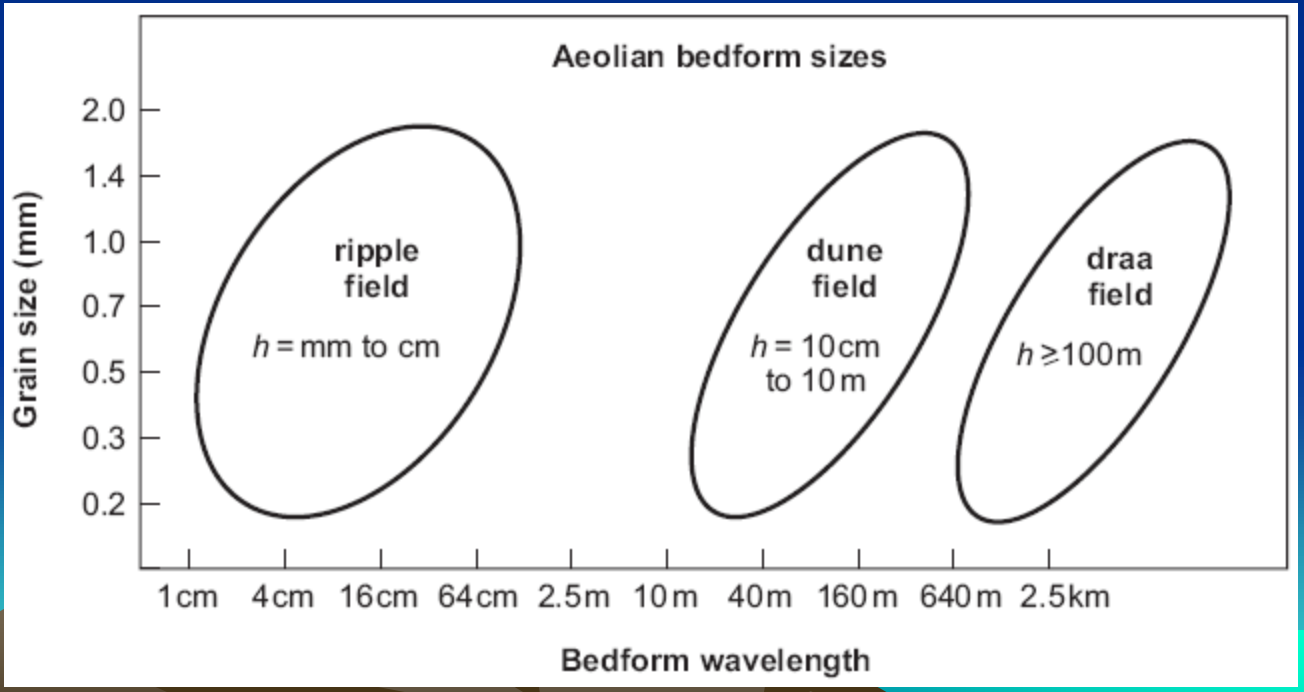
Composition of aeolian deposits

- The abrasive effect of grain impacts during aeolian transport also has an effect on the grain types found in wind-blown deposits.
- When a relatively hard mineral, such as quartz, collides with a less robust mineral, for example mica, the latter will tend to suffer more damage.
- A mixture of different grain types becomes reduced to a grain assemblage that consists of very resistant minerals such as quartz and similarly robust lithic fragments such as chert.
- Other common minerals, for example feldspar, are likely to be less common in aeolian sandstones, and weak grains such as mica are very rare.
- Most modern and ancient wind-deposited sands are quartz arenites.

AEOLIAN BEDFORMS

The processes of transport and deposition by wind produce bedforms that are in some ways similar to subaqueous bedforms, but with some important differences that can be used to help distinguish aeolian from subaqueous sands.

Three groups can be separated on the basis of their size:
- aeolian ripples,
- dunes
- draas.

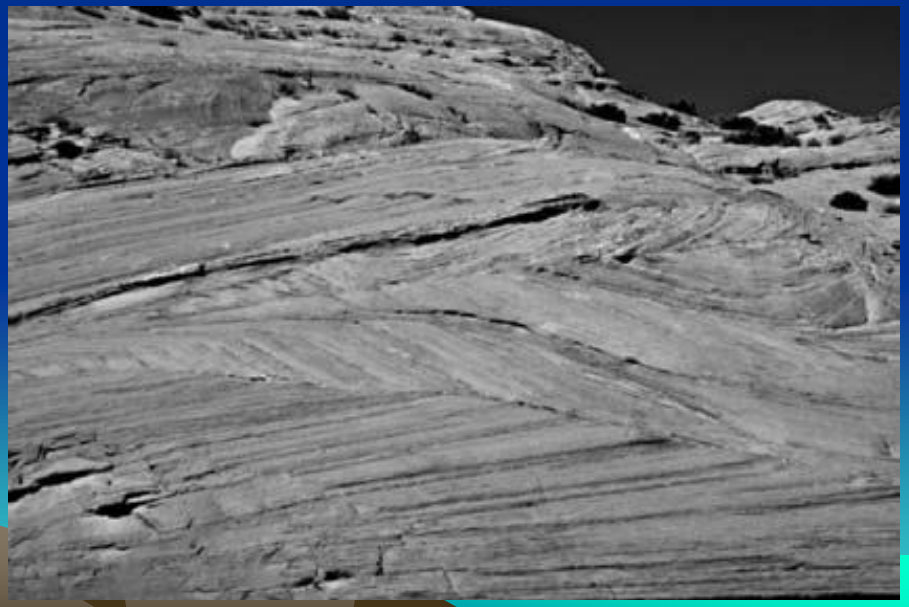


Aeolian ripples, dunes and draas are three distinct types of aeolian bedform.

AEOLIAN BEDFORMS

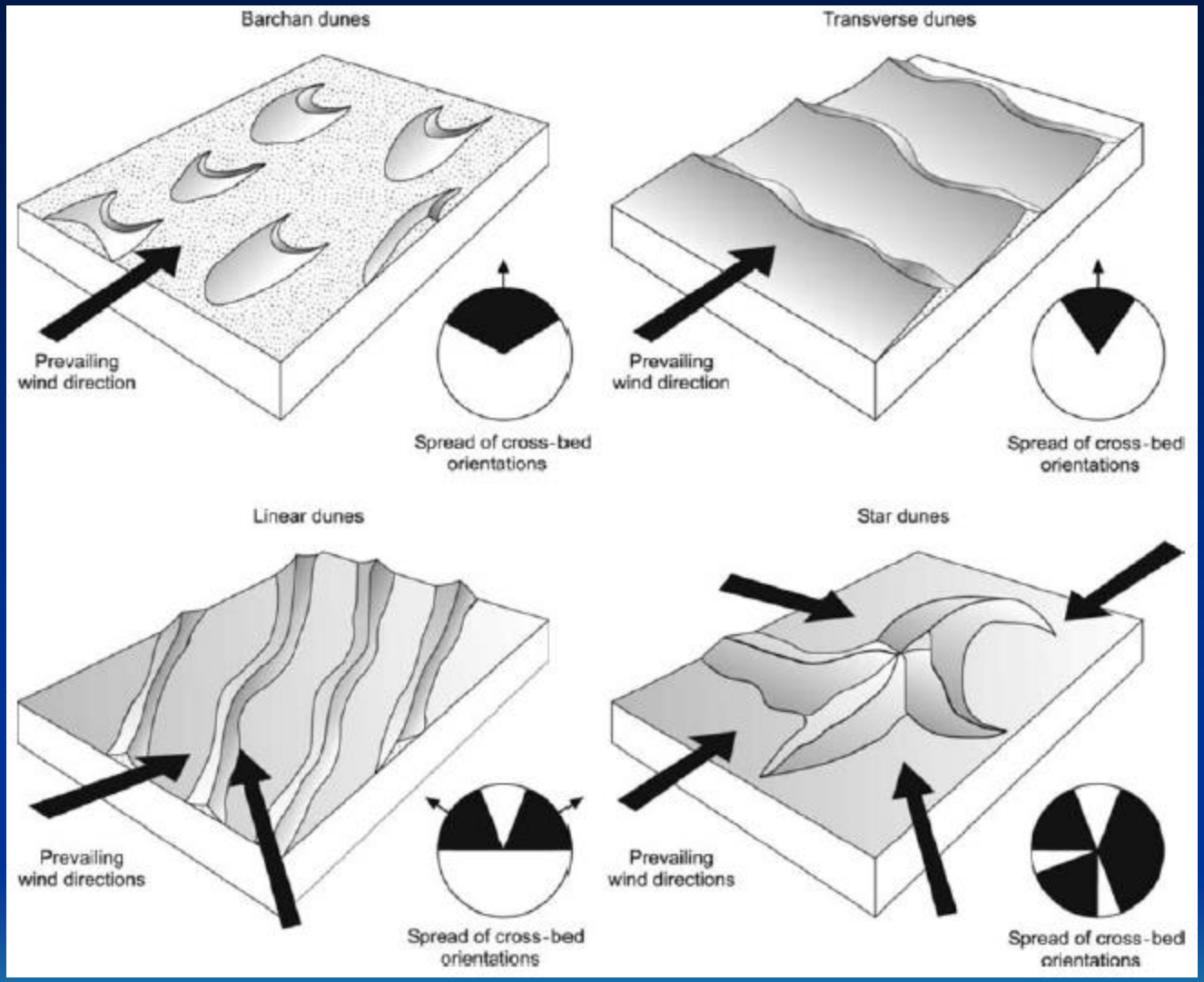
Aeolian ripples superimposed on an aeolian dune.

Aeolian ripples in modern desert sands.



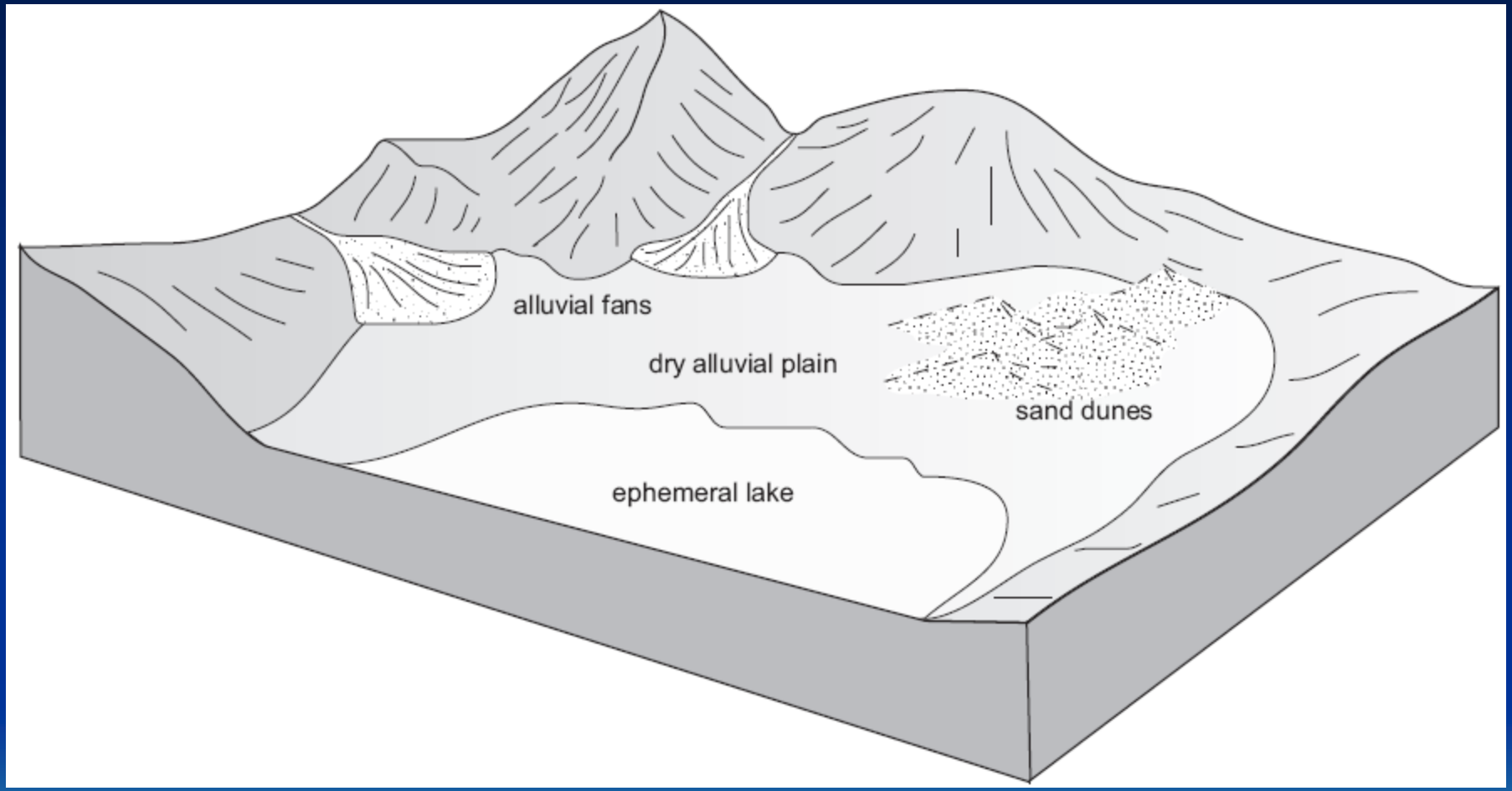
Aeolian dune cross-bedding in sands eposited in a desert: the view is approximately 5m high.

AEOLIAN BEDFORMS



Four of the main aeolian dune types, their forms determined by the direction of the prevailing wind(s) and the availability of sand. The small 'rose diagrams' indicate the likely distribution of palaeowind indicators if the dunes resulted in cross-bedded sandstone.

DESERT ENVIRONMENTS



Depositional environments in arid regions: coarse material is deposited on alluvial fans, sand accumulates to form aeolian dunes and occasional rainfall feeds ephemeral lakes where mud and evaporite minerals are deposited.

Global climate variations

The global distribution of modern deserts: most lie within 408 of the Equator.

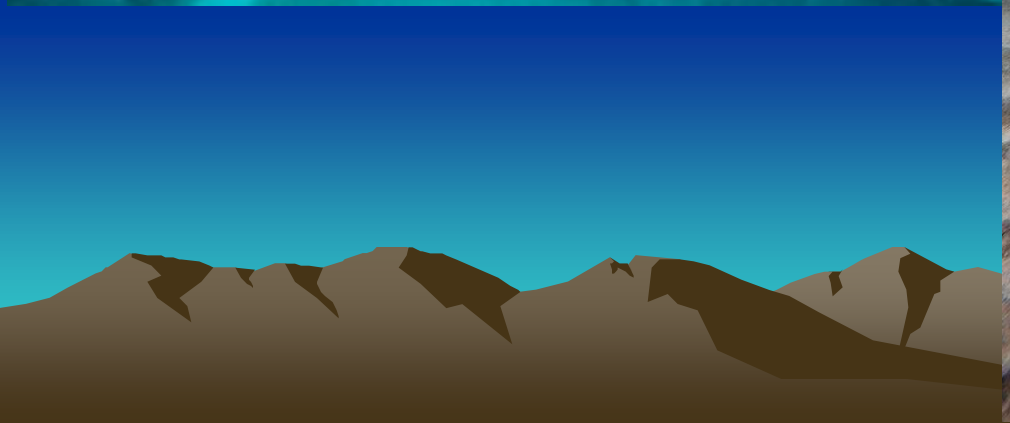
Characteristics of aeolian deposits

- Lithologies – sand and silt only
- Mineralogy – mainly quartz, with rare examples of carbonate or other grains
- Texture – well- to very well-sorted silt to medium sand
- fossils – rare in desert dune deposits, occasional vertebrate bones
- bed geometry – sheets or lenses of sand
- sedimentary structures – large-scale dune crossbedding and parallel stratification in sands
- palaeocurrents – dune orientations reconstructed from cross-bedding indicate wind direction . colour – yellow to red due to iron hydroxides and oxides
- facies associations – occur with alluvial fans, ephemeral river and lake facies in deserts, also with beach deposits or glacial outwash facies

Palaeo-aeolian Deposits and Landforms

Major Indicators for Palaeo-aeolian deposits

- First and most useful for dating purpose, there are ancient lake deposits between some dunes (Ex. Arabia)
- Flooding of dunes by rising sea level, Eastern provinces of Saudi Arabia, where large mega barchans now lie beneath the waters of Arabian Gulf.
- There are palaeosols remains as palaeolithc units in many sand seas particularly in north western part of Sahara.
- Apparent mismatch between the orientation of megadunes and mesodunes.



- Some elements of dune stratigraphy and sedimentology, such as paleosols and clay aggregates, can act as indicators of changing climates, and provide useful evidence for reconstructing past environments in the arid zone.
- Buried soils provide evidence of periods of relative environmental stability, which in the arid zone is usually interpreted to be indicative of more humid conditions
- Alternating inundation and drying of soils rich in swelling clays.

Three processes usually acting together, may preserve palaeo-features in desert dunefields.

1. Secular delaying wind velocity might induce a change from mega-dune to meso-dune formation. It simply indicate the dune activity to inactivity.
2. Secular change in wind direction were invoked a explanations of complex dune pattern in hyper-arid desert. It indicates that periodical change in the desert.
3. Change in rainfall would allow soil formation and surface stabilisation, which would resist surface reactivation in a later return to drier or winder conditions

Extent and location of stabilised dunes:

1. Ancient dunes in high altitutes
2. Ancient dunes in the tropics and sub-tropic region