General Geology

Lesson 9, cont'd

Aeolian landscapes and sediments

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Aeolian landscapes and sediments are those created by the wind.

The word *aeolian* is derived from Aeolus, the god of the winds in Greek mythology

Aeolian landscapes and sediments are created in environments where the wind can have maximum effect on rocks and sediments. For this to be possible, there should be minimum hindrance to the influence of the wind. This means, for the wind to influence the landscape effectively:

1. There should be as little vegetation as possible

2. There should be as little soil as possible

3. There should be as little moisture as possible (so that the regolith will not be soldered together to form a unified, strong layer)

4. Corrasion should be as powerful as possible so as to disintegrate rocks into smaller particles that wind can carry. This usually happens in regions of extreme diurnal temperature fluctuations.

5. There should be strong winds.

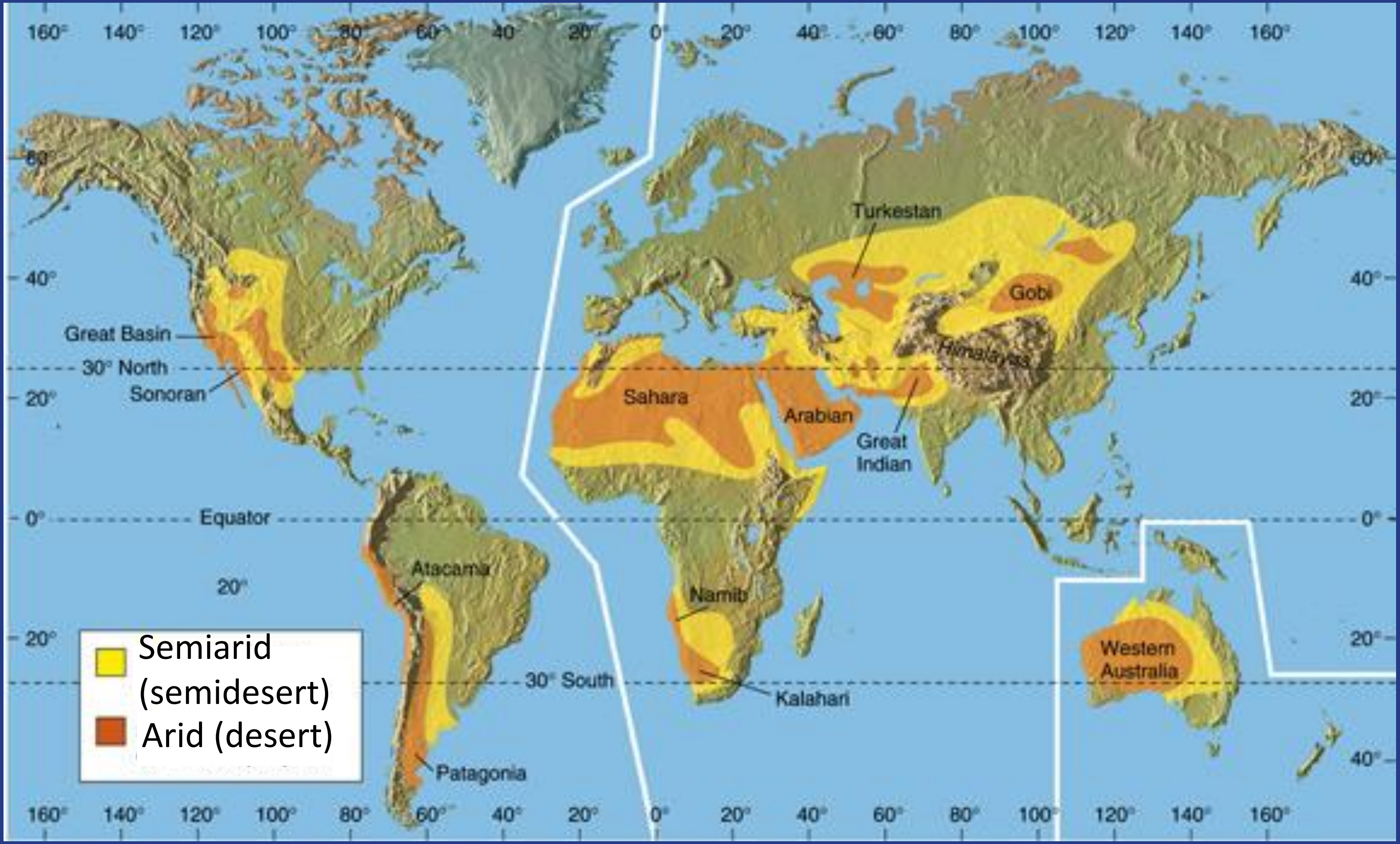
These conditions are invariably met in deserts. That is why aeolian landscapes and sediments are also largely (but not exclusively) desert landscapes and sediments.

In geology a desert is simply a dry place receiving less than 250 mm precipitation annually (in the form of rain, snow, mist or fog).

Deserts do not have to be hot places. Antarctica, for example, is extremely cold, yet its precipitation is less than 200 mm a year and it is thus the world's largest desert. In the cold season, its average temperature is -63°C!

The word desert is derived from the Church Latin *dēsertum*, meaning an abandoned, desolate place. This word is a participle of the Latin verb *dēserere*, meaning to abandon. The English words "to desert" and "deserter" also come from the same root. An uninhabited island is called a "desert island" for the same reason.

A semidesert is a region with a precipitation between 250 and 500 mm annually. If grass-covered (where annual precipitation may rise to 510 mm), they are known as steppes (in Eurasia), savanna (in Africa), shortgrass prairie (in North America), llano (behind the Andes) cerrado (in Brazil) and pampa (in Argentina and Uruguay).

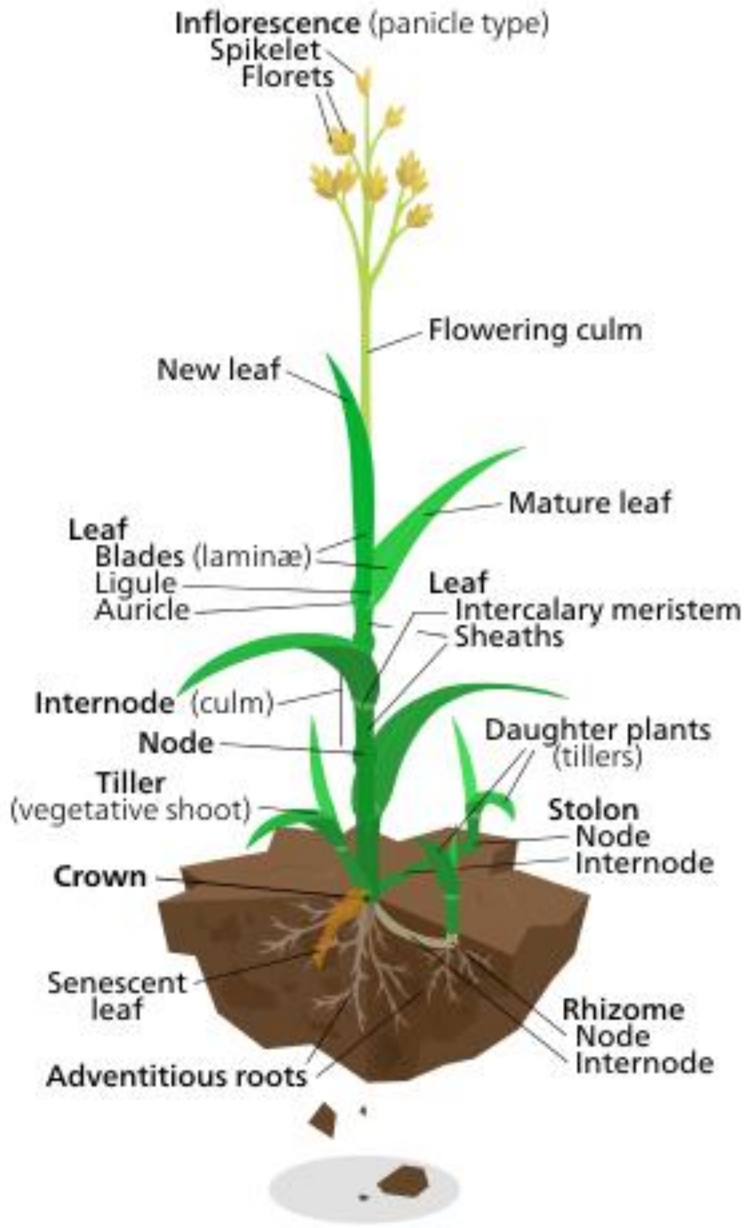


Distribution of deserts and semideserts (=steppes) in the world.

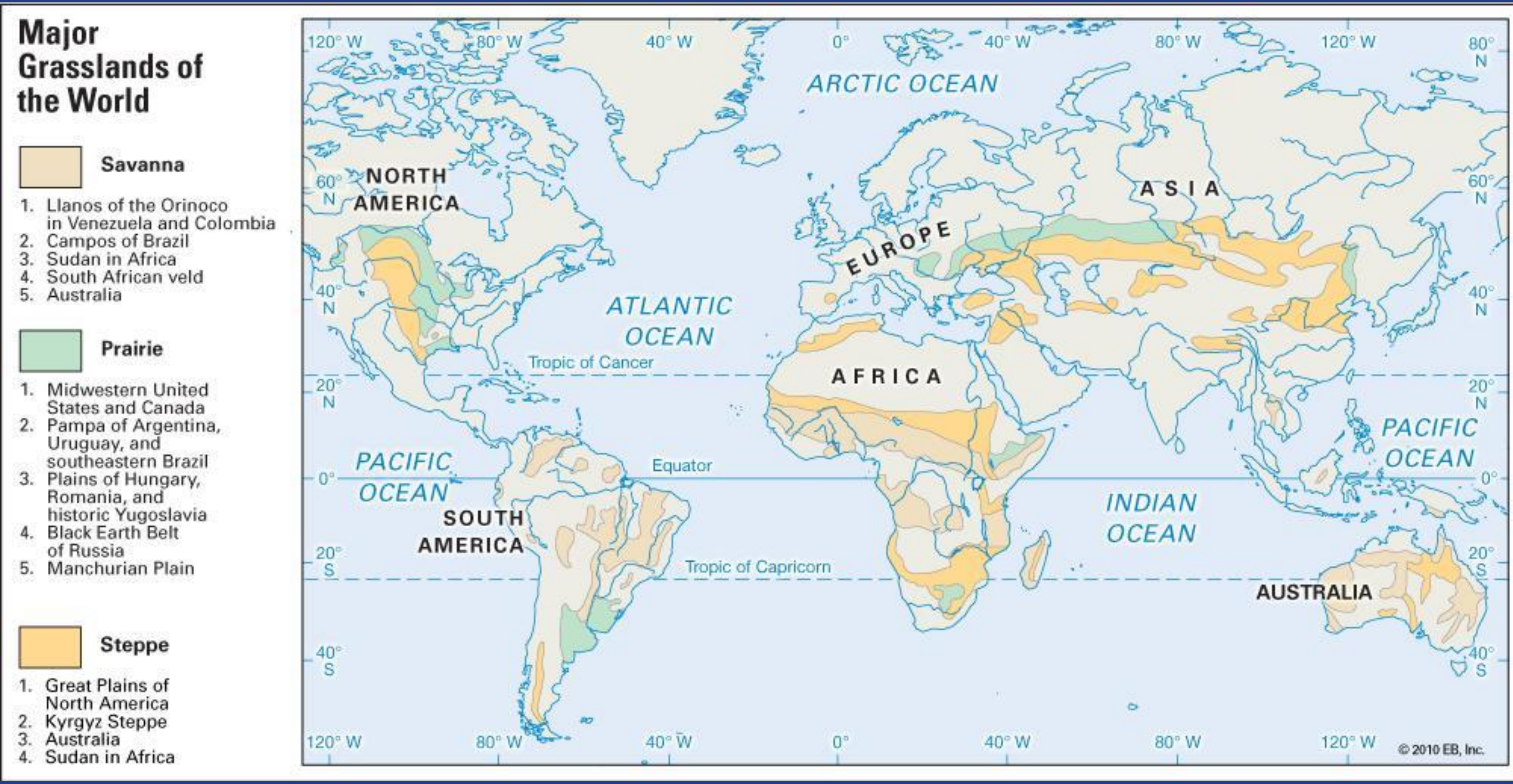
For all the semidesertic grasslands of the world, I find it useful to use a single term, namely steppe. But you should know its equivalent terms in other continents, so that when you read their geographical, geological and ecological literature, you will know what they are talking about.

What is a grass?

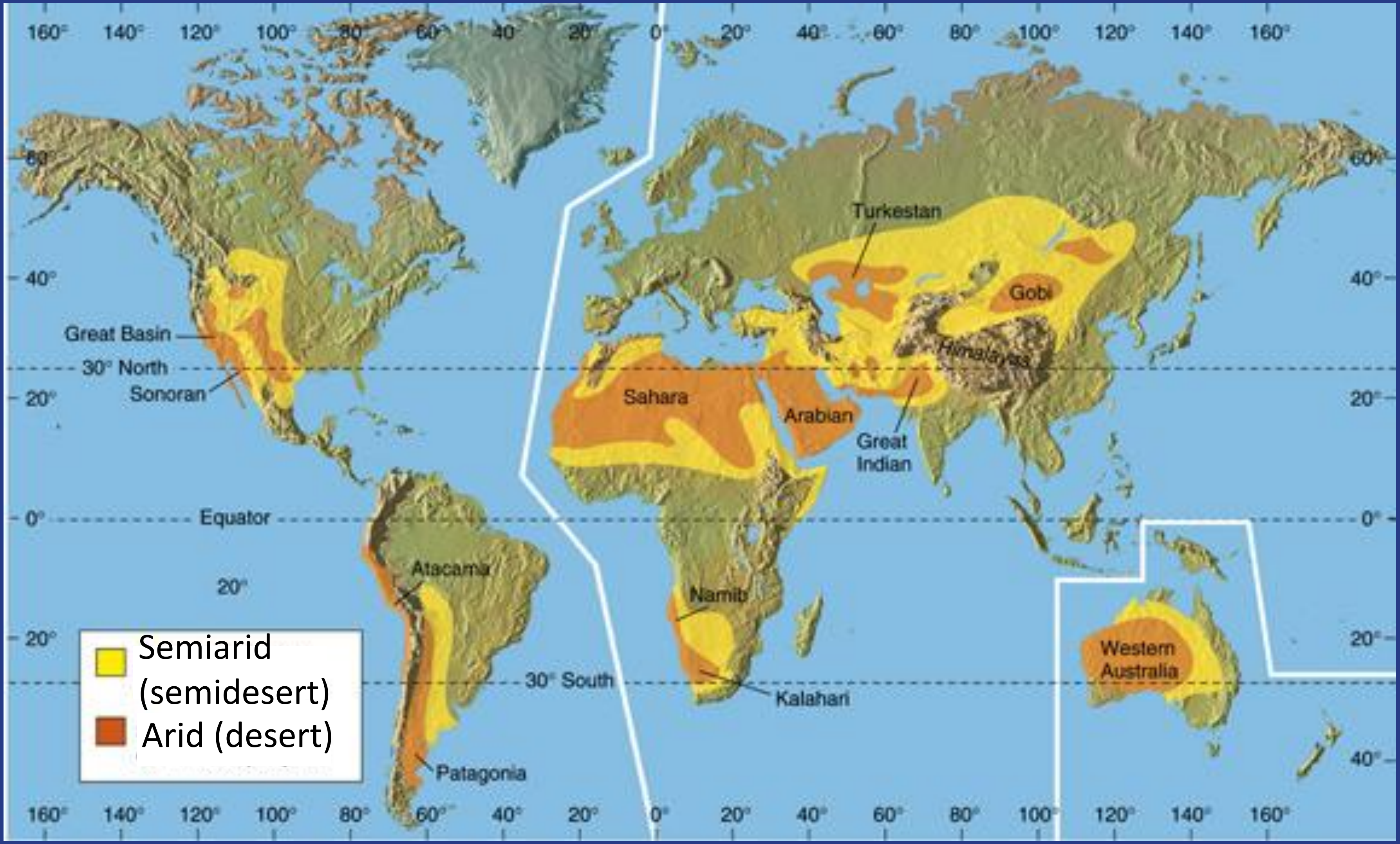
Grasses are the economically most important plant life on earth. They belong to the plant family Poaceae and are flowering plants include the cereal grasses (maize, wheat, barley, millet) bamboos, lawn grasses. They provide food, fuel (in the form of ethanol) and decoration for our gardens and lawns. The family Poaceae contain 780 genera and 12,000 species. They became common towards the end of the Cretaceous and contributed greatly to the evolution of grazing mammals during the Cainozoic.



Organs of a typical lawn grass



Grasslands constitute 20% of the plant cover of the earth



Distribution of deserts and semideserts (=steppes) in the world.

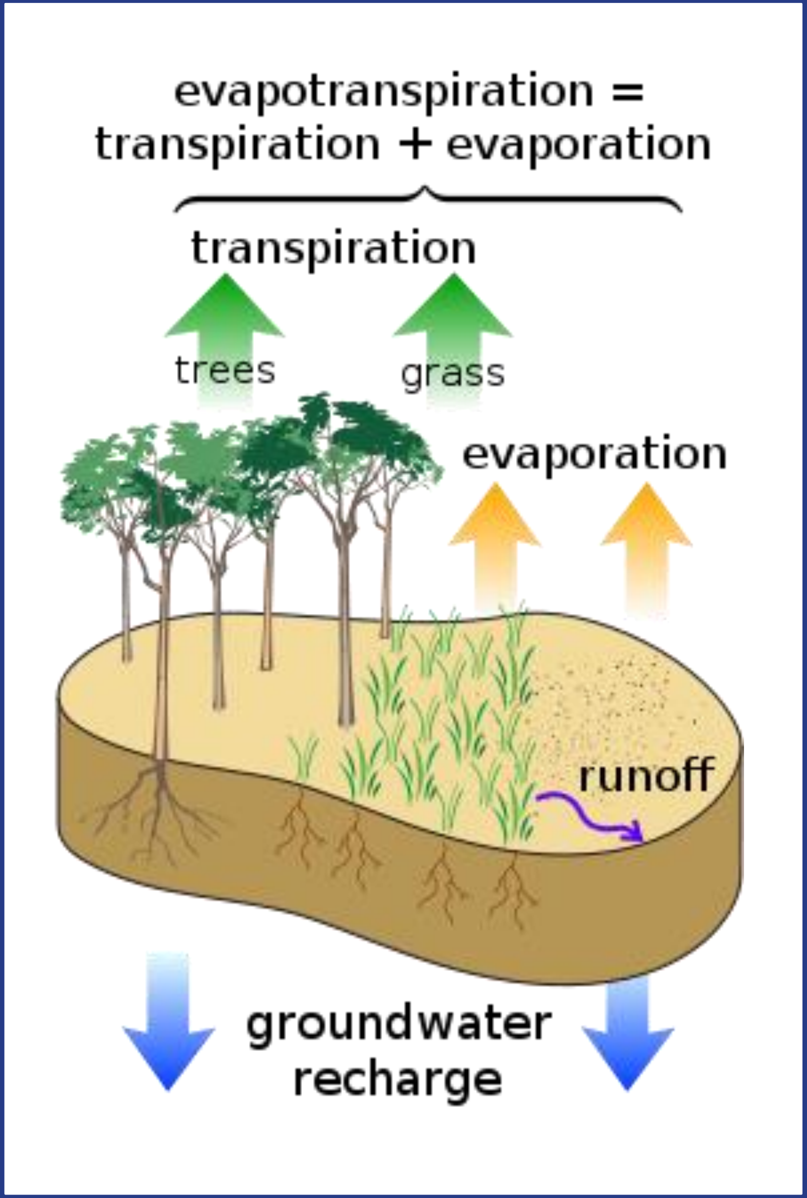
So far we have classified deserts and steppes according to the amount of annual precipitation. While helpful for a quick-and-dirty classification (and that is why it is the most widely used in the world), this method has the major drawback of neglecting the fact that precipitation alone does not determine the humidity (or aridity) of a region. They are determined by, above all, temperature, precipitation regime, evaporation conditions, soil characteristics and thus on the overall geography and even geological history of an area.

The United Nations Environmental Programme (UNEP) recently proposed an aridity index:

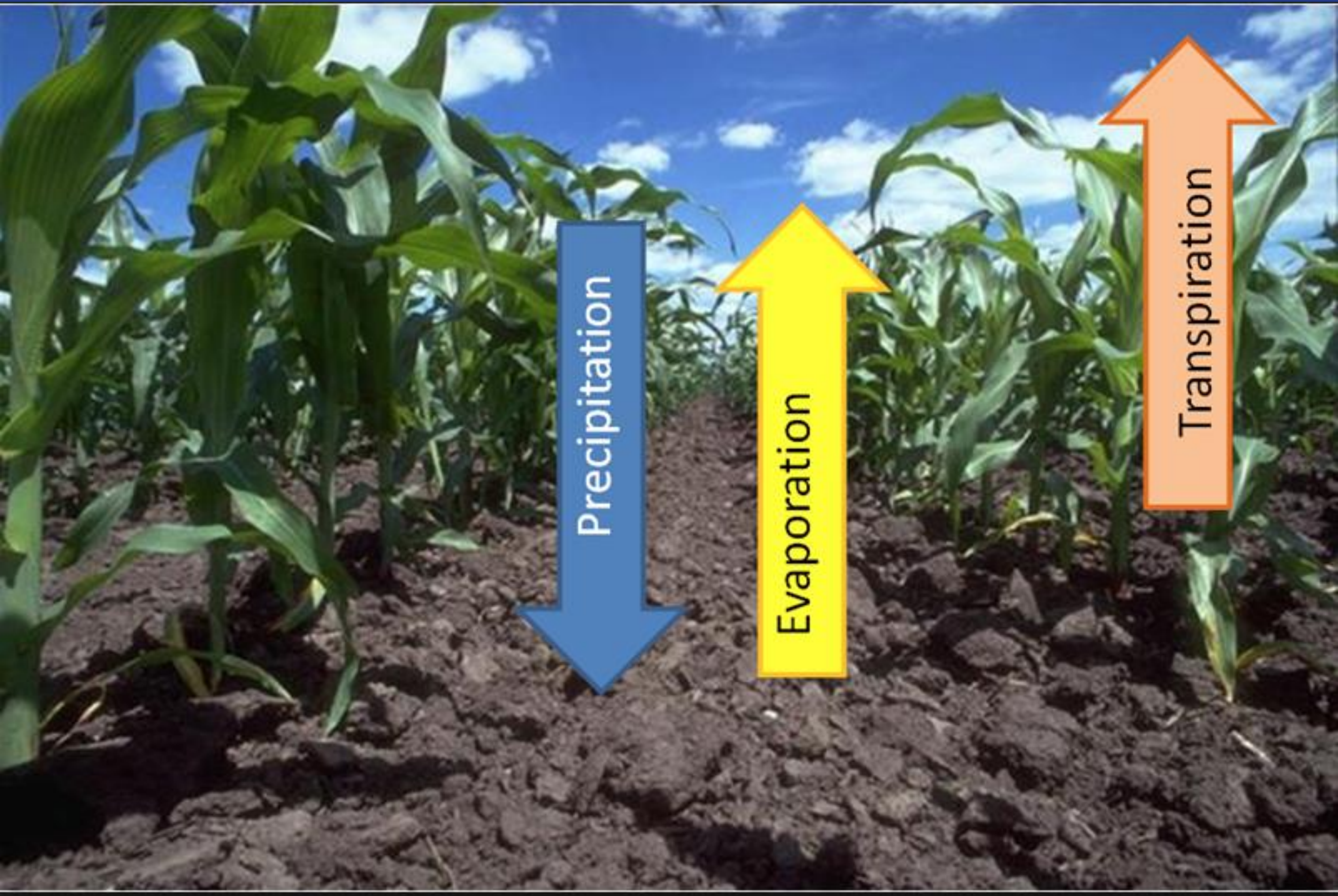
$AI_U = P/PET$

Here AI_U is the aridity index, P is the average annual precipitation and PET is the potential evapotranspiration.

Evapotranspiration is an extremely important concept and we should spend a little time on it.

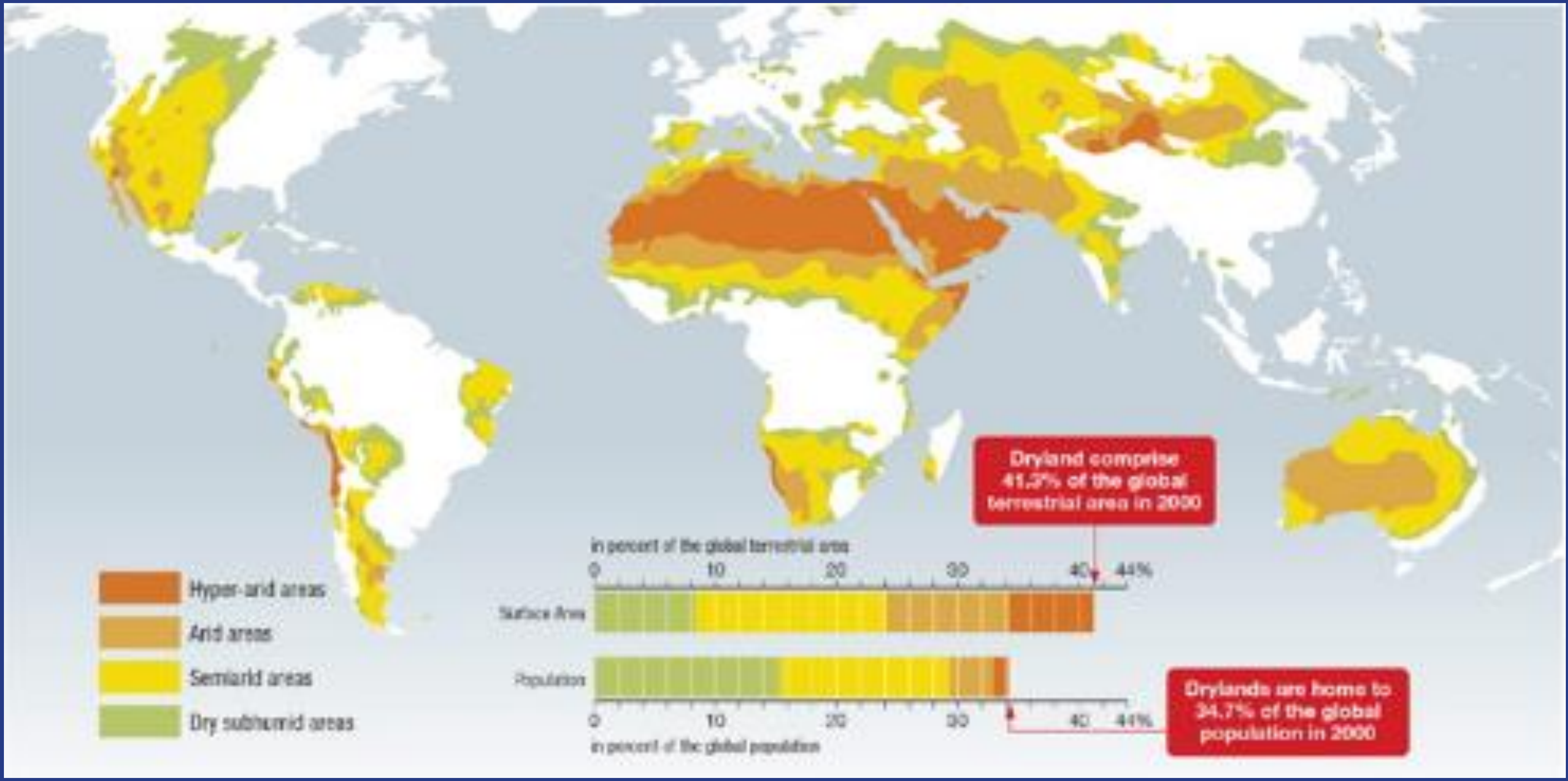


Evapotranspiration may be defined as the total amount of water vapor returned to the atmosphere in any given region. It happens by evaporation from the ground and by the transpiration of the plants.


Precipitation
Evaporation
Transpiration

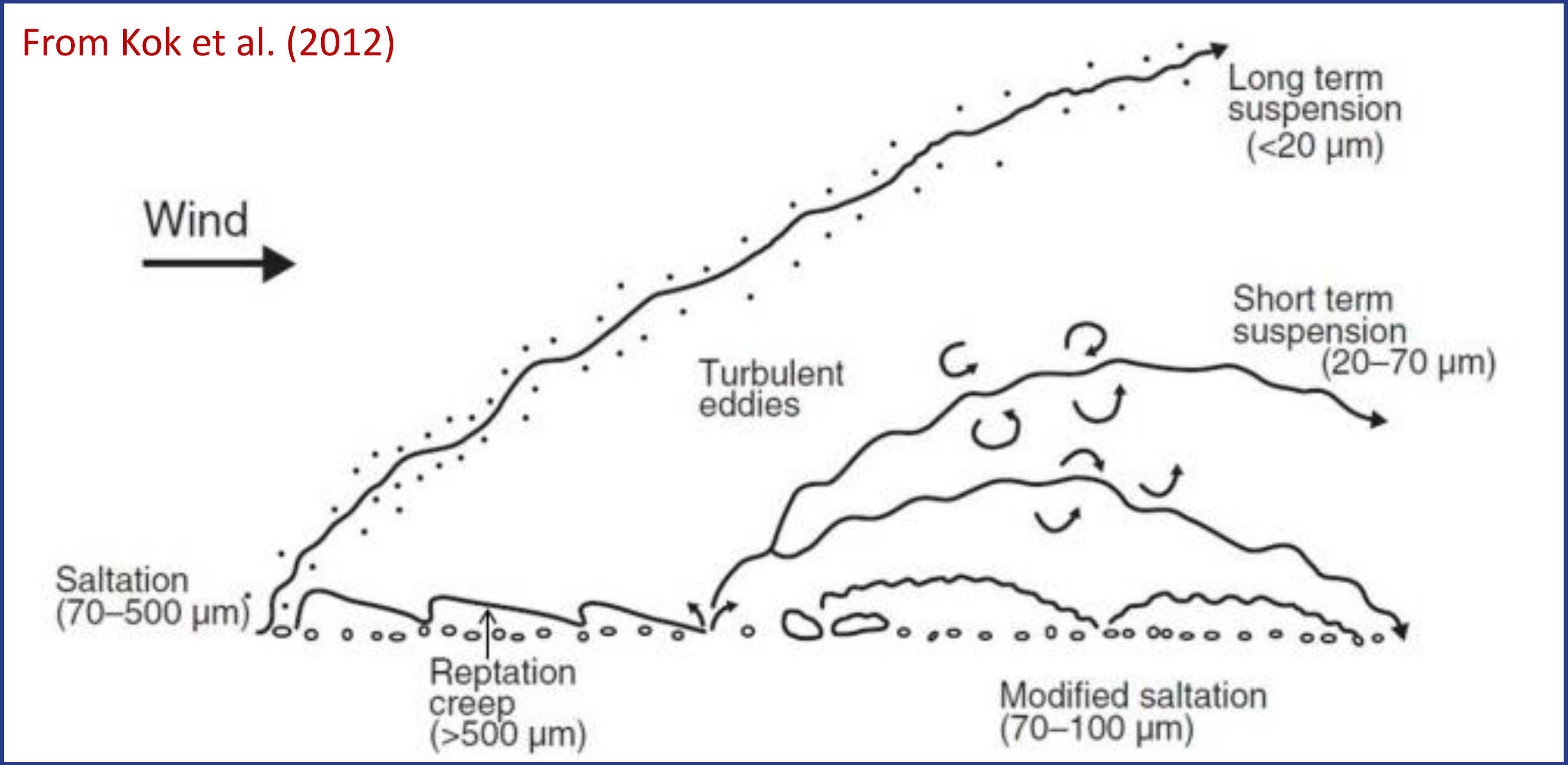
▼Classification of Dryland

Dryland Subtype	Aridity Index	Characteristics
Hyper-arid environments	AI<0.05	There is no seasonal rainfall regime, and these areas offer very limited opportunities for human activity (Desert area).
Arid areas	0.05≤AI<0.20	Annual precipitation values up to about 200 mm in winter rainfall areas and 300 mm in summer rainfall areas. Interannual variability is in the 50-100% range.
Semiarid areas	0.20≤AI<0.50	There are highly seasonal rainfall regimes and annual precipitation values up to 500 mm in winter rainfall areas and 800 mm in summer rainfall areas. Interannual variability is nonetheless high in the 25-50% range.
Dry subhumid areas	0.50≤AI<0.65	Less than 25% interannual rainfall variability and rain-fed agriculture is widely practiced.

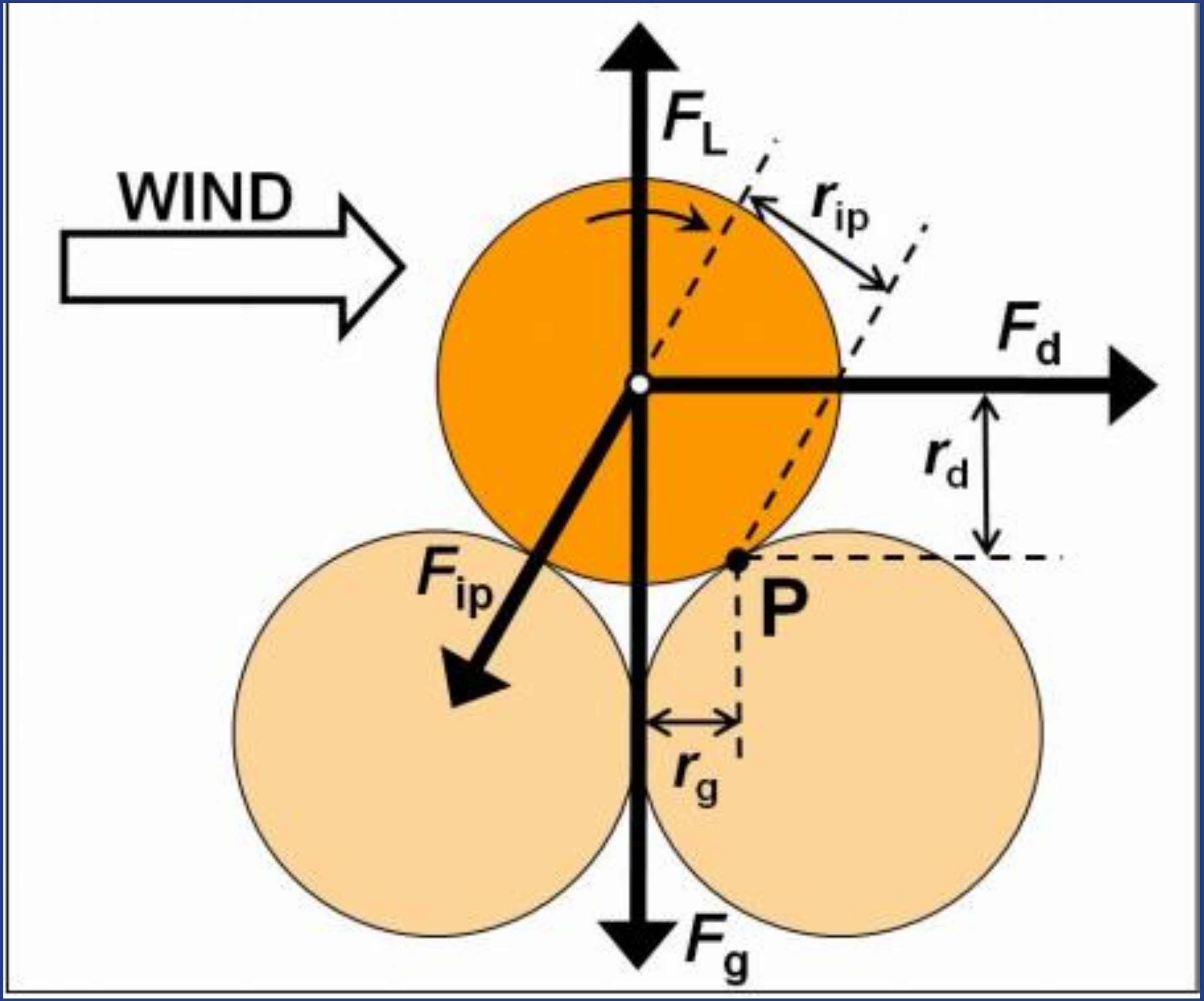


Disintegration of rocks to form sand, Sahara, Libya

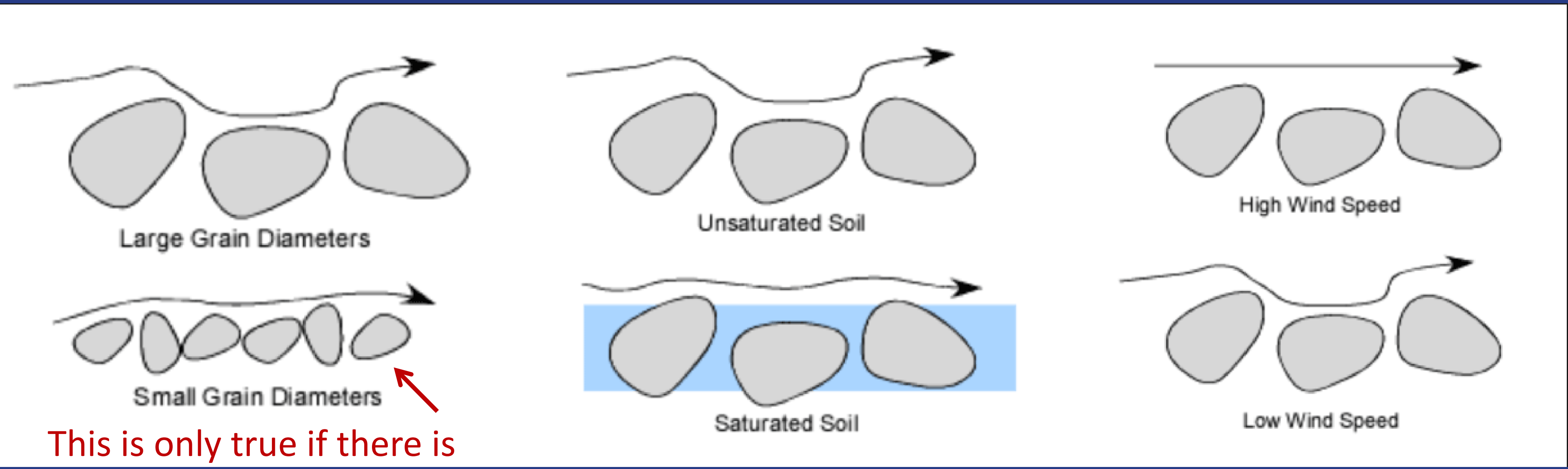
To investigate the formation of landforms and sediments by aeolian processes, we need to know what size particles winds can carry. First let us see what mechanisms of transport the wind uses to transport sand and silt and clay.



But the size of the particles that can be carried by the wind is not only dependent on their size, but also on the wind speed.



Forces acting on a single clastic particle resting on a bed of particles. From Kok et al. (2012)



This is only true if there is some compaction here

The influence of wind speed, grain size and water saturation on plucking of clastic particles from the ground by wind

Threshold Dust-Lofting Wind Speeds for Different Desert Environments

Environment	Threshold Wind Speed
Fine to medium sand in dune-covered areas	4 to 7 m/s (10 to 15 mph) 15 to 20 km/h
Sandy areas with poorly developed desert pavement	9 m/s (20 mph) 30 km/h
Fine material, desert flats	9 to 11 m/s (20 to 25 mph) 30 to 35 km/h
Alluvial fans and crusted salt flats (dry lake beds)	13 to 16 m/s (30 to 35 mph) 40 to 50 km/h
Well-developed desert pavement	18 m/s (40 mph) 60 km/h

Erosional aeolian landforms

- Ventifacts
  - Sand-blasted surfaces
  - Dreikanters
  - Desert mushroom-stones and tables
- Yardangs
- Bornhards and inselbergs

Sand being blown off the Kelso Dunes of the Mojave Desert, California, USA

Adequate crop residue on the surface prevents extensive wind erosion of the soil.

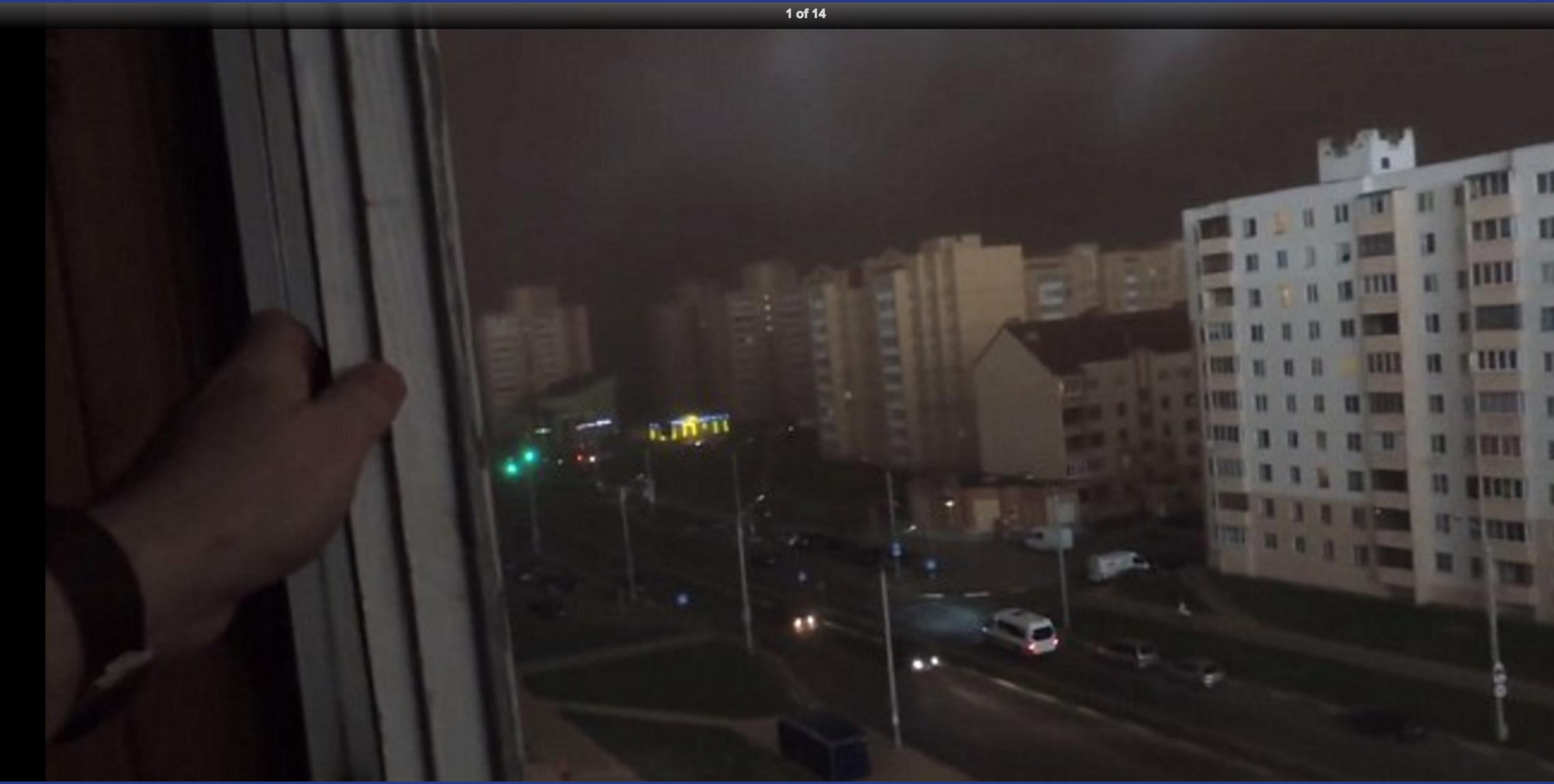
A dust storm invading the city of Phoenix, Arizona, USA

Phoenix during the dust storm

West Texas dust storm on Lubbock, Texas, USA, 19th December 2012, seen from an aeroplane

Before and during the dust storm in Lubbock Texas, USA

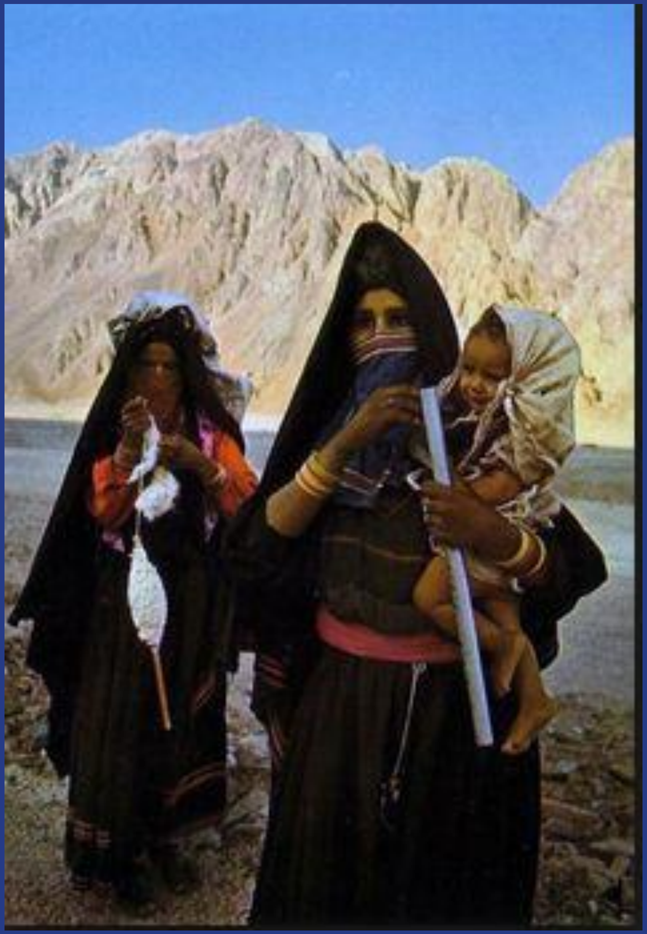
A dust storm invading the city of Golmund in northwest China



Golmund during the dust storm (this is a daytime picture!)

Dubai in the dust storm of 21st February 2015

Dust storm invading Dubai



Covering faces has long been a tradition in the Middle East both for men and women, not because of religion, but to protect themselves from sand blasting.

People walking with covered faces in Jerusalem in front of the Dome of the Rock (*Kubbat al Sahra*) to protect themselves against the blowing sand

Ventifacts

Sand blasted surfaces


POLISHED
SANDBLASTED

A sand-blasted surface of a sandstone

This joint pattern has been sculpted out of the rock by sand blasting.

Taphoni (singular form: taphone) are small and numerous cavities separated from one another commonly by septa formed by sand blasting. The origin of the word taphone is unclear but may come from the Siciliaqn *tafonare* meaning to perforate.

Tafoni from the Isle of Skye, Scotland

Taphoni in current-bedded sandstones created by sand blasting and differential erosion

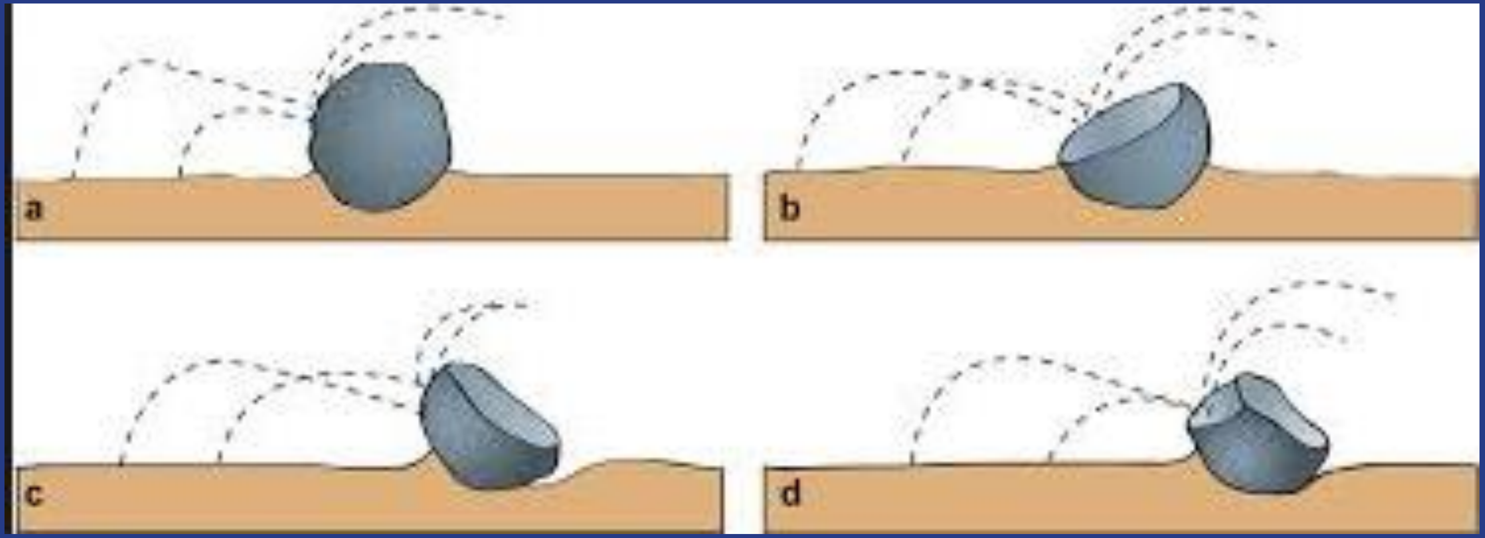
Taphoni created on a sandstone surface by wind blasting in the David Canyon, Utah, USA.

Rhizoliths (mineralised plant roots and stems) laid bare by wind erosion, Rio Lagartos, Yucatan peninsula, Mexico

Erosion by sandblasting of seawater in Marmara Ereğlisi, (Perinthos), Turkey

Dreikanters

A dreikanter is a three-faced, pyramidal stone formed by wind erosion on its three sides. They usually form when a piece of rock eroded on one side by the wind is then turned through a variety of reasons to another side and then has that side exposed to prolonged wind erosion. Dreikanter is a German word simply meaning three-edged.



Dreikanters on the desert floor, Sahara, Libya

Numerous ventifacts on the floor of the Sahara, Libya. Note that they are not all dreikanters!

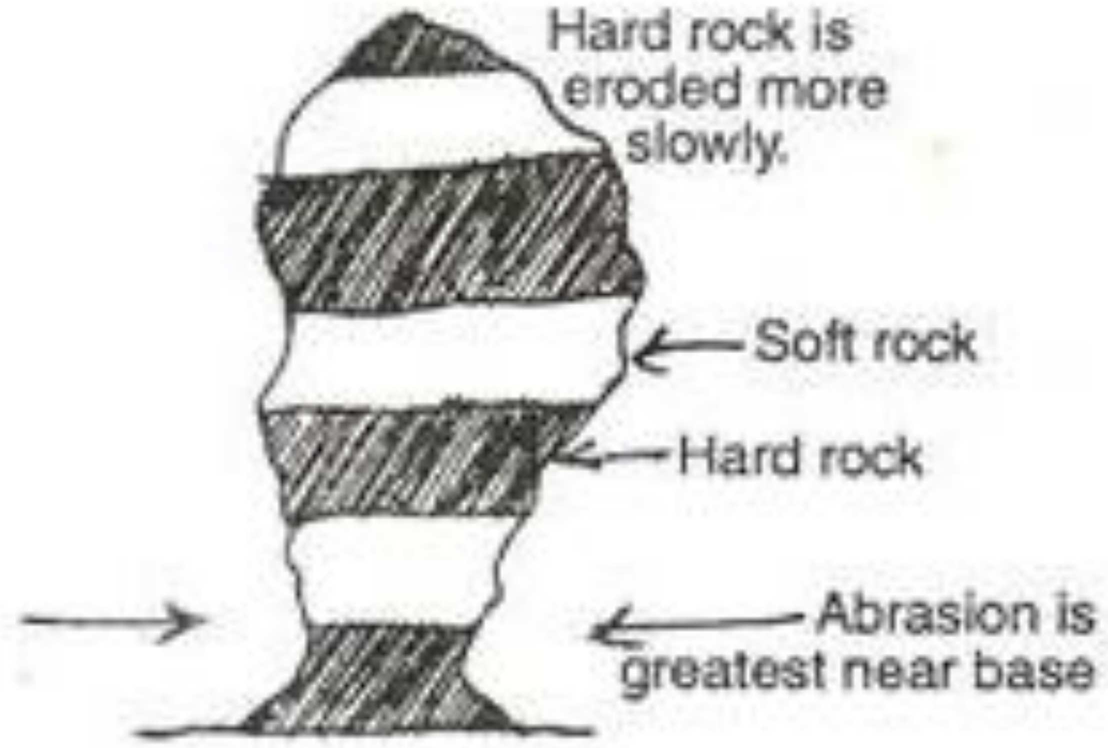
Formation of ventifacts, including dreikanters, in the Sahara, Libya


Sammlung Hincke

Wind-scoured troughs in Coyote Buttes, Southern Utah, USA (the rock is Navajo Sandstone)

A desert mushroom in the Alxa (Ala Shan) geopark,
People’s Republic of China

A mushroom rock in formation, Sahara, Libya



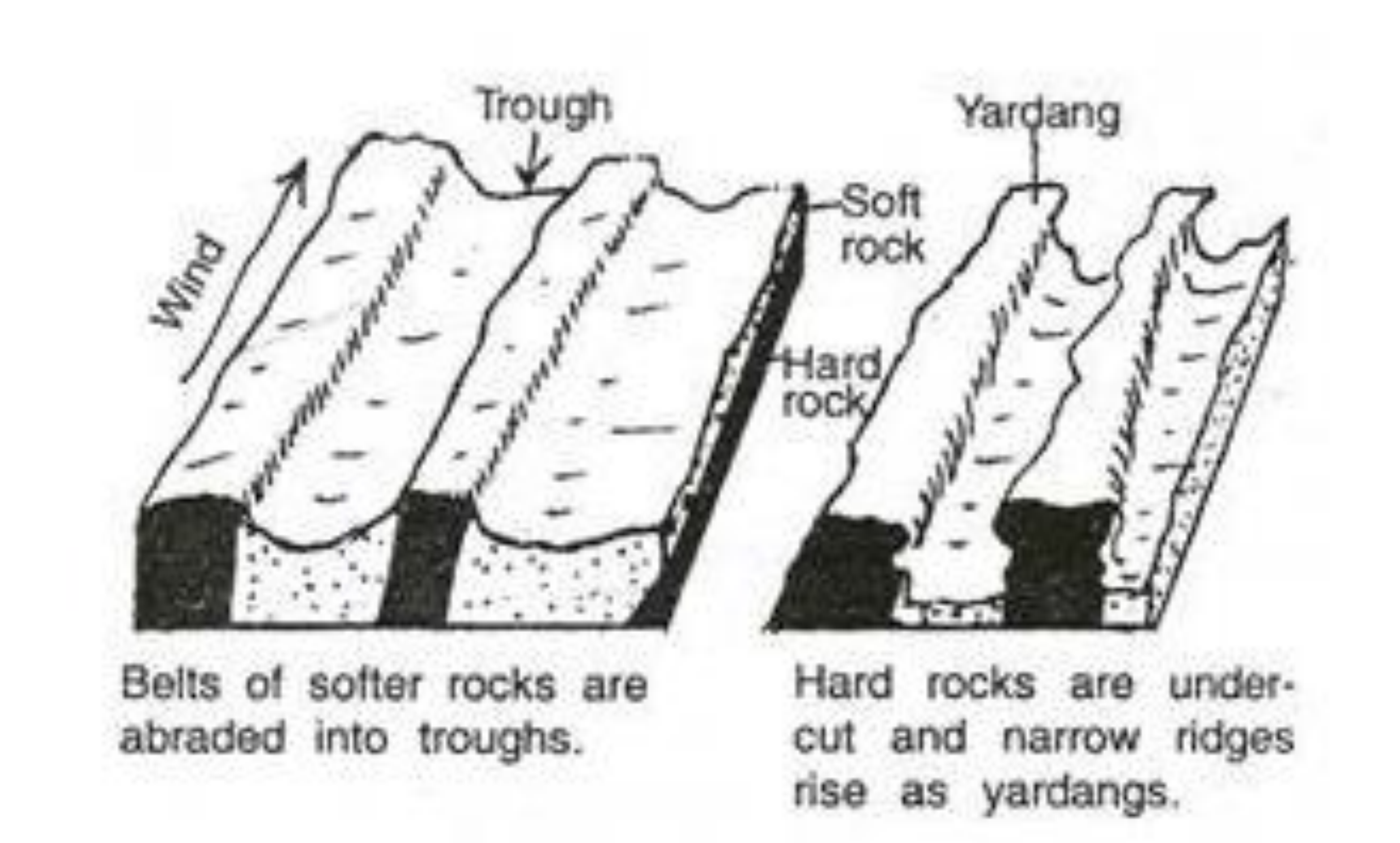
Origin of desert mushrooms or mushroom rocks

A desert table in the Vermilion Cliffs, Arizona, USA

Yardangs

Yardangs in the Gobi Desert, near Yumenguan, People's Republic of China

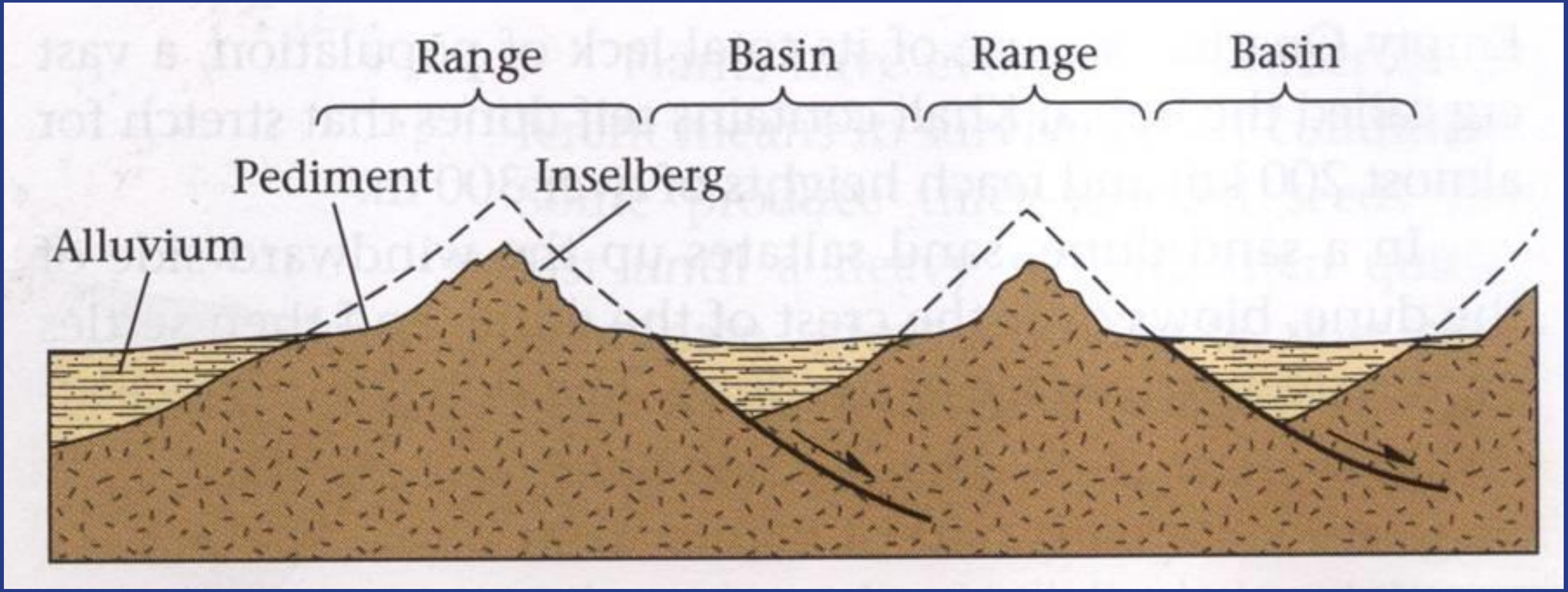
Yardangs in Egypt



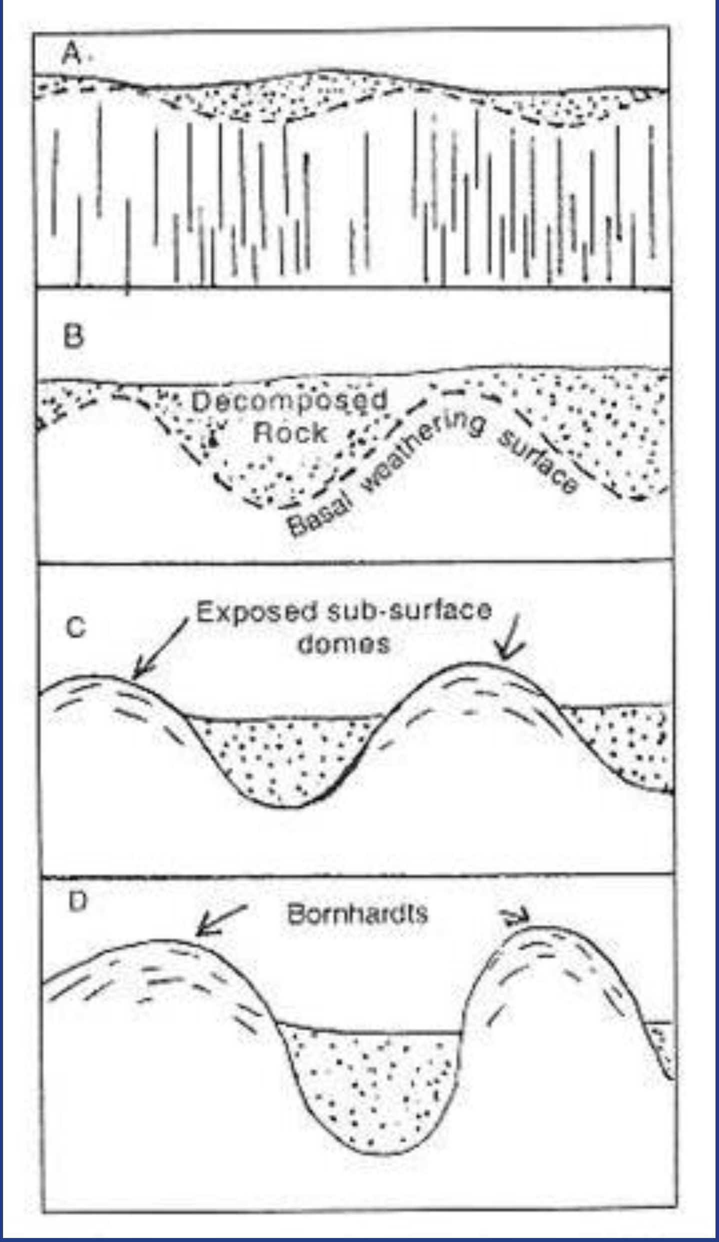
The formation of yardangs.

Inselbergs and bornhards are essentially the same things. They are parts of the basement of the desert deposits sticking out of them because of erosion.

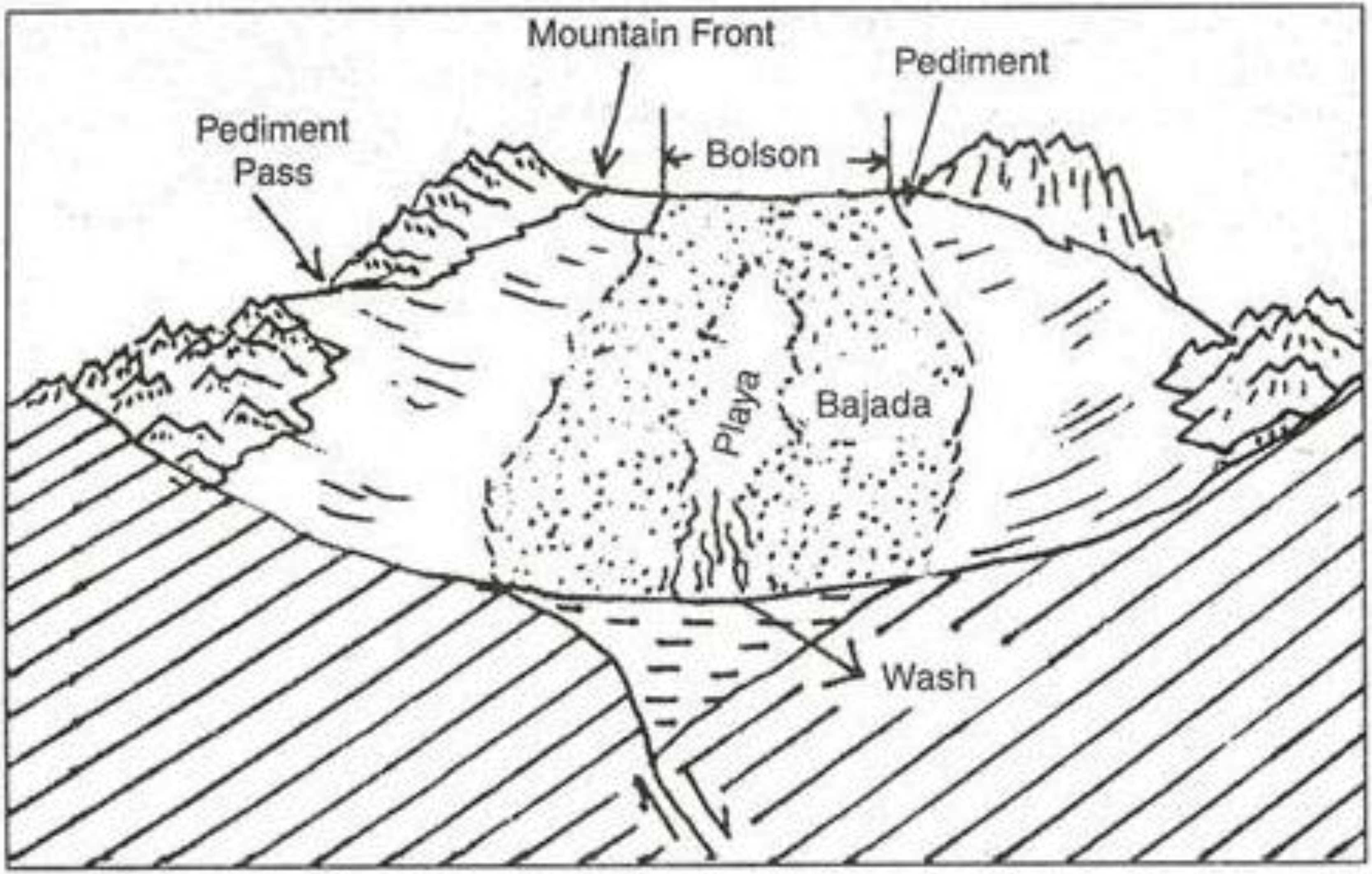
Spitzkoppe, in Namibia, Southwest Africa. A magnificent inselberg.



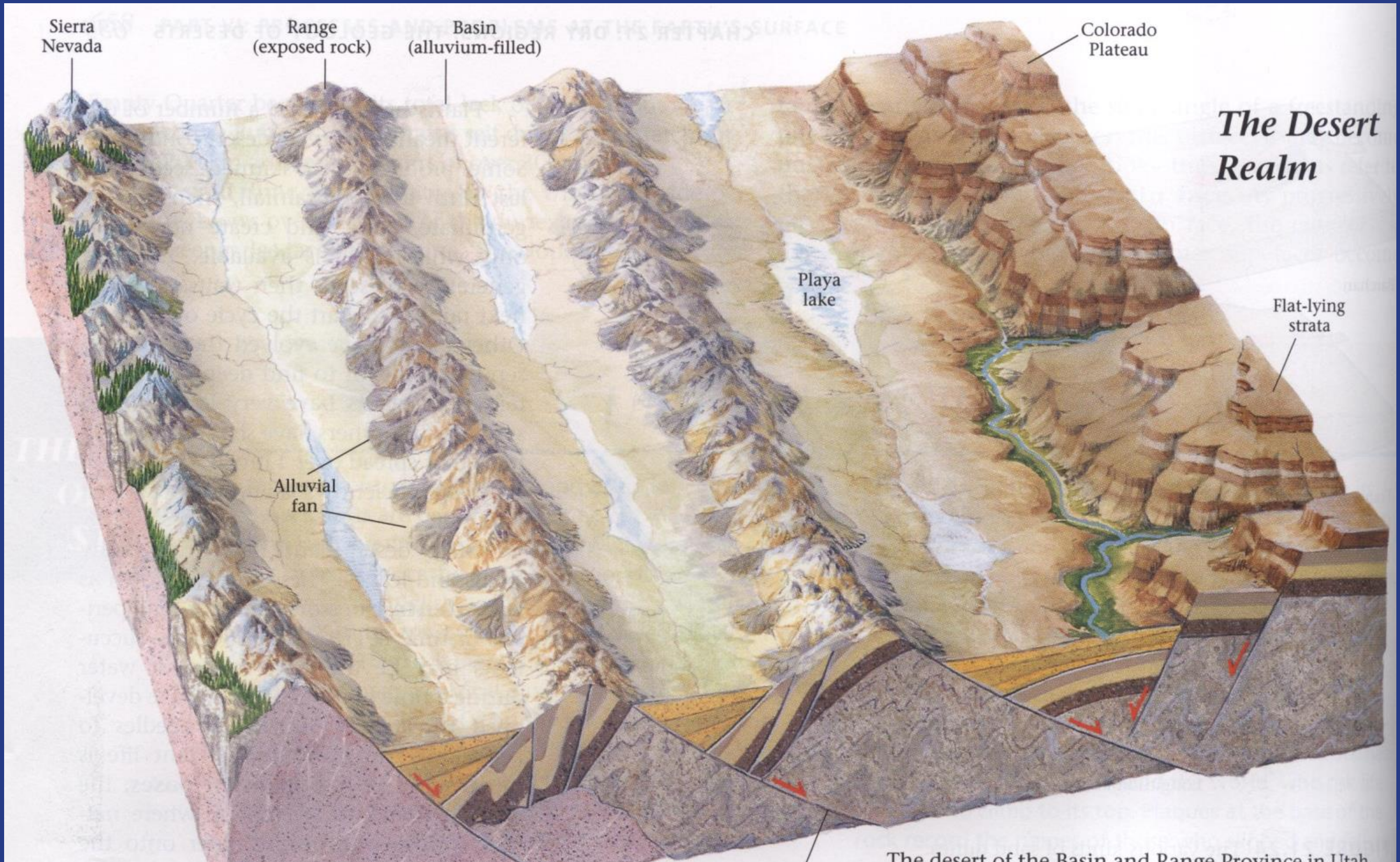
Geomorphological elements of the Basin-and-Range style rifting



Formation of bornhards

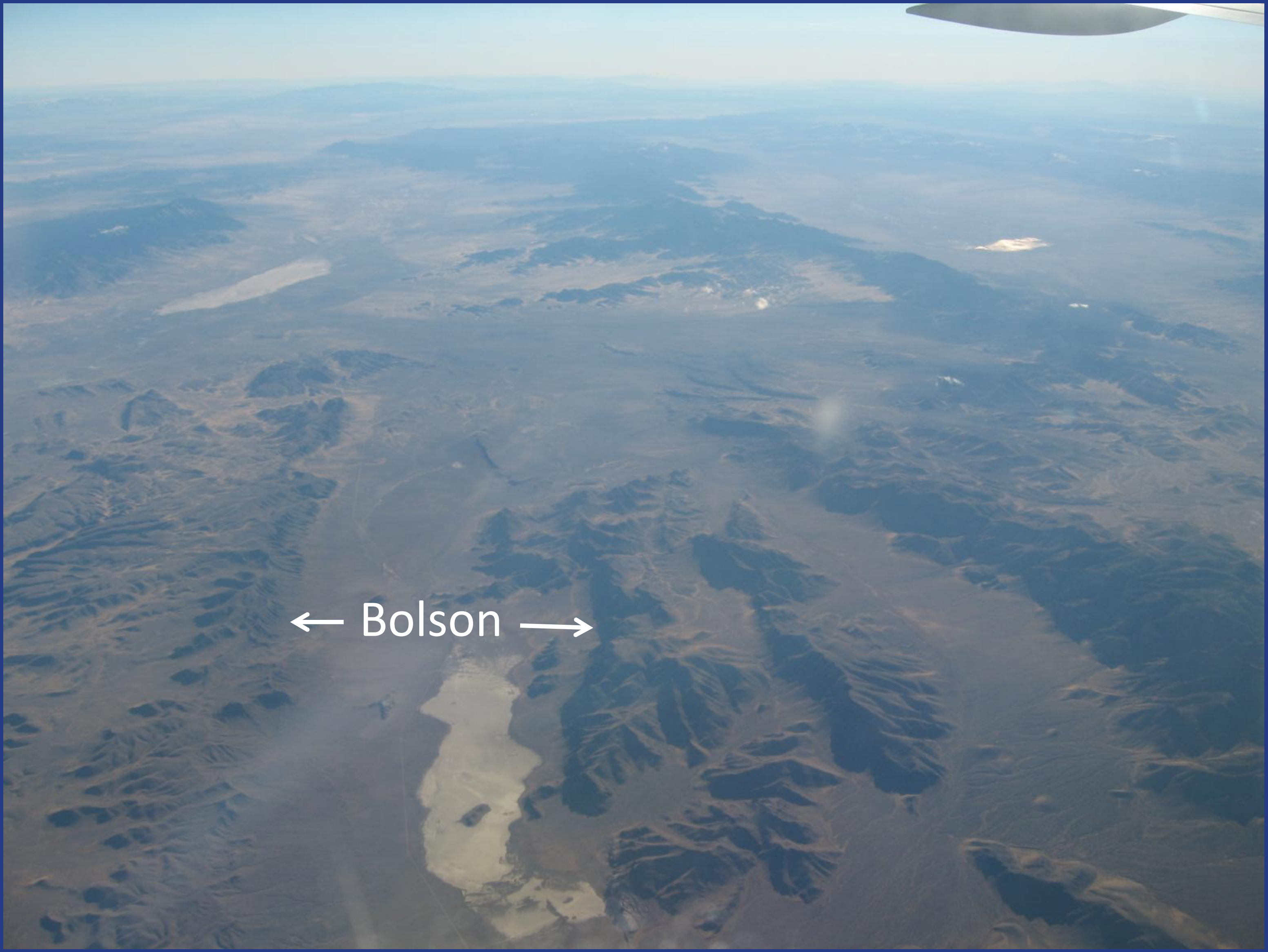


Desert landforms in extensional areas



The desert of the Basin and Range Province in Utah, Nevada, and Arizona consists of alternating basins (grabens or half-grabens) separated by narrow ranges (tilted fault blocks). The Sierra Nevadas, underlain largel

The Basin-and-Range province in the western United States. It is an exteensional area underlying a desert to semi-deset region



Typical Basin-and-Range ranges viewed from the N (Nevada) with three playas in view

A playa in the Basin-and-Range province, Nevada, USA


BAJADA

Depositional aeolian landforms

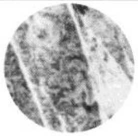
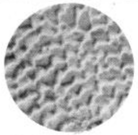
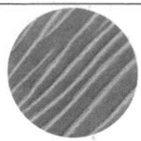
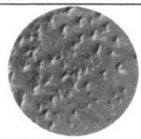
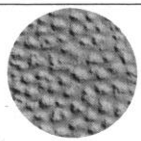
Dunes are the most important aeolian depositional landforms. They mostly determine the sedimentary structures that form in aeolian deposits seen in the geological record. Although the extensive sand blankets cover large areas, it is the dunes that give the aeolian deposits their characteristic signatures.

Dunes

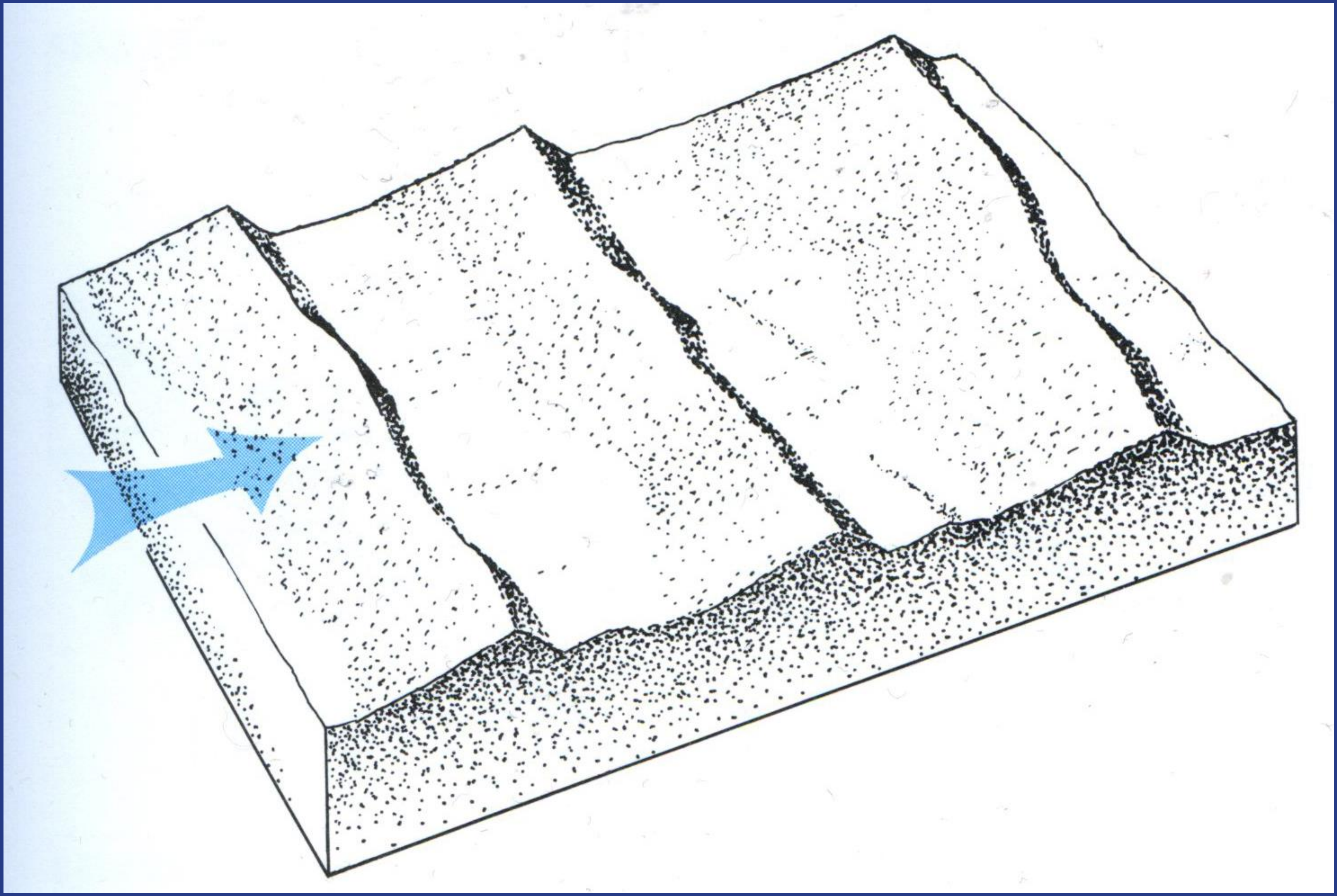
Dunes are sand accumulations of various shapes occurring usually in groups and moving in unison. There is a very large variety of dune shapes and their origin is not always clear. That is why their classification offers some problems. The simples dune classification recognises only two classes: longitudinal dunes and transverse dunes. However, a third type, a star-dune is in neither class.

TABLE 1. — *Terminology of basic dune types and other eolian deposits*

[Examples may show simple or compound dunes; however, they are designated by basic dune type only]

Form	Number of slipfaces	Name used in ground study of form, slipface, and internal structure	Block diagram figure numbers (Chapter A)	Name used in space-imagery and air-photo study of pattern and morphology (Chapters J, K)	Examples from Landsat imagery (0–16 MILES; 0–25 KILOMETRES)
Sheetlike with broad, flat surface	None	Sheet	None, flat surface	Sheet[1]	
Thin, elongate strip	None	Stringer	None, flat surface	Streak[1]	
Circular or elliptical mound	None[2]	Dome	For detail see fig. 7	Dome-shaped	([3])
Crescent in plan view	1	Barchan	For detail see fig. 3	Crescentic: Barchan	([3])
Row of connected crescents in plan view	1	Barchanoid ridge	For detail see fig. 4	Crescentic: Barchanoid ridge	
Asymmetrical ridge	1	Transverse ridge	For detail see fig. 5		
Circular rim of depression	1 or more	Blowout[4]	For detail see fig. 8	Not recognized	([3])
"U" shape in plan view	1 or more	Parabolic[4]	For detail see fig. 9	Parabolic	
Symmetrical ridge	2	Linear (seif)	For detail see fig. 10	Linear	
Asymmetrical ridge	2	Reversing	For detail see fig. 12	Reversing	
Central peak with 3 or more arms	3 or more	Star	For detail see fig. 11	Star	

Dune classification by Edwin D. McKee, United States Geological Survey (USGS)



Transverse dunes. Blue arrow shows the prevailing wind direction

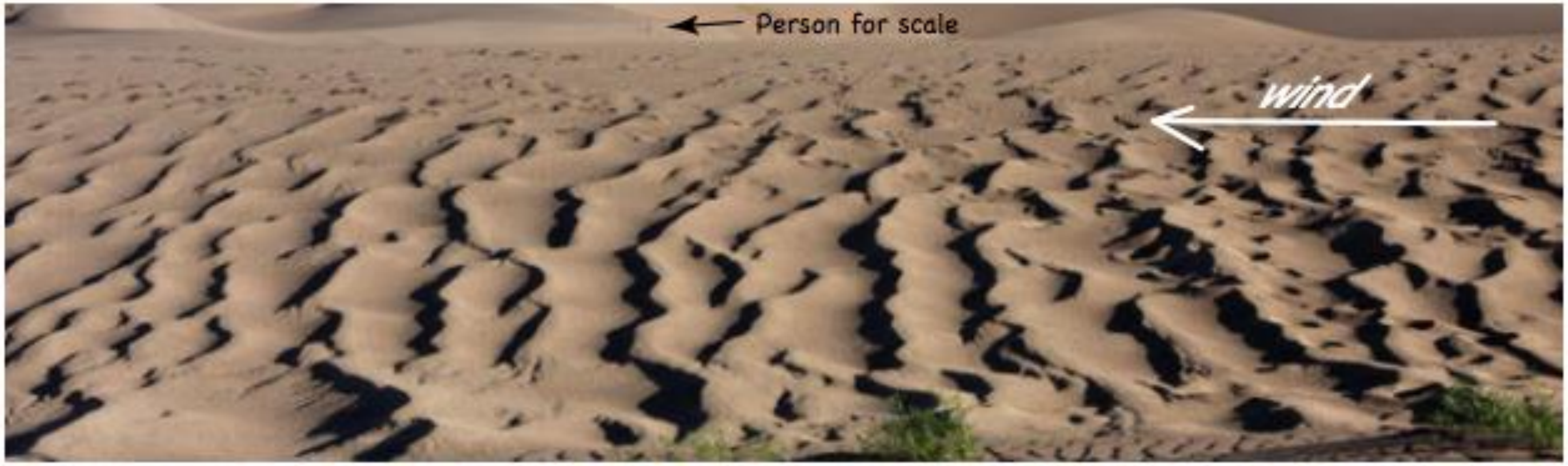
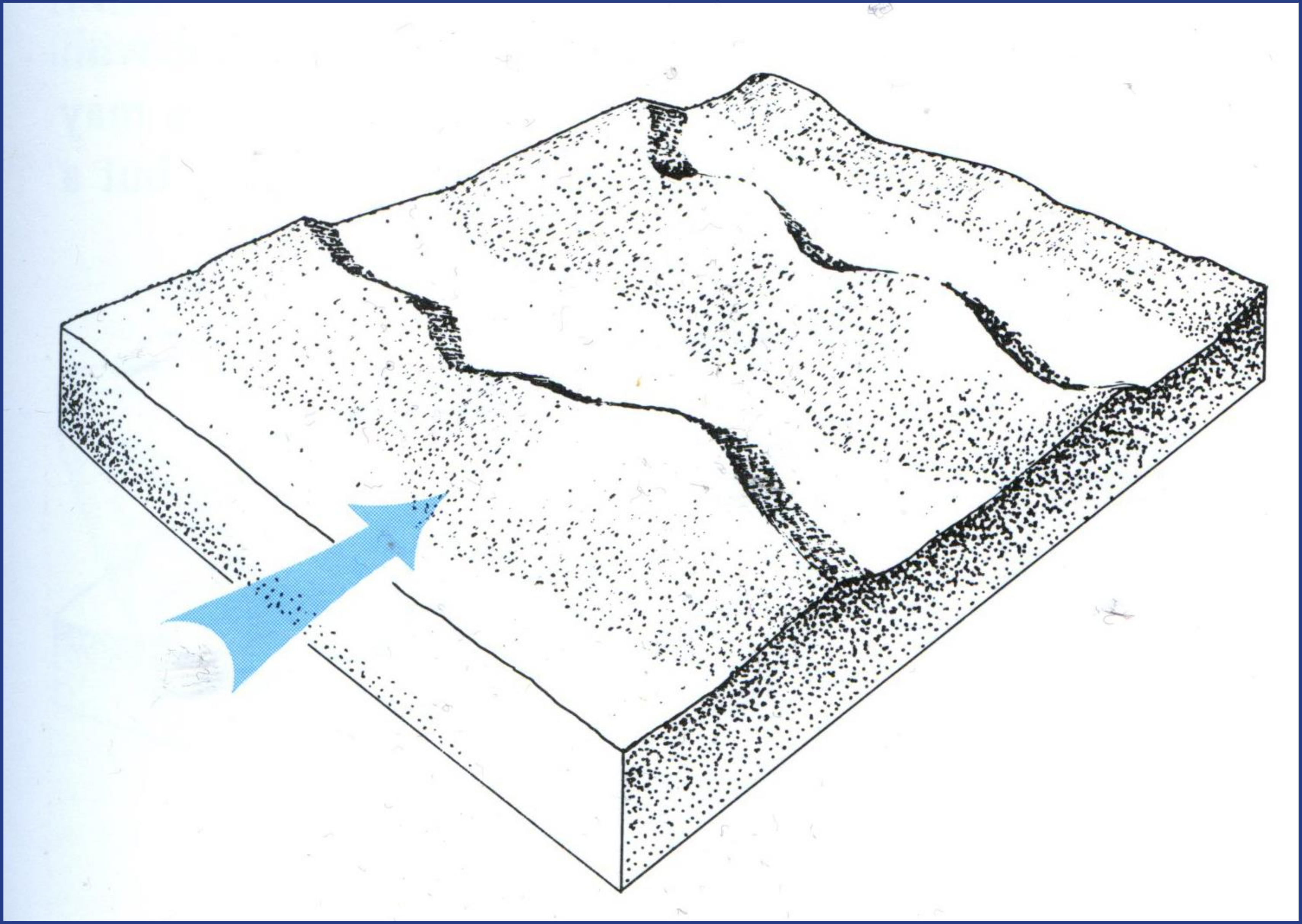
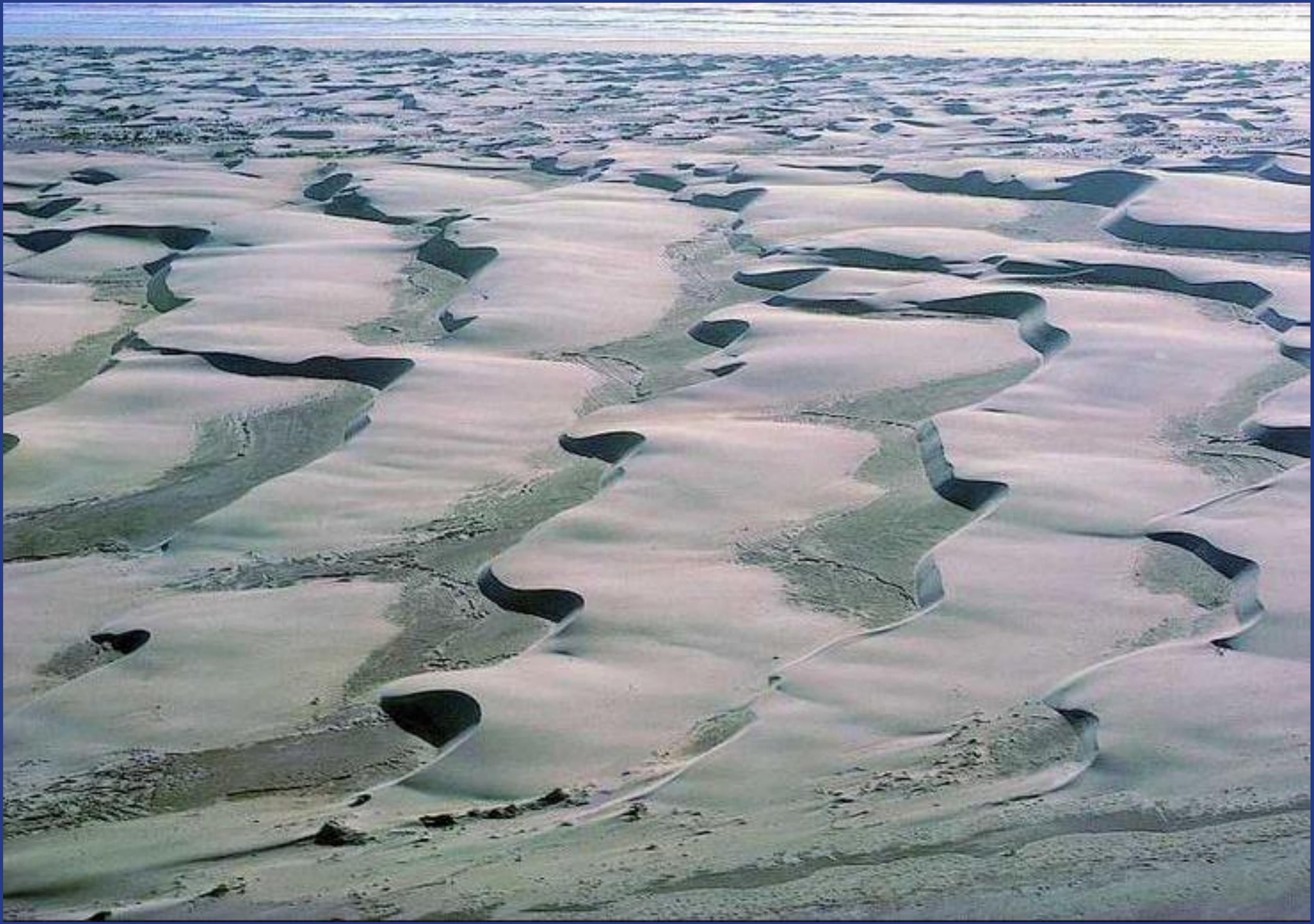


Figure 29. Transverse dunes. In regions of yet greater sand accumulation than in regions of Barchan or Barchanoid dunes, steady prevailing winds produce continuous crests of dune peaks oriented transverse to the prevailing wind direction. Like Barchan and Barchanoid dunes, the crests are cuspate in map view and the steep sides are in the direction that the wind blows. White Arrow is wind direction. (Photo: Ron Wolf - Google Images).

Coalescing transverse dunes.

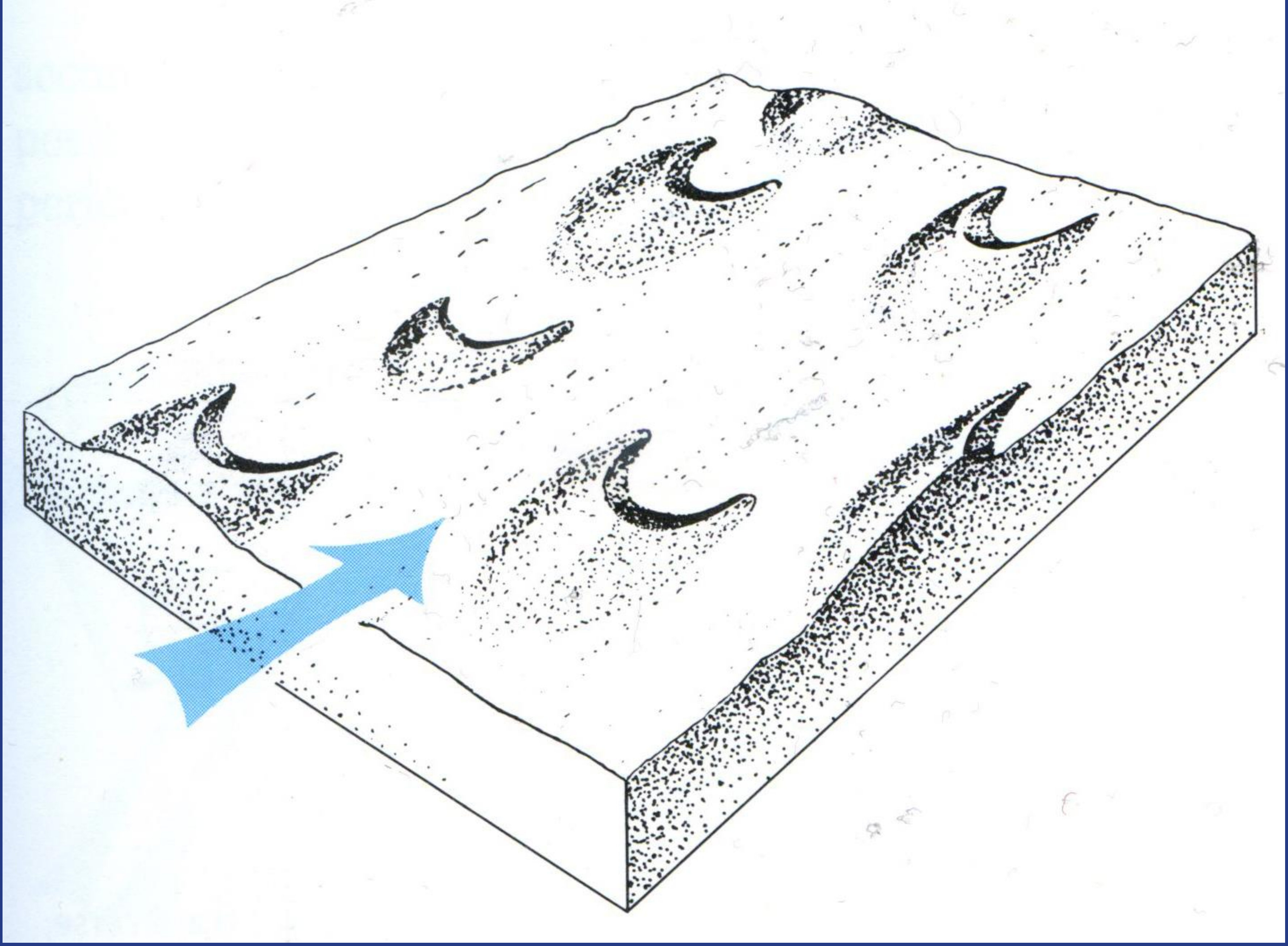


Transverse dunes in the form of barchanoid ridges



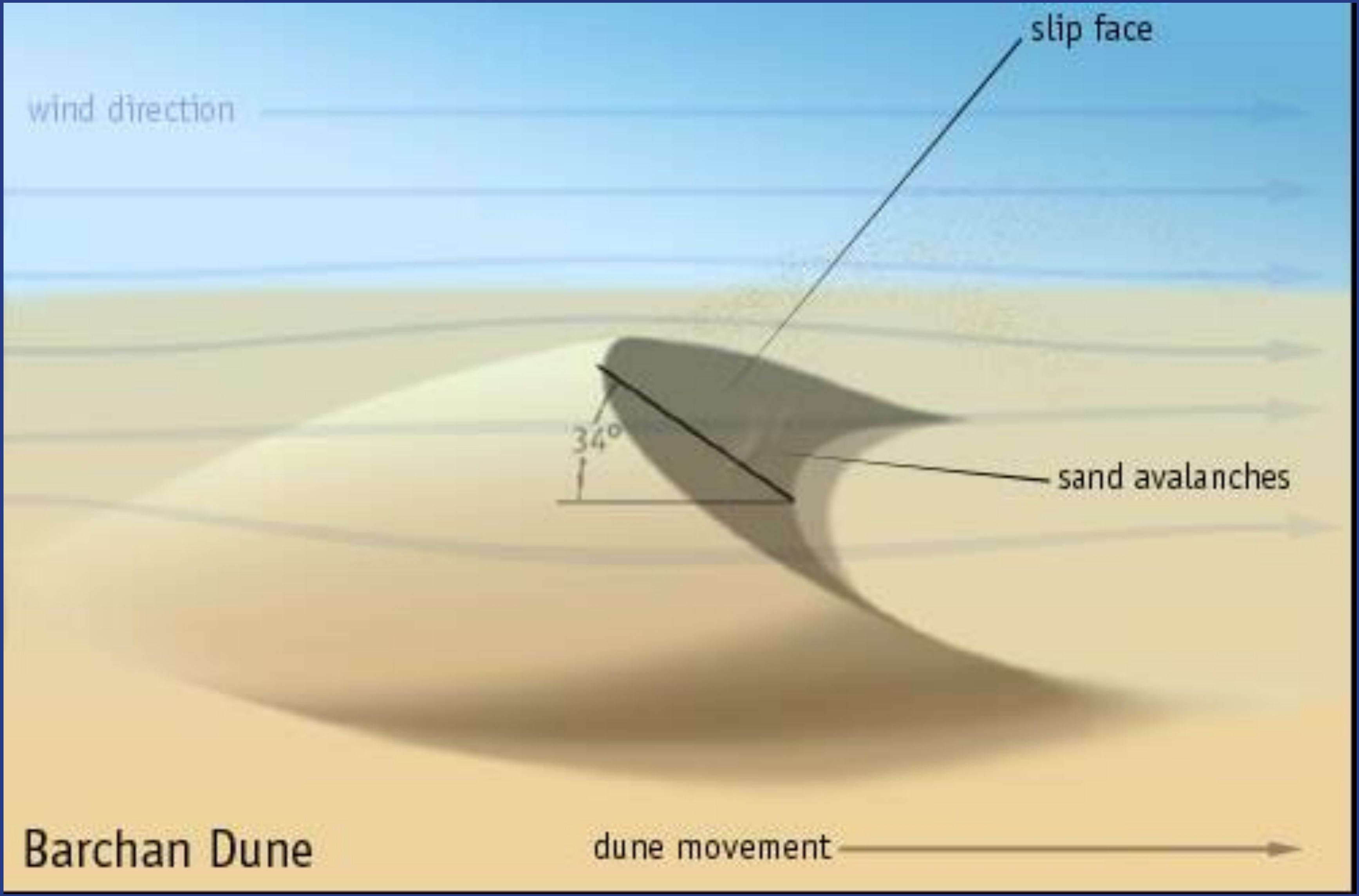
Transverse dunes in the form of barchanoid ridges in the Baja California, Mexico.

Perfectly-formed barchanoid ridges, the so-called Lençóis Maranhenses in northeastern Brazil



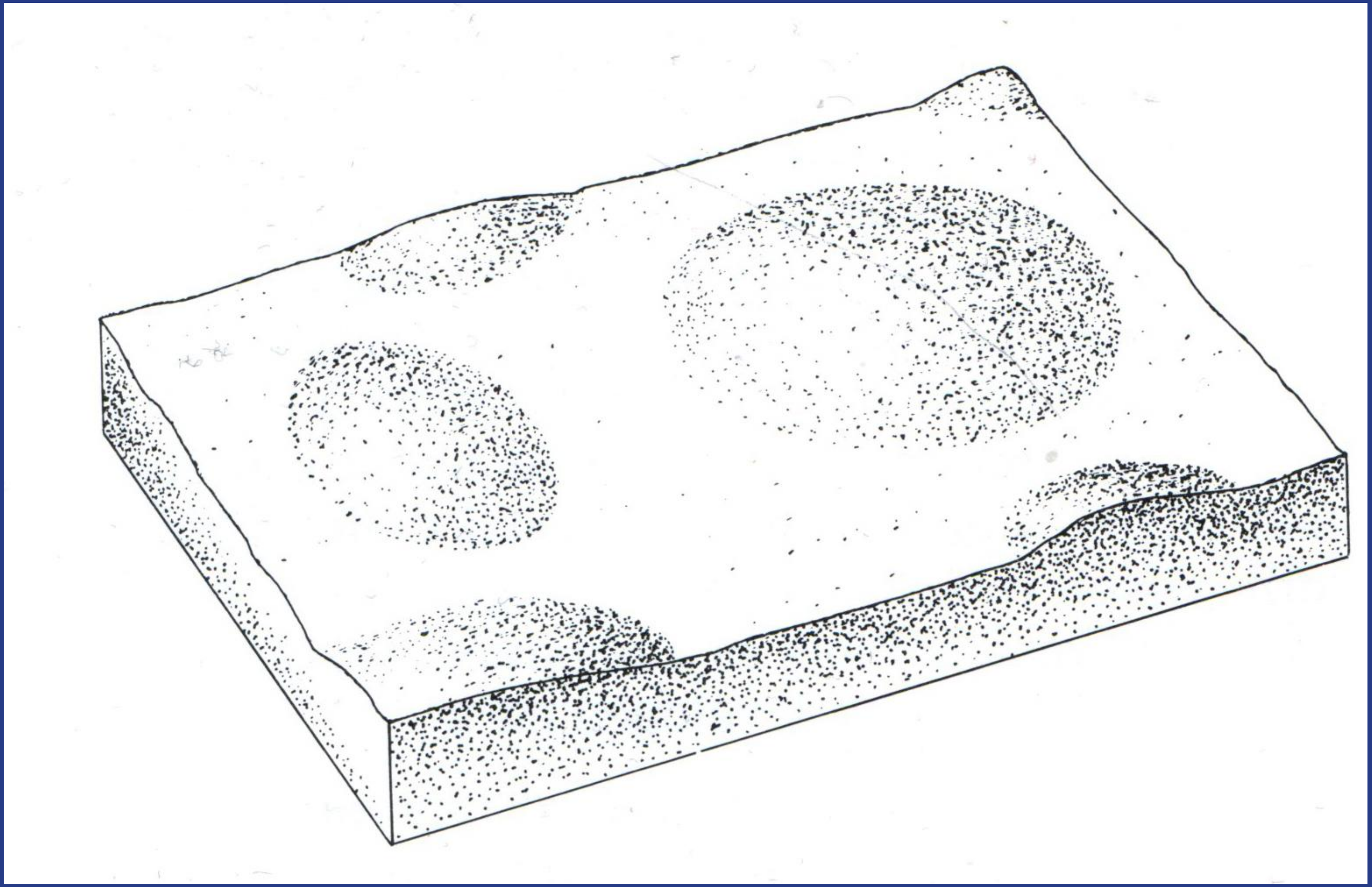
Barchan dunes

Barchans are crescentric dunes with the pointed ends of the crescent showing the prevailing wind direction. The word “barchan” is of Turkic origin, used in Central Asia, and was introduced into the geological terminology by the Russian explorer Alexander Middendorf in 1881.



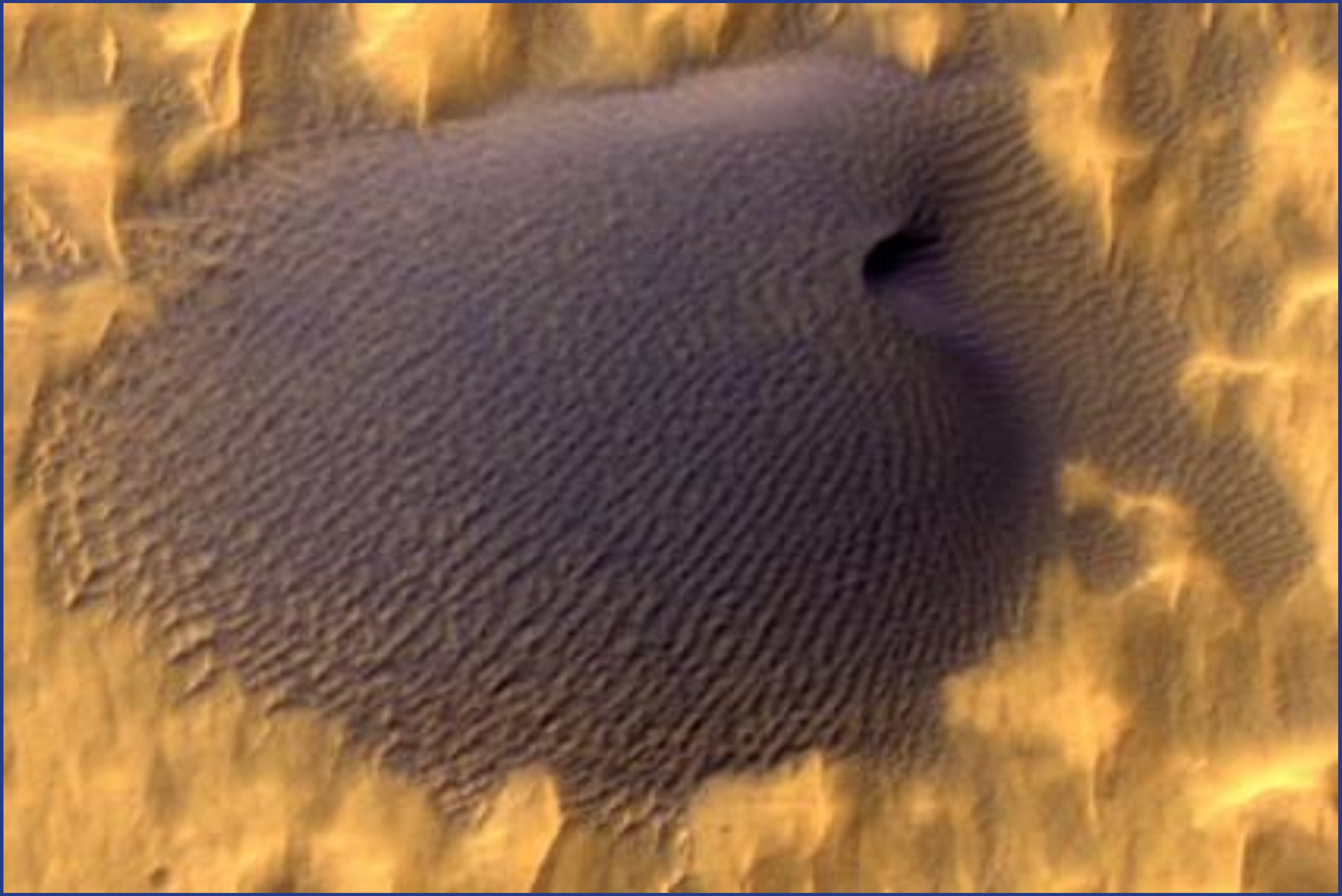
A barchan dune

Barkhans in Qatar, Arabian Peninsula



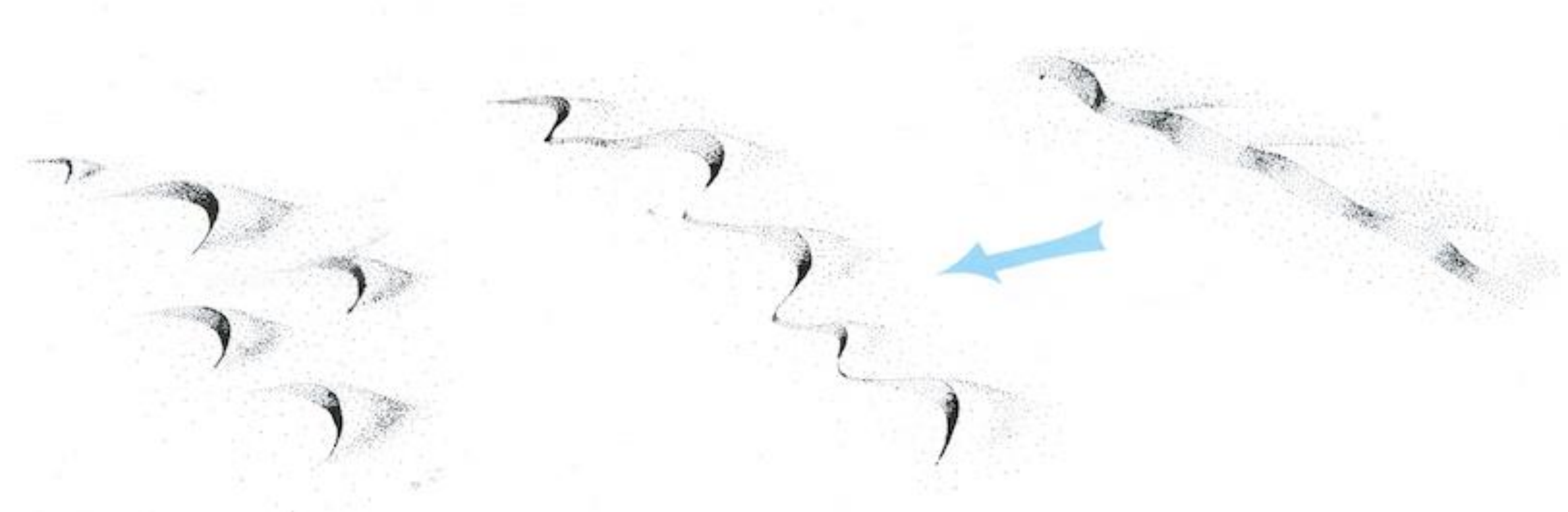
Dome dunes or sand shields

Sand shields and nebhas.

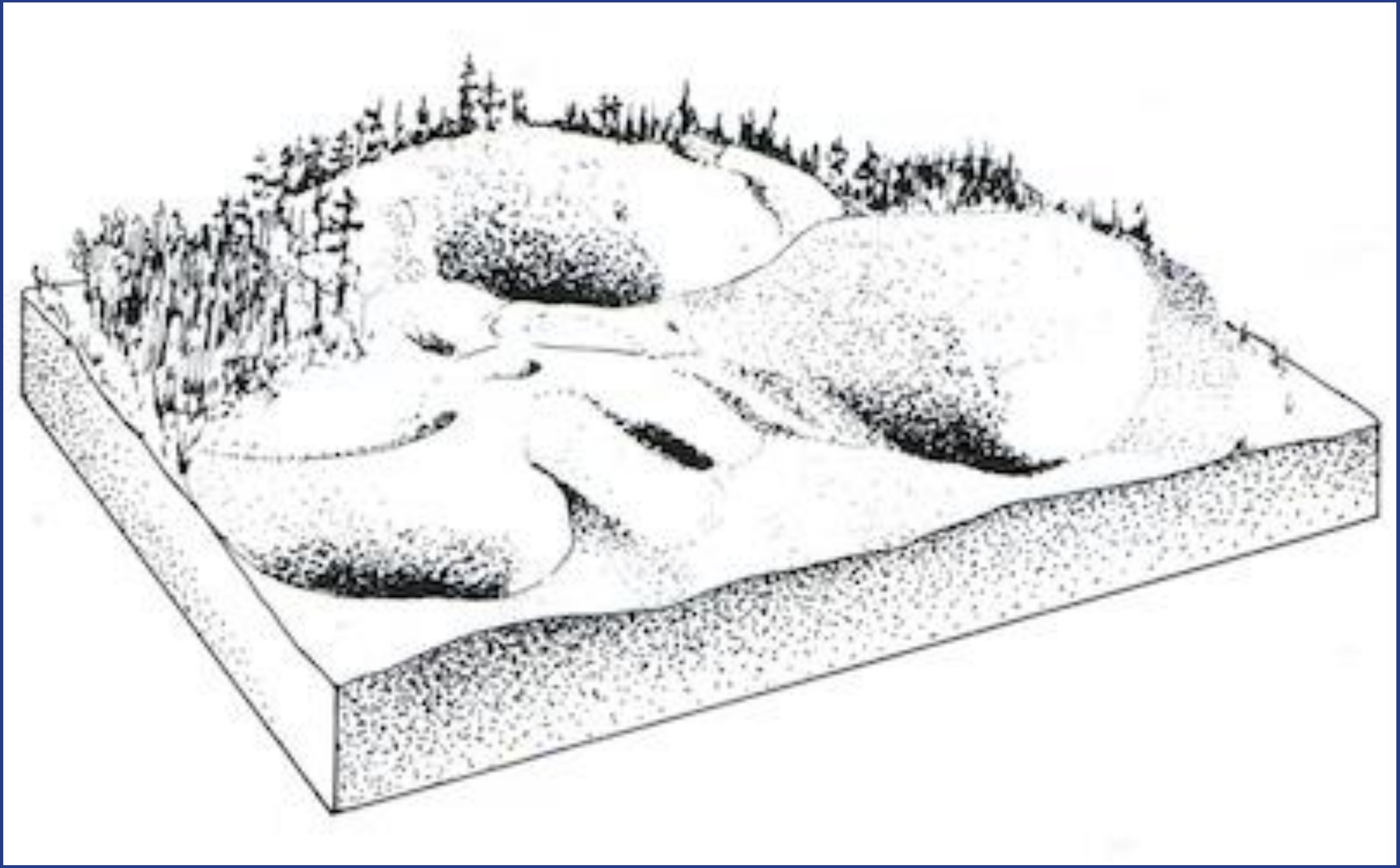


A barchan forming from a sand shield. Such barchans in embryo are called nebhas.

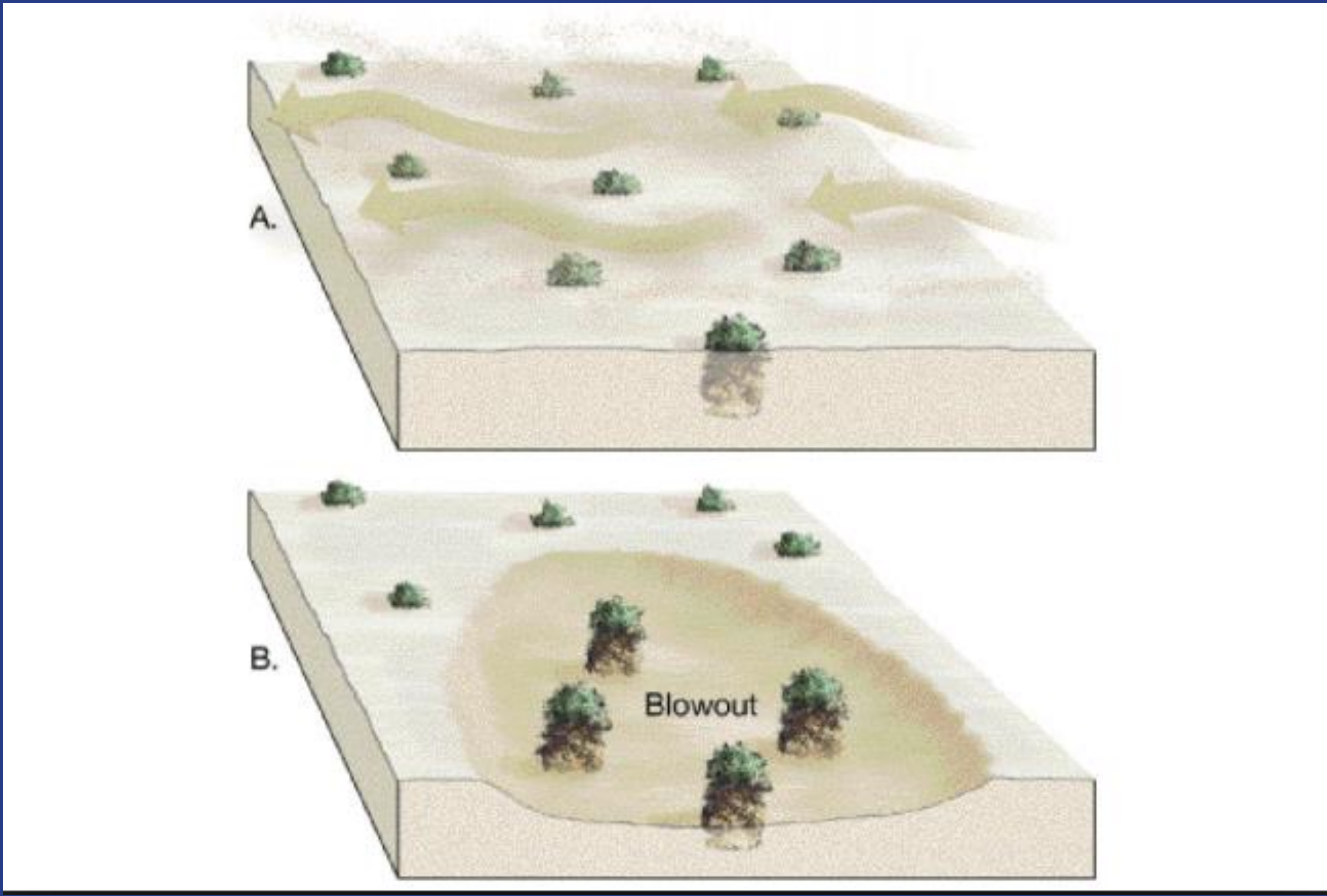
Barchans in a group (above). A barchan dune (below)



Evolution of barchans from transverse dunes. The evolution shown here indicates diminishing sand supply.



Blowout dunes

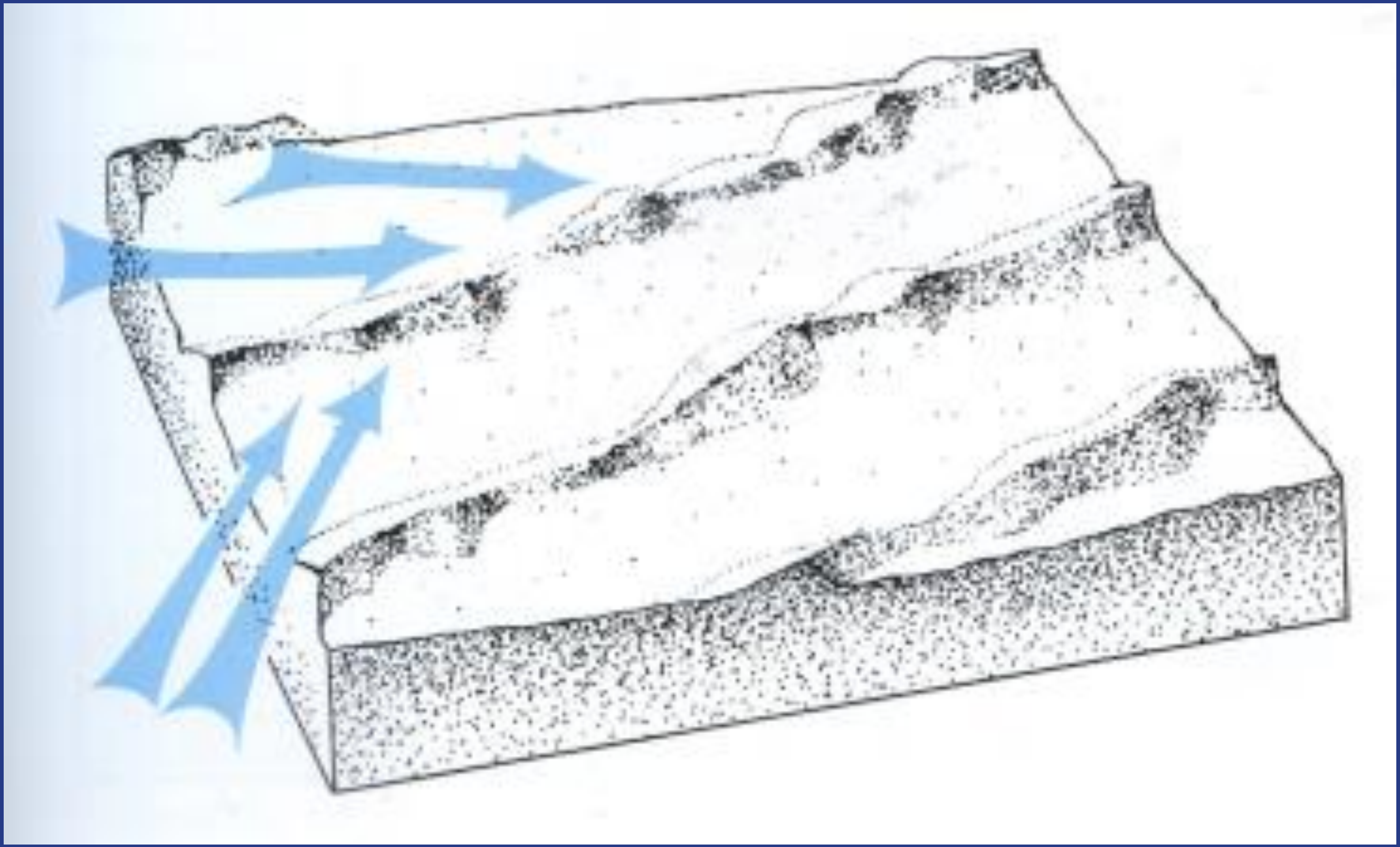


The formation of blowout structures

A blowout structure in the Indiana Dunes State Park, Indiana, USA

A large blowout structure in the Ravenmeols Dunes, northwest England

In places, blowouts may erode down to the water table. This example is from England.

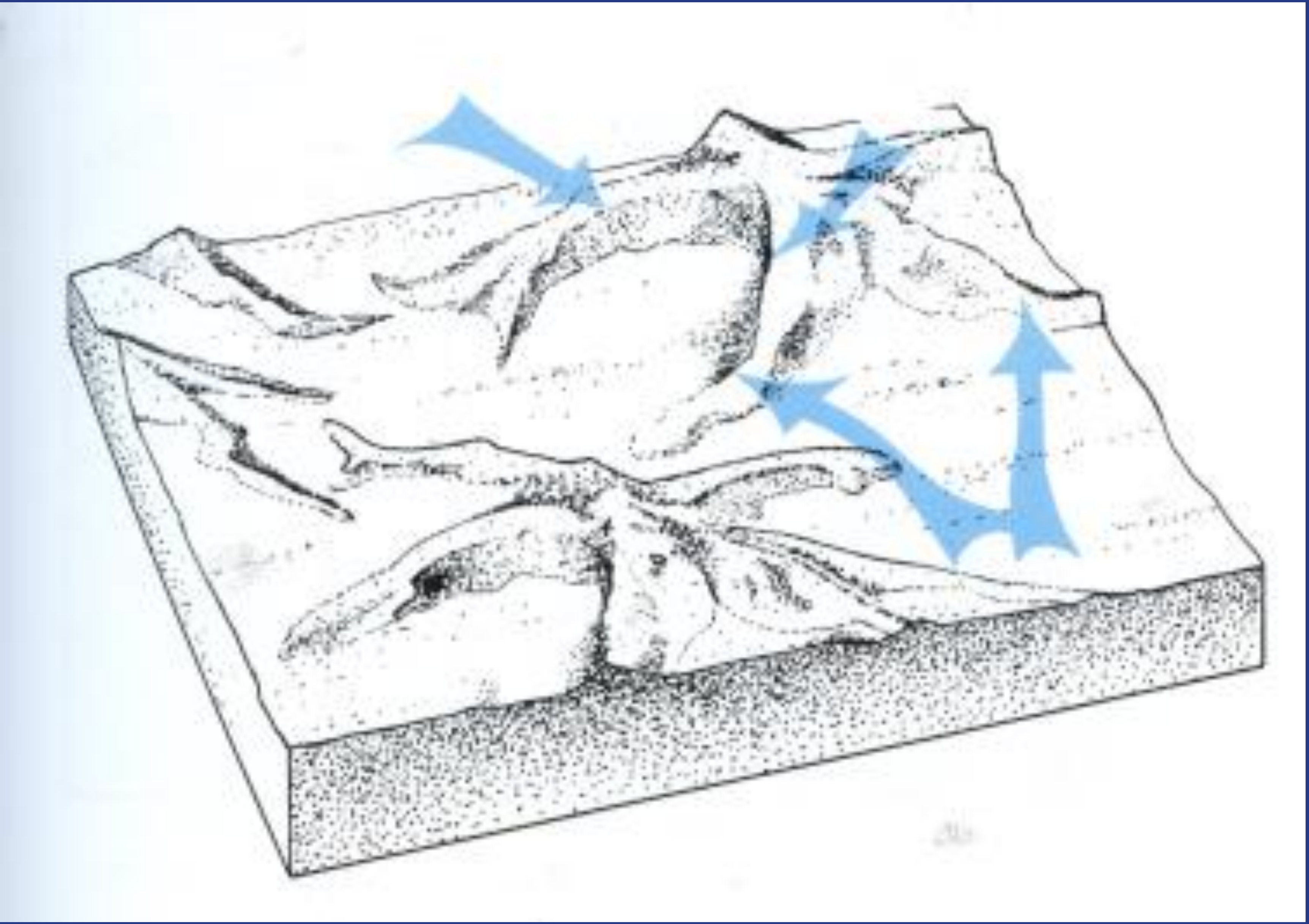


Formation of the longitudinal or “seif” dunes. Seif means sword in Arabic.

Longitudinal or seif dunes in the Sahara, Chad.

Seif dunes in the Death Valley, California, USA

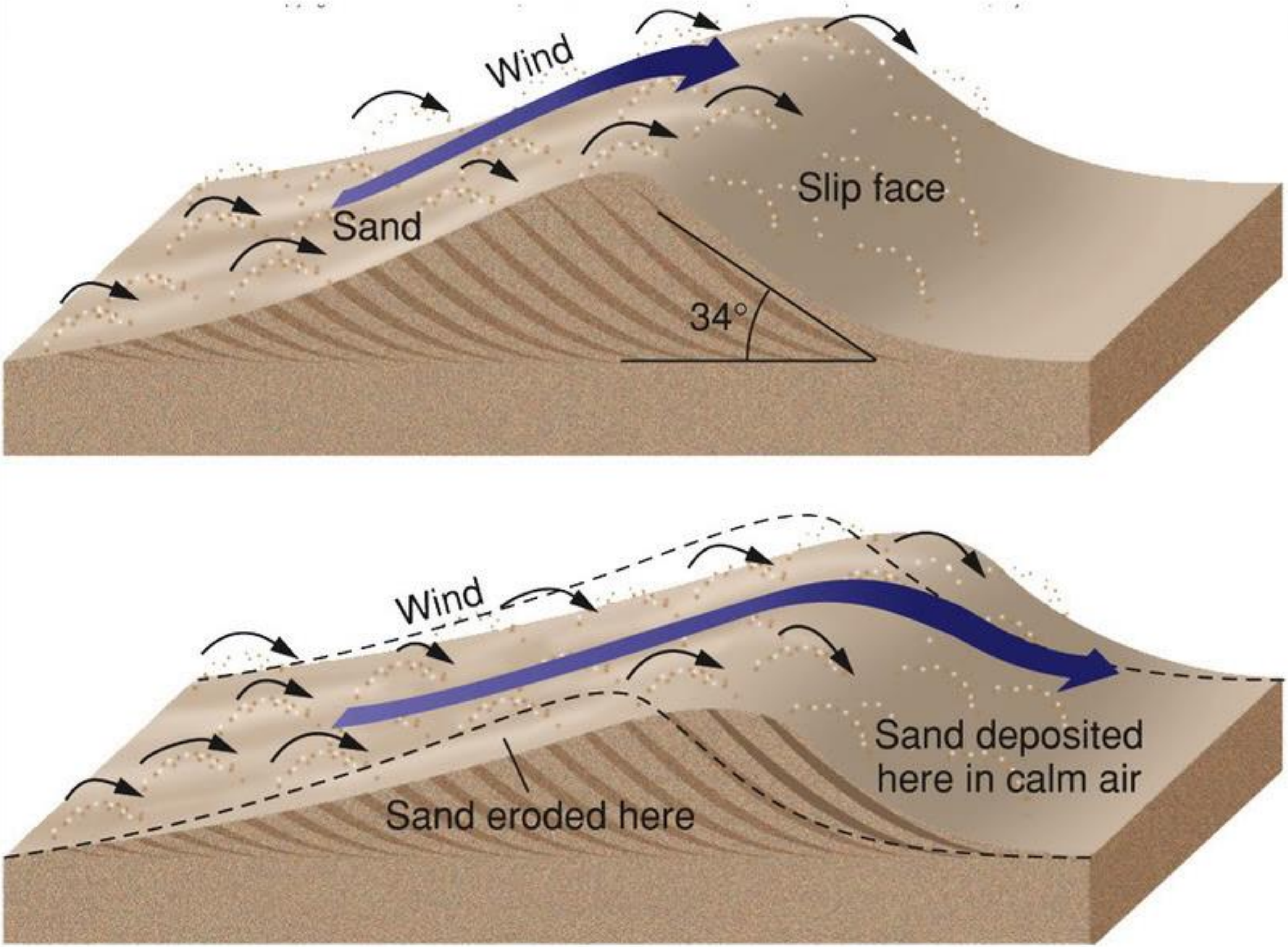
A seif or longitudinal dune behind our camp in the Sahara, Libya

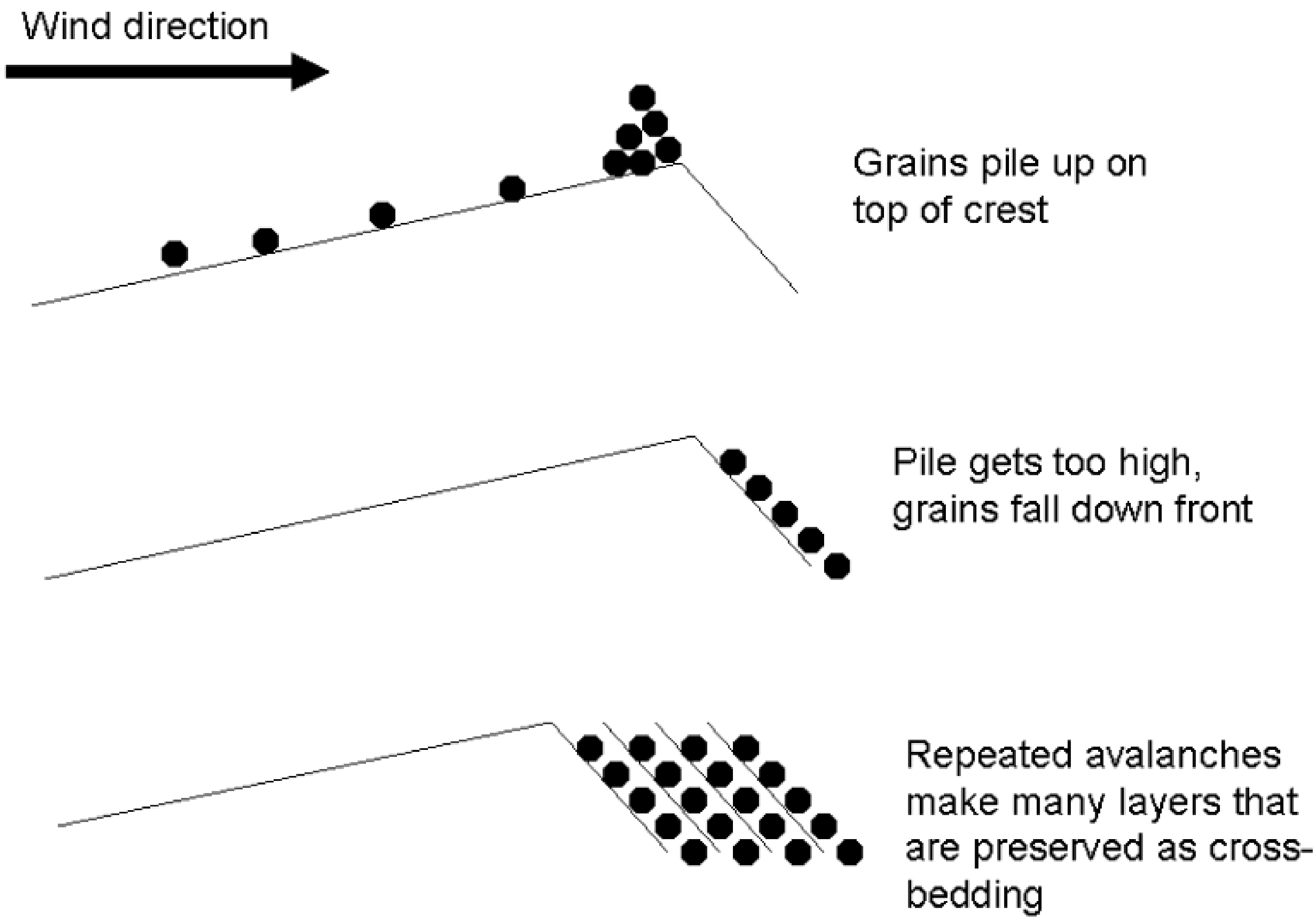


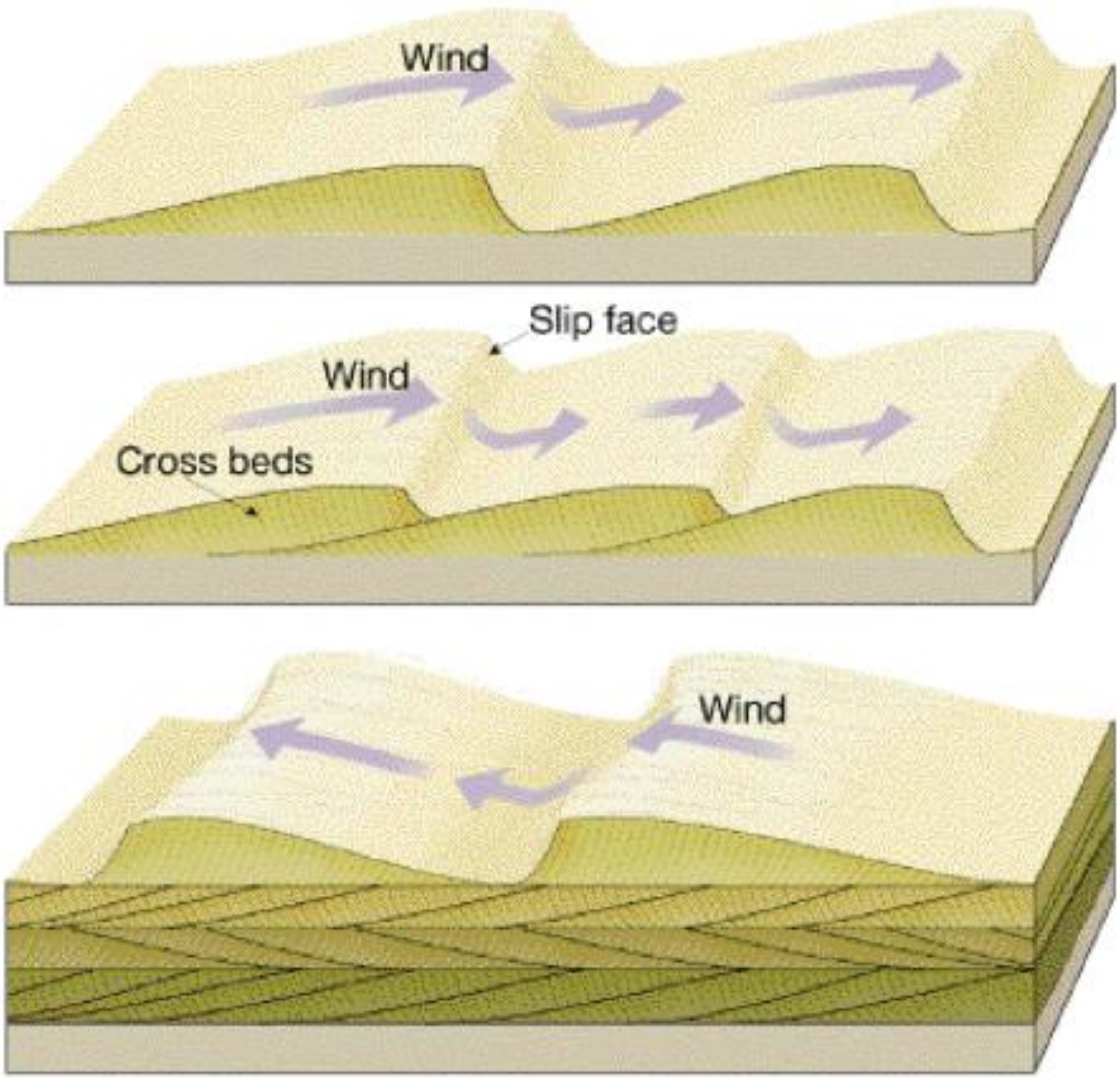
Formation of star dunes

Star dunes from the Rub al-Khali Desert in the Arabian Peninsula (southern Saudi Arabia and Oman)

A star dune


Wind
Sand
Slip face
34°
Wind
Sand eroded here
Sand deposited
here in calm air


Wind direction
Grains pile up on top of crest
Pile gets too high, grains fall down front
Repeated avalanches make many layers that are preserved as cross-bedding


Wind
Slip face
Wind
Cross beds
Wind

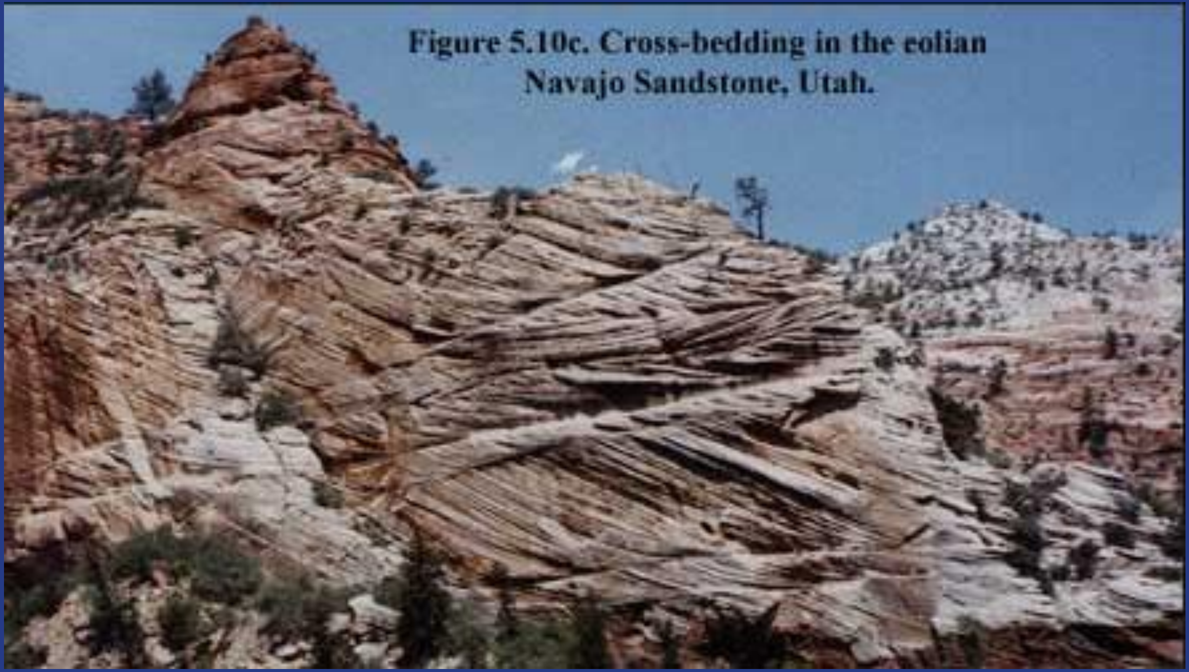


Figure 5.10c. Cross-bedding in the eolian Navajo Sandstone, Utah.

Rubjerg Knude Lighthouse, Denmark. Note here and the subsequent slides the movement of the dunes that both bury and uncover formerly buried buildings!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