Lesson 9: Karst, Coastal and Glacial features

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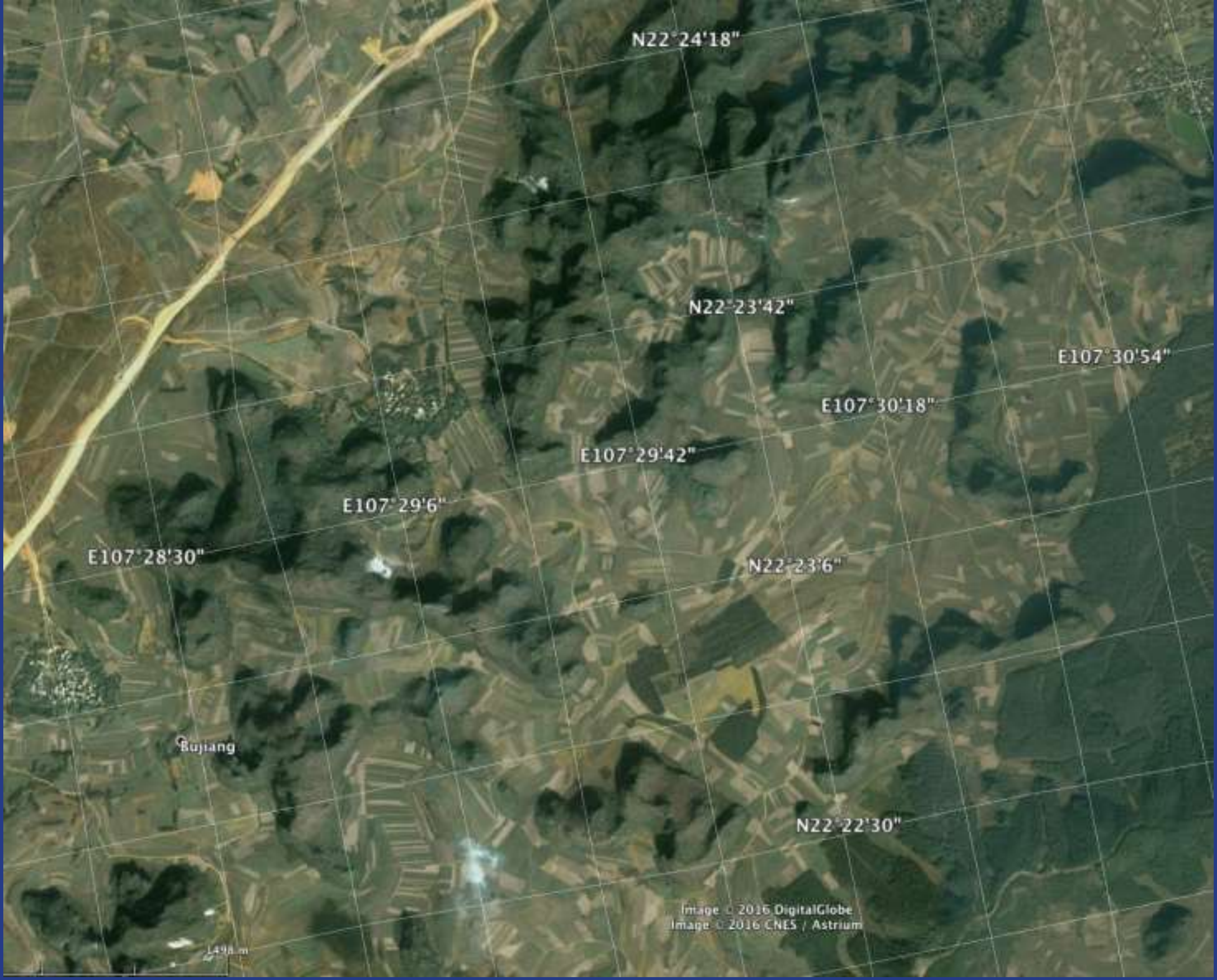
A special manifestation of the work of groundwater in terrains underlain by soluble rock:

Karst topography

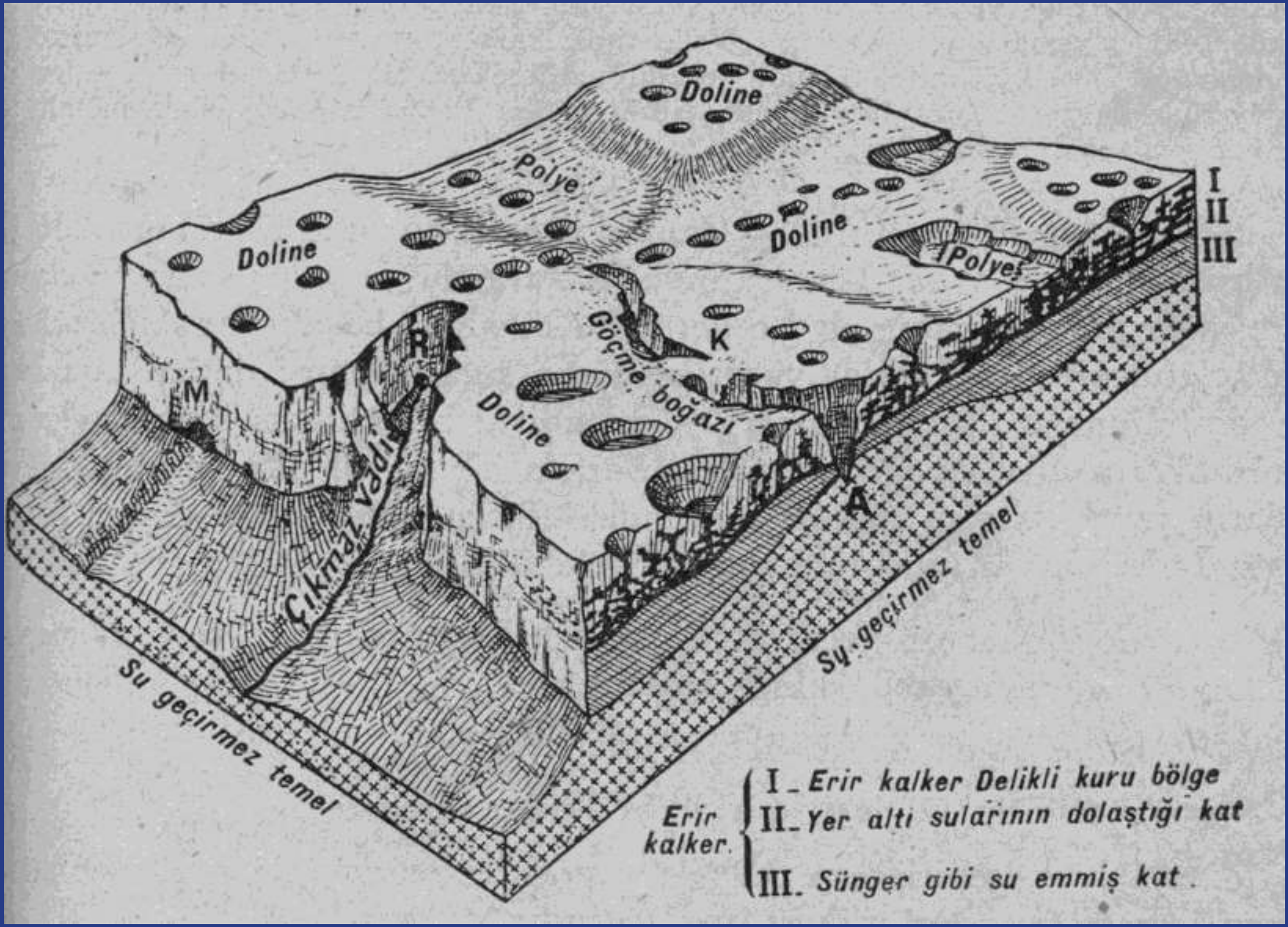
View of a landscape in Croatia

What do you think looks odd in this landscape?



View of a landscape in South China. Anything odd?

View of a landscape in Jamaica. Anything odd about it?



A typical karst landscape.

Calcite dissolves when in contact with carbonic acid (i.e. carbonated water):

The following is the main reaction sequence:

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Water (from rain) + carbondioxide (from the atmosphere and from the soil) → carbonic acid (i.e., carbonated water)

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2\ HCO_3^-$$

This is the cause of widespread limestone dissolution in areas underlain by extensive limestones. This dissolution creates a special group of landforms known as karst topography.

The location of the Carso Plateau (Carso is Karst in German) now divided between Italy and Slovenia. It used to belong entirely to Austria.

The name “karst topography” derives from the name of the Carso plateau. It is there that the German and Austrian, later Serbian scientists extensively studied the topography resulting from the dissolution of carbonate rocks and it is them who named that peculiar topography “karst”, using the German version of the name of the plateau.

Later the great Serbian geographer Jovan Cvijić extended his studies to the entire Balkan Peninsula and showed that the whole Dinaric mountains exhibited a magnificent development of karst topography. That is why most internationally used karst landform terms come from Serbian.

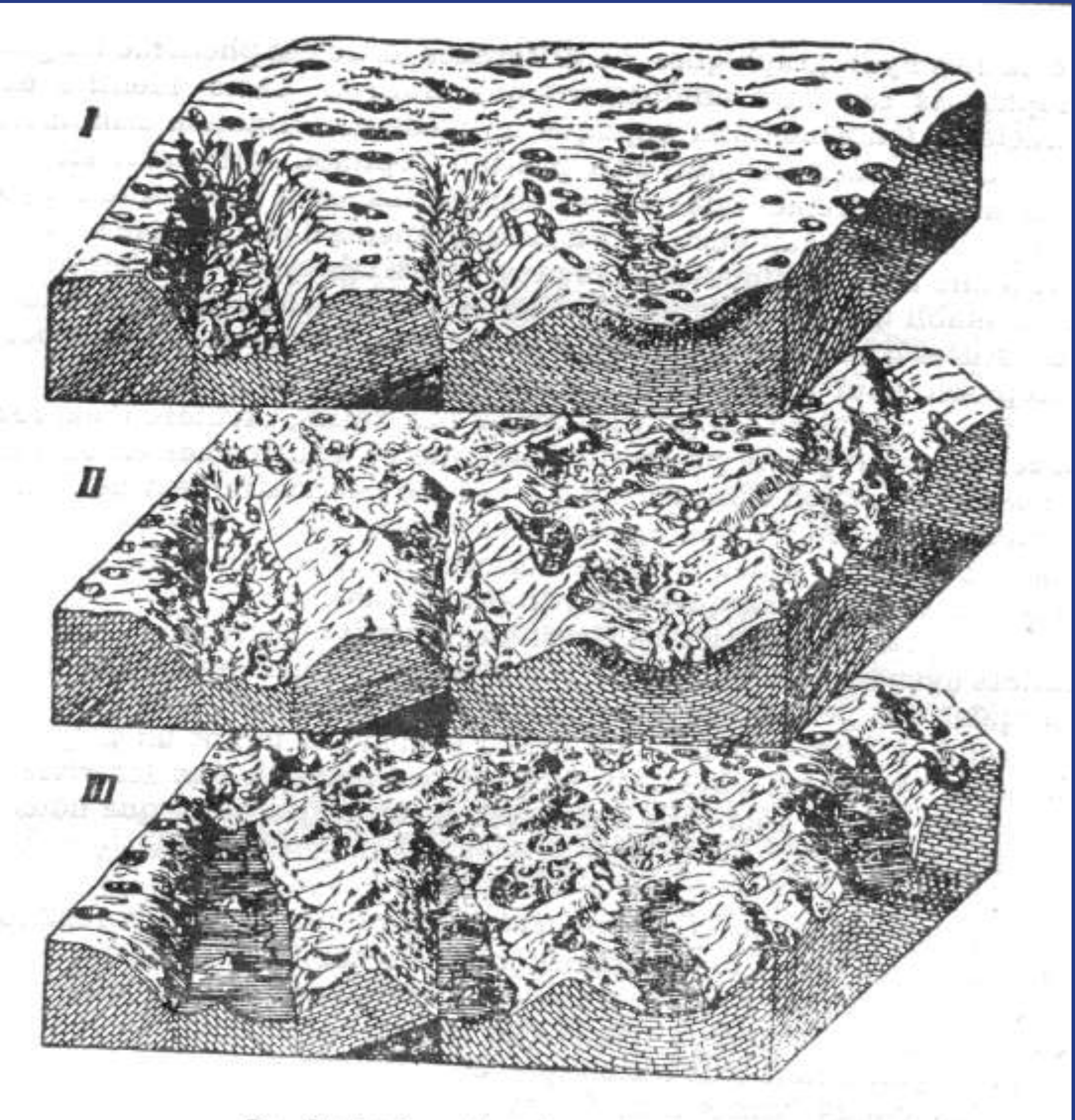
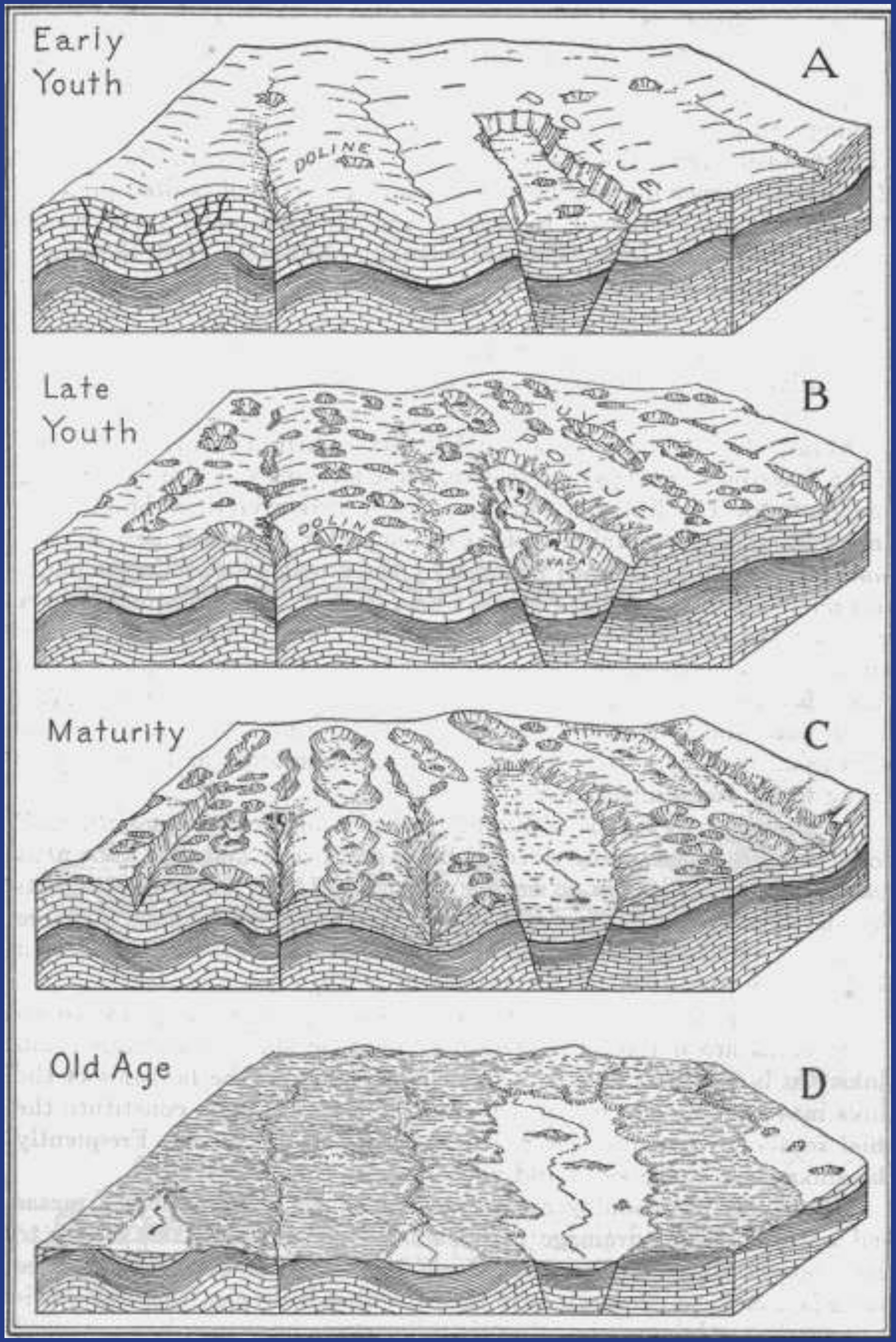


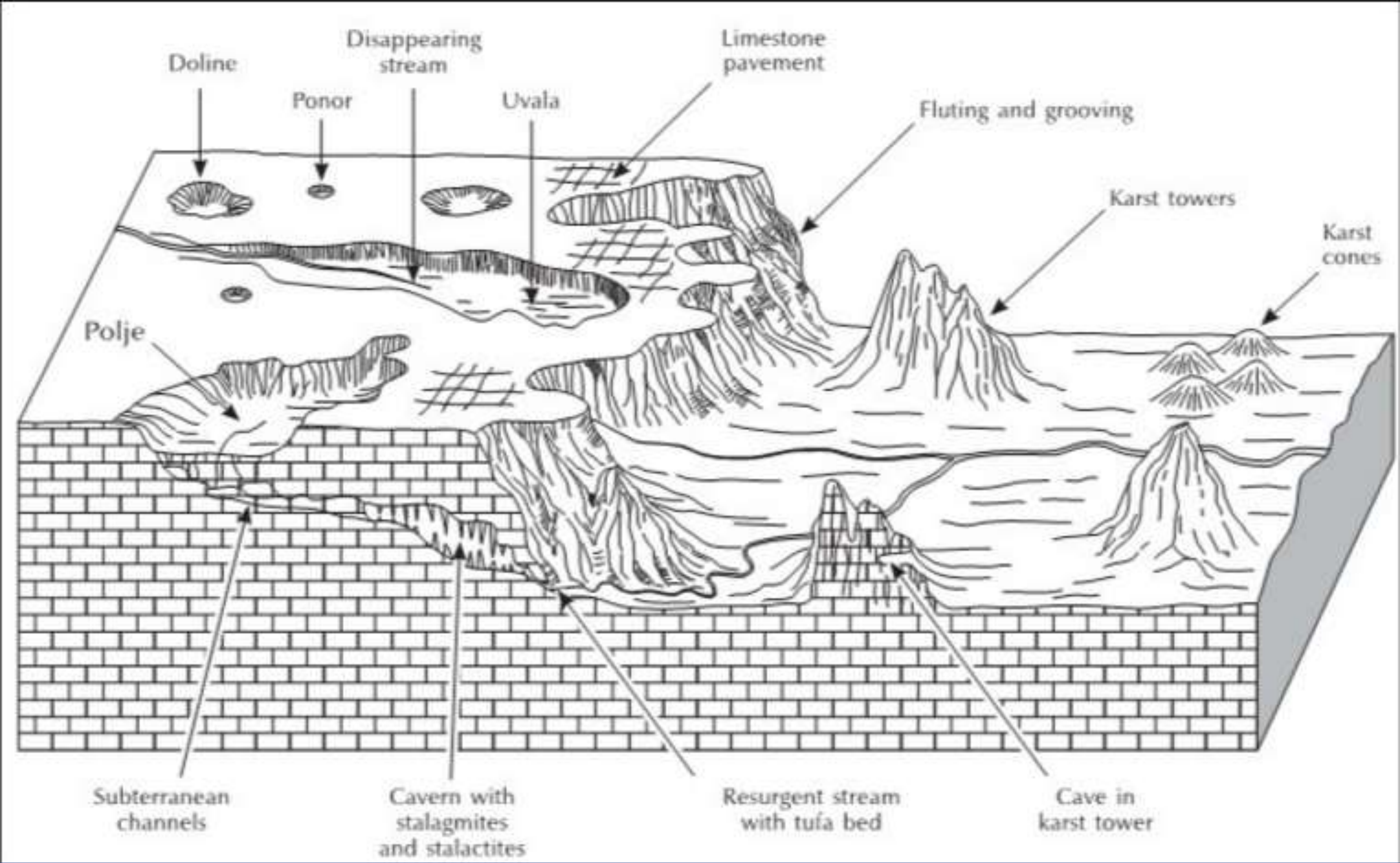
Fig. 23. La formation des poljes karstiques

The evolution of karst topography according to Cvijić (1960)

Professor
Jovan CVIJIĆ (1865-1927)



Evolution of karst topography from the pen of the great American geomorphologist Armin Kohl LOBECK (1886-1958) according to CVIJIĆ' s ideas



Another, but richer block diagram of various karst forms

The most widespread landform in karst terrains is lapiaz (also spelled lapié or lapiez; in German it is called Karren). In southern France, in the region of Languedoc, they are known as cairissa.

The lapiaz form by the dissolution of the surface of the soluble rocks by the weak carbonic acid falling as rain. This dissolution can take the form of tiny rivulets or little pits or even pot-shaped small depressions. In places, the rock face acquires a sponge-like aspect because of lapiaz formation. In some regions the lapiaz take the shape of large, ruinous structures. Such mega-lapiaz have been called “chaos” in southern France (e.g. Chaos de Montpellier-le-Vieux).

Lapiaz in Hérault, France

Lapiaz, Mut Plateau, Turkey (photo by Selçuk Aksay)

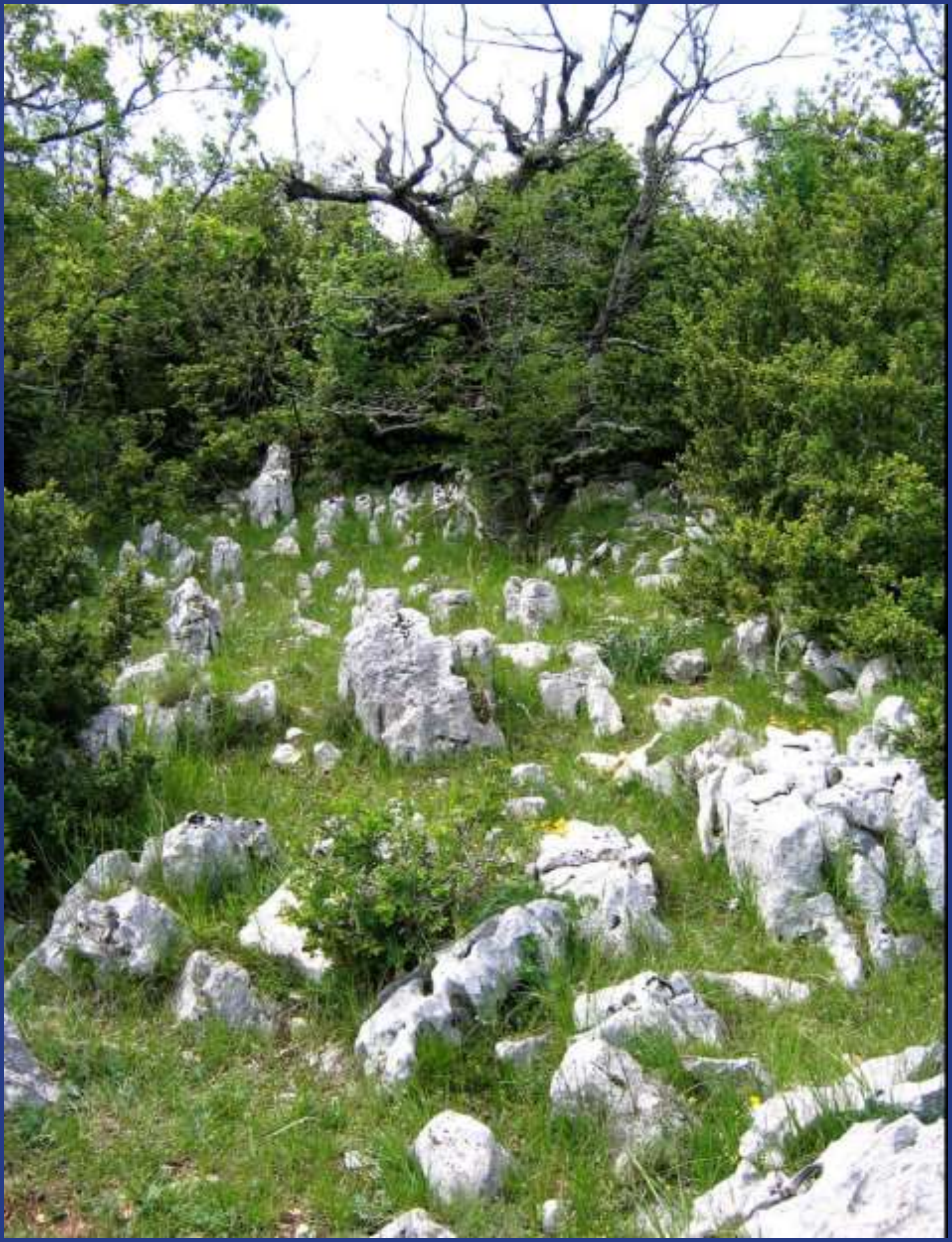
Lapiaz in the calanques region in southern France. Notice the sharpness of the lapiaz divides. In some terranes, such lapiaz destroy shoes.

Lapiez forming by raindrops. Calanques, southern France

Evolving lapiaz: Calanques, southern France

Lapiaz forming by exploiting joints and bedding planes

Lapiaz in the French Alps

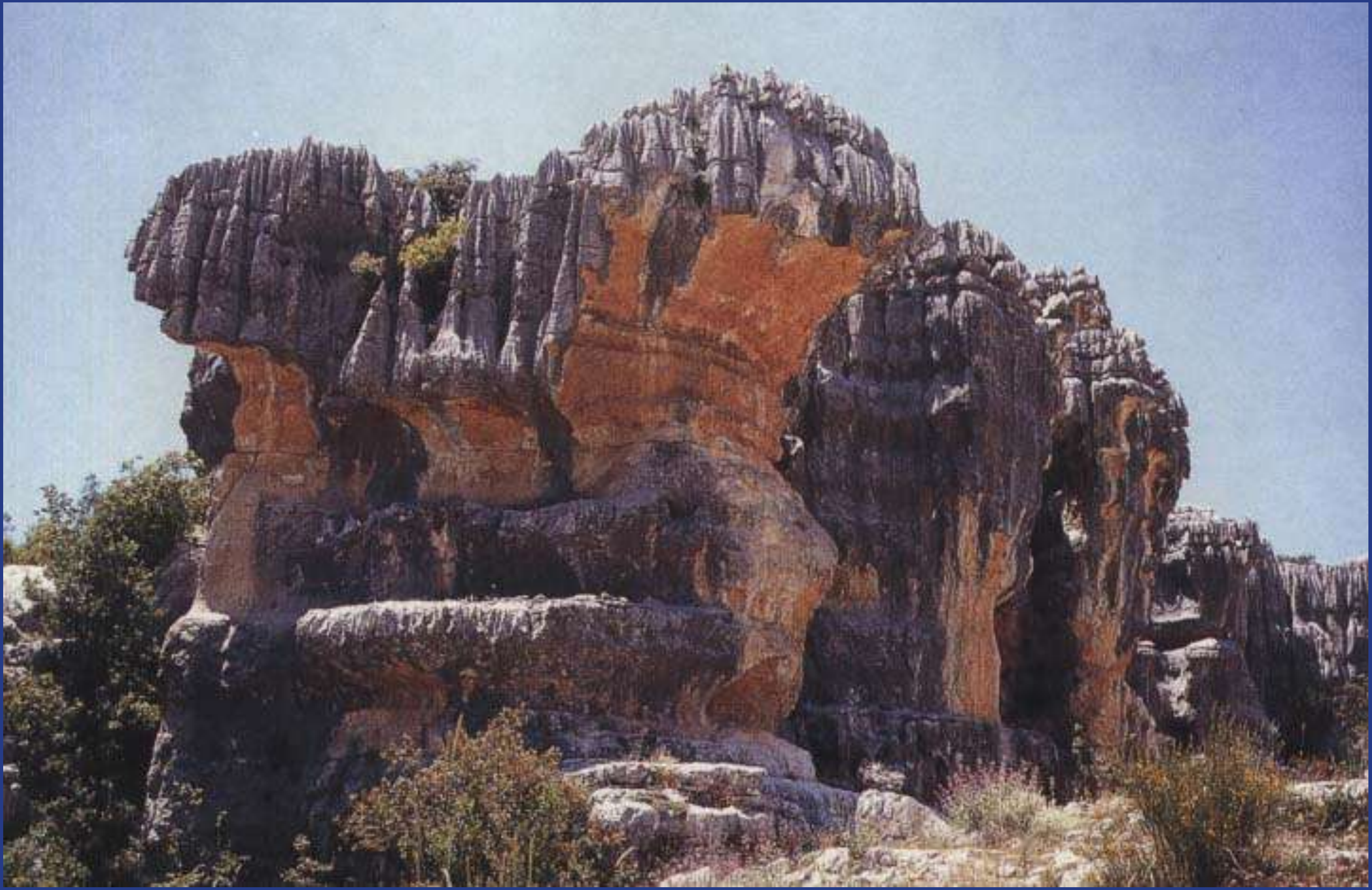


Lapiaz in Hérault, France

Rill-like lapiaz on the Glièeres Plateau, France

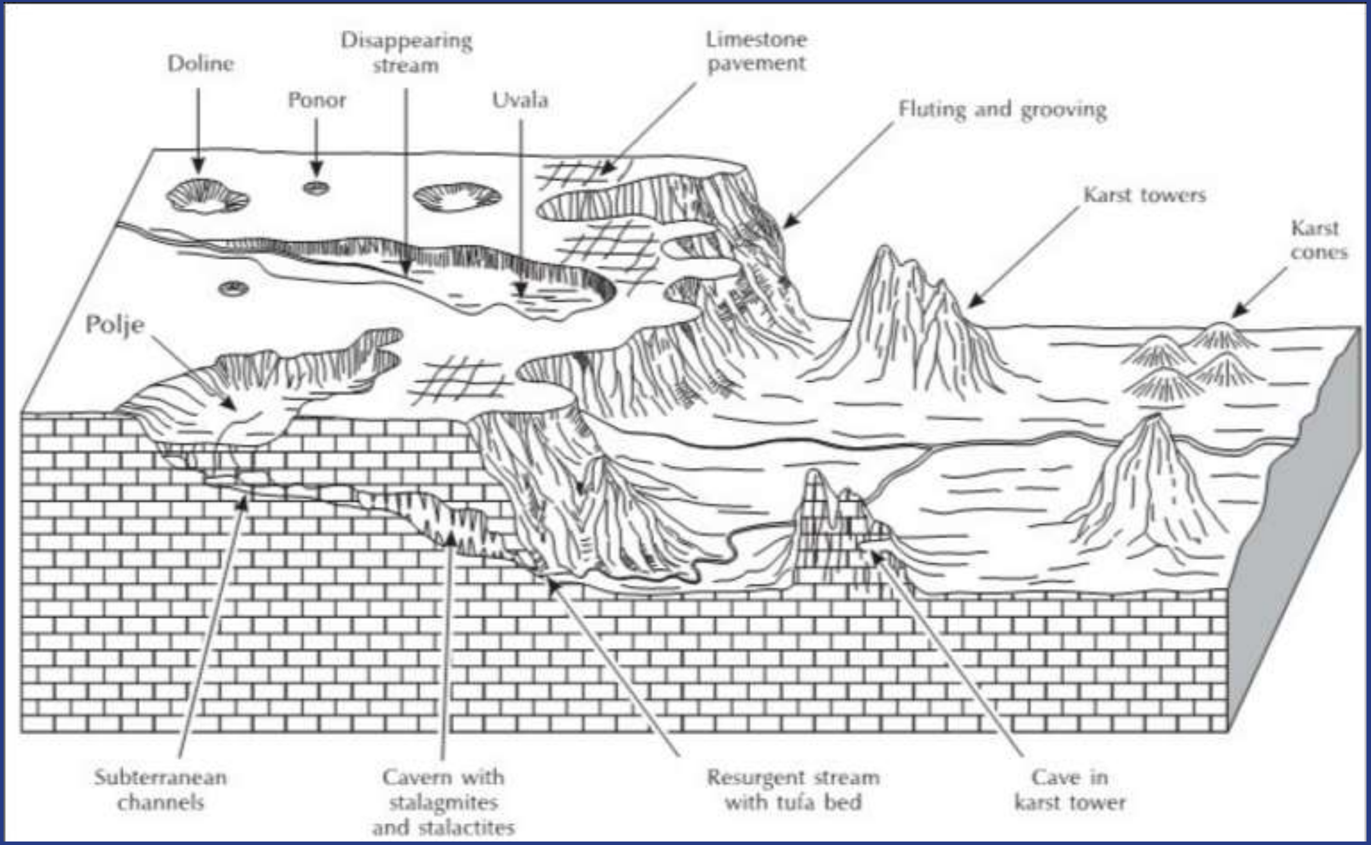
Lapiaz probably exploiting joints at Mount Tendre in the Canton of Vaud in Switzerland.

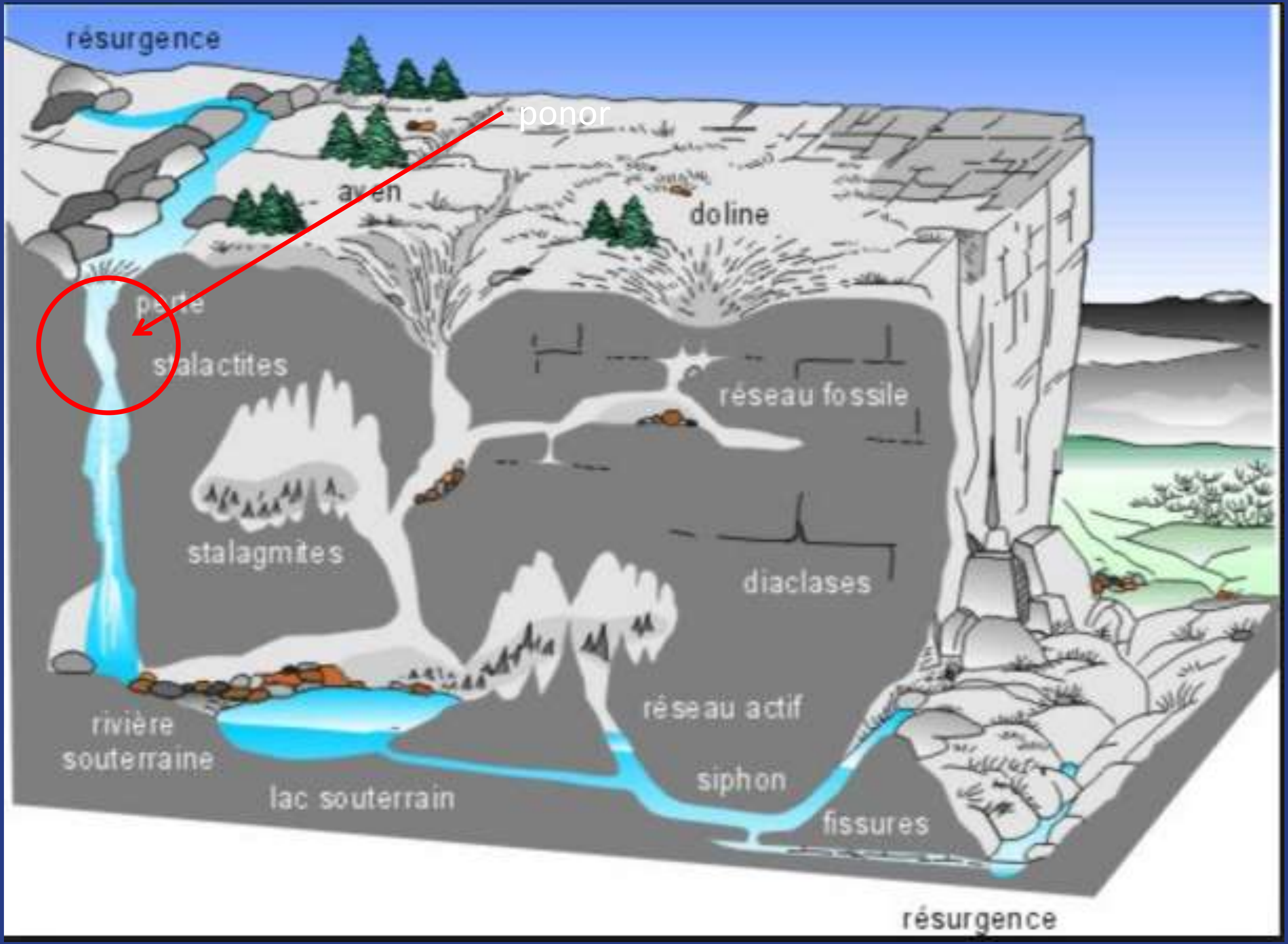
Kamenica-type lapiaz, Mut Plateau, Turkey (photo by Selçuk Aksay)



Mega-lapiaz forming a “chaos”, Feitroun, Lebanon

Eventually, the surface water in karst terrains dissolves avenues into the underground and the surface drainage disappears. The smallest orifices in the landscape at which the surface waters disappear are called ponors. The term ponor comes from old Slavic word *nora*, meaning a pit or a hole in the ground, even an abyss.





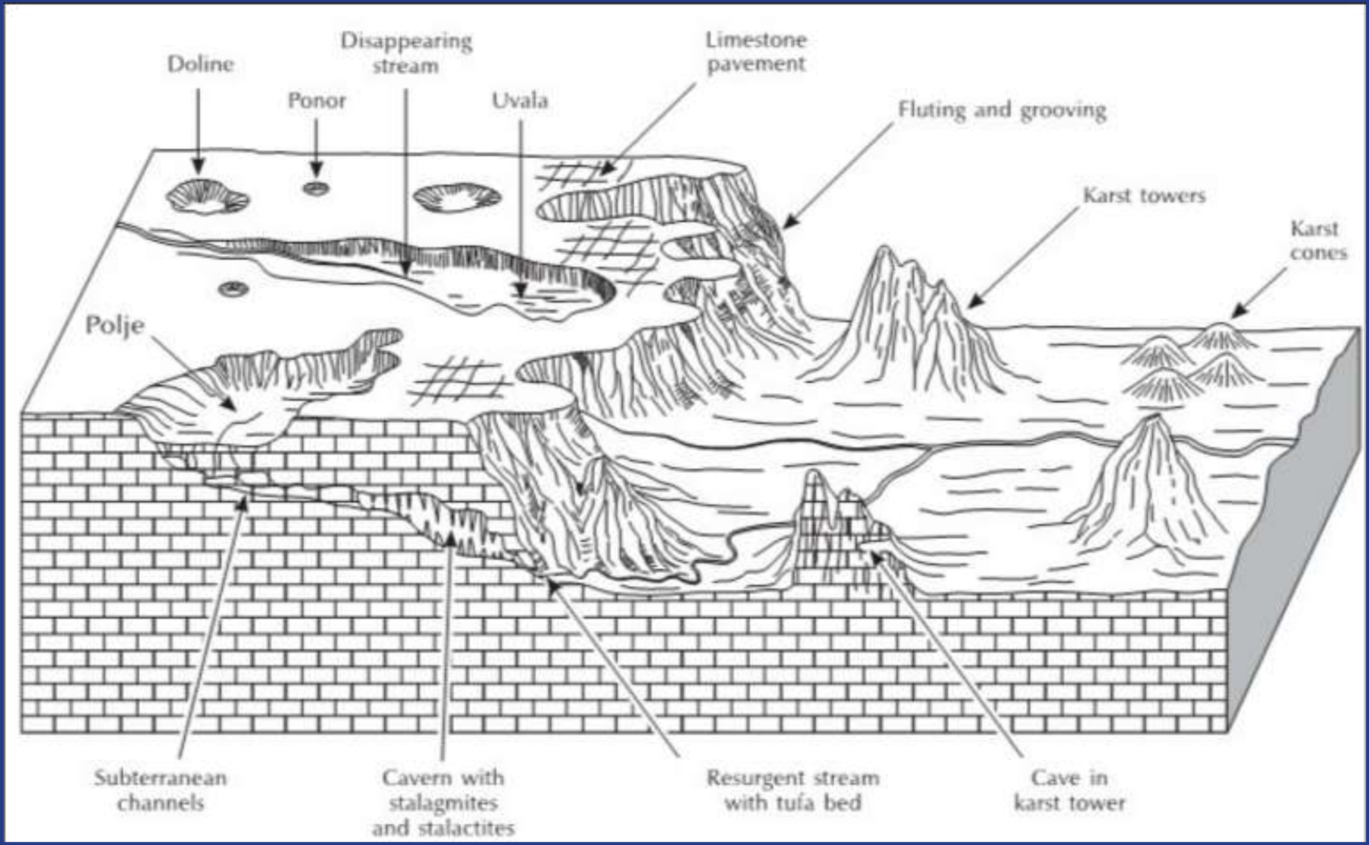
Perte in French means “lost”. It is the equivalent for ponor in the French karstic literature.

A ponor in Germany.

Not all ponors look like holes in the ground like the one in the previous slide. Many resemble small cave entrances.

A ponor is Postojna (former Adelsberg), Slovenia

A ponor in the karst region of Sauerland, west Germany

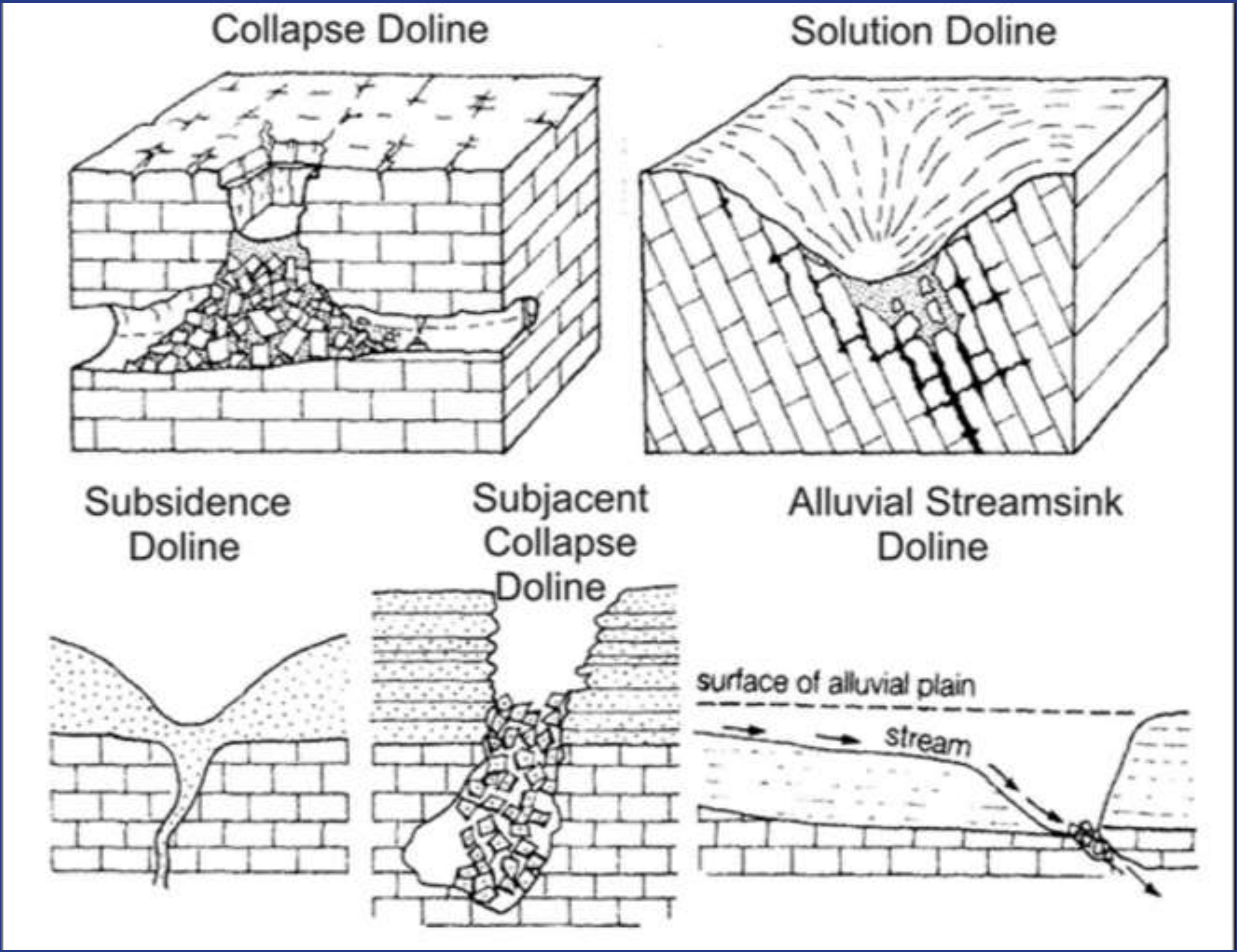


One of the most conspicuous landforms in karstic terrains is small closed depressions called dolines. Doline is also a Slavic word meaning valley, depression. A karstic terrain usually looks like a pot-marked face with numerous dolines.

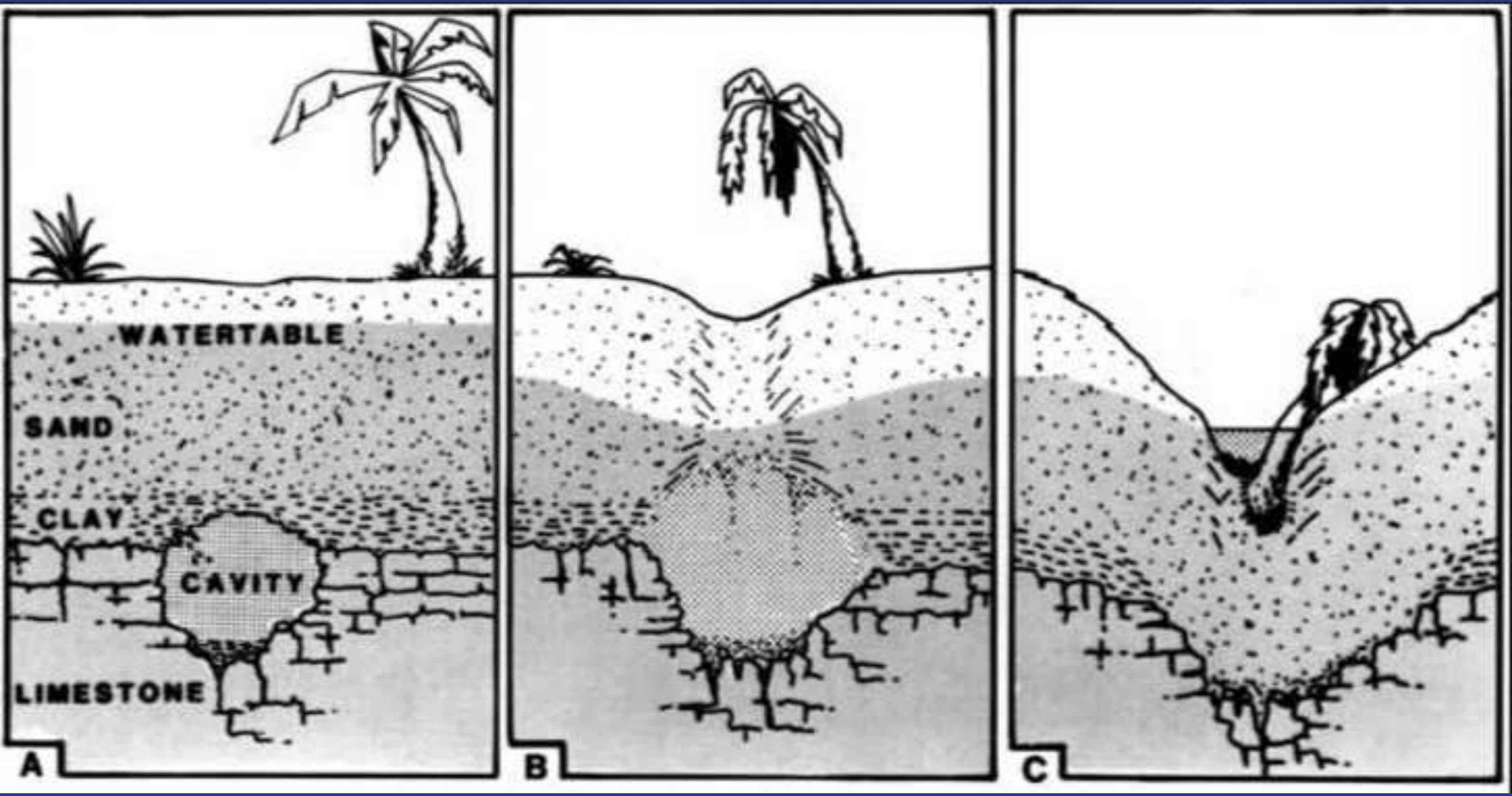
A pot-marked face. This is what a karstic terrain looks like that is dotted with numerous dolines.

Dolines in south Canterbury, England

Another doline landscape, Kentucky, USA

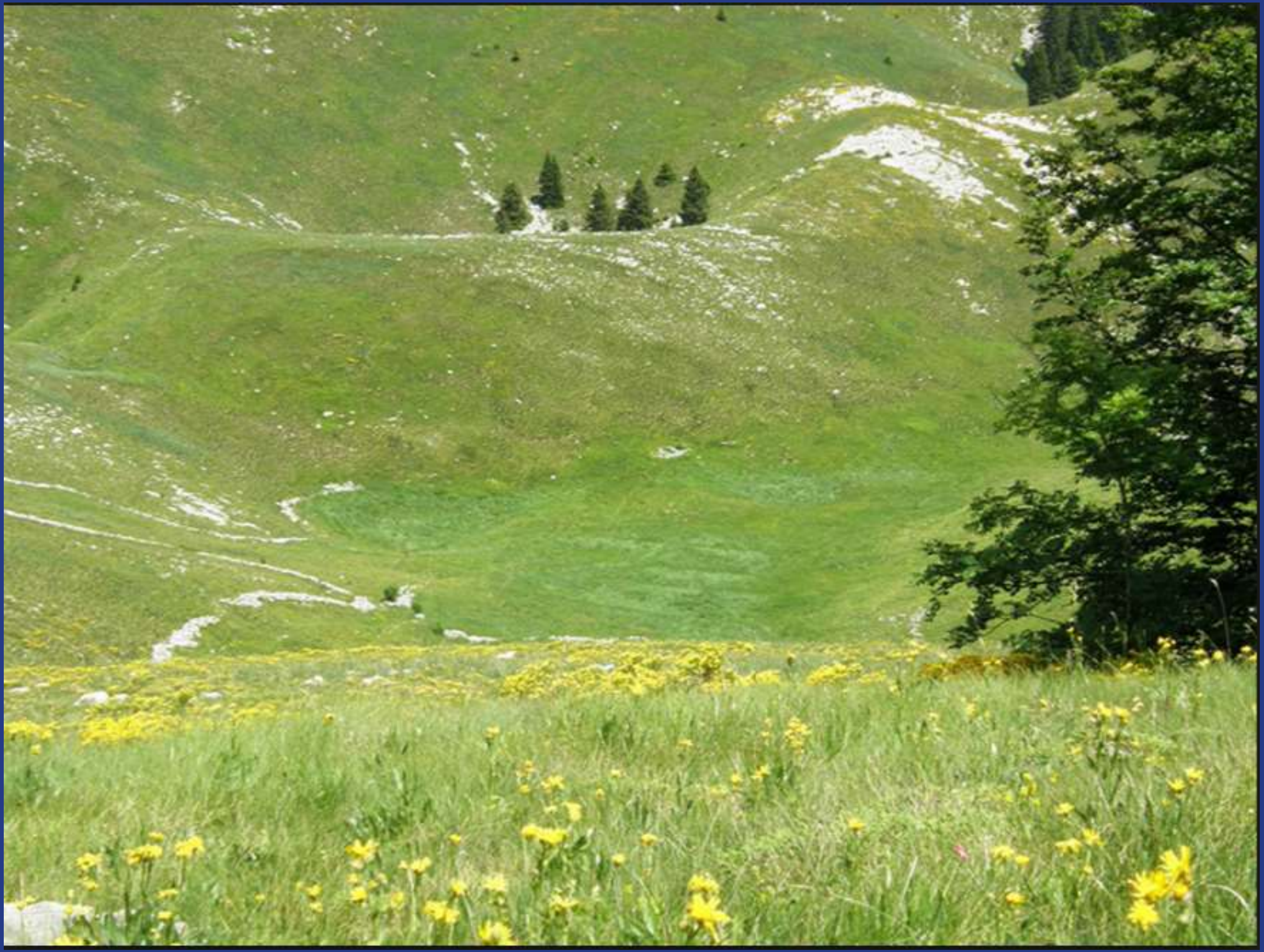


Types of dolines



Formation of a subsidence doline by subterranean dissolution of soluble rock.

A solution doline in the Croatian karst in the Velebit National Park

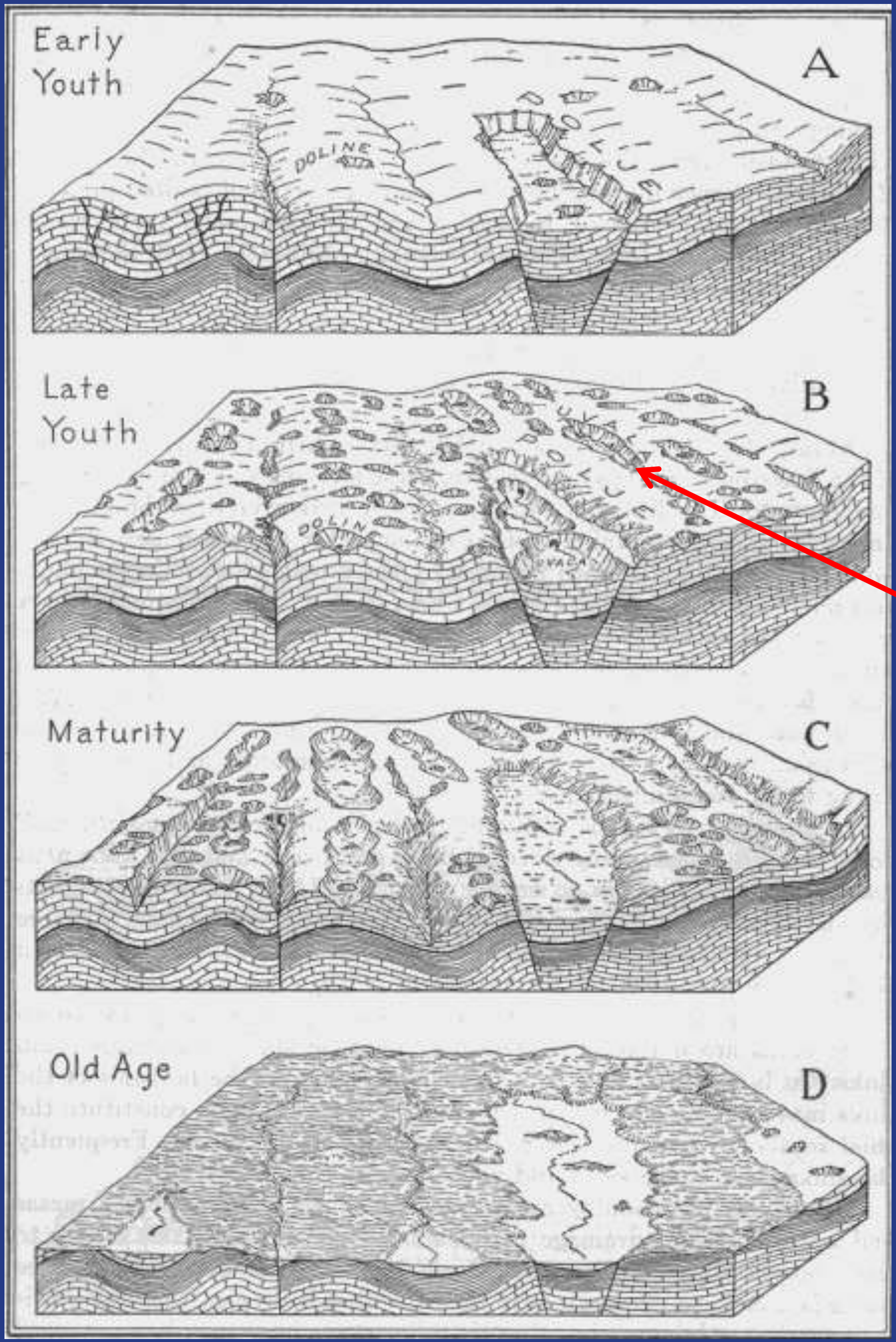


Solution dolines in the Velebit National Park, Croatia

A collapse doline in Florida, USA

A collapse doline in a residential area in Florida, USA

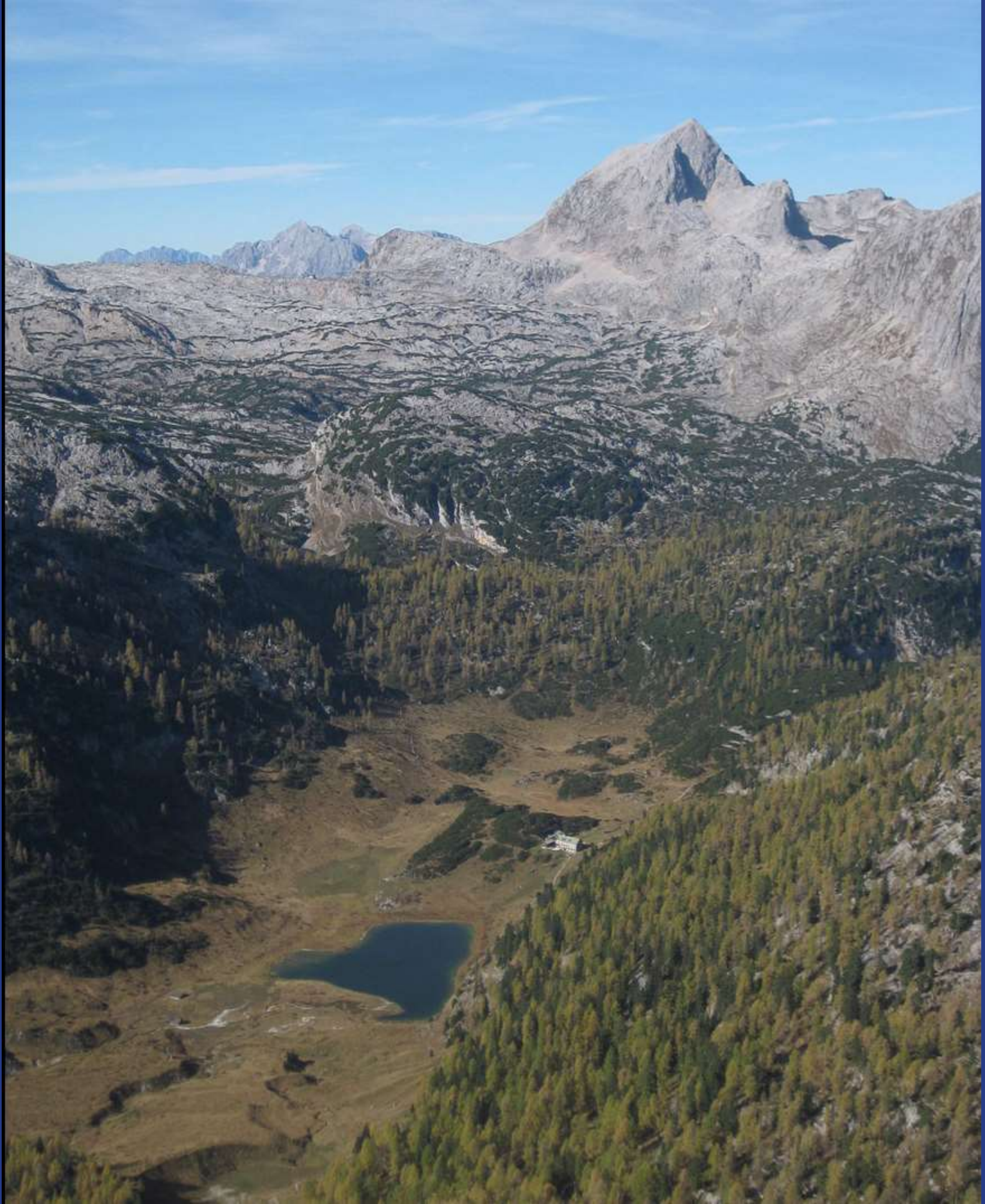
A small doline in Japan



With time many dolines are enlarged and they combine to create a larger karstic depression called uvala.

Jovan Cvijić's sketch of the Četenište Uvala (from Ćalić, 2016). Notice how a number of dolines have combined to create a larger depression forming the uvala.

Veliki Lubenovac uvala in northern Velebit, Croatia



The Funtensee Uvala in Berchtesgaden, Germany, Northern Calcareous Alps.

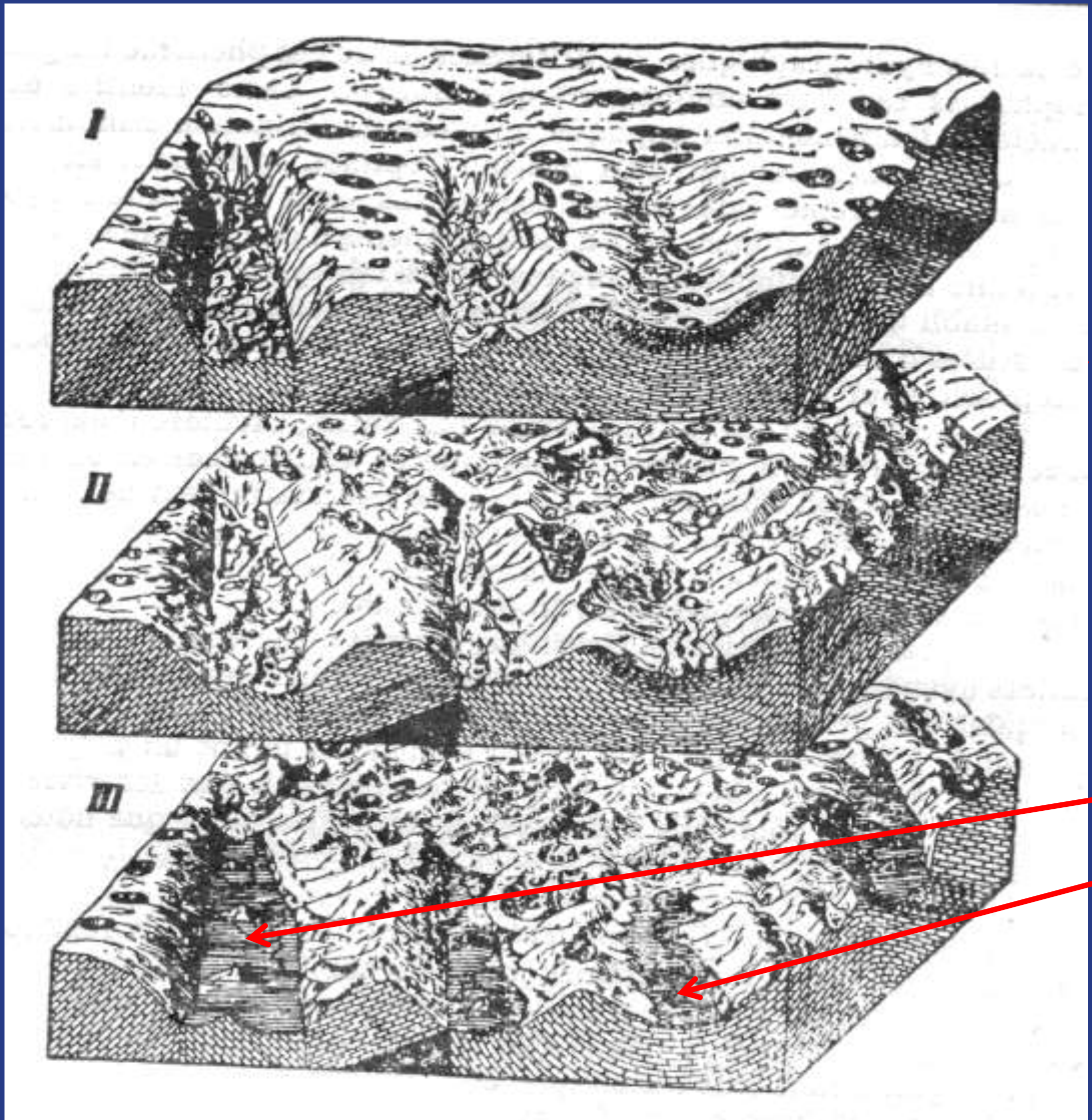
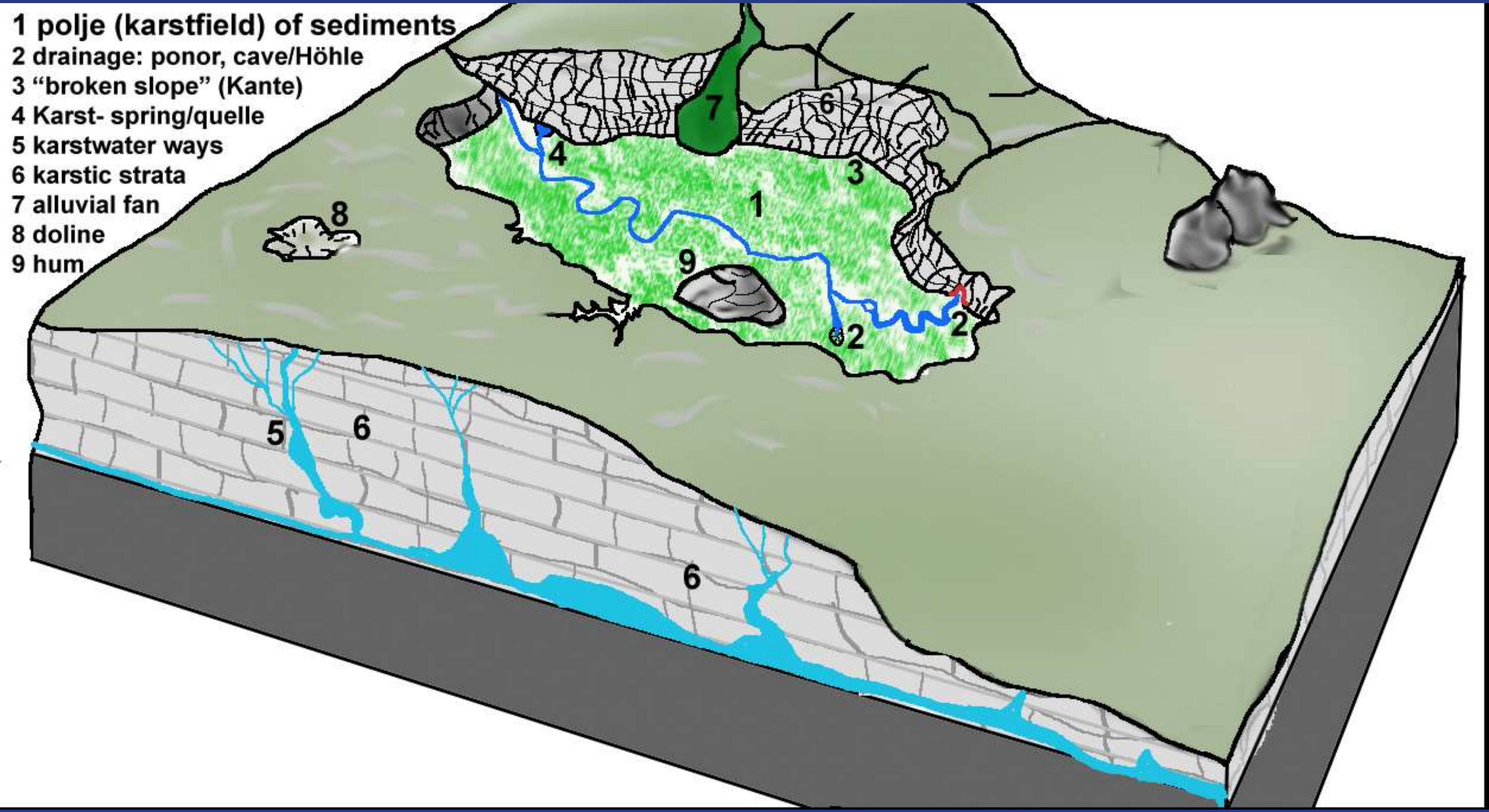
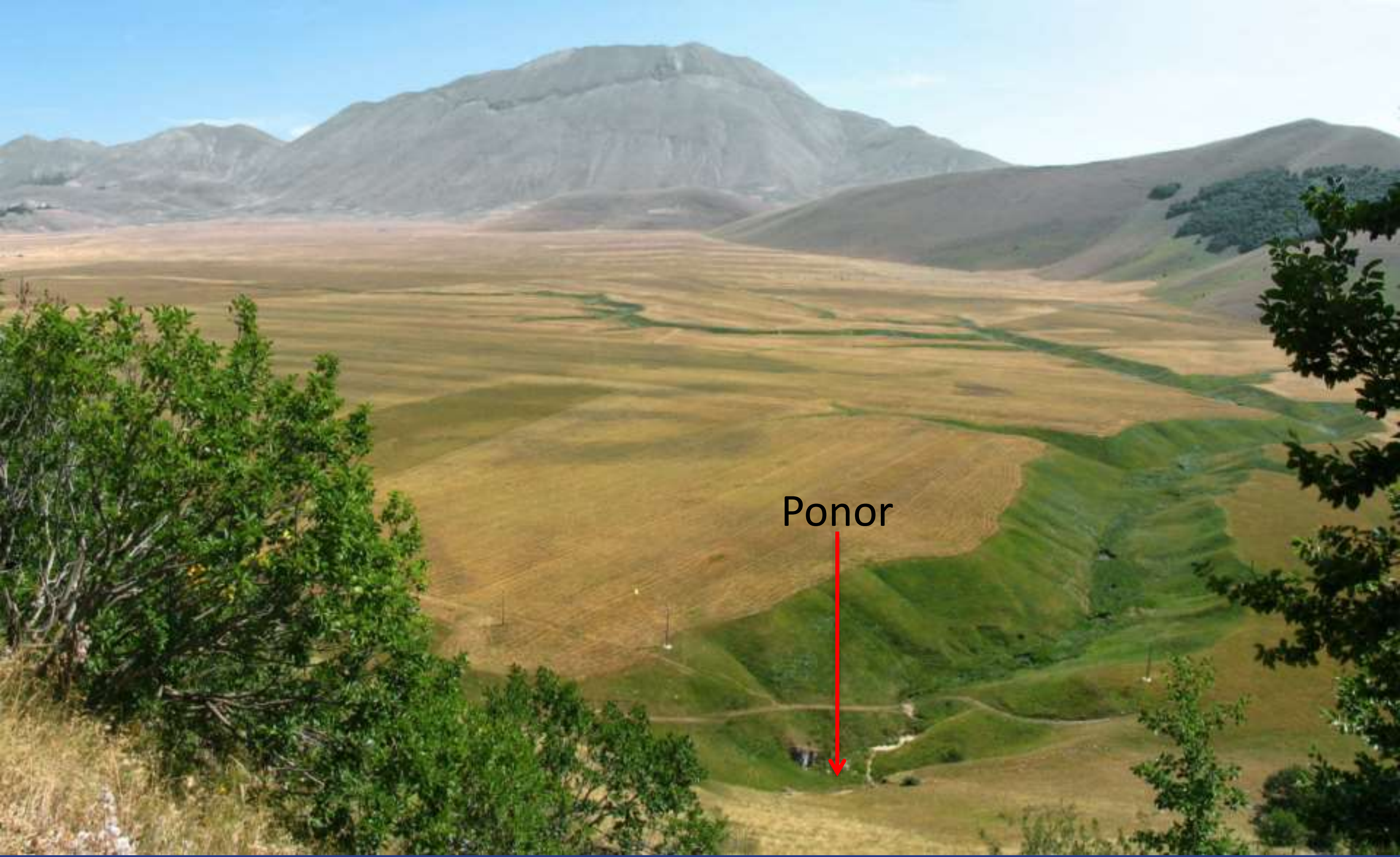


Fig. 23. La formation des poljes karstiques

The largest closed depression in karstic areas are called poljes. The poljes have numerous origins. They can be formed by the karstic enlargement of old grabens, synclines or simply fluvial valleys. One polje may have a composite origin as well.



Terminology of landforms in a polje



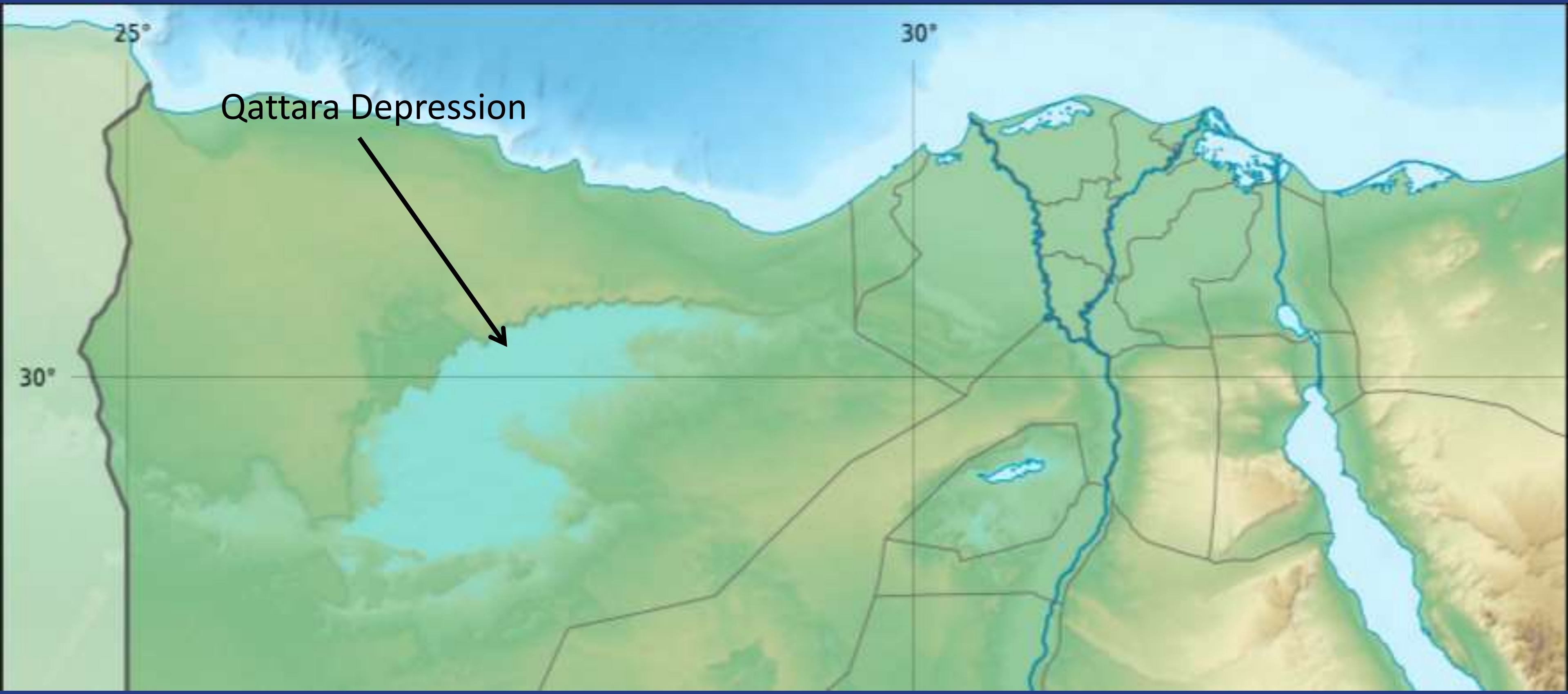
Piano Grande (“great plain”) in the Apennines, a polje.
The ponor seen in the foreground drains the polje.

Llanos de Libar, a polje in southern Spain

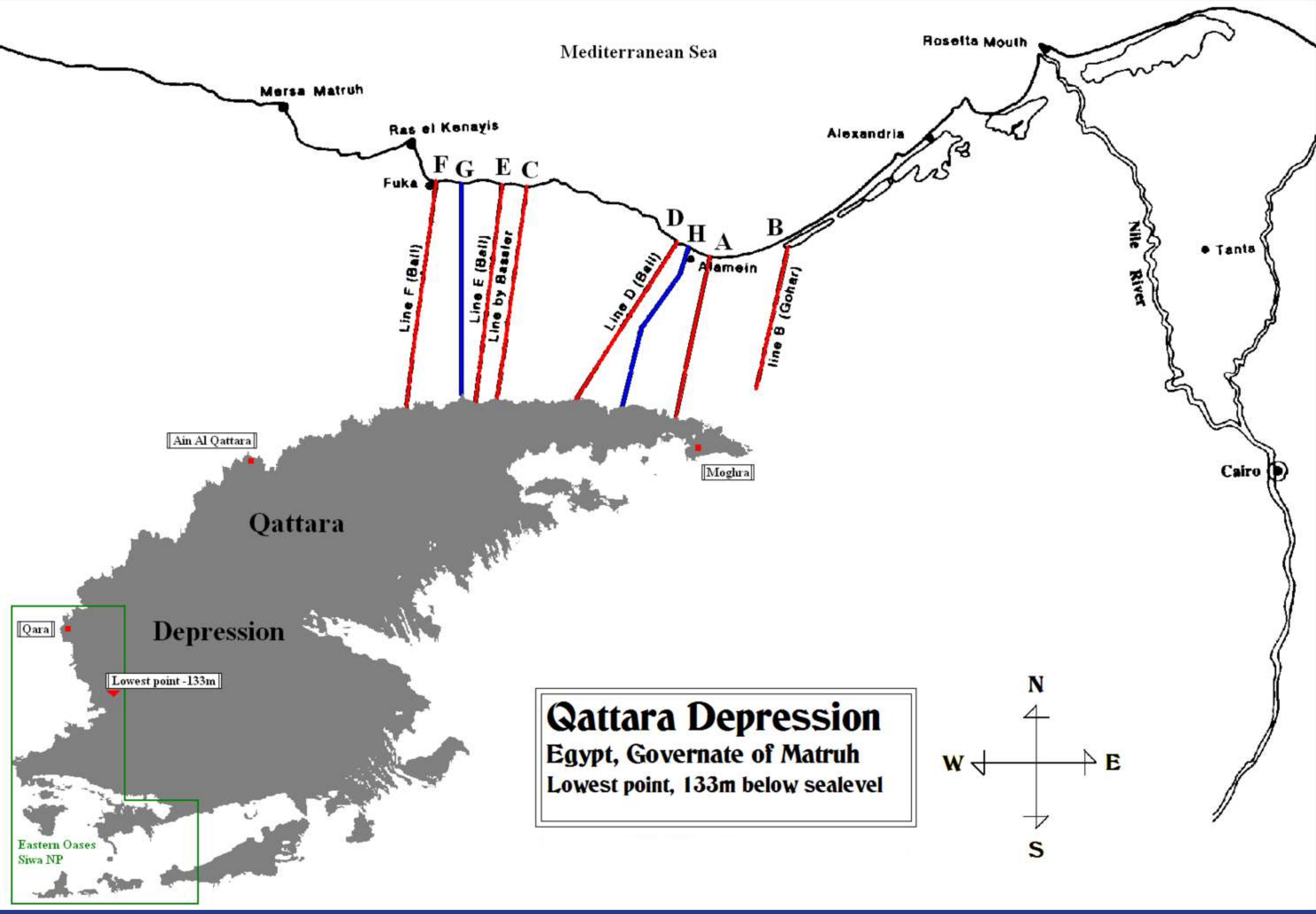
The Gacko Polje in Croatia

The Planinsko Polje during a flood with a hum rising above the flood surface in Slovenia.

The Feneos Polje, northern Peloponnesos, Greece, during a partial flood



World's largest polje: the Qattara depression in Egypt.



World’s largest polje: the Qattara Depression, Egypt

A view of the Qattara Depression with some hums in it

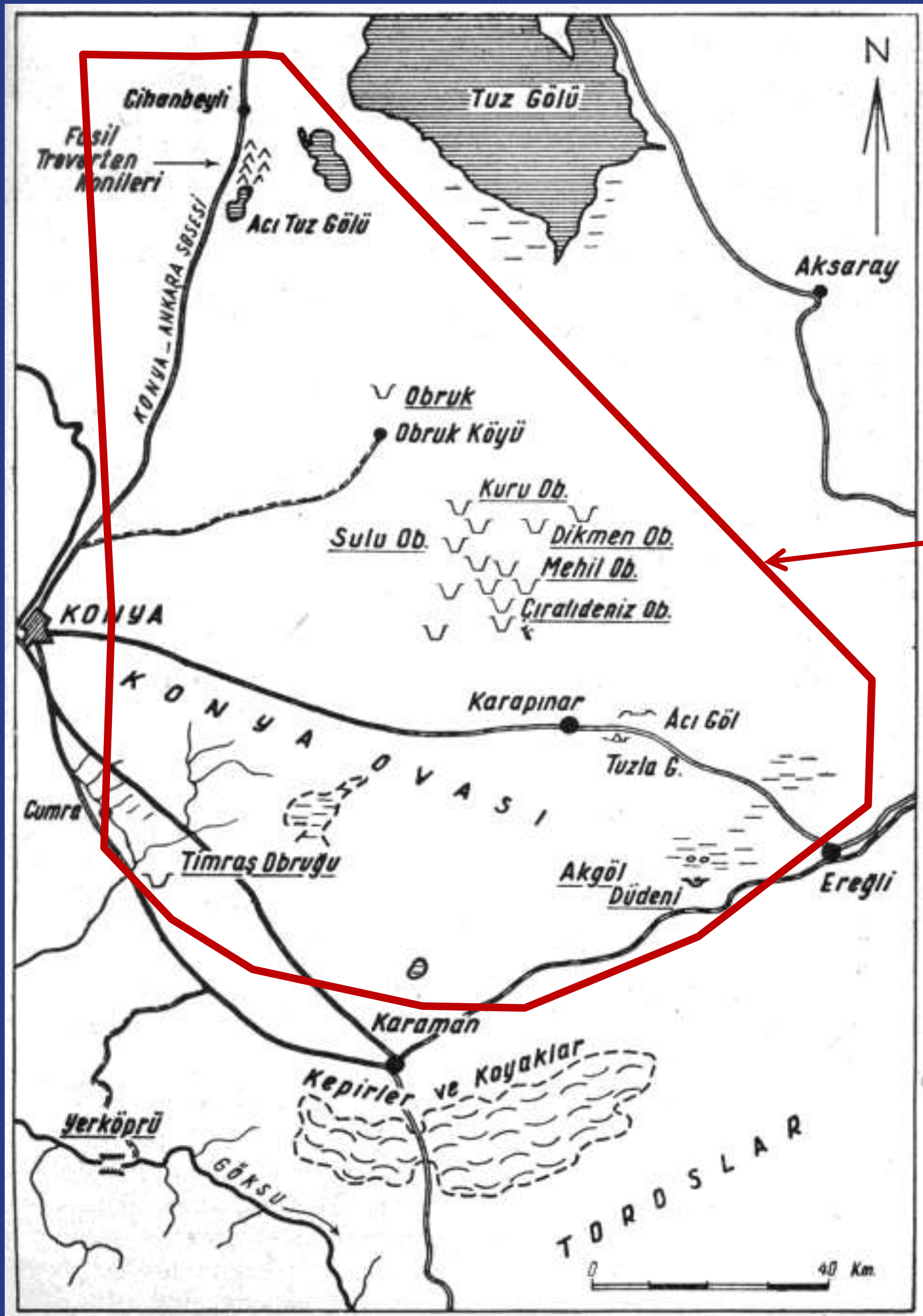
Another view of the Qattara Depression: the polje floor

The Qattara Depression at sunset: hums in the foreground

The Qattara Depression with major hums in it.

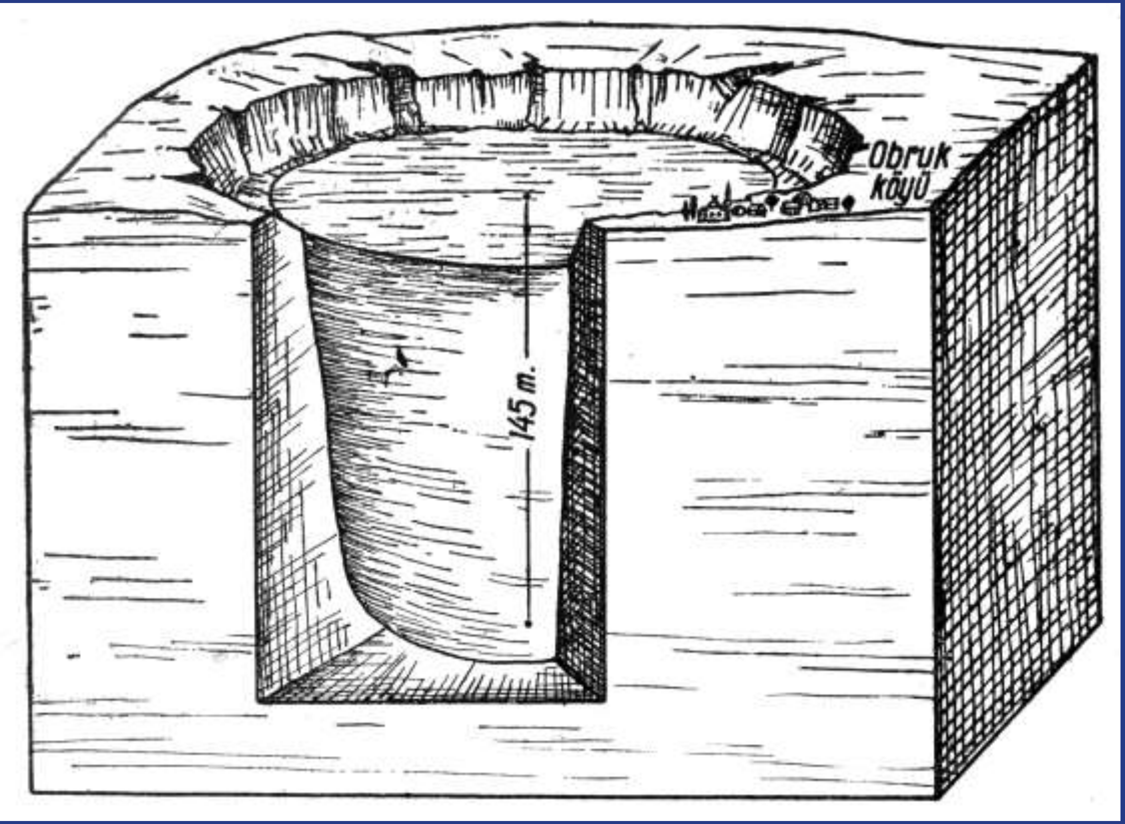
The Mediterranean sea-level may have been lowered more than a kilometre during the late Miocene to the earliest Pliocene interval (8 to 5 million years ago). It was at this time that the base level of karstic erosion also dropped and formed the giant Qattara Depression, the world's largest polje.

In areas of flat-lying beds of soluble rock, a prominent karstic landform is the obruks. An obruk is a large karst pit. The term obruk comes from Turkish and is given to the karst pits in Central Anatolia south of the Salt Lake. But such karst pits are widespread in other areas of karstic development on horizontally-bedded regions (e.g., Florida, USA; Yucatan, Mexico, etc).



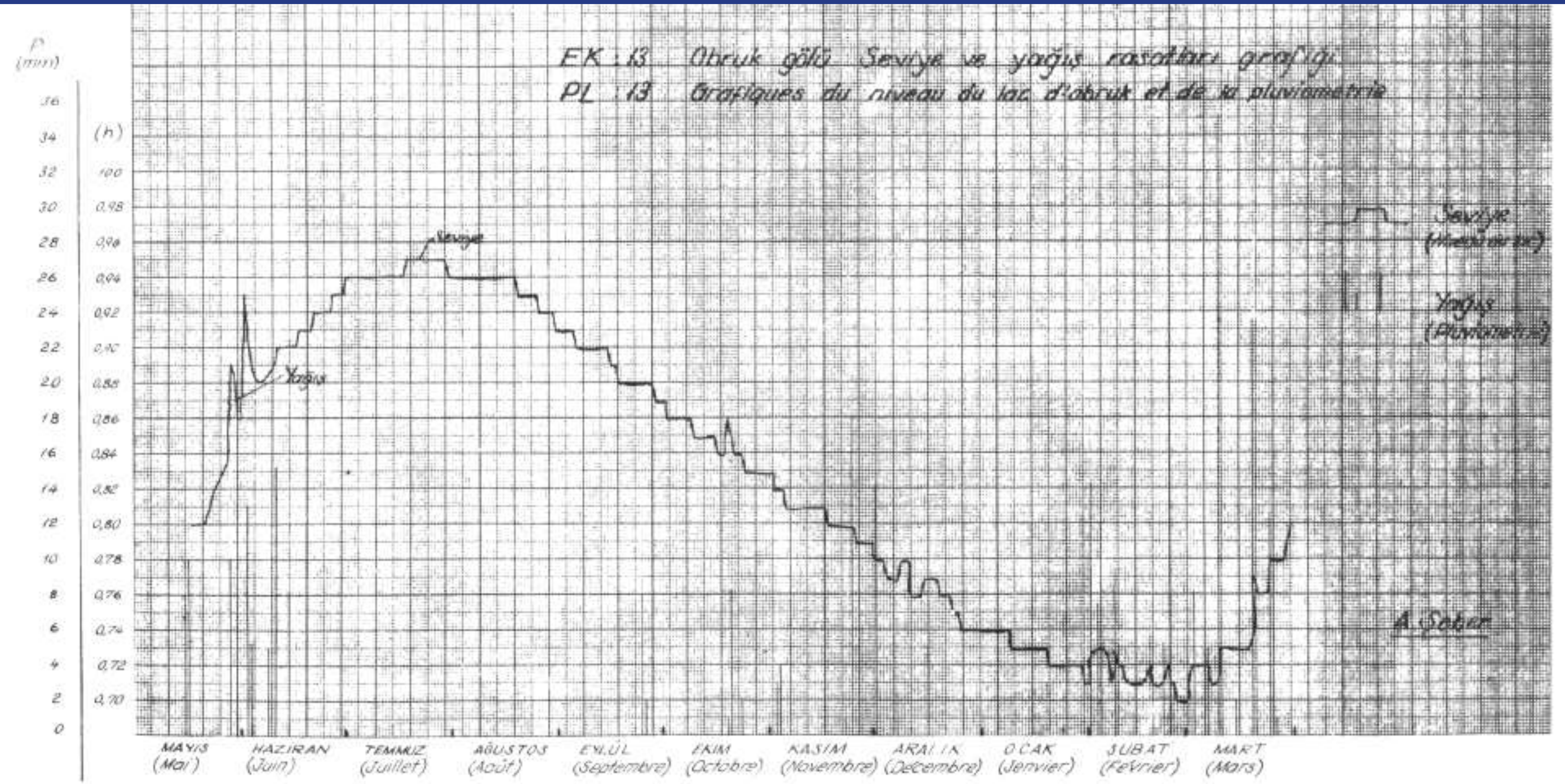
The Obruk Plateau

The obruk of Kızören, central Anatolia, Turkey (photo by Semih Can Ülgen)



Another view of the Kızören obruk, Central Anatolia

An aerial view of the obruk of Kızören, the Obruk Plateau, Central Anatolia, Turkey

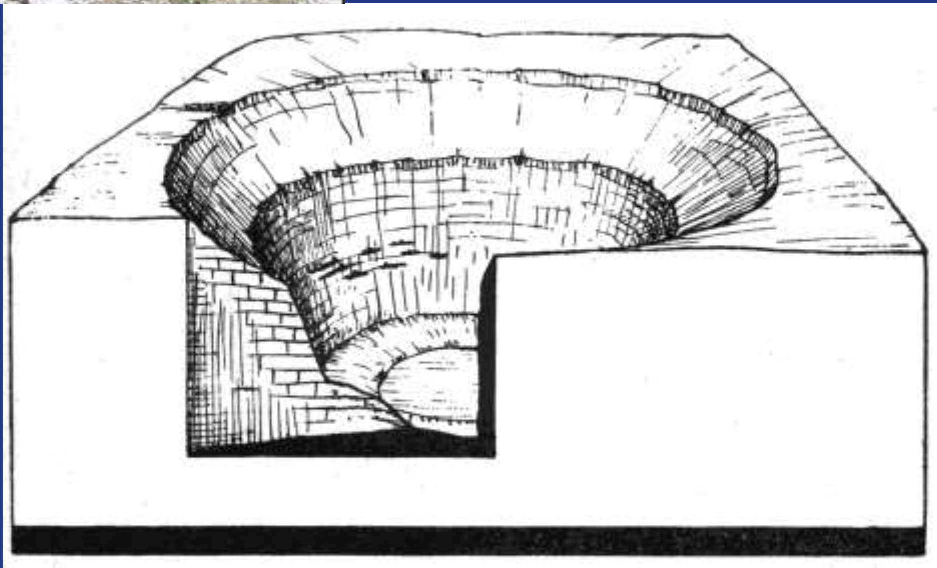


Water-level fluctuations in the Kızören Obruk in 1963 (Şeber, 1964)

The obruk of Kızören: detail of karstic erosion forms

The obruk of Kızören: detail of karstic erosion forms

The Obruk of Çıralı (or Çıralınındeniz) on the Obruk Plateau, Central Anatolia, Turkey

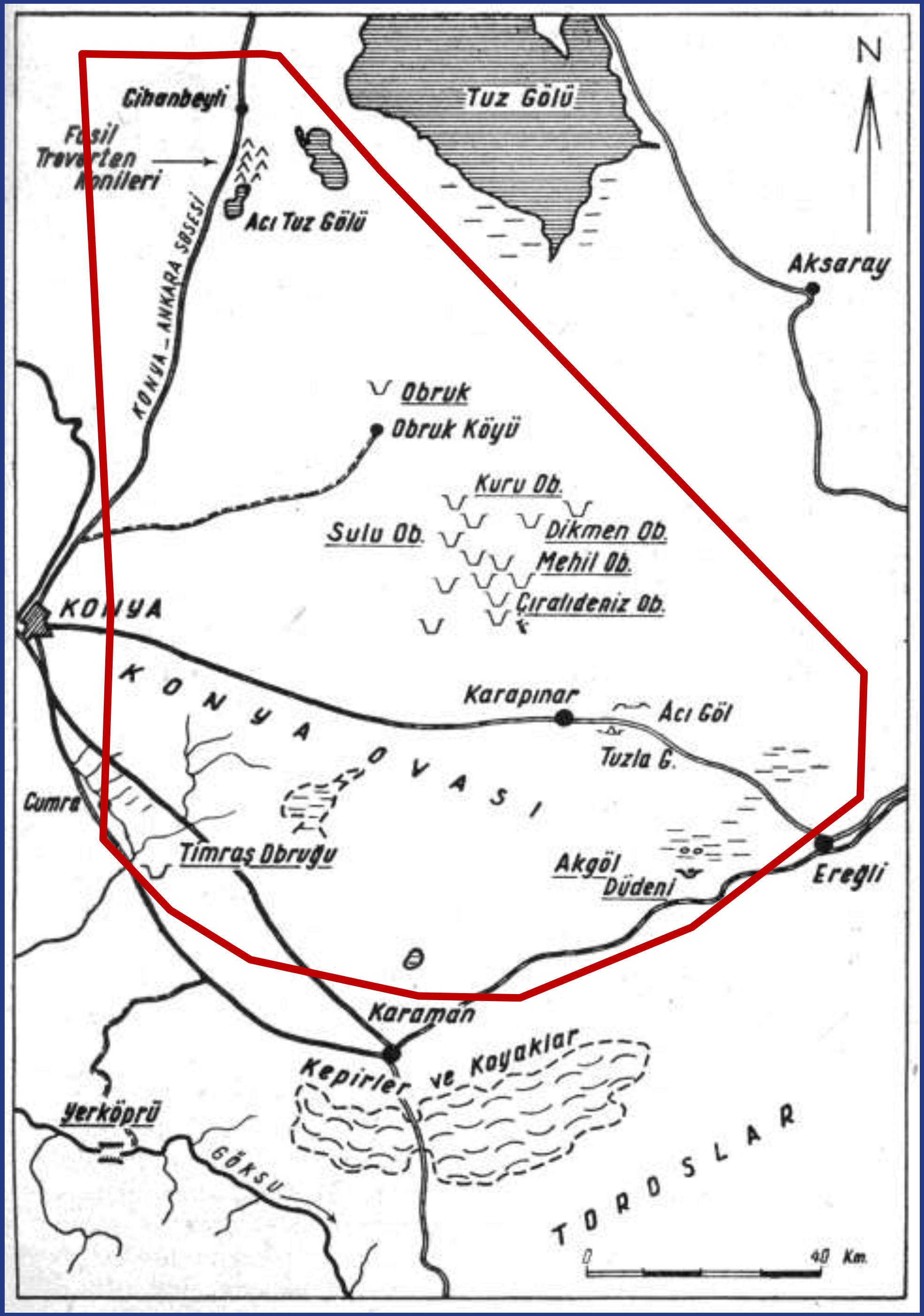


A general impression of the Obruk Plateau in Central Anatolia

Dean’s Blue Hole, an obruk in the Bahamas, Atlantic Ocean

An obruk in Wood Buffalo, Canada

An obruk that suddenly opened up in Guatemala City in 2010, swallowing a three-storey building and killing one person



Another peculiar landform on the Obruk Plateau is the travertine cones seen to the southeast of Cihanbeyli. Such cones are rare features in karst terranes and form a kind of karstic spring.

One of the travertine cones southeast of Cihanbeyli

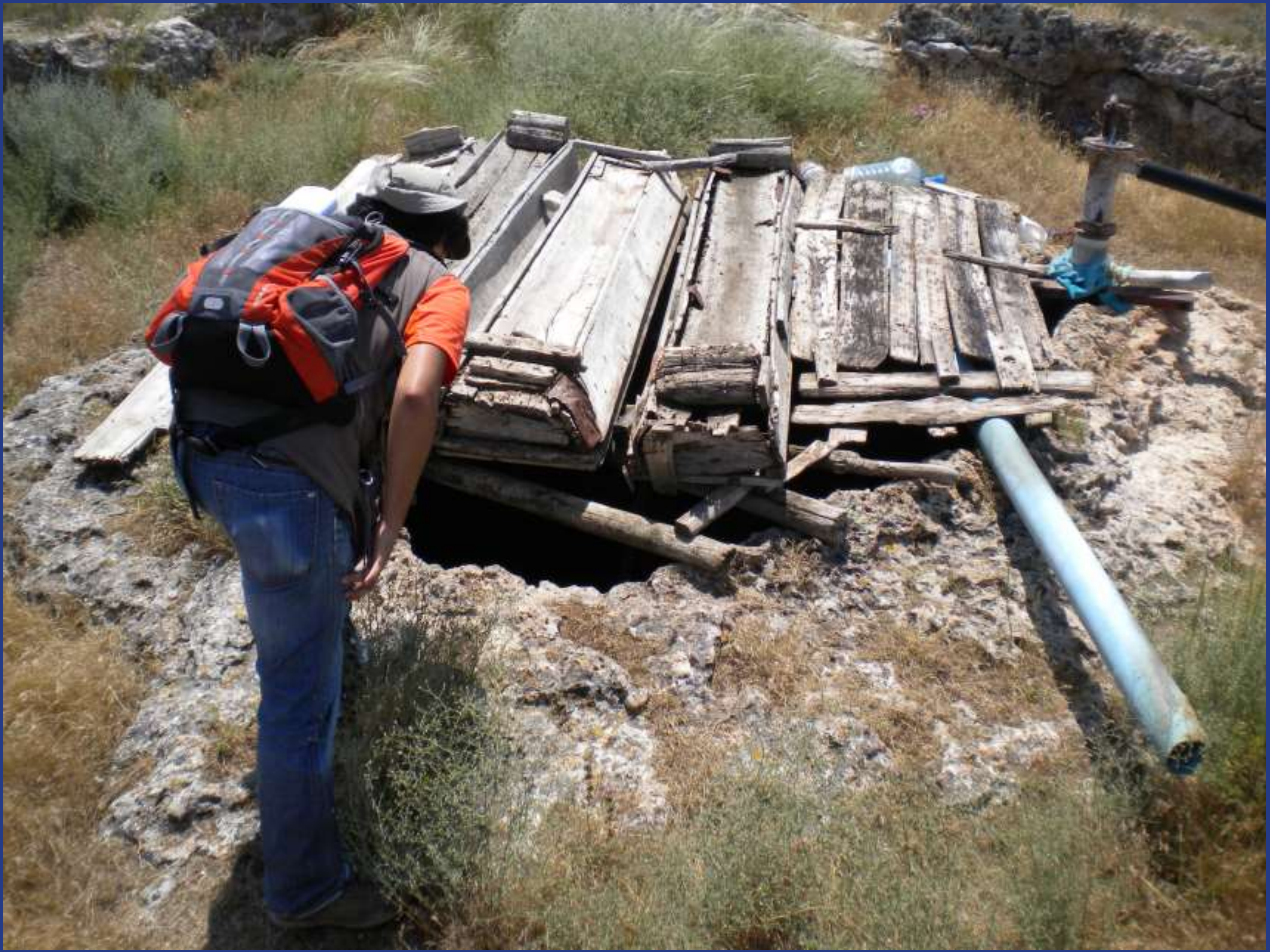
Top view of an inactive cone in the Cihanbeyli area

Travertine layers forming the travertine cones

Another, smaller travertine cone in the Cihanbeyli area

Inside view of an active travertine cone in the Cihanbeyli area

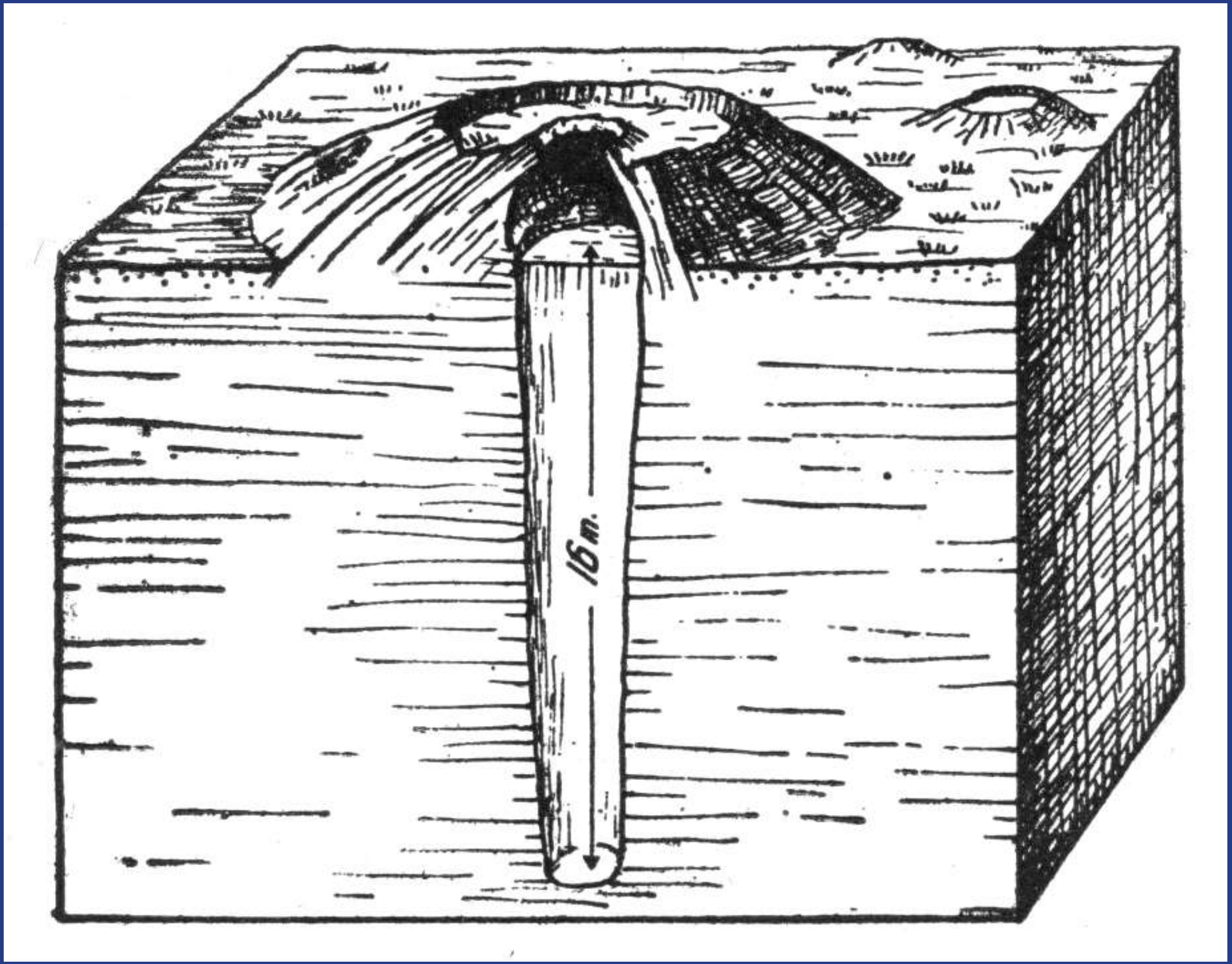
Water level in an active travertine cone in the Cihanbeyli area



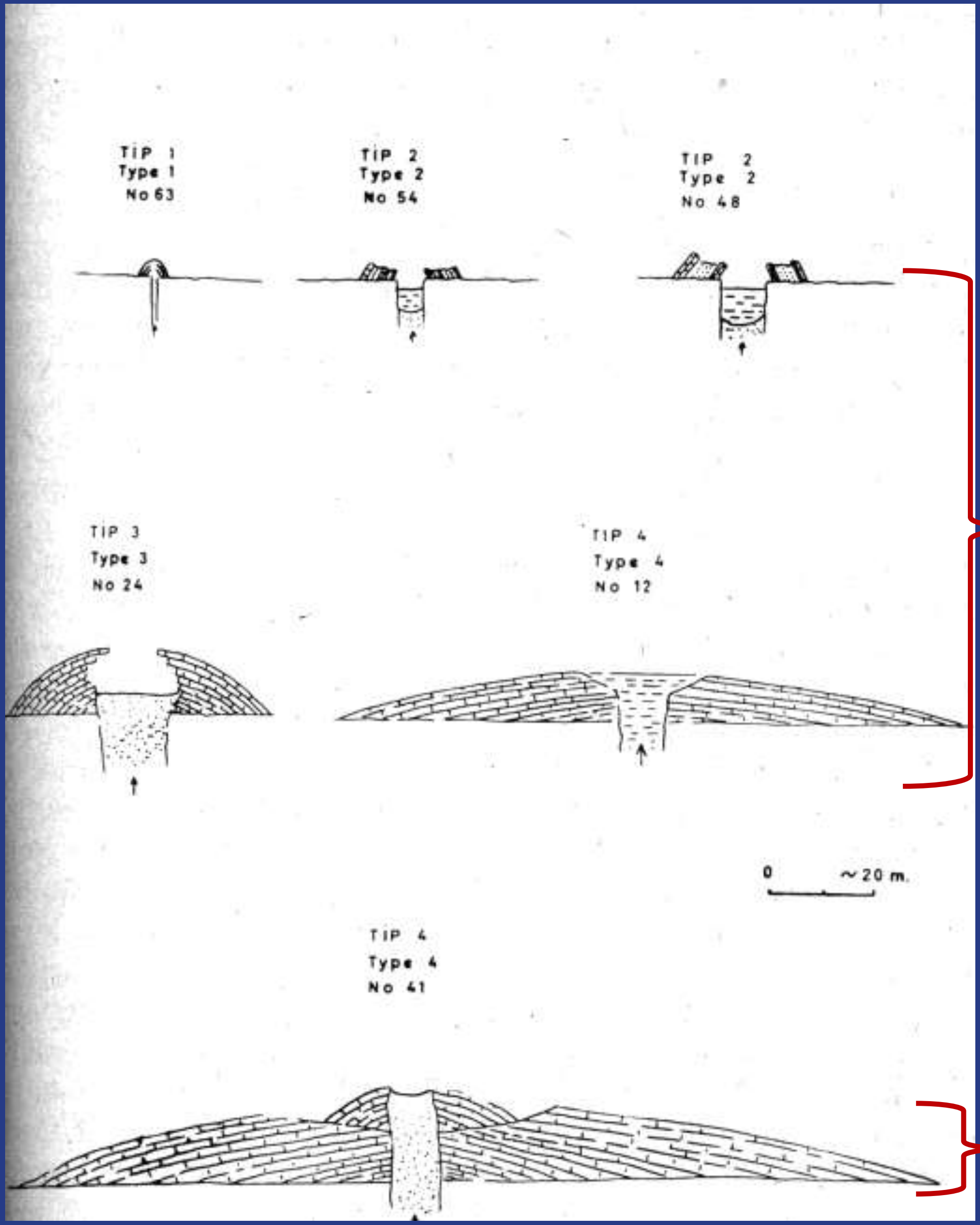
Water being drawn from an active cone in the Cihanbeyli area

Water in the chimney of an active travertine cone in the Cihanbeyli area

Another active travertine cone in the Cihanbeyli area



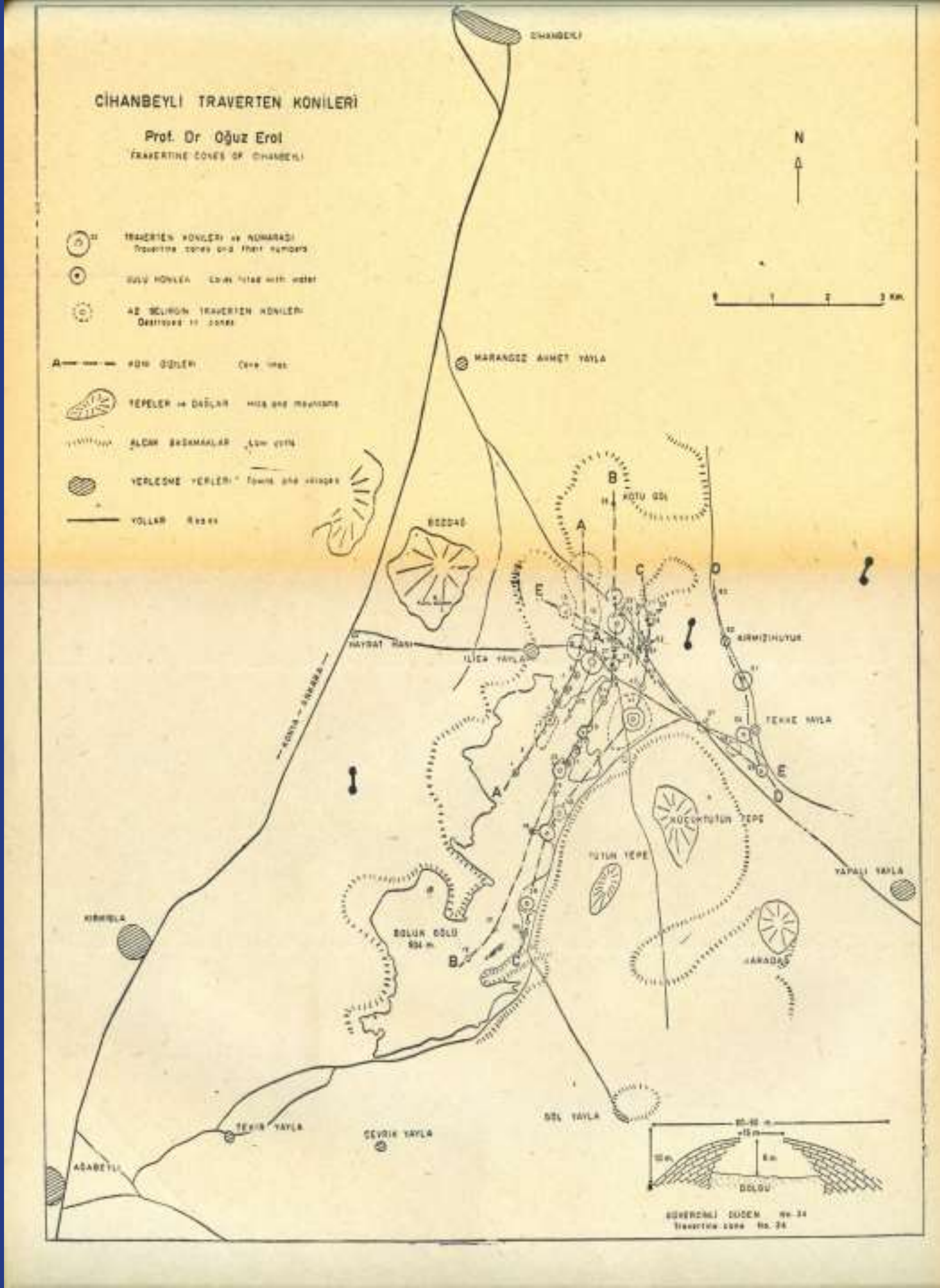
The internal structure of the travertine cones southeast of Cihanbeyli, Central Anatolia, Turkey



Cross-sections of travertine cones southeast of Cihanbeyli. From Erol (1964)

Monocyclic cone types

Polycyclic cone



The distribution of the travertine cones to the sootheast of Cihanbeyli (from Erol, 1964)

An active travertine cone from the “Fairyland” area of the Yellowstone National Park, Wyoming, USA

There are also other kinds of karstic springs. Many are formed simply from the intersection of a subterranean stream with the topography. Such springs emerge from cave systems.

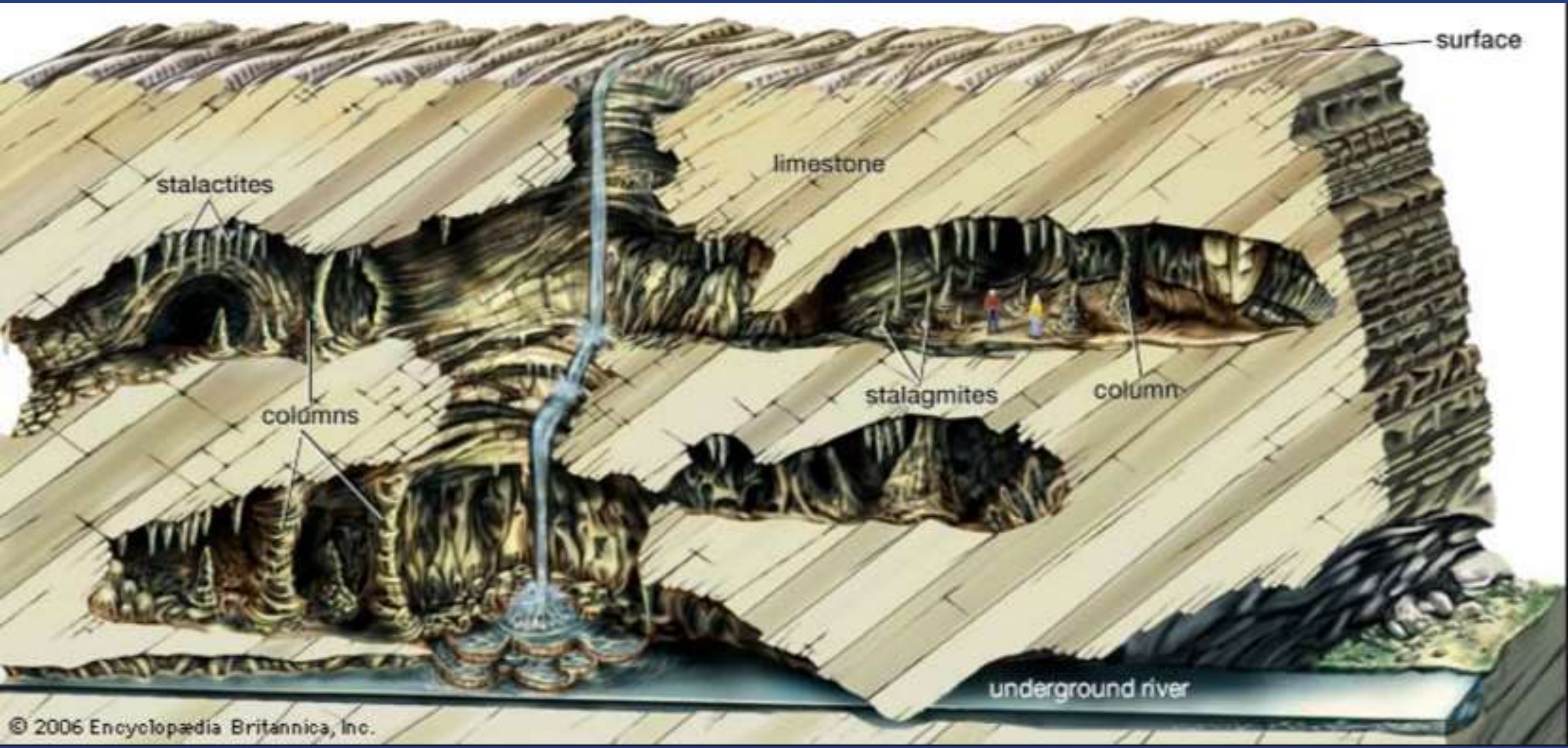
The most famous of the karst springs is the one at Vaucluse in southern France and because of that karstic springs in general are called “vaucluse springs”.

The karstic spring of Vaucluse, the famous *Fontaine de Vaucluse*, the source of the Sourgue River in southern France

The beginnings of the River Sorgue having just emerged from the Vaucluse

We have seen structures that swallow the surface waters and transport them to the underground (ponors) and those that return them to the surface (karstic springs or vaucluse springs). What happens to the subterranean waters in between?

They form the karstic caves, the most spectacular of all the cave forms in the world.



A "textbook representation" of a cave system from the *Encyclopaedia Britannica*. In reality caves are much stranger than the simple diagram here represents.

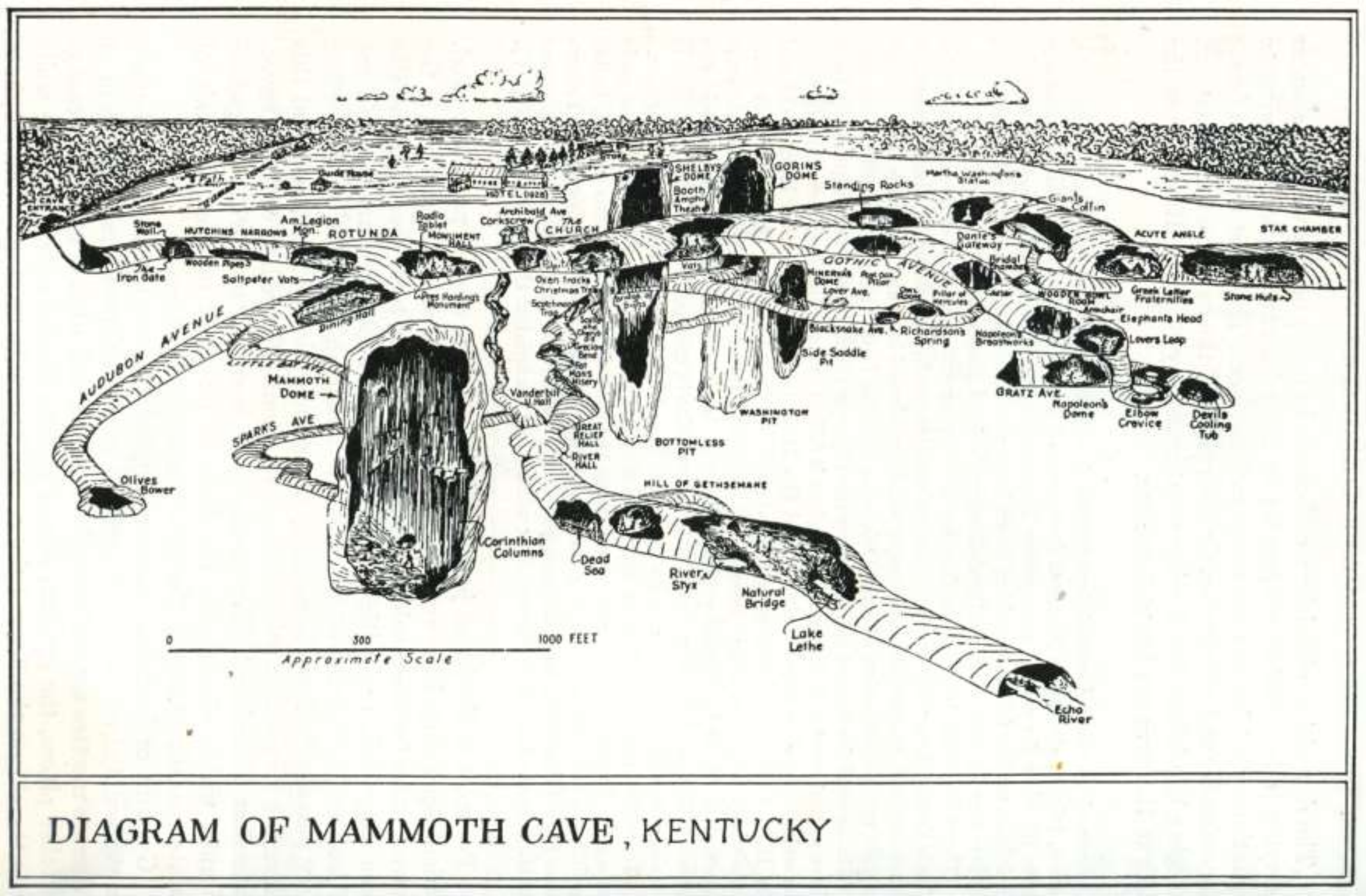
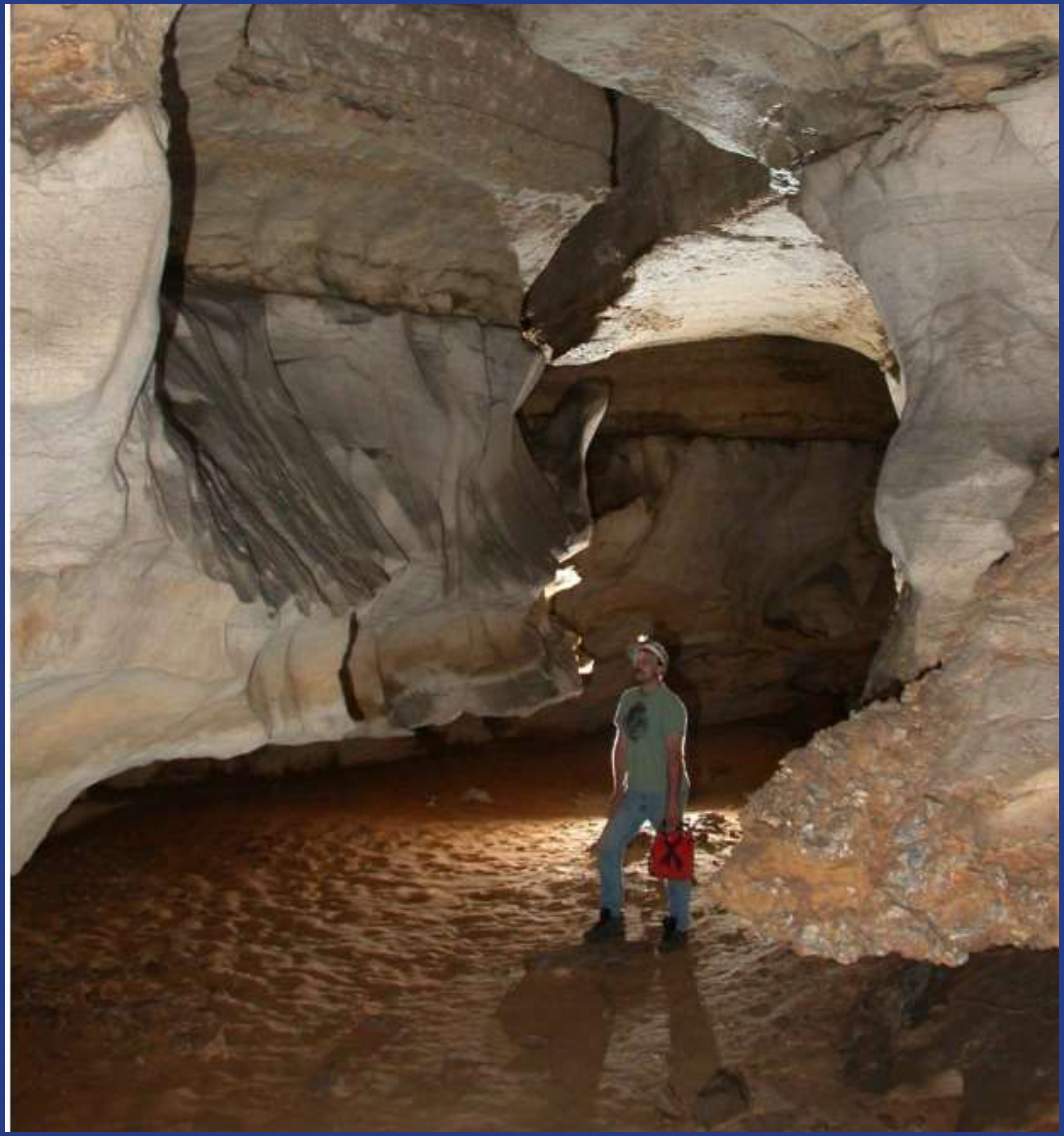


DIAGRAM OF MAMMOTH CAVE, KENTUCKY

A stereogramme of the famous Mammoth Cave in Kentucky, USA, by A. K. Lobeck (1939). It has since been found that the cave is much more extensive.

The “Maelstrom”, a vertical shaft in the Mammoth Cave with flowing water



The “Marion Avenue” in the Mammoth Cave. Notice the flat top and bottom of the ‘”avenue”.

Caves of Indiana: notice the pronounced “flat” cross-sections. These kinds of caves are called “horizontal” caves and they form largely by dissolving the flat-lying strata. It is the case both in Kentucky and here. Such flat-lying strata are rare in Turkey.

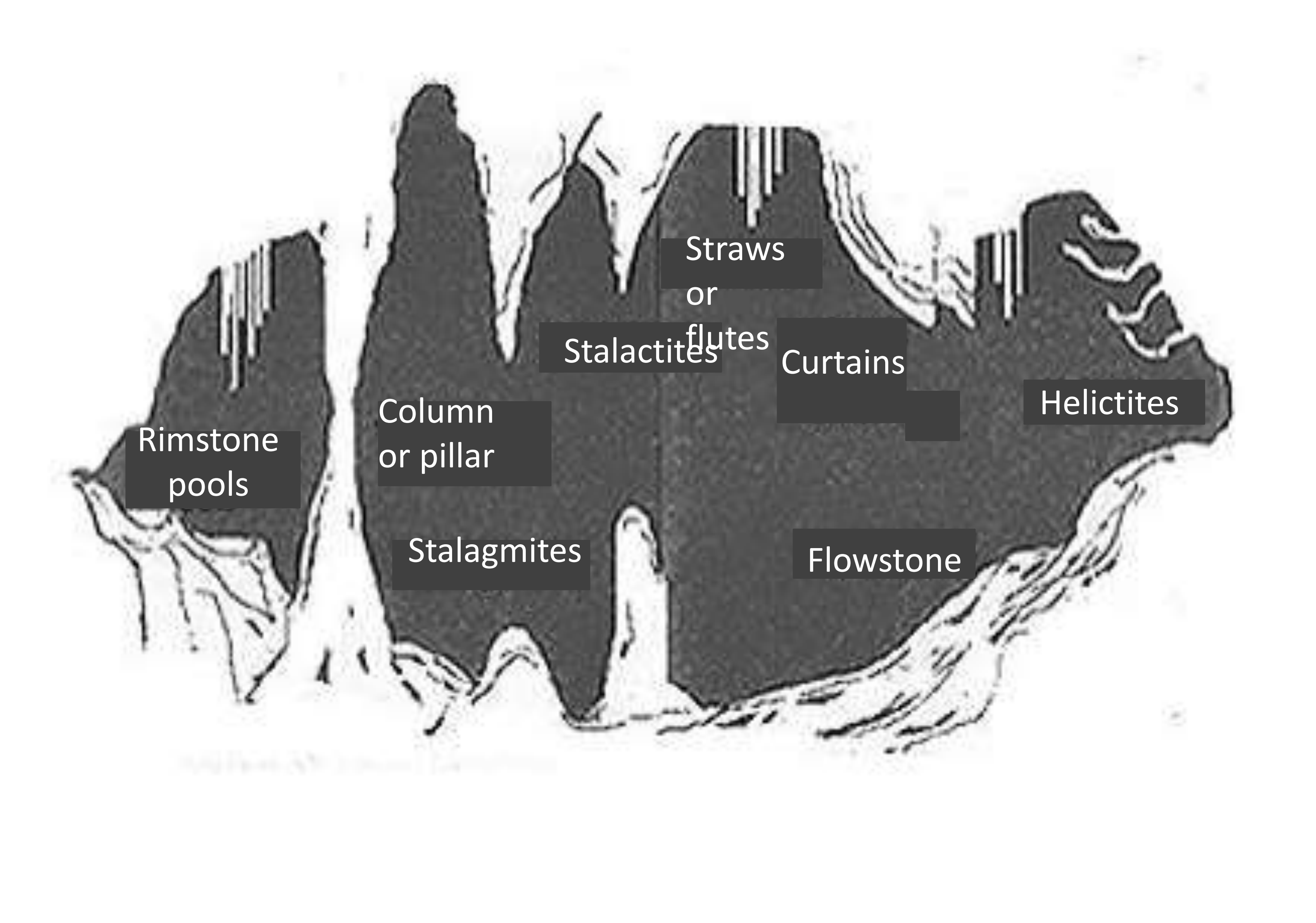
Beginning of cave formation: dissolution of stratal boundaries in the Eocene limestones in the Yarımburgaz Cave, Altınşehir, west of İstanbul.

A vertical cave in İnkaya, Bursa, Turkey. Such caves generally follow the vertical joints in soluble rock formations.

Another vertical cave in the village of İnkaya, Bursa, Turkey.

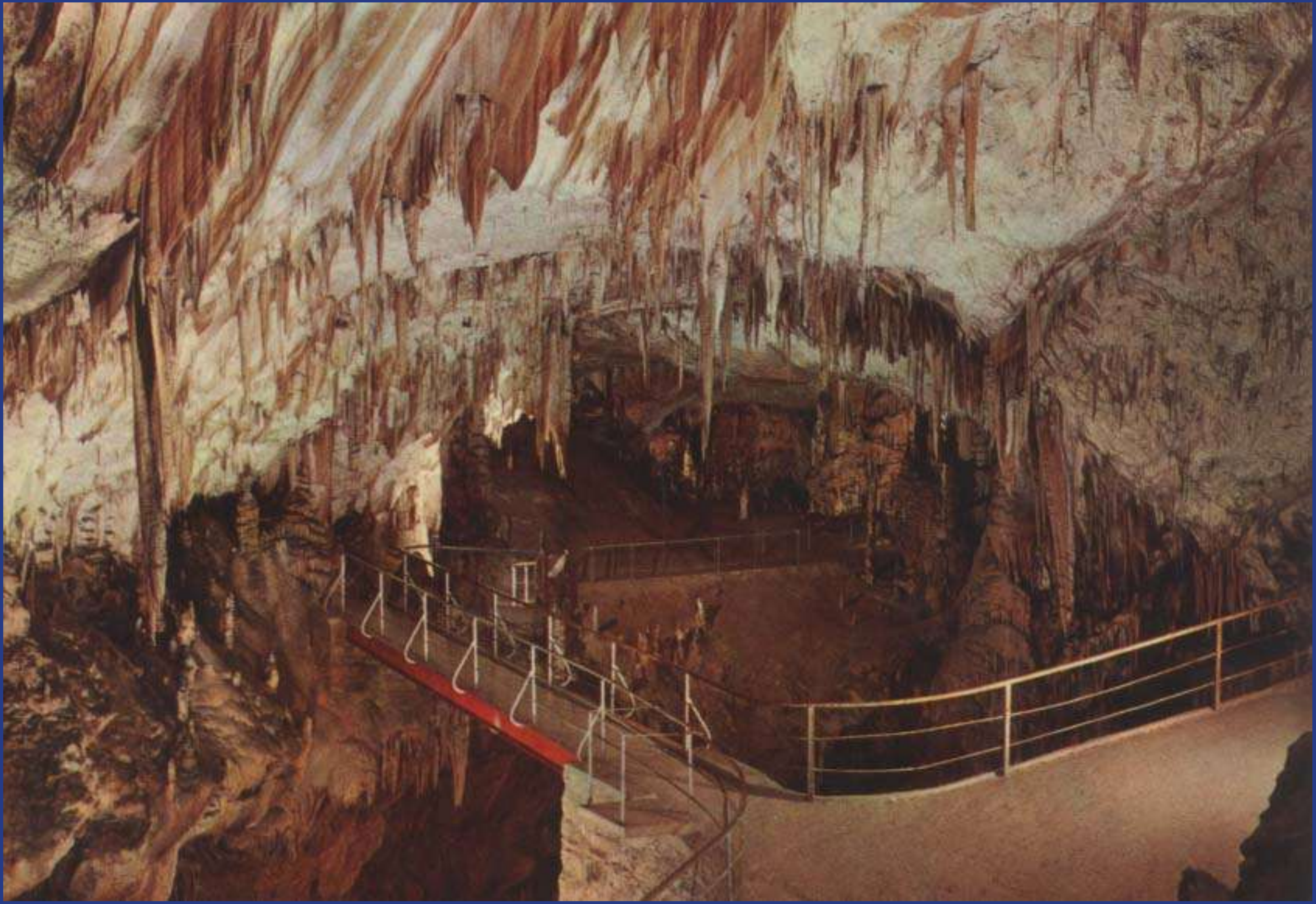
The caves are decorated by deposits laid down by water that seeps from their ceilings and walls. Collectively they are called sinter deposits or speleothems.

There is a huge variety of speleothems, but the most abundant ones are the stalactites (cones hanging from the ceilings of caves) and stalagmites (conical pillars rising from the ground of caves). To remember which is which, just think that stalactites (with a c in the word) hang from the ceiling, whereas stalagmites (with a g in the word) rise from the ground.



The terminology of speleothems

Stalactites, stalagmites and columns in the Marengo Cave, Indiana, USA



Speleothems in the Postojna Cave, Slovenia

The beginning formation of stalactites (most as straws), Yarımburgaz Cave, İstanbul, Turkey

Formation of a stalactite (still only a straw)

Flowstones and curtains, Yarımburgaz Cave, İstanbul, Turkey

Curtains in the Damlataş Cave, Alanya, Turkey.

Flowstones in the İnkaya cave (the eastern one) in the İnkaya Village, Bursa, Turkey

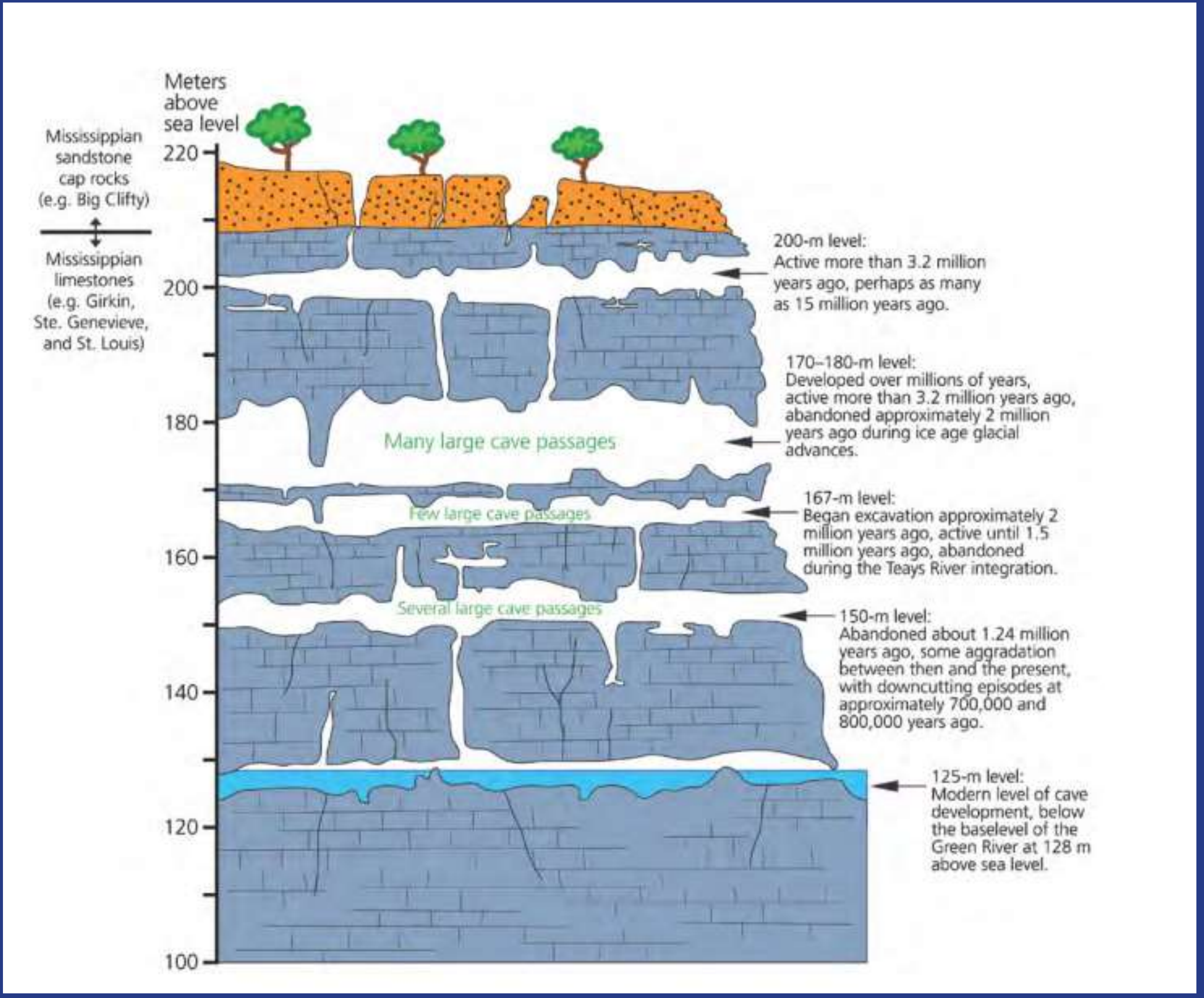
Curtains hanging from the İnkaya cave (western one).

Flowstones in the İnkaya Cave (western), Bursa, Turkey

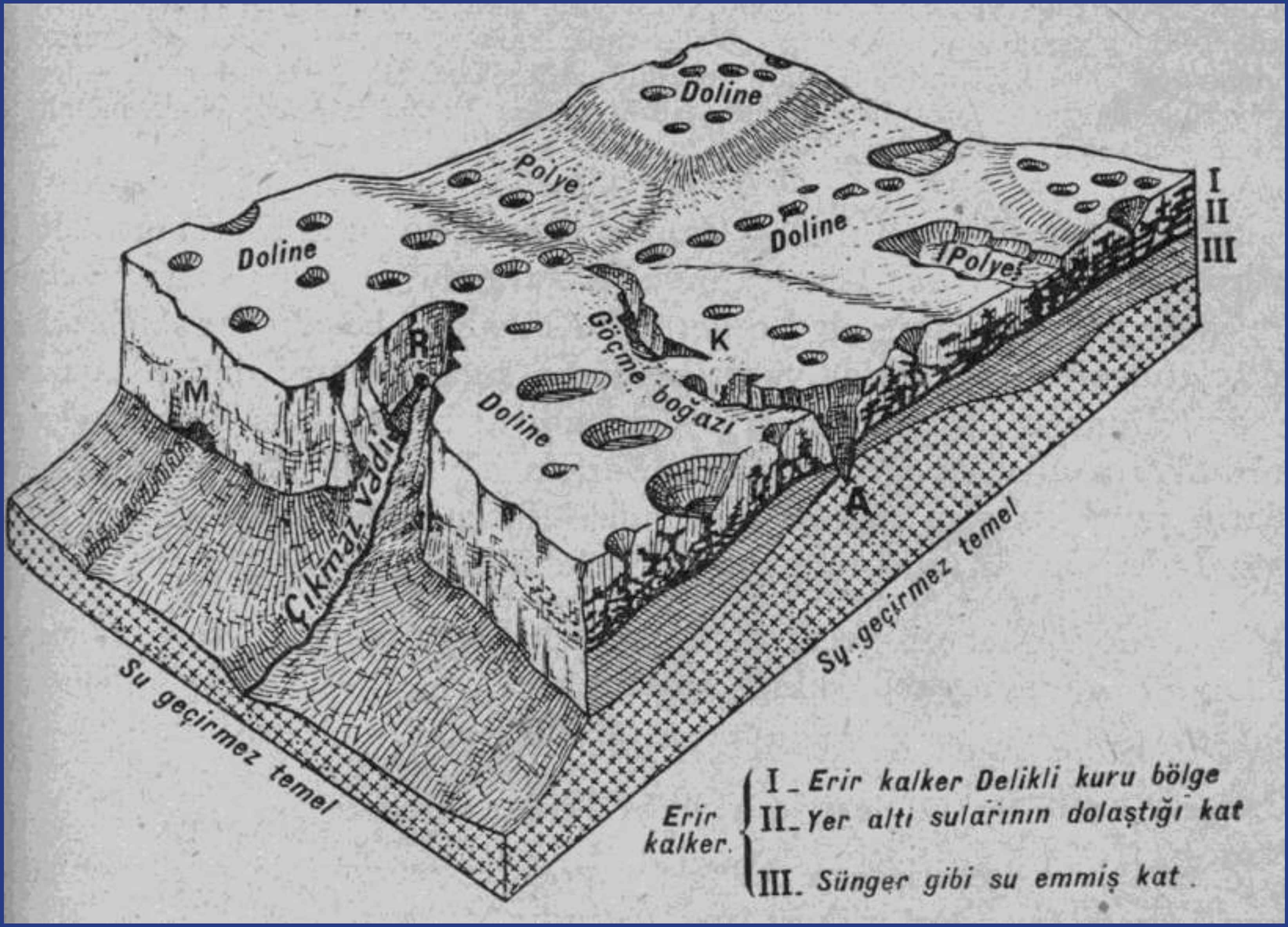
Numerous helictites growing on the walls of the Caverns of Sonora, Texas, USA. In the foreground, a stalagmite and a stalactite united to form a column.

The “Snake Dance Helictite” in the Caverns of Sonora, Texas, USA. Changes in air flow in the cave, climate of the cave and the chemicals feeding the helictite determine the shape (from the *National Geographic*)

This couple of “fried eggs” are actually calcite accumulation in the hole of a broke stalagmite in the Luray Caverns, Virginia, USA

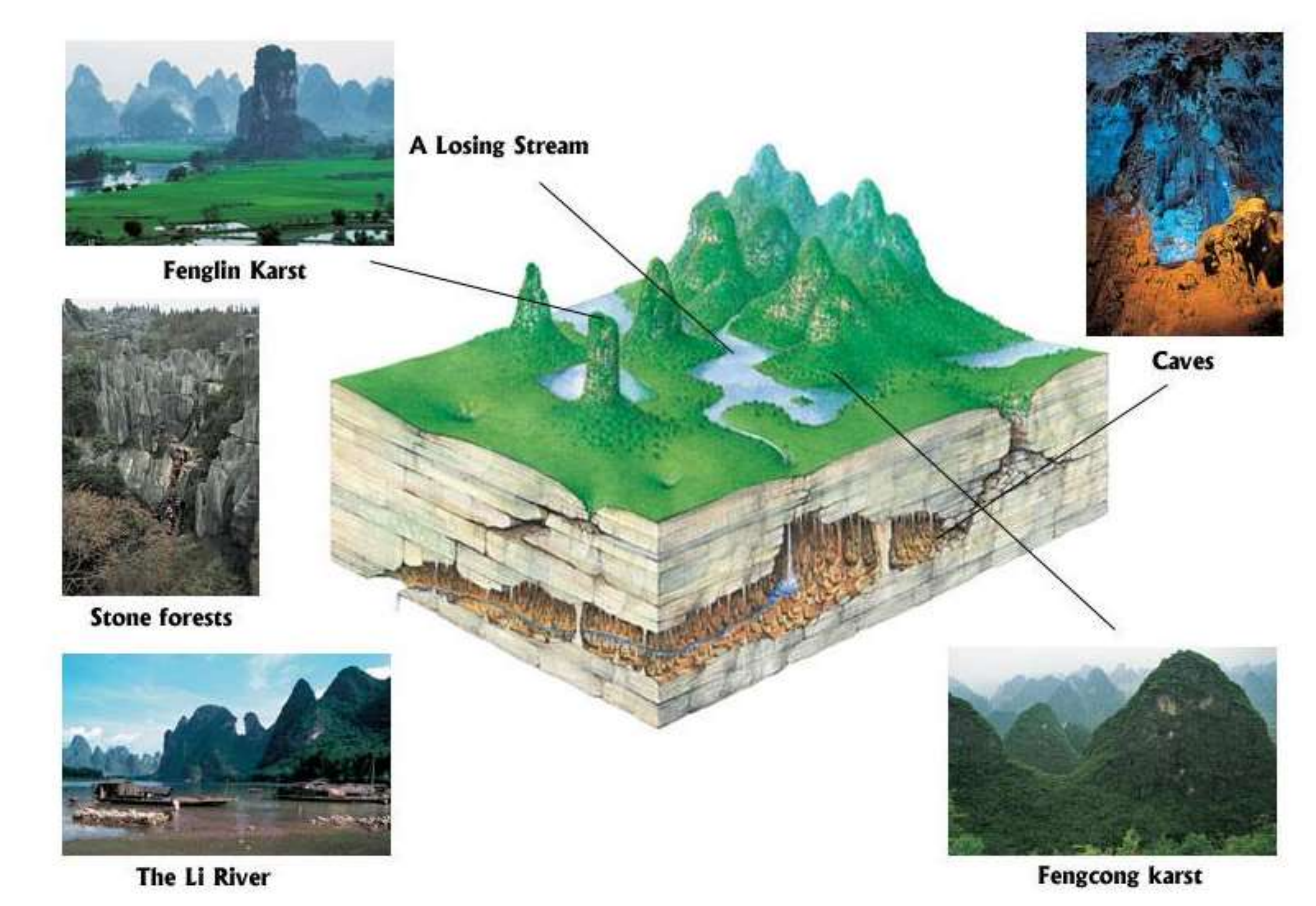


Formation of a complex cave system: Mammoth Cave as an example (from Natural Resource Report NPS/NRSS/GRD/NRR—2011/448)

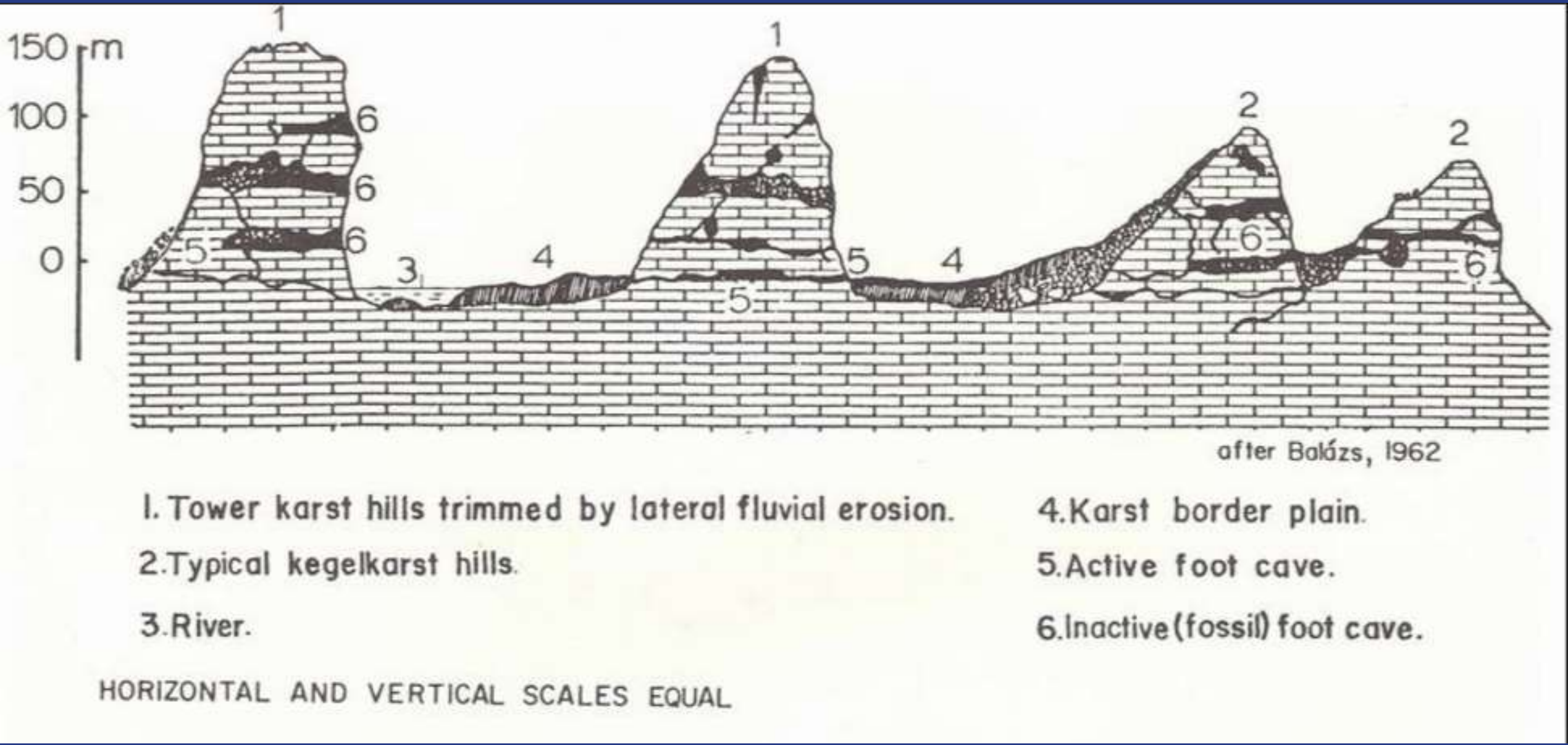


A typical karst landscape. This landscape is “typical” only in temperate climates. In the tropics we encounter a completely different form of karst, called the “tower karst” or “conic karst”.

A typical manifestation of the tower karst, Jamaica



The tower karst of Guangxi, South China



Typical conical or tower karst (*Kegelkarst* in German) landscape. This kind of karst develops in areas of high precipitation and humidity which is typical of tropical climates.

Thermokarst

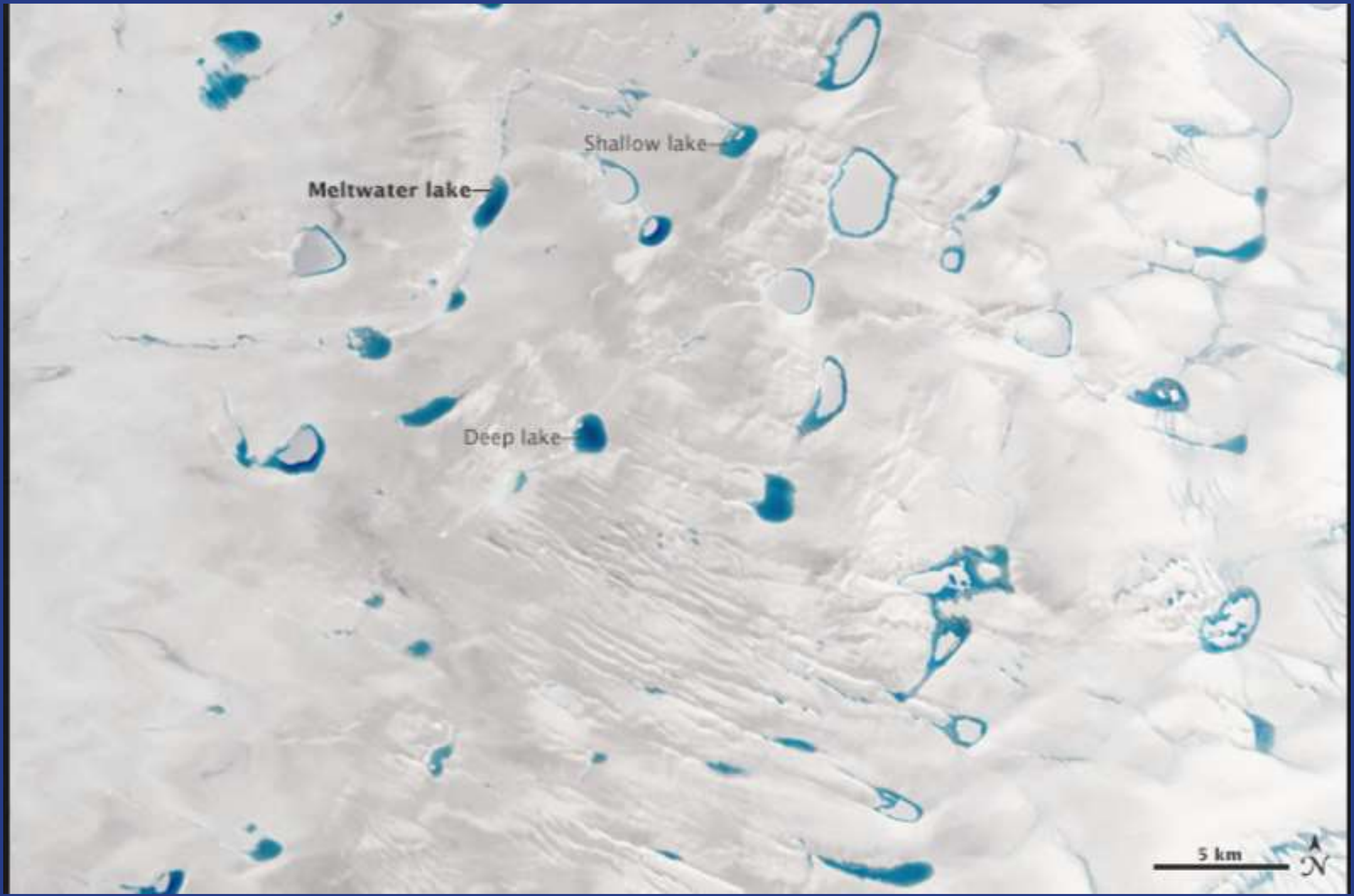
Thermokarst represents the karst features that develop on ice or on rocks covering ice masses by the melting of the ice. Thermokarst is extremely important as a landscape-building process on Mars and on the moons Enceladus and Europa.

The rapid melting of the Greenland ice sheet also produces typical karst features on it.

A large lapiaz field on the Greenland ice sheet

A series of ponors on the Greenland ice sheet

Dolines on the Greenland ice.



Field of dolines on the Greenland ice sheet with one obruk (where it says “deep lake”)

An active ponor on the Greenland ice sheet

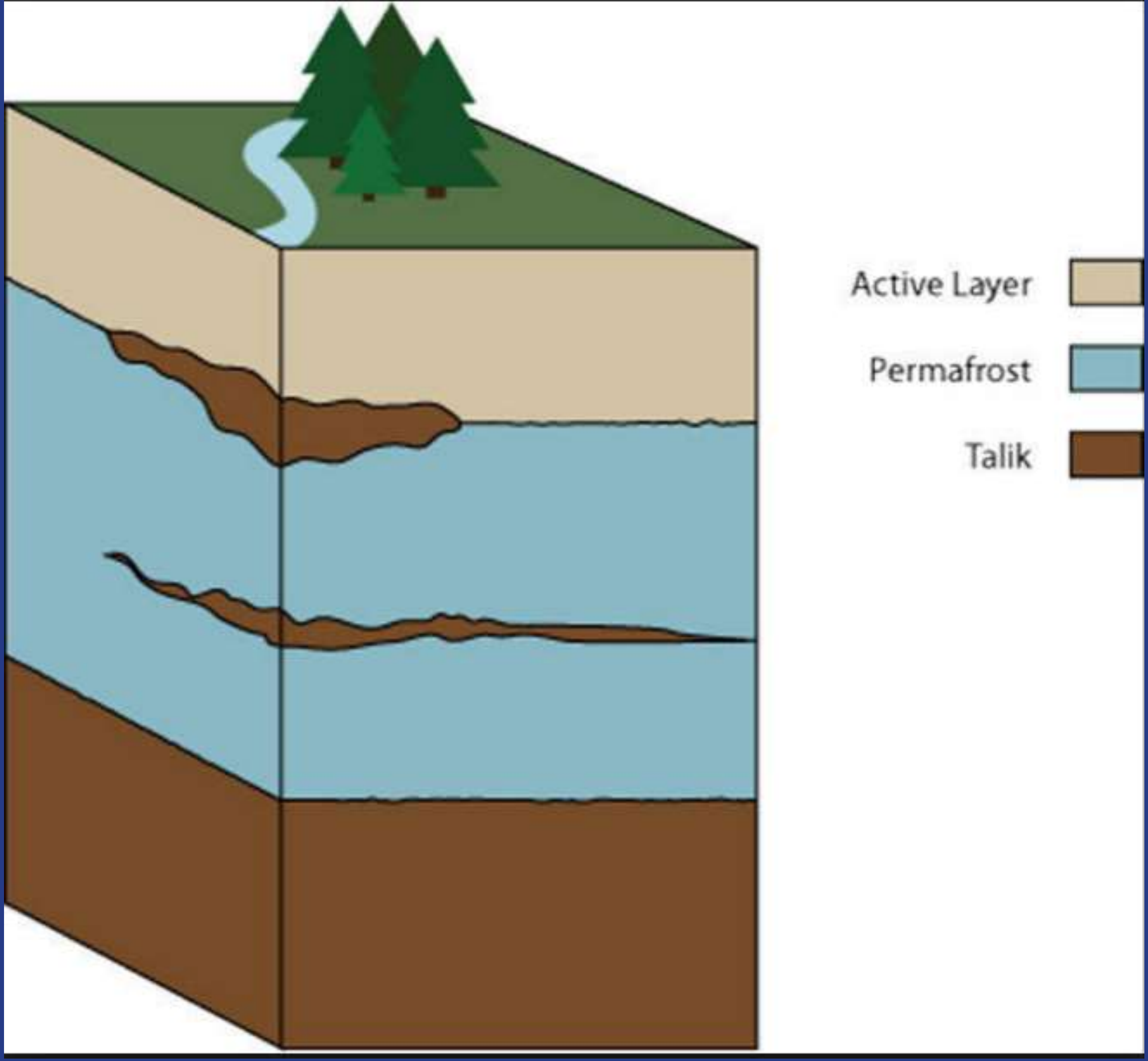
An obruk in the Greenland ice sheet.

A deep canyon with natural bridges cut into the Greenland ice sheet

An ice cave with underground lake and stalactites (“icicles”)

Ice cave with flowstones and stalagmites and straws

An obruk in the permafrost in Siberia. This is one of the most remarkable features forming in thermokarstic areas



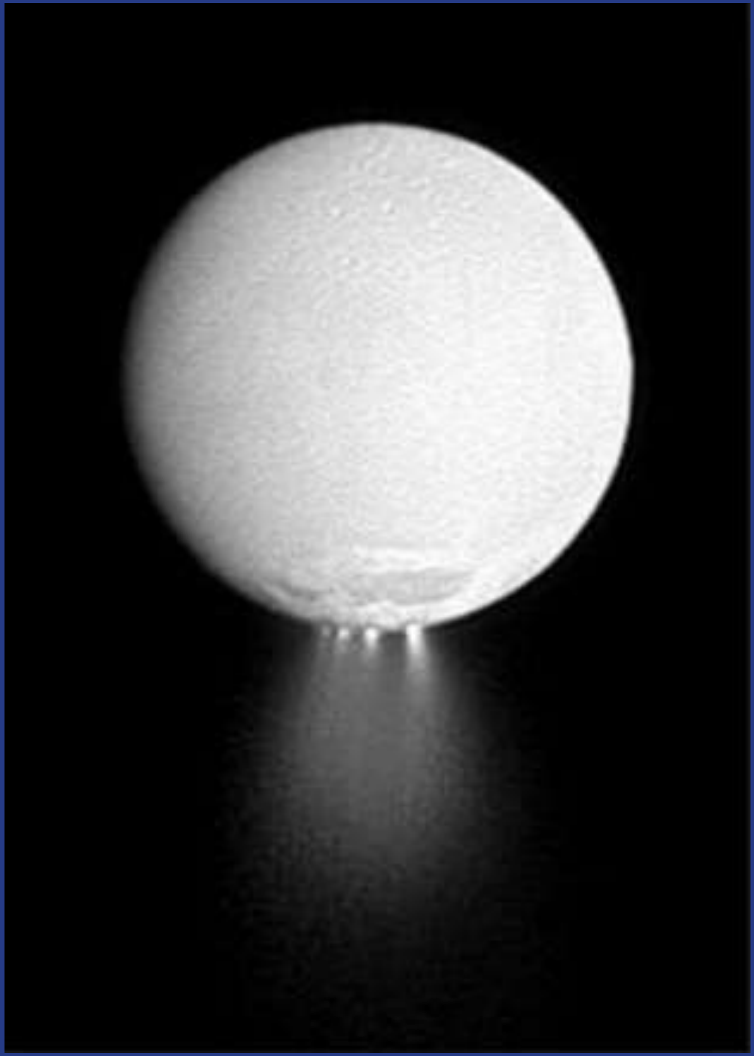
A schematic view of permafrost

Permafrost, Alaska, USA

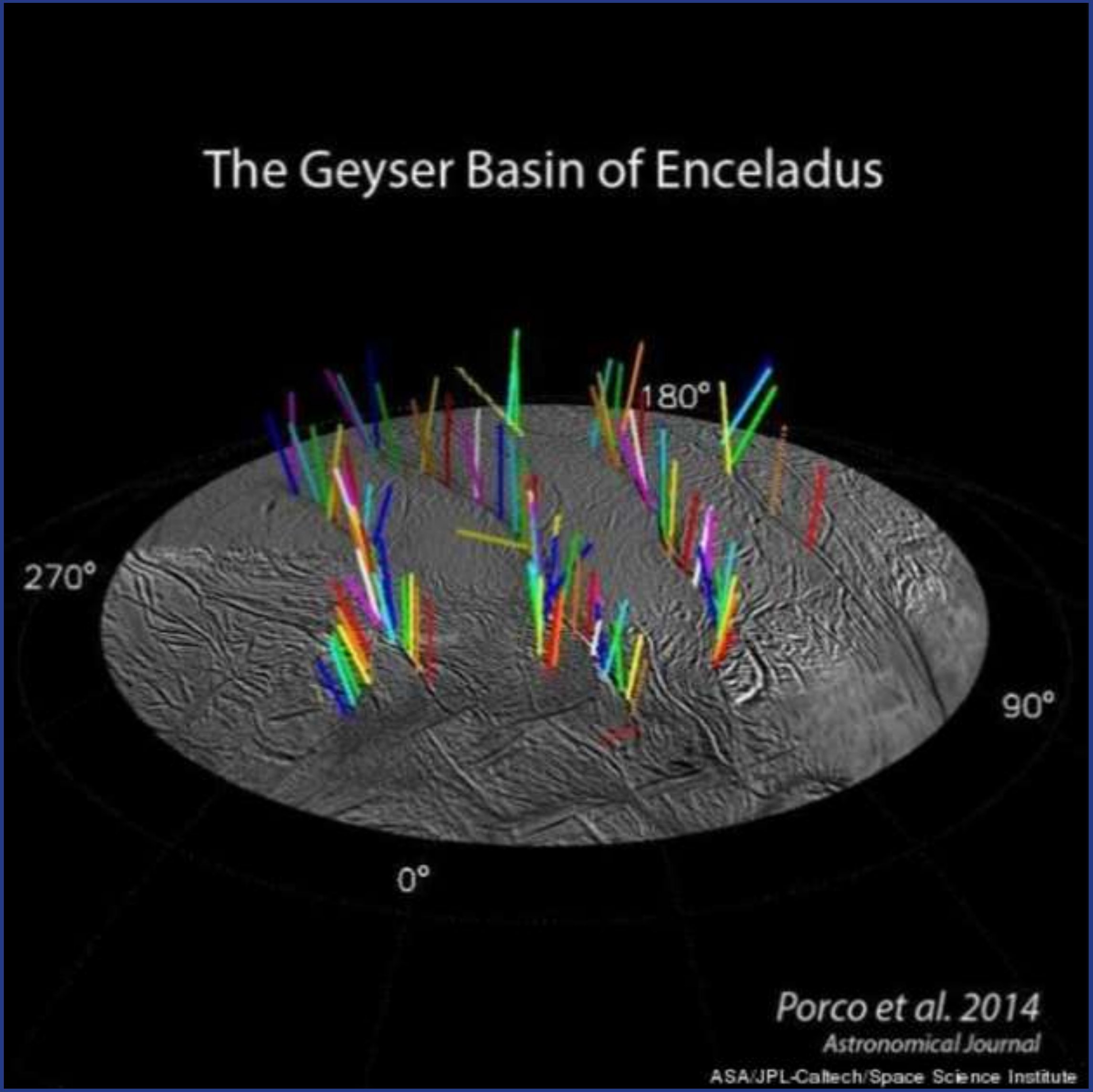
A very ice-rich layer of permafrost, Alaska, USA

Another obruk that opened up in Permafrost.

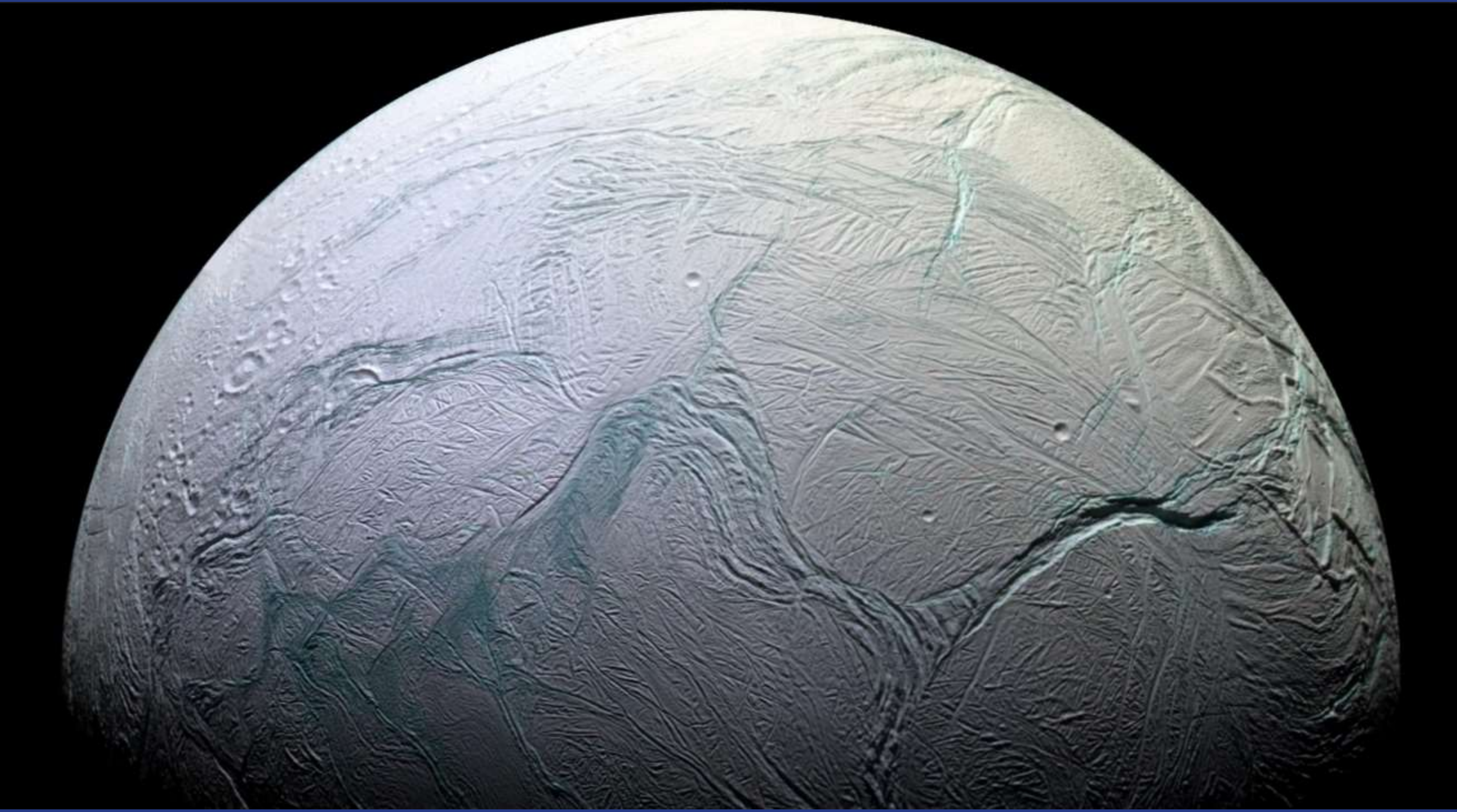
Collapsed building because of sink hole activity in the permafrost of Siberia, Russia



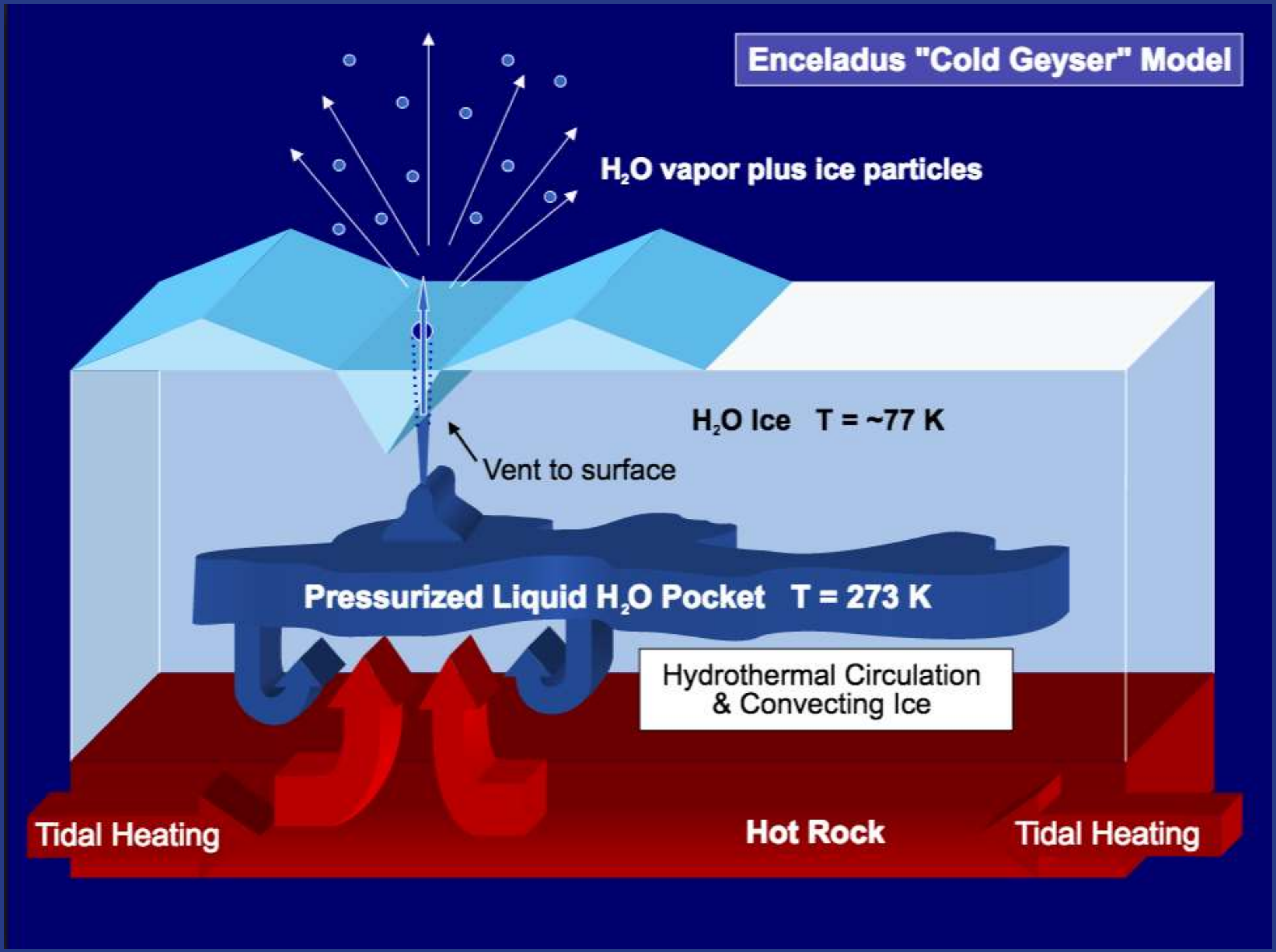
Geysers erupting on the south polar region of Enceladus, one of the moons of Saturn (picture by Cassini spacecraft)



There are about 101 geysers so far discovered on Enceladus

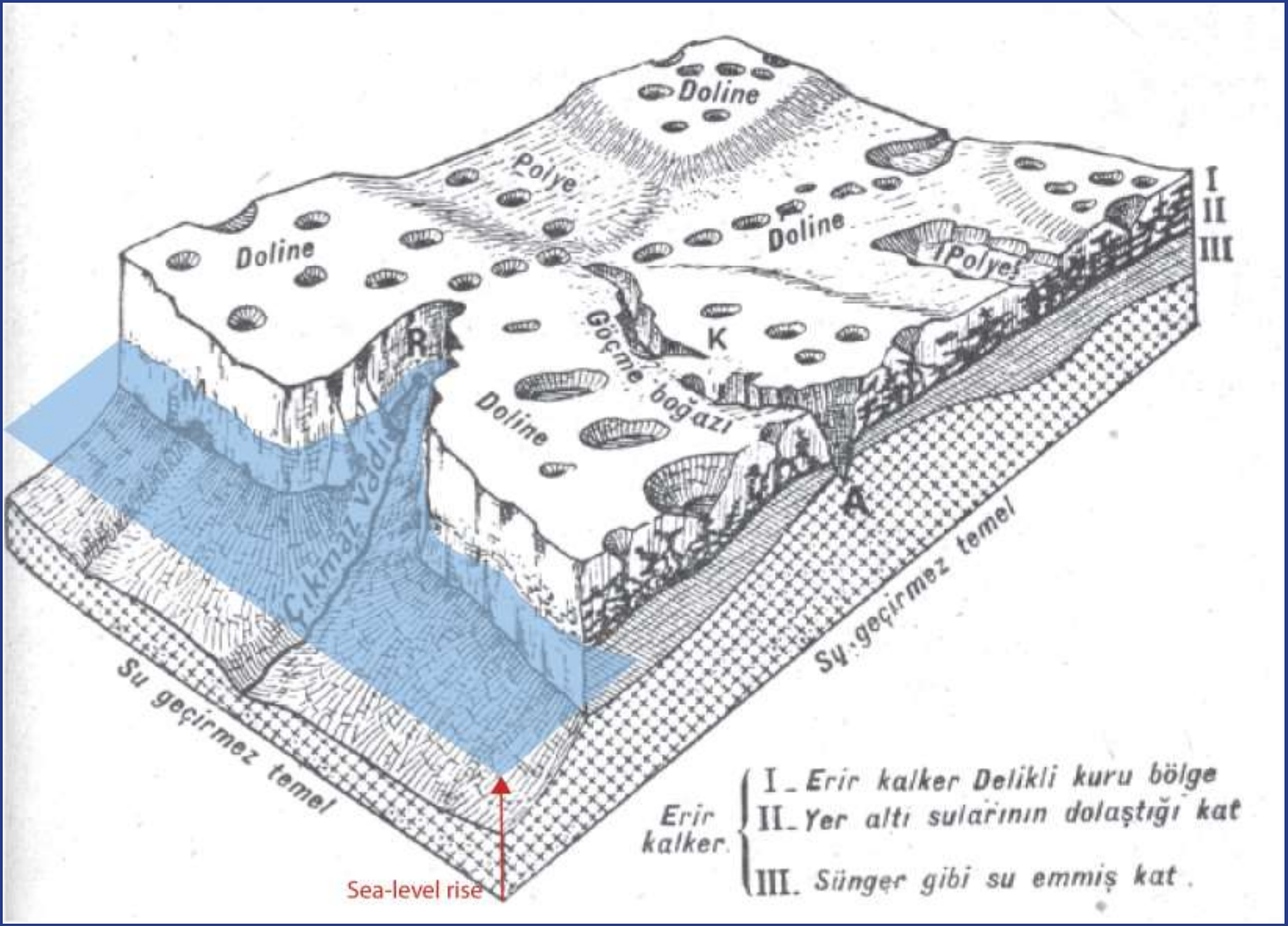


The ice-covered surface of Enceladus. It seems that the geysers are aligned along the plate boundaries within the ice crust.



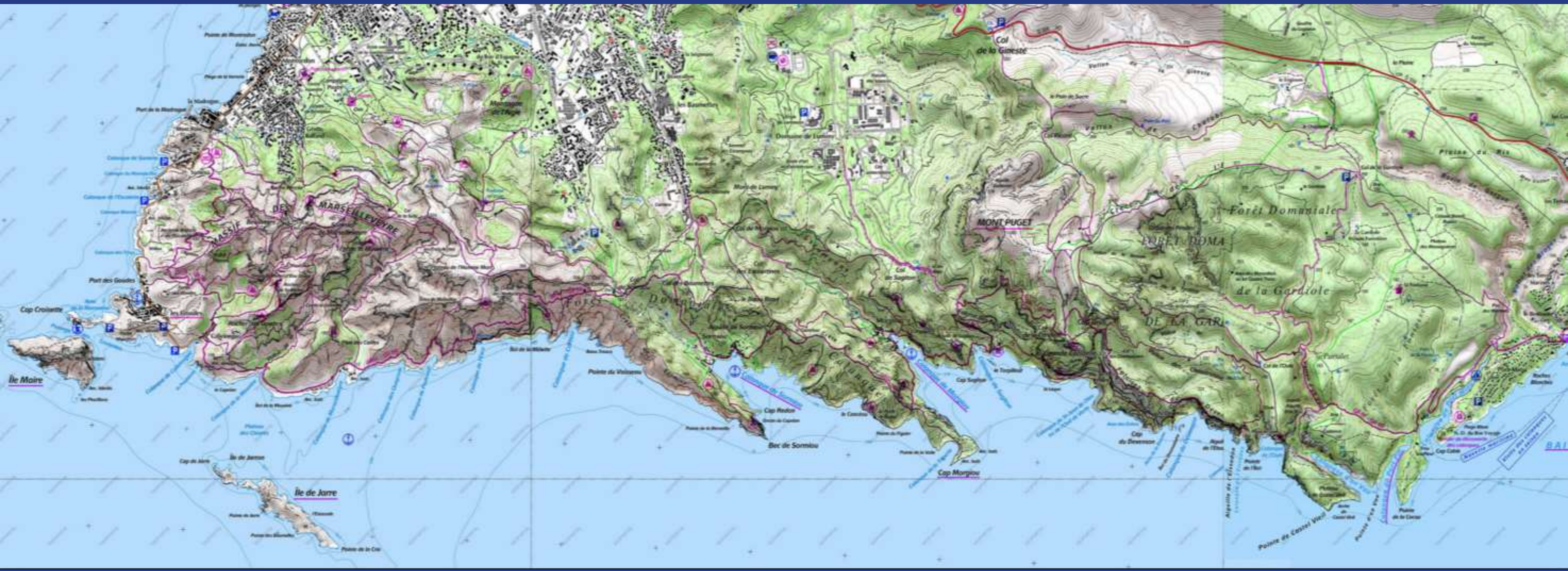
Geyser mechanism model for the Geysers on Enceladus

Karst is important both scientifically and practically. It is important to understand the frozen outer crusts of other planets as well. What I have been able to give you here is a mere skimming of the surface of the karst studies. In a world where water resources are becoming scarcer, the sea-level is rising and the ice sheets and the permafrost are melting, karst is more important than ever.



What happens when the sea-level rises and invades a blind valley in a karstic landscape?

The result is a *calanque*, a drowned karstic valley. The name comes from the drowned karstic valleys of southern France where they are called “calanques”. This is the Calanque En-Veau.



The calanques of southern France

The calanque of Morgiu, southern France, east of Marseille

The beach of the calanque Morgiu

The calanque of Morgiu, seen from the head of the drowned karst valley

With the deltas and the calanques we have come to regions where inland processes interfere with coastal processes. It is now time to look at the coastal geomorphic processes to get an idea of how they create sediments and landforms.

According to the CIA fact book, the total length of coastline in the world is 356,000 km. Turkey has a total coastline length of 7200 km.

However, these lengths are dependent on the evolution of geomorphic processes and the sea-level fluctuations and therefore are subject to constant change.

When we talk about coastal processes we mean the coasts of seas and lakes. To that end we need to know what a sea is, a lake, an ocean.

A sea is a large body of salt water bordering lands. This is the most general usage of the term.

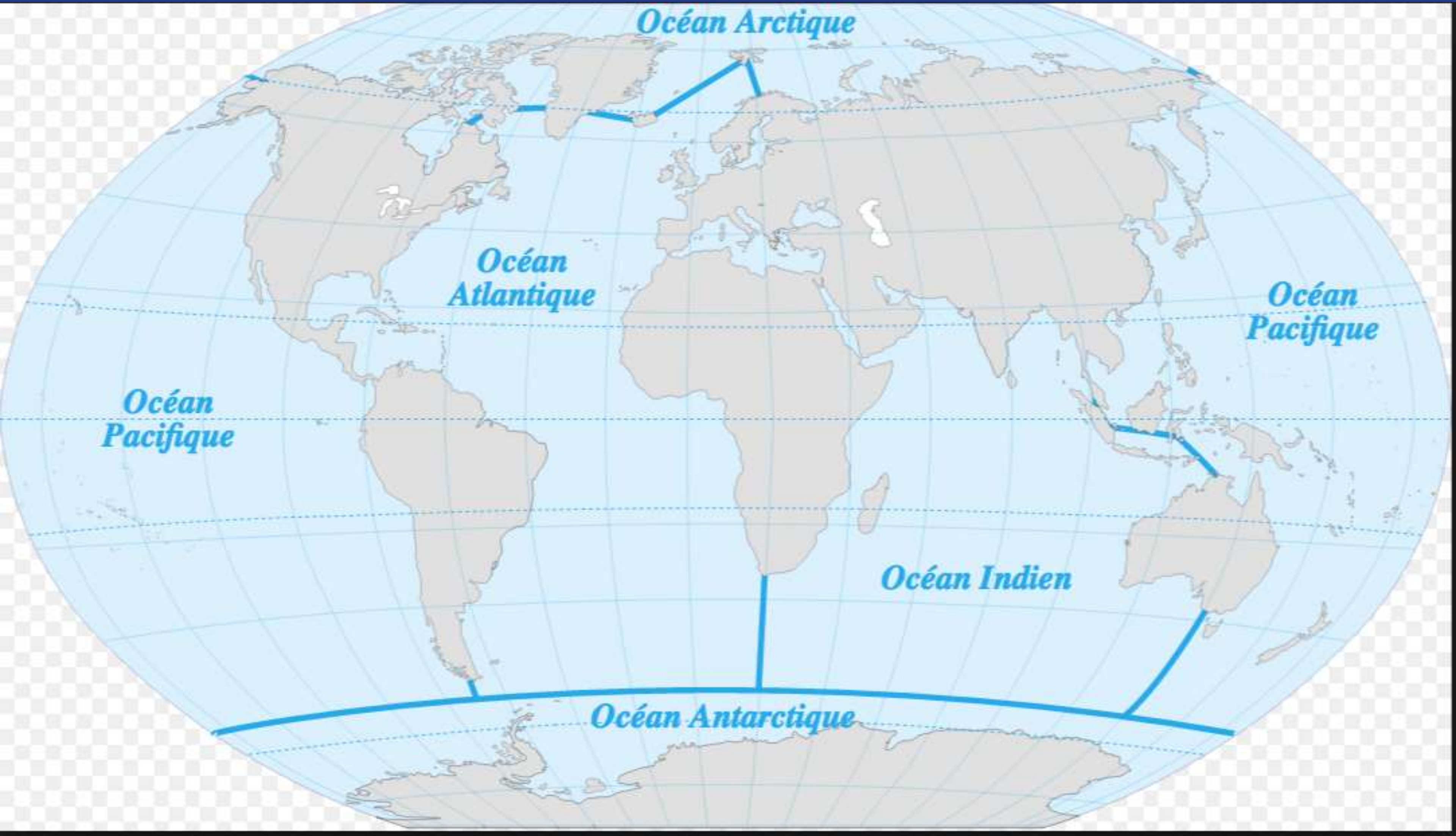
A lake is an inland standing body of water that is not entirely invaded by partially terrestrial and partially aquatic plants.

Ocean is the totality of the contiguous sea water on earth. However, that contiguous body has been subdivided by geographers for facility of description.

Depending on whose definition one takes, there are four or five oceans in the world:

Four-ocean scheme:	Five-ocean scheme:
Atlantic Ocean	Atlantic Ocean
Arctic Ocean	Arctic Ocean
Indian Ocean	Indian Ocean
Pacific Ocean	Pacific Ocean
	Southern Ocean (also called Antarctic Ocean)

World map showing the boundaries of the oceans in a five-ocean scheme

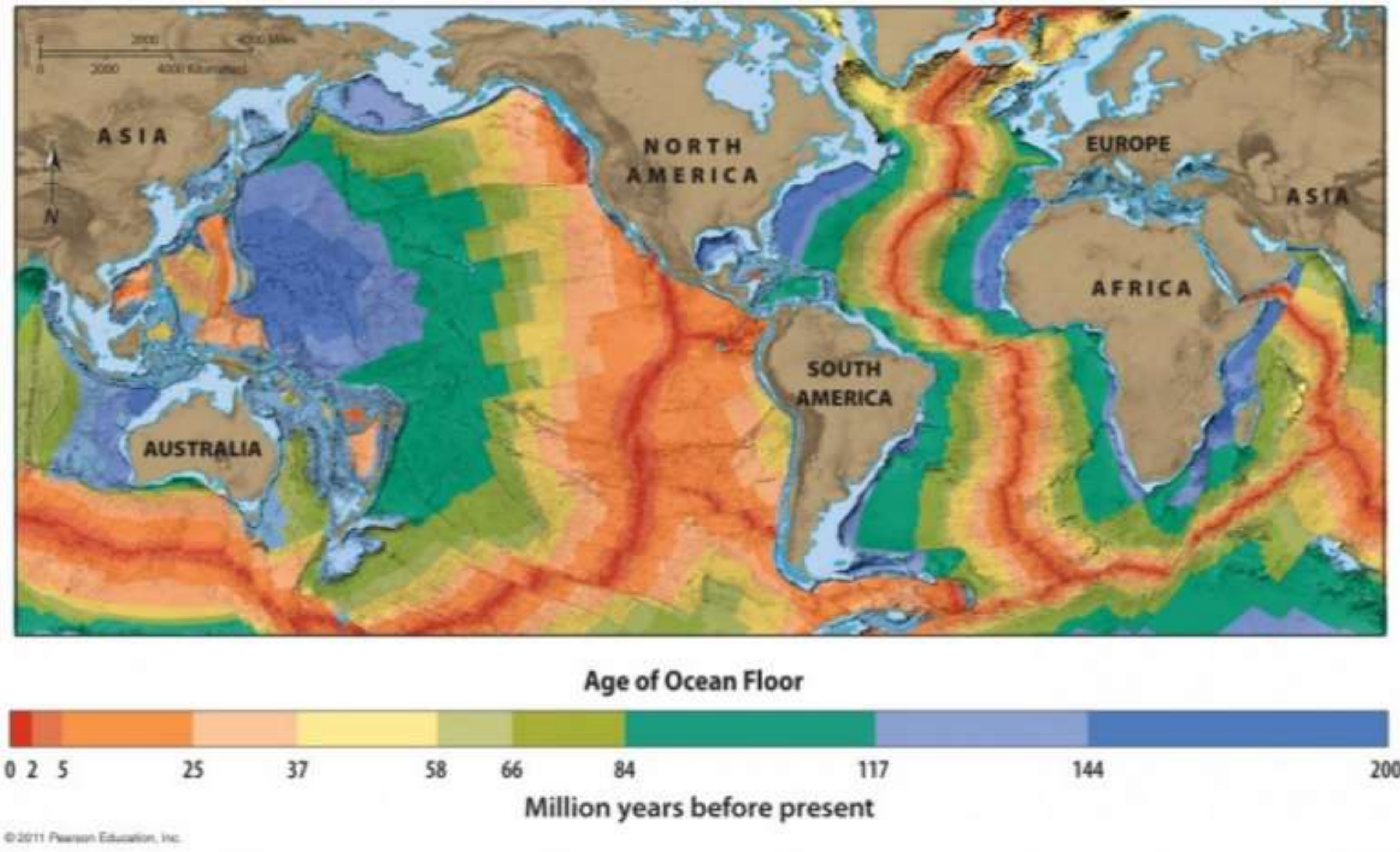


Another map showing the world’s oceans, on which the Southern Ocean is called the Antarctic Ocean

Subdivision of the oceans and the seas bordering them (the seas are parts of the oceans, except the almost land-locked Mediterranean Sea and the Red Sea).

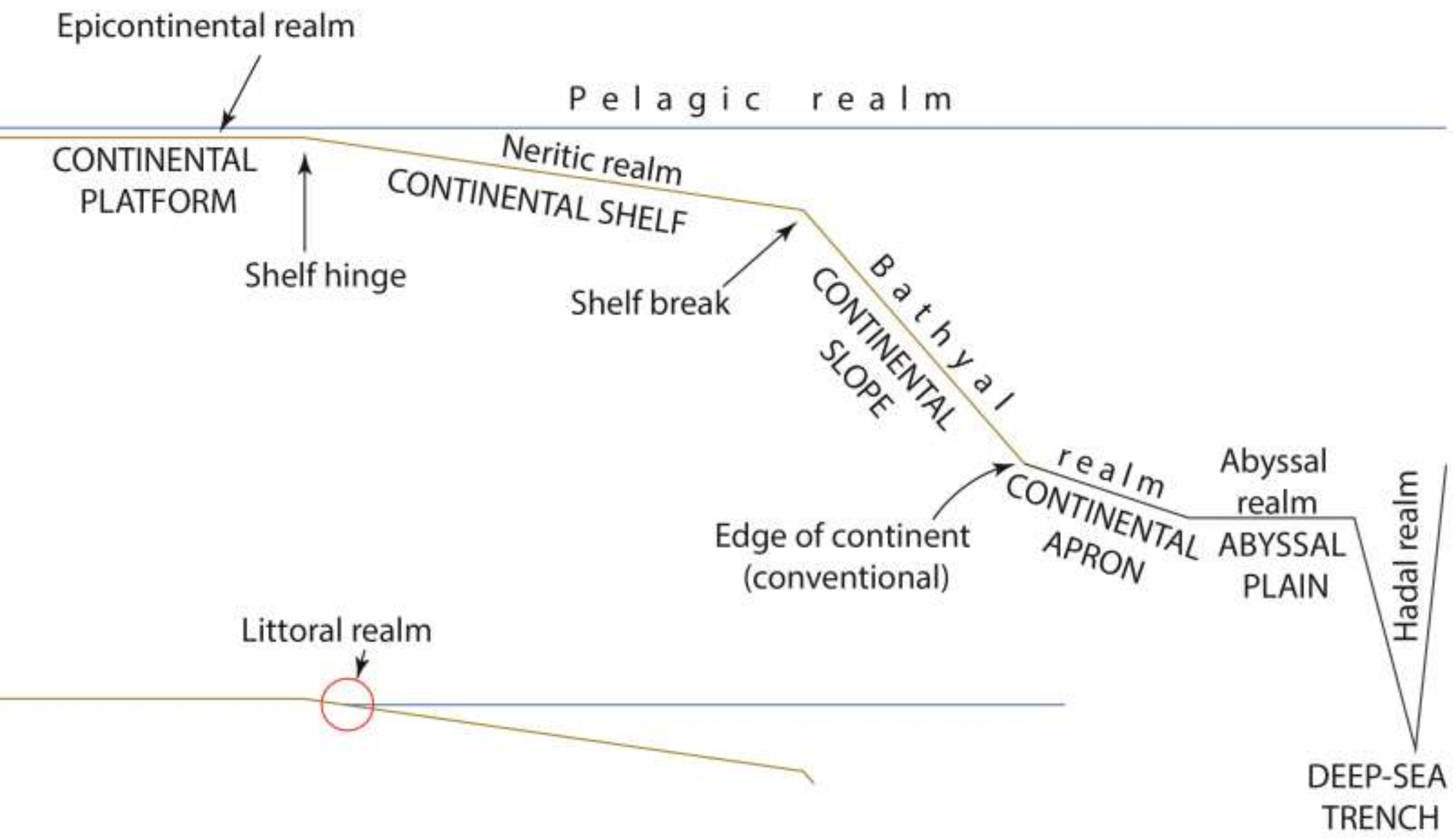
The definition of ocean I have just given is the geographical definition of it. Ocean also has a tectonic definition. According to that definition, an ocean is an area underlain by the oceanic lithosphere. Tectonic oceans are always much less extensive than geographic oceans (except in such insignificant places as the Afar Depression or Iceland) because the geographical oceans also extend onto the continents.

When they extend onto the continental shelves, they are known as shelf seas. When they extend farther than the shelf into the continent, they are known as epicontinental seas. The prefix epi- comes from the Greek ἐπί (*epi*=upon, on).

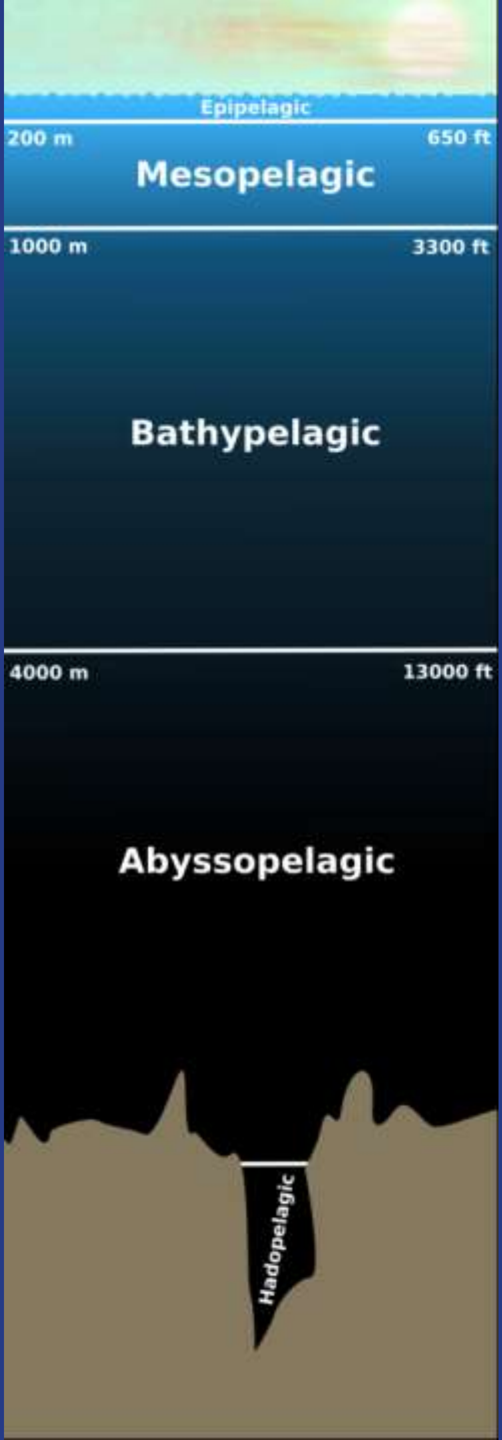


Tectonic oceans and tectonic continents.Age of ocean floor applies only to the oceanic lithosphere and therefore defines the limits of the tectonic ocean.

For the organisms living in the ocean the following terminology applies:
1. Benthos: Living attached to the sea-floor
2. Plancton: Freely floating
3. Necton: Actively Swimming



The oceanic realms



The terminology shown here for the opean oceanic realms has also been suggested, but it is not widely used.

Four sets of processes influence coastal geomorphology and sediment genesis. These are:

1. Land-based processes (weathering, creep, landslides, rock falls, mudflows, sheetwash, rilling, gullying, rivers, etc.)

2. Sea-based processes (waves, currents, sea-ice, etc.)

3. Atmospheric processes (wind, rain, snow, etc.)

4. Organisms (lithophagus animals, reef-building animals, etc.)

Wind waves on water surface

A wave is an oscillation, accompanied by a transfer of energy, that travels thorugh a medium.

Wind waves or waves generated by the wind are those that agitate the surface of water bodies (from oceans to small puddles). The can be a few mm in height or may reach heights of 30 m or so. Wave height in oceans and lakes is a function of

1 the wind velocity,
2 uninterrupted distance of open water over which the wind blows without a significant change in direction,
3 width of area affected by fetch,
4 water depth.

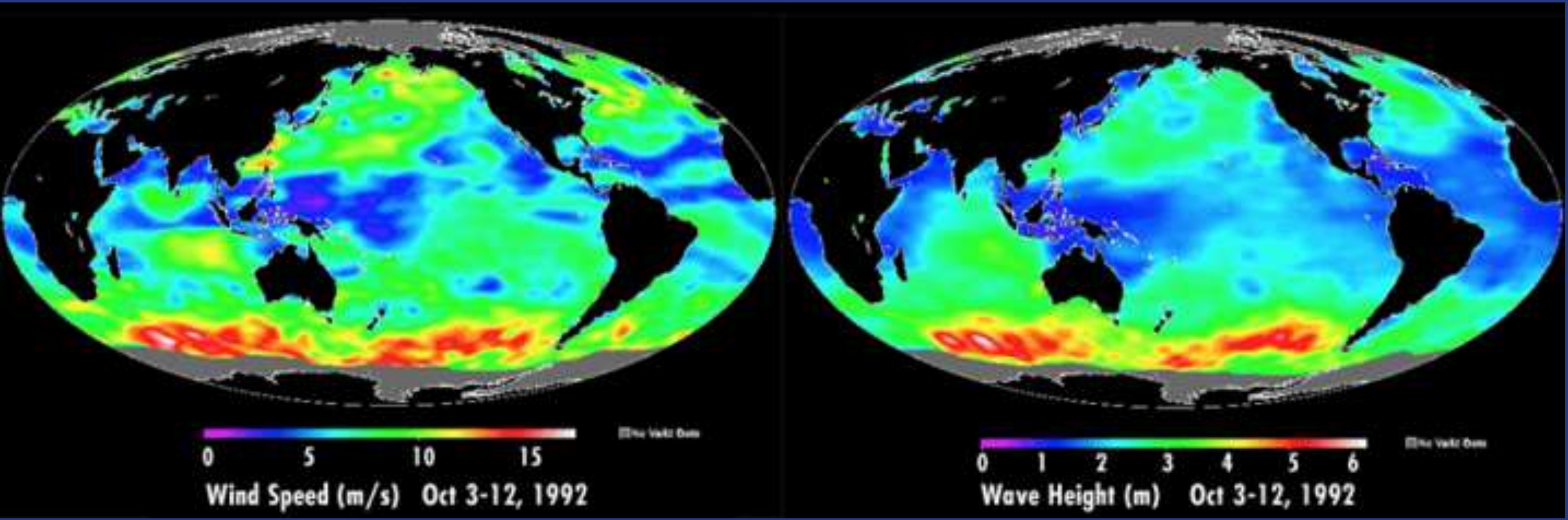
Two main mechanisms generate waves on open water surfaces:

1. Wind fluctuations

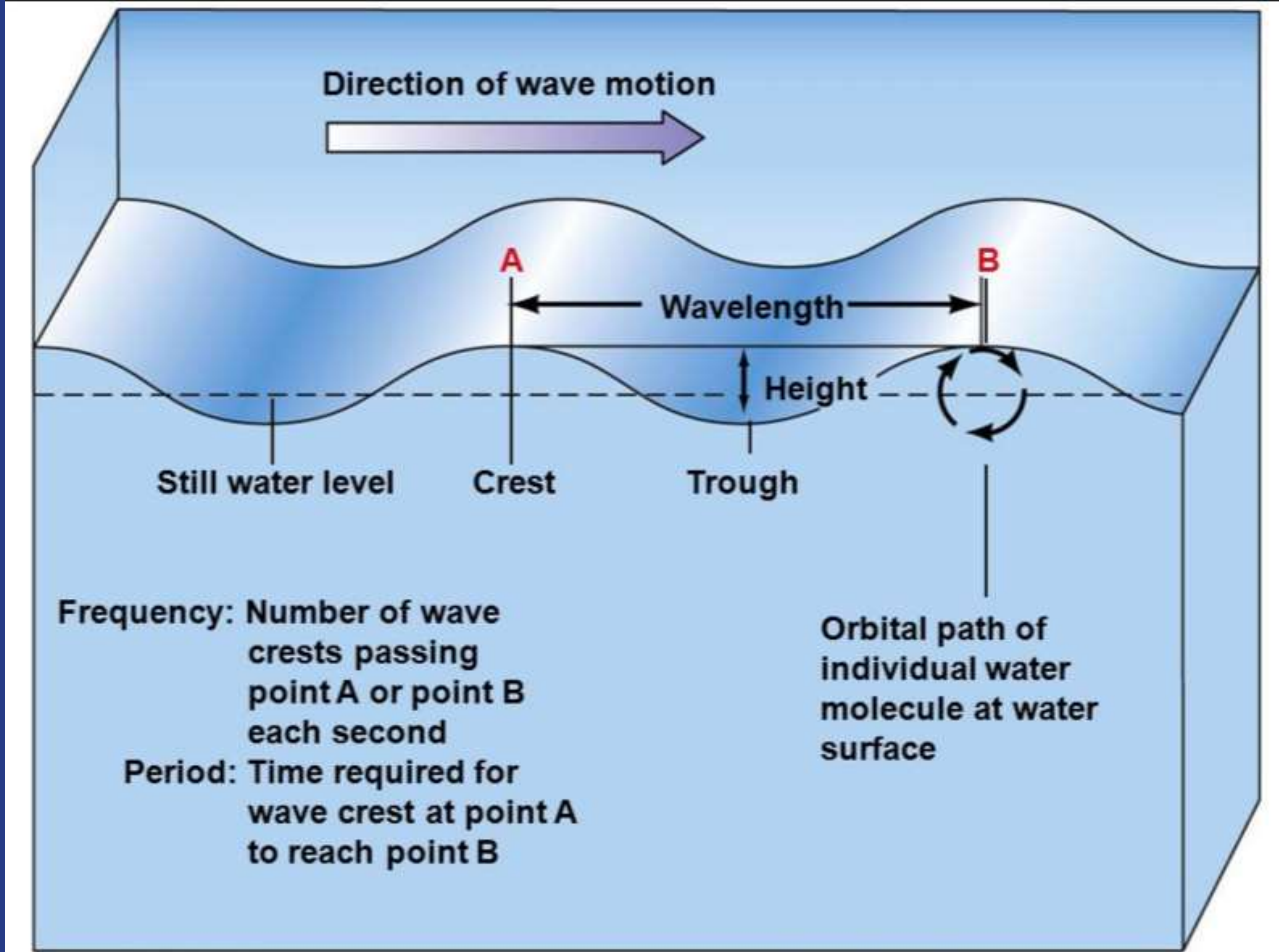
2. Wind shear forces

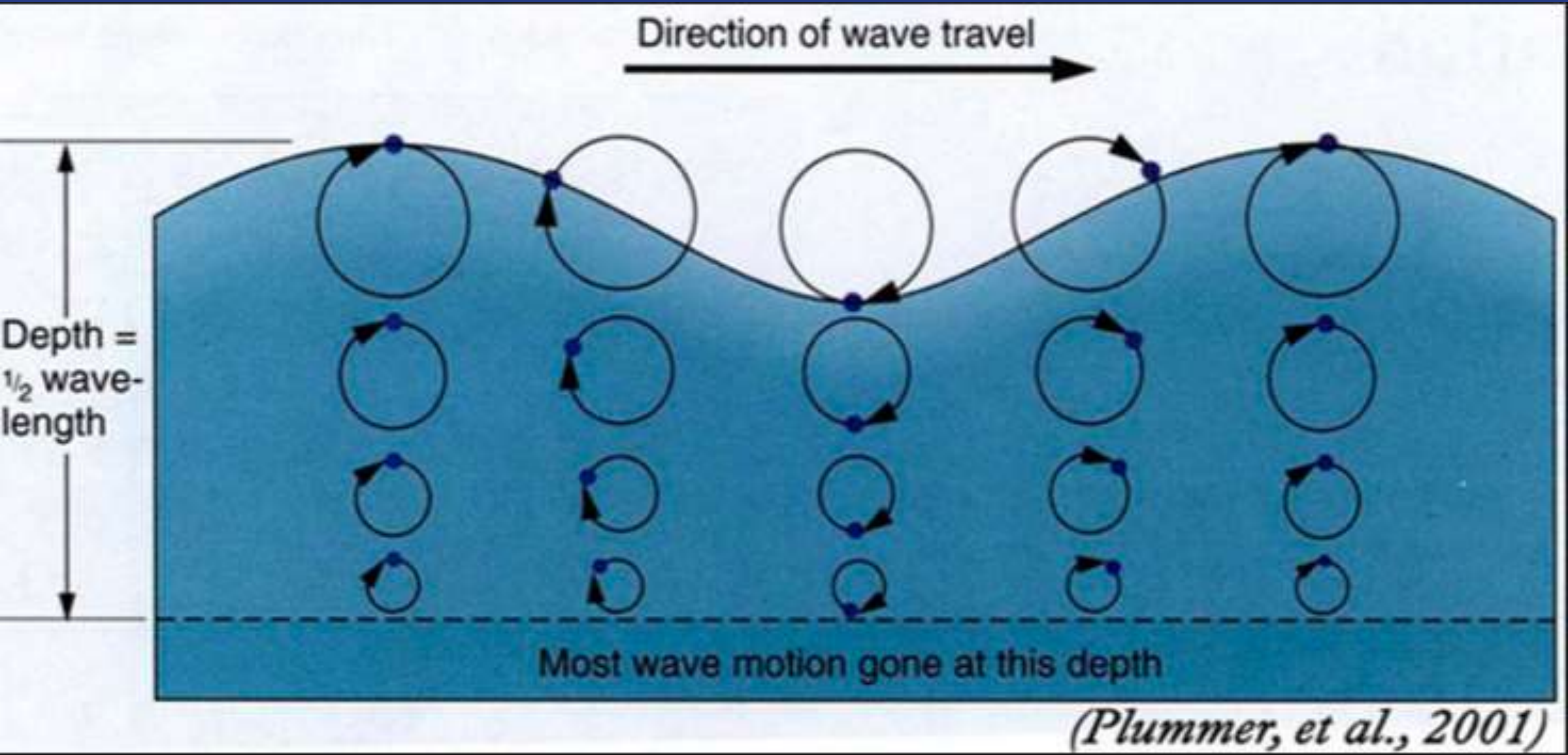
3. Both of these mechanisms are dependent or turbulent flow and unequal pressure appliction on the water surface.

Almost always, both mechanisms work together.

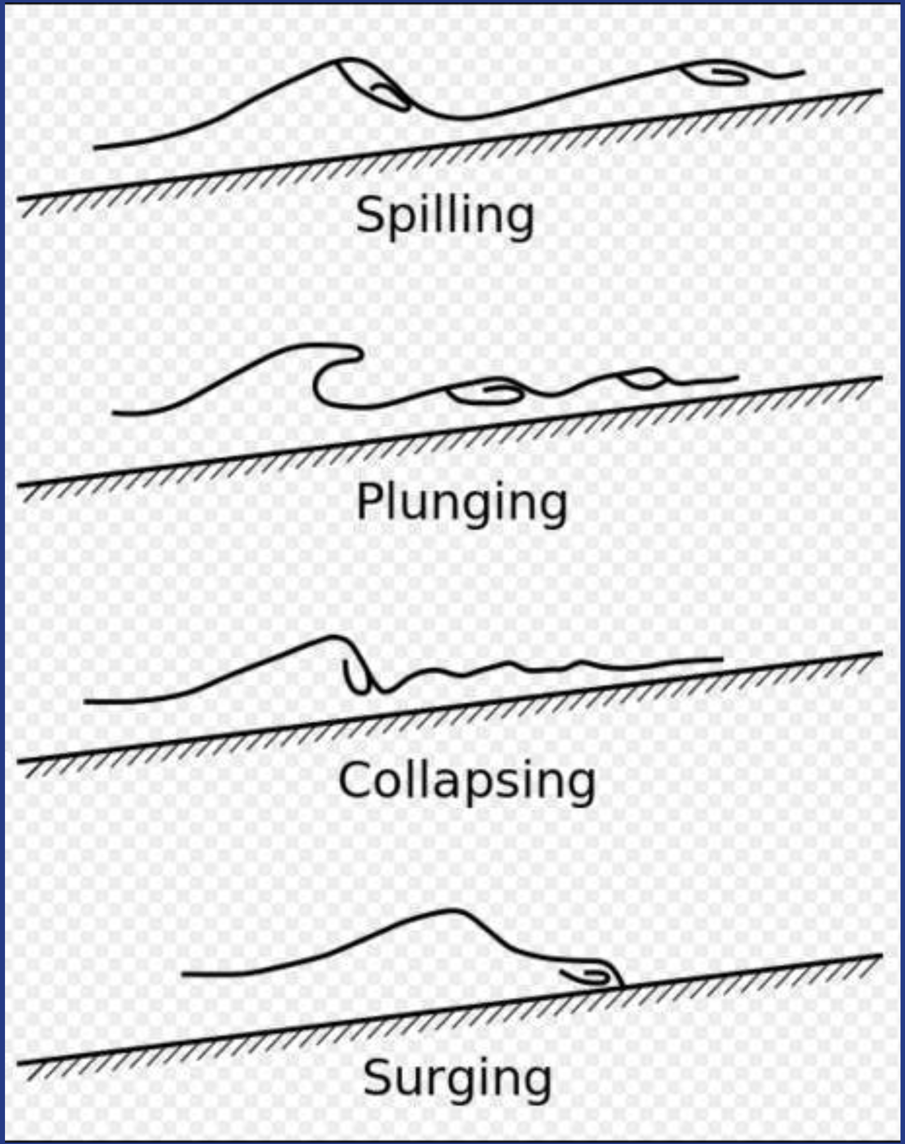


Relationship between wind speed and wave height in the world ocean

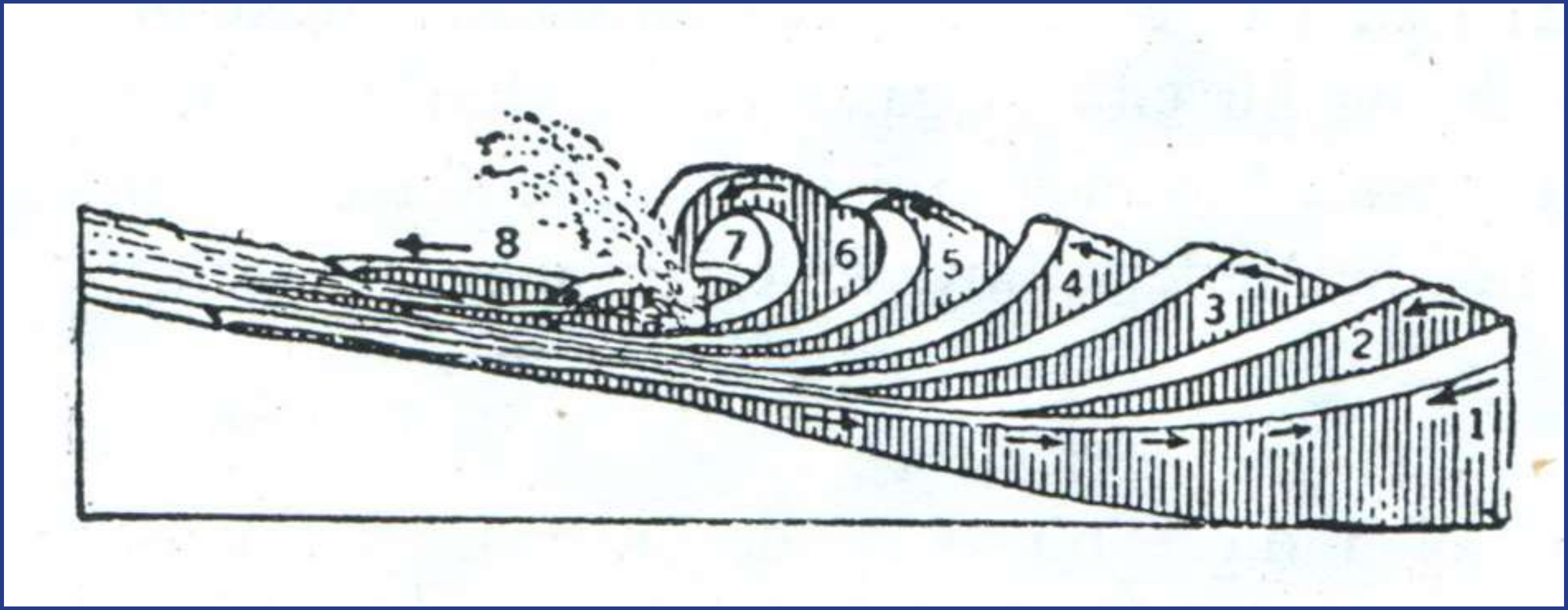

Direction of wave motion
A
B
Wavelength
Height
Still water level
Crest
Trough
Frequency: Number of wave crests passing point A or point B each second
Period: Time required for wave crest at point A to reach point B
Orbital path of individual water molecule at water surface



Basics of wave motion. Waves do not transport particles, but they do transport energy.



When waves break, they do transport material forward and backward. Waves break for two reasons: 1. Wind shear of the crests, 2. Friction of the wave base with the sea-floor



A breaking wave (from Davis). Notice that the breaking wave carries material forward by means of the motion indicated by 1-8 and also backward by means of the arrows showing a reverse current below the advancing wave. Thus a breaking wave can help sculpt the topography of a shore. The closer the breakage zone to a shore, the greater its effect on the morphogenesis.

A wave just before it begins to break: Çeşme, İzmir, Turkey

A wave beginning to break: Çeşme, İzmir, Turkey

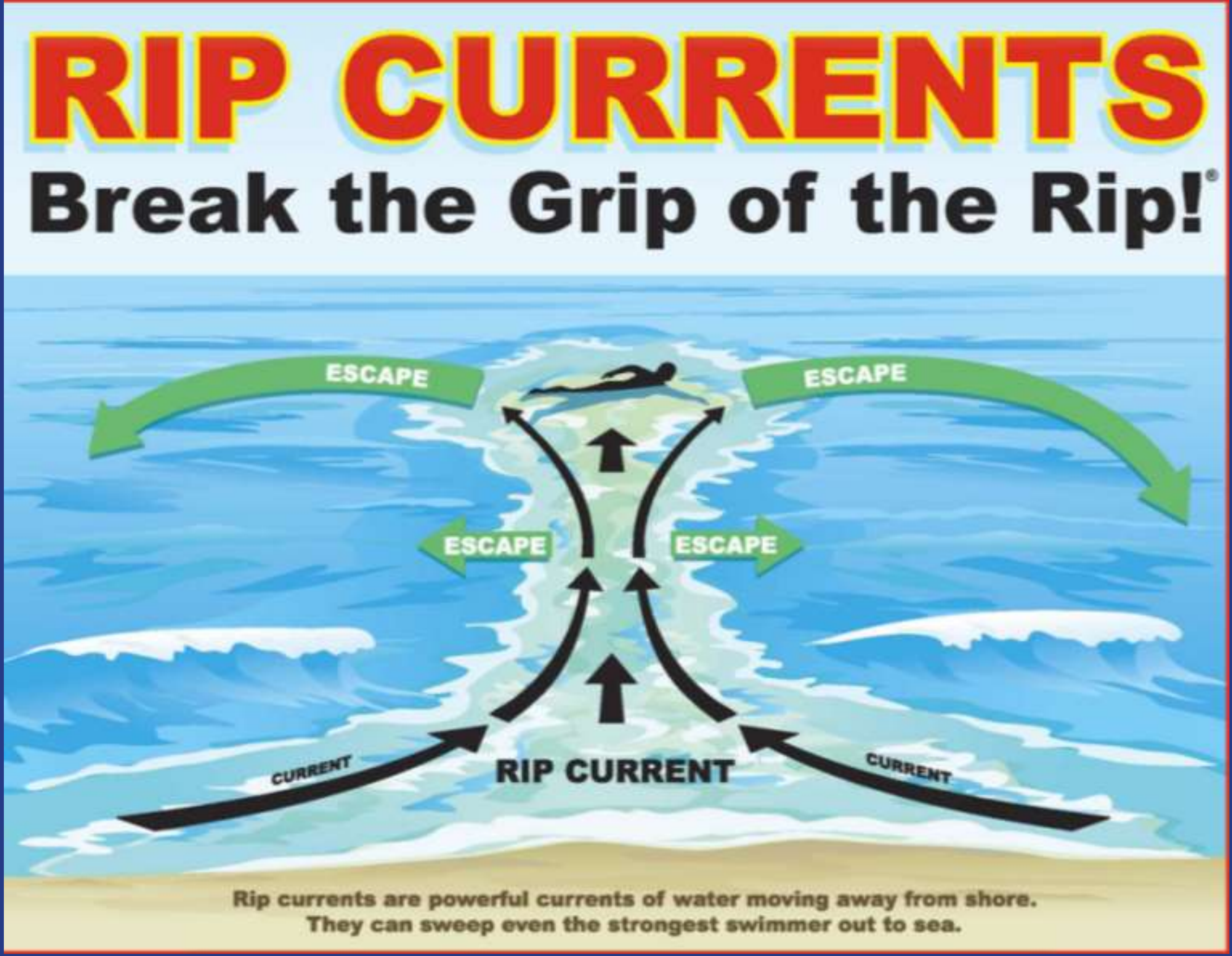
A breaking wave in Çeşme, İzmir, Turkey

Crest of a breaking wave in Çeşme, İzmir, Turkey

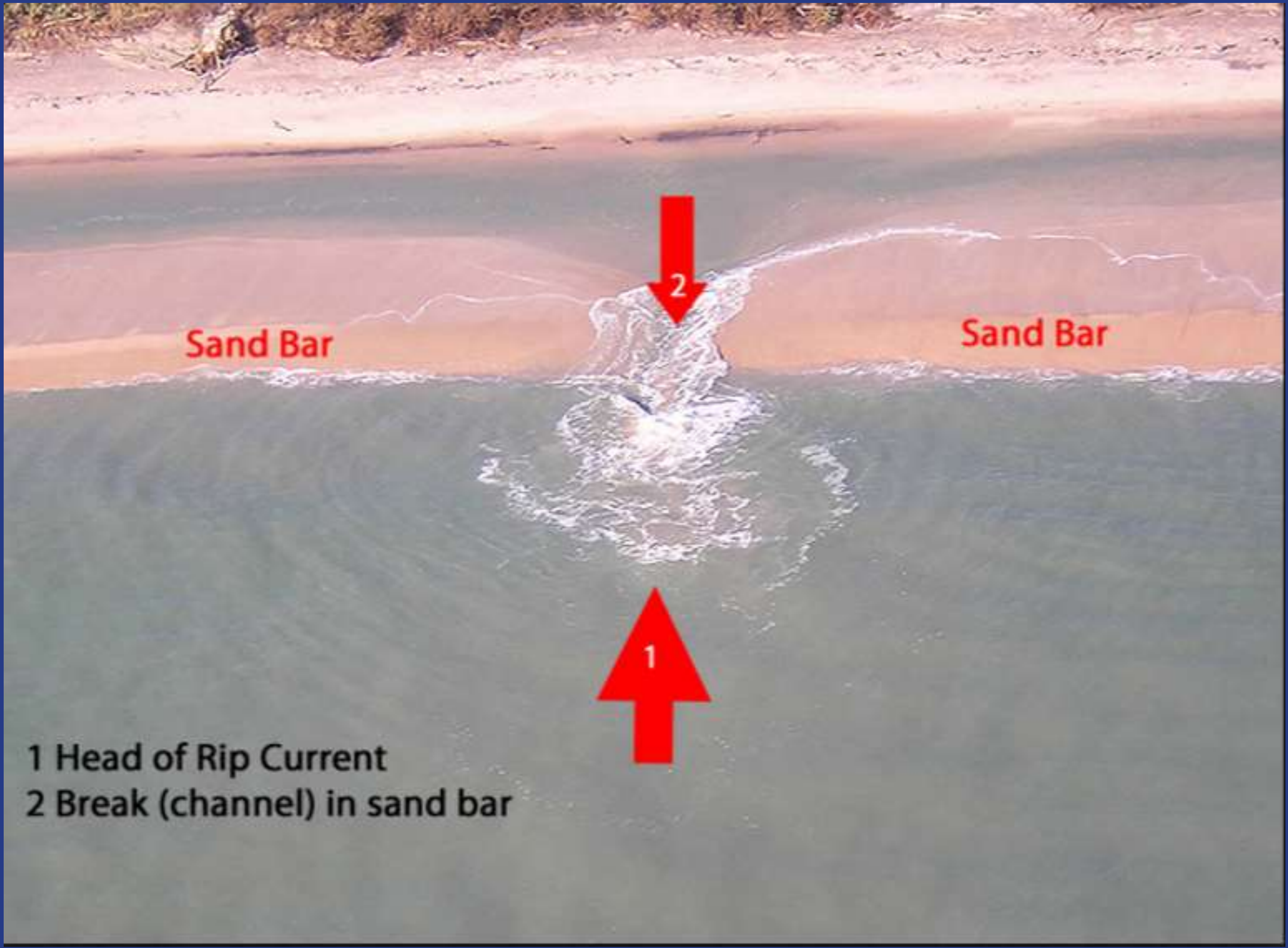
A wave breaking on the beach. Notice how much material is carries: Çeşme, İzmir, Turkey

Notice the amount of sediment agitated by the breaking wave on the beach

Erosion and transportation along beaches really happen mainly because of two types of currents. Rip currents and longshore currents.



Rip currents occur when more water is carried to the beach by the wind than can be take away by uniform return currents below the waves. The extra water gets channelised and returns to the sea by means of strong currents. Rip currents are particularly effective in sweeping fine-grained material out to the sea. They occur in water depths of at most 5 to 10 m.



A rip current breaking a hole in an offshore sand bar

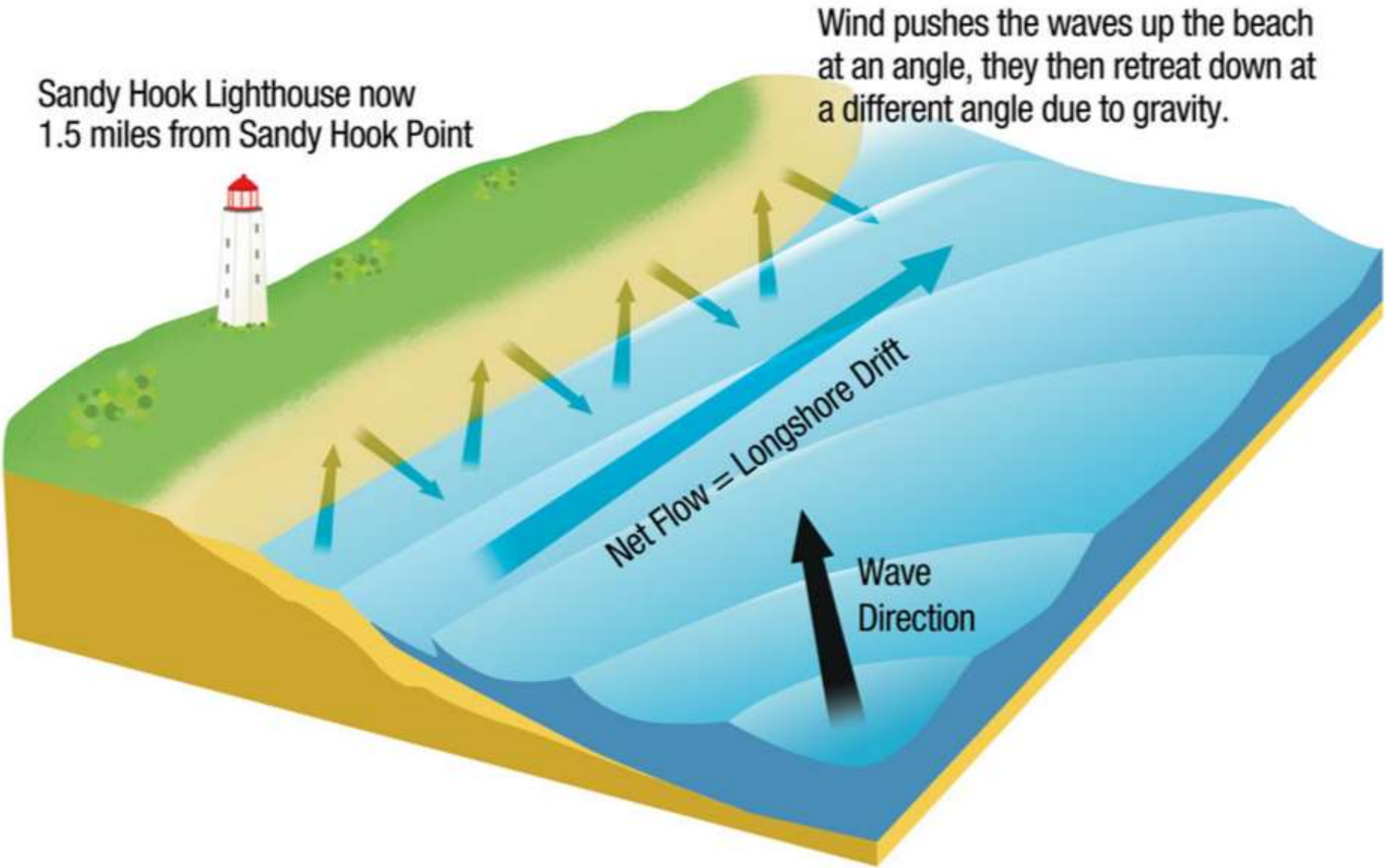
Longshore Currents

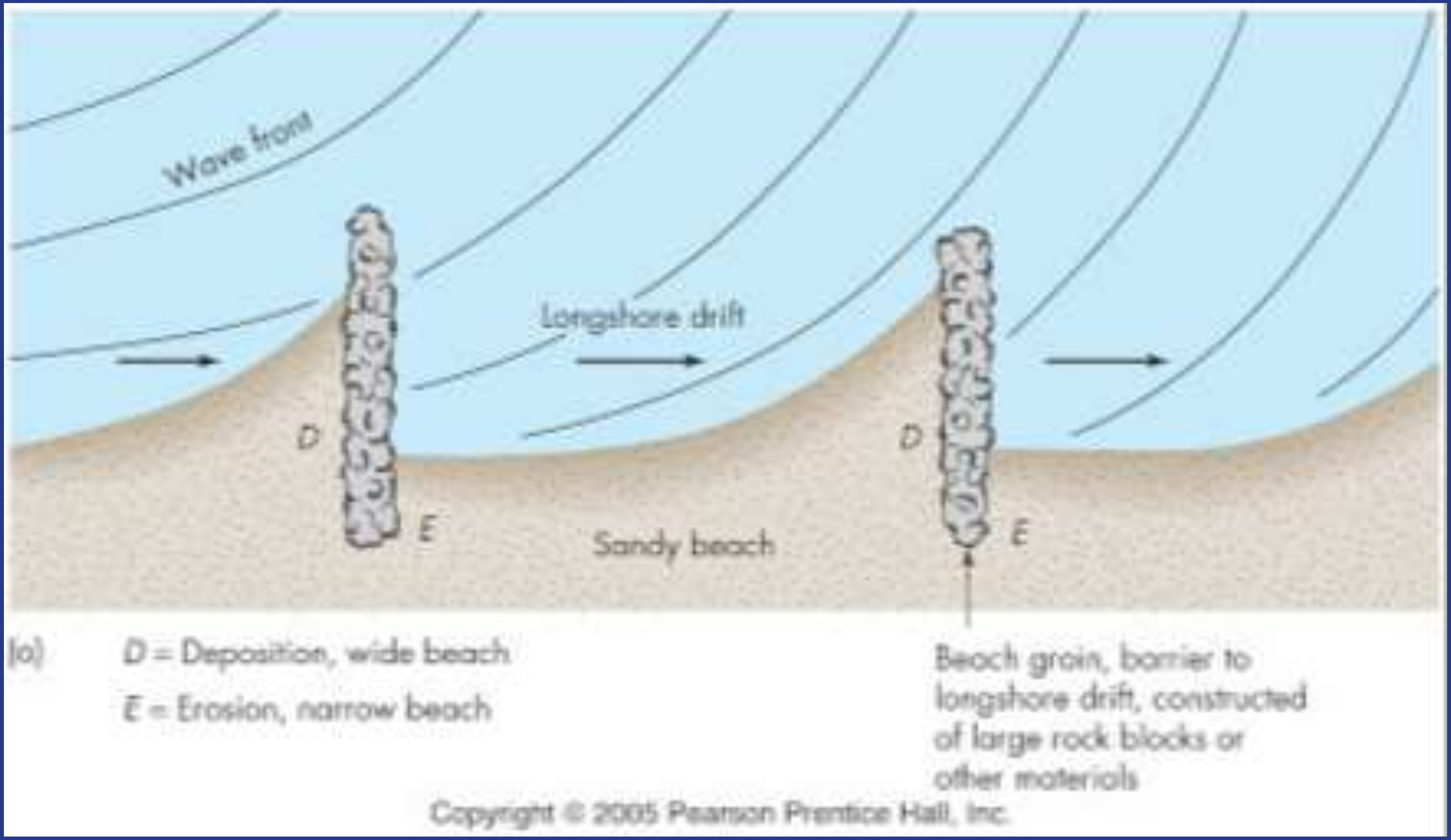
Longshore currents are responsible for most sediment transport in beach environments.

This movement of sand and other sediment both tears down and builds up the coastline.

Unfortunately, longshore currents also carry trash and other types of ocean pollution, spreading it along the shore.

Figure 14 *Longshore currents form where waves approach beaches at an angle.*

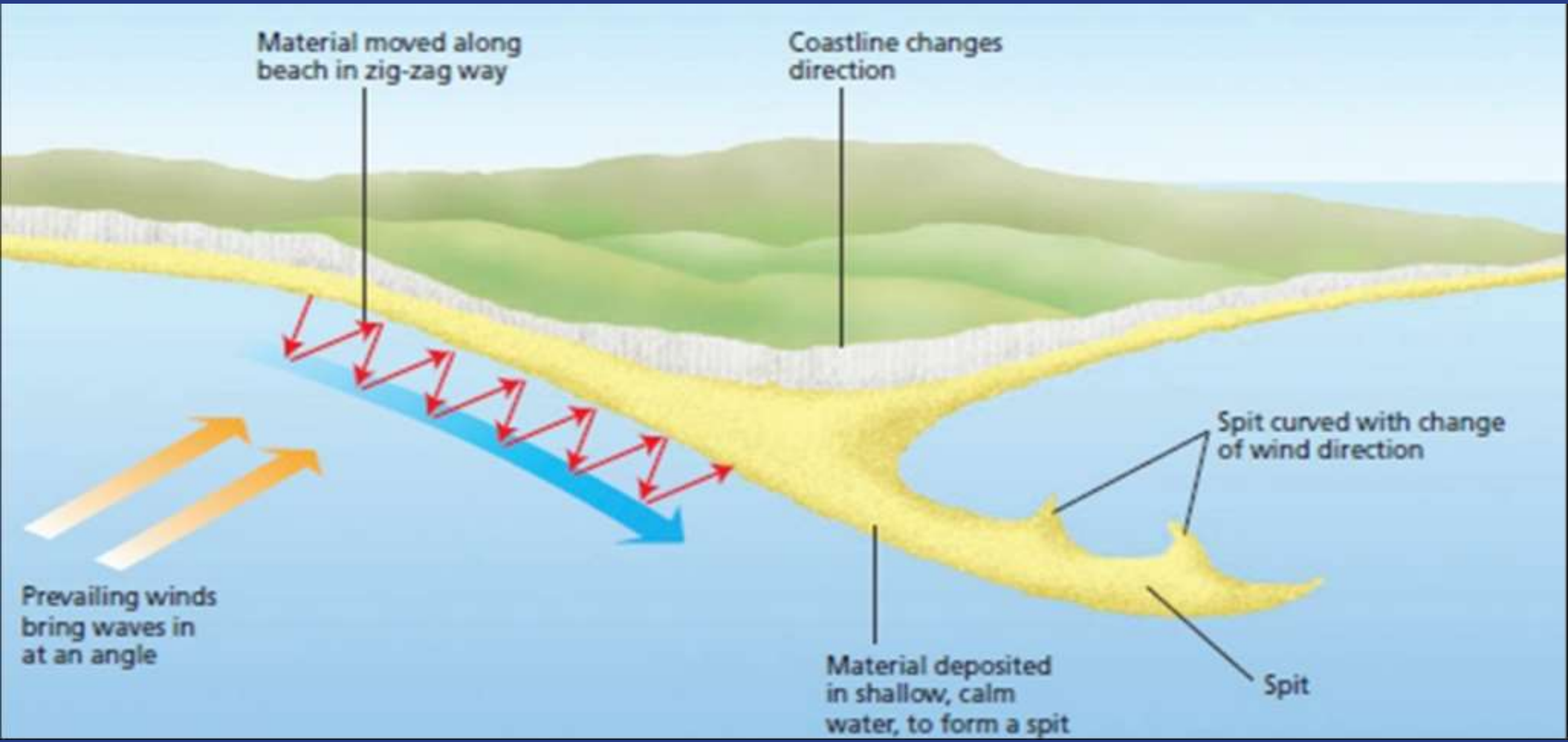

Wind pushes the waves up the beach at an angle, they then retreat down at a different angle due to gravity.
Sandy Hook Lighthouse now 1.5 miles from Sandy Hook Point
Net Flow = Longshore Drift
Wave Direction



Protecting beaches from erosion

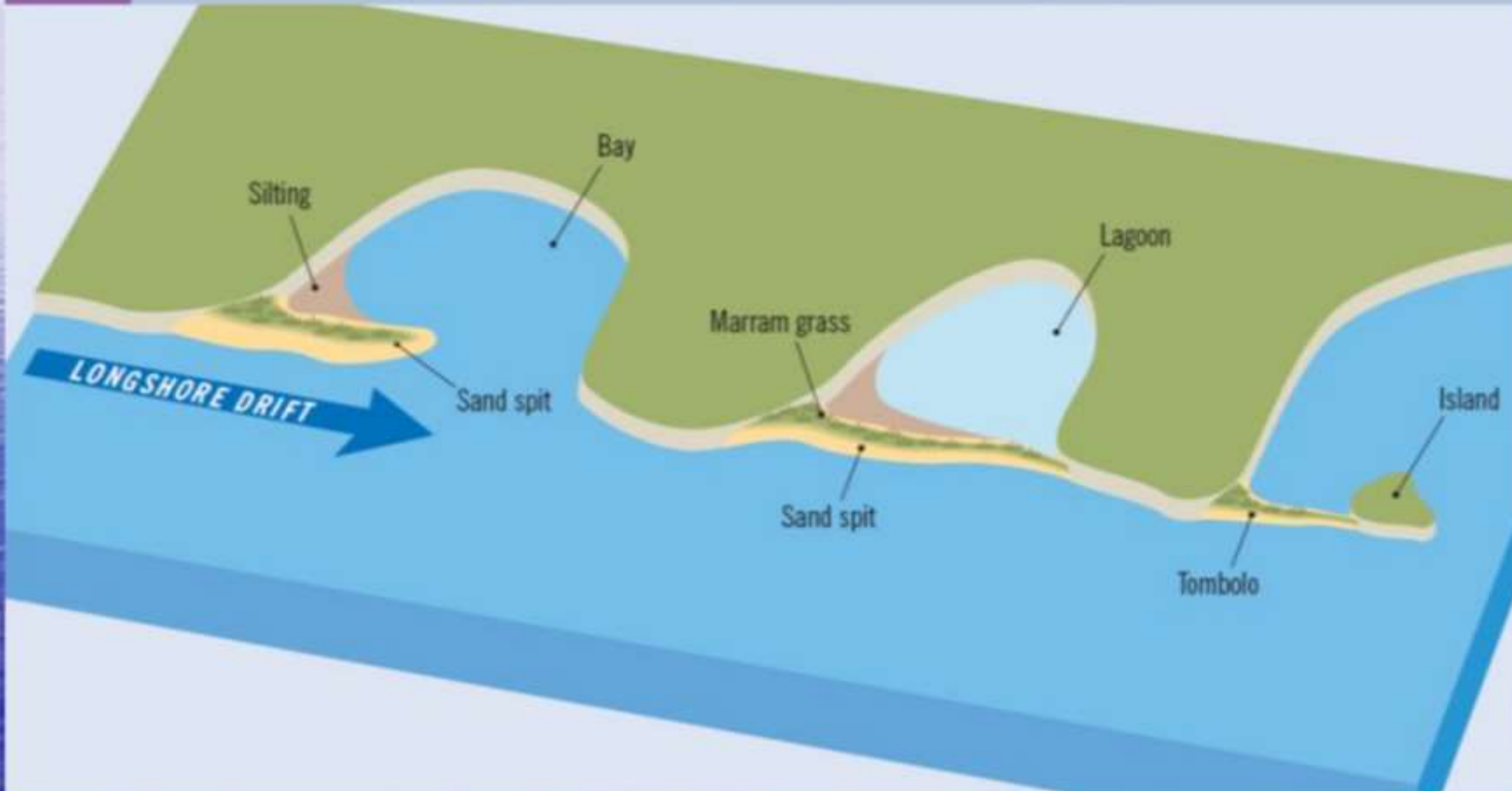
- Can you tell which way the longshore current is moving material?
- Once you put up one groyne, you need to keep building them all along the shore to keep erosion from destroying property downshore from your first structure. Note the severe erosion at the top of the photo where the groynes stop.

Landforms created by the longshore current



Spits, Bars, Tombolo, Lagoon

Fig 2.33 If a sand spit grows, it may block off a bay from the sea, forming a lagoon.



The Küçük Çekmece Lagoon, cut off from the sea by a spit

The spit canal connecting the lagoon with the sea,
Küçükçekmece Lagoon, İstanbul, Turkey

The Büyükçekmece Lagoon cut off from the sea by a spit.

The Lagoon of Ölü Deniz, Fethiye, Turkey

The Lagoon of Kara Bogaz east of the Caspian Sea

When a spit or a bar connects an island with the mainland, a tombolo comes into being. A tombolo, is a depositional coastal landform connecting an island to the mainland by a a spit or a bar. Once attached, the island is then known as a tied island. Several islands tied together by bars rising above the water level are called a tombolo cluster. Two or more tombolos may form an enclosure forming a lagoon. A tombolo may be considered to be a type of isthmus. The term derives from the Italian *tombolo*, which in turn is derived from the Latin *tumulus*, meaning 'mound', and sometimes translated into English as *ayre*.

The tombolo of Kapıdağ, the Sea of Marmara, Turkey

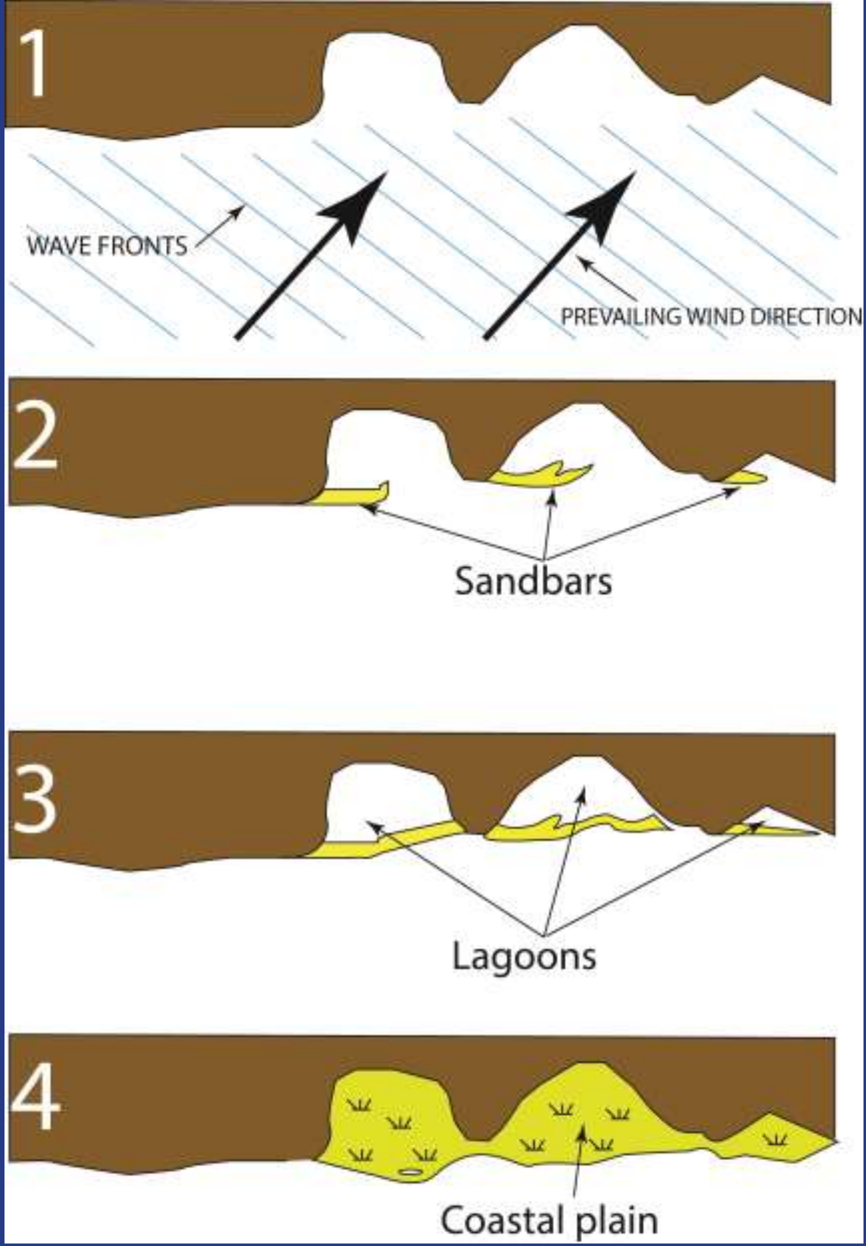
The bar connecting the Kapıdağ to the mainland

St Ninians tombolo, Shetland Islands, Scotland, UK

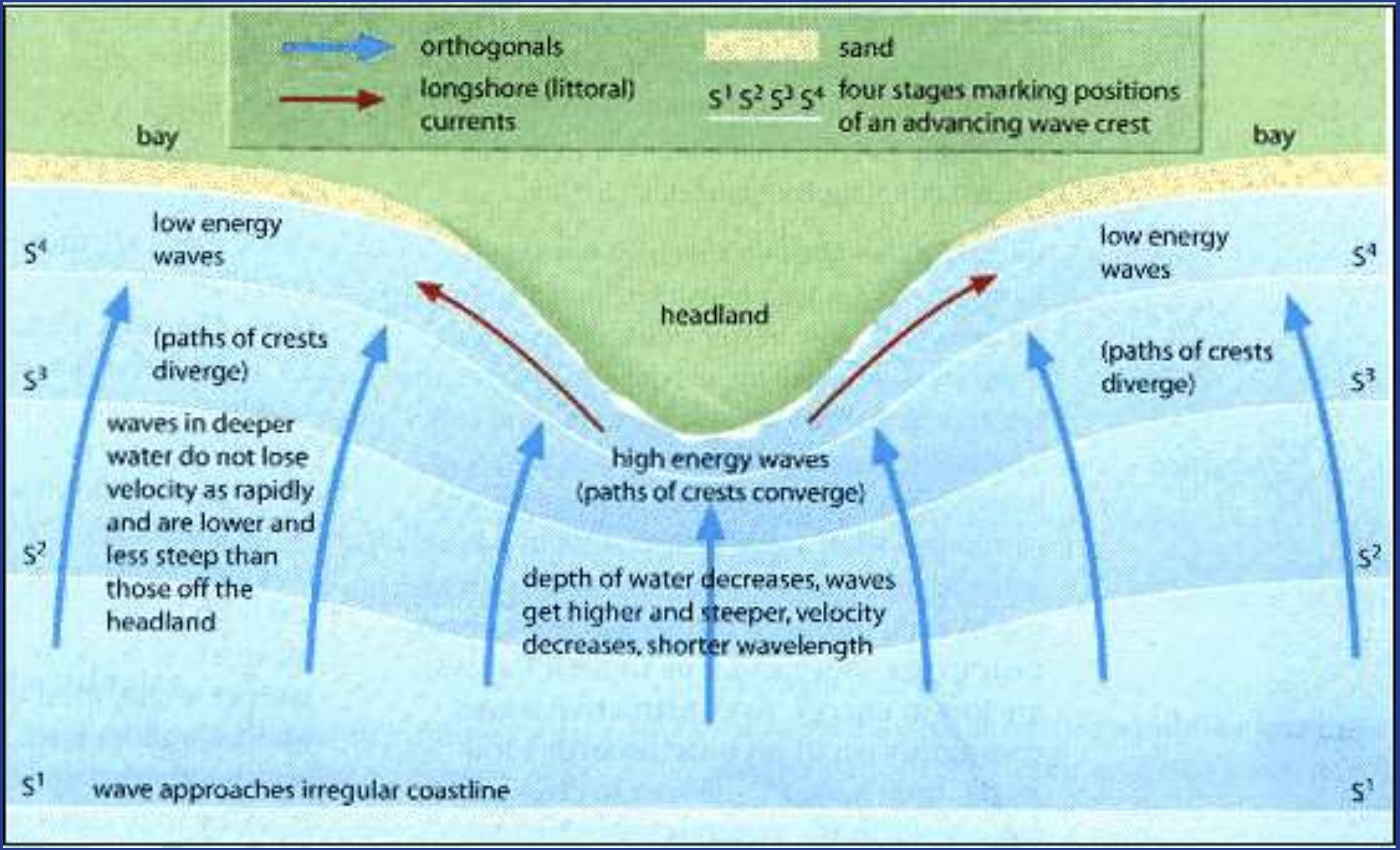
The Koh Nan Yuang in the Gulf of Thailand is a group of three islands connected by tombolos and thus constitutes a tombolo cluster.

An offshore bar is a long narrow ridge of deposited clasticmaterials; sand and shingle can be found lying away from and parallel to a coast. They can be enlarged to form barrier islands.

The Hordle Cliff sand bar, Hampshire, England



Longshore current tends to straighten a previously sinuous coastline by sediment transport and deposition



Waves, even when they hit a sinuous coast head-on, work to straighten it out by eroding the headlands and filling in the embayments as shown here

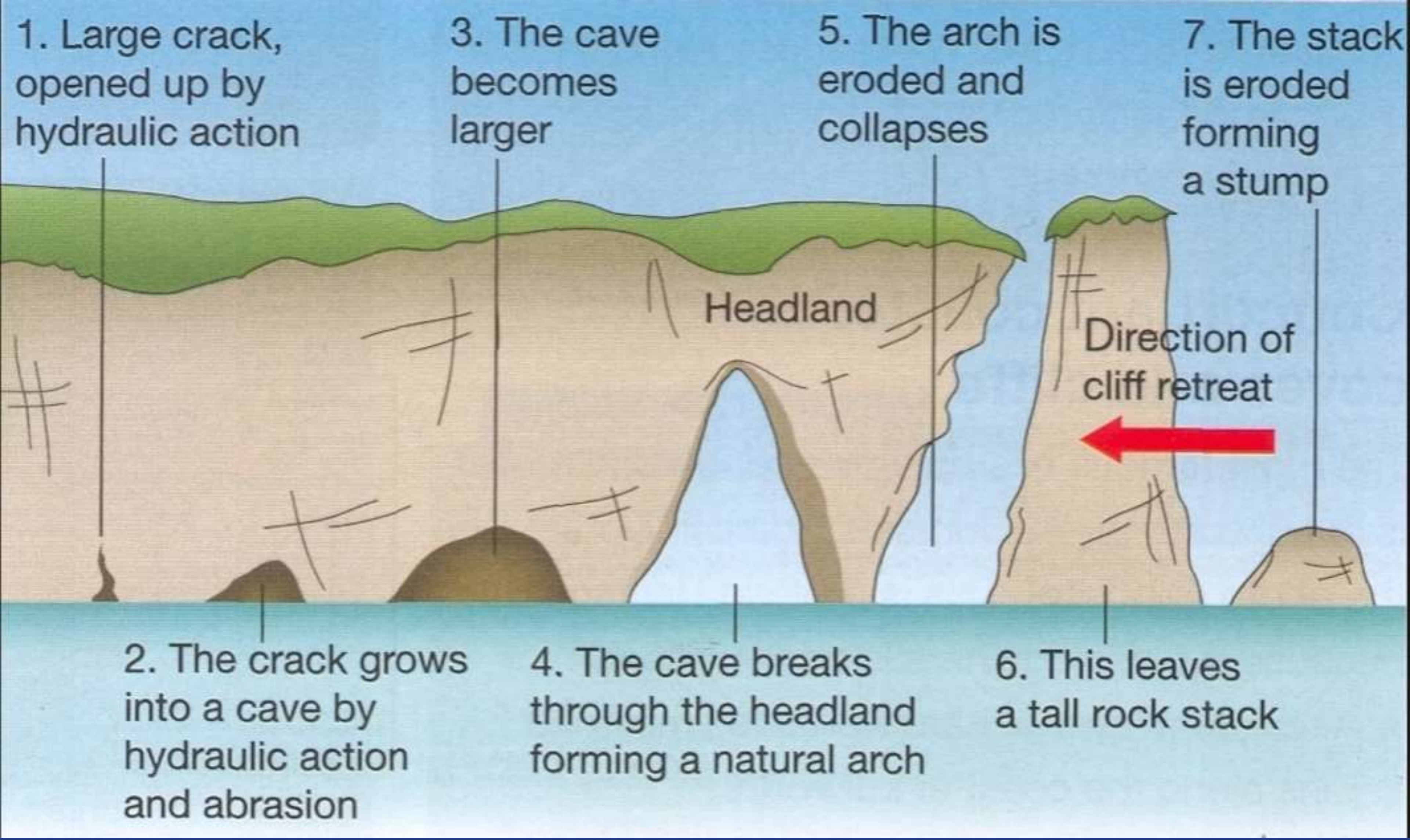
A small “tunnel” opened by wave action at a headland, Mendocino, California, USA

Headland erosion, Oregon coast, USA

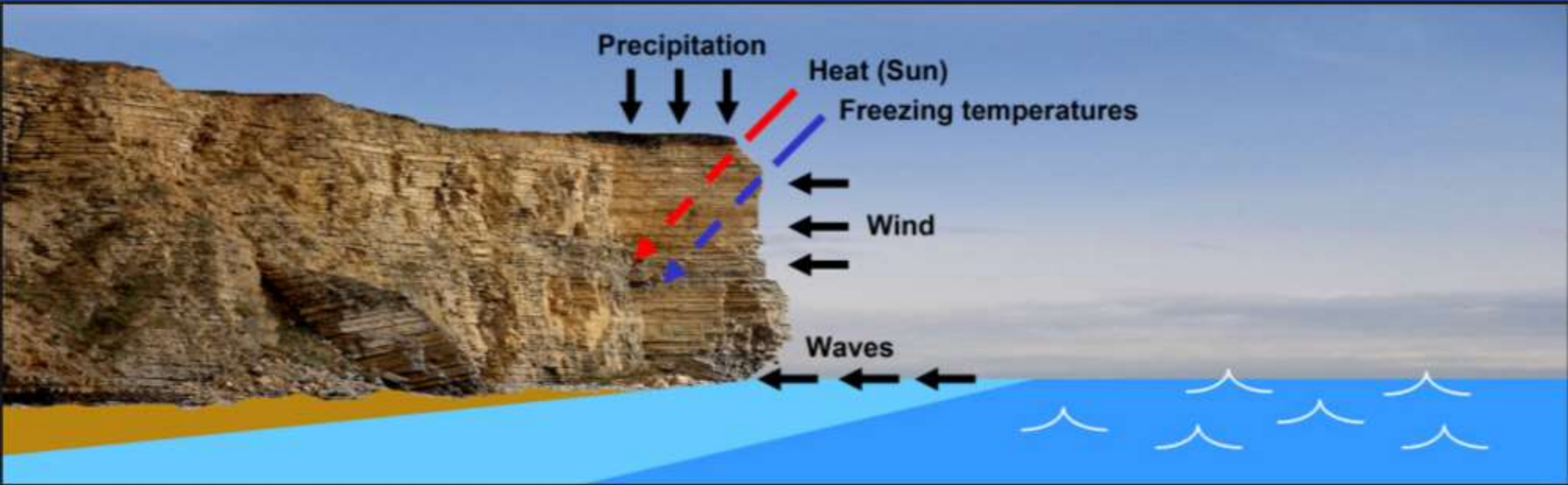
A coastal arch formed by wave erosion at a headland

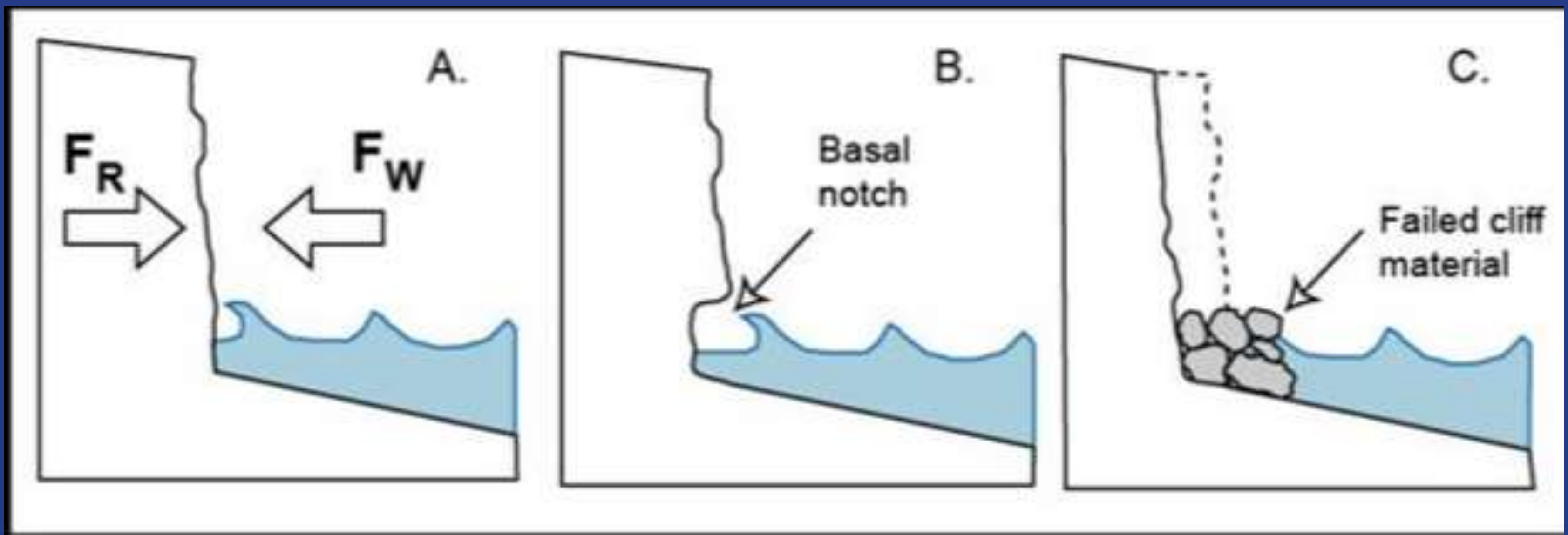
Stacks formed by collapsing of coastal arches in Dorset, England

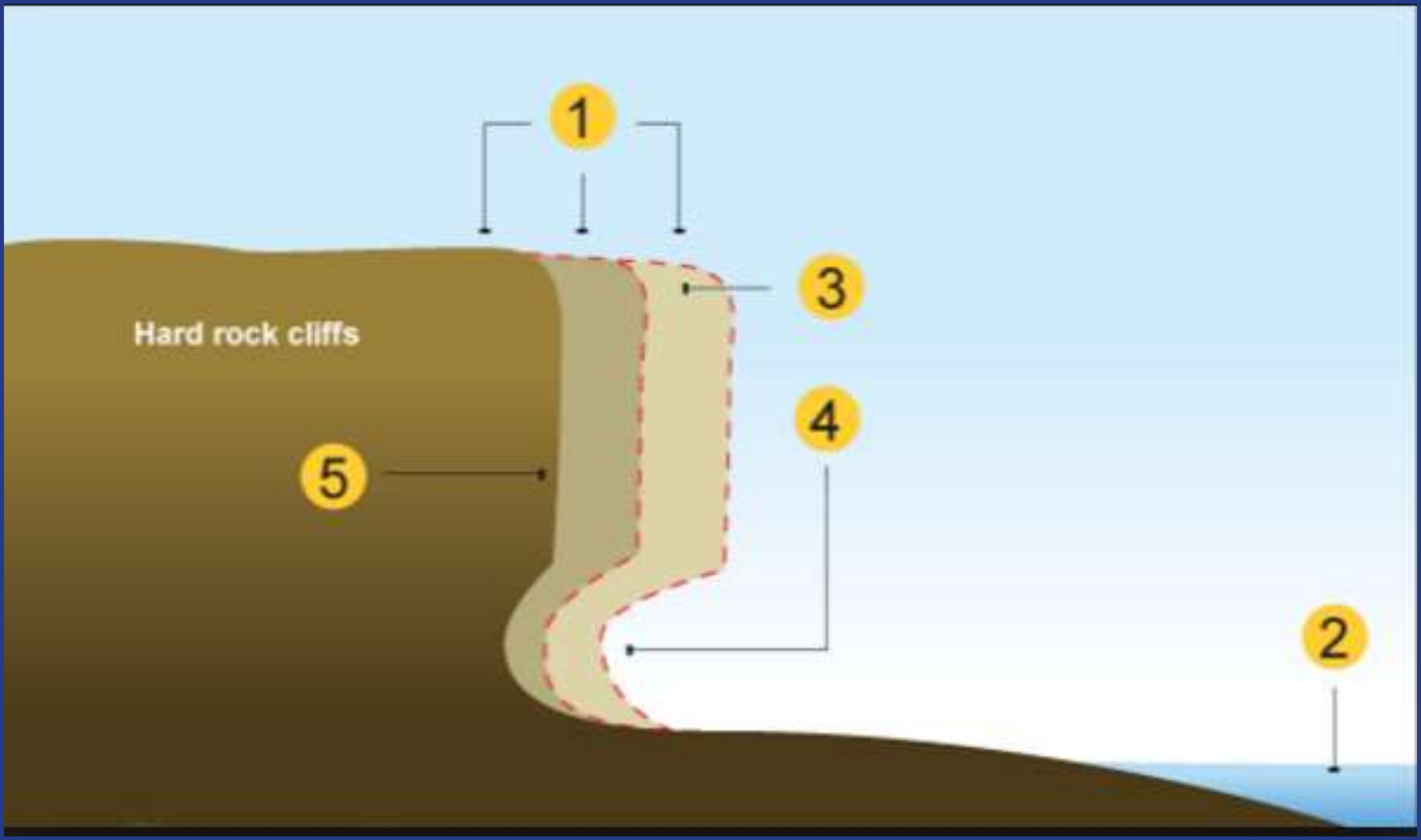
Sea stumps formed by the destruction of a headland, England



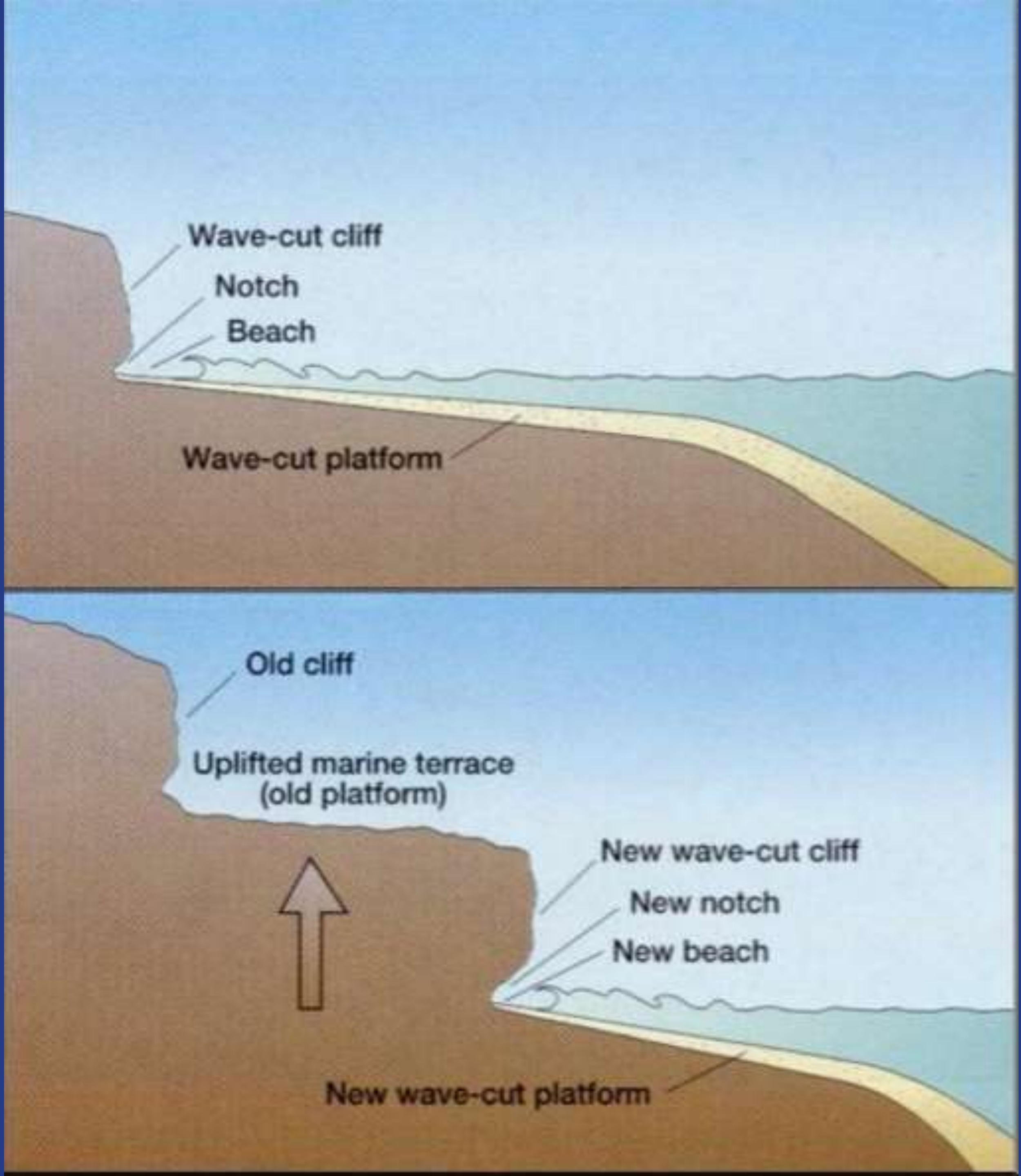
The formation of the coastal features we have seen so far. All of these have been formed by wave action alone, although, locally, fluvial and wind erosion might help.


Precipitation
Heat (Sun)
Freezing temperatures
Wind
Waves

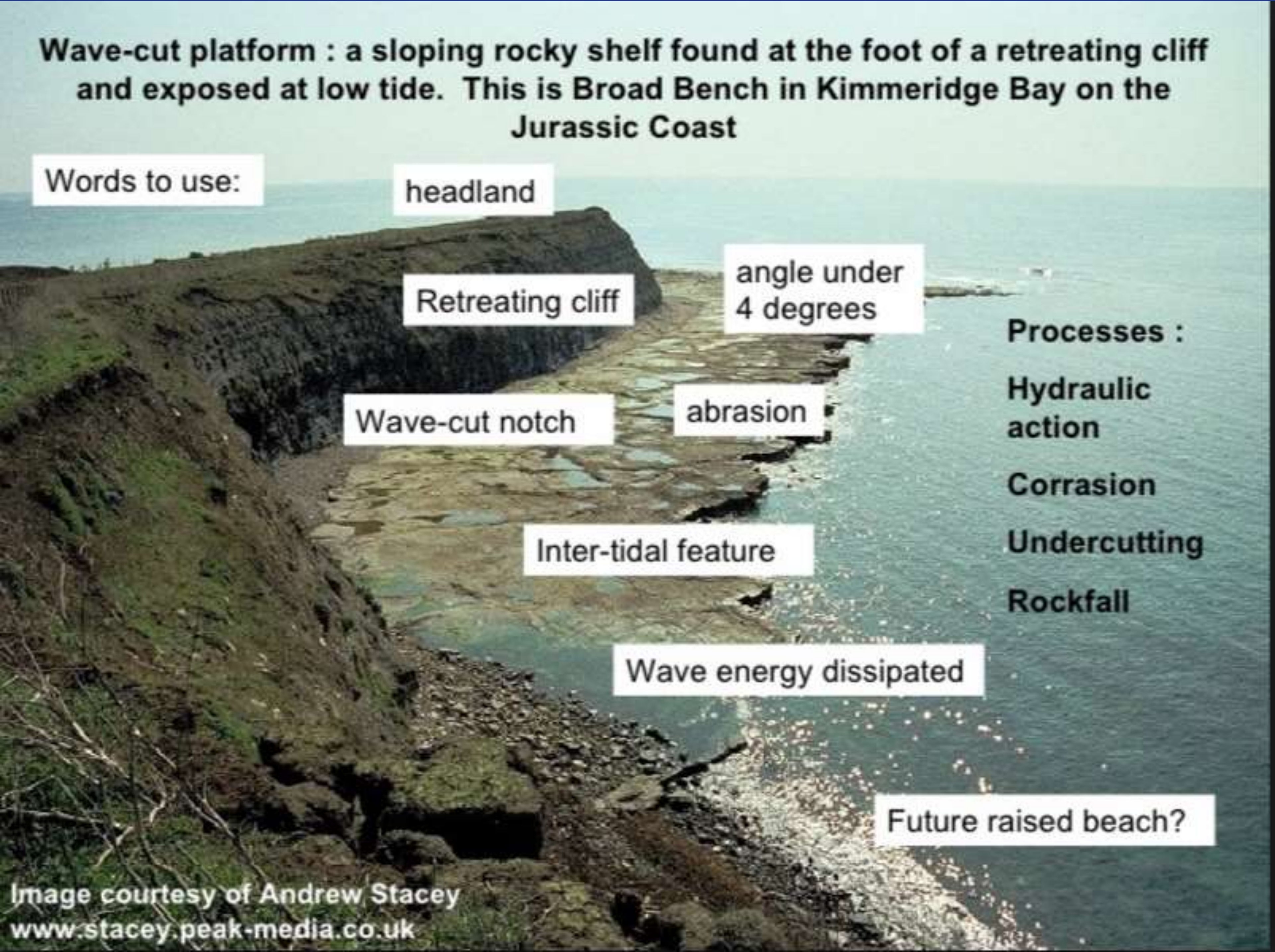

A.
F_R
F_W
B.
Basal notch
C.
Failed cliff material



Cliff retreat and the formation of a wave-cut platform


Wave-cut cliff
Notch
Beach
Wave-cut platform
Old cliff
Uplifted marine terrace
(old platform)
New wave-cut cliff
New notch
New beach
New wave-cut platform

A wave-cut platform in front of a receded cliff


Wave-cut platform : a sloping rocky shelf found at the foot of a retreating cliff and exposed at low tide. This is Broad Bench in Kimmeridge Bay on the Jurassic Coast
Words to use:
headland
Retreating cliff
angle under 4 degrees
Wave-cut notch
abrasion
Inter-tidal feature
Wave energy dissipated
Future raised beach?
Processes :
Hydraulic action
Corrasion
Undercutting
Rockfall
Image courtesy of Andrew Stacey
www.stacey.peak-media.co.uk

A wave-cut notch under an overhanging cliff
and abrasion platform in front of it.

Two examples of wave-cut platforms in front of receded cliffs

What happens when land-based processes and landforms intervene along a coast? We have seen two examples of such cases in the formation of deltas and calanques

Coastlines

Submergent (Drowned coasts)

- Ria coasts (the karstic variety is called calanque coasts)
- Fjord coasts
- Skyer coasts

Neutral

- Deltas
- Volcanic coasts

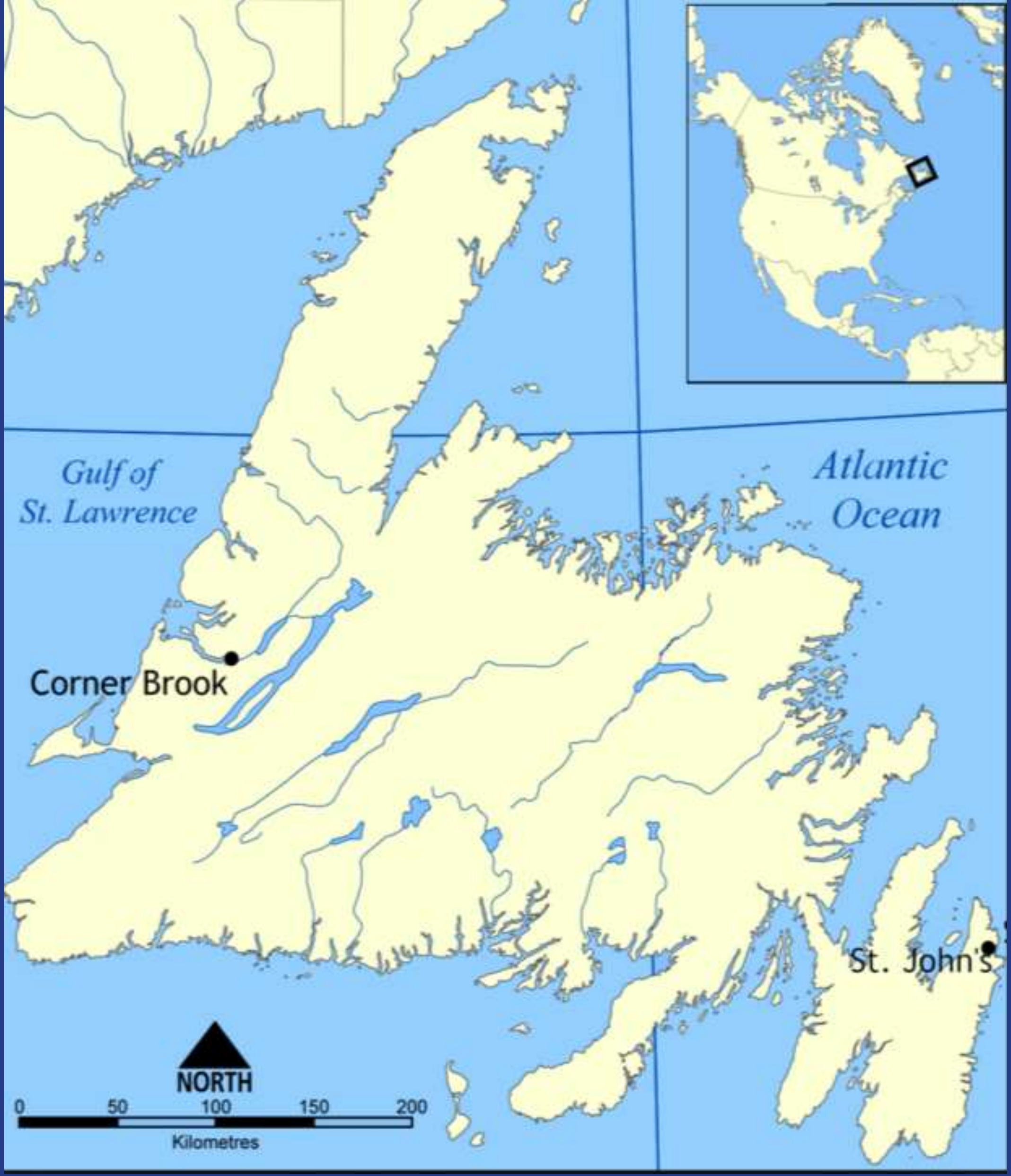
Emergent

- Terraced coasts

Composite

When the sea-level rises or the land sinks allowing the sea to invade river valleys, the resulting coastline is called a ria coast. The word ria comes from the Portoguese and Galician word *ria*, meaning a river. The term was proposed by the Great German geologist and geographer Baron Ferdinand von Richthofen in 1886. Rias are drowned river valleys.

The ria coasts of western Iberian Peninsula



The ria coasts of Newfoundland, Canada

Submergent Coastlines

Sea level rise inundated many coastal valleys creating bays and estuaries. These coasts are often referred to as **Ria** coastlines.

Estuary – An arm of the sea that extends inland i.e., an **inlet**) to meet the mouth of a river.

Assou Bay, Japan, an extreme ria coast

Whan a glacial valley or a glacial valley system is drowned, it results in a fjord. A coastline characterised by fjords is called a fjord coast.

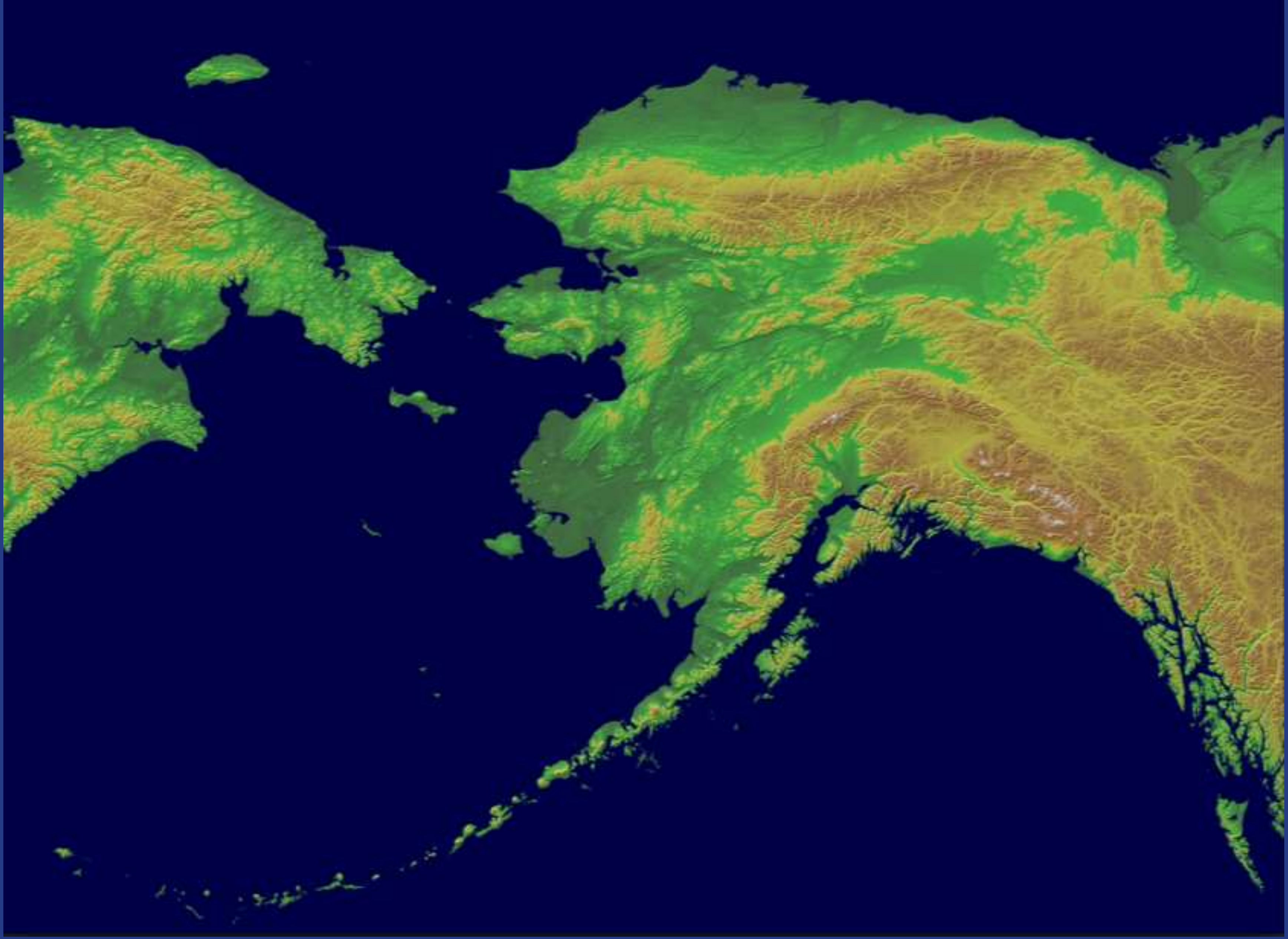
The word fjord comes from the Norwegian and refers to any narrow inlet or a lake-like body. The word has its origin in the ancient Norse word *fjǫrðr* meaning a lake-like body

Two glacial valleys, still occupied by glaciers, passing into fjords in Alaska, USA

A Norwegian fjord, Norway

The head of a Norwegian fjord in which the original U-shaped glacial valley is still seen

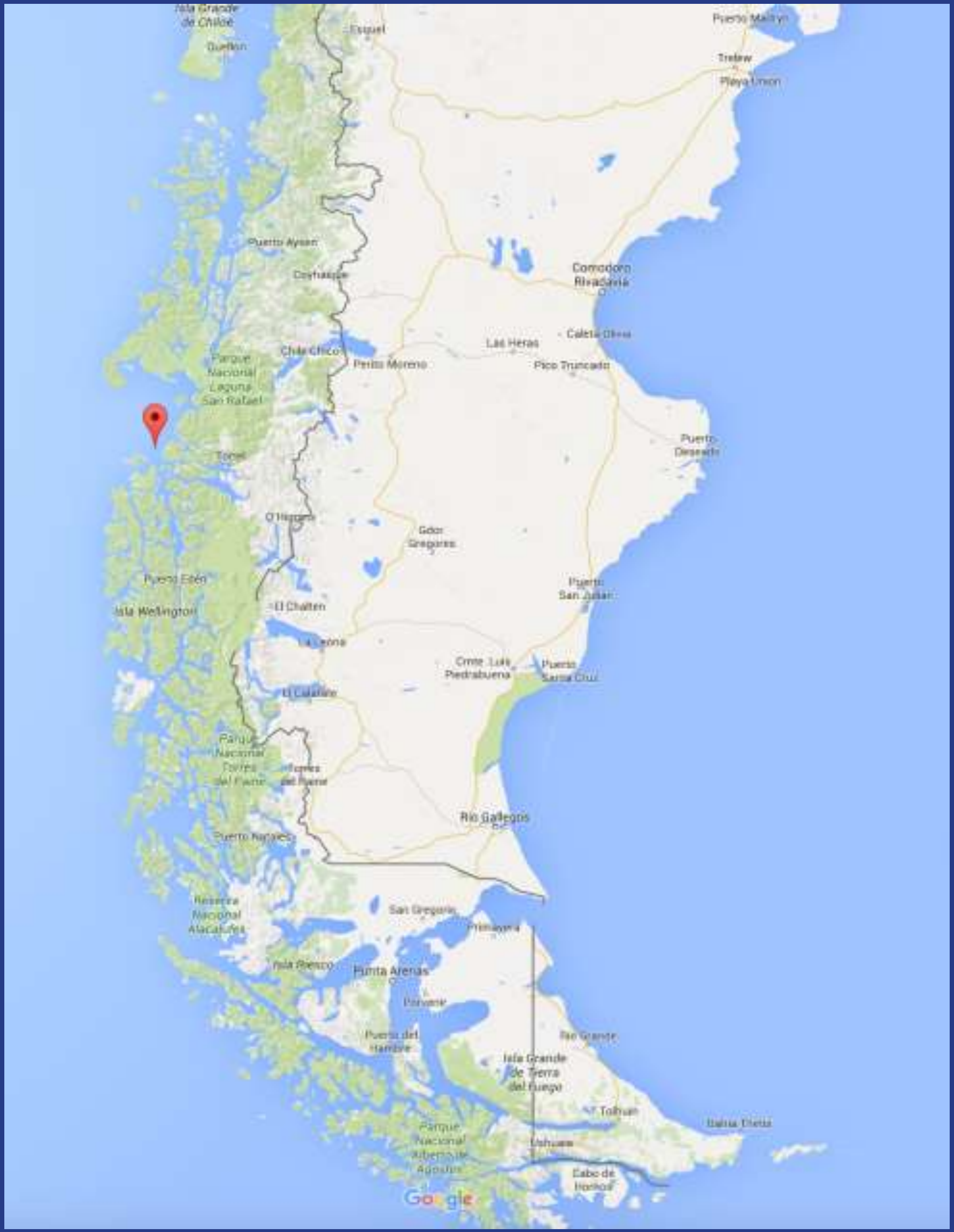
Misty Fjord, Alaska



The fjord coasts of Alaska, USA

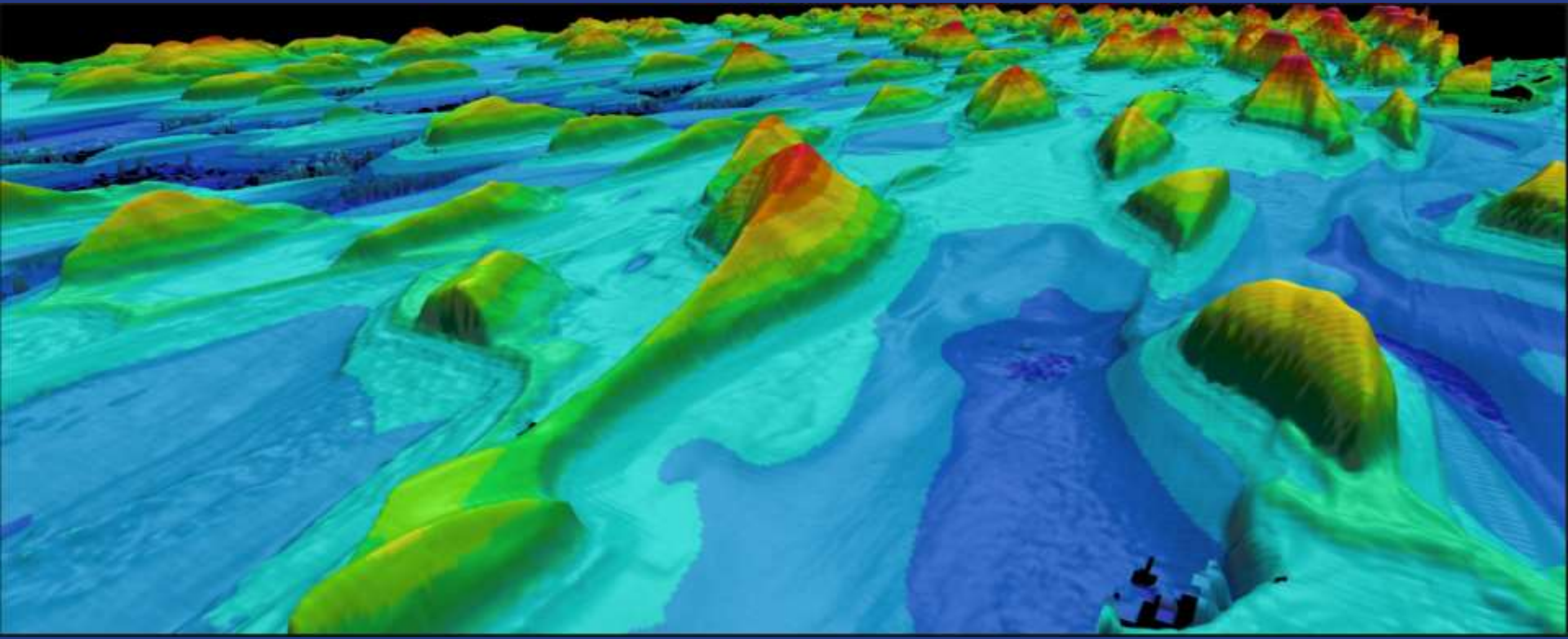
The fjords of Norway

A fjord in the Pumalin Park, Patagonia, Chile, South America



The fjord coasts of Patagonia, Chile, South America

The skyer coast of Clew Bay with drowned drumlins, Ireland



Detailed topography and bathymetry of the Clew Bay drumlins. The Oranges and the reds are the bits sticking out of water

The skyer coast of the Kvarken Archipelago, Finland

Coastlines

Submergent
(Drowned coasts)

Ria coasts
(the karstic variety is called calanque coasts)

Fjord coasts

Skyer coasts

Neutral

Deltas

Volcanic coasts

Emergent

Terraced coasts

Composite

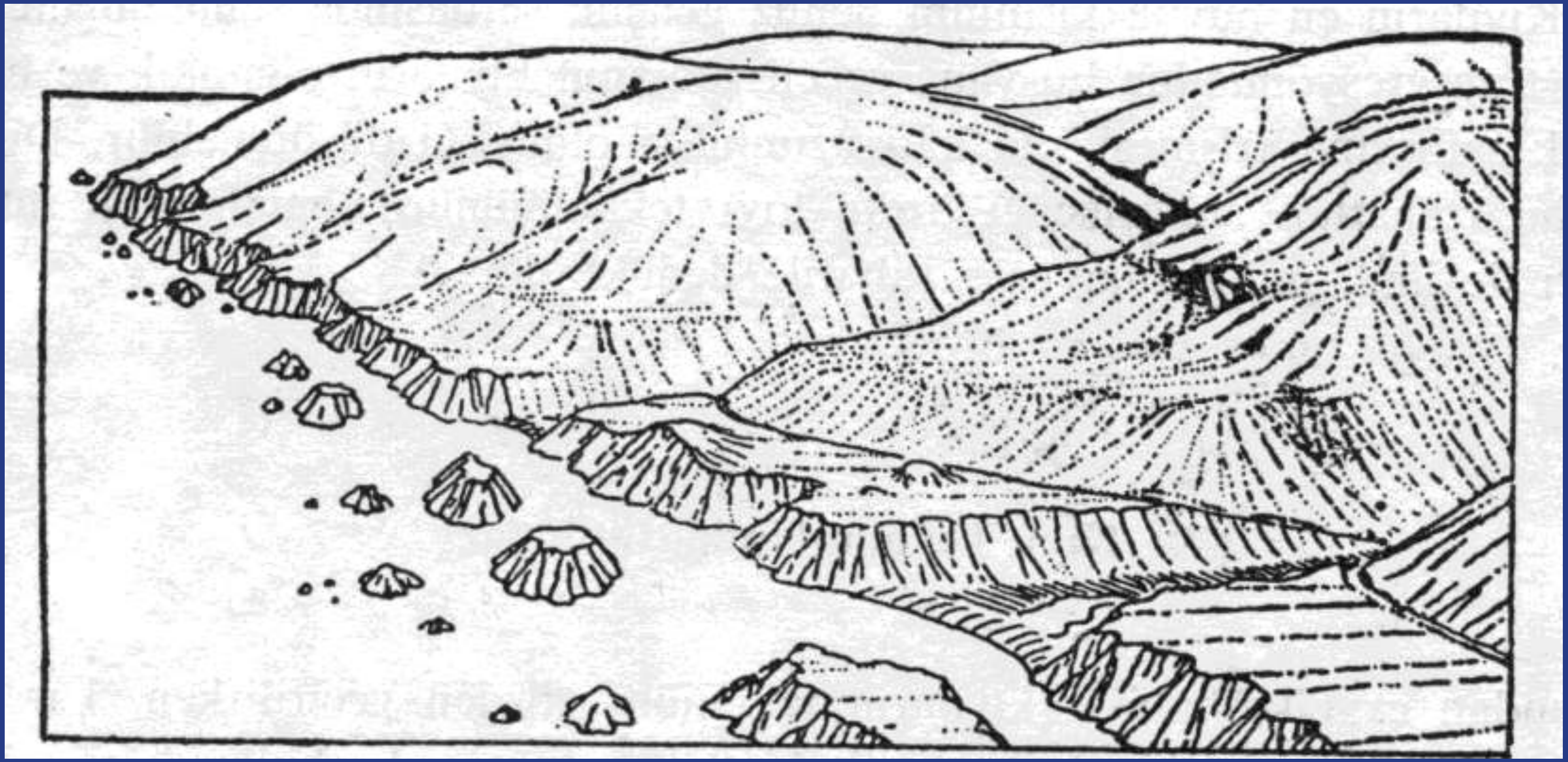
The volcanic coast of Ka'ohe, Hawaii, USA

Volcanic coast at Ka’ohe Bay, Hawaii and the pebble beach consisting entirely of volcanic material.

Volcanic coast with newly-emerging island in the Ogasawara chain of islands, Japan.

Coastlines

- Submergent (Drowned coasts)
  - Ria coasts (the karstic variety is called calanque coasts)
  - Fjord coasts
  - Skyer coasts
- Neutral
  - Deltas
  - Volcanic coasts
- Emergent
  - Terraced coasts
- Composite



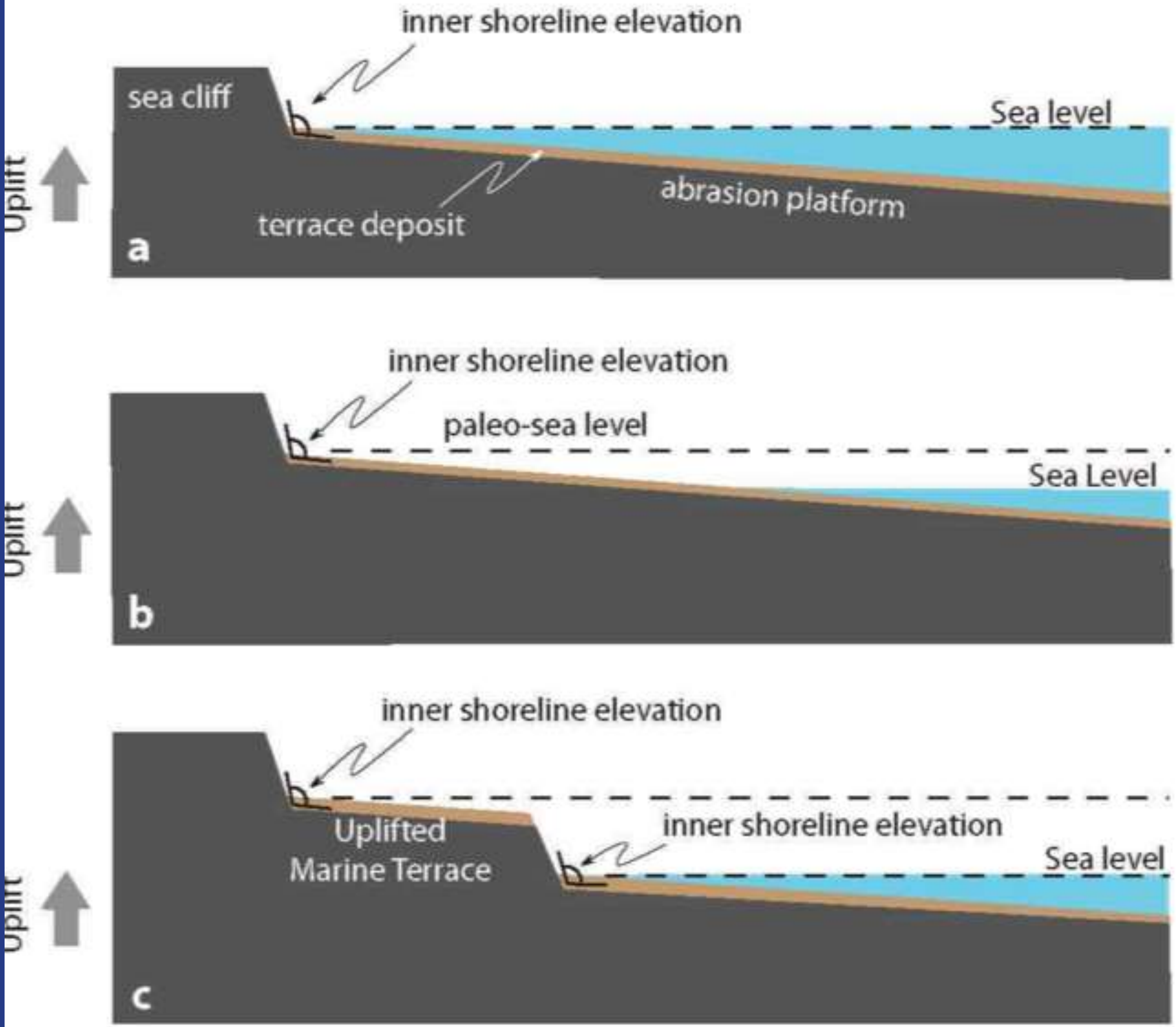
Marine terraces along an emergent coast at Cape Vizcaino, northern California, USA (from Davis)

Cape Vizcaino terrace at the background, California, USA

The formation of marine terraces: with the next uplift the present wave-cut platform will be the terrace no. 2 here and a new wave-cut platform will develop at its foot.

Marine terraces at the Taranaki area, New Zealand

The marine terraces of the San Clemente Island, California


inner shoreline elevation
sea cliff
Sea level
Uplift
abrasion platform
terrace deposit
a
inner shoreline elevation
paleo-sea level
Sea Level
Uplift
b
inner shoreline elevation
Uplifted
Marine Terrace
inner shoreline elevation
Sea level
Uplift
c