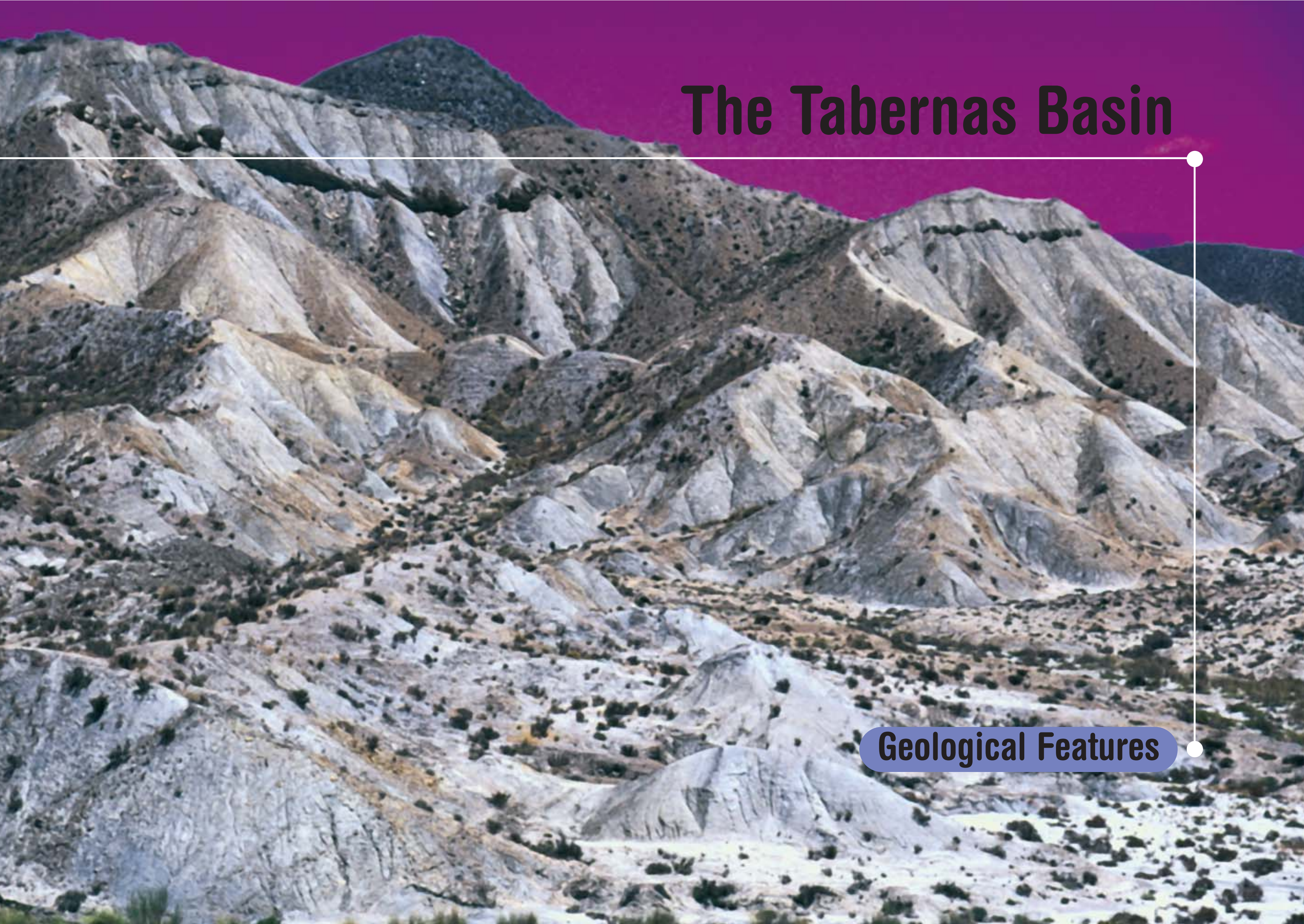
The Tabernas Basin



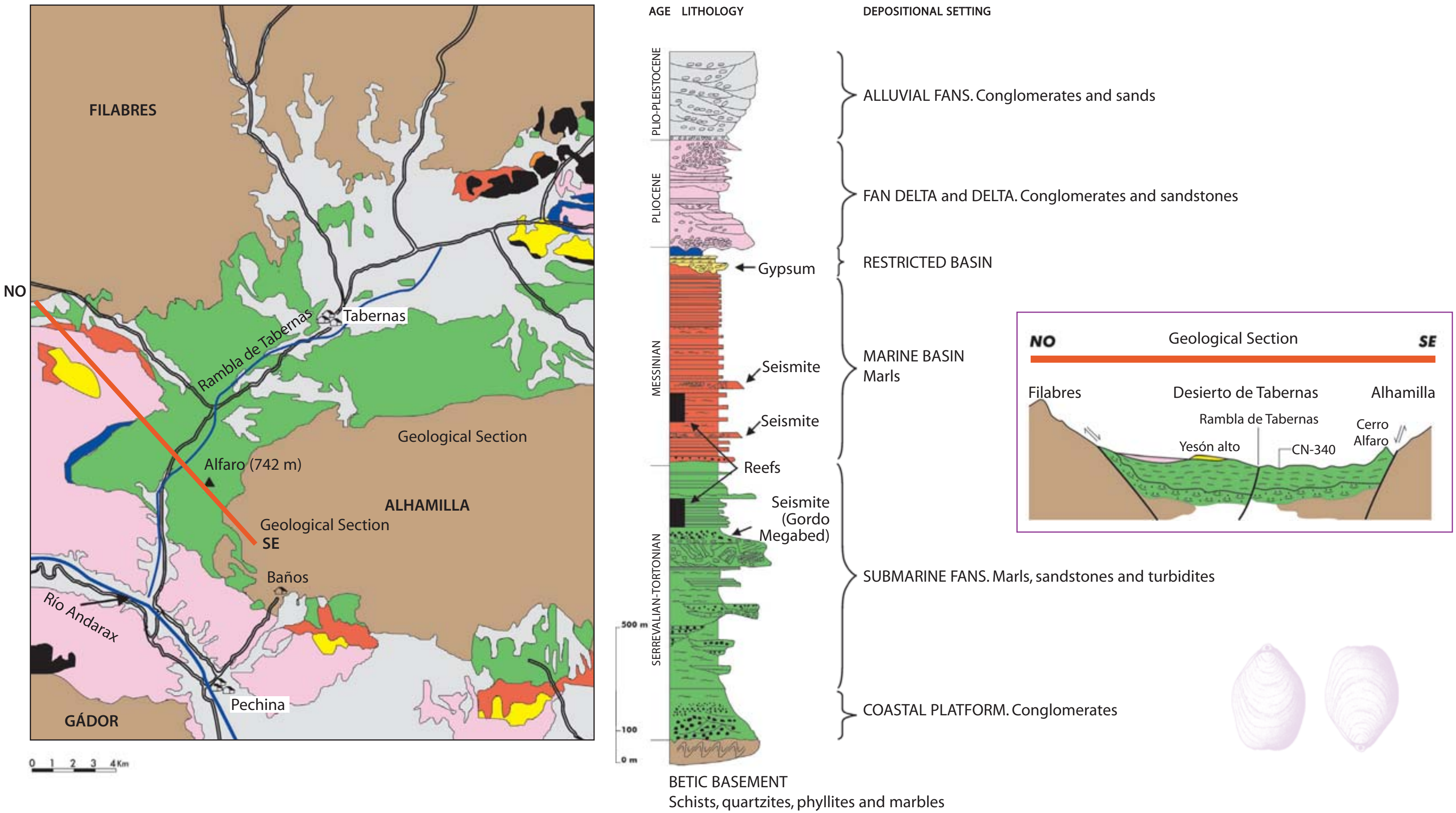
Geological Features

GEOLOGICAL FEATURES AND EVOLUTION

J. C. Braga - José M. Martín

SIMPLIFIED GEOLOGICAL MAP AND STRATIGRAPHICAL SUCCESSION FOR THE TABERNAS BASIN

Taken from Weijermars et al, 1985



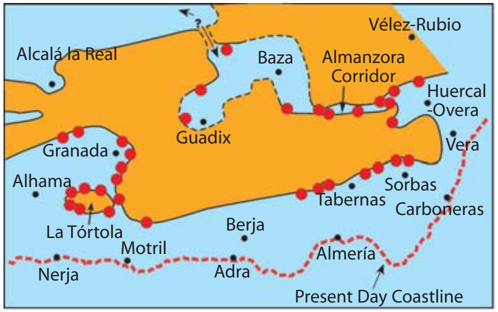
About eight million years ago (in the Miocene) the configuration of emerged and submerged land around the littoral margin of Almería was similar to that of today, but not identical: the sea extended through the territory of the Tabernas Desert up to the foot of the Sierra de los Filabres in whose borders fossil coral reefs of this age formed, reliably marking the position of the ancient coastline. In the slopes of this ancient sea, submarine fans deposited a thick and extensive sedimentary package that the rivers eroded from the emerging relief. This material, comprising alternations of marl and sand, are amongst those which have, to a great part, fashioned the eroded landscape of the Tabernas Desert.

Later, some 7 million years ago (in the Upper Miocene), the Sierra Alhamilla was uplifted, closing a narrow and elongated, marine intermontane basin between this new relief, to the south, and los Filabres, to the north.

In this depositional environment, marine at times, lagoonal for others, the deposition of limestones, marls, muds and sands, and enclosed gypsum, continued up until around 2 million years ago (in the Pliocene, almost at the start of the Quaternary), when the sea ultimately retreated, leaving the sediments exposed to the action of erosive agents.

DISTRIBUTION OF EMERGED LAND 8 MILLION YEARS AGO

1



Reefs

Braga, Martín and Quesada

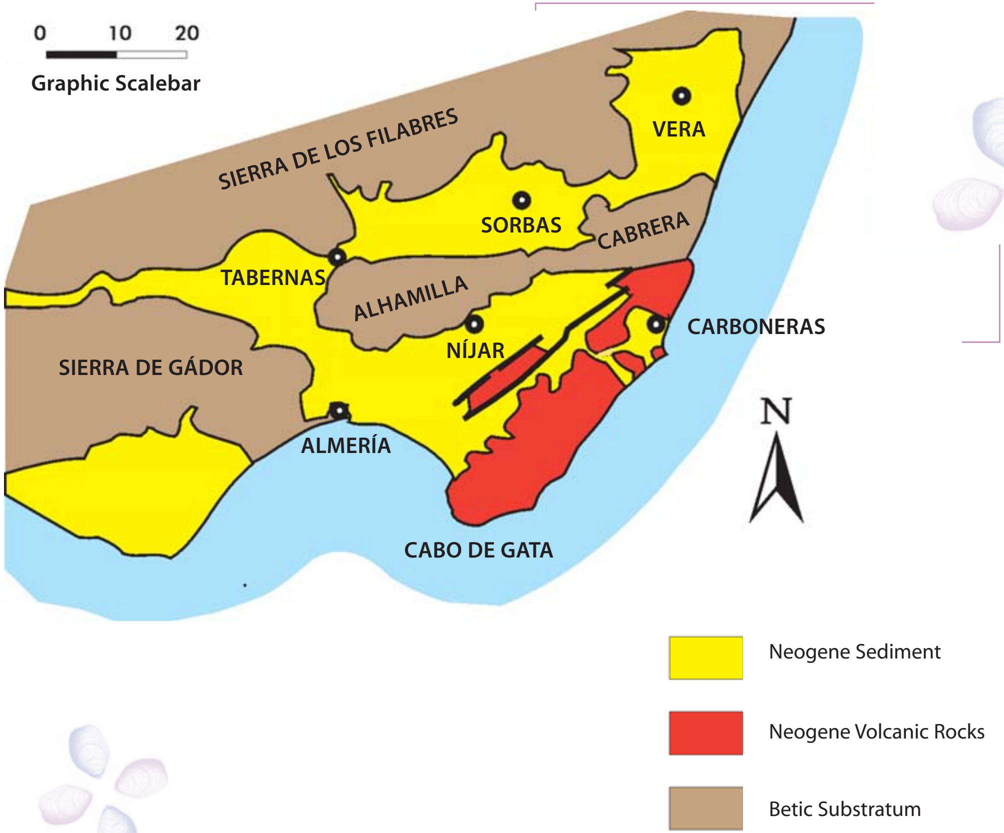
DISTRIBUTION OF EMERGED LAND 7 MILLION YEARS AGO

2

DISTRIBUTION OF EMERGED LAND 4 MILLION YEARS AGO

3

The Tabernas Basin has been configured since then as a long and narrow depression (approximately 20 km in length and 10 km in maximum width) between the Sierra de los Filabres and the Sierra Alhamilla, situated to the west of the Sorbas Basin and in continuation with it.



THE ERODED LANDSCAPE

The soft nature of the sediments that have filled the Tabernas Basin from 10 to 8 million years ago, the slow and continual uplift of the sierras that border it, and the arid yet stormy climate that has characterised this territory for a good part of the more recent Quaternary, have conditioned the model for one of the most spectacular erosive landscapes in continental Europe.

A geological landscape reminiscent of Africa that has captured the attention of geologists, naturalists, geomorphologists, photographers and film producers for generations: the Tabernas Corridor, the most southerly desert in Europe. This spectacular erosive landscape is not, therefore, attributable to human action, but to the concurrence of a series of geological factors and its own natural evolution, upon which the peculiarity of being one of the most important scientific and educational places for the study and comprehension of the natural phenomena of erosion and desertification in the Mediterranean Basin has been conferred.

The temporary and torrential character of precipitation generates a rambla type of fluvial system, normally dry, but which discharges a great amount of sediment and water in an almost instantaneous manner during strong storms. Within them the riverbeds are very broad and well-fitting, with steep and vertical sides, although they generally appear dry.

In the soft and readily eroded foothills, the stream produces grooves, which grow towards rills and runnels, and terminate in furrows separated by sharp crests. This landscape is given the name 'Badlands', alluding to its difficulty for being worked or put into agricultural production.

Turbidite sequences in the Tabernas Desert .

Eroded landscape of the Tabernas Desert.

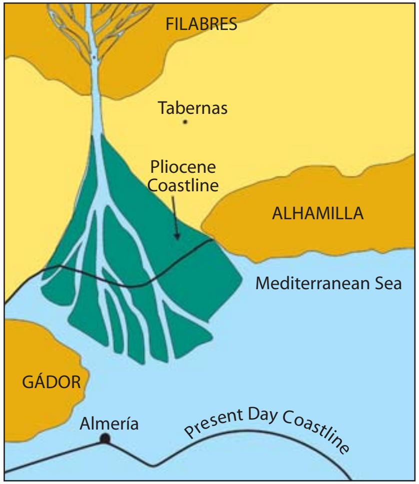
Evolution of the Drainage Network

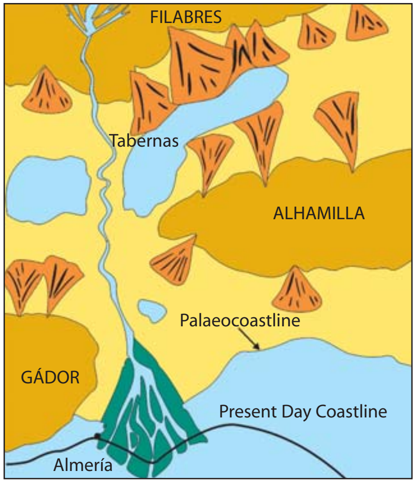
Antonio Martín Penela

4 MILLION YEARS AGO

The eroded landscape of the Tabernas desert is a consequence of the geological evolution of the region over the length of the last 4 million years, and more specifically, of its tectonic and climatic evolution in the past 150,000 years.

In the Lower Pliocene, about 4 million years ago, a fall in sea level took place simultaneously with a strong uplift of the adjacent relieves, Sierra Alhamilla, Sierra Gador and Sierra de los Filabres, already emerged and with some elevation. As a consequence, broad surfaces of the region became emergent and important fan deltas developed that collected water coming from the Sierra de los Filabres. One of these is the precursor of the modern River Andarax, that already occupied a similar position, although its river mouth (outlet) is somewhat displaced to the north, towards the position of La Rioja.





2 MILLION YEARS AGO

During the latter stages of the Pliocene, around 2 million years ago, the elevation of the mountainous relives and the fall in sea level continued, since then practically all of the Province of Almería has become emerged.

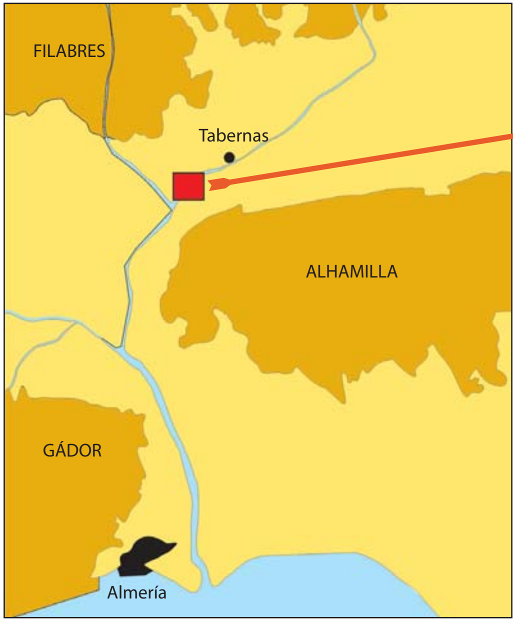
In this period, areas subjected to erosion and areas of sedimentation were differentiated. The latter were represented by small lakes installed in the most low-lying zones, and alluvial fans in those that material coming from the recently-formed mountainous massifs was deposited.

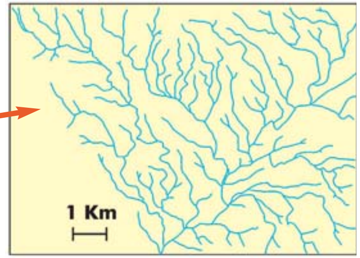
The main drainage during this period were made up of a fluvial system of close appearance to the modern River Andarax, which was forming an important delta in its outlet to the Mediterranean.

THE PRESENT DAY

The establishment of more arid climatic conditions in the Upper Pliocene, led to the total desiccation of lacustrine areas and almost total inactivity in the alluvial fans. It is since this period when erosive processes clearly became dominant in the region, initiating the sculpture of the modern landscape and the development of the fluvial network, which deeply excavated the Neogene and Quaternary sediments in the Tabernas Basin. The Andarax River continued as the principal river, in which all the water from the basin is drained, even if in reality the water and sediment carried by it to the sea is quite scarce.

Since the late Pleistocene, at a time when the modern configuration of the fluvial network was initiated, the factors that have allowed its strong incision, the development of badlands, and its general evolution have been: tectonics, the nature of the material, weak and easily-eroded lithologies, and the climatic conditions.





Distribution of streams in a section of the Rambla de Tabernas. The high drainage density (increased number of streams per unit of surface area) is typical of gullied areas.

Characteristic features of the present-day erosive sculpture in the Tabernas Desert.

Ramblas

Antonio Martín Penela

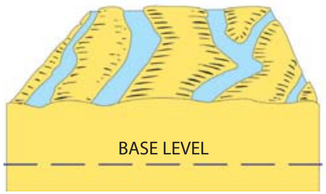
Ramblas constitute the main arteries of the drainage network in the Tabernas Basin. Through these the transport, and also the deposition, of particles coming from the erosion of the basin and the surrounding sierras is achieved.

They comprise braided fluvial systems, characterised by the development of numerous sandy bars between which multiple channels are initiated during flood periods. The flow of water in the riverbed is ephemeral, in the majority of cases, circulating only water from surface currents originating as a result of storms. The erosive processes in the ramblas take place during floods, excavating laterally along the length of its margins.

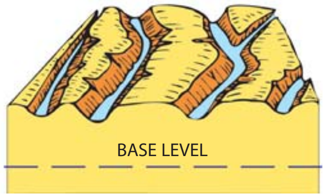
During the last 100,000 years the ramblas have evolved, deepening and widening their river beds, starting to form valleys almost 100 metres deep and river courses whose width exceeds a hundred metres. This important development of rambla valleys is a consequence of a combination of factors such as progressive uplifting of the region, the arid and stormy climate, the soft and erosive nature of the material.

The rivers of the Tabernas Basin are continually down-cutting, trying to reach their equilibrium with the base level of the sea. The occasional torrential precipitation and sparse vegetation cover allows an intense water-bourne erosion that unleashes an intense processes of incision, with a dense drainage network of dendritic type, and abrupt and unstable hillsides.

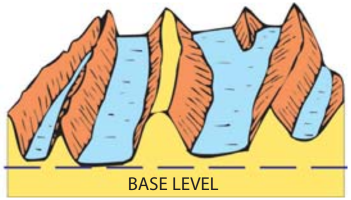
1



2



3



At the end of the Pleistocene incision of the fluvial network was initiated. The ramblas adopt a meandering morphological pattern.

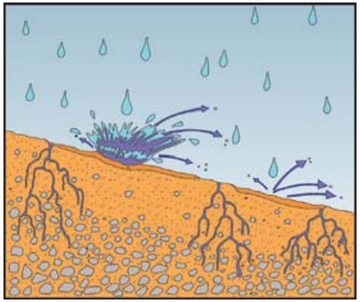
In the Holocene the rivers excavated deeply in order to reach their equilibrium with base level. It produced a generalised incision of the river courses.

Mechanisms of erosion in the desert: currents

Antonio Martín Penela

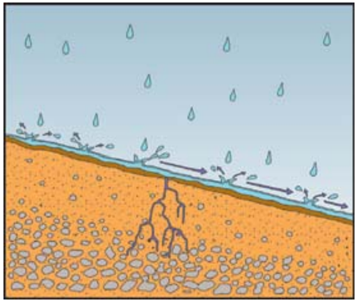
RAINDROP IMPACTS

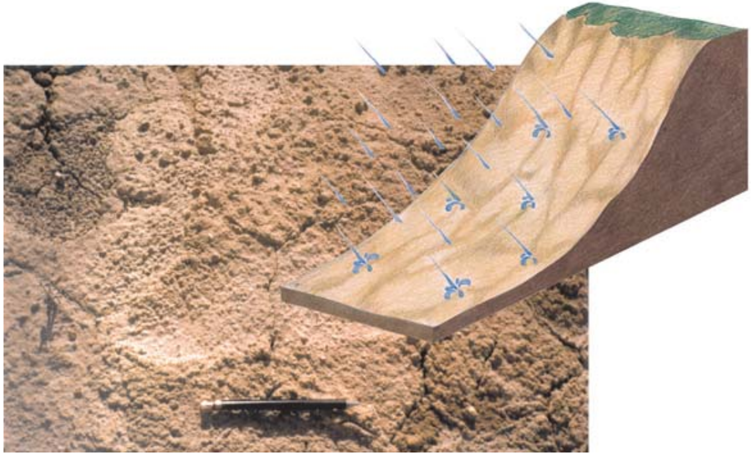
Raindrops tear away particles of the ground that are transported down slope by saltation. This process hardens the surface.



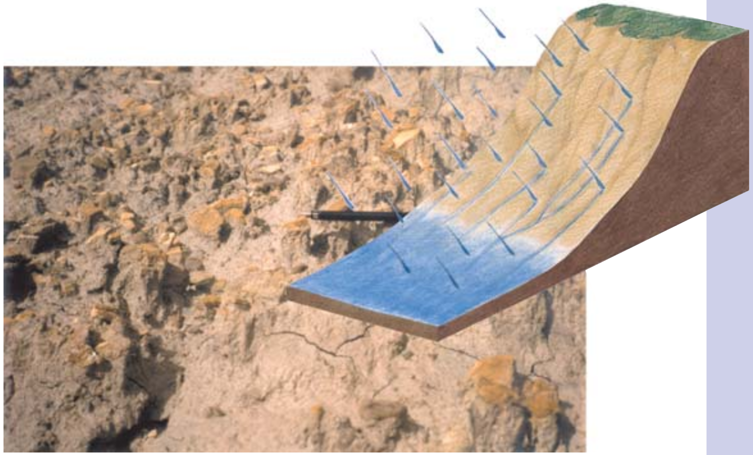
SHEET EROSION

Hardened ground favours the initiation of sheeted flows, helped by the slope, that remove and entrain the material.





Ground encrusted by the effects of raindrop impacts.

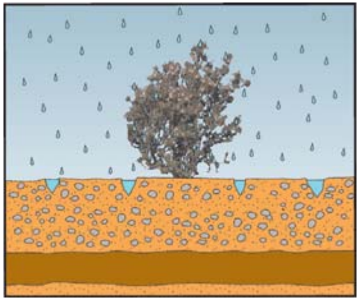


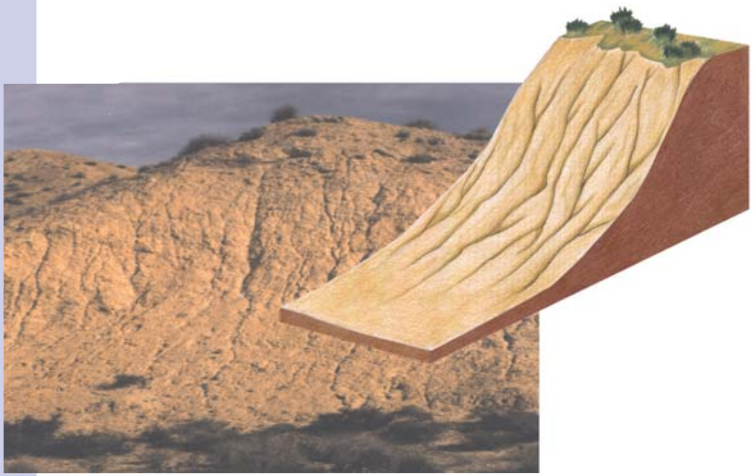
Fairy Chimneys : Small mounds of ground protected from sheet erosion by more resistant fragments of rock.

Mechanisms of erosion in the desert: currents

RILL EROSION

The flow is channelised forming furrows or 'rills'.

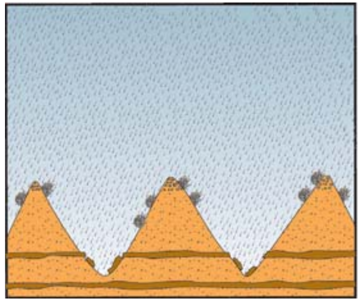




Erosive rills upon slopes are one of the characteristic features of soft hillsides in semi-arid regions.

GULLIES AND BARRANCOS

Deepening of the rills increases the capacity for excavation by concentrated flows, increasing the process until rills are created and barrancos as well.



Typical eroded landscape of gullies, known as 'Badlands'.

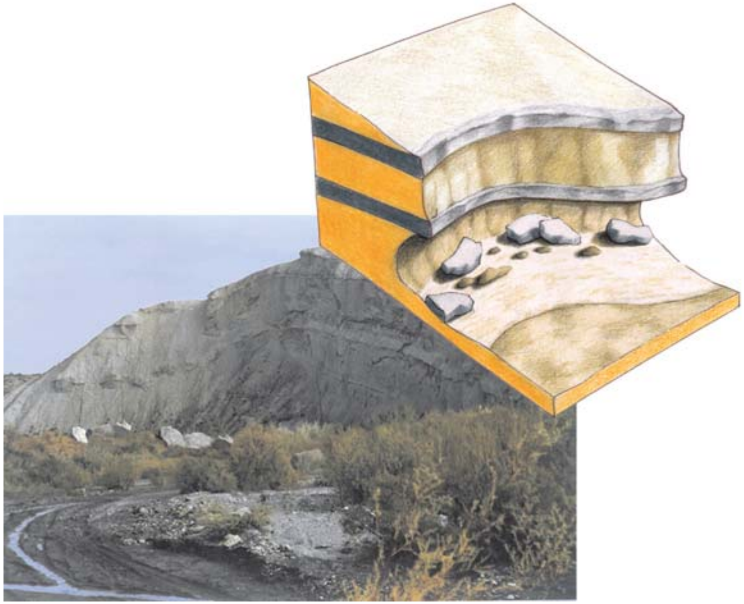
A. Martín Penela

LEDGES FROM THE RETREAT OF SLOPES

Erosion of the softest material forms unstable cornices in the harder material above it, which topple down due to gravity.

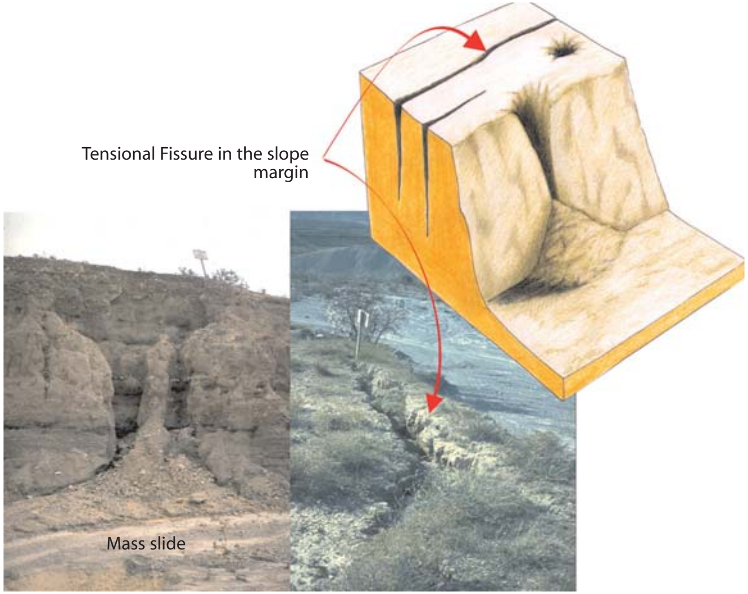
UNDERMINING BY BASAL UNDERCUTTING

Lateral erosion of the slope base in meandering areas causes instability and, afterwards, block falls from above.



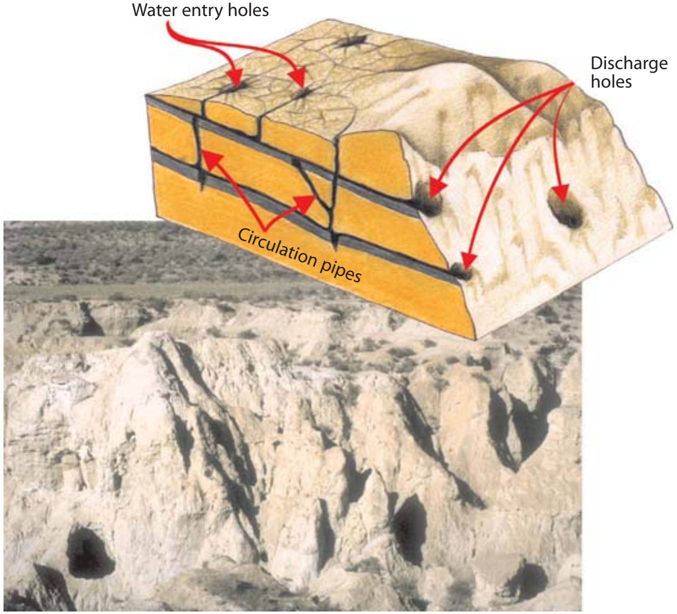
MASS SLIDES

Fissures parallel to the slope allow partial slumping and the collapse of vertical tunnels.



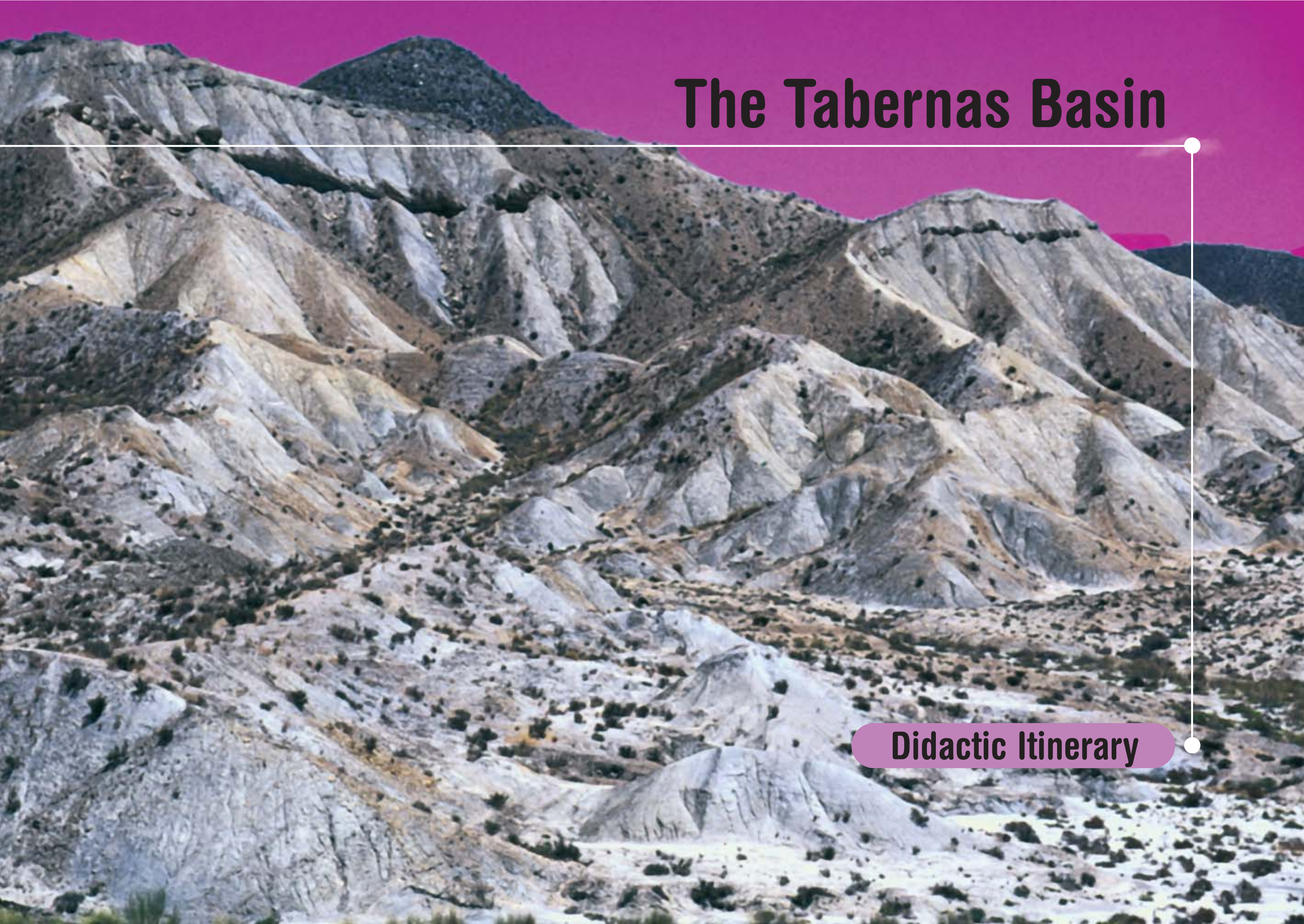
EROSION IN TUNNELS (PIPING)

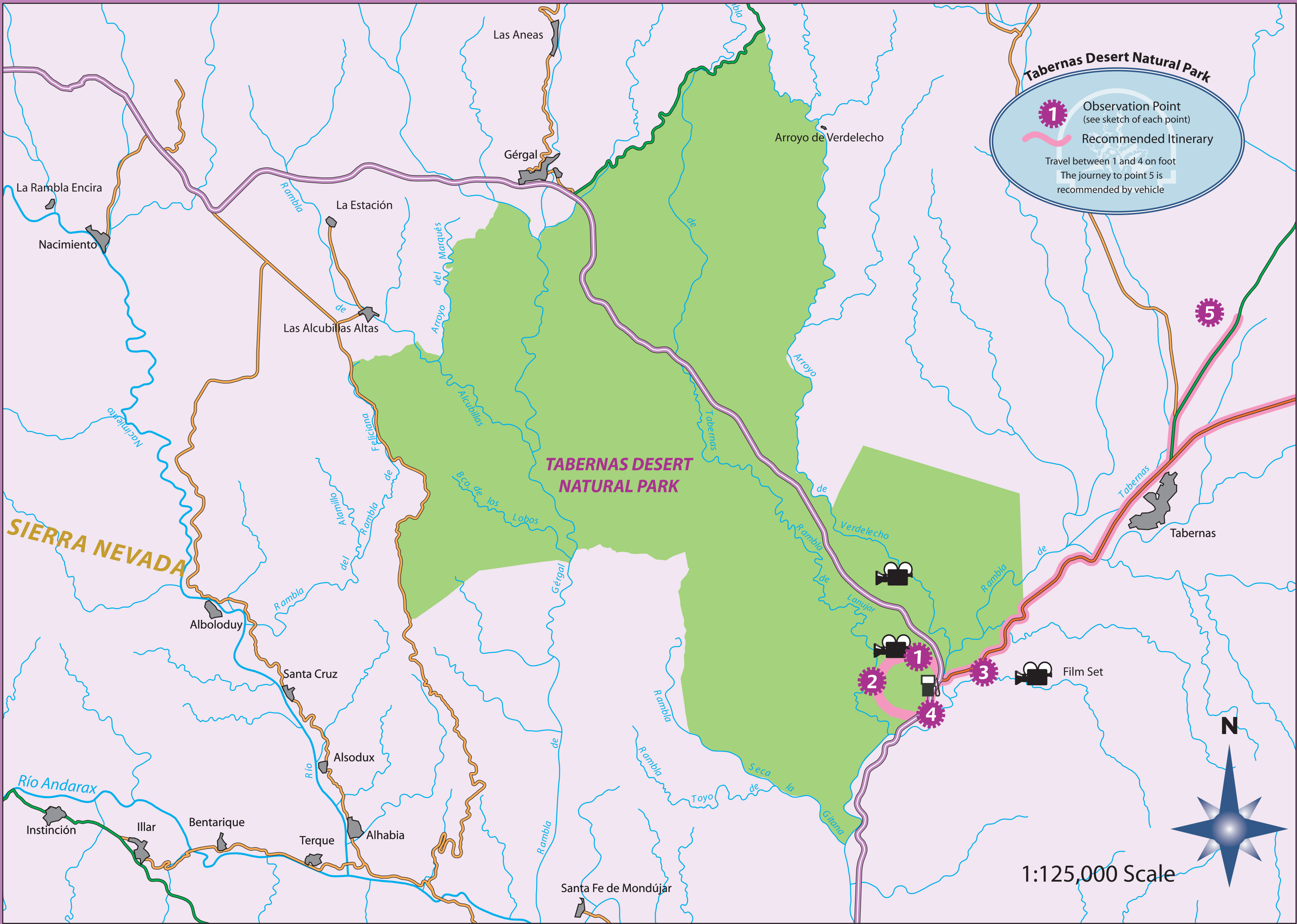
Water penetrates into the ground and generates a network of collectors through which material is removed. The pipes grow progressively and the relief ends in collapse giving rise to pseudokarstic morphologies.



The Tabernas Basin

Didactic Itinerary





Tabernas Desert Natural Park
Observation Point
(see sketch of each point)
Recommended Itinerary
Travel between 1 and 4 on foot
The journey to point 5 is
recommended by vehicle
TABERNAS DESERT
NATURAL PARK
SIERRA NEVADA
Las Aneas
Gérgal
La Rambla Encira
Nacimiento
La Estación
Las Alcubillas Altas
Arroyo de Verdelecho
Tabernas
Film Set
Alboloduy
Santa Cruz
Alsodux
Instinción
Illar
Bentarique
Terque
Alhabia
Santa Fe de Mondújar
Río Andarax
Rambla de Tabernas
Rambla de Lanujar
Arroyo de Verdelecho
Bco. de los Lobos
Rambla Seca de la Gitana
Rambla de Toyo
Rambla de Gérgal
Alcubillas
Arroyo del Marqués
Rambla de Feliciana
Rambla del Alamillo
Nacimiento
N
1:125,000 Scale

1. The turbidite succession of the Tabernas submarine fan

Juan C. Braga - José M. Martín

TURBIDITES

One of the most significant sedimentary features of the Tabernas Basin is the existence of a thick package of detrital sediment deposited around 8 million years ago (in the Tortonian) at the bottom of the sea, at several hundred metres of depth, in a slope setting, at the foot of the slope and on the submarine plain. Two different types of deposits are distinguished:

a) Those of submarine fans, situated at the foot of the slope and associated with turbidity currents, known as turbidites.

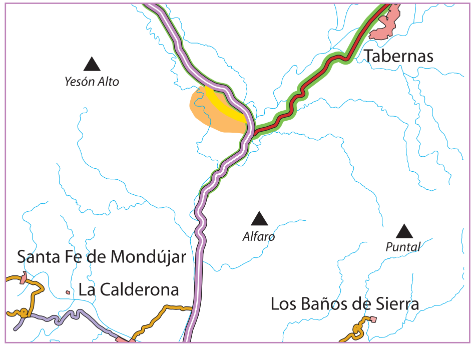
b) Mass failures on the slope, caused by seismic movement (earthquakes) of great magnitude, known as seismites.

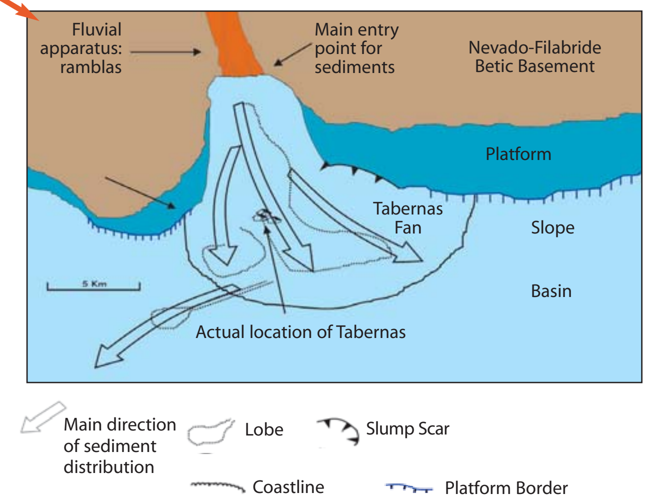
Upon this sedimentary unit characterised by the alternation of decimetre layers of sandstone and marl, the characteristic erosive sculpture ('Badlands') of the Tabernas Desert has been fashioned to a great extent.

8 million years ago (during the Tortonian) the Tabernas Basin had not been differentiated as such, since the relieves that delimited it to the south did not exist, like they do at present; the uplifting of the Sierra Alhamilla was initiated afterwards, around 7 million years ago.

PALAEOGEOGRAPHY OF THE TABERNAS BASIN AROUND 8 MILLION YEARS AGO (TORTONIAN)

With information taken from Kleverlaan, 1989

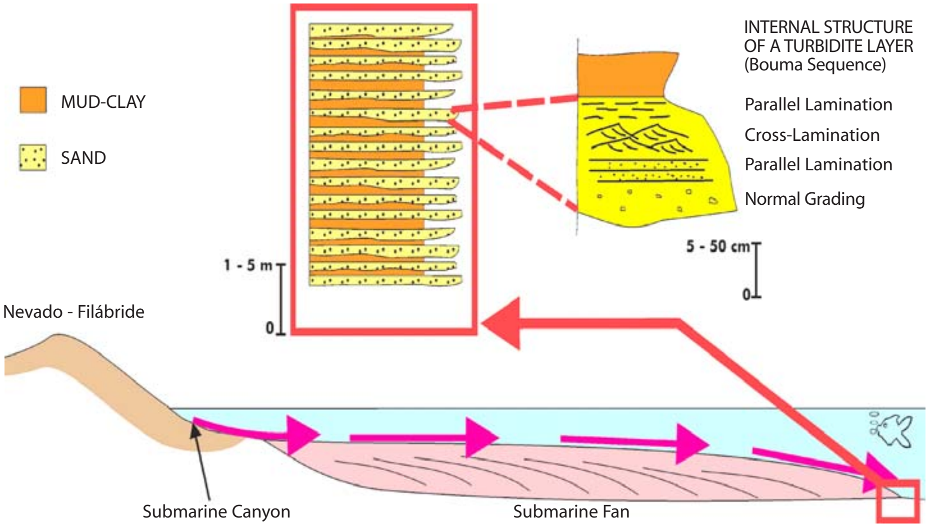




The Tabernas Submarine Fan occupied an area of some 100 km^2 extent. In it one can differentiate the most distinctive elements such as feeder channels, with a conglomerate fill (with clasts of up to several cubic metres), and lobes, that are built as mounded deposits at located at the exit of channels, consisting of sand and mud. The source area of all these sediments is the Sierra de los Filabres, located on the northern margin.

1. The turbidite succession of the Tabernas submarine fan

The turbidite succession that we observe in the Barranco del Poblado Mejicano corresponds to the external zone of the Tabernas Fan and consists of sand layers linked to turbidity currents (suspension of sand and mud with a density of between 1.5 and 2 g/cm^3), intercalated with fine sediments of mud and clay size. Both types of sediment are present in decimetre thick layers. Turbidite currents come from the upper part of the fan, and/or emergent area, or from the platform situated well away from here. The sediments that they transport are essentially deposited in the lobes and at the margin of the fan. The clay and mud layers are deposits that are formed at the bottom of the marine basin between every two turbidite layers.



In response to differential erosion, the turbidite layers, which are laterally very continuous, stand out in the landscape. The succession is actually found to dip towards the north, as a consequence of the later uplift of the Sierra Alhamilla, although the original (very gentle) inclination of the stratified succession was in exactly the opposite sense. The turbidite layers, in detail, consist of sand whose grain size progressively diminishes upwards, and some mud in its upper part. Its deposition is extraordinarily rapid. The most granular (sandy) intervals were deposited over a period of a few hours. The finest (muds) take as much as a few weeks. On the geological timescale deposition of the turbidite may well be considered as almost instantaneous. The frequency of repetition of this process within this zone was approximately one turbiditic event every 700 years. The sediment that is intercalated between the turbidite layers (clay-mud) was, however, deposited very slowly from suspension, in intervals of time from hundreds to thousands of years for each layer.

Fan margin succession. Alternation of hard layers of sandstone turbidites and soft layers consisting of muddy sediments.

SEISMITES

Throughout the turbidite succession observed in the barranco levels of seismites are intercalated within it. Internally they are composed of two types of material: (a) a conglomerate, at the base, with clasts (sometimes up to several cubic metres) encased in a sand and mud-sized matrix, and (b) a sand, in the higher part of the layer, of turbiditic character (up to several metres in thickness). The origin of these layers is tied to slumping of material in the marine platform slope, induced by earthquakes. The poorly-consolidated sediment that exists there, is easily mobilised through the shock produced by a seismic disturbance. If the shock is of sufficient intensity it slides, towards the frontal slope, at the same time disrupting and mixing with the fluid, generating a density flow that is afterwards going to give rise to a basal conglomerate deposit. The upper turbidite corresponds to sand that is lifted into suspension in the roof of the density flow, that is deposited immediately afterwards. Seismites correspond to instantaneous events on the geological timescale. Many of them have a considerable extent, and are suitable as correlation levels (guide levels). Their expanse gives an indirect estimate to the intensity of the earthquake that was generated.

At times in these slides only deformation folds are produced in the layers, without the sediment affected becoming disrupted, generating structures known as 'slumps'. In reality a complete transition exists between several situations, in that many slumps, if they continue through the sliding process, end up by breaking up and generating a breccia (intraformational breccia), whose clasts frequently exhibit irregular geometries, in a recurved form, corresponding to the remains of folds.

Deformation of layers produced by sliding: Slumps

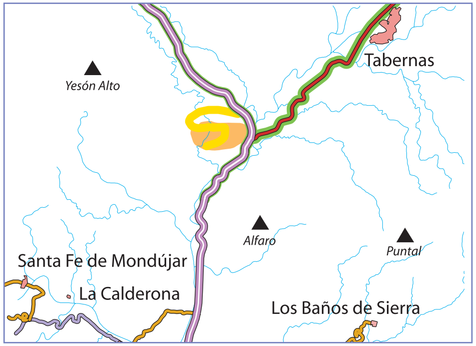
One of the most characteristic levels in the Tabernas Basin, interpreted as a seismite, is known as the 'Gordo Megabed', whose thickness reaches up to 40 metres (Kleverlaan, 1989).

2. The Las Salinas Travertines in the Tabernas Desert

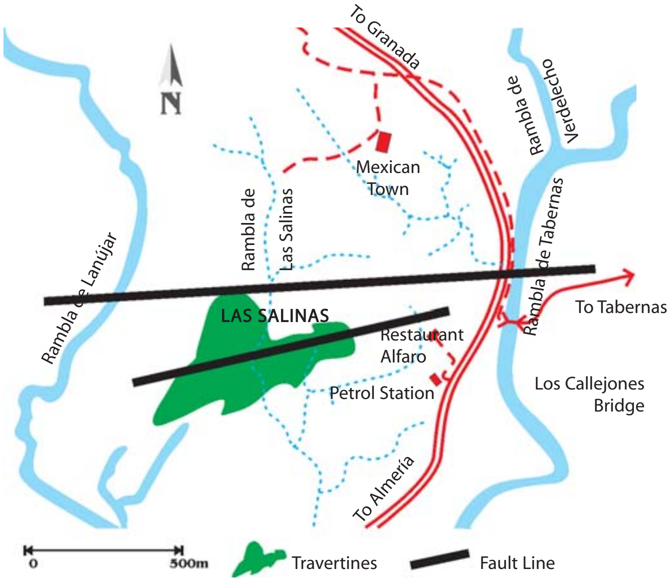
A. Mather - M. Stokes

One of the most surprising, and at the same time poorly known, aspects of recent geological processes that can be observed in the Tabernas Desert is the presence of Quaternary travertine formations from different areas within it. One of the zones where the better and most spectacular development is acquired is located in the place known as Las Salinas.

The precise age of these formations is uncertain for the moment. The process is active at present and most probably it was already in operation during the Pleistocene.



LOCATION OF THE LAS SALINAS TRAVERTINES IN RELATION TO FAULT LINES

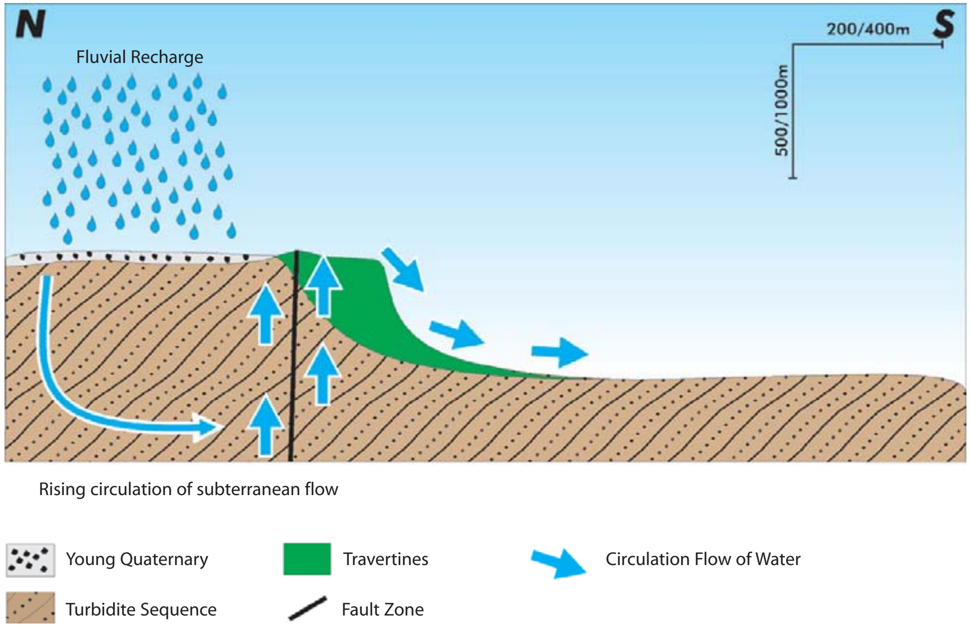


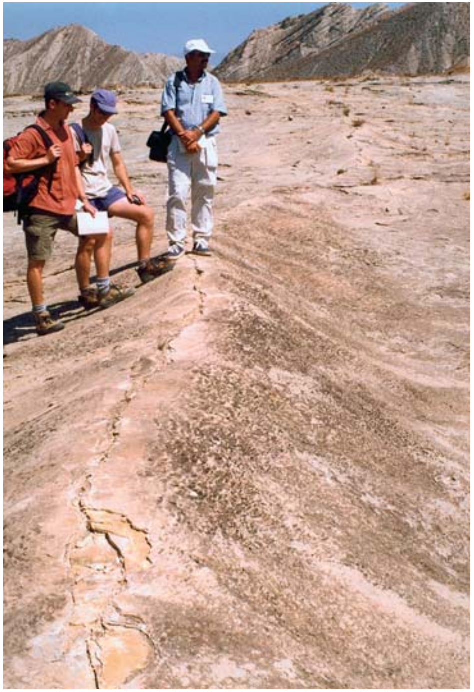
Travertines are a type of natural limestone rock, formed from the precipitation of carbonates out of surface and subterranean water. Modern travertines are developed in very localised zones associated with active streams, at springs in fluvial water courses, and in general, at whatever position a change in the velocity of flowing water is produced, so that the degasification and consequent precipitation of calcium carbonate is favoured.

At Las Salinas it seems clear that its present-day operation is due to the circulation of water, of both pluvial and subterranean origin, at a certain depth that ends up appearing at the surface due to a series of rather important fractures with an approximate east-west orientation.

Thanks to this line of tectonic disturbance, a very slow and continuous stream of water flows out, with a large saline concentration owing, probably, to the washing of saline material from the area of Yesón Alto and to progressive concentration within water from capillary rise.
The carbonate precipitated due to the slope creates typical travertine deposits with laminated and concretionary structures.

IDEALIZED SECTION OF TRAVERTINE GENETIC PROCESSES IN LAS SALINAS, IN RELATION TO THE DISPOSITION OF GEOLOGICAL FRACTURES AND THE CIRCULATING FLOW OF WATER





Surface crest of the fault zone associated with the formation of travertine deposits (Photo, M. Villalobos).

Detail of the internal structure of the travertines (Photo, M. Villalobos).

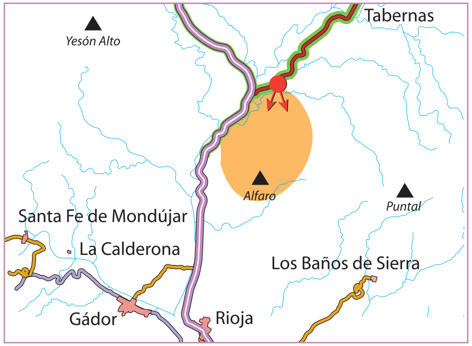
Detail of travertine deposits and salt pseudostalagtites in the accretionary curtain (Photo, M. Villalobos).

General view of the travertine accretionary curtain (Photo, M. Villalobos).

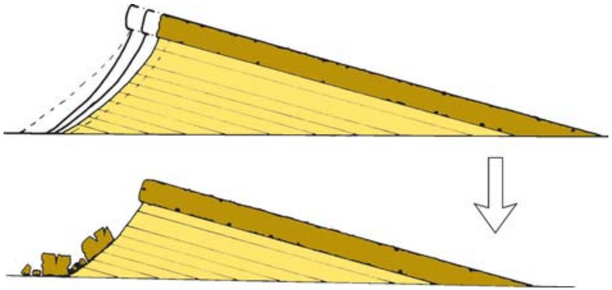
M. Villalobos

A very characteristic morphology in the erosive landscape of the Tabernas Desert are escarpment landforms, especially visible in the Cerro Alfaro district. These consist of inclined layers of hard material, normally sand and/or conglomerate, that protect the much weaker underlying material, usually marls, from erosion.

In the specific case of the Tabernas Desert, the most visible and spectacular examples have the peculiarity that the sense of inclination of the layers (towards the north) is reversed with respect to the original deposition of the layers (towards the south), that is to say, that they have been uplifted from the south and inclined towards the north. This inversion must be seen as due to uplifting of the Sierra Alhamilla, just as reflected in the accompanying figure.

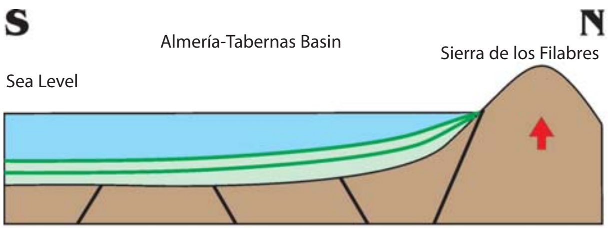


EVOLUTION OF AN ESCARPMENT LANDFORM, WITH A LAYER OF HARD MATERIAL INCLINED ABOVE A PACKAGE OF WEAK MATERIAL THAT IS ERODED LATERALLY

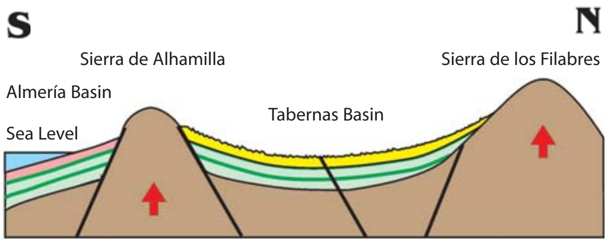


3. The Escarpment landforms of the Cerro Alfaro District

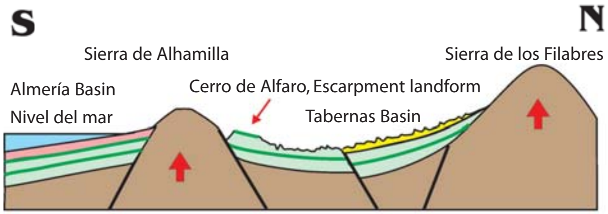
INTERPRETATIVE SECTION FOR THE ESCARPMENT LANDFORMS IN THE CERRO ALFARO DISTRICT IN RELATION TO THE EVOLUTIONARY HISTORY OF THE BASIN AND UPLIFT OF THE SIERRA ALHAMILLA



AROUND 8 MILLION YEARS AGO



AROUND 2 MILLION YEARS AGO



PRESENT DAY

In the period that existed between15 and 6 million years ago (Serravallian – Messinian), the sea washed against the foot of the Sierra se los Filabres. Numerous submarine fans, a continuation of the rivers that drained the sierras, fed sediments into the marine basin, depositing a thick series of turbidites, alternating layers of weak, marl sediments and tough sands and conglomerates.

Approximately 7 million years ago, at the end of the Tortonian, tectonic readjustment had caused emergence of the Sierra Alhamilla block, separating the Tabernas Basin towards the north of the Sierra Alhamilla from the Almería Basin towards the south. They continued to be marine for a significant period of time, up until around 4 million years ago. Uplift of the sierra elevated and brought up turbiditic material already deposited, reversing the inclination of the layers. The post-Messinian deposits were markedly different in these basins.

Since 4 million years ago (Upper Pliocene and Pleistocene) the environment in these basins has been virtually continental. Erosive agents have acted upon exposed material in the basin, especially in Tabernas, forming the erosive landscape that we can observe. The harder layers of the turbidite series create the typical landforms of dipping escarpments, also in a reversed sense to that in which they were deposited.

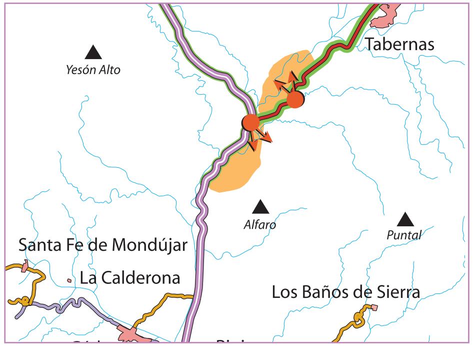
- Post-Messinian deposits of the Almería Basin
- Post-Messinian deposits of the Tabernas Basin
- Serravallian-Messinian deposits of the Almería-Tabernas Basin, hard layers in dark green, softer layers in light green
- Betic Substratum; Nevado-Filábride and Alpujárride complexes

4. Tunnel Erosion (Piping)

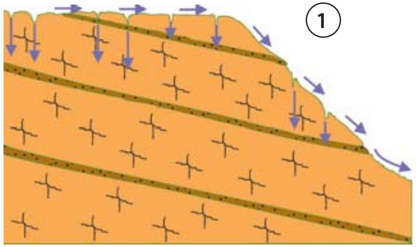
Antonio J. Martín Penela

Tunnel erosion (also known as 'piping') constitutes a peculiar erosive mechanism which may achieve an important development in semi-arid regions. The resulting landforms, of great scenic beauty, are known as 'pseudokarst' or mechanical karst. In the Tabernas Desert they are superbly represented.

It originates from the movement of concentrated flows of water that circulate through poorly consolidated material, producing a washout that gives way to the formation of tubular conduits (tunnels or pipes).

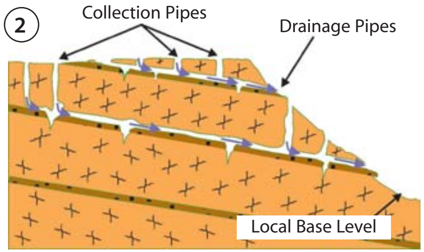


DIFFERENT STAGES OF TUNNEL EROSION



Tunnel erosion is initiated through part of the rainwater permeating into the ground through fissures and cracks on the surface.

Fissures and cracks in the surface.



Collection pipes on a slope, oriented in association with fractures.

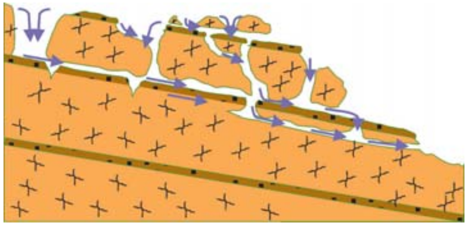
The removal of solid particles through the drainage orifices produces an increase in the size of the existing macropores and fissures, creating more or less complete, continuous channels, that come from the collection pipes or sinkholes through to the drainage pipes. These tunnels can have a diameter between 10 and 40 cm, and a few metres of length.

Drainage pipe close to local base level.

4. Tunnel Erosion (Piping)

DIFFERENT STAGES OF TUNNEL EROSION

3

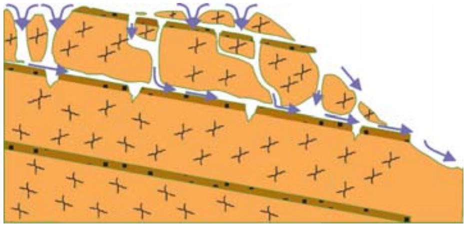


The channels grow progressively until they are made unstable. Partial or total collapse of the walls and roof occur when they are flooded with intense rainwater, causing an excess of weight in the overhangs. The phenomenon may also occur after a significant drought, through the intense cracking of the material, producing a sudden fall.

Large sized collection pipes or sinkholes, originating from the coalescence of several vertical collection pipes with the collapse of their walls.

Failed and abandoned drainage pipe, resulting from the descent of the tunnel network towards local base level.

4



Progressive development of the tunnel network, accompanied by many collapses through part of it. A system of barrancos is initiated in which numerous failed channels and blind valleys with U-shaped sections, are still preserved, that rapidly evolve into V-shaped sections. Altogether, a net retreat of the slope takes place.

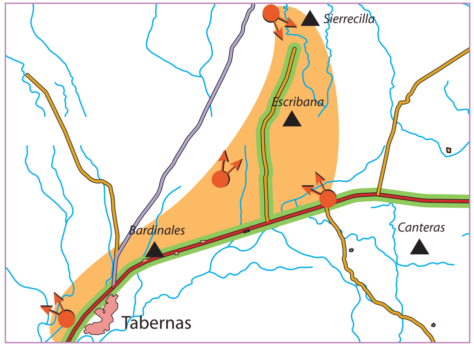
Weathered pseudokarstic morphology which evolves towards a system of gullies.

A. M. Harvey

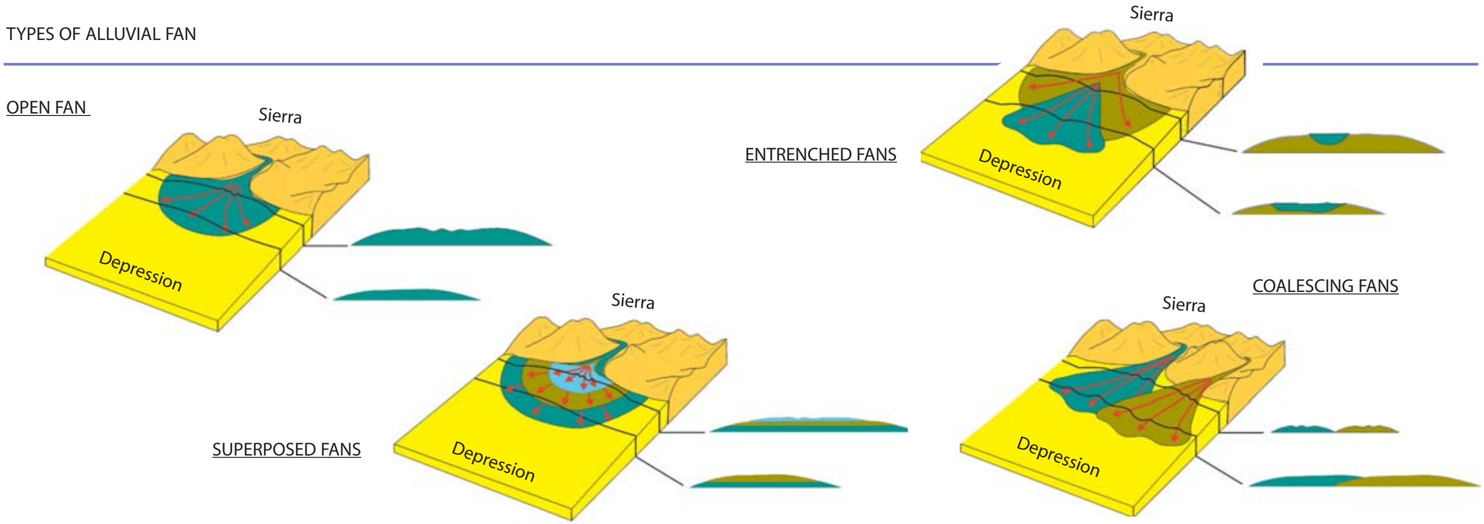
One of the most visible and characteristic features in the recent sculpture of the Tabernas Desert are alluvial fans.

The development of alluvial fans takes place at a break of slope produced at the contact between a more or less mountainous front and a small sedimentary trough. In this morphological setting, when the confined river or rambla courses of the mountainous zone reach the sedimentary basin, with much lower slope, they suffer a sharp reduction in their capacity to transport bedload, generating extensive deposits in the form of a fan.

The lateral superposition of fans in the same front generates a system of coalescing fans. In alluvial fans, the coarsest material is deposited in the more proximal zones (closer to the relieves), while the finer, less-heavy sediment, may be carried to the more distal zones (furthest from the relieves). In the more distal, practically planar parts of the fan, marshy or swampy zones are frequently formed, and include small lagoonal basins that are filled by sediments.



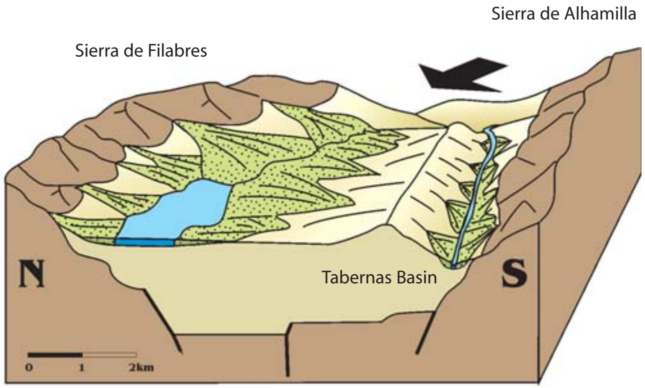
TYPES OF ALLUVIAL FAN



Although alluvial fan morphologies are frequent and obvious throughout the desert zone, in the vicinity of the Tabernas District, it is possible to distinguish an ancient yet still functioning alluvial fan system, that at present feeds into the main drainage of this area, the Rambla de Tabernas, an artery for the removal of sediment and water alike, that are discharged from the fluvial network in the eastern sector of the basin.

View of the lacustrine deposits (photo J. C. Braga).

IDEALIZED SCHEME OF THE ALLUVIAL FAN-LAKE SYSTEM DURING THE PLEISTOCENE IN THE EASTERN SECTOR OF THE TABERNAS BASIN

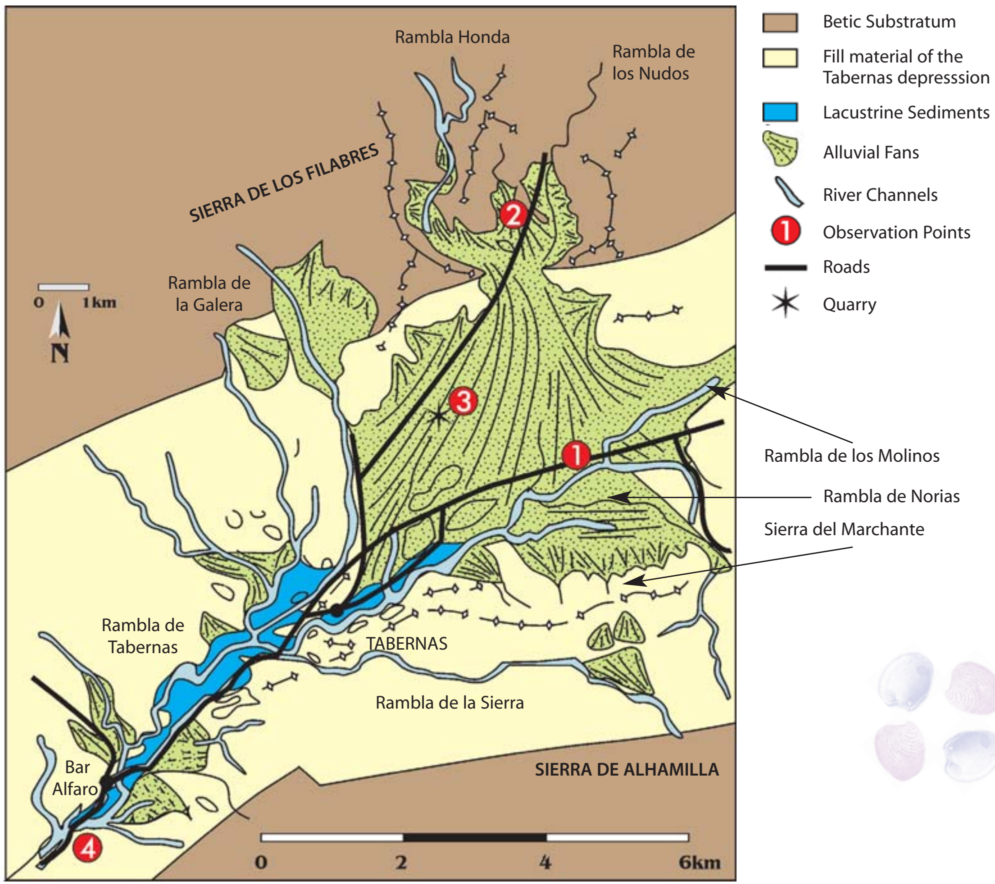


- Betic Substratum
- Sedimentary Fill of the Basin
- Alluvial Fans
- Lake-Lacustrine Deposits
- Principal drainage direction in the basin

The fans started to function during the Pleistocene, after an erosive period that stripped out the upper part of the sediments in the basin.

During the operation of these alluvial features, the basin drainage remained interrupted for some time, generating a lacustrine zone in which around 20 metres of sediments were deposited. These deposits are visible in the vicinity of Tabernas and the Los Callejones bridge (at the junction of the motorway with the old Murcia road).

QUATERNARY DEPOSITS OF THE ALLUVIAL FAN-LAKE SYSTEM IN THE TABERNAS AREA



In the map several places used for field observations are located

1. General view of coalescing alluvial fan deposits in Rambla Honda
2. Coarse river sediments typical of the more proximal part of the alluvial fan, in relation to the supply front from the Los Filabres relief
3. Finer sediments characteristic of distal deposits (visible in the quarry area)
4. Lagoon sediments visible in close vicinity to the Alfaro petrol station