

CHAPTER 19

LOW COASTLINES OF THE IBERIAN PENINSULA



*Saltation of sand in a coastal dune. Morsul beach, Almería
(photo by P. Renard)*

Marine coastal dynamics is responsible for the configuration of the modern coast line, as it distributes, erodes and deposits the sediments carried by fluvial channels when flowing into the sea. This chapter highlights the low coastlands of Spain and the main types of coastal forms as examples of the building activity of the sea since the end of the Tertiary (Pliocene and Quaternary), in the last 5 million years.

The Spanish Mediterranean and South-Atlantic coasts are characterized by the development of wide coastal plains with a sedimentary origin, an enormous geo-

logic and geomorphologic interest, and a great variety of coastal shapes, active and fossil (spits, deltas, dune systems, sea terraces, tidal marshes, coastal lagoons, etc.). There are abundant examples, some of them spectacular, with the added value of being a magnificent record of Quaternary coastal evolution, providing very valuable eustatic and paleoenvironmental data. All these aspects justify the definition of these coasts as a geological framework of international relevance.

Geographically, these coasts are placed in a transitional area between the European oceanic warm cli-

Figure 1, below. *Geological setting of the Mediterranean and South-Atlantic coasts (modified from Capote and De Vicente, 1989).*

- 1) Variscan basement.
- 2) Horizontal Mesozoic between the Iberian and Betic Mountain Ranges.
- 3) Intermediate-type folded chains.
- 4) Alpine Mountain Ranges.
- 5) Tertiary basins.
- 6), 7) and 8) Strike-slip, normal and reverse faults with recent activity.

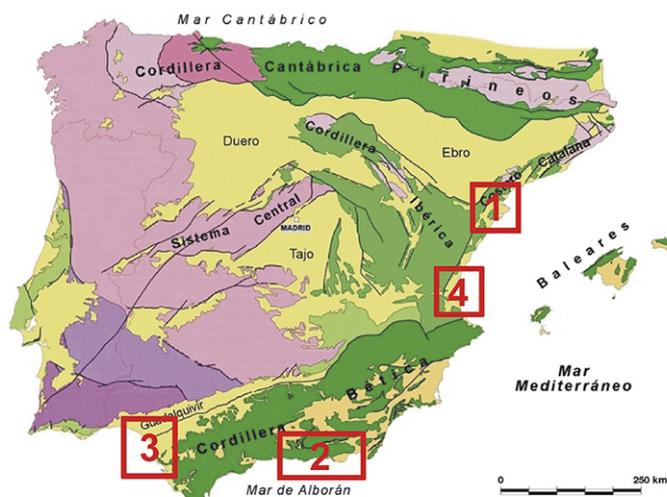


Figure 2, right. *Location of the geosites described in the text:*

- 1) Ebro delta.
- 2) Adra river delta and terraces of the Campo de Dalías.
- 3) Coastal sandbar of Doñana and
- 4) Albufera de Valencia



mates and the African dry and semidry climates, with water exchange between the Atlantic Ocean and the Mediterranean Sea through the Strait of Gibraltar.

Geologically, these coasts are linked to several Alpine structural units and display a remarkable neotectonic activity which has caused many changes in the coast along the Quaternary. This activity is linked to the geotectonic context of the Iberian Plate, between the African and Euro-Asian plates. Interaction between these plates led to two active orogens, the Pyrenees and the Betic Ranges, with important vertical movements creating high reliefs in the Quaternary. Two intermediate mountain systems developed between them: the Catalanian Coastal Mountain Range and the Iberian Mountain Range (Figure 2). In younger geological times, these ranges underwent tensional movements with reactivation of normal faults and formation of several tectonic basins.

The sediment filling of these basins was eroded and transported by the fluvial network, which meant a very important contribution of sediments to the coast, favoring the development of *wide coastal plains* affected by sea dynamics (waves, currents and tides). Linked to these coasts there are spectacular dune systems in the Mediterranean and South-Atlantic coasts. The *coastal wetlands* reach a great development in the Mediterranean coast, forming coastal lagoons, as well as under the South-Atlantic tidal conditions, were they develop wide tidal marshes. A peculiar case of coastal wetland is the *deltas*, whose recent historical

evolution, determined by quick advances and retreats, provides a wealth of information on the dynamics of these systems.

The **deltas** are sediment systems built on the river mouths, when the fluvial solid contribution exceeds the redistribution capacity of sediments by sea dynamics (waves, currents and tides). They are well defined along the Spanish Mediterranean coast (Llobregat, Ebro, Andarax and Adra rivers). Deltas are very sensitive systems whose evolution reflects environmental changes, both antropic and natural, and both in the river basin and in the coastal area.

The **Ebro delta** (Figure 3) is the biggest of the deltaic systems in the Spanish Mediterranean coast (320 km² surface above sea level). Its shape responds to a model where there is a certain balance between river sediment input, wave action and coastal drift, with development of spectacular *sandbars*, *spits* and *coastal lagoons*. The two sandbars developed by the delta are a good example of longitudinal growth sedimentary bodies, whose free accumulating edges are fed from the erosion of their own exposed fronts (Figure 4).

From the XV to the XVIII centuries, human deforestation of the Ebro basin originated a significant progradation of the delta. Since the beginning of the XX century, due to basin regulation, river contribution has decreased, originating a negative coastal balance (calculated around 250,000 m³/year) and a progressive delta erosion with an average yearly retreat of 22 m/year. Part of the sediment is accumulated in the *coastal sandbars* which have prograded hundreds of metres. The delta was designated as a Natural Park, and is included in the Humid Areas of International Importance (RAMSAR, 1993), with 300 bird species of the 600 existing in Europe.

The **river Adra** (Almería) provides the best example of a **delta with anthropic influence**. The development of lead mining in the XVIII and XIX centuries caused a massive deforestation in the nearby Sierra de Gádor, with the consequent increase of runoff in the drainage basin, erosion and transport of sediments leading to delta progradation. In 1875, for health reasons, the original river course was modified flowing 2.5 km east of the city. Since then, a new delta was created in the new mouth (Figure 5). The prevailing eastward coastal drift has caused the erosion of the old delta and the growth of a coastal sandbar on the new delta, which in 1931 even closed a new bay which nowadays makes up the so called *Albufera Honda* (Deep Coastal Lagoon), progressively being filled (Goy and Zazo, 1986). The process has recently formed a new small coastal lagoon (*Albufera Nueva*) between the coast and the previous one.

All along the Valencia, Balearic and Andalusian Mediterranean coast, and the Cadiz Gulf coast there are several **marine terrace** levels. Most of them (4 or 5 of these levels) correspond to middle Pleistocene interglacial episodes, whereas the last interglacial

Figure 3. *Satelite view of the Ebro delta in 1999.*





Figure 4. Dunes on a sandbar in the peninsula of Los Alfaques, Ebro delta (photo by P. Renard).

Figure 5. Geomorphological sketch of the Adra river deltaic complex, indicating recent changes recorded in it (Dabrio and Zazo, 1987, modified from Goy and Zazo, 1986).

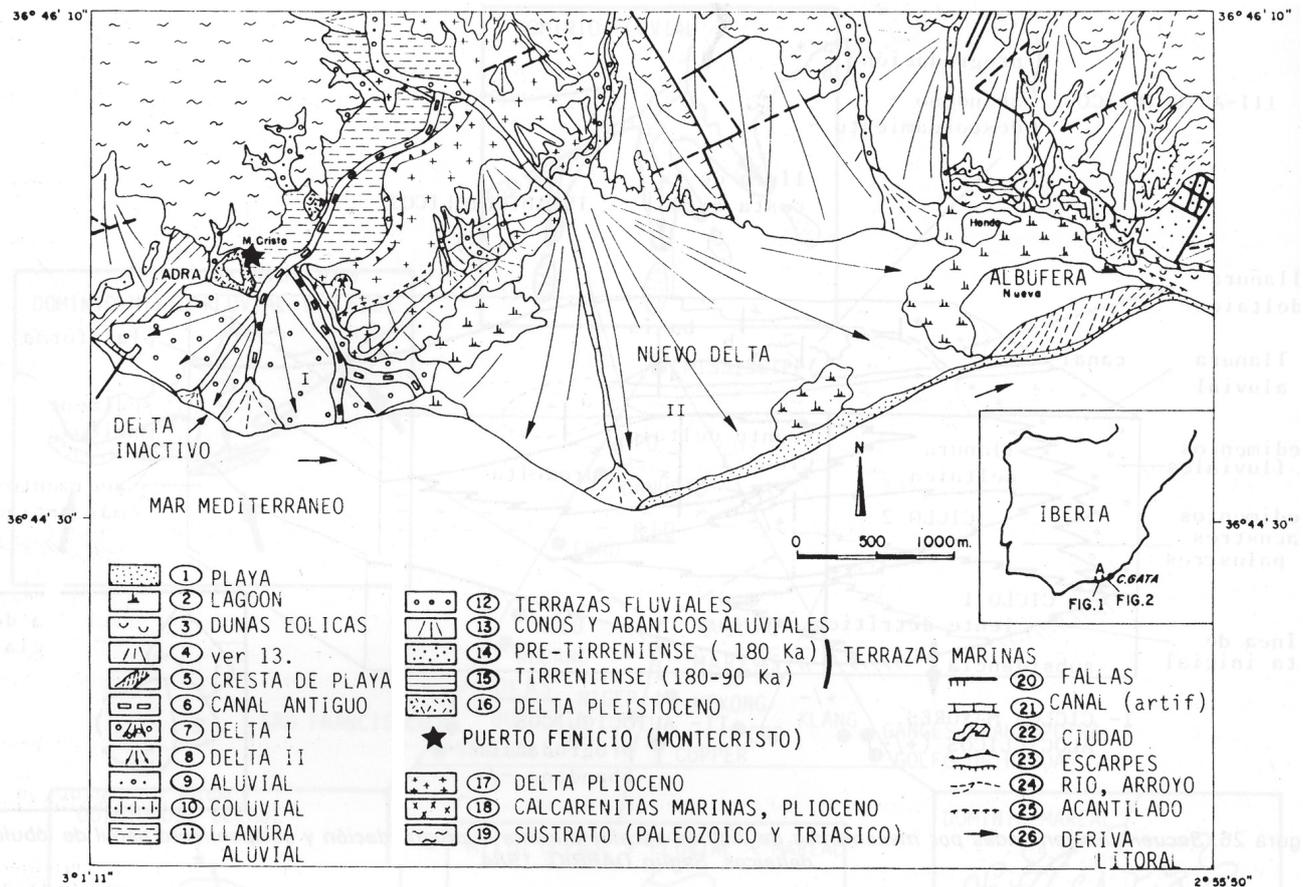




Figure 6. General view of one of the many Pleistocene marine terraces of the Campo de Dalías, formed by cemented conglomerate deposits of old beaches.



Above, detail of a Tirrenian (Late Pleistocene) marine terrace, with bioclasts including remains of the gastropod *Strombus bubonius*, indicative of warm waters (Senegalese fauna).

period (late Pleistocene) is represented by two terrace levels (Zazo and Goy, 2000). Their wide surface extension and good preservation allowed the analysis and dating of these Pleistocene marine levels with high paleoclimatic and paleoenvironmental interest.

The most complete sequence of sea terraces from the last interglacial period is in **Campo de Dalías** (Almería), where at least four terrace levels have been identified with remains of the gastropod *Strombus bubonius*, representative of the typical Senegalese warm-water fauna of the Tirrenian (Figure 6).

Absolute Th/U dating of these levels provides ages of 180,000, 125,000 and 95,000 years, with a less clear age for level IV. Similarly to the coasts of Almería and Murcia, the Tirrenian sea levels in the coasts of Malaga and Cadiz have been used as markers of the recent end-Pleistocene and Holocene vertical tectonic movements in the vicinity of the Strait of Gibraltar.

The low coastlands also create privileged areas to study the eustatic and environmental Holocene and historic changes. Sediment complexes have been identified in different places, formed by **coastal sandbars** and **coastal dunes** marking the evolution of the coast line in the last millennia, centuries or decades. These complexes are usually linked to **coastal sand spits** (Figure 7) whose progradation stages are recorded by more or less parallel sandbars .

The Andalusian Mediterranean coast has withstood progradation since the highest Holocene transgression, 6,500 years ago. This evolution is recorded by four coastal sandbars or beach crest systems extremely

well preserved in some areas (Roquetas, Almería). This kind of record is also identifiable in the coastal sandbars of the South-Atlantic coast (El Rompido, Punta Umbria, Doñana and Valdelagrana).

The **Doñana sand spit**, more than 25 km long and 5 km wide, is the biggest coastal complex in the Iberian Peninsula and one of the biggest in Europe. It is formed by a set of coastal spits created in the Holocene. Over the main sandbar body several big dune edifices are developed, both fossil and active (Figure 8). Protected by this complex are tidal plains linked to the evolution of the Guadalquivir estuary.

The Doñana sand spit shows four big coastal progradation stages between 6,500 and 500 years BP, separated by successive erosional stages. The complex became active around the Middle Pleistocene (Mindel-Riss interglacial), as a consequence of neotectonic activity and the diverse climatic and eustatic fluctuations. The sedimentary record of the Doñana tidal marsh is characterized by sands and muds more than 60m thick with abundant fossil remains which allow the detailed reconstruction of Holocene paleoclimatic, eustatic and environmental changes in the area. The Doñana sand spit underwent continuous progradation during the last 2,000 years at an average rate of 4m/year. This trend is currently decreasing.

In the Doñana tidal marshes, river and sea waters mix together, leading to very important hydrogeological effects on the aquifers and on the type and consequence of its exploitation. The area of Doñana was declared National Park (1969 and 1978) and has all the international recognitions for nature preservation.



Figure 7. Tómbolo sandbar of Trafalgar. The tómbolo is a coastal sandbar connecting an island to the mainland or to another island. They are formed by sedimentation of the sand dragged by waves when they are refracted around the island (photo by F. Moreno Sanz).

Figure 8. Coastal dunes of Doñana. Eolian dunes fixed by natural vegetation (photo by L. Carcavilla).



In the Mediterranean coastal bars and South-Atlantic sand spits there are some very well developed **aeolian dune accumulations**: El Saler (Valencia), Guardamar (Alicante), Doñana (Huelva). They include a record of the last 2000 years which has allowed the reconstruction of the historic aeolian phases of the Spanish South-Atlantic coast.

The biggest field of coastal dunes of the Spanish coast is found in the Doñana sand spit, with the biggest development in the area of El Abalarío, with up to five sequences of dune spits with ages corresponding to the last 18,000 years. There are also other big accumulations of coastal dunes, not directly linked to coastal sand spits but to the action of strong winds near the Strait of Gibraltar: dunes of Trafalgar, Bolonia, Valdeaqueros, Gibraltar, etc.

Finally, the Spanish low coastlands are also characterized by a high number of **lagoon and coastal wetlands** separated from the sea by sand barriers. The complexes of **sandbar-coastal lagoon** of the Mediterranean coast stand out, as they frequently present records reflecting a long geologic and geomorphologic history linked to eustatic oscillations and to diverse climatic and environmental changes.

The Levante (eastern peninsular) coast is formed by a big plain active since the Early Miocene as a subsident area. The coastal lagoons and their closing sandbars are the typical environments of these low coastland areas, whose evolution has caused the smoothing of

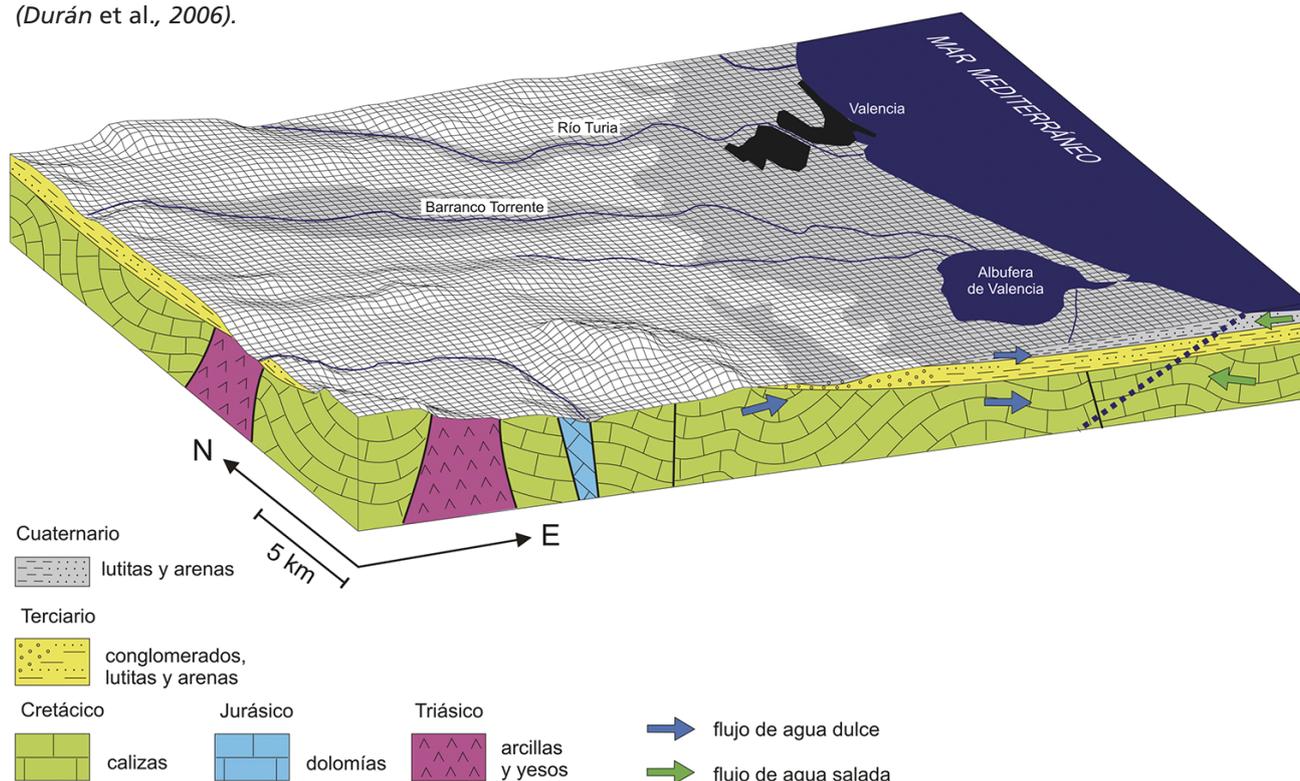
the coast line in the Gulf of Valencia. Most of the current lagoons formed during the maximum Holocene eustatic level, although several morphosedimentary remains from previous sandbars record successive tidal marshes during the Pleistocene and Holocene (Rosselló, 1995).

The **Valencia tidal lagoon** (Figure 9) is the most important one on the Levante coast, with an extension of 2,394 ha and a depth between 0.5 and 2.0 m. Its sandbar was formed after the highest Flandrian eustatic level, and extends along 30 km. Due to artificial filling works and the extension of rice plantations, the permanent wet surface of the Albufera has been historically reduced, and in the last 40 years the sedimentary filling rate has exceeded 3 mm/year.

The *restinga* or sandbar presents three *golas* or mouths, two of them artificial, regulating the lagoon level according to rice cultivation needs, which is the main use of the wetland. The natural closing of the *restinga* occurred 1,100 years ago, causing a change in the salinity regime of the lake.

Several well developed dune spits stand out in the littoral complex, as well as a marshland with a complicated environmental evolution in historical times due to human activity. The Albufera de Valencia is currently a Natural Park and part of the wetlands of international importance (RAMSAR) as well as a special protection zone for birds.

Figure 9. *Block diagram of the Albufera de Valencia and its geologic substrate* (Durán et al., 2006).



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