Evolution of the Iberian Peninsula Coast and Recent Climatic Changes: Port Facilities and Coastal Defence in the Muslim Domain

V. Esteban †; J. J. Díez ‡ and P. Fernández ∞


ABSTRACT


The present study describes the evolution of the coast in the recent quaternary era in the Iberian Peninsula. It analyses the historic cartography available and focuses mainly on the cartographic and documentary information referred to the port facilities in the 10th and 11th Centuries. It is studied in depth three Mediterranean places where the location of port facilities and watchtowers is well documented all andalusí history long: Málaga, Almería and Guardamar. In these three cases, the port facilities of the Muslim period were located in areas that subsequently have had generalized coastal accretions. These port facilities disappeared and the present ones are in new and different locations. It is also presented their relation to other documentary data, analysing the recent climatic changes, especially hydrologic and sedimentary processes. Finally, changes in the recent evolution of the coast are described.

ADDITIONAL INDEX WORDS: Quaternary.

INTRODUCTION

The crisis of the Roman Empire in the third century, the maritime activity and the population of the Mediterranean suffered from a wide period of decline and depression. In the year 711, Muslim troops crossed the Straits of Gibralta and settled down quickly in the Iberian Peninsula. The Arab conquerors and expansion occurred in a time of depressed economy and low level of urbanization and population.

A new Mediterranean order was established from the end of the 10th Century and especially throughout the 11th Century. The independent Emirate of Al-Andalus and the Caliphate of Cordova afterwards marked the acme of the Omeyes’ dynasty and the Arabic culture. Cordova became the centre of cultures and religions, whereas commerce, science, crafts and arts showed a great development.

Normans invaded the coasts of Al-Andalus, attacking Lisbon first and Cádiz and Seville later on. In the Mediterranean, they took possession of Algeciras and burned its Mosque, and sacked the hisn of Orihuela, reaching up to the Ródano afterwards. The naval development undertaken in Al-Andalus (MORALES, 1970; LIROLA, 1993) was induced by its difficulties in rejecting the Norman attacks. The Norman incursions generated the need for controlling the coast and developing a clear coastal defence policy by means of the settlements of ribats and watchtowers, and by constructing an important navy. The naval infrastructure was placed especially in sheltered areas or in those whose facilities permitted the performance of repair jobs.

The ships were built in port settings and facilities, called in Arab dar al-sina or dar al-sara, from which the word “arsenal” comes. In these settings, ships were built and repaired. They were located close to areas rich in wood or where it was easy to get it. Abd al-Rahmán II built many watchtowers (Figure 1) and a navy that confronted the Normans successfully.

In the first half of the 10th Century a real naval policy was carried out to contending for the control of the western Mediterranean. During this century, the economic prosperity, the urban splendor, and the industrial and commercial activity flourished based on the Islam political and military authority and on its commercial, economic and cultural power. The cities and their facilities near the sea are cited in many texts, and their locations are mapped and described in the Muslim literature.

RECENT AND LATE QUATERNARY CLIMATIC CHANGES

The process of global warming seems to have been more or less persistent and relatively fast since the last glaciation. It concerns 15000-30000 years, depending on different authors, though some of them extend it up. It must have suffered meaning fluctuations, in agreement with marine transgressions and regressions. Würm glaciation reached its top with an average temperature of about 5 °C degrees less than at present time. Late Paleolithic ends in Eurasia, ice retired and the warmer climate may have been the principal factor arising the Neolithic in the middle-east (around 11000 years before present). But the transgression decreased 8000 years ago, and could even stop.

Figure 1. Coastal defences, ribats and watchtowers, since the Arab rule is followed by a meaning regression during the cooler next 10th century to the 21st century.
millennium. A very stabilized, likely fluctuating, warmer “Atlantic” period, but still cooler than today, followed for nearly two millennia (emerging Indo-European peoples), before coming a new 2000 years cool period (subboreal) which rose golden Greek world. In the following increasingly warmer millennium the Roman empire emerged and died. The warmest moment of all this postglacial period seems to have happened about 5000 years ago, with 1°C degree approximately above current average temperature.

Consequently climatic changes along “human era” are fairly well known, though not totally well defined. Until recently, only “great changes” have been taken into account, assuming that climate (not weather) could be considered as a constant, for all practical purposes. From then on, other minor climatic changes are receiving increasing attention, particularly those having affected both protohistoric and, over all, historic times.

The generally assumed relation between the carbon dioxide emission rates and some present climatic changes, through the “greenhouse effect”, has led to the meaning perception of the climate variability and its impacts on environment and other human life conditions. And although special alarm was produced by its effect on sea level rise rates, it also drew to the “climatic determination” of the History. Little Ice Ages and genial warm periods in the past have been noticed from literary and other artistic descriptions (LAMB, 1982), but they are being analyzed and quantified now in a more accurate and comprehensive way.

SEA LEVEL CHANGES

The marine transgression has followed the climate evolution as a general rule, with its minor fluctuations, though modified by other isostatic and sedimentary factors; as a matter of fact the sea level has been named used to approximate the quaternary climatic changes. According to Sivan the transgression attenuated in Calcolithic (10000-7000 before present, approximately), and the Flandriense transgression could likely reach its top between 5000 and 3000 years ago, with between 2 and 4 meters above present sea level, falling down until 1 meter under present sea level 2000 years ago.

Close after the first millennium Netherlander Frisia required some shore protection, what might indicate the beginning of a marine transgression (corresponding to the “little climatic optimum”) whose last episode (the last but one of the more comprehensive Flandriense transgression), the Dunquerquian, begun in the 13th Century. On the contrary, a very important generation of “polders” (Beemster, Purmer, Vermur, Shermer) was dried in The Netherlands along and Centuries, beginning a “flood plain” (Beemster, Purmer, Vermur, Shermer) was dried in The Netherlands along 16th and 17th Centuries, taking advantage of the strong regression during the “little ice age”. The average temperature must have decreased rather more than 1°C degree in that period, since it was enough to induce not only volumetric changes (as in the top of Holocene very principally happened, with 1°C degree) but also an important eustatism.

COASTAL MORPHODYNAMICS CHANGES

Shoreline movements, coastal erosions and accretions related to them, are related to sea level changes. Although obvious, the climatic influence on sea level changes has only recently been emphasized in short term analysis, and related to current a) increasing carbon dioxide emissions and rates, b) warmer climate and c) sea level rise. On the other hand, the well-known influence of maritime climate on coastal morphology and morphodynamics appears not to have been fully considered until recently: longshore and onshore-offshore littoral transports, erosive and sedimentary processes and genesis and migration of barrier islands and other forms of sedimentary deposits has been more or less widely studied, though primarily in relationship with current environmental impacts; however, other longer term morphodynamics and pattern changes seem not to have been so extensively considered.

The little Ice Age had practically concluded in the middle of the 18th Century, when the first detailed maps and charts were available. A certain historical determinism seems to relate cooler periods with emergence and domination of nations from Mediterranean and southern and/or lower lands, whilst warmth carried nations on from northern and/or higher areas. The cold of the former “Middle Age” flourished the Mediterranean societies up to the establishing of Muslim and roman-Germanic empires. And the new warmth of the later Middle Age (“little climatic optimum”, 1000-1450) led to their decadence, the emergence of Hansa, the Romanic and Gothic artistic periods and the expansion of wikings. The beginning of the episode known as “little ice age” is widely placed around 1450; the life conditions hardened in all central and northern Europe, becoming extremely cold and dry except in its west end, softened by the Gulf Stream, and have been showed in contemporary documents (LAMB,1975); on the contrary they were mild around the Mediterranean, becoming even wetter (in agreement with the hypotheses of African “pluvial” coinciding with glacial episodes, wealthier and much healthier (decreasing the epidemics, so frequent in the previous period), what led to the “Renaissances”-Christian and Islamic- and permitted the Otman and Spanish empires to establish, among many other meaning events which characterize the Modern Age. The coldness must have been very significant to permit the increase of ice surface in the polar and mountainous areas.

We must notice that transgression and regression movements are not the only climatic effect on littoral morphology. A primary characteristic of the climate is the average and extreme latitudes of the extra tropical cyclones paths. It affects the fetch and, consequently, the effective direction of the wind waves causing littoral processes. If the “answering inertia” of a coastal stretch is under a certain value (barrier islands, pocket beaches) it can changes both in plant and its orientation, becoming more perpendicular to the climatic average wind wave direction (Diez et al., 1986, 1988; Diez, 2000). But also rainfall conditions are relevant to consider different rates of sediments that reach the shoreline.

Figure 2. Map (1696) of the Almería coastal area.
COASTAL FACILITIES IN THE IBERIAN PENINSULA IN THE MUSLIM DOMAIN AND CLIMATIC CHANGES

Since the end of the 10th Century to the 12th Century cities development in the Iberian Peninsula in the coastal areas were related to special economic conditions. The navigation was mainly related to war confrontations. In this period the numerous port facilities and the appearance of the cities (madinas) indicate the intense maritime and commercial relation between the Atlantic littoral of Al-Andalus and the Maghreb. Cities with port facilities are known because they are described in the literature, especially by Arabs geographers. At a time coastal defense is organized by constructing watchtowers and coastal defense settlements, the so called ribats. In the Mediterranean coastal area of the Iberian Peninsula one of the most important ribat was located in Guardamar. This place is located in the mouth of the river Segura. Archeological excavations found nineteen years ago the whole structures of the ribat, covered by an important dune field that was stabilized in the early 20th Century. River Segura was navigable in the 10th Century (Morales, 1970). Ribat was found 280 meters inland from the current shoreline. It means the coastal accretion since that time.

Other coastal facilities were located in the southern part of the Peninsula: Silves, Santa Maria del Algarbe, Saltés, Cádiz, Seville, Algeciras (near the Strait of Gibraltar), Málaga, Almuñécar and Almería (Figure 1). Almería is one of the most important of them. Development of the Almería port facility were carried out along the 10th Century, becoming the most important port in the Muslim Mediterranean area in the 12th Century. Initially it was located in Pechina, 6 miles upstream the Almería river mouth. The river in this period has perfect navigable conditions, as the Figure 2 shows. After that, in the 14th Century (Morales, 1970) Almería arsenal and general port facilities had to be moved to the coastal area due to general siltation in the river mouth. In the Malaga port similar conditions are described. Climatic changes can be considered to explain the general coastal accretion, due to the sediments transport rates increase arriving to the coastal areas in the Iberian Peninsula in the period between 10th and 12th Centuries. After that the situation shows (Figure 3) the Almería river mouth with a relevant deltaic formation.

Results of the work done by the National Institute for the Conservation of Nature (MIMAM, 2003) using the U.S.L.E. equation can be apply over the three areas of study giving us the erosion due upstream each one of the two of three coast areas in tons per hectare and year: 27.06 in Almería (Figure 3), 71.46 in Malaga. To this two first values we must compute the sediment delivery ratio, that can be about 11%. For the last one, Guardamar, we take the data from the main reservoir in the area that cover the main area: 4.17 tons per hectare and year.

These results are associated with a rainfall erosivity factor, R, 60 for Almería, 120 for Malaga and 220 for Guardamar (ICONA, 1988). They were estimated for each area as a linear function of the Maximum daily rainfall with a two year return period, the inter annual average rainfall of the most rainfall month of each year and a zonification factor, by using the following equation:

$$ R = 2,375 + 0,513 \times PD2 - 94,4 \times PMEX - 89,8 \times Z4 $$

$PD2$: Maximum daily rainfall with a two year return period.
$PMEX$: Interannual average rainfall of the most rainfall month of each year.
$Z4$: Zonification factor.

Period between 10th and 12th Centuries is known as an optimum climatic in the Iberian Peninsula. It can be considered warmer and more humid than today average. There is not still a consensus about how much high was this warmer and this increase in the precipitation.

An increase on the rain of 1% translates to the R factor an Increase of 0.5%. If we consider that the study period was about 9% more humid in the more rainy month, the increase in the U.S.L.E. values had been 4.5% higher with the same values for the rest of parameters.

Figure 3. Almería river basin and coastal area showing deltaic formation in the mouth.
CONCLUSIONS

Evolution of the coastline in the recent period has been described. General coastal accretion is described between the 10th and 12th Centuries. This period has to be considered as an optimum climatic in the Iberian Peninsula. It was warmer and more humid than today. Historic cartography available has been analysed, as well as documentary information referred to the Muslim port facilities in the southern part of the Iberian Peninsula. Three Mediterranean places where the location of port facilities and watchtowers is well documented through all Andalusi history long have been studied in depth: Málaga, Almería and Guardamar.

Guardamar ribat is found 280 meters inland from the current shoreline. It means the coastal accretion since that time.

The natural siltation also increases in the Almeria river mouth in this period. In Almeria the deltaic evolution of the former estuary has led to the shoreline advance. Port facilities, initially located 6 miles upstream the Almeria river mouth, had to be moved to a coastal location. It has a great morphodynamic meaning. Similar changes and effects in the Málaga port are described.

In the three cases port facilities of the Muslim period were located in areas with generalized coastal accretions. Those port facilities so subsequently disappeared and the present ones are in new and different whereabouts. Changes have to be related to climatic changes with more capability for sediment transport rates, which is consistent with warmer climate conditions. Relation to other documentary data, analysing changes in the hydrologic and sedimentary processes has been also studied and described.

LITERATURE CITED


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