Holocene Coastline Shifts at the Mediterranean Coast of Andalucia (SE Spain)

Dr. Gerd Hoffmann, Institute for Baltic Sea Research (IOW), Seest. 15, 0-2330 Warnemünde

Abstract

The stratigraphy of Holocene sediments in the valleys of the Mediterranean coast of Andalucia was investigated in a joint program with the German Archaeological Institute Madrid.

The results of the investigations showed a marine transgression into the valleys of this coast in the early Holocene. The marine sediments of the valleys prove a relatively constant sedimentation with a rate of 1 to 2 m per millenium until the end of the 15th century A.D.. After the period of Reconquista, when the catholic Kings of Spain expelled the Arabs from the southern part of the Iberian Peninsula, an enormous increase in the accumulation rate was caused by the deforestation of the hinterland. These sediments of the 16th and 17th centuries mostly have a thickness of up to 20 meters. During this time the valleys were filled up with the eroded soils of the hinterland.

The dominant geomorphological factor for this evolution of landscape was man, supported by a wetter and cooler climate and an increase of torrential rainfalls during the Little Ice Age (1500 - 1750 A.D.).

During this time the rivers of Rio Andarax, Rio Adra, Rio Guadalféo and Rio Velez also developed deltas and coastal plains, where nowadays erosional processes can be observed. They are originated by the coastal, W-E directed "Gibraltar-current". Other reasons for this erosion also are coastal constructions like the harbour of Motril and the missing sediment supply from the hinterland due to the canalisation of the river beds and due to the construction of artificial lakes and dams.

Introduction

In an interdisciplinary project with the German Archaeological Institute Madrid the stratigraphy of Holocene sediments in the valleys of the Mediterranean coast of Andalucia (Fig. 1) was investigated.

The aim of this cooperation between Geology and Archaeology was the investigation of human settlements and the reconstruction of the ecological environment of this area, especially in historical times. A particular interest of this project is the evolution of coastlines during the Holocene period (Arteaga, Hoffmann, Schubart & Schulz, 1988).
Study area

The Mediterranean coast of Andalucia is situated south of the Betic Cordillere, the westernmost alpidic mountains of Europe. The highest elevation of the Iberian Peninsula, the Mulhacen with an altitude of 3481 m height is only 35 km away from this coast. Hence there are steep gradients particularly in the central part of the investigated area.

Climatically there are arid until extremely arid conditions close to the coast and humid conditions in the hinterland. The torrential rainfalls are of particular interest for erosional processes. In the easternmost part of the area with normally 220 mm/year rainfall have been measured 300 mm in 36 hours in October 1973.

The area of investigation is situated between the Rio Almanzora (Province of Almeria) in the east and the Rio Guadarranque (Province of Cadiz) in the west (Figs. 1 and 2). The results presented here are of the valleys of Rio Andarax and of Rio Guadalfeo (Figs. 2, 5 and 6).

Investigation of Holocene sediments

For the investigation of the sediments more than 450 drillings with a hand auger of Eijkelkamp Company (Netherlands, Fig. 9) were carried out. With the mostly used auger bits of 10 cm diameter a maximal depth of 19,50 m was reached (Fig. 7).

The grain size of the Holocene sediments in the investigation area was mostly a sandy silt or a clayish silt. Only a small quantity of the drilled sediment represented fine until coarse sand, gravel or stones.

The most striking macroscopic feature of the sediments is that at a certain depth close to the recent water level the colour of the sediments changes from brown to bluish grey. The colour shows the oxidation state of the iron: the brown colour testifies an oxidated, terrestrial environment and the bluish grey colour an aquatic environment.

Some of the drilling profiles, drawn in relation to the recent sea level, are shown in Fig. 8. Most of the bluish grey sediments have been investigated micropalaeontologically. Many marine and brackish microfossils have been found. These sediments are proof of marine or brackish bays of Holocene age, which had been filled up and covered by brownish flood plain deposits of the different rivers (Figs. 5-8; Hoffmann, 1988). Also the still submarine parts of the pleistocene valleys are filled up with Holocene sediments. Beside of Rio Antas only the submarine valley of Rio Guadalfeo can still be followed by the isobaths (Fig. 4).
Dating methods

Two methods of dating the Holocene sediments were used:  
- the Radiocarbon method and  
- the dating with ceramic fragments

The importance of dating the Holocene sediments by artefacts must be emphasized, especially in connection with the reconstruction of the ancient landscape. Dating with this method is usually not only more exact than Radiocarbon dating, but the lack of organic material in the sediments of the Mediterranean valleys in this area underlines its importance. For saving the ceramic fragments it was necessary to use the auger bits with the diameter of 10 cm.

For better understanding of the landscape evolution also results of archaeological excavations and historical maps (Figs. 2 and 5) have been used. Comparing Figs. 5 and 6 it is striking, that in 1759 Rio Andarax had not yet built a delta.

Summary

Brackish until marine bays of the Mediterranean coast of Andalucia, flooded about 6000 y.b.P. (Fig. 3), still existed in the late Middle Ages. The origin of coastline change are erosional processes in the hinterland and accumulation of the ancient soils in the coastal zone.

This enormous erosion in the late Middle Ages has the following origins (Hoffmann, 1988):  
- deforestation of the hinterland during the expulsion of the Arabs by the Catholic Kings of Spain  
- installation of a non-adapted agriculture particularly in the terraces of the Arabs  
- increasing shipbuilding- (discovery of America) and mining activities  
- foundation of the "mesta"-organisation of goat breeders  
- little glaciation with a colder and wetter climate and a higher amount of torrential rainfall (Lopez Vera, 1986)  
- the influence of anthropogenic activities in the mediterranean subtropics is increased by its border situation between the evergreen forests and the steppe (ROTHER 1984).

To separate anthropogeneous and natural factors the peat profiles, found during this project, should be investigated. Up to now there are only very sparse climatic informations of this coastal region, mostly deriving from botanical investigations of archeological excavations.

Recently erosional processes are noted on all the deltas and coastal plains of the mediterranean coast of Andalucia:  
- Rio Andarax and Campo de Dalias (Almeria)  
- Rio Grande de Adra and Campo de Dalias (Almeria)  
- Rio Guadalfeo and Llanos de Carchuna  
- Rio Velez and coastal plain of Torre del Mar (Malaga)
The origins of the coastal retreat are the following (Drescher & Hoffmann, 1991, Drescher, 1988):
- nearly all the soils of the hinterland have been eroded at the end of Middle Ages, hence a change in the water-household of the rivers took place. Today the soil erosion is accelerated by modern terracing activities with big machines without any protection of the slopes.
- nearly all bigger rivers are canalized and in their upper course have been built artificial lakes, dams and irrigation canals to avoid catastrophes during torrential rainfalls. Hence the suspended material of the rivers, eroded specially during these torrential rainfalls, sedimentate in the artificial lakes upstream or in the Mediterranean, but not on the flood plains. Here it has to be pointed out, that the support of silty and clayish flood plain deposits are also the origin of the fertility of the coastal plains.
- the West-East directed coastal current, so called "Gibraltar current", is the active erosional factor, because Erosion on the above mentioned deltas and coastal plains is noted only on their western side. In former times the erosion by this coastal current was balanced by the accumulation of the old soils of the hinterland.
- and by man’s constructions at the coastline like the harbour of Motril (Fig. 4).

References


Acknowledgements
I like to thank all colleagues of the Geological Institutes in Kiel and Bremen, of the German Archeological Institute Madrid and of the different Institutes in Sevilla, Granada, Malaga, Almeria and Madrid for their help.
The investigation was supported by the Volkswagen Foundation.

Fig. 1: Area of investigation at the Iberian Peninsula
Fig. 1: Area of investigation at the Iberian Peninsula
Fig. 3: Holocene sea-level curve (Hopley 1978)

Fig. 4: Valley of Rio Guadalfeo (Fig. 2). The arrow marks the submarine part of the valley.
Fig. 5: Valley of Río Andarax
(Historical map of 1759)

Fig. 6: Valley of Río Andarax
(Topographical map of 1971)
Fig. 7: Sediment columns of hand drillings
Fig. 9: Hand auger (Eijkelkamp company)

Fig. 10: Peat profiles (age in y.B.P.)
Fig. 8: Landscape evolution of Rio Andarax valley
(a: 6000 y.B.P., b: 230 y.B.P., c: recent situation)