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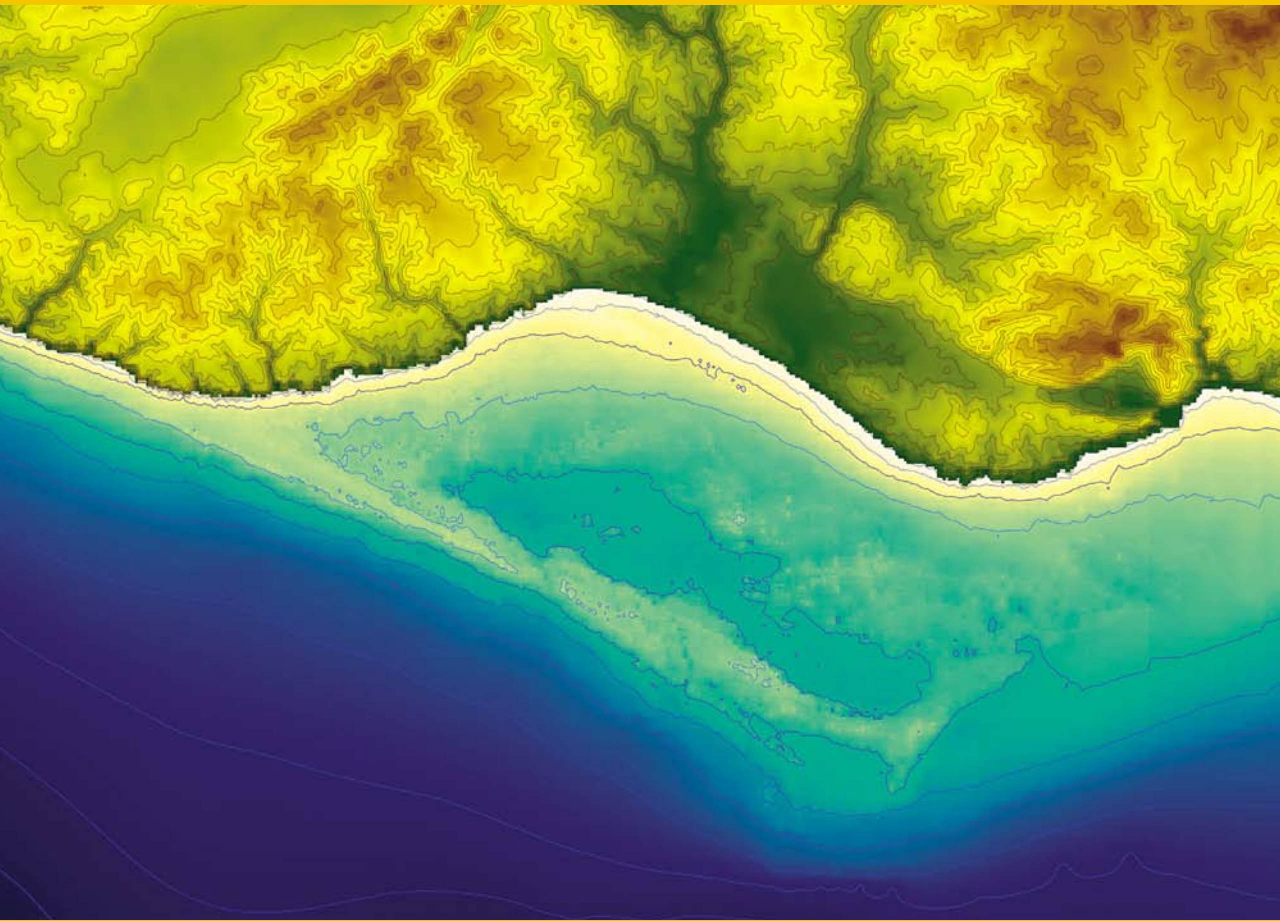

ENVIRONMENTAL CHANGES AND HUMAN
INTERACTION ALONG THE WESTERN ATLANTIC EDGE

MUDANÇAS AMBIENTAIS E INTERAÇÃO HUMANA
NA FACHADA ATLÂNTICA OCIDENTAL

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Eds. A. Campar Almeida, Ana M. S. Bettencourt, D. Moura, Sérgio Monteiro-Rodrigues and Maria Isabel Caetano Alves

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Cover image: Digital terrain model of the Armação de Pêra, Algarve, Portugal (by Leandro Infantini)

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A. Campar Almeida, Ana M. S. Bettencourt,
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Environmental changes and human interaction along the western atlantic edge

Mudanças ambientais e interação humana na fachada atlântica ocidental

2012

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FOREWORD

This book is part of the project on Paleoenvironmental Changes and Anthropisation in the Quaternary of Western Iberia, a study carried out in 2010-2011 by the Portuguese Association for Quaternary Research (*APEQ*). The aim of the project was to bring together a number of research efforts leading to an explanation of environmental changes during the Quaternary, of how human communites responded to those changes, and of the role played by man in altering the landscape of the Western part of the Iberian Peninsula.

The present publication is a follow up to *Paleoenvironmental Changes and Anthropisation in the Quaternary of Western Iberia*, first published in 2010, although this time the geographical scope has been expanded to include the Western Atlantic edge and thus put the Iberian Peninsula in a wider research perspective.

For the most part the articles in this book are based on the papers first presented at "IV Jornadas do Quaternário" / 1st International Conference: Environmental Changes and Human Interaction Along the Western Atlantic Façade, held at the University of Coimbra in 9-10 December 2011.

Coming from a variety of universities and research centres in Portugal, Spain, Scotland, Switzerland, Morocco, Angola and Brazil, the authors of these studies belong to different scientific areas, from geophysics to geology to geography, archaeology and biology, thus reflecting the multidisciplinary nature of Quaternary studies.

The articles are divided into five thematic sections, according to the research interests of the authors involved.

Part I is devoted to methodological issues and opens with Philippa Ascough's article. Ascough's topical theme deals with the need to be cautious when using C14 for absolute ratings of marine samples or man-related remains, as they appear to be older than their terrestrial counterparts. What we have here is the marine reservoir effect (MRE). In the next article, António Monge Soares and his collaborators show how radiocarbon dating carried out in Portugal allowed them to determine the age of a number of apparently contemporary consolidated dunes, dating from somewhere between the last interstadial and the early Holocene. In their study, Ana Gomes, Tomasz Boski and Delminda Moura use the specificity of diatom communities in terms of ecological preferences to carry out paleoenvironmental reconstructions in the Guadiana estuary (S of Portugal) during the Holocene.

Part II is made up of articles on paleoenvironmental change and human activity. Based on their interdisciplinary study of sedimentary deposits found in the archaeological area of Campo Lameiro (Pontevedra, NW of Spain), Manuela Costa Casais and her team offer a model of Holocene environmental evolution. Their findings confirm the occurrence of significant erosion/sedimentation processes starting in the Younger Dryas and throughout the Holocene. According to the authors, some of the discontinuities found in Holocene colluvia coincide with abrupt climate events known to have occurred in the past 10,000 years, namely the 8.2 ka event, the beginning of Neoglaciation, and the 2.8 ka event. But since at least the Neolithic period, human intervention in the landscape must have played an important role in the way the landscape evolved, sometimes with far greater repercussions than those caused by natural phenomena. Alexandre Trindade, Gonçalo Vieira and C. Schaefer used the micromorphology of sediments and of soil slopes to come to a better understanding of their morphogenetic significance and thus arrive at a chronological framework of the late Quaternary in Serra da Estrela (Portugal). Using isotope datings and marine records, C. Muñoz-Sobrino, L. Gomez-Orellana and P. Ramil-Rego draw correlations between pollen sequences that help us understand the regional migration of plant species in the western end of the Cantabrian range (North of Spain) during the Post-glacial. From their pollen analysis of coastal wetlands in northwestern Iberia, L. Gomez-Orellana, P. Ramil-Rego and C. Muñoz-Sobrino derive the conclusion that between 100,000 and 32,000 BP there were conifers alongside temperate deciduous trees on the coast of northwestern Iberia, a region that served as a refuge for mesophilic and thermophilic species. Based on the study of charcoals found in a marsh, João Araújo and his colleagues offer a variation of Serra da Estrela (Portugal) vegetation dating from the end of the last glacial and the Holocene. The authors noticed that this higher concentration of charcoal was concurrent with deforestation between 3,000 and 900 BP. The paleobotanical study of Chalcolithic and Bronze Age sites located in northwestern Iberia, presented in the article by M. Seijo-Martín and his collaborators, uses the logic of operational chains as applied to the exploitation of wood resources. Using this method, the authors attempt to characterise the various stages of this particular activity – from the procurement of timber to its end use –, and from there they proceed to make inferences of a paleotechnological and paleoethnological nature. Their results show a broad-spectrum strategy for procuring firewood and timber, through the use of the resources available in the various landscape units around the habitats: climax forests, brushwood and riparian zones.

Part III covers both the fauna and human activity, *i.e.*, the ways in which humans have used a number of wildlife resources. Mariana Diniz and Pablo Arias's work on the Mesolithic shell middens of Portugal's Sado river aims, among other things, to draw attention to the specificities of these prehistoric sites. For although it is broadly possible to include them in *a typically Euro-Atlantic culturescape* to which the Muge shell middens also belong, there are certain peculiarities that have to be taken into account if one is to build an explanatory model of regional Mesolithic settlement. More specifically, the authors believe that the analysis of these peculiarities may help assess the exact extent to which ecological and cultural factors determined how Mesolithic communities came to choose this territory. While also dealing with Mesolithic shell middens, the study carried out by Rita D. S. Dias and her team focuses on Muge (Portugal) and their article discusses the consequences of the use of spatial distribution models at Cabeço da Amoreira. Their methodology aims at identifying concentrations of artifacts and ecofacts, establishing relationships between lithic materials and osteological remains, and obtaining data on the site formation processes. Olivia Figueiredo, on the other hand, gives us a state-of-the-art type of review on the burial practices identified in Muge's diverse mounds. According to the author, there is ample evidence of the fact that the approximately three hundred skeletons found in Muge were actually the object of intentional, albeit nonstandard, burials. In the context of a much later chronological framework, Cleia Detry and Ana Margarida Arruda sought to identify the causes of the decrease of cockle (Cerastoderma edule) remains and the increase in grooved carpet shell clam (Ruditapes decussatus) and mussel (Mytilus edulis) remains at Monte Molião (Lagos, Portugal) during its Roman occupation. The findings suggest that the variation may be due to environmental changes caused by some sudden, brief event such as a storm or tsunami, leading to the disruption of this cockle-rich estuarine ecosystem. While giving this hypothesis its due, the authors do not rule out the possibility that the changes in the frequency of these molluscs were caused by habit changes with regard to the exploitation of water resources. This study also led to a dietary reconstruction of the inhabitants of Monte Molião.

In Part IV, devoted to mining and its impact on the environment, Nuno Inácio and his collaborators assess the environmental impact of copper mining and metallurgy in the Huelva region (Sw of Spain) in the third millennium BC. Palynological data, chemical analyses of sediments and other biomarkers of the Guadiana, Tinto, Odiel and Guadalquivir drainage basins for the period in question point to severe deforestation with consequent soil erosion as well as land and water contamination by various heavy metals. Based on these impacts, the authors suggest the possibility of copper mining and metallurgy as a specialised activity in the 3rd millennium BC. The Chalcolithic period is also the focus of the research carried out by Patricia Jordan and Nuno Pimentel, who submit a model for the management and movement of lithic resources, namely flint, in the Nazareth-Peniche region (central Portugal). Methodologically, this model derived from the petroarchaeological approach used for the Village of S. Mamede (Óbidos), which in turn resorted, among other things, to petrographic analyses and to studies based on lithic technology.

Part V deals with coastal evolution in four different geographical areas: the Algarve (SW of Iberian Peninsula), Galicia (NW of Iberian Peninsula), Morocco (NW of Africa) and Angola (West Africa). As far as the Algarve is concerned, Delminda Moura, Ana Gomes, Selma Gabriel and J. Horta discuss the relationship between the mean sea level and the coastline and how that relationship is reflected in terms of archaeological finds. L. Infantini, on the other hand, shows the occurrence and probable dynamics of an immersed lagoonal form in the Armação de Pêra bay (Algarve). J. M. García-Rey and X. Vilaseco Vasquez analyse the loss of sand on an island in the ria de Arousa (Galicia) to study its archaeological sites and trace the island's evolution throughout the Quaternary. Pedro Dinis and his colleagues seek to explain the sedimentary dynamics of two river deltas near Benguela, in Angola, an area marked by a sharp seasonal contrast. Finally, El Khalidi, B. Zourarah and A. Aajjane use sequential analysis of aerial photos as well as a geographical information system to explain landscape and coastline changes on a stretch of the Moroccan coastline.

This book is thus the materialisation of APEQ's goals as expressed in the above-mentioned project and in the Association's activity over a two-year period.

A. Campar de Almeida, Ana M. S. Bettencourt,
D. Moura, Sérgio Monteiro-Rodrigues & Maria Isabel Caetano Alves

MEAN SEA LEVEL AND COASTLINE-LATE QUATERNARY

D. Moura[1], A. Gomes, S. Gabriel & J. Horta

Resumo: As zonas costeiras evoluíram ao longo do tempo geológico em consequência da actividade tectónica, das alterações climáticas e das variações do nível médio do mar. Assim, vastas porções das plataformas continentais presentemente submersas, podem potencialmente preservar informação relevante para a reconstituição do paleo clima e das variáveis oceanográficas. Durante as regressões marinhas forçadas pelo sequestro da água na forma de gelo sobre os continentes, a linha de costa migrou no sentido do oceano. As redes de drenagem prologavam-se em direcção ao bordo continental e, na plataforma continental exposta a ventos fortes favorecidos pela degradação da vegetação, geraram-se campos dunares. Pelo contrário, durante as transgressões, a linha de costa migrou no sentido do continente submergindo as paisagens desenvolvidas na plataforma continental. A preservação de aspectos morfológicos como por exemplo, praias, dunas e restingas arenosas, dependeu dos processos morfodinâmicos, sendo os mais importantes as correntes e as ondas. A relação entre a linha de costa e o nível médio do mar, bem como, as variáveis ambientais envolvidas na preservação ou erosão das paisagens intermitentemente submersas e emersas, são aspectos discutidos no presente trabalho.

Palavras-chave: Quaternário; Plataforma continental; Nível médio do mar; Linha de costa.

Abstract: Coastal zones modified along the geological time forced by tectonic activity, climatic and mean sea level changes and thereby can preserve relevant information concerning past climatic and oceanographic conditions. During lowstands derived by glacial conditions, the coastline migrated seaward and, wide portions of the continental shelves where exposed to sub aerial evolution, the drainage net extended far away in the shelf and dune fields overspread favoured by dry cold conditions and vegetation scarcity. In contrast, during deglatiations, the mean sea level rose forcing the landward migration of the coastline leading to the landscapes submersion. The preservation of morphological features such as beaches, dunes and spit bars depended on several environmental variables and processes, such as, erosion, remobilization by currents, waves and mass movements and sedimentary burial. The relationship between the coastline and the mean sea level evolution along the Quaternary, as well as the environmental variables on the landscape preservation and remobilization are under discussion in this work.

Key-words: Quaternary; Continental shelf; Mean sea level; Coastline.

1. INTRODUCTION

The Quaternary is the most recent Geological Period of the Cenozoic Era and is divided in two Epochs: Pleistocene and Holocene. The age of the Pliocene – Pleistocene Boundary (PPB) has been successively adjusted because that boundary should be coincident with

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the onset of glaciations in the North Hemisphere (NH), as defined by the Commission for the Plio-Pleistocene Boundary (Aguirre & Pasini 1985). The first PPB was fixed at 1.8 Ma having as principal assumption that the cold fauna appearance at the Calabrian Basin should represent a phase of extreme global cooling. However, once the decrease of temperature and fauna migrations is neither synchronous nor equal-magnitude at the global scale, that assumption raised several problems on stratigraphic correlations. Currently, the PPB is positioned at 2.6 Ma as proposed in 2007 by the International Union of Quaternary Research (INQUA). Accordingly, The Quaternary Period contains the Gelasian Age previously bellowing to the Pliocene. This decision was supported by the climatic proxies pointing to the occurrence of full glacial conditions at the NH between 3.0 and 2.7 Ma (e.g., Sarnthein *et al.* 2009, Anadón *et al.* 2002, Leroy & Dupont 1996). Changes between forest and steppe according the high-frequency climatic changes that characterizes the Quaternary Period, started at 2.6 Ma at the Iberian Peninsula (Jiménez-Moreno *et al.* 2009). Additionally, the 2.6 Ma PPB shows the advantage of being a synchronous event that is the geopolarity reversal Gauss-Matuyama. The Quaternary Period characterizes by high frequency and high-magnitude climatic changes as showed by the marine isotopic stratigraphy. After 2.6 Ma, 104 Marine Isotopic Stages (MIS) compose several warm-cold cycles. The Last Glacial Period (LGP) contains the MIS 4, 3 and 2. The MIS 3 previously assumed as a warm phase, is now accepted as a transitional phase of extreme climatic instability (Bard 2002) and, therefore, bellowing to the LGP together with MIS 4 and 2 (Meerbeeck *et al.* 2009), during which surface water temperature at the Iberian Margin was between 5 and 12ºC lower than the current one (Abreu *et al.* 2003).

2. MEAN SEA LEVEL

The relative mean sea level (rmsl) is the balance between the ocean basin capacity and the quantity of water, mass water density and oceanic currents. Basins capacity is controlled by tectonics whereas the quantity of water depends mainly on the quantity of ice accumulated in the mainland.

2.1.Upper Pleistocene

Unfortunately, data concerning the rmsl during the MIS 3 (60-27 kyr ago) is scarce in a general way and particularly in the Atlantic Iberian Margin. Around 30 ka, the mean sea level was located about 20 m below the current one at the Cadiz Gulf as testified by beach deposits (Gracia *et al.* 2008). By the end of the Last Glacial Period, an extreme cold event named Last Glacial Maximum (LGM) at 18 kyr BP occurred. During the LGM the rmsl was much lower than the present, ca. 120 to 140 m below the current one (e.g. Dias *et al.* 2000) and, the Atlantic Iberian continental shelf which shelf breaks locates between 120 and 160 m below the water surface, was almost completely emerged. During the LGM lowstand, fresh water at the continental shelf provided by rivers, lakes and seeps must have been of fundamental importance for Human occupation, similarly to the present at the continental areas. Whereas fresh water tables felt at the continental areas as a consequence of msl fall and aridity, its availability increased on the emerged shelf providing coastal oasis (Faure *et al.* 2002). After the LGM, the ice locked on the continental areas began to melt and, as a consequence, the continental shelves began to flood. Between 16 and 13 kyr, msl stabilized at -100 m (Ruddiman & McIntyre 1981). An important cold phase occurred at 11.5 kyr BP-Younger Dryas, due to intense melt waters influx in the Atlantic, leads a new phase of rivers renewed – higher erosional capacity once msl was ca. -40 m below the present. This phase is recorded in the W continental shelf by coarse sediments (Cascalho *et al.* 1994). After the Younger Dryas, the rate of sea level rise was very high during the early Holocene.

2.2. Holocene

The mean sea level (msl) curves for the Holocene are highly variable between different regions seeming that local causes superimpose the eustatic signal. The behaviour of the msl since the LGM is still under debate being far from a global curve. However, authors agree in two points: (i) the Holocene maximum flood was between 6 500 – 5 000 yr BP and, (ii) the rate of the msl rise was faster during the first phase of the Holocene transgression than after the maximum flood (e.g., Fairbanks 1989; Fleming *et al.* 1998; Gehrels 1999; Dabrio *et al.* 2000; Belperio *et al.* 2002; Boski *et al.* 2002; Vött 2007; Zazo *et al.* 2008; Engel *et al.* 2009; Bungenstock & Schäfer 2009). The deglaciation after the LGM was essentially completed by 6000 years ago but sea level went goes changing due to isostatic adjustments even on far field regions where should be expectable a sea level fall due to redistribution of the water in the ocean basins (Peltier 1999). Besides several other authors reported a rmsl above the present one, they concluded that was due to local causes such as crustal movements and elastic rebound or other local processes among them changes in the sedimentary budget, morphological changes or climatic conditions (e.g., Warne & Stanley 1995; Mörner 1999; Li *et al.* 2000; Belperio *et al.* 2002; Razjigaeva *et al.* 2004; Shennan *et al.* 2005; Bungenstock & Schäfer 2009; Schellmann & Radtke 2010). A third scenario was reported by a few authors that describe the existence of local rmsl oscillations inside the present highstand being this effect due to climatic changes, elastic rebound-isostatic uplift and sediment supply (Mörner 1999; Fernández-Salas *et al.* 2003; Lobo *et al.* 2003; Moura *et al.* 2007; Zazo *et al.* 2008). Therefore, a general pattern of global sea-level prevailed during the late Quaternary and since 6000 sea level histories for different regions results from regional effects such as isostatic adjustment and vertical tectonic movement that started to superimpose glacio-eustasy (Fleming *et al.* 1998). Likewise, apart from local oscillations due to changes on sedimentary input as above mentioned, a rmsl higher than the present was never reported at the Atlantic Iberian margin. For instance, at NW Iberia, the Galicia Mud Patch (GMP) is forming in the mid shelf at least after 5320 yr BP meaning that rmsl and hydrographic conditions maintained constant after the Holocene Maximum Transgression, showing only variations of land sediment influx determined by changes in precipitation (Bernardez *et al.* 2008; Lantzch *et al.* 2009).

During the early Holocene, the sea level rose ca. 0.85 m /century (ca. 30 times more than today) until 6500 yr BP when reached -15 to -20 m at the Cadiz Gulf. Between that moment and 5000 yr BP, sea level rise slowed down (0.25 m/century) and the msl approached the present (e.g., Boski *et al.* 2002). Coastal dunes migrated landward, alluviation occurred in the estuaries and coastal lagoons and spit bars began to form in the Atlantic Iberian shelf (e.g., Zazo *et al.* 1994; Freitas *et al.* 2003, Andrade *et al.* 2004; Boski *et al.* 2002). Estuaries began to develop because rivers no longer exported sediment to the outer shelf unless the finer sediments which could reach the inner shelf fossilizing older structures. However, as above referred, the geomorphological evolution of shelf landscapes depended on the space accommodation for sediments, the shelf slope and the balance between the rate of sea level rise and sedimentary input.

3. COASTLINE EVOLUTION

The coastline evolution depends on other environmental variables than the mean sea level changes. In other words, the coastal environments behaviour under the same driver may be highly diverse due to local effects. For instance, when the msl was ca. -20 m ca. 6 kyr, as the result of the shelf morphology and the rocks mechanical strength, the coastline was very close to the current one near Sagres. However, the 6 kyr coastline in flatter morphologies is underwater several miles away from the present (see the -20 m bathymetric contour (Fig.1). Additionally, for the same rate of the msl rise, the landward migration rate of rocky cliffs depends not only on the rock strength but also on the marine climate and exposure to the waves (Nunes *et al.* 2009; Bezerra *et al.* 2011; Moura *et al.* 2011). At the place of the Holocene flooding, coastal environments migrated landward in coastal lowlands and barrier-islands and coastal lagoons formed where the available sediments were pushed to the mainland. In this case, when the accommodation space was insufficient, the former lagoon was itself flooded being now submerged. During the rapid sea level rise in the early Holocene, the sediments quickly filled estuaries because the rivers have lost the ability to export them to the continental shelf. However, the depth to which we can find the same time--line depends on the palaeo topography and therefore chronological horizons are not parallel to the topographic surface. Moreover, when the ratio between sedimentary supply and the accommodation space was higher than the unit (an overfilled valley according to Dalrymple (2006), the estuary was filled in an apparently sea level fall (regressive sequence) during slow rising sea level (transgression). Those examples give us the extension of the problem in researching the coastal evolution and raise some questions: The proxies that we are interpreting are suitable for mean sea level reconstructions and they really traduce the coastline evolution? The very different mean sea level curves reflect site effects or local interpretations of local proxies? Several advances on the Holocene sea level curves are based on salt marshes foraminifer's assemblages collected from drilling cores. Some of these curves results from the age-

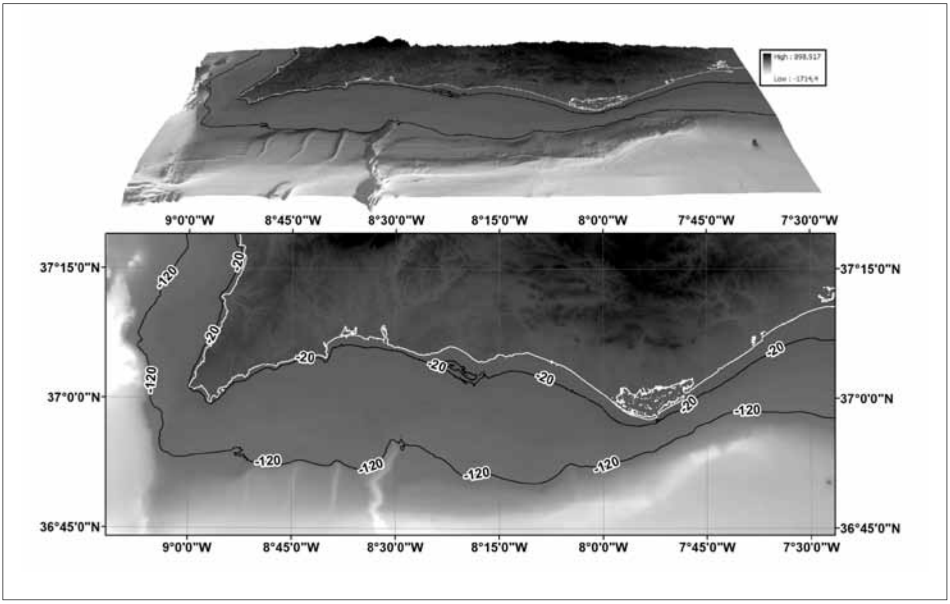

Fig. 1 – The Algarve Margin showing the 20 and 120 m bathymetric contour lines. The image was produced using the tools of Mirone Program (Luís 2007).

-altitude analysis, which traces the evolution of the tidal range fringe along the time but are not accurate enough to provide information about mean sea level (Edwards & Horton 2000). Additionally, the age-altitude models enclose several problems like sediments compactation and erosional events. Moreover, transgressive events have been reported based on the increase of the relative percentages of planktonic foraminifera in the salt marshes communities. However, this fact may be related with morphological changes, such as barrier systems formation, inlets' closure, aperture or migration, more than with marine transgressions (Li *et al.* 2000). Beachrocks are among the morphological features used in msl reconstructions but a beachrock in a macrotidal environment give a mean sea level imprecision of at least four metres. Therefore, extremely careful is required on the msl proxy's interpretation.

4. FINAL REMARKS

The relative mean sea level and the coastline changes besides being dependent variables they are not the same and, the scientific research on coastal evolution must correctly interpret the morphodynamic processes. At the continental shelves, landscapes experienced a polygenic evolution, (underwater and aerial) depending on the sea level changes. The landscape degree of preservation is determined by several mechanisms and its possible to address at least four scenarios: (i) Rocky landscape sculpted by aerial weathering during marine regressions were rapidly submerged during the Holocene flood, keeping the original forms; (ii) Rocky landscape sculpted by aerial weathering suffered waves assailing during a long time span and would be total or partially eroded;

(iii) Sedimentary bodies like dunes and beaches were cemented and rapidly flooded maintaining its original characteristics and, (iv) Sedimentary bodies were partial or totally destroyed and the sediment reused to new sedimentary structures.

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