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Quaternary Land-Ocean Interactions: Driving Mechanisms and Coastal Responses

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Abstract Book

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Universidade do Algarve, Faro, Portugal

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INQUA Commission on Marine and Coastal Processes

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Quaternary Land-Ocean Interactions: Driving Mechanisms and Coastal Responses

Fifth IGCP 495 Meeting

Faro, Portugal
27th October – 1st November 2008

BOOK OF ABSTRACTS

Edited by :
Tomasz Boski and Duarte Nuno Ramos Duarte

CIMA – Centre for Marine and Environmental Research
Universidade do Algarve

Foreword

For almost quarter of a century the International Geological Correlation Programme - IGCP has provided the framework for a worldwide exchange of scientific information and common research in sea-level change and coastal evolution. Our present perception of the complexity of that process results, to a large extent, from scientific collaboration, which has developed under the auspices of UNESCO. The topic itself which, was discussed initially only within a small community of earth scientists, has became in recent years a hot issue of socioeconomic and political importance. Growing public awareness of the threats presented by the phenomenon of sea level change is an additional challenge to the scientific community which, should be answered by more and improved scientific data and by a better transfer of recent knowledge to the public domain. Moreover it is an opportunity to prove that the answers to the present and future questions of environmental relevance may be found in the geological archives of the terrestrial past.

CIMA –Centre for Marine and Environmental Research of the Universidade do Algarve is hosting the conference of IGCP project # 495 at exactly on 10th anniversary of its foundation. We are proud of that distinction and we hope that our guests will be rewarded for their presence by a high level of discussions and by the convincing and well interpreted evidence of coastal changes along the Southern Portuguese coast. Finally we would like to express our thanks to the Portuguese Science Foundation – FCT, The Municipalities of Faro, Lagos and Odemira and University of Algarve for their support in organizing the meeting.

On behalf of the organizing committee
Tomasz Boski

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RADIOCARBON DATING OF MARINE SAMPLES FROM GULF OF CADIZ

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1. Introduction

As is well known, the ocean reservoir is deficient in radiocarbon compared with the atmosphere – so, a reservoir age exists for the ocean. This reservoir age is usually called marine or ocean reservoir effect. Radiocarbon dates on marine samples have not been used as extensively as terrestrial samples for the setting up of absolute chronologies because interpreting these dates is complicated by oceanographic factors. Consequently to set up chronologies for a particular area using this kind of samples a previous research concerning the oceanographic conditions and the marine reservoir effect of that area is needed in order to obtain accurate and reliable results.

Concerning our study area, the Gulf of Cadiz, it must be noted that the Gulf receives and mixes outflowing Mediterranean water and is influenced by Portuguese and Moroccan coastal currents and by an extension of the Azores Current. These various influences result in a complex circulation pattern. South of the Azores Islands, the Azores Current coincides with the Azores Front, which marks the north-eastern boundary of the North Atlantic subtropical gyre. The Azores Front corresponds to a zone of strong hydrographical transition, not only in terms of temperature but also in the structure of the water column – it is characterised by locally intense upwelling (Rogerson et al. 2004). At present, the Azores Front does not penetrated into the Gulf of Cadiz, even though the front resides in the Atlantic Ocean at the same latitude as the Gulf of Cadiz. Besides this, due to the configuration of the eastern coastline of the Gulf of Cadiz wind-driven coastal upwelling is nonexistent off south-western Atlantic Spain, contrarily to the situation occurring off other coasts of the Atlantic Iberia, from Cape Ortegal to Cape São Vicente and even at the southern coast of Portugal (Soares 2005).

Stuiver et al. (1986) modeled the response of the world oceans to atmospheric ^{14}C variations. From this model a parameter, denoted as ΔR, is defined as the difference between the reservoir age of the mixed layer of the regional ocean and the reservoir age of the mixed layer of the average world ocean in AD 1950. ΔR values are often determined for a particular geographical region by radiocarbon dating of pairs of samples of same age but of different reservoir origin (terrestrial and marine) and converting the terrestrial biosphere sample radiocarbon age into a marine model age; this marine model age was then deducted from the radiocarbon age of the associated marine sample to yield ΔR (Stuiver and Braziunas 1993).

2. Methodology

Pairs of closely associated samples (marine shells / charred wood or bones) from archaeological contexts were collected from some Portuguese and Spanish archaeological sites in the Gulf of Cadiz coastal region. It is assumed that the deposition of both types of samples was simultaneous, i.e. that the time of death of the different organisms is the same.

We measured the ^{14}C content by means of the liquid scintillation technique. Stable isotope enrichment values ($\delta^{13}C$) were determined for the CO_2 gas produced at the initial stage of benzene synthesis. ΔR values were calculated by converting the terrestrial biosphere sample radiocarbon age from each archaeological context into a marine model age; this marine model age was then deducted from the radiocarbon age of the associated marine shell sample to yield ΔR.

3. Results and the main findings

Positive high ΔR values can be correlated with a strong upwelling, while low or negative ΔR values correspond with a weak, or even nonexistent, upwelling. High ΔR values were determined for the Gulf of Cadiz for the time interval 4400-4000 BP. They are consistent with a strong upwelling in the region. Conversely the negative values obtained for the time interval immediately before 4400 BP or after 2000 BP point out to a nonexistent upwelling in the eastern region of the Gulf of Cadiz. The upwelling detected between 4400 and 4000 BP is probably not related with the intensity and the direction of the wind prevailing in that coastal region but more likely with the position of the Azores Front. A similar situation has been verified in two periods between the Last Glacial Maximum and the Holocene, which is explained by the extension of the Azores Front eastward along the Azores Current into the Gulf of Cadiz (Rogerson et al. 2004). A weighted mean value for ΔR can be calculated taking into account all the negative values determined for this region. The calculated weighted mean for ΔR is -135 ± 20 ^{14}C yr. For the time interval with positive ΔR values, we must be careful and wait for more results in order to determine (if possible) a mean value to be used with the marine calibration curve.

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REVISITING IMPLICIT RELATIONSHIPS BETWEEN OXYGEN ISOTOPE COMPOSITION IN FORAMINIFERS AND OCEAN SALINITY, MASS AND VOLUME (CF. SEA-LEVEL)

Claude Hillaire-Marcel
GEOTOP

Since the reassessment of oxygen paleotemperatures in the ocean by N. Shackleton, in the late 60s, most papers using isotopic records in planktic or benthic foraminifers implied some direct relationship between oxygen isotope in seawater and the ice/ocean volume, thus some linkage with salinity, sea level, etc. Such assumptions are also made when incorporating "isotopic modules" in coupled models. Here, using the Goddard Institute data base (Smith et al., 1999: http://data.giss.nasa.gov/o18data/) we intend to examine deeper, linkages between salinity and oxygen isotope ratios in seawater, their change through time, as well as the recording of water isotopic composition by foraminifers and its potential variability.

Changes in isotopic composition of precipitations and of ice meltwaters, in time and space, tune the isotopic properties of the fresh water end-member diluting the ocean. In addition, rates of sea-ice formation and evaporative conditions in the ocean play a further role on the salt and oxygen isotope contents of water masses. A large array of salinity (or potential density) vs. δ^{18}Owater relationships are indeed observed. "Surface" waters (0-400 m) define a large scatter with 5 "attractors": i) high $\delta^{18}O\omega$-brines from evaporative basins, ii) low $\delta^{18}O\omega$-brines brines resulting from sea-ice formation, iii) Arctic rivers, iv) Himalayan & NW Europe rivers, v) the Amazon. In contradistinction, deep-water masses (400-2500m) essentially derive from two sources: i) in the North Atlantic, deep Arctic waters, ii) elsewhere, deep Antarctic waters, both fed by low $\delta^{18}O\omega$-brines resulting from sea-ice formation. The intermediate ocean shows three major contributors: i) waters from evaporative basins, ii) Arctic rivers and iii) Arctic brines.

The genetic « isotopic » history of ocean water masses is thus more complex than that of a system solely governed by i) mixing with freshwater and ii) evaporative losses. As a consequence, the oxygen 18-salinity (density) relationship should carry a specific signature for any given water mass. At the ocean scale, residence time and mixing of these water masses, as well as the time dependent-achievement of proxy-tracer equilibrium in each of them, will also result in variable recordings of mass transfers into the hydrosphere, notably between ice-sheets and ocean, both in amplitude and time, thus making direct correlations of isotopic records, particularly for benthic foraminiferal assemblages (see figure), and their linkage to past sea-levels potentially misleading. Future work should be devoted to the combining of ^{18}O-data with other tracers (e.g., Nd) to fully label water masses and their sources. Advances in the modeling of mixing processes in the ocean should also help to better constrain potential linkages between basin/water mass specific $\delta^{18}O\omega$ and the paleocean mass.

IDENTIFICATION AND EVALUATION OF DECADAL TO MILLENNIUM HAZARDOUS COASTAL HIGH WAVE ENERGY EVENTS ALONG THE BRAZILIAN COAST

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1. Introduction and objective

High wave energy events, mainly when associated to spring tides and storm surges, have caused dramatic impacts on coastal zone along the Brazilian coast. Several works are concerned about prevision of this events using meteorological and wave records. Also several works have been performed to evaluate the impacts of secular sea-level rise on coastal zones; but little attention has been given to the long-term (decadal to millennium) recurrence of high wave energy events and their potential impact on Brazilian coastal zone. This work aims to identify and to evaluate the magnitude, frequency and hazardousness of coastal late Holocene high wave energy events. To achieve this objective, there were preliminarily identified several potential morphologic and sedimentary indicators of these events.

2. Methodology and preliminary results

Inside the Paranaguá estuarine complex, southern Brazil, at the mangrove sandy mud tidal flats, there was observed shelly chenier, which was attributed to wave action inside the estuary. At fair weather conditions, very fine sand, mud and organic matter are deposited on the tidal flat. A high wave energy event could be necessary to erode the sediments and concentrate the tidal flat benthos shells (e.g. oysters). Therefore, probably the shell age is next to the building up ridge age. Then dating the ridges could help to know the frequency of these high-energy events inside the estuary. Also at the outermost part of the Paranaguá estuarine complex there is a sand wave field that was interpreted as the flood ramp of a flood tidal delta (Angulo 1999). The sand wave morphology suggests they move landward, but measured tidal currents at spring tide and fair weather conditions suggested that at these conditions the net sand transport is seaward (Araújo 2001). Therefore, it is possible to consider that main sand transport occurred during high-energy events. Organic matter very fine laminas were identified at sand waves cores (Araújo 2001), which probably corresponds to vegetal debris deposited mainly over the sand waves during calm waters, as could be observed at present time. When the sand waves moved, they buried the vegetal debris. Therefore, dating these laminas could help to identify the frequency of high energy events. On the open sea coast there were identified two possible indicators of high energy events near Barreta beach, on Rio Grande do Norte coast (6º South latitude) and Ilha Comprida, southern São Paulo coast (25º South latitude). On the Brazilian northeastern open sea coast there are conspicuous beach-rocks that were studied since Branner (1902). Near the Barreta beach there were observed medium to very large beach-rock tabular boulders disposed like a beach berm along hundreds of meters. Preliminary local inhabitants' information suggested that no human action was involved at this disposition, at least in the last 3 or 4 decades. The imbricate position and other morphologic evidences, like boulders deposited landward the beach-rocks, suggest that the boulders were deposited by a high wave energy event. The boulders weight and shape could help to determine the wave energy necessary to transport them to the present position. The boulders are incrusted of different mollusks hard part, mainly oyster shells and vermetid tubes. These remains are out of their living positions. Probably the mollusks died when the boulders were moved to the present position. Therefore dating these remains could help to identify when the event occurred and the boulder size and positions could help to determine the wave energy. In Ilha Comprida there were identified hummocky cross stratification at the upper part of the island stratigraphic sequence. The island is constituted by a sandy regressive Holocene barrier (Giannini et al. 2008). The island shows conspicuous beach-foredune-ridges morphology, except at the older portion (Martin & Suguio 1978, Giannini et al. 2008). This characteristic and other evidences induced Martin & Suguio (1978) to consider that this older island part without beach-foredune-ridges correspond to a Pleistocene barrier that was submerged during the 6-5 kyr Holocene sea-level highstand, that eroded the ridge morphology. The occurrence of a typical upper nearshore/foreshore regressive sequence overtopped by hummocky cross stratification suggests that after the formation of the regressive barrier it was over flooded by a high energy event that could have eroded the former morphology and deposited the hummocky cross stratified sand. If this hypothesis is correct, this high-energy event probably could be found at other same age coastal sectors. Optically stimulated luminescent (OSL) datations could help to date this event.

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THE GENESIS OF THE DUTCH COASTAL DELTA DURING THE HOLOCENE. NEW PALAEOGEOGRAPHICAL MAPS OF THE NETHERLANDS: COMPOSITION AND APPLICATIONS

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In our thinking and policy concerning the development and maintenance of the Dutch delta the current status quo is generally taken for granted: It is the present situation which should be maintained. However, the long-term evolution of the area indicates that the landscape is by no means static; it has been and still is a matter of "dynamic equilibrium". The coastal areas adjust continuously to changing limiting conditions imposed by nature and man: The sea level continues to rise and the ground level continues to subside; the climate is changing; the salt marshes and peat areas have been considerably reduced by reclamations and cultivations and anthropogenic activities such as extraction of gas and fishery affect the current "natural" tidal ecosystems.

When long time periods are considered, large-scale changes in the landscape can be noticed. At the beginning of the Holocene -- the current warm era which started about 11.000 years ago – the coastal areas moved inland due to the then rapidly rising sea level. During the Mid Holocene this development turned: the rise in the sea level began to decrease and as a result the coastal zone of the western Netherlands prograded seawards. From the earliest stages of the development of the Holocene fluvial- and coastal landscape onwards man has lived and worked in the wetlands. Initially, the occupants adapted themselves to the drowning coastal- and fluvial landscape and when the area became too wet they moved to new dry areas such as the river dunes in the Rhine-Maas delta. Later, from the Iron Age onwards, the occupants did not always move to the save and higher grounds anymore. Instead, they began to protect themselves against marine flooding by the building of dwelling mounds. Higher silted-up areas such as salt marshes were occupied in this way. Still later, from the late Middle Ages onwards, man protected himself against marine and fluvial flooding by the large-scale construction of dikes.

The Dutch have learned to live with the risks of marine and fluvial flooding. During the past millennium, though, these risks were mainly due to human interventions in the landscape (e.g., artificial soil subsidence). The management of the coastal areas requires a communal and well-organized effort; it is not a coincidence that the District Water Boards are the most ancient institutions in our country.

The Holocene geology and landscape development of the Dutch delta were described and mapped in 1986 by Zagwijn in his book entitled "Nederland in het Holoceen" ("The Netherlands during the Holocene"). In an annex to this book the development of the landscape was visualized by means of ten palaeogeographical reconstructions of the Netherlands. This easily accessible book is still a standard work, widely used for education purposes and for non-specialist publications on the genesis of the Netherlands.

After the publication of Zagwijn's book a great deal of new geological/sedimentological, archaeological, and historical-geographical research has been carried out by various institutes, universities and companies. A path breaking study on the long-run development of the Dutch coast was conducted in the early 1990s as part of the "Kustgeneseproject" (Coastal Genesis Project) of Rijkswaterstaat (Ministry of Public Works). In this study great interest was attached to regional factors and processes such as rise in the sea level, geometry of the tidal basins, sediment sinks and sources, tidal volume and tidal amplitude in the marine basins and last-but-not-least man.

The facts that (1) Zagwijn's book has become outdated after 20 years and (2) too little attention has been paid to the role of human interference in the landscape development have given rise to the composition of a new series of palaeogeographical maps (with legends) of the Netherlands.

The maps in the palaeogeographical series visualize the palaeolandscape of approximately: 9000, 5500, 3850, 2750, 1500 and 500 B.C., and 100, 800, 1500 and 2000 A.D., respectively. Moreover, two maps displaying the top of the Pleistocene deposits are part of the series of maps. One map includes the Holocene tidal channels (indicated as a separate unit), on the other map they have been left out. The latter map is the reconstruction map of the Pleistocene surface at the beginning of the Holocene. These top-Pleistocene maps belong to the most important basic maps of the palaeogeographical reconstructions.

The series of maps is aimed at the following target groups and disciplines: geology (a.o. long-term coastal development), archaeology (a.o. archaeological prospection), landscape development and policy ("sounding board" for future interferences in the landscape), education (higher education and secondary schools) and the interested Dutch public.

During the presentation we will go into the construction of the maps and the sources that have been used. The used mapping scale is a very important factor in this respect. In the near future the maps will continuously be adjusted and improved on the basis of new data and insights. In the digital era adjusting and reprinting of the maps is relatively simple. Thus, the maps concern a "dynamic data base" for which an excellent map version management is a prerequisite. The national palaeogeographical maps, like the old maps, will be among the most widely used maps of the Netherlands. During the lecture we will go into the various possible applications of these national maps and - naturally following this - into what specific regional and local palaeogeographical maps could add to the national maps.

INTRODUCING THE FORAMINIFERA INDEX OF MARINE INFLUENCE (FIMI) BASED ON THE PALEO-ASSEMBLAGES OF BENTHIC FORAMINIFERA FROM THE GUADIANA RIVER ESTUARY (SOUTH OF PORTUGAL)

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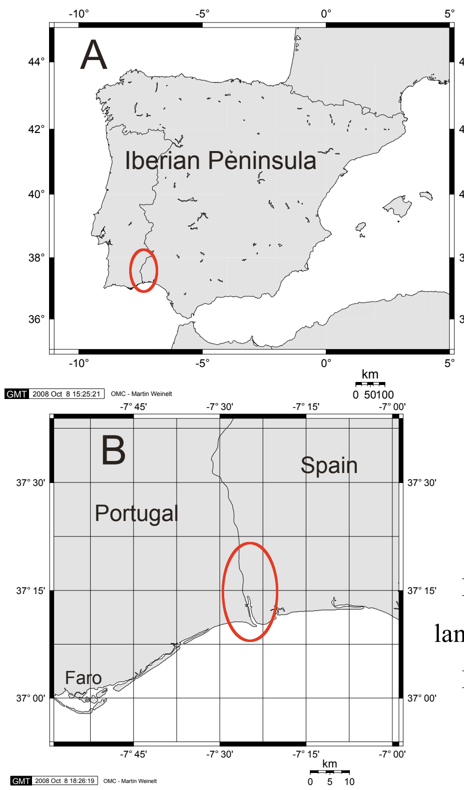
1. Geographical and geological setting of the study area:

In the framework of EU INTERREG program II and IIIa, projects DISIPOL and MEGASIG, a multi-proxy study of the environmental changes occurred within Guadiana River Estuary was undertaken. The research focused on the sedimentary record of the most recent post-glacial sea level transgression, and as a result a chronologic reconstruction of the estuarine infilling was proposed (Boski *et al*., 2002; Boski *et al*., 2008). The paleo-environmental analysis based on the micro-faunal content was investigated in five boreholes (CM1, CM2, CM3, CM4 and CM5, Fig. 1) which were drilled within the intertidal range of lower/middle estuary.



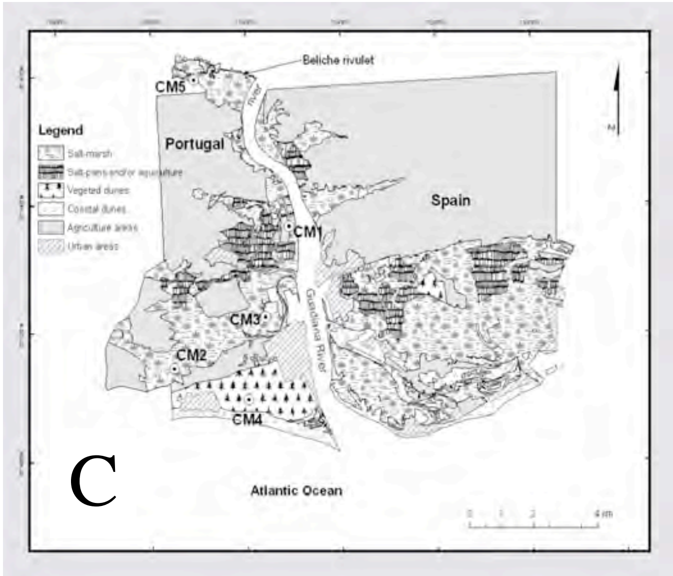


Figure 1- Regional setting of the study area (A and B), present land cover unit and location of the boreholes within the Guadiana Estuary (C).

2. Methodology

The great variety of benthic foraminifera paleo-assemblages recorded in the five sedimentary sequences as well a large quantity of complementary information required the application of data treatment techniques in order to categorize and summarize these informations. In the population data analysis some parameters were calculated, namely the Shannon diversity index, the Pielou's Evenness, the species dominance and constancy, the Agglutinated/Calcareous ratio and Q mode analysis. The best approach resulted from the application of classification analysis to the data obtained from the 230 samples collected in the five boreholes, which individualized four different assemblages of benthic foraminifera. Each assemblage represents a different paleo-environment to which is ascribed a different degree of the Foraminifera Index of Marine Influence (FIMI). The samples barren of foraminifers or with insufficient number of individuals to define an assemblage (less than 100 tests) were considered and gather in one (FIMI 1) of the 5 different degrees of FIMI which were recognized.

3. Results and the main findings

The degree of marine influence, or confinement indexes provide one of the most sensitive tools for studying sea level changes (Debenay, 1995) and has been used widely all over the world. In the present study the analysis of variation in benthic foraminifera content throughout five boreholes drilled in Guadiana River Estuary enabled the identification of five paleo-environments that occurred during the Holocene, each one with a different Foraminifera Index of Marine Influence (FIMI). The FIMI 1 represents samples with no foraminifers, which could indicate a terrestrial environment with no marine influence or a depositional environment not ideal to the *post-mortem* preservation of the tests. The FIMI 2 was represents the upper intertidal level and is almost exclusively populated by agglutinated forms (*Trochammina macrescens*, *Trochammina inflata*, *Trochammina* spp., *Ammobaculites* sp.) and inner linings, indicating high sub-aerial exposure times. The FIMI 3 represents the middle intertidal level, predominantly colonized by agglutinated forms and/or inner linings and a significant number of carbonate tests showing pronounced dissolution, thus characterizing confinement of middle to low marsh zones. The FIMI 4 was defined as low intertidal and is dominated (more than 60% of the individuals) by the estuarine association of *Ammonia beccarii* and *Haynesina germanica* together with *Elphidium* spp. and miliolids, characterizing a moderately confined environment of the low marsh and all the mud flats zones. The FIMI 5 indicates a lowermost intertidal level which is defined by the presence of the estuarine species *A. beccarii* and *H. germanica* associated with forms preferring greater marine influence, namely, the species *Cibicides lobatulus*, *Planorbulina mediterranensis*, *Asterigerinata mamilla*, *Brizalina spp*. and *Discorbis* sp., occurring as well an increase in Diversity index and in the number of small and indeterminate tests.

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SEA LEVEL VARIATION: THREAT AND ADVANTAGE TO THE SMALL ISLAND AND COASTAL PLAIN AREA OF INDONESIAN ARCHIPELAGO

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1. Geological and geographical setting of study area:

Indonesia, as an equatorial archipelago, consists of big and smaller islands that had been resulted from on going convergence of several active megaplates. Active volcanic and tectonic vertical movements are actively working, produced new island or enlarge coastal plain. Tropical climate and eustatic sea level also give influence to the different evolution of archipelago as well producing its landform and profile. As the tropical archipelago, Indonesia belongs to the longest coastline and largest coastal plain area which are sensitive to the influences coming from marine as well the atmospheric process.

The large and lowlying land, are found along the east coast of Sumatra, north coast of Java, south coast of Papua and almost around Kalimantan island. Small and lowlying islands are found in almost shallow sea, it mostly had been produced since Holocene where the sea level was relatively high. Those reefs flat were emerged due to the hydro-isostatic rebound following the rapid sealevel rise. Coastal plain now almost supports 30% of total population and almost 50% economic acivity. About 20% of the 5000 small islands are the low lying land types and 20% of it is the heavily populated island.

2. Methodology and approach:

IPCC scenario on the sea level rise predict that in 75 years, sea level will be globally 50 t0 60 cm higher than present position, if there is not any significant effort to reduce the green house gasses that induce global warming. This creeping threat of sea level rise will cause serious negative impact to most of the large coastal plain and low lying small island. Coastal erosion as well as inundation will increase every year in frequency as well on larger coverage. Excessive fresh water abstraction in coastal plain will be followed by such land subsidence, but also reduces on the storage capacity of ground water, it will be followed by serious salt water encroachment. Change on the environment due to the salt water inundation will harm most of the coastal plain and fresh water wetland biota. Rapid rise of sea level could stress certain species of reef biota that produce sediment flux in order to keep the sand forming the stable coastline. But, positive impact of slow rise sea level could give such benefit to the extension of large coral reef.

3. Results and main finding:

Based on the geological setting of Indonesian Island, it can be recognized that there are three main zones that represent the present tectonic activity. Outer arc zone of an on going subduction zone is relatively active under the uplift movement while the inner basin is relatively under the weak subsidence due to the settlement of thick sediment cover. Coastal and offshore of the tectonic opening zone there are had been under the tectonic subsidence. Cratonic zone is a relatively stable area, which coastal area just under the influence of the sea level rise.

So based on that geological setting, Indonesian archipelago that is under the different tectonic movement can be divided into several regions which respon and its degree of fulnerability, differs from region to others. Extreme weather and climate condition are necessarily put into consideration as it give important factors to the sea condition giving different degree of influence. Understanding of the land - sea interaction and local dynamic weather is necessary to produce a model of hazard map on slow onset impact of sea level rise in Indonesia Archipelago.

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SEDIMENTARY DYNAMICS OF THE MASPALOMAS UPPER SHELF (CANARY ISLANDS)

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1. Geographical and geological setting of the study area

The study area is the upper insular platform located in front of the Maspalomas dune field and the beaches of Maspalomas and El Inglés (south of Gran Canaria, 27º44´N, 15º 36´W), with an approximate surface of 6 km^2.

Previous studies have shown that this sedimentary system is very active, with a generalised tendency of erosion of the dune system (Hernández *et al*., 2007) and a alternation of accretion and erosion cycles on the beaches (Fontán *et al*, 2008).

The Maspalomas upper shelf is characterised by a gradual depth descent of up to -15m, increasing rapidly to more than -40m due to the existence of a submarine steep slope.

The processes on the submerged zone are clearly related to the sedimentary dynamics of the beaches and dunes (Sánchez-Pérez *et al.,* 2005), even though their sedimentary influx has not been quantified to date.

2. Methodology

The seasonal morphological changes on the submerged platform of Maspalomas were obtained by the comparing batimetric surveys with a multi-beam echo sounder (January 2007) and a mono-beam echo sounder (August 2007, November 2007 and February 2008) combined with differential GPS position system (Almazán *et al*., 2002). Complementary, and thanks to the eco-cartographic study commisioned by the MMA, it was also possible to compare the January 2007 survey with a survey performed on 2000.

The batymetric data analysis was complemented with the upper shelf sedimentary facies cartography, using data obtained with a side scan sonar in August 2007.

3. Results

Short term analysis shows that the upper shelf of Maspalomas presents an intense sedimentary dynamics. Thus, during the analysed period, an accumulative tendency can be identified on the submerged sector in front of the north part of the El Inglés Beach, which contrasts with an erosive tendency on the submerged and deepest sector to the south of the Maspalomas Beach. However, at the end of the annual cycle, zones with topographic changes inferior to 1 m. are predominant on the study area.

The sedimentary budget of the submerged area for the period comprised between 2000 and 2007 results in a slight erosive general tendency, with a displacement of the bathymetric contours of -5 and -10m to the coast and the existence of a predominant erosive area next to the -1 m contour. Positive accumulative areas, with vertical variations up to +2 m, where identified to the East of Punta de la Bajeta and close to the western limit of Maspalomas Beach. For the total submerged area analysed between 2000 and 2007, it was computed a sedimentary deficit of approximately $2.2x10^6$ m^3.

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HOLOCENE SEA LEVEL CHANGE AND THE INFILL OF INCISED VALLEY SYSTEMS ON THE SOUTHEAST COAST OF AUSTRALIA

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1. Geographical and geological setting of the study area

The coastal geomorphology of the southern coast of Australia is characterised by alternating rocky headlands and incised bedrock valleys partially filled with late Quaternary sediments. The valley-fill successions are represented by bay-beaches, intertidal sand- and mud-flats, deltaic plains and numerous estuaries that have formed in lowstand incised valley systems (Roy *et al*., 1980; Sloss *et al*., 2005, 2006a, b). Due to its relatively tectonically stable setting, the southeast cost of Australia provides an ideal location to examine Holocene relative sea-level changes (Lambeck and Nakada, 1990).

2. Methodology

A revised Holocene sea level curve for the southeast coast of Australia is presented based on a review of 112 published geochronological results for mangrove roots, fossil molluscs preserved in estuarine successions, and fixed biological indicators. It is supplemented by 50 amino acid racemisation and 40 radiocarbon derived ages on fossil molluscs from transgressive sandsheet facies preserved in back-barrier settings within incised valley systems along the southern coast of New South Wales (Sloss *et al*., 2007).

3. Results and the main findings

Between 9400 – 9000 cal yr BP rising sea-level during the most recent post-glacial marine transgression attained an elevation between 15 and 11 m below present mean sea level (PMSL). Sea level continued to rise to -5 m by 8500 cal yr BP. Between 8300 and 8000 years ago sea-level had risen to 3.5 m below PMSL. During this time rising sea level inundated shallow incised bedrock valleys. Sea level attained present sea level between 7900 and 7700 cal yr BP and continued to rise to a maximum of +1.5 m by 7400 cal yr BP. This is 700 – 900 years earlier than previous estimates (Thom and Roy, 1985), however it is consistent with predicted curve based on the glacio-hydro-isostatic model (Lambeck and Nakada, 1990). The culmination of the Holocene marine transgression was followed by sea-level highstand that lasted until about 2000 years ago, followed by a relatively slow and smooth regression of sea-level from +1.5 m to present level. A series of minor negative and positive oscillations in relative sea-level during the mid to late-Holocene are superimposed over the Holocene sea-level highstand. However, the precise nature of the oscillations are difficult to quantify due to problems associated with accurately determining palaeo-tidal and wave regimes, climatic conditions and the antecedent morphology of the shallow marine environments during the mid-Holocene.

Results from this study also indicate that geomorphological evolution of barrier estuaries that formed in relatively broad and shallow incised valleys (<30m) and in narrow, deeper incised valleys (>40m) has been shown to be different to previously established models. In particular, the early stage of sedimentary infill is characterised by the deposition of a near basin-wide transgressive sandsheet extending up to near present sea-level as rising sea level breached remnants of Last Interglacial barriers during the most recent postglacial marine transgression (*ca*. 12000 – 7000 years cal yr BP). This contrasts with established models for barrier estuary evolution on the southeast coast of Australia, where transgressive sand sheets are restricted to the mouths of incised valleys and back-barrier central basin muds lie directly over the antecedent Pleistocene landsurface (Sloss *et al*., 2006a, b; 2007).

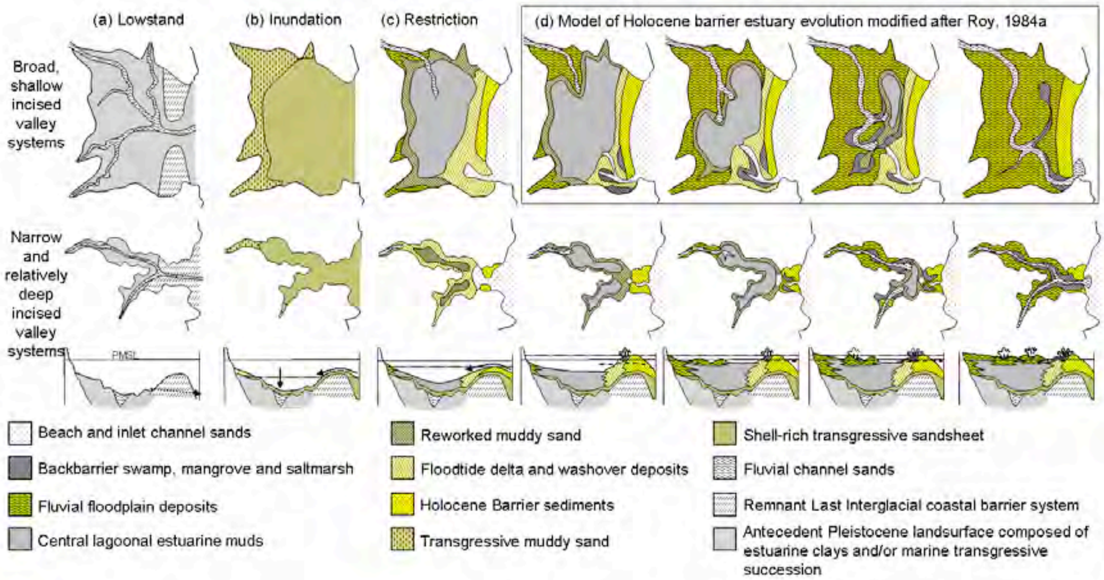

Figure 1: Sedimentary fill in broad, relatively shallow incised valleys and in narrow, deeper incised valleys. The model shows (a) the lowstand incised valley system and remnant interglacial barrier; (b) the deposition of a transgressive sandsheet *c.* 8300 years ago; (c) open marine conditions lasting to *c.* 5000 years ago; and (d) previously established model of barrier estuary evolution showing the extension of the central lagoonal mud basin and fluvial progradation (modified after Roy, 1980, 1984; Sloss *et al*., 2006a, b, 2007).

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GREENLAND ICE SHEET HISTORY AND RELATIVE SEA-LEVEL CHANGE IN THE LAST FEW CENTURIES; DRIVING MECHANISMS OF SEA-LEVEL CHANGE

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1. Background and study location

A combination of model simulations, satellite observations and airborne altimeter data all suggest that rising northern hemisphere temperatures are causing accelerated melting of the Greenland Ice Sheet (GIS). A consequence of this is that the GIS is now thought to be making an increasingly positive contribution to global sea-level rise. However, many of these observations are based on data that have been collected over just a few years, or perhaps a decade at most. A major challenge is therefore the need to place these relatively brief time series into the appropriate context of the longer term trajectory of the ice sheet's mass balance.

One of the most powerful longer-term constraints on ice sheet mass balance are relative sea-level (RSL) observations that measure long-term trends in postglacial rebound. Conventional RSL data (e.g. raised beaches and isolation basins) are able to resolve millennial-scale trends and provide targets for glacio-isostatic adjustment (GIA) models of the ice sheet (e.g. Long et al., 2008; Long et al., in press). But, unfortunately these data are unable resolve high resolution (decimeter) changes in RSL in the last few centuries and so cannot provide the necessary context for the recent satellite-based observations.

In this paper, we combine a micro-fossil based transfer function with ^{14}C, ^{210}Pb and ^{137}Cs dating methods to reconstruct century-scale changes in RSL change from two salt marshes located close to the towns of Sisimiut (Søndre Strømfjord) and Aasiaat (Disko Bugt).

2. Results

We present stratigraphic data from thin (<20 cm thick) sediment sequences from the two study sites. Sample locations were chosen to minimize the effects of sediment compaction and frost heave. We use a transfer function based on contemporary diatom samples collected from each field area to reconstruct former changes in RSL from multiple sediment profiles.

Our late Holocene RSL data demonstrate an upwards trend in RSL during the last few millennia (Long et al., in press). At Sisimiut, RSL rose c. 4 m since c. 1.2 ka cal. yr BP, whilst in Disko Bugt the equivalent rise has been c. 2 m. However, our new records add detail to the last 750 yr and suggest that there was an abrupt slow-down in RSL after ~ AD 1600 at both of these sites and that RSL has changed little since.

3. Discussion

There are two aspects of this research that warrant particular attention. The first is that both sites record a near identical record of RSL change during the last 750 cal. yrs. This indicates that the RSL histories are recording regional processes operating across a significant part of West Greenland and not local processes. The second is that there is a sharp deceleration in RSL at ~ AD 1600 after which RSL stayed stable. The rapidity of this change is confirmed by the litho and biostratigraphy of the salt marshes examined, in each case by multiple sediment sequences. It is unlikely that this records a change in non-Greenland processes, such as a slow-down in the rate of forebulge collapse associated with the Laurentide ice sheet or a reduction in 'eustatic' sea level rise. Instead, we suggest that the deceleration records more local, Greenland processes, most likely associated with a reduction in ice sheet mass balance from this time onwards.

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LAST INTERGLACIAL COASTAL ENVIRONMENTS IN THE MEDITERRANEAN-SAHARAN TRANSITION ZONE

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The coast of Tunisia is situated at the transition between the western Mediterranean and the Saharan desert climate. The sediments of this coastal strip should allow for inferring shifts of the two climate belts in the past if an accurate chronology of the coastal deposits is available. In addition to existing U-series ages from S-Tunisia we have here analysed and dated littoral deposits of nine coastal sites in North and central Tunisia using optical dating techniques.

The optical ages range from 156 ka to 62 ka (2σ level) and cluster around the last interglacial period (~125-75 ka). Littoral sedimentation cessed at ~ 80 ka when the coast became sediment starved in the course of the falling sea level.

Sediment analyses indicate that during MIS 5 foredunes, paired spits or coastal barriers existed at the north, the central and the south Tunisian coast. While the sediment composition at the north coast did not change, the central and south coast show a drastic change from a quartz- to a carbonate-dominated sedimentation. The components of the carbonate-rich sediment indicate a change of salinity, temperature and P_{CO2}.of the coastal sea water and, in addition, a change of sediment supply to the coast.

This paper presents the chronology of coastal sediments and the change of coastal parameters during MIS 5. It compares these changes with climate data inferred from terrestrial records in the Sahara and deep sea records in the Ionian Sea to further understand the link between the Saharan desert margin and the Mediterranean Sea during the last interglacial.

GEOARCHEOLOGICAL RECONSTRUCTION OF LAGOON DEVELOPMENT IN THE ALGARVE REGION (SOUTH PORTUGAL)

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1. Geographical an geological setting of the study area

Five silted lagoons in the Algarve region of South Portugal are used for reconstruction of different influences like climate, human impact, paleorelief sea level changes and strong events on coast evolution since the Neolithic time. The current focus of data interpretation is aimed at two neighbouring estuaries 19 and respectively 14 km west of Faro.

2. Methodology

Drillings in different lagoons of the Algarve region contain the whole sequences from the fluvial sediments during the early Holocene, marine transgression facies during the middle Holocene and the marine/fluvial sediment deposits until present. The sediments of these archives allow high resolution analyses of geochemical and palynological signals, while geophysical measurements give an impression of the sediment composition and succession.

3. Results and the main findings

By comparing the development of different lagoonal systems it is possible to evaluate the effect of regional influences (climate, sea level changes, events) and local factors (paleorelief, land use).

Palynological investigations in the lagoons of Vilamoura and Vale de Lobo show distinct anthropogenic influences since 3500 cal. BP by increasing values in maquis, cereals and open land communities. Sedimentological results show that the siltation in both archives started in different times. While the lagoon of Vale de Lobo documents a start of the siltation at least around 7000 cal. BP, the sediments of the Vilamoura lagoon indicate a silty/clayey infill since 4000 cal. BP. This could be an effect of the catchment setting as well as a result of the drilling location in the lagoon or the paleovalley structures in the underground.

In both lagoons the siltation process was nearly finished before the Roman Period (Hilbich et al., 2008; Teichner, 2005). During this time the estuaries were characterized by salt marsh vegetation and wet meadow communities. Additionally the results show an influence of strong events (tsunamis?) on the lagoon development.

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THE MID-EEMIAN COOLING LAND AND SEA CONECTIONS: ORBITALLY FORCED SEA ICE EXTEND AND ITS INFLUENCE ON THE THERMOHALINE CIRCULATION.

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1. Methodology

This paper details the results of intercomparisons between continental and marine records of a cooling complex event known as the Mid Eemian Cooling (MEEC 122-117ka) (Maslin et al., 1998). This event is mostly record in North-Western Europe and Euro-Siberian Arctic, both by vegetation and glaciers. It is never recorded inland in Northern and Southern America. In Africa, it is mostly recorded in form of aridity. Specific features are recorded in NGRIP and GISP ice cores but not in Vostok nor EPICA. It is characterized by two thermal minima peaking at 122-120 ka and 119-117 ka respectively separating a marine high stand at 125 ka (about 6m above the MSL) and a second at 116 ka, close to the MSL.

2. Continental data

The MEEC is characterized by an ice sheet formation similar to the Younger Dryas extent in Iceland, with a Southwestern calving Vatnajökull (Van Vliet-Lanoë et al., 2007) and a thinning of 200 m only of the Greenland Ice sheet (Tarasov & Peltier, 2003). Sea ice re-extended from 80°N to reach 45°S along the southern coast of Brittany with walrus, ice rafted basaltic cobbles from SW Iceland (Hallegouet & van Vliet-Lanoë., 1989; Van Vliet-Lanoë et al., 2006) and vegetation shift (Müller and Kukla, 2003) on Europe. On southern Europe, it is marked by aridity without marked cooling (Gandouin et al., 2007) and a chilling of the Mediterranean sea surface (Kallel et al., 2003).

3. Results

Coupling data provided by published marine deep sea cores over the world - with land records, especially along the Northern Atlantic and - with recent shift in THC related with the end of the Little Ice Age and the Global Warming , we are able to reconstruct:

(1) a major deflection of the Gulf Stream due to the disappearance of the surface Irminger Current responsible for the first cold event of the MEEC boosted by orbital forcing with a limited impact in southern oceans,

(2) a second event due to orbital asynchronuity (3 ka), mostly marked in the Southern Ocean and aridity on Southern Africa but not clearly in Vostok ice core, probably also related to a temporary sea ice re-extent in the cooling trend initiated from 128 ka recorded in the Southern Ocean. This cooling trend is delayed from 115 ka in the Northern Atlantic. The Thermohaline Circulation never stopped after the Eemian Thermal Optimum.

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LATE HOLOCENE COASTAL EVOLUTION IN RELATION TO THE GEOLOGICAL DEVELOPMENT OF THE BELGIAN COASTAL AREA

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1. Introduction

Belgium has a 67 km stretch of coastline which is straight and closed with the exception of the mouth of one small and shallow estuary in the west, the IJzer. It is a tide-dominated (macrotidal to mesotidal) wave-exposed coast with a mean significant wave height of about 1 m and situated at a broad and relatively shallow continental shelf. The physical conditions are identical along the small stretch of coastline. However, the development of dunes is quite different comparing the western and eastern part of the coast. In the west, the area covered with dunes, reaching a height between 7 and 20 m, is about 2 km wide. In the eastern part, the dunes are low and very narrow with one exception. In some locations, the dunes are even absent. Also the effect of severe storms on the beaches is different being more important in the east than in the west.

2. Results

A series of drillings and cone penetration tests recently carried out along the entire coastline in the framework of coastal defense, revealed the late Quaternary setting in particular in the eastern part. The latter has never been subject to systematical mapping in contrast with the western part, and therefore, only site specific data points are available and the depositional history is not well documented. A comparison between west and east along the coastline shows three major differences in the geological setting. 1. The morphology of the top of the Pleistocene subsoil deepens in western direction from about 0 m until –15 m in the palaeovalley of the IJzer estuary. 2. The late Pleistocene deposits in the east consist of about 3 m thick Weichselian coversands overlying tidal-flat and open-marine deposits of the Last Interglacial. In the west, coversands are absent and the thick Holocene sequence overlies directly the open-marine deposits of the Last Interglacial. 3. The Holocene sequence shows the most important difference. In the west, it consists entirely of coastal-barrier deposits. Moreover, these deposits have a lateral extension landwards of almost 4 km. In the east, coastal-barrier deposits are completely missing. In stead, the sequence along the coastline consists of back-barrier deposits with mud covering the basal peat. Where the top of the Pleistocene subsoil is deep enough, few intercalated peat beds occur. The back-barrier sequence is deeply incised by sand and mud-filled tidal channels. A concentration of open-marine shells (*Spisula*) in a channel fill documents that the shells have been stripped off from the seabed due to erosion. Their age (2176-1888 cal BP) indicates that the erosion happened in the late Holocene, in the period that peat accumulation came to an end. *Cerastoderma* in living position in a mud-filled channel in the same area dated at 310-540 AD documents that the channel was still active in medieval times.

3. Discussion and Conclusion

Such a situation of a back-barrier sequence right at the coastline is not a normal situation. The normal situation is a lateral transition from sea to land of the barrier sequence followed by the back-barrier sequence which is the case in the western part. This indicates that the eastern part experienced severe shoreface erosion and a landward shift of the coastline during the late Holocene whereby the barrier sequence, and possibly a part of the back-barrier sequence, have been completely eroded. It is assumed that the morphology of the Pleistocene subsoil is one of the causes of this striking difference. The Pleistocene subsoil shows two major palaeovalleys: the IJzer in the southwest and the Oosterschelde (The Netherlands) in the northeast. Few small ones might have been present between them in the eastern coastal area. The divide between the two major palaeovalleys developed into a headland once the sea level started to rise in the Holocene. The headland experienced erosion while in the mean time, the palaeovalleys were filled. From about 6800 cal BP, the latter prograded beyond the present-day coastline resulting in a wide area of barrier deposits. This means that during the early Holocene the major part of the present-day eastern coastal area was a higher lying area consisting of Weichselian coversands which stretched far seawards of the present-day coastline. This was the situation until about 6800 years ago when the sea reached a level sufficiently high to inundate the headland at the location of the present-day coastal area. The progradation changed into shoreface erosion and a landward shift of the coastline for the entire coastal area. When exactly this change initially started, is not known yet, but in the area which is now the coastal plain, it happened probably slightly before 2000 cal BP when the tidal system re-entered the plain. The landward shift of the coastline continued until medieval times. The re-entrance of the tidal system was associated with deep incision of tidal channels which got sand filled, except for the central part of the plain, where they are filled with interlayered sand and mud.

The tendency of alignment to a straight coastline resulted in the total erosion of the headland, the barrier and part of the back-barrier deposits in the east while at the location of the palaeovalleys, a part of the barrier sequence remained. It is also at these locations that the present dunes are well developed. The barrier sequence, and more particularly the tidal deltas, provided sufficient sandy sediments for their development. This was and is not the case for the areas in the east, except for one location. The cross-section along the coastline at that location shows a major sand-filled channel. It is most probable that it also had a tidal delta which supplied the necessary sand for the dune development there.

EVOLUTION OF THE LAGOONAL AND ESTUARINE SYSTEMS DURING LATE QUATERNARY ALONG THE SOUTH-EAST COAST INDIA: PALYNOLOGICAL IMPLICATION

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1. Geographical and geological setting of the study area

East coast of India lies between 7° to 17° North Latitude and is characterized by shallow geomorphology. The south-east coast of Peninsular India comprises of numerous rivers/streams which are essentially monsoon driven and therefore, the sedimentary sequences are considered excellent repositories of palaeomonsoon and palaeo-sea level records. It is known that the fresh water flux to the Bay of Bengal is governed by summer monsoons creating salinity gradient even in the Eastern Arabian Sea (Chadonkar et al., 2005). At present two major delta forming rivers are Krishna-Godavari and Cauvery protected by mangroves in pockets. The tide in this area plays an important role in the transportation of sediments to Bay of Bengal during N-E and pre-monsoon periods (Reddy, et al., 1994).

2. Methodology

Several shallow to deep cores and sections from the estuarine /lagoonal areas of Godavari, Palar, Penner and Cauvery Rivers were identified for palynological and sedimentological study. The shallow cores (2- 4m deep) were retrieved using Eijelkemp piston corer or gravity corer. Some of the exposed river cut sections and trenches were also used for the study. On land deep boreholes upto 200m depth and off shore gravity cores in Bay of Bengal were studied in collaboration with Delta Studies Institute under sponsored projects of Department of Ocean Development and Oil and Natural Gas Corporation Ltd. Dehradun.

3. Results and the main findings

Palynological study of sediments along the south-east coast reveals the climate & sea level induced changes in vegetation pattern since the Pleistocene period. Based on Radiocarbon dates and its extrapolation in deeper sediments (~200m) our results show signatures similar to the period of Marine Isotopic Stage 5a during which the shoreline was several kms inland from the present day shoreline. The vegetation comprised of semi-evergreen to evergreen and moist deciduous forest. Presence of *Rhododendron* (now found at higher altitudes in Western ghats and Himalayan region, India) indicate cool climate and heterogeneity in plant assemblage in the study area. However, mangroves are less represented although other forms like foraminifera and dinoflagellate cysts indicate palaeoshoreline. The vegetation during the Last Glacial Maximum (LGM) comprised of open savanna woodland type and no signs of palaeoshoreline is evident inland. Mangrove evidences indicating palaeoshoreline was again recorded on land during 6-7 ka. Moist deciduous to dry deciduous forest along with swampy palynomorphs comprised this phase. Palynological study in three off shore (Bay of Bengal) cores ranging from 2 to 5m deep below 1000-2000m seawater depth show a very good land-sea sediment palynological correlation. The middle Holocene mangrove evidences on land are recorded 3-4m below mean sea level in the southern most part whereas it is 3-4 m above mean sea level in the northern part of the south-east coast. This points to neotectonic activity in the region whereby either the northern part has uplifted or the southern part has undergone subsidence only after its deposition which affected the mangroves at large during Late Holocene. Our results reveal that Pleistocene period (5a) was marked by strengthened north-east monsoon and cooler climate. The climatic climax ended as the Last Glacial Maximum when the sea level fell to -120m. Vegetation in the region perhaps took refuge as riparian forest in pockets during this period which rejuvenated during Holocene warm climate. Mangroves existed in abundance until Middle Holocene all along the east coast. The climate and sea level changes during Late Holocene (2000-1500yrs. BP) was quite vulnerable for mangroves resulting into the present day pockets of mangroves. This is attributed to hydro-geomorphological changes enhanced by anthropogenic activity in the study area.

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RETROSPECTIVES OF THE CHANGING PERCEPTION OF SEA LEVEL CHANGES ESPECIALLY IN THE PAST 50 YEARS

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"I have myself seen what once was solid ground disappear into the se, and I have heard of land risen out of the sea", Ovidius wrote some 2000 years ago. Here we are, still discussion and debating Sea Level Changes. There are reasons, however, to plead for observational facts.

1. Early ideas in the 18th and 19th centuries

In the 18th century the observed changes in sea level were explained in terms of changes in the level of the ocean, in the solid ground level or changes in the Earth's rate of rotation. In the 19th century the theories of glacial eustatic lowering at Ice Ages, the slow subsidence of the ocean floors, the deflection of the plume line due to denudation and the glacial mass attraction of water appeared. The glacial isostatic concept became a new paradigm with De Geer's 1888 paper.

2. Achievements in the early 20th centuries

In the first half of the 20th the observational database improved tremendously. Multiple Ice Ages were recorded. Dating remained a major obstacle for refined sea level reconstructions (with the exception of Lidén's varve-dated postglacial sea level record of 1938).

3. The changing views in the last 50 years

With the introduction of the radiocarbon dating method much changed and it was now possible to achieve age determinations of various paleo-sea-level indicators. The changes in ocean level were believed to be parallel all over the globe, and the word "eustasy" was defined as "simultaneous changes in global sea level". In this spirit Fairbridge (1961) made his famous global compilation of sea level changes in a high-amplitude oscillation curve. Shepard (1963) answered with a smoothly rising curve. At the same time Jelgersma (1961) had shown by well-dated stratigraphy the Holocene sea level rise in Holland was smooth with minor possible irregularities. Personally, I was able to present a comprehensive analysis indicating the sea was rising with moderate oscillations (Mörner, 1969). This was the focus of intensive sea level debates. In 1971, I called the attention to the fact the real problem neither was oscillation vs smooth nor above vs below the present in Mid-Holocene time, but that most curves seemed to converge at about 8000 C14-yrs BP suggesting that the ocean level distribution was changing with time. This was the incitements to formulation to the concept of geoid changes (Mörner, 1976). At the same time, the global effects of glacial loading started to be discussed (Cathles, 1975, Clark et al., 1978).

Whilst the IGCP-61 project was launched to determine the global eustatic sea level curve, its follower, IGCP-200, was set to record the global differences. It was time to change to old concept of "eustasy", and in 1986, I proposed a redefinition to "changes in ocean level", in opposition to changes in land level, and regardless of causation, with the implication that each region had to define its on "regional eustatic curve".

Today, we have arrived in a strange sea level debate where facts and observations no longer are the prime factors but the scenario of global warming. It is time to go back to field observations because there, only there, is where we have meaningful sea level research, which may flourish and put the subject forward.

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THE FIRST EVIDENCE OF A HIGHER THAN PRESENT MID-HOLOCENE SEA LEVEL ON THE ATLANTIC COAST OF NORTH AMERICA FROM SOUTH CAROLINA, US

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1. Geographical setting of study area

The area of study is the South Carolina coastline (USA) from the state line of North Carolina to about 200km south. Four areas are discussed-Singleton Swash, Murrells Inlet, Price's Inlet and North Inlet. Many vibracores have been collected at all these inlets with respect to looking for both sea-level markers and hurricane traces.

2. Methodology

Once the vibracores were collected they were split, photographed, and sampled for microfossil examination and suitable C-14 dating materials. Samples were wet sieved and examined with a binocular microscope for foraminifera and other microfossils. The assemblages were used to relocate sea levels with a precision of +/-10cm which are the basis of this paper. In one inlet (Singleton) we were also interested in traces of ancient hurricanes. Carbon-14 dating was done usually on salt marsh peat or sometimes shells.

3. Results and main findings

There has been debate for many years regarding the presence of a higher than present mid-Holocene sea level along the east coast of North America even though these are common along the South American east coast and many other non Quaternaryglaciated areas. One was reported in Texas however it is isolated. However along the South Carolina coast in the USA there is a wide band of "regressive" beach ridges that have been suggested to be anything from Stage 5e to mid-Holocene but not verified. Some of these beach ridges were cored at Price's and North Inlets and salt marsh and freshwater peats underlying these beaches were dated-the dates are younger than mid- Holocene so the beaches must be younger and part of the mid-Holocene rapid rise of sea level reported already from this area.

In previous work we had discovered a sea-level excursion of rise and fall between 5kya and 4kya in Murrells Inlet but never one that actually was equal to or higher than present although there has been a sea level higher. However in re-examining older data from South Carolina and looking at airphotos it was obvious there had been sea levels at least as high as present in the late Holocene but there had been no marsh material collected to verify both the age and elevation of former sea levels.

In new coring we found that sea level had fluctuated between -3m and less than -1m below present a few times between 4kya and 1kya in a series of beach ridges from Prices Inlet, SC. The importance of these data, as WR Peltier pointed out to the senior author, is that a mid- Holocene highstand as high as present here will fundamentally change the numerical models for sea level in North America and possibly help to explain some of the discrepancies between the field and model results; this will dramatically increase the predictive capacity of the models to forecast possible global sea-level rise.

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IMPROVED UNDERSTANDING OF SEA-LEVELS AND THE ROLE OF VERTICAL TECTONIC MOVEMENTS DURING THE LAST 2000 YEARS ALONG THE EASTERN MEDITERRANEAN COASTLINE

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The observed relative sea-level (RSL) values (submerged, uplifted or at present MSL), reflect a superposition of eustatic, isostatic and tectonic components. For the last 2000 years, the data obtained for sea levels along the Levant coast consist of bio-markers, mainly the *Dendropoma petraeum*, which is a fixed vermitide that builds abrasion platform rims, and on archaeological indicators. The observed data are compared with a numerical model for calculating the change in sea level as a function of eustasy and glaciohydroisostasy in the eastern Mediterranean, therefore isolating the tectonic factor.

The *Dendropoma* is considered to be a good RSL indicator in the eastern and southern Mediterranean, due to its narrow range of habitat at the sea surface (+/-10cm). The present study examines fossil *Dendropoma* samples gathered along the Levant coast, from northern Israel to eastern Turkey. Conventional radiocarbon dates (from Turkey, Syria and partly in Lebanon) and ^{14}C AMS (from Lebanon and Israel) yield reliable ages.

Archaeological indications for palaeo sea-levels in the east Mediterranean are used mainly in Israel. Previous research concluded that sea levels were close to the present level during the Early Roman period, which is about 2000 years ago, and were lower by about 30-40 cm during the Crusader period, which is the 11th to 13th centuries AD. Most of the *Dendropoma* ages obtained for the coast of Israel are from the last millennium, and confirm the lower level during the Crusader period. On-going research suggests better resolution of sea-level also for the Roman period along the coast of Israel, based on coastal man-made structures, such as fishponds, swimming pools and flushing channels.

The coast of Israel has been found to be tectonically stable during the whole Holocene, with higher confidence for the last 2000 years. The isostatic effect was also found to be negligible. This means that the sea-level curve of the coast of Israel represents mainly the eustatic component, and therefore can serve as a reference to other Levant coasts, and maybe even to other Mediterranean coasts

The comparison between the observations and the model show a general northward increase in tectonic uplift of the Levant coast. The differential uplift rates from Lebanon to Turkey, correspond well with the major tectonic segments comprising the Levant continental margin since the Pleistocene

ACTIVE FAULTS, GIANT DUNES AND CRITICAL BENTHIC HABITATS IN THE INLAND SEA OF SOUTHERN GEORGIA BASIN: AN INTERNATIONAL INTERDISCIPLINARY MAPPING PROGRAM

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Abstract

1. Geographical and geological setting of the study area:

The northern Pacific margin of North America has been subject to active tectonism, dramatic sea level change and vigorous storm and tidal energy since glacial times resulting in a complex seafloor and coastal zone. Examples are presented from the inland sea of southern Georgia Basin, along the Canada/US boundary.

2. Methodology:

Extensive multibeam mapping at a grid resolution between 2 m, using a Simrad 3002 300 kHz system, and 5 m, using a Simrad 1002 95 kHz system, provides detailed mapping of surficial geology, geohazards and habitats from the shelf to the coastal zone.

3. Results and the main findings:

Active faults, over 125 km in length, extend from the US onshore, to the offshore, and back onshore into Canada near the city of Victoria. Adjacent to the faults are giant symmetrical dunes with wave-lengths between 100 and 300 m and dune heights up to 28 m. Currents, with velocities ranging between 0.2 to 2.2 m s^{-1}, are dominated by semi-diurnal tidal streams that are continually modified by wind and estuarine circulation. Bathymetric restriction of the tidally dominated flow between the inland seas and the open Pacific has resulted in the development of the subaqueous dune fields and amplification of the fault morphology. In addition, the past and present active physical processes have created a variety of fish habitats, such as steep, near vertical rock walls, stacked boulders (e.g., moraines and rockfalls), which offer habitat for juvenile and adult rockfish (*Sebastes* spp.), subaqueous dunes that shelter sand lances and other organisms and provide foraging habitat for bottom fish, and raised glacial deposits that allow for the formation of sponge reefs.

RECENT RAPID SEA-LEVEL RISE IN THE SW PACIFIC

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We present proxy sea-level data from Tasmania and New Zealand which provide evidence of very rapid rates of 20th century sea-level rise in comparison with sea-level changes in preceding centuries. We investigated the bio- and lithostratigraphy of salt marshes in southern New Zealand and Tasmania and used fossil foraminifera in core sections to reconstruct sea-level changes. We dated the sequences with AMS^{14}C and a range of stratigraphic markers (pollen, Pb concentrations, ^{206}Pb/^{207}Pb ratios, charcoal and ^{137}Cs) which, when linked with historical documentation, provide useful ages for key horizons in the cores.

We found that recent salt-marsh accumulation in the region has occurred primarily in direct response to 20th century sea-level rise. The reconstruction from a salt marsh at Pounawea (Otago, New Zealand) shows a slow sea-level rise of 0.3±0.3 mm/yr between AD 1450 and 1900, but a fast rise during the 20th century of 2.8±0.5 mm/yr, in agreement with the rate of 2.5±0.3 mm/yr measured by the Lyttelton tide gauge between 1925 and 2000. Our site in southeastern Tasmania (Little Swanport Estuary) can be compared with the Port Arthur sea-level observations made in 1841-1842, possibly the oldest direct sea-level measurements in the southern hemisphere. Sea level in southeastern Tasmania was stable during the 19th century and rose at ~2 mm/yr during the 20th century. In agreement with earlier work in the North Atlantic, the salt marshes in New Zealand and Tasmania provide a valuable sedimentary archive of the history of recent sea-level changes and show consistent evidence of a 19th to 20th century sea-level acceleration.

ECOLOGICAL EFFECTS OF HOLOCENE SEA LEVEL RISE ON THE EASTERN BLACK SEA COAST

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1. Geographical and geological setting of the study area

The land on the eastern shores of the Black Sea, known as Colchis since ancient times, is a vast alluvial lowland at the foot of the Caucasus Mountains. A system of mires, swamps and lagoons stretches for 100 km along the coast. The Ispani mire system is the southernmost of these, situated near the town of Kobuleti in SW Georgia. The study site (41º 52´ N, 41º 48´ E) is a raised bog, 1.5 km from the Black Sea. The area has a mild, maritime climate, with 2365 mm of annual precipitation and a mean annual temperature of 15º C. Its vegetation is mostly agricultural (tea and citrus plantations) and pastoral, with smaller areas of remnant Colchic liana forest, alder swamps and mire vegetation.

2. Methods

A 950-cm sediment core was collected from the Ispani-II mire using a D-section corer. Pollen extractions were performed using standard techniques (see Connor et al., 2007). We identified 450-3000 pollen grains per sample and analysed the data using Detrended Correspondence Analysis (DCA). Three AMS radiocarbon dates were obtained for the sequence.

3. Results and the main findings

Comprehensive lithological investigations along the Black Sea coast of Georgia have produced a curve of Late Quaternary sea level changes (Tvalchrelidze *et al*., 2004). The timing and influence of transgressions and regressions in Georgia differs slightly from the scheme for the Black Sea as a whole because of rapid tectonic subsidence and coastal alluviation. The major Holocene sea level rise – the 'New Black Sea' transgression – occurred around 7000-6000 cal. yr BP, peaking between 4300-3200 cal. yr BP. Near Kobuleti, the transgression built marine terraces 4.5-5.0 m above the present relative sea level. It was followed by the Phangorian regression (3200-2300 cal. yr BP), in which relative sea levels dropped by up to 15 m. The next transgression – the Nymphaean – began around 2000 cal. yr BP and led to a 2.0-2.5 m sea level rise and a marine ingression 250 m inland from the coast near Kobuleti. Sea level changes during the last 1000 years have been relatively minor.

How did these dynamic sea level changes influence the vegetation and human settlements along the eastern Black Sea coast? Pollen data from the Ispani mire indicate a four-phase history of vegetation around the mire: (1) chestnut woods from 5600-4500 cal. yr BP; (2) shrubby vegetation from 4500-1900 cal. yr BP; (3) dense beech-hornbeam forest from 1900-30 cal. yr BP; and (4) a recent phase of deforestation beginning in the 20th century. The timing of the first three phases corresponds to sea level changes in the Black Sea. Chestnut is a tree very intolerant of poor soil drainage and declined as groundwater rose during the New Black Sea transgression. More open vegetation formations appeared as human settlements populated the Kobuleti coast during the Phanagorian regression. The subsequent Nymphaean transgression initiated peat formation at the Ispani site and the beginning of the beech-hornbeam phase of vegetation development.

These results can be viewed in the light of archaeological investigations of settlements that are now underwater or buried beneath metres of peat (Dzhanelidze, 1980). A prehistoric settlement at Ispani was abandoned in the late 3rd millennium BC, at the peak of the New Black Sea transgression. Younger settlements (late 1st millennium BC) have been discovered on the bed of Lake Palaeostomi, a coastal lagoon near the town of Poti. These data suggest that Holocene sea level rise had a major impact on seaside settlements in Georgia and was the primary factor in coastal vegetation change.

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RECOGNISING SUBTIDAL FORAMINIFERAL ASSEMBLAGES: IMPLICATIONS FOR QUANTITATIVE SEA-LEVEL RECONSTRUCTIONS USING A FORAMINIFERA-BASED TRANSFER FUNCTION

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1. Background and study location

Foraminifera-based transfer function models are increasingly used to provide decimeter-scale sea-level change reconstructions (e.g., Boomer and Horton, 2006; Horton and Edwards, 2006; Gehrels *et al.*, 2008). A recent trend has been to extend the range of modern foraminiferal training sets (which form the basis for reconstructions) in temperate locations beyond vegetated uppermost intertidal salt marshes onto intertidal mudflats down to Mid Tide Level (MTL) where calcareous foraminiferal species dominate (Boomer and Horton, 2006; Edwards and Horton, 2006; Horton and Edwards, 2006). Horton *et al.* (2007) take this idea further by developing and applying a foraminifera-based transfer function model based on modern samples from a tropical subtidal environment.

This raises an important issue about selecting an appropriate elevation for a modern training set used to calibrate fossil calcareous foraminiferal assemblages. This study analyses calcareous foraminifera from the tropical location of Cleveland Bay in northern Queensland, Australia to investigate the impact of different elevation ranges on resultant sea-level reconstructions.

2. Results

Most calcareous foraminiferal species found in cores occur in both modern intertidal and shallow subtidal environments. A lack of independent measures to indicate whether fossil assemblages come from intertidal environments forces use of a training set that includes intertidal and subtidal environments. This results in decreased precision compared to using a training set solely from intertidal environments. The widely used method of assessing model fit to fossil assemblages (Modern Analogue Technique) often fails to discriminate between acceptable and unacceptable reconstructions. This shows that assessing the reliability of reconstructions should not be limited to the results produced by MAT. However in this study I have not been able to identify an alternative reliability test which can discriminate between intertidal and shallow subtidal environments from calcareous foraminiferal assemblages.

3. Discussion

In tropical mangrove environments with no independent method of assessing the environment of deposition, transfer functions based on calcareous foraminifera must include modern training set samples from both intertidal and shallow subtidal environments to allow accurate reconstructions. This suggests that more research is required in temperate locations to investigate whether transfer function sea-level reconstructions based on calcareous foraminifera sample a sufficient elevation range to produce reliable reconstructions.

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HOLOCENE SEA-LEVEL CHANGE IN NEW ZEALAND: A REVIEW

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1. Geographical and geological setting of the study area

Gibb's (1986) benchmark paper integrated sea-level records from throughout New Zealand, presenting a widely utilised sea-level history for the region that indicates that present mean sea-level (PMSL) was attained c. 6700 cal yr BP. This contrasts with recent research from the eastern seaboard of Australia which indicates an earlier culmination of the Holocene marine transgression (e.g. Horton et al. 2007; Sloss et al. 2007). Recent research in New Zealand has focused on reconstructing Holocene depositional environments within the context of the established sea level curve (e.g. Abrahim et al. 2008; Heap & Nichol 1997). However, there has been no effort to utilise this data to refine the Holocene sea level history of the region. This study reviews data collected since the construction of Gibb's (1986) Holocene sea-level curve in order to elucidate a more detailed sea-level history of the New Zealand archipelago.

2. Methodology

A revised Holocene sea-level curve for the New Zealand archipelago is presented based on 141 dates compiled from 26 published and unpublished reports, papers and theses. Data has been restricted to studies which present both an accurate description of the facies association and relate dated material to an established vertical datum. All dates were calibrated to sidereal years. Calibration of fossil molluscs utilised the marine model calibration curve Marine04 with a ΔR value of -7±45 to correct for the marine reservoir effect. For wood, peat and other materials that derive their carbon from terrestrial sources the non-marine calibration curve for the Southern Hemisphere was used.

3. Results and main findings

Sea-level rose from -5 m PMSL c. 8500 cal yr BP to +0.3 m above present mean sea-level (PMSL) by 7550 cal yr BP (Figure 1). While this is 500-1000 years earlier than previous estimates (Gibb 1986), it is consistent with recent reconstructions of Holocene sea-level change for the east coast of Australia (e.g. Horton et al., 2007; Sloss et al., 2007). However, the rate of rise in New Zealand is substantially less than along the Australian east coast. From 7550-5800 cal yr BP sea-level rose to +0.8 m PMSL. Sea-level then fluctuated ±0.2 m until c. 4500 cal yr BP, when it reached maximum elevation of +1.0 m PMSL. This mid-Holocene sea-level maximum in New Zealand c. 4500 cal yr BP was predicted by Hull (1985) and Woodroffe et al. (1983), and is reflected in stratigraphic studies (e.g. Heap & Nichol 1997; Hicks & Nichol 2007; Abrahim 2008). From 4500-3000 cal yr BP sea level fell from +1.0 m to +0.2 m PMSL followed by a rapid transgression from 3000-2700 cal yr BP where sea-level rose to +1.0 m PMSL. Sea-level remained stable at this level until 2000 cal yr BP, when it fell to present mean sea-level. These relative highs and lows of sea-level from 4500-2000 cal yr BP were hypothesised by Heap & Nichol (1997) to control phases of beach ridge development, though they lacked unequivocal evidence for these sea-level fluctuations. Similarly, periods of lower sea-level c. 3000 cal yr BP and after 2000 cal yr BP coincide with periods of dune formation in Northland (Brook 1999).

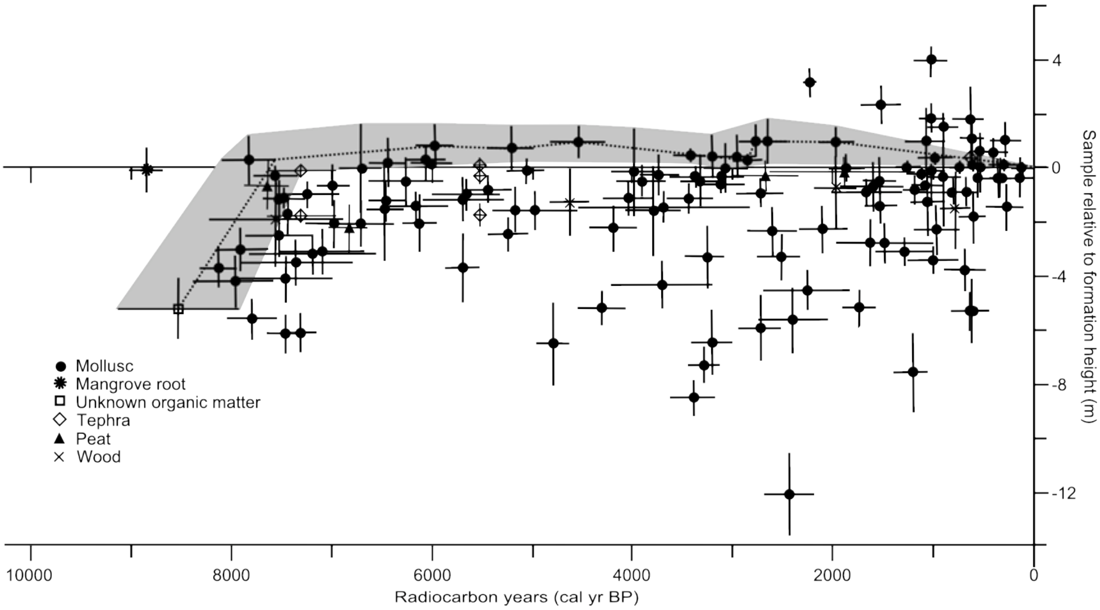

Figure 1: Revised Holocene sea-level curve for New Zealand based on 141 published and unpublished radiocarbon ages calibrated to sidereal years. The shaded area representing the envelope of relative Holocene sea-level rise is based on the synthesis of previously published data and new data obtained in this study.

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COLD-WARM SPELLS PICKING THE LAST ~ 100 KA AT XERACO LAGOON (WESTERN MEDITERRANEAN, SPAIN)

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1. Geographical and geological setting of the study area

The continuous 50 m-long core of XE02 rotation core (Fig. 1) offers a record of the climate and sea-level changes in the Western Mediterranean during the last ca. 100 Ka.

2. Methodology

Techniques used include textural, mineralogical, and geochemical analyses, macro-(mollusk) and micropaleontology (ostracods and foraminifers), pollen and AMS radio-carbon dating.

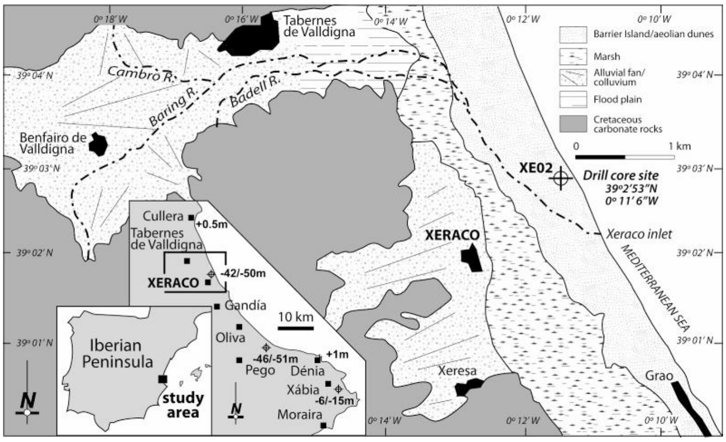

Fig. 1. - Location map and elevations (asl/bsl) of OIS5 deposits.

3. Results and main findings

Sedimentary facies. Most sediments in the core (Fig 2) record coastal lowland settings with brackish to fresh waters. No open-marine conditions have been identified, although there are several incursions of the back barrier realms (washovers and aeolian dunes) marking approximations of the shoreline. Holocene beach barrier deposits do occur at the uppermost part of the core. The main facies identified are: **Beach barrier**: Fossiliferous sands with marine isotopic signal, mollusks (*Glycymeris, Tellina, Dosinia*), foraminifers (*Elphidium, Rosalina, Neoconorbina, Lobatula*), and ostracods (*Cyprideis torosa, Loxoconcha elliptica, Cushamanidea elongata, Semicytherura sulcata*). **Aeolian dune**: Yellow, well sorted, almost non-fossiliferous sands with terrestrial isotopic signal. **Brackish lake/swamp**: Green to grey mudstones with mollusks (*Cerastoderma glaucum*), foraminifers (*Ammonia becarii*, *Elphidium esxcavatum*, *Haynesina germanica*), ostracods (*C. torosa, L. elliptica, S. sulcata*), and marine isotopic signal. Marine influence to these environments is recorded as white/yellowish sand, with two subtypes: **distal washover sands**, with characteristic isotopic signal, contain transported remains of foraminifers (*Bulliminella elegantisima*, *Aubignyna perlucida*) and ostracods (*C. torosa, L. elliptica, S. sulcata*); in addition, **proximal washover sands** contain *Glycymeris* and *Murex*. **Fresh-water lake/swamp**: Green to grey mudstones with terrestrial isotopic signal, ostracods (*Iliocycpris giba,* Thecamebids), and gastropods (*Planorbis*). **Pedogenic processes and desiccation** are marked by hydromorphism, and carbonate nodules.

Pollen record includes associations of warm, temperate, cool and cold episodes and humid and dry conditions. The couples warm or temperate/humid and cold/dry are usually well marked. The first is represented by mesophyllus species (*Olea, Corylus, Alnus* and *Quercus*, both decidous and evergreen); the second by steppic species and *Pinus*.

Interpretation. Taking into account the previous information (see Fig.2) and the published data of last interglacial deposits (112±17Ka) recognized between -51 and -44 m (Pego 1, Viñals, 1996), Xábia 1 (-6 to -15 m) with oolitic facies typical of the early OIS 5, we conclude a late OIS 5 age for the brackish lagoon with marine influence, mostly under warm, humid conditions penetrated between -49 and -43.5 m. The cold, dry period recorded between 43.5 and ~-37 m may represent the OIS 4. Between -37 and -16.4 m, warm temperate lagoon environments with variable marine (washover) influence are punctuated by desiccation events, usually related to cold and dry (pollen), thought to represent Heinrich events (H) inside the OIS 3, as recognized in the Mediterranean by very cold events with low sea surface temperature (Martrat et al, 2004). The maximum warm conditions recorded in the core (-16.3m) are thought to represent the Bölling-Allerød event (B-A, ~13-15 Ka BP).

The dominantly sandy upper part records successively the Holocene transgression (-15 to -11.5 m) with retrograding back barrier and coastal dune settings and local desiccations of coastal lakes, the arrival of beach environments around 5700 cal BP (-11.5 to -10 m) and (-7.5m). Then, a change in coastal dynamics ca. 2200 cal BP is recorded as in other Mediterranean coasts (Goy et al., 2003; Zazo et al., 2008).

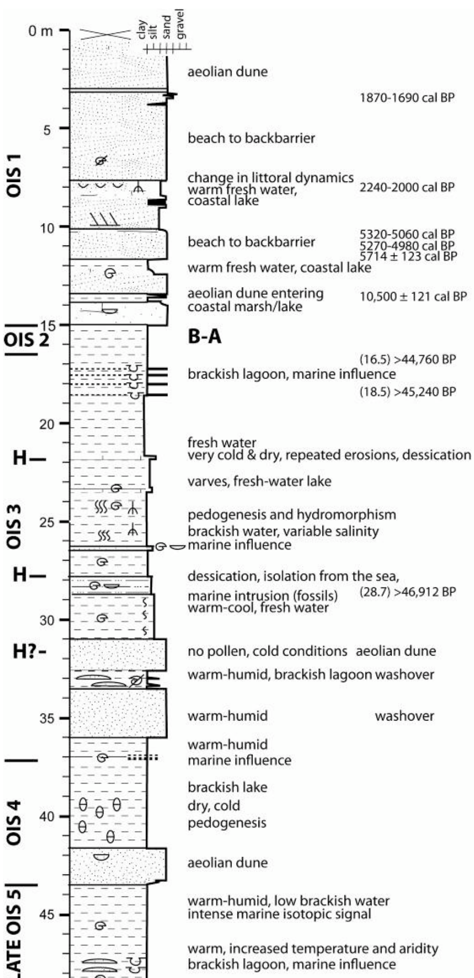

Fig. 2. Stratigraphic section Xeraco 02

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GEOMOPHOLOGIC EVOLUCTION OF MONDEGO ESTUARY MOUTH (PORTUGAL) SINCE XIX CENTURY

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1. Study area and main goals

The Mondego river mouth is located immediately in the central part of W Portuguese littoral, south of Figueira da Foz city. its physiography has been regularized for decades. Supplied by the longitudinal sand drift predominantly from North to South, the adjacent coastal area, is fringed by sandy beaches medium grain sands (Abecassis *et al*, 1962). The hydrodynamics of the coastal area adjacent to the river mouth is controlled by the wave and tide action, and is defined as a mixed energy (wave-dominated) costal area according to Hayes (1979 *in*, Department of the Army, 1995). The geomorphologic evolution of Mondego river mouth, and the identification of the responsible natural and anthropogenic factors for the last 200 years, are the main goals of this study. For that purpose, we merged field observations with the data from historical maps, and aerial photographs covering the period since 1801 and 1959 respectively.

2. Geomorphologic evolution of the Mondego Estury in the historical times

The deforestation of the Mondego hydrographic basin which increased dramatically since XII century ie. after the Foundation of the Portuguese state, impacted the hydrologic and sedimentary characteristics of the river. The rate of erosion in the middle and upper river sectors accelerated as well as the sedimentation rate in the lower river course (Matos, 1985; Mariano & Silva, 1990). In order to resolve the problem of excessive sediment accumulation, the construction of an artificial channel was carried out at the end of the XVIII. This human intervention enhanced the transport of sediments from the watershed to the coastal zone (Fig.1.1).

The first attempt to stabilize the river mouth date back to 1837. It was done in order to promote the sediment transport out the estuary, and to reduce the longitudinal mobility of the sand banks, which put at risk the entire maritime trade (fig.1.2). Other interventions were made in an attempt to controle the constant formation of sandbanks in the estuary, and the formation of a long sand bar, which shifted the river mouth further south against the St^{a}. Catarina Fort (fig.1.4-8). This sand bar reached a length of more than 1100 meters andt its displacement, fueled by a strong littoral drift particularly intense in shallow environments (Abecasis *et al,* 1962; Baptista *et al,* 1995), reached several hundreds of meters per year. Abecasis & Matias (1973) associated that process with a strong fluvial sediment supply, and Duarte & Reis (1992) also mentioned the action of the seasonal Mondego floods responsible for keeping the river mouth open (fig.1.11-19).

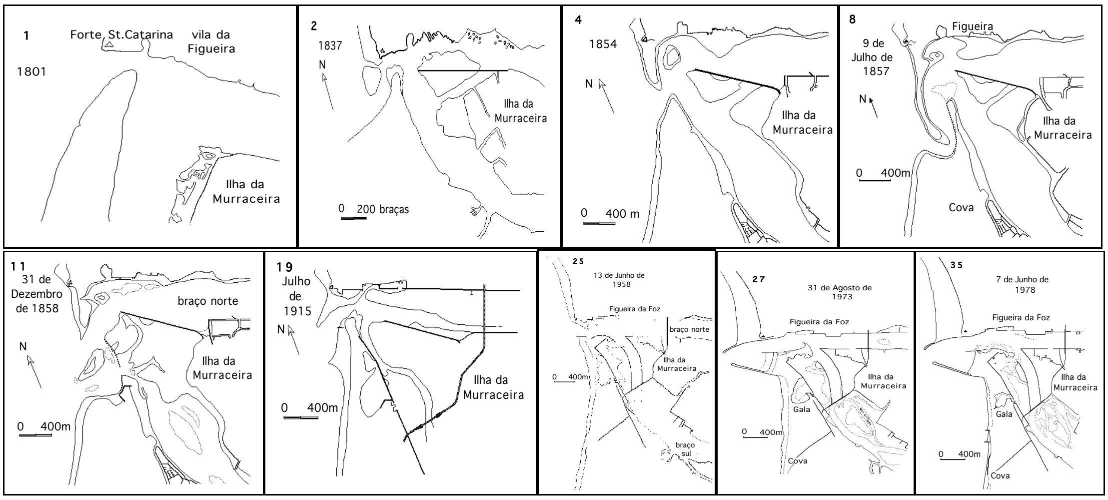

Figure 1 – Maps and aerial photography interpretation of Mondego river mouth obtained and modified from Ministério das Obras Públicas (1966), and from flies of Portuguese Air Force.

Since the sixties the Mondego mouth was stabilized by two long jetties perpendicular to the coastline, which interrupted the littoral drift. These structures have been largely responsible for the accumulation of coastal sediments above the north jetty and for strong coastal erosion below south jetty (Duarte & Reis, 1992) (fig.1.27-35). Meanwhile, the construction of several dams along the Mondego watershed caused a decrease of the sediment supply to the sea, by ca 80% (Dias, 1990. The structures built for coastal protection, and to stabilize the river mouth and the lower course main channel, have transformed the Mondego estuary into a sediment trap, mainly of marine provenance. According to Dias (1990) the above processes combined with the sea level rise are held responsible for the widespread retreat of the Portuguese coastline, observed during the last century.

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LATE HOLOCENE COASTAL-FLUVIAL CHANGES IN THE JEBLEH PLAIN (SYRIA) -- NEW GEOLOGICAL EVIDENCE FOR THE ARCHAEOLOGICAL STORY OF ANCIENT GIBALLA

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1. Geographical and geological setting of the study area

The Jebleh plain is located on the east coast of the Mediterranean Sea in Syria, some 30 km south of the harbour town of Lattakia (Fig. 1). During the last decade, a Belgian-Syrian team excavated the remains of a Bronze Age city Tell Tweini, situated in the Jebleh plain. The archaeological site lies 1.7 km landward of the present-day coastline at the confluence of the rivers Rumailiah and Al-Fawar (Fig. 2). According to the current state of the archaeological research, the site was occupied from ca. 2600-2400 BC and most probably can be associated with Giballa, the southern most harbour of the Ugarit Kingdom which lasted until ca. 333BC.

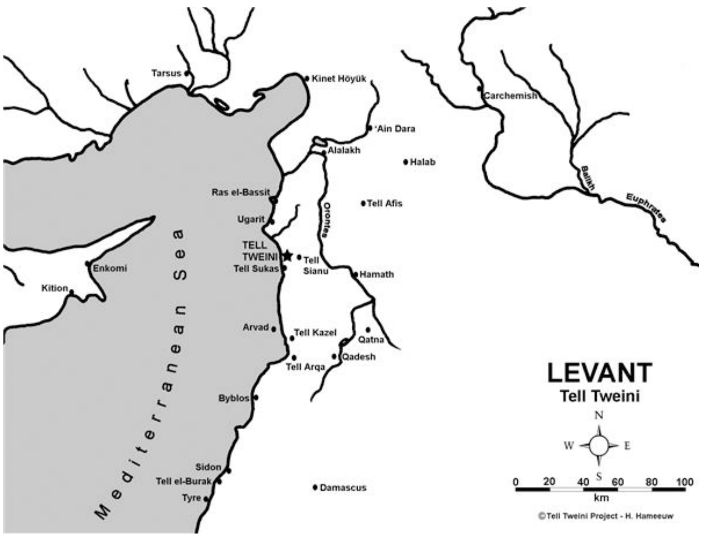

Fig. 1. Location of the archaeological site Tell Tweini along the Eastern Mediterranean coastline, Syria.

2. Methodology

Recently geological fieldwork was carried out to test the hypothesis if Tell Tweini is indeed to be identified with the ancient harbour town Giballa. For the first time the sedimentary sequence of the Jebleh plain was investigated in the context of coastal evolution, relative sea-level change and neo-tectonics. The facies of the sediment succession in undisturbed hand-operated cores were identified on the basis of lithology, sedimentary structures and macrofossils. Reworked fragmented ceramics present in the cores were collected for analysis. Radiocarbon dates, historical and archaeological data will provide chronological control.

3. Results and main findings

The preliminary field results indicate that the sedimentary sequence can be subdivided from the base to the top into a marine, lagoonal, marsh and fluvial deposition unit. Notably, the marine sediments were found at an elevation above present-day mean sea level indicating possible neo-tectonic displacement(s) in the past. Along the present-day coastline, uplifted platforms and notches were identified, also providing evidence for an uplifted shoreline. Recent research (Morhange et al., 2006) on the Lebanese coast (elevated shoreline at ca. +1.2 to +1.4 m and +0.8 m) suggested comparable neotectonic displacements between 3000 BP and the 6th century AD.

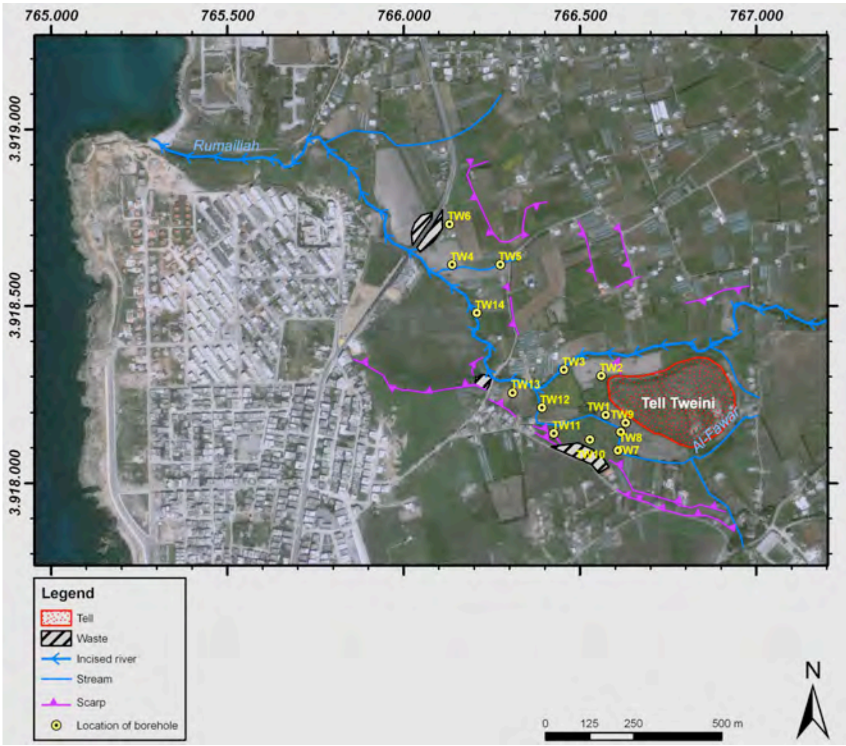

Fig. 2. Map of the Jebleh plain showing the location of the archaeological site Tell Tweini, the modern town of Jebleh and the boreholes.

It is suggested that during the early and middle Holocene, the Jebleh plain was an embayment under coastal conditions. Drowning of the palaeovalley of the Rumailiah resulted in the landward shift of the coastline. These new findings indicate that Tell Tweini is most probably the ancient city of Giballa and had the function of a sea-harbour. From the start of the Hellenistic period (ca. 333 BC) urbanisation shifted towards the location of the modern town of Jebleh.

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SEA-LEVEL CHANGES DURING THE ANTHROPOCENE IN THE SOUTHERN BAY OF BISCAY

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1. Geographical and geological setting of the study area

Marshes in the southern Bay of Biscay are few and fragmentary. They are restricted to the inner parts of the small estuaries that sporadically interrupt the continuous cliffs that characterize this coastal area. Marsh reclamation for agricultural and disease-eradication purposes was initiated in the 17th century, and was particularly intense since the second half of the 19th century. However, during the last few decades agriculture has been in decline and previous cultivated areas have been abandoned. The lack of dyke maintenance has allowed tidal estuarine water to invade these once artificially isolated areas and, consequently, halophytic vegetation is rapidly recolonizing them. All study sites come from estuaries (Barbadun, Plentzia and Urdaibai) with similar mesotidal ranges (2.5 m).

2. Methodology

We collected 73 surface sediment samples and six 50 cm-sediment cores for micropalaeontological analysis in the Muskiz, Isuskiza, Ostrada, Txipio, Mape and Axpe-Busturia marshes. Sampling sites were chosen as representative of different marsh subenvironments in terms of elevation above mean sea level and distance from the main estuarine channel, including different vegetated and unvegetated areas. We measured topographic elevation for all modern samples and cores and this information is presented relative to the local ordnance datum. Tidal inundation frequency at each study area was calculated and compared with the closest tide gauge, and elevations relative to Mean Higher High Water (MHHW) were standardized. Hence, the elevations are expressed as a standardized water level index (SWLI). Microfossil, geochemical, 210-Pb and 137-Cs data have been obtained from these samples.

3. Results and main findings

Detrended Cannonical Correspondence Analysis of the training set with SWLI as the only environmental variable has produced a gradient length of 3.38. This indicates a unimodal nature of the foraminiferal abundance data with respect to SWLI. Thus, we used a unimodal-based method of regression and calibration, known as weighted averaging partial least squares (WA-PLS). The model selected used samples above a standardized water-level index of 160, thus removing lower elevation samples. Using component one, the relationship between observed and tidal foraminiferal-predicted elevation was very strong, a result that illustrated the robust performance of the WA-PLS transfer function (r^2_{jack}=0.81). These results indicated that reconstructions of former sea levels are possible ($RMSEP_{jack}$=11.6). The precision of this transfer functions is comparable to other foraminifera-based transfer functions from the northern Atlantic Ocean. Following back transformation of the SWLI values, the models have a precision of ±0.11 m.

In order to assess the accuracy and regional significance of salt-marsh reconstructions of former sea level based on foraminiferal transfer functions, we have compared the calibration of the foraminiferal assemblages of salt-marsh cores from different estuaries using the regional transfer function constructed for the southern Bay of Biscay. The foraminifera-based reconstructions were placed into a temporal framework using ^{137}Cs, heavy metal concentrations, and ^{210}Pb-derived sediment accumulation rates. The resulting relative sea-level curve has been compared with the nearest tide-gauge data (Santander). RSL trends from core sediments are in excellent agreement among them and in very good agreement with instrumental data, providing a regional relative sea-level rise of 1.9 mm yr^{-1} for the 20th century, with none or little variation during the 19th century. However, we have to consider the full vertical errors derived from the reconstruction, and therefore the error introduced into the calculated trend, and the restriction in the interpretation of the 19th century sea-level reconstruction derived from the low number of sea-level index points and their large temporal errors.

Acknowledgements

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LIMESTONE TUFFS OF THE RIBEIRA DA ASSECA (TAVIRA): A PROXY FOR A MIDDLE HOLOCENE CLIMATIC EVENT

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1. Geographical and geological setting of the study area

In Eastern Algarve, near Tavira, along a segment of 1.5 km of the Ribeira da Asseca, (Asseca streamlet) a system of three limestone tuffs barrages developed originating waterfalls. These three barrages are responsible for a change in altitude of the thalweg from 11 m (above sea level) to 52 m. The valley has a roughly E-W direction and was excavated in Upper Triassic sediments. The northern hillslope was excavated in Upper Carboniferous metasediments, while the southern one was excavated in Lower Jurassic limestone.

The sedimentary infill of the streamlet includes red clay-rich deposits interlayered with sand-rich or conglomeratic bars. The stratigraphic relation between these sediments and the limestone tuffs was not clearly established, up to this moment, although the data collected at the outcrops supports that the limestone tuffs represents an episode of carbonate sedimentation vertically bounded by detritic sedimentation.

The tuffs are well layered, with the thickness of the individual layers ranging from 0.5 cm to 10 cm. The carbonates often mould macrophytes, leafs and other plant remains. Freshwater molluscs were collected and studied. These suggest that the water column was never very deep, with zones of low and high hydrodynamics, which is compatible with the existence of fine grained sediments juxtaposed with sands and gravels.

2. Methodology

Two exploratory sampling campaigns were done in the limestone tuffs barrage system. The first set of samples was collected for dating using the U/Th decay series and the radiocarbon while the second set of samples was used for pollen and macropaleobotanical analysis. The U/Th analyses were done by thermal ionisation mass spectrometry at the *Forschungsstelle für radiometrische*

Altersbestimmung von Wasser und Sedimenten facilities and the radiocarbon dating was done by accelerator mass spectrometry. For the palynological studies the standard methodology with the HCl, KOH and HF series of treatments was used to reduce the samples to their pollen and spore content and the pollen quantification was made with the exotic markers method (Stockmarr, 1971).

A more thorough continuous line-sampling was done on each of the three outcrops of the limestone tuffs to determine the variations in oxygen and carbon stable isotope ratios in each section.

The mineralogical composition of the limestone tuffs was controlled using X-ray diffraction with a D8 Discover Bruker-AXS instrument, operating with Cu-Kα radiation and 40kV accelerating voltage and 30mA current. The 2θ range was 3-75º, step size of 0.05º and step time 2s. The diffractograms analysis and phase identification was done using the EVA Bruker-AXS software and the PDF-2 ICDD database.

3. Results and Discussion

The main results can be synthesised as follow: (i) the limestone tuffs are mainly composed of calcite (>95 % wt) and the quartz and clay minerals are believed to post-date the calcium carbonate precipitation with the deposition related to a phase of karstification and speleothem development ; (ii) the U/Th dating give ages between 5.8 ± 2.1 ky and 7.1 ± 1.6 ky although the high errors involved can stretch the time limits of the tuffs precipitation to a time interval beginning around the 3 ky and extending close to 9 ky; (iii) the radiocarbon dating give ages between 3770 ± 30 and 6560 ± 50 y which is in good agreement with the values obtained from the U/Th system; (iv) there is a periodic change in the $\delta^{18}O$ and $\delta^{13}C$ composition of the tuff layers; (v) the palynological content of the samples has low concentrations, low diversity and reflect a pollen spectra rather recent; (vi) the limestone tuffs are covered by an argillaceous deposit rich in freshwater gastropod from shallow depths (1-2 m) that can be used to constrain the end of the calcium carbonate precipitation.

4. Aknowledgments

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SEA-LEVEL CHANGES DURING THE HOLOCENE IN THE SOUTHERN BAY OF BISCAY

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1. Geographical and geological setting of the study area

The coastal area of the southern Bay of Biscay is characterized by Palaeozoic-Mesozoic-Cenozoic sedimentary rocks forming high cliffs interrupted by short, narrow estuaries that are separated from the open sea by sandbars, beaches and dune deposits. The morphology and extent of the different estuarine sedimentary environments are constantly altered by erosion and deposition of sediments, and they are sensitive to even small environmental changes.

The study was conducted in two estuaries with similar mesotidal ranges. The Bilbao estuary was originally the most extensive estuarine area on the Cantabrian coast of northern Spain. The modern estuary is 15 km long and is formed mainly by the tidal part of the Nervion river. Today this estuary is a largely artificial system which bears little resemblance to the original environment. On the other hand, the Urdaibai estuary is formed by the tidal part of the Oka river, covers an area of 765 ha, and occupies the flat bottom of the 11.6 km long, 1 km wide alluvial valley.

This area can be considered tectonically stable at a temporal scale of 10,000 years, it is relatively far from the former centres of glaciation and therefore the average rate of eustatic change will be the major contribution to sea-level changes. It is also strategically placed between two areas relatively well studied regarding sea-level changes and opposing the north American coast where most high-resolution sea-level studies have been conducted.

2. Methodology

In order to establish the general framework of the sea-level rise during the Holocene at the regional level, 61 samples recovered from 20 boreholes and one trench were analyzed for sedimentological and micropalaeontological content and radiocarbon dating. Samples were selected as representative of different estuarine areas and different elevations above sea level. Depths are referred always to local ordnance datum. The boreholes were drilled on areas considered to be representative of the different estuarine subenvironments using a rotary drill that produced a core approximately 10 cm in diameter. In each case, the borehole terminated in Cretaceous basement.

In the laboratory, the samples were dried in an oven at 60°C and then weighed. They were wet sieved through a 63 µm mesh, dried, and weighed again to determine the proportion of sand. The foraminifera were concentrated using trichloroethylene. These preparation techniques were carried out carefully in order to reduce possible destruction of the more delicate taxa. Samples were split into fractions using a splitter and all specimens contained in a fraction were picked. Generally around 300 individuals were picked, mounted, and identified from each sample.

Radiocarbon dating was carried out using forty five shell samples, ten wood samples, one bone sample and four samples were dated using foraminiferal tests (*Ammonia tepida*). Twenty seven of them were large enough for radiometric analysis and C-14 content was quantified by measuring emanating radiation which occurs during the decay process. Of those, four samples contained less than 1 gram of final carbon and were analyzed with extended counting to enhance precision. The other thirty four samples were very small and required direct atomic counting using an accelerator mass spectrometer. All radiocarbon dates were calibrated into calendar years before present (cal yr BP) using CALIB 5.0.1. The dates obtained on shell material have been also corrected for the marine reservoir effect (apparent surface-water age), which has been estimated to be around 400 years on the Bay of Biscay.

3. Results and main findings

Foraminiferal assemblages and sand content combined with 14-C dating in the sedimentary successions of the Bilbao and Urdaibai estuaries reflect sea-level and palaeoclimate change during the Holocene providing the first sea-level curve of local and regional significance. During Late glacial to early Holocene low sea-level conditions, sedimentation was represented by fluviatile gravels and coarse sands (lowstand systems tract-LST). During the transgressive systems tract (TST) the sea level rose very fast from ~ 26 m bmsl at ca 9000 cal yr BP to ~ 5 m bmsl (~ 3 m bmsl if isostatic displacement is not considered) at ca 7000 cal yr BP. During the HST, since ca 7000 cal yr BP, sea-level rise rate slowed down significantly reaching current level at ca 3000 cal yr BP. This is in excellent agreement with other regional and global sea-level curves. Additionally, climatic changes during the Holocene are also reflected, although those can not be interpreted in terms of sea-level oscillations and instead represent transgressive/regressive surfaces that could provide misleading sea-level index points.

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LATE PLEISTOCENE AND HOLOCENE RELATIVE SEA-LEVEL CURVE AND PALAEOGEOGRAPHY OF THE LOWER TAGUS VALLEY (PORTUGAL)

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1. Geographical and geological setting of the study area

This study focuses on the Lower Tagus Valley in Portugal, where deep glacial incision created accommodation space for a sedimentary record since ~20 000 cal BP, making this a unique site along the European Atlantic margin with respect to palaeogeographic and sea-level changes.

2. Methodology

Based on nine cross sections and 55 radiocarbon dates together with a newly created relative sea-level curve, we constructed five palaeogeographic maps of the infill of the Lower Tagus Valley since ~20 000 cal BP.

3. Results and the main findings

We illustrate that relative sea-level rise and fluvial sediment supply were the prime forcing factors determining the depositional history and palaeogeographic changes. Around 20 000 cal BP a deeply incised braided river existed, which was directly connected to the ocean across the narrow continental shelf. After that (~12 000 cal BP) the gradually moister and warmer climate caused a change to a single-channel river. During the following period (12 000-7000 cal BP) relative sea-level rise resulted in a transgression in the Lower Tagus Valley and the establishment of extensive tidal environments. After relative sea-level rise had ended (~7000 cal BP) the valley was progressively filled by a fluvial wedge and tidally influenced bayhead delta. Since ~1000 cal BP the valley-fill history was dominated by increased sediment input due to human-induced degradation of catchment slopes. Generally, climate was of subordinate importance during the entire studied period, merely causing a single-channel river resulting from the change from the cold Heinrich event 1 to the temperate Bölling-Allerød interstadial. Despite the tectonic activity in the region, neotectonic uplift or subsidence were limited, as supported by the horizontal relative sea-level curve since ~7000 cal BP. Neotectonics played a minor role due to the large distance from the Fennoscandian ice sheet and the narrow continental shelf, which prohibited strong glacio- and hydro-isostatic movements.

HOLOCENE SEA-LEVEL CHANGE IN THE DYFI ESTUARY, WEST WALES, UK

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1. Geographical and Geological Setting of the Study area

Relative sea-level predictions for the Welsh coastline produced by glacio-isostatic adjustment models show that the estuaries of west Wales, and in particular the Dyfi estuary, occupy a crucial location with regards to Holocene sea-level studies. Modellers of the glacio-isostatic adjustment process (e.g. Peltier, Lambeck and others) suggest that relative sea-level in the region attained a sea-level highstand equal to, or greater than, present day sea level around 4000 years before present (Edwards, 2006). In North West Wales this highstand is estimated to have reached heights around 3 m above modern day sea level and is predicted to decrease in altitude with increasing distance southwards. However, these model predictions have yet to be supported by reliable field data. Although the Dyfi estuary has a long and rich history of ecological, lithological and biostratigraphical research, reliable sea-level data remain very sparse.

2. Methodology

A series of cores were sampled from the south western extent of the Dyfi estuary in June 2008 and were subjected to litho- and biostratigraphical (diatoms) analyses to provide preliminary insights into the palaeoenvironmental history of the estuary.

3. Results and main findings

Preliminary corings have identified a 'salt-marsh clay' wedge contained within a *Sphagnum* and *Calluna* peat deposit, confirming with the earlier work of Godwin and Newton (1938). Preliminary diatom analyses (this study) suggest that this unit was formed under salt-marsh conditions. Once radiocarbon and lead-210 analyses have been completed it will be possible to provide age constraints on this period of salt-marsh formation and relate this to former relative sea levels, with the ultimate aim of providing reliable sea-level data for testing geophysical model predictions.

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MARINE-FLUVIAL INTERACTIONS DURING RAPID SLR IN THE EARLY-MIDDLE HOLOCENE, WESTERN NETHERLANDS

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1. Research questions and geological setting

The study area is located in the western Netherlands where Rhine and Meuse debouch into the North Sea. The purpose of this study is twofold: 1) establish a local sea/groundwater-level curve for the period 11-7.5 kyr cal BP, 2) reconstruct interactions of marine and fluvial sedimentary systems.

The studied deposits bury the Rhine-Meuse palaeo-valley of the last glacial (Busschers et al., 2007). Earliest Holocene (Preboreal) fluvial deposits map out as incised channel belts within the palaeo-valley. During the subsequent transgression the area drowned and changed into an estuary with adjacent back-barrier basins behind embryonic barrier ridges (e.g. Beets and Van der Spek, 2000; Berendsen and Stouthamer, 2000).

2. Materials and Methods

Data for the reconstruction of marine/fluvial interactions were collected using existing archives of core descriptions, cone penetrations test, pollen/diatom, radiocarbon and OSL-dating. In addition new corings were executed. Seismic data was acquired using an X-star chirp-pulse system in a 1 km x 0.25 km grid. Sea-level/groundwater index points were obtained by dating basal peat layers from deltaic fluvial and upper most estuarine settings in the study area.

3. Results

Prior to 8 kyr cal BP, the index points, show the rate of groundwater-table rise to gradually increase, especially after 8.5 kyr cal BP. However rates of rise remained lower than contemporary rates of SLR. Around 8.4-8.3, SLR seems to have accelerated briefly, probably linked to a global sea-level jump of 0.5-1 m that is related to the following 8.2k-climate event. After 8 ka, index-points reproduce existing reconstructions of relative SLR for the study area.

SLR induced a transition from incisive to aggrading river systems that started ~ 9 kyr cal BP (Hijma et al., subm.). Drowning of the southern North Sea allowed wave-action after ~8.5 kyr BP to build-up embryonic barrier systems along a coastline *west* of the modern coast. Between that 'late Boreal' coastline and Rotterdam, back-barrier basins flanked the Rhine-Meuse estuary. After 8 kyr cal BP the Rhine mouth avulsed northward into back-barrier basins. Seismic data revealed back-barrier channels, of which the in-fills date from this this period. . This was caused by increased fluvial sedimentation into the basins, resulting in a decrease of tidal prism. The sand "hunger" of the back-barrier channels was stilled by marine erosion of offshore located sediments from the abandoned river mouth to the south. The eroded sediments were transported northward and alongshore into the back-barrier basins. Below the back-barrier deposits well preserved terrestrial deposits (inland aeolian dunes, peat and clay) were recognized.

Between 7.4 and 6.5 kyr cal BP, complete make-over of the Dutch coast took place. The Rhine avulsed further north and the location of the main branch remained stable until ~2 kyr cal BP (Berendsen and Stouthamer, 2000). The seismic data indicate that during that time the barrier-system was overstepped to a position near the present coastline. In following centuries, the barrier-system migrated a further 10 km inland. The evidence for barrier overstepping rather than gradual inland migration is indirect. Would the barrier-system have retreated continuously, scour features of tidal inlet channels should dissect back-barrier deposits. The lack of any of such features in the seismic data in a 50-km wide zone parallel to the modern coast favours stepwise retreat. Wave-action after overstepping eroded the top 3-6 m of the back-barrier deposits (Rieu et al., 2005). Overstepping was probably stimulated by the fore mentioned increased sedimentation into the back-barrier basins. The resulting decrease in gradient caused the basin to widen as SLR was still rapid. This can lead to overstepping (Rampino and Sanders, 1980; Swift, 1968).

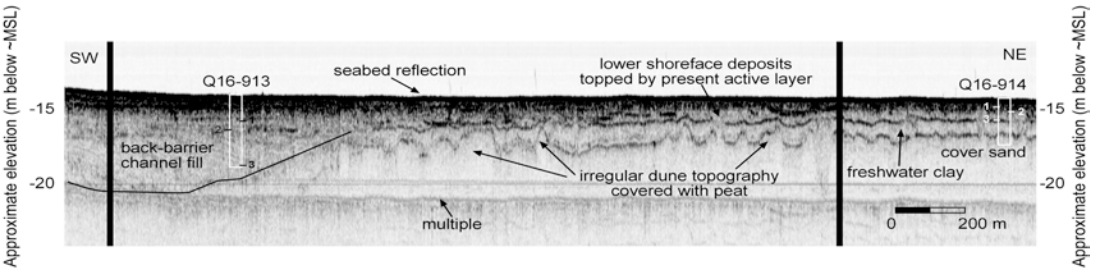

Fig. 1. Seismic cross-section showing a back-barrier channel fill besides well preserved terrestrial deposits.

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THE GEOMORPHOLOGY AND STRATIGRAPHIC EVOLUTION OF LATE HOLOCENE BACKBARRIER, SANTA CATARINA STATE MID-SOUTH, SOUTHERN BRAZIL

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1. Geographical and geological setting of the study area

The purpose of this paper is describe the morphology features and Holocene sedimentary succession to a sector backbarrier located Santa Catarina State Mid-South coast between the city of Laguna and Jaguaruna.

2. Methodology

The geomorphologic and succession of backbarrier deposits were investigated, respectivement, through aerial photo analysis, trenching and vibracore. During this investigation we attempted to distinguish the deposits with a paucity of sedimentary structures, fossils, and detailed grain size analysis. Four vibracore reaching deep of 2m were obtained on the backbarrier of Santa Catarina State mid-south coast, as well as 10 trenches of various sizes (up to 1,5 long and 1m deep) were excavated in distinct morphology features. The morphology features were interpreted through aerial photo in scale scale 1:25000 based on flights of the years 1978/1977 and 1956.

3. Results and the main findings

In the backbarrier between Laguna and Jaguaruna mid-coast of Santa Catarina State were recognized by photo interpretation four remarkable morphologic feature: lagoon margin associated emerged and submerged transverse bars and beach ridges, supratidal to embayed intertidal salt marsh, lagoonal inlet (with associated flood-tide deltas) and active and inactive aeolian parabolic dunes. In moment the examination of the stratigraphic cross of trenches and core discriminate 2m of succession of backbarrier deposits. Three layers are distinguished from base to top of the deposits. The lower layer of the succession occurs between about 2 and 1 m deep, consists fine sand characterized by the abundant occurrence of *Anomalocardia brasilina* and more rarely *Tivella sp, Diplodonta sp, Divaricella sp, Crossostrea sp, Tagellus sp, Cerithium sp, Lucinidae sp.* The shell evidence of abrasion or physicajl damage and can occur both as articulated and disarticulated valves. This reworked shells of *Anomalocardia brasiliana* were collected and dated. The results give a maximum age of about 5303-5652 years AP and minimum age of about 1852-2247 years AP. At this time interval, a gently oscillating decline of relative sea level (RSL) occurred, after a Holocene sea level maximum of 2.1±1.0 m at 5916-5587 cal years BP (Angulo et al. 2006).The intermediate layer with less than 50cm thick comprises deposits of medium to fine sand with fragments shells. This first 1.5m of the sucession shows gradual filling and lagoonward progradation of shallow lagoon margin, submitted to tide- and wave-induced currents. The layer than cover the lagoon deposits, in the top of succession, is dominated by 50cm-thick of fine sand with abundant plant debris, including *in situ* roots, and no shells. The upper layer consists mainly for deposits from the aeolian dunes The stratigraphic suggest the vertical regressive succession represents the progressive backbarrier landward migration and emersion under conditions of declining sea level.

Acknowledgments:

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QUATERNARY HEAVY MINERAL SIGNATURE ALONG THE ALGARVE COAST, SOUTH PORTUGAL

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Heavy mineral assemblages in sandy sediments from coastal zones may represent good tracers for reconstructing the paths and sources of their constituents, contributing therefore to the assessment of the interactions between land and ocean (e.g. Deer *et al*., 1992). However, processes occurring in the coastal zones themselves can also alter the original signal and therefore they also have to be considered as important factors influencing the heavy mineral signatures.

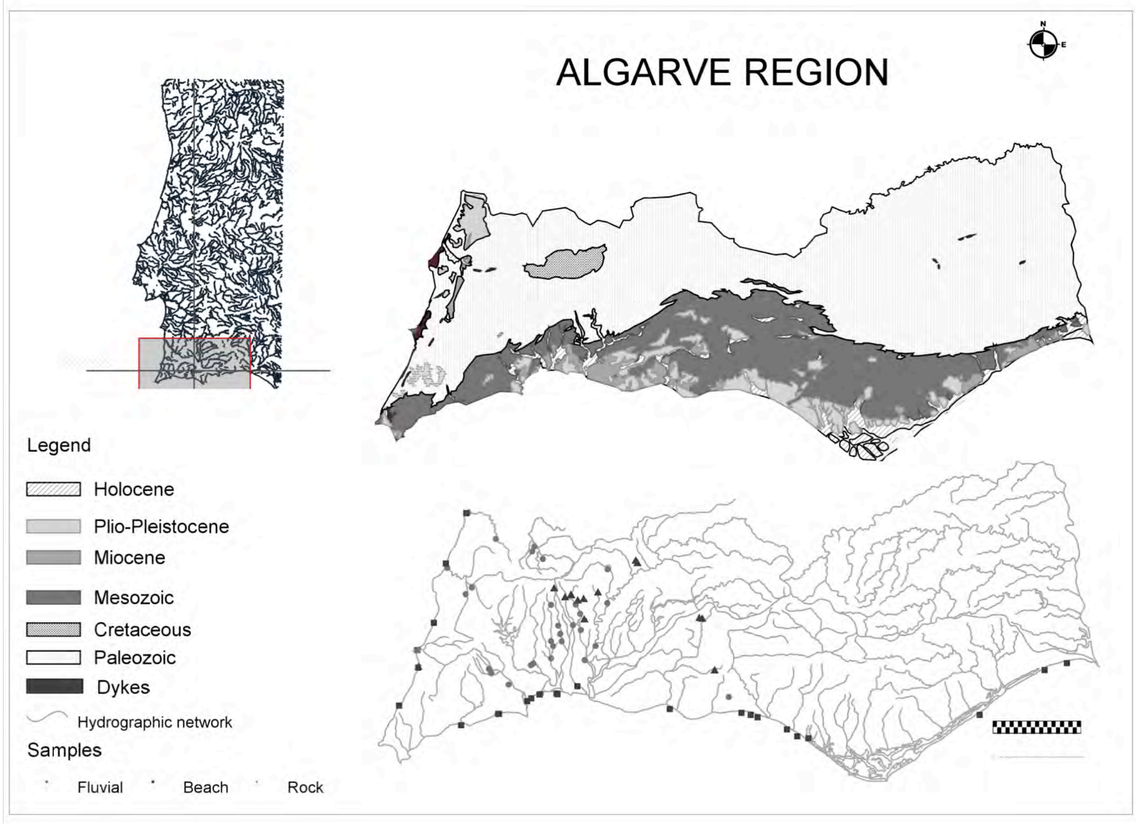

Figure 1: Geological and hydrological maps of the region of study. Sampling sites are also shown for fluvial and beach sediments as well as for rock samples.

1. Geographical and geological setting of the study area

The present work has been developed in the Algarve region, the southern most region of Portugal, which is delimited by the Atlantic Ocean on its western and southern coast, and by Alentejo Portuguese region and Spain, on its northern and eastern borders respectively. The Algarve geology can be described from a general point of view as becoming younger from north to south (Fig. 1, Feio, 1952). Indeed, the northern part of the region is mainly represented by schists and greywackes from the Palaeozoic, which are intruded in the western side by a massif of nephelinic syenite of cretaceous age, forming the Serra of Monchique (Fig.1, Sousa, 1926). Southward of the Palaeozoic formations, lay the infilling formations of the Algarve sedimentary Basin consisting of limestones and calacarenites from the Mesozoic as well as fluvio-marine detrital deposits from Miocene and Plio-Pleistocene. Finally, the Holocene deposits occur mainly along the southern littoral zone, the Ria Formosa lagoon and barrier-island system constituting a example oh these deposits (Fig. 1, Pereira, 1990).

2. Methodology

Around 60 samples have been analysed for their heavy mineral's content. Rock samples have been crushed to the grain size of sand. All samples have then been sieved at 200 µm and heavy minerals separated from the bulk sediment based on their density and magnetic susceptibility. Minerals have been observed under binocular and when need under scanning electron microscope coupled to X –Ray detector for acquiring their elemental composition.

3. Results and the main findings

Eighteen mineral species have been identified among which zircon, titanite, staurolite, anatase, garnet, rutile and tourmaline. Whereas detrital zircons do not seem to differ between the different assemblages nor in shape or colour, titanite seems to show a rounding effect along rivers, which source in Serra of Monchique, towards the shore allowing therefore to be used as a tracer of this source rock.

In general, the observed heavy mineral assemblages show some differences between samples from rivers and beaches as well as between samples from the western coast and the southern coast. However, the main observed differences are based on semi-quantitative abundances, meaning that processes of relative dilution or concentration driven by local wind and/or water currents may be responsible for the observed results.

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Poster presentations

DIRECTIONAL MARKERS OF INCOMING TSUNAMI AS SIGNATURE OF SOURCE-AREA

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1. Introduction

The directions of an incoming tsunami and of the coastal run-up are not always the same, as they depend on the submerged-emerged topography, although both are evidenced by sedimentary markers or other, biological and anthropogenic, ones. The moment when this knowledge can be applied to the coastal record of past tsunamigenic events, such as the Holocene, has still not arrived, although it would be of immense interest, as it would help us establish recurrence of run-up in especially vulnerable zones.

2. Methodology

In the last decade, numerous investigations have focused on the Holocene geological record of high-energy events (tsunami, storm, hurricane, cyclone). Lag deposits associated with tsunamis are characterized by large boulders, boulder ridges, pebbles, and shells high above the modern storm level, washover fans, bioclastic sand sheets with signs of bidirectional flows, sandy layers intercalated in muddy deposits, or shell-bearing deposits sandwiched by fossil soils. In these records, the directional markers of the incoming tsunami and run-up are more difficult to detect, and the only vestiges are erosional morphological indicators (e.g. cliff, fresh scarp, seepage gully, creek, broken beach-ridge / sand-spit), lag deposits (e.g. imbricated boulders and blocks, boulder ridge, boulder field, megaclast), and archaeological evidence (e.g. fallen columns and walls in position, and broken linear structures with aligned fragments, imbricated ceramic remains).

3. The 1755 Lisbon Earthquake example

Although the Atlantic bed of European coasts is at considerably less seismic risk than that of the Pacific or Indian Oceans, there is historical and geological evidence of seismogenetic tsunamis that affected Western Europe. The most active zone is situated to the SW of Portugal (Cape St. Vincent), apparently the source of the last and most destructive tsunami – that known as “1755 Lisbon Earthquake”, M_w 8.7. The historical evidence and geomarkers that this tsunami has left on the Portuguese and Spanish coasts can serve as an example to test the use of such indicators in the localisation of its epicentral zone. The greater or lesser precision in the search will depend on the quality and reliability of the markers used and on the suitability of the coastal outcrop. Obviously, local refraction/diffraction effects play an important role, but a very important factor is undoubtedly the local beach slope.

In the last few years, various sites have been suggested for the origin of this earthquake, based on seismic, tsunamigenic, and geodynamic methods (Fonseca, 2005). Despite the increasingly abundant data available on the direction of the incoming tsunami and its run-up on these Atlantic coasts, reliable evidence was recorded at only some places. At Cape Raso (W Lisbon), the geomarkers indicate that the wave came from the SW to SSW (Scheffers and Kelletat, 2005), in the bay of Cádiz from the W to WNW (Dabrio et al., 2000; Blanc, 2008), and at the Cape of Trafalgar, from the WNW (Gracia et al., 2006).

The geographic intersection of these directions initially defines a possible epicentral area, located on Gorringe Bank, a zone previously indicated by other authors as a possible candidate, and which today shows considerable seismic activity, above all in active thrust faults such as the Gorringe Fault. Thus, the origin of the earthquake should be located in the possible epicentral area and on the intersection between the Gorringe fault-line and the line joining Trafalgar and the possible epicentral area. Future, more-detailed studies with geomarkers on these and other coastal outcrops will enable the possible site of this earthquake to be located more exactly.

4. Acknowledgements

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THE LATE QUATERNARY GEOMORPHOLOGY OF THE MANAWATU COASTAL PLAIN, NORTH ISLAND, NEW ZEALAND

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1. Geographical and geological setting of the study area

The Manawatu region comprises the south western portion of the c. 40,000 km^2 Wanganui Basin that extends from Mt Taranaki in the north, to Kapiti Island in the south. The basin formed in a subsiding back-arc position, related to the modern Pacific–Australia plate boundary. Prior to uplift in the late Quaternary, rates of sedimentation within the Wanganui Basin broadly matched those of regional subsidence. As a result, the basin fill comprises numerous cycles of deep and shallow marine sedimentary successions related to glacio-eustatic sea-level cycles, representing one of the most complete and undeformed shelf and shallow marine Plio–Pleistocene records in the world (e.g., Pillans, 1983; Abbott and Carter, 1994).

2. Methodology

This review examines prior investigations of the geomorphological evolution of the Manawatu coastal plain, with a focus on the Last Glacial Maximum (LGM) when lowered sea levels resulted in fluvial incision into Plio-Pleistocene sediments. Rising sea levels during the Holocene postglacial marine transgression and the subsequent sea level highstand, led to significant infilling of accommodation space in the incised valley by estuarine and fluvial processes. This eventually formed a broad coastal plain, overlain by the most extensive transgressive dune field in New Zealand.

3. Results and the main findings

The geomorphology of the Manawatu coastal plain and coastal landscape has largely been controlled by sea-level fluctuations over the last glacial cycle. Falling sea levels leading into the LGM, together with tectonic uplift, resulted in the exposure of Last Interglacial (LIG) marine deposits and the subsequent dissection of a seaward-sloping raised marine terrace. Remnants of the LIG terrace are well preserved in the Manawatu district, forming broad planar surfaces flanking the adjacent Tararua-Ruahine Range. During the LGM the palaeo-Manawatu River incised a deep, wide valley. The deposition of fluvial gravels throughout the lower reaches has formed numerous paired terraces (Clement and Fuller, 2007). An episode of aeolian activity during the LGM resulted in the formation of localised parabolic sand dunes that lie on the LGM aggradation surface (Shepherd, 1985; Duller, 1996; Hawke and McConchie, 2005).

During the Holocene postglacial marine transgression c. 6500 years ago rising sea levels inundated the incised valley (Gibb, 1986; Shepherd 1987). During this time natural barriers formed by subdued anticlines isolated the incised valley from oceanic influences, resulting in the formation of a low-energy estuarine environment which facilitated partial infilling of the incised valley. During the Holocene highstand (c. 3000 years ago) estuarine deposition was succeeded by fluvial deposition and floodplain aggradation. Simultaneously, the dominant westerly swell supplied sediment to the nearshore environment. Subsequently, this sediment was transported further inland by prevailing west-north-westerly winds, forming the most extensive transgressive dune field in New Zealand over there distinct phases:

1. The Foxton Phase (6500 – 1600 years ago), being the most extensive phase of dune migration extending up to 16 km inland with dunes rising to a maximum elevation of 30 m.
2. The Motuiti Phase (1000 – 500 years ago) of dune migration, extending up to 11 km from the coast. Possibly associated with the de-vegetation of previously stabilised dunes accompanying Maori occupation which began in the Manawatu region 650 – 700 years ago.
3. The Waitarere Phase (<120 years), in which a coastal belt of active and stabilised dunes formed between 0.5 to 4 km inland. This phase of dune activity has been partly attributed to the destabilising of dunes associated with European settlement of the Manawatu, particularly overgrazing and the burning of original vegetation. However, as dune mobalisation is a natural process it appears that European modification of the landscape only assisted in dune activity.

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STRATIGRAPHIC, SEDIMENTOLOGICAL AND GEOARCHEOLOGICAL RECORDS IN NORTHERN FRANCE, COTENTIN AND BRITTANY: SIGNATURE OF STORM SURGES AND THEIR CONTINENTAL IMPACT

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1) Methodology

High resolution stratigraphic, sedimentological, eustatic and palaeo-climatic data were originally obtained on coastal dunes of northern France (Boulonnais and Picardy). This study is constrained by more than 60 new radiocarbon dating, by calibration of old data sets (for a total of 290 dating used) and by decompaction of peats and mud from core samples. This work allowed establishing a regional chronostratigraphic framework, which is then applied to the coasts of the North Sea, the English Channel and the French Atlantic. This inter-comparison study allowed the reconstruction of a palaeo-environmental sequence of events then translated in terms of a sequence stratigraphy of the Holocene sedimentary prism. After the definition of this first general chronostratigraphic context and the evidence of storms impact, we have integrated palaeo-ecological, archaeological and historical data. To combine these different sources, we have maintained our study in several spatial and temporal scales. This step leads to precise the chronological context of the coastal evolution, notably in the most recent periods.

2) Results

One of the main important features of this work is the evidence of an increase in frequency and violence of storms since the Roman times. This period is characterized by the build-up of the coastal dunes and by sporadic marine inundations under storm surges (e.g. characterized by interstratifications of dune and marine sands, often compacted). These events are generally mistaken for a true transgression, in the use of the traditional Dunkerquian transgressions model. The new bores prospecting always associated with radiochronological and sedimentological data have contributed to refine the chronostratigraphic sequences, in a first time on a regional scale and, in a second time, on the more global context of the Western Europe.

The fluvial dynamic and the progressive silting up of estuaries (e.g. in Picardy or in Cotentin), considerably limit today the navigation and the direct exchanges between populations. However, from the Bronze Age to the Modern Period, these coasts had been used as a link between the populations of British Isles, and those of the continent and of northern coastal domains.

Three major cultural periods, at a regional scale, are concerned: the old Protohistory, the Early Middle Ages (VI-Xth centuries) and the transition between Middle Ages and the Modern Period. On studied sites, the acquisition of palaeo-ecological data precises not only the main phases of marine trangressions, but are also used to characterize the specific/local influence of storm surges (e.g. temporay flooding in coastal marshes).

In parallel, the informations from old maps, in form of anomalies in parcel boundaries or modifications of coastline or of river layout, contribute to “modelize” the morphological evolution of the valleys, coastal marshes/mires, and dune complexes. The compilation of these sources opens perspectives: historical documents (e.g. terriers, hagiography, diplomatic), selected for their land and hydrographic information’s, supply, more than the rare maps, specific elements on the palaeo-morphology of the present estuarine zone. Compiling the informations from all these different proxies contribute to undrestand the palaeo-environmental evolution of coastal sites and to reconstruct the physical constrains for old and more recent settlements.

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SITE EFFECT VULNERABILITY & COASTAL RESPONSE TO SEISMIC EVENTS IN ALGARVE

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1. Geographical and geological setting of the study area

The geotectonic setting of the Algarve region, South Portugal, favours seismicity as shown by the historical and instrumentally recorded earthquake data. The most outspoken among them is the Lisbon tsunami occurred in 1755. Morphological and topographic features, local lithology, structural setting and basin architecture control propagation of the seismic waves and are termed jointly as site or local effect. The latter may aggravate the earthquake consequences through the amplification of the substrate movement and/or increase in the shaking time. Quaternary sediments (Ergin et al., 2004; Harbi et al., 2007) and basin architecture (Semblat et al., 2005) are fundamental issues.

Geomorphology of Algarve is characterized by a W-E tectonically controlled sedimentary basin. Northern hills were modelled onto Palaeozoic flysch units bordering to the south with a gently downslope area called *barrocal* where karstified Mesozoic and Cenozoic carbonate rocks predominate. The coastal area is differentiated in western rocky and sandy cliffs (Mesozoic and Miocene) and eastern Holocene barrier island system. The Algarve coastal zone is a strongly seasonal human impacted area.

2. Methodology

The main issue of the project was the production of a seismic hazard map for the Algarve region. Several factors that potentially contribute to the site effect were studied, parameterized and spatially detailed. These are by decreasing order of importance: (i) The consolidation degree, (ii) karstification, (iii) sedimentary basin architecture and, (iv) slope (as a function of lithological type).

To each one of the four parameters a hazard index was attributed (5 classes from 0 to 4) and a final expression was calculated:

$$\text{Global Hazard Index} = \text{Lithology} + \text{Width} + \text{karstification} + \text{Slope}$$

All data was prepared in ArcGIS *shape* and *grid* formats.

3. Results and the main findings

The global seismic hazard index (GSHI) shows a positive relationship with the three geomorphologic domains: (i) low GSHI in the Palaeozoic rocks in the northern part of the province; (ii) medium GSHI in the central Mesozoic and Cenozoic units and, (iii) high GSHI in the Miocene carbonates and Quaternary sediments that mostly outcrop in the littoral plain (Fig. 1). The referred results traduce the high importance of the rocks and sediments' lithification degree for the local effect on the seismic wave's propagation. Nonetheless, the Miocene palaeokarst filled by clastic sediment greatly contributes to the high seismic hazard index on the littoral zone.

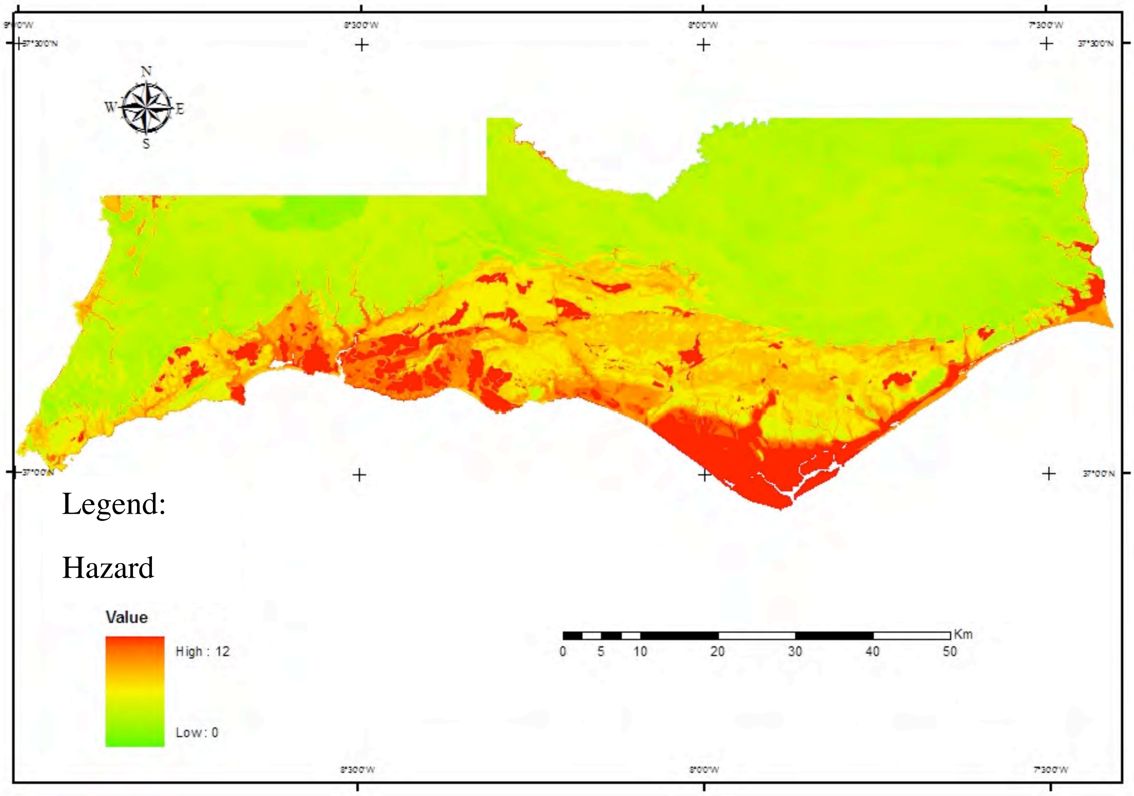

Figure 1 – Site effect on the seismic hazard index in Algarve region

4. Acknowledgements

This project was fund by the Portuguese Civil Protection National Authority. Site effect is part of a multidisciplinary study to implement a seismic and tsunami simulator.

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FRESH WATER IN THE REEF ISLAND COMPLEX: MITIGATION AND ANTICIPATION TO THE GLOBAL SEA LEVEL RISE. (CASE IN DERAWAN ISLAND, EAST KALIMANTAN)

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1. Geographical and geological setting of study area

Derawan Island is one of the reef islands that had been developed since the last maximum glacial on the sandy – muddy substrate in front of Berau Estuary. This region is part of sub Berau basin, part of the larger Tarakan basin which geologically setting is under the extensional tectonic opening that separated Kalimantan (Borneo) and Sulawesi (Celebes), forming Makassar Strait. Some active vertical faults are paralel to the coast, cut the area into blocks that are subsiding, forming a NNW-SSE elongation of reef platform. North south strong current, part of Indonesian Through Flow, passing through, and sweep the heavy load sediment from the estuary, far to the south keeping the estuary water is almost clear. This allows the continuous vertical development of the reef in the on going subsiding environment through time following sea level variation since Quaternary period. Some drill holes had been made down to 80 m depth to obtain continuous core samples in the reef island and in the delta plain. Those reveal that, instead the subsidence phase that had influenced, sedimentation in this area also had been interrupted by such unconformity due to the transgression-regression of the last Quaternary sea level variations. Thick sediment and catch up reef of Holocene to Recent, formed the existing morphological view in this area. Coarse carbonate sediments that are derived from the reef, transported, dispersed and deposited, then built the small island. Meteoric water is trapped and accumulated in the shallow sand's aquifer. Soon people found that there is enough fresh water and habitable space to live, the island became occupied and water used as daily consumption.

2. Methodology and approach

On the present trend of global sea level rice of and tectonic subsidence, hence the islands are under the more than 4 mm/y rate relative sea level rise. This brings the islands into a slow on set disaster to the reef islands which on going threats are the erosion, inundation to the land and the salt water enchroachment to the fresh water aquifer system. On going trend of the increasing population and its activity in those islands that is followed by the increasing of fresh water exploitation, will increase the stress to the fresh water balance. Thinning fresh water lenses will cause shallowing salt water column to the level that may change fresh water environment and kill the biota.

Resistivity measurement had been conducted to obtain geological pattern of small island and the distribution of fres, brackish and saline water in the sand and gravely sand sediment of coral reef island. Core drilling had been done to obtain long core samples up to 80 m depth that consists Holocene down to Upper Quaternary sediment sequences.

3. Results and the main finding

Coral ref island Derawan had been built as the carbonate sequence of a catch up reef. The reef is sitting upon the gray to black well laminated clay to fine sand sediments deposited in the shallow marine environment. The carbonate sequence consists mainly of reef debris. Upper layer of sediment sequence of Derawan consists of coarse sandy carbonate, deposited on the shallow reef platform. This thick (5-8 m) unconsolidated carbonat sand is the main aquifer of the fresh meteoroc water for the island. Fresh water is trapped, forming a lenses upon the saline water.

To mitigate the threat of reducing on fresh water in the island, treatments should be enforced, as well as increasing the capacity of the shallow fresh water aquifer and to avoid spoiling out meteoric water during heavy rain by introducing a natural filter as mangrove along the coastline. Excessive evapotranspiration also should be maintained as well as uncontrolled fresh water exploitation that coming from anthropogenic activity. Those need the understanding of geological condition, oceanic and atmospheric variation, but also antrhopogenic influence that is working to the island and its environment.

Fresh water well system had been made which system just allow fresh water flow into the tank through the screen that had been placed in the level of fresh water depth. Introducing plantation in the beach may produce fine grain soil that keep fresh meteoric water in the aquifer spill out to the sea during low tide.

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NEW DATA ON THE SEA LEVEL RISE AND SEDIMENT INFILLING IN ESTUARIES OF MIRA AND GUADIANA, PORTUGAL – A COMPARISON

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1. Geographical and geological setting of the study area

The Mira Estuary is located in a valley deeply cut into the coastal platform, formed in Carboniferous shales and grawackes. The studied borehole VN1 was located (37º42'44''N 8º45'04'' W) in a saltmarsh covering the lateral bar of the meandring river, ca 6 km from the mouth. It reached the bed rock at 51m depth. The Guadiana Estuary borehole CM6 was located (37º14'58''N, 7º25'46'' W) ca. 8.5 km from the river mouth, within the marsh intertidal range of a lateral sediment bar and reached the substratum at 72.5 m. It is

2. Methodology

Both drillings were carried out with a WIRTH Bo drilling rig using bentonite slurry and steel. Besides the routine core descriptions, mineralogical, granullometric and microfauna analyses were carried out. The benthic foraminifera identification and counting was performed on 200 -300 tests, recovered from the sediment fraction comprised between 500 and 64 μm.

3. Results and the main findings

The lithological profile of VN1 consists of 4 units. The basal gravels and sands of indeterrmined age are overlain by a silt layer capped by peat with measured radiocarbon age of 11141 yr calBP at the depth of 43.2 meters. From the 6 samples so far taken only one sample from the basal layer contains diverse foraminifera including *Cibicides lobatulus* (34,15%), and diversified planktonic species (21,95%). This would idicate a marine/estuarine period from before the LGM or it is an affect of contamination. The following unit, which is a sandy horizon, was interpreted on about 50 % of the whole record due to the low recovery of core. Nevertheless it appears as a remarkably homogeneous 33,5 m thick body of sand with a generally rich foraminifera fauna indicating a very energetic exchange with the coastal sea. In that aspect VN1 recorded a completely different environment than the nearby Mira-CP1 borehole, studied by Alday et al. (2006). In the basal part *Elphidium excavatum*, *Haynesina germanica Ammonia beccarii* dominate but are replaced progressively by *Cibicides lobatulus*, *Elphidium crispum*, *Rosalina* spp. with a growing participation o planctonic species. Agglutinated taxa are represented by Textulária. In the middle of this segment the age of dated bivalve (9034 yr cal BP) indicates that marine must be established in the Mira Estuary before the beginning of Holocene. This trend of growing marine influence and constant high hydrodynamism ends at about 9.9 m depth. Indeed the topmost segment of sedimentary column is entirely silty and deposited in marsh environment /mudflat environment

The profile CM6 (Guadiana) has an almost inverse sequence of sedimentation. From its base at ca 63m to 17 m depth it is entirely silty. There was a complete lack of datable items from the base opwards to 24 m depth. However, through the comparison with a well established age model of the nearby CM5 (Boski et all. 2008) profile we may assume that fully marine conditions, indicated by foraminifera index (FIMI 5), at 63 m depth must date back to a previous marine highstand. Towards the top FIMI rises progressively to value 5 only at 13.2 m depth, certainly at the apogee of the Holocene transgression ca 6970 yr.calBP. The dominant foraminifera are *Amonia beccarii* e *H. germanica* associated to the shelf forms, namely: *Cibicides lobatulus*, *Planorbulina mediterranensis*, *Asterigerinata mamilla*, *Brizalina sp*. e *Discorbis* sp. From that depth upwards the lithological column has variable texture with a reach foraminifera fauna.

When compared to the VN1 profile of Mira estuary, core CM6 presents more intervals with no foraminifera fauna. These disruptions in faunal record, and very gradual attainment of marine conditions in CM6 may be explained by: a) larger distance to the sea, b) an order o magnitude greater fluvial discharge of Gudiana River when compared with Mira and c) a proximity of small tributary Aroyo Pedrosa. More complementary work will be done on the sampled material in order to improve the age model for both cores and to obtain more complete faunistic record.

Acknowledgments: this work was done in the framwork of FCT PTDC/CLI/ 68488/2006 project EVEDUS– estuarine valley evolution during the eustatic sea-level rise – Assessment Of Climate Change Impacts Through The Confrontation Of Paleo Environemntal Data With Two Types Of Models.

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THE HOLOCENE EVOLUTION OF THE CANCHE ESTUARY AND THE INFLUENCE OF STORMINESS, PICARDY, FRANCE

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1. Methodology

The Canche estuary is located in Northern France, at the northern edge of the Picardy coastal plain. This estuary which drains the southern slope of the Boulonnais is both tide- and wavedominated. The right bank of the estuary is partially constrained by a fossil marine cliff excavated in chalk and by a tectonic flexural zone. Offshore, below the littoral prism, a second flexural direction, parallel to the coastline is constrained by the subsidence of the English Channel. The infilling of the Canche estuary is analysed to understand its shaping as also its control by raising Late Holocene storminess. Our work is based on the compilation of 42 cores with pre-existing geological data base (BRGM) to improve the knowledge of the sedimentary record and refine the regional eustatic curve. These data were completed by grain size analysis and by ^{14}C dating on shells and peat's to allocate in time morphological/sequence boundaries.

2. Data

Along the right bank of the estuary, 4 storm beach ridges are stacked to the Paleo-cliff and have been constrained by ^{14}C AMS. The oldest one is located in elevation between +8 and +13,2 m NGF; it probably dates back to the Eemian (MIS 5e). The second one yielded an age of 3420 ± 50 Cal Yr BC (onset of the Subboreal) and reaches +6,5 m NGF. The 2 others have been found by coring; the first one was found between -1 to -2,5 m NGF (Subboreal /Subatlantic transition) and the last one between +2 /+3m NGF from which the upper deposits have been dated at 1015 ±35 Cal AD (hurricane which occur around 900 AD from historical sources). A similar record, but less preserved exists on the left bank, at Villiers.

At the shore face, the sandy bodies mostly accumulated younger than the Roman storehouse relicts preserved on the Subboreal/Subatlantic surface. This accumulation is thicker at the estuary mouth than the Atlantic body (eustatic maximum). These sandy bodies were accumulated by the successive stacking of offshore sands banks on low stand marine abrasion surfaces created by enhanced storminess, especially during the Merovingian Cooling and the Little Ice Age. The base of the last deposition (LIA) is dated from 1100 Cal AD. The basement of present-day middle estuary is much older and accumulated from the late Boreal and the Atlantic (ex-Calaisian), directly in connection to the shore face. This estuary was rapidly closed by a north-eastward prograding spit superimposed on a compound Paleo-point bar (Quaternary and Pliocene in age) responsible for a fining up of sedimentation in the middle and upper estuary. Atlantic sediments were found in core at the level of the present mouth although absent under coastal dunes and explained by river dominance. During the Subboreal regression, the formers units are incised by creeks and this inner part of the estuary is gradually isolated from the coast by the build up of “old” coastal dunes and by the silting up under anthropic influence. The regressive ravinement surface during the early Subboreal, sealed by peat and the transgressive ravinement surface at the base of the Subatlantic (ex-Dunquerkian) are both observed at the coast and in the middle estuary. Here Merovingian and LIA deposits are limited to a silting up recently accentuated by agricultural practices.

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BRACKISH TIDAL MARSH AND PLANTS LIMITS (CAMINHA, PORTUGAL)

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1. Regional setting

Caminha tidal-marsh is developed on the left margin of the Minho River at the confluence with a small tributary, the Coura River. The Minho River defines the political border with Spain along the Galicia region. Its watershed drains the rainiest region of Portugal, with an average annual precipitation of 1600 mm, characteristic of a wet Atlantic climate, and runs over an area dominated by acid igneous and metamorphic rocks. The estuary behaves as "partially mixed" and presents a semi-diurnal, high-mesotidal regime, where the amplitude of the astronomical spring tide may reach 4m. The estuary is very shallow due to widespread siltation, which associated with the river discharge, prevents extensive penetration of a salt wedge and allows the complete flushing out of sea-water during ebb tide.

2. Methodology

The salinity has been measured in estuarine bottom waters during high and low spring tides and in sediment interstitial water. Altimetric data have been obtained using a total station from a bench mark connected to the national altimetric datum (Cascais) using the GPS differential positioning combined with a regional geoid model (Catalão, 2006). Tidal elevations have been measured inside the Minho estuary in spring and neap conditions using a pressure transducer, to evaluate differences in phase and amplitude between measured and reference tides in the main closest port. These data were compared with tidal elevations yielded for each site by the FCUL astronomical tide prediction model (Antunes, 2007). This series was further processed to compute submersion time for each location as a function of ground elevation. The succession of high and low waters elevations were used to estimate average values, which can be further used to determine mean high and low water springs and neaps.

3. Results and the main findings

Halophytic plants distribution through intertidal domain, define a consistent vertical salt marsh zonation in temperate regions. *Spartina* dominance between the mean high waters neap and the mean high waters corresponds to the low marsh zone (*e.g.* Davis and Fitzgerald, 2004). Above this level the dominance of *Spartina* is usually replaced by *Salicornia* and *Halimione* genera that define the high marsh zone till the highest high water (HHW), where the occurrence of terrestrial plants marks the upper limit of salt marsh (*e.g.* Davis and Fitzgerald, 2004). This general distribution was found in several Portuguese estuaries like Lima, Tagus, Sado and Mira. Important differences from the Minho estuary marsh of Caminha are reported in this communication. The lower limit of marsh plants is recorded at 0.48m, at the highest low water level (0.47m), and the first occurrence of terrestrial plants (*Fraxinus* trees) appears at 1.64m, between the mean high waters (1.47m) and the mean high waters spring (1.81m). So the low and high limits of Caminha tidal marsh are both recorded 0.60m below the altitudes of the expected tide levels (tab.1). This means that, in one hand the lower marsh plants are submerged more than 50% of the time around the year, instead of 20% approximately, in other hand the trees line that should be above HHW level, where time submersion is 0%, are submerged around 5% of the year (tab. 1). The lowering of the plants limits seems to reflect the brackish character of the Caminha tidal marsh, also verified by the study of foraminifera assemblages distribution (*e.g.* Fatela *et al*., 2007; Moreno *et al*., 2005, 2006). Comparing the studied transect with reference values (*e.g.* Mira; tab.1), the salinity records of interstitial water of Caminha marsh are much lower. Like in foraminifera assemblages the distribution of marsh plants depends on the altitude/time submersion, but a clear control of estuarine waters salinity must be considered.

Table 1. Environmental parameters at plants limits in the Minho and Mira estuaries.

Estuary		Plants	Lower limit (m)	Submersion time %	Salinity ‰ Spring	Salinity ‰ Fall	HLW (m)	MtL (m)	MHWN (m)	HHW (m)
	Minho	*Spartina grass*	0.48	53.9	15.8	15.8	0.47	0.56	1.09	2.26
		Fraxinus tree	1.64	4.9	7.7	10.4				
	Mira	*Spartina grass*	0.80	21.3	37.0	35.9	0.02	0.19	0.72	1.89
		Terrestrial plants	2.04	0.0	-	-				

Altimetric data are reported to the mean sea level (Cascais *datum*); Salinity values are from sediment interstitial water; HLW: highest low water; MtL: mean tidal level inside the estuary; MHWN: mean high water neap; HHW: highest high water.

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*LAGOA DA APÚLI*A – A RESIDUAL LAGOON FROM LATE HOLOCENE (NW COASTAL ZONE OF PORTUGAL)

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1. Geographical and geological setting of the study area

The *lagoa da Apúl*ia is a residual lagoon from Late Holocene, a unique feature of the NW coastal landscape, still in a continentalization process, located in Esposende.

2. Methodology

The methodology used in this study consisted in: 1) geophysical prospection (electrical and georadar) for detection of the bedrock depth, structural control and sedimentary thickness; 2) coring for sample collection; 3) sedimentary analysis (size analysis, mineralogy, geochemical data); 4) paleoecological analysis (diatom and foram); 5) radiocarbon dating (of peaty layers).

3. Results and the main findings

The lagoon is structural controlled by NW-SE faults and seems to be linked with the ocean at some time (presence of bio-indicators of salt intrusion).

The first infill phase can be attributed to a fluvial environment. To this episode, another corresponding to a lagoon environment took place. On this environment, episodes of different hidrodynamics related to local (such as migration of creeks) or regional factors (climatic changes) are represented by sudden change of facies. The first phase of sedimentary infill was much less dynamic than the second, during which great sedimentary transport took place, promoting the silting up of the lagoon environment (before the 13^{th} and 15^{th} centuries). The mean infill rate after this time was still great (5.6-7.4 mm/yr), having decreased after the 15^{th}-17^{th} centuries. Just the last phase of the *lagoa da Apúlia* has aeolian influence and pedogenesis, corresponding to LIA times.

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PALEOENVIRONMENTAL CHANGES IN THE GUADIANA INNER SHELF DURING THE LAST 5000 YEARS: BENTHIC FORAMINIFERAL AND SEDIMENTOLOGICAL EVIDENCE

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1. Geographical and geological setting of the study area

The Guadiana River is the main sediment supplier to the adjacent continental shelf (Northern Gulf of Cadiz) and the sediments are predominantly transported eastwards by the littoral drift (e.g. Gonzalez *et al*., 2004). The inner shelf sediment cover is characterized by sandy deposits that connect with a prodeltaic wedge of sandy mud and mud forming an oblong mud patch. The middle shelf is characterized by an extensive mud patch of very fine-grained clayey material, cut north to south by a transgressive wedge of muddy gravely sands and muddy sands (Gonzalez *et al*., 2004). The paleoenvironmental changes occurred in this area will be analyzed in a sedimentary sequence (core 8) extracted from the prodeltaic wedge.

2. Methodology

The 376 cm long core 8 was taken with a vibrocorer at 22 water depth. Grain size analyses of fine fraction was analysed using the pipette method and coarse fraction was separated by dry-sieving. A total of 174 samples were studied. AMS radiocarbon dating was carried out using mixed benthic foraminifera. The study of benthic foraminifera was based on 38 samples collected from the core at intervals of 10 cm. The fraction >63µm was analysed, a minimum of 300 tests in each sample, were collected, identified, counted and relative abundances calculated.

3. Results and main findings

The core 8 reflects the sedimentary sequences occurred in the inner shelf of the Guadiana during the last ca. 5000 yr. Cal BP, which corresponds to the period when the present mean sea level was reached in this region (Boski *et al*., 2002).

The results show two general behaviours for different periods (Fig. 1). The first period between 4870-5437 yr. Cal BP (core base) and 1319-1533 yr. Cal BP (160 cm from the top). The fine and coarse fraction have similar percentages, with exception of the silt-clay unit between 318-288 cm (Fig. 1a). This trend is accompanied by decreasing of benthic foraminifera per 10 cm^3 (Fig. 1b) and by higher percentages of *Asterigerinata mamila* and *Planorbulina mediterranensis* (Fig. 1c and d). The second period, from 1319-1533 yr. Cal BP (160 cm) until present days (5 cm), is characterised by increasing of the silt-clay fraction with sporadic levels of coarser material (Fig. 1a). The number of benthic foraminifera per 10 cm^3 (Fig. 1b) is lower in the second period, and without a specific tendency. Species like *Bolivina ordinaria* or *Bulimina aculeata* (Fig. 1e and f) present higher abundances in this period. Comparing the obtained data with the components of the sand fraction for the same core (Pinheiro *et al*., 2006) (Fig. 1g) and the benthic foraminifera biotopes for the Guadiana shelf (Mendes *et al*., 2004) (Fig. 1h) it is possible do see the same two general periods. From the base of the core until 1319-1533 yr. Cal BP, the sand components and benthic foraminifera biotopes are relatively constant. This sedimentary sequence could be interpreted as an environment under the direct influence of Guadiana River, possibly related with the existence of an active oriental tributary (Estrabão – Geografia, III, 1, 9), with deposition of coarser material and presence of benthic foraminifera species characteristic from coastal environments. At the second period from 1319-1533 yr. Cal BP to the top of the core, the biogenic components decrease gradually, and higher abundances of benthic foraminifera species normally associated with deeper environments occurred. This period could be interpreted as an environment placed after the Guadiana oriental tributary enclosing, without fluvial direct influence, which reflects the actual depositional system, and the prodeltaic wedge formation.

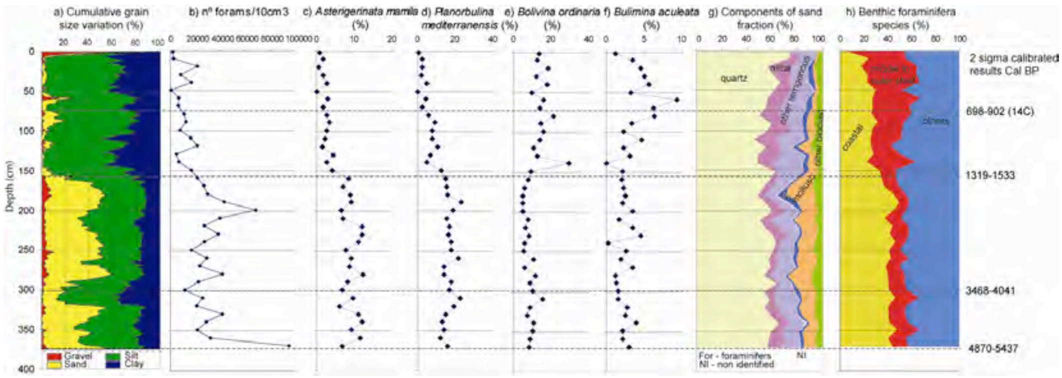

Figure 1. Analyses carried for core 8 and dating results (Cal BP): a) cumulative grain size variation; b) number of benthic foraminifera per 10 cm^3; abundances of: c) *Asterigerinata mamila*; d) *Planorbulina mediterranensis*; e) *Bolivina ordinaria*; f) *Bulimina aculeata*; g) components of sand fraction (adapted from Pinheiro et al, 2006); h) cumulative variation of coastal, middle to outer shelf and others foraminifera species.

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NUMERICAL MODELLING OF A LISBON TYPE TSUNAMI EVENT AT BOCA DO RIO, SOUTH OF PORTUGAL

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This paper is a work on the numerical modelling of a tsunami wave originated from an earthquake modelled with magnitude M_w=8.7 using a fault located southwest of the Iberian peninsula near the Gorringe bank. The tsunami wave propagation is performed using the numerical models COMCOT[1] and SWAN[2] and the near shore propagation and inundation is modelled using AnuGA model[3] from Geoscience Australia at the study site of Boca do Rio on the Portuguese south coast. Historical data at the site from past tsunamis, namely the 1755 Lisbon tsunami, is available as well as the extents of a sedimentary tsunami deposit layer attributed to the same event. A comparison between the model results and the data available from a similar intensity tsunami is performed.

1. Geographical setting of the study área

Boca do Rio is located on the south Portuguese coast in the Algarve region, about 20 km from Sagres, the southwest corner of Portugal. Boca do Rio is a fluvial valley where a small estuary occurs. This lowland consists of a flood plain of three waterlines, *Ribeira de Budens*, *Ribeira de Boi* and *Ribeira de Vale Barão*. It is separated from the sea by a sandy barrier orientated from west to east.

Figure 1: *Boca do Rio location.*

2. Methodology

The purpose of the study is not to try to reproduce the 1755 Lisbon tsunami but instead to model an event with a source model of similar intensity. To the present date, the exact source mechanism for the most known tsunami in Portugal is not fully known. We use one of the proposed source models from the 2006 DEFRA report [4], in which tsunami simulations of Lisbon type events are performed in order to evaluate the hazard at the UK coast. The source model location is shown in figure 2, the fault has a north-south orientation. Estimations of magnitude of the 1755 earthquake vary between 8.5 and 9.0 (Abe 1979 in [4]). We adopted in this study a magnitude of the earthquake of 8.7.

The initial water displacement originated by the earthquake, is modelled according to the work of Mansinha & Smylie[5], that admits the ocean surface displacement reflects the cosismic deformation.

The computed free surface elevation is the input in the form of initial conditions in the COMCOT and SWAN models which handle the wave propagation from the source to nearshore. Both numerical models solve the non-linear shallow water wave equations (NLSW), the set-up used was a regular grid with a spatial resolution of 800 m to represent the bathymetry, a total simulation time of 3000 s and saving step of 10 s. The free-surface elevation and horizontal momentum variation in time were then input into the AnuGA model for detailed propagation to the shoreline and inundation modelling. AnuGA uses a mesh with triangular cells allowing for different resolutions. In all the coastline area and Boca do Rio valley area we used triangles with a maximum area of 200 m^2, meaning an approximate distance of 20 m between each bathymetry and topography point.

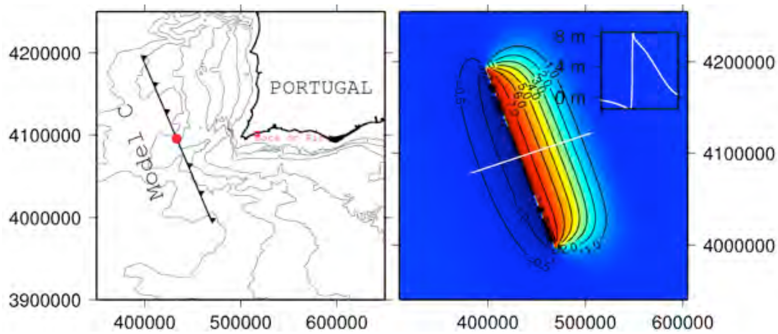

Figure 2: *Fault location on the left, initial free surface displacement with contours and profile of water elevation on the right.*

Water elevation was obtained in the detailed area at intervals of 10 s. From these results the wave run-up, run-in and limits of the maximum inundation were obtained. The modelled data was then compared with historical data from the 1755 Lisbon event [6,7] at the study site. A comparison with the extent of the tsunami sedimentary deposits derived from the work of Hindson & Andrade[8] is also provided.

3. Results and the main findings

	max. run-up (m)	max. run-in (m)
Historical data	11 to 13	1375
Sedimentary deposit	-	980
AnuGA input COMCOT	12.6	839.7
AnuGA input SWAN	11.4	836.9

Table 1: *Summary of results obtained from modelling and data available in literature for Boca do Rio*

The historical reports on the 1755 Lisbon tsunami at Boca do Rio states that through the fresh water waterline on the day of the earthquake the sea entered in an extension of *"1/4 de légoa"*, about 1375m with a height of *"10 a 12 varas"*, about 11 to 13m.

A summary of the modelled run-up and run-in results is presented in table 1, the data from the historical reports is also shown and the run-in distance obtained from the limits of the sand layer at Boca do Rio from the work of Hindson & Andrade [8]. According to the authors the sedimentary layer is identified as a tsunami deposit and is believed to have been due to the 1755 Lisbon tsunami.

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A LATITUDINALTRANSECT OF GRAVEL SPITS ACROSS THE CHUKCHI SEA AS PROXIES FOR STORM ACTIVITY IN THE LAST 1500 YEARS: DEERING, PT. HOPE AND PT. BARROW, ALASKA, U.S.A.

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1 Geological Setting

Numerous beach ridges and spits have built at opposing directions in the south, central and northern Chukchi Sea, north of Bering Strait (Shepard and Wanless 1971, Mason 1990). Three prominent spits provide a multi-proxy latitudinal record for increased erosion and storm intensity affecting the northwest coast of Alaska from Kotzebue Sound to Pt. Barrow, further extending records from beach ridge complexes (cf. Mason 1990, Mason and Jordan 1993). The region is microtidal, and seismically inactive, and was unglaciated throughout the Pleistocene (Mason et al. 1995). Despite lengthy ice cover, storm surges elevate sea level between 1 to 4 m (cf. Lynch et al. 2008, contra to the eustatic model of sea level rise proposed from elevated drift wood by Hume (1965). Only minimal eustatic sea-level rise (0.3mm/yr) has occurred since 2000 cal yr BC, as recorded in a regional series of ^{14}C dated marsh peats (Brown and Sellman 1966, Jordan and Mason 1999, Mason and Jordan 2002). The three spits are spaced across 500 km from 65º to 70º N. lat. and are drift-oriented features, reflecting wave climates from the northwest (Deering), the southeast (Pt. Hope) and the southwest (Pt. Barrow).

2 Methods

A series of facies observations on lithology, clast size and sedimentary structures were obtained from extensive trenches placed during sewage construction at Deering, from erosion-truncated storm ridges (Barrow) and archaeological excavations at all three sites. Extensive ^{14}C data sets (n=65) provide absolute age control, although archaeological ages provide many limiting age controls, with additional assays obtained in 1997-1999 and 2003-07. A more complete record has emerged from 2003-07 research, based on stratigraphic profiling and ^{14}C dating along the eroding north margin of the spit, as well as trenches (n=10) and test pits (n=>15).

3 Conclusions

The southernmost spit at Deering, sheltered within Kotzebue Sound, is a composite feature with northwesterly storms prevalent prior to AD 600 and after AD 900, as established from a prominent surface horizon underlain and overtopped by thick gravel beds; on occasional gravel laminae intruded a backbarrier marsh and are bracketed by ^{14}C ages between AD 1000 and 1200. After AD 1400, the Deering spit underwent a rapid progradation and the construction of sand dunes to the east.. The northwestward building Pt Hope spit at the northwest tip of the Lisburne Peninsula contains 28 gravel and sand ridges that formed since the last centuries BC. Ridge and swale width at Pt Hope are proxies of storm recurrence and indicate that closely spaced storms built wide ridges prior to AD 400, ca. AD 600, with decreasing frequency in the centuries after AD 800 (Mason 1990). The Point Barrow spit developed at the junction of the Chukchi and Beaufort Seas, under the influence of west and southwesterly currents that eroded updrift bluffs and mobilized shelf sediments.

Stratigraphic observations, aided by ^{14}C ages reveal the complexity of the evolution of the Pt Barrow spit. Research by Péwé and Church (1962) and Hume (1965) indicated that the Barrow spit formed much as other spits in the Chukchi Sea region, through a horizontal sequence of beach ridge addition, with the oldest deposits along the lagoon and the youngest beaches and storm deposits on the Chukchi Sea. Peat atop the oldest part of the spit formed in the last centuries BC at a sea level that was ca. 1 m below the present level. Storm intensity remained comparatively low until ca. AD 200; subsequently, several storm surges >2.5 m in elevation constructed the Nuvuk ridge, and continued until ca. AD 800. A series of lower ridges built between AD 800 and 1200, under the influence of frequent less intense surges (<2m above sea level) and persistent erosion during a less ice-covered Chukchi Sea. A high ridge built during the Little Ice Age, as larger storm surges were prevalent. The proxy record from the three spit complexes indicates that storms intensified during cold periods, and mobilized shelf deposits in excess of the bluff erosion that occurred during less icy warm intervals.

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MORPHODINAMIC PROCESS BASED MODEL APPLIED TO LONG-TERM STUDIES

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1. Introduction

The objective of this work is to obtain a long-term morphodynamic evolution using a process based model, applied to the mesotidal Guadiana Estuary (Portugal – Spain border, S. Iberian Peninsula) which was sediment infilled since the Last Glacial Maximum.

Traditionally long-term morphological and basin infill modelling studies comprehend simulations carried out by conceptual, geometric, behaviour-oriented, or, more recently, dynamic abstracted diffusion models [2]. The increase of computational capability and the development of new mathematical approaches, allowed the use of more complex models. In this new approach, numerical algorithms are used to solve explicitly the physical equations of the relevant processes, coupled with empirical and semi-empirical equations for the unresolved phenomena. That will create the possibility of working with a wide range of time and space scales; and to include dynamic forcings and boundary conditions.

2. Methodology

The MOHID modeling system was the chosen model to perform these simulations. It's a model that simulates explicitly the hydrodynamic, the sand transport and the bottom's dynamics. A schematic bathymetry of an estuary was constructed, covering an area with 50 km length and 1 km width. The tide was imposed at the bathymetry's open boundary and the freshwater input was neglected. The period considered for the simulations of the evolution model was 2000 years. Then, the results obtained were compared with other approaches of morphodynamic's models [1].

This kind of model involves a significant computational effort and also a substantial calculation time. In order to improve and hasten the achievement of the results, an extrapolation scheme is proposed and tested against standard runs. The scheme consists in a sequence of successive runs followed by linear extrapolation of the depth evolution during a certain time period. To facilitate the analysis of the different cases, several parameters were used, such as the water volume, total eroded volume, maximum depth relative difference, total eroded volume relative difference and depth related quadratic mean error.

3. Results and main findings

When comparing the results obtained with MOHID and by other models it's possible to observe some differences between them. Such differences are expected since the considered models present different assumptions. In spite of that, is possible to observe a similar behavior of the profile curves.

In what concerns the reduction of computation time and the differences between the considered cases and the continuous run, the best results were obtained by runs of 100 years followed by interpolation of 200 years. These results indicate that the morphodynamic extrapolation scheme is able to reduce computational load to 1/3 of the total time, with small losses of accuracy, therefore maintaining the data consistency.

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CONTRASTING STYLES OF SEDIMENTATION IN THE GUADIANA CONTINENTAL SHELF DURING THE HOLOCENE

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1. Regional setting of the study area

The continental shelf depositional system of Northern Gulf of Cadiz (SW Iberia, eastern Atlantic Ocean) (Figure 1) is strongly influenced by eastward Atlantic inflow currents, which help set inner shelf sand dune facies and mid-shelf prodeltaic mud belts, and are active since early Holocene [1]. The Guadiana River is one of the main regional sediment sources to the shelf [2]. Its estuary is an important fluvio-marine system that went through maximum flooding at ca. 6400-5000yr Cal. BP, and is now in advanced state of infilling [3]. Bedload sediments exported through the estuary concentrate in the shelf above 15 m water depth [2]. Fine sediments established a W-E high-stand deposit in the middle shelf, the Guadiana Mud Patch [1] (Figure 1). The sedimentary sequence of vibrocore 20 (inner shelf) was analyzed and compared with previews results of vibrocore 16 (middle shelf) [4], to understand Holocene depositional mechanisms in different continental shelf domains.

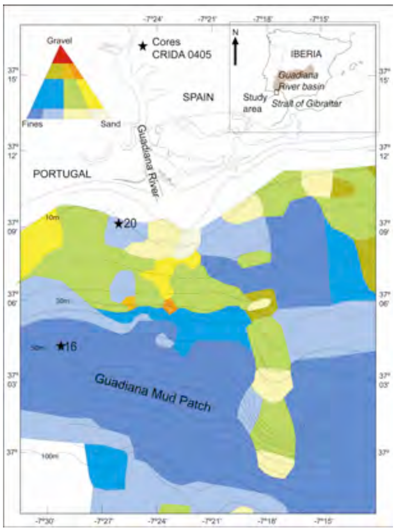

Figure 1: Location of the study area and superficial sediments in the Guadiana continental shelf (adapted from Gonzalez *et al*., 2004).

2. Methodology

Vibrocore 20 (342 cm length, 12,8 m water depth) was collected in the Guadiana inner shelf (Figure 1). Grain-size determination (Φ scale intervals) was made sequentially along the core. Coarse fraction (sand) composition was determined every 10 cm under a binocular microscope by identifying 100 grains in each sand fraction. Composition was also determined for gravel-sized sediments. Morphoscopic and shape analyses of quartz used 100 grains in each fraction 1-2Φ. Radiocarbon (^{14}C) AMS dating of core levels was made with mollusc shells.

3. Results and main findings

The depositional sequence of core 20 reveals two main periods of contrasting sedimentation in the Guadiana inner shelf, since early Holocene until present-day. From 8960-8600yr Cal. BP (core base) until ca. 1000 yr Cal. BP sediments are almost exclusively dominated by sand. Gravel is also significant, particularly until around 1870-1690yr Cal. BP. Terrigenous (mainly quartz) dominate sediments along this period. In the latter, the presence of specific elements, namely feldspars, schists/greywackes and aggregates (usually fragments of igneous/metamorphic rocks) which today concentrate in shelf sediments just off the Guadiana River mouth [2], seem to indicate an enhanced direct influence of the river discharges in this area of the inner shelf during a considerable part of the Holocene. A similar pattern has already been detected in the middle shelf (core 16, Figure 1) for sediments of early to mid Holocene, extending the river's more direct influence far off its present-day location, during periods of lower sea-level [4]. Around 1870-1690yr Cal. BP terrigenous elements associated with the direct influence of the Guadiana practically disappear from the sedimentary record, which becomes dominated by bioclasts, mainly molluscs. At ca. 1000yr Cal. BP a major shift in the depositional patterns of the inner shelf sets the transition to recent times, just as was detected for the middle shelf area [4]. Different shelf domains exhibit diverse sedimentological responses, which are active until today. In the middle shelf (core 16 location) it corresponded to enhanced fine sedimentation that set the installation of the Mud Patch. In the inner shelf, the last 1000yr were also characterized by higher amounts of silt and clay but with an alternation of fine and coarse-grained depositional events, possibly due to periods of more intense storminess and/or floods that could be related with climatic oscillations and higher anthropic impact in the region. Changes in the shelf's overall sedimentary dynamics in the transition to the last 1000yr seem to have been triggered by important regional scale events, namely the Guadiana Estuary recent evolutionary trends. Ancient sources [5] indicate the existence of a second eastern tributary of the Guadiana Estuary around 2000yr Cal. BP, which would deviate part of the river flow and sediment load, and was possibly active until ca. 1400yr Cal. BP. At this time, the estuary should have reached its present-day configuration and set new deposition patterns in the adjacent shelf.

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VULNERABILITY ASSESSMENT OF SHORELINE RETREAT DUE TO ACCELERATED SEA LEVEL RISE

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Introduction

The coastal zone of the Guadiana estuary located at Portugal and Spain border is highly vulnerable to sea-level rise due to its low beach slope, geomorphology and high erosion rate. The total coastline selected for the present study predominantly consists of sandy beaches. The Portuguese side of the coastline is a large littoral spit with transverse progradation and separated from the mainland by a marsh. Aeolian dunes are developed at the seaward side of this spit. The Spanish side consists of an array of old barrier islands transformed into elongated spit and separated by salt marsh. The main objective of this study was to predict and map the shoreline retreat due to sea level rise at the end of 21st century and thereby to identify the most vulnerable sectors of 15 km stretch of adjacent coastline of the Guadiana estuary.

Methodology

The shoreline evolution rate (SER) was derived from aerial photographs of 1996 and 2005 for each transect established with 250 m intervals along the coastline. Moving averages of SER over five transects were used for projecting the shoreline position at the end of 21st century (S_{100}). The shoreline due to accelerated sea level rise (S_{100C}) was obtained by adjusting S_{100} using the Bruun rule. Only upper bound values of three sea level rise scenarios given in IPCC 2007 (B1-38 cm, A1B-48 cm and A1FI-59 cm) were considered for the present study. The total area at risk of retreating with sea level rise was mapped using S_{100C} and the present shoreline defined in a digital elevation model (DEM). Physical impacts on natural (sand dunes, marsh land and forest land) and artificial (urban area, industrial area and agricultural land) habitats due to shoreline retreat with accelerated sea level rise were estimated for B1, A1B and A1FI scenarios using digital thematic maps superimposed on DEM. The total length of roads and number of buildings at risk from each municipalities and country were estimated using Geographical Information System tools.

Results and main findings

The adjacent coastline of the Guadiana estuary shows high temporal and spatial variation since it is affected by natural and human forcings to different degrees. Based on the SER, five distinct zones can be identified along the coastline from 258000 to 272000 m (Figure 1). The coastal stretch from 258000 to 260000 m and from 262000 to 266000 m show high accretion rate ranging from 0 to 4.3 m/yr and 0 to 3.8 m/yr, respectively. The jetty at the west bank of the Guadiana river mouth is mainly responsible for holding long shore sediment drift resulting the later accretion zone in the

Portuguese side. The coastal stretch from 260000 to 262000 m is dynamically stable showing no net shoreline erosion considered in this region during this time span. On the whole, the average shoreline retreat in Portuguese side of the coastline is 10, 20 and 40 m for sea level rise scenarios of B1, A1B and A1FI respectively. The vulnerability of shoreline retreat is aggravated due to shore defence structures resulting in severe erosion in the Spanish side of the Guadiana coastline, especially, the coastal stretch from 266000-270000 m where the maximum SER is 4.8 m/yr. Western part of this stretch is eroding slower than the eastern side as frequent sand nourishment programmes have been carried out to maintain its tourist attractiveness.

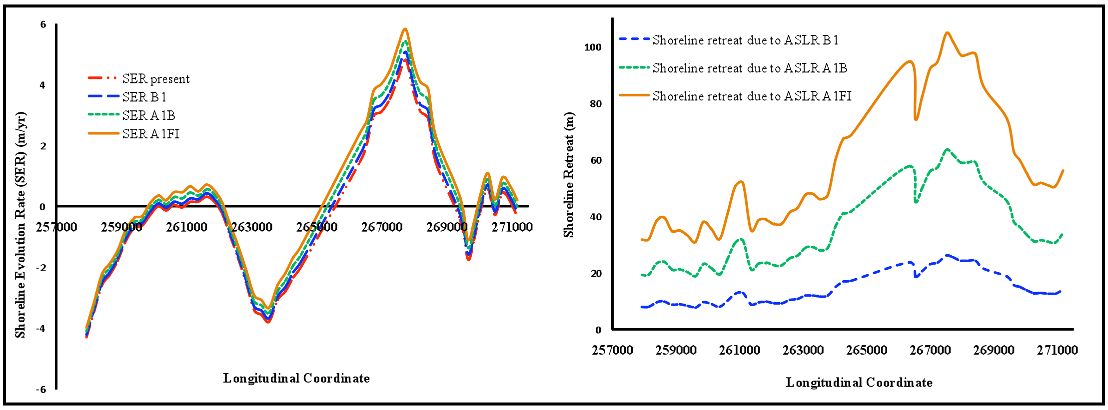

Figure 1: Variation of shoreline evolution rate and retreat for B1, A1B and A1FI sea level rise scenarios (Datum Coordinates Intern_1924_Transverse_Mercator_Megasig).

The total land loss from Portuguese coastal side under the present SER is 0.35 km^2 and that would increase by 9%, 20% 37% with the rise of sea level by 38, 48 and 59 cm, respectively by the end of 21st century (Figure 2). The total land loss from Spanish side is 1.59 km^2 under present SER and it will increase by 6%, 14% and 22% for sea level rise scenarios of B1, A1B and A1FI respectively. The impact on roads is insignificant in the Portuguese side of the estuary compared to that of Spanish side. There would be 11.9 km loss of road length under the present SER and it will increase up to 13.8 km under the worst case sea level rise scenario (A1FI). The total urban area affected is also significant in Spanish side. Sand dunes and beaches are the most vulnerable natural habitat on both sides of the coastline. However, the loss of protected area from the Portuguese side is comparatively significant.

Figure 2: Shoreline retreat under the present and accelerated rate of sea level rise References.

Acknowledgments: this work was done in the framwork of FCT PTDC/CLI/ 68488/2006 project EVEDUS– estuarine valley evolution during the eustatic sea-level rise – Assessment Of Climate Change Impacts Through The Confrontation Of Paleo Environemntal Data With Two Types Of Models.

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COASTAL EVOLUTION OF THE GUADIANA ESTUARY DURING THE HOLOCENE - RECONSTRUCTING THE PALAEOVALLEY MORPHOLOGY

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1. Introduction

Large-scale coastal behaviour models consider the evolution of coastal features over long periods of time, which can range from decades to millennia (Cowell and Thom, 1994). It can be approached by the combined evaluation of the primary driving factors of coastal evolution. On an estuary, these factors are mainly the relative sea level change, the rate of sediment supply and the palaeovalley morphology, which determines the accommodation space for fluvial and marine sediments. Aiming to model the Holocene evolution of the Guadiana estuary using GIS raster modelling, a digital elevation model (DEM) of the Guadiana estuary palaeovalley has been developed in order to define the setting over which sea-level rise and variable rates of sediment supply produced the present day estuary.

2. Geographical setting of the study area

The terminal segment of the Guadiana River is a narrow, deeply incised bedrock controlled estuary experiencing the final stages of sediment infilling along with coastal progradation. During the past Glacial period lowstands the river valley was developed, cutting the Paleozoic and Mesozoic substratum and also the gravel deposits accumulated during Marine Isotope Stadium (MIS) 3 or 5e in the deepest parts of the estuary (Boski et al., 2002). Throughout the Holocene the estuary presented two main phases of sedimentary infilling. The first phase ended around 7000 cal yr BP and occurred during accelerated sea-level rise with sedimentation rates of 7.6 mm/yr. Since then the sedimentation has remained stable with lower rates of vertical accretion, lower than 1 mm/yr, but with a progressive reduction in the water surface due to horizontal accretion, which has lead to the present narrow estuary experiencing the final stages of its sedimentary infilling (Boski et al., 2008).

3. Methodology

For the simulation of the estuarine evolution the digital elevation model (DEM) of the Guadiana estuary Holocene palaeovalley was constructed. It was developed through GIS based interpolation procedures, applied to data derived from cored boreholes, geophysical surveys and also

by geologic and stratigraphic interpretation. Upon this palaeovalley DEM and using map algebra, the vertical aggradation of sediment according to defined parameters and time-steps is computed.
Data from borehole analyses made possible the identification of the sedimentary response of the Guadiana Estuary in precise locations corresponding to the borehole location. Although this by itself already allows to reconstruc the estuary's evolution, the use of tridimensional modeling techniques enables a refinement in terms of palaeosurface generation and, therefore, contributes to the increasing accuracy in the knowledge of the Guadiana Estuary recent geological evolution. The evaluation of model results against the chronostratigrapy of the Guadiana estuary enables to validate and complement palaeoenvironmental reconstructions of estuarine evolution, particularly in terms of accreted sediment volume within the estuary. This, in turn, can be useful for estimating carbon trapping during Holocene sea-level rise and quantitatively access the role of estuaries in the global carbon cycle.

Acknowledgments: this work was done in the framwork of FCT PTDC/CLI/ 68488/2006 project EVEDUS– estuarine valley evolution during the eustatic sea-level rise – Assessment Of Climate Change Impacts Through The Confrontation Of Paleo Environemntal Data With Two Types Of Models.

4. Literature

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THE HOLOCENE EVOLUTION OF THE PEARL RIVER DELTA

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1. Geographical and geological setting of the study area

The Holocene evolution of the Pearl River Delta (PRD) in southern China was first summarised by Huang et al. (1982) and Li et al., (1990) based on more than a thousand borehole records. Recent studies (e.g. Huang et al., 2004; Zong et al., 2006; Wu et al., 2007; Zong et al., in press) have synthesised much of the available data and shed new light on the evolution of the PRD.

2. Methodology

Seven sediment cores were obtained from the delta plain and estuary for sedimentary and microfossil analyses using push or rotary coring depending on the resistance of the sediments (for details see Zong et al., in press). Another 18 core records were chosen from literature to complement the study (Huang et al., 1982; Li et al., 1990). A series of cross sections across the deltaic plains and the estuary were constructed (Figure 2). Supplementary information was provided by 279 other core records and a model for the early-Holocene palaeo-landform evolution developed. 34 calibrated radiocarbon dates were obtained to constrain the evolutionary history.

3. Results and the main findings

The sedimentary record indicates that at the start of the Holocene the receiving basin was filled with older (possibly OIS Stage 5e) estuarine silts, fluvial sands and gravels, with bedrock exposed in many parts of the basin (Figure 1A). The depth of the receiving basin varies between 5 m and ~20 m. In the mouth of the basin, valleys incised to 25 m to 30 m. The shallow nature of the receiving basin resulted in initial marine inundation as late as 9000 cal. years BP (Zong, 2004). Based on the core records initial sedimentation took place along palaeo-river channels. This phase of sedimentation is recorded as fine sand between -19 m and -12 m that coincides with strong monsoon-driven freshwater discharge (Wang et al., 2005). Around the same time, the deeper part of the receiving basin was inundated by the sea. This phase of sedimentation corresponds to a rise in relative sea level from -20 m to -12 m (Zong 2004) with strong marine influence recorded at the base of a key core. Around 8200 cal. years BP, the inner part of the receiving basin was under shallow tidal conditions with strong fluvial input, whilst the seaward part of the basin was under open estuarine conditions (Figure 1B). This initial phase was followed by a period of widespread marine inundation in the receiving basin, as a result of sharp rises in relative sea level from -12 m to -3 m (Zong, 2004) between 8200 and 7000 cal. years BP (Bird et al., 2007). The rising sea level resulted in the sea advancing for about 75 km from core DL1 to the apex of the North and West Rivers delta plain. The deltaic shoreline was also pushed as far back as the apex of the East River delta plain. This widespread marine transgression in the receiving basin changed the sedimentary environments of the basin significantly with a switch from tidal sandy sedimentation along delta plain channels to deltaic silt and clay deposition within the receiving basin. Subsequent weakening in the monsoon resulted in less sediment delivery and slower rates of delta progradation during the mid Holocene (6000-2000 cal. years BP). The last 2000 years have been dominated by human influences on delta sedimentation and form.

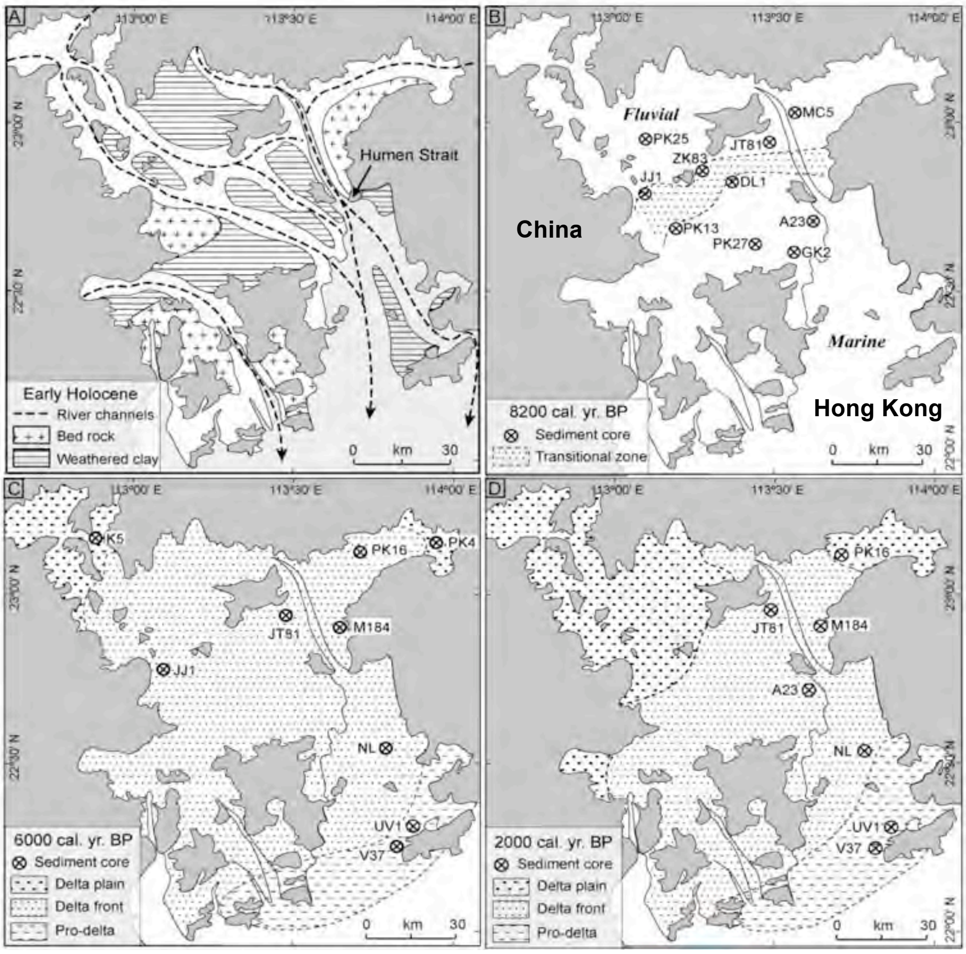

Figure 3 Map A shows the early-Holocene palaeo-landscapes of the receiving basin, with major palaeo-valleys filled with coarse sands and gravels, areas of bedrock exposed, and areas of older marine deposits capped by weathered clay or desiccated crust. Map B shows the marine limit before c. 8200 cal. years BP, based on sedimentary evidence of the initial phase of sedimentation. Map C shows the deltaic sedimentary environments within the receiving basin when the rise in sea level stabilised and shoreline retreated to its landward-most position around 6000 cal. years BP. Map D shows the deltaic sedimentary environments within the receiving basin around 2000 cal. years BP (from Zong et al., in press).

4. Main findings

The Holocene evolutionary history of the Pearl River delta, illustrates the development and driving mechanisms of the system and their effects in changing sedimentation characteristics and landforms. Sea-level change has been the major controlling factor determining the base level and available accommodation space. Strong monsoonal runoff brought large amounts of sediment from the catchment to the receiving basin, where the sediments were reworked by strong tidal currents and settled as deltaic deposits. The delta prograded natural initially before progradation rate was controlled by the amount of anthropogenically influenced sediment supply. This study demonstrates the importance of understanding key driving mechanisms of deltaic landform development and changes. It is particularly important in large deltas as in the near future as global climate is to change, sea level may rise, and human behaviour towards the highly dynamical environment such as this will also change.

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RELATIONSHIP BETWEEN WAVE ENERGY AND COASTAL MORPHOLOGY IN THE CENTRAL ALGARVE ROCKY COAST (GALÉ TO OLHOS DE ÁGUA)

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1. Geographical and geological setting of the study area

The study area (Galé to Olhos de Água, central Algarve, Portugal), exposes the the Miocene Lagos-Portimão Carbonate Formation (Pais, 1982). The layers of metric thickness alternate vertically between biocalcarenites, siltstones and limestone inclined up to 10º SW and show remarkable lateral continuity. An exception is the sector between São Rafael and Baleeira, where coastal cliffs respectively expose Cretaceous marls and Jurassic crystalline limestone (Marques, 1997; Albardeiro, 2004; Moura *et al.*, 2006).

2. Methodology

The coastal zones' geomorphological evolution is the result of subaerial weathering and marine abrasion. The main goal of the present work is to quantify the role of wave action in a geomorphic process in sculpturing the shore platforms. For that purpose, a numerical model of wave propagation (STWAVE) was used to determine differences in breaking wave characteristics along the study area. This program was used inside an operational toolbox (SMS 9.2) that allows data pre-processing from a GIS software (ArcGIS 9.2). The MATLAB R2007a software was used to obtain significant wave heights and wave energy at the breaking position along the study area, for each tested condition. The different coastal morphologies and mass movements were identified on the field and compared with the described evolution in literature (Marques, 1997). Since the study area presents strong longshore variation in exposition to the waves and different wave energies, several sections were defined. It was then possible to analyze the frequency of occurrence of a given coastal morphology and the frequency of mass movements for each section and compare with longshore variations on wave energy for both average and storm conditions.

3. Results and the main finding

The evolution of littoral landscapes depends on both continental and marine processes as well as on the rock characteristics (e.g., composition, texture, structure and fracturing). Consequently, the rock vulnerability to direct wave attack is directly proportional to its degree of weathering and inversely proportional to its hardness. The intensity of the wave attack on the cliff foot depends on the offshore and onshore wave characteristics, the surrounding bathymetry, the beach and shore platforms topography, the coastline orientation, the existence of storm surge and the tidal range. The marine action can be enhanced by specific weather conditions in the coastal zone, such as the occurrence of strong winds (Emery & Kuhn, 1982; Sunamura, 1983, 1992).

The results of this study indicate a clear energetic differentiation between the considered coastal sections, depending on their exposure to the waves (e.g. SW vs. SE), with some sections showing higher energy incident and others a reasonable protection to the wave action. It was still possible to observe a clear contrast between areas of promontories and headlands (high energy) and bays or pocket beaches (low energy) regarding wave incidence and energy.

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TSUNAMI DEPOSITED SANDSHEETS: A REVIEW

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1. Introduction

20 years after the publication of key initial studies on sandy tsunami deposits from the Scottish and western North American coasts the palaeotsunami research community has expanded considerably. The field now incorporates not only geologists and geomorphologists but computer and mathematical modellers, geophysicists, chronology experts, palaeontologists, hydrologists and ecologists. The 20 year anniversary of these initial studies presents a good opportunity to reflect on the progress made in the field, evaluate some recent criticisms and highlight knowledge gaps for future study.

2. The early days

Until the late 1980's the study of tsunami predominantly involved seismologists, numerical modellers, geophysicists and historians. In particular, historians played a valuable role by providing detailed documentary information on former tsunamis from around the world (Dawson and Shi, 2000). Often, historical accounts would provide estimates of frequency-magnitude relationships for past tsunami events and hence provide information on future tsunami risk for different areas. Geologists paid little attention to tsunami records in recent coastal stratigraphy until 1987 and 1988, when two papers were published one from the United States west coast (Atwater, 1987) and another from the Scottish coast (Dawson et al., 1988). The paper by Atwater (1987) linked prehistoric earthquakes with geological evidence from the outer coast of Washington State, U.S.A. This evidence included sheets of marine sediment visible in coastal stratigraphic sequences that were interpreted as prehistoric (palaeo-) tsunami deposits. Around the same time Dawson et al. (1988) in a study of uplifted coastal sedimentary sequences in Scotland, described an unusual sand deposit which they linked to a prehistoric tsunami event. They hypothesized the event was the result of the Storegga slide, one of the world's largest submarine slides that took place approximately 7100 14C years ago on the continental shelf edge west of Norway.

3. The last 20 years

Although geological investigations of former tsunami remain a relatively new research area, the last twenty years has seen a plethora of academic papers on the topic. A wide range of sedimentary evidence from different locations has been attributed to a series of former tsunami (see reviews by Dawson and Shi, 2000; Goff et al., 2001; Bryant, 2001; Scheffers and Kelletat, 2003; Kortekass and Dawson, 2007). Many authors have argued that tsunami are frequently associated with the deposition of continuous and discontinuous sediment sheets across large areas of the coastal zone, provided that there is an adequate sediment supply (e.g., Dawson, 1999; Goff et al., 2001). Although tsunami deposits are mostly characterised by sheets of sediment, they are also frequently represented by boulder accumulations (see reviews of Scheffers and Kelletat, 2003; Kelletat, in press). In addition, microfossil assemblages of diatoms and foraminifera contained within tsunami-deposited sandsheets may provide additional information on the nature of onshore transport of sediment from deeper water (Dominey-Howes, 1996; Hemphill-Haley, 1996). Other aspects such and mineralogy (Switzer et al, 2005) and sediment chemistry (Chague-Goff, et al., 2000; Chague-Goff and Goff, 1999; Szczuciñski et al, 2005) may also be affective proxies for tsunami dynamics.

4. Distinguishing between storm and tsunami deposits in sandsheets

The generation, propagation and run up of tsunami and storm surge are characteristically different. Tsunami waves propagate away from the source region where disturbance of the water column generates waves with small amplitude, long period and long wavelength that travel at high velocity (Geist, 1999). At the coast tsunami waves slow in velocity and rise in amplitude before inundating the coastline with high velocity. In contrast severe low pressure systems such as tropical cyclones can induce long-wavelength, low-amplitude sea surface displacements called storm surges. A storm surge migrates with the storm and is the result of a combination of wind stress and falling atmospheric pressure (McInness and Hubbert, 2001). The water elevation (inundation) caused by storm surges at a coastal location involves four components: (1) the storm surge, (2) storm waves, (3) wave setup and (4) the astronomical tide (Cheung, et al. 2003).

In the open ocean the wavelength and amplitude can be similar for storm surge and tsunami with both being markedly longer in wavelength than wind generated waves. The difference in velocity, wave set-up, period and water volume at the coast mean tsunami and storm surge can be differentiated in terms of velocity, period and repetition of inundation, likely bed shear stress and back flow characteristics. For example Dawson (1994) and Dawson and Stewart, (2007) proposed that it is the unique characteristics of tsunami run-up wave behaviour (with respect to storm waves) that produces a distinctive style of sedimentation across the coastal zone, although this has recently been challenged by Bridge (in press). The long period between tsunami waves (often 20 minutes to more than an hour) mean the time period between inundation of a coastline can vary from hours to days (Dawson, 1994). This long period often allows for alternate periods of tsunami inflow and outflow which can deposit sedimentary beds that contain distinct sedimentary features indicative of alternating landward and seaward flow (Nanaymama and Shigeno, 2006).

Sandsheets found in low energy back-barrier environments are often indicative of washover deposition by storm surge, large waves or tsunami (Witter et al. 2001). Differentiating between these deposits in geological sequences can only be accomplished by developing well-defined facies models that incorporate mineralogical and sedimentological features from deposits of known origins. Recent research into modern tsunami and storm events (Goff et al 2001; Nanayama et al. 2000; Gelfenbaum and Jaffe, 2003; Sedgwick and Davis, 2003; Switzer et al. 2004; Switzer and Jones, 2008a; Morton et al., 2007) has provided several key identifiable and differentiating sedimentary features that may assist the investigation of older sequences (Table 1). In particular storm and tsunami deposits can be reportedly differentiated by comparing and contrasting the contact with the underlying sediments (recently challenged by Bridge, in press); the range of identifiable source sediments; the degree to which the sediments are sorted; the presence and thickness of graded beds; and evidence for directional flow changes (Kortekaas, 2002; Switzer and Jones, 2008b).

In back barrier environments storms overwash events are usually non-erosional events that cause little erosion of the back barrier substrate. In direct contrast tsunami deposits often contain rip-up clasts of the underlying stratigraphy (Gelfenbaum and Jaffe, 2003; Kortekaas, 2002). Direct contrasts also exist in sediment source, with storm deposits eroding mainly beach face and dune material whereas tsunami erode material from a much larger range of environments (Nanayama et al., 2000; Switzer et al., 2005; Switzer and Jones, 2008b). Other diagnostic criteria such as sediment sorting characteristics and the presence and nature of graded beds, are inherently related to the source area of sediments. Differential sorting and graded beds require a range of grains sizes; it is apparent that in some cases a restricted grain size range can make it difficult to use these criteria with any interpretive confidence (Switzer and Jones, 2008b). Finally the presence of sedimentary features that indicate uni-directional or bi-directional flow has been cited as definitive of storm or tsunami with storms characterised by uni-directional flow (Nanayama et al., 2000; Nanayama and Shigeno, 2006).

5. Main findings

There are no globally applicable tsunami criteria obtainable from sedimentological studies (Kortekaas, 2002; Switzer and Jones, 2008b). What can be compiled for the many deposits attributed to tsunami is a suite of sedimentary features or commonalities, often called signatures (Bryant, 2001; Kortekass, 2002; Goff et al., 2001, 2004; Kortekaas and Dawson, 2007; Switzer and Jones, 2008b). These signatures must be considered in terms of the local setting as they are very much site dependant. Palaeo-washover deposits can only be attributed to an event type through careful analysis of spatial features such as the elevation, lateral extent and run-up of the deposit along with sedimentary features such as grading, the presence of intraclasts, and particle size distribution of the sediments (Table 2). These analyses when combined may lead to a suite of evidence that can point to storm or tsunami as the likely depositional agent. Unfortunately when considered alone many of the characteristics are equivocal. In fact most of the signatures presented, including the presence of marine diatoms (Hemphill-Haley, 1996; Dawson and Smith, 2000) or increases in particular elemental concentrations (Chague Goff-and Goff, 1999; Goff and Chague-Goff, 1999; Chague Goff et al. 2000; Goff et al., 2001) only indicate the marine origin of the sediments and inundation by ocean water.

Hence storm surges, sea level change or regional subsidence may show similar sedimentological characteristics (Witter et al., 2001).

Recent work by Witter et al. (2001), Kortekaas (2002), Switzer et al. (2004), Switzer (2008b) and Bridge (in press) have recognized the equivocal nature of many so called tsunami signatures found in sandsheets. This stated, there remain many cases in the literature where a tsunami or storm origin is stated with little consideration given to alternative interpretations. Although work continues on the differences between tsunami and storm deposits, their preservation and recognition in the geological record remains subject to much uncertainty and conjecture.

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Diagnostic criteria	Storm deposits	Tsunami deposits
Contact with underlying sediments	Sharp contact non-erosional. Deposits drape existing landforms and are less erosional	Sharp often erosional contact with eroded clasts incorporated into the lower parts of the deposit. Some material may be 'rafted' and appear in the upper layers of the deposit
Source sediments	Mainly nearshore material. Washover sandsheets dominated by beach and nearshore sand	Wide range of material from inner shelf to terrestrial debris. Extensive erosion by the event allows incorporation of material from a wide variety of landforms
Sorting	Generally poor to moderately sorted material with a unimodal particle size distribution	Poorly sorted sand, clasts and debris often bimodal in particle size distribution.
Graded beds	Thin (<3 cm) laminae with foreset or tabular bedding defining landward accretion	Thick (>5 cm) often chaotic beds sometimes graded. Sediments can appear as massive, laminated, normally or reverse graded beds.
Flow direction	Unidirectional landward flow. Generally little terrestrial material is included in the deposit	Bi-directional flow ~180º with backflow deposits that contain terrestrial material

Table 2. Proposed diagnostic criteria for differentiating between storm and tsunami deposits in the geological record (from Switzer and Jones, 2008).

Reported tsunami signatures	Applicability to distinguishing between storm and tsunami
Deposit of thin anomalous lenses of sediment composed of marine material (Minoura and Nakaya, 1991; Shi *et al.,* 1995, Dawson and Shi, 1996; Goff *et al.,* 2001, 2004; Gelfenbaum and Jaffe, 2003; Kortekaas, 2003; Morton *et al.,* 2007)	Thin lenses of sandy sediment can also be attributed to storm surge and in rare cases aeolian deflation of dunes. Deposits are often attributed to tsunami by their spatial distribution and position in the landscape. Thick, large volume lenses of marine sediment in environments such as back-barrier lagoons or lakes may be attributed to tsunami or storm. Distance inland is not a diagnostic criteria for differentiating between storm and tsunami. eg Nott (2003; 2006) recorded inundation of the Western Australian coast by tropical cyclone Vance in 1999 several hundreds of metres inland.
Deposits fine and thin inland (Shi *et al.,* 1995; Clague *et al.,* 2000; Goff *et al.,* 2001; Dawson and Stewart, 2007; Morton *et al.,* 2007)	Landward fining is generally indicative of a marine origin rather than a fluvial origin. In addition to landward fining, most washover deposits thin inland as a result of decreasing energy away from the sea. This characteristic is found in both tsunami and storm deposits and should not be considered diagnostic for either process.
Lower contact is unconformable or erosional (Minoura and Nakaya, 1991; Nanayama *et al.,* 2000; Dawson and Stewart, 2007)	Tsunami deposits are often recorded as significantly erosional as they strike the coast. This is supported by the presence of intraclasts of the underlying material within the lower parts of the deposit. In contrast, the majority of literature on storm deposits indicates that storm washover is generally depositional with little erosion.
Graded bedding within the deposit. (Dawson *et al.,* 1991; Shi *et al.,* 1995; Goff *et al.,* 2001, 2004; Gelfenbaum and Jaffe, 2003; Tuttle *et al.,* 2004; Switzer and Jones *in press*)	Originally many tsunami deposits were identified as containing graded beds that exhibited fining up sequences indicative of each wave of a tsunami train. Recent studies indicate that bedding in modern tsunami deposits often contains a mixture of normal or reverse graded beds. It also noted that often massive bedding with little structure is found in tsunami deposits. In contrast storm deposits are usually composed of many thin laterally extensive near-horizontal bedforms.
Increase in marine diatoms. (Hemphill-Haley, 1996; Dawson and Smith, 2000; Sawai, 2002; Bondevik *et al.,* 2005; Dawson, 2007)	The presence of marine diatoms or mixed assemblages is indicative of a marine origin for the deposit. Both storms and tsunami are capable of transporting marine diatoms during washover events. The presence of broken or fractured diatoms is indicative of high energy, although further investigation is needed before broken or marine diatoms can be used as a distinguishing criterion.
Marine microfauna including Foraminifera and Ostracoda. (Hindson *et al.,* 1998, Clague *et al.,* 1999, Goff *et al.,* 2001)	The analysis and identification of marine microfaunal assemblages has been used as evidence for storm and tsunami deposition. Future investigation of this technique may yield a distinguishable criterion if statistically significant differences in assemblages can be attributed to each event. Until this is resolved the presence of marine microfauna only indicates a marine incursion.
Geochemical signatures (Chague-Goff *et al.,* 2000; Goff and Chague-Goff 1999; Goff *et al.,* 2001)	Increases in the elemental concentration of sodium, sulphate, chlorine, calcium and magnesium have been recorded in washover deposits attributed to tsunami in New Zealand. In most cases a change in geochemistry is indicative of inundation by seawater and cannot be used as indicative of either process.
Shells and shell-rich sand deposits (Bryant *et al.,* 1992, 1996; Goff *et al.,* 2001; Dawson and Stewart, 2007)	Marine macrofauna (shells) are indicative of marine origin of the sediment. The presence of shelly beds in both storm and tsunami deposits indicates that shelly lenses or shelly-sand deposits are not diagnostic of either event. It may be possible to attribute shelly lenses to tsunami if the shell assemblage can be traced to a source not affected by the action of storm events.
Bi-modal particle size distributions (Shi *et al.,* 1995; Goff *et al.,* 2001, 2004)	Generally storm deposits (particularly washover sand deposits) have uni-modal particle size distributions. Studies of modern tsunami deposits indicate that these deposits are often bi-modal, with a second sediment population derived from offshore (fine sediments) or backwash (coarse sediments). Bi-modal poorly sorted sediments may be indicative of tsunami deposition.
Generally poorly sorted and can contain material indicative of many sources (Nakata and Minoura, 1991; Goff *et al.,* 2001, 2004; Tuttle *et al.,* 2004)	Generally tsunami deposits tend to be much more poorly sorted than storm deposits. This signature should however be treated with caution as tsunami and storm deposits are both a product of their source. It is logical to conclude that a poorly sorted source would generate a poorly sorted deposit.

Table 1 - Reported sedimentary features or 'signatures' with key references from the literature. Column 2 presents a discussion of their applicability to differentiating between storm and tsunami in the geological record. It is apparent that many tsunami signatures are applicable to both storm and tsunami. For a full reference list see Switzer and Jones, 2008).

Authors list

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