Third IGCP 495 Meeting

Quaternary Land-Ocean Interaction: Natural and Human Forcings on Coastal Evolution

September, 2006

Santa Catarina and Paraná, Brazil

Program Schedule and Book of Abstracts

Organizes

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September 17-22, 2006
Balneário Camboriú, Santa Catarina, Brazil

IGCP-495 Quaternary Land-Ocean Interactions:
Driving Mechanisms and Coastal Responses.
Project Leaders: Professor Antony J. Long
Dr M. Shahidul Islam

PROGRAM SCHEDULE

Sunday, 17 September

17:00 – 19:00	Registration
19:00	Ice-break party

Monday, 18 September

Chairman Dr. Rodolfo J. Angulo	
09:00 – 09:30	**Opening session** Dr Antony Long
09:30 – 10:30	**Conference:** Dr. Guilherme C. Lessa - Brazilian coastal bays: large estuaries in a regressive coast
10:30 – 11:00	*Coffe-break*
Chairman Dr. Guilherme C. Lessa	
11:00 – 11:30	Angulo R.J., Lessa G.C., Souza M.C. Holocene barrier evolutionary model of Paranaguá and Itapoá, southern Brazil
11:30 – 12:00	Baeteman C. Sediment variations supported by radiocarbon dates as fingerprints for processes of coastal changes in the late Holocene deposits of a tide-dominated coastal lowland
12:00 – 14:00	*Lunch*
Chairman Dr. Antonio H.F. Klein	
14:00 – 14:30	Boski, T., Fletcher, W., Camacho, S., Moura, D., Veiga-Pires, C., Terefenko, P. Filling patterns and climatic change recorded in two estuaries in Algarve
14:30 – 15:00	Gehrels R., Newnham R., Marshall W., Wilson G., Southall K., Hayward B., Mooney S. A 20th century southern hemisphere sea-level acceleration recorded in a New Zealand salt marsh
15:00 – 15:30	Hassane M., Benhafid M.S., Ayadi A. Détermination du coefficient de frottement du fond pour l'action combinée de la houle et du courant d'écoulement
15:30 – 16:00	*Coffe-break*
Chairman Dr. Antonio H.F. Klein	
16:00 – 16:30	Heyvaert V.M.A., Baeteman C., Weerts H., Dawson S., Sharma C., Gehrels R. The development of the Mesopotamian marshes: a product of the progradation of the Karun-mega fan under decelerating sea-level rise
16:30 – 17:00	Horton B., Day J., Gunn J., Folan W., Yáñez-Arancibia A. Post-glacial coastal margin productivity and the emergence of civilizations
17:00 – 17:30	Lane P., Donnelly J. A Millennial-scale record of intense New England hurricanes preserved in kettle pond sediments
17:30 – 18:00	Long, A., Roberts D., Dawson S. The first Holocene relative sea-level curve from the southeast sector of the Greenland ice sheet
20:00	*Conference Dinner*

Tuesday, 19 September 2006

Chairman Dr. Rodolfo J. Angulo	
09:30 – 10:30	**Conference**: Dr. Sérgio R. Dillenburg – A Holocene geology and geomorphology of Brazilian coastal barriers

10:30 – 11:00	*Coffe-break*
Chairman Dr. Sérgio R. Dillenburg	
11:00 – 11:30	Miettinen A., Jansson H. Late Holocene sea level changes along the SW coast of Finland – evidence of anomalies in the glacio-isostatic land uplift?
11:30 – 12:00	Szkornik K., Gehrels R., Kirby J., Kent M., Charman D. Using diatom-based transfer functions to reconstruct Holocene sea-level changes: highlighting the need for caution in model selection and in interpreting predictions
12:00 – 14:00	*Lunch*
Chairman Dr. Antony Long	
14:00 – 14:30	Woodroffe S. Foraminifera-based reconstructions of mid-late Holocene sea-level change from north Queensland, Australia.
14:30 – 15:00	Woodruff, Jonathan D., Donnelly, Jeffrey P. New overwash and sea-level reconstructions from saint Kitts, west Indies
15:00 – 15:30	*Coffe-break*
15:30 – 16:30	Poster sessions
Branco J.C., Angulo R.J., Souza M.C. Pleistocene barrier evolution at Paraná, southern Brazil: preliminary results Buynevich I.V., Cleary W.J., Fitzgerald D.M., Klein A.H.F., Asp N.E., Hein C., Veiga F.A., Angulo R.J., Petermann R.M. Modern and ancient erosion indicators on a high-energy coast: Camboriú peninsula and Navegantes plain, SC, Brazil Fitzgerald D.M., Cleary W.J., Buynevich I.V., Hein C., Klein, Antonio H.F., Asp N.E., Angulo R.J., Veiga F.A., Petermann R.M., Vintém G. Variability of strandplain development in Santa Catarina, Brazil Lamour M.R., Angulo R.J. Dredging influence on coastal dynamics at Paranaguá estuarine complex mouth – Brazil Szkornik K., Gehrels R., Murray A. Little ice age sand invasion of the Ho Bugt salt marshes during low relative sea level Veiga F.A., Angulo R.J., Brandini F.P., Pessenda L.C.R. Southern Brazil submerged beachrocks: preliminary results Zazo C., Goy J. L., Dabrio C.J., Lario J., Borja F., Bardají T., Silva P.G., Cabero, A. Holocene coastal archive of climate and sea-level oscillations in the Spanish Atlantic-Mediterranean region: millennial to decadal periodicities.	
16:30 – 17:00	Discussion of emergent ideas – Dr. Antony Long
17:00 – 17:30	IGCP 495 business meeting – Dr. Antony Long
17:30 – 18:00	Fieldtrip introduction – Dr. Antonio F. Klein and Dr. Rodolfo J. Angulo

Wednesday to Friday, 20 to 22 of September

Full days field excursions to Santa Catarina and Paraná coasts

CONFERENCES

LESSA G.C. Brazilian coastal bays: large estuaries in a regressive coast

DILLENBURG S.R. Holocene geology and geomorphology of Brazilian coastal barriers

ABSTRACTS

ANGULO R.J., LESSA G.C., SOUZA M.C. Holocene barrier evolutionary model of Paranaguá and Itapoá, southern Brazil

BAETEMAN C. Sediment variations supported by radiocarbon dates as fingerprints for processes of coastal changes in the late Holocene deposits of a tide-dominated coastal lowland

BOSKI, T., FLETCHER, W., CAMACHO, S., MOURA, D., VEIGA-PIRES, C., TEREFENKO, P. Filling patterns and climatic change recorded in two estuaries in Algarve

BRANCO J.C., ANGULO R.J., SOUZA M.C. Pleistocene barrier evolution at Paraná, southern Brazil: preliminary results

BUYNEVICH I.V., CLEARY W.J., FITZGERALD D.M., KLEIN A.H.F., ASP N.E., HEIN C., VEIGA F.A., ANGULO R.J., PETERMANN R.M. Modern and ancient erosion indicators on a high-energy coast: Camboriú Peninsula and Navegantes plain, SC, Brazil

FITZGERALD D.M., CLEARY W.J., BUYNEVICH I.V., HEIN C., KLEIN, ANTONIO H.F., ASP N.E., ANGULO R.J., VEIGA F.A., PETERMANN R.M., VINTÉM G. Variability of strandplain development in Santa Catarina, Brazil

GEHRELS R., NEWNHAM R., MARSHALL W., WILSON G., SOUTHALL K., HAYWARD B., MOONEY S. A 20th century southern hemisphere sea-level acceleration recorded in a New Zealand salt marsh

HASSANE M., BENHAFID M.S., AYADI A. Détermination du coefficient de frottement du fond pour l'action combinée de la houle et du courant d'écoulement

HEYVAERT V.M.A., BAETEMAN C., WEERTS H., DAWSON S., SHARMA C., GEHRELS R. The development of the Mesopotamian marshes: a product of the progradation of the Karun-mega fan under decelerating sea-level rise

HORTON B., DAY J., GUNN J., FOLAN W., YÁÑEZ-ARANCIBIA A. Post-glacial coastal margin productivity and the emergence of civilizations

LAMOUR M.R., ANGULO R.J. Dredging influence on coastal dynamics at Paranaguá estuarine complex mouth – Brazil

LANE P., DONNELLY J. A Millennial-scale record of intense New England hurricanes preserved in kettle pond sediments

LONG, A., ROBERTS D., DAWSON S. The first Holocene relative sea-level curve from the southeast sector of the Greenland ice sheet

MIETTINEN A., JANSSON H. Late Holocene sea level changes along the SW coast of Finland – evidence of anomalies in the glacio-isostatic land uplift?

SZKORNIK K., GEHRELS R., KIRBY J., KENT M., CHARMAN D. Using diatom-based transfer functions to reconstruct Holocene sea-level changes: highlighting the need for caution in model selection and in interpreting predictions

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VEIGA F.A., ANGULO R.J., BRANDINI F.P., PESSENDA L.C.R. Southern Brazil submerged beachrocks: preliminary results

WOODROFFE S. Foraminifera-based reconstructions of mid-late Holocene sea-level change from north Queensland, Australia.

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BRAZILIAN COASTAL BAYS: LARGE ESTUARIES IN A REGRESSIVE COAST

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Several definitions of estuaries exist in the literature, reflecting the wide diversity of scientists dedicated to its investigation. Considering the geological sciences, the most used definition has been that proposed by Dalrymple et al (1992), that considers estuary as the distal portion of a drowned valley extending from the landward limit of tidal facies at its head to the seaward limit of coastal facies at its mouth. Estuaries are thus associated with an acomodation space landward of the coastline, and the complete infilling of such an space results in the extinction of the estuary.

Maintenance of the accommodation space in transgressive coasts is possible when sea level rising rate is higher than sedimentation rate. In coasts where sea level is stable, the estuary life span is determined by the ratio between depth and sedimentation rate. The life span in regressive coasts is greatly diminished due to the sum of the sedimentation and sea-level fall rates.

The Brazilian coast has undergone a relative fall of sea level of about 3,5 m in the last 6000 years, and as a result elevated coastal terraces, large scale coastal progradation and infilling of incised valleys are widespread. Some of the largest Brazilian river “deltas”, such as Paraíba do Sul (RJ) and Doce (ES) rivers, present geomorphologic evidence of paleo estuaries abutting the strandplains (Dominguez et al. 1992). Evidence of extinct estuaries are also observed in river valleys deprived of deltaic features at their outlets, such as Itajai-Açu (SC) (Caruso Junior 1993) and Ribeira de Iguape (SP) rivers. Therefore, classical coastal plain estuaries no longer exist along the Brazilian coast, with the exception of the northern coastal sector where large-scale subsidence has apparently occurred throughout the Holocene.

In spite of this regressive scenario and large scale coastal progradation, there still remains large estuaries in the country, within which are located the most important harbors. This paper is organized with the aim to present a summary of the existing geological, geomorphological and hydrodynamical information of the most important

Brazilian estuaries and to incite a debate on what were the factors that influenced their maintenance in such a regressive coast.

An investigation of Brazilian coast with satellite images (1:25.000 and 1:50.000) allowed for the identification of 34 estuaries larger than 50 km^2, being 15 in the north, 11 in the northeast, 4 in the southeast and 4 in the south region (Fig. 1). Amongst these estuaries, only 7 present drainage basins larger than 10.000 km^2, which is explained by the control exerted by the coastal massifs on the establishment of the continental drainage. Small drainage basins provide potentially small discharge. Moreover, the larger catchment areas in the northeast drain semi-arid regions, and smaller discharges are also anticipated.

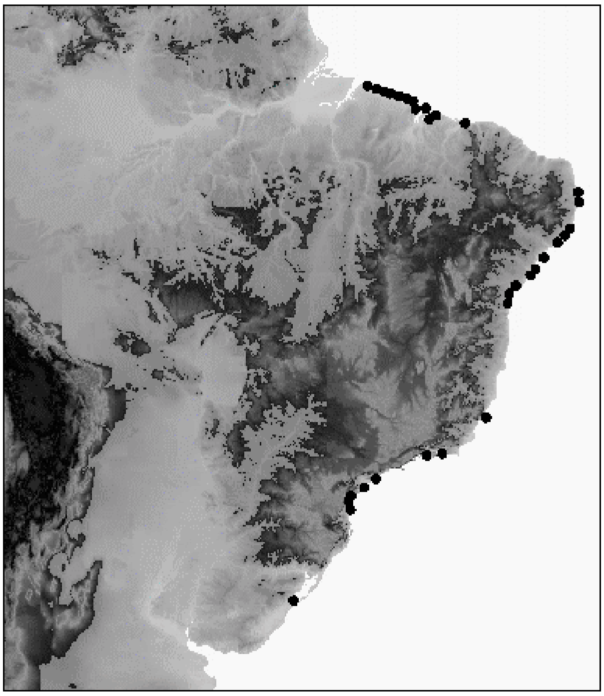

Figure 1: Location of the 34 estuaries larger than 50 km^2 along the Brazilian coast.

Few estuaries have been charted, and thus analysis of the accommodation space is limited to those with port facilities. The volumes vary between 10^9 e 10^{11} m^3, with Baía de Todos os Santos (13º S) the one with the largest measured volume (~$1.1x10^{11}$ m^3). The estuarine volume in itself only provides an approximation of the estuary preservation potential – larger volumes relates to a longer infilling time. With the lack of sediment discharge data the relative infilling rate of the estuaries can be preliminarily compared with the ratio of estuary volume and the water discharge (taking as an assumption that the sediment discharge is linearly correlated to the water discharge). The ratios for three of the four largest estuaries (Paranaguá, Guanabara e Todos os Santos bay) vary between 210 days (Paranaguá) and 8500 days (Todos os Santos). This suggests that sediment-infilling speed may vary in one order of magnitude.

Hydrodynamic data suggest that most of the estuaries are hypersynchronous, and most of them present evidence of ebb-dominant circulation, which give rise to large ebb-tidal deltas. This present condition suggests little participation of marine sediments in the infilling process.

Little information exists on the distribution of the sedimentary facies, both on the sirface and subsurface. With the information available in the literature (Lessa et al. 1998, 2000, Kjerfve et al 1997, Quaresma et al. 2000) its observed that the bays of Paranaguá, Guanabara and Todos os Santos present marine sand close to the mouth, and a muddy facies capping a significant part of the inner half of the estuaries. Bay head deltas are reported fo the bays of Paranaguá and Todos os Santos. Subsurface geologic data suggest a similar pattern of sediment deposition, with transgressive marine sands at the outer estuary half being covered by regressive, more than 10 m thick muddy sediments.

The existence of large estuaries in the Brazilian coast is apparently conditioned by a small supply of riverine sediments and by local subsidence. Few studies have been undertaken to investigate the existence of recent vertical adjustments of the substrate within the estuaries, but it is a fact that they are associated with large morphotectonic structures. The few evidence favoring subsidence of the estuarine regions are given by Martin et al. (1986) and Carvalho (2000) at Todos os Santos Bay, where up to 3 m displacement is suggested for the last 5000 years. Souza-Filho et al. (2006) suggest that relative mean sea level has not overtaken the present mean sea level in the Holocene in north Brazil, as the subsidence of a large coastal graben has sunk about 500 km of the coast. Its is proposed, as a point for debate, that the Brazilian estuaries are associated with subsiding coastal sectors, and that this process has been the most important factor in controlling the preservation of the estuaries in the Late Holocene.

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HOLOCENE GEOLOGY AND GEOMORPHOLOGY OF BRAZILIAN COASTAL BARRIERS

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The Brazilian coast is approximately 8,500 km long. In a south-north direction it ranges from latitude -33° 46' to +4° 19' (4,200 km). It occurs on a continental margin related to a rifted plate boundary formed in Early Cretaceous times. This very long coast shows a great variation in its geological structure, drainage systems and in oceanographic and climatic conditions, which have determined the existence of a variable spectrum of coastal barrier systems. In the following, characteristics of the geology and geomorphology of the Brazilian Holocene barriers will be briefly outlined.

The Holocene Barriers of Rio Grande do Sul

Rio Grande do Sul (RS) is characterized by a monotonous and gentle undulating barrier coast. It is a typical wave-dominated coast with a combination of a moderate to high wave energy, and a very low microtidal regime (~ 30 cm). These characteristics, together with a great abundance of sediment and a gentle continental shelf slope has established perfect conditions for the existence of coastal barriers along this coast. The Holocene barrier occurs along the entire 625 of RS coast, and it shows two discontinuities only: at Rio Grande and Tramandaí. During the Middle and Late Holocene it did not exhibit a uniform evolution. In coastal re-entrants, regressive (prograded) barriers occur, whereas on protruding sectors of the coast, transgressive (retrograded) barriers occur. Both regressive and transgressive barriers are dominated by, and capped with transgressive dunefields. From Torres to Tramandaí and from Estreito to Verga the Holocene barrier has a regressive nature, with the barrier showing a maximum progradation of 4.7 km and 14 km, respectively, that started at the final stages of the Post Glacial Marine Transgression (~ 7 ka). From

Tramandaí to Mostardas the barrier seems to be stable (aggradational?), or alternating between transgressive and regressive conditions, while from Mostardas to Estreito it is typically transgressive.

The Holocene Barrier Systems of the central and southern Santa Catarina coast

The coastline of Santa Catarina is also wave-dominated with a tidal range varying from 50 to 100 cm. This coast is dominated by prograded barriers also capped with transgressive dunefields south of Santa Catarina Island, and prograded barriers dominated by beach ridge/chenier plains and relict foredune plains north of the Island. The transgressive dunefield barriers mainly occur in zeta-formed headland-bay beaches. Dunefield migration is to the SW south of SC Island, and to the North on SC island. Where the coast parallels the prevailing wind, dunefield migration is alongshore (e.g. Guarda do Embau, Farol do Santa Marta), and as the coastline orientation trends more northerly the dunefield migration becomes increasingly oblique to the coast. Three sites (Pinheira, Gi, and Passo de Torres-Santa Marta) display a complex suite of foredune ridges and transgressive dunefields which indicate that at least some of the dunefields have prograded to various degrees in the Holocene.

The Holocene Barrier Systems of the northern Santa Catarina and Paraná coasts

From Barra Velha (northern Santa Catarina) to Ilha do Cardoso (south of São Paulo), in a coastal segment of about 200 km, four coastal plains and three estuarine systems occur. Spring tide at Paranaguá can reach 1.7 m in range. The development of the Holocene barriers and the paleogeographic evolution of these coastal plains are intimately related with the morphodynamics of these estuarine systems. The Holocene barriers are essentially prograded foredune plains, showing a widening towards the north that might be a result of a net northward litoral drift. There is evidence at Paranaguá that spits might have been common features at the initial stages of the Holocene barrier formation at about 6,000 ^{14}C cal BP. If a transgressive barrier has existed it was probably eroded by meandering estuarine channels. At Paranaguá the barrier has prograded 5.5 km in the last 4,000 years, with the last 3,5 km of progradation taking place in the last 2,800 years, under a sea level fall of about 2.0 m.

The Ilha Comprida Barrier System, southern São Paulo coast

The most important barrier system of the São Paulo coast is the Ilha Comprida prograded barrier. It is ~65 km long and ~2.5 km wide. The spring tidal range reachs up to 1,2 m. Barrier progradation occurred in three main phases. The first (6,000 ^{14}C cal years BP to approximately 3.5 ky BP) is marked by the formation of nearly 70% of the barrier. The second phase, between 3.5 and 2 ky BP, shows a relative decline in progradation, which has increased again during the third and last important phase which started at 2 ky BP. Barrier morphology is in general characterized by foredune ridges. At the northern end parabolic dunes and transgressive dunefields occur.

The Holocene Barrier Strandplains of the State of Bahia

The state of Bahia has the longest coastline in Brazil, totaling almost 1000 km. Tidal range along the coast is slightly over 2 m (lower mesotidal) and exhibits a small tendency to increase from south to north. The main coastal barriers are also prograded barriers (strandplains) with beach or foredune ridges. Some are associated with rivers (Jequitinhonha, Lagoa Encantada and Itapicuru). Studies of these barriers have showed that the local physiography plays a much more important role in progradation than an association with a major river delivering sediments, as is the case of Caravelas and Lagoa Encantada barriers. For instance, at Caravelas, changes in shoreline orientation and reef development have produced changes in the coastal hydrodynamics, producing longshore transport convergence. However, at Itapicuru, almost no progradation took place during the Holocene due to the absence of a suitable physiography to trap sediments in this area.

The Mesotidal Barriers of Rio Grande do Norte

The State of Rio Grande do Norte (RN) is situated in the northeastern part of Brazil along the Atlantic Ocean and comprises two different sectors: a northern N-S trending sector, extending from Paraiba (PB)/ Rio Grande do Norte (RN) border to Touros, where the maximum spring tidal range is 2.2 m; and an eastern E-W trending sector, extending from Touros to the RN/ Ceará (CE) border, with a maximum spring tidal range of 3.3 m. Barriers at the Rio Grande do Norte coast are characterized by attached barriers at the N-S trending east coast, and barrier islands-spit systems on the E-W trending north coast.

From a morphodynamic point of view, the N-S Sector is a wave-dominated coast with active sea cliffs carved into tablelands alternating with reef-or dune-barrier sections, while the E-W Sector is a mixed-energy complex of wave-dominated and tide-dominated coast.

The Barriers of Ceará, Piauí and Maranhão States, northeast Brazil

The States of Ceara and Piauí, and eastern Maranhão comprise three principal barrier types, namely, spit complexes, attached transgressive dunefield barriers, and moderate to very large scale prograded transgressive dunefield barriers. On this coastal sector the average spring tidal range is 3.4 at Ceará and it progressively increases up to Maranhão. The southeastern coast is erosional and dominated by attached barriers where the dunefields abut, and/or climb the Barreiras formation. Where rivers locally supply sediment, single and multiple spits are formed, and prograded barriers dominate. A few of these spits display foredune ridges but most have sand sheets and dunefields. North of Fortaleza, large scale active and relict transgressive dunefields predominate. Many have spits on the downdrift (western) margin, many are headland bypass systems, almost all display multiple phases of development, several have massive dunes, and many are clearly prograded barriers.

Transgressive barrier estuarine systems of Pará and Maranhão States, Amazon region

The coast of Pará and western Maranhão is characterized by several large macrotidal barrier-estuarine systems that harbor the largest mangrove area in the world, with approximately 7,600 km^2. The spring tidal range here can reach 5.4 m and there is a westerly littoral drift. As a result of a low gradient coast, tides play an important role in coastal dynamics. The coast is dominated by mud sedimentation and the mangrove forest systems become more pronounced to the northwest of the Amazon River and into Amapá State. East of Baia de Marajó, there are also significant sand deposits, and multiple spits, barrier islands and barriers have been formed in the Holocene. Some of the barriers also display dune systems (e.g. Salinopolis). One of the above mentioned barrier-estuarine systems is the Caeté system, which is considered as a morphostratigraphic model for the region. Its coastal evolution during the last 5,100 ^{14}C yr B.P. has been apparently modulated by small scale subsidence events, with the onset of three phases of barrier development.

HOLOCENE BARRIER EVOLUTIONARY MODEL OF PARANAGUÁ AND ITAPOÁ, SOUTHERN BRAZIL

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Curved ridges visible in aerial photographs and channel scouring and inlet fill sequences in the GPR profiles in the most internal part of the barriers of Itapoá-Guaratuba and Paranaguá suggest that spits might have been common features at the initial stages of the Holocene barrier formation. Spit growth aided the formation of small estuaries close to the PMT maximum both in Paranaguá and Itapoá coastal plains. Radiocarbon dating of estuarine deposits provided an age of 6,489-5,629 ^{14}C cal BP, which coincides with the time of sea level maximum suggested by Angulo et al. (2006). Spit growth must have been associated with intense littoral drift, as suggested by Roy et al. (1994) for open coasts under stable or slowly-varying sea level.

The Pleistocene substrate in Paranaguá, and bedrock outcrops in Itapoá, was probable anchoring points for spit development. In both cases, the establishment of an estuarine area and meandering channels behind the spits promoted the erosion of both Pleistocene and Holocene barriers.

Curved beach ridges suggest that spits grew both from the northeast and southwest. Opposing directions of spit progradation suggest reversals of the net-longshore sediment drift during coastal progradation. A northward drift has been, however, dominant during coastal progradation, as indicated by changes in the orientation of the beach-ridges. At least in the northern part of Paranaguá coastal plain, rotation of the prograding shoreline under the influence of northward littoral drift is clearly observed on aerial photographs.

Few paleo-shoreline positions with chronological control are identified in the Paranaguá barrier: the shoreline associated with the transgression maximum and the shorelines associated with the paleoshorefaces dated at the sand pit in the middle of the Holocene barrier. If the transgressive barrier ever existed, the meandering estuarine channels must have eroded most of them in Paranaguá and Itapoá-Guaratuba coastal plains. In Superagüi coastal plain, where the Holocene barrier is apparently fully encroached against its Pleistocene counterpart, the contact between the Pleistocene and Holocene barriers illustrates what the contact between the two barriers could have been like in Paranaguá and Itapoá in the case the estuarine channels did not exist. The first foredune-ridges on Superagüi truncate small infilled drainage channels incised upon the Pleistocene barrier.

At the sand pit in Paranaguá barrier, the 4,200 yr ^{14}C cal B.P paleo shoreface can suggest a position for the paleo shoreline on the basis of the present shoreface profile. Textural and depth similarities between the sedimentary sequences in the sand pit and on the present shoreface point to the maintenance of the profile during barrier progradation. The barrier isochrones point to very little coastal progradation in the first 1,000 years after sea level maximum, when sea level might have fallen between 0.5 to 1 m.

Limited or no coastal progradation of Paranaguá, and possibly Itapoá-Guaratuba barrier within this time period could be related to the morphodynamic character of the estuaries at the Holocene sea-level maximum. Extensive marine sand deposition inside Paranaguá estuary is indicated by a transgressive sand sheet (Lessa et al. 1998) and extensive flood tidal delta deposits (Lessa et al. 2000, Araújo 2001). Barbosa and Suguio (1999) also indicate a paleo flood tidal delta inside Baía de Guaratuba. The initial estuary sand trapping is ascribed to a flood-dominant tidal-current regime at a time the estuary had not yet developed intertidal areas extensive enough to promote the present ebb-dominant condition.

Coastal progradation in Paranaguá apparently started at about 4,000 yr ^{14}C cal BP and shifted the shoreline 2,000 m seawards during the next 1,500 years. Normal coastal progradation is well documented in the GPR profiles, which shows seaward dipping reflectors with gradients between 5 ^{o} and 8 ^{o}, reaching 2 m of depth. These gradients are equivalent to those of the present beach face under stormy conditions.

Coastal progradation occurred with a northward barrier extension and an initial rotation of the shoreline possibly ascribed to a shadow zone of rocky islands fronting Ilha do Mel. Active sedimentation on the flood-tidal deltas was apparently halted at about 3,500 yr ^{14}C cal BP, as indicated by radiocarbon dating of the shell deposit. Lessening the sediment volume removed from the coastal system would have allowed coastal progradation. This initial morphodynamic change, which eventually led to a complete reversal of the estuarine net-sediment transport direction, was associated with an increase of the intertidal areas, caused by sedimentation and sea-level fall. 3.5 km of barrier progradation in Paranaguá occurred in the last 2,800 years, with a sea level fall of about 2.0 m. Within this time the northern extremity of the barrier continued to extend northwards, generating the offset that presently exists between the orientation of the estuary mouth and the flood-tidal deltas. It suggests that the core of the barrier sediments are related to channel fill, as the barrier migrated over an estuary entrance that might have become increasingly narrower and deeper, with the onset of ebb-dominant conditions. A tidal diastem is likely to occur at the base of the Holocene barrier deposits at this location. A fully ebb-dominant condition in Baía de Paranaguá might have been established in the last few thousand years, with the onset of a hydraulic groin that helped to steer the shoreline further to the northeast. The growth of an ebb-tidal delta dampened wave height close to the entrance of the Baía de Paranaguá, lowering the elevation of the barrier in the last 3 km at the northern end of the barrier by at least 1 m in relation to sections further south. Dune systems have developed very recently on the coastal plains, perhaps only in the last few hundred years. A gastropod-shell radiocarbon date from the contact between beach and aeolian sediments at the innermost foredune ridge at Ararapira spit provided an age of 336-0 ^{14}C cal yr BP (Angulo et al. 2006). Reasons for such late dune growth are not yet known, but might be related to sea level stabilization or climatic oscillations such as dryer or stormier periods.

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SEDIMENT VARIATIONS SUPPORTED BY RADIOCARBON DATES AS FINGERPRINTS FOR PROCESSES OF COASTAL CHANGES IN THE LATE HOLOCENE DEPOSITS OF A TIDE-DOMINATED COASTAL LOWLAND

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The late Holocene deposits of the Belgian coastal plain were formed by a renewed expansion of the tidal environment after a period of 2-3 ka years of almost uninterrupted peat growth. The expansion of the tidal environment was associated with the formation of tidal channels which eroded deeply into the mid and early Holocene sediments, and sometimes into the Pleistocene subsoil. In general, the late Holocene deposits comprise a 1-2 m thick, apparently homogeneous tidal-flat mud. Organic horizons or peat beds are no longer present with few exceptions. The overall texture of the infilled channels consists of fine sand for its major part with a thickness that varies between 5 and 25 m. The upper part of the channel infill, here called the final fill, consists of laminated mud and fine sand often strongly burrowed. The final fill reflects the eventual silting-up phase of the channel. In the surroundings of the infilled channels, the post-peat deposits show lateral and vertical sediment variations. These changes in lithology used to be interpreted as a result of transgressions and regressions.

Since the sea-level curves of the Southern North Sea coastal lowlands do not show sea-level fluctuations for the past 2500 years (except in northern Germany), the mechanisms and processes that led to the sediment variations have to be determined. Therefore, the sediment characteristics and chronology of the post-peat deposits have been investigated in detail in shallow outcrops with special attention to the final infill of the tidal channels.

The results show several steps in the formation of the post-peat deposits. The deep vertical incision is followed by sedimentation with high energetic conditions whereby erosion and sedimentation alternate. The large age differences (c. 1000 years) between the peat dates and shell dates from the overlying clastic deposits suggest that areas in the surroundings of the channels became in a subtidal position with minimum sedimentation. At first, all the available sediment was used to fill the deepened channels. The subtidal position was a result of the collapse of the peat due to drainage when the channels cut into the peat bog. It took at least 500 years before the channels were filled and their surroundings became in an intertidal position between about 1400 and 1200 cal BP documented by the ubiquitous presence of *Scrobicularia*. This period is represented by the final fill whereby the channel cross-section, sediment supply, tidal prism, and sea level were in equilibrium. Following this low-energy silting-up phase which lasted until about 1150 cal BP, the high-energy conditions prevailed again. Open marine sediments were brought in, pointing to shoreface erosion and a landward shift of the coastline. In this period the channels started to migrate laterally. This process led to the reworking of the deposits of the salt marshes and mudflats adjacent to the channels and in seaward areas. Also the final fill of the channel itself experienced shallow erosion and reworking, but with minimum transportation. The lateral migration was prompted by a shortage of accommodation space. Sea-level rise was very slow and consequently did not create further accommodation space in the plain which was in an inter- and supratidal position. On the basis of only one radiocarbon date, it is suggested that the eventual and complete silting up of the channels and the plain did not happen before 560 cal BP.

The detailed sedimentological investigation of the late Holocene deposits in shallow outcrops supported by radiocarbon dates from shells highlighted several issues which are of wider methodological interest for the study of tide-dominated coastal lowlands.

- The results show that over short distances sediment successions caused by the same event can vary significantly.
- The sedimentation was discontinuously and the changes happened rapidly.
- The different channel systems experienced the same process, but not necessary at the same time because the channels progressively invaded the peat bog with the enlargement of their tidal prism and the channels also reacted to local situations. Consequently, the mechanism of coastal change may be identical for the entire plain but the timing is certainly not.

- The repeatedly reworking of the deposits (sometimes without any apparent lithological change) implies that the radiocarbon dates of the shells must be considered carefully. It is essential to integrate the results in a wider stratigraphic context. The same remark applies for microfossil analyses.
- The main controls on the sedimentation of the late Holocene deposits were the slow sea-level rise, the availability of sediment, and the change in size of the tidal prism of the channels.

FILLING PATTERNS AND CLIMATIC CHANGE RECORDED IN TWO ESTUARIES IN ALGARVE

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The present abstract reports the results of benthic foraminifera, sedimentological and palynological investigation of 2 cores (coded CM5 from the Guadiana/Beliche Estuary site and G2 from Almargem Estuary site) site which represent the inner estuary, sheltered conditions and 2 cores (coded G1, and G3) from the Gilão/Almargem Estuary which represent the dynamic outer estuarine situation.

The Algarve coastline is located at the passive continental margin of South West Iberian Peninsula. In geomorphological terms, the Eastern coastal sector where both studied estuaries are located, is dominated by the Ria Formosa Barrier Islands System enclosing a lagoonar body along ca 50 km. The wave regime is predominantly from SW, associated mainly with swell from the Atlantic Ocean. The strong longshore current is west-to-east and the mean tidal range is 2 m i.e. mesotidal. The Gilão – Almargem estuary site represents the terminal segment of two small river basins totalling ca. 290 km^2 and draining a predominantly Mesozoic carbonate and Miocene siliciclastic substratum. At the second site, 20 km eastward, the Beliche River drains a basin of about 125 km^2, which is placed exclusively on

Carboniferous shales and greywackes. The Beliche-Guadiana confluence lies within the reaches of the present estuary of the Guadiana. The latter is in the terminal stage of sediment infilling of the paleovalley which was incised down to 80 m depth, during the glacial lowstands.

The sediment profiles obtained through the drilling of 4 boreholes into the Quaternary infill of Beliche-Guadiana and Gilão-Almargem estuaries permitted to assess the processes of sedimentation during the postglacial sea level rise since ca 13000 cal BP.

The sedimentary stratigraphic record may be regarded as a stack of sediment increments separated by surfaces of hiatus which) are occurring at all levels of resolution. In other words, according to Sadler (1999), the rate of accumulation is a property of both the depositional system and the time-scale. Translated to the conditions of the progressively drowned paleovalley, a time continuous sedimentary record may be accommodated in a period of spatially constant separation between surface of water and of sediment boundary. The projection of the depths within the sedimentary column of what was inferred to be the sedimentation surfaces, against the age of items found on that surfaces was plotted for the studied boreholes in figure 1.

The more sheltered sites (boreholes CM5 and G2) offered an almost continuous record of sediment accumulation expressed by a conspicuous monotony in an environment of tidal flat or salt marsh as indicated by the Foraminiferal Index of Marine Influence (FIMI).

However, this paleoecological proxy requires further refinements through the actualistic studies and must be interpreted in the context of complex diagenetic processes driven by the anaerobic respiration of organic matter and by underground water circulation. Organic molecular markers (Gonzalez Vila et al. 2003) and sediment structural characteristics (Boski et al. 2006) indicate that in both sheltered environments, notwithstanding the existing time lag, the initial sediment infilling is fine grained and the sediment surface covered by salt marsh vegetation. The subsequent phase of infilling corresponds by the criteria to barren mud flat.

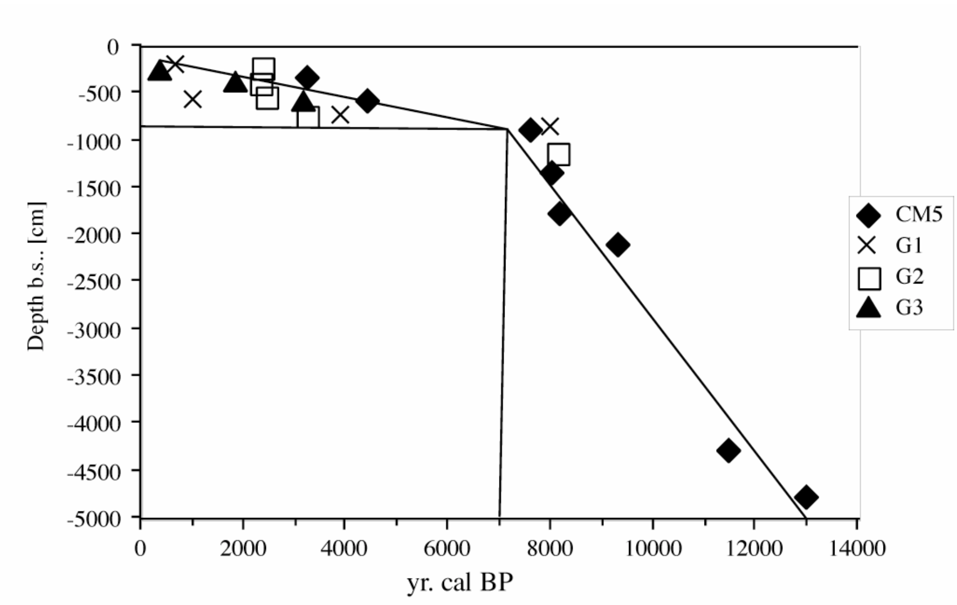

Figure 1: Two segment plot of sediment accumulation within estuarine valleys of Beliche and Almargem/Gilão rivers.

Due to its sedimetological characteristics the CM5 borehole was intensly studied from the point of view of pollen content (Fletcher et al. 2006 submitted). In the absence of lacustrine deposits it offers an almost continuous record of 13 000 yrs of vertically accreted sediments. This record provides the first dated Late-glacial pollen record from Southern Portugal. A distinct Late-glacial pollen assemblage is recorded with high level of *Pinus, Juniperus* and *Ephera Distachya* type. Within the Late-glacial sediments, a vegetation event is recorded with decline of desiduous and evergreen *Quercus* and an expansion of dry- and cold-tolerant taxa. This vegetation event, supported by the radiocarbon dates, is considered an expression of climatic deterrioration associated with Allerod/Younger Dryas transition. The vegetation of the Early Holocene is interprted as a mosaic of pinwood, oak forest and shrub communities. From ca 9800 cal BP, the presence of evergreen, sclerophyllous shrub taxa (*Olea, Phillyrea, Pistacia*) is recorded and from ca 9000 cal BP, the dominance of *Quercus* forest. Between 9000 to 5200 cal BP occurred the maximum Holocene forest development with contraction of *Pinus silvestris* and predominance of deciduous and evergreen *Quercus* and well developed riparian woodlands of Alnus and Fraxinus. The expansion of scrub and open ground taxa recorded at ca 7800 – 7400 cal BP signals probably the first anthropogenic clearance event. From 5200 cal BP a widespread replacement of forest by scrub communities and open ground happened, due to human activities. Between 4100 and 2500 cal BP, the maximum development of shrublands is recorded, suggesting impacts of grazing by domesticated animals and burning activities. Further expansion of open ground witnessed by Plantago Lanceolata, indicates intensification of human impacts during the Roman and Moorish times.

The sediment profiles from boreholes G1 and G3 in the Gilão - Almargem estuarine area provided information about the more discontinuous process of sedimentation in estuarine bars, controlled by the influx of sandy sediments transported by the longshore current since ca 8000 cal yrs BP.

All the data combined provided a 2 segment plot of sediment accumulation from ca 13000 cal yrs BP to the present (fig.1). Between 13000 cal yrs BP and 7000 cal yrs BP the level of the sediment surface rose at a rate of 7.6 mm yr-1. Since then the process of sedimentation in the studied sites slowed down to ca. 0.9 mm yr-1 and was characterized by local discontinuities. This means that the sediment accumulation was not any more confined to the incised depression (ie. palleovalley) but occurred on drowned costal plain causing “patchy pattern” of deposition.

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PLEISTOCENE BARRIER EVOLUTION AT PARANÁ, SOUTHERN BRAZIL: PRELIMINARY RESULTS

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Along the Brazilian coast three Pleistocene barriers and one Holocene barrier were recognized (Villwock *et al.* 1986). In the coast of Paraná only two main barrier systems could be recognized; one formed during the Late Pleistocene and the other during the Holocene (Martin et al. 1988a, Angulo 1992). Souza (2005) and Angulo *et al.* (2007) described the facies and proposed an evolutionary model for the Holocene barrier. For the Pleistocene barrier there are only few and fragmentary descriptions (Bigarella et al. 1978, Tessler & Suguio 1987, Angulo 1992). This works aims to describe the facies and propose an evolutionary model for the Paraná Pleistocene barrier. The facies descriptions were performed at sand exploitation quarries near Paranaguá Town where there was possible the observation it was possible to observe outcrops 100m wide and 15 m high. At the bottom quarries 6 m vibracores were taken.

The Center-South Paraná coastal plain shows a triangular form. Angulo (1992) distinguished Pleistocene and Holocene barriers and Holocene paleolagoonal sediments (Figure 1).

In the studied area the Pleistocene barrier is composed by fine to medium sand, with granule and gravel, with poor selection and subrounded shape. These sedimentary characteristics differ from Holocene barrier that is composed mainly by fine to medium sand (Souza 2005). These differences could be related with more contribution of immature continental sediments at the Pleistocene barrier that is closer to the Serra do Mar mountains.

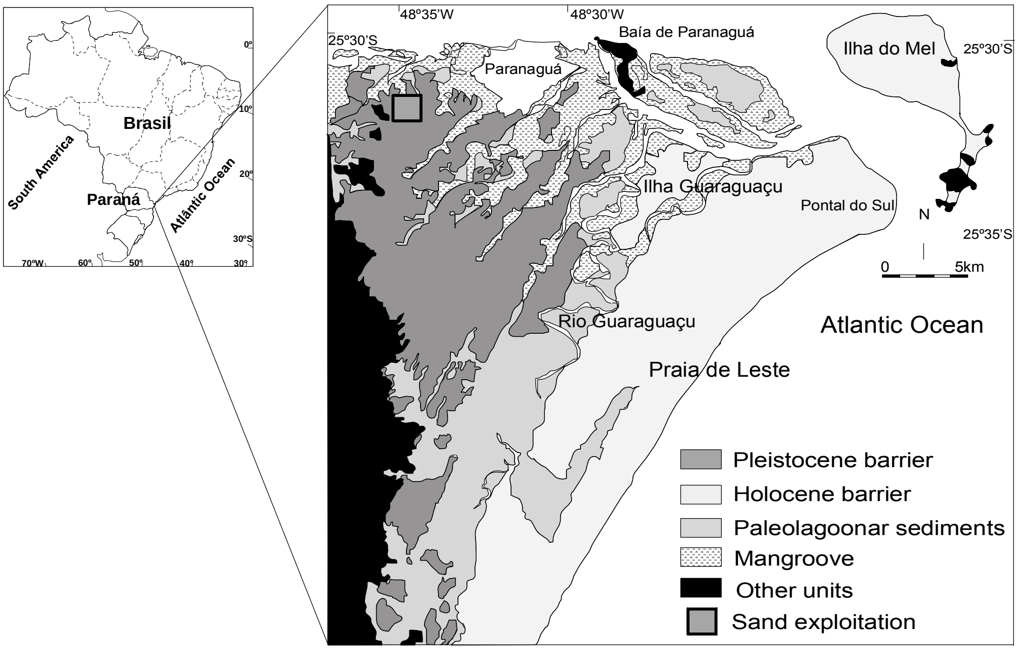

Figure 01: Location map.

At the quarries the barrier thickness is about 10 m, but the upper barrier facies (upper shoreface and beach) are missing. Probably the barrier was partially eroded by a fluvial system during low sea-level stand. Morphological evidences of fluvial erosion over the Pleistocene barrier are conspicuous at Paraná and Santa Catarina coastal plains (Angulo & Suguio 1994, Angulo & Souza, 2004).

The main identified facies in Pleistocene barrier were sand with swaley cross stratification (Ssc), tabular cross stratification (Sp), trough cross stratification (St), sigmoidal cross stratification (Ssg), mud with linsen (Fl) and massive mud (Fm). Tubes, borrows, shell moulds, trunks and root fragments and vegetal debris were also identified in some facies (Figure 2).

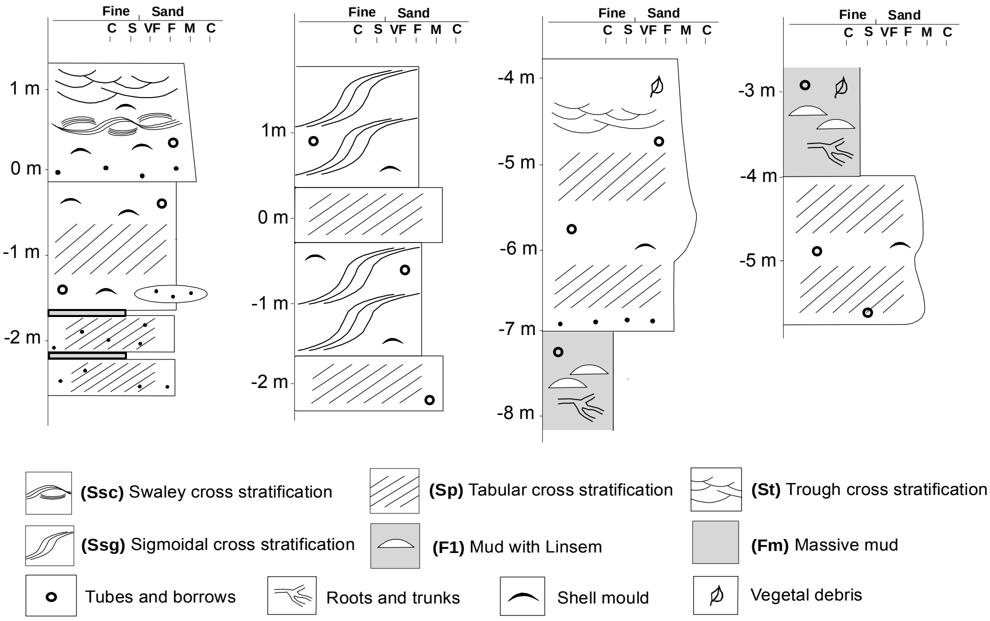

Figure 02: Main facies identified at the Paranaguá Pleistocene barrier.

The Ssc facies is composed by fine to coarse sand, poorly selected with subrounded grains. Shell moulds and symmetrical ripples were also identified. Sp and SSg facies are composed by fine to medium sand with very fine to medium pebbles and mud drapes. St facies is composed by fine to medium sand with small shell moulds. Preferential paleocurrent directions measured on the large cross stratification sets are to NW. Below sandy facies barrier there are FI and Fm facies, highly bioturbated with transported trunks and root fragments and other vegetal debris.

A ^{14}C datation performed on a wood sample resulted in 41,200 + 3,400/-2,350 years B.P. This age is close to the ^{14}C range. Similar ages obtained from Pleistocene barriers samples at different Brazilian coast sectors were attributed to contamination (Martin *et al*. 1988b; Angulo 2002; Souza 2005). $^{234}U/^{238}U$ datation performed on corals below a correlate Pleistocene barrier showed around 120,000 years B.P. (Matin *et al.* 1988b). Therefore the Paranaguá barrier could be attributed to the 5e stages.

The facies association and paleocurrent directions suggest that the barrier, at the studied sector, develops as a spit that grows northwestward over an estuarine inlet.

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MODERN AND ANCIENT EROSION INDICATORS ON A HIGH-ENERGY COAST: CAMBORIÚ PENINSULA AND NAVEGANTES PLAIN, SC, BRAZIL

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The evolution of dynamic sandy shorelines is often punctuated by episodes of erosion and retreat, however documenting the lasting legacy of such events in sand-dominated coastal sequences presents a challenging task. The moderate-relief coast of Camboriú Peninsula (CP; Ilhota to Laranjeiras) and the adjacent Navegantes coastal plain in northern Santa Catarina state, Brazil, exhibit a variety of geomorphic and sedimentological features which were used to assess the impact of high-energy events. The 0.5-2.0-km-long, headland-segmented, coarse-grained, reflective beaches of CP contrast with a 10-km-long, fine-grained, dissipative beach of the Navegantes plain. Morphological indicators of erosion include steep dune and berm scarps, as well as small washout channels produced by rainfall-induced runoff. These features are often modified by subsequent deposition but can be identified by their diagnostic reflection geometries and variable-angle truncation in ground-penetrating radar (GPR) images. Comparison of surficial and subsurface erosional

features is used to extend the existing record of severe storms, such as the 2004 Santa Catarina cyclone, into geologic past.

Complementing morphological indicators of erosion are lithological anomalies associated with late-stage storm lag formation. In addition to using accessory minerals for provenance of coastal sands, heavy-mineral concentrations (HMCs) are often observed on beaches following high-energy conditions. HMCs are easily identifiable in sediment cores and produce strong reflections on GPR profiles; e.g., a buried beach scarp imaged at Estaleiro Beach (CP) coincides with a magnetite-enriched horizon. At Navegantes, the magnetic susceptibility measurements of vibracore subsamples allow quantitative assessment of heavy mineral abundance, with susceptibility affected primarily by magnetite. Volume susceptibility values (dimensionless units, $x10^{-5}$ SI) range from 1600 to 3200 for the 10-30-cm-thick HMCs, in contrast to 4-15 for background quartzose sands. This study demonstrates the potential of using multiple geoindicators for reconstructing erosion history along sandy coasts.

VARIABILITY OF STRANDPLAIN DEVELOPMENT IN SANTA CATARINA, BRAZIL

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The central Santa Catarina coast of Brazil has a relatively narrow discontinuous coastal plain that is bordered by Archaean to Proterozoic-aged crystalline rocks. Exposed granitic plutons form numerous low relief headlands that dominate this section of coast. The irregular coastline has been largely smoothed due to the deposition of extensive strandplains (2-8 km wide) with sediment derived from small rivers and the continental shelf. Forcing the coastal progradation was the mid-Holocene (5-6 ka BP) sea-level fall of 2 to 4 m. Rivers can be directly linked to the construction of some strandplains, such as Tijucas (Tijucas River) and Navegantes Plains (Itajai River), but other strandplains, including those comprising much of the exposed coast along the Ilha de Santa Catarina can only be attributed to shelf sand deposits. Preliminary work on the strandplain coast, including limited surveying, coring, and geophysical studies, has shown that the plains have low gradients and are composed of dune/beach ridges and chenier systems. Ground-penetrating radar

(GPR) transects reveal that the plains have evolved through shoreface and foreshore accretion producing low-angle, ubiquitous seaward dipping clinoforms.

Data collected from Navegantes, Tijucas, and Pinheira strandplains indicate that considerable variability exists in the sedimentology, stratigraphy, and facies architecture among these plains, resulting from differences in wave exposure, the origin, volume and composition of the sediment supply, and antecedent topography of the coastal basin. The Tijucas Plain contains extensive mud deposits in the form of cheniers, overbank deposits, mud tidal flats, whereas mud is much less abundant on Navegantes and Pinheira Plains and primarily forms a surface cover (< 1.2 m thick) between some of the ridges. GPR records reveal that all plains exhibit truncated reflectors suggesting that erosional events have contributed to the morphology of the ridges and have influenced sedimentation patterns and the resulting stratification. The angle of the clinoforms varies among plains and appears to be related to grain size and wave energy. The greater apparent dip of the Pinheira versus Navegantes Plains may be due to the more protected nature and lower wave environment of the Pinheira Plain as compared to the exposed Navegantes Plain.

Location	**Grain size of ridges**	**Apparent dip angle of ridge reflectors**	**Slope of modern shoreface**
Navegantes Plain	Fine to medium fine sand	1.5 - 2.5°	2.5 - 3.5°
Tijucas Plain	Medium to coarse sand	9.0 -10.0°	5 - 6°
Pinheira Plain	Fine sand	4.0 - 5.0°	3 - 4°

The Navegantes Plain formed north of the Itajai River and extends 2 to 8 km inland. The plain is composed of fine-grained sediment and is directly exposed to open-ocean waves, excepting the northernmost region that is protected by a large bedrock promontory. The plain exhibits mostly monotonous, shallow seaward-dipping strata representing shoreface accretion. Except for regions within 0.5 km of the coast, well-developed dunes are absent. Sandy ridges are occasionally interrupted by muddy swales, 10 to 30 m in width. The landward portion of these ridges is composed of shallow, landward dipping strata that grade seaward into flat-lying then seaward dipping layers. The seaward dipping layers that comprise most of the plain are occasionally truncated by more steeply dipping surfaces seen in GPR records as sharp reflectors formed due the concentration of heavy minerals during storms.

Preliminary results of radiocarbon dating of basal wetland organics suggest coastal progradation on the order of 1 m/year during the past 1,300 – 1,500 years.

The Tijucas Plain extends 5 km inland abutting a laterally discontinuous 4-m high sand ridge that is initially interpreted as the Stage 5e Pleistocene shoreline. Seaward of this feature the Holocene highstand ridge is recognized by landward dipping strata overlying mud, which are interpreted to represent overwash deposition building into lagoon during the transgressive phase of landward barrier migration. In GPR section the landward dipping reflectors are truncated by steep seaward-dipping beds that extend uninterruptedly for about 700 m. Further seaward, mud deposition gradually becomes an important component of the plain in the form of chenier development. In this section of the plain individual ridges are composed of shallow landward-dipping layers along the backside of the ridge that transitions to a mound like composite of strata in a seaward direction. These units are often truncated by steep seaward-dipping prograding clinoforms. In some locations of the plain a second set of seaward-dipping reflectors is seen in the deeper portion of GPR profiles. This unit is separated from the overlying unit by semi-continuous, flat-lying reflectors. The deep set of seaward-dipping reflectors may represent deeper-water filling of the basin, or they maybe associated with shoreface progradation during the regression that followed the Pleistocene 5e highstand. The overall thickness of the sand lithosome appears to thin seaward and maybe related to decreasing accommodation space.

The 4-km wide Pinheira Plain is a tight semicircular strandplain sequence that has developed in the partial shadow of Ilha de Santa Catarina and in the protection of fronting islands. A small stream discharges sediment northwest of the plain, but the arcuate formation and orientation of the ridges appear to be a product of refracted ocean waves and not riverine processes. Pinheira ridges are closely spaced and monotonous in their progradational style as seen in vertical aerial photographs and shore-normal GPR transects. Ridge crests are 1 to 2 m in height excepting a discontinuous dune ridge in the rear of the plain that is 3 to 4 m in elevation. Individual ridges are separated from each other by shallow swales containing mud deposits less than a meter in thickness. Individual ridges are composed of three units: 1) bottom unit is the most uniform and consists of shallow seaward dipping layers that become nearly horizontal with depth; 2) middle unit that exhibits highly variable strata including shallow to steeply seaward dipping layers, shallow landward dipping layers, and relatively thin steeply landward dipping beds (thickness < 0.5 m). The presence of ridges and runnels on the modern beach suggests that landward migrating bars formed the landward dipping bed; 3). The uppermost unit consists of beach and incipient dune facies that contain a variety of bed orientations. The overall geometry of the upper two units is mushroom-shaped in cross-section with a preponderance of seaward-dipping strata.

Initial chronology of the plains indicates that GPR reflectors represent annual-scale shore accretion. Thus, these progradational sequences contain a comprehensive sedimentological record of event markers and clues to the timing and magnitude of climatic changes. Truncations within the reflectors are evidence of major erosional events, whereas uniform prograding clinoforms represent periods of tranquility and climatic stability. Future detailed geophysical and sedimentological studies and results from ongoing radiocarbon dating will help unravel the history of these plains.

A 20TH CENTURY SOUTHERN HEMISPHERE SEA-LEVEL ACCELERATION RECORDED IN A NEW ZEALAND SALT MARSH

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Long observational records of sea-level change are rare, especially in the southern hemisphere. The Permanent Service for Mean Sea Level lists only 18 southern hemisphere tide-gauge records that have at least 35 years of data for the period 1950-2000 and only 8 with at least 60 years of data for the period 1900-2000. The latter include: Buenos Aires and Quequen in Argentina; Fremantle, Sydney and Newcastle in Australia; and Dunedin, Lyttelton and Auckland in New Zealand. Of these, the records of Buenos Aires and Dunedin are known to be affected by river runoff and wharf subsidence, respectively (Douglas, 2001; Hannah, 2004), leaving only six long tide-gauge records that can be used in global analyses of sea-level accelerations in response to climate change (cf. Church and White, 2006). The starting dates for these six records are 1918 (Quequen), 1897 (Fremantle), 1886 (Sydney), 1926 (Newcastle), 1924 (Lyttelton) and 1904 (Auckland), highlighting the fact that tide-gauge records in the southern hemisphere are of little use when comparing 19th and 20th century rates of sea-level rise.

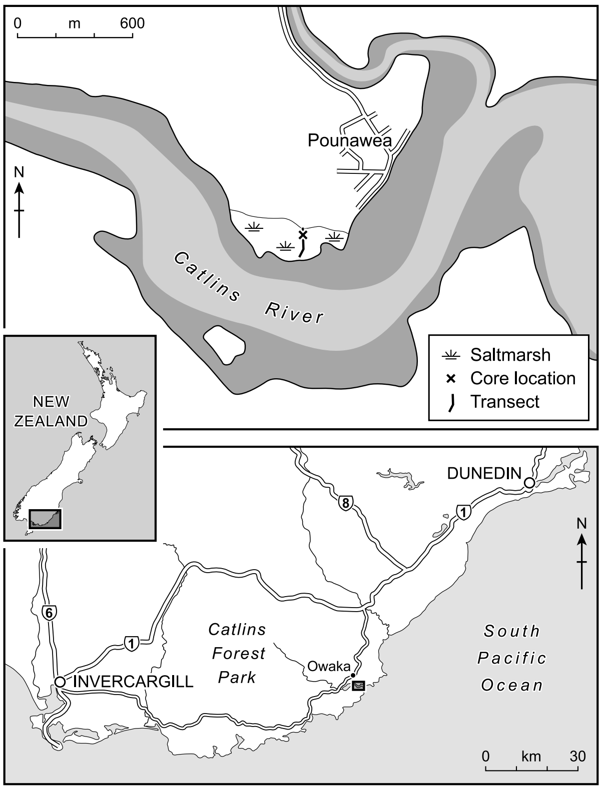

Figure 1: Location map

Figure 2: Fieldwork in Pounawea salt marsh. The position of the marsh in the Catlins River estuary is indicated by the arrow (view is towards the west).

Data archaeology has recently uncovered a record from Tasmania which includes important observations made by amateur scientists in 1841-1842 (Pugh et al. 2002, Hunter et al. 2003). Although these types of records contain gaps, they provide important information on 19th century sea-level positions and it is hoped that similar records will be uncovered in the future. However, at present the only feasible way of reconstructing sea-level changes at high resolution from before the tide-gauge era is through the use of proxy studies.

Recent investigations in the North Atlantic (Donnelly et al. 2003, Gehrels et al. 2005, Gehrels et al. in press) have shown that proxy records from salt marshes can serve as valuable ‘substitutes’ along coastlines where tide-gauge records are not available. They have two important advantages over tide-gauge records: 1) they filter out much of the interannual variability; and 2) they can be extended back in time to cover pre-industrial times. In this paper we report on a salt-marsh proxy sea-level record obtained from Pounawea, situated along a tectonically stable portion of the Catlins coast in southeastern New Zealand. This is the first southern hemisphere proxy sea-level record that allows a direct comparison between the rate of 20th century sea-level rise and rates of sea-level change during the preceding centuries.

In order to reconstruct sea-level changes at Pounawea salt marsh we first documented the stratigraphy of the marsh in 11 short cores along a cross-marsh transect. We also investigated the vertical distributions of live and dead foraminiferal abundances based on 31 surface samples and determined that dead foraminiferal abundances can be used as a proxy for sea level to within ±5 cm or better (Southall et al. 2006). In an undisturbed part of the marsh we collected a representative 0.5 m core and analysed the fossil foraminifera to reconstruct the changes in elevation of the marsh relative to tide levels. We dated the sequence using AMS^{14}C and ^{210}Pb. In addition we used a number of stratigraphic markers which, when linked with historical documentation, provided useful ages for key horizons in the core. These markers (pollen, Pb concentrations, ^{206}Pb/^{207}Pb ratios, charcoal and ^{137}Cs) produced indirect historical ages for the invasion of European plant species (~1880, Wilson 1993), onset of industrialisation (~1880), the ‘Big [forest] Fire’ (1935, Wilson 1993), the establishment of pine plantations (1950s) and the peak of nuclear bomb testing (1964). At 0.38 m core depth we obtained three AMS^{14}C ages on a small plant fragment of 410±40 BP, 420±40 BP and 410±40 BP (Beta 206520, 206521 and 206522). The averaged age of 413±23 BP or AD 1435-1499 (95% relative probability at 2 sigma) provides the only constraint on the chronology before 1880.

Relative sea-level changes at Pounawea can be reconstructed from the accumulation history of the marsh by taking account of the elevation at which the sediments were originally deposited (the 'indicative meaning') as inferred from the foraminiferal analyses. The reconstruction shows a slow sea-level rise of 0.2±0.3 mm/yr between AD 1450 and 1900. The reconstructed rate during the 20th century is markedly faster and is estimated at 3.1±0.1 mm/yr, in reasonable agreement with the rate of 2.5±0.3 mm/yr measured by the Lyttelton tide gauge between 1925 and 2000.

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DÉTERMINATION DU COEFFICIENT DE FROTTEMENT DU FOND POUR L'ACTION COMBINÉE DE LA HOULE ET DU COURANT D'ÉCOULEMENT

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Les vagues de vent générées sur la surface libre des courants dans les cours d'eau (fleuves, grands canaux, etc.), les retenues et en zone côtière, sont susceptibles de donner naissance à des vitesses de fond comparables à celles des courants de décharge. A cet effet, il est indispensable de prendre en considération, dans le calcul des érosions générales et locales, l'influence simultanée de la houle et des courants d'écoulement sur le mouvement des sédiments.

La contrainte de cisaillement au fond, proportionnelle au coefficient de frottement au fond, est le principal paramètre de détermination de la dynamique des sédiments. Donc la détermination du coefficient de frottement au fond dans les conditions de l'action combinée de la houle et des courants représente un intérêt scientifique et pratique certain.

Nous avons examiné les différentes méthodes existantes de détermination du coefficient de frottement au fond dans les conditions de l'action combinée houle-courant. Un algorithme propre de calcul du coefficient de frottement au fond et d'autres paramètres cinématiques, pour l'action combinée houle-courant, a été proposé. Une vérification expérimentale de la méthode de calcul proposée a été effectuée. La possibilité de son application pour la détermination du début d'entraînement des sédiments a été mise en évidence.

Mots-clés : action combinée houle-courant, coefficient de frottement au fond, contrainte de cisaillement au fond, érosion, dynamique des sédiments, courant favorable.

THE DEVELOPMENT OF THE MESOPOTAMIAN MARSHES: A PRODUCT OF THE PROGRADATION OF THE KARUN-MEGA FAN UNDER DECELERATING SEA-LEVEL RISE

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The lower Khuzestan plain is a major sedimentary basin, located directly to the west of the Shatt-El Arab estuary along the Iraq-Iran border. It forms the south-eastern extension of the Lower Mesopotamian plain. The inland area of the Lower Khuzestan plain is dominated by sediment input of the rivers Karun, Karkheh and Jarrahi. Research on the fluvial systems in the Shatt-el Arab region has primarily focussed on the Holocene evolution of the 'twin rivers' Tigris and Euphates. However, the third tributary of the Shatt-el Arab, the Karun river, has also played a major role in the sedimentary evolution of the lower Mesopotamian plain and has triggered the development of the famous 'Mesopotamian marshes'.

In this study, the Holocene sedimentary sequence of the Lower Khuzestan plain has been investigated through lithological facies and palaeoecological analyses (foraminifera and diatoms) in hand-operated gouge cores and shallow outcrops supported by radiocarbon dates. Results show that the early Holocene transgression rapidly occupied the shelf and invaded the ancestral valley of the Shatt el-Arab and Tigris. This resulted in the development of extended tidal flats. Deceleration of sea-level rise after approximately 5500 cal yrs BP, together with more arid conditions, allowed aggradation of extensive coastal sabkhas while the position of the coastline remained relatively stable. Continued deceleration of sea-level rise initiated progradation of the coastline from ca. 2500 cal yrs BP onwards. This process was driven by the development of a Karun megafan.

This paper will focus on the reconstruction of the late Holocene evolution of the area directly to the east of the Hawr-al Hawiza marshes in the northern part of the Lower Khuzestan plain. The Hawr-al Hawiza marshes form the easternmost part of the 'Mesopotamian marshes'. The sedimentary sequence in the northern part of the plain consists of a brown compact clay, overlain by a 1 to 2 m thick bluish to greenish blue mud, characterized towards the top by the presence of mollusc shells (*Corbicula sp., Melanoids sp. and Melanopsis sp.*) and thin layers of black peaty mud or organic gyttja. These organic-rich horizons are younger than 1240 cal yrs BP. Microfaunal remains of foraminifera and diatoms are common in the bluish mud deposits. Foraminifera are restricted to two assemblages: (1) an *Ammonia beccarii* assemblage, reflecting marine-brackish very shallow marine conditions and (2) an allochthonous Tertiary *Heterohelix navarroensis* assemblage, reflecting the input of fluvial sediments from the hinterland. The diatom assemblage represents a typical estuarine environment. High counts of fresh-brackish taxa attest to shallow, low energy intertidal conditions. Towards the top of the bluish mud, the organic horizons are characterized by the presence of more freshwater taxa. The upper part of the sedimentary sequence consists of a 4 to 5 m thick packet of brown silty clay, interpreted as a deposit of the river Karkheh.

It is suggested that the northern part of the plain was a shallow water nearshore, brackish to freshwater marsh environment, which became infilled by sediments of the river Karkheh from ca. 1240 cal yrs BP onwards. We suggest that the development of this restricted environment and its infill by the Karkheh were triggered by the nodal-avulsion controlled development of the Karun mega fan in the central and southern part of the plain.

The progradational development of the Karun mega fan, in conjunction with the Wadi Batin fan (Pleistocene) in Iraq, restricted the initial width of the tidal embayment until it finally became dammed near the city of Khorramshar, located along the present-day Shatt-el Arab. This narrowing and subsequent damming impeded the drainage and therefore caused the upstream development of extensive brackish-freshwater marshes, i.e. the Mesopotamian marshes (Hawr-al Hammar and Hawr-al Hawiza marshes). The infill of the eastern extension of the Hawr-al Hawiza marshes was dominated by the changing position of the Karkheh river system. The first avulsion of the Karkheh is closely related to the last avulsion of the Karun at ca. 1240-1000 cal yrs BP. The last avulsion of the river Karkheh is the result of human intervention, and caused the final infill of the northern part of the brackish-freshwater marshes around AD 1825.

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POST-GLACIAL COASTAL MARGIN PRODUCTIVITY AND THE EMERGENCE OF CIVILIZATIONS

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Initial phases of early civilizations coincided with enriched, coastal margin resources following sea-level stabilization in the middle Holocene. For 100kyr modern humans were nomadic hunter-gatherers, the only evidence of settled life being the emergence of small Neolithic settlements during the early Holocene (~13-7kyr BP). Complex social organizations (CSOs), the precursor of civilization, emerged suddenly ~6kyr ago , coinciding with significant changes in the global environment and climate. A century of controversy surrounds factors that might have enabled local CSO development. Recent evidence from several regions suggests that ranked societies first occurred near coastal margin environments, but there is little understanding of this process on a global scale. Here we show that the stabilization of sea level and the resultant order of magnitude increase in productivity of coastal margin ecosystems (CMEs) provides an explanation not only of the timing and location of emerging civilizations, but also their nature. The increased availability of high quality nutrition was a pre-requisite for development of urban lifestyles and the temporal pattern and magnitude of this increase determined the type of social structure that evolved to manage these new resources.

DREDGING INFLUENCE ON COASTAL DYNAMICS AT PARANAGUÁ ESTUARINE COMPLEX MOUTH – BRAZIL

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The littoral of Paraná State is characterized by short oceanic extension and large well developed estuaries. The Guaratuba bay, located at south portion of the shoreline has short superficial extension, with fishing and recreational activities. It presents only one mouth, with sandy shoals deposited as an ebb tidal delta. The Paranaguá estuarine complex (PEC), located on central-north portion of the littoral, has two main axis called Laranjeiras bay (north-south axis), used likewise Guaratuba bay, and Paranaguá bay (east-west axis), where port activities are developed. This estuarine complex presents two mouths with ebb tidal deltas developed (on the near continental shelf) (< 20 m depth; Figure 1). These ebb tidal deltas are composed by many shallow areas (< 6 m depth) called Galheta shoal (margin SW and NE) on the south mouth, and Sueste, das Palmas e do Superagüi shoals, on the north mouth. At the external portion of the PEC are observed others shoals associated to mouth dynamics called Saco do Limoeiro and Saco do Tambarutaca. These features vary in bathymetry and area in short periods causing changes in the adjacent coastal area. The south mouth of PEC has been dredged since 1972, when the navigable channel to Paranaguá port was opened (Galheta channel). This operation modifies the local coastal dynamic, obstructing the natural bypassing of sediments from south to north portion of the coast. Thus, a sediment trap was created by the navigable channel. The combination of these factors may drives intense changes observed at Pontal do Sul coastal village, Ilha do Mel and north mouth coast line. Although this coastal changes may be caused by natural dynamics, and the damage at the shoreline affects these fragile ecosystems and urban areas. These problems demands substantial economic resources to fix it up.

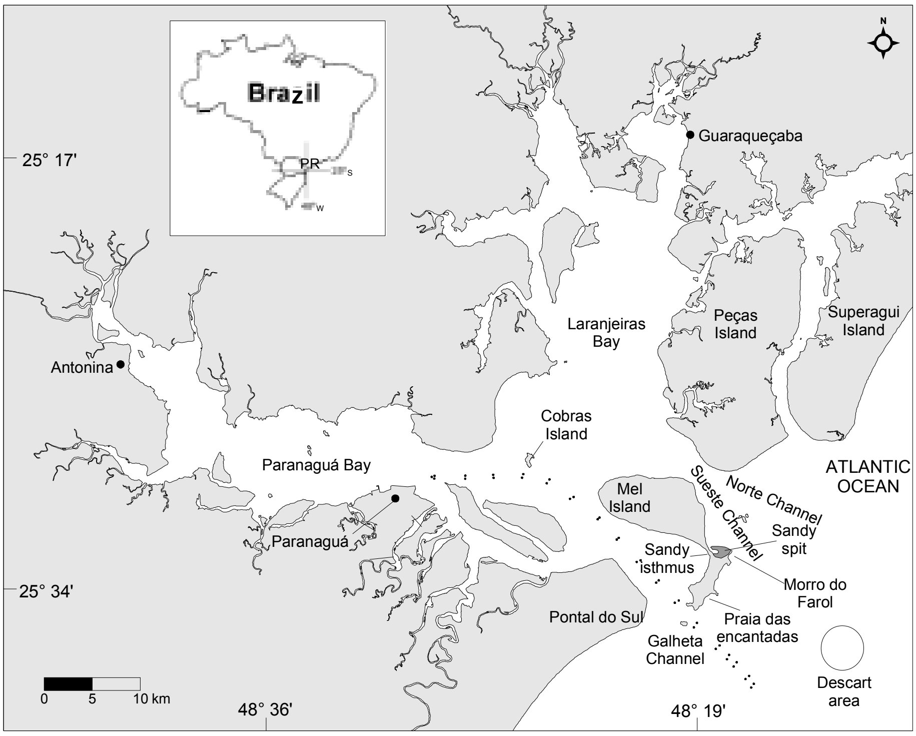

Figure 1: Localization map of main features at Paranaguá estuarine complex mouth.

Many changes on shoreline configuration of PEC mouth were observed. As an example there is the partial rupture of Ilha do Mel sandy isthmus in 2001, which was latterly naturally reconstructed. Associated to this event, a sandy spit was formed near Morro do Farol, at the same island. The sandy spit seems to protect the sandy isthmus of the coastal dynamics. Significant changes on the configuration of the ebb tidal deltas sandy shoals localized at the north mouth of PEC and the deposition of sediments on the Praia das Encantadas were observed, where there were rocks outcrops and nowadays there is a large sandy beach.

The deposition areas of dredging material are located on the NE portion of south mouth, near Galheta channel. This place is localized in front of Praia das Encantadas, and very close of Morro do Farol and the sandy isthmus of Ilha do Mel. This human induced bypassing may be connected with the PEC mouth shoreline changes. The dredging material transported by waves can nourish the Praia das Encantadas and the sandy spit near Morro do Farol, acting as an artificial source of sediments to north localities.

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A MILLENNIAL-SCALE RECORD OF INTENSE NEW ENGLAND HURRICANES PRESERVED IN KETTLE POND SEDIMENTS

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During the last few years, the number of intense hurricanes in the Atlantic has increased compared to recent decades and the human and economic impact of tropical cyclones on the United States has been substantial. This recent increase in tropical cyclone activity has inspired both concern and controversy. The concern is that human-induced global warming may be fueling high-powered hurricane seasons. The controversy is over how or even if this link can be conclusively made with the data that are available.

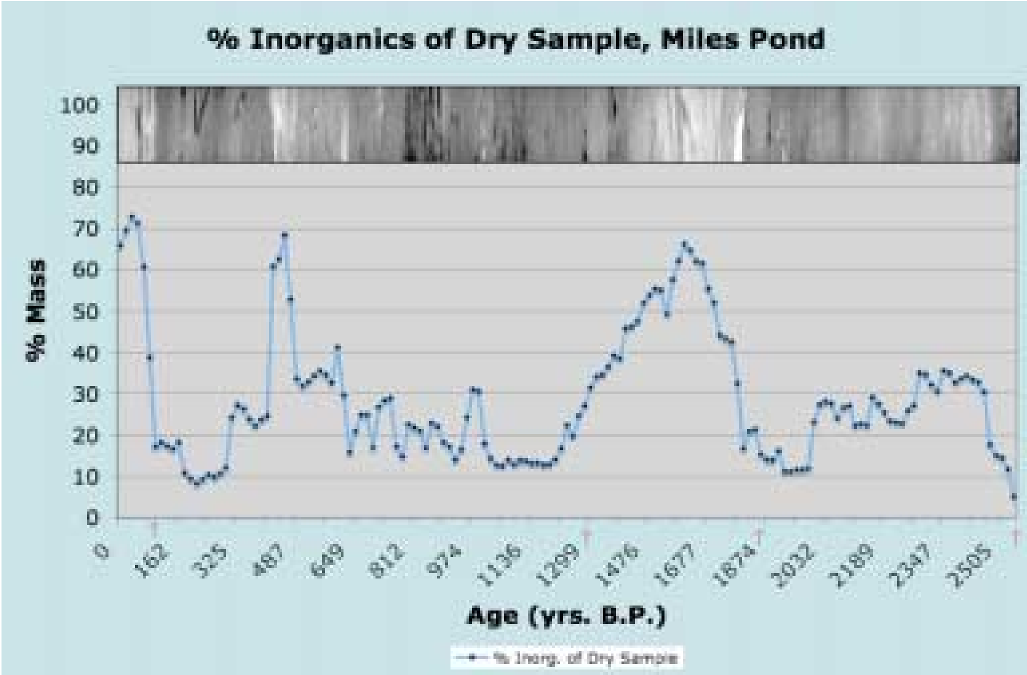
Both theory and observation reveal that the maximum potential intensity (MPI) a storm can achieve increases with the temperature gradient between the sea-surface and the lower stratosphere (Emanuel 1987). In this way, warming of ocean temperatures could lead to more intense storms by raising their MPI. Using available hurricane datasets, some investigators have detected an increase in the number of intense storms (Webster, et. al. 2005) and in the power dissipated by hurricanes (Emanuel 2005) over the last few decades. It has been argued that these changes are linked to a rise in sea-surface temperature in the tropics. Such findings have been disputed by other investigators who claim that these conclusions cannot be supported by historical datasets that are not of great enough quality for a long enough period of time to detect secular trends (Landsea and Pielke 2005).

Conclusively defining the connection between tropical cyclone activity and climate may require longer records than observational datasets can provide. During the past few years, a great deal of progress has been made in identifying proxies of hurricane activity. Thus far, the records reaching farthest back in time have come from overwash deposits in backbarrier marshes, lagoons and ponds (Donnelly et. al. 2001; Liu and Fearn 2000). Sediment cores from these environments contain layers of sand and other marine materials that are introduced during hurricane storm surges. These layers can be dated to provide a chronology of hurricane landfalls at a site.

Comparing the distribution of paleohurricane events in both space and time with proxies of other climate variables (such as sea-surface temperature) could help clarify the interaction between hurricanes and climate. Also, such records provide a more wide-angled view of coastal risk by enabling millennial-scale estimations for the frequency of extreme storm surge events at different locations along the coast. This information is particularly valuable for estimating risk in locations where intense hurricanes occur but are rare in the historic record.

New England is susceptible to occasional impacts by destructive tropical cyclones. However, only a few of these events have occurred in the region since European settlement. Though hurricanes here are rare relative to other parts of the US East Coast, they can produce extensive destruction when they move rapidly out of the lower latitudes and strike the densely populated New England coast. Buzzards Bay in southeastern Massachusetts is particularly vulnerable to coastal flooding with its south-north orientation and geometry that can magnify storm surges when hurricanes make landfall to the west of Cape Cod. Kettle ponds around the bay preserve these enhanced surge events as detectible sedimentary layers. Sand and marine materials are transported to and deposited in these ponds creating records of intense surge events that extend back at least 2500 years.

Existing work on paleohurricanes has focused on sites that are separated from the ocean by a dynamic barrier such as a sand dune. Changes in the height of a sand barrier through time can confound changes in the frequency of tropical cyclone activity. The advantage of kettle ponds is that they are typically situated further upland behind a stable barrier of glacial till. Thus, barrier dynamics are less important in the interpretation of the sedimentary record retrieved from kettle ponds. Furthermore, clusters of kettle ponds with differing flooding thresholds could be used to constrain the magnitudes of paleo storm surge events.



Above, a radiograph shows dense (white) layers in a sediment core from a kettle pond in Falmouth, Massachusetts. These dense layers correspond with increases in the inorganic fraction of the sediment (LOI data shown). These dense layers of inorganic material that punctuate the pond's mostly organic sediments are interpreted as hurricane event deposits. Red arrows indicate radiocarbon dates.

Sediment cores from several kettle ponds along the shores of Buzzards Bay reveal a record of historical and pre-colonial paleohurricanes affecting the area. We used loss on ignition, sediment density (from radiographs), x-ray fluorescence geochemical data, and radiocarbon dates to detect and date hurricane surge layers within the cores (see above figure). High-resolution x-ray fluorescence analyses of the cores yielded geochemical signatures that may be related to regional climate shifts and/or periods of varying hurricane activity. These results provide a new record of past hurricane activity in New England and represent the first use of kettle pond sediments for this purpose. We demonstrate the usefulness of these sedimentary basins in reconstructing hurricane history for the purposes of quantifying long-term risk and understanding tropical cyclone climate.

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THE FIRST HOLOCENE RELATIVE SEA-LEVEL CURVE FROM THE SOUTHEAST SECTOR OF THE GREENLAND ICE SHEET

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It is remarkable that despite the importance of the Greenland Ice Sheet (GIS) to our understanding Late Devensian and Holocene sea-level changes no sea-level data exist for the entire southeast sector of the ice sheet between Scoresby Sund and Nanortalik. In this paper we present the results of a programme of research designed to address this data deficiency by constructing the first Holocene relative sea-level (RSL) curve from the region. Our work is based on an analysis of four raised “isolation basins”, as well as two lakes that developed above the local marine limit and provide limiting ages on the timing of deglaciation. The field area is located close to Angamassaliq. Our findings define a rapid fall in RSL from at least 70 m a.s.l at c. 11 ka cal. yrs BP to close to present by c. 6.7 ka cal. yrs BP. We find no evidence that RSL was higher than present for the last 6ka cal. yrs BP. These new data plot altitudinally below data from the Scoresby Sund area in central east Greenland, and above existing RSL data from the Nanortaliq area located close to the southern tip of Greenland. We identify significant differences between the data we present and the predictions of current geophysical models, in terms of the timing and the amplitude of RSL change. We argue that there is a reasonable probability that widespread evidence for late Holocene crustal subsidence and RSL rise, already well-established along the western sector of the ice sheet, also occurred along the east coast of the GIS.

LATE HOLOCENE SEA LEVEL CHANGES ALONG THE SW COAST OF FINLAND – EVIDENCE OF ANOMALIES IN THE GLACIO-ISOSTATIC LAND UPLIFT?

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The Late Holocene relative sea level changes were investigated along the south-western coast of Finland, Gulf of Finland, Baltic Sea, by studying a total of 13 isolation basins located on five areas (Kirkkonummi, Orslandet, Tenhola, Älgö and Prästkulla), which cover of 120 km of Finnish coastline with a narrow archipelago. Also results from three previously studied isolation basins were used in this study. The methods employed were lithostratigraphic interpretation, diatoms and ^{14}C analyses.

The sea level history varies on study areas. The 3000 years old Baltic Sea shoreline is located about 11 m above present sea level in Prästkulla, and about 8 m a.s.l. in Kirkkonummi. These differences are due to the different land uplift rate, which continues to slow down when moving eastwards from Prästkulla towards Kirkkonummi. The lowering main trend in relative sea level has been prevailed along the south-western coast of Finland during the late Holocene. Results suggest land uplift anomalies on two areas (Tenhola and Orslandet) in where the data shows deep bends in the relative sea level lowering. They are the first verified late Holocene land uplift anomalies detected in Finnish sea level data.

USING DIATOM-BASED TRANSFER FUNCTIONS TO RECONSTRUCT HOLOCENE SEA-LEVEL CHANGES: HIGHLIGHTING THE NEED FOR CAUTION IN MODEL SELECTION AND IN INTERPRETING PREDICTIONS

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Transfer functions have become a popular tool in studies which use microfossils to reconstruct former sea levels. The application of transfer functions is based on the uniformitarianism principle that the present-day altitudinal relationship of micro-organisms to sea level can be used to reconstruct the former sea level from the microfossils preserved in coastal sediments. However, this methodology is not flawless and this paper highlights some of the problems associated with the application of diatom-based transfer functions in a Holocene sea-level study in western Denmark.

Modern diatom assemblages and associated environmental variables (Salinity, pH, LOI, grain size) were collected from salt marshes in Ho Bugt, western Denmark (Figure 1). The relationship between diatom assemblages and associated environmental variables was explored using ordination techniques (DCCA, CCA), to determine the controlling influence on contemporary diatom distributions and to assess the potential use of diatoms as sea-level indicators. We developed weighted averaging (WA) and weighted-averaging partial least squares (WA-PLS) transfer functions based on 140 surface samples from six transect locations, spanning a range of salt-marsh environments within Ho Bugt. Although the WA-PLS transfer function performed best in terms of root mean squared error of prediction (RMSEP) and coefficient of determination (r^2), cross-validation of the modern training set established that the WA transfer function produced more 'realistic' estimates.

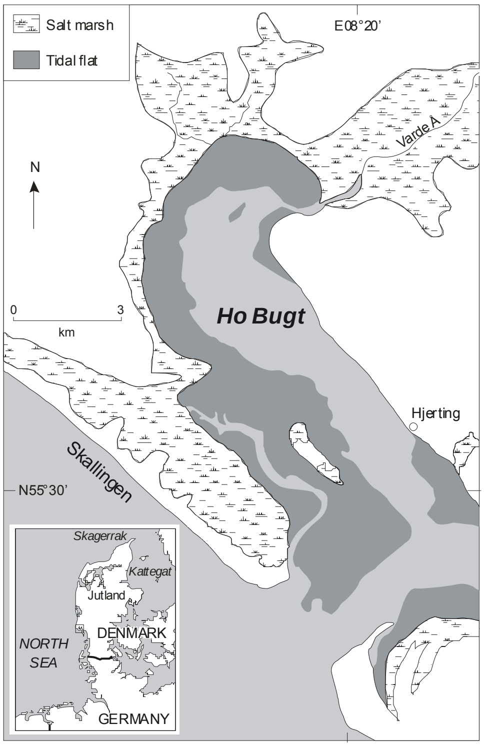

Figure 1: Location map.

The resulting WA transfer function was applied to reconstruct former salt-marsh surface elevations from core RØ1 collected from Røgel salt marsh, Ho Bugt. Application of the transfer function to this core has highlighted some of the major problems associated with the use of transfer functions in this type of study. In particular, the presence of 'no-analogue' species in the core can produce erroneous and unrealistic transfer function estimates and misleading relative sea-level predictions.

Positive spatial autocorrelation remains a major issue in the development of transfer functions and has, thus far, largely been ignored. The collection of samples from line transects, as is the case in this study and in most sea-level investigations, violates the assumptions of most statistical analyses (Legendre and Fortin, 1989; Telford and Birks, 2005). Recent studies have highlighted the likely over-optimistic estimates of RMSEP and r^2, and inappropriate model choice when spatial autocorrelation is present in the data set (Telford and Birks, 2005). This study is currently examining the possibility of accounting for or 'removing' this correlation within training sets, leading to more robust transfer-function predictions.

Figure 2: Fieldwork in Ho Bugt, western Denmark.

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LITTLE ICE AGE SAND INVASION OF THE HO BUGT SALT MARSHES DURING LOW RELATIVE SEA LEVEL

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Lithostratigrapical investigations of the salt marshes around Ho Bugt in the northernmost part of the Danish Wadden Sea reveal an extensive sand unit within the salt-marsh stratigraphy. This sand unit, found c.18 – 25 cms below the salt-marsh surface and up to 1 metre thick in places, extends across much of the western side of the embayment.

We use optically stimulated luminescence dating (OSL) to obtain ages for this sand unit. Two dates from the bottom of the sand unit at Røgel and Oksby Enge, 1464 A.D. ± 40 years and 1514 A.D. ± 30 years respectively, suggest that sand invasion began during the early part of the Little Ice Age. These dates are consistent with historical records which document the problems caused by drifting sands in western Denmark during the 15th and 16th centuries (Lamb, 1991). A third date, from the top of the sand unit at Røgel, returned a date of 1554 A.D. ± 30 years.

Cores and exposed cliff sections in salt marshes around Ho Bugt were subjected to litho- and biostratigraphical analyses to reconstruct palaeoenvironmental changes. Diatoms were sampled from the modern environment to establish their relationship with water levels. Using an improved version of an established diatom-based transfer function (Szkornik et al., 2006) alongside OSL, lead-210 (^{210}Pb) and radiocarbon (^{14}C) dates, we establish a new sea-level history for Ho Bugt. Our results suggest that during the main period of sand invasion, palaeo-marsh surface heights were above present and relative sea-level was lower. Several authors have hypothesised the links between sand movements and relative sea-level changes (e.g. Christiansen et al., 1990; Orford et al., 2000; Wilson et al., 2001) however, this study is the first to confirm such a link in the same stratigraphic section.

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SOUTHERN BRAZIL SUBMERGED BEACHROCKS: PRELIMINARY RESULTS.

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Beachrock formation in Brazil mostly occurs at northeast region (Figure 1). There is no data about actual beachrocks formations further Southern from the Bahia state since the water temperature is not favorable to carbonate precipitation at present (Bigarella 1975). However, after the occurrence of major storms on the Paraná State coast, it is common to find sandstones fragments (2 to 15 cm) at the beaches. Theses rocks have different stages of lithification and contain many shell fragments. The rocks surfaces are quite irregular suggesting differential weathering related to ocean water action.

With information provided by local fisherman and trawler boats logbooks, it was possible to locate at the inner continental shelf of the State of Paraná two sandstone sites approximately 15 km and 30 km distant from the present coast. Using scuba diving equipment, two discontinuous outcrop sites of sandstones were found. Although many incrustations on the rock surface by innumerous marine organisms, some samples were collected to perform laboratories analysis to determinate composition and genesis of these rocks. Thin sections were prepared for polarized microscope observation and two ^{14}C dating were also performed.

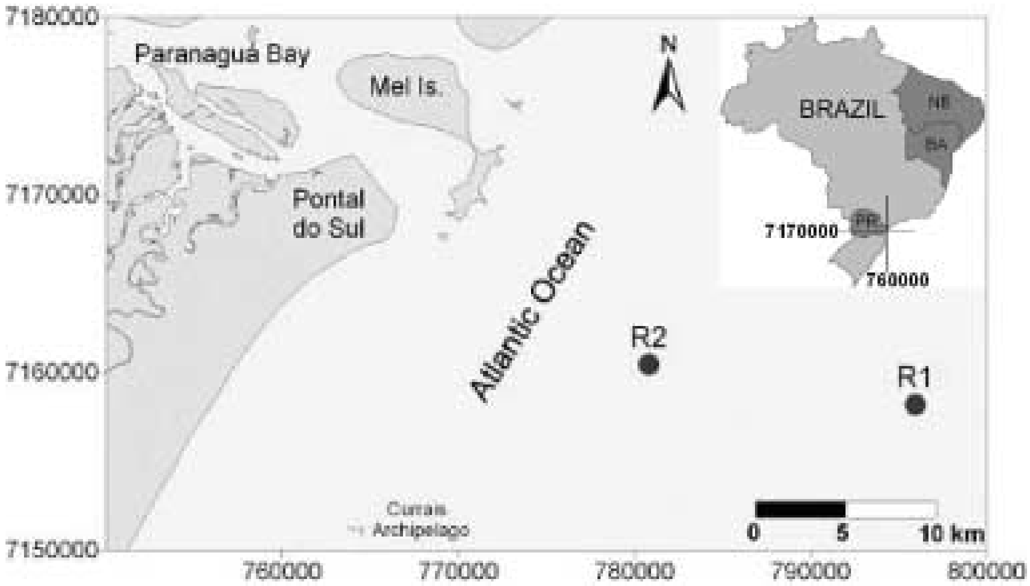

Figure 1: The study area with the sandstones sites indicated (R1 and R2). Northeastern Brazilian region (NE); Bahia State (BA); Paraná State (PR).

The sandstones are composed by quartz (70%) and feldspars grains. Olivine and biotite crystals occur as traces. Micritic textured carbonate crystals predominantly compose the cement (25% of the rock). Wood fragments and shell bioclasts are also present. In some parts of the thin section the carbonate crystals are well developed and can be identified, suggesting different stages of cement crystallization (figure 2).

The results of the X-Ray Difratometry analysis give quartz and aragonite as the major mineralogical components of the sample and, in lower rates, occurs calcite (probably rodocrosite). ^{14}C dating of the 18 meters (R2) water depth sample gives 8,500 years B.P. as the age of the rock formation and the 33 meters (R1) water depth sample gives ^{14}C age of 25,000 years B.P. Despite the material used to perform dating was from the rock cement, some reworked shells could influence carbon rates and the ages must be considered as maximum ages (ANGULO *et al*. 2002).

These rocks are very similar to the Holocene inorganic reefs described by BIGARELLA (1975) in the northeast of Brazil along the preset coast. They are composed by quartz grains involved by carbonate cement with abundant shell fragments and interpreted as beachrocks. The predominance of aragonite instead of calcite, suggests higher ocean water temperatures during rock formation that in present days on the south Brazilian coasts. Carbonate waters precipitates mostly aragonite when hot and calcite when cold. However, aragonite is present in many shells and can be mixed as a rock component to deceive the chemical results (DANA, 1959).

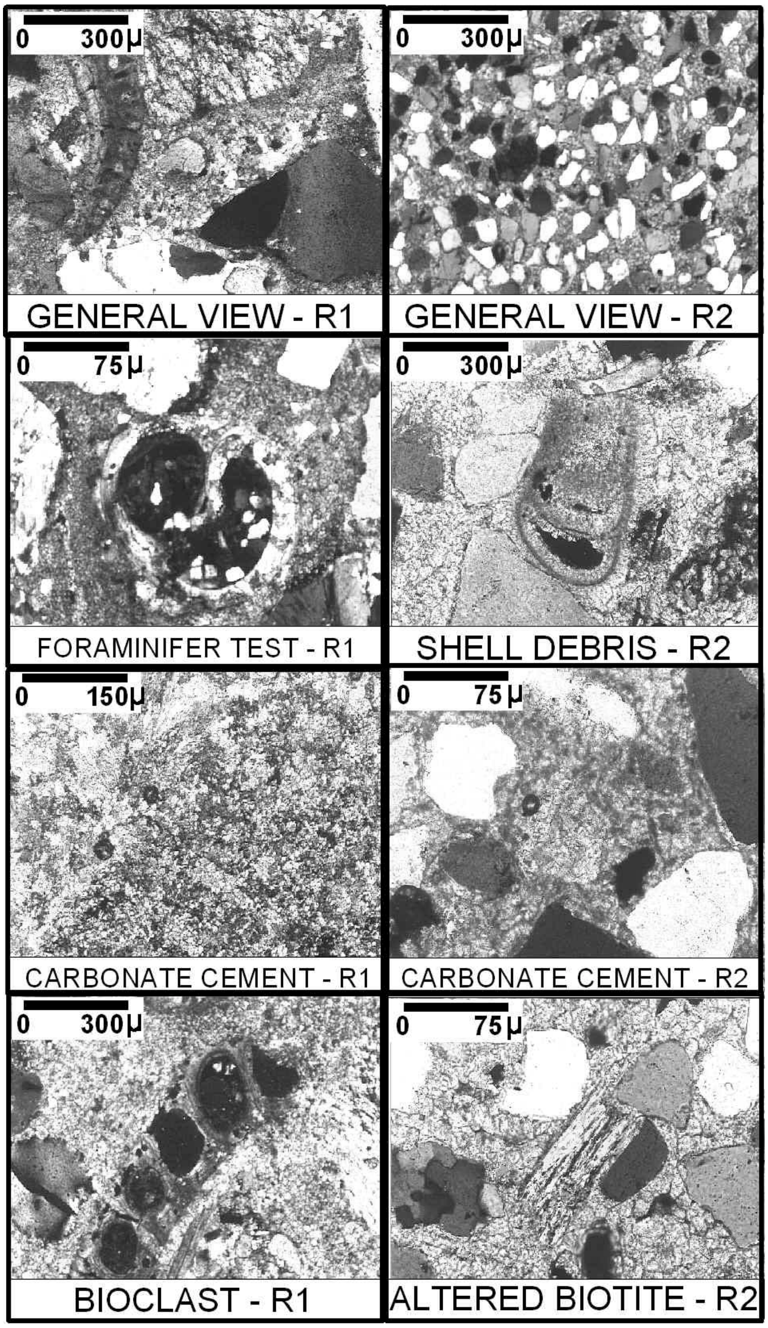

Figure 2: Thin section images of R1 e R2 sites.

Beachrocks could be formed 3 meters below surface so; 8,700 years B.P. mean sea level (MSL) could be 15 meters below present level. Considering that 5,100 years B.P. MSL was 3.5 meter above the present level according with local paleo-sea level curves (ANGULO *et al*., 2006), we have 18.5 meters of difference in 3,600 years. That results in 0.51cm.y^{-1} as sea level rise rate in Holocene. Likewise, if MSL was 100 meters below present 18,000 years B.P. and 30 meters below present 25,100 years B.P., there was 70 meters of difference in 7,100 years. That gives 0,99cm.y^{-1} as sea level fall rate before last glacial maximum. Poor values of $\delta^{13}C$ (-44 ‰) suggest methane influence in a lagunar or swampy environment for the R2 sample. Values of -1 ‰ of δ13C (R1) do not indicate this influence so the rock that outcrops at R1 site was probably formed in a beach environment. Further studies are needed to comprehend beachrock formation in different environments and contribute to the Holocene coastal evolutional models for this area.

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FORAMINIFERA-BASED RECONSTRUCTIONS OF MID-LATE HOLOCENE SEA-LEVEL CHANGE FROM NORTH QUEENSLAND, AUSTRALIA.

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Using foraminifera as sea-level indicators rests on the assumption that their distribution is related to sea level in a quantifiable manner and by establishing this vertical relationship with a specified tide level, former positions of relative sea-level may be determined. In temperate areas agglutinated upper intertidal foraminifera are well preserved in fossil sediments. Therefore relatively precise quantitative sea-level reconstructions are possible using modern training sets which cover short elevation gradients excluding calcareous assemblages from low intertidal and subtidal environments (e.g. Gehrels, 2000; Gehrels *et al.*, 2005; Horton and Edwards, 2005). However sediment cores taken from Cleveland Bay in north Queensland, Australia to quantitatively reconstruct mid/late Holocene sea-level changes contain calcareous foraminifera in minerogenic horizons but no foraminifera in organic horizons (Woodroffe *et al.*, 2005). The reason for this is unknown, but may to be due to a series of interrelated factors including burrowing by fiddler crabs and molluscs, increased air and water temperature, biological turnover and predation in tropical intertidal environments.

I collected modern foraminiferal samples and environmental information from equally spaced elevation intervals between Mean Tide Level (MTL) and 5.3 m below Lowest Astronomical Tide level (LAT) in Cleveland Bay, north Queensland, Australia to investigate the usefulness of calcareous assemblages from low intertidal/shallow subtidal environments as fossil sea-level indicators. A resultant transfer function has good predictive ability, with an r^2 of 0.96 and RMSEP of 0.43 m. The error term is large compared to studies using agglutinated foraminifera and a short environmental gradient (e.g. Gehrels *et al.*, 2005), but the error term compares favourably to the errors associated with other indicators such as coral, mangrove sediments and fossil oyster beds, also used as palaeo sea-level indicators along this coastline.

By creating new sea-level index points and re-calibrating existing ones from other indicators I infer the general form of the mid/late Holocene sea-level record in central North Queensland as sea level rising above its present value prior to 6700 cal years BP, with relatively stable sea level 1-2.3 m above present between 6700-5000 cal years BP, and between 1-2.8 m above present between 5000-3000 cal years BP. This is followed by sea-level fall to between 0.4-0.8 m above present until 1200 cal years BP and subsequent slow fall to present.

Sea-level data support the theory of a gradual end to global ice sheet melt, with melting ending after 5000 cal years BP. Geophysical models of mid/late Holocene sea-level change in North Queensland both underestimate and overestimate the volume of global ice melt during the mid/late Holocene. The height of the high stand is controlled primarily by earth model parameters, including lithospheric thickness, upper and lower mantle viscosity. Increasing knowledge about the change in eustatic signal during the Holocene improves understanding of driving mechanisms for the change, and aids understanding of how climate and sea level interacted during the mid Holocene when the rate of eustatic sea-level rise was similar to that being experienced today.

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NEW OVERWASH AND SEA-LEVEL RECONSTRUCTIONS FROM SAINT KITTS, WEST INDIES

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Tropical cyclones are among the most hazardous of natural disasters on earth, responsible for substantial losses in both human life and economic resources (Henderson-Sellers et al., 1998). Recent work suggests that human-induced global warming may result in an increase in the overall number of intensity tropical storms (≥category 3; sustained winds > 50 m/s) throughout the world (Emanuel, 2005; Webster et al., 2005). In addition, studies also suggest that global warming may accelerate the rate of sea-level rise, making coastal communities even more vulnerable to these catastrophic events. The relatively short duration of modern observations; however, make it difficult to identify with certainty whether global temperatures are the dominant control on intense tropical cyclone activity (Landsea et al., 2006), and stress the need for improved tropical cyclone records, particularly on longer timescales. In addition, in order to understand how coastal communities will be affected by future storm activity it is important to understand how coastal systems such as barrier beach environments have responded to past changes in sea-level, especially during previous periods of increased hurricane activity.

Previous research demonstrates that sediments collected from backbarrier environments such as coastal lagoons can contain anomalous coarse grain deposits which provide a stratigraphic record of past periods of overwash activity (Donnelly et al., 2001; Donnelly et al., 2004; Liu and Fearn, 1993, 2000). In addition, recent work by Woodruff et al., (2005) suggests that bathymetry within these shallow basins are often in steady-state with sea-level and measured sedimentation rates within these basins may be a fairly good proxy for past rates of regional sea-level rise. Local alterations to beach morphology; however, can change the sensitivity of a single lagoon system in recording flood events through time. In addition, bathymetric changes in a lagoon due to phenomena such as inlet development can be misinterpreted as being associated with rapid changes in sea-level rise. Results from multiple lagoon sites are therefore required in order to confidently distinguish region fluctuation in storm activity and sea-level rise from those due to local changes in lagoon morphology.

Here we present new analyses for sediments collected from two back barrier lagoons on the island of Saint Kitts, West Indies and compare these results with previous analyses performed on the neighboring island of Vieques, Puerto Rico (Figure 1). Stratigraphies from both island sites reveal consistent paleoclimatic records of intense overwash activity dating back over 4500 years. A transition from high to low overwash activity at approximately 1000 yrs BP is observed at all sites and is consistent with previous tropical cyclone reconstructions developed for the Gulf Coast of North America (Liu and Fearn, 1993, 2000). This observed transition in overwash activity at approximately 1000 yrs BP is also synchronous with an increase in El Nino activity (Moy et al., 2002) and a reduction in storminess over Western Cameroon, Africa (Nguetsop et al., 2004), both of which climatic shifts would suggest a transition in conditions at approximately 1000 yrs BP from those which would increase hurricane activity in the Western Atlantic to those which would suppress it (Gray, 1990; Gray, 1984).

In addition to overwash activity, sedimentation rates observed in lagoons on the islands of Saint Kitts and Vieques are also remarkably similar to each other and are consistent with previous rates of sea-level rise developed for the region based on the C^{14} dates of *Acropora palmata* coral and *Rhizopora mangle* intertidal mangrove peat (Hubbard et al., 2005; Toscano and Macintyre, 2003). These results suggest that lagoon bathymetry on Saint Kitts and Vieques has remained in a steady state with sea-level rise throughout the mid-to-late Holocene, with coastal morphology remaining relatively constant during past intervals of hyperactive hurricane activity.

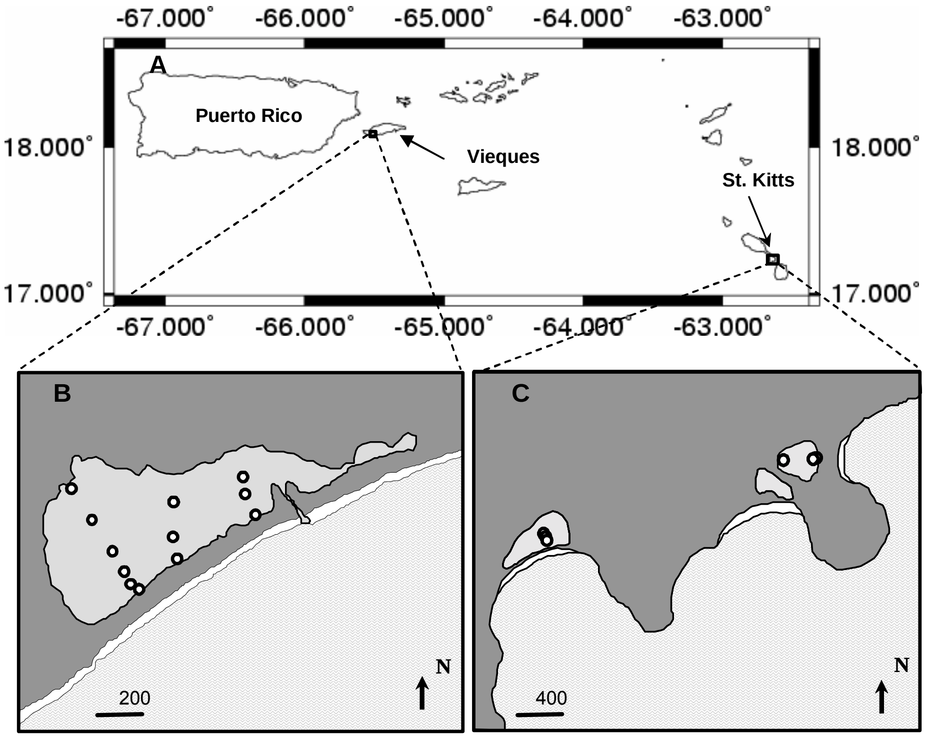

Figure 1: Northeastern Caribbean regional map (A), and site maps for studied lagoons on the islands of Vieques (B) and St. Kitts (C). Circles in B and C represent coring locations within lagoons.

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HOLOCENE COASTAL ARCHIVE OF CLIMATE AND SEA-LEVEL OSCILLATIONS IN THE SPANISH ATLANTIC-MEDITERRANEAN REGION: MILLENNIAL TO DECADAL PERIODICITIES.

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Coastal zones are an outstanding archive for records of past climate and sea level changes, especially in some sedimentary exposed sequences such as beach-barrier systems. In this work, we analyze the Holocene systems outcropping along the Spanish Atlantic-Mediterranean region (Fig.1) in order to investigate the main driving mechanisms controlling coastal evolution over the past ~7Kyr.

Previous studies in this littoral suggested a decadal periodicity related to solar activity cycle (Zazo et al., 1994) and North Atlantic Oscillation (NAO) index variability (Rodriguez-Ramirez et al., 2000) for beach barrier generation. In the most complete beach-barrier system of the Almeria coast, Goy et al.(2003) deduced quasi-millennial and decadal periodicities in coastal progradation, suggesting a relationship with cold Bond events and NAO index oscillations/solar activity cycles.

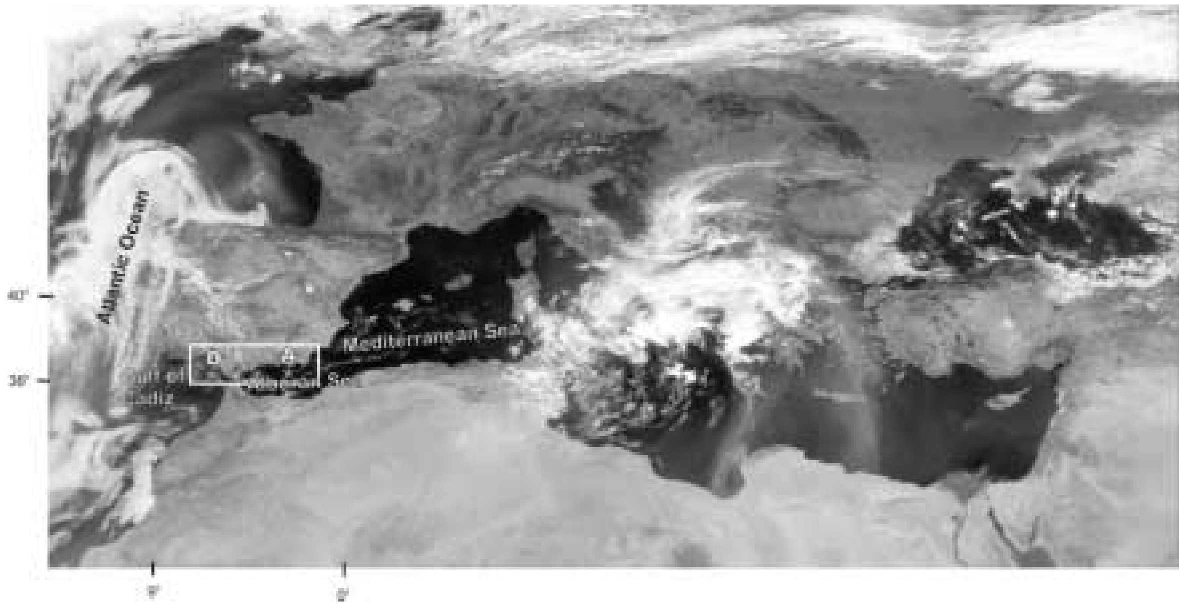

Figure 1: Location of the study area. A-Almeria, D-Doñana National Park, ★ marine cores cited in text.

The records of two marine cores in the Alboran Sea and the Gulf of Cadiz demonstrate a high correlation with North Atlantic climate variability and cyclicity over the past 50Kyr (Cacho et al., 2002). The general cooling trend of sea surface temperature (SST) following maximum Holocene values was interrupted by some short cooling (1-2ºC) events that occurred at intervals of 1,500 yrs or 740 yrs between events.

In the present work we used a methodology based on mapping and sedimentological facies analyses in order to identify the upper shoreface-lower foreshore boundary that is considered to represent the sea-level datum at the time of beach-ridge deposition. Samples on molluscs were taken in trenches where the 3D stratigraphic architecture of deposits was clearly established. Radiocarbon ages were calibrated and the reservoir effect was corrected. Obviously recycled samples were not taken into account for calculations.

The exposed beach-barrier system on the Mediterranean uplifted coast of Almeria (Fig.1) started to develop during the Middle Holocene at around 7.4 Kyr. The grain size of the beach-ridges is coarse sand to fine gravel with 15% bioclasts. Ridges that record beach progradation occur (Figs.2, 3a) as couplets separated by a narrow intervening depression or swale. Adjacent couplets are separated by slightly wider swales. In turn, pairs of couplets are separated by still wider swales. One noteworthy aspect is that the swales found every four beach ridges become noticeably wider, resulting in an obvious configuration of groups of “**sets”** (Figs.2, 3a, b). Using these features, Goy et al. (2003) identified six **"prograding units”** (group of sets) distinguished by changes in set configuration (height and width of the beach ridge/swale couplets), large swales or erosional surfaces, orientation, etc.

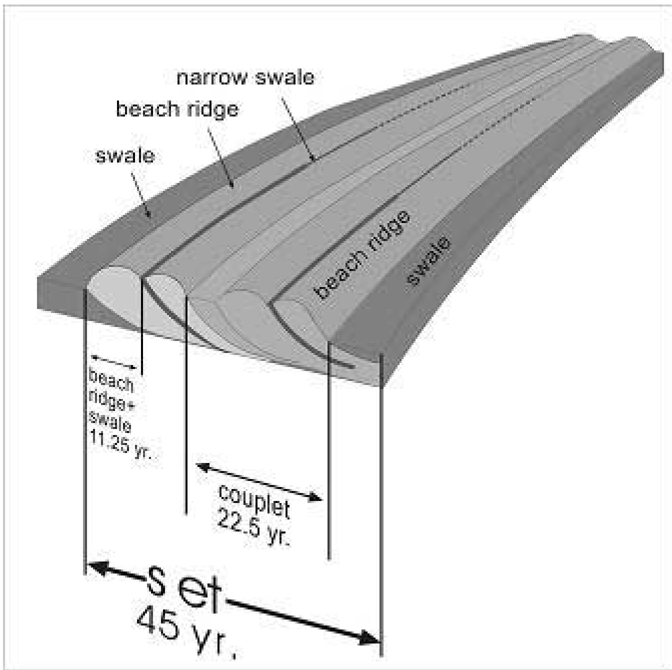

Figure 2: General configuration of beach ridges and swales in Almeria coast. Decadal (after Goy *et al.* 2003).

On the Atlantic coast, exposed beach-barrier systems (Fig.3b) started to develop around 3Kyr. The grain size of the beach ridges is medium to fine sands, with less than 10% bioclasts. Three **prograding units** can be distinguished with configurations similar to those described on the Mediterranean coast. However, they are less conspicuous due to the grain size difference and probably because, as suggested by Rohling and De Rijk (1999), the Alboran Sea worked as a concentration basin for climate-oceanographic signals over the last 25Kyr.

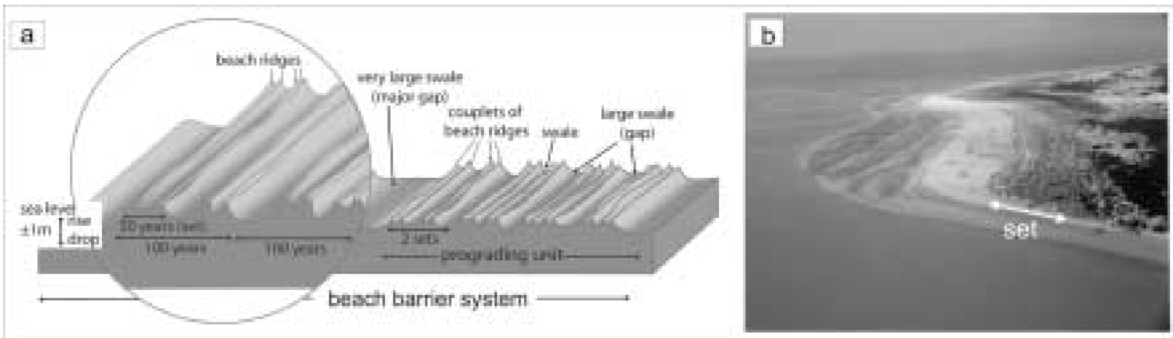

Figure 3: a) Beach ridges and swales configuration in Doñana coast. Decadal periodicity involved in their genesis. b) Aerial view of Doñana beach- barrier system.

Millennial cyclicity

Represented by short periods (600 to 300 yrs) during which coastal progradation was interrupted or decreased .These periods separating “prograding units” are associated with increased aridity, lower intensity in winds from the SSW, and relatively low sea level. Some of these periods coincide with Bond cool events (Bond et al., 1997) at ~1.4Kyr on the Atlantic coast, at ~2.8Kyr on both the Mediterranean and Atlantic coasts, and at ~5.9Kyr on the Mediterranean coast. These arid periods correlate with SST cooling events deduced by Cacho et al. (2002) in the Alboran Sea and the Gulf of Cadiz.

Centennial cyclicity

Represented by very short periods occurring every 400 yrs on the Mediterranean coast for the last 3Kyr, and every 100 yrs on the Atlantic coast for the last 500yrs. Increased storminess and intensity in WSW winds is thought to be responsible for this cyclicity.

Decadal Cyclicity

This cyclicity is observed in the generation of a beach ridge (11 yrs) or beach ridge **set (**50 yrs). The NAO index variability and/or sunspot cycles seem to be responsible for this cyclicity.

Sea level

Oscillations over the last 7.4 Kyr do not deviate by more than 1m. A general trend in fall sea level has been recorded over the last 5Kyr.

Climate

Coastal area progradation in these latitudes is more sensitive to variability in precipitation than oscillations in temperature. Prevailing wind direction and intensity are among the most important and determining factors in coastal evolution.

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Supporting