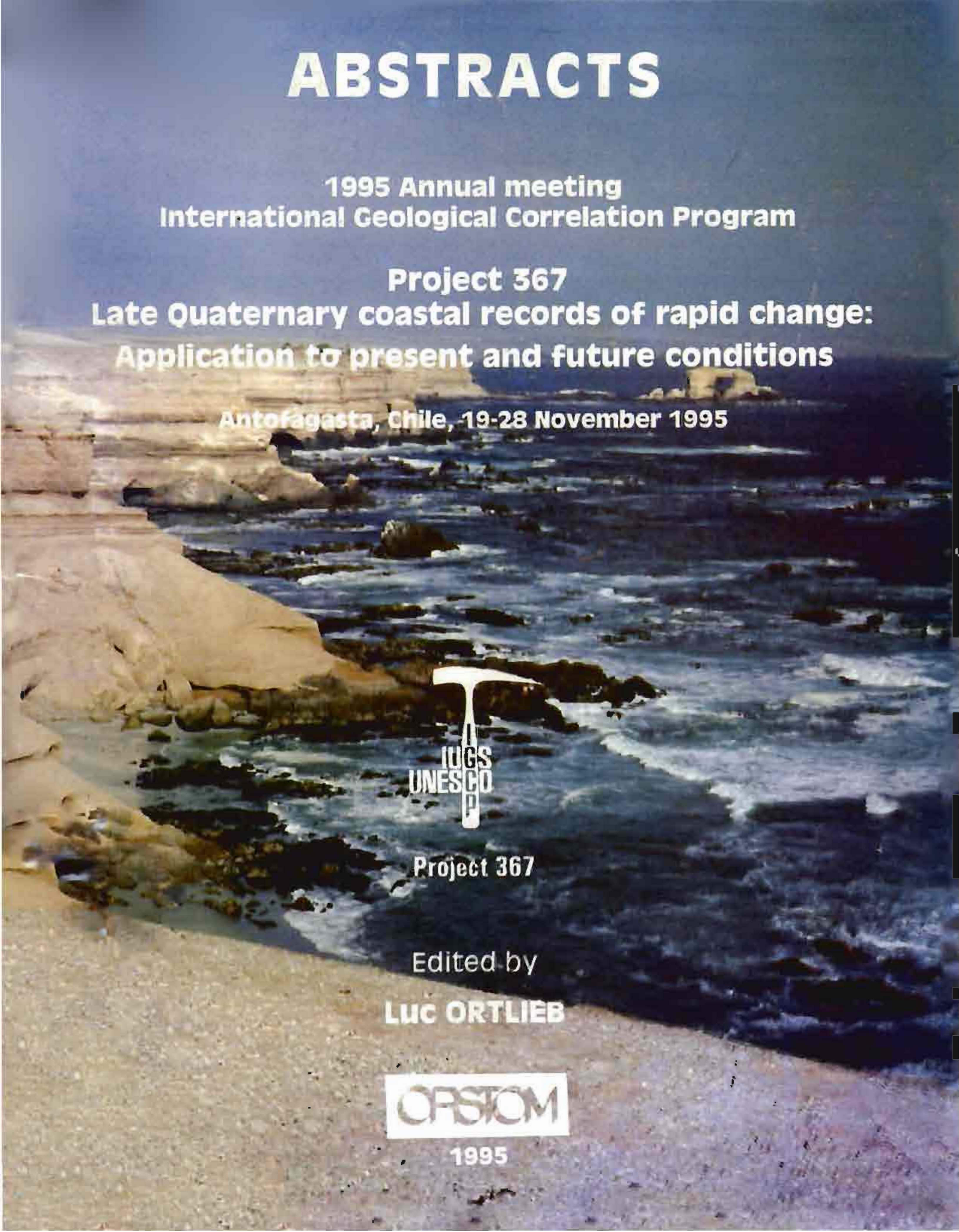

# ABSTRACTS

**1995 Annual meeting**
**International Geological Correlation Program**

## Project 367
## Late Quaternary coastal records of rapid change: Application to present and future conditions

**Antofagasta, Chile, 19-28 November 1995**

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**Project 367**

Edited by

**Luc ORTLIEB**

ORSTOM

1995

International Geological Correlation Program

**1995 Annual meeting of IGCP Project 367**

# LATE QUATERNARY COASTAL RECORDS OF RAPID CHANGE: Application to present and future conditions

ANTOFAGASTA, Chile, 19-28 November 1995

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# ABSTRACTS

of papers presented at the

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**INQUA Quaternary Shorelines Commission,**
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**and CONICYT**

**Project 367**

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# ABSTRACT VOLUME

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# HOLOCENE ENVIRONMENTAL AND CLIMATIC CHANGE RECORD IN THE MOLLUSCAN FAUNA FROM THE COASTAL AREA OF BUENOS AIRES PROVINCE (ARGENTINA)

**Marina L. AGUIRRE**

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Palaeoenvironmental changes along the coastal area of north-eastern Argentina (SW Atlantic), originated by different sea-level stands since the late Pleistocene, are revealed by the palaeoecology of the bivalves revised and by the whole qualitative and quantitative molluscan composition from marginal marine deposits. An attempt is made to add new evidence for the reconstruction of the recent climatic history along the bonaerensian littoral in SE South America, in comparison with other areas of the Southern Hemisphere.

The available evidence from the late Quaternary molluscan assemblages along the NE bonaerensian coastal area allows to recognize:

1) a higher sea-level stand (mostly littoral beach ridges at + 2.5-5m a.m.s.l.) corresponding to the Holocene interglacial (ca. 8,000-2,000 $^{14}$C yrs. B. P.; minimum 0.048 to 0.121 D/L ages on *Mactra isabelleana*)

2) the maximum of the Holocene transgression at least ca. 7,600 B.P. and the peak of the climatic optimum ("Hypsithermal") between ca. 7,600 and 5,000 B. P.(53% warm water taxa)

3) a period from around 5,000 to ca. 2,000 characterized by climatic seasonality, most probably with alternating 'cool' events after ca. 4,000 B. P. (drop in temeperature and lower sea-level trend) (11% warm water taxa).

4) the occurrence of *Glycymeris longior*, in low quantities (<0.5 %), only in the southern ridges, suggests that at least by ca. 2,800 B. P. normal marine salinity conditions had not been reached in Mar Chiquita area, still remaining brackish to polyhaline. This is also confirmed by the Sr/Ca ratios on shells from these deposits and is likely a result of Antarctic ice melting along the southwestern Atlantic and an increased rainfall.

5) present-like sea surface temperature conditions only after ca. 2,000 B. P.

6) present-like salinity and substrate conditions may have been established approximately after ca. 2,000 B. P.

7) during the last ca. 7,000 yr period, the bivalve *Noetia bisulcata* seems to represent the best palaeoclimatic indicator, i. e. warmer shallow oceanic waters. This species, with the maximum percentages and more complete population structure in the sand-shell ridges (minor barrier spits) from Punta Indio (ca. 7,600-5,000 B. P.), together with the higest diversity and the different molluscan composition, suggests maximum temperatures during the accumulation of these deposits (probably during a short-term reversal of the oceanic and atmospheric circulation patterns, in agreement with recent similar evidence for the central Brazilian coastal area and the Argentinian plains).

A cool event of reduced salinity can be recognized at the Pleistocene-Holocene boundary, confirming the two steps model of climatic change by the end of the Pleistocene proposed previously on the basis of palynological and glaciological evidence for southern South America.

The molluscan fauna from older (minimum >35,000 $^{14}$C yrs. B.P.), more restricted marine deposits (+ 6-10 m a. m.s.l.) occurring in the proximities of the beach ridges, may have been originated during an interstadial. Preliminary results on the Sr/Ca ratios of *Mactra isabelleana* shells confirm a mixed but not normal marine environment. Further sampling and dating of these molluscan assemblages is needed, however, to establish wether they could correspond to a previous Pleistocene marine transgression (isotope substage 5 ?; minimum 0.387 D/L age for *M. isabelleana*).

Although some of the localities lack accurate chronological control, this preliminary approach represents the only proxy data available for the late Quaternary along the bonaerensian littoral based on the marine evidence. As a whole, the short events recognized are apparently similar to those in other areas of the Southern Hemisphere (i.e. Burrows, 1979; Rabassa & Clapperton, 1990; Partridge, 1993; Avery, 1993; Newsome & Pickett, 1993; Scott, 1993). However, further studies including new dating and supplementary information provided by the geochemical and isotopic analysis of the shells, as well as microfossils, pollen and vegetational data, are necessary to provide a detailed model of palaeoclimatic evolution for the study area and to confirm or reject the climatic pattern proposed here.

**KEY WORDS**: late Quaternary, molluscan assemblages, marginal marine deposits, recent environmental and climatic change, sea-level fluctuations.

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# PRELIMINARY EVIDENCE FOR A LATE HOLOCENE MAJOR STORM SURGE DEPOSIT IN THE COASTAL PLAIN OF BELGIUM

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Recently two open sections in the western part of the Belgian coastal plain revealed a distinctive layer of fine sand that contrasts markedly with the surrounding deposits. The first section is located 200 m landwards from an Old or Inner coastal dune barrier, the second one at about 500 m landwards from the present- day coastal dune barrier. The sand layer is 5 to 10 cm in thickness, and forms a separate wedge that can be followed over more than 100 m. At site No. 1 it occurs at 2m above OD, and in site No. 2 at +2.6 m, viz. 1.30 m below surface. In both sites, the sand layer consists of light grey to brown grey loose fine sand with shell detritus and small clay balls. No sedimentary structures have been observed in the layer. The lower boundary in particular shows clear evidence of erosion. Both colour and texture display a marked difference to the normal coastal deposits in which the sand layer occurs, namely dark grey silty clay deposits characterised by penetration of reed rhizomes and Scrobicularia plana, sediments from a tidal mud flat.

The sand layer at site No. 1 most probably can be correlated stratigraphically to a remarkable lag deposit found between + 0.5 m and + 2.5 m in 5 boreholes located at the southern edge of the Inner Dunes over a distance of about 5 km. The lag deposit, with increasing thickness (from 15 cm to 1 m) in seaward direction, shows different facies: concentration of shells, medium shelly sand with pebbles at the base, fine shelly sand with angular gravel and numerous clay and peat balls, and medium sand with a concentration of pebbles and strongly weathered shells.

Few 14-C dates of the deposits above and below the lag deposit, and the stratigraphical position of the prominent sand layer indicate that it has been deposited later than 4250 y BP, but before 3150 y BP.

The coarse nature of the lag deposit, very uncommon in the Holocene coastal deposits of this plain, and a sudden change in depositional environment suggest a high energy deposition and most probably a catastrophic single event of marine origin.
In view of the broad spread of the lag deposit (over about 5 km) it is unlikely to simply interpret it as a washover deposit.

The evidence at present suggests that most probably the lag deposit and related prominent sand layer which are in contrast to the remainder of the coastal plain deposits resulted from a storm surge of unusual magnitude.

# HISTORICAL COASTAL ELEVATION CHANGES IN CHILE

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Coastal elevation changes in subduction zones are direct consequence, at the time of earthquake occurrence, of the fault location and rupture mode on it. Several examples of well documented co and post-seismic coastal elevation changes are found in Chile; these are the 1960 (Mw=9.5) southern Chile, the 1985 (Mw=8.0) central Chile and 1995 (Mw=8.1) Antofagasta earthquakes.

The 1985 Central Chile earthquake is the best studied earthquake in Chile.

Historical accounts of large earthquakes in this region begin in 1575. The sequence of large earthquakes continues in 1647, 1730, 1822, 1906 and the most recent is the 1985 event. The latter was preceeded, at the northern extreme of the rupture region, by an MS=7.5 earthquake in 1971. Although recurrence intervals are fairly regular (82±6 years), rupture lengths, widths and displacements differ by a factor of two or more. The questions that remains is: How is the slip difference accomodated from cycle to cycle? Two extreme examples of the sequence of earthquakes are the 1730 and 1985 events. The 1730 earthquake has been the largest event reported in the region; it generated a sizeable tsunami with its corresponding large sea floor vertical displacements. The March 3, 1985 earthquake (Ms=7.8), on the other hand, has been one of the smallest, but best studied events in the sequence. Aftershock surveys, body-wave modeling, surface wave analysis and geodetic estimates revealed a rupture length of approximately 160 km in a north-south orientation with maximum slip of about 2.5 m. Fault slip during the following year, evidenced by measurements of sea level at Valparaiso and tilt in a nearby lake, is at least of the same order of magnitude as the coseismic displacement. The shape of the signal is the same as that observed at Rapel lake, with a maximum amplitude of 50 cm. These changes are explained as slow displacement on different parts of the fault which did not rupture in the coseismic stage. Hence, the total 1985 fault process involved an area that extends both updip and downdip of the coseismic rupture, as required by the time dependent observations. Coastal elevations changes reported after the 1906 event in the same region, indicate that fault slip must have occurred in different portions of the seismogenic plane, particularly toward regions showing relatively low slip for the 1971-1985 sequence.

The great Chilean earthquake of May 22, 1960, with a moment magnitude of 9.5 has been the largest seismic event recorded in this century [Kanamori, 1977].

Remarkable changes in land levels were observed in a region 1000 km long by 200 km wide. Extreme coseismic changes ranged from 5.7 m of uplift in Guamblin Island to 2.7 m of subsidence in Valdivia. Plafker and Savage [1970] analyzed the static deformation data and presented teleseismic surface wave evidence to support their preferred uniform slip dislocation model that involved between 20 and 40 m of dip slip on a rupture 1000 km long and at least 60 km wide. Plafker [1972] re-analyzed the static deformation and deduced a model involving a rupture 120 km wide by 1000 km long dipping 20¡ E with 20 m of dip slip. Linde and Silver [1989] explained the elevation changes as the product of a rupture with variable slip in the down-dip direction. Because of the depth extent for this event, deeper than the mean depth of the seismogenic zone, 48 to 52 km [Tichelaar and Ruff, 1991], they concluded that part of the slip should be aseismic. They interpreted this aseismic component as a slow precursory event in the downdip extension of the rupture region previously proposed by Kanamori and Cipar [1974] and Cifuentes and Silver [1989]. Barrientos and Ward [1990] performed an inversion ofthe elevation change data, survey lines and sea level changes, and triangulation information to determine a variable slip model. They inferred that most of the slip was concentrated on a narrow 900-km long by 150 km wide band parallel to the coast with maximum slip of 40 m. Several patches of moment release, isolated from the main concentration of moment release, were found at 80 to 110 km depth, presumably indicating aseismic slip. Due to the size of the coseismic displacement, large postseismic readjustments are expected.

Tide gage records at Puerto Montt, referenced to a mareograph in Talcahuano, indicate a large (at least 75 cm) postseismic uplift of the region following the 1960 Mw=9.5 event. Field observations carried out in 1989 at the same locations of previous measurements in 1968 are consistent with tide gage records. The postseismic elevation changes are modeled as the result of propagating creep on the downdip extension of the coseismic fault. For a 30¡ E fault dip, minimum square error indicates a fault creep velocity of 4-6 km/yr and slip amplitude of 3-5 m.

The most recent large earthquake in Chile has been the July 30, 1995 event.
With a moment-magnitude of 8.1, its rupture zone extended in an area of approximately 160 km by 70 km. GPS observations (Ruegg et al., in preparation) and coastal elevation changes (Ortlieb et al., this issue) indicate that the coast moved nearly 1 m towards the west-south-west in relation to a bench mark located in Iquique. The coast was subjected to uplifts ranging up to 40 cm.
Preliminary models which indicate localized large fault displacements will be discussed.

In general, elastic models can reproduce the coseismic elevation changes fairly well. For uniform slip dislocations, as those observed in thrust zones, these models predict uplifts beneath the ocean and a smaller amount of subsidence inland. One of the key elements in these models is the down-dip extension of the fault. This parameter determines the expected coastal behavior, whether it is uplift or subsidence. For the three earthquakes described above we establish this down-dip extension, or the depth of seismic coupling, and interpolate it to other regions along Chile.

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# EVIDENCES FOR SHORT TERM RETREATING TRENDS OF THE SHORELINE

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In many places of the present shoreline zone, sharp-based offshore bar or beach barrier sand overlie thin-bedded fine sands and muds. Ancient analogues are commonly interpreted as lowstand shoreface deposits lying on an erosional surface cut into the shelf during a relative sea-level fall. New observations may challenge this interpretation by providing evidence of such a sequence developped during a recent shoreline retreat in a highstand phase without any significant change in sea level.

Two examples of such a superimposition are provided by wave-dominated clastic shorefaces and an attempt is made to describe the conditions of their construction. One of them is a microtidal environment of the Senegal coast (Saloum delta, Sangomar spit), the other one is a non-tidal environment (French Mediterranean coast, Gulf of Lions).

In the Saloum, the littoral cross-section of l'Epave du Tiran shows a dune sand deposits overlying a man-made shell accumulation, dated 600 years BP, and a layer of green muds formed in a lagoon at the back of an ancient beach barrier whose remnants are dated 3150 years BP. The receding of this ancient beach barrier is demonstrated by mapping the former offshore extension of a littoral sand clearly defined, in the region, by a grain-size signature. Other observations in the region of the Saloum delta give evidence of a large occurrence of this kind of evolution along the whole Sangomar sedimentary spit.

In the Gulf of Lions, vibrocores were sampled from the shore and the shoreface of the Thau lagoon lido. The geological record of recent and present sedimentation exhibits varied littoral sands overlying ancient deposits showing fine muddy sand and, at the very bottom of the sections, shoreface sands including fragments of beachrock. Datation give an age of 6490 to 6680 years BP for the underlying sediment. This muddy fine sand has been interpreted as a lagoonal deposits showing enrichment in organic matter and a typical facies which spread widely over all the lagon environments in the region. An evolution similar to that proposed for the Sangomar region may be considered here but furthermore various evidences are given of a very recent (some centuries) receding displacement of the beach barrier. Different lines of wrecks may be observed along this part of the Gulf of Lions, showing that the shoal determined by the offshore bars migrated successively landwards as the littoral sedimentary prism displaced equipollently.

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# A RECENT APPLICATION OF AMINO ACID EPIMERIZATION TO DATING OF MIXED-AGE MARINE DEPOSITS OF CENTRAL AND SOUTHERN ITALY.

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Amino Acid Epimerization (AAE) analyses have traditionally been used primarly for correlation and dating of Pleistocene marine units. The method relies on the slow interconversion of L-amino acids, within the indigenous protein preserved in the carbonate matrix of molluscan shells, to increasing proportions of their respective D-configurations until an equilibrium mixture of D- and L-amino acids is attained. In this study, we rely on the ratio of D-alloisoleucine to L-isoleucine (aile/ile) in the genera Glycymeris collected from Pleistocene and Holocene mixed-age marine units. AAE results are in good agreement with those obtained for the same sediments by $^{230}Th/^{234}U$, ESR (Electron Spin Resonance) and $^{14}C$.

In the Montalto di Castro and Tarquinia areas, Latium-Central Italy, four marine mixed-age deposits were identified. Sampled sites are (see Table): S. Agostino Nuovo (0.39±0.02; 0.48±0.02), Podere S. Pietro (0.38±0.02; 0.54±0.01), Lestra dell'Ospedale (0.48±0.02; 0.58±0.03) and Bandita S. Pantaleo (0.45±0.03; 0.59±0.04). As shown in Table, the values obtained in these four deposits by ESR and $^{230}Th/^{234}U$ methods evidence a marine episode. The other mixed-age deposits identified are (see Table): S. Reparata, Sardinia, (0.27±0.02; 0.38±0.02); Manca della Vozza, (0.50±0.02; 0.57±0.01) and Archi, (0.35±0.02; 0.49±0.01), Calabria-Southern Italy; Gallipoli, Apulia-Southern Italy, (0.30±0.01; 0.41±0.04); Milazzo, Sicily, (0.29±0.02; 0.41±0.03) and Sapri, Campania-Southern Italy, (0.33±0.02; 0.09±0.02). From Manca della Vozza, a $^{230}Th/^{234}U$ investigation was also performed. The analysis, which was made on two *Cerastoderma lamarcki cotronensis* samples found at the same elevation (170 m a.s.l.) as the 8 *Glycimeris insubricus* samples, gave the following ages: $311^{+70,-46}$ Ka and $191^{+24,-20}$ Ka (see Table). These results are in good agreement with those obtained by AAE and evidence the mixed-age deposit. From Sapri deposit (see Table), two Radiocarbon analyses were made on the same *Glycimeris* spp. samples analyzed by AAE giving the following ages: 5510±100 BP and >40,000 BP. In this deposit the Radiocarbon dates evidence two marine episodes, too; they are in good agreement with those obtained by AAE.

Finally, AAE method showed to be very useful to unravel the chronology of mixed-age deposits because the analyses can usually be carried out on individual shells (analysis requires only 100-200 mg of shell) and, therefore, a large number of samples can be dated from a particular deposit.

(see Table next page)

TABLE - Mixed-age marine deposits of Central and Southern Italy.

| Site | Elev. (m a.s.l.) | Glycymeris spp. $\overline{X} \pm \sigma$ (n)(a) | AAE (Ka) | ESR (Ka) | Th/U (Ka) | $^{14}C$ (years BP) |
|---|---|---|---|---|---|---|
| Sant'Agostino Nuovo (1) | 14 | 0.39±0.02 ( 2)<br>0.48±0.02 (12) | ~120<br>~200 | 163 ÷ 178 | 156±12 | |
| Podere San Pietro (1) | 25 | 0.38±0.02 ( 6)<br>0.54±0.01 ( 2) | ~120<br>~200 | 102 ÷ 118 | $99^{+18,-6}$; $115^{+15,-13}$ | |
| Lestra dell' Ospedale (1) | 45 | 0.48±0.02 (13)<br>0.58±0.03 (20) | ~200<br>~300 | 211±50 | $200^{+56,-20}$ | |
| Bandita San Pantaleo (1) | 55 | 0.45±0.03 ( 4)<br>0.59±0.04 (13) | ~200<br>~300 | 202 ÷ 259 | 212 ± 38 | |
| Santa Reparata (2) | 1 | 0.27±0.02 ( 3)<br>0.38±0.02 ( 6) | ~70<br>~120 | | | |
| Manca della Vozza (3) | 170 | 0.50±0.02 ( 4)<br>0.57±0.01 ( 4) | ~200<br>~300 | | $191^{+24,-20}$<br>$311^{+70,-46}$ | |
| Archi (4) | 110 | 0.35±0.02 ( 7)<br>0.49±0.01 ( 4) | ~120<br>~200 | | | |
| Gallipoli (5) | 4 | 0.30±0.01 ( 7)<br>0.41±0.04 (12) | ~100<br>~120 | | | |
| Capo Milazzo (6) | 55 | 0.29±0.02 ( 9)<br>0.41±0.03 ( 2) | ~100<br>~120 | | | |
| Sapri (Limito) (7) | 15 | 0.33±0.02 (14)<br>0.09±0.02 ( 3) | ~100<br><10,000 | | | >40,000<br>5510±100 |

(a) aile/ile (D-alloisoleucine/L-isoleucine) ratios are given as mean ( $\overline{X}$ ), standard deviation ($\sigma$) and number of shells analyzed (n).

(1) Montalto di Castro and Tarquinia area, Latium, Central Italy.

(2) Sardinia.

(3) Crotone Peninsula, Calabria, Southern Italy.

(4) Calabria, Southern Italy.

(5) Apulia, Southern Italy.

(6) Sicily.

(7) Campania, Southern Italy.

# SHORELINES IN NORTHERN SPITSBERGEN RAPID COASTAL CHANGE AT THE PLEISTOCENE/HOLOCENE BOUNDARY

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Northern Andréeland is bordered by more than one hundred shorelines which are the result of the glacio-isostatic rebound after the last deglaciation. Reinsdyrflya is dominated by morainic material; marine deposits are less obvious and often disturbed by cryoturbation. The radiocarbon ages presented here range from 11,535 to 8,775 a BP, the altitudes of the dated samples from 39 to 2 m asl. In the outer Woodfiord region, the major glacio-isostatic rebound occurred during the final phase of the Weichselian and in the early Holocene. As expected, the ages become younger towards the inner fiord which documents its later deglaciation. Offloading was also more intense in the inner Woodfiord: fossils of the same age -9,700 a BP- can be found at 2 m asl. in the outer fiord, whereas they were uplifted to 26 m in the inner fiord. For southern Reinsdyrflya, the average uplift was 2.3m per century between 11.5 and 9.9 ka BP; it was specially strong from 10 to 9.9 ka BP. In the inner Woodfliord at Wigdehlpynten, upflit started later due to the longer glaciation. There it reached an average rate of 2.6 m/cent. between 9.7 and 8.8 ka BP. The active cliff documents a recent transgression and the termination of the glacio-isostatic rebound.

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# EVOLUTIVE CHARACTERISTICS OF THE SOUTHERN COASTAL PLAIN OF THE RÍO DE LA PLATA

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The coastal plain of the southern margin of the Río de la Plata evolved over a substratum modelated during the Holocene transgression. Its present configuration is the result of the progradation processes accompanying the last sea level fall.

The coastal plain evolution was controled by the interaction of such diverse parameters as hydrometeorological (wind-wave relation, currents and tidal climate), migration of a muddy depocenter, relative sea-level fluctuations and geometry of the preholocene surface. Geometry and sea level fluctuations determine the distribution, extension and development of the sedimentary sequence, while hydrometeorological conditions determine the rate of sediment supply and transport.

The most important feature of the preholocene surface geometry was the ancient fluvial valley of the Río de la Plata. When the last rise of sea level reached the upper border of the valley, a protruding headland located at the southeastern edge of the coastal plain behave as a point of attack of the incoming waves coming from the SE. This induced the formation of two littoral currents drifting in opposite directions, one to the northwest (towards the Río de la Plata), and the other to the southwest (towards the Samborombon bay), conditions that are still occurring.

The formation of a muddy depocenter was the result of fine sediments accumulation from an estuarine turbidity maximun zone (TMZ) formed in a zone of maximun salinity gradient (MSGZ) originated by mixing of fluvial and marine waters. The depocenter migrated according to the displacement of the MSGZ during the rise and fall of sea level.

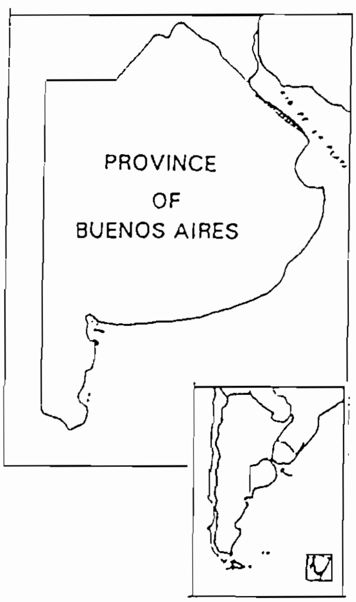
Relative sea level fluctuations show both a transgresive phase from 18000 to 6000 yrs BP and a regressive phase from 6000 yrs BP to its present position (see description of sea level curve in this volume).

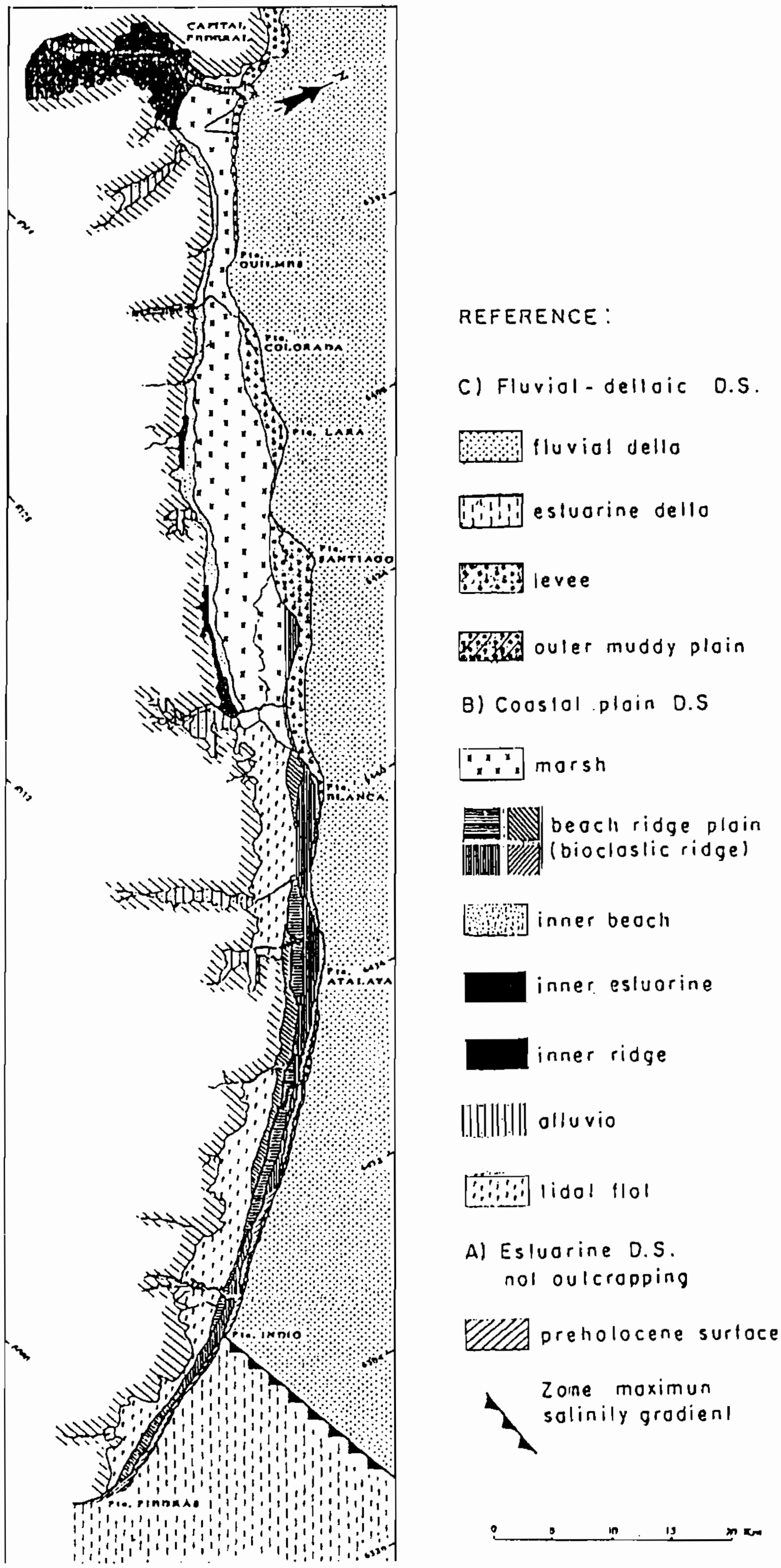
The coastal plain evolution is sintetized in three stages: estuarine, coastal plain and fluvial-deltaic. Each one of them is characterized by a different facies associations that can be considered as Depositional Systems, which are part of a Holocene Depositional Sequence.

**Estuarine:** represents the earlier stage of coastal plain evolution, when fine sediments associated to the MSGZ filled the ancient fluvial valley during the rise of sea level.

**Coastal plain:** is related to littoral drift northward of the headland located at the southeastern edge (Punta Piedras) during the earlier and middle stages of coastal progradation (regressive phase). The process gave origin to two different depositinal environments: proximal and distal, according to the distance to headland. The proximal environment is associated to beach ridges and spits formation which grew northward attached to the headland. Open estuarine conditions prevailed in this moment. Two facies were recognized, a lower, sandy facies, resulting from a lower wave energy level, and an upper, bioclastic facies, resulting from a highest wave energy level. Silty sands facies acumulated on a tidal flat behind the ridges. The distal environment is represented by low energy beaches and marshes formed on the inner parts of the estuarine by an excesive supply of sediments closed to the MSGZ.

Fluvial-deltaic: is the final stage of evolution related to the advance of deltaic facies following the passage of the MSGZ to the south during the regressive phase. An enormous sediment supply coming from the Paraná river led to accumulate different sedimentary facies under similar hydrodynamic conditions than the present ones, varying from the coarser deposits at the mouth of the Paraná river to the finer deposits (prodelta facies) in the outer border of the Río de la Plata next to the shelf. The deposits characterizing this stage on the coastal plain represent the environmental change from estuarine to fluvial conditions in the area.



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# RELATIVE SEA LEVEL CHANGES IN THE RíO DE LA PLATA DURING THE HOLOCENE

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The regional study carried out at the Río de la Plata allowed to obtain a curve of relative sea level variations from 8600 yrs BP until the present.

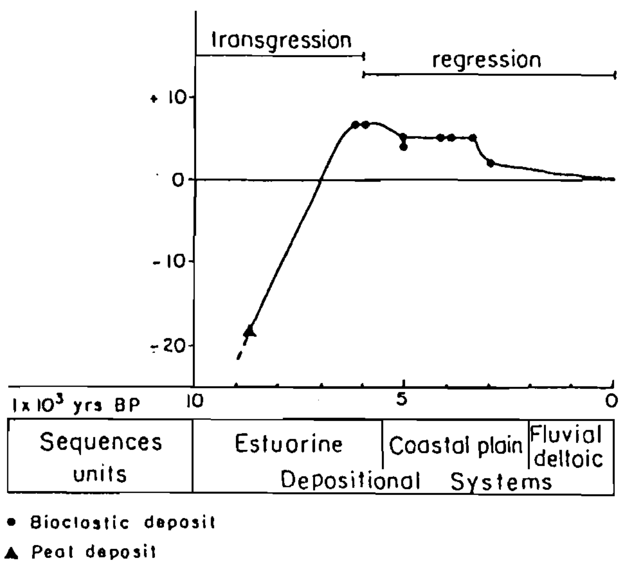
Ten radiocarbon datings selected from a total of 25 were used to build the curve. Except for the older one, that comes from a peat deposit, the other samples belong to beach deposits.

Different parts of the curve can be correlated with geological events that have occurred during the evolution of the Río de la Plata.

This study confirms that the Río de la Plata was affected by a rapid transgressive event before 8600 yrs BP, with a mean velocity of sea level rise of about 9.4 mm/y. The transgressve event begun about 18000/20000 yrs ago.

At about 8000 yrs BP the velocity of rise slowed down. At 7000 yrs BP the sea level position was similar to that of the present level, before reaching the maximun highstand at 6000 yrs BP. This event was characterized by the development of a broad abrasion platform as a result of the process of ravinement.

The deposits originated during the transgressive event filled up the ancient fluvial valley of the Río de la Plata as a result of a migrating depocenter related to the mud floculation process in the zone of maximun salinity gradient produced by mixing of fresh and salt water.




The maximun highstand of sea level was documented at 6000 yrs BP at an altitude of +6.5 m. This age coincide with other registers from different areas of the Argentine coast between 33°-54° S, whereas differences in altitude are evident.

The regresive event was characterized by a discontinuous fall in sea level. Between 6000 and 5000 years BP the sea level decresed from 6.5 to 5 m at a rate of 1.5 mm/y. Between 5000 and 3500 yrs BP there was a period of stability with no major variations. Between 3500 to 2900 yrs BP a rapid sea level fall from 5 to 2.5 m took place with a velocity of 5.8 mm/y. A coastal plain depositional system, with beach ridges, tidal flats and marshes development, was accummulated during those stages.

Finally, a slow fall in sea level started about 2900 yrs BP and reached the present position, at a velocity of 0.5 mm/y. A rapid progradation took place in the Río de la Plata due to a great input of fluvial sediments that constituite a deltaic depositional system.

Geomorphological evidences, like the presence of steps separating beach rigdes, reveal that sea level fall could have experimented minor changes in its velocity as well as stability moments that are not shown by the curve. Short interruptions in the geological record can be explained either by the same minor changes in sea level or by changes in wave climate.

Paleoclimatic and biogeographic information (Tonni, 1992 and Iriondo and Garcia, 1993), reveal that a warm, wet climate dominated between 8500 and 3500 y BP which includes the maximun temperature moment (González **et al**, 1983) occured at 6000 yrs BP, whereas a change to semiarid climatic conditions ocurred at 3500 yrs BP, which roughly corresponds to marked sea level fall herein documented.

Flexures shown by the curve at 5000 and 3500 yrs BP also coincide with the eustatic episodes defined by Weiler and González (1990).

Probably tectonics effects can be explained by the existence of steps on the preholocene surface as well as the stratigraphically anomalus position of holocene inner beaches.

Present considerations indicate that holocene sea level fluctuations in the Río de la Plata were mainly controled by climatic changes, although tectonic effect could have played also a secondary role.

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# GEOLOGY OF NORTHERN CHILE. AN OVERVIEW

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The geology of northern Chile, an important segment of the Central Andes, can be divided into two main chapters. The oldest, including Precambrian up to Triassic times is described as the Preandean cycle. It is poorly known and has a scarce representation in the stratigraphical column. Precambrian rocks are described in a few outcrops and some authors assume that they represent terranes. The Paleozoic rocks correspond to marine and continental sediments, volcanic rocks and different magmatic pulses, specially in Carboniferous-Permian times.

The second "cycle" is described as the Andean one and of a time span starting in upper Triassic up to the present. Its model corresponds to an active continental border history with an oceanic plate (Nazca) subducting under a continental one (South-American Plate). The main features are:

- The geological "units" (formations, faults, intrusives, ore deposits) are trending NS-NNW. Some very important changes can be observed along these "belts", and it is assumed that they corresponded to changes in the subduction angle.
- Between Triassic and Neocomian times, marine basins associated to a magmatic belt have a wide distribution. The magmatic belt will progressively shift to the east, to finally reach its present position. Intrusive pulses are represented at different ages. It ends with continental sedimentation and volcanic activity.
- From Neocomian times on, and after an important sequence of tectonic phases and an intense erosion, sedimentation starts associated in upper Cretaceous to volcanic activity that will reach up to Eocene times. Hypabyssal intrusives are very common. Intrusive pulses are also present.
- In Oligocene, after a tectonic phase, volcanic activity disminishes and the main porphyry copper of the region are emplaced.
- From Miocene up today, volcanic activity and continental sedimentation are the main geological events. To the west, the continental border was farther to the west than at present. Intrusive pulses can be recognized.

The principal structures are represented by two regional fault systems that can be longer than 1000 km. The Atacama system is emplaced in the Coastal Range and the West Fissure system in the Precordillera Region. Other two important fault systems are emplaced along the Central Depression and the Altiplano.

Geomorphology corrresponds to tectonic blocks trending N-S with a general sketch of "ranges and basins" shaped under the influence of arid to semi-arid climates.

# EFFECT OF BARRIER SIZE AND OFFSHORE SLOPE ON RATES OF COASTAL CHANGE DUE TO SEA LEVEL RISE AND LITTORAL SAND LOSS

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Computer experiments were undertaken using a mass-balance model (Cowell et. al., 1995, Roy et al., 1994) to derive practical relationships for the effect of sea-level rise on different coastal geomorphologies. The inherent uncertainty was dealt with through stochastic simulation. The results of the simulations were used to distil generalised relationships, and associated uncertainty bands, for coastal recession as a function of the height of the barrier crest and offshore slope for a given sea-level rise.

Shoreline recession rates vary inversely to barrier height (as expected) and offshore slope. However, when sea levels rise slowly, the direct impacts of sea-level rise are subordinate to the effects of variations in the littoral sediment budget, even when transport residuals are too small to be detected using existing theory or through field measurements. The comparison is illustrated in Figure 1 for conditions typical of the central part of the southeast Australian coast. Here sediment characteristics indicate that the shoreface is active over decades to water depths c.25 metres, which typically lie 1500 metres offshore. Littoral sediment fluxes are conservatively estimated at 200,000 $m^3$ per year. Figure 1a shows the recession of a 10 m high barrier due to a sea-level rise totalling 1 metre. Changes such as these, equivalent to a very pessimistic Greenhouse scenario, have taken hundreds of years during the Holocene on coasts still experiencing relative sea-level rise. However, this rate of shoreline recession is minor compared to that shown in Figure 1b for a deficit in the littoral sediment budget amounting to only 0.5% of the annual flux rate, occurring for a period of only 5 years, and without any rise in sea level. The significance of this sensitivity of shoreline evolution to littoral sediment budgets gives rise to the expectation that regional shoreline changes can become complicated and erratic under conditions where littoral sediment budgets vary in space and time. In an accompanying paper at this conference, Roy and Cowell propose that this erratic behaviour in large-scale coastal behaviour is particularly likely to occur on coastal plain-coasts under conditions where sea-level change is slow or static.

The paper also presents general relationships for shoreline recession due to littoral sand loss and sea-level rise, as a simple function of barrier size and rates of littoral sand loss. However, the comparative behaviour illustrated in Figure 1 is a common feature across the full range of barrier sizes and offshore slopes that were modeled.

(see figure next page)

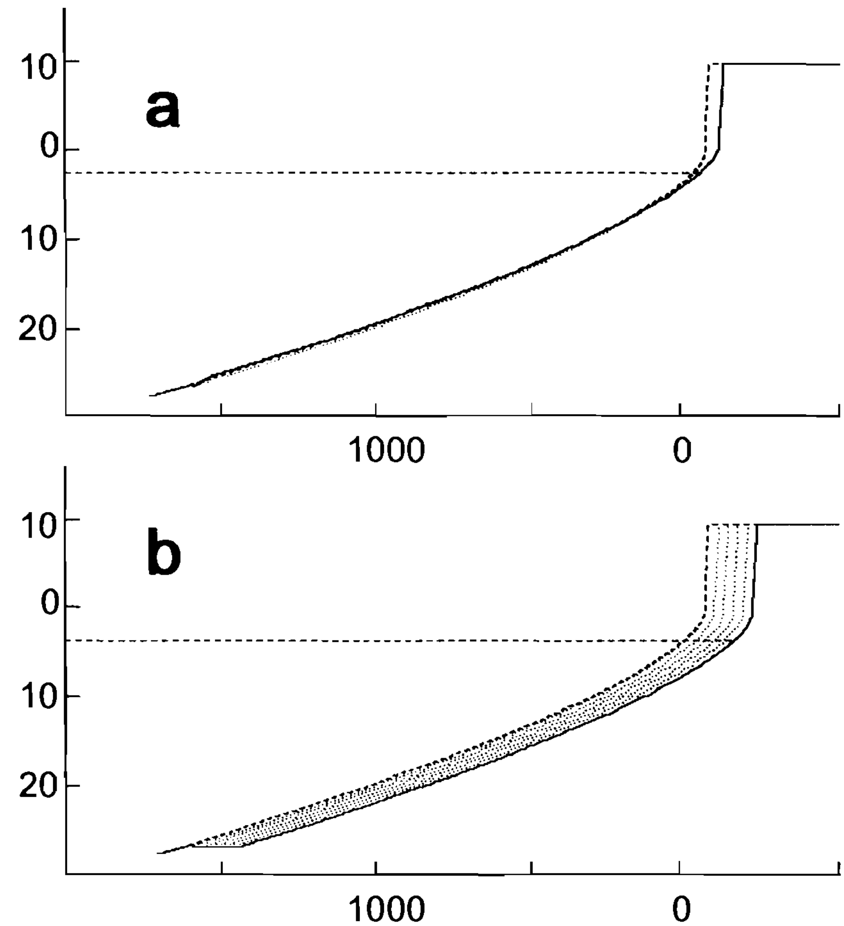


Figure 1. Shoreline recession due to a) a 1 m rise in sea level, and b) an annual sediment loss at 0.5% of the net flux over 5 years. The distance and depth to the toe of the shoreface is 1500 and 25 m; the barrier crest is 10 m high.

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# TSUNAMI SEDIMENTATION

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The recognition of coastal sediments attrributable to past tsunamis is essential if one is to distinguish these sediments from those deposited by former storm surges and long-term changes in relative sea level. The view that tsunamis deposit sediment is a relatively new one and consequently there are only a limited number of studies that provide information on the patterns of sedimentation that take place during episodes of tsunami runup and backwash. Most accounts present informtion on sedimentary deposits interpreted as having been laid down by past tsunamis. By contrast, there are only a small number of studies that describe coastal sediment sequences that have been directly observed to have been deposited by modern tsunamis.

A review is presented here of the principal investigations that describe tsunami deposits. Most of these accounts describe distinct sediment wedges that rise in altitude and taper inland. In most cases it is assumed that sedimentation principally takes place during periods of flood runup. However, backwash flow can be a locally important process and the interaction of a series of waves within a tsunami wave train can produce complex patterns of sedimentation. Recent detailed studies of sediments deposited by the Flores tsunami of December 1992 and the Java (Rajegwesi) tsunami of June 1994 indicate that an important process of sedimentation may take place during periods of tsunami flooding as a result of the complex flow direction changes that take place following the culmination of individual episodes of flood runup and before the initiation of backwash currents. Together, the research indicates that the processes of tsunami sedimentation may represent a unique set of geomorphic and hydraulic processes in coastal environments.

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# RECENT FORE-ARC TECTONICS IN THE ANTOFAGASTA REGION, NORTHERN CHILE

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During three weeks a neotectonic field work has been carried out in the Antofagasta area, between 22.5°S and 24.5°S as the first stage of the neotectonic part of a long term French-Chilean research project (Institut de Physique du Globe de Strasbourg/ORSTOM and Departamento de Geofisica, Universidad de Chile). Among others, one aim of the project is to improve the understanding of the interaction between the subduction process and the continental deformation in the fore-arc region. The seismological part of this project already permitted to draw a precise picture of the geometry of the subducting slab and to establish the state of stress along the subduction zone (Comte et al, 1994; Delouis et al., 1995).

Within this frame, the present work was designed to acquire an overview of the fore-arc tectonics in the region and to produce a coherent interpretation of the faulting process. Previous to the field work, aerial photographs covering the Atacama Fault System and the Mejillones peninsula have been extensively studied so as to identify the main fault traces and to determine where faults cut into alluvial formations. Recent works in the area have demonstrated that the Atacama Fault System has undergone left-lateral displacement contemporaneous with the development of the Jurassic - early Cretaceous magmatic arc in the present coastal cordillera (Naranjo et al., 1984; Herve, 1987a; Thiele and Pincheira, 1987; Scheuber and Andriesen, 1990). It has been indicated that part of the Atacama Fault System has been reactivated since late Tertiary as normal faults (Arabasz, 1971; Okada, 1971; Herve, 1987b; Naranjo, 1987). On the other hand, Armijo and Thiele (1990) proposed a predominent left-lateral displacement for the recent activity of the Atacama Fault System, near Antofagasta. Those two points of view are contradictory and further work on this problem was needed.

About 70 places of neotectonic interest formerly identified on the aerial photographs were visited, mainly along the main branch of the Atacama Fault System (Salar del Carmen, Paposo segments), the Cerro Fortuna, Cerro Moreno Faults and the Mejillones peninsula. We explored also some other features we identified eastwards on the aerial photographs, that we named the Navidad and the Barazarte faults (Fig. 1).

The observations gathered concern mainly the relative displacement of pre-faulting structures at the metric to decametric scale, such as pre-faulting topogaphy (mounds and stream channels), variation of scarp height where old topography is affected by faulting, parallel or "en echellon" arrays of tensile cracks, and pressure ridges. The relative chronology of ruptures was based on qualitative appreciacion of the scarp's surface freshness, its color relative to the displaced surface (scarps patina). Some scarps appear very eroded, for instance along the Paposo and Caleta Colosso faults segments. On the contrary, in several places, fault scarps have a very fresh appearance and are little or nearly not eroded, for example in the La Negra sector and in some portions of the Salar del Carmen and Cerro Fortuna Faults.

Field observations indicate that normal faulting prevails in the area, but we identified horizontal components of relative displacement too, both left-lateral and right-lateral. The orientation of pure normal faults ranges between N350° and N20°. Tensile cracks are often observed parallel to the main scarp of those faults. The lateral component is observed to vary with the azimuth of the faults. Faults oriented more towards the NW-SE have a right-lateral component while those oriented more to the NE-SW have a left-lateral component. Therefore, the component of relative displacement varies quite coherently with the strike of the faults and is indicative of EW extension. To quantify the stress regime we applied to the field observations an algorithm of inversion of the stress tensor orientations and shape factor. Results clearly indicate an extensional stress regime with the $\sigma_3$ (minimum stress compression) horizontal, striking in the EW direction, and $\sigma_1$ (maximum stress compression) vertical. Normal faulting is attested too by the widespread 'half-graben' structure at the decakilometric scale.

Main tilted blocs are limited by normal faults oriented close to NS, dipping towards the East. Some of those faults have huge uplifted foot walls and rather eroded scarps, as the Paposo segment and the Quebrada Ordonez faults, others have only moderately eroded scarps , as the Cerro Fortuna fault. Hence, the forearc region near Antofagasta seems to have been under an extensional tectonic regime for a long time (since Miocene ?). The erosional rate in this desertic region is particularly slow and allows an exceptional preservation of the tectonic structures. However, much fresher scarps attest of repeated ruptures under EW extension in the very recent (historical ?) time. The overall field observations show the compatibility of the faulting in the whole covered area with the EW extension but do not support Armijo and Thiele's proposal (1990) that the Atacama Fault System would concentrate left-latteral displacement while the EW extension would be limited to the Mejillones block. The existence of an extensional stress regime at a convergent plate boundary may seem contradictory. However, extension may occur as a local modification of the general compressional state caused either by some crustal bending effect or by a transient disturbance of the stress field following the occurrence of very strong subduction earthquakes. A further exploration of those two possible explanations has to be done by numerical modeling.

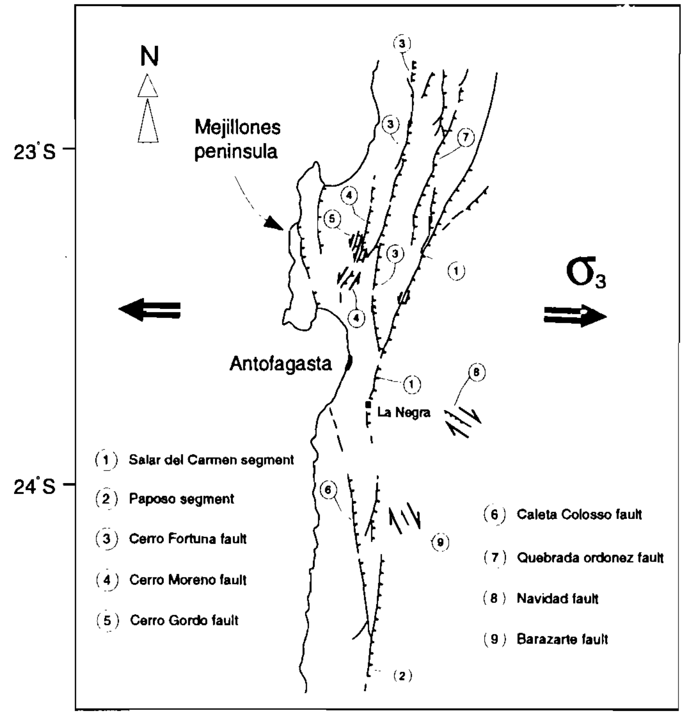


Figure 1 : main faults in the Antofagasta area. Ticks indicate the downthrow direction for normal faulting and double arrows show the horizontal component of movement (the larger the horizontal component, the larger the arrows).

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# SHORELINE EVOLUTION IN PORTUGAL SINCE THE LAST GLACIAL MAXIMUM: A REVIEW OF CURRENT KNOWLEDGE

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The first proposal and until the present moment the only one, of the mean sea level variations during the last 18 000 years, was proposed by Dias (1985). Due to the scarcity of radiometric datings, the morphological features of the shelf , the genetic characteristics of the sediment bodies and their relative age were also used in setting the sea level rise curve. The scenario presented in this model was later confirmed by a series of C-14 datings. It's combination with detailed geomorphologic analysis of shelf features permitted to reconstruct the shape and position of the coast line since the Last Glacial Maximum, during the deglaciation and Holocene (Dias, 1987).Though the curve was established for Northern Portuguese coast, it's confrontation with the work done on other Portuguese shelf & coastal segments (*e.g.:* Quevauviller, 1986; Quevauviller & Moita, 1986; Moita, 1971, 1986; Monteiro et al., 1982; Monteiro & Moita, 1971)) validated the regional applicability of this curve.

According to the cited sources , the shoreline was ca. 140 m below the present sea level during the last Glacial Maximum i.e.. close to the shelf brake. Multiple aspects of the past coastal features are well documented , mainly in the Northern segment (e.g.: Dias, 1987, Rodrigues & Dias, 1989; Rodrigues *et al.*, 1991). The polar front reached the latitude of Portuguese shelf (*e.g.:* McIntyre et al., 1976; Molina-Cruz & Thiede, 1978, Pujol, 1980) , hence the water temperature close to the shore was below 4°C in winter but at the open ocean was reaching 10°C (Thiede, 1977, 1978; Molina-Cruz & Thiede, 1978). Also the West Iberian upwelling was more intense than the present (Rognon, 1980). The rainy season was longer than present, characterised by highest precipitation in autumn and winter (Daveau, 1980) and responsible for the high sediment load in fluvial discharge into the shelf, as deduced from sedimentologic and geomorphologic evidences (e.g.: Dias & Nittrouer, 1984; Magalhães & Dias, 1992; Abrantes *et al.*, 1994; Cascalho et al., 1994). The salinity of coastal waters was also lower as inferred from microfaunal data (Nascimento & Silva, 1989).

The traces of the last deglaciation are not very clear on Portuguese platform. The landward shoreline migration was slow initially (18 000 to 13 000 yr BP), to become fast from 13 000 to 11 000 yr. BP. The estuaries could not reach the equilibrium with the rising base level , therefore the volume of sediments reaching the shelf was small and their granulometry essentially fine.

The Younger Dryas, is well marked on Portuguese Shelf by various morphological features and by extensive coarse grain deposits formed during massive sedimentary influx resulting from high rainfall and temporary lowering of base level (Dias, 1987; Rodrigues & Dias, 1989; Magalhães & Dias, 1992; Abrantes *et al.*, 1994; Rodrigues *et al.*, 1991). About 10 kyr. BP the sea level started to rise fast and in 2000 yr. sums up 40 m (Dias, 1985, 1987). The similar rate was observed on French Atlantic shelf (Ters, 1976). The migration of the coast line was so fast that the further processes were unable to destroy past sedimentary features.

The features like cliffs and submerse abrasion platforms left by migrating coast line were recently studied by means of ROV (Remote Operated Vehicle), and during deep scuba diving campaigns (e.g.: Dias et al., 1991, 1992; Groupe ERLIDES, 1992, Pereira & Regnauld,1994).

Between 3000 and 5 000 yr. BP the sea level reached the present values. However the shape of littoral fringe was substantially different from the one which is observed today. The coast was predominantly rocky, intensely incised, and the estuaries were much wider. A significant flux of sediments from estuaries seawards initiated later, depending on sedimentation histeresis in each individual estuary. The gathered data suggest that the most intense transfer of sediments onto the shelf and the resulting smoothening and straightening of the shoreline, occurred during the Little Ice Age (Dias, 1990). During this period which lasted until the end of the last century the impacts of anthropic activity became visible and in general regressive trend predominated . Since that time one observes a clearly transgressive trend whose causes lie in the human activities in drainage basins linked to this coastal segment (Dias, 1990), or in the secular sea level rise (Taborda, 1992).

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# TEMPORAL VARIABILITY OF SOME BIOCEANOGRAPHIC PARAMETERS IN THE BAY OF ANTOFAGASTA, CHILE

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Seasonal and interannual variation of some bioceanographic parameters at Bay of Antofagasta are described for the period december 1991 to may 1995 from roughly monthly measurements at a fixed station, ca. 10 miles offshore. The variables under study were surface temperature, thermocline depth, depth of the mixed layer, phytoplankton biomass (PB) and zooplankton biomass (ZB). Surface temperature was also controlled at an inshore station

For the whole period, surface temperature varied between 13.13 and 21.07°C at the offshore station. At the inshore station a similar range was found for temperature measured early in the morning. The two measurements were highly correlated ($F_{1,37} = 97.06$, $P < 0.01$) indicating that the simpler and low-cost inshore measurement was sufficient to cover temperature variability in the bay on a seasonal and annual time scale. The cross-correlation function for the two measurements was also significant for the time lags = 0, 1 and 2.

Temperature variation showed significant autocorrelation components at high frequencies (lag = 1, 2) revealing periodicity. Spectral analysis carried out on surface temperature and the mean temperature of the water column (0 to 50 m) reveals significant annual and six months cycles. Furthermore a significant negative trend was observed for the mean temperature of the water column (0-50 m). This was interpreted as a gradual cooling of the water column from 1991-92 when "El Niño" was detected until 1995. Thus 1994 and 1995 were much colder than the two previous years. A more global conclusion suggests that the area is presently undergoing a cold period and is mostly controlled by subantarctic waters of the Humboldt current.

Partial correlation revealed association between the biological variables PB and ZB and between some biological and physical variables. The variables PB and ZB do not show significant autocorrelation indicating lack of seasonality. There was a significant cross-correlation between depth of thermocline, estimated as the depth of the 14°C isotherm, and the zooplankton biomass of small zooplankton. Various pulses and behaviour of the bioceanographic parameters are discussed in the context of potential indicators for large scale oceanographic events.

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# A SEARCH FOR PALEOCEANOGRAPHIC AND PALEOCLIMATIC CHANGES DURING THE LAST 2,000 YEARS IN NORTHERN CHILE

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The extreme aridity of the coastal desert of northern Chile is the result of a singular interaction of oceanic and atmospheric processes. The northbound cold Humboldt Current and the eastern branch of the SE Pacific anticyclonic cell combine their effects to strongly reduce the evaporation of water from the Pacific Ocean and, furthermore to limit the transfer of humid air inland. Additional orographic factors (the 700 to 1,000-m-high Coastal Scarp of northern Chile on one hand, and the Andes Cordillera on the other) strongly reinforce the arid conditions in the heart of the Atacama desert, in the Pampa del Tamarugal and the central valley. In spite of the phenomenon referred to as « invierno boliviano », or « invierno altiplánico » which brings some rainfall to the northeasternmost part of the Chilean territory, the blocking of humid air from the Amazonian and Atlantic regions is particularly effective, and seems to have remain so, for a long time during the Quaternary.

At an interannual time scale, the current climate and oceanographic conditions of northern Chile are altered by the El Niño-Southern Oscillation system. Though, the El Niño conditions do not provoke systematically rainfall in the arid northern Chile, in the same way that they induce excess precipitation on the coast of northern Peru, or in central Chile. A historical analysis of the rainfall events during the last two centuries in northern Chile (Ortlieb, 1994,1995) showed that El Niño years may be « rainy » (not more than a few cm of precipitation, in any case!) but not always. The impact of the El Niño phenomenon is stronger and more straightforward along the coastal region (onshore, as well as in the nearshore and offshore areas). The elevation of nearshore sea surface temperatures and the reduction of primary productivity affect seriously the marine life and the whole trophic chain along the north Chilean coast.

In the bay of Mejillones (23°S), we investigated the possibility that relatively shallow marine sediments (about 100 m depth) provide some record of former oceanic conditions, and subsequently of climatic fluctuations. A series of Phleger cores, several decimetres (up to one meter) long were collected in 1993. The first results (1994-95) obtained in the PALEOBAME program (ORSTOM-Univ.de Antofagasta) were encouraging since it was confirmed that hypoxic conditions, found on the bottom of the bay (below a 50 m depth) strongly limited the bioturbation and were thus favourable for a sedimentary record of former oceanographic conditions. The dark greenish muds are most often grossly laminated and the stratification is well preserved in the cores. The sediments are rich in organic matter and contain abundant diatoms, foraminifers, and fish remains. Variations of relative abundance of phyto- and zooplancton, and of fish scales, through regular sampling every cm downcore, are being investigated in several cores from the western and central part of the 15 km wide bay. Preliminary radiocarbon dating (on bulk de-carbonated sediment) suggests sedimentation rates in the order of 250 mm/$10^3$ y (but locally of as much as 500 mm/$10^3$ y). These rates are very high if it is taken into account that they reflect a strong productivity. The terrigenous input in the bay is essentially limited to eolian sediments, because the extreme aridity practically prevents any runoff.

On-going research aims to reconstruct paleoenvironmental conditions, and their variations, with a decadal-to-centennial resolution, in the course of the last few thousand years. These studies thus tend to detect variations in the oceanic circulation pattern and in the intensity of the local upwelling system (Punta Angamos). Preliminary results (Ortlieb *et al.*, 1994, 1995) from the first cores suggested that the sedimentary record of Mejillones Bay may have registered a cold-water episode and beforehand, warmer-than-present conditions. During the latter episode, sardine replaced anchovy (as observed during present-day strong El Niño events) while the water column was stratified and the sea bottom was submitted to an intensified hypoxia (large predominance of *Bolivina seminuda* among the benthic foraminifers). Based on the chronological framework of the cores, it was suggested that the former, cooler, episode be correlated with the Little Ice Age, and the latter episode with the Warm Medieval Interval. More work is needed to characterise the distinct oceanographic regimes which may have existed in the bay in a recent past, and to identify the signature of these variations in the sedimentary record for each group of bioindicators under consideration (pelagic fishes, planctonic and benthic foraminifers, diatoms and silicoflagelates).

In spite of their preliminary character, the current studies on a time scale as short as the last millennia constitute a new line of investigation along the South-American Pacific coast. Altogether, the exceptional aridity of the bordering continent, the existence of an nearby upwelling centre, a particular geographic disposition of the embayment with respect to the dominant currents, a shallow depth, and the hypoxic conditions of the bottom, make of the bay of Mejillones a particularly suitable site for the reconstitution of some variations, at the decadal scale, of circulation patterns in the eastern Pacific Ocean and of paleoproductivity, which in turn can be related to paleoclimatic changes of the last centuries and millennia.

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# RAPID ENVIRONMENTAL CHANGES IN NEW ENGLAND COASTAL MARSHES

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Estimating the extent of anthropogenic impacts on salt-marsh ecosystems is a difficult task, because processes that affect the evolution of marshes, such as sedimentation, peat formation, and hydrology, contain a 'natural' component as well as a 'human-impact' component. In New England, the end of the Little Ice Age (ca. 1700-1800 AD) is an important 'target' for separating these components. Studies from Connecticut and Chesapeake Bay indicate that sea levels around 1700 AD were rising at rates that are comparable to present-day rates. Human interference with sedimentation patterns through coastal development and agricultural activities was still negligible in New England around 200 BP. Therefore, coastal conditions at the end of the Little Ice Age provide a benchmark against which present (disturbed) marsh environments are compared.

Examination of peats, as well as the fossil plants, foraminifera, and other organisms that the peats contain, help identify palaeo-marsh environments, their geometry and ecological relationships. One problem involved with obtaining high-resolution environmental records from marsh peats is the influence of changes in sedimentation rate. Obtaining cores from the upper 'mature' marsh, where accommodation space is largely filled, minimises this problem but recognition of plant remains in cores can be difficult and their relationship to tide levels ambiguous. Close to the landward edge of the marsh, species diversity of plants is high and plants often grow in 'mosaic' patterns. Here, assemblages of agglutinated foraminifera are very suitable as environmental indicators in addition to plants. Assemblages are clearly zoned according to elevation and few species occur, which facilitates identification. This study includes marsh foraminiferal records from sites in Maine (Machiasport, Gouldsboro, Phippsburg, Wells) and Connecticut (Clinton) as well as historical evidence of major vegetation changes in Pemaquid (Maine).

The surface distribution of foraminifera was studied along transects in all sites where fossil foraminiferal records were obtained. The relationship between foraminiferal assemblages and elevation on the modern marsh made it possible to reconstruct palaeo-elevations of the marsh surface from the foraminiferal stratigraphy. Useful elevation 'markers' are monospecific occurrences of *Trochammina macrescens* near the highest astronomical tide level, and peak abundances of *Tiphotrocha comprimata* between mean high water and mean higher high water.

Results confirm the increased rates of sea-level rise around 1700 AD in the region. This sea-level acceleration was accompanied by a landward shift of foraminiferal zones and plant zones. However, more dramatic environmental changes have occurred in the past century. In Pemaquid Beach, comparison of current marsh vegetation with a vegetation map drawn by Charles Davis in 1914 shows the complete conversion from a freshwater marsh into a salt marsh. In Wells, similar vegetation changes are evident. Freshwater marsh is being colonised by salt-marsh vegetation, while ponds are widening. Peats are subsequently eroded by meandering tidal channels, resulting in a stratigraphy of a freshwater basal peat unconformably overlain by low marsh peat or mud. A working hypothesis of our ongoing research is that the most recent changes in coastal marsh environments are caused by man's disturbance of local hydrology and/or sediments sources and pathways.

International Geological Correlation Program Project 367: ***Late Quaternary coastal records of rapid change:*** *Application to present and future conditions. IInd Annual Meeting (Antofagasta, Chile, 19-28 Nov. 1995), Abstr. vol.*

# GLOBAL AND REGIONAL FACTORS CONTROLLING CHANGES OF COASTLINES IN SOUTHERN IBERIA DURING THE HOLOCENE.

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"Global" factors such as the general sea-level rise from ca. 10,000 to ca. 7,000 yr BP, have controlled the changes in coastlines during the Holocene. Additional regional factors such as tectonics, the interchange of Atlantic and Mediterranean waters with inputs depending on climatic conditions particularly cyclonic/anticyclonic regimes, and the location along the coast of sources of sediment supply (river mouths), strongly conditioned the palaeogeographical evolution of the littoral zones during the last 7,000 yr. Detailed mapping of estuary and retreating barrier islands, sedimentological analysis and environmental interpretation of sediments in outcrop and drill cores, and $^{14}C$ dating allowed us to detect a general rise of sea level between 10,000 and 7,000 yr. BP. both in the Atlantic (Dabrio et al.,1995) and in the Mediterranean (Dupre et al,1989) coasts.

Since 7,000 yr BP. the tectonic behaviour of each particular coastal area and its location with respect to the areas of sediment input will determine if there will be progradation and/or vertical coastal aggradation, and, even more important, where and when this would take place. Uplifting areas near the river mouths are dominated by progradation that generates subaerially-exposed systems of barrier islands. We have recognised two main episodes of progradation inside these systems: the older one extended from 6,900 to 2,700 yr BP.; the younger one extended from 2,400 yr BP. to Present (Zazo et al., 1994 a,b).

Subsiding areas are dominated by vertical aggradation. The only exposed coastal units belong to the younger phase of progradation.

A prominent shift in the direction of prevailing winds both in the Atlantic and Mediterranean Spanish coasts produced reversions of longshore drift (Goy et al.,1986) and systems of coastal dunes (Borja and Diaz del Olmo,1995) suggesting a major climate change ca. 2,400 yr. BP.

Coastal progradation reached a maximum ca. 500 yr. BP. (Lario et al., in press).

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# LATE QUATERNARY SEA LEVEL FLUCTUATIONS AND NEOTECTONICS IN THE NORTHWEST COASTAL ZONE OF PORTUGAL

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The northwest coastal zone of Portugal is located between the Minho river (boundary with Spain) and the Serra da Boa Viagem-Mondego cape.

In many of its segment a fast inland beach migration and cliff retreat, with thinning of the beaches, is observed. Historical documents show that these processes were already under way at the end of the XIXth century.

Coastal engineering structures, such as groins and revetments, have tried to fight against the effects of the process. However, they have contributed to an increasing inland beach migration and cliff retreat at the dowdrift side of the structures. This evidence, on the other hand, allowed the observation in the cliffs and on the foreshore of the beaches situated downdrift of the structures, of an alternance the tidal, aeolian and lagoonal beds, and the horizons (A1 + A2 + B) of the podzol.

Radiocarbon dating and sedimentological data, particularly the sedimentary structures, made the establishement of a lithostratigraphic secession possible. The units of this sucession are as follow:

1. Maceda Beach Formation, aged of 29,000 ± 690 to 13,255 ± 685 yr BP;
2. Cortegaça Beach Formation aged of 6,050 ± 60 to 950 ± 80 yr BP;

3.1 Aguçadoura tijuca Formation, aged of 2,340 ± 90 to 420 ± 110 yr BP ;

3.2 Silvalde-Paramos tijuca Formation aged of 2,310 ± 90 to 500 ± 80 yr BP.

As the inland beach migration and cliff retreat has been observed since, at least, the end of the XIXth century, the authors conclude that the process cannot be only explained by the sea level rising related to the greenhouse effect and the reduction of the sand volume transported by the rivers. At the time, the industrialization and the fossil fuel consumption could not contribute enough to the greenhouse effect and dams did not exist in the fluvial networks of the north Portugal.

The authors show that in addition that marginal tectonic deformation must be taken into account. This deformation, active during the Pleistocene, the Holocene and presently, at least regionally and locally, contributes to the present day sea level rising.

The statigraphic sucession and the paleoenvironments, defined in the northwest coastal zone of Portugal, show that the zone is unstable. A current program of geophysical prospection has already revealed the existence of faults in the area covering the Pleistocene and Holocene Formations.

# PALYNOLOGICAL INTERPRETATION OF EARLY-HOLOCENE SUBMERGED SHORELINES ON THE CONTINENTAL SHELF, NORTHEAST QUEENSLAND, AUSTRALIA

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This paper reviews recent modern pollen studies from coastal Northeast Queensland, and present preliminary results for pollen analysis of marine sediment cores from the adjacent Continental Shelf. The modern pollen studies from a range of coastal physiographic and climatic setting provide pollen signatures for various mangrove, saltmarsh and freshwater swamp communities in the region today. These data are used for comparison with fossil pollen assemblages from marine cores, to aid in vegetational, paleoclimatic and relative sea level reconstructions for mid-to outer-shelf localities.

*Vegetational reconstructions*

The early-Holocene fossil pollen data confirm the former widespread occurrence of mangrove and saltmarsh communities on the Continental Shelf, in which *Rhizophora, Ceriops, Avicennia* and the Chenopodiaceae were prominent plant taxa. Regional vegetation was dominated by sclerophyll communities, while tropical rainforests, typical of some sections of the coast and lowlands today, were relatively rare.

*Paleoclimatic reconstructions*

The former widespread occurrence of coastal saltmarsh communities, and a more regional predominance of sclerophyll communities over rainforest, indicates low rainfail conditions on the exposed Continental Shelf during the early-Holocene, similar to drier areas of the north Queensland coast today. This complies with regional climatic records from the near-by Atherton Tableland, and is consistent with the subdued Continental Shelf topography which would not have received significant orographic rainfall, in contrast to humid, mountainous coast in the region today.

*Sea level reconstructions*

A time-depth plot for an early-Holocene relative sea level records is based on radiocarbon dating of intertidal muds identified by their pollen content. Preliminary results suggest that outer shelf sea level indicators are deeper for their age than indicators at inner shelf and modern coastal sites. Downwarping of the Continental Shelf as a response to isostatic loading since the beginning of the Last Glacial Marine Transgression may account for the discrepancy. This finding has implications for reef facies growth models at outer shelf locations, and for Holocene geomorphological reconstructions which suggest a mid-Holocene "high energy window" scenario for the North Queensland coast.

# MOLLUSKS AS INDICATORS OF PALEOCEANOGRAPHIC CHANGES IN NORTHERN CHILE

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Because of their natural abundance and easy preservation, the hard carbonate shells of mollusks are a useful source of information on former conditions prevailing in the nearshore area, at distinct time scales. Pleistocene fossils from uplifted marine terraces as well as shellfish collected by ancient populations and accumulated in archaeological shellmounds may prove to be valuable indicators on on several aspects of coastal changes. In northern Chile, some paleoceanographic interpretations based on these elements were intended in the framework of archaeological studies; in contrast, Pleistocene molluscan assemblages of the numerous marine terraces of the area had not been used to detect such paleoclimatic and paleoceanographic bioindicators.

Considering the time scale of the last decades, only a few scattered observations were made in relation with the episodical El Niño anomaly. Actually, besides a particular study performed in the area of Iquique (Marincovich, 1973), little is known about the biogeographic distribution of the present-day molluscan fauna along the northernmost 1,000 km of Chilean coast. Some progress is currently made in this direction through an extensive sampling of the northern Chile coast, involving altogether: commonly living species and fossil (Holocene and Pleistocene) material (Ortlieb et al., 1994; Ortlieb & Guzmán, 1994; Guzmán & Ortlieb, 1995). In this matter, special attention is paid to the occurrence of anomalous (extralimital) species and comparative relative abundance of faunal elements throughout the Quaternary.

*El Niño impacts and interannual oceanographic changes*

During the El Niño events of 1971-72 and 1982-83, Tomicic (1992) observed that a few species of Peruvian mollusks suddenly appeared in the northern part of San Jorge Bay (at Antofagasta). *Donax peruvianus* and *Aplysia* spp. appeared in both circumstances, while *Atrina maura, A.* cf. *A. independencia* (?) and *Pteria sterna* were observed only during the 1982-83 event. *Bursa ventricosa* was recorded by Tomicic in 1972 in the same locality. Relatively numerous samples of *B. ventricosa* shells collected as drift material on the beach of Bolsico (S of Santa María Island, 23°30' S), where the species is not registered as living nowadays, probably constitute also an evidence for some oceano-climatic anomaly that occurred in the course of the last decades or centuries. But, as noted by Tomicic, the larval and further development of extralimital species during short-term oceanographic anomalies like El Niño is possible, in northern Chile, only in a restricted number of protected embayments, like Bolsico and La Rinconada locality (23° 28' S).

*Mollusks and oceanographic changes during the Holocene*

Emerged Holocene marine deposits are scarce along the coast of northern Chile, but one such outcrop of coastal sands was found at Michilla (23°40' S). This locality, dated 7,000 BP (Leonard & Wehmiller, 1991; Ortlieb et al., in prep.) shows the occurrence of the pelecypod *Mulinia* cf. *M. edulis* which is completely absent nowadays in the area. This species which used to be the most common, and most abundant, pelecypod in many embayments of the coast of northern Chile and of the southern half of the Peruvian coast during the late Quaternary (Ortlieb et al., 1990, 1994; Díaz & Ortlieb, 1993; Ortlieb & Guzmán, 1994) is presently reported only south of the latitude of Coquimbo (30°S). We previously hypothesized that *Mulinia* cf. *M. edulis* probably disappeared (for some reason yet to establish) before the end of the Pleistocene. The recent discovery of shells of this species in a 7,000 BP deposit, i.e. during the Holocene highest stand of sea-level, shed a new light on the problem of the southward shift of the northern boundary of its distribution range: the drastic shrinking of the latitudinal range of this species (by at least 1,000 km in the Holocene, and some 3,000 km since the last interglacial) was not yet completed by the mid-Holocene. Shells of other pelecypod species (*Eurhomalea lenticularis, Venus antiqua, Choromytilus chorus*) not presently living in the area are also being found, albeit in small numbers, in Holocene (archaeological or natural) deposits.

In the archaeological site of Abtao-1 (23° 30'S), Llagostera (1979) described a progressive diminution of mussel shells (*Choromytilus chorus*) in a chronological sequence dated between 5350 and 4,000 BP. As this observation was accompanied by an increase of remains of a rather warm-water fish (*Trachurus symmetricus*), he inferred a relative warming up of the coastal waters in the mid-Holocene. In another older archaeological site (Quebrada Las Conchas, 9700-9400 BP), the presence of otoliths of several species of fish which are currently living at the latitude of southern Ecuador led the same author to interpret that definitely much warmer conditions had existed previously in Bahia San Jorge, at the very beginning of the Holocene. But, as the accompagnying molluscan fauna in the site does not point toward clearly warmer conditions (midden shells do not differ from those in the present-day nearshore area), it was envisaged that the water warming inferred from the ichtyofauna may depict short-time anomalies episodes. Through geochemical analyses on the otoliths and on penecontemporaneous mollusk shells, we shall try to determine seawater paleotemperatures prevailing in the area at ca. 9500 BP, and hope to be able to interpret whether the warmer conditions were standing (for decades/centuries) or episodical (on an interannual time scale).

*Changes of oceanographic conditions during the Pleistocene*

The comparison of the faunal composition of coastal sediments coeval with the last Pleistocene high seastands (isotopic stages 5, 7, 9, 11 and older ones) in northern Chile, particularly in the Mejillones Peninsula, shows that little variation occurred during the Middle and Late Pleistocene, at the regional scale (Ortlieb & Guzmán, 1994). Nevertheless, we recently discovered a «Thermal anomalous molluscan assemblage» (TAMA of authors), near La Rinconada (23°25' S), which is tentatively assigned a ca. 400 ka age. This « TAMA » includes a series of species which are presently living north of the latitude of Lima (12°S) or in the restricted area of Paracas (14°S) (*Trachycardium procerum, Arcopsis solida*), or even north of Sechura Bay (5° S) (*Mactra velata, Megapitaria aurantiaca, Anomia peruviana, Ostrea megodon, Bulla punctulata, Cerithium stercusmuscarum, Olivella* sp., *Turbo* cf *T. fluctuosus).* The occurrence of these warm-water species in a particular locality of the southern Mejillones Peninsula is interpreted as an evidence for regionally warmer conditions, reinforced by favourable paleogeographical factors.

With respect to the present-day living fauna, the Pleistocene mollusks of Northern Chile generally show a significantly greater species diversity. Understanding the factors that controlled this biodiversity reduction, particularly since the last interglacial, but possibly also within the Holocene, might have important implications in terms of paleoceanographioc changes.

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# DIAGENETIC-U UPTAKE BY FOSSIL MOLLUSKS: CHRONOLOGICAL IMPLICATIONS

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Live mollusk shells contain from a few ppb (e.g., land snail shells) to a few tens of ppb (marine mollusks) of U. Through diagenetic processes, from 1 to 2 orders of magnitude more uranium is incorporated into the shell, likely at the favour of the decay of its organic lining and in relation to the shell porosity, as suggested by specific U-uptake rates observed in distinct taxa from similar deposits (e.g., *Thais/Patella/Arca/ Strombus*...of modern/Holocene/last interglacial ages).

There are geological situations allowing early diagenetic U-uptake to occur (i.e., within a few hundred years), and a fast closure of the radioactive system to follow. They include (i) early cementation of the embedding sediment (e.g., beach rocks), (ii) rapid emergence under arid conditions of the fossiliferous deposits, (iii) fossilisation in reduced sediment (i.e., with minimum U mobility).

Illustrative examples of such favourable situations include, respectively (i) cemented beach rocks and terraces from Tyrrhenian and Jandian deposits (Western Mediterranea & Eastern Canary Islands), (ii) raised marine terraces from Northern arid Chile, (iii) reduced infratidal deposits (Nova Scotia), etc. In such situations, $^{230}$Th ages can be derived.

They allow the assignement of the corresponding marine units to a precise high sea level episode, at least for the last two interglacials (isotopic stages 7 and 5e/c/a). In cases when reworking of fossils from older units into younger ones is frequent, statistically significant sets of samples should be "dated" by U-Series isotopes in combination with other "dating" approaches (physical methods, amino-acid racemisation rates). The long term diagenetic evolution of U/Th systems in corals does not differ from that of mollusk shells. The only difference lie in the initial "buffer" of about 3 ppm of authigenic U present in the coral skeleton. As a consequence, minor diagenetic U fluxes through fossil corals have a lesser impact on their $^{230}$Th ages than for mollusk shells. Unfortunately corals are not abundant around most coastlines and attempts at dating mollusks must thus be made.

The long term evolution of both mollusk and coral carbonates, with respect to U-Th systematics, is comparable. Asymptotic trends are often observed, resulting either in "final" ages for fossils beyond U-Th dating range (e.g., Pliocene oysters from the Gulf of California), or in increasing excesses in $^{230}$Th and $^{234}$U over their respective parent isotope (e.g., pre-Tyrrhenian samples of Mediterranea with activity ratios $>>$ 1).

# ALLO/ISOLEUCINE (A/I) AND TH/U MEASUREMENTS IN MOLLUSK SHELLS FROM MICHILLA AND MEJILLONES BAY, NORTHERN CHILE

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Modern Holocene and Late Pleistocene deposits from Michilla (22°40'S), a site already studied by Leonard & Wehmiller [1] yielded coherent A/I, $^{14}$C-AMS and Th/U-TIMS data. They allow to define aminozones corresponding to isotopic stages (IS) 7, 5 and 1. Comparative measurements indicate almost identical racemisation rates for *Mesodesma donacium, Mulinia* cf *M. edulis* and *Protothaca thaca* with A/I ratios of ~ 0.60, 0.40 and 0.13, for IS 7, 5 and 1, respectively. The last two sets of values are in agreement with those found by Leonard & Wehmiller (1991) on *Protothaca* and *Mulinia* shells (respectively). Higher rates are observed in *Eurhomalea lenticularis* and *Crepipatella* sp. with values of ~ 0.70 and 0.25, for IS 5 and 1, respectively. In nearby sites, *M. donacium, M. edulis* and *P. thaca* yielded A/I ratios of ~0.70 for higher terraces possibly formed during IS 9. Compared to other sequences, the Michilla series of marine deposits showed much less reworking of shells from older units into younger ones. There, data also indicate fast post-depositionnal U-uptake in mollusk shells (with a marine $^{234}$U/$^{238}$U signature): a close agreement is observed between $^{230}$Th and $^{14}$C ages (~ 7 ka) in the Holocene terrace. Finally, arid conditions in the area likely resulted in a minimum U-mobility after emergence of the deposits as shown by the narrow clusters of $^{230}$Th ages obtained for the last two interglacial deposits.

In the southwestern end of the bay of Mejillones, at El Rincon (23°05'S), a site already well documented by Radtke [2], high, poorly clustered A/I ratios (> >0.8), were obtained in mollusk shells from marine terraces ranging in elevation between 12 to ~45 m above present sea level. These deposits yielded $^{230}$Th apparent ages scattered between 120 and 155 ka, and high $^{234}$U/$^{238}$U ratios (~1.2 to ~1.3) allowing to discard a marine origin for the uranium. These values indicate that the raised marine deposits of the area incorporated shells reworked from a pool of fairly old material (i.e., originally from IS 7 and older interglacials). In these shells, late diagenetic U-uptake occurred and resulted in "young" apparent $^{230}$Th ages. Similar anomalies were also observed by Radtke.

At other sites from the Antofagasta area, results falling into any of the above categories were obtained. Generally, reasonable assumptions can be made about the age of the last one or the last two interglacial terraces, although unequivocal assignment of IS 5 deposits to substage 5e or 5c is not possible, based on the available set of data.

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# TIDES IN THE NORTHEAST ATLANTIC: PAST, PRESENT AND FUTURE

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A two-dimensional tidal model of the northeast Atlantic (Flather, 1981; Andersen et al, in press) is used to simulate the M2, S2, Meu2, M4, MS4 and M6 tides for present sea level and with mean water level lowered or raised by a uniform number of metres over the model area. M2+S2 tides predict the spring tidal range, although the other constituents are needed to predict spring tides in shallow water areas (Doodson & Warburg, 1941) which existed on the northwest European shelf at lower sea levels. The accuracy of the assumptions made in modelling is assessed.

The relative amplitudes of the different tidal constituents vary depending on model water depth. Changes in the northeast Atlantic tides are relatively minor for tidal simulations with water depths 30 metres below to 5 metres above present levels. However, the situation is more complicated in the shallower waters of the northwest European shelf. Examples of the changes are given from a number of locations.

Results from the northeast Atlantic model are used to run larger scale models of Morecambe Bay (Flather & Heaps, 1975) on the west coast of Britain and The Wash (Hinton, 1992, 1995) on the east coast. The tidal changes within these embayments highlight the local nature of the variations and the importance of the scale at which modelling is carried out. Overall, the results emphasise the need for consideration of tidal range changes rather than simply mean sea level change in studies of coastal evolution. Suggestions for the way forward with tidal modelling techniques are made.

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# LATE HOLOCENE LANDSCAPE DEVELOPMENT IN THE NORTH FRISIAN TIDAL FLATS (NORTH SEA, SCHLESWIG-HOLSTEIN, GERMANY)

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The North Frisian tidal flats are situated on the North Sea coast south of the German-Danish border. In the southern part of this area the marine Holocene sedimentary succession sometimes exceeds 20 metres in thickness. It is characterized by frequent lateral and vertical lithofacies division.

Due to considerable compaction of clayey sediments during the first millennium AD the surface of the marsh was lowered. At the end of this period when the sea level had decreased, man occupied and cultivated the marsh area. In the beginning of the second millennium AD the sea level rose again. In 1362 AD a heavy storm surge flooded the whole marsh area in southern North Frisia. Large parts of the marsh could no longer be protected against the sea and became tidal flats.

This event is recorded in different ways in the sequence of layers:

- by a rapid change in the lithofacies of the deposits,
- by a layer of reworked peat (developed during the first millennium BC).

It is remarkable that the stormsurge of 1362 AD did not affect adjacent parts of the marsh in the same way.

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# RAPID COASTLINE SHIFT DURING LATE HOLOCENE AT THE MEDITERRANEAN COAST OF ANDALUCIA, SE SPAIN

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In an interdisciplinary research project between geology and archeology the stratigraphy of the Holocene sediments in the valleys of the Mediterranean coast of Andalucia was investigated. The research areas are the coastal valleys between the province of Almeria in the east and the bay of Algeciras close to Gibraltar in the west.

The results of the drillings showed a marine transgression into the valleys of this coast in early Holocene. The marine sediments in the bays south of the Sierra Nevada mountains prove a relatively constant sedimentation rate of 1 to 2 m per millenium until the end of the 15th century A.D.. After the period of Reconquista, when the catholic kings of Spain expelled the Arabs from the southern part of the Iberian peninsula, an enormous increase in the accumulation rate was caused by a deforestation of the hinterland. These sediments of the 16th and 17th century mostly have a thickness of up to 20 meters. During this time the valleys were filled up with the eroded soils of the hinterland (HOFFMANN 1988, 1995).

The enormous erosion in the late Middle ages has anthropogeneous and natural origins:
- deforestation of the hinterland during the expulsation of the Arabs by the Catholic Kings of Spain
- installation of a non-adapted agriculture particularly in the terraces of the Arabs
- increasing shipbuilding (discovery of America) and mining activities
- foundation of the "mesta" organisation of goat breeders
- little ice age with a colder and wetter climate and a higher amount of torrential rainfall.

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

Recently erosional processes are noted on all deltas and coastal plains between Almeria and Gibraltar. The origins of this coastal retreat are the following (DRESCHER & HOFFMANN 1991):
- the soils of the hinterland are nearly completely eroded. Today the soil erosion again is accelerated by modern terracing activities without any protection of the slopes.
- nearly all rivers are canalized and in their upper course have been built artificial lakes and dams to avoid catastrophes during torrential rainfalls. Hence the suspended material sedimentates in the artiificial lakes or in the Mediterranean, but not on the flood plains. In former times the erosion by the west-east directed "Gibraltar-Current" was balanced by the sediment input of the hinterland.
- the construction of harbours (Adra, Motril) also causes coastline changes

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# MORPHOLOGIC STABILITY OF SOME GERMAN SUPRATIDAL SANDS UNDER A RISING SEA LEVEL

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The North Frisian supratidal sands are located at the seaward border of the German Wadden Sea. They occupy a total area about 28 $Km^2$ and possess neither dunes nor a vegetation cover. Previous investigations have documented that the sands have been migrating landward at least since 1947. These sands have great ecological as well as coastal defense significance and as a result, were subjected to a process-response analysis.

From 1947 to 1991, the sands moved in an eastward direction over a distance ranging from 250 m in the south to 1600 m in the north. It is suggested that this movement occurred in response to a 0.49 cm/yr rise of mean high water (MHW). Consequently, 36 to 42 million $m^3$ of sediment was released from the upper beaches of the sands deposited at the surface and the spits of the sands. The increase in elevation was sufficient to balance the observed MHW-rise. Thus, most of the sediment eroded from the western side was used to raise and lengthen the sand. The actual sediment redistribution (morphodynamics) is probably controlled by overwash and spit forming processes, operating within a framework of a rising sea level and increasing storminess.

It is suggested that a direct correlation between the height of the sands and the MHW-level exists. The correlation is probably governed by the flooding frecuency.

# PLEISTOCENE AND HOLOCENE BEACHES AND ESTUARIES ALONG THE SOUTHERN BARRIER OF BUENOS AIRES, ARGENTINA

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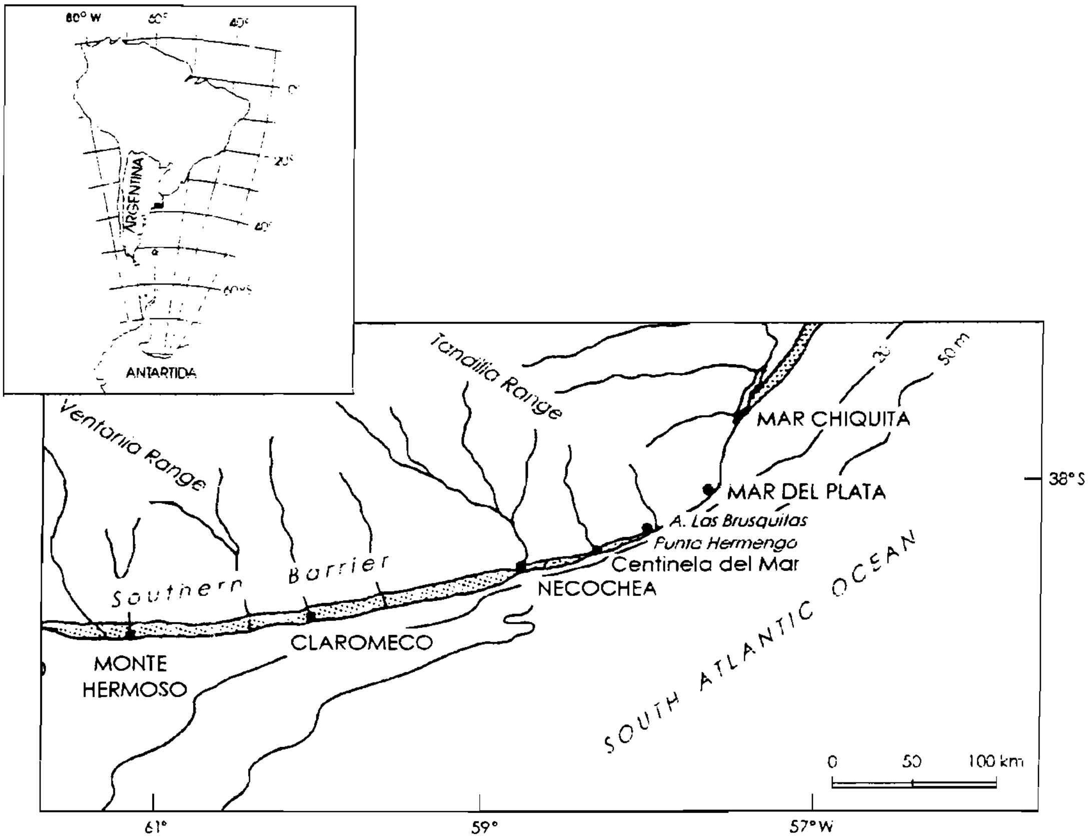
Buenos Aires aggradation plain has a good record of Quaternary sea-level fluctuations. To the east of the Tandilia Range, Pleistocene beaches elevation respond to the tectonic behaviour of the Salado Basin. Holocene beaches indicate a maximum transgression higher than 2m. The low relief permitted an extended horizontal record of beach/chenier plain interfingered with estuarine environments (coastal lagoons, marshes) covered by a sandy (Eastern) barrier.

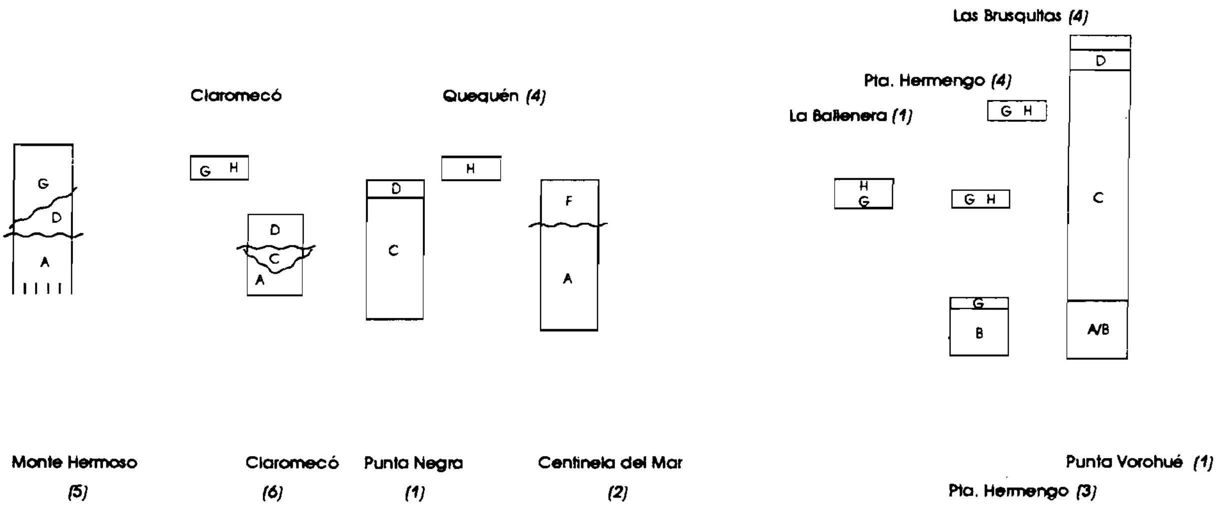
Between the Tandilia and Ventania ranges, the location of Pleistocene and Holocene beaches are related to a former higher relief; i.e.attached to low-altitude cliffs and underneath cliff-top dunes composing the Southern Barrier. At Claromecó, Pleistocene gravel beaches mostly composed of caliche pebbles occurred at heights between 4 and 7m, and overlying estuarine environments. Beaches of same age are at 10m at Mar del Plata Harbourd and Arroyo Sotelo (west of Mar Chiquita Lagoon).

Holocene beaches were recognized at Claromecó and Costa Bonita at expected altitudes (c.2-4 m) although those at Punta Mogotes are extraordinarily high (6m). Estuarines Holocene sequences are related laterally to present inlets (Las Brusquitas, La Ballenera, Quequén Grande, Claromecó, Quequén Salado). They are seldomly thicker than 2.4m, and comprised basal thicker layers of black muds; to the top, the layers are finer, of coarser grain size and white colors.

Grain-size analysis were comparatively performed to Pleistocene, mid-Holocene and Present beaches. Sangamonian beaches were gravelly or coarser than medium sand (mean). Holocene beaches were usually coarser than medium sand; but dominantly shelly to the north of Mar del Plata, and composed of volcanic clasts to the south of this city. Modern beaches are dominantly fine sand, except at some erosive beaches between the Mar del Plata capes. They have a lesser content of shells than those of mid-Holocene.

(see figure next page)

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|---|---|---|---|---|
| *HOLOCENO* | H | Platense | *(1)* | *Frenguelli, 1928* |
| | G | Lujanense | *(2)* | *Kaglievich, 1959* |
| | F | Bonaerense | *(3)* | *Tonni y Fidalgo, 1982* |
| | E | Prebonaerense | *(4)* | *Isla et.al., 1986* |
| *PLEISTOCENO* | D | Belgranense | *(5)* | *Zavala, 1993* |
| | C | Prebelgranense | *(6)* | *This paper* |
| | B | Ensenadense (loess) | | |
| *PLIOCENO* | A | Preensenadense (Montehermosense, Chapadmalalense) | | |

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# STRATIGRAPHY AND DEPOSITIONAL HISTORY OF A HOLOCENE TRANSGRESSIVE VALLEY-FILL SEQUENCE: EVIDENCE FOR A LATE HOLOCENE FLUCTUATION IN SEA-LEVEL RISE

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Over 100 cores from the Leipsic River valley (a tidal tributary of the Delaware Bay) are used to reconstruct the Holocene history of the valley-fill sequence. The ongoing Holocene marine transgression is drowning the valley resulting in a bay-ward thickening wedge of sediments. The valley-fill sequence is well preserved, as it is situated landward of the Holocene shoreface ravinement zone.

In addition to the expected general pattern of Holocene transgressive submergence, the stratigraphic sequence reveals an abrupt transgressive facies transition where subtidal muds overlie tidal wetland deposits. Radiocarbon dates place this facies transition at about 2000 years BP. Coeval facies transitions involving similar lithologies are also observed in other areas of the Delaware Bay, suggesting that this transgression is most likely caused by an acceleration in the local rate of relative sea-level rise.

In this area lithostratigraphic units are useful for defining broad classes of depositional environments but provide limited information about the salinity of paleoenvironments. Because the onset of the Holocene transgression may not necessarily be marked by a distinct lithologic contact in these environments, it is essential to use other tools to identify shifts in paleosalinity. The relative abundance of agglutinated foraminifera and arcellaceans provides a sensitive tool to identify freshwater and brackish deposits within these sediments.

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# THE MASTOGLOIA SEA TRANSGRESSION IN THE LIGHT OF SEISMIC INVESTIGATIONS

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## 1. The Mastogloia Sea Transgression.

During the considerable warming of the climate, connected with the Atlantic chronozone (climatic optimum of the Holocene), at the beginning of this period, the Baltic Sea regains gradually a convenient connection with the North Sea. At the same time the salty waters gradually penetrate through Danish straits and afterwards through the strait Darss into the proper Baltic basin.

The gradual penetration of salty waters of the North Sea into the Baltic at the beginning of the middle Holocene is connected with the transcient period existing between the Ancylus Lake and Littorina Sea. This period is called Mastogloia Sea from a diatom Mastogloia Smithii. Many scientists share the opinion, that the Mastogloia Sea is an early development stage of the Littorina Sea.

From the seismic cross-section it follows that the transgression occurred in seven at least marine subphases (Figure 1). The most rapid was the phase M-I, during which the shore line shifted at the distance of ca 2 km. During its maximum the sea-level reached 35.5 m below m.s.l. The large rate of this transgression is evidenced by the pattern of the erosional surface, which is here almost flat (Figure 1). The consecutive subphase M-I is already somewhat slower, because at that time the shore line shifts at the distance 1.5 km. During its maximum the sea-level reaches 34.0 m below m.s.l. (Figure 1).

The subsequent subphases, starting from M-III to M-VI are decidedly slower and during them the shore line shifts only at the distance of 400-500 m. During the maximum of the subphase M-VI the sea-level was at 27 m below m.s.l. The marine transgression occurring more slowly at that time is clearly reflected in the sloping erosional surface. The subphace M-VII is already much faster, the analyzed surface provides an exact evidence of this (Figure 1). It should be stated that, during the maximum of the transgression, the sea waters of the Mastogloia Sea reached the level of 18.5 m below m.s.l.

Cooling of the climate was the cause of a considerable regression of the Mastogloia Sea. In that time the sea-level fell down to 26.0 m below m.s.l. In this situation there was formed a characteristic regressive cliff which has persisted in a fragment on the present bottom of the Baltic Sea (Figure 1).

(see figure next page)

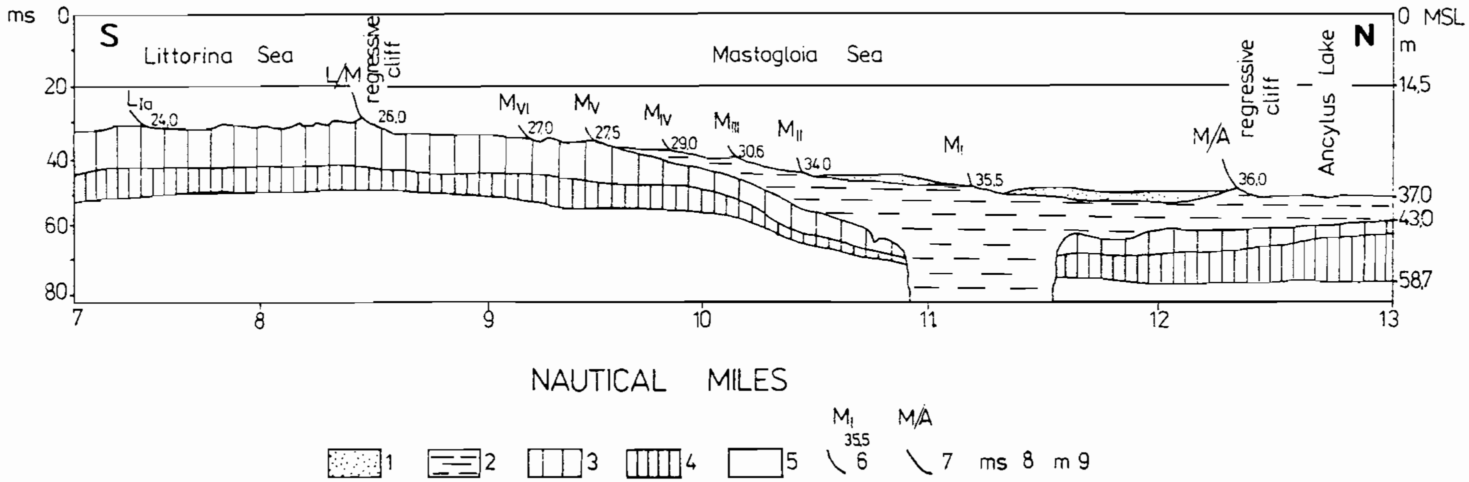


Figure1. Geological cross-section through the area of the old Mastogloia Sea.

1) sandy sediments of old shallow coastal zones (middle Holocene); (2) silt-clay sediments (Pleistocene); (3)glacial tills (Pleistocene); (4) glacial tills (older glaciations, Pleistocene); (5) substrate of the Quaternary (Tertiary or Cretaceous); (6) Mastogloia Sea cliff and maximum sea-level in phase M-I (m below m.s.l.);(7)boundary line between Ancylus Lake and Mastogloia Sea; (8) metric scale (meters).

International Geological Correlation Program Project 367: ***Late Quaternary coastal records of rapid change:*** *Application to present and future conditions. IInd Annual Meeting (Antofagasta, Chile, 19-28 Nov. 1995), Abstr. vol.*

# EARLY HOLOCENE EVOLUTION OF THE BALTIC SEA IN THE LIGHT OF SEISMIC INVESTIGATION

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## 1. Introduction.

Valuable information concerning the Quaternary in the region of the present floor of the Baltic Sea and evolution of this basin in the early and middle Holocene has been obtained from seismic-reflection data. These investigations have been carried out with the method of continuous seismic profilling, basing on EG.G system, USA produce, which author had interpreted. The results of investigations concern to the Baltic area situated near central Polish coast. Author presents the seismic cross-sections executed in Section of Geomorphology and Marine Geology of the Institute of Meteorology and Water Management (Maritime Division) in Gdynia.

## 2. Early Holocene Evolution of the Baltic Sea.

In the period of Preboreal Yoldia Sea, the Bornholm Deep and the Gdansk Deep, which were connected with the Slupsk Channel were gulfs of this marine basin. Large areas of the present bottom of the Baltic Sea adjoining the present-day Polish coast were represented by a land. According to the author the South-Middle Sandbank was an island in that time. The seismic research carried out in the region of Slupsk Channel enabbled to determine the reach of the old basin of the Yoldia Sea, the maximum sea-level and paleobathymetric conditions. The analysis of the ancient erosional surfaces led to determination of the old marine shores of this basin created in Quaternary deposits or in older substrate. In the southern part a marine cliff is clearly seen. It was formed in the Permian-Mesozoic structural complex and Tertiary sediments. Distinct erosional platform at the lower part of the cliff is here created. It is situated at the depth of 67.5 m below m.s.l. During the maximum of this transgression at the coastal zone a sandy cover, clearly visible at the northern side of the Slupsk Channel has been created. This cover of 0.5-2.0 m thickness is stretching on the distance of 2.5 km, representing in this way the ancient coastal zone of the Yoldia Sea. In that time this basin is relatively shallow here, since the depths reach only 15 m.

The glacioisostatic movements and the ancient Narke strait had caused its considerable shallowing and afterwards total isolation from the North Sea. In this situation the Baltic basin started to change gradually into a freshwater lake. This originated a new phase in the Baltic history, called the Ancylus Lake (from a snail Ancylus fluviatilis).In the period of Ancylus Lake author on base of seismic cross-section divides five distinct transgressive phases. The author in this work has marked these places on the bottom of the Baltic, within range of which the maximum sea-level and the corresponding shore line got stabilized for certain time. After some time a consecutive transgression phase destroys former shore line, and on this place there is created an erosional surface of the transgressing water basin. In this situation there have been determined phases, and in some cases even subphases of consecutive transgressions of the Baltic Sea.

The Ancylus transgression starts from the lowest part of regressive cliff of Echeneis Sea, i.e. from the value 52.5 m below m.s.l., and in the first phase A-I is very quick. In that time a large area was destroyed on the length of 9 km. During the maximum of this transgression the water level reached the value of 43.5 m below m.s.l. The next phase A-II was still relatively rapid and during that time the Ancylus Lake shifted its shoreline on the lenght of 5.5 km. During this phase the stabilization of the maximum level of the Ancylus water occurred at the depth of 41.5 m below m.s.l. The subsequent two phases A-III and A-IV are already distinctly slower. In that time the shore line shifted on the lenght of 2-3 km. During the maximum of these transgressive phases, the lake waters rose to the level of 39.5 m and 37.0 m below m.s.l. The further sequence of the Ancylus transgression is invisible on the seismic cross-section, because this area was destroyed during the consecutive development stage of the Baltic Sea. Probably there existed two more transgressive phases and during the last one the maximum level has stabilized. This level was then at the depth of 23 m below m.s.l. After certain time there occurred the Ancylus regression, very quick at the beginning time. On the seismic cross-section there is well preserved a fragment of the ancient regressive shore of the Ancylus Lake.The analysis of the structural situation proved, that the lowest water level in this basin was at the depth of 36 m below m.s.l. During the existence of the Ancylus Lake, in some places particularly connected with former shore lines, there occurs sedimentation of sandy deposits of thickness from 2-3 m.

# CYCLICAL TRANSGRESSIONS OF THE BALTIC SEA DURING THE LAST 8000 YEARS AGO

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## 1. Middle Holocene Transgressions.

A first phase (cycle) of the middle Holocene transgression is marked by the invasion of the Littorina Sea (L-I). The Littorina transgression in the region of the Baltic Sea was mainly the results of progressive and accelerated melting of the Laurentide continental ice sheet. At this time the Baltic became connected with the North Sea through the Danish Straits.

The Littorina transgressive cycle L-I (6277 - 5963 yrs.BC) is represented by the rapid rate of sea-level rise, calculated at 41.4 mm/yr.This is the highest rate of sea-level rise found in the whole of the middle and late Holocene in the Baltic region. During the maximum of this transgression the sea-level rose to 13 m below m.s.l. (Figure 1). The regression caused, that the marine waters fell down to 17 m below m.s.l. The Littorina transgressive cycle L-II (5649 - 5335 yrs.BC) is also represented by the rapid rate of sea-level rise. This rate reaches a value of 31.8 mm/yr. In the maximum of the transgression, the sea-level rose to 7 m below m.s.l. (Figure 1). During the regression, marine waters fell down to 10 m below m.s.l. The Littorina transgressive cycle L-III (5021 - 4707 yrs.BC) still belongs to the first half of the middle Holocene. In that time marine waters were rising at a rate of 17.5 mm/yr, and the sea-level rose to 4.5 m below m.s.l. (Figure 1). During the regression, marine waters fell down to 6.5 m below m.s.l. The Littorina transgressive cycle L-IV (4393 - 4079 yrs.BC) already belongs to the second half of the middle Holocene. At the maximum of the transgression, the sea-level reached 3 m below m.s.l. (Figure 1), and marine waters were rising at a rate of 11.1 mm/yr. In that time the regression caused, that the marine waters fell down to 5.0 m below m.s.l. The Littorina transgressive cycle L-V (3765 - 3451 yrs.BC) corresponds to the end of the middle Holocene. In the maximum of the transgression, the sea-level rose to 1.7 m below m.s.l. (Figure 1), and marine waters were rising at a rate of 10 mm/yr. The later regression caused a rapid retreat - a drop in water level to 4 m below m.s.l.

## 2. Late Holocene Transgressions.

In the first half of late Holocene many places of the study area occurred the terrestrial conditions on the hinterland of the coastal zone. The second half of late Holocene, corresponding to the Subatlantic chronozone, was associated with successive transgressions of the Baltic Sea. The Limnaea transgressive cycle Lm-V (625 - 311 yrs.BC) was the fastest in the second half of the late Holocene. In the the maximum of the transgression, the sea-level rose to 0.5 m below m.s.l. (Figure 1), and marine waters were rising at a rate of 4.8 mm/yr. During the regression, marine waters fell down to 1.3 m below m.s.l. The Mya transgressive cycle Ma-I (3 -317 yrs.AD) was slower than the previous cycle. In the maximum of this transgression, the sea-level rose to 0.5 m below m.s.l. (Figure 1), and marine waters reached the rate of 2.5 mm/yr. The next transgressive cycles of the Baltic Ma-II (631-945 yrs.AD), Ma-III (1259-1573 yrs.AD), Ma-IV (1887 yrs.AD-present day) were slower than the first one. In that time the rates were the following : 2.5 ; 3.5 ; 1.0 - 1.9 mm/yr.

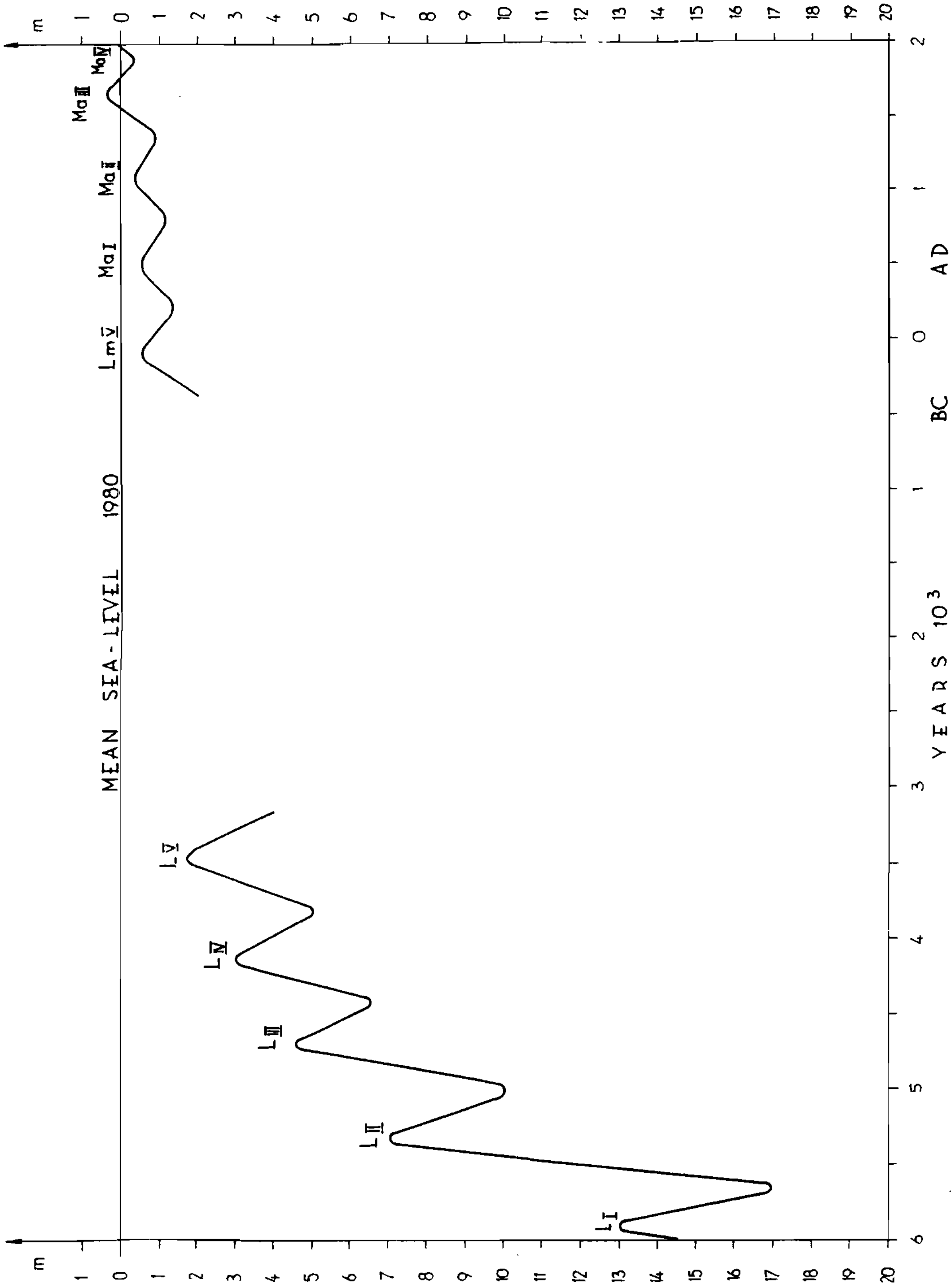


Figure 1. Middle and Late Holocene fluctuations of sea-levels of the Baltic Sea on the central Polish coast.

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# SHORELINE EROSION, CLIMATIC CHANGE AND SEALEVEL OSCILLATIONS ON ISLANDS OF THE NORTHSEA AND THE BALTIC SEA

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The development of the german schorelines of Northsea and Baltic is characterized by a strong postglacial sea-level rise until 4000 to 5000 years before present and a slow rise with oscillations in the following periods. In the present a strong oscillation is taking place.

A typical example is the development of the island of Sylt on the Northsea. In the central part of the island we find glacial moraines with cliffs, in the north and south extended spits with dunes, and in the east holocene marshlands and tidal flats. About 2000 years ago the western coast, faced to the Northsea, was situated about 3 km farther in the west. The average amount of marine erosion since then reached up to 1,5 m/year. Parts of the recent tidal flats were before 2000 years marshlands. Parts of the marshlands meanwhile are inundated and eroded. Severe changes occered in the 17th century

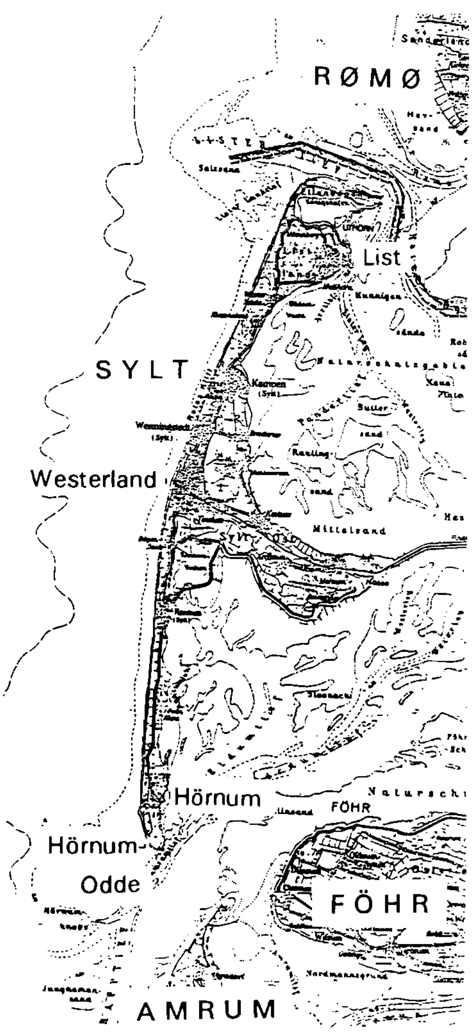
Since appoximate 1965/1970 the erosion increased again. In the last 10 years the anual expense for coastal protection exceeded 10 millions of mark. The most dramatic development is observed on the Hörnum Odde in the south of Sylt. During storms the erosion rose up to 20 m/day, and a multiple amount in the full year.

This disastrous development is caused by a complex of factors, in part of climatic origin. One factor is, that the duration and strength of storms from westerly direction increased significant, pressing the water into the German Bay, and the length of time with a rise of the sealevel of 2 m and more increased too. Another factor of importance is the enlargement of the tidal range. During 25 years the high tide level rose, according to FÜHRBÖTER & JENSEN, by 16 cm, the low tide level lowered a few cm. The energy impact to the shoreline was intensified.

In relation to these factors the importance of a sea-level rise in this part of the Northsea coast is difficult to recognize. It is to be expected, that the effect is relatively low.

Additional factors may be seen in changes in the tidal channels, and extended erosion of tidal flats, caused by the hydrogaphic changes, and in coastal protection work not adapted to the natural conditions.

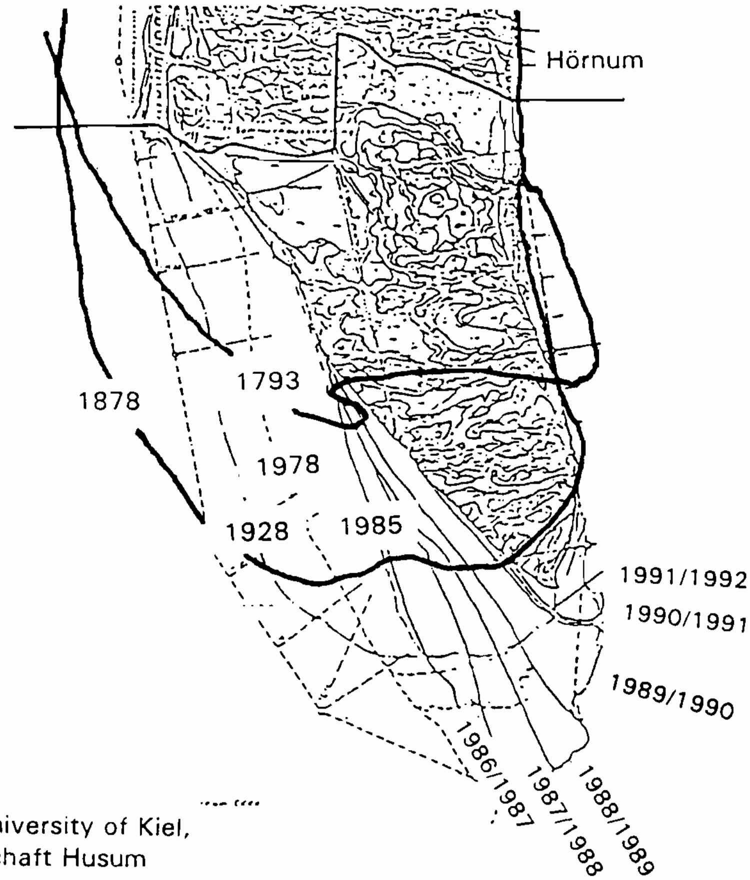
Corresponding observations are registered on the sandbars on the seawarւ border of the tidal flats. The annual eastward migration is 80 .n/year in many years. On the Shorelines of the Baltic Sea similar oscillations can be found, however, the influence of the sea-level rise is relatively higher. The consequences of the actual development are subject to intense investgation.




The island of Sylt

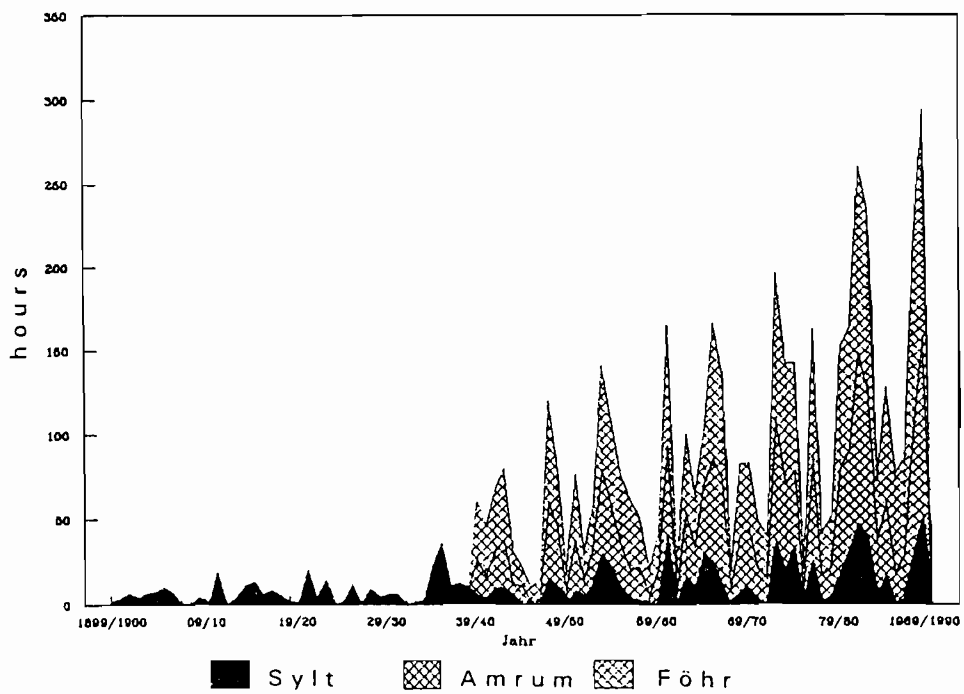
Development of
Hörnum-Odde 1793 - 1992

400m




According to
Group of Geology of Shorelines, University of Kiel,
and Amt für Land und Wasserwirtschaft Husum

Hours with
Sealevel
above + 2m
during storm



# A METHODOLOGY FOR ASSESSING THE EVOLUTION OF THE COASTAL ZONE OF THE SOUTH-WEST TAIWAN

**Jiun-Chuan LIN**

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The coastal zone of south-west Taiwan is characterised by muddy tidal plains, offshore bars, spits and lagoons, and coastal sand dunes. These geomorphic features form an essential part of the natural defenses against sea-level change and coastal and tidal processes. Recent increases in industrial and commercial activities within the coastal zone have resulted in modifications to the coastline as a result of coastal engineerig works. These works have modified the coastal and tidal regime, resulting in degradation of the natural first-line of defence against the sea and significant changes to the coastal landscape.

A methodology to quantify these changes for the area bounded by the Pei-Kang River and Tseng-Wen River in terms of landuse, sea-level change, subsidence and topographic change has been developed. The methodology utilises time-series aerial photographs, remote sensing images, geomorphological maps and field mapping and attribute data collection using global positioning system.

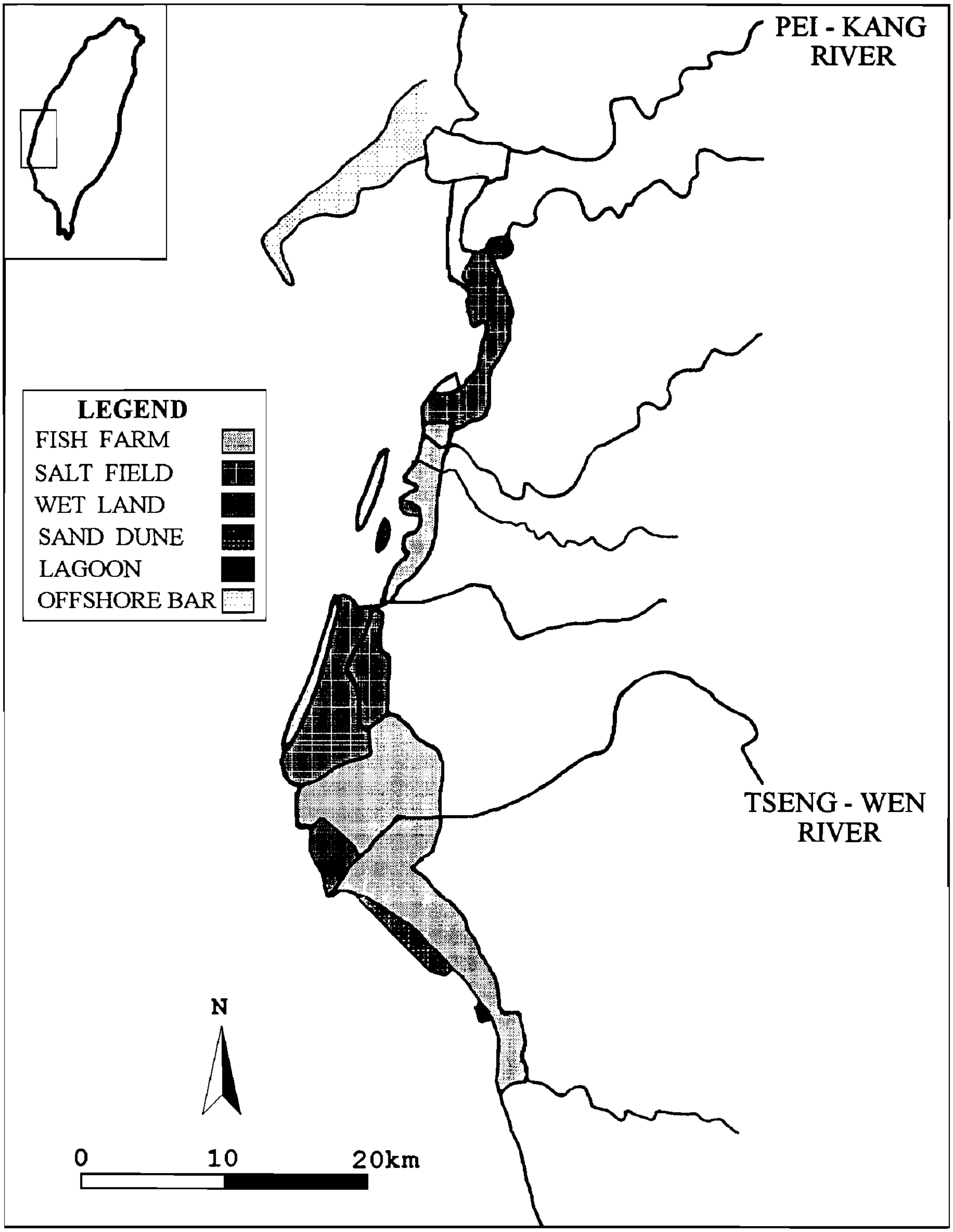
The result of this investigation demonstrate the importance of natural coastal structures in acting as a first-line of coastal defence and protection in Taiwan. Attention is drawn to:

(1) Inappropiate designed or mis-placed coastal engineering structures which may destroy or reduce the effectiveness of neighbouring natural and engineered structures leading to storm damage, flooding and encroachment by the sea;

(2) The need for a coordinated, coastal management program to regulate on-shore activities, in particular the substraction of ground water within the coastal zone. This research demonstrates the significant subsidence and in-land ground water flow of the sea water;

(3) The need for the establishment of a coastal zone information system (CZIS) for the on-line management of, and the planning and coordination of future development within the coastal zone.

(see figure next page)


PEI - KANG
RIVER
LEGEND
FISH FARM
SALT FIELD
WET LAND
SAND DUNE
LAGOON
OFFSHORE BAR
TSENG - WEN
RIVER
N
0
10
20km

# SEA-LEVEL CHANGES AND EARTHQUAKES DURING THE LAST 5000 YEARS IN WASHINGTON

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The aim of this paper is to test the evidence for the earthquake deformation cycle, which previous authors have argued has controlled coastal sedimentation in the Cascadia subduction zone of western North America. Detailed investigations of Johns River using litho, bio- and chronostratigraphic techniques has identified eight submergence events during the last 5000 years. Each of these is accompanied by a change in sedimentation which is broadly commensurate with that predicted by the earthquake deformation cycle. Estimating the magnitude of subsidence accompanying each submergence event is difficult, largely because of the lack of appropriate depositional analogues for the immediate post-earthquake environments.

Separating the relative importance of seismic versus non-seismic changes in relative sea-level is not yet possible. However, the biostratigraphic data from two of the eight organic-rich units studied suggest that non-seismic coastal processes influenced the sea-level record of Johns River until as recently as 3600 BP. No evidence for non-seismic sea-level changes are recorded in the study area since 3600 BP. The chronology of coastal evolution in the study area is dominated by negative sea-level tendencies, in contrast to that recorded on passive coastal margins in NW Europe. Whether these negative tendencies reflect periods of inter-seismic strain accumulation and land uplift is not yet clear as simple infilling of a submerged coastal landscape with estuarine and saltmarsh sediments may cause a similar stratigraphic signature.

# HISTORICAL SEISMICITY OF CHILE

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The theory of the continental derivation states the advance of the South American Continent westward, pressing and breaking the Plate of Nazca. Having this idea in mind, this work attempts to show some interesting aspects of seismicity in the national territory.

As one of the main objectives is to make people become aware of the high seismic risk in our country, only earthquakes of magnitude equal or superior to six on the Richter Scales will be analyzed. These types of earthquakes are supposed to cause, at least, great panic thus being very risky for people.

After a thorough research in files and libraries, a list containing 670 earthquakes with the above mentioned characteristics was prepared. In order to make a better analysis, these were divided into three categories.

Group I : Earthquakes of magnitude between 6 and 7 degrees Richter than usually reach an intensity VI-VII-VIII on Mercalli.
Group II: Earthquakes of magnitude between 7 and 8 degrees Richter that usually reach an intensity IX-X on Mercalli.
Group III: Earthquakes of magnitude equal or superior to 8 on Richter scale with an intensity above grade X on Mercalli.

To analyze the seismic characteristics of the different regions of the territory, the country has been divided into six zones:

| | | |
|---|---|---|
| $1^{st}$ Zone : | Arica to Quillagua | (Tarapaca) |
| $2^{nd}$ Zone : | Quillagua to Chañaral | (Antofagasta) |
| $3^{rd}$ Zona : | Chañaral to Los Vilos | ("Norte Chico") |
| $4^{th}$ Zone : | Los Vilos to Concepción | (Central Zone) |
| $5^{th}$ Zone : | Concepción to Puerto Montt | (Southern Zone) |
| $6^{th}$ Zone : | Puerto Montt to Punta Arenas | (Austral Zone) |

When a distribution was made of the 670 earthquakes into the zones and categories already mentioned, we came across the following table:

| ZONE | | GROUP I | GROUP II | GROUP III | TOTAL |
|---|---|---|---|---|---|
| I | ARICA - QUILLAGUA | 124 | 33 | 3 | 160 |
| II | QUILLAGUA - CHAÑARAL | 130 | 16 | 1 | 147 |
| III | CHAÑARAL - LOS VILOS | 123 | 24 | 3 | 150 |
| V | LOS VILOS - CONCEPCION | 94 | 9 | 5 | 198 |
| IV | CONCEPCION-PTO.MONTT | 47 | 20 | 9 | 76 |
| VI | PTO.MONTT-PTA.ARENAS | 24 | 5 | - | 29 |
| TOTAL | | 542 | 107 | 21 | 670 |

If we analyze these data, it can be concluded that starting from the Central Zone, the earthquakes diminish in quantity but they increase in intensity and magnitude, so the released energy and thus the displacement of the continent westward is, on the long range, constant.

When studying seismicity in the different zones of the country, we can observe on each of them some interesting chraracteristics that are worthwhile mentioning; the seismic gap on the First Region, the low intensity that earthquakes of great magnitude reach in Anrofagasta, the seismic crisis in the "Norte Chico", the lack of tsunamis in the Central Zone and the enormous quantity of earthquakes belonging to the third group in the Southern Zone.

Finally, an analysis of the great earthquakes, that is to say, those that have reached a magnitude equal or bigger than eight on the Richter Scale is made. We can observe in this study a certain geographic sequence of those earthquakes which demand further studies and also reinforce the existence of seismic gap in the extreme Northern Zone.

It is also wortwhile observing the time intervals that separate these catastrophes. In some cases there are coincidences that should be analyzed with greater depth in further studies.

# A FIVE-YEAR SEISMOLOGICAL MONITORING OF THE ANTOFAGASTA AREA, NORTHERN CHILE, BY A LOCAL TELEMETRIC SEISMIC NETWORK

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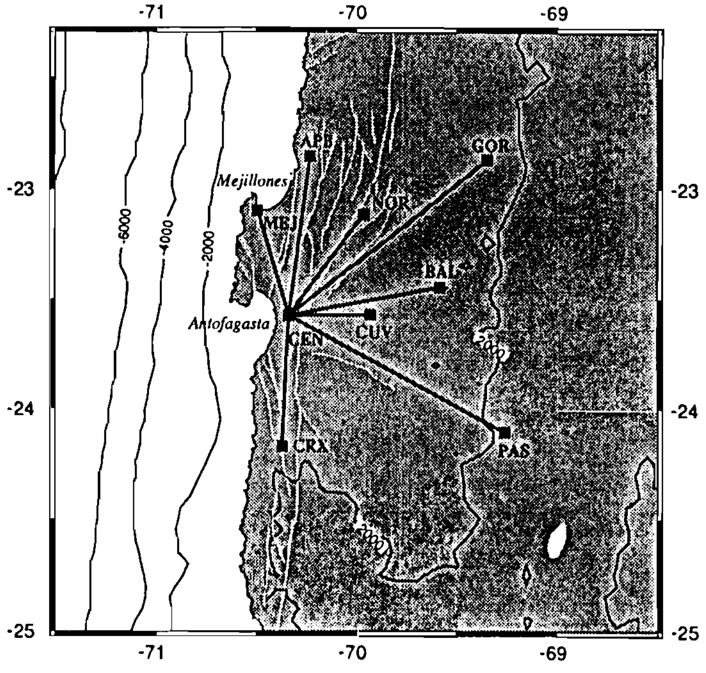
During June, 1990, The Institut de Physique du Globe of Strasbourg (France), ORSTOM (France) and the University of Chile (Chile) installed a telemetric seismic network of nine short period stations around the city of Antofagasta, in order to monitor the local microseismicity localized on the southern edge of the rupture zone of the 1877's Northern Chile earthquake of magnitude $M_w$ 8.8. Each station sends continuously by radio the movement of the ground to a data center localized in Los Morros (CEN). The triggering and recording process are performed at CEN. In addition, the seismograms are sent simultaneously by radio to another data center in Antofagasta city and recorded on a harddisk. We detect earthquakes of magnitude greater than 2. The data set of more than five years of local seismicity is complete, even before, during and after the Antofagasta earthquake of last July 30, 1995 of magnitude $M_w$ 8.1, except for some power cuts and transmission failures. On the other hand, due to the desert conditions, most of the geological features (faults, folds), differential movements (coastal uplifts) or sea level variations (tsunamis, marine terraces) have been preserved from the erosion in an unexpected satisfactory state.

Since 8000 years B.C, the coast of Northern Chile has been occupied by different autochtone ethnic groups despite its arid climate conditions and quasi no water resources. During the last century, mainly nitrate field exploitations and copper and silver mining activities caused the migration of many settlers and the development of harbors as Cobija, Iquique or Antofagasta. Nevertheless, the available historical information about the regional seismicity is scarce and are reliable only from the 1870's, as the May 10, 1877, well documented seismic event. Therefore, only a short historical seismic sequence is known and the seismic gap hazard theory poorly constrains the prediction of the occurrence of the next big earthquakes in the region. Nevertheless, it is usually admitted that the recurrence time of large seismic events is of about 111 ± 33 years and these events associated with the subduction of the Nazca plate beneath the South American plate. The 1877's Northern Chile earthquake of magnitude Mw 8.8, is the last of a set which occurred between Arica (19°S) and Mejillones Peninsula (23°S), over a distance of about 500 km. In spite of the high seismic energy liberated during the cataclysm, the main damages were produced by the tsunami wave which destroyed completely the Bolivian harbor of Cobija (22.5°S).

With the threshold used in the Antofagasta telemetric local network, between five and ten earthquakes are daily recorded. Although the network is installed mainly on the coast, events about 400 km from the coast can be detected and localized. First of all, we observe that the seismicity is continuously distributed along the slab from the trench at a depth of about 30 km to depths of about 200 km inland, corresponding to the limits of the network coverage. In addition, slightly horizontal variation of the shap of the descending Nazca plate is observed across the Mejillones peninsula and could correspond to the transition zone between the northern steep part of the slab and the southerner quasi horizontal one. If we accept that the hypocenters maps the upper part of the downgoing Nazca oceanic plate, then, the slab in the Northern Chile region dips eastward, from the trench, with an angle of about 25°. The source mechanisms of the earthquakes are, in general, similar along the Nazca plate subduction zone: thrust events at depths less than 60 km as the result of the compressional stress field and normal focal mechanisms for deeper events associated with a tensional stress regime. The compressional stress regime is due to the coupled plate interface between the tectonic plates. Around 100 km depth, a double seismic zone with normal faultings underneath compressional events has been observed.

During the five years of monitoring of the telemetric local network, neither seismicity shallower than 20 km has been detected, nor micro-earthquake pattern down to surficial faults. In the region, the Atacama fault system and the Coastal Scarp are the two dominant geological structures of Quaternary age. They are still producing controversies about the age of their last seismic activity. In the Mejillones Peninsula, Mejillones and Morro Jorgino faults, on the western side of the peninsula, are normal faults, whereas Cerro Moreno and Cerro Fortuna faults on the eastern limits, are mainly left-lateral. Along the Atacama fault system, normal and left-lateral displacement are observed. Moreover, there is no evident correlations between thrust events which occur on the seismogenic zone between the oceanic and the continental overriding plates and the fault system slips. In particular, after the large thrust Antofagasta earthquake of magnitude $M_W$ 8.1 of the July 30, 1995, which was localized underneath the Mejillones Peninsula, between Morro Jorgino and Cerro Moreno faults, no displacement has been observed on the major fault systems. Probably, because this event was not too large enough to liberate the sufficient seismic energy to trigger the faults and active them. Another possibility is, from recent times, that the subduction process and the fault activity are decoupled. However, the Antofagasta event of last July 30 produced decimetric coastal uplifts in the Mejillones Peninsula.




Antofagasta Telemetric Seismic Network: solid squares are the seismic stations. White curves are the Atacama Fault System and the Coastal Scarp. Topography and bathymetry are shown by contours at 2000 m intervals.

# LIQUEFACTION AND VARVE DISTURBANCE AS EVIDENCE OF PALEOSEISMIC EVENTS AND TSUNAMIS: THE AUTUMN 10,430 BP EVENT IN SWEDEN.

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A sudden ingression of salt water is recorded in varve -1073 (today equalling 10,430 years BP). This was taken as the onset of the Yoldia Sea stage. The varve -1073 has the character of a "drainage varve". This was originally taken as evidence of its correlation with the drainage of the Baltic Ice Lake at Billingen. The special character of this varve was explained by Morner (1981, 1985, 1995) in terms of a major seismic event (i.e. this varve is a paleo-seismite). This Spring, a series of sedimentary sections became available along the newly established railway and highway between Södertälje and Strängnäs. Two sections gave perfectly clear evidence of a high-amplitude ground shaking; i.e. a paleoseismic event. In a third section there was a beautiful sequence of glacial varves with the change between fresh-water and salt-water environment very well visible. The lower clay unit included shaken parts and the contact between the two clays was erosive in the disturbed part of the section. In the concordant part, it was possible to count the varves carefully. In the disturbed part, the summer unit of the first slat-water varve was missing. This enable us to give an exraordinarily precise dating of the earthquake. It occurred 10,430 years BP in the Autumn. In a fourth section, there was a fault of 6-8 m through-height with melted silica, foliated rock, carbonate precipitation and unconsolidated fracture zone material.

In total, this earthquake affected such a large area that it seems reasonable to count with a corresponding magnitude of 8 on the Richter-scale. It must have set up a huge tsunami-wave that washed the Narke Straight free of ice-bergs and pack-ice so that the marine water could suddenly invade the entire Baltic basin within one year (varve -1073 = year 10,430 BP).

The Swedish glacial varves quite often show outstanding examples of seismically disturbed (shaken and liquefied) sediments. Several events have been identified (Table 1). Ir the Stockholm area, it has also been possible to identify a sequence of events with a spacing of only about 20 years.

Hence the varve chronology may provide us with information about the exact age, the areal size of deformation and the recurrence time of multiple events (Table 1; Stockholm 1-3).

(see Table 1 on the reverse)

Table 1. **Some paleoseismic events in Sweden**

| age | magnitude | name |
|---|---|---|
| ~ 12,000 | 6 - 7 | Äspö (subglacial) |
| 11,700 | 7+ | Kinnarumma |
| 10,469 | 6 - 7 | Stockholm-1 |
| 10,447 | 6 - 7 | Stockholm-2 |
| autumn 10,430 | 8+ | Mariefred-1Stockholm-3 |
| ~ 10,400 | 6 - 7 | Billingen |
| 9,663 | 7 - 8 | Iggesund |
| 9,287 | 6 - 7 | Sundsval |
| ~ 9,150 | 8+ | Lansjärv |
| ~ 9,000 | 8+ | Pärve |
| ~ 8,500 | 7? | Storuman (not yet confirmed) |
| ~ 3,700 | 6 - 7 | Mariefred-2 |
| ~ 1,000 | 6 - 7 | Torekov (not yet confirmed) |

**... and some large historical events**

| | | |
|---|---|---|
| AD 1497 | ~ 4.8 | Vänern |
| AD 1759 | ~ 5,3 | Skagerack-Bohuslän |
| AD 1904 | ~ 5,4 - 6.0 | Bohuslän-Skagerack |

International Geological Correlation Program Project 367: *Late Quaternary coastal records of rapid change: Application to present and future conditions. IInd Annual Meeting (Antofagasta, Chile, 19-28 Nov. 1995), Abstr. vol.*

# RAPID EVENTS IN LATE QUATERNARY COASTAL EVOLUTION AN AUSTRALIAN PERSPECTIVE

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Several geologic and geomorphologic attributes have rendered the distinctive character of the Australian coastline, and its record of Quaternary coastal evolution. Situated within a tectonic plate and remote from active plate boundaries, Australia has experienced minimal Quaternary volcanism, apart from the hotspot centres in southeastern Australia. Similarly, few coastal areas are characterised by dramatic uplift as documented for plate boundaries, but in places, evidence for neotectonic activity can be confidently distinguished from smaller scale, hydro-isostatic feedback effects (e.g. Coorong coastal plain in South Australia and Tasmania). The extensive network of internal drainage, low topographic relief and extensive aridity ensures that few rivers debouch to the open ocean. Historically, this has assisted the development of extensive successions of Neogene-Quaternary, temperate carbonates in southern Australia and prevented the formation of deltas. Despite these characteristics, Australia displays considerable diversity in Quaternary coastal evolution. Evidence for rapid events in the Quaternary evolution of the Australian coastline is apparent over contrasting temporal and spatial scales. The significance of different coastal processes and events, and their preservation potential in the geomorphologic and stratigraphic record is scale-dependent and directly related to their frequency and magnitude. At the longer interval scale, recent advances include clearer definition of the timing of the last interglacial maximum (oxygen isotope substage 5e; ~133 to 116 ka) based on TIMS uranium-series disequilibrium dating of corals from the Abrolhos Islands, Western Australia, as well as modelling glacio-hydro-isostatic variations in the Late Pleistocene and Holocene sea surface from a range of coastal settings. At the intermediate timescale, the pattern of sea-level fluctuations following the culmination of the marine transgression (~7 ka) which immediately followed the last glaciation (Stage 2), is beginning to be resolved both spatially and temporally with greater clarity. Evidence for shorter-term, but higher magnitude events such as Holocene and Late Pleistocene tsunami, have also been documented from several sites along the southern New South Wales coastline, but whether some of these features are in fact, the product of high-intensity storms at a magnitudes not previously witnessed by humans requires further scrutiny.

# POTENTIAL TSUNAMI EFFECTS IN LA SERENA AREA NORTH-CENTRAL CHILE

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The potential menace of a tsunami in the area of Coquimbo Bay arises from the 37 phenomena registered since 1572. This situation generates conditions of risk and hazard for the numerous localities and touristic facilities on the coast of the bay, the tendency of which is to increase in number. This potential growth is associated to conurbation phenomena between La Serena and Coquimbo as a consequence of a growing touristic development.

The methods used consisted in the application of the tsunami intensity analysis: Magnitude of the Seismic Generator, Tsunami in Function of the 100 m Isobath, Maximum Tsunami related with Slope and Tsunami in Function of the Prevention System Applied in Hawai. Information about the natural and socio-economic elements in the area was correlated to the specific methods of analysis (cartographically) which generated the delimitations of risk and hazard units.

In this way, Coquimbo Bay is characterized as having an important human population, living under a potential tsunami menace. 11,726 people live within the boundaries of 2674 hectares. 16,950 live permanently in this area and 4,776 add to them during the summer season. The hectares in hazard are 359 and those in risky conditions are 2,268.

Finally, for this specific area of study, the criterion recommended to define anti-tsunami safety areas corresponds to the results of the method applied in Hawai, whose results coincide with the surface established in the historical frequency analysis of this bay. The application of this methods revealed that the potentially affected surface covers an area of 2,248 hectares, though the results achieved by the isobath method covers a larger surface (2,262 hectares). This is an important antecedent at the moment of analyzing the prevention model to use in the planification measures.

# COSEISMIC COASTAL UPLIFT DURING THE 1995 ANTOFAGASTA EARTHQUAKE

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The $M_s$ 7.3 Antofagasta earthquake which occurred on July 30, 1995 is the largest of the century in northern Chile. The local permanent seismological network (ORSTOM/ I.P.G-Strasbourg/ Univ. de Chile) located the event at 23°26.7'S, 70°28.6'W and at a depth of 36 km. According to the calculated seismic moment (Mw 8.1) and the distribution of the aftershocks, the rupture zone extended in an area of approximately 160 (or 180) km by 70 km, between Mejillones and Paposo.

Evidence of superficial deformation was rather limited, considering the magnitude of the event. A quick but careful search for reactivation of faulting activity along the numerous recent fault scarps known in the area, including the Mejillones Peninsula, the Atacama Fault Zone, and the coastal strip between El Cobre and Paposo did not reveal any significant motion related to the earthquake. The most evident manifestations of the co-seismic deformation were limited to gravity slides which occurred along the unstable coastal cliffs of the northern end of Antofagasta bay or of Caleta Herradura de Mejillones, and caving-in of loose ground (road embankment, in-fills in the quays of Antofagasta). The only small open fractures which were observed in the field were located atop the coastal cliffs, and are related to the gravity sliding of large blocks downcliff. Near Blanco Encalada (24°20'S) were noted some circular structures (diameter of several tens of metres) formed in stabilised dunes at the foot of the Coastal Scarp that indicate some packing down phenomena.

GPS measurements performed a few weeks after the quake, on the southern part of a large scale network set in 1991-92, suggest superficial horizontal motions of the order of 1 metre (mainly westwards extension) and positive relative uplift motions of the coastal area with respect to the foot of the Andes Cordillera (by an amount of as much as 0,5 m) (see Ruegg et al. this volume).

Along the coastline was found a bio-indicator of the vertical uplift motions that provides an apparently precise record of the deformation at a much smaller scale than GPS monitoring. The indicator was a conspicuous white fringe, of variable width, observed at low tide in rocky coastal sectors of the bay of Antofagasta, the western Mejillones Peninsula and the area between El Cobre (24°15' S) and Paposo (25° S). The fringe that appeared after the quake was a belt of dead « lithothamnium », a crustose corallinaceae (calcareous « red » algae, or Rhodophyta). These common algae, of pink colour, are found in the upper part of the infralittoral zone, on bedrock as well as on boulders and cobbles, in areas normally exposed to the waves. The limit of the lithothamnium crust is well defined as the line below which no drying-up occurs at low tide. In the Antofagasta area, where the mean tidal range is of about one metre, the upper limit of the lithothamnium crust lies at some 20 cm above the mean (monthly) lower low water. The whitening of the algae was produced by desiccation and exposure to natural radiation. In localities not exposed to strong waves and splash, the white fringe was fairly horizontal. Its width corresponded to the area which had suffered desiccation (and subsequent exposure to UV radiation), even during a short lapse (a few minutes?) at low tide, during the days/weeks which followed the earthquake.

The survey of the distribution and width of the white fringe of lithothamnium was performed in August and September 1995 (necessarily at low tide). The variation of width of the algal fringe provided an exceptional indication of the amount of uplift in all the localities monitored (Figure). The measurements thus showed that :

- the southwesternmost part of the Mejillones registered the strongest uplift motions (max. 40 cm),
- the eastern shores of the bay of Antofagasta experienced very little uplift (a few cm),
- in the south-eastern bay of Antofagasta, at Coloso, a localised uplift (25 cm) might be related to some fault reactivation,
- between Paposo and El Cobre, only one locality registered a positive vertical motion (12 cm) (Figure)
- no vertical motions were recorded in the northern Mejillones Peninsula.

Three months after the quake (late october), the white fringe vanished away. A photographic control indicates that the upper limit of the living lithothamnium fringe has not moved with respect to its post-seismic position: no subsidence has occurred yet. Nevertheless, it is expected that some vertical motions will occur at least locally. At Coloso, the present +6 m elevation of the marine terrace formed during the last interglacial maximum (120,000 y ago) suggests that in this locality no significant uplift has occurred at the time scale of the Late Quaternary.

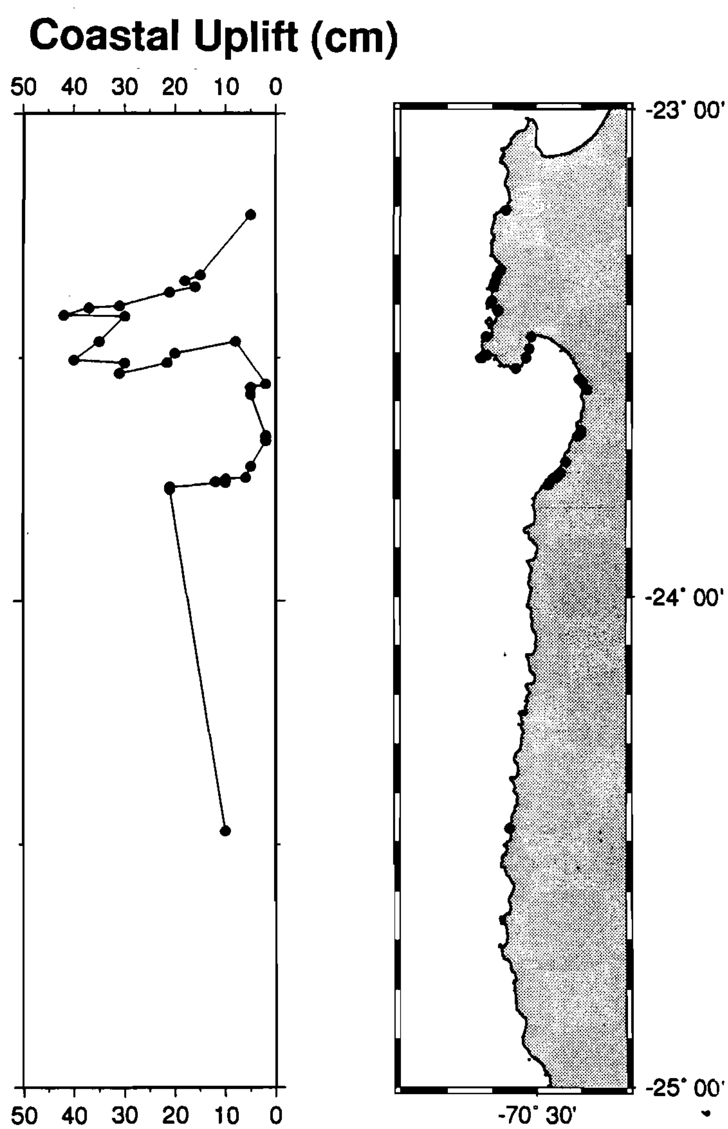


Figure: Coseismic uplift motion of the July 30, 1995 Antofagasta earthquake as recorded in the intertidal zone, along the coast of northern Chile, between 23and 25°S. The width of a dead lithothamnium fringe is interpreted as a proxy of the coastal vertical motion (left plot); monitored localities are indicated on the sketch map.

# QUATERNARY COASTAL EVOLUTION OF THE HORNITOS AREA (NORTHERN CHILE) IN THE LAST 300,000 YEARS: NEOTECTONIC INTERPRETATIONS.

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The Hornitos area (22° 54' S), with its sequence of well-developed staircased marine terraces, is becoming a classical locality for the study of the marine Quaternary in northern Chile. Herm (1969) correlated the three conspicuous terraces of the area with the Serena I, Serena II, and Herradura I terraces identified in the Coquimbo-La Serena region. Radtke (1985, 1989) obtained the first geochronological results through ESR and U-series dating and suggested that the youngest Pleistocene terrace was of last interglacial age, while the two older terraces could be assigned to the Middle and/or Early Pleistocene. More recently, a detailed chrono- and morphostratigraphical study was undertaken at Hornitos, because the area offers a favourable geomorphological setting and because it is located on the northern reaches of the bay of Mejillones, thus making possible lateral correlations with the extensive beach-ridge sequence of Pampa Mejillones. In a preliminary report (Ortlieb et al., 1994), which included some aminoacid racemisation and a few U-series results (through $\alpha$-spectrometry), we inferred that the lowest, most conspicuous, marine terrace at Hormitos, was probably of substage 5e age, the second more elevated one of isotopic stage 7, and the highest elevated terrace was possibly of isotopic stage 9 age. In that previous paper we hypothesized that immediately south of Hornitos (Chacaya), some low-lying marine terraces may be related to one or two younger Late Pleistocene high seastands corresponding to Isotopic Substages 5c and/or 5a.

The detailed morphostratigraphic study of the area between Punta Yayes and Chacaya, combined with photogeologic mapping as well as with 15 U-series measurements and some 115 amino-acid racemisation analyses, resulted in a more refined interpretation of the chronology of marine deposits associated with the last episodes of high sea-level stand. In most cases, the analytical results are internally consistent and coherent with the morphostratigraphic interpretation.

Despite frequent reworking from higher and older fossiliferous deposits, allo/isoleucine measurements (A/I) in *Mulinia edulis*, *Mesodesma donacium* and *Protothaca thaca* shells, data available from the Hornitos area suggest the following aminostratigraphic interpretations: clusters of A/I values of 0.36/0.42 would correspond to Isotopic Substage (IS) 5c, 0.49-0.51 to IS 5e, 0,61-65 to IS 7, 0,69-73 to IS 9, and 0,80 to IS 11. This regional aminostratigraphic scale is consistent with previous results we obtained in southern Peru (Ortlieb & Macharé, 1990, Ortlieb et al., 1992, 1996), but differs from the aminostratigraphic interpretation of Hsu et al. (1989) for northern Chile and southern Peru.

Mollusk shell samples from the outer edge of the lowest Pleistocene terrace (top of the Holocene seacliff, at +18/+25 m asl) were dated between 103 and 109 ka (5 apparent ages calculated from TIMS analyses). In several cases (albeit not all) where the TIMS U-series results point to younger than 125 ka ages, morphostratigraphic and A/I data also suggest a younger than IS-5e age (as the highest sestand of the last interglacial). In one locality, also from the lower terrace (Punta Yayes), mollusks provided U-series apparent ages of 116/124 ka and A/I ratios of 0.50: this locality is assigned an IS 5e age. Actually, geological and morphostratigraphic evidence indicate that the lowest marine terrace at Hornitos did register at least two sea level fluctuations. In spite of its flat surface (due to the latest Quaternary alluvial cover), the first terrace of Hornitos recorded two late Pleistocene high seastands, that we propose to correlate with IS 5c and 5e. The +36 m elevation of the inner edge of the low terrace, which records the IS 5e highest stand of sea level, provides a mean uplift rate estimate of 240 mm/$10^3$ y (if it is assumed that the paleo-sea level was a few m above present datum). The remnants of the IS 5c high sea stand, found at up to +25 m, indicate that, if the regional uplift rate remained constant through time, the paleo-sea level would have been close to the present datum (and not as much as 10 m below, for instance).

The second higher marine terrace at Hornitos is the least developed of the three. It is much narrower than the other two and disappears in the northern part of the bay. Its maximum elevation varies between +50 and +63 m to the east and north-east of Hornitos (but is higher elevated to the south of Hornitos). Two episodes of high seastand were locally observed within the sedimentary cover of the terrace. Some A/I results and a single U-series apparent age support the morphostratigraphic interpretation of an IS 7 (7a and 7c) age.

The third higher terrace is very wide, particularly east of Hornitos. Its inner edge, hidden by the alluvial fans formed at the foot of the Coastal Cordillera, is at a higher elevation than +80 m. Numerous quebrada cuts perpendicular to the coast show that the thin sedimentary cover of this flat terrace consists in a series of prograding units of coarse beach deposits set in offlap. A close cluster of A/I results (mean values: *P. thaca*= 0.73; *M. edulis*= 0.71; *M. donacium*= 0.69; *Venus antiqua*= 0.70) strongly suggests an assignment of the IS 9 (ca. 330 ka) to this locality (+75 m elevation). The A/I results support a lateral correlation with the deposits associated with the marine abrasion surface which cuts the Pliocene substrate at the northern end of Antofagasta Bay (La Portada), where apparent U-series ages of 280-290 ka were obtained. Furthermore, the lack of warm-water species in the molluscan fauna of the third terrace of Hornitos also supports a tentative assignment of these deposits to the marine transgression that predated the IS 11 (identified by the occurrence of *Trachycardium procerum* shells in Mejillones peninsula, Guzmán et al., 1995; Ortlieb et al., in prep.).

East of Chacaya, a narrow outcrop of coastal deposit, at an +100 m elevation,is interpreted as older than the third terrace of Hornitos. The oldest remnant of Pleistocene marine transgression indentified in the area, was observed at a +170 m elevation due east of Punta Yayes.

The chronostratigraphic interpretation of the remnants of marine terraces in the Hornitos area suggests a relatively continuous uplift motion during the last 300,000 y, with a mean value of the order of 240 mm/$10^3$y (at least immediately east of Hornitos). Nevertheless some tectonic motions did occur since the end of the Middle Pleistocene in the region. Two fault systems oriented N120-140° and N20-30°, and a few N-S trending faults, were mildly reactivated, both north and south of Hornitos (Pta Yayes and Pta Chacaya). Two tectonic blocks can thus be distinguished: one in Caleta Yayes-Hornitos, and another one in Caleta Chacaya. The attitude of the Pleistocene shorelines in the whole study area points to a small-amplitude tilt, toward the south, of each block (except may be during the IS 7 period). The tilt motions of the faulted blocks are interpreted as minor readjustments linked to the active deformation which has been occurring in the half-graben of northern Mejillones Peninsula, for the last several hundred thousand years.

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# TYPHOON (STORM SURGE) DEPOSITS IN A COASTAL ZONE, WESTERN COAST (YELLOW SEA) OF KOREA

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Most of coastal zone along the western coast (Yellow Sea) of Korea is fronted by broad intertidial sand and mudflats which have been deposited in a high-tide-range (more than 4.5 m tidal range in average) environment that is subjected periodically to strong summer-season typhoon and winter-season surge.

Observations on the oyster shell bed with more than 47 cm thickness developed in the Gaipri rocky Point, Mooan-Gun, west coast of Korea find a sharp boundary between the oyster shell bed and underlying soil bed (granitic soil profil A and B). This boundary between oyster shell bed and granitic soils is 820 cm high above the mean spring tide level, and faces due west in geographic orientation, suggesting eastward migrating typhoon from the center of the Yellow Sea. The isotope carbon 14 ($^{14}C$) age of oyster shell is 3610 ± 70 yr BP.

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# A TECTONIC PAROXYSM IN THE EASTERN MEDITERRANEAN DURING HISTORICAL TIMES

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**Abstract.** After a discussion of some criteria which enable coastal indicators of rapid (coseismic) vertical movement to be identified and distinguished from evidence of more gradual relative sea-level changes, significant marks of rapid vertical movements are discussed in several coastal areas of the eastern Mediterranean. These include geomorphological, petrological, marine, archaeological and radiometric evidence. Most coastal sectors which show evidence of Holocene coseismic uplift in Greece and the Eastern Mediterranean were raised during a short period called here the Early Byzantine tectonic paroxysm (EBTP) between the middle of the fourth and the middle of the sixth century A.D. The areas uplifted at that time include Cephalonia and Zante in the Ionian Islands, Lechaion and the Perachora Peninsula in the Gulf of Corinth, the Pelion coast of Thessaly, Antikythira and the whole of western Crete, a coastal sector near Alanya in southern Turkey, and the entire Levant coast from Hatay (Turkey) to Syria and the Lebanon. The amount of the EBTP uplift was generally between 0.5 m and 1.0 m but reached a maximum of about 9 m in southwestern Crete. In several areas (Zante, Pelion coast, Antikythira, western Crete, Alanya), the EBTP uplifted shoreline is the only evidence of Holocene emergence. In other areas, however, a similar uplift occurred earlier in the Holocene (Levant coast), or more recently (Cephalonia). Evidence of preseismic subsidence prior to the EBTP uplift has been reported from Thessaly, Antikythira, and Crete; in both the latter islands, the EBTP uplift was preceded by a series of about 10 coseismic small subsidence movements, each measuring some tens of centimeters, which took place in the preceding 3000 years. No evidence was observed of postseismic vertical displacements.

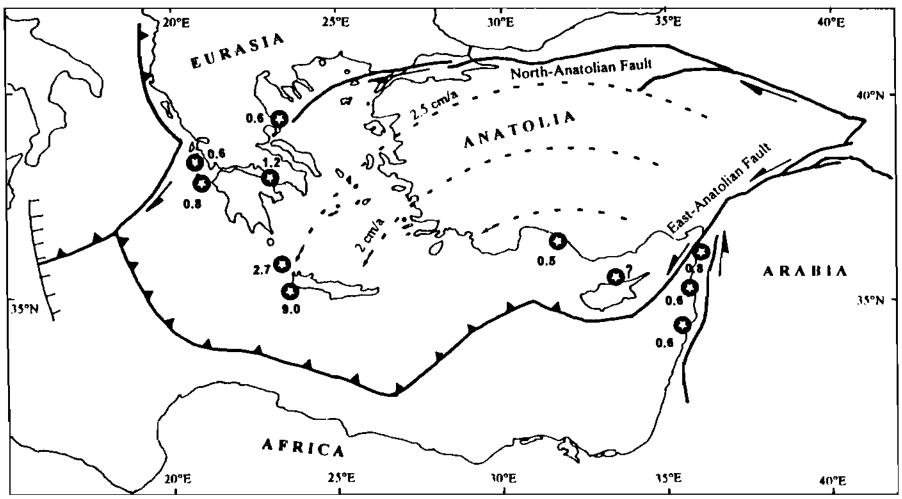


**Figure:** Sketch of plate boundaries and motions in the eastern Mediterranean area. Stars: radiocarbon-dated shorelines uplifted during the EBTP and amounts of uplift in metres. Dotted line: active subduction trench, (according to *Le Pichon and Angelier, 1979)*. The edge of the Mediterranean Ridge accretionary wedge is identified as a solid line with triangles. Dashed lines correspond to the rigid rotation best fitting the Anatolian extrusion (according to *Le Pichon et al, 1995)*.

# GEOCHRONOLOGY OF THE PLEISTOCENE REEFS OF KIKAI-JIMA (RYUKYU ISLANDS, JAPAN)

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Kikai-jima (28°19'N, 129°59'E) is located in the northern part of the Ryukyu or Nansei Islands and is the nearest island to Ryukyu Trench in the east of the island chain. Its Quaternary limestones uncomformably lie on the Shimariji Group, which is of Late Miocene to Early Pleistocene age. The Shimariji Group began to fold in the Latest Pliocene to Early Pleistocene. Quaternary Terraces are formed of raised coral reefs as a veneer on the bedrock. This Ryukyu Groups is widely distributed in the Ryukyu Island Arc and consists of Pleistocene coral reef limestone and associated terrigenous deposits. On Kikai this group can be subdivided in a Lower and Upper Subgroup. The Lower Group was probably deposited at 600,000 to 800,000 yrs in the Lower Middle Pleistocene (IKEDA et al. 1991). The Upper Subgroup was correlated with warm periods of the oxygen isotope stage 7 and 5(e), the substages 5a and 5c (up to 185 and 195 m a.s.l.) as well as two interstadial of stage 3 (40,000 and 50-65,000 yrs, up to 30 and 50 m a.s.l.) (KONISHI et al. 1974, KOBA et al.1985, OMURA 1984,1988). Samples of the 5e stage were found on the highest terrace up to 224 m a.s.l. which indicate a strong uplift of Kikai-jima.

Nevertheless, some doubts on the age of the reef tracts and the calculation of paleo sea-levels remain. A reexamination of some localities and new dating results (Th/U (16) and ESR (35)) support the doubts that Kikai-jima is not an ideal tool for establishing paleo sea-levels.

# SEISMIC ACTIVITY AND ICE-PUSH ACTION ON THE SEASHORES OF THE EASTERN BALTIC

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More than 40 earthquakes have been recorded in the present Baltic republics since 1670. In 1670, 1827, 1877, 1881 and 1976 their intensity reached 5 - 6 on the MSK-64 scale in the northern part of the area. Rather powerful was the Osmussaar earthquake (magnitude M = 4.7 in the epicentre) on October 25, 1976. Concentration of epicentres to the western and northern parts of Estonia shows that these areas are tectonically most active, however, the location of epicentres is not always clear. The epicentre of the Osmussaar earthquake was supposed to be related to a fault zone running from the Central Baltic via the Island of Hiiumaa to the coast of Finland.

The earthquakes have caused remarkable changes in cliffed coasts, connected with the North-Estonian (Ordovician) and West-Estonian (Silurian ) up to 56 m high escarpments. Particularly large accumulations of fallen limestone blocks occurred in 1976 in front of the deeply dipping escarpments in Osmussaar Island. Cornices, wave-cut notches and vertical tectonic joints in the bedrock facilitate the downfall of huge blocks onto the shore where they later on for decades protect the cliff from abrasion and affect the longshore drift of sediments.

The formation of shorelines was also highly predetermined by the tectonic and glaciotectonic uplift of the earth's crust, particularly in the north-western part of the territory, which after the retreat of the last glaciers rose to a height of more than 70 m above the contemporary sea level. Owing to the uplift, well preserved coastal forms in Estonia occur at more than 20 levels.

Rapid changes on the beaches are also due to the ice-push action. Ridges of pressure ice up to 10-15 m high generated by persistent unidirectional winds and pushed forward against the shore with enormous force play a great role in shaping the shore and transporting of huge erratic boulders (up to 930 $m^3$ in volume and 58 m in perimetre) in the coastal area. Ice-push is at its greatest on the shores with an abundance of loose material, e.g. on sandy beaches at Pärnu where under the compressing and ploughing influence of the ice deep furrows are often formed on the beach and coastal slope. On till shores furrows frequently occur behind the blocks moved by the thrust of expanding ice. Occasionally, stone walls tens of metres long and blocks several metres in diameter are encountered. Often they are in front of the scarps, defending the latter from the later erosion. However, also sea ice itself protects the beaches from erosion, which in milder, ice-free winters is much more intensive. But, at the same time, the up-pressured sea ice can cause extremely rapid changes in the coastal area, which are locally comparable with the results of earthquakes.

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# HOLOCENE SEA LEVEL VARIATIONS AND GEOMORPHOLOGICAL RESPONSE : AN EXEMPLE IN NORTHERN BRITTANY (FRANCE)

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In northern Brittany (French coast of the western part of the English Channel) the Holocene period is caracterized by an almost constant sea level rise. The only regression period took place between 3000 and 2500 BP. The geomorphological reponse to this sea level rise is highly variable in space. In Baie du Mont Saint Michel the coast line migrated sea ward. In Saint Malo some dune systems have build up in situ without any lateral movement. Some other sites on the coast line show a landward displacement.

In a small exposed bay, The Anse du Verger (between Saint Malo and Mont Saint Michel) a marsh is enclosed behind a dune system which has been piling up in situ for the last 4000 years (Regnauld et al, 1995). This dune is fed from the eroded material of a cliff, located updrift. In order to reconstruct the entire Holocene history of this peculiar geomorphological system thirty five cores (and two at sea) have been made, together with cross sections, E.D.M., field and laboratory works.

In the western part of this site prehistoric artifacts have been found in cross section (in the dune) and dated. The sudden abandon of the settlement is due to a high and single storm surge, with wash overs covering the former cooking relicts and fires. It is dated from after 2460 (conventional BP). In the eastern part of the site the cores go down to eight meters and to 10320 (uncalibrated BP). The rocky basement topography of the site may be constructed and put into a E.D.M. It is attributed to a late glacial event, during which the migmatites were reduced to clasts and moved down slope. The Holocene displays successive sequences of peat growing, marsh extension, silt accumulation, with occasional sand lenses. Some of them may be correlated to storm surges (mid Holocene period), others are not and their interpretation is still questionable. After 3000 BP occasional floods are more common and the filling of the marsh is well correlated with the chronology of dune building. A large part of the sediment is furnished by the cliff retreat, but no precise chronology of this retreat have been established.

From old maps air photos (the first before WW2) the present (meso scale) evolution of the site has been studied. It was mainly retreating because of human activities and sand extractions until the 80, when it was first protected. Since then accumulation is dominant. At last field work was done during storms in order to understand the micro scale evolution.

A comparison is attempted between the accumulation/retreat rates which are obtained out of Holocene (macro scale), 100 years (meso scale) and 3 days (micro scale) data. This set of information is used to better understand the present day response, and its variability, to the observed sea level rise.

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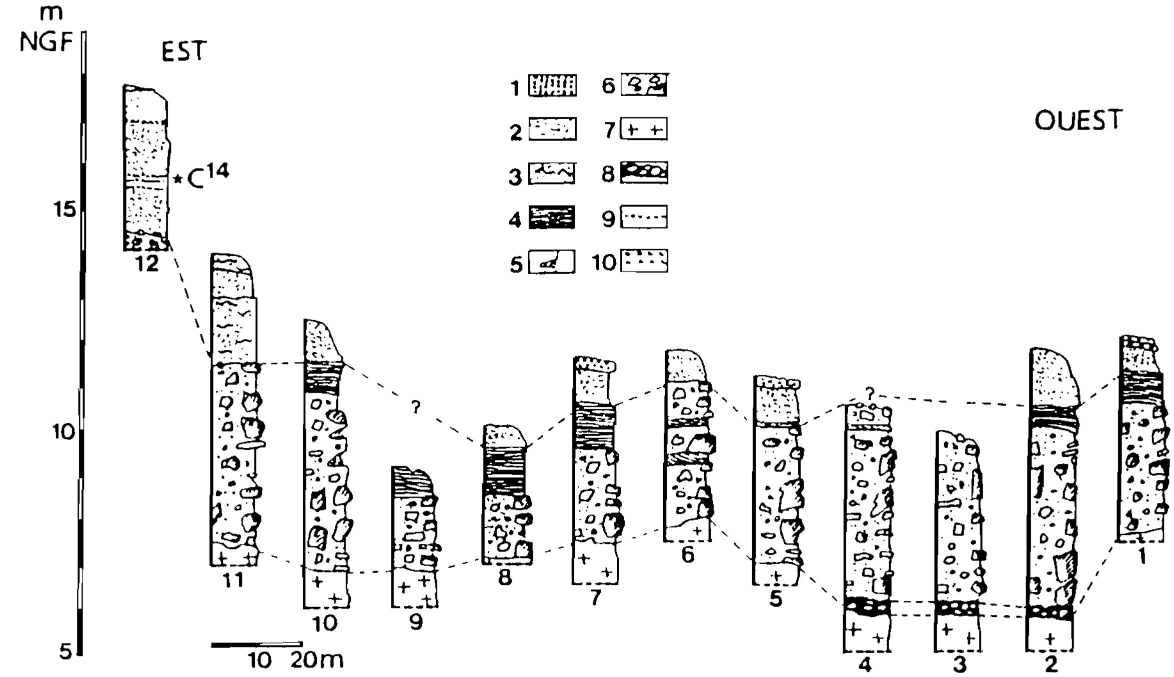
(See Figure, next page)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# QUATERNARY MORPHOSEDIMENTARY RELATION BETWEEN VALENCIAN COAST (WESTERN MEDITERRANEAN) AND THE SUBMARINE SHELF

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This works presents a synthesis of the results obtained up to date in a multidisciplinary project known as PROYECTO LA NAO, carried out along the Valencia littoral, (Western Mediterranean, Spain) under the initiative of the Departament of Geography in Valencia.

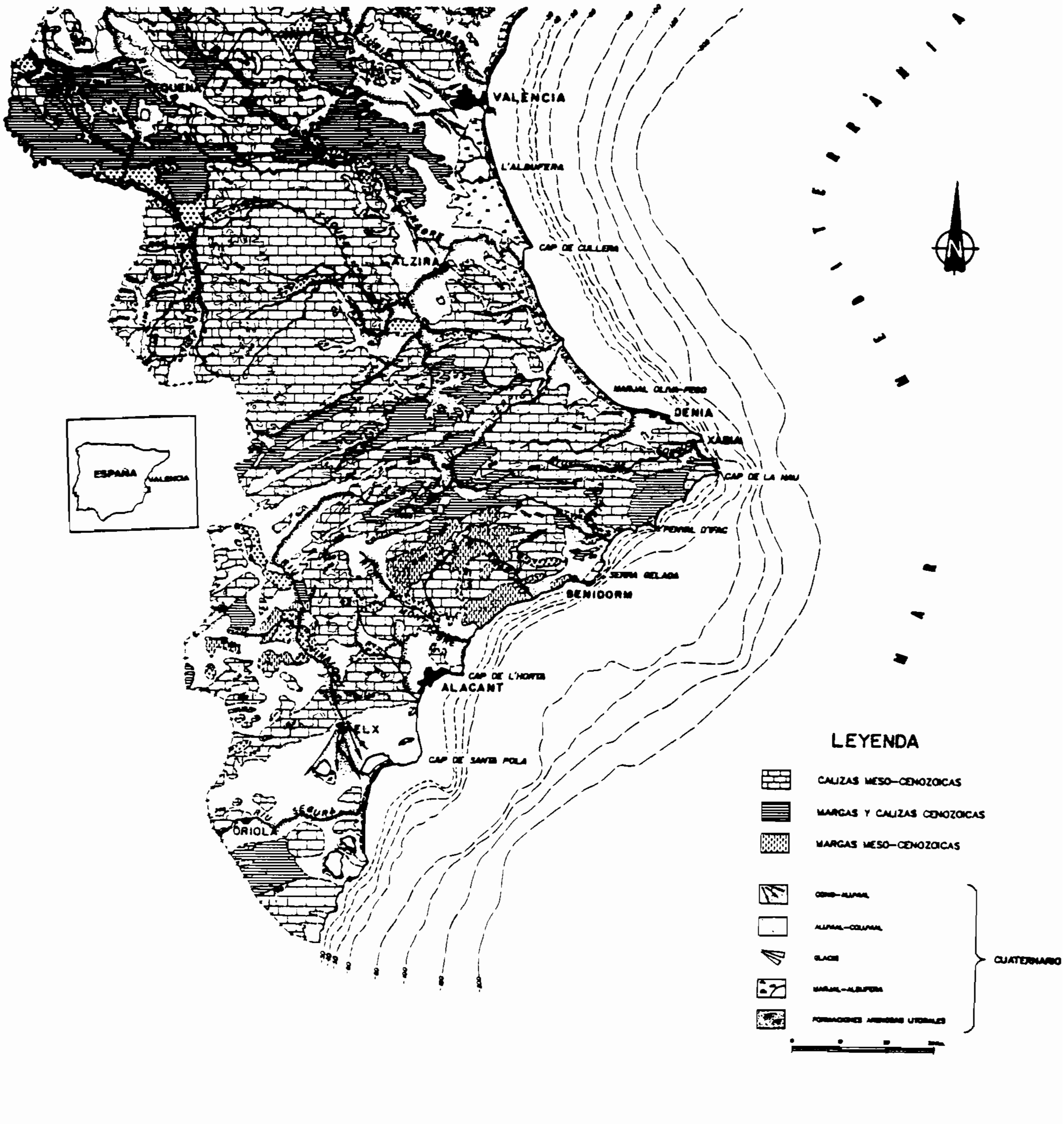
The general aim of this study is to attempt the morphosedimentary correlation between emerged coastal areas and submarine domain. Methodology employed consist on the geomorphological and sedimentological approach of the continental sectors combined with the geophysical study of the midle and internal shelf (high resolution sismic profiles analysis).

Since 1990, three marine/continental campaigns have been accomplished, (La Nao'90, Nao'92 and Nao'94), along the coastline from Valencia to Alicante (fig.1). Five morphosedimentary areas with special litostratigraphic characteristics and neotectonic behaviour have been individualized in the continental sector. With regard to the submarine domain, the sedimentary units, structural features and neotectonics show at least three different general sectors, where Sant Antoni Cape means a first order threshold.

Between the diverse data, the inestability of that littoral sector along the Quaternary, both in the continental as in the submarine domain could be outlined:

To the North, (Valencia Gulf), the emerged zones show a subsident tendency. The Quaternary sedimentation on the shelf is controlled by the continuous sinking which makes possible a progressive migration landwards of some littoral deposits, corresponding to the interglacial transgressive maximum. To the South land and shelf are directly influenced by the tectonic activity of Betic fractures (Cádiz Alicante system), that induces the block stepped sinking. Locally, the recent collapse of littoral segments has interrupted the direction of ancient fluvial networks and formed depressions where small Holocene lagoons have been installed. In the sumerged area, the substratum experiments a differential subsidence, which stops the conservation of complete littoral Quaternary sedimentary sequences associated to the periods of high sea-level.

(see Figure next page)


VALÈNCIA
ALZIRA
DENIA
XÀBIA
BENIDORM
ALACANT
ELX
ESPAÑA
LEYENDA
CALIZAS MESO-CENOZOICAS
MARGAS Y CALIZAS CENOZOICAS
MARGAS MESO-CENOZOICAS

# RECENT COASTAL EVOLUTION OF THE DOÑANA NATIONAL PARK (S. SPAIN)

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Since last Holocene sea level rise, dated on the 6,900 yr. B.P., several depositional littoral landforms were generated throughout the outlet of Guadalquivir river, that prograded along the predominant longshore drift (towards the East). Those prograding episodes (beach-ridge plains) were developed immediately after the peak of maximum sea level being associated with a relative steady state or a moderate sea level fall. The minor sea level fluctuations were controlled by the coastal dynamic factors largely depending on the regional palaeoclimatic models and on exchange of waters between the Atlantic ocean and the Mediterranean sea.

The first coastal prograding event occurred during 6,900-4,900 yr. B.P., although we lack enough isotopic dating. We suppose an initial evolution for the Doñana spit and, perhaps, La Algaida spit, both related with the most ancient and high marshland at the Doñana National Park.In the beginning, the Guadalquivir estuary size was wider and deeper than now, being mainly marine environment.

The older littoral formations (A-1) dated on the 4,735 yr. B.P. (calibrated age) show erosional events. Previous spit-barriers were broken by several inlets and coastal morphology was like barrier islands (A-2). This period was a new dominant marine environment with strong erosion on cliffs and retrograding coastline.

Afterwards, another sedimentary event was produced (4,500- 2,100 yr B.P.), surrounding the ancient eroded barriers (B-1). The size of the Guadalquivir estuary decreased (B-2) due to the increasing marsh deposits and to the beginning of a fluvial environment.

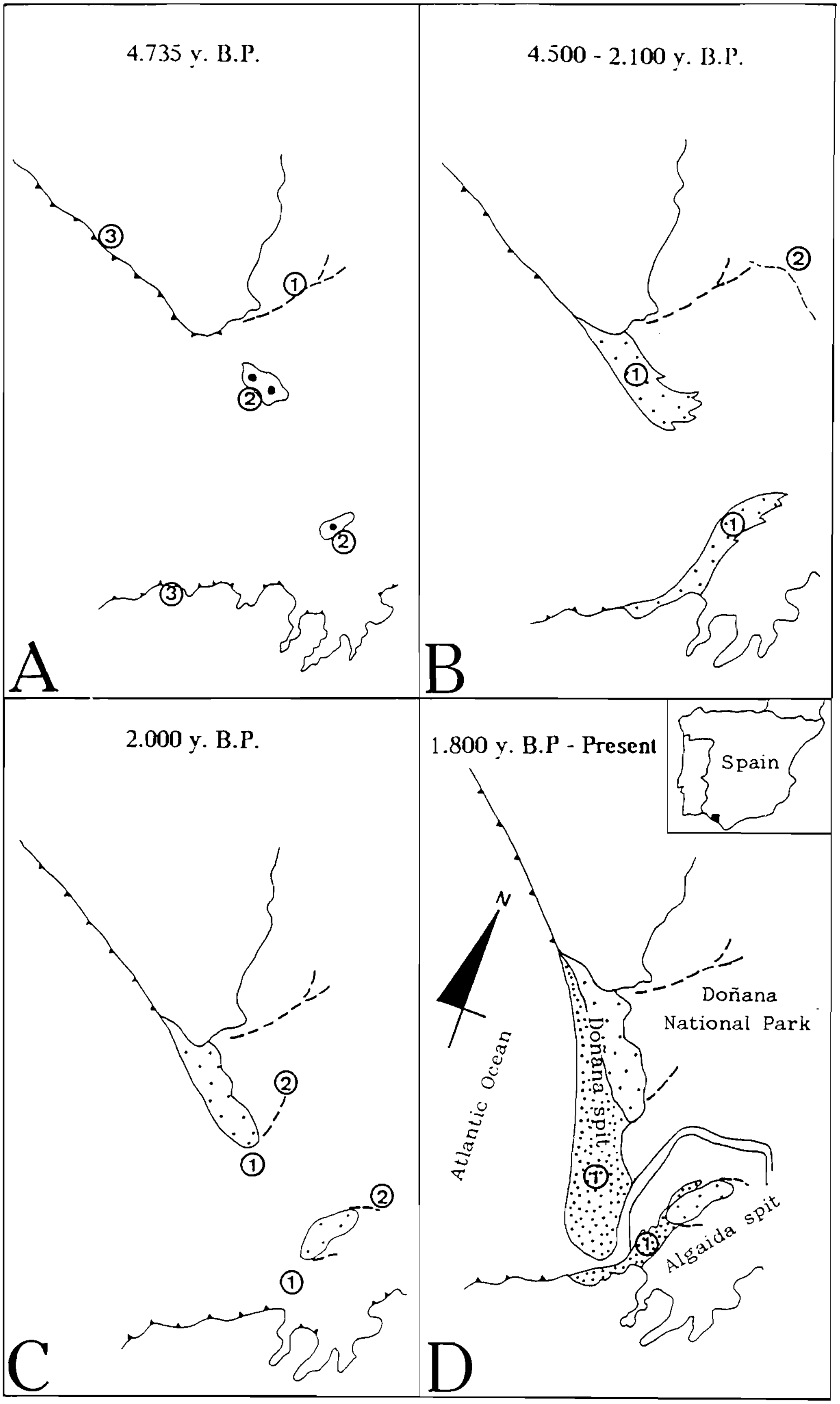
About 2,000 years ago, the prograding finished, starting a new erosion cycle (C-1). The main sedimentary littoral landforms are inner barriers (C-2) and erosional surfaces. The previous cliffed shoreline went backwards again.

From the 1,800 yr. B.P. the coastal prograding was the prevailing action (D-1), with several eroded interruptions intercalated (1,400 & 1,000 yr. B.P.). The estuary of the Guadalquivir river is at the present-day (Doñana National Park) like a estuarine delta with a inactive marshland and a dominant fluvial environment.

Generally, the erosional events suggest that the incursion of Atlantic waters into the estuary enhancing, increasing the typical estuarine fauna (Cerastoderma). On the contrary, the coastal sedimentary events being related to the fluvial activity produced the biological crisis around 3,550 & 1,870 yr. B.P. (c. a.) with frequent shells depostis at the shore of the palaeoestuaries.

*ACKNOWLEDGEMENTS: Supported by the Spanish DGICYT Projects PB91-0622 & PB94-1090.*

(see Figure next page)


4.735 y. B.P.
4.500 - 2.100 y. B.P.
2.000 y. B.P.
1.800 y. B.P - Present
A
B
C
D
Spain
N
Doñana
National Park
Atlantic Ocean
Doñana spit
Algaida spit

International Geological Correlation Program Project 367: *Late Quaternary coastal records of rapid change: Application to present and future conditions. IInd Annual Meeting (Antofagasta, Chile, 19-28 Nov. 1995), Abstr. vol.*

# CHAOTIC COASTAL BEHAVIOUR UNDER CONDITIONS OF SLOWLY RISING SEA LEVEL

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Large-Scale Coastal Behaviour (LSCB) results from small incremental changes in the coastal sediment budget (sediment residuals) over decades to millennia. Because residuals are very much smaller than temporal beach fluctuations, they cannot be measured directly. Simulation modelling is the only way of testing the relative importance (sensitivity) of individual factors involved in LSCB. Recent computer modelling based on principles of geomorphic shape and mass balance (Cowell et al., 1992 and in press; Roy et al., 1995) has identified three independent factors primarily responsible for LSCB: (1) relative sea-level movements (2) external sediment supply/loss, and (3) morphology of the pre-existing landsurface. When the sea is rising or falling rapidly (> 1.0m/century) on low-gradient, coastal plain coasts, frequent overwashing of the barrier surface results in quasi-continuous barrier retreat (Fig. 1). Under these conditions LSCB is overwhelmingly a response to changing sea level; external sediment gains or losses have only a minor effect. However, when the rate of relative sea level change slows down to less than about 0.3m/century, local factors related to sediment supply become increasingly important in determining LSCB. For a time, they can either counteract or exacerbate the effect of a slow marine transgression and, under these conditions, LSCB becomes increasingly erratic and unpredictable. Figure 2 illustrate punctuated coastal changes that could be expected to occur locally on a low gradient (barrier island) coast with slowly rising sea level. Shoreface responses that include slow recession, stability, rapid recession and progradation, affect individual sectors of coasts and may last for centuries. Cycles have different durations and intensities related to the rates of net sediment fluxes and the distance between coastal cells. The resulting finite response times introduce unpredictable phase relationships between changes on adjacent sectors of coast. Consequently, the behaviour of the coast as a whole appears chaotic.

In contrast, on quasi-stable coasts (especially coasts compartmented by bedrock headlands) where relative sea level changes in the late Holocene have been extremely small, sediment budgets have tended to be more constant and trends in LSCB are more predictable.

Cowell, P. J., Roy, P. S., and Jones, R. A., 1992. Shoreface Translation Model: Computer Simulation of Coastal-Sand-Body Response to Sea level Rise. Mathematics and Computers in Simulation, 33, 603-8.

Cowell, P. J., Roy, P. S., and Jones, R. A., (In Press): simulation of large-scale coastal change using a morphological behaviour model. Marine Geology, Special Issue on Large Scale Coastal Behaviour.

Roy, P. S., Cowell, P.J., Ferland, M.A. and Thom, B. G., 1994: Wave dominated coasts. In Coastal Evolution, R. W. G. Carter and Woodroffe, C. D. (Eds), Cambridge University Press, 121-86.

FIGURE 1

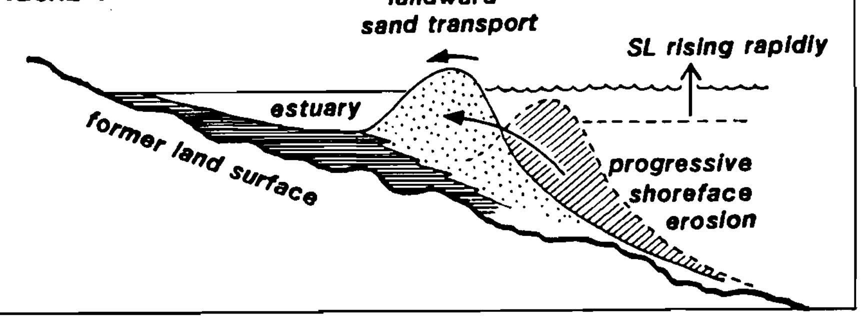

**FIGURE 2**

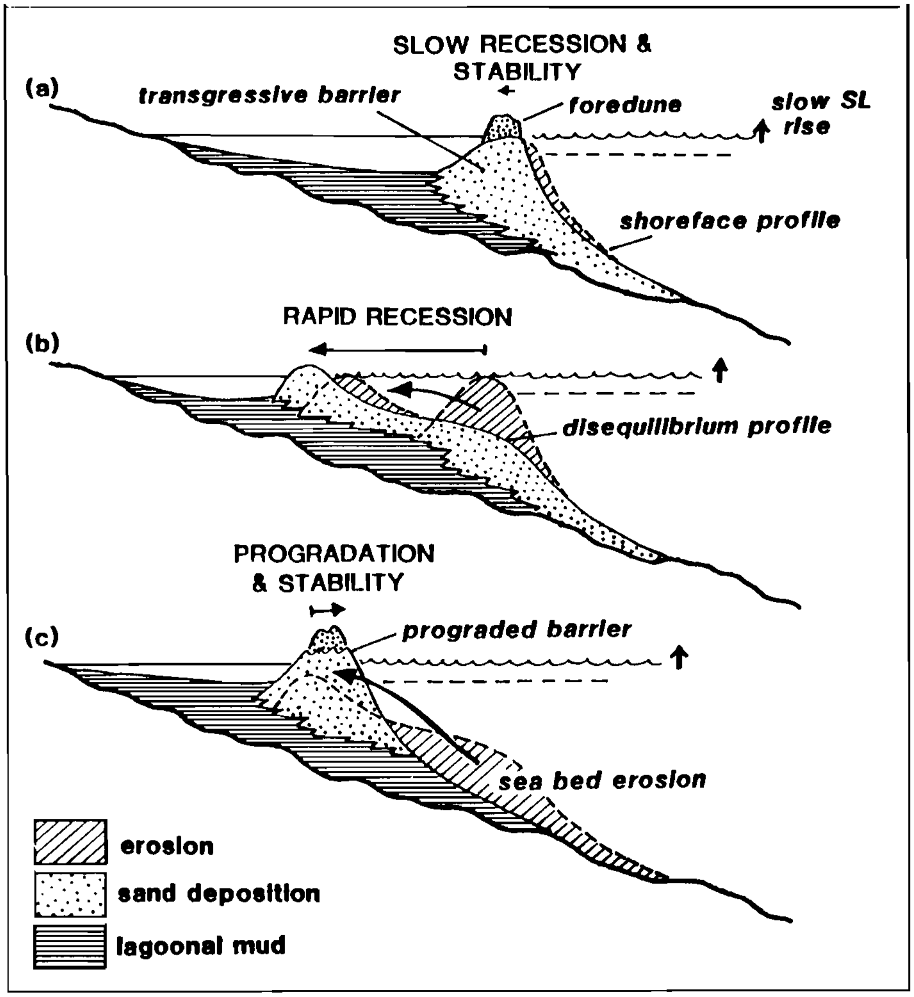


Figure 2 (a-c) shows a hypothetical sequence of local coastal changes on a low gradient, barrier coast with slowly rising sea level. Changes in wave action or inlet bypassing that add sand to a downdrift sector of the coast tends to stabilise the barrier shoreline and allow foredunes to grow on the barrier surface (a). Foredunes retard washover processes and slows the rate of shoreface retreat. As a result, the rising sea gradually drowns the barrier superstructure in situ, the lagoon deepens and the shoreface profile probably steepens (a). Eventually the barrier is overtopped by large storms and the shoreline suddenly jumps landward perhaps hundreds of metres (b). Erosional shoreface retreat is rapid and accompanied by renewed washovers on the new barrier surface (b). The resulting disequilibrium profile offshore is abnormally flat which promotes onshore sand transport (c). As the shoreface profile equilibrates, the increased supply of shelf sand causes coastal recession to slow, then reverse as the coast both progrades and aggrades; lagoonal muds may be exposed on the offshore sea bed (c). Eventually conditions stabilise and foredunes begin to develop thus commencing a new cycle of barrier drowning and overstepping.

# QUANTIFICATION OF THE 1995 ANTOFAGASTA EARTHQUAKE FROM GEODETIC MEASUREMENTS AND MODELLING

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**and collaborators.**

The July 30,1995, Antofagasta earthquake is the largest for this century in the coastal region of North Chile where the historical record of seismicity includes only a sequence of two great subduction earthquakes (8.5-9) in 1868 and 1877. The latest of these two earthquakes extended roughly from latitude 18.5°S to 23°S, which is considered as a locked area. The location of the main shock is for the present time only determined from teleseismic records (23.36° S, 70.36° W, h= 36 USGS data bank). The centroid moment tensor determined from the global seismic network by various institutions gives a first estimation of the size of the earthquake (Moment : 1.7 $10^{21}$ N-m, Mw=8.1) and of the focal mechanism (inverse faulting dipping 19° towards E direction).

On an other hand the distribution of the aftershock defines approximately the size of the rupture zone 180 x 70 km, that roughly corresponds with the seismic moment. The partial remeasurement in August 1995 of a large geodetic GPS network installed in 1992 permitted the quantification of the coseismic displacements associated with this earthquake.

Preliminary results indicate horizontal movements of the order of 1 m of the coastal bench marks towards the west with a small component to the south. Bench marks located inland subsided several tens of cm. One bench mark located in Mejillones Peninsula was uplifted more than 15 cm.

A first interpretation of the displacement field, in which the main fault is considered as a dislocation with uniform slip reveals that the northern extreme of the fault is constrained to be roughly at the level of the Mejillones Peninsula at latitude 23.2° S; the southern extreme of the fault is constrained only by the extension of the aftershock area up to latitude 25.0° S. Assuming a dip angle of 19°, the most probable fault plane extends between 15 and 37 km depth. The slip vector is of the order of 5 m.

# A NEW SEA-LEVEL CURVE FROM NOVA SCOTIA: EVIDENCE FOR A RAPID ACCELERATION OF SEA-LEVEL RISE IN THE LATE MID-HOLOCENE.

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A new late Holocene sea-level curve is presented from the Atlantic coast of Nova Scotia. Contrary to earlier data from the same area, this curve starts at 4400 sideral years before present (BP) and shows a rapid acceleration between 4400 and 3800 BP which coincides with a similar acceleration already reported from the Northumberland Strait (Nova Scotia) and an oscillation observed in South Carolina. Comparing the two Nova Scotia curves suggests the acceleration lasts just over 1000 years and has a vertical extent of 10m.

One puzzling fact is that the 10m vertical extent in Nova Scotia is 8 m more than the same event in South Carolina and it cannot be accounted for simply by postglacial isostatic depression, since that occurs on a much longer time scale.

Closer examination of most of the sea-level curves from northeastern North America reveals that either the record is missing from this interval, or it is inconsistent. We suggest that this acceleration is part of a global response that coincides with the end of the mid-Holocene warming period, possibly indicating a lag response between warming and ice melt.

# TRACES OF RAPID SEA-LEVEL CHANGES DURING THE INTRA-WURMIAN INTERSTADIALS AND POSTGLACIAL TRANSGRESSION: EXAMPLES FROM THE WHITE SEA AND THE SEA OF JAPAN, RUSSIA

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An analysis of morphology and sedimentary sequences of sea coasts may provide with valuable information on coastal response to rapid sea-level changes. Series of ancient depositional coastal bodies, both emerged and submerged, exist on the south-east coast of the White Sea and on the continental coast of the Sea of Japan. They aged from the intra-Wurmian interstadials and postglacial transgression and present a unique possibility for the studies on morphological responses to the variations in the rate of sea-level changes and other parameters of coastal evolution.

The primary importance of the rate of sea-level changes and sediment budget of the coastal segment is obvious from the analysis of these examples. The Brunn Rule and its modifications are of limited aplication to the prediction of shoreline movement under the sea-level change. A moderate underwater coastal slope and an excessive or insufficient sediment supply may result in the prevalence of deposition during sea-level rise and erosion during its fall. In general, the faster sea-level rise, the higher the possibility of burial, drowning, or destruction of the coastal depositional body. The faster the sea-level fall, the more probable the preservation of depositional bodies above the retreating sea, e.g. in the form of beach ridges and coastal dunes.

Sediment budget of a coastal segment usually becomes the dominant factor in coastal evolution under sea-level changes, notably in cases where there is either heavily excessive or insufficient supply of sediment. Both situations may result in a dominantly landward movement of sediments. Moderate inclination of the underwater coastal slope is possibly another precondition for such a response.

As a first approximation, a model of coastal development under accelerating sea-level rise is established for the conditions of excessive and insufficient sediment supply on sand coast. Under the former a moderate acceleration of sea-level rise causes the change from mobilization of sediment at a beachface and formation of a beach ridge to the landward translation of the coastal depositional body and, then, to its transformation. An extreme acceleration causes burial of the coastal depositional body by a trangressive sedimentary sequence. Under the latter mobilization of existing scarce sediments turns to a landward movement of a depositional body, erosion of its seaward slope, drowning, and partial destruction. The extreme acceleration may bring, in some cases, the total grading of the coastal zone profile. These response patterns may be interpreted in terms of a turn from quasi-equilibrium to disequilibrium evolution.

# CHANGES IN SEDIMENTARY PROCESSES AND ENVIRONMENTS ON THE TIDAL FLATS OF GAROLIM BAY, THE WESTERN COAST OF KOREA

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Garolim Bay is located in the mid-western coast of Korea, which represents a unique sedimentary environment because the tidal flats are widely developed with 22 to 6 km in width as a result of a large tidal range of more than 6 m in average. In addition, barriers and spits do not exist in front of tese tidal flats, so that these areas are unprotected from periodical impacts of high energy such as winter storms and typoons as well as daily activity of waves and tidal currents. The size of Garolim Bay is about 18 km long and about 8 km wide, and the average tidal range is about 4.63 m with the maximum tidal velocity of about 2 m/sec.

The purpose of the study is to determine changes of sedimentary environments at present and in the past short-term, and their controlling factors based on periodical observations upon surface sediment distribution and sedimentation rates, and is to compare with changes in lateral and vertical sedimentary facies from cancores and pushcores. Most of surface sediments in the bay are composed of muds except main tidal channels and tidal flats near the mouth of the bay which consist of sands and muddy sands.

To compare the contrast areas, two localities (the line-D area where is located in the sand ridge and mudflats near the mouth of the bay and the line-S area in the tidal mudflats of the inner bay) are chosen. Analysis of grain-size and measurement of sedimentation rates on the surface during each two-month interval shows that the line-D area comprises a lot of variations in the subtidal zone, indicating dynamic processes of bedload transport by waves and tidal currents. Well-developed small and mega ripples on the sand ridge also support this interpretation. On the other hand, sedimentation rates in the line-S area show the continuous accumulation but are variable near the main tidal channel of the subtidal zone. Based on the sediment transport path model by Mclaren and Bowles (1985), surface sediments in the line-D area are chiefly transported landward, whilst those in the line-S area is primarily transported and settled by the suspension and no further transportation occurred.

The prominent characteristics of cancores on the sand ridge of the line-D area are coarse sands with rare bioturbation and well-developed sedimentary structures such as cross-beddings and ripples. The above characteristics of cancores are believed to be mostly formed by the predominant process of bedload transport which are also observed by several methods of surface sediments, indicating dynamic and unstable environments. Some cancores collected from the sand ridge show more than two to three shell layers (mostly oyster layers) that are believed to be formed by high energy processes, probably either by winter storms or by typhoons. The top section of some cancores at the edge of the tidal channel contain over 95% sands (mostly fine sands), while the low sections are composed of finer sediments, mainly of silts. Some cores show alternation of silts (about 6 - 7 phi) and sands (about 3 phi), indicating oscillations of energy regimes. In the area of line-S, the cancores show much finer sediments than those in the line-D area. The vertical sedimentary sequences from the cancores of the line-S area are characterized by severe bioturbation with discontinuous parallel laminations and thin lenticular laminations (less than mm in scale).

The composition of grain-size from the cancores in the line-S area is similar to that of surface sediments, so that settling from suspeded sediments has been a major transport mechanism to the line-S area. Additionally, low sedimentation rates in this area implies a relatively stable environment. At the edge of main tidal channel in the line-S area, the cancore showed that thin sand layers overlied silt and clayey silt sections, indicating shlow slow encroachment of sands toward the tidal mudflats in this area, which might be related to local relative sea-level rise. This phenomenon is also found in the main tidal channel of the line-D area.

Consequently. ongoing processes of surface sediments and a short- term processes of sedimentary sequences in the present tidal flats of Garolim Bay represent that sands in the line-D area are transported landward as bedload processes by waves and tidal currents daily in addition to periodical impacts of high energy. In contrast, sediments in the line-S area are deposited by settling processes, from suspended sediments, providing continuous slow accumulations but no further higher energy which could enough cause bedload or resuspension.

Otherwise, in the tidal channel of the subtidal zone from both areas, coarse sediments are slowly migrating landward.

# MORPHOSEDIMENTARY BEHAVIOUR OF THE DELTAIC FRINGE IN COMPARISON TO THE RELATIVE SEA-LEVEL RISE ON THE RHONE DELTA

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For the first time original maregraphic data obtained in the Camargue area have been analysed (maregraph of the "Grau de la Dent" installed by the "Compagnie du Salin du Midi"). The long term series (about one hundred years) has been compared with the data recorded in the Marseille area (PIRAZZOLI, 1986 ; BLANC *et al.* 1990). The results show that relative sea-level rise was different at each of the sites. In the Camargue, the relative rise in sea level is equal to 2.1 mm/year, in Marseille 1.1 mm/year **(figure 1)**.

The secular trend obtained shows a value similar to those described in the literature (PIRAZZOLI, 1986 ; GORNITZ *et al*, 1982, 1987 ; BLANC *et al*, 1990 ; WIGLEY *et al.* 1992). The difference of 1 mm/year is attributed to subsidence movements that affect the Rhone delta principally localized along the littoral fringe. They can be explained, in part, by man's intervention in morphosedimentary processes of the delta system. Nevertheless, this value is also close to the plurimillennium estimation obtained in the eastern part of deltaïc fringe from the study of the archeological sites (L'HOMER, 1992) and focuses on the long term geological forcing agent.

The sediment supply is an important factor in setting off the impact of relative sea-level rise. The study of the sedimentation behaviour focused on the mi-secular evolution of the deltaïc coast **(figure 2)** using imagery processing and the recent accretion pattern of the beaches using the $^{137}Cs$ dating method. The global sediment budget over the last fifty years is positive but the analysis by different sectors shows that the eastern part of the mouth of the Rhone has prograded while the wertern part has eroded **(figure 3)**. Cores were taken on the beaches on either side of the mouth of the Rhone. The chronology has been estimated by $^{137}Cs$ isotope analyses. The results show that the deposit is recent for the two sectors studied (after 1950). A minimum value of the rate of sedimentation equal to +1 cm/year is suggested. Nevertheless the concentration of $^{137}Cs$ seems to indicate that the sedimentation rate could be higher than 1cm/year in the eastern part.

The morphosedimentary behaviour shows that the eastern part of the mouth of the Rhone delta is not threatened by the relative sea level rise. The evolution of the coast in this area shows that the supply of sediment seems to be enough to off set the rise of sea level. The western part remains vulnerable.

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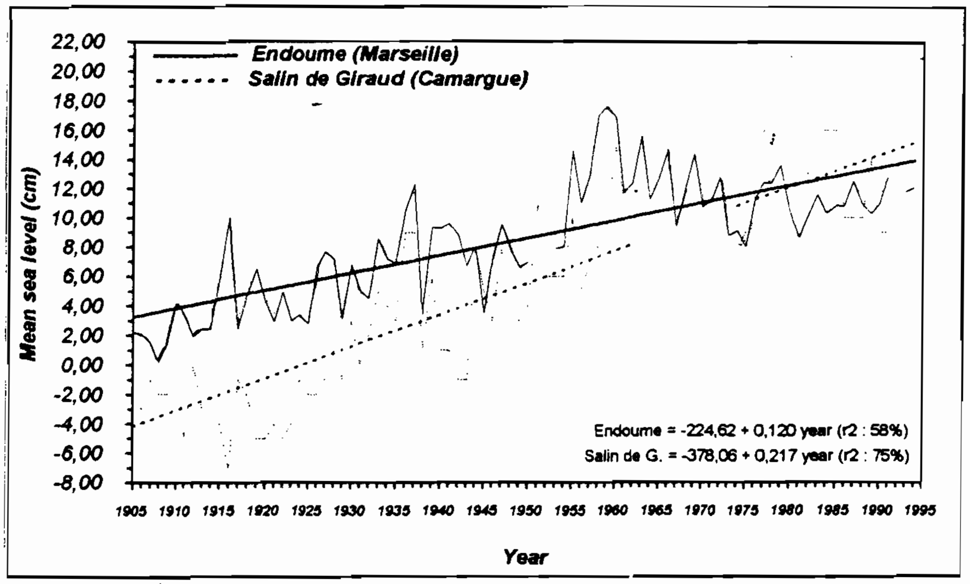


**FIGURE 1** - *Secular trend analysis of the R-S-L-R using linear regression*

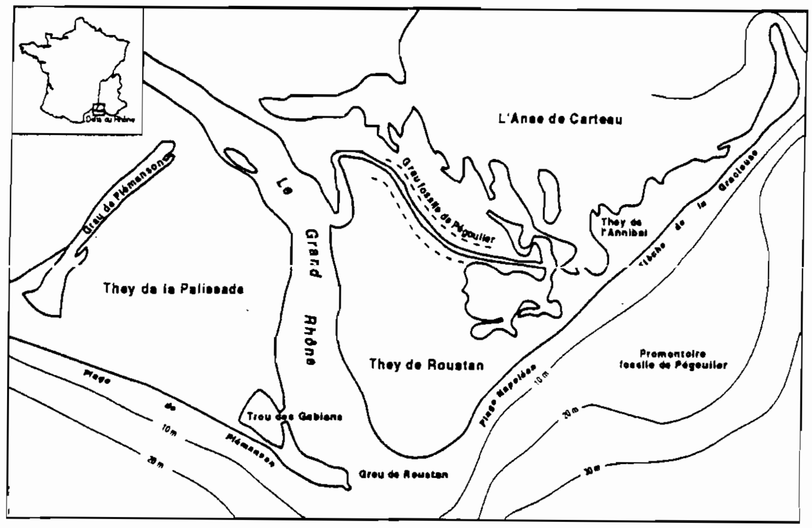


**FIGURE 2** - *Location map of the studied area*

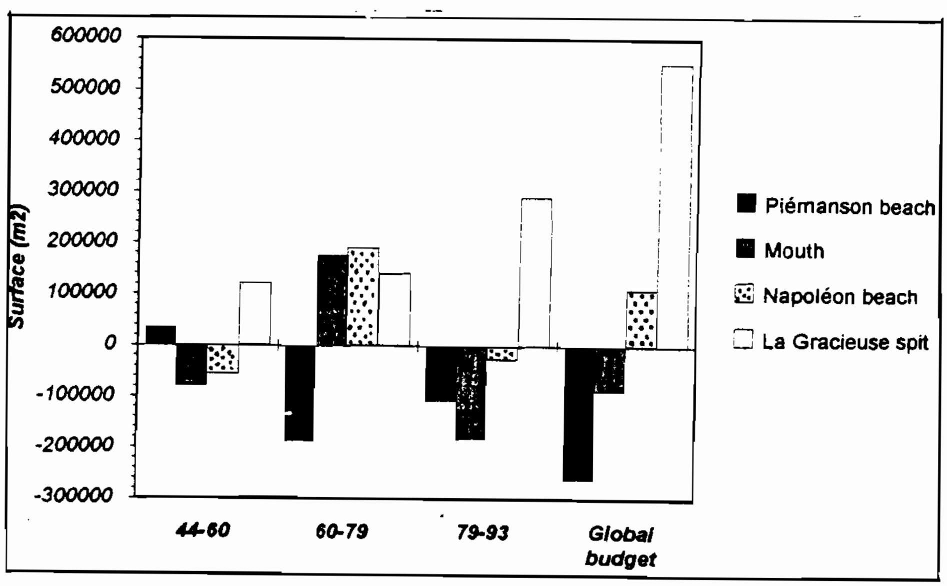


**FIGURE 3** - *Evolution of the global sediment budget by different sectors*

# TECTONIC UPLIFT NEAR 13°N, WEST COAST OF INDIA

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Karnataka coast which is a part of the West Coast of India is being studied intensively, as the area in prone to severe erosion during monsoon. The southern part of Karnataka Coast is categorizad as « rocky coast with barriers » and is transitional in character from the cliffed Konkan coast to the north and alluvial plain coast of Malabar to the south. During the course of detailed beach profile studies, it came to light that though some pockets are undergoing erosion, taken as a whole, the south Karnataka beaches are accreting. This surprising result led to a detailed investigation of the possible causative factors. Study of satellite images, has shown that there are a number of beach ridges alternating with swales, indicating progradation of land. The progradation of the land is also confirmed by the configuration of the shoreline which is convex towards the sea. The results of beach erosion/accretion studies bring out that erosion is dominant during monsoon (May to August) and accretion during the remaining months. When the entire stretch of 25 km is taken into consideration, there is a greater volume of sand accreted than eroded indicating widening of the beaches in most of the areas. Comparation of earlier offshore bathymetric records with the present day data indicates that there is a significant shift of contours seaward which reflects shallowing of seabed.

South of Mulki, near Surathkal an oyster colony, which is now dead, is seen fringing a gneissic outcrop. This colony is above the inter-tidal zone which points to a relative fall in sea-level. The shells, which have been dated by $^{14}C$ method, indicate that the shells are post 1950 AD. The tide gauge data for Mangalore (obtained through Permanent Service for Mean sea Level) shows that during the past 25 years there is on the average, a fall in sea level of 1 $mm.a^{-1}$.

North of Mulki, are a group of islands generally known as St. Mary Islands. The rocks here are rhyodacites and are known for their well developed columnar joints. The islands have wave cut platforms at different elevations, the highest being at 10 m. The other terraces are aproximately at 6 m, 3.0 m and 1.5 m and 0 m indicating a relative fall in sea-level/rise in land. The rapid uplift of land is ascribed to intraplate deformation resulting from sea-floor spreading in the Indian Ocean.

# LATE HOLOCENE ALLUVIAL SEDIMENTATION IN THE ANTOFAGASTA COASTAL AREA, CHILE

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The town of Antofagasta (23°40' S, 70°23 W) was built along the seashore upon a narrow strip (0.5 km to 1 km wide) of coastal lowland at the foot of the steep Cordillera de la Costa (FIgure1). Immediately to the east of Antofagasta, the major Coastal Escarpment of northern Chile is about 700 m high. The coastal area corresponds to a series of steplike, largely eroded, marine platforms which were cut upon the andesitic lava flows of the Jurassic La Negra Formation. The terrace elevation varies between a few metres and more than 120 m asl.

The climate is characterized by an extreme aridity. The mean annual rainfall, calculated on a interannual basis during the last century or so, amounts to about 4.7 (Dir. Gen. de Aguas, unpubl.). The temperature is mild (mean annual value is 17.5°C) . The relative humidity is elevated only at an altitude of a few hundred metres above sea level, during winter months (camanchaca). The high stability of the atmospheric conditions and the lack of rainfall are closely related to the effects of the Humboldt Current and the Southern Pacific anticyclonic cell.

Practically continuous rainfall records are available for the last century (trustable data since 1904). Like in other desert areas, rainfall is essentially sporadic and of variable amount. At a regional level, the major rainfall events occurred in 1940 and 1991, and produced serious flooding disasters. The amount of precipitation registered during these two events was of the order of 40 mm, but varied from north to south within the city. In both cases, the rainfall episodes lasted about three hours. The stronger intensity of the rainfall in the southern part of town (with respect to the airport area) was assigned to a local convective phenomenon, probably due to topographic and geographic factors (Dir. Gen. de Aguas, unpubl.).

The extreme scarcity of rainfall explains the lack of vegetation and of a cohesive soil cover in the Atacama Desert in general, and in the surroundings of Antofagasta in particular. As a consequence, the rainfalls, even those of low intensity, originate mud flows which can be destructive. The major destructions and casualties (more than a hundred deaths in 1991) provoked by the floods (« *aluviones* ») in Antofagasta are not due to the intensity of the rainfall itself, but rather to the to the sudden concentration of waters and mudflows in the *quebradas* (=usually dry river valleys) which open out in the upper part of the city, at the foot of the escarpment. The *quebradas* that open out on the Antofagasta coastal area are of distinct sizes. Many of them are fed by small watersheds, with a planimetric surface varying between 0.1 and 10 km². Another series of larger watersheds (surface of 20-40 km²), within the Cordillera de la Costa, feed the large *quebradas* of La Chimba, Salar del Carmen, La Cadena and Jorgino. The *Quebrada* El Guay is a true (normally dry) river valley and an outlet of a still larger watershed. Finally, the *Quebrada* La Negra, the largest of all, cut across the whole Cordillera de la Costa and has been capturing, during the Quaternary, part of the drainage of the Central Depression. The size of the alluvial fans and cones is directly related to the size of the feeding watersheds. The *quebradas* corresponding to the largest watersheds produced large alluvial fans (typically more than 2 km²) with slope angle of less than 4°, while at the outlet of the smaller *quebradas* are found smaller alluvial cones (0.5 km²) and steeper slope angle (5-10°).

The stratigraphic record of the alluvial sedimentation within the lower part of *quebradas* shows that in the lapse of the last century, the infill of deposits was important: their total (cumulated) thickness amounts to about 2 m in the case of the smaller *quebradas,* and up to 8 m thick in *quebradas* like that of Qda. Jorgino, or Qda. La Negra. The alluvial and mud flow deposits (between 2 and 6 events in the last 100 yr or so) are made of an abundant sandy matrix (with a varying proportion of silt) with angular to subangular clasts of various size (coarse sand, gravel, pebbles and small blocks). Sedimentologic analyses show that the sand fraction usually presents evidence of both eolian and alluvial previous reworking. In the southern part of the study area, the matrix is much more abundant than at Antofagasta, as a result of the more extensive eolian sand cover, the substrate composition, and the geometric parametres of the watershed. It may be added that the amount of sand transported to the seashore during rainfall events like that of 1991 is so abundant that it may induce profound, long lasting, changes in the intertidal zone: four years after 1991, a 2 m thick layer of sand is still accumulated on the beach which used to be a bare rocky sector at the mouth of Qda. El Guay, four years ago.

On-going studies on the alluvial record in the Antofagasta area aim to determine the climatic evolution of this coastal sector of the Atacama Desert during the Holocene, and to establish recurrence intervals of the major events, although the latter aspect is hampered by the general lack of any organic material that could be submitted to radiocarbon dating.

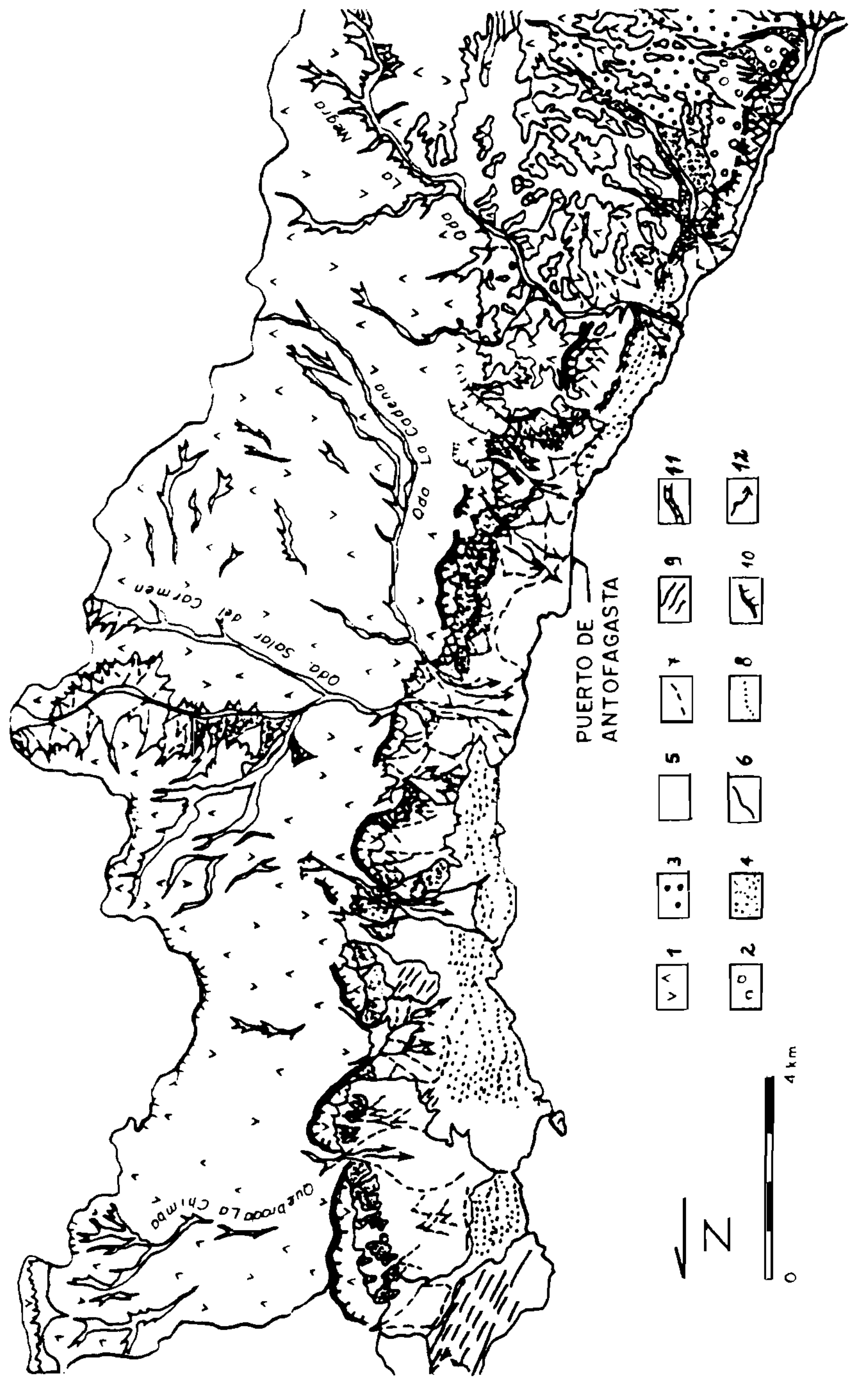


Fig. 1.- **Major geomorphic features in the Antofagasta area in relation with the alluvial sedimentation.**
1- La Negra Fm. (Jurassic). 2- Caleta Coloso Fm. (Cretaceous). 3- Tertiary alluvial units. 4- Early (?) Pleistocene. 5- Middle and Late Quaternary alluvial/colluvial/eolian units. 6- Geological contact. 7- Boundary of Late Quaternary alluvial cone. 8- Morphological scarps (Middle Pleistocene paleo-seacliffs in many cases). 9- Longitudinal dunes. 10- Major Coastal Scarp of northern Chile. 11- Early (?) Pleistocene paleo-seacliff cutting the «Pliocene» Antofagasta Terrace. 12- Flow directions of the 1991 alluvial flood.

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# YOUNG TECTONIC MOVEMENTS AT THE CONTINENTAL SLOPE SOUTHWEST OF ANTOFAGASTA

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The geological data are part of the results obtained during a four week travel with the german research vessel "SONNE" from September, 17$^{th}$ to October, 15$^{th}$ 1995 between Arica and Valparaiso. The main research area is located between 22°S and 24°S and extends from the 12 miles zone in the east on the South American Plate to the subducting Nazca Plate in the west. The geological sampling is backed by extensive geophysical studies such as refraction and reflection seismics, hydrosweep, measurements of fluid flow and heat flow and mapping of the sea floor.

Young vertical movements on the continental plate are of special interest: commonly blocks of continental crust sliding downslope in direction to the trench, but locally vertical uplift occurs also. The latter can be observed some 100 km southwest of Antofagasta. In this area a mountain ridge is elevated up to 1000 m above the surrounding sea floor level of 2500 m depth. On the top of the ridge a sequence of distal turbidites of Pliocene age was sampled, whereas the related fan deposits were found in a "basin" located in the east of the ridge. The interpretation of the ridge as a horst-structure is preliminary at the given state of the investigation.

# RESEARCH IN REMOTE SENSING, DYNAMIC MODELS, GEOGRAPHIC INFORMATION SYSTEM AND DSS FOR INTEGRATED COASTAL ZONE MANAGEMENT SYSTEM

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The ITC has started an ambitious research programme which should result in an Integrated Coastal Zone Management (ICZM) System through four sub-projects. The first sub-project aims to develop the methodologies for the generation of optimum remote sensing data sets leading to better interpretation of conventional and new remote sensing images, (e.g.,SAR interferometry, CCD video, SONAR, LIDAR, etc.), the complementary use of conventional and new remote sensing images, and the integration between remote sensing, GIS, and modelling through hypotheses generation, evaluation/validation and parameters estimation.

The second sub-project services to qualitative and quantitative analysis prediction of coastal landscape development under influence of natural (morpho-dynamic and hydro-ecologic) processes and human impacts, based on dynamic models and remote sensing and GIS application.

The third sub-project is designated to develop a 4-D GIS working platform to support the data integration of remote sensing and in-situ measurements, and the qualitative and quantitative analysis prediction of coastal landscape development. A spatio-temporal GIS shell will service for developing procedures to support decision making in ICZM.

The fourth sub-project aims to develop a methodology and a tool for assessing the hazard and the risk vulnerability for adequate coastal zone management in space and time, and for the evaluation of coastal zone management strategies, based on the spatio-temporal GIS working platform and physical, morpho-dynamic, and eco-hydrologic modelling.

# THE ONSET OF THE HUMBOLDT CURRENT: ITS REVISED GEOLOGICAL AND PALEONTOLOGICAL DATING

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The establishment of the Humboldt Current, defined in this presentation as a cool Neogene northward oceanic flow, began during the early Late Miocene (about 10 Ma). Il would be associated to the development of the modern Antartic Cryosphere ocean system at that time, and connected to the initial establishment of West Antartic Ice-sheet, the opening of Drake Passage and the Antartic Circumpolar Current (ACC). This same event would also have determined the increased upwelling conditions prevailing throughout the South East Pacific margin since the beginning of Late Miocene. In regional terms, the onset of the Humboldt Current would be linked to the global cooling and world-wide regression initiated during the early Late Miocene (lower part of N16, about 10 Ma). Along the northern part of the Chilean Coast, the presence of the Humboldt Current is related to increased aridity, including reduced long-term erosion rates and the cessation of the previous active supergene metal enrichment (copper, silver, gold, etc.). The uplift of the Central Andes Cordillera during the early Late Miocene (ca. 10 Ma), providing a rain shadow for the precipitation derived from the Amazona Basin and Central Argentina, contributed to reinforce the aridity of northern Chile and Peru.


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