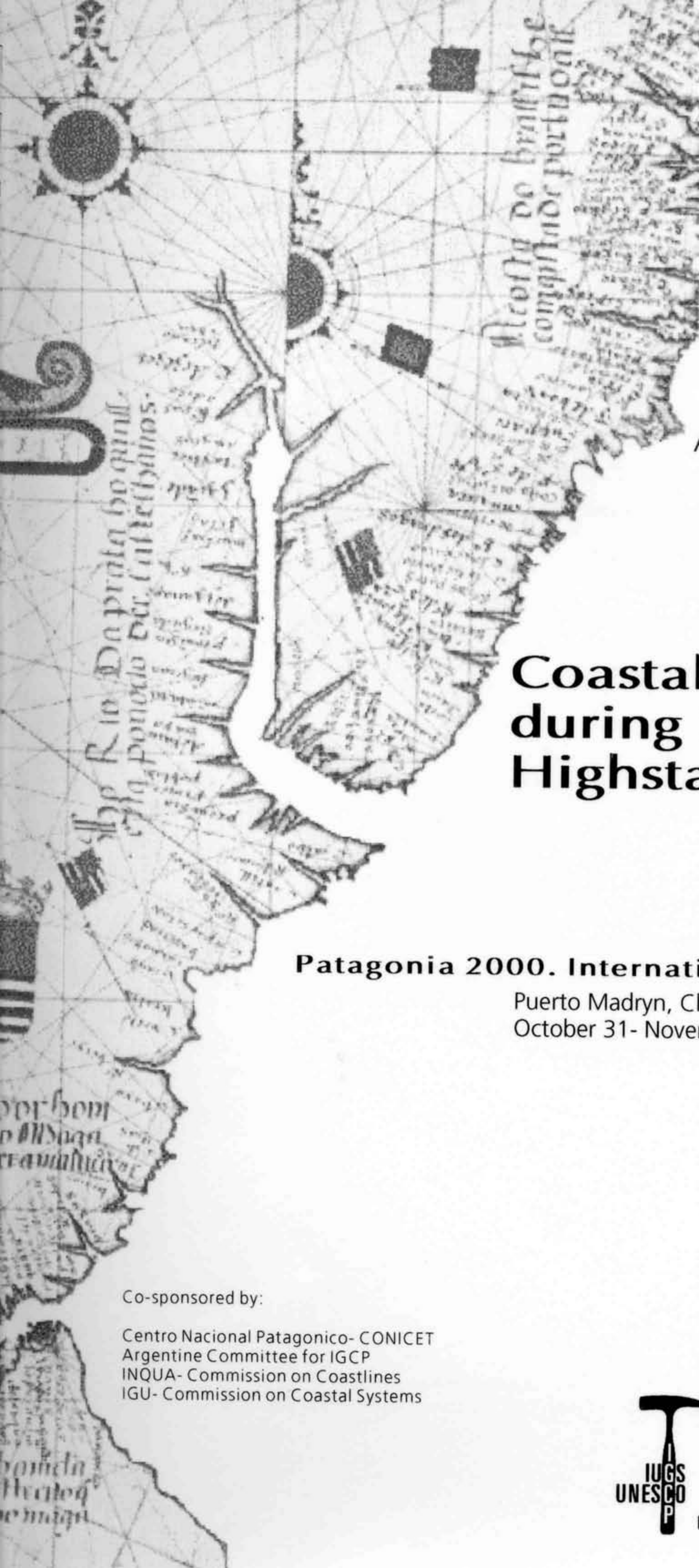

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The postglacial sealevel rise within the Guadiana Estuary - a contribution to a regional record in the Gulf of Cadiz

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Abstract

In the Guadiana River Estuary, the Holocene estuarine infill is underlain by coarse delta fan sediments enclosing salt marsh deposits, dating back to isotope stage 5e or a stage 3 interstadial highstands. The sedimentary sequence which may reach 40 m thickness, was laid either directly on gravels or on top of fluvial sands deposited probably between 11000 and 10000 yrs. BP. An accelerated phase of infilling of the estuary by clayey sediments, deposited in the tidal flat/marsh regime began at ca. 9800 yr. BP when the sea level was about 39 m below the present. In the western part of the Gulf of Cadiz the sediments of the same age lie ca. 10 m higher what may be due to either local isostatic adjustments or to valey slope movements. Between 7500 and 7000 BP the central part of the estuary started to accommodate coarser sediments, partially introduced from the shelf. The first phase of the Holocene sea level rise at a rate of 0.85 m/century terminated at ca 6500yr. BP. Since then, the predominantly sandy sedimentation initiated within the estuary. After the second phase of a slower rise at the rate of 0.3 m/century, which lasted until ca. 5000 yrs. BP, the sea approached the present level.

Discussion

5 boreholes coded CM1, CM2, CM3, CM4 and CM5 were drilled through the entire sequence of sediments filling the terminal part of Guadiana River paleovalley. The Guadiana is one of the most important rivers on the Iberian Peninsula with a total length is 730 km, the last 200 km forming a natural border between Portugal and Spain. In this section the river bed is cut into the Hercynian basement consisting of Carboniferous schists and greywackes and follows a N-S path defined during the Quaternary (Vidal et al., 1993). The resistance offered by the basement rocks to the river erosion defined the pattern of the river valley which is narrow and deep: 600 m wide and about 70 m deep below mean sea level, ca. 7 km inland from the mouth.

In its present state the Guadiana estuary is experiencing its final stage of infilling. On the western (Portuguese) side of the terminal segment a lateral accretion of fine sand/mud banks occurs whereas the Spanish side is under erosion. This trend seems to be prevailing for the period of the Holocene infilling which was accompanied by the eastward migration of the axis of the principal estuarine channel, leading to the observed asymmetry in the incision of the river valley. During the Last Glacial Maximum, 18 ka ago, when mean sea-level in the Gulf of Cadiz was ca. 120 m lower than present (Hernández Molina et.al., 1994) the Guadiana river reached the peak of its eroding capacity. The deepest part of the valley was probably eroded into the gravels deposited during the Isotopic Stage (IS) 3, down to the Paleozoic substratum, 80 m below the present msl. All the 5 boreholes crossed the gravelly level composed mostly of recycled quartz pebbles from Plio-Pleistocene rañas and fragments of basement rocks. However, the data from destructive boreholes indicate that these coarse sediments which may reach 35m in thickness contain frequent intercalations of finer sediments, a fact also confirmed by geotechnical tests done before the bridge construction.

In bore-hole CM4 the two pebbly units are separated by a very compact, oxidized, clearly continental swamp/fluvial series dated 16980 yr. BP on the organic debris, whose isotopic composition

$\delta 13C = -28.5‰$) points clearly to the terrestrial origins. Consequently, the gravely river fan which was deposited on a narrow coastal plain must have experienced at least two phases of accretion, the last probably over the 16 -13 ky BP period of rapid sea level rise (Dias et all., 2000). Different depths of the gravel surface unconformity observed in the studied boreholes reflect either irregularities of palaeo-relief and/or probable existence of a buried terrace system produced during the lowstand erosion periods. The upper gravel level in borehole CM4, which is separated by continental fine sediments bearing traces of subaerial exposure, may well be a reworked remnant of such a prograding delta fan/braided plain. During the sea transgression such a remnant could become a wave resistant beach ridge permitting a later anchoring of the coastal sand bar. There is no clear evidence of the retention of finer, sandy sediments in the study area prior to about 10 -11 ky BP, except in the bore hole CM2 (unit II) and CM4 (unit V). In the former, unidentified shells were dated in the argilaceous level on top of the 1m layer of fine, moderately sorted micaceous sand and gave the age of 10130 yr. BP at -8.54m. In a complete absence of estuarine microfauna in this unit, it was considered to be of continental origin and the dated shells a recycled material, as the depth of 8.5 m seems to be incompatible with the pre-Holocene age.

However, in CM4, the identical micaceous laminated sand provides no datable materials but in both cases the fluvial origin of the sediments was attributed to a possible small tributary of the main valley. The borehole CM5 in Boina River valley (small tributary ca. 2 km NW from borehole CM1) gave a 14C age of 10990 y BP on wood fragments, recovered also from a similar fluvial micaceous sand layer laying on top of basal gravels at the depth of 48m. This figure is consistent with a Younger Dryas sea level proposed for the Iberian shelf by Dias et al. (2000). Consequently, it seems that the transition from highly energetic fluvial conditions, observed in terminal segment of Guadiana valley at the end of Pleistocene to the low energy central zone of estuary in Holocene, was a brief event which left an unimpressive record of a submetric sandy layer deposited in the environment of the inner estuary. The relatively narrow shelf (ca. 20 km of the Guadiana mouth) did not permit a more important accumulation of transgressive sands within the inner estuary, which otherwise would have occurred during a spatially more extended approach of the shoreline and a stronger tidal influence. The scarcity of sands marking the beginning of the Holocene transgression was observed also in other estuaries in the Gulf of Cadiz by Dabrio et al. (2000). The age at which the estuarine marsh sediment started to cover the fluvial series may be obtained by the extrapolation of the depth/age relation of the three deepest datings in bore hole CM1, to the depth of gravel surface (Fig. 1). The regression line calculated from these points has a squared Pearson correlation coefficient $r2 = 0.997$ yielding the sea level rise rate = 0.85 m/century and the beginning of Holocene sedimentation at the depth of 39 m. The data from Guadalete and Odiel estuaries (Dabrio et all., 2000) in the same figure indicate the same age of sedimentation in the western part of the Gulf of Cadiz, ca. 10 m above. Tentatively this may be explained by isostatic uplift in the latter area or by mass movements, which affected the Guadiana infill.

Notwithstanding the observed lithological differences, the Holocene sedimentary infill observed in boreholes CM1 and CM2 yielded records of two distinct sedimentary facies with a boundary between 6200 to 7000 yrs BP respectively in each of them. In CM1 the boundary is set at the 16,2 m depth. It separates a sequence of rhythmic fining-up series (unit V) corresponding to point bar facies from the lower, fine sediment mostly dominated by clayey, bioturbated facies (unit II to IV). Vegetal fragments, mud balls, and frequent flaser structures suggest an upper intertidal flat environment under continuous influence of tidal currents. Reddish clayey layers observed in this unit indicate occasional events of supply of materials rich in ferruginous pigments, eroded from Plio-Pleistocene formations cropping out along Algarve - Andaluzia coasts (Boski et all. 1999).

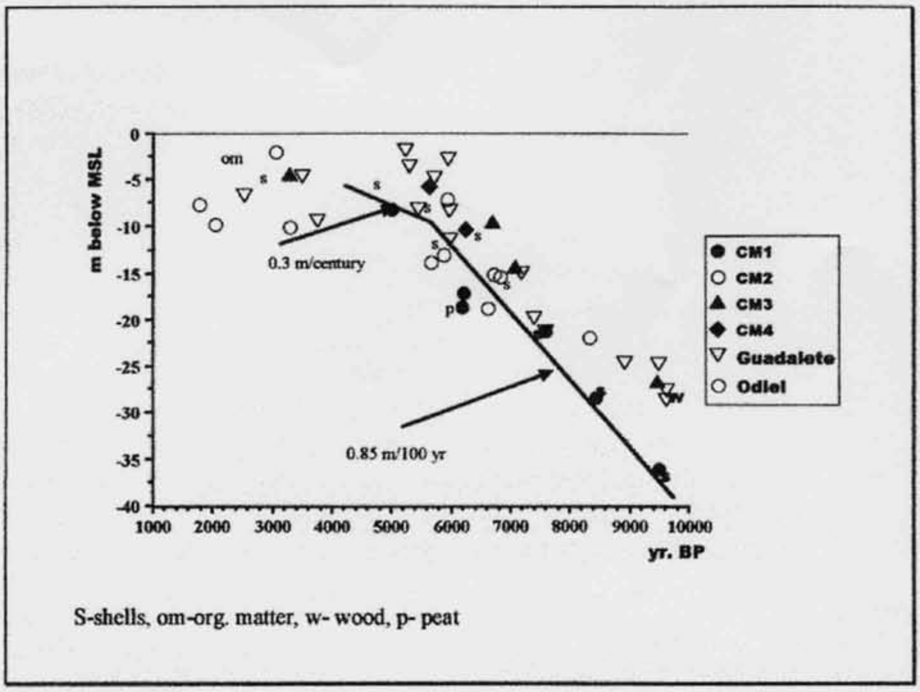

Fig.1 Dated sediment levels from the Guadiana estuary compared with data from the Tinto-Odiel and Guadalete estuaries (Dabrio et all., 2000)

In fact during the transgression, the drown fluvial valleys may have received alternating fluxes of fluvial and estuarine material as a consequence of an interplay between the rates of sea level rise, sediment supply and the accommodating space. Likewise due to the fast sea level rise in the corresponding period, the fine sediment load could have been effectively trapped and fixed by the salt marsh vegetation which in turn could have maintained a constant position in relation to the tidal flooding. The reported discrete centimetric peatty levels indicate recurrence of brackish/fresh water conditions.

In bore-hole CM2 the upper marsh clayey sequence is in unit III, composed almost exclusively of clay deposited in a confined lagoonal environment sheltered by the sand spit to the South, occupied at present by Monte Gordo dune field. These low energy conditions prevailed throughout the entire period of deposition i.e. since ca 7000 yr. BP. The latter figure was obtained from extrapolation of an apparently constant sedimentation rate between two dated levels 2780 yr. BP at 4.25m depth and 5950 yr. BP at 7.15m depth.

Sediments drilled between 31.2m and 16.5m (unit II) in borehole CM3, belong to a remarkably homogeneous facies of clays, very rich in vegetal remains with some bioclastic deposits from channel lags. These facies are typical for confined marshes developed within the reaches of a central estuarine basin where agglutinated foraminifera species dependent on fine sediment account for almost 100% of the entire assemblage. The two 14C dates so far obtained (9470 yr. BP at 26.9 and 7080 yr. BP at 14.52 m) point once more to the conditions of the sea level rising at an accelerated rate of 0,6-1 m per century. The lithofacies from 16.4.m to 1.5 m depth, are mostly fine sand with frequent channel lags, indicating a shift in the environment to increasing tidal energy. The observed replacement of the upper marsh foraminifera by lower marsh species, as it happened in our case around 7500 -7000 yr. BP. must have occurred when the sea level rise became faster than marsh accretion. Combining these figures (after taking into account the sediment compaction) with the recent dating of the submerged rocky shore ridges on Algarve shelf by Teixeira (1999, which gave the sea levels of -20 m below the present at 7400 yr. BP and -11 m at 5860 yr. BP suggests that shelf sands became an important component of the estuarine infill between 6500-7000 yr.BP. According to Zazo et al. (1994) in that period begun the first phase (H1) of barrier progradation along the Gulf of Cadiz coast, which enabled the enclosing of coastal lagoons .

From the four cases considered, the sedimentary column of the CM4 borehole is certainly the most complex. Two gravel units (I and IV) enclose the marsh sediments (unit II) overlain by a swamp/creek laminated and hardened deposit (unit III) which experienced prolonged subaerial exposure inferred from the presence of carbonate nodules and oxidised levels. The marsh sediments are date back most probably to one of the highstands during the isotopic stage (IS) V, ca 128 ka (Zazo, 1999) or to the IS III highstand (Dabrio et al., 2000), ca. 25-30 ka. The first evidence of marine sedimentation in a predominantly sandy unit VI is the shell rich, gravel layer at 15.2 m. The existing datings 6250 yr. BP at -15.2 m, 5640 yr BP at - 9.75m and 6200 yr.BP at -7m point to a very fast accretion process of a coastal bar (with all necessary reserves imposed by the highly dynamic environment). The uppermost 3 m of sands are barren of shells and contain abundant remnants of flora, indicating that their deposition occurred in a subaerial environment of the coastal dune system.

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