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Changes in sedimentation trends in SW Iberia Holocene estuaries (Spain)

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Abstract

An analysis of sedimentation rates during the Holocene in estuaries in the southwestern coast of the Iberian Peninsula using depth/age diagrams reveals the existence of two distinct phases. The first, between ca. 10,000 and 6500 Cal BP, still in the transgressive phase, yields values of sedimentation rates of 5 mm/yr. The second phase extends after the maximum transgressive (ca. 6500 Cal BP) until the present, with sedimentation rates of 1.5–2 mm/yr. These results support the idea that marine sedimentation began during the transgressive phase and continued during the highstand phase, far beyond the time of the transgressive maximum, as postulated in some previous papers.

1. Introduction

During recent years several studies approached the evolution of the southwestern coast of the Iberian Peninsula during the Holocene. Some of them focused on the evolution of spit barrier systems (Zazo et al., 1994, 1996; Lario et al., 1995; Lario, 1996; Rodríguez-Ramírez et al., 1996), whereas other papers studied the sedimentary infill of the Flandrian estuaries (Dabrio et al., 1995, 1999, 2000; Goy et al., 1996; Lario, 1996; Pendón et al., 1998; Borrego et al., 1999). These studies used the maximum superficial extension of the open estuaries to date the age of the transgressive maximum at ca. 6500–6000 yr BP (Zazo et al., 1994). They also showed that the filling of the estuaries began during the Holocene transgression, coeval to a fast sea-level rise. Therefore, the filling continued after the transgressive maximum during the highstand phase that extends to the present (Goy et al., 1996; Lario, 1996; Dabrio et al., 1999, 2000).

We have carried out an analysis of sedimentation rates during the whole phase of infilling in three estuaries of the southwestern coast of Spain in the Iberian Peninsula (Fig. 1) that contributes to refine the available data regarding their depositional trends. As summarised in Dabrio et al. (2000), the first marine influence in the estuaries during the last postglacial transgression occurred at ca.10,000 yr BP. After the maximum flooding (ca. 6500 yr BP) the rate of eustatic rise decreased dramatically, and the estuarine filling followed a two-fold pattern governed by the progressive change from vertical accretion to lateral (centripetal) progradation.

A database of radiocarbon data in the estuaries formed using the available figures from previous papers (Table 1) allows the construction of diagrams that plot calibrated ages (x-axis) versus depth of samples in the core (y-axis). Therefore the diagrams can be used for comparing the results in the three estuaries (Fig. 2).

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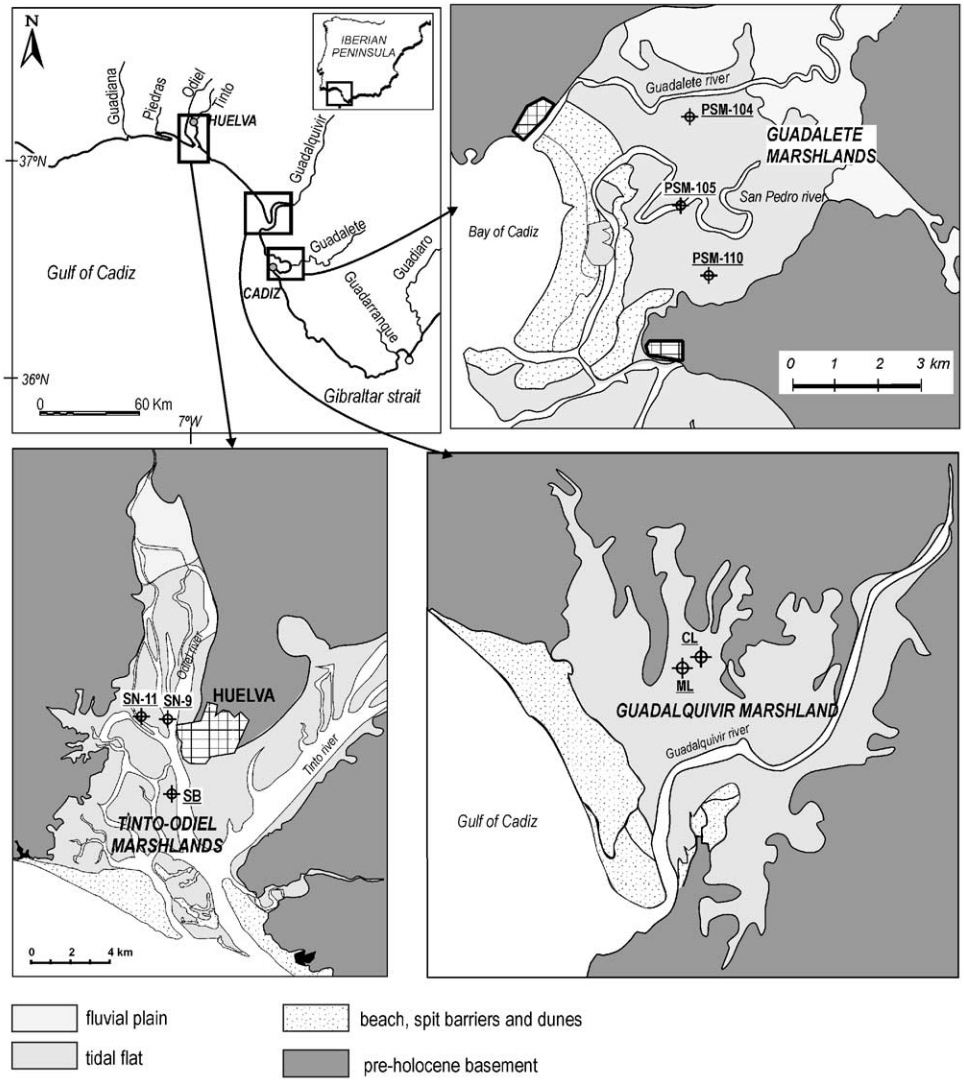

Fig. 1. Location of studied Holocene estuaries.

As radiocarbon dating has been carried out in samples of organic matter and in shells, the reservoir effect in shells has been corrected using two samples collected at the same depth from a core drilled in the Guadalquivir estuary. These samples consisted of plant remains (sample UtC-4028, radiocarbon age: 2490 ± 60 yr BP) and a bivalve shell (sample UtC-4031, radiocarbon age: 2930 ± 60 yr BP). The local reservoir effect has been calculated as 440 ± 85 yr (Lario, 1996; Dabrio et al., 1999, 2000). Although it is evident that a larger number of samples would be needed to obtain a reliable value of this parameter, the obtained value is significantly similar to the 400–500 yr calculated for areas of the North Atlantic affected by the Gulf Stream by Harkness (1983), Stuiver et al. (1986), Bard (1988), Southon et al. (1990) and Siani et al. (2000). Further treatment of data included calibration of radiocarbon ages (Table 1) using the CALIB Program, revised version 4.2 (Stuiver and Reimer, 1993; Stuiver et al, 1998).

Furthermore, observations from stratigraphic sequences (Roy et al., 1994; Nichols and Biggs, 1980) show that during the transgressive phase (when the Transgressive System Tract, TST, is deposited) the mean rate of sea-level rise (MRSLR) is usually higher than the sedimentation rate (SR), while during the highstand phase (when the Highstand System Tract, HST, is deposited) the MRSLR is lower than the SR. In the studied estuaries, Dabrio et al. (2000) found that the rates of sediment input in the estuaries surpassed the rate of sea-level rise after the maximum transgression.

2. Tinto-Odiel estuary

Many radiocarbon dates of samples collected from cores drilled in various parts of the estuary have been published (Pendón et al., 1998; Borrego et al., 1999; Dabrio et al., 1999, 2000). The sampling covers an

Table 1
Radiocarbon data

Sample	Locality	Lab[a]	Depth (m)	^{14}C yr BP	Error	Cal BP[b]	Reference
Guadalete estuary							
PSM104/C0	Guadalete	GX-20913	−4.8	3505	55	3790	Goy et al., 1996
PSM104/C3	Guadalete	GX-20914	−8.3	5885	60	6270	Goy et al., 1996
PSM104/C5	Guadalete	GX-20925	−11.55	6420	45	6850	Goy et al., 1996
PSM104/C9	Guadalete	GX-20916	−15.2	7620	55	8015	Goy et al., 1996
PSM104/C11	Guadalete	GX-20917	−20	7840	45	8280	Goy et al., 1996
PSM104/C15	Guadalete	GX-20918	−21.5	8040	55	8420	Goy et al., 1996
PSM104/C20	Guadalete	GX-20919	−24.77	8915	100	10040	Dabrio et al., 1995
PSM104/C21	Guadalete	GX-20920	−24.95	9495	340	10710	Dabrio et al., 1995
PSM102/18	Guadalete	GX-21802	−3	6405	95	6815	Dabrio et al., 2000
PSM102/3	Guadalete	GX-21803	−8,5	6420	65	6850	Dabrio et al., 2000
PSM105/3	Guadalete	GX-21840	−6	550	105	130	Dabrio et al., 2000
PSM105/4	Guadalete	GX-21804	−1.6	650	50	270	Dabrio et al., 2000
PSM105/5	Guadalete	GX-21839	−1	275	155	305	Dabrio et al., 2000
PSM106/5	Guadalete	GX-21841	−2	5240	690	5970	Dabrio et al., 2000
PSM107/1	Guadalete	GX-21842	−28.2	9620	170	10925	Dabrio et al., 2000
PSM108/6	Guadalete	GX-21805	−6.8	2985	50	2730	Dabrio et al., 2000
PSM109/4	Guadalete	GX-21843	−27.8	9620	260	10925	Dabrio et al., 2000
PSM109/7	Guadalete	GX-21806	−9.5	4210	60	4240	Dabrio et al., 2000
PSM110/1	Guadalete	GX-21807	−3.8	5750	55	6155	Dabrio et al., 2000
PSM110/2	Guadalete	GX-21808	−5	6180	55	6570	Dabrio et al., 2000
Tinto-Odiel estuary							
SN9/1	Odiel	GX-21809	−22	8780	65	9420	Dabrio et al., 2000
SN9/2	Odiel	GX-21810	−18.8	7070	60	7510	Dabrio et al., 2000
SN9/3	Odiel	GX-21811	−15.5	7265	60	7660	Dabrio et al., 2000
SN9/4	Odiel	GX-21812	−13.8	6115	55	6530	Dabrio et al., 2000
SN9/5	Odiel	GX-21813	−13.05	6310	55	6750	Dabrio et al., 2000
SN9/6	Odiel	GX-21814	−9.75	2490	50	2120	Dabrio et al., 2000
SN9/7	Odiel	GX-21815	−5.5	1400	55	910	Dabrio et al., 2000
SN11/2	Odiel	GX-21817	−3.3	655	45	265	Dabrio et al., 2000
SN11/3	Odiel	GX-21844	−7.6	2220	240	1770	Dabrio et al., 2000
SN11/4	Odiel	GX-21818	−10	3735	60	3600	Dabrio et al., 2000
SN11/5	Odiel	GX-21819	−15.2	7155	80	7540	Dabrio et al., 2000
VEC-10	Odiel	GX-VEC-10	−4	3180	135	2915	Pendón et al., 1998
SB-28	Odiel	GX-21288	−32.5	8720	260	9060	Pendón et al., 1998
SB-9	Odiel	GX-21287	−10	5390	150	5705	Pendón et al., 1998
VH-5	Odiel	BAR-VH5	−5.6	1800	80	1295	Pendón et al., 1998
VT-8	Tinto	BAR-VT8	−2.4	1620	70	1150	Pendón et al., 1998
VT-15	Tinto	BAR-VT15	−4.1	3240	100	2990	Pendón et al., 1998
VR-3	Domingo Rubio	BAR-VR3	−3.4	3090	60	2795	Pendón et al., 1998
Guadalquivir estuary							
ML97/7,3	Mari López	GX-23839	−7.3	3915	50	3830	Zazo et al., 1999
ML97/10,85	Mari López	GX-23840	−10.85	5370	50	5680	Zazo et al., 1999
CL-S1-M14	Casa del Lobo	GX-23359	−7.9	5040	70	5310	
CL-S1-M6-1	Casa del Lobo	GX-23358	−3.7	4320	60	4395	

[a] Laboratories Code: GX—Geochron Laboratories, Massachusetts, USA; BAR—Barcelona, Spain.
[b] Calibrated with the Programme CALIB 4.2, Stuiver and Reimer, 1993; Stuiver et al., 1998.

almost continuous record of the Late Pleistocene and Holocene sequence.

We have plotted the data of the Holocene estuary fill in a depth/age diagram (Fig. 2a). The diagram shows that until near 6500 Cal BP the sedimentation rates exceed 3 mm/yr and, even in the case of the SB core (Pendón et al., 1998), rates of 5 mm/yr are surpassed. This is understandable since this core is located in an external zone of the estuary, where the pre-Flandrian relief (produced as a result of the incised valley topography developed during the Last Glacial sea-level fall) left enough accommodation space.

This result indicates that the rate of sea-level rise should be higher than 3 mm/yr, at least between 10,000 and 6500 Cal BP. The diagram also shows that, after 6500 Cal BP, sedimentation rates decreased to 1 mm/yr in all the cores, suggesting values of sea-level rates lower than this figure. This is in agreement with the

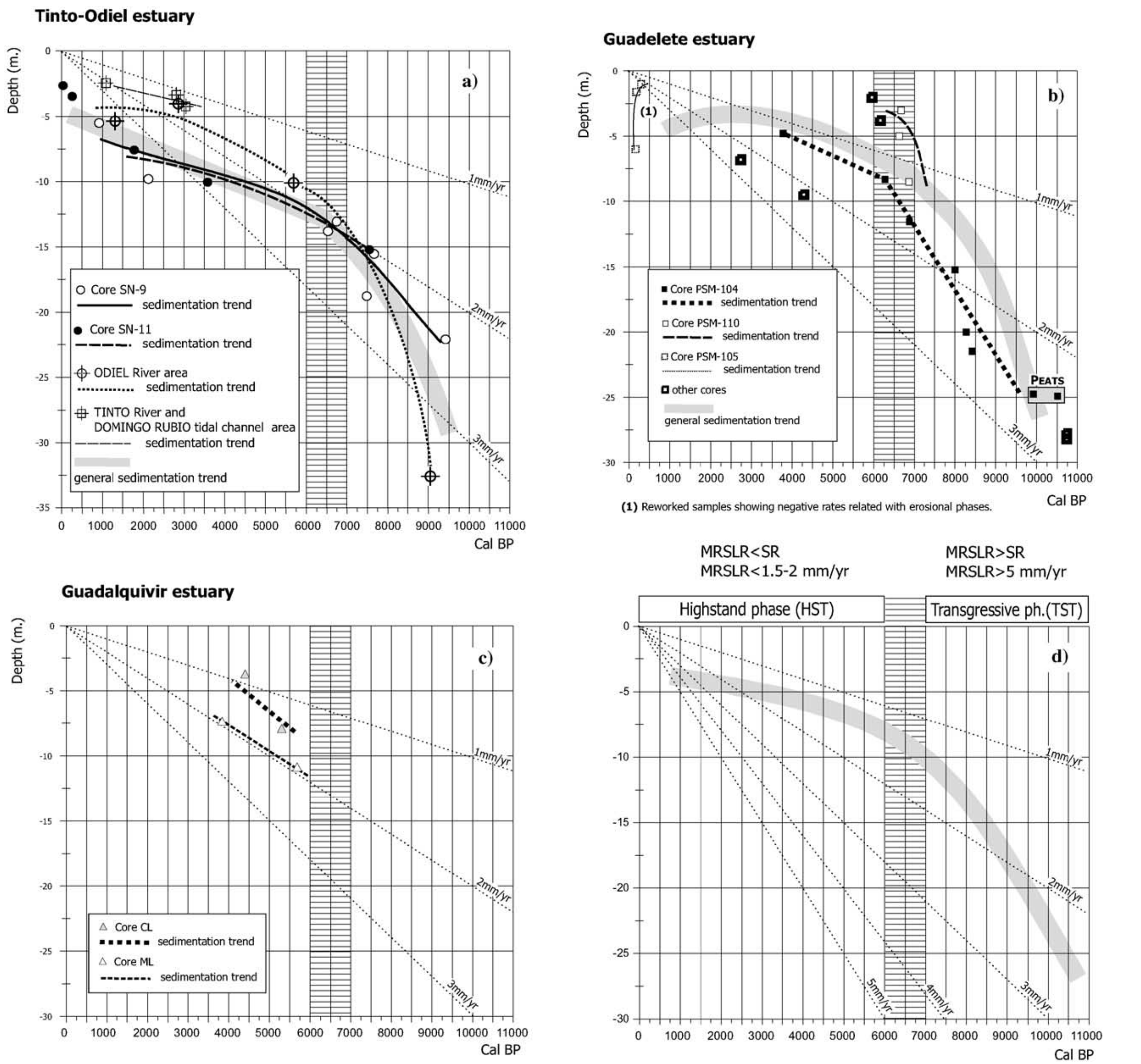

Fig. 2. Sedimentation rates and trends deduced for Holocene estuarine sequences: (a) Tinto-Odiel estuary; (b) Guadalete estuary; (c) Guadalquivir estuary; (d) general trend.

presumable stabilisation following the transgressive maximum.

3. Guadalete estuary

Data from Guadalete marshland comes from 11 drill cores described by Goy et al. (1996), Lario (1996) and Dabrio et al. (1995, 1999, 2000) where the Late Pleistocene–Holocene sequence is well exposed. Cores PSM-104 in the centre of the Holocene estuary, and PSM-110 (Fig. 2b) yielded the most continuous sets of data. The top of the underlying paleotopography generated during the Last Glacial has been situated at a depth of 28 m at this locality. A peat layer at a depth of 25 m records a stop or deceleration in the sea-level rise at ca.10,500 Cal BP. Since then until ca.6500 Cal BP rates of sea-level rise accelerated (Goy et al. 1996; Lario, 1996; Dabrio et al., 1999, 2000).

Sedimentation rates calculated using the depth/age diagram are 5 mm/yr (Fig. 2b), indicating rates of sea-level rise higher than these data. After ca. 6500 Cal BP values of vertical sedimentation rates decreased abruptly to 1–1.5 mm/yr. This can be explained as reflecting a change in sedimentation trend from mainly aggradational to progradational, and suggests rates of sea-level rise lower than this value, in agreement with essentially still-stand conditions found during the highstand. These data support the values of sea level-rise rates calculated by Dabrio et al. (2000).

Data from core PSM-105, located in the bed of the river San Pedro, show an inversion in radiocarbon data represented by negative values of sedimentation rates. This will be explained by sample reworking related to erosion and incision of the fluvial/tidal channel system taking place in the last 400 years, and interpreted as a result of anthropogenic factors (changes in cultivation methods and deforestation) and also climatic factors (increase in torrential rains, major floods and other catastrophic events) (Borja, 1992; Brückner and Hoffman, 1992; Lario et al., 1995).

4. Guadalquivir estuary

Radiocarbon dates from samples in cores of the Guadalquivir estuary (Zazo et al., 1999) cover only the last 6000 years, inside the highstand phase (Fig. 2c). The low values of sedimentation rates obtained (lower than 2.5 mm/yr) are consistent with those postulated for the still-stand conditions. Nevertheless, it is obvious that we need more radiocarbon data to refine these figures.

5. Conclusions

Because the sedimentation in estuaries is not homogeneous and synchronous in the entire basin, analyses of sedimentation rates using data from cores should be done separately for each core. Despite some local variations in the sedimentation rates, the present analysis proves that sedimentation rates in Holocene estuarine sequences of SW Spain followed two evident trends (Fig. 2d).

A first phase, between ca. 10,000 and 6500 Cal BP (i.e. the transgressive phase), with sedimentation rates of 5 mm/yr was characterised by aggradation in the estuarine basin, with significant contribution from distal deposits of prograding bay-head deltas and fine-grained marine sediments.

The second phase extends after the transgressive maximum, between ca. 6500 Cal BP and present, (i.e., during the highstand phase), with rates of sedimentation lower than 2 mm/yr, and prevailing centripetal progradation of morpho-sedimentary systems (Goy et al., 1996). Rates of sea-level rise during the transgressive phase were higher than 5 mm/yr, while during the highstand phase the sea has been almost stable, with rates of sea-level rise lower than 1.5 mm/yr. These results demonstrate that the rate of sea-level rise decreased after 6500 Cal BP, when the rate of sedimentation input in the estuaries surpassed the rate of sea-level rise, as postulated by Dabrio et al. (2000).

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