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During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

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Quaternary coastal morphology and sea level changes

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Onshore-offshore comparison of late Holocene highstand deposits in the Gulf of Cadiz margin (SW Iberian Peninsula): a record of high-frequency environmental fluctuations.

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Introduction

In the Gulf of Cadiz margin (SW Iberian Peninsula), littoral spit progradation has been controlled by high-frequency sea-level changes during the late Holocene highstand period. Progradational intervals have been related with periods of sea-level stabilization or gentle fall, whereas erosive intervals have been related to rising sea-levels (Lario et al., 1995; Goy et al., 1996; Rodríguez-Ramírez et al., 1996).

A two-fold progradational pattern has been documented within the recent highstand period in Gulf of Cadiz estuarine systems, such as the Guadalete, Guadalquivir, Tinto-Odiel, Piedras and Guadiana (Zazo et al., 1994, 1996; Lario et al., 1995; Goy et al., 1996; Rodríguez-Ramírez et al., 1996; Dabrio et al., 2000; Lobo et al., in press).

Two shorter progradational phases have been identified within each major phase, constituting four progradational phases (H1 to H4) whose timing has been estimated from ^{14}C and shell aminoacid dating, archeological and historical

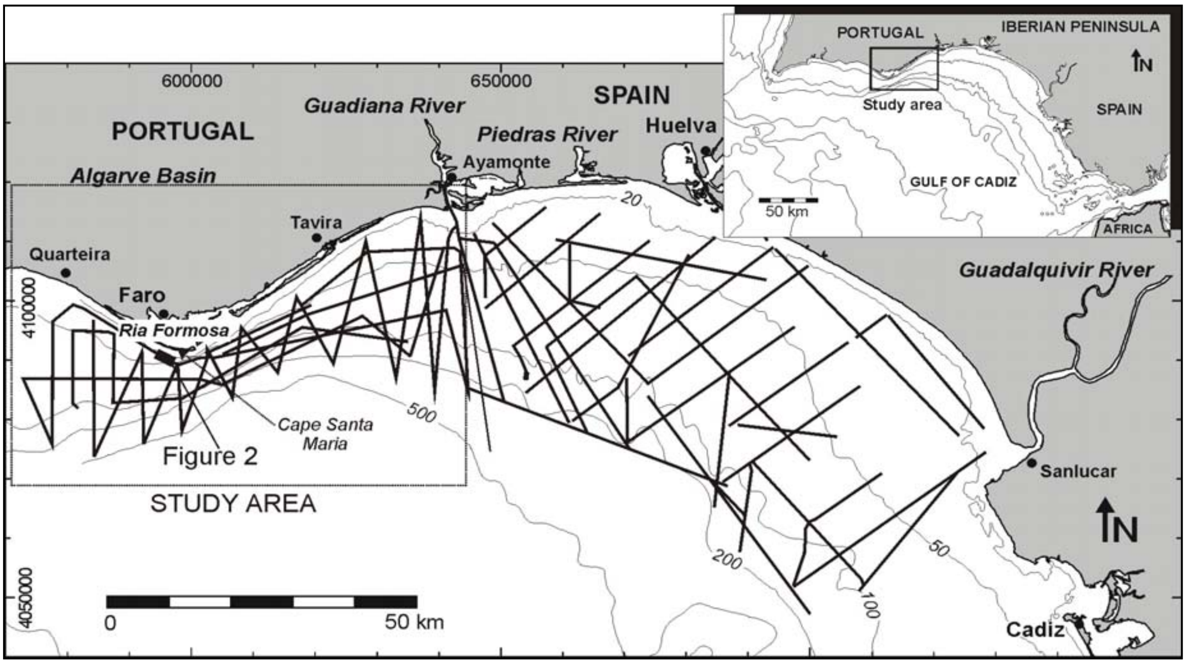

Figure 1. Geographical position of study area, showing the location of high-resolution seismic profiles.

studies conducted in spit systems: H1 (6.5-4.5 ka BP), H2 (4.2-2.7 ka BP), H3 (2.4-1.1 ka BP) and H4 (1 ka BP to present-day).

A similar stacking pattern have been identified in the Iberian infralittoral and inner shelf domains, where the late Holocene deposits show two progradational-aggradational cycles which have been related with the two major coastal progradational phases (Hernández-Molina et al., 1994; Zazo et al., 1996; Somoza et al., 1998; Fernández-Salas et al., in press). The objectives of this study are to: 1) investigate the internal structure of other shallow marine deposits of the Gulf of Cadiz; 2) make a comparison with the internal structure of coastal spits defined in previous works; 3) characterise the leading cyclicities of late Holocene highstand deposits.

A set of geophysical records was interpreted following standard seismic stratigraphy concepts, in order to study the internal structure of shallow marine deposits. The seismic source was a Uniboom system (Geopulse™: 280 Jul, shot delay of 500 ms, recording scale of 200 ms). For the purposes of this study, we have focused on the shelf sector located between the Guadiana river (Spain-Portugal border) and the Portuguese town of Quarteira (Fig. 1).

Internal structure of shallow marine deposits

Two main shallow marine deposits have been investigated in the study area (Fig. 1): the Guadiana inner wedge and the Faro-Tavira wedge. They are included into the late Holocene highstand systems tract (HST) in the Gulf of Cadiz shelf (Lobo et al., submitted).

The Guadiana inner wedge is a lobate deposit located in front of the Guadiana river to a depth of 40 m, interpreted as the modern submarine portions of a wave-dominated delta (Lobo et al., submitted). The internal structure shows two seaward prograding units (proximal and distal) bounded by a non erosional downlap surface.

The Faro-Tavira wedge is a shallow marine deposit that occurs to a depth of 25-30 m interpreted as an infralittoral prograding wedge generated by offshore sediment flux of downwelling storm currents (Hernández-Molina et al., 2000).

It displays an elongated pattern around Cape Santa Maria with two main depocenters (Lobo et al., submitted):

a) The Tavira depocenter. Its internal structure shows fourseismic units, which are arranged in two progradational-aggradational intervals dominated by progradational wedges. The lower interval shows a sigmoid wedge capped by a sheet drape. The upper interval shows a tangential-oblique wedge with five minor progradational sets capped by a surficial sheet drape.

b) The Faro depocenter is characterised by the lateral stacking of minor progradational (MPSs) and aggradational sets (MASs). These minor sets are numbered from bottom to top (MPS 1 to MPS 12, and MAS 1 to MAS 7).

In general, progradational sets are thicker than aggradational ones. Progradational sets are wedge-shaped, and show oblique configurations, although some sigmoidal progradational sets intercalated within thicker aggradational sets are also observed.

Aggradational sets MASs are sheet-shaped and show mainly aggradational configurations. Within the Faro depocenter it is possible to distinguish a lower interval characterised by the repetition of MPS-MAS motifs, and an upper interval formed by MPSs (8 to 12) (Fig. 2).The internal structure of the Tavira and the Faro depocenters are broadly comparable, as two equivalent intervals (lower and upper) attributed to two major progradational sets can be identified in both sediment bodies. These intervals would be equivalent to the two Guadiana wedge units.

The lower sigmoid wedge-sheet drape interval of the Tavira depocenter would correlate with the interval showing the repetition of MPS-MAS motifs of the Faro depocenter. The final part of this lower interval of the Faro depocenter shows a MPS (7) intercalated within two thicker MASs (6 and 7). These three minor sets would correspond to the sheet drape identified in the lower interval of the Tavira depocenter. The upper tangential-oblique wedge-sheet drape interval of the Tavira depocenter would therefore correlate with the upper interval of the Faro depocenter, where five MPSs (MPS 8 to MPS 12) are stacked laterally.

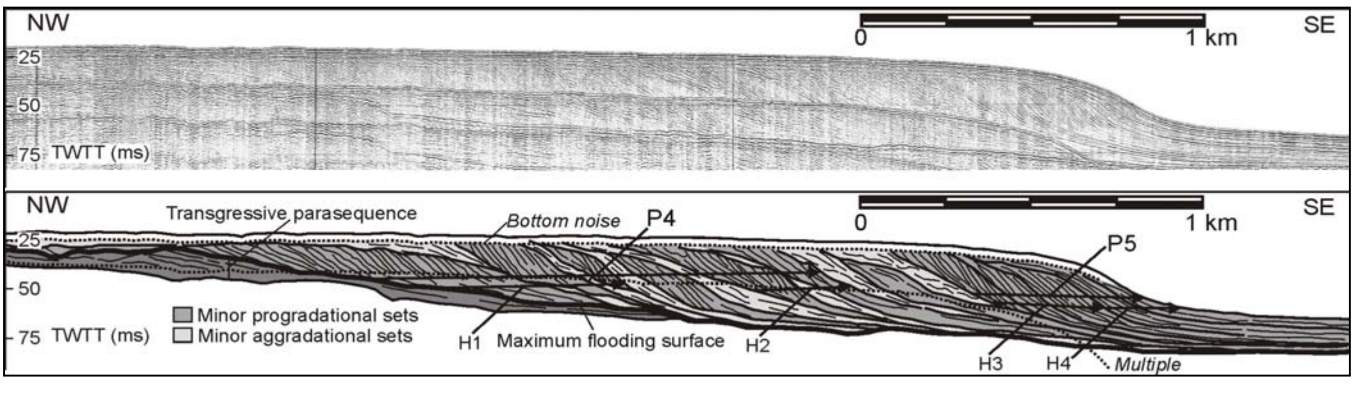

Figure 2. Seismic section and interpretation of the Faro progradational wedge, with indication of major (P4 and P5) and middle (H1 to H4) progradational phases and minor progradational-aggradational sets.

Onshore-offshore comparison

The internal structure of the identified shallow marine deposits was compared with the internal structure of coastal spits. The two major progradational sets (P4+P5) within shallow marine deposits would be equivalent to the two major progradational littoral phases. Thus, P4 (H1+H2) would be represented by the lower sigmoidal wedge in the Tavira depocenter and by the MPS 1 to MPS 6 interval in the Faro depocenter. Consequently, P5 (H3+H4) would be represented by the upper tangential-oblique wedge in the Tavira depocenter and by the MPS 8 to MPS 12 interval in the Faro depocenter. The P4 to P5 transition would be represented by the lower sheet drape in the Tavira depocenter, and by the MAS 6 to MAS 7 interval in the Faro depocenter. To refine the comparison, we consider the complex structure of the Faro depocenter, where it is possible to observe a dominantly aggradational interval between MAS 3 and MAS 4, with an intercalated MPS (4). This segment would separate two intervals dominated by MPSs, which would be equivalent to the progradational phases H1 and H2 within P4. The distinction between progradational phases H3 and H4 within P5 is more difficult, due to the absence of aggradational sets in the upper major progradational set of the Faro depocenter.

However, we benefited from detailed geomorphological analysis carried out in the emerged spit systems (Zazo et al., 1994; Lario et al., 1995), where H3+H4 are composed of five minor progradational sets. H3 would be constituted by three minor progradational sets, whereas H4 would be constituted by two minor progradational sets. Consequently, H3 would be represented by the MPS 8 to MPS 10 interval, whereas H4 would be represented by the MPS 11 to MPS 12 interval.

The record of late Holocene high-frequency environmental changes

The comparison between emerged coastal deposits and shallow marine deposits of the Gulf of Cadiz allow to propose a high-frequency late Holocene record of environmental fluctuations, led by relative sea-level and/or by climatic/oceanographic changes, and which generated significant sediment supply fluctuations.

It was assumed that progradational events are related to stable to falling sea-levels (Hernández-Molina et al., 1994; Goy et al., 1996), whereas aggradational events constitute the record of sea-level rises (Hernández-Molina et al., 1994).

Time constraints are provided for the post-glacial transgressive maximum (PTM), dated at about 6.5 ka BP (Zazo et al., 1994; Lario et al., 1995), and for the three major gaps separating the progradational events H1 to H4 (Zazo et al., 1994; Lario et al., 1995; Dabrio et al., 2000; amongst others).

The first major progradational phase P4 was modulated by five minor signals of about 600-700 years.

These cycles were asymmetric, probably characterised by prolonged, very gentle sea-level falls followed by rapid rises.

However, the third and fifth cycles would have been more symmetric, due to higher sea-level rises (H1-H2 and H2-H3 transitions), which are recorded by intervals showing increased MASs development. The occurrence of an intercalated MPS between those thicker MASs suggests that these two higher sea-level rises were not uniform. The second major progradational phase P5 would also have been modulated by five minor signals, whose periodicity would be of about 400 years. The absence of MASs within P5 would be an indicator of the more asymmetric character of Intra-P5 cycles in comparison to intra-P4 cycles.

Conclusions

The comparison of the internal structure between emerged coastal deposits and shallow marine deposits formed during the late Holocene highstand period in the Gulf of Cadiz margin allowed to define a hierarchical pattern of progradational events which were probably controlled by the influence of high-frequency environmental fluctuations. The recent highstand deposits are composed of two major progradational sets (P4 and P5) separated by an aggradational set. These two major sets are related to two 3 ka long sea-level cycles. These major progradational sets are internally composed of minor progradational (MPSs) and aggradational sets (MASs), which are the result of higher frequency cycles. P4 is composed of the repetition of MPS-MAS motifs that are controlled by 600-700 years long cycles. P5 is composed of MPSs that were controlled by 400 years long cycles. The absence of MASs within P5 probably indicates the influence of more strongly asymmetric cycles during this recent 3 ka cycle.

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