

FORAMINIFERA AS TSUNAMI TRACERS IN HOLOCENE SEQUENCES OF SOUTHWESTERN SPAIN

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Resumen (Foraminíferos como trazadores de tsunamis en secuencias holocenas del Suroeste de España): El objetivo de este trabajo es la identificación de eventos de alta energía (tsunamis?) en el P.N. de Doñana a partir del análisis de asociaciones de foraminíferos, llevado a cabo en un testigo corto, y comparar estos datos con el registro del tsunami de 1755 que tuvo lugar en el SO de la Península Ibérica, donde los foraminíferos se han mostrado como indicadores muy útiles para caracterizar los paleoambientes pre- y postsunami y delimitar capas tsunamigénicas. El resultado de integrar el estudio de asociaciones de foraminíferos con los resultados de trabajos previos se traduce en una aproximación pluridisciplinar que mejora la precisión de los estudios destinados al reconocimiento de eventos de alta energía.

Palabras clave: Tsunami, foraminífero, Holoceno, SO de España
Key words: Tsunami, foraminifera, Holocene, SW Spain

INTRODUCTION

The southwestern Spanish coast is a low-probability tsunamigenic area (e.g., Reicherter, 2001), although sixteen tsunami have been documented for the time-period between 218 BC and 1900 AD (Campos, 1991). These high-energy events have tremendous morphological effects and drastic ecological impacts in coastal areas (Borrero, 2005) and cause the deposition of sedimentary beds with characteristic textural and mineralogical features (e.g., Babu et al., 2007).

Located in the southwestern part of Spain (Fig. 1), Doñana National Park is one of the largest wetlands (~500 km²) in Europe. According to Rodríguez-Vidal et al. (2011) the 218-209 BC tsunami caused the deposition of sandy and shelly ridges. Three evolutionary phases can be distinguished in the sedimentary record: 1) Pre-tsunami phase, where the continuous growth of the Doñana spit-barrier and the progressive infilling induced the formation of new brackish marsh; 2) Tsunami phase, where a tsunami eroded both the Doñana and La Algaida spit-barriers, introducing sandy sediment with shells and rounded clasts towards the inner part of the estuary; and 3) Post-tsunami phase, characterized by the accumulation of bioclastic sediments over the lagoon margins, windblown sand facies, and an increasing infilling of the lagoon, with a progressive transition towards intertidal-supratidal conditions.

The morphological and sedimentological changes in the coast triggered by such high-energy event were similar to (or even greater) the 1755 AD Lisbon tsunami event. Probably, around that time, the Gulf of Cádiz estuaries were still poorly protected by coastal barriers, and tsunami waves could penetrate many kilometres deep inside, flooding the coeval inner lagoons and tidal plains.

The present paper describes a preliminary study of the foraminiferal assemblages of one drill core, located near a chenier plain in Las Nuevas (Fig. 1, core D). The chenier plains present a complex system of sandy and shelly ridges formations in this

area, and are evidence of an intense erosional event. The results are combined with previous studies (e.g., Ruiz et al., 2004, 2005,) made for the same purpose in this area, which provides a complete multidisciplinary approach that increases the accuracy of previous studies.

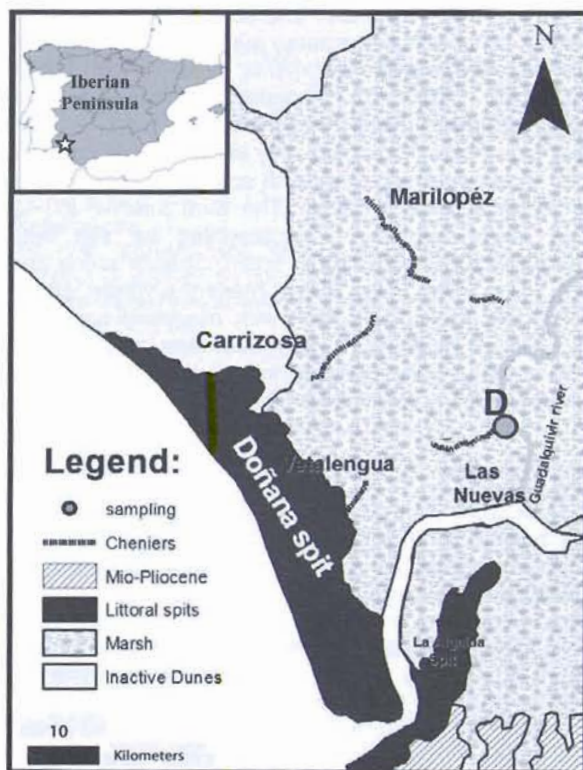


Fig. 1: Doñana National Park geological map adapted from Ruiz et al. (2008) showing the location of the studied core D

GEOMORPHOLOGICAL SETTING

This estuary includes the Doñana National Park where fluvial levees flanking the Guadalquivir river and its former courses, with two main directions, namely N-S and W-E. These fluvial levees have a variable width (300-1500 m) and length (up to 3-5

km), reaching heights of 0.8 to 1 m above the adjacent marshes. The high elevated areas (2-2.5 m above the marsh level) are occupied by characteristic accumulations of bivalves, with beach ridge morphology. They are elongated (3-6 km), with a narrow width (20-30 m) and thickness (0.5 -0.7 m) and can be classified as cheniers (Rodríguez-Ramírez et al., 2008).

METHODOLOGY

The area of Las Nuevas was selected for coring, because it contains the main geomorphological features of the estuary. One core (D) was collected with a 20 mm diameter vibracore reaching up to 1.6 m depth (Ruiz et al., 2004). Approximately 15 g of 22 samples were taken for microfossil analysis, as they were selected according to the main sedimentary changes observed in the core. These samples were washed through a 63 µm sieve to remove the mud fraction and then dried. If possible, more than 300 foraminifera from each sample were picked and identified onto faunal microscope slides. Both the ratio between marine and hyposaline species and the total number of individuals/gram in each sample were calculated (Fig. 2).

CORE DESCRIPTION

The core D (Fig. 2) presents a lower interval (162-129 cm below surface) characterized by massive, bluish clays with very sparse macrofauna. Above this layer, very similar sediments (129-63 cm below surface) present abundant fragments of phanerogams and numerous roots. This homogeneous lithology is only interrupted at depth of 91-79 cm by a silty level with scattered fragments of bivalves (*Cardium edule*). The third interval (63-43 cm below surface) is represented by silts with frequent shells of *Cardium edule*, *Spisula solida* and *Rissoa* sp. The upper 43 cm present a yellow, sandy body composed of quartz, with abundant and well-preserved molluscs (mainly *Cardium edule*). This macrofauna was disposed in massive beds or with horizontal plane lamination.

RESULTS

- Ecological groups of foraminifera. Two main groups of benthic foraminifera may be distinguished, each one constituted by species with analogous ecology (Murray 1971):

(a) hyposaline lagoons and estuaries assemblage constituted by *Ammonia tepida*, *Haynesina germanica*, *Elphidium oceanensis*, *Elphidium cuvillieri*, *Discorbis williamsoni* and *Quinqueloculina seminulum*; and (b) continental shelf/marine assemblage constituted by *Nonion granosum*, *Bolivina* spp., *Brizalina* spp., *Buliminella elegantissima*, *Elphidium complanatum*, *Elphidium crispum*, *Quinqueloculina stelligera*, *Adelosina longistrata*, *Lagena* sp., *Miliolinella subrotunda*,

Bulimina elongata, *Bulimina gibba*, *Uvigerina peregrina*, *Spirallina vivipara*, *Planorbulina mediterraneensis*, *Cibicides lobatulus*, *Stainforthia* sp., *Dentalina* sp., *Rosalina* spp., *Epistominella* sp., *Hoeglundina elegans*, *Asterigerinata mammilla* and *Nonion fabum*, *Pararotalia* sp.

- Zonation of the core. The foraminifera analysis of core D allow us to differentiate five zones in the recent palaeoenvironmental evolution of this Doñana sector.

Zone D1 (162-129 cm): marked by the presence of planktonic foraminifera (~50 ind/g) and low abundance of benthic foraminifera.

Zone D2a (129-91 cm): marked by a diminution of the planktonic and low abundance of benthic individuals.

Zone D2b (91-79 cm): showing an absence of foraminifera at the base, followed by an increasing density towards the top, in both benthic and planktonic species.

Zone D2/D3a (79-45 cm): characterized by the presence of both hyposaline/estuarine and continental shelf benthic foraminifera, as well as planktonic individuals.

Zone D3b (45-30 cm): characterized by an abrupt increase of both benthic foraminifera diversity and density towards the top and similar occurrence of hyposaline lagoon/estuarine and marine assemblages together with planktonic species.

DISCUSSION AND CONCLUSIONS

The lower zone D1 (162-129 cm below surface), shows a foraminiferal assemblage mainly dominated planktonic species and low abundance of benthic foraminifera, corresponding to an open lagoon environment under marine influence. This is in agreement with the previously ostracoda environmental description as a lagoon environment by Ruiz et al., 2004.

Zone D2a is marked by a diminution of the planktonic species and low abundance of benthic individuals, corresponding to a restricted mud flat or marsh. This zone corresponds to a subunit of the ostracoda D2 zonation, described as a restricted mud flat environment by Ruiz (2004).

Zone D2b shows an absence of foraminifera at the base, followed by an increasing density towards the top, in both benthic and planktonic species. These results are in accordance with the existence of reworked macrofauna (fragments of scaphopods, bryozoans and sponges) previously observed in this layer and interpreted as a storm deposit (tempestite) deposited in the marine sector of the estuary.

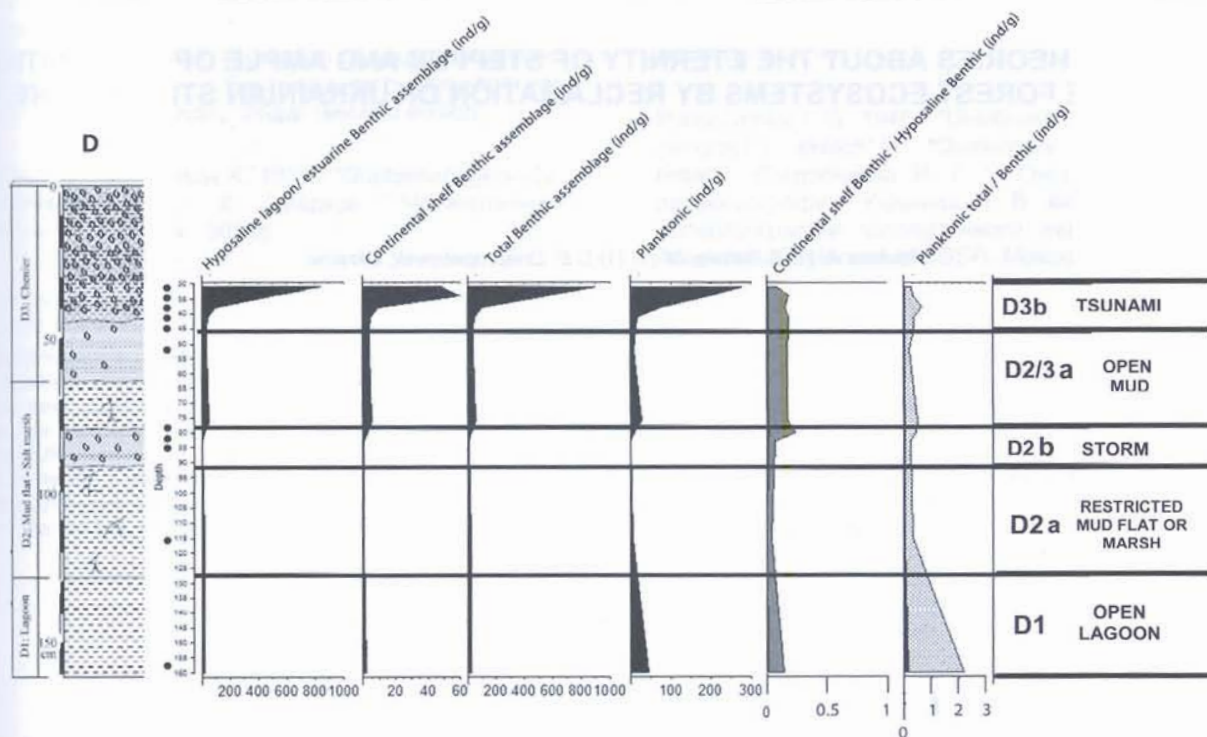


Fig. 2: Abundance and assemblages of foraminifera in the core (number of individuals per gram). Zonation presented on the left side of the figure is from Ruiz et al., 2005, whereas the zonation on the right side is proposed in the present work, based on foraminiferal assemblages.

Zone D2/D3a represents a transitional zone, marked by the presence of both hyposaline/estuarine and continental shelf benthic foraminifera as well as planktonic individuals, and corresponding to a more open mud flat environment.

Zone D3b shows an increase in density of all species towards the top, with presence of coastal marine foraminiferal assemblages and a larger number of planktonic species. Ruiz et al. (2004) described this D3 subzone as a chenier produced by a high-energy event (tsunami?) that probably occurred around 218-209 BC (Rodríguez-Vidal et al., 2011), which final result is the accumulation of massive beds of estuarine macrofossils in the intertidal-supratidal areas of the lagoon.

In the present work we observe that this high-energy events leads to a change in foraminiferal assemblages, which was not observed in previous ostracods analysis. This suggests that foraminifera are more adequate to record extreme environmental changes, mostly through the ratio between coastal marine and hyposaline assemblages and the presence of planktonic individuals. However, higher resolution analysis is needed for better constraining the event.

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