HOLOCENE HISTORY OF RIA FORMOSA COASTAL LAGOON SYSTEM (SOUTHERN PORTUGAL): BOREHOLE EVIDENCE AND THREEDIMENSIONAL PALEOTOPOGRAPHY

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Abstract (Holocene history of Ria Formosa coastal lagoon system, southern Portugal: borehole evidence and threedimensional paleotopography): *A paleotopographic model of Ria Formosa is presented based on two borehole campaigns and a systematic comparison with previous works, revealing the existence of a complex network of fluvial valleys. Vertical sediment profiles showed a mosaic of changing depositional environments, resulting from local hydrodynamics, sedimentary sources and, to an extent, by the structurally inherited accommodation space. Sedimentological, geochemical and micropaleontological data were put in the context of an age model obtained from ^{14}C datings, pointing to the existence of an estuarine environment subjected to a rapid coastal flooding from ca. 10000 to 7500 cal. years B.P., followed by a period of infilling in an increasingly confined coastal lagoon environment.*

Key words*: Ria Formosa coastal lagoon, pre-Holocene paleotopography, transitional environments*

INTRODUCTION

In general terms, coastal systems geomorphology results from the interaction between sediment availability, both terrestrial and marine, and its transport mechanisms, dictated by fluvial and marine hydrodynamics (Carter and Woodroffe, 1994). Sea level plays therefore an important role.

Although with different global patterns, the Tardiglacial to early-Holocene period was marked by a rapid sea level rise rate, reaching an early to mid-Holocene inflexion point on which it slowed down substantially (Fairbanks, 1989; Pirazzoli and Pluet, 1991; Smith et al., 2011). This deceleration constitutes the base level for a generalized worldwide coastal modification (Stanley, 1995).

In the Atlantic Iberian coastal systems, deposition begun as a result of the Tardiglacial/early-Holocene marine transgression, inundating and quickly infilling deeply incised Pleistocene river valleys such as Guadiana (Boski et al., 2008), Guadalquivir (Dabrio et al., 2000) and Tejo (Vis et al., 2008). During this phase, vertical accretion dominated the depositional environment (e.g. Delgado et al., 2012). The following period from mid-Holocene until present, having the sea level reached a high stand between 6500 and 5600 years BP (Dabrio et al., 2000; Moura et al., 2007). Sedimentation rates were reduced (Delgado et al., 2012; Lario et al., 2002), pointing to a change in sedimentary dynamics. Subsequent evolution assumed a more regional and complex pattern with new coastal features emergence such as sand barriers, spits and coastal lagoons (Dias et al., 2000).

Despite its size, socio-economic importance and Natural Park status, the knowledge of Ria Formosa's formation and subsequent evolution is still very incomplete. Previous works suggested models dictated by barrier island migration towards the continent during the rapid transgression phase, later reworked by extreme events and prevailing hydrodynamic conditions (Andrade et al., 2004; Bettencourt, 1994; Pilkey et al., 1989). Although it is implied that the general architecture of the barrier chain may reflect the inherited shelf morphology, none of the previous models completely explains the present-day triangular shape of Ria Formosa.

As such, present work intends to contribute to the reconstruction of the Holocene geomorphological development of Ria Formosa. A greater emphasis was given to the underlying paleosurface and to the sediment infill architecture.

BACKGROUND

The Ria Formosa is a costal lagoon enclosed behind a system of five barrier islands and two spits, extending nearly 55km. Its unusual triangular shape elongates ca. 6km in front of Faro. The mesotidal, semidiurnal tidal regime ranges between an average of 2.8m and 1.3m for spring and neap tides respectively, although ranges of 3.5m can be reached (Pacheco et al., 2008). Since the beginning of the 20th century, land reclamation takes place, modifying the maximum tidal range (Arnaud-Fassetta et al., 2006). The Ria Formosa system is characterized by a large intertidal unit (ca. 90% of its area), predominating large salt marshes, sand and muddy flats, and a complex channels network (Andrade et al., 2004). The bordering central land unit is composed of Plistocene red sand with a few rounded pebbles of quartz and iron nodules (Chester, 2012), cut through by several tributaries paleovalleys.

METHODS

Two borehole campaigns were carried out performing 41 manual Auger and 5 mechanical coring sites (RFM and RF codes respectively). Site selection mainly followed the axes of terminal stretches of existing tributary valleys (fig. 1). Manual cores were photographed and described *in situ*, annotating stratigraphy, colour, textural class, sedimentary features, visible organic content, and preserved mollusk shells or bioclasts. Core length ranged between 8.6m and 1.55m with a diameter of ca. 35mm. On average, samples were collected and preserved every 0.8m. Mechanical cores were integrally preserved in laboratory, ranging between 26.5m and 11m in length with a diameter of 102mm. Mechanical cores were split longitudinally in two halves, recording the same macroscopic information as in the manual cores. On average, samples were collected every 0.6m. All samples were later used for ^{14}C AMS dating and for sedimentological, geochemical and micropaleontological analysis after careful selection. Core data was incorporated in log profiles using LogPlot®7 and RockWorks®15. Borehole location and elevation was recorded with a Trimble®R6 GPS Receiver.

In order to reconstruct the Ria Formosa underlying substrate surface, available datasets were georreferenced and matched in ArcGIS®10, using PT- TM06/ETRS89 datum and corrected in terms of vertical elevation to mean sea level. Where possible, the Plistocene/unconsolidated sediments contact layer was identified in the aforementioned boreholes and in other borehole campaign sources (Bettencourt, 1994; Andrade et al., 2004; Faro's Airport geotechnical surveys, n.d.). Offshore rocky outcrops location, late 19th century maximum tidal range, and actual topobathymetric digital elevation model of Ria Formosa (unpublished data) were also combined. A hydrologically corrected three-dimensional paleotopography was then interpolated, minimizing sinks or depressions.

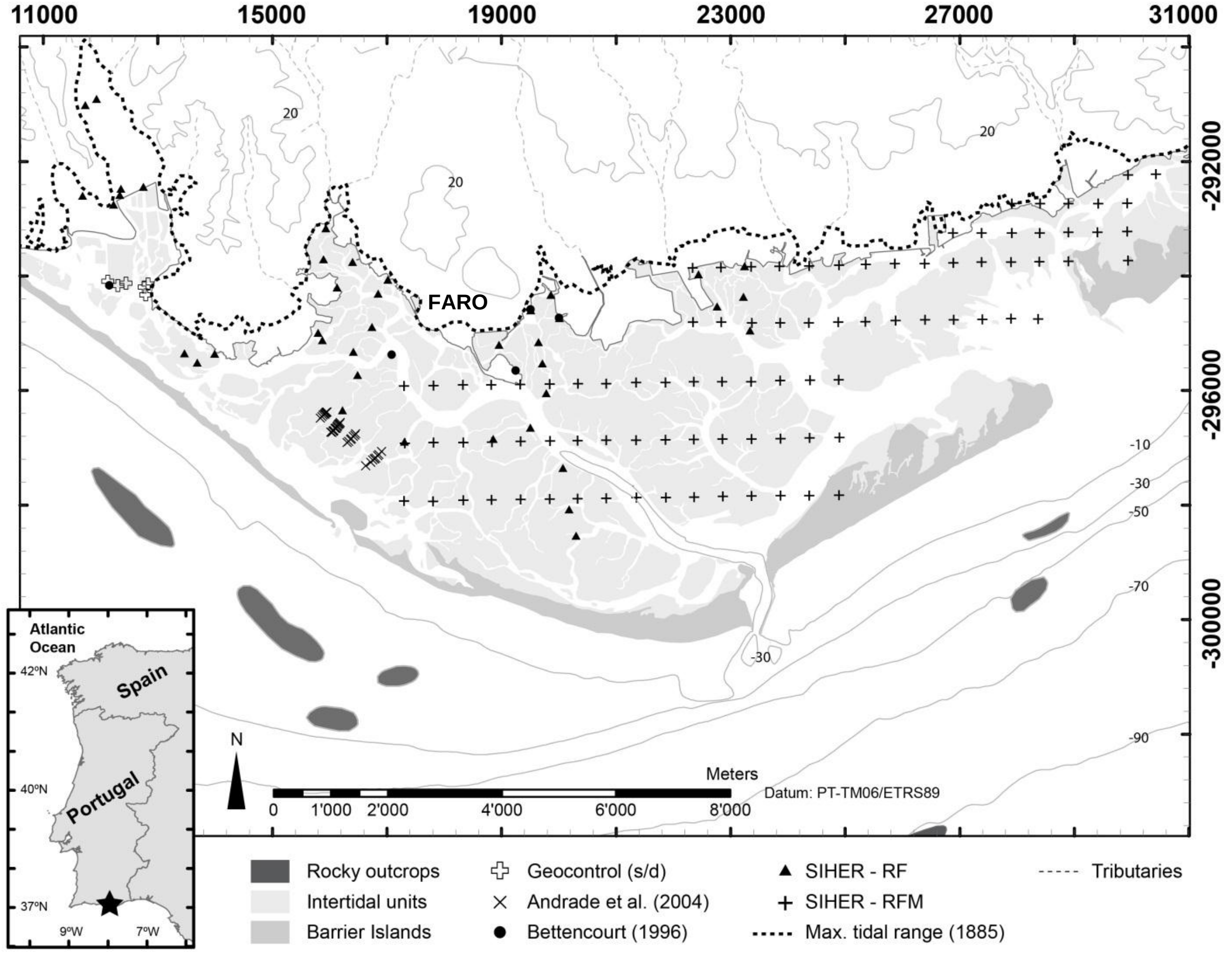

Fig. 1: Location map showing central part of Ria Formosa, highlighting: boreholes sites; main morphosedimentary units; topobathymetric isolines; maximum tidal range (actual and in 1885); and tributaries valleys. Note that some tributaries were realigned through land reclamation.

RESULTS AND DISCUSSION

The paleotopography digital terrain model based on, existing borehole data and extrapolation of surface geomorphic features, shows a more complex than expected network of fluvial paleovalleys, following the discharge position of today's tributaries (fig.2). Five major talwegs can be individualized until the -20m isoline. Not surprisingly, nowadays main tidal channels of Ria Formosa gently follow the paleotalwegs, namely in the esteiro de Ramalhete and canal de Faro-Olhão. The most striking feature is the existence of two extended platforms until the -30m range, separated by the central talweg, both NW-SE oriented. Terrain elevations stand out over these platforms, generating river paleovalley diversion in front of Faro.

This inherited geomorphological architecture allowed the tailoring of different hydrodynamic settings, which ultimately would lead to segmented sedimentary bodies with particular deposition environments.

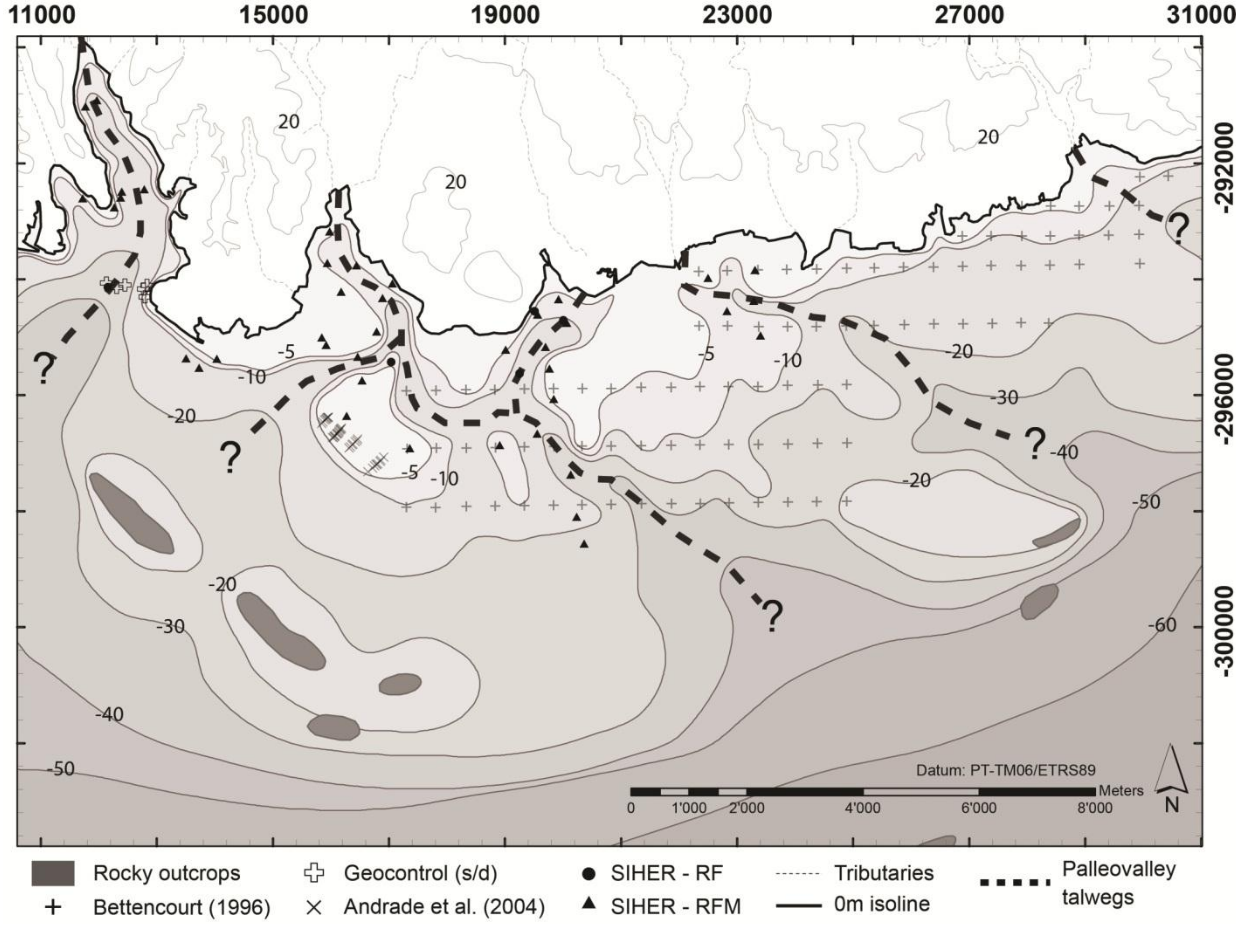

Fig. 2: Paleotopography digital terrain model map of Ria Formosa central part. In 95 out of 211 of the cores the identification of the underlying Pleistocene substrate was possible. In the remaining 116 the limit was considered 2m bellow the total core depth.

Visual interpretation of sediment facies in the 45 boreholes allowed the identification of at least two major depositional areas. At west, the ribeira de S. Lourenço paleovalley, shows a transitional environment, starting in a lower energy estuarine setting. A higher energy open estuary environment follows, dominating sand facies that changes to a lower energy setting, with clayey silts deposition. Finally, sand facies become dominant, indicating a new change in the environmental setting, most likely due to a total breaching of the preceding enclosed estuary. Preliminary analysis of micropaleontological content (Pereira et al., 2013; Gomes et al., 2013 – this issue) indicate a estuarine setting in the first phase, that changes to a more open estuary setting, persisting until the last ca.1,5m.

In the central part of Ria Formosa, fluvial paleovalleys appear to have a more narrow and incised nature (fig.2), allowing the neighboring areas to infill in a much lower energy setting, with continuous profiles of clayey silt. Micropaleontological content (Pereira et al., 2013 – this issue) point to great sea water exchange rate between these sheltered areas and the open sea.

The nearly 20 samples collected for ^{14}C AMS dating (namely mollusks shells or organic debris preserved in the sediment) mark the first stage of the Ria Formosa infill between ca. 10.000 years cal. BP and 7.500 years ca. BP (fig.3). During this phase, the rapid early Holocene transgression is expressed by at least 5.4mm/year deposition rate, a value significantly similar to the recently proposed regional sea level rise models (Boski et al., 2008; Delgado et al., 2012).

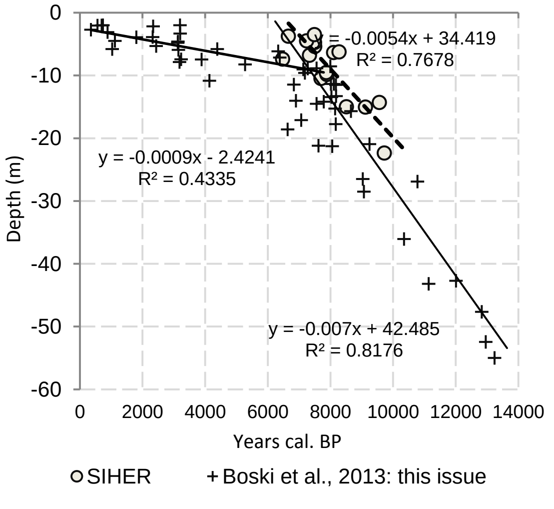

Fig. 3: Depth/Age model for SW Iberian Peninsula. Solid lines consider a 6500 years cal. BP regression inflexion moment. Dotted line represents only the Depth/Age regression in Ria Formosa.

Although with no datable element, the following phase is marked by a much slower depositional rate. It is unclear what this cause of this absence. Different sediment erosion or reworking might be at the source of this problem.

Matching the proposed regional sea level rise rate with the paleotopography three-dimensional model it is possible to simulate the mean sea level position in different Holocene chronological snapshots (fig.4). The aforementioned major depositional areas become more evident. The rapid early Holocene transgression quickly floods most of the immerse features. By ca. 5.000 years cal. BP (fig.4-5), sea level was close to its present position. It is assumed that during this time the coastal lagoon begins to acquire its present shape. The existence of a large and deep paleovalley in the outer reach of Ria Formosa must have proved to be a natural obstacle to the W-E oriented longshore sediment drift. Barrier island system must have attained its current outline after the infill of this paleovalley, lagging the enclosure of the coastal lagoon some thousand years. Micropaleontological data (Pereira et al., 2013; Gomes et al., 2013 – this issue;) suggest an ecological shift in the 3.000 years cal. BP horizon, with a greater predominance of brackish species, thus implying a enclosement of the coastal system.

CONCLUSIONS

This work presents a first approach to the multiproxy interpretation of the Ria Formosa Holocene geomorphological evolution. None the less it corroborates and fits to the sea level rise model for the southwestern Iberian Peninsula, clearly divided in two main phases: (i) rapid rise and flooding of coastal features in the Tardiglacial to early Holocene period; and (ii) drastic deceleration of sea level rise rate to values similar to nowadays.

Still major tasks lie ahead, being required to further include other sources of data in a single Holocene reconstruction storyline, specifically by analyzing in more detail the collected sedimentological, geochemical, micropaleontological samples.

The interpretation of the sedimentary record archives in coastal environments, embracing the Tardiglacial to Holocene period, proves to be a valuable resource for coastal dynamics reconstruction and future evolution extrapolation.

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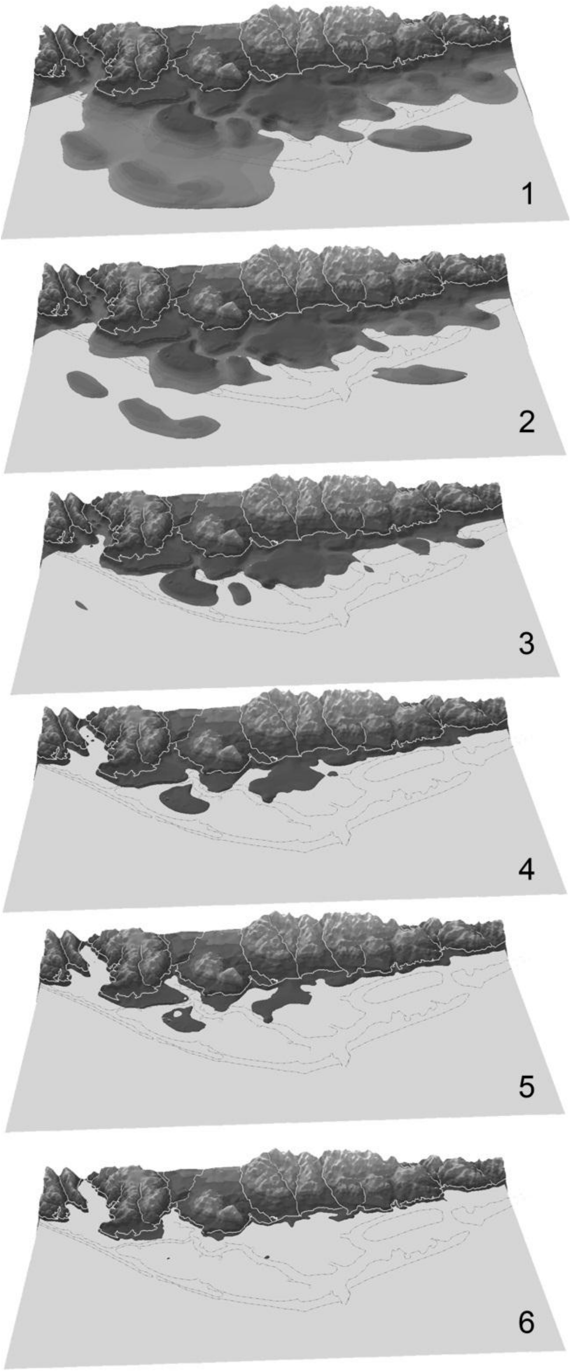

Fig. 4: Simulation of Ria Formosa Holocene sea level rise using paleotopography surface model. Sea level position is inferred as an approximate value according to Delgado et al. 2012. 1: ca. 10.000 years BP; 2: ca. 9.000 years BP; 3: ca. 8.000 years BP; 4: ca. 7.000 years BP; 5. ca. 5.000 years BP; 6: ca. 3.000 years BP. Dotted lines outline present day barrier islands position and main tidal channels.

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