Multiproxy approach to characterize an overwash deposit: Oualidia lagoon (Moroccan Atlantic coast)

Caracterización multidisciplinar de un depósito de overwash: laguna costera de Oualidia (costa Atlántica marroquí)

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RESUMEN

Se han analizado muestras sedimentologicas y micropaleontologicas de un sondeo realizado en el extremo sur oeste de la laguna costera de Oualidia (Marruecos). Los resultados obtenidos muestran una secuencia de relleno que presenta una evolución desde materiales submareales con influencia marina hasta que la zona se colmata y aparece un medio marismeño. La zona intermedia de la secuencia presenta materiales arenosos con influencia marina que se hacen mas restringidos, como indica el predominio de materiales fangosos y foraminíferos típicos de ambientes salobres. Esta secuencia está truncada en el techo por la presencia de un deposito de overwash. Mientras que este depósito pueda diferenciarse netamente de los materiales infrayacentes, es imposible concluir que esta combinación de técnicas pueda utilizarse para identificar depósitos de tormenta en el registro fósil. Los resultados obtenidos, sugieren, sin embargo, que este tipo de depósitos podrían diferenciarse en secuencias continuas de depósitos marismeños y por tanto podrían proporcionar información relevante de la frecuencia e intensidad de tormentas ocurridas en el pasado. Esos estudios han de tener en cuenta, sin embargo, otros aspectos sindeposicionales, como son la bioturbación o la preservación de las capas sedimentarias.

Key words: *Overwash deposits, Oualidia lagoon, sedimentology, foraminifera, Atlantic coast.*

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Introduction

Under the current climatic scenario of global warming, it is expected an increase in storminess along the coastal areas of the North Atlantic Ocean. To this factor, we have to add rising sea-levels, with global estimates of + 0.6 (IPCC, 2007) to > 1 m (e.g. Rahmstorf, 2007, Parry, 2000) by the end of the 21st century in worst-case scenarios. This is expected to have a large impact in coastal barriers. As a result, there is a growing interest in erosion and deposition processes along these areas. In fact, recent storm events inducing barrier breaching and retrogradation have demonstrated the economic impacts of these events and the need to better understand the driving processes (Hippensteel and Martin, 1999). Storms are major agents in coastal evolution and this is even more critical in barrier coasts (Andrade *et al.*, 2004).

If storminess increases over time, one possible result in coastal areas is triggering or enhancement of roll-over, added by multiple barrier breaching and this, in a rising sea level scenario, could have a dramatic impact in those areas. Geological studies of these deposits could help to improve our understanding of the long-term variability of the storm frequency and magnitude that apparently has been changing over the last 150 years (Hippensteel and Martin, 1999; Andrade *et al.*, 2004).

In this study, we analyze the sedimentological and micropaleontological signatures of the Oualidia washover (Moroccan Atlantic coast) and sediments beneath, in order to provide insights into the back-barrier depositional processes, including storm-generated overwash, aiming to improve our present-day ability to identify signatures of such events in the sedimentary geological record.

Study area

Oualidia lagoon is located on the North Atlantic Ocean (32º40'42''N-32º47'07''N and 8º52'30''W-9º02'50''W; Fig. 1). The lagoon is 7 km long and 0.5 km wide and its elongation follow the general southwest-northeast trend of the coastline. One major inlet (150 m wide and 2 m deep) allows water exchanges with the ocean and tides are conveyed by one meandering main channel (2 m mean depth) that further divides into small creeks feeding lagoonal marshes. The general morphology is controlled by a Plio- Quaternary abandoned cliff running along the eastern margin of the lagoon and at the seaward

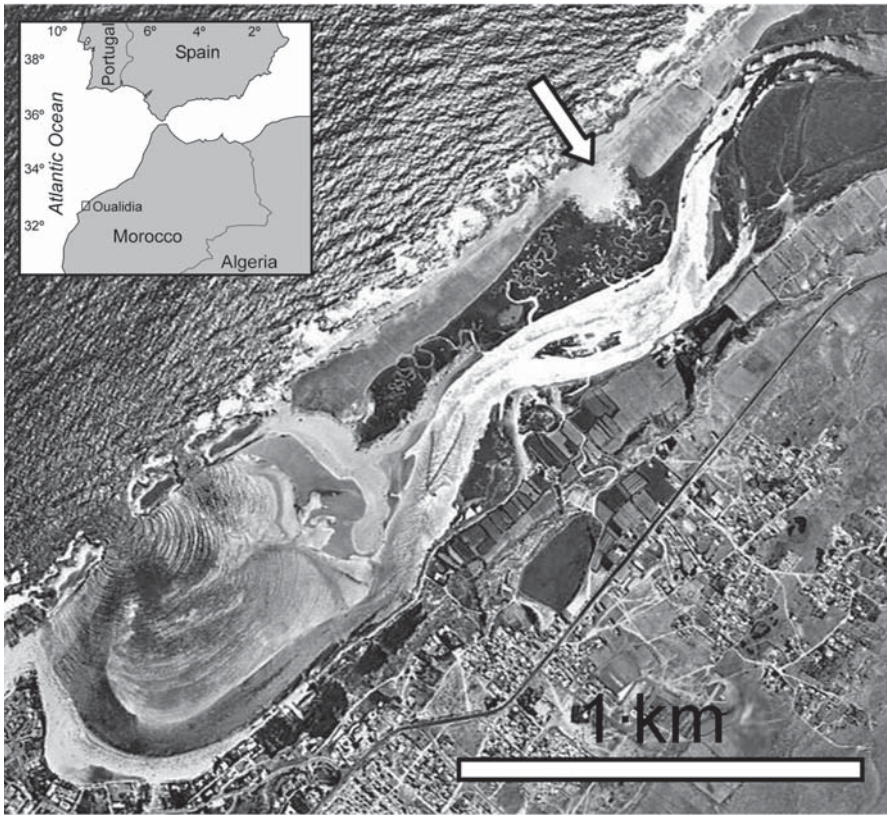

Fig. 1.- Location map and areal photograph. The arrow indicates the sampling area.

Fig. 1.- Mapa de localización y fotografía áerea. La flecha indica la zona de muestreo.

margin by a laterally discontinuous outcrop of aeolianite (Zourarah *et al.*, 2007), partly covered by an active beach-foredune system. The washover described in this study includes a corridor lowering the foredune ridge and a sandy lobe invading the lagoonal high marsh (Fig. 1).

Materials and Methods

Coring of the Oualidia washover and sediments beneath was undertaken using a combination of Edelman and gauge augers and a van der Staay suction corer down to *ca* 2 m below surface. The sediments were described in the field for color, texture, nature and geometry of contacts and fossil contents. Present-day beach samples were also collected. Upon returning to the laboratory samples were processes for sedimentological and foraminifera analysis. Sedimentological studies (12 samples) included grain size analysis (sediment coarser than 63 µm by sieving and the undersized fraction using a Malvern laser particle analyzer), pH was calculated by an electrometric method ,determination of the organic matter content (OM) by loss of weight on ignition and determination of the $CaCO_3$ content (correspondent to bioclasts) using an Eikelkamp calcimeter . The dimensional and sorting classification of sand follows the classification of Friedman and Sanders (1978).

Thirteen samples of the Oualidia core and two modern beach samples were analyzed for foraminiferal content. Samples were sieved through a 1 mm sieve (to remove large organic fragments) and through a 63 µm sieve to wash and remove clay and silt material. Tests were picked until a representative number of more than 300 individuals was obtained, and then studied under a stereoscopic binocular microscope using reflected light. The total number of samples analysed was 15, and more than 4500 foraminifera were identified.

Results and Discussion

Figure 2 and 3 summarize sedimentological and foraminiferal results.

The study of the core allowed to identify three main lithostratigraphic units, with contrasting texture (mean grain size, sorting and sand/mud ratio), bioclastic and organic matter content (Fig. 2).

Lower unit A (89-190 cm depth) - this unit is made of coarse to medium slightly muddy carbonate sand ($CaCO_3$ > 80%), moderately to poorly sorted, with low OM content (< 3%).

Unit B (37-89 cm depth) - this Unit may be sub-divided in two sub-Units:

Sub-Unit B_I (60-89 cm depth) consists of muddy sand at the base grading upward to sandy mud (the sand component being fine and well sorted). The $CaCO_3$ content is lower (30 to 60%) and OM values slightly increase (3 to 4%).

Sub-Unit B_II (37-60 cm depth) consists of organic (OM 7 to 10%) mud, with the lowest values of both $CaCO_3$ (6 to 12%) and sand in the whole core.

Upper unit C (0-37 cm depth) - this unit is made of clean medium to coarse, well sorted carbonate ($CaCO_3$ > 85 %) sand, with low OM (< 3 %) content.

The present-day beach is made of clean, carbonate (94% $CaCO_3$), medium and very well sorted sand.

Similarly, micropaleontological data suggest 4 foraminiferal assemblage zones (FAZs) matching the lithostratigraphic units (Fig. 3).

FAZ_IV (89-190cm depth) - this zone is dominated by the allochthonous species (i.e., open marine foraminifera) *Cibicides lobatulus* and *Elphidium crispum* with lesser abundances of *Ammonia beccarii*. Those are robust species that can be transported long distances. FAZ_III (60-89 cm depth) is dominated solely by *C. lobatulus* accompanied by *A. beccarii*, *E. crispum* and *Haynesina germanica*. The main difference between FAZIV and FAZ_III is the presence of *H. germanica* that is a typical species from brackish waters.

FAZ_II (37-60 cm depth) is highly dominated by agglutinant species, mainly *Jadammina macrescens*, although *C. lobatulus* is still significant.

On top of FAZ_II, FAZ_I (0-37 cm depth), is dominated by *C. lobatulus, A. beccarii*, *E. crispum* with lesser abundances of milliods (e.g., *Miliolinella subrotunda* and *Massilina* spp.).

Samples recovered from the modern beach environment showed a dominance of the allochthonous species *E. crispum, C. lobatulus* and *A. beccarii*, with lesser abundances of milliods (e.g., *Miliolinella subrotunda*). This assemblage is similar to that described in FAZ_I (washover), differing in the relative presence of *E. crispum* and *Miliolinella subrotunda* (greater in the beach deposits).

Sedimentological and paleoecological results indicate that sediment accumulated

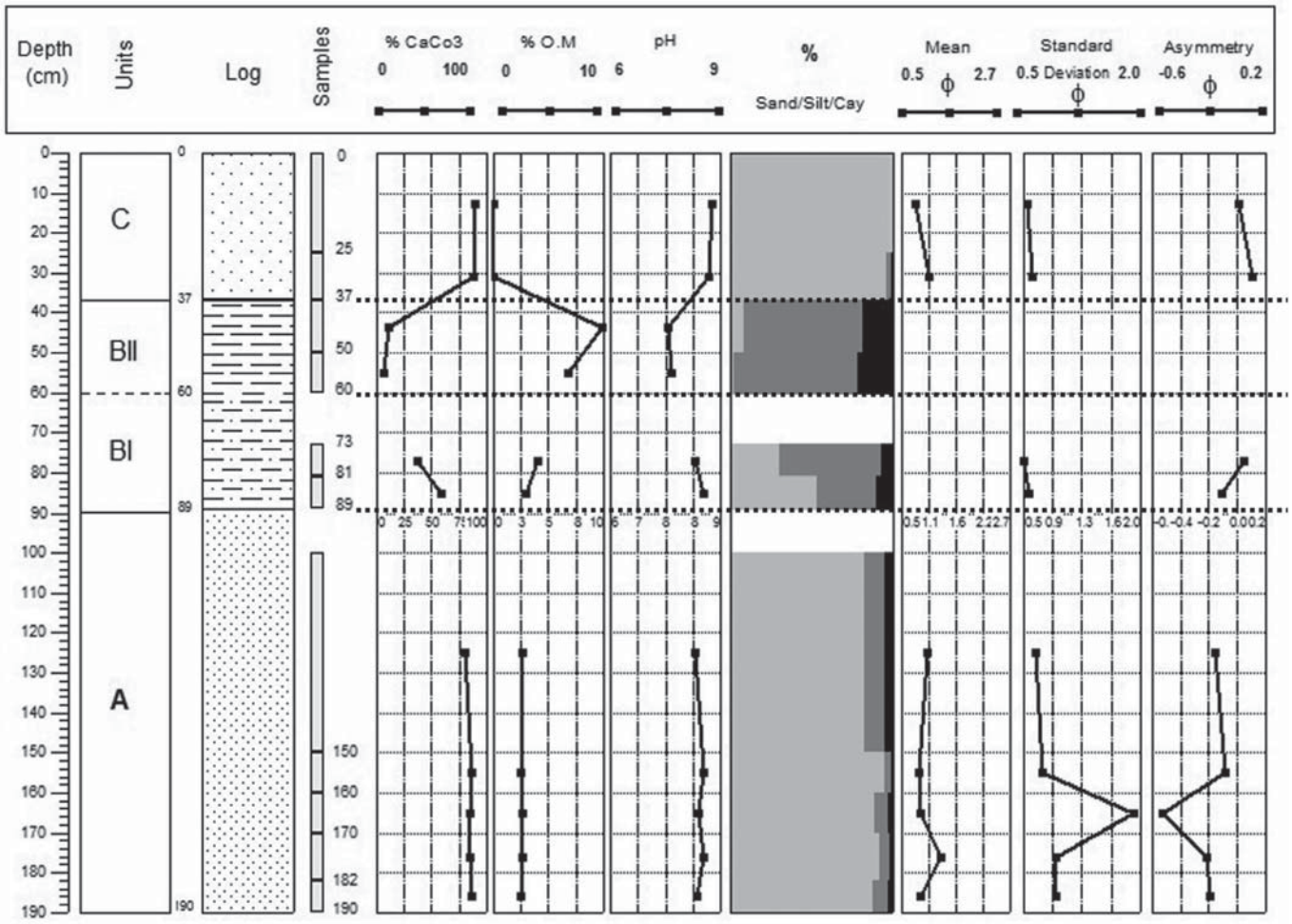

Fig. 2.- Core units, Log, $CaCO_3$ (%), organic matter (%), pH, relative abundance of sand, clay and silt and sedimentological parameters analyzed.

Fig. 2.- Unidades identificadas en el sondeo, Log, CaCO3 (%), material orgánica (%), pH, abundancia relativa de arena, arcillas y limos y parámetros sedimentológicos analizados.

in the south west part of the Oualidia lagoon represents a progressively shallowing and infilling lagoon, with open-marine coarser sediments at the base that became finer and typical of a more restricted environment towards the top, culminating with salt marsh sediments as the accommodation space was reduced, on top of which the overwash deposit is found.

The base of the sequence (Unit A and FAZ_IV) is dominated by coarse carbonate sand with allocththonous foraminifera; broken tests and angular grains are common, indicating a highly energetic depositional environment connected to the open sea, possibly corresponding to a subtidal channel or to an intertidal sand flat, under full marine influence. Sub-unit B_I and FAZ_III indicate a clear environmental change. Muddy sediment together with the presence of *H. germanica* indicate restricted conditions, that could represent evolution towards a mud flat developing at a higher elevation in relation to the tidal frame. The sequence ends up with marsh deposits (Sub-unit B_II and FAZ_II) implying a generalized process of silting up, sediments of terrestial origin being essentially redistributed by tidal currents in a confined environment. Marsh sediments currently dominate the surrounding area and here are represented by highly organic clayey silt with the presence of *Jadammina macrescens.*

A clear sedimentological disruption marks the transition between the marsh sediments and the overwash deposit (Unit C and FAZ_I). This deposit is strongly similar in sedimentological and micropaleontological terms to the beach deposits and its position on top of marsh sediments strongly indicates in the stratigraphic record its association with a catastrophic event (e.g., storm).

The combined use of micropaleontological and sedimentological proxies to deconvolve former sedimentological environments is a very powerful technique that has been intensively applied. Furthermore, foraminifera alone have been proposed as indicators of overwash deposits (Hippensteel and Martin, 1999). From this study, however, it is apparent that, besides some marked differences between the overwash deposits and the shallow subtidal and intertidal deposits, this technique does not allow to definitively differentiate both deposits at the present and further proxies should be used. On the other hand, in areas of extensive development of marsh environments over extended periods of time, this technique could provide an insight into the frequency and intensity of storms represented by these deposits. These studies would require, however, well-developed chronological framework and fully understand of other depositional factors such as bioturbation and preservation of the sedimentary layers.

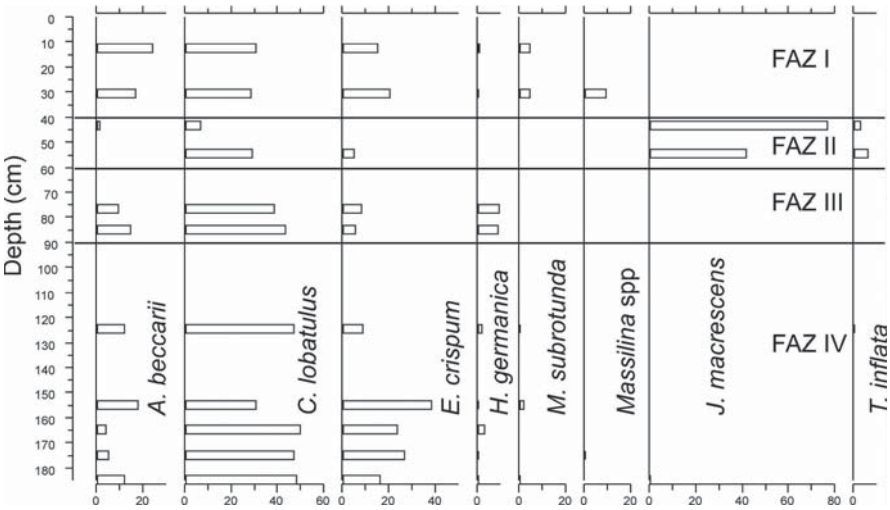

Fig. 3.- Main foraminiferal species relative abundances with depth (cm). FAZ – foraminiferal assemblage zones.

Fig. 3.- Distribución de las abundancias relativas de las especies principales de foraminíferos según la profundidad (cm).

Conclusions

A combined sedimentological and micropalentological approach has allowed to identify the environmental evolution of the southwest area of the Oualidia lagoon that ranges from subtidal open marine to restricted marsh sediments in a filling upward sequence, covered by overwash deposits.

This technique has been proved useful to identify overwash deposits based on their unique characteristics. However, in order to identify overwash deposits in the fossil record those have to be deposited within continuous marsh sequences, since at the present they cannot be definitively differentiate from shallow subtidal to intertidal deposits.

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