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**HOLOCENE COASTAL PROGRADATION CHANGES AND  
PEAT BOG DEVELOPMENT IN SW SPANISH COAST**

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**Abstract**

The peat bog evolution in the Laguna de las Madres from 5,500 <sup>14</sup>C yr BP shows the progradation/erosion phases recorded in the coastal spit bar systems developed in the spanish atlantic-mediterranean littoral.

Sedimentological and vegetation data recorded in cores of the peat bog exhibit a marked environmental change. At around 5.480 ± 60 <sup>14</sup>C yr BP a brackish and humid environment corresponding to a lagoon stage is recorded; in this moment the outflow of Arroyo Madre del Avilar is partially closed because the littoral spit bar system of Punta Arenilla start to prograde. The pollen record shows a high contents of *Chenopodiaceae* and *Isoetaceae*. At around 4,000 <sup>14</sup>C yr BP the outflow of Arroyo Madre del Avilar is definitely disconnected form the open sea due to an increase in the development of dune ridges over the spit bar systems, and the lagoon become a peat bog, with a pollen record dominated by *Cyperaceae* (*Carex*).

This change at ca. 4,000 <sup>14</sup>C yr BP is recorded in the spit bar systems by a period of no progradation and by a relative highstand of sea level.

**Introduction**

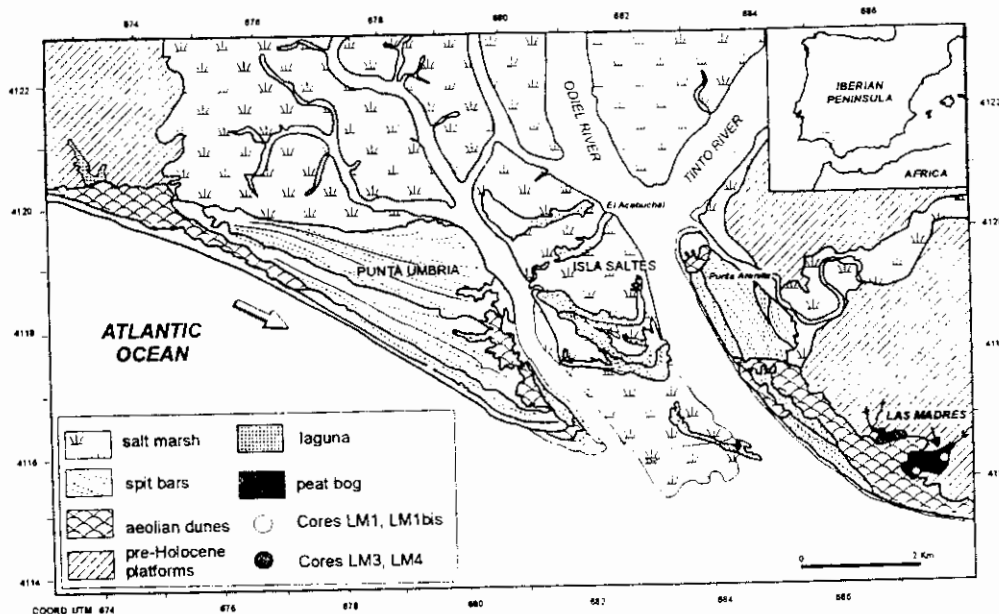
Wide tidal flats develop in the estuary of Tinto and Odiel rivers ([Figure 1](#)) over bodies of estuarine accretion mostly of marine origin but also terrestrial, (Borrego, 1992). The closing of this

estuary is driven by the development of the spit bars of Punta Umbría, Isla Saltés (southeastern extension of the first one) and Punta Arenilla.

In the eastern border of the estuary, several "lagunas" have developed as a consequence of the closing of different streams that formerly flowed into the sea. The seasonal character of these streams causes the total summer desiccation in some of them but not in the Laguna de las Madres (Figure 1) which is the southernmost laguna. Continuous supply of water along the whole year allows a high development of vegetation, giving rise to significant accumulations of organic matter and consequently important peat deposits which have even been exploited (Cáceres, 1995).

Peat accumulation in the Laguna de Las Madres reaches a thickness of 5m. The first palynological studies as well as core drills, carried out by Menéndez Amor & Florschütz (1964), gave an age of ca. 5,500  $^{14}\text{C}$  yr BP for the beginning of the development of these peat deposits. Later pollen analyses have been done by Stevenson (1985), but without isotopic dating.

The rareness of this kind of deposits in the atlantic spanish littoral has promoted the joint financial support of several research Projects in order to carry out continuous and undisturbed drillings, as well as more  $^{14}\text{C}$  datings. This work represent a preliminary synthesis of the results obtained up to the moment.



**Figure 1.-** Location of the Laguna de las Madres within the morphosedimentary framework of Tinto-Odiel estuary.

### Coastal progradation and erosion

The morphosedimentary and  $^{14}\text{C}$  dating analysis carried out in holocene spit bar systems, estuaries, alluvial plains, etc, both in the atlantic and mediterranean spanish littorals (Zazo *et al.*, 1994; Lario *et al.*, 1995; Zazo *et al.*, 1996) suggest the existence of two important coastal progradation phases. Each constituted by two spit bars (H1 and H2, for the earliest, H3 and H4 for the youngest one). They are separated by a period of no progradation (visible as a prominent swale)

or coastal erosion. Likewise, each one of these spits (H) is separated from the following one by a small sedimentary gap or no progradation phase.

The time elapsed during these progradation phases has been determined by  $^{14}\text{C}$  measurements as follows: 1st progradation phase between 6,450 and 3,000  $^{14}\text{C}$  yr BP (spit bars H1 and H2, with an intervening sedimentary gap at ca. 4,000  $^{14}\text{C}$  yr BP); and the 2nd progradation phase between 2,750  $^{14}\text{C}$  yr BP and present (spit bars H3 and H4, with an intervening sedimentary gap between 1,200 and 1,050  $^{14}\text{C}$  yr BP).

### Atlantic littoral

In the Gulf of Cadiz, the major spit bar systems are from west to east: Ayamonte, Piedras, Punta Umbría, Punta Arenilla, Doñana and Valdelagrana. The geodynamic characteristics of the area, and specially the tectonic factor, promote the emerged systems to be less developed than in the mediterranean littoral, so that the first progradation phase never outcrops totally.

Sample	Locality	Laborator y	$^{14}\text{C}$ yr BP	Material	Unit	Reference
C-6 (LM-4)	Las Madres	LGQ-1021	960 ± 200	peat	peat bog	
C-7 (LM-4)	Las Madres	LGQ-1022	1,090 ± 170	peat	peat bog	
C-8 (LM-4)	Las Madres	LGQ-1023	1,150 ± 190	peat	peat bog	
C-3 (LM-3)	Las Madres	LGQ-1024	1,570 ± 180	peat	peat bog	
C-4 (LM-3)	Las Madres	LGQ-1019	2,570 ± 200	peat	peat bog	
C-5 (LM-3)	Las Madres	LGQ-1020	3,410 ± 180	peat	peat bog	
LM-1bis (M-11)	Las Madres	UTC-4029	2,550 ± 50*	peat	peat bog	
LM-1bis (M-14b)	Las Madres	UTC-4027	3,520 ± 60*	peat	peat bog	
LM-1bis (M-16b)	Las Madres	UTC-4036	4,450 ± 70*	organic mud	lagoon	
LM-1 (M-9)	Las Madres	UTC-4023	5,480 ± 60 *	organic sand	dune	
-----	Las Madres	L.BF	4,450 ± 75	peat	peat bog	M.A. & F. (1964)
-----	Las Madres	L.BF	2,220 ± 80	peat	peat bog	

**Table 1.-**  $^{14}\text{C}$  ages of Laguna de las Madres peat bog. **Laboratories:** LGQ - Lab. de Géologie du Quaternaire, CNRS, Luminy, 13288-Marseille, France; UTC - R.J. Van de Graaf Lab. 35080 TA-Utrecht, The Netherlands; L.BF. - Lab. Biophysics, Univ. of Groningen, The Netherlands.

(\*): AMS

(M.A. & F., 1964): Menéndez Amor & Florschütz, 1964)

In the Laguna de las Madres area, south of the Tinto-Odiel estuary, the development and evolution of the three spit bar systems (Punta Umbría, Isla de Saltés and Punta Arenillas, [Figura 1](#)) conditioned the evolution of peat bog. The results obtained up to the moment of  $^{14}\text{C}$  datings in Punta Umbría (Goy *et al.*, in press), Isla Saltés and Punta Arenillas ([Table 1](#)) suggest that the former Laguna de las Madres lagoon, (5,000  $^{14}\text{C}$  yr BP probable starting of Punta Arenilla spit bar system)

became a peat bog at ca 4,000 <sup>14</sup>C yr BP, when the outflow of the Laguna was blocked leading to the initiation of the peat bog development by drainage imperance.

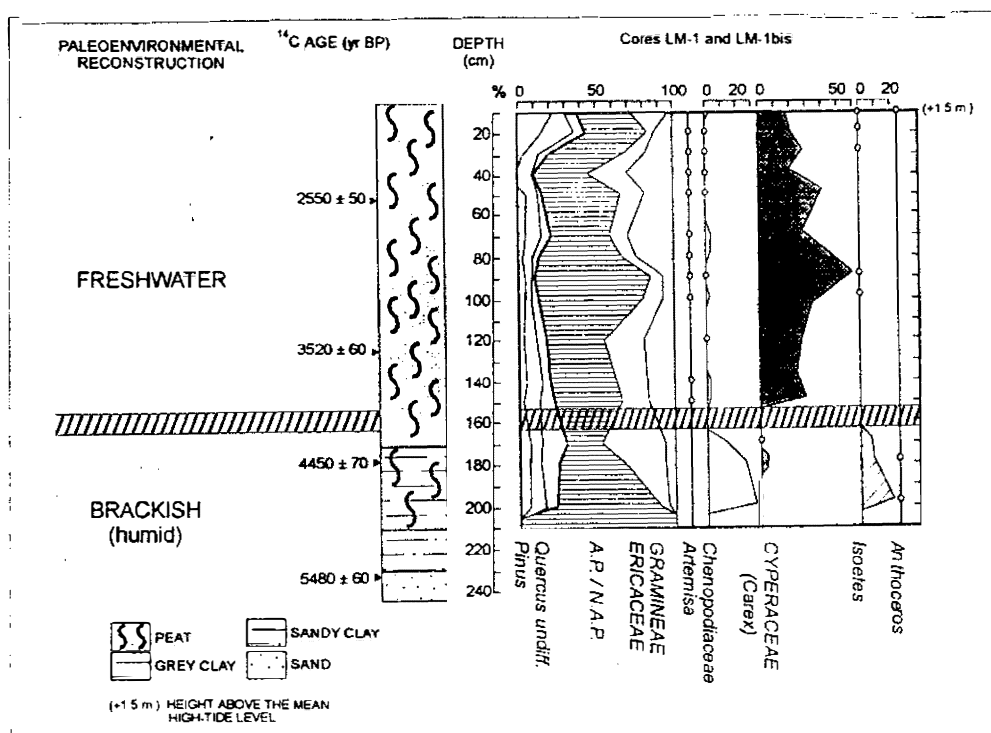


Figure 2.- Synthetic pollen diagram of Las Madres peat bog

### Pollen analyses

The complete pollen sequence of the Laguna de las Madres peat deposit is deduced by the comparison of three columns that constitute an almost total deposit of around 5m in thickness (Menéndez Amor & Florschütz, 1964) of peat, previous to its industrial exploitation.

Two of these sequences, LM-4 and LM-3, are located in the northeasternmost part of the laguna (Figura 1) the later 200m downstream from the other. The samples in LM-4 (C-6, C-7 and C-8) were carried out in the scarpment left by the exploitation of the peat at an height of around +5m over mean sea level. The pollen sampling was done in the first 0.65m, as well as for the <sup>14</sup>C dating (Table 1, C-6 to C-8 from top to bottom), below this height dune sand started to appear.

The sampling in LM-3 was carried out by rotational drill, downstream of the former one in the axis of the depression and with the top located at +3.5m above MSL. The total thickness of the peat deposit reached 3m, and the sampling for <sup>14</sup>C dating was located as follows: C-3 at 0.5m, C-4 at 2m and C-5 at 2.75m. One meter of organic sand appear below the peat deposit, and the appearance of gravels at 4m indicates the previous transport of Arroyo Las Madres flowing into the laguna.

The top of the sequence, which is represented by the sites LM-3 and LM-4, is characterized by the abundance of *Ericaceae* and *Cistaceae* marking the degradation of the natural environment.

The most detailed pollen analysis (every 5cm) has been carried out in the drillings LM-1 and LM-1 bis, 50m downstream of the former ones (Figure 1) using Russian corer.

The preliminary study of LM-1 and LM-1 bis from Laguna de las Madres shows the clear difference (Figure 2) between the clayey levels at the base of the sequence (2.10-1.70 m) that are characterized by high contents of *Chenopodiaceae* and *Isoetaceae*, indicating a humid and brackish environment, and the upper levels (1.70-0 m) dominated by *Cyperaceae* (*Carex*) indicative of a fresh-water environment. At these later levels *Ericaceae* are well represented, together with *Quercus pedunculata*, while *Pinus* percentage increases in the 40 upper centimeters of the sequence.

The results of the pollen analysis together with the sedimentological and radiocarbon dating data, suggest that an important environmental change in the Laguna at around 4,000 <sup>14</sup>C yr BP, passing from a brackish and humid environment, related to lagoon conditions, to a fresh water environment, when the laguna become totally isolated from the sea. Interruptions in peat deposition at ca. 1,150 <sup>14</sup>C yr BP seem to be due to increased development of dune systems over the laguna.

### Conclusions

The peat bog of Laguna de las Madres began to develop as a consequence of the growth of Punta Arenillas spit bar towards the inner part of the Tinto-Odiel estuary (NW). The results obtained in cores drilled in the Laguna de las Madres indicate an age of at least 5,480 ± 60 <sup>14</sup>C yr BP for the beginning of the spit bar growth, when a lagoon environment started to develop in the outflow of Arroyo Madre del Avilar. The dune systems associated to the beach ridges of Punta Arenillas spit bar increased at ca. 4,000 <sup>14</sup>C yr BP, causing the transformation of the lagoon into a peat bog. This feature involves an important paleoenvironmental change, from brackish and humid to freshwater, as demonstrated by the sudden disappearance of *Chenopodiaceae* and *Isoetaceae* and the increase of *Cyperaceae* (*Carex*). At present the laguna has been artificially drained and the peat can only be observed at low tides, showing the important erosional processes suffered by this littoral sector.

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