Palaeogeography, Palaeoclimatology, Palaeoecology 295 (2010) 332–343

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Palaeoecological significance of Late Pleistocene pine macrofossils in the lower Guadalquivir Basin (Doñana natural park, southwestern Spain)

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A R T I C L E I N F O

Article history:
Received 10 December 2009
Received in revised form 17 June 2010
Accepted 19 June 2010
Available online 25 June 2010

Keywords:
Palaeoecology
Palaeobotany
Iberian Peninsula
Late Pleistocene
Fossil wood
Pinus

A B S T R A C T

This paper reports on analysis of plant macrofossils in aeolian deposits exposed in El Asperillo cliff in the Province of Huelva. A significant find of a large number of macrofossils of *Pinus* (*Pinus pinaster* Ait. and *Pinus nigra* Arnold) makes a major contribution to our understanding of the role of Pine in the Upper Pleistocene landscapes of Iberia. *P. pinaster* Ait. and *P. nigra* Arnold, are meso-microthermic species and inhabited valleys excavated in aeolian sediments mainly deposited during OIS 4 and OIS 3 (based on OSL and radiocarbon ages). Their presence in these valleys during the last part of OIS4 and OIS 3 reflects a significant fall in temperature during certain periods of these isotopic stages and helps us better understand the response of coastal dynamics to climate change.

Published by Elsevier B.V.

1. Introduction

Although the Guadalquivir Basin, occupies some 68,321 km^2 of the Iberian Peninsula, the evolution of its plant landscapes has not been well-studied due to the scarcity of sites of different ages. Indeed, no information on paleovegetation is available at all for much of the Pliocene and Quaternary. In addition, the Guadalquivir Basin has been populated by different cultures since very ancient times, and extensive human activity — especially in the river valley — has left very few areas with pre-anthropogenic vegetation (Costa Tenorio et al.,1997).

Although the area has been the subject of many geological studies, in particular those dealing with geomorphology (Caratini and Viguier, 1973; Pastor et al., 1976; Zazo et al., 1981; Borja and Díaz del Olmo, 1994, 1996; Dabrio et al., 1996; Zazo et al., 1999a, 2005, 2008a), very few palaeobotanical studies of the area have been undertaken. Paleovegetation evolution during the Neogene has been studied at the following sites. For the Miocene, sites of Tortonian–Messinian age such as those at Cantillana and Gibraleón in the Province of Sevilla, and Arenas del Rey in the Province of Granada (Valle and Rivas Carballo, 1990) have been investigated. For the Pliocene, only one site in the entire Guadalquivir basin (Barrón et al, 2003) — that of Lepe (Province of Huelva) — has been investigated. For the Pleistocene information is restricted to the Upper Pleistocene (Fig. 1) and includes the palynological studies of Stevenson (1984) and Zazo et al. (1999a), on the El Asperillo cliff in the Province of Huelva, which provided the data for the present work. In the Doñana marshlands, Yll et al. (2003) undertook a palynological study on sediments recovered from Mari Lopez borehole (ML-97) dated as Upper Pleistocene and Holocene For the interior of the basin, the only work performed has been that of Rodríguez-Vidal et al. (2003), who investigated the Cueva de la Sima (a cave to the north of modern-day Seville). Finally, Caratini and Viguier (1973) studied the Holocene of the El Asperillo cliff, and Stevenson (1985) and Stevenson and Moore (1988) studied the same period at the La Laguna de Las Madres and El Acebrón sites. Until the present work, no palaeobotanical studies had been published on the area's Quaternary plant macrofossil remains.

The majority of the above studies indicate the presence of pines and or pine forests throughout the Upper Pleistocene and Holocene, although there is some controversy regarding the dynamics of these plant formations and their importance in the landscape (Caratini and Viguier, 1973; Stevenson, 1984, 1985; Stevenson and Moore, 1988). Pine pollen is present in all the diagrams produced, sometimes making up large proportions of the total (Zazo et al., 1999a,b; Yll et al., 2003). However, its possible allochthonous origin has hindered the interpretation of the importance of pine trees in the basin, especially since some authors do not consider pine forests to be native to the area (Rivas Martínez, 1987). Even if it is accepted that the pollen record is that of local trees, doubts remain regarding the species of pine that occupied the pre-Holocene and even Holocene landscapes of the basin. To date, the only proposal (based on pollen studies alone) regarding the identity of these pine species makes reference to *Pinus*

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0031-0182/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.palaeo.2010.06.013

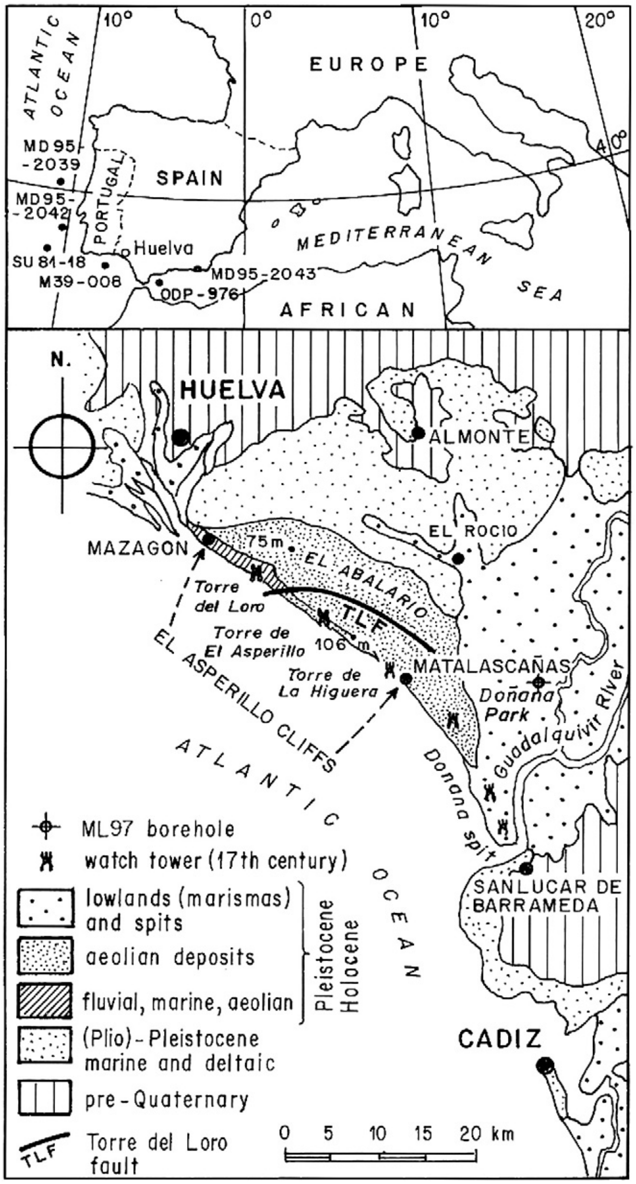

Fig. 1. Location and geological sketch of the Abalario area (Mari López core: ML-97). Location of the marine cores cited in the text.
Simplified from Zazo et al. (2005).

pinea L. and *Pinus halepensis* Mill. (Caratini and Viguier, 1973). Studies on plant macrofossils could contribute significantly to the elucidation of their true identity.

The main aim of this work was to arrive at a palaeoenvironmental reconstruction of the El Asperillo site using information provided by fossil macroremains and palynological and morphological data. The results obtained aid our understanding of the evolution of the landscape during the Upper Pleistocene, and help clarify the role of pine trees in the Guadalquivir Basin for this period. In addition, they improve our knowledge of the response of coastal dynamics to climatic change recorded on the millennial scale during OIS 3 by marine cores (Fig. 1) (see Sánchez Goñi et al., 2000; Pailler and Bard, 2002).

2. Geologic and physiographic setting

The study site is located in the Abalario area (Gulf of Cádiz), a morphological dome elongated NW–SE that separates the Neogene Guadalquivir Basin from the Atlantic Ocean. The dome serves as an anchor point of the Holocene spit barrier of Doñana that encloses the marshlands of the lower Guadalquivir. The mean altitude of the dome throughout the watershed is 70–75 m above mean sea level (asl), but its real ridge-line is located near the El Asperillo cliff, where active dunes reach a maximum altitude of 106 m. The northeast limit of the Abalario dome is the Rocina river. To the southwest, the Asperillo cliff dissects the dome and forms the present coastline. This cliff extends for 28 km between the villages of Mazagón and Matalascañas, with an altitude of around 16–20 m. The drainage pattern of the dome is asymmetric, with the longer streams inland. In contrast, the littoral flank has short gullies that dissect the present sea cliff (Fig. 1). The internal structure of the dome is exposed along the cliff. Neotectonic activity along the coast is revealed by gravitational faults such as the Torre del Loro Fault (TLF), which exerted major control over sedimentation during the late Pleistocene. Zazo et al. (1999a, 2005) showed that the TLF separates two palaeogeographic domains. The upthrown block contains fluvial, marine and aeolian deposits (in ascending stratigraphic order), whereas the downthrown block trapped aeolian sediment units U1 to U3 (separated by wide erosional surfaces). Adjacent to the TLF, units U2 and U3 are tilted W–NW (Fig. 2). Wood macrofossils were recovered near the TLF (Fig. 3) in the middle-upper part of U2, which, based on OSL and radiocarbon dating, is thought to have developed mainly during OIS 4, and OIS 3 (Zazo et al., 2005). This aeolian unit accumulated under W, NW and SW prevailing winds. The climate in the Gulf of Cádiz is of the Mediterranean-Atlantic type, with a mean annual rainfall around 500 mm $year^{-1}$. Mean temperatures range between 16 and 17 °C, with a thermal amplitude of 10–16 °C. The prevailing winds blow from the SW. Nowadays, *Pinus pinea* is widespread on the sandy soils of El Asperillo Cliff while *Juniperus phoenicea, J. oxycedrus* and other Mediterranean shrubs appear covering the deeper sand sheets and dunes.

3. Materials and methods

Wood macrofossils were collected from the cliff between kilometre marks 12 and 16 (Fig. 2) at an altitude of between 0 and 3.5 m asl, (the mean high water level was taken as the mean sea level).

3.1. Wood analysis

Twenty two macrofossils were studied, corresponding to non-carbonised pieces of wood (except for one piece) (Fig. 3). The 21 wood fossils were subjected to traditional micrographic analysis (Schweingruber, 1978; García et al., 2002). The carbonised specimen was manually fractured and anatomical characteristics examined by reflection microscopy (Chabal et al., 1999).

The samples were identified by referring to the classic wood anatomy studies of Greguss (1947, 1955), Jacquiot et al. (1955, 1973), Peraza (1964), García and Guindeo (1988, 1990) and Schweingruber (1990). When possible, they were also compared to specimens in the reference collections of the *U.D. Botánica*, *U.D. de Tecnología de la Madera* and the *U.D. de Anatomía de la Escuela Técnica Superior de Ingenieros de Montes* (Madrid, Spain).

Some authors indicate that identification at the species level of wood from montane Iberian pines (including *Pinus sylvestris, Pinus nigra* and *P. uncinata*) is problematic and sometimes impossible (Schweingruber, 1990; Carcaillet and Vernet, 2001). However, others (Greguss, 1955; Jacquiot, 1955; Peraza, 1964; García and Guindeo, 1988) indicate the existence of diagnostic features that can be used for this purpose, especially when the number of macroremains is large and well preserved, and when young wood is avoided (which can show a great deal of intraspecific variation) (Mutz et al., 2004; Figueiral and Carcaillet, 2005). The excellent state of preservation of the present specimens and their great thickness allowed identifications to be made while ignoring