Plant Ecol
DOI 10.1007/s11258-008-9439-5

Anthracological evidence suggests naturalness of *Pinus pinaster* in inland southwestern Iberia

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Received: 19 December 2007 / Accepted: 17 May 2008

Abstract The study of well-preserved archaeological charcoals in the pre-Roman Iron Age settlement of Castillejos II (Badajoz, Spain) is used to reconstruct environmental conditions and land-use practices in vegetation landscapes in the southwest of the Iberian Peninsula before the arrival of Roman civilization. The results support that, while evergreen *Quercus* forests dominated during the Holocene, *Pinus pinaster* existed as a natural element of southwestern Iberian Peninsula vegetation. Although its presence could be linked to anthropogenic disturbance or fire history, it is suggested that *P. pinaster* populations survived during the Holocene in the region, mixed with oaks or in monospecific stands in mountain enclaves. This hypothesis contrasts with previous assumptions that *P. pinaster* was not autochthonous in the area.

Keywords Archaeobotany · Biogeography · Holocene · Iberian Peninsula · *Pinus pinaster* · Vegetation history

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Introduction

The natural range of *Pinus pinaster* Aiton spans the Western Mediterranean (Fig. 1), including the Iberian Peninsula, France, Italy and northwestern Africa, over a wide range of substrates (i.e. limestones, dolomitic, granitic or sandy substrates). Although in historical times some naturalists verified the existence of pines in southwestern Iberia (e.g. Prat 1754; Gandoger 1917; Ceballos and Bolaños 1930) today most botanists consider *P. pinaster* to have an anthropogenic origin throughout this area (Franco 1986; Ladero 1987; Devesa 1995). In western Andalusia, it is only recognized as potential vegetation in the peridotites of Sierra Bermeja (near Estepona, Málaga) (Valle 2003).

In the southwest of the Iberian Peninsula, little information is available on Holocene vegetation dynamics. Moreover, recent human activity and the lack of palaeobotanical deposits in this area hamper the interpretation of the present vegetation, especially in the Guadiana and Guadalquivir basins. In addition, regarding the palaeobotanical information, it is difficult to reliably distinguish the different taxa of *Pinus* L. subgen. *Pinus* in pollen records. Therefore, the pollen diagrams of *Pinus* on the scanty Holocene sequences of southern Iberia are sometimes difficult to interpret.

The application of palaeoecological records to assess species naturalness has been highlighted several times (see Alcalde et al. 2006; Willis and

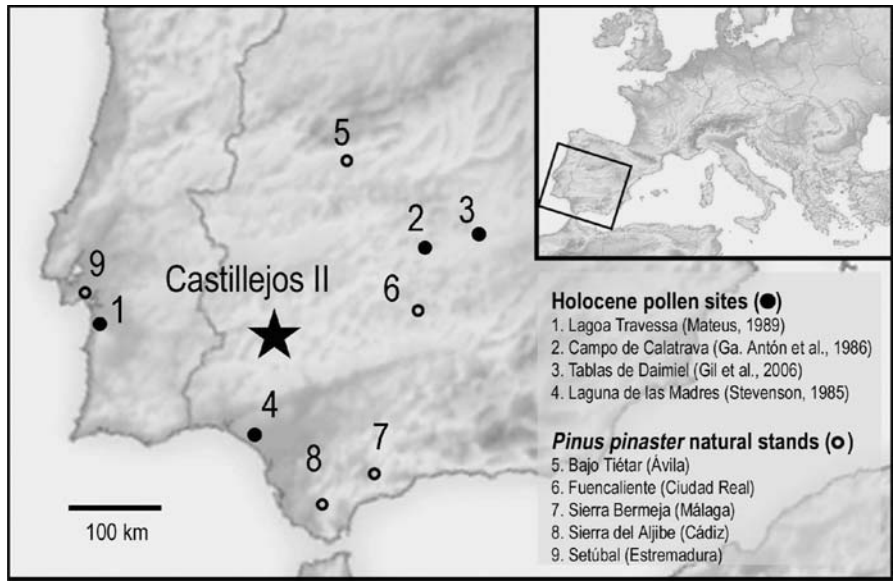

Fig. 1 Location of the site and the places cited in the text

Birks 2006), and the information provided by archeological remains has been useful in management and conservation at local scales. In this study, we identify the charcoal remains of an Iron Age settlement in Badajoz (southwestern Iberia), to help reconstruct the vegetation landscape before its profound modification by the Roman civilization.

Study area, materials and methods

The site studied is located in Castillejos (Fuente de Cantos, Badajoz, Spain Lat: 38.247/Long: 6.309), on a Precambrian siliceous substrate, 550 m above sea level (Fig. 1). The site is located in a relatively flat region extending north to the Guadiana depression and dominated to the south by the Sierra de Tentudia.

Compared to the rest of the Iberian territories, the southwestern Iberian Peninsula is relatively homogeneous in terms of physiography, soils and climate. Elevations rarely reach 1,000 m. The climate of the region is Mediterranean with intense summer drought. Mean annual temperature ranges from 15 to 18°C and mean annual precipitation ranges from 400 to 800 mm, rising to a maximum of 1,100 mm. In low-mountain areas, the bedrock type is mostly siliceous (from the Hesperian Massif basement) and in the Guadiana and Guadalquivir basin Tertiary marine sediments give rise to fertile soils. Present landscape is dominated by evergreen Holm oak (*Quercus ilex* ssp. *ballota* (Desf.) Samp.) and Cork oak (*Quercus* suber L.) open woodland agroforestry systems. This landscape is called "dehesa" in Spain and "montado" in Portugal.

Excavations in the settlement of Castillejos II revealed that the site has a history spanning Neolithic to Roman periods, when the settlement was burned and the people were forced to disperse (Fernández Corrales et al. 2004). Charcoals from the excavation conducted by Ildefonso Ramírez in 2002 and 2003 were sent for study to the 'Historia y Dinámica del Paisaje vegetal' research group of the Universidad Politécnica de Madrid.

A good state of preservation of charcoals allowed the analysis of all the samples using reflection microscopy. The analytic procedures used are reported in Chabal et al. (1999). The identification was made with the aid of common keys of wood anatomy identification (Greguss 1955, 1959; Jacquiot 1955; Peraza 1964; García and Guindeo 1988; Schweingrüber 1990). Special attention was paid to the identification of the *Pinus* remains (Fig. 2).

A chronology was already established from relative archaeological dating, which is much more precise in this context than other dating methods. Nevertheless, an AMS radiocarbon date was obtained in the Centro Nacional de Aceleradores (Sevilla, Spain) for a *P. pinaster* charcoal. This date was calibrated using the CALIB 5.0 software (Stuiver and Reimer 1993, version 5.0) with the IntCal04 data set (Reimer et al. 2004).

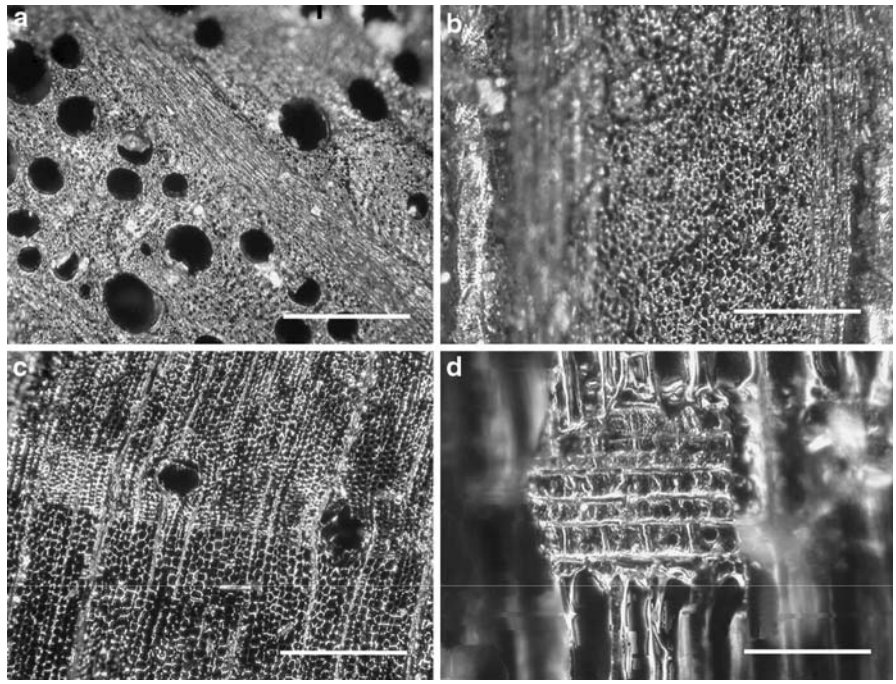

Fig. 2 *Quercus* subgen. *Sclerophyllodrys* (*Quercus ilex* ssp. *ballota* type): (**a**) transverse section showing diffuse-porous wood and big solitary vessels. Scale bar: 0.7 mm. (**b**) Wide multiseriate rays of 0.5–1.6 mm wide. S.B.: 0.5 mm. *P. pinaster*: (**c**) Axial tissue without vessels. Growth ring easily distinct. Resin canals large with thin-walled epithelial cells. S.B.: 0.5 mm. (**d**) Heterocellular rays, with tracheid walls weakly dentate. Cross-fields with 3–4 pinoid pits. S.B.: 0.1 mm

Results

Wood remains were recovered from the Late Iron Age layer (Late Holocene) (Fernández Corrales et al. 2004). In this pre-Roman settlement, we identified 55 charcoal fragments from four different taxa: *Quercus* subgen. *Sclerophyllodrys (*i.e. *Quercus ilex* ssp. *ballota* type), *P. pinaster*, *Cistus* and *Fraxinus* (Table 1). The majority of the studied remains belonged to construction elements, but one of the samples came from a wooden wheel and some others from tools. AMS radiocarbon dating (Code CNA123) yielded an age of 2235 ± 40 BP (2152-2338, 2 sigma Cal BP, Late Holocene) and fit perfectly with the previously reported archaeological dating.

Discussion

Palaeobotanical studies have already proved the presence and importance of Mediterranean pine forests on the Iberian landscapes during the Quaternary, in both the Mediterranean and the Atlantic regions (i.e. Mateus 1989; Carrión et al. 2000; Franco et al. 2005).

Due to the difficulties that arise in *Pinus* pollen identification, macrofossil analysis of wood and strobili is of great significance, as it provides evidence at the species level. The presence of *P. pinaster* throughout the Holocene has already been demonstrated by its macroremains in a variety of ecological settings in the northern Iberian peninsula (Figueiral 1995; Alcalde et al. 2004; Rubiales et al. 2005) as well as in the inland mountains of eastern Iberia: Sistema Ibérico, Cordilleras Béticas (Carrión et al. 2000; Rodríguez-Ariza 2000), proving its natural origin in this areas.

Taking into account the detailed Spanish *P. pinaster* chorology given by Alía et al. (1996), Castillejos site is located more than 150 km south of the nearest recognized natural stand for this taxon (Lower Tiétar region). Other interesting natural *P. pinaster* stands can be found at the same distance surrounding the Castillejos settlement (Sierra del Aljibe, Cádiz; Fuencaliente, Ciudad Real; Sierra de Ronda, Málaga; Setúbal, Portugal).

Our results reveal the natural presence of *P. pinaster* in the region before the Roman occupation of the southwestern interior of the Iberian Peninsula. The nature of the remains (construction elements) renders the assumption of long distance transport by humans during prehistoric times improbable. The importance of this taxon in the past vegetal landscape is still uncertain. Most of the anthracological studies

Table 1 Castillejos II: absolute frequencies of taxa from Late Iron Age

Excavation unit	Number of samples	Identification
UE 8	5	*Quercus* subgen. *Sclerophyllodrys*
UE 43	1	*Pinus pinaster*
UE 47	10	*Quercus* subgen. *Sclerophyllodrys*
UE 48	1	*Quercus* subgen. *Sclerophyllodrys*
UE 76	8	*Quercus* subgen. *Sclerophyllodrys*
UE 78	2	*Quercus* subgen. *Sclerophyllodrys*
UE 101	10	*Cistus* sp.
UE 153	14	*Pinus pinaster*
UE 157	1	*Quercus* subgen. *Sclerophyllodrys*
	1	*Pinus pinaster*
UE 189	2	*Fraxinus angustifolia* type

in inland southern Portugal did not detect *Pinus* charcoals (Queiroz 2001; Duque Espino 2005), although *Pinus* remains were recently reported by Rodríguez et al. (2006). Palynological investigations provide information about Holocene *Pinus* pollen in the Guadiana basin: Campo de Calatrava, Ciudad Real (García Antón et al. 1986); Tablas de Daimiel, Ciudad Real (Dorado et al. 1996; Gil García et al. 2002); coastal sandy grounds in Huelva (Stevenson 1984, 1985; Stevenson and Moore 1988) and the Muge Basin, Portugal (van der Schriek et al. in press). Moderate or low *Pinus* pollen percentages are reported in all these cores, compared to other sites in the northern, central and eastern parts of the Iberian Peninsula. However, the pollen findings are likely to refer to *Pinus pinea*, since this species is more thermophilous than *P. pinaster* and occurs commonly in southwestern Iberian coastal areas. Various macroremains of *P. pinea* have been identified along the Atlantic coasts (Martínez and Montero 2004).

The abundance of wood remains of *Quercus* subgen. *Sclerophyllodrys* (almost certainly *Quercus ilex* ssp. *ballota*) accords with the Holocene evidence concerning the tree species composition of southwestern Iberian forests (Duque Espino 2005; Rodríguez et al. 2006). Under those evergreen oak trees, serial or understorey shrubs (*Cistus* sp.) would dominate in open areas.

On the one hand, human disturbance (including anthropogenic fire) may have provoked woodland clearance, permitting the access of heliophilous elements such as *Pinus* or *Cistus*. *P. pinaster* could prosper here. On the other hand, high recurrence of fires seems to favour resprouters (such as oaks) over pines, despite these pines' fire adaptations such as serotinous cones, thick bark and others (Gallegos et al. 2003). However, the lower significance of Mediterranean pines (including *P. pinaster*) in the inland areas of southwestern Iberia is somehow related to the higher environmental homogeneity (in terms of soils and physiography) and the relatively mild climate (Morla 1993). These conditions allow large-scale autogenic processes to predominate and hence favour sciophilous trees like oaks over heliophilous elements. Nevertheless, the existence of areas where edaphic drought (e.g. sands substrates, as in the Tietar basin), fire protection (e.g. granite boulders of Fuencaliente, Sierra Madrona and sandstones of Sierra del Aljibe) or severe erosion occurs prevents the above-mentioned succession processes that would have led to pine disappearance on a regional scale.

Acknowledgements The authors wish to thank Cristina Alcalde for the processing of some samples and Fernando Gómez Manzaneque and José María Postigo for providing useful suggestions on this report. The remains were kindly supplied by Ildefonso Ramírez. Kevin Wood corrected the English manuscript. This work was partially supported by the Spanish Ministerio de Educación y Ciencia under grant CGL-2006-02956-BOS.

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