Cretaceous Research 51 (2014) 112–120

Contents lists available at ScienceDirect

Cretaceous Research

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

Early Cretaceous woods of Figueira da Foz Formation in western Portugal: Palaeoenviromental, palaeoclimatic and palaeobiogeographic insights

Mário Miguel Mendes [a, *], Jorge Dinis [b], Luis García Esteban [c], Paloma de Palacios [c], Francisco García Fernández [c], João Pais [a]

[a] Universidade Nova de Lisboa, CICEGe, Departamento de Ciências da Terra, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, Portugal
[b] Universidade de Coimbra, IMAR-Marine and Environmental Research Centre, Largo Marquês de Pombal, 3000-272 Coimbra, Portugal
[c] Universidad Politécnica de Madrid, Escuela Técnica Superior de Ingenieros de Montes, Departamento de Ingeniería Forestal, Ciudad Universitaria, 28040 Madrid, Spain

ARTICLE INFO

Article history:
Received 25 February 2014
Accepted in revised form 9 June 2014
Available online 3 July 2014

Keywords:
Conifers
Fossil wood
Protocupressinoxylon
Palaeobiogeography
Palaeoclimate
Portugal

ABSTRACT

Fossil woods of the genus *Protocupressinoxylon* Eckhold are reported from the Lower Cretaceous (upper Aptian – lower Albian) of Casal do Estortiga, near Santa Catarina da Serra, Lusitanian Basin, western Portugal. The three silicified specimens show up to 7-μm-thick-walled, rounded to polygonal tracheids; homogeneous rays, separated by 2–8 cell rows (in average 3–4); normal or traumatic, diffuse axial parenchyma with abundant cell content; and no resin canal but abundant resin content. The cupressoid conifers dominated the border between the temperate wet tropical belt and the arid mid-latitude belt. The indistinct growth rings suggest no marked seasonality in western Portugal, as it was also suggested in the Iberian Mountain System. Several other climate proxies of the trunk-bearing unit confirm that the wood was deposited under a warm and wet climate. During the Early Cretaceous, the Iberian Peninsula was a connecting bridge between Laurasia and northern Gondwana, acting as a large regional ecotone. Although the Iberian Peninsula was dominated by a Laurasian component, climatic differences between the two regions were driving forces behind biogeographical relationships in the western Tethys.

1. Introduction

During the mid-Cretaceous Iberia was located in the border between the mid-latitude warm humid and the tropical-equatorial hot-arid climate belts (Chumakov et al., 1995; Spicer and Skelton, 2003; Sellwood and Valdes, 2006). Its palaeogeographic position is also noteworthy being between the Euro-Sinian (Laurasian) and Equatorial (northern Gondwana) floristic zones, also closely related to climatic belts (Vakhrameev, 1991). Thus, the Iberian Peninsula acted as either a bridge or a barrier on continental biota, most probably because of climatic niche partitioning (Philippe et al., 2003, 2004). Furthermore, it stood between the Boreal and Central-Atlantic domains, and between the Atlantic and Tethyan realms, through the palaeo-Strait of Gibraltar.

The mid-Cretaceous was also a particular period in the Earth history with important biota turnovers, such as the raise to dominance of angiosperms, as well as and with pronounced global greenhouse climate, widespread and recurrent Oceanic Anoxic Events, and major eruptive phases (Large Igneous Provinces). It is widely accepted now that these conditions were interrelated. However consensual integrated models are still lacking despite the progresses made in the last decades on the mechanisms and feedbacks. Global climate is probably the field in which quantitative approaches are the most advanced, though the last available numerical simulations for the Cretaceous show inconsistencies with the geological evidence (Hunter et al., 2013). This means that people still need to keep developing palaeontology and sedimentology based proxies, and calibration and validation in forecasting. Among these proxies, plant fossil features can be used in inferring temperature, moisture and seasonality, since they allow robust comparisons with nearest living relatives (e.g., Chaloner and Creber, 1990).

The Cretaceous vegetation in the Iberian Peninsula needs to be better understood, especially in some areas with still limited

* Corresponding author. Universidade Nova de Lisboa, CICEGe, Departamento de Ciências da Terra, Faculdade de Ciências e Tecnologia, 2829-516 Caparica, Portugal. Tel.: +351 21 2948573; fax: +351 21 2948556.
E-mail address: mmmendes@mail.telepac.pt (M.M. Mendes).

http://dx.doi.org/10.1016/j.cretres.2014.06.004
0195-6671/

reports of plant fossil assemblages. The Lusitanian Basin in the western Portuguese margin had a substantial number of palaeobotanical studies since the nineteenth century (e.g., Saporta and Choffat, 1894; Teixeira, 1948; Boureau, 1949; Friis et al., 2010), and even some dealing with the palaeoenvironments (e.g., Gomez et al., 2001, 2002; Mendes et al., 2011, 2014; Heimhofer et al., 2012).

Fossil wood, mainly those of conifers, is frequently used to reconstruct the Early Cretaceous vegetation, and is no exception to the scarcity of data, as few records have been reported from the Iberian Peninsula. Moreover, most fossil wood localities from the Jurassic and the Cretaceous are located in the Spanish Iberian Mountain System.

In this paper we report a new fossil wood of the conifer genus *Protocupressinoxylon* Eckhold from the Lower Cretaceous of Santa Catarina da Serra, Lusitanian Basin, western Portugal. It extends the geographical distribution of this important palaeobiogeographic and palaeoclimatic proxy. It also contrasts with earlier hypotheses about the mid-Cretaceous in this key region, and suggests a high significance in regional palaeoenvironmental reconstructions.

2. Previous fossil wood trunks in the Upper Jurassic and the Lower Cretaceous of Iberia

From the Kimmeridgian of the Asturias, in the Lastres Formation, two specimens of lignite wood belonging to *Agathoxylon* Hartig and *Protocupressinoxylon* Eckhold were reported by Valenzuela et al. (1998) and Philippe et al. (2010). In the northern Iberian System, Gómez-Férnandez and Meléndez (1993) documented the presence of wood trunks in the conglomerates of the Ágreda Alloformation (Tithonian, province of Soria); Crisafulli et al. (2008) recorded fossil trunks of conifers Carazuelo (Tithonian – Berriasian from the Soria province), although the trunks could not be identified due to their poor preservation.

In the Iberian Mountain System on the border of the regions of Maestrazgo and Bajo Aragón, Lemoigne and Marin (1972) described *Cupressinoxylon hortii* Stopes, *Cupressinoxylon* sp., *Dadoxylon* sp., *Dadoxylon* aff. *Araucarioxylon* sp. and *Xenoxylon* sp. from the Lower Cretaceous (Berriasian-Barremian) of Ladruñán, Seno and Oliete, Teruel province. Barale and Viera (1991) described a silicified trunk *Dadoxylon* (*Araucarioxylon*) *riojense* nov. sp. from the Valanginian-Hauterivian of Igea, La Rioja province. Morillo and Meléndez (1972) referred the occurrence of unidentified gymnosperms from the Barremian-Aptian near San Leonardo of Castellote, Teruel province. Gomez et al. (1999) described *Agathoxylon* sp. from the Albian of Escucha Formation, Teruel province. Aguirrezabala and Viera (1980, 1983) reported unidentified fossil trunks from the Lower Cretaceous near Bretún, Yanguas and Santa Cruz de Yanguas, Soria province. Díez et al. (1996) referred a site with fossil tree trunks from the Albian in Castellote, Teruel province, although these woody fossils were not identified taxonomically. Del Nido et al. (1998) described a new species of *Pinoxylon riojanus* from the Aptian of the Cameros Basin. Doublet and Garcia (2004) described *Agathoxylon riojense* in the same area (Cameros Basin). Also in the Cameros Basin, from the Lower Cretaceous (Barremian – Aptian) of the Castrillo de la Reina Formation, in Hacinas, Esteban et al. (2006) described fossil trunks of *Protopodocarpoxylon haciniensis* García Esteban & Palacios and *Agathoxylon* sp.

In Portugal, a fossil wood assigned to the genus *Prototaxodioxylon* sp. was reported by Mohr and Schultka (2000) from the famous Kimmeridgian lignite mine of Guimarota, near Leiria, western Portugal. Boureau (1949) described a silicified wood *Dadoxylon teixeirae* from the Upper Jurassic of Cadriceira, near Torres Vedras locality, western Portugal. Boureau and Moitinho de Almeida (1951) changed the age to the Early Cretaceous, and in fact the fossil trunk was collected from the upper Hauterivian – lower Barremian of Fonte Grada Formation (Fig. 1). Boureau (1957) and Esteban et al. (2006) reassigned the wood specimen to the genus *Protopodocarpoxylon* and *Brachyoxylon*, respectively.

3. Geological setting

3.1. Stratigraphy

The Lusitanian Basin developed in the western Iberian margin during the Mesozoic in the context of Pangaea fragmentation and opening of the North Atlantic. It was a non-volcanic rift basin, evolving to an Atlantic-type margin. The basin is defined over the Variscan basement, and bounded to the east by the Hesperian Massif and to the west by the Berlengas horst. Stretching NNE-SSW for 200 km, it is 100 km wide and the infill reaches a maximum of 5 km (Kullberg et al., 2013). After two rifting phases, the passive/drifting phase started at the late Aptian and is marked by an important breakup unconformity. The Cretaceous outcrops at Aveiro (North) to the Arrábida hills (South). The pre-Aptian record is restricted to the southern part of the basin, corresponding to a shallow marine depocentre in the Lisbon to Arrábida region grading W and NW to a siliciclastic fluvial environment. The post-breakup late Aptian – early Albian record is fully continental, and corresponds to the northern onshore record of the Figueira da Foz Formation. This phase was followed by a transgressive (to the NNW) carbonate platform deposition peaking in the late Cenomanian, when the basin was fully filled (Dinis et al., 2008).

The specimens were contained in deposits belonging to the Calvaria Member, the lower member of the Figueira da Foz Formation (Dinis, 2001). According to Teixeira et al. (1968), based on regional correlations and the vegetal macroremains assemblage studied by Teixeira (1948), this part of the sequence is Berriasian-

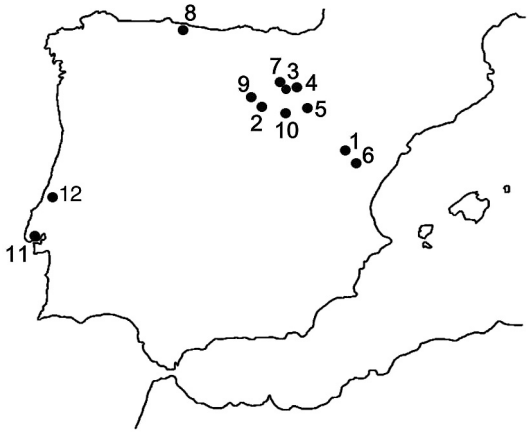

Fig. 1. Xylological data from the Upper Jurassic–Lower Cretaceous of Iberia. **1**. Ladruñán, Seno and Oliete (Teruel province, Spain), Early Cretaceous (Lemoigne and Marin, 1972; Gomez et al., 1999). **2**. San Leonardo de Yague (Soria province, Spain), Barremian-Aptian (Morillo and Meléndez, 1972). **3**. Bretún, Yanguas and Santa Cruz de Yanguas (Soria province, Spain), Early Cretaceous (Aguirrezabala and Viera 1980, 1983). **4**. Igea, (La Rioja province, Spain), Valanginian–Hauterivian (Barale and Viera, 1991). **5**. Ágreda (Soria province, Spain), Tithonian-Berriasian (Gómez-Férnandez and Meléndez, 1994). **6**. Castellote (Teruel province, Spain) Albian (Díez et al., 1996). **7**. Soto de Cameros (La Rioja province Spain), Aptian (Del Nido et al., 1998; Doublet and Garcia, 2004). **8**. Ribadesella (Asturias province, Spain), Kimmeridgian (Valenzuela et al., 1998; Philippe et al., 2010). **9**. Hacinas, (Burgos province, Spain), Aptian-Barremian, (Esteban et al., 2006) **10**. Carazuelo (Soria province, Spain), Early Cretaceous (Crisafulli et al., 2008). **11**. Cadriceira (Torres Vedras, Portugal), Hauterivian-Barremian (Boureau, 1949, 1957). **12**. Guimarota coal mine (Leiria, Portugal), Kimmeridgian (Mohr and Schultka, 2000).