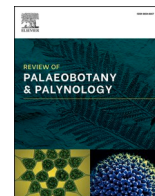


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Research papers

Portuguese historical palaeobotanical collections reveal a new species of late Palaeozoic marattialean fern

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ARTICLE INFO

Keywords:

Portuguese Carboniferous
Douro Carboniferous Basin
São Pedro da Cova
Gzhelian
Cyathocarpus
Marattialean ferns

ABSTRACT

A new Late Pennsylvanian marattialean species, *Cyathocarpus felicianoi* sp. nov., is described and illustrated from the Douro Carboniferous Basin, northwestern Portugal, from Stephanian C (upper Gzhelian, Upper Pennsylvanian) deposits. The studied fossil material is composed of penultimate and ultimate sterile 'pecopterid' frond fragments preserved as adpressions and belongs to the Carlos Teixeira's collection, an invaluable palaeobotanical collection from the Portuguese geological surveys. The description of this new fern fossil-species based on historical palaeobotanical collections, highlights the importance of natural history collections for the advancement of science, especially regarding the knowledge about diversity and richness of marattialean ferns of Euramerican Carboniferous.

1. Introduction

The Portuguese museums have a large repository of palaeontological collections. In their historical collections, there are many fossils that remained unstudied for several decades, and that have become new and important discoveries in recent years (e.g., [Ausich et al., 2007](#); [Smith et al., 2012](#); [Correia et al., 2023](#)).

The palaeobotanical collections associated with the Carlos Teixeira's research constitute one of the most significant historical archives of fossil flora from the Carboniferous of Portugal. From the first references in the mid-19th century and developed during the mid-20th century, these collections are closely linked to geological knowledge and revisions of plant fossils mainly from occurrences near Oporto (Criaz-Serra de Rates, Casais-Alvarelos, and Ervedosa), Douro, Buçaco and Santa Susana Carboniferous basins ([Wagner, 1983](#); [Wagner and Lemos de Sousa, 1983](#); [Lemos de Sousa and Wagner, 1983, 1985](#)). The collections are presently housed at the several museums including LNEG – National Laboratory of Energy and Geology (Geological Survey), Geological Museum and Portuguese Museum of Mineral Deposits, Faculty of Sciences Oporto University, Faculty of Sciences Lisbon University, and University of Trás-os-Montes e Alto Douro (UTAD).

A dedicated collection was assembled during the geological exploration campaigns conducted in the Douro Carboniferous Basin

(Stephanian C, upper Gzhelian, Upper Pennsylvanian; [Fig. 1](#)), particularly those associated with the drilling programs of the early 1930s. The plant fossils recovered from the first boreholes in the São Pedro da Cova and Midões sectors, formed the core of what later became the “LNEG Carlos Teixeira Collection”. Although the fossils were originally gathered by technical staff without a documented selection protocol, the material was preserved and stored for several decades, providing a unique stratigraphic record of the Portuguese continental Carboniferous. During the 1940s, Carlos Teixeira (1910–1982) undertook a comprehensive revision of this assemblage. Through detailed taxonomic assessment and systematic classification, he produced handwritten labels and catalogues that remain integral components of the collection today. The subsequent relocation of the collection in the 1960s to the facilities of the LNEG, following the inauguration of the São Mamede de Infesta Campus, ensured its long-term preservation under institutional stewardship. This collection remained unstudied and preserved in the original storage, whose its importance has been devalued for almost 80 years. Only recently has it undergone a thorough re-examination, allowing for the first modern assessment of its taxonomic, stratigraphic, and historical significance. This renewed investigation has demonstrated the scientific importance of the collection, enabling the identification of new species and reaffirming its relevance within the Portuguese palaeobotanical research. (See [Table 1](#).)

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Received 4 March 2026; Received in revised form 24 March 2026; Accepted 24 March 2026

Available online 31 March 2026

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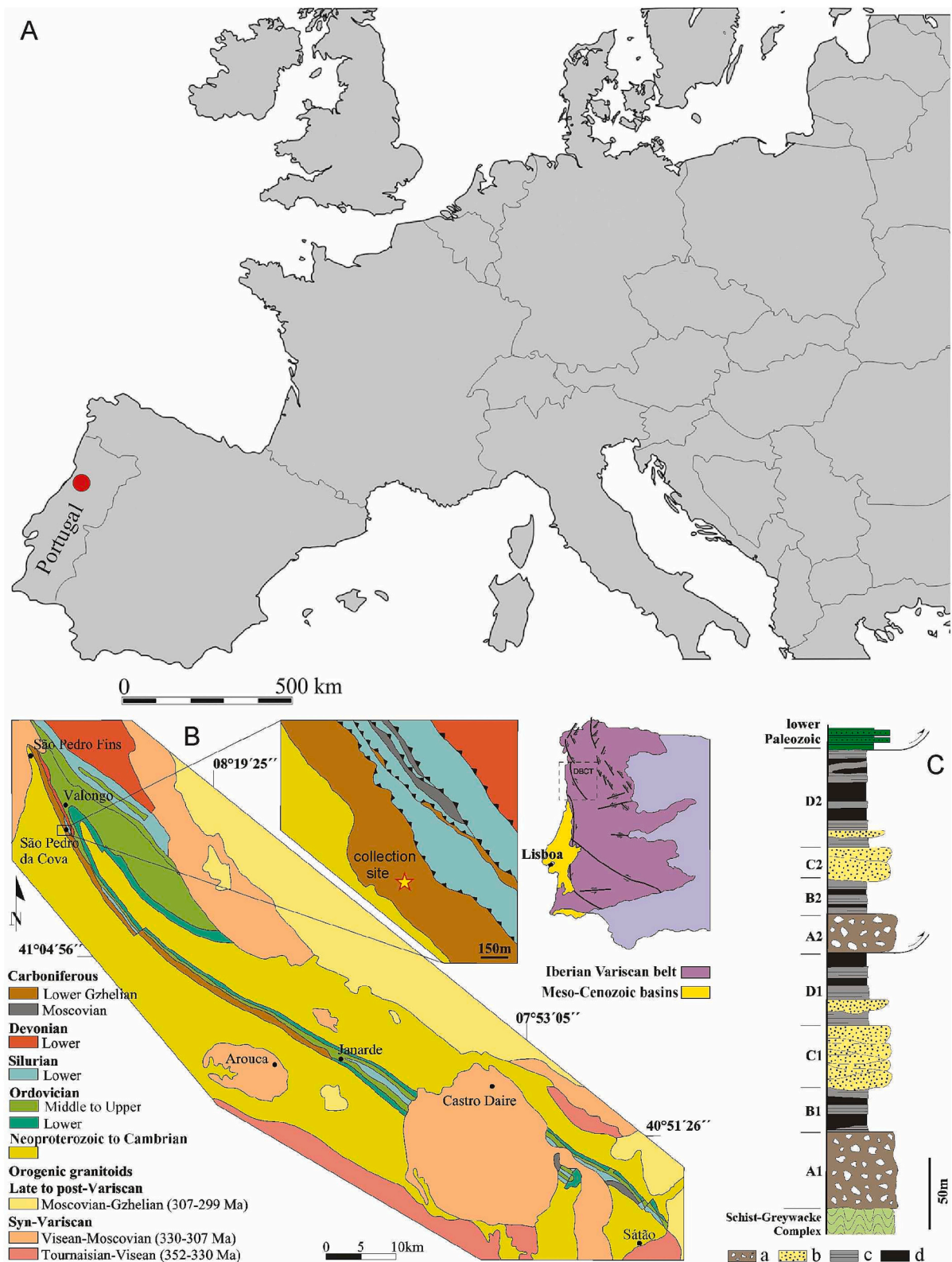


Fig. 1. (A) Geographical map with the occurrence of the new marattialean ‘pecopterid’ species marked with a red circle (map modified from Pšenicka et al., 2017). (B) Regional geological setting of the Douro Carboniferous Basin (DCB); northwestern Portugal; highlighting Upper Pennsylvanian (Stephanian C/upper Gzhelian) strata. The geological map of the DCB shows the geology of the São Pedro da Cova region and the collection site of *Pecopteris felicianoii* sp. nov.; marked with a star. (C) The stratigraphy of the DCB; showing relevant tectonic-sedimentary units (TSUs: A1–D2). At lower right are the lithologies illustrated in (C); principally a; breccias; b; conglomerates and sandstones; c; siltstones and shales; and d; and coal beds. (B) and (C) are adapted from Correia et al. (2021, fig. 1). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1

Summary of the comparative morphological and morphometric characters between *Cyathocarpus felicianoi* sp. nov. and similar marattialean ‘pecopterid’ species. Data compiled from descriptions and figures according to authors cited (including data from present work).

Species	General form of pinnule	Pinnule length/width (in mm)	Margin type	Vein density (per cm on margin)	Lateral-veins pattern	Midvein
<i>Cyathocarpus hemitelioides</i>	Elongate-linguaeform, apically rounded	5–8/1.5–2.5	Entire (non-crenulate) and parallel margins; non-marginally (basally) decurrent	18 veins	Generally simple, straight and very-spaced veins	Strong and decurrent until the apex
<i>Cyathocarpus arborea</i>	Small and linguaeform, apically rounded	4.0/2.0	Entire and parallel margins; non-marginally decurrent	25 veins	Simple and very-spaced Generally simple and well-spaced, with a few bifurcate veins;	Thin and decurrent until the apex
‘ <i>Pecopteris</i> ’ <i>paleacea</i>	Small and linguaeform, apically rounded	4.0/2.0	Entire and parallel margins; non-marginally decurrent	20 veins	moderately inclined, straight to slightly curved	Thin and decurrent until the apex
‘ <i>Pecopteris</i> ’ <i>monyi</i>	Broad and linguaeform, apically rounded	5–9/2–3	Entire and parallel margins; marginally decurrent	24 veins	Mixed simple and once divided lateral veins	Strong and relatively sinuous; decurrent? until the apex
‘ <i>Pecopteris</i> ’ <i>melendezi</i>	Relatively narrow, apically rounded	6–8/3–4	Entire and parallel margins; marginally decurrent	24 veins	Simple and very-spaced; straight and moderately inclined	Relatively thin? and decurrent until the apex
<i>Cyathocarpus felicianoi</i> sp. nov.	Broadly lingulate, apically rounded-obtuse	6–9/4–5	Crenulate margins; marginally (basally) decurrent	14–16 veins (few in number)	Generally simple and very-spaced, with a few bifurcate ones; straight to slightly curved	Thin and decurrent until the apex



Plate I. General view of the holotype (LNEG-23746) of *Cyathocarpus felicianoi* sp. nov.

The Carlos Teixeira's collection now serves as a valuable reference for studies in biostratigraphy and sedimentary evolution of the Portuguese carboniferous basins, while also preserving evidence of the historical development of geological sciences in Portugal and the

pioneering contributions of Carlos Teixeira on the Carboniferous Palaeobotany in the Iberian Peninsula. Today, the Carlos Teixeira's collection forms an essential part of the Portuguese Museum of Mineral Deposits and the São Pedro da Cova collection representing an

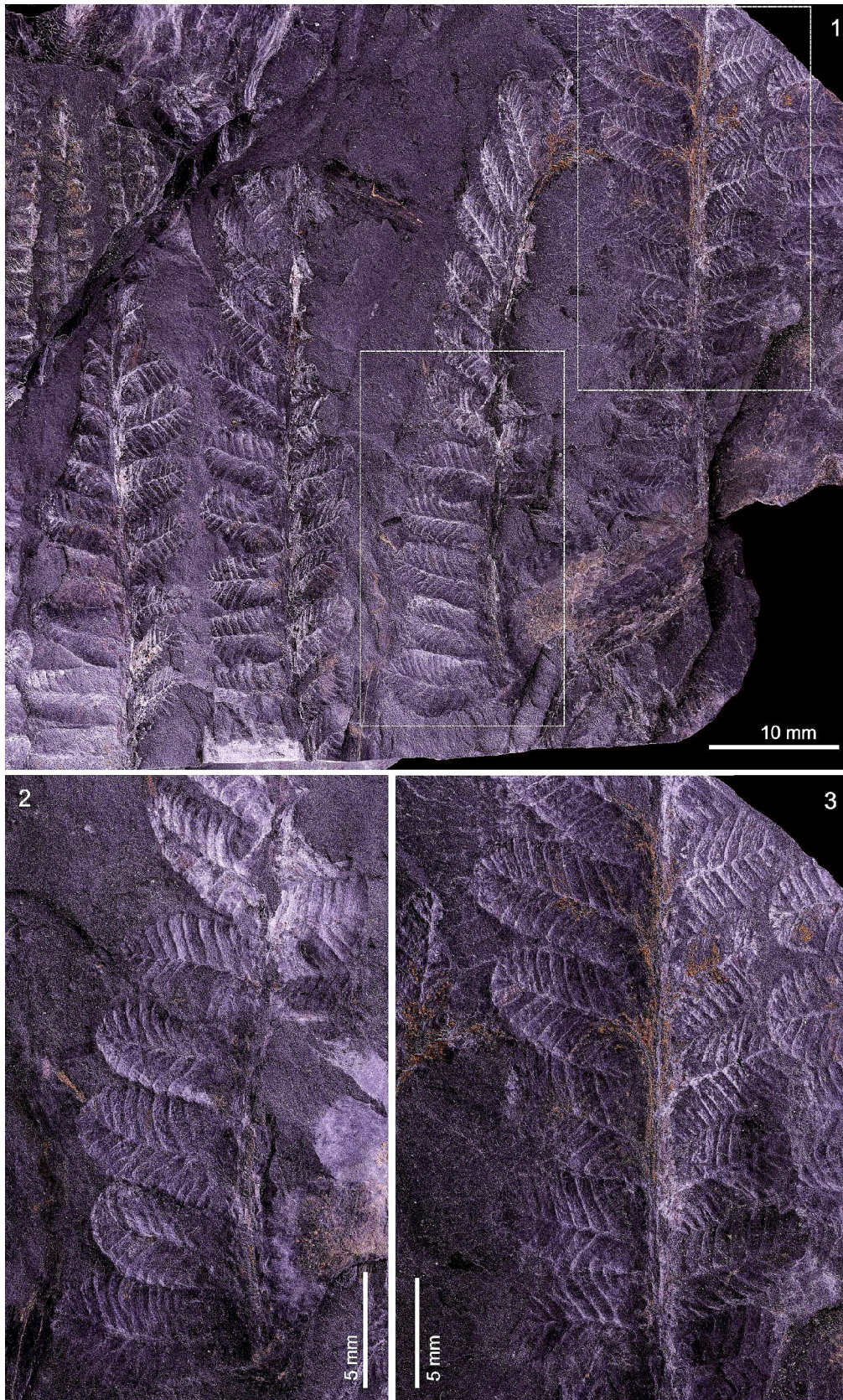


Plate II. Details of the holotype of *Cyathocarpus felicianoi* sp. nov.

1 – Fragment of a pinna of the penultimate order which shows the lingulate and broad form of pinnules

2–3 – Enlargement of rectangular boxes in Plate II, 1, showing broadly lingulate pinnules with slightly crenulate margins, as well as generally simple and very-spaced, lateral veins and thin midveins.



Plate III. Holotype of *Cyathocarpus felicianoi* sp. nov. whitened with sublimated ammonium chloride, enhancing the morphological features such as the margins and venation of the pinnules.

invaluable historical and scientific resource.

2. Carlos Teixeira's palaeobotanical collection

In this paper, a new fern fossil-species (Plates I–IV) is described and illustrated from the Carlos Teixeira Collection of the LNEG (São Mamede de Infesta, Portugal). The Carlos Teixeira Collection is a historical palaeobotanical collection composed primarily of plant fossils, comprising of about 1036 adpression fossil specimens. These specimens were recovered during the execution of the first series of boreholes drilled in the São Pedro da Cova and Midões sectors (boreholes I to XVI). These boreholes were carried out by the *Instituto Português dos Combustíveis* in the 1930s as part of an assessment of coal (anthracite) reserves in the Douro Carboniferous Basin (Fig. 1B, C). The Carboniferous plant fossils were collected by the technicians who accompanied the drilling operations, following explicit instructions to gather any fossil material encountered, although the criteria guiding the selection of these specimens remain unknown. The collection was subsequently stored in two wood cabinets, likely housed in the former facilities of the *Serviço de Fomento Mineiro*, between the 1930s and 1950s.

Carlos Teixeira becoming aware of the collection undertook its revision. He classified and identified the plant fossils, providing hand-written labels that have been preserved in the collection, until the present day. This classification effort resulted in two published studies, conducted between 1942 and 1945 (Teixeira and Medeiros, 1943; Teixeira, 1946).

3. Preparation of fossil sample and repository

The studied fossil specimen of the new species described herein was photographed using a Canon EOS 77D camera coupled with a Canon EF 100 mm f/2.8 L macro lens, mounted on a copystand. The holotype was subsequently whitened with sublimated ammonium chloride to enhance morphological features such as the margins and venation of the pinnules. The resulting images were focus-stacked using Helicon Focus software (v. 7.6.1). The type specimen is stored in the Carlos Teixeira Collection of the LNEG (São Mamede de Infesta, Portugal).

4. Systematic palaeobotany

Division: Filicophyta

Class: Polypodiopsida (ex-Marattiopsida) Doweld, 2001

Order: MARATTIALES Prantl, 1874

Family: PSARONIACEAE Stenzel, 1906

(or Asterothecaceae Engler and Gilg, 1919)

Genus: **Cyathocarpus** Weiss, 1869 emend. Cleal, 2015

Type species (lectotype): *Cyathocarpus arborea* (Sternberg) Weiss, 1869 (basonym *Pecopteris arborea* Sternberg, 1825 = *Filicites arborescens* von Schlotheim, 1820 nom. illegit.). Designated by Mosbrugger (1983).

Cyathocarpus felicianoi Correia, Šimůnek and Pereira, sp. nov.

Plant Fossil Names Registry Number: PFN003618.

Etymology: The specific epithet “*felicianoi*” is named after the José Feliciano, a distinguished geologist and esteemed colleague from LNEG. J.Feliciano is a field geologist and the head of the Laboratory (Technology Mineral Unit) at the LNEG of São Mamede Infesta Campus, where this collection is housed.

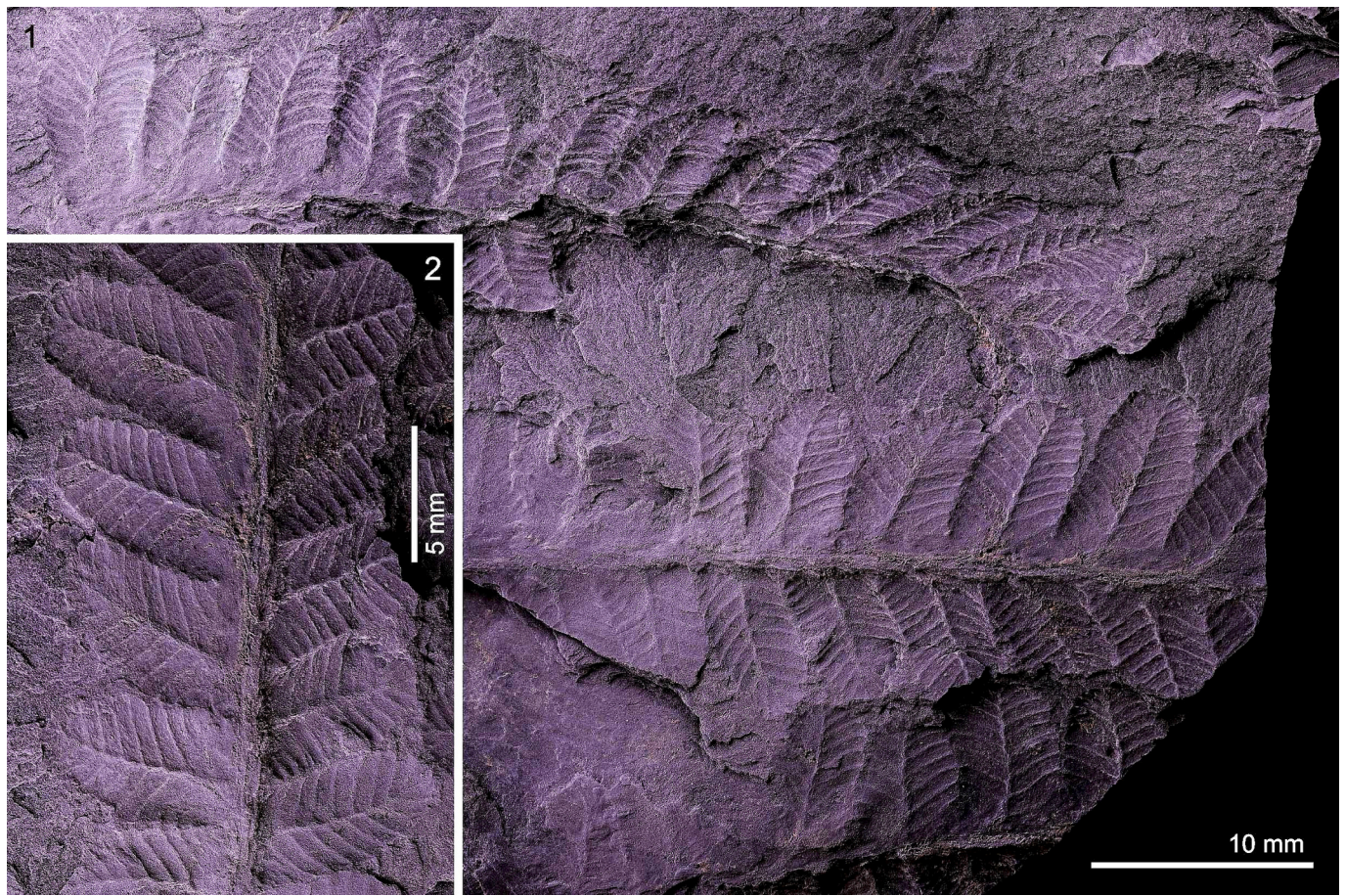


Plate IV. Details of the holotype of *Cyathocarpus felicianoi* sp. nov. with sublimated ammonium chloride.

1 – Fragments of two ultimate pinnae.

2 – Enlarged detail of the foliage in [Plate IV](#), 1, showing broadly lingulate pinnules with slightly crenulate margins, as well as generally simple lateral and very-spaced veins intermingled with a few bifurcate ones, and thin midveins (see [Fig. 2](#) for more details on venation).

Diagnosis: Broad pectopterid (*Pecopteris*-like) pinnules with lingulate shape, marginally decurrent, having slightly crenulate margins and rounded-obtuse apices. Lateral veins generally simple, intermingled with a few bifurcate ones, very-spaced and few in number (14–16 veins per cm at the pinnule margin), moderately inclined, and straight to slightly curved; thin and decurrent midveins.

Type specimen: Holotype specimen is designated here on [Plates I–IV](#) with collection number “LNEG-23746”.

Type locality: São Pedro da Cova region, Douro Carboniferous Basin (northwestern Portugal; [Fig. 1](#)).

Stratigraphic age: Stephanian C (late Gzhelian), Late Pennsylvanian, Carboniferous.

Description of the holotype: The holotype (LNEG-23746; [Plates I–IV](#)) is a large fragment of frond divided into pinnae of ultimate and penultimate order. The different frond parts are sterile and show broad pinnules of pectopterid (*Pecopteris*-like) form. The rachis of the penultimate order is 4–5 mm wide and ultimate rachises are 0.3–0.8 mm wide. The ultimate pinnae are 43–50 mm long and are inserted obliquely from the penultimate rachis at about 60° to 68° and are relatively spaced ([Plate I](#); [Plate II](#), 1; [Plates III](#)). The pinnules are 6–9 mm long and 4–5 mm wide, broadly lingulate and marginally (basally) decurrent, having slightly crenulate margins and rounded-obtuse apices; the pinnules are attached to the rachis obliquely and perpendicularly ([Plates I–IV](#); [Figs. 2](#), 3A). The midvein of pinnules is thin and decurrent. The lateral veins are generally simple (undivided), intermingled with a few bifurcate ones, especially on lower parts of pinnules ([Plate III](#); [Plate IV](#), 1, 2; [Figs. 2](#), 3A) and proximal pinnules of the ultimate pinnae ([Plate IV](#), 1). The lateral veins

are very-spaced, straight to slightly curved, and moderately inclined ([Plate II](#), 2, 3; [Plate IV](#), 1, 2; [Figs. 2](#), 3A), forming angles between 40° (at upper parts of pinnule) and 85° (at middle parts of pinnule) with midvein and 50–90° with margin of pinnule. The venation density is about 14–16 veins per cm at the pinnule margin.

5. Discussion and comparison

Pecopteris-like marattialean species are the most abundant pteridopsid taxa. [Clea](#) (2015) has proposed a new taxonomic classification for marattialean (Marattiales) species attributed to widely understood genus *Pecopteris* sensu [Brongniart, 1828](#). Because the type species of *Pecopteris* is a tedeleacean plant (Botryopteridales); according to [Clea \(2015\)](#); only *Pecopteris*-like tedeleacean species belongs to *Pecopteris* sensu stricto ([Correia et al., 2018](#)). Without preserved reproductive structures; a reliable taxonomic attribution based only on sterile ‘pectopterid’ fronds can be difficult. However; the venation pattern with simple to once bifurcate veins (see [Figs. 1](#); 2A) preserved in the new pectopterid fern species here erected ([Plates I–IV](#)) suggests that it likely belong to the marattialean fossil-genus *Cyathocarpus*. The most pectopterid species attributed to *Cyathocarpus* present venation patterns with generally simple to once divided veins ([Clea, 2015](#); [Sun et al., 2017](#); [Guo et al., 2024](#); [Correia et al., 2025](#); [Rizk and Cariglino, 2026](#)).

Among the most similar Pennsylvanian marattialean pectopterid species, *Cyathocarpus hemitelioides* ([Brongniart](#)) [Mosbrugger, 1983](#) have decurrent marginally pinnules with rounded-obtuse apices; displaying a venation pattern similar to that of *Cyathocarpus felicianoi* sp. nov.; with

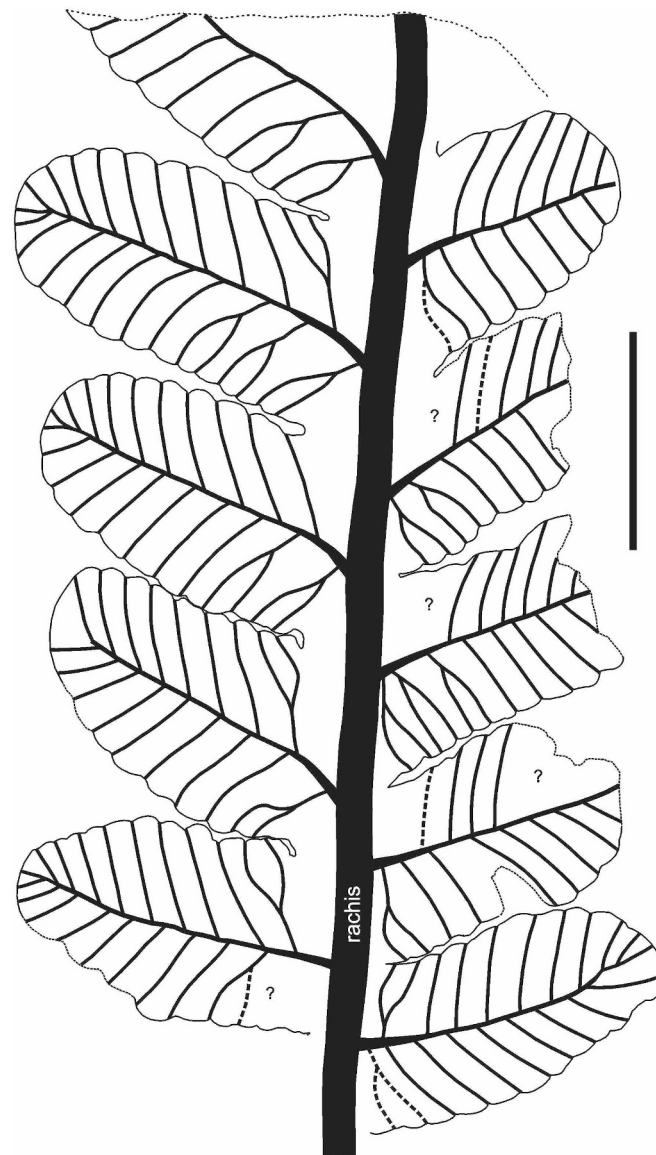


Fig. 2. Line drawing of ultimate pinna of *Cyathocarpus felicianoi* sp. nov. illustrated in Plate IV. Scale bar 5 mm.

generally simple; straight and very-spaced veins. However; the pinnules of *C. hemitelioides* are significantly narrow; having entire (non-crenulate) and parallel margins and generally strong midveins (e.g.; Wagner, 1964; pl. 55; 113; Boureau and Doubinger, 1975; fig. 49; Wagner et al., 1985; pl. 5; 4; DiMichele et al., 2018, pl. IV, 5; see also Fig. 2A, B).

Cyathocarpus arborea Sternberg, 1825 emend. Weiss, 1869 shows a venation pattern similar to that of *C. felicianoi* sp. nov.; with simple and very-spaced veins. However; pinnules of *C. arborea* are significantly smaller and non-marginally decurrent; having entire (non-crenulate) and parallel margins (e.g.; Wagner, 1964; pl. 35; 78; Boureau and Doubinger, 1975; fig. 14; Barthel, 2016, fig. 133; see also Fig. 2A, C).

'*Pecopteris*' (*Cyathocarpus*?) *paleacea* Zeiller, 1888 also shows small pinnules with generally simple and well-spaced veins; intermingled with a few bifurcate ones; moderately inclined; straight to slightly curved; and as well as thin midveins (e.g.; Wagner, 1964; pl. 61; 127; 128; pl. 72; 154; pl. 73; 155; pl. 74; 156; Boureau and Doubinger, 1975, fig. 89). However, the pinnules of *P. paleacea* are significantly smaller and have entire (non-crenulate), relatively parallel, and marginally non-decurrent margins (see Fig. 2A, D).

'*Pecopteris*' (*Cyathocarpus*?) *monyi* Zeiller, 1888 shows broad pinnules with rounded-obtuse apices and mixed simple and once divided

lateral veins. However; *C. felicianoi* sp. nov. differs from *P. monyi* by having slightly crenulate margins; while *P. monyi* has completely entire margins. Moreover; *P. monyi* pinnules show strong and relatively sinuous midveins; having bifurcate veins more frequent (e.g.; Wagner, 1964; pl. 31; 70; Knight, 1971; pl. 5; 1; Wagner and Lemos de Sousa, 1983; pl. III; 2; pl. VII; 2; pl. X; 4; Wagner et al., 1985; p. 473; pl. 4; 1; Barthel, 2016; figs. 152; 153; DiMichele et al., 2018; pl. IV; 1–4). On the contrary; *C. felicianoi* sp. nov. has significantly thin midveins and divided veins are rarer; occurring mainly in the lower parts of pinnules (see Figs. 1; 2A; E). These dissimilarities are also present in '*Pecopteris*' (*Cyathocarpus*?) *jongmansii* Wagner, 1962 (detailed description of species in Boureau and Doubinger, 1975; p. 82); which has a venation pattern similar to that of *P. monyi* (additional comments in Boureau and Doubinger, 1975, p. 110).

C. felicianoi sp. nov. also resembles '*Pecopteris*' (*Cyathocarpus*?) *melendezii*, another pecopterid species described by Wagner (1962); which has decurrent marginally pinnules with simple lateral veins and relatively thin? midveins (e.g.; Boureau and Doubinger, 1975; fig. 76). However; *C. felicianoi* sp. nov. has broadly lingulate pinnules with slightly crenulate margins; while *P. melendezii* shows relatively narrow pinnules with parallel and entire margins (see Fig. 2A; F). *P. melendezii*

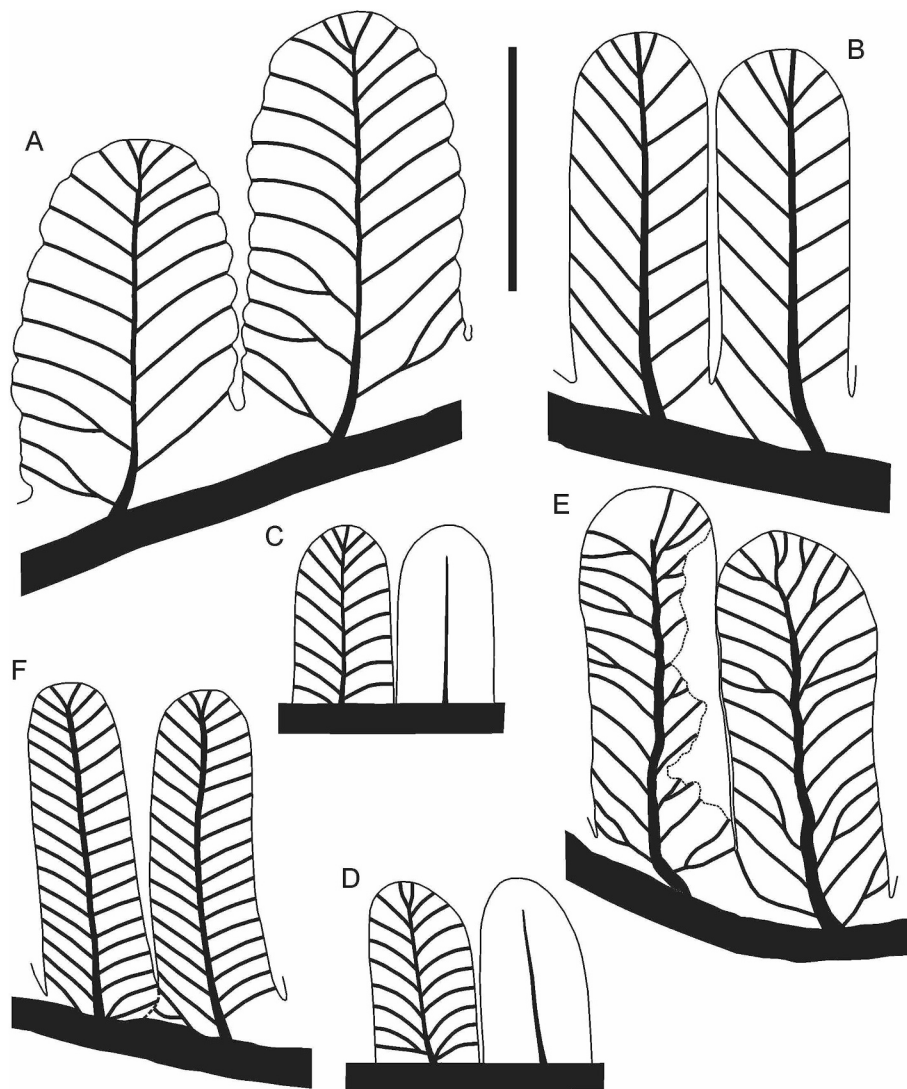


Fig. 3. Comparison of pinnules with similar marattialean ‘pecopterid’ species. (A) Pinnule shape and venation of *Cyathocarpus felicianoi* sp. nov. (B) Pinnule shape and venation of *Cyathocarpus hemitelioides* based on Wagner (1964, pl. 55, 113) and Boureau and Doubinger (1975, fig. 49). (C) Pinnule shape and venation of *Cyathocarpus arborea* based on Wagner (1964, pl. 35, 78) and Boureau and Doubinger (1975, fig. 14). (D) Pinnule shape and venation of ‘*Pecopteris*’ *paleacea* based on Wagner (1964, pl. 74, 156) and Boureau and Doubinger (1975, fig. 89). (E) Pinnule shape and venation of ‘*Pecopteris*’ *monyi* based on Barthel (2016, fig. 152). (F) Pinnule shape and venation of ‘*Pecopteris*’ *melendezii* from holotype illustrated in Boureau and Doubinger (1975, fig. 76). Scale bar (estimated for all species) 5 mm.

has similarities with *C. hemitelioides* and *C. arborea* in the venation pattern (additional comments in Boureau and Doubinger, 1975, p. 104), but they differ from other morphological features, such as the shape and size of pinnules and number of veins.

The marattialean fossil-genera *Lobatopteris* sensu Wagner, 1959 and *Crenulopteris* sensu Wittry et al., 2014 have also crenulate or lobed pinnule margins (e.g.; Correia et al., 2019), however, multiply divided vein enter each lobe. In case of *C. felicianoi* sp. nov., an undivided vein leads to the pinnule margin just in the place between two lobes. This case is not known at other representatives of the fossil-genus *Cyathocarpus*.

6. Conclusion

The Late Pennsylvanian marattialean species, *Cyathocarpus felicianoi* Correia et al. sp. nov., from the Carlos Teixeira’s palaeobotanical collection is distinguished from other marattialean species primarily by its broadly lingulate pinnules with slightly crenulate margins and generally simple and very-spaced veins.

This species comes from the São Pedro da Cova region, in the Douro

Carboniferous Basin (Stephanian C, upper Gzhelian, Upper Pennsylvanian). It belongs to the Carlos Teixeira’s collection from 1940s, that is now split into LNEG – National Laboratory of Energy and Geology (Geological Survey), Portuguese Museum of Mineral Deposits and the São Pedro da Cova collection. This historical palaeobotanical collection comprises a large repository of plant fossils from the Portuguese Carboniferous, many of which are potentially new for science and need to be investigated in future studies.

Funding

This study was supported by Fundação para a Ciência e a Tecnologia, I.P. (Portugal) in the frame of UID/00073/2025, UID/PRR/00073/2025 and UID/PRR2/00073/2025 projects of the R&D unit of Geosciences Center (University of Coimbra, Portugal). Grant Agency of the Czech Republic – grant project GA CR 25-16958S.

Declaration of competing interest

No potential conflict of interest was reported by the author(s).

Acknowledgements

The authors express their sincere gratitude to Maria Luísa Matos, curator of the Museum Collections at the LNEG Campus in São Mamede de Infesta, where the Carlos Teixeira's collection is housed, and to José Feliciano, head of the Laboratory of the Mineral Technology Unit at the same campus. Their dedicated work in preserving, organising, and facilitating access to these historical geological and palaeobotanical collections has been essential in supporting research and stimulating new scientific studies based on these unique materials. The authors also are grateful to Sofia Pereira (Geosciences Center of University of Coimbra, Portugal) for her support on the photographic documentation. Finally, we thank Prof. M. Popa (Bucharest) and an anonymous reviewer for their constructive comments that helped improve the submitted manuscript.

Data availability

The authors confirm that all data necessary for supporting the scientific findings of this paper have been provided.

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