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RESEARCH ARTICLE

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Anatomical characteristics of fossil wood collected from the Manchar Formation (Miocene), Thano Bula Khan, Sindh, Pakistan

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Abstract

The characterization of petrified wood provides valuable information about paleoclimatology and geological history and helps to reconstruct the past forest flora of different parts of the earth. The present study was undertaken to evaluate the anatomical characteristics of fossil wood of the Miocene age collected from the Manchar Formation exposed at Thano Bula Khan, Sindh, Pakistan. In order to carry out a detailed anatomical investigation, three-dimensional sections were prepared using a petrotome. The microscopic analysis allowed us to study vessel size and arrangement, wood parenchyma, fibers, and xylem rays. Based on the comparison between recent and fossil wood, we concluded that the investigated characters are comparable with those of the genus *Atalantia* Corrêa of the Rutaceae family. Therefore, it was named as *Atalantioxylon thanobolensis* sp. nov. with reference to the location of Thano Bula Khan from which the fossil wood was collected.

Keywords

Atalantioxylon thanobolensis sp. nov. Rutaceae, fossil wood, Manchar Formation, Pakistan

Introduction

The anatomical study of fossil wood has long been proven as an effective instrument for determining the flora of the paleo-forest. The anatomical study of fossil wood provides useful features for the taxonomy of fossil plant and represents an important tool in determining the flora of paleo-forests. Moreover, xylotomical data can also be useful for paleo-ecological reconstruction. As suggested by Visscher and Jagels (2003), the identification of fossil wood gives valuable information on paleo-ecosystems and paleo-environments in the absence of reproductive or vegetative plant organs. Recently, Acarca et al. (2018) evaluated and identified the silicified wood belonging to Miocene forests. Based on paleobotanical studies, a variety of dicot wood flora was described by Akkemik et al. (2018) from the Miocene age in Ankara Turkey, confirming the paleoclimatic conditions (a xeric-low mountainous forest prevailing under a semi-dry climate). Anatomical studies of dicotyledonous fossil wood species from Sindh region of Pakistan were reported by various authors, such as Khan and Rehmatullah (1968), Rehmatullah (1971), Khan and Rajput (1976), Bhutto et al. (1993), Ahmed et al. (2007), Shar et al. (2010), Soomro et al. (2016) and Mangi et al. (2020). Rajput and Khan (1984) identified gymnosperm and monocot wood from the Sindh province. De Franceschi et al. (2008) also found some dicotyledonous fossil wood in the lower portions of the Chitarwal Formation, Sulaiman Range, eastern Baluchistan, while fossil woods from the province of Punjab (Pakistan) have also been documented by Soomro et al. (2016a, b; 2017). The current work aims to characterize the fossil wood obtained from the Manchar Formation of the Miocene Age at Thano Bula Khan, Sindh (Pakistan).

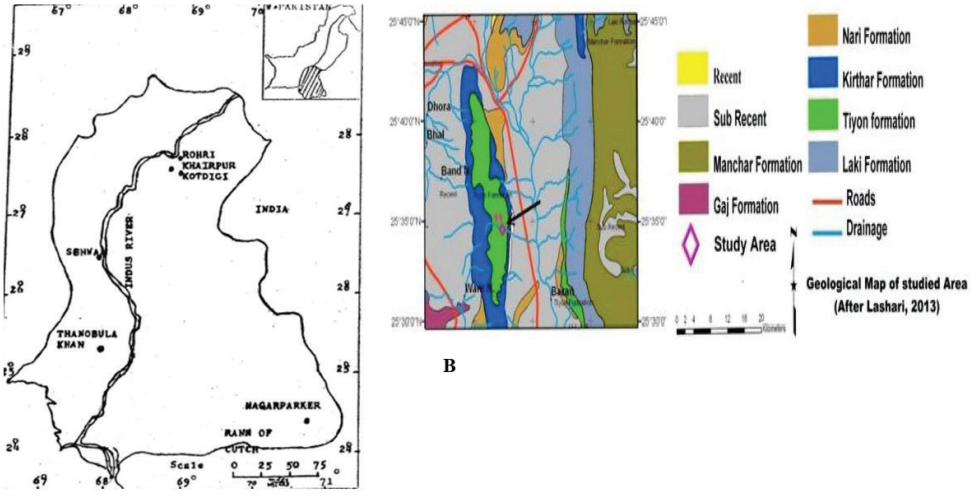

Figure 1. A map of Sindh (Pakistan), showing the area of Thano Bula Khan from where the fossil wood was collected **B** geological map showing the Manchar Formation exposed in the study area.

Material and methods

The fossil wood sample of the Manchar Formation (TB35) was taken from Thano Bula Khan (25°24'35"N, 67°46'27"E, district of Jamshoro, Sindh, Pakistan). The size of the sample was 20 cm in length and 4.5 cm in width. The colour of the fossil wood was noted to determine the depositional material. Using the ground thin-section method described by Opała-Owczarek et al. (2020), nine thin sections were prepared (cross, tangential and radial planes). All the samples were carefully observed under the microscope and all their anatomical features were noted. Photography was carried out with a digital microscope available at the Paleobotany Laboratory, Institute of Plant Sciences, University of Sindh, Jamshoro.

Results

Family: Rutaceae

Genus: *Atalantia* Corrêa

***Atalantioxylon thanobolensis* sp. nov.**

Diagnosis. Wood diffuse porous, growth ring present, demarcated by a line of terminal parenchyma, vessels small to medium in size, tangential diameter 45–134 μm, radial diameter 67–180 μm, solitary and in radial multiples of 2–5 evenly distributed over 24–30 mm^2. Vessel members 150–400 μm long with simple oblique perforation. Intervessel pit pairs about 3–5μm in diameter, bordered alternate, circular to oval in shape. Parenchyma terminal, paratracheal parenchyma sparse. Xylem rays 1–3 (mostly 2) seriate 8–34 cells, 80–550 μm in height, distributed over 5–7 mm^2. Ray tissue homogeneous, with only procumbent cells. Fibers moderately thick-walled with lumen 15–20 μm in diameter, polygonal in cross-section, non-septate, 450–660 μm long.

***Holotype*.** The specimen was given the name "TB 35" (holotype shown in Fig. 2). It consists of silicified wood collected 10 km south-west of Thano Bula Khan, by the first author.

Horizon. Manchar Formation. Age: Pliocene to Upper Miocene.

Morphological description. The present fossil was anatomically identified from a well-preserved secondary wood sample measuring 20 cm in length and 4.5 cm in width. The color of the fossilized wood is light brown with shine indicating deposition of silicates.

Anatomical analysis. Cross section. Wood diffuse porous, growth ring present, demarcated by a line of terminal parenchyma vessels small to medium in size, solitary and mostly in radial multiples of 2–5, mostly evenly distributed but in some places showing crowding at the beginning of the growth ring, circular to oval when

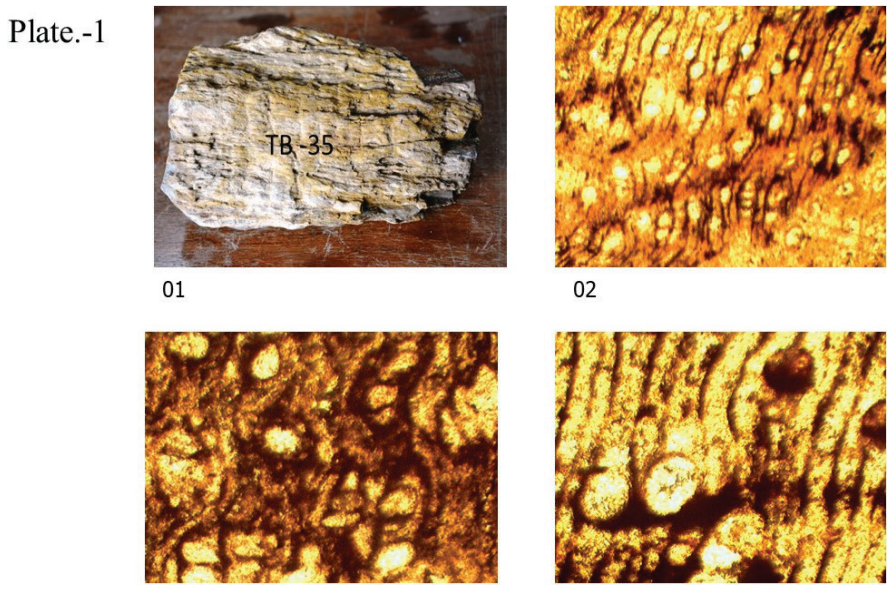

Figure 2. *Atalantioxylon thanobolensis* sp. nov. Plate 1-01: Macrograph of the fossil wood TB 35. Plate 1-02: Cross section showing general distribution of vessels and parenchyma (×40). Plate 1-03: Cross section showing general distribution of vessels and parenchyma. (×100). Plate 1-04: Cross section showing details of vessels and parenchyma. (×200).

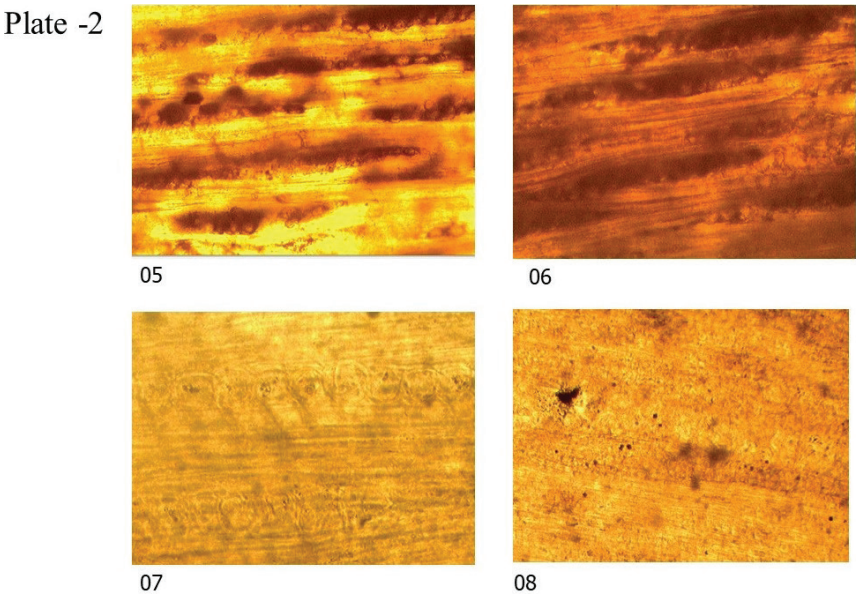

Figure 3. *Atalantioxylon thanobolensis* sp. nov. Plate 2-05 Tangential section showing general distribution of xylem rays and fibers (×40). Plate 2-06 Tangential section showing general distribution of xylem rays and fibers (×100). Plate 2-07 Tangential section showing details of xylem rays (×400). Plate 2-08 Tangential section showing general distribution of xylem rays and fibers (×200).

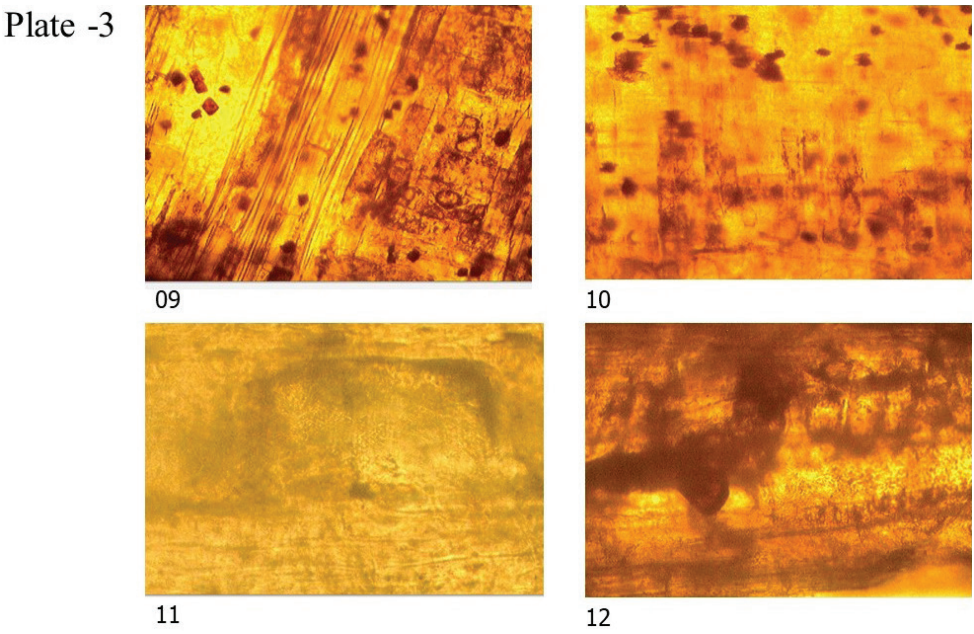

Figure 4. *Atalantioxylon thanobolensis* sp. nov. Plate 3-09 Radial longitudinal section showing arrangement of fibers (×40). Plate 3-10 Radial longitudinal section showing arrangement of fibers (×40). Plate 3-11 Radial longitudinal section showing vessel end-walls and pits (×200). Plate 3-12 Radial longitudinal section showing pits on wall of vessels (×100).

solitary, sometimes elliptical due to pressure during fossilization. Tylosis present, parenchyma paratracheal, terminal, and apotracheal; the latter diffuse, while paratracheal parenchyma is sparse, present as few cells around some of the vessels; terminal parenchyma forms 2–3 seriate continuous lines demarcating the growth rings; diffuse parenchyma very sparse, difficult to locate in cross section, fibers thick-walled and non-septate (Fig. 2).

Tangential longitudinal section. Vessels evenly distributed, 170–390 μm long with oblique ends and 73–273 μm wide. Perforation simple intervessel pit pairs about 3–6 μm diameter, bordered alternate circular to oval in shape. Xylem rays small to medium 1–3 (mostly 2) seriate 5–7 mm^2, 8–34 cells, 80 -550 μm in height, separated by rows of fibers. Ray cells polygonal in tangential section often with dark content ray tissue, homogenous made up of procumbent cells; fibers elongated, non-septate, 15–20 μm in diameter, 450–630 μm in length (Fig. 3).

Radial longitudinal section. Vessel segments elongated with oblique end, length of the vessel members, 175–395 μm, width 84–275 μm, vessel walls 10–12 μm thick. Intervessel pit pairs about 4–6 μm in diameter, bordered alternate, circular to oval in shape. Parenchyma cells attached to the vessels 20–25 μm in diameter and 45–60 μm in length. Xylem ray cells 8–34, 80–556 μm long (Fig. 4).

Discussion

Comparison with modern wood

The principal anatomical characters of the petrified wood samples are: small to medium sized vessels, thin bands of terminal parenchyma along with scanty and diffuse paratracheal parenchyma; 1–3 (mostly 2) seriate, homogeneous xylem rays and moderately thick-wall, non-septate fibers strongly indicate the affinity of this fossil wood with the Rutaceae (Metcalfe and Chalk 1950; Stoel and Borman 2008). A detailed anatomical study of various genera of this family revealed a close resemblance of the studied fossil wood with the modern woods of *Atalantia* Corrêa. A comparison was made with the wood of *Atalantia monophylla* DC., *Atalantia. missionis* Oliv., and *Limonia acidissima* L. The fossil wood under consideration resembles very closely the woods of both these species in all the anatomical characters, such as distribution of vessels, vessel shape and size, parenchyma arrangement, 1–3 seriate, homogeneous xylem rays, and non-septate fibers. The only difference observed between the fossil wood and the modern wood of the fore-mentioned species is the presence of crystalliferous apotracheal parenchyma in the modern wood while it is absent in the fossil wood. Given the resemblance of the fossil wood with the wood of both *Atalantia* and *Limonia*, we proposed a new genus *Atalantioxylon*.

The genus *Atalantia* is limited to the Indian subcontinent where it is present with four species and two varieties. The infra-generic classification and the species limits of the genus are, however, not well established due to the presence of intermediate forms. Two species, *A. monophylla* (L.) DC. and *A. racemosa* Wight & Arn. are extensively distributed, while the third species, *A. wightii* Yu.Tanaka is endemic to Pakistan (Rameshkumar et al. 2020).

Comparison with fossil wood

Chitaley and Shallon (1962) described a fossil wood from the Deccan near Nagpur; they placed their fossil wood in the family Rutaceae but from its photographs and text figures it does not appear to belong to this family. It also differs markedly from the fos-

Table 1. Comparison of the new species with *Atalantioxylon indicum* Lakhanpal.

Species	Wood	Vessels	Wood Parenchyma	Xylem	Fibres
Atalantioxylon indicum Lakhanpal	Diffuse porous	Vessels medium to large in size, up to 350 µm	Axial parenchyma absent or extremely rare, paratracheal parenchyma scanty, forming few cells around the vessel	Ray width 1 to 3 cells; all ray cells procumbent, 4–12 mm	Non-septate
Atalantioxylon thanobolensis sp. nov.	Diffuse porous	Vessels small to medium in size; tangential diameter 45–134 µm; radial diameter 67–180 µm; solitary and in radial multiples of 2–5, evenly distributed over 24–30 mm^2	Parenchyma paratracheal, terminal and apotracheal; apotracheal diffuse; paratracheal sparse, present as few cells around some of the vessels; terminal parenchyma forms 2–3 seriate continuous lines demarcating the growth ring	Xylem rays fine to medium 1–3 (mostly 2) seriate, over 5–7 mm^2; 8–34 cells 80 -550 µm long separated by rows of fibers. Rays cells polygonal in tangential section often with dark content; ray tissue homogeneous made up of procumbent cells	Non-septate

Table 2. Geographical and stratigraphical data of fossils related to the genus *Atalantioxylon*.

Species	Reference	Locality	Geological age
Atalantioxylon indicum Lakhanpal, Prakash & Bande	Lakhanpal et al. (1978)	Mandla, District, Madhya Pradesh, India	Paleocene
Atalantioxylon thanobolensis sp. nov.	This paper	Thano Bula Khan, Pakistan	Miocene

sil wood under investigation in the absence of terminal parenchyma and in having two types of xylem rays, short and long, made up of both heterogeneous procumbent cells and erect cell. The fossil wood of *Atalantioxylon indicum* from Madhya Pradesh in India was the first authentic record of a member of the Rutaceae in fossil state (Lakhanpal et al. 1978). The differences observed between the fossil wood under investigation and the previously reported fossil wood from India regard the size of vessels and slightly dissimilar parenchyma cells (Table 1). Hence, the studied fossil wood is assigned a new species name, viz. *Atalantioxylon thanobolensis* sp. nov.

Conclusion

A new species, *Atalantioxylon thanobolensis* is described from Sindh, Pakistan. The presence of other Rutaceae fossil species of *Atalantioxylon* in the subcontinent and their resemblance with the actual genus *Atalantia* suggest that a tropical climate existed in the past in the sub-continent.

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