

Gymnospermous woods from the Late Cenozoic sediments of Rajasthan, western India

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(Received 11 May, 2011; revised version accepted 13 June, 2011)

ABSTRACT

Guleria JS & Shukla A 2011. Gymnospermous woods from the Late Cenozoic sediments of Rajasthan, western India. The Palaeobotanist 60(2): 355-362.

The paper describes two gymnospermous woods, namely *Araucarioxylon* Kraus, 1870 and *Podocarpoxyton* Gothän, 1905 from the Late Cenozoic sediments (Shumar Formation) of district Jaisalmer, Rajasthan, western India. The woods indicate favourable climatic conditions for the growth of mesic vegetation in Rajasthan till Plio-Pleistocene time compared to the xeric vegetation and drier conditions in the area today.

Key-words—Fossil woods, *Araucarioxylon*, *Podocarpoxyton*, Late Cenozoic, Jaisalmer, Rajasthan, India.

भारत के पश्चिमी राजस्थान के पश्च नूतनजीव अवसादों से प्राप्त अनावृतबीजी काष्ठें

जे.एस. गुलेरिया एवं अनुमेहा शुक्ला

सारांश

यह शोध-पत्र जिला जैसलमेर, राजस्थान, पश्चिमी भारत के पश्च नूतनजीव अवसादों (शुमार शैलसमूह) से प्राप्त *एरोकैरिऑक्सीलॉन* क्रौस, 1870 एवं *पोडोकार्पोक्सीलॉन* गोथान, 1905 नामक दो अनावृतबीजी काष्ठें वर्णित करता है। काष्ठें, क्षेत्र में आज मरुद्भिदी वनस्पति एवं शुष्कीय स्थितियों की तुलना में अति-अत्यंतनूतन समय तक राजस्थान में मेसिक वनस्पति की बढ़वार हेतु अनुकूल जलवायवी स्थितियाँ इंगित करती हैं।

संकेत-शब्द—जीवाश्म काष्ठें, *एरोकैरिऑक्सीलॉन*, *पोडोकार्पोक्सीलॉन*, पश्च नूतनजीव, जैसलमेर, राजस्थान, भारत।

INTRODUCTION

A few fossil woods have been described hitherto from the Tertiary sediments of Rajasthan. For the first time, Guleria in 1984 described a *Mangifera* L. wood from Late Tertiary sediments of Jaisalmer District. Subsequently, a number of fossil woods belonging to the families Lythraceae, Fabaceae, Combretaceae, Rhamnaceae, Sonneratiaceae and Dipterocarpaceae were described from Tertiary sediments of Bikaner District (Guleria, 1990, 1992a, 1996). Harsh and Sharma (1988, 1995) reported a gymnospermous wood *Araucarioxylon* Kraus and nine species of genus *Lagerstroemia* L. from Bikaner District, respectively. It is, however, difficult to conceive the occurrence of nine species of a genus at the same spot.

The species reported are, infact, the variations of two already described species of *Lagerstroemia* from the same locality (Guleria, 1990) and one may be the same as *Ziziphus* Mill., reported by Guleria (1992a). Some more fossil woods from Bikaner, viz. *Barringtonia* Forst. & Forst. belonging to the family Lecythidaceae and five species of Combretaceous woods, three belonging to *Terminalia* L. and two to *Anogeissus* Wall. were reported by Harsh *et al.* (1993).

MATERIAL AND METHODS

The petrified material being described here belongs to the Shumar Formation. The investigated assemblage is similar to the wood assemblage recovered from the Kanakawati Series/

Sandhan Formation (Plio-Pleistocene) of Kachchh (Biswas, 1965, 1971; Biswas & Raju, 1973; Lakhanpal *et al.*, 1984). The sediments of Shumar Formation can be seen around Biprasar Village, nearby Ramgarh-Longewala Road sections and Shumarwali talai area. The age of the formation is unsettled due to lack of any palaeontological control and has been suggested to be post-Eocene to Quaternary or even younger (DasGupta, 1975; Singh, 1982; Bhandari, 1999). However, in view of the close lithological and plant fossil similarity between Sandhan Formation of Kachchh and Shumar Formation, the age of Shumar Formation is considered as Plio-Pleistocene till more precise age could be determined (Fig. 2). The authors examined the wood assemblage and found that most of them belong to angiosperms, except for two which belong to gymnosperms and are being described here, although their occurrence was reported earlier (Guleria, 1992b).

A large number of fossil woods were found scattered on top of the Khuiala Limestone ridge situated about 3-5 km east of the Habur Village near Hema Ki Dhani (Fig. 1) and on way to village Biprasar, about 45-50 km north-west of Jaisalmer. The woods are petrified, cherty and smooth. For the study of xylotomical characters, woods were cut into thin sections, viz. transverse/cross, tangential and radial longitudinal sections and their slides were prepared. The thin sections were

examined under high power microscope after smearing the surface with glycerin. Identification of the fossil woods was done by making comparative study of a large number of modern woods both from thin sections and published literature. The anatomical terms used in describing the fossil woods are those adopted by Wheeler *et al.* (1986) and the International Association of Wood Anatomists (IAWA, 1989).

SYSTEMATICS

Family—ARAUCARIACEAE

Genus—ARAUCARIOXYLON Kraus, 1870

Araucarioxylon jaisalmerensis sp. nov.

(Pl. 1.1-5)

Diagnosis—Growth rings discernible, but not conspicuous; wall thickness of tracheids changing very minutely (Pl. 1.1-2), tracheids usually filled with gummy material (Pl. 1.1-4). *Early wood* zone quite wide, occupying more than 95% portion of the wood, consisting of 31-62 rows of tracheidal cells (Pl. 1.1-2); tracheids thin walled, circular to polygonal, with wide lumen, having radial diameter of 35-67 μm , tangential diameter 20-47 μm , 345-520 cells per sq mm. *Late wood* forming very narrow zone of 1-2 rows of tracheidal cells; tracheids relatively thick walled (Pl. 1.2), radial diameter 22-45 μm , tangential diameter 20-44 μm ; cells flattened to elliptic, tangential wall smooth. *Parenchyma* absent. *Rays* fine, predominantly uniseriate, rarely biseriate (Pl. 1.3), composed of circular to slightly elongated cells, homocellular (Pl. 1.4), 2-30 (mostly 2-12) cells or 40-1,150 μm in height; ray cells thin walled, smooth, filled with dark gummy contents (Pl. 1.1-4), cracks seen as septa like feature in the TLS (Pl. 1.3). *Tracheidal pits* on radial walls, 1-2 seriate, contiguous, alternate when biseriate, hexagonal in shape (Pl. 1.5), 10-16 μm in diameter. *Cross Field pits* not clearly seen due to poor preservation. *Bars of Sanio* absent. *Resin Canals* absent.

Holotype—Specimen No. BSIP 14208.

Repository—Birbal Sahni Institute of Palaeobotany, Lucknow.

Horizon and Locality—Shumar Formation; Hema Ki Dhani, near Habur Village, Jaisalmer District, Rajasthan.

Age—Plio-Pleistocene.

Etymology—After the Jaisalmer District of Rajasthan from where the fossil was collected.

No. of specimen studied—A single piece of petrified wood measuring about 7.0 cm in length and 4.3 cm in width. The preservation of the wood is workable.

Affinities—The presence of growth rings, almost uniseriate rays, tracheids with alternate, hexagonal (araucaroid) pits on the radial walls show affinity of the fossil with the

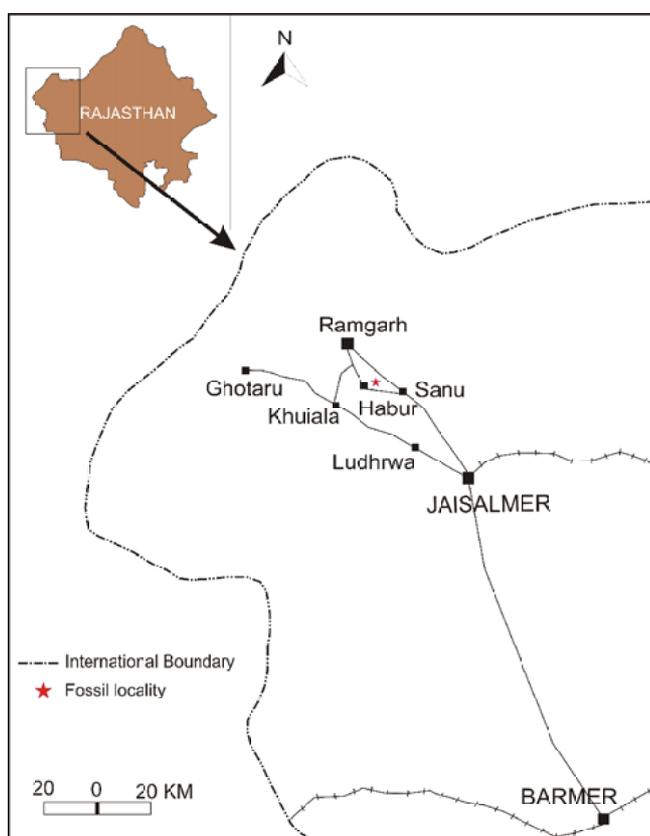


Fig. 1—Map showing fossil locality in Jaisalmer District.

modern woods of the family Araucariaceae. The family is represented by three genera, viz. *Araucaria* Juss., *Agathis* Salisb. and *Wollemia* Jones, Hill & Allen (Mabberley, 1997) which show overlapping xybotomical characters and are difficult to distinguish (Greguss, 1955, 1972; Heady *et al.*, 2002). Hence the fossil may represent the wood of *Araucaria-Agathis-Wollemia*.

Two organ genera have been instituted for the fossil woods showing affinity with the modern woods of the family Araucariaceae, viz. *Dadoxylon* Endlicher (1847) and *Araucarioxylon* Kraus (1870, in Schimper, 1870-72). However, there is difference of opinion among the palaeobotanists about the nomenclature of fossil woods with araucaroid pitting and this has been discussed in detail by Lepekhina (1972); Bose and Maheshwari (1974); Lakhanpal *et al.* (1977); Srivastava and Prakash (1984) and Trivedi and Srivastava (1989). Araucarian fossil woods, particularly recovered from the Tertiary sediments have been assigned to the genus *Araucarioxylon* Kraus (1870). Since the present fossil shows all the characters of an araucarian wood so it has been placed under the genus *Araucarioxylon* Kraus.

A number of araucarian woods have been described from the Tertiary sediments of India under the generic name *Dadoxylon* and *Araucarioxylon*. Following Lepekhina's (1972) view about the genus *Araucarioxylon* and *Dadoxylon*, Trivedi and Srivastava (1989) transferred the known Indian Tertiary *Dadoxylon* spp. under the genus *Araucarioxylon*. However, while doing so they did not mention anything about the two other *Dadoxylon* spp. (*Dadoxylon* sp. cf. *D. barakarensis* and *Dadoxylon* sp. cf. *D. jamudhiense*) reported by Mahabale and Satyanarayana (1978) from the Rajahmundry Sandstones (Oligo-Miocene) of Andhra Pradesh. It seems they were not aware of the publication of Mahabale and Satyanarayana (1978). However, the close resemblance of the two Oligo-Miocene species with the Palaeozoic species raises doubt about the exact provenance of these woods. Since Gondwana sediments are in close proximity of the Rajahmundry Sandstones (see Map 2 of Mahabale & Satyanarayana, 1978), there is a possibility that the woods might have come from the Gondwana sediments. The mixing of the flora at Rajahmundry has already been pointed out by Guleria (1992b, p. 291), hence the above two *Dadoxylon* species are not being taken into consideration. Thus the *Araucarioxylon* species known from the Tertiary sediments of India are: *Araucarioxylon deccani* (Shukla) Trivedi & Srivastava, 1989; *A. resinsum* (Shukla) Trivedi & Srivastava, 1989; *A. chhindwarensis* Billimoria (1948); *A. eocenium* (Chitale) Trivedi & Srivastava, 1989; *A. shuklai* (Singhai) Trivedi & Srivastava, 1989; *A. mohgaensis*, Lakhanpal *et al.*, 1977; *Araucarioxylon* sp. Srivastava & Prakash, 1984; *A. bikanerense* Harsh & Sharma, 1988; *A. kerienne* Trivedi & Srivastava, 1989.

Amongst the above species, 1-3 (4) seriate radial tracheidal pits and greater amount of late wood are found in

Araucarioxylon resinsum, *A. chhindwarensis*, *A. eocenium* and *A. mohgaensis* as compared to 1-2 seriate radial pits and 1-2 celled late wood in the present fossil. *Araucarioxylon deccani* differs in having fairly wide late wood zone and relatively longer rays (2-49 celled) with greater frequency of biseriate rays. *A. kerienne* also differs in having uniseriate, shorter rays (2-12 celled) and relatively wider late wood. *Araucarioxylon* sp. of Srivastava and Prakash also differs in having 1-3 seriate radial tracheidal pits and short uniseriate rays (1-7 cells).

Like *A. eocenium* and some of the other *Araucarioxylon* species, *A. bikanerense* differs from the present fossil in having 1-3 seriate radial tracheidal pits and uniseriate rays. Further 4-6 long elliptical cross field pits touching the upper and lower border of cross fields in *A. bikanerense* make it very peculiar

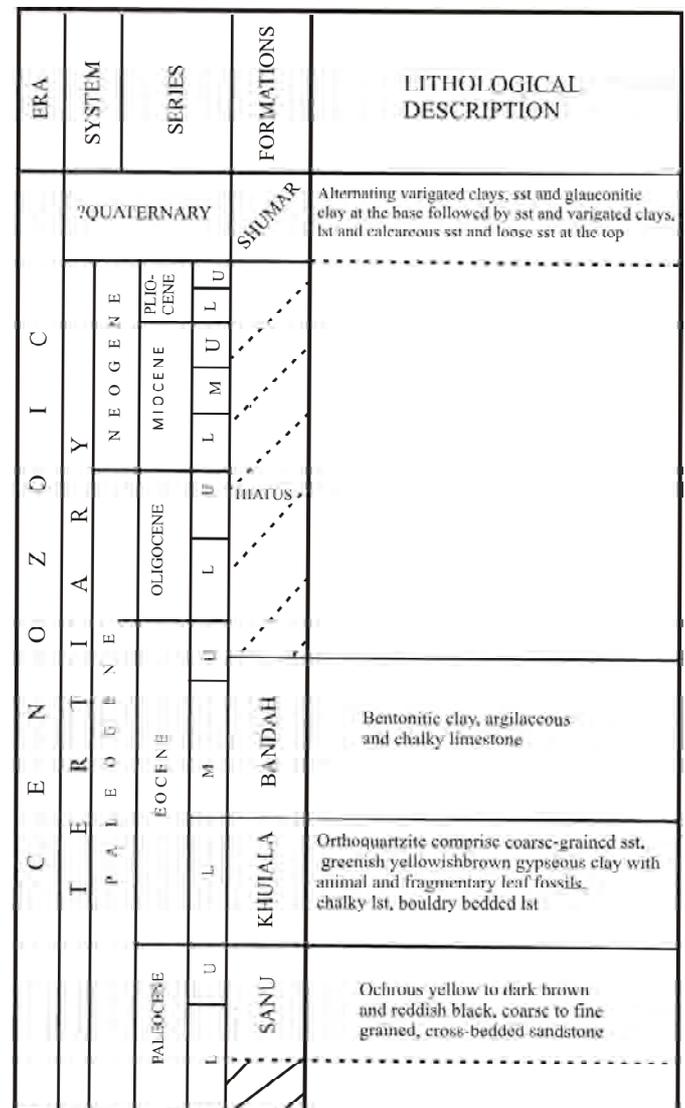


Fig. 2—Stratigraphic sequence of Jaisalmer Basin (after Dasgupta, 1975; Singh, 1982; Bhandari, 1999).

species as this type of character is neither seen in any Tertiary gymnospermous wood nor in the extant woods of Araucariaceae. Such type of cross field pits may be seen in older gymnospermous woods. The authors of *A. bikanerense* (Harsh & Sharma, 1988) did not mention the exact locality and geological horizon from where the fossil wood was recovered. It seems, it is an older reworked gymnospermous wood and the exact provenance of the wood needs to be looked into.

Since the present wood differs from all the known *Araucarioxylon* species, a new specific name, *A. jaisalmerensis* is assigned to it.

Family—PODOCARPACEAE

Genus—PODOCARPOXYLON Gothän, 1905

Podocarpoxyylon kutchensis Lakhanpal *et al.*, 1975

(Pl. 2.1-5)

Description—The fossil wood is about 7.5 cm in length and 4 cm in width, having satisfactory preservation. *Growth rings* distinct, discernible but not conspicuous, wall thickness of tracheids changes from early to late wood, tracheids usually filled with gummy material (Pl. 2.1-3). *Late wood* zone very limited, about 1-4 cells or 60-100 µm in width, composed of thick walled, compactly arranged, squarish to tangentially elongated tracheids (Pl. 2.2), measuring about 10-20 µm in tangential diameter and 19-25 µm in radial diameter. *Early wood* forming more than 90% of the growth zone, consisting of comparatively thin walled (Pl. 2.2), polygonal, rectangular, radially elongated tracheids with wide lumen arranged in rows, measuring about 18-28 µm in tangential diameter, 28-40 µm in radial diameter. *Parenchyma* scanty, difficult to distinguish in the cross section, seen as a few diffuse cells among the tracheids. *Tracheidal pits* present on radial as well as tangential walls of the tracheids; pits on radial walls are in one or two rows (Pl. 2.5), opposite to sub-opposite when in two rows, 8-10 µm in diameter. *Xylem rays* fine, homogeneous, evenly distributed, almost uniseriate, rarely with a biseriate part, 2-25 cells sometimes reaching up to 50 cells or 30-815 µm in length, made up of round to slightly elongated cells as seen in tangential section (Pl. 2.3), ray cells filled with gummy material (Pl. 2.2, 4). *Bars of Sanio* absent. *Cross field pits* could not be seen due to poor preservation. *Resin ducts* absent.

Figured Specimen—Specimen No. BSIP 14209.

Repository—Birbal Sahni Institute of Palaeobotany, Lucknow.

Horizon and Locality—Shumar Formation; Hema Ki Dhani, near Habur Village, Jaisalmer District, Rajasthan.

Age—Plio-Pleistocene.

No. of specimen studied—A single piece of petrified wood having satisfactory preservation.

Affinities—The above mentioned anatomical characters indicate affinity of the fossil with the family Podocarpaceae. Genera of the family Podocarpaceae can be distinguished on the basis of absence or presence of parenchyma and the height of rays (for details see Greguss, 1955, 1972; Lakhanpal *et al.*, 1975; Bande & Prakash, 1984; Trivedi & Srivastava, 1989; Bera & Sen, 2004). Amongst the 19 genera of the Podocarpaceae (Chase & Reveal, 2009) parenchyma is absent in some of them like *Phyllocladus* Mirbel. and *Sciadopitys* Siebold & Zucc. and xylem rays are not more than 25 cells high in rest of the genera excepting *Podocarpus* L' Hérít. in which rays are up to 60 cells high (Greguss, 1955, 1972). As the present fossil wood possesses rays up to 50 cells in height, it has been assigned to the genus *Podocarpus*. The fossil wood has been compared with the available modern species of *Podocarpus* and found close to the *P. wallichianus* C. Presl. Both share almost all the anatomical characters except for the rays which are almost uniseriate in *P. wallichianus* against a few biseriate rays present in the fossil wood.

Podocarpaceous woods have been described under different organ genera, viz. *Podocarpoxyylon* Gothän (1905), *Phyllocladoxylon* Gothän (1905), *Mesembrioxylon* Seward (1919) and *Circoporoxylon* Kräusel (1949). Before 1975, seven species of podocarpaceous woods were known from the Tertiary sediments of India, five from the Cuddalore Series of Pondicherry, viz. *Mesembrioxylon schmidianum* Sahni (1931), *M. sahnii* Ramanujam (1953) *M. tiruvakkaraianum* Ramanujam (1953), *M. speciosum* Ramanujam (1954), *M. mahabalei* Agashe (1969) and two, viz. *M. fusiform* Sahni and *M. dudukurensis* Mahabale & Rao (1973) from Rajahmundry area of Andhra Pradesh. Out of these, *M. schmidianum* Sahni was transferred to *Podocarpoxyylon schmidianum* by Kräusel (1949). Lakhanpal *et al.* (1975) while describing *Podocarpoxyylon kutchensis* suggested that the above mentioned remaining species need critical study before assigning them to genus *Podocarpoxyylon/Phyllocladoxylon/Mesembrioxylon/Circoporoxylon*. In 1978, Mahabale and Satyanarayana described two more species of *Mesembrioxylon*, viz. *M. rajmahalense* Jain and *Mesembrioxylon* sp. cf. *M.*

PLATE 1

Araucarioxylon jaisalmerensis sp. nov. →

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| 1-2. Cross section of the fossil wood showing the late wood and early wood zone. Museum No. BSIP 14208-1. | 4. Radial Longitudinal Section of the fossil wood showing homocellular rays. Museum No. BSIP 14208-3. |
| 3. Tangential Longitudinal Section of the fossil wood showing long uniseriate rays. Museum No. BSIP 14208-2. | 5. Radial Longitudinal Section of the fossil wood showing uni-biseriate hexagonal pits. Museum No. BSIP 14208-3. |

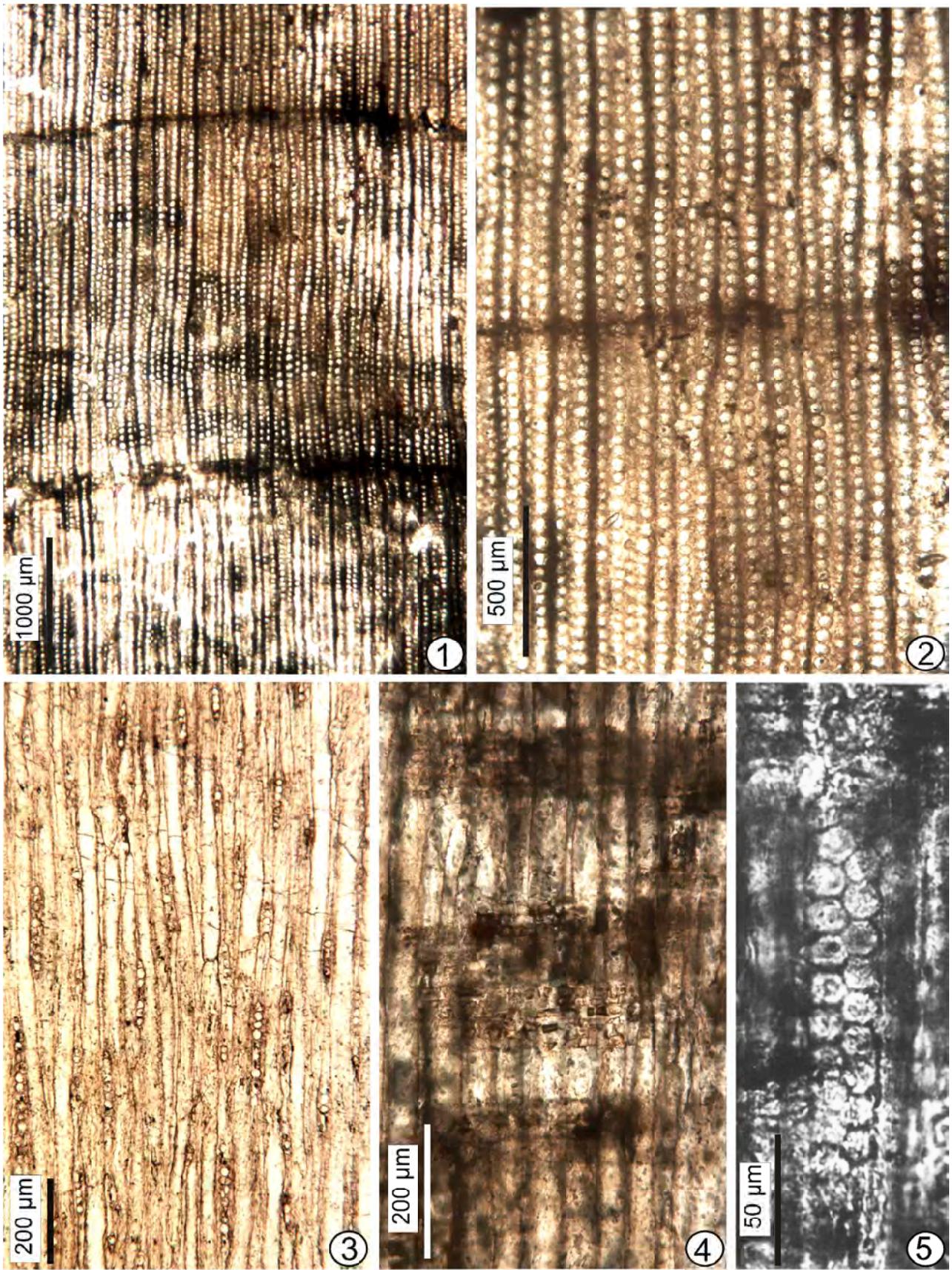


PLATE 1

dudukurensis from the Rajahmundry Sandstones of Andhra Pradesh. Trivedi and Srivastava (1989) without referring to the *Mesembrioxylon* species reported from the Andhra Pradesh, transferred the earlier known four *Mesembrioxylon* species reported by Ramanujam and Agashe (*op. cit*) under the genus *Podocarpoxyton*. The present authors have not taken into consideration the *Mesembrioxylon* species reported by Mahabale and Rao (1973) and Mahabale and Satyanarayana (1978) for the reasons cited on earlier ages.

At present ten species of *Podocarpoxyton* are known from the Indian Tertiary sediments. They are as follows: *Podocarpoxyton schmidianum* (Sahni) Kräusel, 1949; *P. sahnii* (Ramanujam) Trivedi & Srivastava, 1989; *P. tiruvakkaraianum* (Ramanujam) Trivedi & Srivastava, 1989; *P. speciosum* (Ramanujam) Trivedi & Srivastava, 1989; *P. mahabalei* (Agashe) Trivedi & Srivastava, 1989; *P. kutchensis* Lakhanpal *et al.*, 1975; *P. vikramii* Bande & Prakash, 1984; *P. deccanensis* Trivedi & Srivastava, 1989; *P. pantii* Bera & Sen, 2004; *P. manipurensis* Mehrotra & Mandaokar, 2010.

Out of these, *Podocarpoxyton speciosum* and *P. vikramii* differ from the present fossil in possessing *Bars of Sanio*. *P. tiruvakkaraianum*, *P. vikramii*, *P. pantii* and *P. manipurensis* differ in having only uniseriate rays. Likewise *P. sahnii* and *P. pantii* differ in the absence of parenchyma. Moreover, in the former, rays are 1-3 seriate. Abundant hexagonal crystals in *P. deccanensis* differentiate it from the present fossil. Further, single row of radial tracheidal pits in *P. deccanensis* and *P. mahabalei* differentiate the two species from the present fossil. *P. schmidianum* and *P. manipurensis* are closer to the present fossil but both of them differ in height of rays. In *P. schmidianum*, the rays are go up to 100 cells, whereas in *P. manipurensis* they are short, 1-9 cells high only, compared to maximum height of 50 cells in the present fossil. From the above comparison it is clear that the present fossil differs from all the above mentioned species and shows best resemblance with *P. kutchensis*, reported from the equivalent sediments (Plio-Pleistocene- Kankawati Series) of Kachchh, Gujarat, hence it is described under the same name.

PRESENT DISTRIBUTION OF ARAUCARIA AND PODOCARPUS

Araucariaceae consists of three genera, namely *Agathis* Salisbury, *Araucaria* de Jussieu and *Wollemia* Jones, Hill & Allen which are confined to the Southern Hemisphere (Mabberley, 1997). The genus *Agathis* consists of 13 species and is exclusively found in the eastern part of the Southern

Hemisphere extending from Philippines to New Zealand and Malaya to New Caledonia. The genus *Araucaria* includes 18 species and is presently distributed in New Caledonia, New Guinea, eastern Australia, Chile-Argentina Cordillera and Brazil. The genus *Wollemia*, is represented by a single species, *W. nobilis* confined to New South Wales, Australia (Mabberley, 1997). The family Podocarpaceae consists of 19 genera and has wide distribution in the Southern Hemisphere (Chase & Reveal, 2009). The genus *Podocarpus* L' Herit consists of evergreen trees and shrubs and is represented by two species in India, viz. *Podocarpus nerifolius* D. Don and *P. wallichianus* C. Presl. The former is inhabitant of evergreen climax forests of eastern Himalaya and is found up to 900 m in Sikkim, Arunachal Pradesh, Khasi Hills and the Andamans, whereas, the latter is the only naturally occurring conifer in south India and is found in Western Ghats from the Nilgiri southwards, Assam and Great Nicobar Island usually at an altitude of 900-1500 m (Sahni, 1990).

DISCUSSION

The occurrence of genus *Araucaria* de Jussieu and *Podocarpus* L' Herit. ex Pers in the Plio-Pleistocene sediments of Rajasthan has a great significance as these elements are largely tropical to subtropical in nature and found in the moist and humid type of climate. Both the genera are distributed predominantly in Southern Hemisphere. They were the prominent members of Jurassic-Lower Cretaceous vegetation of India. With the advent of Angiosperms, these Gymnosperms started declining in India and by Plio-Pleistocene time, Araucariaceae totally disappeared and Podocarpaceae is represented only by two species of the genus *Podocarpus*, confined to small pockets in India. Presence of gymnosperms in association with the evergreen to deciduous elements in Rajasthan supports the view that climate of Rajasthan was much better in the past compared to present day dry and desertic conditions prevailing in the areas. The occurrence of *Podocarpus* woods in south and central India, Kachchh in the west and Manipur and West Bengal in the east indicates that the genus was wide spread in India during the Tertiary and has gradually declined in its distribution. *Podocarpus* is the last remnant of the southern conifers in India. The authors take this opportunity to draw the attention of foresters, botanists and other concerned authorities to protect and conserve the genus before it gets extinct in India like the genus *Araucaria*.

PLATE 2

Podocarpoxyton kutchensis Lakhanpal *et al.*, 1975



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| <p>1-2. Cross Sections of the fossil wood showing growth rings and early wood and late wood zones. Museum No. BSIP 14209-1.</p> <p>3. Tangential Longitudinal Section of the fossil wood showing long uniseriate rays. Museum No. BSIP 14209-2.</p> | <p>4. Radial Longitudinal Section of the fossil wood showing homocellular rays. Museum No. BSIP 14209-3.</p> <p>5. Radial Longitudinal Section of the fossil wood showing circular pits on the wall of tracheids. Museum No. BSIP 14209-3.</p> |
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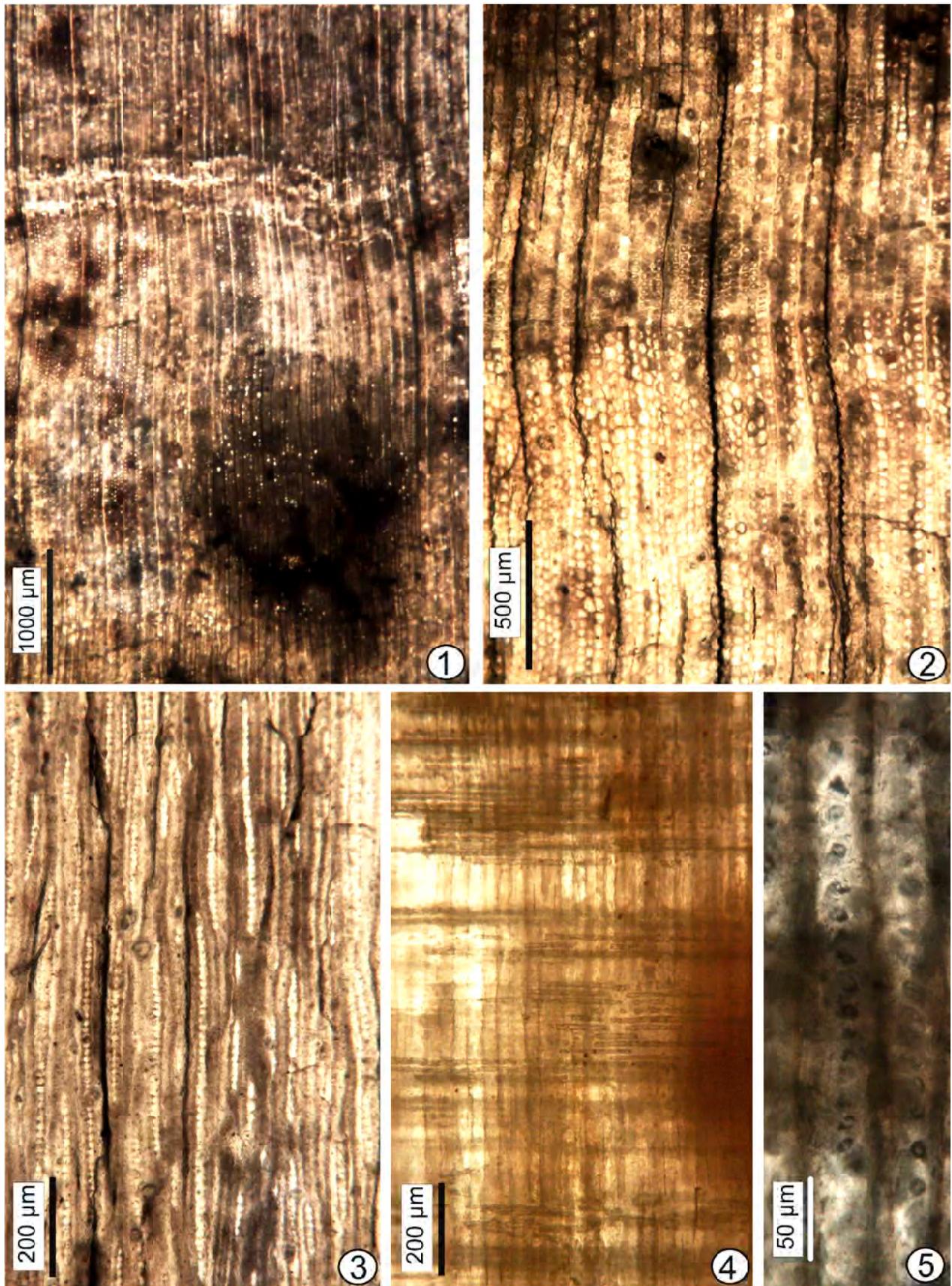


PLATE 2

Acknowledgements—The authors are thankful to Dr N.C. Mehrotra, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for encouragement, providing infrastructure facilities and permission to publish this work.

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