Further contribution to the Neogene flora of northeast India and significance of the occurrence of African element*

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Fossil dicotyledonous woods, viz., *Dipterocarpoxylon bolpurense* Ghosh & Roy, *Canarioxylon indicum* Ghosh & Roy, *Euphorioxylon indicum* Awasthi *et al.*, *Julbernardia palaeoglobiflora* sp. nov., *Barringtonioxylon deccanense* Shallom and *Madhuca palaeolongifolia* sp.nov. are recorded from the Namsang beds at Deomali, Arunachal Pradesh. They show close similarity with the woods of extant *Dipterocarpus, Canarium, Euphoria, Julbernardia, Barringtonia and Madhuca,* respectively. The affinity of *Madhucoxylon cacharense* Prakash & Tripathi of the family Sapotaceae, known from the Tipam Sandstone of Hailakandi in Assam, has been revised. It shows closest resemblance with the wood of *Manilkara* rather than *Madhuca* and therefore renamed as *Manilkara cacharense* (Prakash & Tripathi) comb. nov.

An analysis of the floral assemblage of Namsang beds indicates very warm and humid tropical climate at and around Deomali, northeastern India during Upper Miocene-Pliocene. Occurrence of the African genus *Julbernardia* provides further evidence of phytogeographical link between Indian subcontinent and Africa during that time.

Key-words—Fossil woods, dicotyledons, Neogene, northeast India.

INTRODUCTION

THE Neogene sediments in northeast India are well developed over a greater part of the region. The chief geological formations are known as Surma, Tipam, Dupitila and Dihing Groups in ascending order. The latter three formations, exposed at many places in the region ranging in age from Upper Miocene to Pliocene, contain rich deposits of fossil dicotyledonous woods.

The rocks of Tipam Group (Upper Miocene) are divided into Tipam Sandstone and Girujan Clay. The latter is distinct by its argillaceous character and can be distinguished from the former in having mottled clays and mottled sandstones. The Tipam Group is unconformably overlain by Dupitila Group (Upper Mio-Pliocene). In Upper Assam, the Dupitilas are represented by the fluviatile Namsang Group consisting of coarse to gritty, poorly consolidated sandstone, mottled clay, conglomerate which at places are almost entirely composed of coal pebbles derived from the Barail Coal (Karunakaran, 1974). The Dupitila/Namsang Formation is succeeded by a typically fluviatile Pliocene deposits—the Dihing Group consisting of thick pebble beds alternating with coarse, soft sandstone, clay, grit and conglomerates containing half decomposed plant remains. The unconformable relationship between the Dihings and Namsangs is well exposed along the Dihing River section near Jaipur (Jeypore) in Upper Assam.

Systematic study of fossil woods from the Namsang beds in the vicinity of Deomali has been carried out by Ghosh & Kazmi (1958), Prakash (1965, 1966), Prakash & Awasthi (1970, 1971), Lakhanpal *et al.*(1981), Awasthi & Prakash (1987) and Awasthi (1989) who identified a number of taxa belonging to several important dicotyledonous families.

With a view to generate more palaeobotanical data for precise reconstruction of the Neogene floristics and interpreting the palaeoenvironment and phytogeography of the region, further investigations of fossil woods from Namsang beds have been undertaken. The woods were collected earlier by one of us (N.A.) from the Namsang River beds at Deomali. Out of the material investigated, six new taxa have been identified and described from the

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Namsang beds besides reinvestigating *Madhucoxylon cacharense* Prakash & Tripathi (1977).

The word specimens and slides are deposited in the Museum, Birbal Sahin Inshlute of Palacobotaniy, Lucknow.

SYSTEMATIC DESCRIPTION

Family — Dipterocarpaceae

Genus - *Dipterocarpoxylon* Holden emend. Den Berger 1927

Dipterocarpoxylon bolpurense Ghosh & Roy 1979
Pl. 1, figs 1,2

Description — *Wood* diffuse-porous. *Growth rings* absent. *Vessels* mostly large to medium-sized, t.d. 120-220 µm, r.d. 140-288 µm, solitary, usually round to oval, occasionally deformed due to compression, evenly distributed, 6-10 per sq mm (Pl.1, fig.1); tyloses occasionally present; vessel- members 360-800 µm in length with obique to horizontal ends; perforations simple. *Tracheids* vasicentric, intermingled with paratracheal parenchyma forming sheath around vessels. *Parenchyma* scanty paratracheal to uniseriate vasicentric, apotracheal diffuse, also enclosing vertical gum canals, occasionally extending sideways joining other gum canals and forming 2-4 celled thick and shrt or broken tangential bands; parenchyma cells 24-40 µm in dameter and 100-200 µm in length. *Xylem rays* 1-4 (mostly 3) seriate, 4-8 per mm; ray tissue heterogeneous, uniseriate rays consisting of either upright or both procumbent and upright cells, 8-20 µm in width and 5-13 cells or 120-680 µm in height; multiseriate rays consisting of procumbent cells through the median portion and 1-7 marginal rows of upright ells at one or both the ends, 32-68 µm in width and 10-46 cells or 120-1480 µm in height; sheath cells occasionally present (Pl.1, fig.2). *Fibres* libriform, angular in cros section, non-septate, 8-20 µm in diameter and 560-1080 µm in length. *Gum canals* vertical, small, t.d. 44-92 µm, r.d. 68- 144 µm, mostly round to oval, occasionally deformed due to compression, usually solitary, occasionally in short tangential rows of 4-5, enclosed by parenchyma (Pl.1, fig. 1).

Specimen — BSIP No. 36783.

Locality — Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Miocene-Pliocene.

Affinities — The important anatomical characters of the fossil wood are: vessels almost exclusively solitary, vasicentric tracheids present, parenchyma vasicentric to diffuse, gum canals vertical occurring as solitary or in short tangential rows enclosed by parenchymatous sheath, xylem rays 1-4 seriate, heterocellular with some sheath cells and fibres thick-walled non-septate. These features indicate the affinity of the fossil with the woods of the genus *Dipterocarpus* Gaertn. of Dipterocarpaceae. A detailed comparison of fossil with its several species shows near resemblance with *D. baudii* Korth and *D. lawii* Hook. f. (BSIP Xylarium Slide nos. 3094, 2332, 2106).

Among fossil woods of *Dipterocarpus* so far reported from various Neogene sediments of India, as listed by Prakash (1973) and subsequently described by Awasthi (1974, 1980), Prakash (1975, 1978, 1981), Ghosh & Roy (1979), Trivedi & Ahuja (1980), Guleria (1983), Yadav (1989) the present fossil wood is comparable to *D. kalaicharparense* Eyde (1963) and *D. bolpurense* Ghosh & Roy (1979), known from the Tertiary of Garo Hills, Meghalaya, and Birbhum District, West Bengal, respectively. Of these, the former slightly differs from our fossil in the absence of tyloses, presence of abundant apotracheal parenchyma and relatively broad rays, while the latter shows close similarity in all the features. Therefore, it is being placed under the same species.

Dipterocarpus baudii and *D lawii,* which show resemblance with our fossil, are found in evergreen forests

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Plate 1 →

Dipterocarpoxylon bolpurense Ghosh & Roy

1. Cross section showing vessels and gum canals, x 45; Slide no. BSIP 36783-I.
2. Tangential longitudinal section showing xylem rays and fibres, x 45; Slide no. BSIP 36783-II.

Canarioxylon indicum Ghosh & Roy

3. Cross section showing vessels with tyloses, x 45; Slide no. BSIP-36784-I.
4. Cross section magnified to show scanty paratracheal parenchyma, x 95; Slide no. BSIP 36784-I.
5. Tangential longitudinal section showing xylem rays and fibres, x 95; Slide no. BSIP 36784-II.

Euphorioxylon indicum Awasthi *et al.*

6. Cross section showing vessels, x 45; Slide no. BSIP 36785-I.
7. Tangential longitudinal section showing xylem rays, x 95 ; Slide no. BSIP 36785-II.

Julbernardia palaeoglobiflora sp. nov.

8. Cross section showing distribution patterns of parenchyma and vessels, x 45; Slide no. BSIP 36786-I.
9. Tangential longitudinal section showing xylem rays, X 95; Slide no. BSIP 36786-II.

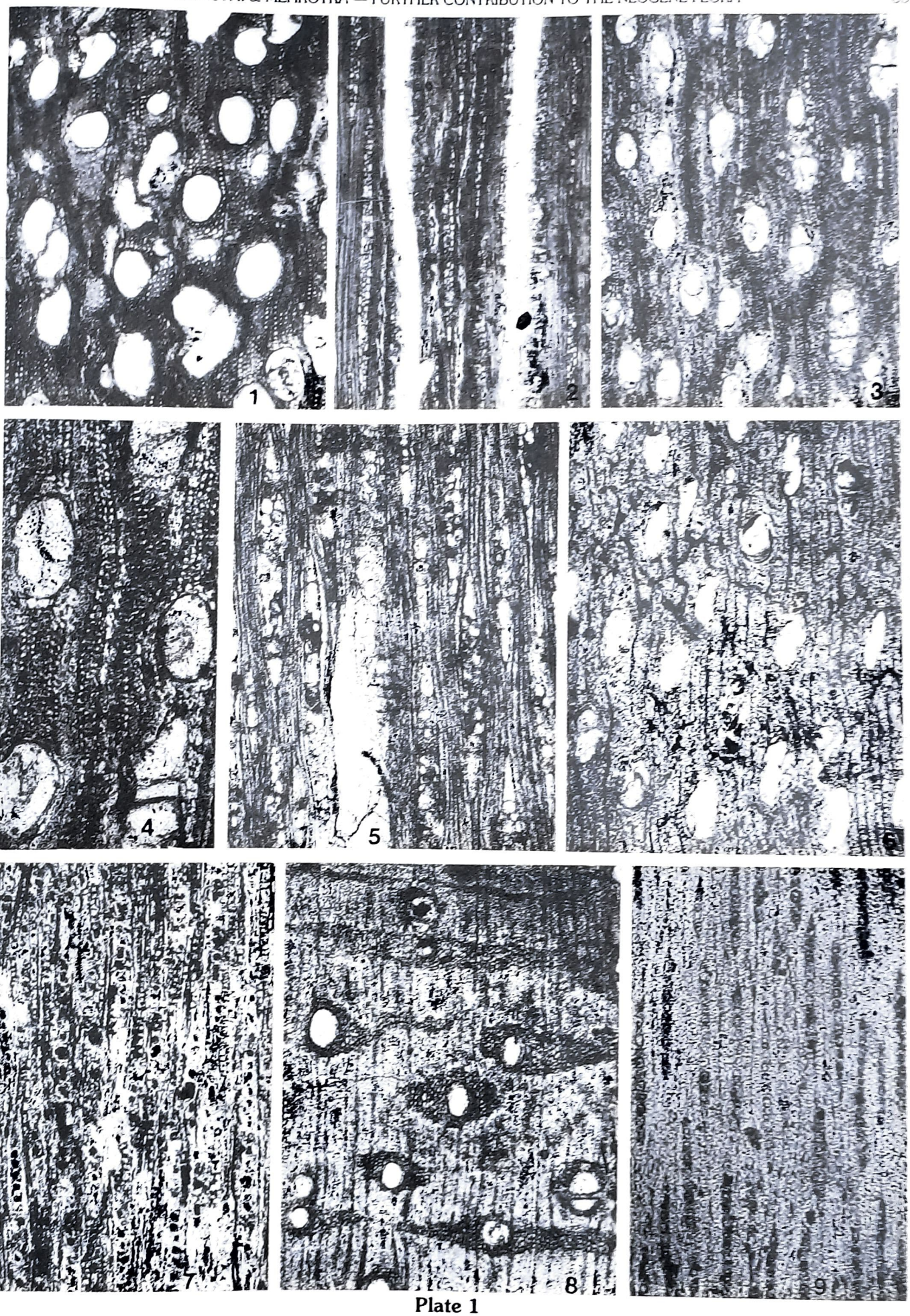

Plate 1

of Myanmar, Sumatra, Thailand, Malaya Peninsula, Cambodia and Cochin-China (Ghosh, 1958; Hayashi *et al.*, 1973).

Family — Burseraceae

Genus — *Canarioxylon* Prakash, Brezinova & Awasthi 1974

Canarioxylon indicum Ghosh & Roy 1978
Pl.1, figs 3-5

Description — Wood diffuse-porous. *Growth rings* not observed. *Vessels* mostly small to medium, occasionally large in size, t.d. 56-160 µm, r.d. 52-240 µm, solitary and in radial multiples of 2-4 (-5), rarely in tangential pairs or clusters, circular or oval when solitary, evenly distributed, 12-20 per sq mm (Pl.1, fig.3), profusely tylosed; vessel-members 125-400 µm in length with oblique to horizontal ends; perforations simple; intervessel pits bordered, alternate, large, 8-10 µm in diameter with linear to lenticular apertures, circular to oval in shape but appearing polygonal due to crowding. *Parenchyma* scanty paratraceal occurring as a few cells around *vessels* (Pl.1, fig. 4); cells 40-60µm in length and 16-20 µm in diameter. *Xylem rays* (mostly 1-2) seriate, 8-10 per mm; ray tissue heterogeneous; uniseriate rays made up of either upright cells or both procumbent and upright cells, 20-28 µm in width and 2-12 cells or 140-540 µm in height; multiseriate rays consisting of procumbent cells through the median portion and 1-5 marginal rows of upright cells at one or both the ends, 40-80 µm in width and 7-40 cells or 320-900 µm in height (Pl.l,fig.5); end to end ray fusion observed. *Fibres* semi-libriform, polygonal in cross section, septate, 6-8 µm in diameter and 320-480 µm in length.

Specimen — BSIP No. 36784.

Locality— Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Mio-Pliocene.

Affinities — Small to medium-sized vessels plugged with tyloses, large linear intervessel pits, scanty paratracheal parenchyma, thin, hetrocellular xylem rays and thick walled septate fibres are the important features of the fossil wood. These features indicate its affinities with Burseraceae. As the woods of the family are homogeneous in their anatomy, their generic and specific differentiation is usually not possible (Awasthi & Srivastava, 1989). However, our fossil shows close resemblance in almost all the xylotomical characters with *Canarium subulatum* Guillaumin.

Amongst nine species of fossil woods of Burseraceae reported so far from India and abroad (See Awasthi & Srivastava, 1989), our fossil possesses similar features as exhibited by *Canarium Indicum* Ghosh & Roy (1978). This species is known from Mio-Pliocene of Santiniketan near Bolpur, Birbhum District, West Bengal.

Canarium Linn., a genus of usually tree, occasionally shrubs or pseudoliana, consists of approximately 100 species, distributed in tropical Asia, Africa, North Australia and Myanmar (Ghosh *et al.*, 1963; Willis, 1973). In India, it is represented by 8 species occurring in Western Ghats, Assam, Bengal, Sikkim and Andaman Island (Gamble, 1972; Santapau & Henry, 1973).

Family — Sapindaceae

Genus — *Euphorioxylon* Awasthi, Guleria & Lakhanpal 1982

Euphorioxylon indicum
Awasthi, Guleria & Lakhanpal 1982
Pl. 1, figs 6-7

Description — Wood diffuse-porous. Growth rings not observed. *Vessels* usually small to medium, occasionally large, t.d. 60-160 µm, r.d. 100-240 µm, solitary and in radial multiples of 2-4, usually round to oval in shape, sometimes flattened due to compression, evenly distributed, 8-16 per sq mm (Pl. 1, fig.6), sometimes filled with dark contents; vessel-members 480-640 mm in length with horizontal to oblique ends; perforations simple; intervessel pits bordered, alternate, 4-5 µm in diameter. *Parenchyma* scanty paratracheal; parenchyma cells about 40-60 µm in length and 20-22 µm in width. *Xylem rays* almost exclusively uniseriate, 13-16 per µm, 12-24 µm in width and 9-46 cells or 200-720 µm in height, made up of procumbent cells only (Pl.1, fig.7); ray tissue homogeneous. *Fibres* polygonal in cross section, about 4-12 µm in diameter, thick-walled, non-septate.

Specimen — BSIP No. 36785.

Locality — Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Miocene-Pliocene.

Affinities — The important characters of the fossil are: vessels small to medium-sized, intervessel pits small, parenchyma scanty paratracheal, xylem rays almost exclusively uniseriate homocellular and fibres non-septate which clearly indicate its affinities with the xylotomically inseparable taxa, e.g., *Euphoria longana, Litchi chinensis and Otonephelium stipulaceum* (Ramesh Rao, 1963; Mehrotra, 1987) of the family Sapindaceae. Awasthi *et al.* (1982) instituted the genus *Euphorioxylon*

for the fossil woods displaying the characters of this generic complex. So far, two species of this genus are known, viz., *Euphorioxylon indicum* Awasthi *et al.* (1982) from the Cuddalore Series of Pondicherry and Kankawati Series of Kachchh and *E. deccanense* Mehrotra (1987) from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. The present fossil resembles the former while differs from the latter in the size and frequency of vessels.

Euphoria longana is distributed throughout the Western Ghats extending to Sri Lanka, Assam, South China, Myanmar and Malaya. *Litchi chinensis* is a native of China and *Otonephelium stipulaceum* is confined to the evergreen forests of Western Ghats from Nilgiri southwards (Ramesh Rao, 1963).

Family—Fabaceae

Genus — *Julbernardia* Pellegr.

Julbernardia palaeoglobiflora sp. nov.
Pl.1, figs 8,9; Pl.2, fig.1

Description — Wood diffuse porous. *Growth rings* present due to terminal parenchyma and smaller vesels. *Vesels* small to medium, occasionally very small to large in size, t.d. 40-200 µm, r.d. 36-220 µm, solitary as well as in radial multiples of 2-5, evenly distributed, round to oval when solitary, with flat contact walls when in multiples, 6-14 per sq mm (Pl.1, fig.8), dark contents seen in some of the vessels; vessel-members 140-480 µm in length with oblique to horizontal ends; perforations simple; intervessel pits bordered, alternate, oval, 6-8µm in diameter, vestured. *Parenchyma* paratracheal and terminal, paratracheal parenchyma vasicentric to aliform, forming up to 5 cells wide sheath around vessels to confluent and banded, bands 2-5 cells thick ; cells 28-32 µm in diameter and 60-80 µm in length (Pl.1, fig.8; Pl.2, fig.1). *Xylem* rays almost exclusively uniseriate, sometimes paird cells also seen, 14-20 per mm, 12-36 µm in width and 4-18 cells or 60- 400 µm in height, made up of procumbent cells only (Pl.1, fig.9); ray tissue homogeneous. *Fibres* semi-libriform, non-septate, angular in cross section, 12-20 µm in diameter.

Holotype — BSIP No. 36786.

Locality— Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Miocene-Pliocene.

Affinities—The fossil wood is characterized by small to medium-sized vessels, simple perforation plate, vestured inter-vessel pit-pairs, terminal and vasicentric to aliform-confluent banded parenchyma, almost exclusively uniseriate, homocellular xylem rays and non-septate fibres. These features indicate its affinities with the woods of Fabaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Normand, 1950; Kribs, 1959; Miles, 1978; Rao *et al.*, 1972). From a detailed comparison with the modern wood slides, photographs and published descriptions of a number of taxa of the family, it was found that the fossil shows close resemblance with *Parkia singularis* Miq., *Isoberlinia niembaensis* (De Wild.) Duvign and *Julbernardia globiflora* (Benth.) Troupin. *Parkia singularis* though resembling the fossil in the nature and distribution of vessels and parenchyma, differs from it in having relatively longer and broader xylem rays (Desch, 1957; Hayashi *et al.*, 1973). Similarly, *I. niembaensis* can also be differentiated from it in having paratracheal parenchyma relatively abundant. Lastly, it is *Julbernardia globiflora* with which the fossil wood shows closest resemblance in all the xylotomical characters (Lebacq, 1957).

In view of its close similarity with the woods of the genus *Julbernardia* Pellegr, the fossil wood has been assigned to it and named as *Julbernardia palaeoglobiflora* sp.nov. The specific name indicates the antiquity of *J. globiflora*..

The genus *Julbernardia* consists of 11 species which are found in tropical Africa (Willis, 1973).

Family— Lecythidaceae

Genus—*Barringtonioxylon* Shallom 1960

Barringtonioxylon deccanense Shallom 1960
Pl.2, figs 2-4

Description — Wood diffuse-porous. Growth rings absent. *Vessels* small to medium-sized, t.d. 56-164 µm, r.d. 68-172 µm, mostly solitary, occasionally in pairs, round to oval, occasionally deformed due to compression, evenly distributed, 9-17 per sq mm (Pl.2, fig.2), usually filled with dark contents; vessel-members 440-560 µm in length with horizontal to oblique ends; perforations simple; intervessel pits bordered, alternate, round to oval, 8-10 µm in diamater, with seemingly lenticular apertures. *Parenchyma* both paratracheal and apotracheal, paratracheal scanty, apotracheal diffuse to diffuse-in-aggregate, forming 1-2 cells thick tangential lines (Pl.2, fig. 2); parenchyma cells 48-108 µm in length, 16-40 µm in width. *Xylem rays* 1-5 seriate, 7-10 per mm; ray tissue heterogeneous, uniseriate rays consisting of upright cells, 20-28 µm in width, 3-17 cells or 240-800 µm in height; multiseriate rays consisting of procumbent cells through the median portion and 1-6 marginal rows of upright cells at one or both the ends, 40-140 µm in width, 12-42 cells

or 440-1680 µm in height (Pl.2, figs 3, 4); sheath cells occasionally present, end to end ray fusion observed; procumbent cells 44-60 µm in radial length, 16-28 µm in tangential height; upright cells 20-32 µm in radial length, 40-48 µm in tangential height. *Fibres* semi-libriform, angular in cross section, non-septate, 8-16 µm in diameter.

Specimen — BSIP No. 36787.

Locality — Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Miocene-Pliocene.

Affinities — The important anatomical characters of the fossil, such as, small to medium-sized vessels, scanty paratracheal to diffuse-in-aggregate parenchyma, 1-5 seriate, heterogeneous xylem rays, non-septate fibres and large intervessel pits indicate that it belongs to thegenus *Barringtonia* of the family Lecythidaceae. From a detailed comparison with the woods of several species of *Barringtonia* it was found that the fossil wood is very similar to that of *B. acutangula* (Linn.) Gaertn.

The genus *Barringtonioxylon* Shallom (1960), instituted for the fossil woods resembling *Barringtonia,* consists of five species, viz., *B. deccanense* (Shallom, 1960), *B. eopterocarpum* (Prakash & Dayal, 1965), *B. mandlaensis* (Bande & Khatri, 1980) from the Deccan Intertrappean beds of India, *B.arcotense* (Awasthi, 1970) from the Tertiary of South India and *B. assamicum* (Prakash & Tripathi, 1972) from the Tertiary of Assam. Among these the present fossil is very similar to *B. deccanense* in almost all the xylotomical characters.

Among the extant species of *Barringtonia, B. acutangula* with which the fossil wood shows close resemblance, is distributed in the sub-Himalayan region from Ganga eastwards to Bengal and Assam, also in Madhya Pradesh and coastal districts of the Peninsula along the banks of rivers and on swampy land (Shahi & Taneja, 1982).

Family — Sapotaceae

Genus — *Manilkara* Adanson

Manilkara cacharense (Prakash & Tripathi) comb. nov.
Pl.2, figs 8-10

1977 *Madhucoxylon cacharense* Parakash & Tripathi p.142, pl.2, figs 7, 9; text-fig.23

Prakash and Tripathi (1977) described a fossil wood as *Madhucoxylon* from the Tipam Sandstone near Hailakandi, Assam, showing its close similarity to that of the genus *Madhuca.* While examining the type slides of this fossil to compare with a new fossil wood of Sapotaceae being described in this paper, the present authors observed that in *Madhucoxylon cacharense* chambered crystals are present which were not observed by Prakash and Tripathi (1977). Presence or absence of crystalliferous parenchyma/fibres is often considered as one of the important and diagnostic characters in distinguishing the woods of different genera and species of the same family. According to Pearson and Brown (1932) crystalliferous parenchyma strands are present in *Manilkara* and absent in *Madhuca.* This was further confirmed from examination of thin sections of the woods of both the genera. In view of this the identification of fossil wood *Madhucoxylon cacharense* with *Madhuca* is incorrect. However, in having crystalliferous parenchyma strands as well as in all other anatomical details, it is closer to *Manilkara.* Therefore, *Madhucoxylon cacharense* is placed under the genus *Manilkara* and named *Manilkara cacharense* (Prakash & Tripathi) comb. nov.

Among the extant species of *Manilkara,* this fossil shows similarity with the woods of *Manilkara hexandra* (Roxb.) Dub. and *M.littoralis* (Kurz) Dub.

Fossil wood of *Manilkara* is known from the Oligocene of South Bohemia, Czechoslovakia, described as

Plate 2

Julbernardia palaeoglobiflora sp. nov.

1. Cross section magnified to show parenchyma, x 95 ; Slide no. BSIP 36786-I.

Barringtonioxylon deccanense Shallom

2. Cross section showing shape, size and distribution of vessels, x 45; Slide no. BSIP 36787-I.
3. Tangential longitudinal section showing xylem rays, x 45; Slide no. BSIP 36787-II.
4. Tangential longitudinal section magnified showing details of ray cells, x 95; Slide no. BSIP 36787-II.

Madhuca palaeolongifolia sp. nov.

5. Cross section showing distribution pattern of vessels and parenchyma, x 45; Slide no. BSIP 36788-I.
6. Tangential longitudinal section showing xylem rays, x 95; Slide no. BSIP 36788-II.
7. Radial longitudinal section showing heterogeneous ray tissue, x 95; Slide no. BSIP 36788-III.

Manilkara cacharense (Prakash & Tripathi) comb. nov.

8. Cross section showing distribution pattern of vessels and parenchyma, x 95; Slide no. BSIP 33917/5040.
9. Tangential longitudinal section showing xylem rays and fibres, x 95; Slide no. BSIP 33917/5041.
10. Parenchyma strands magnified showing crystals, x 400; Slide no. BSIP 33917/5041.

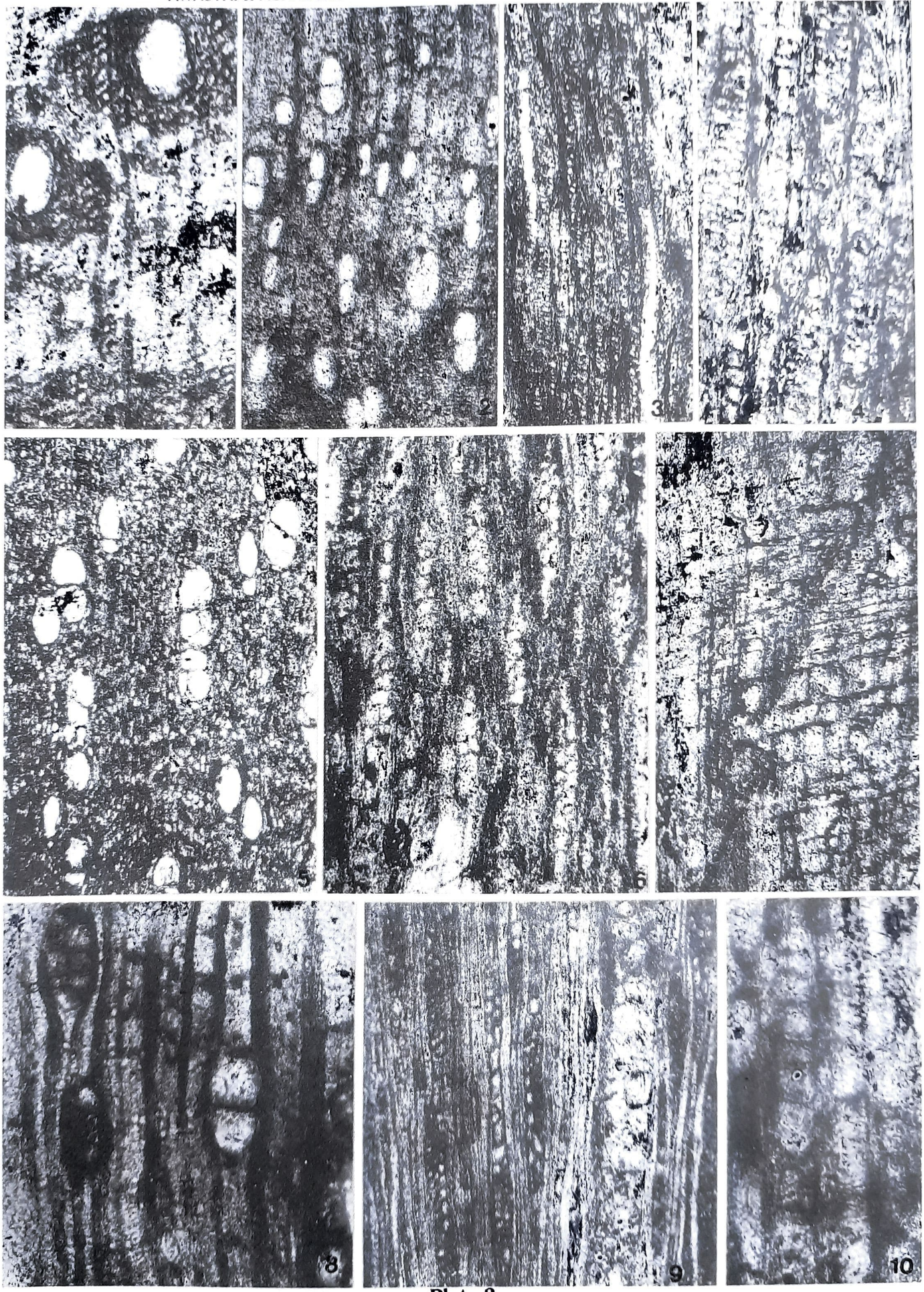

Plate 2

Manilkaroxylon bohemicum by Prakash *et al.* (1974). The present fossil wood differs from *Manilkara cacharense* in having vessels large, i.e., upto 310 µm in diameter and a few other minor characters. The other species, *Manilkaroxyon crystallophora* described by Grambast-Fessard (1968) from the Upper Miocene of Castellane in southeast France, is doubtful as far as its identification is concerned owing to the absence of crystalliferous parenchyma strands. However, it may belong to the genus *Madhuca*.

The genus *Manilkara* consists of about 70 species of trees, widely distributed in the tropics of the world. Three species are knwon to occur in India, of which *M. hexandra and M. littoralis* are found in dry forests of Deccan, Eastern Ghats, Orissa, Tamil Nadu, extending north to Pachmari Hills, west to Gujarat and along the coasts of the Andaman and Nicobar Islands (Purkayastha & Kazmi, 1982).

Revised description — *Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium, rarely very small, t.d. 48-160 µm, r.d. 40-180 µm, solitary as well as in radial multiples of 2-8, rarely in tangential pairs or clusters, round to oval when solitary, with flat contact walls when in multiples, 14-22 per sq mm, evenly distributed (Pl.2, fig.8), tylosed; vessel-members 180-400 µm in length with oblique to horizontal ends; perforations simple; intervessel pits bordered, alternate, oval, 6-10 µm in diameter with linear-lenticular apertures; tracheids rarely present, vasicentric. *Parenchyma* apotracheal, diffuse to diffuse in-aggregate, forming 1-2 seriate, broken or irregular tangetial lines; chambered crystals frequently present in parenchyma strands (Pl. 2, fig.10), parenchyma cells 40-120 µm in length and 16-40 µm in diameter. *Xylem rays* 1-3 (mostly 2) seriate, 10-17 per mm; ray tissue heterogeneous, uniseriate rays made up of upright cells only, 12-24 µm in width and 2-9 cells or 120-240 µm in height; multiseriate rays made up of procumbent cells through median portion and 1-8 rows of upright cells at one or both the ends, 40-50 µm in width and 6-31 cells or 100-1200 µm in height (Pl.2, fig.9); end to end ray fusion commonly present; crystals occasionally present. *Fibres* thick-walled, angular in cross section, non-septate, 8-12 µm in diameter, 560-1440 µm in length.

Holotype — BSIP No.33917.

Locality — Sultanicherra near Hailakandi, District Cachar, Assam.

Horizon & Age — Tipam Sandstones; Upper Miocene.

Genus — *Madhuca* Gmelin

Madhuca palaeolongifolia sp.nov.
Pl.2, figs 5-7

Description — *Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* small to large, rarely very small, t.d. 52-200 µm, r.d. 48-240 µm, solitary as well as in radial multiples of 2-6, sometimes in clusters or oblique pattern, more or less evenly distributed, round to oval, with flat contact walls when in multiples, 9-18 per sq mm (Pl.2, fig. 5), tylosed; vessel-members 80-440 µm in length with oblique to horizontal ends; perforations simple; intervessel pits bordered, alternate, oval, about 6µm in diameter with linear-lenticular apertures; a few vasicentric tracheids present, confined to immediate vicinity of vessels or vessel groups. *Parenchyma* apotracheal, diffuse to diffuse-in-aggregate in the form of predominantly uniseriate, broken or irregular, tangential lines; parenchyma cells 140-220 µm in length and 20-28 µm in diameter (Pl.2, fig.5). *Xylem rays* mostly 1-2 (rarely 3) seriate, 8-11 per mm; ray tissue heterogeneous, uniseriate rays consisting of upright cells only, 28-60 µm in width and 3-12 cells or 160-400 µm in height; multiseriate rays consisting of procumbent cells through the median portion and 2-9 rows of upright or square cells at one or both the ends, 40-88µm in width and 6-25 cells or 240-1120 µm in height (Pl.2, fig.6), end to end ray fusion common, crystals present in ray cells; procumbent cells 44-76 µm in radial length, 12-32 µm in tangential height ; upright or squarish cells 40-72 µm in tangential height and 32-68 µm in radial length (Pl.2, fig.7). *Fibres* libriform, angular in cross section, 16-20 µm in diameter, non-septate.

Holotype — BSIP No. 36788.

Locality — Namsang River bed, Deomali, Arunachal Pradesh.

Horizon & Age — Namsang beds; Upper Miocene-Pliocene.

Affinities — In having the important characters, such as, vessels small to large arranged mostly in long radial multiples, tylosed, parenchyma diffuse to diffuse-in-aggregate forming uniseriate broken irregular tangential lines, vasicentric tracheids, fibres non-septate, thick-walled and the xylem rays fine, heterocellular the fossil wood is comparable to that of *Madhuca* Gmelin. However, considering the hitherto described features collectively it shows close similarity with *Madhuca longifolia* (Koenig) McBride (Herb. Slide no. BSIP 321).

As this is the first authentic record of fossil wood of *Madhuca*, it is being described as *Madhuca palaeolongifolia* sp.nov. The specific name signifies close similarity

with the wood of *Madhuca longifolia*.

The genus *Madhuca* consists of about 85 species, distributed in India, Southeast Asia and Australia. Five species are known to occur in India. *M. longifolia* is a large tree found in the West Coast, dry forests of South Kanara, Malabar and Travancore at low elevations.

PALAEOECOLOGICAL AND PHYTOGEOGRAPHICAL CONSIDERATIONS

As given in table 1, 27 species belonging to 25 genera of 15 families of dicotyledons have so far been recognized in this flora. The flora is dominated by evergreen elements, followed by moist deciduous (Table 1), which clearly points towards a tropical humid climate with heavy precipitation during Upper Miocene-Pliocene in the vicinity of Deomali, north-east India. More or less similar climatic conditions prevail in the region today as most of the modern equivalents of this fossil assemblage, viz., *Pterygota alata (Sterculia alata), Euphoria longana, Mangifera indica, Bauhinia* spp., *Albizia lebbek, Millettia pulchra, Cynometra polyandra, lagerstroemia villosa, Barringtonia acutangula, Madhuca* spp., *Sideroxylon gradifolium, Diospyros* spp., lauraceous genera *(Cinnamomum, Litsea, Phoebe,* etc.) and *Bischofia* are continued to occur there but in restricted areas. The other significant taxa which do not occur in northeast India are: *Calophyllum inophyllum, Dipterocarpus* spp., *Heritiera fomes, Kingiodendron pinnatum, Afzelia (Intsia), Terminalia coriacea, Antiaris toxicaria,* etc. However, at present, these are confined to the evergreen- moist deciduous forests of Western Ghats, Andaman Island, Bangladesh, Myanmar and Malayan region. This fossil assemblage also includes some important littoral/coastal and swampy mangrove elements, viz., *Calophyllum inophyllum, Heritiera fomes, Afzelia (Intsia), Cynometra ramiflora,* which point to the near shore deposition of the Namsang sediments. Thus these taxa provide evidence of the extension of sea shore, which was hundreds of kilometers north of the present shore line of West Bengal and Bangladesh.

Changes in climate and physiography mainly caused by the uplift of Himalaya and southward regression of sea during post Middle Miocene time brought considerable alteration in the floral patterns. As a result, some of the taxa could adapt to the changed conditions and continued to flourish there while some other either got extinct from the region or migrated to other suitable places, as is evidenced from the distribution pattern of modern equivalent species of fossil taxa (Table 1).

Occurrence of fossil wood of *Julbernardia* in the Namsang sediments is significant as it provides further evidence of phytogeographical relationship between India and Africa. Earlier, from Kutch and Rajasthan, Guleria (1984, 1990) reported fossil woods of the African genera *Isoberlinia, Baphia, Tetrapleura, Erythrophleum, Entandophrgma and Khaya.* All these taxa including *Julbernardia* presumably of African origin, seem to have entered the Indian subcontinent after it had established land connection with Africa during Miocene. This was the time when maximum diversification and exchange of the floral elements between these continents had taken place.

Table 1. Fossil plants from Namsang beds of Deomali, Arunachal Pradesh

Fossil taxa	Comparable extant taxa	Distribution	Forest Types
Clusiaceae			
Calophyllum eoinophyllum Prakash 1966	*Calophyllum inophyllum*	West Coast from Konkan southwards, Andaman Islands and Myanmar	Tropical littoral and swampy
Dipterocarpaceae			
**Dipterocarpoxylon bolpurense* Ghosh & Roy	*Dipterocarpus baudii, D. lawii*	Myanmar, Sumatra, Malayan Peninsula	Tropical wet evergreen to semi evergreen
Shoreoxylon deomaliense Prakash & Awasthi 1970	*Shorea* spp. (other than Indian species)	Myanmar and Malayan Peninsula	Tropical evergreen
Sterculiaceae			
Sterculioxylon varmahii Lakhanpal *et al.* 1981	*Sterculia alata*	North-east India,Western Ghats, Bangladesh and Andaman Islands	Tropical semi-evergreen to tropical moist deciduous
Heritieroxylon arunachalensis Lakhanpal *et al.* 1981	Heritiera fomes	Sunderbans along Chittagong Coast, Myanmar	Tropical littoral and swampy
Burseraceae			
**Canarioxylon indicum* Ghosh & Roy	*Canarium* spp.	Western Ghats, Assam, Bengal, Sikkim and Andaman Islands	Tropical wet evergreen to moist deciduous

Fossil taxa	Comparable extant taxa	Distribution	Forest Types
Burseroxylon garugoides Lakhanpal *et al.* 1981	Garuga pinnata	Throughout India, Myanmar and Bangladesh	Tropical semi-evergreen to dry deciduous
Sapindaceae			
**Euphorioxylon indicum* Awasthi *et al.*	*Euphoria longana, Litchi chinensis, Otonephelium stipulaceum*	Western Ghats, Assam, Myanmar, China, Sri Lanka and Malaysia	Tropical wet evergreen or semi-evergreen to montane sub-tropical
Anacardiaceae			
Mangiferoxylon assamicum Prakash & Tripathi; Lakhanpal *et al.* 1981	*Mangifera indica*	Himalayan region ascending upto 1000 m from Kumaon to Bhutan, Khasi Hills, Myanmar and Western Peninsula	Tropical wet evergreen to tropical dry deciduous
Fabaceae			
Kingiodendron prepinnatum Awasthi & Prakash 1987	*Kingiodendron pinnatum*	Western Ghats from South Kanara to Kerala and Tirunelveli	Tropical wet evergreen to semi-evergreen
Bauhinia deomalica Awasthi & Prakash 1987	*Bauhinia foveolata, B. racemosa*	Sub-Himalayan tract ascending upto 1, 500 m and throughout central, western and southern India, Myanmar and Sri Lanka	Tropical moist deciduous to dry deciduous
Albizinium eolebbekianum Lakhanpal *et al.*1981	*Albizia lebbek*	Throughout India from the Indus east-wards along the Sub-Himalaya to Assam, Myanmar and Andamans	Tropical wet evergreen to dry deciduous and also dry evergreen
Millettioxylon palaeopulchra Lakhanpal *et al.* 1981	*Millettia pulchra*	Khasi Hills in Meghalaya and Upper Myanmar upto 1200 m	Tropical moist deciduous to dry deciduous
Pahudioxylon deomaliense Prakash 1965	*Afzelia- Intsia*	Sunderbans, Andamans, Myanmar and Malayan Peninsula	Tropical littoral and swampy
Cynometroxylon holdenii (Gupta) Prakash & Bande; Prakash & Awasthi 1971	*Cynometra polyandra, C. ramiflora*	Khasi and Cachar Hills, Sunderbans to Chittagong and Tenasserim, Andamans and coast of Konkan and Kanara	Tropical wet evergreen to semi-evergreen, littoral and swampy
**Julbernardia palaeoglobiflora* sp. nov.	*Julbernardia globiflora*	Tropical Africa	
Combretaceae			
Terminalioxylon coriaceum Prakash & Awasthi 1971	*Terminalia coriacea*	Drier parts of Madras State and Central India	Tropical moist deciduous to dry deciduous
Terminalioxylon tertiarum Prakash 1966	*T.tomentosa*	Deccan, Sub-Himalayan tracts of northwest Provinces, Nepal, Sikkim, Myanmar and Sri Lanka	Tropical to subtropical semi-evergreen to moist and dry deciduous
Lecythidaceae			
**Barringtonioxylon deccanense* Shallom	*Barringtonia acutangula*	Sub-Himalayan tract fom Ganga eastwards to Bengal and Assam, Madhya Pradesh and coastal districts of Peninsula	Tropical littoral and swampy to dry deciduous
Lythraceae			
Lagerstroemioxylon deomaliensis Lakhanpal *et al.* 1981	*Lagerstroemia villosa*	Eastern Himalaya, Sikkim, Pegu, Martaban and Upper Myanmar	Tropical moist deciduous to dry deciduous

Fossil taxa	Comparable extant taxa	Distribution	Forest Types
Sapotaceae			
Madhuca palaeolongifolia sp. nov.	*Madhuca longifolia*	West Coast, South Kanara, Malabar and Travancore	Tropical wet evergreen
Siderinium deomaliense Prakash & Awasthi 1970	*Sideroxylon grandifolium*	Khasi Hills, Sylhet and hills of Martaban	Tropical moist deciduous
Ebenaceae			
Ebenoxylon indicum Ghosh & Kazmi 1958	*Diospyros- Maba*	Throughout India	Tropical wet evergreen, semi-evergreen, moist and dry deciduous
Lauraceae			
Laurinoxylon namsangensis Lakhanpal *et al.* 1981	–	–	–
L. deomaliensis	–	–	–
Lakhanpal *et al.* 1981			
Bischofiaceae			
Bischofia palaeojavanica Awasthi 1989	*Bischofia javanica*	Throughout India and Myanmar	Tropical wet evergreen to moist deciduous and littoral and swampy
Moraceae			
Antiaris deomaliensis Awasthi 1989	*Antiaris toxicaria*	Western Ghats, Sri Lanka and Myanmar	Tropical wet evergreen to semi-evergreen.

Species marked (*) are described in this paper.

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