ABSTRACT

Fossil woods resembling those of *Dipterocarpus*, *Albizia*, *Cassia*, *Cynometra*, *Millettia* and a species of *Dryoxylon* are described in the present paper from the Lower Siwalik beds of Khokhra near Jalagarh in Himachal Pradesh. These are *Dipterocarpoxylon sivalicus* sp. nov., *D. nalagarhense* sp. nov., *D. pre-macrocarpum* sp. nov., *Albizziurn vel precedenceum* gen. et sp. nov., *Cassiniurn pretradili gen. et sp. nov.*, *Cynometroxylon indicum* Chowdhury & Ghosh, *Millettioxylon pongamieus* sp. nov., and *Dryoxylon nahanai* sp. nov. Present distribution of the modern comparable forms of the fossil species indicates a more humid climate in this region during the Lower Siwalik period. *Dipterocarpus*, which was once so profuse in this region, now grows in northeastern and southern parts of India. This is because of a drier climate that has prevailed in this region since the Pliocene.

INTRODUCTION

The Siwalik beds commenced depositing during the Middle Miocene in the depression caused by the rising of the mountain chains in Northern India, its sediments coming from the denudation of newly formed mountains. The depositions formed the low outermost hills of the Himalayas known as Siwalik System, named after the Siwalik hills which were first known to science with important palaeontological findings. The short streams flowing down the mountains kept the water fresh in the basin of deposition and the rising high mountain chains brought a monsoon climate and a high degree of precipitation in this region, where a rich flora flourished during this period.

The Siwaliks are divided into three major divisions, ranging in age from the Middle Miocene to the Lower Pleistocene. There are two marked unconformities within the system. The Siwalik beds are composed of sandstones, grits, conglomerates, pseudo-conglomerates, clays and silts. The characters of the sediments indicate that the basin of deposition was first brackish and that it became increasingly fresh and also there is a variation from lacustrine to fluvial conditions. The chief subdivisions of the Siwaliks are given in Krishnan (1960, p. 545).

Although lot of work has been done on the vertebrate fossils of the Siwaliks, only a few fossil plants have so far been described in detail from these beds. However, the Siwaliks are also very rich in plant fossils and a number of localities are known along the southern foothills of the Himalayas. Recently a detailed study has been taken up at this Institute both on the mega and micro plant remains from these beds. It was in 1931 that Sahni first recorded two species of fossil palm woods, *Palmoxylon wadiai* and *P. jammuense* from the Upper Siwalik conglomerate of Jammu. These were described in detail in 1964 (Sahni, 1964).

From the "Middle Conglomerate zone" of the Middle Siwaliks, west of the village Khundian near Jwalamukhi, Ghosh & Ghosh (1958) described a fossil wood of *Anisoptera* as *Anisopteroxylon jwalamukhi*. Pathak (1969) described leaf-impressions closely comparable to modern species of *Castanopsis tribuloides*, *Cinnamomum tamala*, *Litsea polyantha*, *Machilus villosa*, *Bridelia stipularis*, *H. verrucosa*, *Mallotus philippinensis* and *Rhododendron leptodorum* from the Middle Siwaliks of Darjeeling district.

In 1968 Varma described leaf-impressions from the Hardwar beds and assigned them to *Meliaceaxyllum mahagonites*, *Eucalyptphyllum raoi*, *Diospyros embryopterisites* and *Croton tegelis*. Numerous fragments of long, thin grass blades with prominent midrib and the lamina showing closely packed parallel veins are also known from these beds which may belong to upper part of the Lower Siwaliks or lower part of the Middle Siwaliks. Two fossil woods are
also known from the Lower-Middle Siwalik beds of Mohand near Dehra Dun (Rawat, 1964, 1964-65). These are Dipterocarposylon sp. and Bauhinioxyylon indicum, the latter being recorded without any illustrations.

Some impressions of grass-like leaves of Poacites sivalicus were first described by Sahni (1964) from the Lower Siwalik Marl in Poonch. Some more leaf-impressions have also been described from the Lower Siwalik beds of Balu-Goloa near Jwalamukhi in Himachal Pradesh. These have been assigned to Zizyphus, Berchemia, Smilax, Lagerstroemia, Ficus and Fissistigma (Lakhanpal, 1965, 1967, 1968, 1969; Lakhanpal & Dayal, 1966). A fruit closely comparable to Dalbergia sissoo is also known from Balu-Goloa (Lakhanpal & Dayal, 1966).

Besides the fossil woods and leaf-impressions eighteen taxa of charophytes are recently known from the Tatrot formation of the Upper Siwaliks (Bhatia & Mathur, 1970). Tewari and Sharma (1972) have also described in detail some new species of fossil charophytes from the Upper Siwalik beds near Chandigarh.

Some microfossil studies have also been done on the Siwalik beds. Noteworthy amongst these are by Banerjee (1968) on the Lower and Middle Siwaliks of the Bhakra-Nangal area in Punjab and Lukose (1969) on the Middle Siwaliks of Raxaul, Bihar, besides a few other investigations carried out by Nandi (1972) and Nandi and Bandopadhyay (1970).

The present collection of fossil woods was made from the Lower Siwalik beds near the village of Khokhra at a distance of about 2 km south of Nalagarh in Himachal Pradesh. This locality can be reached from Kalka and lies at a distance of 35 km north of this town. The Lower Siwalik beds are also known as Nahan beds which correspond mainly with the Chinji stage. Near Nalagarh the succession is uninterupted and the beds of Dagshai-Kasauli or Murree series in all probability pass up conformably into the Nahans, the general purple colour of the former changing gradually to the prevailing grey (Pepper and salt) of the softer Nahan sandstones through a succession of passage beds which, if not part of Kasauli group, may represent the Kamlial stage. It is from these Nahan beds near Nalagarh that a rich collection of fossil woods has been made. Most of the fossil woods do not show satisfactory preservation although the ones described here are somewhat better preserved. These have been sectioned in transverse, tangential and radial planes and a number of thin sections prepared from each wood so as to get a clear picture of their anatomical structures. Seven of them have been identified to modern genera, while one has been tentatively referred to the family Meliaceae.

**SYSTEMATIC DESCRIPTION**

**Family — Dipterocarpaceae**

**Genus — Dipterocarposylon** Hold. emend Den Berger, 1927

1. *Dipterocarposylon sivalicus* sp. nov.

   Pl. 1, figs. 1-3

This fossil wood is represented by single piece of mature secondary xylem measuring 10 cm in length and 7 cm in diameter.

**Topography** — Wood diffuse-porous. **Growth rings** absent. Vessels visible to the naked eye, mostly large, almost always solitary, 5-6-(7) per sq mm, with rays contiguous on one or both the sides (Pl. 1, fig. 1); tyloses present. **Vasicentric tracheids** sparse paratracheal associated with the parenchyma with numerous bordered pits. **Parenchyma** mostly apotracheal, the paratracheal being very scanty, present around some of the vessels; apotracheal parenchyma mostly found as diffuse, solitary cells, sometimes diffuse-in-aggregate forming irregular pattern in the fibrous tracts between the xylem rays (Pl. 1, fig. 3); several rows of parenchyma cells often surround the gum ducts and form a thick layer frequently extending tangentially and uniting with the parenchyma from neighbouring canals. **Xylem rays** fine to broad, 1-5-(6) seriate (Pl. 1, fig. 2), often uniseriate, 15-64 μ, wide, and about 250-1125 μ high, closely spaced, 7-14 per mm; ray tissue heterogeneous with rays composed of both upright
and procumbent cells; uniseriate rays consisting of both upright and procumbent cells; broad rays 2-5-(6) cells wide with square or upright cells at one or both the ends and procumbent cells in the middle portion; sheath cells without contents, commonly present on the flanks. Fibres well preserved at some places, irregularly arranged in between consecutive xylem rays. Gum canals abundant, vertical, single or usually in pairs and sometimes in short tangential rows of 3-6.

Elements — Vessels thin-walled, walls about 6 µ thick, t.d. 160-240 µ, r.d. 180-400 µ, round to oval or elliptical due to pressure during fossilization; vessel-members 160-500 µ long, with truncate or sometimes tapered ends; perforations simple; inter-vessel pit-pairs could not be seen. Parenchyma cells thin-walled, t.d. 16 µ, height 40-60 µ. Ray cells thin-walled; procumbent cells of polygonal shape in tangential section, vertical height 12-16 µ, radial length 32-40 µ; upright cells with vertical height 28-40 µ, radial length 20-24 µ. Fibres libriform, thick-walled with small lumen, polygonal in cross section, non-septate; interfibre pits could not be seen. Gum canals uniformly distributed, small, 40-68 µ in diameter, round to oval, encircled by several seriate parenchymatous sheath.

Affinities — Vertical gum canals and the vasicentric tracheids of the present fossil wood indicate that the nearest affinity of this wood is with the family Dipterocarpaceae. Further, the presence of medium to large (mostly large) vessels; abundant, rarely solitary, mostly in short tangential groups of 2-8 or more gum canals; and the heterocellular xylem rays with sheath cells on the flanks point out towards a close resemblance of the fossil with the modern wood of Dipterocarpus, especially with the species, Dipterocarpus indicus (F.R.I. No. 464/D 6219). The fossil wood of Dipterocarpoxyylon sivalicus resembles the modern wood of Dipterocarpus indicus in the size and distribution pattern of the vessels, in the type of perforation plates, in parenchyma distribution, and the fibre and ray structure.

A large number of fossil woods belonging to Dipterocarpus are known (Prakash, 1973, Table 1, p. 51). Those described from the Tertiary of India are Dipterocarpoxyylon chowdhurii Ghosh (1956) and D. kalaicharporensis Eyde (1963) from Assam, D. malavii Ghosh & Ghosh (1959) from Kutch, and Dipterocarpoxyylon sp. Rawat (1964) from the Siwalik beds of Mohan in Uttar Pradesh. Of these Indian species, Dipterocarpoxyylon chowdhurii is the closest but it also differs from the present Siwalik wood in having more abundant, diffuse-in-aggregate parenchyma arranged closely and in appreciably taller xylem rays with more frequent sheath cells. The lines of parenchyma are sometimes seen and the xylem rays are somewhat smaller in Dipterocarpoxyylon sivalicus. Similarly Dipterocarpoxyylon malavii differs from Dipterocarpoxyylon sivalicus in possessing slightly smaller vessels (t.d. 100-221 µ, r.d. 112-350 µ) and in having comparatively narrower, 1-5 seriate xylem rays. Dipterocarpoxyylon kalaicharporensis is also quite distinct in having large gum canals and somewhat narrower, 1-5 (mostly 3-4) seriate xylem rays. Lastly Dipterocarpoxyylon sp. also differs from Dipterocarpoxyylon sivalicus in having large gum ducts and narrower xylem rays.

Since the present fossil wood compares very well with the modern woods of Dipterocarpus and is quite different from all the species of Dipterocarpoxyylon so far known from India and outside, it is described here as a new species, Dipterocarpoxyylon sivalicus.

Dipterocarpus is a rather large genus with about 80 species, widely distributed in the Indo-Malayan region. The range of its distribution is from South India and Ceylon in the west to the Philippines in the east. About 13 species grow in the Indian zone (Andamans, Burma, Ceylon, India and Pakistan). The species Dipterocarpus indicus Bedd. syn. D. turbinatus Dyer (in part) which shows close resemblance with the present fossil wood grows in the west-coast evergreen forests from North Kanara southwards. It is a common tree in the Tellichery Ghats of the North Malabar Division, as also in Travancore. It also occurs in the Andamans, Assam, Burma, Bangla Desh, Cochin-China and Thailand (Chowdhury & Ghosh, 1958, pp. 116-117).

SPECIFIC DIAGNOSIS

Dipterocarpoxyylon sivalicus sp. nov.

180-400 μ, almost always solitary, round to oval, 5-7 per sq mm; tyloses present; vessel members 160-500 μ long with truncate or tapered ends; perforations simple; intervessel pit-pairs not seen. Vasicentric tracheids sparse, paratracheal associated with the parenchyma and with numerous bordered pits. Parenchyma mostly apotracheal, present as diffuse, solitary cells, sometimes diffuse-in-aggregate, and more often surrounding the gum ducts; paratracheal parenchyma scanty. Xylem rays 1-5-(6) seriate, often uniseriate, 7-14 per mm; ray tissue heterogeneous, rays heterocellular; sheath cells commonly present on the flanks of the broad xylem rays. Fibres libriform, thick-walled, polygonal, non-septate; inter-fibre pits could not be seen. Gum canals abundant, vertical, solitary or usually in pairs, sometimes in short tangential rows of 3-6, small, 40-68 μ in diameter and round to oval in shape.

Holotype — B.S.I.P. Museum No. 118/1014.

2. Diptercarpoxyylon nalagarhense sp. nov.

Pl. 1, fig. 4; Pl. 2, figs. 5, 6

This species is based on a piece of decorticated secondary wood measuring about 8 cm in length and 12 cm in diameter.

Topography—Wood diffuse-porous. Growth rings absent. Vessels visible to the naked eye, large to medium sized, mostly solitary, rarely in pairs, 4-5-(6) per sq mm; tyloses present, vessels sometimes plugged with black gummy deposits (Pl. 2, fig. 5). Vasicentric tracheids sparse, paratracheal with numerous bordered pits. Parenchyma mostly apotracheal, the paratracheal being scarcely present in association with vessels; apotracheal parenchyma abundant, diffuse to diffuse-in-aggregate forming short tangential uniseriate to sometimes 2-seriate lines in the fibrous ground mass forming irregular pattern (Pl. 1, fig. 4); several rows of parenchyma cells usually surround the gum ducts forming a thick layer (Pl. 2, fig. 5). Xylem rays fine to mostly broad, 1-8-9-(10) seriate (Pl. 2, fig. 6), sometimes uniseriate, 16-150 μ wide and about 225-1425 μ high, closely spaced, 4-7 per mm; ray tissue heterogeneous with rays composed of both upright and procumbent cells (Pl. 2, fig. 6); broad rays up to 1425 μ wide with square or upright cells at one or both the ends and procumbent cells in the middle portion; sheath cells sometimes present on the flanks. Fibres irregularly arranged in between two consecutive xylem rays. Gum canals not very common, vertical, single or in pairs (Pl. 2, fig. 5), occasionally in short tangential rows of 3-4-(5).

Elements — Vessels thick walled, walls about 8-10 μ thick, t.d. 105-255 μ, r.d. 150-360 μ, round to oval (Pl. 2, fig. 5); vessel members 210-525 μ long usually with truncate ends; perforations simple; intervessel pit pairs could not be seen. Parenchyma cells thin walled, t.d. 12-15 μ, height 48-100 μ. Ray cells thin walled; procumbent cells of polygonal shape in tangential section, vertical height 16-20 μ, radial length 28-48 μ; upright cells with vertical height 32-36 μ, radial length 12-15 μ. Fibres libriform, thick walled, polygonal in cross section, non-septate; interfibre pits not preserved. Gum canals 90-200 μ in diameter, round to oval, encircled by multiserate parenchymatous sheath.

Affinities — Because of the presence of small vertical gum canals, vasicentric tracheids, abundantly diffuse to diffuse-in-aggregate parenchyma and the heterocellular xylem rays with some sheath cells, the affinity of this fossil wood is with the genus Dipterocarpus of the family Dipterocarpaceae, although it also shows a superficial resemblance to the mature secondary xylem of Anisoptera of the same family. However, in Anisoptera the gum canals are minute, usually solitary and the sheath cells are frequent in the xylem rays, often forming a continuous sheath along the flanks. A survey of all the available woods of the genus Dipterocarpus shows that the nearest affinity of the fossil is with Dipterocarpus dyeri (F.R.I. No. A1159/1B691 and A1160/1B6892). The size and distribution of the vessels in Diptercarpoxyylon nalagarhense agree with the vessel size and their distribution in Dipterocarpus dyeri. Besides, the distribution of parenchyma appears to be almost identical in both as is also the fibre structure. The xylem rays of this fossil wood and of Dipterocarpus dyeri are basically similar, although there are slight differences.

Of all the species of Dipterocarpoxyylon so far known from the Indian region, Diptero-
**SPECIFIC DIAGNOSIS**

*Dipterocarpoxylon nalagarhense* sp. nov.

**Wood** diffuse-porous. Growth rings absent. 

**Vessels** large to medium sized, t.d. 105-255 μ, r.d. 150-360 μ, mostly solitary, round to oval, 4-6 per sq mm; tyloses present; vessel members 210-525 μ, in length, usually with truncate ends; perforations simple; inter-vessel pit-pairs could not be seen. 

**Vasicentric tracheids** sparse, associated with vessels and profusely pitted. 

**Parenchyma** mostly apotracheal as diffuse to diffuse-in-aggregate forming short, uniseriate to sometimes biseriate, tangential lines and also surrounding the gum canals; paratracheal parenchyma scarce. 

**Xylem rays** 1-5 seriate (Pl. 2, fig. 8), sometimes uniseriate, 22-105 μ wide and about 225-1575 μ high, 6-10 per mm; ray tissue heterogeneous with rays composed of both upright and procumbent cells (Pl. 2, fig. 8); sheath cells present on the flanks in between procumbent cells. **Fibres** irregularly arranged in between the xylem rays.

**Gum canals** vertical, moderately large, solitary or in pairs, occasionally in tangential rows of 3 (Pl. 2, fig. 7).

**Elements**—Vessels moderately thick walled, t.d. 150-270 μ, r.d. 180-330 μ, oval in shape; vessel elements 150-600 μ long usually with truncate ends; perforations simple; inter-vessel pit pairs not seen. 

**Parenchyma** cells thin walled, t.d. 16-20 μ, height up to 100 μ. 

**Ray cells** thin walled; procumbent cells 20-40 μ in vertical height, 44-60 μ in radial length; upright cells 40-60 μ in vertical height, 20-28 μ in radial length. 

**Fibres** libriform, thick walled, polygonal in cross section, non-septate; interfibre pits not seen. 

**Gum canals** large, 135-225 μ in diameter, round to oval, encircled by thick parenchymatous sheath (Pl. 2, fig. 7).

**Affinities**—The present fossil wood most closely resembles the modern wood of *Dipterocarpus* of the family Dipterocarpaceae, although it also shows a superficial resemblance to the mature secondary xylem of *Anisoptera* of the same family. The gum canals in *Anisoptera* are, however, minute.
and usually solitary and the sheath cells are quite frequent in the xylem rays often forming a continuous sheath along the flanks. A survey of all available woods of the genus *Dipterocarpus* indicates that the nearest affinity of the fossil is with *Dipterocarpus macrocarpus* (F.R.I. No. A961).

A large number of fossil woods belonging to *Dipterocarpus* are known. However, those nearly comparable to the present species are *Dipterocarboxylon malavii* Ghosh & Ghosh (1959) from Kutch, *D. kalaichara肺炎* Eyde (1963) and *D. chowdhrui* Ghosh (1956) from Assam, and *D. sivalicus* Prakash from the Lower Siwalik beds of NJ-lagarh described in the preceding pages. However, all these species differ quite distinctly from the present fossil wood. Thus, *Dipterocarboxylon malavii* differs from *Dipterocarboxylon premacrocarpum* in having slightly bigger vessels, more abundant, diffuse to diffuse-in-aggregate parenchyma and in smaller gum canals. Similarly *Dipterocarboxylon kalaichara肺炎* is also distinct from *D. premacrocarpum* in possessing larger pores and frequent, long, uniseriate extensions in the xylem rays. *Dipterocarboxylon chowdhrui* is distinct in having abundant diffuse to diffuse-in-aggregate parenchyma, slightly broader xylem rays with more sheath cells and in somewhat smaller gum canals. Lastly *Dipterocarboxylon sivalicus* known from the same beds also differs from the present fossil in having smaller gum ducts and somewhat broader xylem rays. The diffuse-in-aggregate parenchyma is also more frequent in *D. sivalicus* than in the present fossil wood.

As this fossil wood compares closely with the modern species *Dipterocarpus macrocarpus* and is quite distinct from all the species of *Dipterocarboxylon* so far known, it is described here as a new species, *Dipterocarboxylon premacrocarpum*. *Dipterocarpus macrocarpus* Vesque, the closest known species grows in Sibagar, Lakhimpur, Naga hills in Assam, Mergui and Tenasserim in Burma (Chowdhury & Ghosh, 1958, p. 116).

**SPECIFIC DIAGNOSIS**

*Dipterocarboxylon premacrocarpum* sp. nov.

Wood diffuse-porous. **Growth rings** absent. **Vessels** large to medium-sized, t.d. 150-270 μ, r.d. 180-330 μ, solitary, oval, 4-6 per sq mm; sometimes plugged with tyloses or gummy deposits; vessel members 150-600 μ long with truncate ends; perforations simple; intervessel pit-pairs not seen. **Vasicentric tracheids** sparse, paratracheal associated with the parenchyma with numerous bordered pits. **Parenchyma** mostly apotracheal occurring as diffuse cells sometimes forming short lines and more often surrounding the gum ducts; paratracheal parenchyma scarce. **Xylem rays** 1-5 seriate, sometimes uniseriate, 22-105 μ broad, and about 225-1575 μ high, 6-10 per mm; ray tissue heterogeneous with rays composed of both upright and procumbent cells; sheath cells present. **Fibres** libriform, thick walled, polygonal in cross section, nonseptate. **Gum canals** vertical, round to oval, moderately large, 135-225 μ in diameter, solitary or in pairs, occasionally in tangential rows of 3, encircled by thick parenchymatous sheath.

**Holotype** — B.S.I.P. Museum No. 108/1014.

**Family** — **LEGUMINOSAE**

**Genus** — *Alibizzinium* gen.nov.

4. *Alibizzinium colebekianum* sp. nov.

Pl. 3, figs. 9, 11, 12

The specimen described below is a small piece of petrified wood 10 cm in diameter and 7.5 cm in length.

**Topography**—Wood diffuse-porous. **Growth rings** present delimited by smaller vessels and the terminal parenchyma (Pl. 3, fig. 9). **Vessels** large to medium-sized mostly solitary, sometimes in radial multiples of 2-3 cells, 3-5 per sq mm, mostly empty (Pl. 3, fig. 9). **Parenchyma** both apotracheal and paratracheal (Pl. 3, fig. 9); apotracheal parenchyma diffuse and forming narrow lines of terminal parenchyma; paratracheal parenchyma vasicentric to mostly aliform, occasionally confluent joining adjacent vessels; parenchyma sheath quite thick around the vessels. **Xylem rays** fine to medium, 1.3-4 (mostly 2-3) seriate (Pl. 3, fig. 12), 7-10 per mm; ray tissue homogeneous with rays composed of procumbent cells only. **Fibres** not aligned in distinct radial rows.
Elements — Vessels thin walled, the walls about 6 μ thick, t.d. 150-300 μ, r.d. 150-330 μ, round to oval in shape, those in radial multiples flattened at the places of contact; vessel segments short, 150-375 μ in length usually with truncate ends; perforations simple; intervessel pit-pairs vestured, alternate, oval to elliptical in shape, 6-10 μ in diameter with linear to lenticular apertures (Pl. 3, fig. 11). Parenchyma cells thin walled, 16-28 μ in diameter, 48-100 μ in length, sometimes crystalliferous. Ray cells thin walled, procumbent cells 12-20 μ in tangential height and 48-70 μ in radial length. Fibres nonlibriform to semi­ libriform, polygonal in cross section, septate and 10-20 μ in diameter; interfibre pits not preserved.

Affinities — The fossil wood most closely resembles the modern wood of the leguminous genus Albizzia, although it also shows a superficial resemblance to the mature secondary xylem of Acacia (A. lenticularis), Cassia (C. nodosa) and Afzelia-Intsia. However, the fibres are nonseptate and the paratracheal parenchyma more often forms a halo in Acacia lenticularis. Similarly Cassia nodosa has larger vessels and the paratracheal parenchyma is aliform with long wings, sometimes joining each other. Afzelia and Intsia also differ from the present fossil wood in having nonseptate fibres and the xylem rays are sometimes arranged in echelon, whereas the fossil wood has septate fibres, nonstoried xylem rays and vasicentric to mostly aliform parenchyma.


The present fossil wood resembles the modern wood of Albizzia lebbek in the size and distributional pattern of the vessels, in the type of perforation plates and intervacular pit-pairs, in parenchyma distribution, and the fibre and ray structure. However, Albizzia lebbek differs from this fossil wood in having somewhat bigger vessels in some specimens; this is, however, a variable feature.

A large number of fossil woods belonging to the family Leguminosae are known (Müller-Stoll & Mädel, 1967). However, woods related to Albizzia are limited to only a few references in the literature. It was in 1935 that Niktin first described a fossil wood resembling the modern wood of Albizzia julibrissin Durazz. from the Pliocene of Eastern Georgia and named it as Alizzoxylon kyrmicum. This species is based on a very badly preserved specimen of fossil wood in which libriform fibres and the wood parenchyma are not very well preserved. Niktin did not mention the parenchyma pattern and the presence of septate fibres and these features are also not clear from the illustrations given by him. Consequently, Müller-Stoll & Mädel (1967) are of the opinion that this fossil wood has nothing to do with the genus Albizzia although it belongs to the family Leguminosae. Therefore, on these grounds, they regard Alizzoxylon Niktin (1935) as “genus dubium”. In 1960 when Ramanujam again instituted the form genus Alizzoxylon, he had no information about the work of Niktin. Hence, Alizzoxylon Ramanujam is a later homonym of Alizzoxylon Niktin and cannot be used according to article 64 of the International Code of Botanical Nomenclature. Besides, the name Alizzoxylon Niktin (1935) being “nomen dubium” must be rejected. Consequently, Müller-Stoll & Mädel (1967) instituted a new name Ingoxylon to include the fossils showing the wood structure of the extant genera Inga, Albizzia, Piptadenia, Pithe-
celllobium, Leucaena and some species of Azelia. Although these genera show a somewhat similar wood structure but some of them can easily be distinguished by their minute anatomical details. Therefore, to include all of them under one name would be too ambiguous. Because Albizzia is anatomically distinct, it is proposed to separate this genus and institute a new name, Albizzinium for the fossil woods of Albizzia. As the present fossil wood shows a close resemblance to the modern species Albizzia lebbek, it is assigned to Albizzinium and named as Albizzinium colebbekianum sp. nov.

Fossil woods assigned to Albizzia are Albizzioxylon sahnii described by Ramanujam (1960) from the Miocene of South India, and Albizzia vantagiensis Prakash & Barghoorn (1961) from the Miocene of Columbia Basalts in Washington. In 1967, Müller-Stoll & Mädel transferred Albizzioxylon sahnii Ramanujam to Ingoxylon sahnii (Ramanujam) and Albizzia vantagiensis Prakash & Barghoorn to Tetrapleuroxylon vantagiense (Prakash & Barghoorn) assigning the latter to the genus Tetrapleura due to presence of non-septate fibres in Albizzia vantagiensis. However, it should be noted here that the modern woods of Albizzia, which almost always show septate fibres, do not exhibit non-septate fibres in some specimens of Albizzia procera. Similarly in Albizzia stipulata the fibres are partly septate. Therefore, only this criteria is insufficient to separate the woods of the two organ genera, Ingoxylon and Tetrapleuroxylon instituted by Müller-Stoll & Mädel (1967). Recently Awasthi (1975) further examined Albizzioxylon sahnii and found that this fossil wood actually belongs to Azelia-Intisia. Consequently, he transferred it to Pakhularoxylon sahnii Ghosh & Kazmi. Albizzia vantagiensis, the only other fossil wood showing relationship with this genus differs from the present fossil in having mostly 3-seriate xylem rays and nonseptate fibres.

Albizzia is rather a large genus of trees and shrubs, widely scattered throughout the tropics and subtropics of Asia, Africa, Australia, and one species is also found in Mexico. Albizzia lebbek Benth., with which the present fossil wood closely resembles, grows throughout India (except in Sind) from the Indus eastwards along the sub-Himalayas to Assam, and in Burma and the Andamans (Pearson & Brown, 1932, pp. 454-455).

**GENERIC DIAGNOSIS**

*Albizzinium* gen. nov.

Wood diffuse-porous. Growth rings distinct, delimited by terminal parenchyma. Vessels large to medium-sized, mostly solitary; perforations simple; intervessel pith pairs vestured, alternate usually medium in size. Parenchyma terminal, diffuse and vasicentric to mostly aliform, occasionally joining adjacent vessels; cells crystalliferous. Xylem rays 1-6 seriate, homogeneous, composed of procumbent cells. Fibres non-libriform to libriform, almost always septate.

**SPECIFIC DIAGNOSIS**

*Albizzinium colebbekianum* sp. nov.

Wood diffuse-porous. Growth rings present, delimited by smaller vessels and terminal parenchyma. Vessels large to medium-sized, mostly solitary, sometimes in radial multiples of 2-3 cells, 3-5 per sq mm, mostly empty; vessel segments short, 150-375 μ, long, usually truncate; perforations simple; intervessel pith-pairs vestured, alternate, 6-10 μ in diameter with linear-lenticular apertures. Parenchyma paratracheal and apotracheal; paratracheal parenchyma vasicentric to mostly aliform occasionally confluent joining adjacent vessels; apotracheal parenchyma terminal and diffuse scattered among the fibres; cells sometimes crystalliferous. Xylem rays 1-3-(4) seriate; ray tissue homogeneous. Fibres non-libriform to semilibriform with big lumen, septate.

**Holotype** — B.S.I.P. Museum No. 150/1014.

**Genus** — Cassiniu111. gen. novo

5. *Cassinium* prefistulai sp. nov.

Pl. 4, figs. 14, 16, 17

The present fossil wood consists of a single specimen of petrified mature second-
ary xylem measuring 7 cm in diameter and 9 cm in length.

**Topography** — Wood diffuse-porous. Growth rings delimited by smaller vessels and lines of terminal parenchyma. Vessels small to large, mostly solitary (Pl. 4, fig. 14), sometimes in pairs or in short radial rows of 3-4 cells, 3-7 per sq mm, mostly empty, sometimes plugged with brownish black deposits. *Parenchyma* both apotracheal and paratracheal (Pl. 4, fig. 14); apotracheal parenchyma forming lines of terminal parenchyma; paratracheal parenchyma aliform to mostly confluent forming broad, undulating bands joining adjacent vessels; parenchyma sheath quite thick around the vessels. *Xylem rays* fine to medium, 1-4 rays composed mostly of procumbent cells. Fibres not aligned in distinct radial rows.

**Elements** — Vessels slightly thicker walled, the walls about 10 μ thick, t.d. 40-240 μ, r.d. 60-300 μ, usually round in shape, those in radial multiples flattened at the places of contact; vessel segments short, 300-600 μ, long with truncate ends; perforations simple; intervessel pit-pairs (Pl. 4, fig. 17), vestured, alternate, 8-10 μ in diameter with linear-lenticular apertures. *Parenchyma cells* thin walled 15-30 μ in diameter, 60-90 μ in length; chambered crystalliferous parenchyma sometimes present. *Ray cells* thin walled, procumbent cells about 20 μ in tangential height and 40-80 μ in radial length; cells sometimes crystalliferous. *Fibres* libriform to semilibriform, polygonal in cross section, 1-4 seriate, 20 μ in diameter, 500-600 μ in length; interfibre pits not seen.

**Affinities** — Structural features of the fossil wood indicate, after extensive comparison, that its closest affinities are with the modern genus *Cassia* in which a near resemblance can be seen with the species *Cassia fistula* (F.R.I. No. A 3521 & B7478). However, the fossil also shows a superficial resemblance to the mature secondary xylem of *Parkia roxburghii* which has thinner walled fibres and the confluent parenchyma frequent forming large bands due to which it can be easily distinguished from the present fossil wood. Our survey included the study of thin sections of eight species of the genus *Cassia* and published description of these and three other species. Thin sections were examined from the woods of *Cassia auriculata* Linn., *C. fistula* Linn., *C. marginata* Roxb., *C. nodosa* Buch.-Ham., *C. siamea* Lam., *C. grandis* Linn., *C. javanica* Linn., and *C. aubrevillei* Pellet..
Thus, Cassia siamea and C. auriculatae are quite distinct from Peltophorium and Xylia in having banded parenchyma, while Cassia nodosa, C. marginata and C. manii can also be distinguished from Xylia dolabiformis, X. evansi and X. xylocarpha in the presence of septate fibres and somewhat different parenchyma pattern. Peltophorium vogeliamum although possesses septate fibres like some Cassia, but it differs from Cassia manii, C. nodosa and C. marginata in having mostly vasieentric parenchyma with some scattered cells. Peltophorium dasyrachis and P. pherocarpum have predominantly aliform parenchyma. Cassia siamea, C. fistula, C. fistulosa and C. javanica (Kanerhira, 1934) can also be distinguished from Peltophorium in the presence of non septate fibres. Cassia fistula is further distinguished from Peltophorum and Xylia in having homogeneous to weakly heterogeneous xylem rays, whereas the xylem rays are only homogeneous in Peltophorum and Xylia.

Therefore, it is suggested that all those fossil woods which can be definitely assigned to Cassia should, henceforth, be placed under a new generic name, Cassinium; instead of dumping them under a comprehensive form genus Peltophoroxylon Müller Stoll & Mädel, which should now be used for the fossil woods of Peltophorum and Xylia.

A critical analysis of all the fossil woods so far referred to Cassioxyylon Felix (1882) and Peltophoroxylon Müller-Stoll & Mädel (1967) reveals that those belonging to Cassia are not many (Ramanujam, 1967; Müller-Stoll & Mädel, 1967; Prakash, 1967, 1970). These are now named as Cassinium variigatum (Ramanujam) comb. nov., Cassinium borooahii (Prakash) comb. nov., Cassinium cassinoides (Prakash & Awasthi) comb. nov., and Cassinium cassinidosum (Prakash) comb. nov. All these differ quite distinctly from the present fossil wood.

Thus Cassinium variigatum (Ramanujam, 1960) differs from the present fossil in possessing somewhat narrower, 1-3 seriate xylem rays and septate fibres. C. borooahii (Prakash, 1967) also differs in having usually banded parenchyma besides possessing 1-3 seriate, homogeneous xylem rays. Similarly, C. cassinoides (Prakash & Awasthi, 1970) is different from the present species in having slightly narrower (1-3 seriate), homogeneous xylem rays and mostly aliform parenchyma.

Lastly, C. cassinodosum (Prakash, 1970) is also distinct from this Siwalik wood in having narrower, 1-2 seriate, homogeneous xylem rays and septate fibres. However, the xylem rays are 1-4 seriate and homogeneous to weakly heterogeneous, the fibres are non septate and the parenchyma is terminal and aliform to mostly confluent in the present fossil wood.

Since the present fossil wood is quite different from all the species of Cassinium so far known, it is being described as a new species, Cassinium prefistulai, the specific name indicating a close resemblance with the modern wood of Cassia fistula which is one of the most wide spread Indian forest trees, occurring throughout the forests of India, Burma and Ceylon.

**GENERIC DIAGNOSIS**

Cassinium gen. nov.

Wood diffuse-porous. Growth rings distinct to somewhat indistinct. Vessels regularly distributed, small to large, solitary and in short radial groups; perforations simple; intervessel pits alternate, vestured. Parenchyma terminal, vasicentric to aliform and confluent or banded and/or diffuse. Xylem rays homogeneous or weakly heterogeneous sometimes with one row of square or upright cells, 1-5 cells broad. Fibres libriform to semilibriform, septate or non-septate.

**SPECIFIC DIAGNOSIS**

Cassinium prefistulai sp. nov.

Wood diffuse-porous. Growth rings distinct, delimited by smaller vessels and terminal parenchyma. Vessels small to large, mostly
solitary, sometimes in radial multiples of 2-4 cells, t.d. 40-240 μ, r.d. 60-300 μ, mostly empty, 3-5 per sq mm, vessel members 300-600 μ long with truncate ends; intervessel pit-pairs bordered, vented, alternate, 8-10 μ in diameter with lenticular apertures. Parenchyma terminal, aliform to mostly confluent and diffuse; cells sometimes crystalliferous. Xylem rays 1-4 (mostly 2-3) seriate, 6-10 rays per mm; ray tissue homogeneous to weakly heterogeneous, rays mostly composed of procumbent cells. Fibres libriform to semilibriform, thick walled, polygonal and nonseptate.

Holotype — B.S.I.P. Museum No. 27/0/4.

Genus — **Cynometroxylon** Chowdhury & Ghosh, 1946

6. **Cynometroxylon indicum** Chowdhury & Ghosh, 1946

Pl. 5, figs. 19, 20

The present fossil consists of a small piece of secondary wood measuring 4 cm in diameter and 4.5 cm in length.

As the present fossil wood is identical to **Cynometroxylon indicum** Chowdhury & Ghosh (1946), it is assigned to it. It shows a near resemblance to the modern woods of **Cynometra polyandra** (F.R.I. No. 205/B 5911) and **C. ramiflora** (F.R.I. No. A 598). **Cynometra polyandra** is a large tree found in Assam, in the khasia Hills, Sylhet and Cachar (Pearson & Brown, 1937, p. 406), while **C. ramiflora** occurs in the sea coast tidal forests of Sunderbans, South India, Burma, the Andamans and Ceylon (Gamble, 1903). **Cynometroxylon indicum** is widely known in the Mio-Pliocene of India occurring near Deomali in Arunachal Pradesh (Prakash & Awasthi, 1971), in North Cachar and Mikir Hills of Assam (Chowdhury & Ghosh, 1946; Prakash, 1967) in the North-east, and near Pondicherry in the Cuddalore series of South India (Ramanujam & Raghu Rama Rao, 1966). It is now recorded from near Nalagarh in Himachal Pradesh in the North-west.


Genus — **Millettioxylon** Awasthi, 1967

7. **Millettioxylon pongamensis** sp. nov.

Pl. 6, figs. 25, 27, 29, 30

The present species is based on a well preserved solitary specimen of petrified secondary wood measuring 5 cm in diameter and 4.5 cm in length.

**Topography** — Wood diffuse-porous. Growth rings present. Vessels small to medium-sized, mostly solitary (Pl. 6, fig. 25), often in radial multiples of 2 to 3 or sometimes of 4 cells, 4-6 per sq mm, almost always empty, sometimes plugged with black deposits. Parenchyma apotracheal in thick, concentric bands (Pl. 6, fig. 25) alternating with the fibres and partially or wholly encircling the vessels, usually undulating and occasionally forking to join the bands above or below, generally more or less of equal width as the fibre bands; parenchyma bands 3-7 cells thick. Xylem rays fine to medium, 1-3 (mostly 2) seriate (Pl. 6, fig. 27), rarely triseriate, usually storied (Pl. 6, fig. 29), and 10-14 per mm; ray tissue homogeneous with rays composed of procumbent cells.

**Elements** — Vessels thick walled, the walls about 8 μ thick, t.d. 60-180 μ, r.d. 90-260 μ, usually oval in shape, those in radial multiples flattened at the places of contact; vessel segments storied, short, 300-400 μ long, usually with truncate ends; perforations simple; intervessel pit-pairs bordered, vented, alternate, 6-9 μ in diameter with lenticular apertures (Pl. 6, fig. 29). Parenchyma cells (Pl. 6, fig. 27) thin walled 30-45 μ in diameter, 60-150 μ in length; chambered crystalliferous cells sometimes present; strands storied. Ray cells thin walled, procumbent cell 12-16 μ in tangential height and 30-40 μ in radial length; cells crystalliferous. Fibres libriform, thick-walled, nonseptate, nonstoried, polygonal in cross section, 15-30 μ in diameter; interfibre pits could not be seen. Ripple marks present due to storied parenchyma, xylem rays and the vessel segments (Pl. 6, fig. 29).

**Affinities** — The combination of structural features of this fossil wood indicates its affinity with the modern woods of **Millettia** and **Pongamia**, although it also shows a superficial resemblance to the mature secondary xylem of **Crabta** (**C. affinis**), **Dialium**, **Swartzia**, (**S. cubensis**, **S. fistuloides**,
<table>
<thead>
<tr>
<th>Modern Species</th>
<th>Anatomical Groups</th>
<th>Vessel Elements</th>
<th>Parenchyma</th>
<th>Xylem Rays</th>
<th>Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Pongamia glabra</td>
<td>Group I</td>
<td>+</td>
<td>Storied</td>
<td>Homogeneous, 1-4 (mostly 2-3) seriate +</td>
<td>Moderately thick walled</td>
</tr>
<tr>
<td>2. Millettia prainii</td>
<td>Genus — Millettioxyylon</td>
<td>+</td>
<td>Moderately broad bands predominant</td>
<td>+</td>
<td>Homogeneously thick walled</td>
</tr>
<tr>
<td>3. M. pendula</td>
<td>Group I</td>
<td>+</td>
<td>Homogeneous, 1-3-4 (mostly 2-3) seriate +</td>
<td>Very thick walled</td>
<td></td>
</tr>
<tr>
<td>4. Millettia brandisiana</td>
<td>Group II</td>
<td>+</td>
<td>1-6 seriate +</td>
<td>Homogeneous to weakly heterogeneous, 1-8 seriate +</td>
<td>Very thick walled</td>
</tr>
<tr>
<td>5. M. auriculata</td>
<td>Group I</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>6. M. atile</td>
<td>Group I</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>7. M. griffoviana</td>
<td>Group I</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-5 (mostly 1-4) seriate +</td>
<td>Very thick walled</td>
</tr>
<tr>
<td>8. M. laurentii</td>
<td>Group I</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-5 (mostly 1-4) seriate +</td>
<td>Very thick walled</td>
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<tr>
<td>9. M. coffra</td>
<td>Group I</td>
<td>+</td>
<td>Broad rays +</td>
<td>Homogeneous, 1-4 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>10. M. racemosa</td>
<td>Group I</td>
<td>+</td>
<td>1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
<td></td>
</tr>
<tr>
<td>11. M. thompsonii</td>
<td>Group I</td>
<td>+</td>
<td>1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
<td></td>
</tr>
<tr>
<td>12. M. macrosachyba</td>
<td>Group I</td>
<td>+</td>
<td>1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
<td></td>
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<tr>
<td>13. M. atropurpurea</td>
<td>Group I</td>
<td>+</td>
<td>1-5 (mostly 1-4) seriate +</td>
<td>Thick walled</td>
<td></td>
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<tr>
<td>14. Millettia pulchra</td>
<td>Group II</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous to heterogeneous, 1-2 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>15. M. drastica</td>
<td>Group II</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>16. Garibis affinis</td>
<td>Group II</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>17. Dialium travancorium</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>18. D. angolense</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>19. D. gossweilerii</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>20. D. corbisieri</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>21. D. pachyphyllum</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>22. D. pendadrum</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>23. D. excisum</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>24. D. zirkeli</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>25. D. guianense</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>26. D. diaacastum</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>27. D. dinklengi</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>28. Swartzia tomentosa</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>29. S. banesi</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
<tr>
<td>30. S. cubensis</td>
<td>Group III</td>
<td>+</td>
<td>1-7 seriate +</td>
<td>Homogeneous, 1-3 (mostly 2) seriate +</td>
<td>Thick walled</td>
</tr>
</tbody>
</table>
S. bauania, S. tomentosa), Cynometra (C. alexandrii), Lonchocarpus, and Bauhinia. However, the parenchyma bands of Craibia, Dialium and Swartzia cubensis are narrow and the xylem rays are mostly 1-2 seriate, whereas the fossil possesses broad parenchyma bands and somewhat broader xylem rays. In Swartzia fistuloides although the parenchyma bands are broad like the fossil wood but the xylem rays are only 1-2 seriate in width. Cynometra alexandrii also differs from the fossil wood in having crowded vessels, undulating parenchyma bands and higher and heterocellular xylem rays. In Lonchocarpus the parenchyma bands are more broad than the fossil wood, although the species, L. sericeus and L. hondurensis show nearly similar xylem rays which are storied along with the parenchyma strands and the vessel elements. The xylem rays in Bauhinia are 1-2 seriate and long with frequent uniseriates.


The size and distributional pattern of vessels in Millettioxylon pongamienisis and Millettia prainii are almost identical. Further both in Millettia prainii and Millettioxylon pongamienisis the perforation plates are exclusively simple, the intervacular pit-pairs are alternate, ventured and the vessel elements are storied. The distribution of parenchyma is almost identical in both as is the fibre structure. The parenchyma is storied, crystalliferous and arranged in predominantly broad bands. The xylem rays of the fossil wood and those of Millettia prainii are basically similar consisting of 1-3 (mostly 2) seriate, homogeneous, storied rays with some of the ray cells slightly swollen and crystalliferous. The only difference between the two is that the parenchyma strands are 2-4 celled in the living but 2-4-6 celled in the fossil, both having a higher percentage of 4 celled than 2-celled strands. Number of parenchyma cells in a strand may be used to distinguish the woods of Millettia and Pongamia but it has to be statistically verified from a large number of specimens belonging to different plants grown in different environments before anything definite could be said about this. However, with the limited number of specimens of Millettia and Pongamia available to us it has been seen that both possess 2-4 celled parenchyma strands but Pongamia has predominantly 2-celled strands (about 90%) whereas Millettia has a larger proportion of 4-celled strands (about 65-70%).

In 1967 Awasthi instituted the form genus Millettioxylon for a fossil wood resembling Millettia from the Cuddalore series of South India. Recently while studying the modern woods of Leguminosae for identifying the present fossil, the author also examined a number of species of Millettia, Dialium, Pongamia, Craibia, Lonchocarpus, and Swartzia which revealed wood structure nearly comparable to each other and even identical in some cases (Table 1). It would appear from this study that the woods of Millettia can be divided into three groups of which one is allied to Pongamia glabra while the other also includes the woods of Craibia, Dialium and Swartzia and the third consists chiefly of Millettia woods. Thus, the woods of Millettia prainii, M. pendula and Pongamia glabra are put together as they are almost identical and difficult to be distinguished anatomically. They consist of predominantly broad parenchyma bands, 1-4 seriate, homogeneous xylem rays, nonseptate fibres and the storied vessel segments, parenchyma strands and xylem rays. It is suggested that the fossil woods of these should be assigned to Millettioxylon Awasthi (1967) primarily instituted for a Tertiary wood resembling that of Millettia pendula. The other group which incudes only the woods.
of *Milletia* can be distinguished from the former in having usually broader, more than four seriate xylem rays and predominantly broad parenchyma bands or aliform to confluent parenchyma with storied to non-storied parenchyma strands and the xylem rays. These may be designated by the name *Eumilletioxylon* being composed of true *Milletias*. This group can further be divided into two subgroups, one with storied xylem rays and the other with non-storied rays. Some species of the latter also show somewhat similar wood structure to *Lonchocarpus cappasa* which can, however, be differentiated from these *Milletias* in having slightly broader xylem rays. The third group, which comprises the woods of *Milletia pulchra*, *M. drastica*, *Cratia affinis*, *Dialium* and *Swartzia* (*S. cubensis*, *S. baumia*), is characterised by predominantly narrow parenchyma bands, narrow, homogeneous xylem rays, and the storied parenchyma and rays. This is quite distinct from the other two groups. The fossil woods resembling these modern woods may be designated by the name *Dialiumoxylon* after the woods of the genus *Dialium* which constitutes the majority.

As the present fossil wood shows the anatomical characters of the first group and closely resembles *Milletia praemii*, it is assigned to the organ genus *Milletioxylon* Awasthi (1967). The only other fossil wood of *Milletioxylon* is *M. indica* (Awasthi, 1967) known from the Mio-Pliocene of Cuddalore series. It differs from the present fossil wood in possessing heterocellular xylem rays, somewhat broader parenchyma bands and storied fibres. However, the xylem rays are homocellular composed of procumbent cells and the fibres are nonstoried in the present fossil wood. Consequently, it is assigned to a new species, *Milletioxylon pongamiosensis*, the species name indicating its resemblance also with the wood of *Pongamia glabra*.

*Milletia* consists of over 130 species of climbing shrubs and trees, widely scattered throughout the tropical and subtropical regions of Africa, Indo-Malaya, China and Australia. Approximately 25 species occur in India and *Milletia praemii* with which the present fossil wood resembles most grows in Assam along the right bank of Monas and Tura-Dalu Road in Garo Hills (Kanjilal, Kanjilal & Das, 1938).

**SPECIFIC DIAGNOSIS**

*Milletioxylon pongamiosensis* sp. nov.

Wood diffuse-porous. Growth rings present. Vessels small to medium-sized, mostly solitary, often in radial multiples of 2-3 or more cells, t.d. 60-180 μ, r.d. 90-260 μ, almost always empty, 4-6 per sq mm; vessel segments storied, 300-400 μ long, usually with truncate ends; perforations simple; intervessel pits vestured, alternate, 6-8 μ in diameter with lenticular apertures. Parenchyma in thick concentric bands alternating with the fibres; strands storied, sometimes crystalliferous. Xylem rays 1-3 (mostly 2) seriate, homogeneous, storied, 10-14 per mm; cells sometimes crystalliferous. Fibres liberiform, thick walled, nonseptate, nonstoried, polygonal in cross-section and 15-20 μ in diameter. Ripple marks present due to storied parenchyma strands, rays and the vessel elements.

**Holotype** — B.S.I.P. Museum No. 18/1014.

**Dryoxylon Schleiden, 1853**

8. *Dryoxylon nahai* sp. nov.

Pl. 5, figs. 23, 24

The fossil wood consists of decorticated secondary xylem measuring 6 cm in diameter and 5 cm in length. It shows poor preservation.

**Topography** — Wood diffuse-porous. Growth rings indistinct. Vessels small to medium-sized, solitary (Pl. 5, fig. 23) and in radial multiples of mostly 2 cells, 6-9 per sq mm, sometimes plugged with gummy deposits. Parenchyma paratracheal, vasicentric to aliform-confluent (Pl. 5, fig. 23) usually forming irregular, short undulating bands in the ground tissue. Xylem rays 1-4 seriate, 15-70 μ wide and 130-600 μ high, 8-15 per mm; ray tissue homogeneous with rays composed of procumbent cells only. Fibres irregularly arranged in between the consecutive xylem rays.

**Elements** — Vessels thin walled, the walls about 4 μ thick, t.d. 50-150 μ, r.d. 75-190 μ, oval to irregular in shape owing to pressure during fossilization; vessel elements 400-450 μ long. Parenchyma cells thin walled, t.d. 8-10 μ, height 40-80 μ. Ray cells thin walled; procumbent cells 15-18
### TABLE 2

**Fossil species** | **Modern comparable species** | **Modern distribution**
--- | --- | ---

**MONOCOTYLEDONS**

<table>
<thead>
<tr>
<th>Similaceae</th>
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<tbody>
<tr>
<td>1. <em>Smilax</em> sp. Lakhanpal &amp; Dayal</td>
<td><em>Smilax macrophylla</em></td>
<td>Tropical Himalaya from Kumaon eastwards, Assam, Bengal, Chittagong, Burma, Central Provinces, Coskan</td>
</tr>
<tr>
<td></td>
<td><em>S. roxburghiana</em></td>
<td>Tropical Himalaya from Garhwal eastwards, Sylhet, Cachar, the Khasi Hills and Bihar</td>
</tr>
<tr>
<td></td>
<td><em>S. prolific</em></td>
<td>Tropical western Himalaya, Sylhet, Bengal, Bihar, Burma, Deccan Peninsula, Ceylon</td>
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</table>

**DICOTYLEDONS**

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<th>Anonaceae</th>
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<tr>
<td>2. <em>Fissistigma senii</em> Lakhanpal</td>
<td><em>Fissistigma wallichii</em></td>
<td>Bangla Desh, Assam, Sylhet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dipterocarpaceae</th>
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<tbody>
<tr>
<td>3. <em>Dipterocarpoxylon sivalicus</em> Prakash</td>
<td><em>Dipterocarpus indicus</em></td>
<td>West coast evergreen forests from North Kanara southwards; also occurs in Andamans, Assam, Burma, Bangla Desh, Cochin China &amp; Thailand</td>
</tr>
<tr>
<td>4. <em>D. malagense</em> Prakash</td>
<td><em>Dipterocarpus dyeri</em></td>
<td>Burma, Indo-China, Thailand &amp; Malaya</td>
</tr>
<tr>
<td>5. <em>D. premacrocarpum</em> Prakash</td>
<td><em>Dipterocarpus macrocarpum</em></td>
<td>Assam &amp; Burma</td>
</tr>
</tbody>
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<tr>
<th>Rhamnaceae</th>
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<tbody>
<tr>
<td>7. <em>Berchemia balugoloensis</em> Lakhanpal</td>
<td><em>Berchemia floribunda</em></td>
<td>Tropical Himalaya from Jhelum to Sikkim, Bangla Desh &amp; Khasi mountains; often grows in swampy ground; ascends up to about 1400 metres</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Leguminosae</th>
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<tr>
<td>8. <em>Dalbergia sisso</em></td>
<td><em>Dalbergia sisso</em></td>
<td>In plains through India proper ascending to 500 metres in Central Himalayas</td>
</tr>
<tr>
<td>9. <em>Albizia lebbeck</em> Prakash</td>
<td><em>Albizia lebbeck</em></td>
<td>Throughout India (except in Srid) from Indus eastwards along the sub-Himalayas to Assam, in Burma and Andamans</td>
</tr>
<tr>
<td>10. <em>Cassia fistula</em> Prakash</td>
<td><em>Cassia fistula</em></td>
<td>Throughout the forests of India, Burma &amp; Ceylon</td>
</tr>
<tr>
<td>11. <em>Cynometra polyandra</em> Chowdhury &amp; Ghosh</td>
<td><em>Cynometra polyandra</em></td>
<td>Assam, in Khasi Hills, Sylhet and Cachar</td>
</tr>
<tr>
<td>12. <em>Milletia prainii</em> Prakash</td>
<td><em>Milletia prainii</em></td>
<td>Sea coast tidal forests of Sundarbans, South India, Burma, the Andamans and Ceylon</td>
</tr>
<tr>
<td>13. <em>Lagerstroemia sp.</em> Lakhanpal &amp; Dayal</td>
<td><em>Lagerstroemia spp.</em></td>
<td>Assam along the right bank of Monas and Tura-Dalu road in Garo Hills</td>
</tr>
<tr>
<td>14. <em>Ficus procunia</em> Lakhanpal</td>
<td><em>Ficus cunia</em></td>
<td>Sub-Himalayan tracts from Chenab to Bhutan, Central India, Assam, Chittagong &amp; Burma; ascends up to an altitude of 1200 metres</td>
</tr>
</tbody>
</table>
μ in vertical height, 20-25 μ in radial length. *Fiores libriform*, thick walled, polygonal in cross section, nonseptate; interfibre pits indistinct.

**Affinities** — Because of poor preservation of the fossil wood it has not been possible to study the anatomical structures in great detail. Therefore, it is not possible to assign this fossil precisely even to any family of the dicotyledons. However, with the knowledge of the available structural details, it indicates somewhat near resemblance with the wood structure of the families Meliaceae and Leguminosae. In view of its uncertain affinities, it is proposed here to include this under the non-committal genus *Dryoxylon* Schleiden (see Schmid, 1853), till further investigation of well preserved material shows its undoubted affinities with some extant genus or family. It is specifically described as *Dryoxylon nahanai* sp. nov.

**DISCUSSION**

The Lower Siwalik beds supposed to be very rich in plant fossils have so far yielded few well preserved leaf-impresions from Balugola near Jawalamukhi and a number of fossil woods from Khokhra near Nagalgarh in Himachal Pradesh. These have been assigned to modern genera and compared closely with the extant species shown in Table 2 with their modern distribution.

Present distribution of the modern comparable forms of the fossil species indicates that most of the taxa now grow in areas where there is more atmospheric precipitation suggesting some sort of climatic change in northwestern India after the Pliocene times. The total extinction of *Dipterocarpus* from this region and its migration towards east and south in moist and humid places further suggests prevalence of drier climate in the late Siwalik period. The late Tertiary desiccation in north-western India forced the moist loving species to move towards east to Assam, Burma and adjoining areas where the climate was more favourable for their survival. This may be due to change in wind currents, orogenic movements or some sort of climatic catastrophe and will be analysed in detail when more data is forthcoming about the fossil flora of the Siwaliks.

**REFERENCES**


EXPLANATION OF PLATES

PLATE 1

1. Dipterocarpoxylon sivalicus sp. nov.—Cross-section of the fossil wood showing vessel distribution and gum canals. x 30. Slide No. 4723/118-1014

2. Dipterocarpoxylon sivalicus sp. nov.—Tangential longitudinal section of the fossil wood showing xylem rays. x 60. Slide No. 4724/118-1014

3. Dipterocarpoxylon sivalicus sp. nov.—Cross-section of the fossil wood magnified to show parenchyma distribution. x 90. Slide No. 4725/118-1014

4. Dipterocarpoxylon nalagarhense sp. nov.—Cross-section of the fossil wood magnified to show parenchyma pattern. x 90. Slide No. 4726/138-1014

PLATE 2

5. Dipterocarpoxylon nalagarhense sp. nov.—Cross-section of the fossil wood under low power showing vessel distribution and gum canals. x 30. Slide No. 4727/138-1014

6. Dipterocarpoxylon nalagarhense sp. nov.—Tangential longitudinal section of the fossil showing xylem rays. x 40. Slide No. 4728/138-1014

7. Dipterocarpoxylon premacarput sp. nov.—Cross-section of the fossil wood showing vessel distribution and gum canals. x 30. Slide No. 4722/108-1014

8. Dipterocarpoxylon premacarput sp. nov.—Tangential longitudinal section of the fossil showing xylem rays. x 50. Slide No. 4730/108-1014

PLATE 3

9. Albizziniwn eolebbekiallwn gen. et sp. nov.—Cross-section of the fossil wood showing shape, size and distribution of vessels, and parenchyma pattern. x 30. Slide No. 4731/150-1014
10. *Albizia lebbeck* - Cross-section of the modern wood showing similar shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \).

11. *Albizziuni um colebbeckianum* gen. et sp. nov. — Magnified intervessel pit-pairs. \( \times 320 \). Slide No. 4732/150-1014.

12. *Albizziuni um colebbeckianum* gen. et sp. nov. — Tangential longitudinal section of the fossil wood showing similar shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \). Slide No. 4733/150-1014.

13. *Albizzia lebbeck* — Tangential longitudinal section of the modern wood showing similar xylem rays. \( \times 65 \).

**PLATE 4**

14. *Cassinium prefistulai* gen. et sp. nov. — Cross-section of the fossil wood showing shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \). Slide No. 4734/27-1014.

15. *Cassia fistula* — Cross-section of the modern wood showing similar shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \).

16. *Cassinium prefistulai* gen. et sp. nov. — Tangential longitudinal section of the fossil wood showing xylem rays. \( \times 65 \). Slide No. 4735/27-1014.

17. *Cassinium prefistulai* gen. et sp. nov. — Magnified intervessel pit-pairs. \( \times 320 \). Slide No. 4736/27-1014.

18. *Cassia fistula* — Tangential longitudinal section of the modern wood showing xylem rays. \( \times 65 \).

**PLATE 5**

19. *Cynometroxylon indicum* Chowdhury & Ghosh — Cross-section of the fossil wood showing shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \). Slide No. 4737/39-1014.

20. *Cynometra polyandra* — Cross-section of the modern wood showing similar shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \).

21. *Cynometroxylon indicum* Chowdhury & Ghosh — Tangential longitudinal section of the fossil showing xylem rays. \( \times 65 \). Slide No. 4738/39-1014.

22. *Cynometra polyandra* — Tangential longitudinal section of the modern wood showing similar type and distribution of xylem rays. \( \times 65 \).

23. *Dryoxylon nahanai* sp. nov. — Cross-section of the fossil wood under low power to show vessel and parenchyma distribution. \( \times 30 \). Slide No. 4739/7-1014.

24. *Dryoxylon nahanai* sp. nov. — Tangential longitudinal section of the fossil wood. \( \times 75 \). Slide No. 4740/7-1014.

25. *Millettioxylon pongamiensis* sp. nov. — Cross-section of the fossil wood showing shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \). Slide No. 4741/18-1014.

26. *Millettia prainii* — Cross-section of the modern wood showing similar shape, size and distribution of vessels and parenchyma pattern. \( \times 30 \).

27. *Millettioxylon pongamiensis* sp. nov. — Tangential longitudinal section of the fossil wood showing xylem rays. \( \times 65 \). Slide No. 4742/18-1014.

28. *Millettia prainii* — Tangential longitudinal section of the modern wood showing similar type and distribution of xylem rays. \( \times 65 \).

29. *Millettioxylon pongamiensis* sp. nov. — Tangential longitudinal section of the fossil wood showing xylem rays and vessel elements. \( \times 40 \). Slide No. 4743/18-1014.

30. *Millettioxylon pongamiensis* sp. nov. — Magnified intervessel pit-pairs. \( \times 320 \). Slide No. 4742/18-1014.