FOSSIL WOODS FROM THE LOWER SIWALIK BEDS OF HIMACHAL PRADESH, INDIA

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ABSTRACT

Fossil woods resembling those of *Dipterocarpus, Albizzia, Cassia, Cynometra, Millettia* and a species of *Dryoxylon* are described in the present paper from the Lower Siwalik beds of Khokhra near Nalagarh in Himachal Pradesh. These are *Dipterocarpoxylon sivalicus* sp. nov., *D. nalagarhense* sp. nov., *D. premacrocarpum* sp. nov., *Albizzinium eolebbekianum* gen. et sp. nov., *Cassinium prefistulai* gen. et sp. nov., *Cynometroxylon indicum* Chowdhury & Ghosh, *Millettioxylon pongamiensis* 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 north-eastern 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 fluviatile 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 foot hills 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, B. verrucosa, Mallotus philippinensis* and *Rhododendron lepidotum* from the Middle Siwaliks of Darjeeling district.

In 1968 Varma described leaf-impressions from the Hardwar beds and assigned them to *Meliaceaephyllum mahagonites, Eucalyptophyllum 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 *Dipterocarpoxylon* sp. and *Bauhinioxylon 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 uninterrupted 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 — *Dipterocarpoxylon* Hold. emend Den Berger, 1927

1. *Dipterocarpoxylon 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 tailed 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 *Dipterocarpoxylon 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 *Dipterocarpoxylon chowdhurii* Ghosh (1956) and *D. kalaicharparense* Eyde (1963) from Assam, *D. malavii* Ghosh & Ghosh (1959) from Kutch, and *Dipterocarpoxylon* sp. Rawat (1964) from the Siwalik beds of Mohand in Uttar Pradesh. Of these Indian species, *Dipterocarpoxylon 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 *Dipterocarpoxylon sivalicus*. Similarly *Dipterocarpoxylon malavii* differs from *Dipterocarpoxylon 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. *Dipterocarpoxylon kalaicharparense* is also quite distinct in having large gum canals and somewhat narrower, 1-5 (mostly 3-4) seriate xylem rays. Lastly *Dipterocarpoxylon* sp. also differs from *Dipterocarpoxylon 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 *Dipterocarpoxylon* so far known from India and outside, it is described here as a new species, *Dipterocarpoxylon 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

Dipterocarpoxylon sivalicus sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* mostly large, t.d. 160-240 μ, r.d.

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 tailed 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. *Dipterocarpoxylon 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 multiseriate 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/B6891 and A1160/B6892). The size and distribution of the vessels in *Dipterocarpoxylon 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 *Dipterocarpoxyla* so far known from the Indian region, *Diptero-*

carpoxylon tertiarum Prakash (Prakash, 1965, 1973) is nearest to the present fossil in wood structure. However, it also differs from *Dipterocarpoxylon nalagarhense* in having slightly larger vessels (t.d. 135-315 μ, r.d. 150-420 μ) and in comparatively narrower, 1-8-(9) seriate xylem rays. The vessels are somewhat smaller (t.d. 105-255 μ, r.d. 150-360 μ) and the xylem rays are broader, 1-10 seriate in *D. nalagarhense*. As the fossil wood is quite different from all the species of *Dipterocarpoxylon* known till now, it is assigned to a new species, *Dipterocarpoxylon nalagarhense*, the specific name is after the name of the town Nalagarh, near which it has been discovered.

The modern species *Dipterocarpus dyeri* Pierre ex De Laness which shows closest resemblance with the present fossil wood grows in Burma, Indo-China, Thailand and Malaya Peninsula (Chowdhury & Ghosh, 1958, p. 115).

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* 1-8-9-(10) seriate, sometimes uniseriate, 16-150 μ broad, 225-1425 μ high, 4-7 per mm; ray tissue heterogeneous, rays heterocellular composed of both upright and procumbent cells; sheath cells sometimes present on the flanks of the multiseriate rays. *Fibres* libriform, thickwalled, polygonal, nonseptate. *Gum canals* vertical, single or in pairs, occasionally in short tangential rows of 3-4-(5), 90-200 μ in diameter and round to oval in shape.

Holotype — B.S.I.P. Museum No. 138/1014.

3. *Dipterocarpoxylon premacrocarpum* sp. nov.
Pl. 2, figs. 7, 8

The fossil wood consists of a single piece of petrified mature secondary xylem measuring 5 cm in length and 4 cm in dinmeter.

Topography - Wood diffuse-porous. *Growth rings* absent. *Vessels* large to medium-sized, almost always solitary (Pl. 2, fig. 7), 4-6 per sq mm, sometimes plugged with tyloses or gummy deposits. *Vasicentric tracheids* scanty paratracheal with numerous bordered pits. *Parenchyma* mostly apotracheal, paratracheal being scarcely present round the vessels (Pl. 2, fig. 7); apotracheal parenchyma diffuse occurring as 1-2 cells, sometimes also forming lines in the ground tissue and in several rows of cells forming thick sheaths around the gum canals (Pl. 2, fig. 7). *Xylem rays* moderately broad, 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, nonseptate; 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 *Dipterocarpoxylon malavii* Ghosh & Ghosh (1959) from Kutch, *D. kalaicharparense* Eyde (1963) and *D. chowdhurii* Ghosh (1956) from Assam, and *D. sivalicus* Prakash from the Lower Siwalik beds of Nalagarh described in the preceeding pages. However, all these species differ quite distinctly from the present fossil wood. Thus, *Dipterocarpoxylon malavii* differs from *Dipterocarpoxylon premacrocarpum* in having slightly bigger vessels, more abundant, diffuse to diffuse-in-aggregate parenchyma and in smaller gum canals. Similarly *Dipterocarpoxylon kalaicharparense* is also distinct from *D. premacrocarpum* in possessing larger pores and frequent, long, uniseriate extensions in the xylem rays. *Dipterocarpoxylon chowdhurii* 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 *Dipterocarpoxylon 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 *Dipterocarpoxylon* so far known, it is described here as a new species, *Dipterocarpoxylon premacrocarpum*. *Dipterocarpus macrocarpus* Vesque, the closest known species grows in Sibsagar, Lakhimpur, Naga hills in Assam, Mergui and Tenasserim in Burma (Chowdhury & Ghosh, 1958, p. 116).

SPECIFIC DIAGNOSIS

Dipterocarpoxylon 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 eolebbekianum* 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 semilibriform, 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.

A survey of all available woods of the genus *Albizzia* indicates that the nearest affinity of the fossil is with *Albizzia lebbek* Benth. (F.R.I. No. A 5445/B 1453). This survey included the study of thin sections of *Albizzia lebbek* Benth., *A. amara* Boiv., *A. lucida* Benth., *A. mollis* F. Muell., *A. molucana* Mig., *A. odorattissima* Benth., *A. procera* Benth., *A. stipulata* Biov., *A. coriaria* Welw., *A. falcata* Backer, *A. toona* Bailey, *A. zygia* Mech., *A. versicolor* Welw., ex Oliver, *A. sassa* Chiov., *A. ferruginea* Benth., and *A. lebbekioides* Benth., and published description of eleven other species. The latter are *A. montana* Benth., *A. tomentella* Miq. (Moll & Janssonius, 1914, pp. 193-195), *A. acle* (Blanco) Merr., *A. marginata* Merr., (Kanehira, 1924, p. 25; Kribs, 1959, pp. 63, 64, fig. 163), *A. gummifera* C. A. Smith, *A. caribaea* (Urban) Brit. & Rose. (Kribs, 1959, pp. 64, 65, figs. 396-397), *A. adianthifolia* (Schum.) W. F. Wight, *A. grandibracteata* Taub. (Brazier & Franklin, 1961, pp. 43, 44), *A. xanthoxylon* C. T. White & Francis (Henderson, 1953, p. 36, fig. 166), *A. chinensis* (Osb.) Merr. (Reyes, 1938, pp. 117, 118, pl. 16, fig. 1), and *A. retusa* Benth. (Schneider, 1916, pp. 116-118, pl. 2, fig. 15).

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 intervascular 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 *Albizzioxylon hyrcanicum*. 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 *Albizzioxylon* Niktin (1935) as "genus dubium". In 1960 when Ramanujam again instituted the form genus *Albizzioxylon*, he had no information about the work of Niktin. Hence, *Albizzioxylon* Ramanujam is a later homonym of *Albizzioxylon* Niktin and cannot be used according to article 64 of the International Code of Botanical Nomenclature. Besides, the name *Albizzioxylon* 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-*

cellobium, *Leucaena* and some species of *Afzelia*. 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 eolebbekianum* sp. nov.

Fossil woods assigned to *Albizzia* are *Abizzioxylon sahnii* described by Ramanujam (1960) from the Mio-Pliocene 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 nonseptate fibres in *Albizzia vantagiensis*. However, it should be noted here that the modern woods of *Albizzia*, which almost always show septate fibres, do 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 *Afzelia-Intsia*. Consequently, he transferred it to *Pahudioxylon 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 pit-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.

Genotype — *Albizzinium eolebbekianum* sp. nov.

SPECIFIC DIAGNOSIS

Albizzinium eolebbekianum sp. nov.

Wood diffuse-porous. *Growth rings* present, delimited by smaller vessels and terminal parenchyma. *Vessels* large to medium-sized, t.d. 150-300 μ, r.d. 150-330 μ, 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 pit-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 — *Cassinium* gen. nov.

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 20μ in tangential height and 40-80 μ in radial length; cells sometimes crystalliferous. *Fibres* libriform to semilibriform, polygonal in cross section, nonseptate, 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 is 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* Pellegr., while published description and figures of *Cassia fastuosa* Willd. (Kribs, 1959, p. 70, fig. 173), *C. timorensis* D. C. (Moll & Janssonius, 1914, pp. 106-107) and *C. mannii* Oliv. (Lebacq, 1957) were consulted for detailed comparison. Both in the fossil wood and the modern wood of *Cassia fistula* the vessels are small to large, solitary and similarly distributed with simple perforation plates and similar intervessel pit-pairs, the parenchyma is terminal and aliform to mostly confluent, the xylem rays are 1-4 (mostly 2-3) seriate, homogeneous to weakly heterogeneous, composed of mostly procumbent cells, and the fibres are nonseptate and thick walled. Besides, the ray and parenchyma cells are sometimes crystalliferous in both.

In 1882, Felix described a fossil wood from the ?Tertiary of Antigua and named it *Cassioxylon anomalum* as he thought it to resemble the modern wood of *Cassia speciosa*. Müller-Stoll & Mädel (1967), while working on the fossil woods of Leguminosae, re-examined the type slides of *Cassioxylon anomalum* and found that this fossil wood does not show any affinities with the genus *Cassia* and may not even belong to the family Leguminosae. Therefore, the use of the name *Cassioxylon* Felix (1882) for the fossil woods of *Cassia* is untenable and vague and need to be rejected because of different affinities of the type specimen. Consequently, Müller-Stoll & Mädel (1967) proposed the generic name *Peltophoroxylon* to include the fossil woods belonging to the extant genera *Cassia*, *Peltophorum* and *Xylia* as the modern woods of these genera are nearly similar to each other in structural details. In 1970 the author (Prakash & Awasthi, 1970, p. 37) emended its generic diagnosis so as to include all the fossil woods of *Cassia*, *Peltophorum* and *Xylia* as the previous diagnosis did not contain the anatomical features of some of the species of the above three genera. Recently a further critical examination of the modern woods of all the species of *Cassia* available to us and the thin sections and published description of *Peltophorum grande*, *P. vogelianum* Walp., *P. dasyrachis* Kurz., *P. pterocarpum* Backer., *Xylia xylocarpa*

Taub., *X. dolabiformis* Benth., and *X.evansii* Hutch (Pearson & Brown, 1932; Normand, 1950; Desch, 1957; Kribs, 1959) have shown that the genus *Cassia* can be separated from *Peltophorum* and *Xylia* by the minute details of wood structure also. Thus *Cassia siamea* and *C. aubrevillei* are quite distinct from *Peltophorum* and *Xylia* in having banded parenchyma, while *Cassia nodosa*, *C. marginata* and *C. mannii* can also be distinguished from *Xylia dolabiformis*, *X. evansii* and *X. xylocarpa* in the presence of septate fibres and somewhat different parenchyma pattern. *Peltophorum vogelianum* although possesses septate fibres like some *Cassia*, but it differs from *Cassia mannii*, *C. nodosa* and *C. marginata* in having mostly vasicentric parenchyma with some scattered cells. *Peltophorum dasyrachis* and *P. pterocarpum* have predominantly aliform parenchyma. *Cassia siamea*, *C. fistula*, *C. fastuosa* and *C. javanica* (Kanehira, 1924) can also be distinguished from *Peltophorum* in the presence of nonseptate 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, hence forth, 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 *Cassioxylon* 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, 1973; Prakash & Awasthi, 1970). These are now named as *Cassinium variegatum* (Ramanujam) comb. nov., *Cassinium borooahii* (Prakash) comb. nov., *Cassinium cassioides* (Prakash & Awasthi) comb. nov., and *Cassinium cassinodosum* (Prakash) comb. nov. All these differ quite distinctly from the present fossil wood.

Thus *Cassinium variegatum* (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. cassioides* (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, 1973) 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 nonseptate 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 nonseptate.

Genotype — *Cassinium prefistulai* sp. nov.

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, vestured, alternate, 8-10 μ in diameter with linear-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. 27/1014.

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 cm 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, 1932, p. 406), while *C. ramiflora* occurs in the sea coast tidal forests of Sunderbans, South India, Burma, the Andamans and Ceylon (Gamble, 1902).

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.

Specimen — B.S.I.P. Museum No. 39/1014.

Genus — *Millettioxylon* Awasthi, 1967

7. *Millettioxylon pongamiensis* 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 2-3 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 2-7 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, vestured, alternate, 6-8 μ in diameter with lenticular apertures (Pl. 6, fig. 30). *Parenchyma cells* (Pl. 6, fig. 27) thin walled 30-45 μ in diameter, 60-200 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, 15-20 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 *Craibia* (*C. affinis*), *Dialium*, *Swartzia*, (*S. cubensis*, *S. fistuloides*,

TABLE 1

Modern species	Anatomical Groups	Vessel Elements	Parenchyma		Xylem Rays		Fibres
		Storied	Distribution	Storied	Nature/Width	Storied	
1. *Pongamia glabra*	Group I Genus — *Millettioxylon*	+	Moderately broad bands predominant	+	Homogeneous, 1-4 (mostly 2-3) seriate	+	Moderately thick walled
2. *Millettia prainii*		+	Moderately broad bands predominant	+	Homogeneous, 1-3-(4) (mostly 2-3) seriate	+	Moderately thick walled
3. *M. pendula*		+	Moderately broad bands predominant	+	Homogeneous, 1-4 (mostly 2-3) seriate	+	Very thick walled
4. *Millettia brandisiana*	Group II Genus — *Eumillettioxylon*		Very broad bands	+	Homogeneous, 1-5 (mostly 1, 4-5) seriate	+	Thick walled
5. *M. auriculata*			Broad bands close		1-6 seriate		Thick walled
6. *M. atite*			Very broad bands	+	Homogeneous to weakly heterogeneous, 1-5 seriate	–	Very thick walled
7. *M. griffoniana*		+	Moderately broad bands	+	Homogeneous, 1-8 seriate	–	Thick walled
8. *M. laurentii*			Very broad bands	+	Homogeneous, 1-5 (mostly 3-4) seriate	+	Very thick walled
9. *M. caffra*				+	1-7 seriate	–	Very thick walled
10. *M. racemosa*			Confluent forming broad bands	–	Broad rays		Thick walled
11. *M. thompsonii*			Moderately broad bands	+	1-5 (mostly 3-4) seriate	+	Thick walled
12. *M. macrostachya*		+	Narrow aliform-confluent	+	Homogeneous, 1-7 seriate	–	Thick walled
13. *M. atropurpurea*		+	Broad aliform-confluent	+	Homogeneous, 1-4 seriate	–	Thick walled
14. *Millettia pulchra*	Group III Genus — *Dialiumoxylon*	+	Predominantly narrow bands	+	Homogeneous to heterogeneous, 1-2 (mostly 2) seriate	+	Moderately thick walled
15. *M. drastica*		+	Predominantly narrow bands	+	Homogeneous, 1-3 (mostly 2) seriate	+	Thick walled
16. *Craibia affinis*		+	Predominantly narrow bands	+	Homogeneous, 1-3 (mostly 2) seriate	+	Thick walled
17. *Dialium travancoricum*		+	Predominantly narrow bands	+	Homogeneous, 1-2 seriate	+	Thick walled
18. *D. angolense*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
19. *D. gossweilerii*		+	Predominantly narrow bands	+	Homogeneous, 1-2 seriate	+	Thick walled
20. *D. corbisieri*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
21. *D. pachyphyllum*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
22. *D. pentadrum*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
23. *D. excelsum*		+	Predominantly narrow bands	+	Homogeneous, 1-4 seriate	+	Thick walled
24. *D. zirkeli*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
25. *D. guianense*		+	Predominantly narrow bands	+	Homogeneous, 1-4 (mostly 2-3) seriate	+	Thick walled
26. *D. divaricatum*		+	Predominantly narrow bands	+	Homogeneous, 1-4 seriate	+	Thick walled
27. *D. dinklagei*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
28. *Swartzia tomentosa*		+	Predominantly narrow bands	+	Heterogeneous, 1-3 seriate	+	Thick walled
29. *S. bannia*		+	Predominantly narrow bands	+	Homogeneous, 1-3 seriate	+	Thick walled
30. *S. cubensis*		+	Predominantly narrow bands	+	Homogeneous, 1-2 seriate	+	Thick walled

S. bannia, *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.

A survey of all the available woods of *Millettia* and *Pongamia* indicates that the nearest affinity of the fossil is with *Millettia prainii* Dun., *M. pendula* Benth., and *Pongamia glabra* Vent. but more close to *Millettia prainii* Dun. (F.R.I. No. A 4379). Our survey included the study of thin sections of the woods of *Millettia atropurpurea* Benth., *M. macrostachya* Coll. & Hemsl., *M. prainii* Dun., *M. pendula* Benth., *M. pulchra* Kurz., *M. drastica* Welv. ex Baker, *M. brandisiana* Kurz., *M. auriculata* Baker., *M. racemosa* Benth., *M. caffra* Meissn., *M. thompsonii*, *M. atite*, *M. laurentii* Willd., *M. grandis*, *M. versicolor* Weliv., *Millettia* sp. and *Pongamia glabra* Vent. and published description of *Millettia laurentii* Willd. (Kribs, 1959, p. 87, fig. 413), *M. griffoniana* Baill. (Normand, 1950, pl. 53), *M. pendula* Benth., and *Pongamia glabra* Vent. (Pearson & Brown, 1932, pp. 350-351, 400-401, figs. 125, 139).

The size and distributional pattern of vessels in *Millettioxylon pongamiensis* and *Millettia prainii* are almost identical. Further both in *Millettia prainii* and *Millettioxylon pongamiensis* the perforation plates are exclusively simple, the intervascular pit-pairs are alternate, vestured 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 inculdes only the woods

of *Millettia* 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 *Eumillettioxylon* being composed of true *Millettias*. 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 *Millettias* in having slightly broader xylem rays. The third group, which comprises the woods of *Millettia pulchra*, *M. drastica*, *Craibia affinis*, *Dialium* and *Swartzia* (*S. cubensis*, *S. bannia*), 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 *Millettia prainii*, it is assigned to the organ genus *Millettioxylon* Awasthi (1967). The only other fossil wood of *Millettioxylon* is *M. indicum* (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, *Millettioxylon pongamiensis*, the species name indicating its resemblance also with the wood of *Pongamia glabra*.

Millettia consists of over 130 species of climbing shrubs and trees, widely scattered through out the tropical and subtropical regions of Africa, Indo-Malaya, China and Australia. Approximately 25 species occur in India and *Millettia prainii* 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

Millettioxylon pongamiensis 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* libriform, thick walled, non-septate, 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 nahanai* 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 120-600 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		
Similaceae		
1. *Smilax* sp. Lakhanpal & Dayal	*Smilax macrophylla*	Tropical Himalaya from Kumaon eastwards, Assam, Bengal, Chhittagong, Burma, Central Provinces, Concan
	S. roxourghiana	Tropical Himalaya from Garhwal eastwards, Sylhet, Cachar, the Khasi Hills and Bihar
	S. prolifera	Tropical western Himalaya, Sylhet, Bengal, Bihar, Burma, Deccan Peninsula, Ceylon
DICOTYLEDONS		
Anonaceae		
2. *Fissistigma senii* Lakhanpal	*Fissistigma wallichi*	Bangla Desh, Assam, Sylhet
Dipterocarpaceae		
3. *Dipterocarpoxylon sivalicus* Prakash	*Dipterocarpus indicus*	West coast evergreen forests from North Kanara southwards; also occurs in Andamans, Assam, Burma, Bangla Desh, Cochin China & Thailand
4. *D. nalagarhense* Prakash	*Dipterocarpus dyeri*	Burma, Indo-China, Thailand & Malaya
5. *D. premacrocarpum* Prakash	*Dipterocarpus macrocarpus*	Assam & Burma
Rhamnaceae		
6. *Zizyphus sivalicus* Lakhanpal	*Zizyphus incurva*	Nepal, Bhutan, Assam, Burma
7. *Berchemia balugoloensis* Lakhanpal	*Berchemia floribunda*	Tropical Himalaya from Jhelum to Sikkim, Bangla Desh & Khasi mountains; often grows in swampy ground; ascends up to about 1400 metres
Leguminosae		
8. *Dalbergia sisso*	*Dalbergia sisso*	In plains through India proper ascending to 500 metres in Central Himalayas
9. *Albizzinium eolebbekianum* Prakash	*Albizzia lebbek*	Throughout India (except in Sind) from Indus eastwards along the sub-Himalayas to Assam, in Burma and Andamans
10. *Cassinium prefistulai* Prakash	*Cassia fistula*	Throughout the forests of India, Burma & Ceylon
11. *Cynometroxylon indicum* Chowdhury & Ghosh	*Cynometra polyandra*	Assam, in Khasi Hills, Sylhet and Cachar
	C. ramiflora	Sea coast tidal forests of Sunderbans, South India, Burma, the Andamans and Ceylon
12. *Millettioxylon pongamiensis* Prakash	*Millettia prainii*	Assam along the right bank of Monas and Tura-Dalu road in Garo Hills
Lythraceae		
13. *Lagerstroemia* sp. Lakhanpal & Dayal	*Lagerstroemia* spp.	
Moraceae		
14. *Ficus precunia* Lakhanpal	*Ficus cunia*	Sub-Himalayan tracts from Chenab to Bhutan, Central India, Assam, Chhittagong & Burma; ascends up to an altitude of 1200 metres

μ in vertical height, 20-25 μ in radial length. *Fibres* 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-commital 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-impressions from Balugoloa near Jwalamukhi and a number of fossil woods from Khokhra near Nalagarh 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.

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EXPLANATION OF PLATES

PLATE 1

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

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

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

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

PLATE 2

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

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

7. *Dipterocarpoxylon premacrocarpum* sp. nov.— Cross-section of the fossil wood showing vessel distribution and gum canals. × 30. Slide No. 4729/108-1014.

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

PLATE 3

9. *Albizzinium eolebbekianum* gen. et sp. nov.— Cross-section of the fossil wood showing shape, size and distribution of vessels, and parenchyma pattern. × 30. Slide No. 4731/150-1014.

10. *Albizzia lebbek* — Cross-section of the modern wood showing similar shape, size and distribution of vessels and parenchyma pattern. × 30.

1 . *Albizzinium eolebbekianum* gen. et sp. nov.— Magnified intervessel pit-pairs. × 320. Slide No. 4732/150-1014.

12. *Albizzinium eolebbekianum* gen. et sp. nov.— Tangential longitudinal section of the fossil wood showing xylem rays. × 65. Slide No. 4733/150-1014.

13. *Albizzia lebbek* — Tangential longitudinal section of the modern wood showing similar xylem rays. × 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. × 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. × 30.

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

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

18. *Cassia fistula* — Tangential longitudinal section of the modern wood showing xylem rays. × 65.

PLATE 5

19. *Cynometroxylon indicum* Chowdhury & Ghosh — Cross-section of the fossil wood showing shape, size and distribution of vessels and parenchyma pattern. × 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. × 30.

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

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

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

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

PLATE 6

25. *Millettioxylon pongamiensis* sp. nov.— Cross-section of the fossil wood showing shape, size and distribution of vessels and parenchyma pattern. × 30. Slide No. 47-41/18-1014.

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

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

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

29. *Millettioxylon pongameinsis* sp. nov.— Tangential longitudinal section of the fossil in low power showing storied xylem rays and vessel elements. × 40. Slide No. 4743/18-1014.

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

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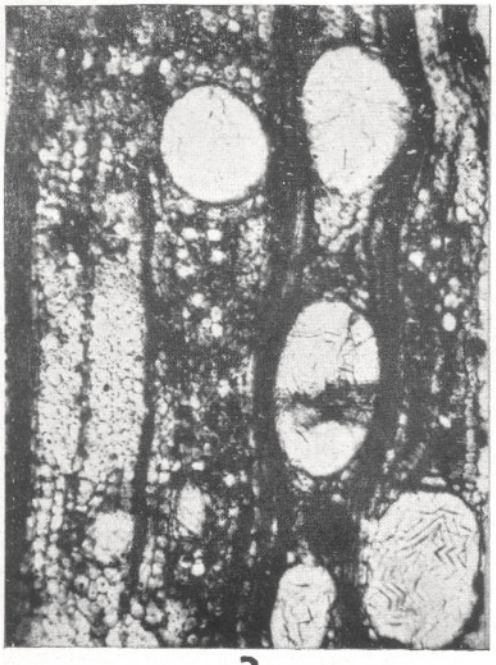

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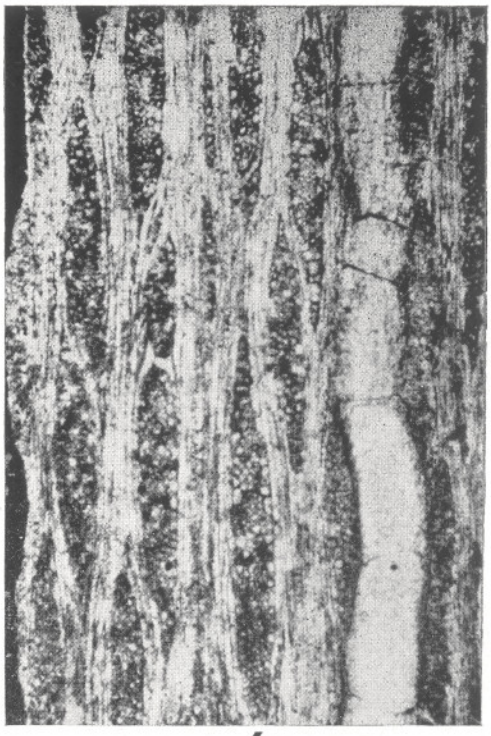

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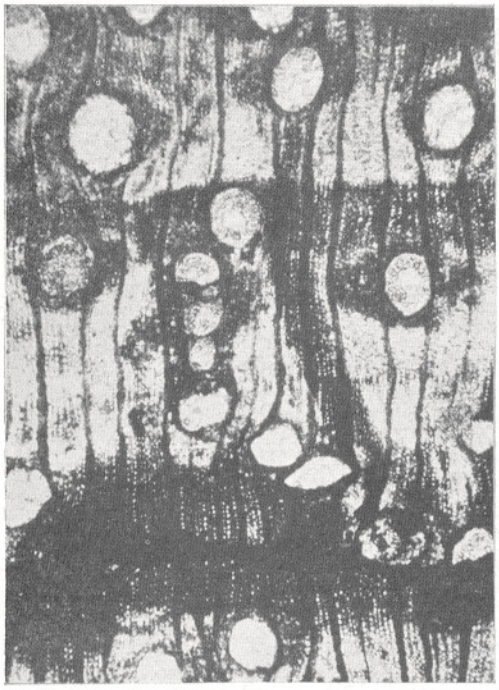

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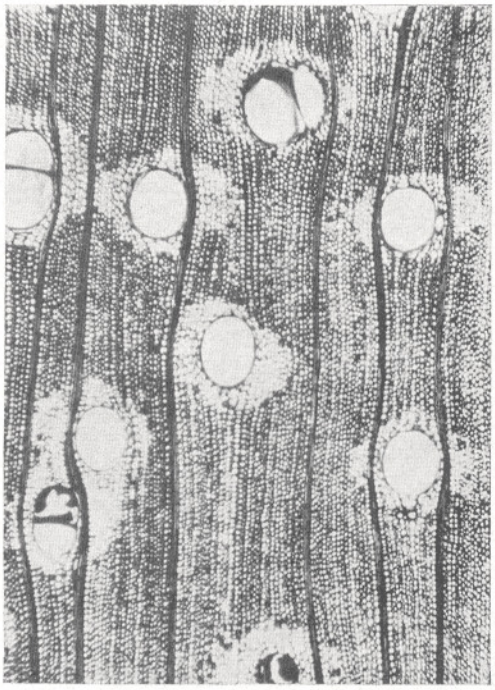

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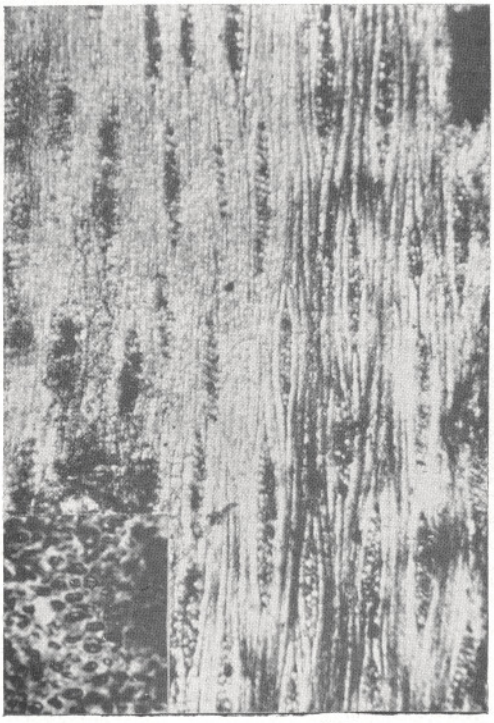

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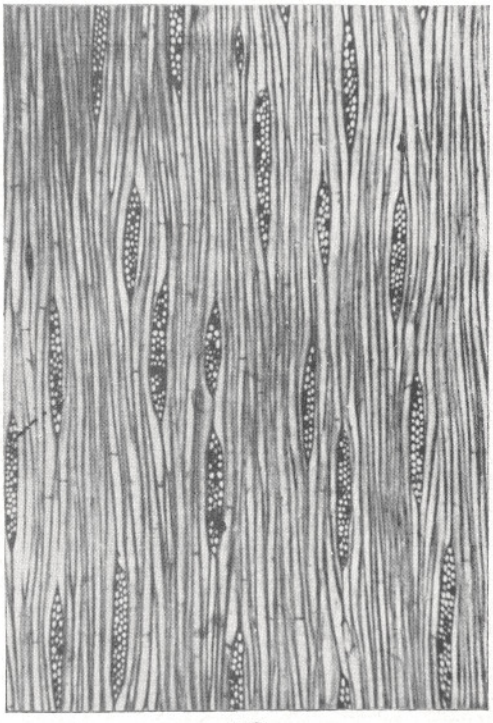

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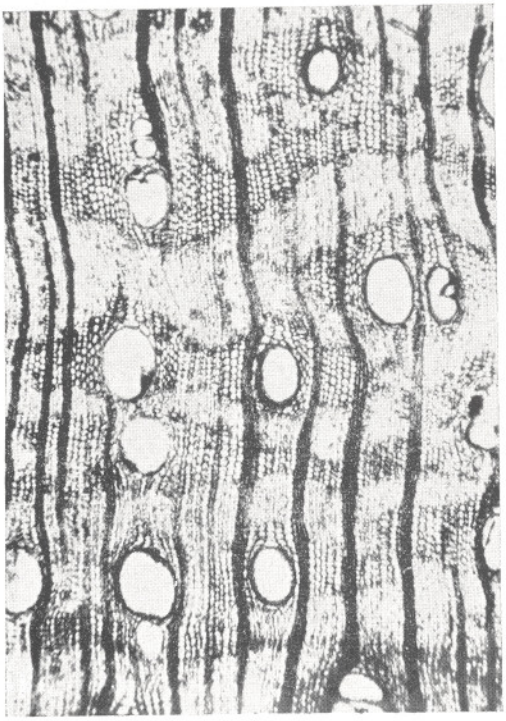

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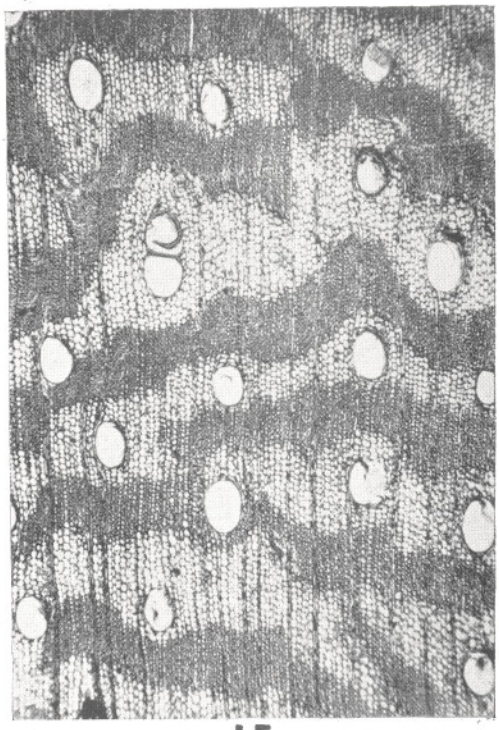

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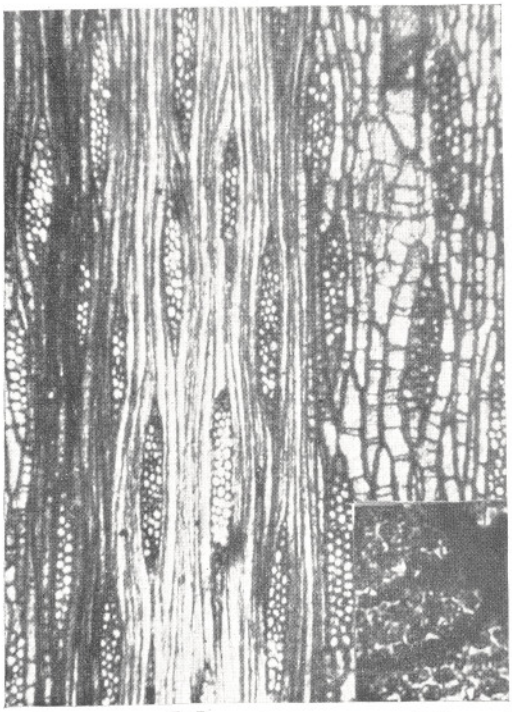

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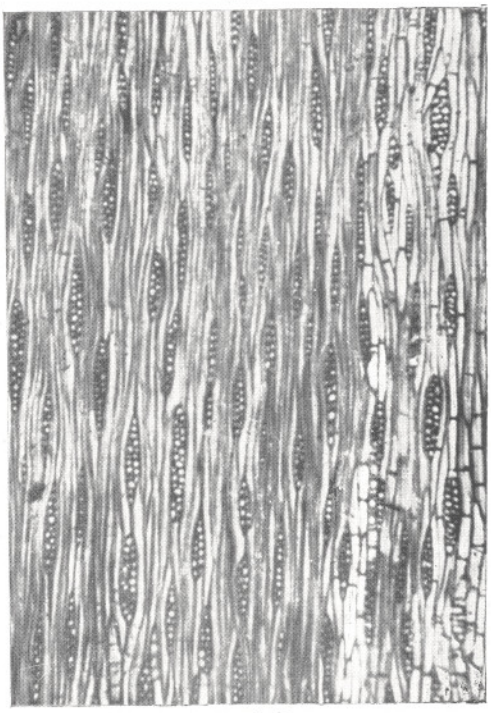

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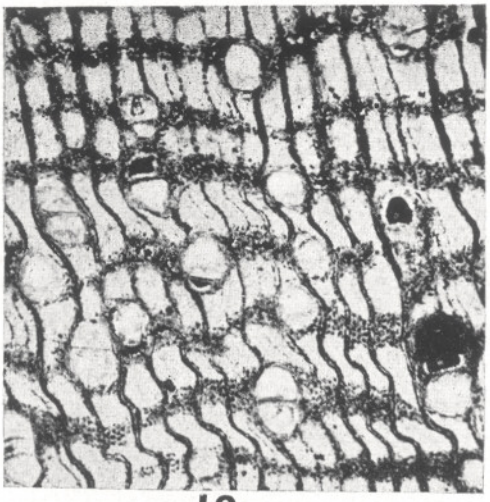

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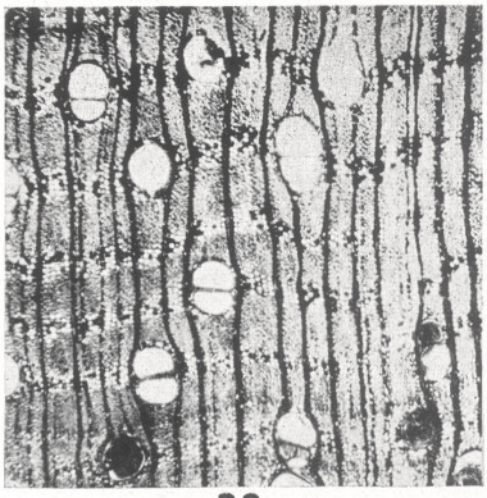

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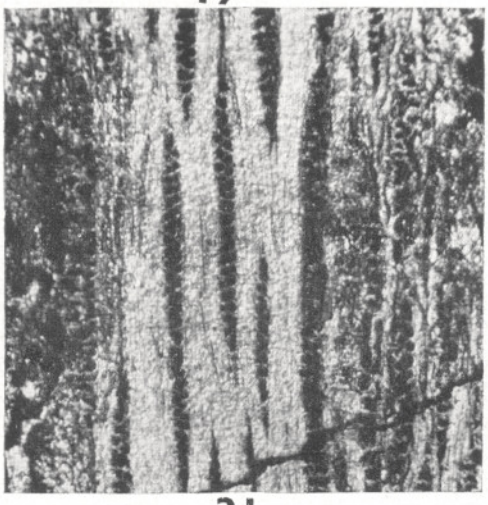

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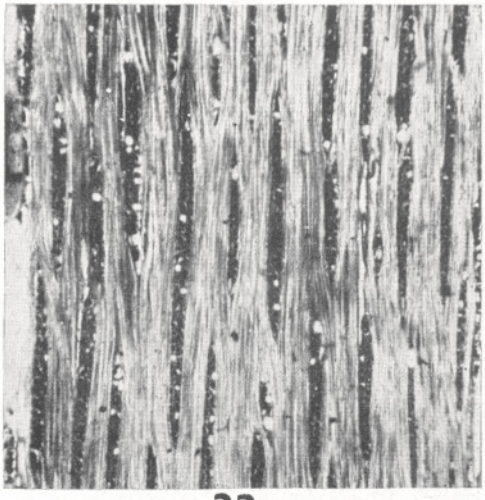

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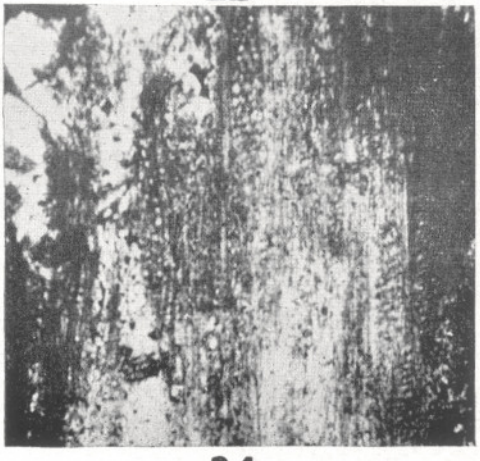

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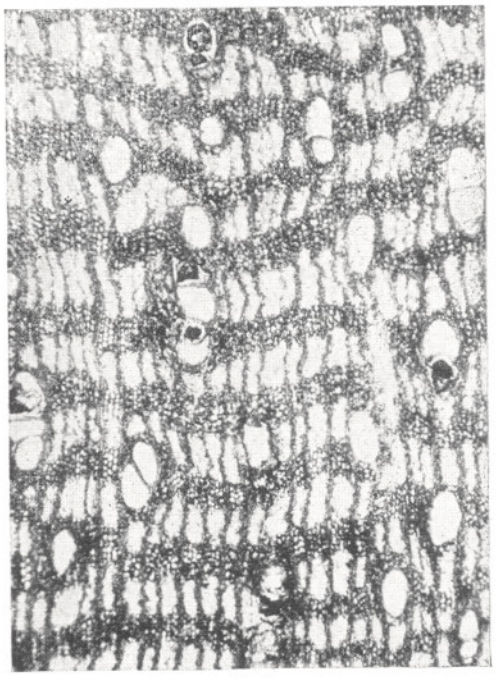

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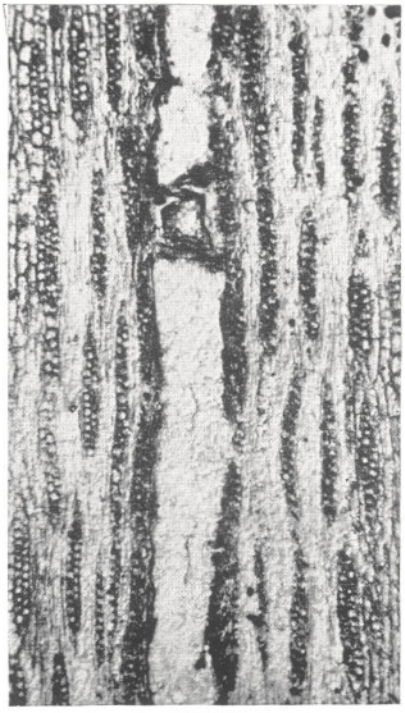

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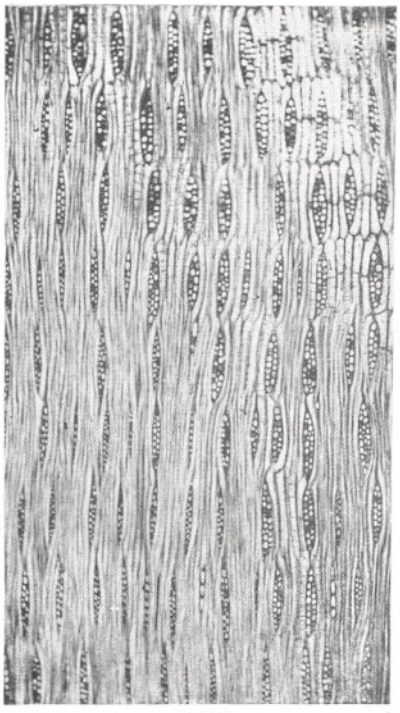

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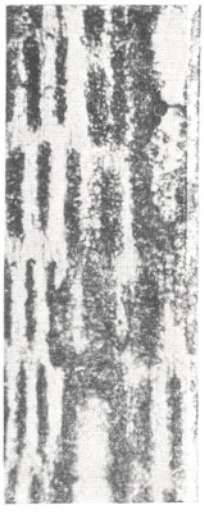

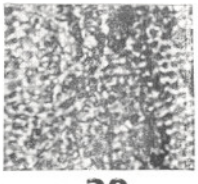

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