SOME FOSSIL DICOTYLEDONOUS WOODS FROM THE TERTIARY OF EASTERN INDIA

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ABSTRACT

Fossil woods representing the genera *Calophyllum* of Guttiferae, *Terminalia* of Combretaceae, and *Afzelia* and *Intsia* of Leguminosae have been identified from the Tertiary beds of NEFA. The wood specimens were collected from the bed of River Namsang near the headquarters of the Khonsa Forest Division at Deomali. These woods are of interest anatomically as well as from the standpoint of their palaeogeographic distribution.

INTRODUCTION

IN December 1963, a large collection of fossil woods was made from the bed of River Namsang, near the headquarters of the Khonsa Forest Division, at Deomali in Tirap Frontier Division, NEFA, with the help received from the Director of Geology and Mining, Assam, and the Director of Forests, NEFA. The present study is based only on a few specimens of this collection but it is proposed to expand the taxonomic treatment of this petrified flora as additional material is examined. Here this paper deals with the systematic description of the fossil woods belonging to the families Guttiferae, Combretaceae, and Leguminosae.

The fossil woods are Tertiary, probably Middle Miocene, in age. They appear to have been derived from the Tipam series which are exposed in the vicinity of the locality in Upper Assam. Fragments and stems of silicified in woods are known to occur quite frequently in Tipam sandstones.

In general the preservation of structural details of the woods is quite satisfactory. Some parts of the specimens are varicoloured due to iron mineral stain which makes the anatomical details clearer than in the unstained parts.

SYSTEMATIC DESCRIPTIONS

FAMILY — GUTTIFERAE

Genus — *Calophylloxylon* Lakhanpal & Awasthi 1964

Calophylloxylon eoinophyllum sp. nov.

The present species is based on a petrified secondary wood measuring about 9 cm. in length and 8-11 cm. in diameter. The preservation of the fossil wood is fairly good.

Topography — Wood diffuse-porous (PL. 2, FIG. 7). *Growth rings* absent. *Vessels* visible with the naked eye, large to medium-sized, almost always solitary, characteristically grouped in oblique radial lines (PL. 2, FIG. 7) or definite echelon arrangement, 2-5 per sq. mm., heavily occluded with thin-walled tyloses (PL. 1, FIG. 1). *Vasicentric tracheids* paratracheal, forming narrow sheath around the vessels (PL. 1, FIG. 1), sometimes interrupted by the rays, occasionally uniting proximate pores. *Parenchyma* visible with a hand lens, apotracheal in continuous or broken, rather closely spaced, slightly wavy, concentric, tangential bands (PL. 1, FIG. 1; PL. 2, FIG. 7), 2-4 (usually of 2-3) cells wide, and 26-36 or more per cm. in distribution. *Xylem rays* not visible without a hand lens, fine (PL. 1, FIG. 3), mostly uniseriate, sometimes biseriate, 20-52 μ broad, closely spaced, 10-15 per mm.; ray-tissue heterogeneous (PL. 1, FIG. 5) with rays composed of both procumbent and upright cells; uniseriate rays about 20 μ in width, variable in height, 52-675 μ and 2-16 cells high; biseriate rays formed by addition of another row of cells; ray cells with copious reddish-brown gummy infiltration, sometimes with crystals in enlarged cells (PL. 1, FIG. 3). *Fibres* appear to be arranged in distinct radial rows.

Elements — Vessels thin-walled, the walls about 4 μ thick, t.d. 180-405 μ, r.d. 180-390 μ, or even smaller, round to oval in cross-section, sometimes variously shaped due to compression during fossilization; vessel-members with truncate ends; perforations, simple; inter-vessel pit-pairs not seen. *Vasicentric tracheids* nearly as long as fibres-about 15-30 μ in diameter with numerous oval bordered pits with slit-like orifice. *Parenchyma cells* thin-walled, t.d. 16-20 μ, height 240-330 μ; cells appear to be crystalliferous. *Ray cells* thin-walled, the walls about 2 μ thick; cells variously shaped, t.d. 16-32 μ; procumbent cells with r.d. 64-120 μ, vertical height 20-45 μ; upright

cells r.d. 30-45 μ, vertical height 45-75 μ. *Fibres* slightly thick-walled with big lumina (TEXT-FIG. 1), the walls about 2-3 μ thick, non-septate, angular in cross-section, t.d. 8-20 μ, r.d. 10-18 μ; inter-fibre pits not seen.

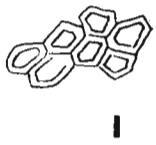
Affinities — Two important structural features of the present fossil wood are the almost exclusively solitary vessels with a marked oblique pattern and the presence of vasicentric tracheids with conspicuous bordered pits. The oblique arrangement of vessel distribution is so limited among the dicotyledonous woods (METCALFE & CHALK, 1950) that most of them are eliminated and the comparison of the fossil wood could be made only with the members of the following families which possess this character:

Anacardiaceae	Myoporaceae
Betulaceae	Myrtaceae
Bignoniaceae	Myrsinaceae
Burseraceae	Ochnaceae
Calycanthaceae	Olacaceae
Casuarinaceae	Oliniaceae
Compositae	Papaveraceae
Datiscaceae	Passifloraceae
Dipterocarpaceae	Pittosporaceae
Epacridaceae	Quinaceae
Erythroxylaceae	Rhamnaceae
Escalloniaceae	Rubiaceae
Euphorbiaceae	Rutaceae
Fagaceae	Rosaceae
Guttiferae	Salicaceae
Hypericaceae	Sapotaceae
Juglandaceae	Sapindaceae
Lauraceae	Simaroubaceae
Leguminosae	Sonneratiaceae
Meliaceae	Umbelliferae
Moraceae	Zygophyllaceao

The vasicentric tracheids, which also characterize this Assam fossil wood, are present only in some of the families, a list of which has already been given by Metcalfe & Chalk (1950, p. 1351). A study of these families indicates that this character together with the oblique pattern of vessels is restricted only to the following few families:

Casuarinaceae	Ochnaceae
Compositae	Olacaceae
Dipterocarpaceae	Quinaceae
Fagaceae	Rutaceae
Guttiferae 'B'	Sapotaceae
Hypericaceae	Simaroubaceae
Lauraceae	Zygophyllaceae
Myrtaceae	

In the above families, solitary and large to medium-sized vessels so characteristic of this wood are present only in Guttiferae, Dipterocarpaceae, Myrtaceae, Casuarinaceae and Fagaceae.



TEXT-FIG. 1 — *Calophylloxylon eoinophyllum* sp. nov., Magnified fibres in cross-section × 300.

The family Dipterocarpaceae stands quite apart and can easily be eliminated because of the presence of normal vertical gum canals in the wood.

Myrtaceae, Casuarinaceae and Fagaceae, on the other hand, on closer comparison with the fossil wood, also differ from it in the nature of xylem rays and the parenchyma pattern. Lastly, it is only in the family Guttiferae that the present fossil wood shows resemblance with the wood structure of the genera *Calophyllum* and *Mesua*. These two genera show a remarkable similarity in structural details of the secondary xylem, despite much divergence in other morphological features. However, a detailed anatomical comparison indicates that the closest affinities of the fossil wood are with the mature secondary xylem of the modern genus *Calophyllum* L. The wood of *Mesua* can be distinguished from that of *Calophyllum* in having extremely thicker-walled fibres with small lumina, which is hardly visible even under high magnification, as opposed to thinner-walled fibres in *Calophyllum*. Also in *Mesua* the tyloses are sometimes abundant and sclerosed, whereas the *Calophyllum* always possesses thin-walled tyloses. Moreover, the parenchyma bands are much more closely placed in *Mesua* as compared to *Calophyllum*, in which the bands are as a rule widely and irregularly spaced.

A survey of all the available woods of the genus *Calophyllum* indicates that the closest resemblance of the fossil is with *C. inophyllum* L. (PL. 1, FIGS. 1, 2, 3, 4). Our survey included the study of thin sections of the woods of 18 species of this genus, viz., *Calophyllum amoenum* Wall., *C. kunstleri* King, *C. polyanthum* Wall., *C. spectabile* Willd., *C. tomentosum* Wight, *C. venustum* King, *C. wightianum* Wall., *C. inophyllum* L., *C. blancoi* Pl. & Tr., *C. costatum* F. M. Bailey, *C. pulcherrimum* Wall., *C. brasilience* Camb., *C. wallichianum* Pl. & Tr., *Calophyl-*

lum sp. (Java), *Calophyllum* sp. (Sandakan), *Calophyllum* sp. (kuala-Lumpur) and *Calophyllum* sp. (Singapur), and their published descriptions (KANEHIRA, 1924a, p. 2, 1924b, p. 3; PEARSON & BROWN, 1932, pp. 44-54, FIGS. 17-21; METCALFE & CHALK, 1950, pp. 175-177, FIGS. 43 I & K; CHOWDHURY & GHOSH, 1958, pp. 70-73, FIGS. 57-63; KRIBS, 1959, p. 45, FIGS. 137-138; BRAZIER & FRANKLIN, 1961, p. 38; HENDERSON, 1953, FIG. 120; MOLL & JANSSONIUS, 1906, pp. 272-278, FIG. 34). In addition to this published descriptions and figures of *Calophyllum hasskarlii* Teijsm. et Binn. ex Planch. et Triana, *C. venulosum* Zoll., *C. teysmanni* Miq. (MOLL & JANSSONIUS, 1906, pp. 278-282) and *C. saigonense* Pierre (LECOMTE, 1926, PL. 38) were also consulted. The species *Calophyllum inophyllum* which resembles the present fossil wood, shows some variation in its wood structure especially in the parenchyma pattern and the xylem rays. An examination of the thin sections of the wood of *C. inophyllum* taken from the wood samples from Kuala-Lumpur, Malaya; Manila, Philippines; Hokkaido, Japan; Queensland, Australia, and India shows that the parenchyma bands are continuous or broken, thin to thick (upto 6 cells broad), both closely and widely placed (PL. 1, FIGS. 2, 6) and the rays are usually uniseriate to sometimes biseriate. There is a close resemblance of this fossil wood with the wood structure seen in the wood specimens from India (F.R.I. No. A 1942, B 2257) and Philippines (F.R.I. No. F 293, p. 1) but more so with the latter.

The size and distribution of vessels in the present fossil wood nearly agree with the distributional pattern in the modern wood of *Calophyllum inophyllum*. Both in *C. inophyllum* and in the fossil species the perforations are simple, the vessels are thin-walled, tylosed and more or less similar in shape. However, due to compression during fossilization the vessels are often elliptical or variously shaped in the fossil.

The distribution of parenchyma appears to be almost identical in both, as is the structure of the fibres. The parenchyma bands are thinner, usually 2-3 seriate, closely spaced, continuous or broken and sinuous. In both, the parenchyma cells are crystalliferous.

Also, the xylem rays of the fossil wood and *C. inophyllum* are basically similar, the ray tissue being heterogeneous in nature and the rays are usually uniseriate, sometimes biseriate, the cells occasionally containing crystals. In both the rays are more or less equally high but sometimes slightly longer rays are seen in the fossil wood.

The general agreement, as well as numerous microscopic details of anatomical structure, provide sufficient evidence to identify this Assam fossil wood as belonging to the genus *Calophyllum*. Since the present fossil wood shows strong resemblance with the extant species *C. inophyllum*, it is being assigned to the genus *Calophylloxylon* Lakhanpal & Awasthi (1964) and described as *C. eoinophyllum*, the specific name indicating its geological antiquity.

The species *C. inophyllum* with which the present fossil wood shows strong resemblance, is a moderate-sized tree in most localities, attaining a large size in S. Tenasserim. It is found along the coast above high water mark and in the mangrove forest of Burma, down the West Coast from Konkan southwards, along the Orissa Coast, common in Tenasserim and in the Andamans (PEARSON & BROWN, 1932, p. 45).

With the available data known to the author, the fossil record of the genus *Calophyllum* from India and abroad is very meagre. So far it is known by two fossil woods from the Tertiary beds of South Arcot district, Madras in South India (LAKHANPAL & AWASTHI, 1964) and the fruits nearly comparable to that of *Calophyllum trapezifolium* from the Eocene of Fullers' earth bed at Kapurdi in Rajasthan (LAKHANPAL & BOSE, 1951).

The two fossil woods of *Calophyllum* are *Calophylloxylon indicum* and *C. cuddalorense* which show marked differences from the present fossil wood. Thus *C. indicum* differs from *C. eoinophyllum* in having smaller vessels and in somewhat thicker (2-7 seriate) tangential bands of parenchyma which are usually widely spaced. Similarly, *C. cuddalorense* also differs from the present fossil wood in possessing thicker (2-9 seriate) parenchyma bands and in vessels which show a tendency to be arranged in groups. Crystalliferous parenchyma strands and enlarged crystalliferous ray cells seen in *C. eoinophyllum* are not recorded from both the fossil woods of *C. cuddalorense* and *C. indicum*.

SPECIFIC DIAGNOSIS

Calophylloxylon eoinophyllum sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* large to medium-sized, t.d. 180-405 μ, r.d. 180-390 μ, thin-walled, exclusively solitary, characteristically arranged in oblique radial lines, circular to oval, sometimes variously shaped due to compression during fossilization, 2-5 per sq. mm.; tyloses abundant, thin-walled; perforations simple; vessel-members with truncate ends. Vessel-tracheid pits many, oval with wide border and short slit-like horizontal to slightly oblique orifice. *Vasicentric tracheids* paratracheal forming narrow sheath around the vessels; pits similar to vessel-tracheid pits. *Parenchyma* apotracheal in continuous or broken, closely spaced, sinuous, concentric, tangential bands, usually 2-3 cells thick; bands 26-36 per cm.; cells crystalliferous, thin-walled, t.d. 16-20 μ, height 240-330 μ. *Xylem rays* 1-2 (mostly 1-) seriate, sometimes biseriate formed by addition of another row of cells, 20-52 μ broad and 2-16 cells high, closely spaced, 10-15 per mm.; ray-tissue heterogeneous with rays composed of both procumbent and upright cells; ray cells with copious reddish brown gummy infiltration, sometimes with crystals in enlarged cells. *Fibres* aligned in radial rows, angular in cross-section, non-libriform, slightly thick walled with big lumina, walls 2-3 μ thick, non-septate; inter-fibre pits not seen.

Holotype — B.S.I.P. Museum No. 33743.

Locality — Bed of the River Namsang near the Divisional Forest Office, at Deomali, in Tirap Frontier Division, NEFA.

Horizon — Probably washed away from Tipam sandstones.

Age — Tertiary (Middle Miocene).

FAMILY — COMBRETACEAE

Genus — *Terminalioxylon* Shönfeld 1947

Terminalioxylon tertiarum sp. nov.

The structural features recorded here are from a piece of decorticated secondary wood measuring 15 cm. in length and 6·6-12 cm. in diameter. The preservation of the anatomical features in the present fossil wood is quite satisfactory so as to enable the author to record even the minute structural details.

Topography — *Wood* diffuse-porous (Pl. 4, Fig. 17). *Growth rings* not very conspicuous, delimited by smaller vessels and sometimes by a narrow line of terminal parenchyma. *Vessels* visible as pin holes to the naked eye, their orifices clearly seen with a hand lens, evenly distributed, large to medium-sized and rarely small, mostly solitary often in radial multiples of 2-4 cells (Pl. 2, Fig. 10; Pl. 4, Fig. 17); 2-7 per sq. mm., mostly empty or occasionally plugged with brownish black gummy deposits; tyloses present in some vessels. *Parenchyma* apotracheal and paratracheal; apotracheal parenchyma both as diffuse, restricted to occasional cells in the fibrous tract, and terminal occurring at some of the growth rings in 1-2 cells thick, broken lines; paratracheal parenchyma mostly as narrow, vasicentric sheath round the pores (Pl. 2, Fig. 10; Pl. 3, Fig. 16), often aliform and occasionally confluent. *Xylem rays* indistinct to the naked eye, clearly seen under the microscope, fine (Pl. 2, Figs. 8 & 11), 1-2 (mostly uniseriate) cells and 12-36 μ wide, usually short, 44-855 μ high, 10-15 per mm.; ray tissue homogeneous with rays composed of procumbent cells only; uniseriate rays quite common, 2-29 cells and 44-855 μ high (usually short); biseriate rays up to 36 μ wide and 450 μ high. The rays show some variation in structure; they are short to long at most of the places, and usually composed of squarish to rectangular cells (Pl. 2, Fig. 11), while at some places they are small and crowded formed of rounded to oblong cells (Pl. 2, Fig. 8). *Fibres* aligned in distinct radial rows between the two consecutive rays. *Intercellular canals* traumatic, vertical (Pl. 4, Fig. 17), embedded in parenchymatous tissue and arranged in tangential rows at infrequent intervals, about 100-400 μ in diameter.

Elements — *Vessels* thick-walled, walls about 8 μ thick, t.d. of solitary vessels 125-270 μ, r.d. 150-390 μ, oval to elliptical and irregular in cross-section due to pressure during fossilization, those in radial multiples slightly flattened at the places of contact; vessel-members short to medium-sized, 150-450 μ long, usually with truncate ends; perforations simple; inter-vessel pit-pairs vestured (Text-fig. 2), alternate to sub-opposite, 8-10 μ in diameter; vessel-parenchyma pits and vessel-rays pits not preserved. *Parenchyma cells* thin-walled,

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TEXT-FIG. 2 — *Terminalioxylon tertiarum* sp. nov., Vestured intervessel pit-pairs × 680.

mostly with reddish-brown gummy infiltration, t.d. 10-20 μ, height 32-100 μ; crystals present? *Ray cells* thin-walled with brownish black deposits; cells all procumbent of various shapes and sizes as seen in tangential sections, square, rectangular and oval to round in shape, t.d. 20-48 μ, vertical height 18-40 μ, radial length 52-90 μ; enlarged crystalliferous cells commonly present (PL. 2, FIGS. 8, 11). *Fibres* not very well preserved, thin-walled (PL. 2, FIG. 10; PL. 3, FIG. 16), polygonal to variously shaped in cross-section, t.d. 10-24 μ, r.d. 8-20 μ, often septate; interfibre pits not seen.

Affinities — The traumatic vertical canals and the vestured intervessel pit-pairs characteristic of the present fossil wood are so limited in distribution among the dicotyledons that the comparison of the fossil is restricted only to few families. According to Record (1936, pp. 18-19) and Metcalfe & Chalk (1950, p. 1353) traumatic vertical canals are known to occur in the wood of the members of following families:

Ampelidaceae	Malvaceae
Bombacaceae	Moringaceae
Boraginaceae	Myrtaceae
Burseraceae	Proteaceae
Combretaceae	Rosaceae
Elaeagnaceae	Rutaceae
Elaeocarpaceae	Sapindaceae
Euphorbiaceae	Simaroubaceae
Hamamelidaceae	Sterculiaceae
Lecythidaceae	Styraceae
Leguminosae	Vochysiaceae

In the families listed above, vestured inter-vessel pits are found only in Euphorbiaceae, Leguminosae, Myrtaceae, Vochysiaceae and Combretaceae (METCALFE & CHALK, 1950, p. 1350). A detailed comparison of these families with the structural features of the fossil wood indicates that the wood of the genus *Terminalia* L. of the family Combretaceae exhibits similar combination of anatomical characters as shown by the fossil and the closest resemblance of the fossil within this genus is with *Terminalia tomentosa* and *T. myriocarpa* but more so with the former (PL. 2, FIGS. 8-11; PL. 3, FIGS. 12-15). Our survey included the study of thin sections of the woods of sixteen Indian species of *Terminalia*, viz., *T. tomentosa* Wight et Arn., *T. travancorensis* Wight et Arn., *T. oliveri* Brandis, *T. paniculata* Roth, *T. procera* Roxb., *T. pyrifolia* Kurz, *T. arjuna* Wight et Arn., *T. angustifolia* Roxb., *T. bellerica* Roxb., *T. bialata* Steud., *T. catappa* L., *T. chebula* Retz., *T. citrina* Roxb. ex Flem., *T. manii* King, *T. myriocarpa* Heurch et Muell. and about a dozen foreign species, viz., *Terminalia triptera* Stapf, (Siam), *T. comintana* (Balco.) Merrill (Manila), *T. edulis* F. Muell. (Philippines), *T.* sp. (Java), *T. altissima* A. Chev. (Ivory Coast), *T. amazonia* (Gmel.) Exell. (Equader), *T. brownii* Fresen. (*T. cycloptera* R. Br.) (Uganda), *T. superva* Engl. & Diels (Belgian Congo), *T. ivorensis* A. Chev. (French Africa) and *T. catappa* L. from Philippines. Besides, published descriptions of these (MOLL & JANSSONIUS, 1914, pp. 368-373 & 375-377, FIG. 187; PEARSON & BROWN, 1932, pp. 497-537, FIGS. 168-179; KANEHIRA, 1924a, pp. 11-12, FIG. 4; KANEHIRA, 1934b, pp. 32, 33; CHOWDHURY, 1932, pp. 14, 15, PLS. 23, 24, 25; CHOWDHURY, 1939, PL. 4, FIGS. 1-4; CHOWDHURY, 1945, p. 20, PL. 9; NORMAND, 1960, pp. 291-293, PL. 126; KRIBS, 1959, pp. 28-31, FIGS. 103-106, 109-111 & 354; HENDERSON, 1953, FIGS. 65-72) and seven other species of *Terminalia*, viz., *T. nitens* Presl, *T. oocarpa* Merrill, *T. calamansanai* Rolfe (KANEHIRA, 1924b, pp. 32, 33), *T. januarensis* DC., *T. guyanensis* Eich. (KRIBS, 1959, pp. 29, 30, 31, FIGS. 107, 354), *T. javanica* Miq., *T. teysmannii* Koord. et Valet. (MOLL & JANSSONIUS, 1914, pp. 374, 375, 377-378, FIG. 188) has also been consulted.

The fossil wood shows strong resemblance with the wood of *Terminalia tomentosa* in the size and distributional pattern of vessels, in the inter-vessel pit-pairs, in the type of perforation plates, in the parenchyma distribution and in the nature of xylem rays and the fibres. However, the fossil wood differs from the extant wood of this species in the absence of terminal parenchyma at all the growth rings. The traumatic gum canals of the fossil wood are similar to those present in the modern wood of *T. myriocarpa* in which the terminal parenchyma is like that of the fossil wood.

Terminalia tomentosa with which the present fossil wood compares most, is probably the most widely distributed of all the important Indian trees. It is found in the west from Kangra in the Punjab to Assam in the east, and southwards in the Peninsula to Travancore, except in the arid zones of Punjab, Sind, and Rajputana. It occurs all over Burma, except in the North Shan States, Arakan and South Tenasserim, where it is scare (PEARSON & BROWN, 1932, p. 519).

Only eleven fossil woods showing resemblance to the genus *Terminalia* are so far known. These are *Terminalioxylon naranjo*, Schönfeld (1947) and *T. porosum*, Schönfeld (1947) from the Tertiary of Columbia, South America, *T. annamiense*, Boureau (1950) from the Pliocene of Indochina, *T. edengense*, Boureau (1955) from Late Eocene of Sahara, *T. fezzanense*, Boureau (1958) from the Tertiary of the desert of Calancho in Africa, *T. mortandrense*, Navale (1956), *T. sahnii*, Navale (1956), *T. felixi*, Ramanujam (1956) and *T. speciosum*, Ramanujan (1956) from the Tertiary (Mio-Pliocene) of South Arcot district, in South India, *T. chowdhurii* Prakash & Navale (1963) from the Tertiary of Assam and the fossil wood of *Terminalia tomentosa* from the Tertiary of Burma (CHOWDHURY & TANDON, 1964). All these fossil woods differ quite markedly from the present fossil wood in a number of characters which have been summarized in the accompanying Table 1.

It is evident from the above comparison that the present fossil wood belongs to the genus *Terminalia* and is quite distinct from all the species of *Terminalioxylon* so far known. As such it is assigned to a new species, *Terminalioxylon tertiarum* sp. nov., the specific name indicating the age of the fossil wood.

SPECIFIC DIAGNOSIS

Terminalioxylon tertiarum sp. nov.

Wood diffuse-porous. *Growth rings* not very conspicuous, delimited by smaller vessels and sometimes by a narrow line of terminal parenchyma. *Vessels* large to medium-sized, t.d. of solitary vessels 125-270 μ, r.d. 150-390 μ, mostly solitary, often in radial multiples of 2-4 cells, oval to elliptical in shape, often irregular in cross-section due to pressure during fossilization, thick-walled, mostly empty, sometimes tylosed, occasionally plugged with resinous or gummy deposits, 2-7 per sq. mm.; vessel-members short to medium-sized, 150-450 μ long usually with truncate ends; perforations simple; intervascular pit-pairs vestured, alternate to sub-opposite, 8-10 μ in diameter. *Parenchyma* both paratracheal and apotracheal; paratracheal mostly as vasicentric sheath around the pores, often aliform and occasionally confluent; apotracheal parenchyma occurring as 1-2 seriate lines at some of the growth rings; also diffuse as occasional cells in the fibrous tract; cells thin-walled, t.d. 10-20 μ, height 32-100 μ; crystals present? *Xylem rays* fine, 1-2 (mostly 1) seriate and 12-36 μ broad, 10-15 per mm.; ray tissue homogeneous with rays composed of procumbent cells only; uniseriate rays quite common, usually short, 2-29 cells and 44-855 μ high; biseriate rays upto 36 μ wide and 450 μ high; cells thin-walled, square, rectangular, oval or round in shape as seen in tangential section; t.d. 20-48 μ, vertical height 18-40 μ, radial length 52-90 μ; enlarged crystalliferous cells commonly present. *Fibres* non-libriform, often septate, thin-walled, polygonal in cross-section, t.d. 10-24 μ, r.d. 8-20 μ. *Intercellular canals* traumatic, vertical, embedded in parenchymatous tissue and arranged in tangential rows at infrequent intervals, 100-400 μ in size.

Holotype — B.S.I.P. Museum No. 33744.

Locality — Bed of the River Namsang, near the Divisional Forest Office, at Deomali, in Tirap Frontier Division, NEFA.

Horizon — Probably washed away from Tipam sandstones.

Age — Tertiary (Middle Miocene).

FAMILY — LEGUMINOSAE

Genus — *Pahudioxylon* Chowdhury, Ghosh & Kazmi 1960

Pahudioxylon sahnii Ghosh & Kazmi 1961

The petrified wood described here consists only of secondary xylem measuring about 13 cm. in length and 4-4·5 cm. in diameter. It is brownish black in colour and shows excellent preservation in the anatomical details. As the fossil was picked up from the bed of a river, it is in the form of a small elliptical pebble, very smooth alround.

Topography — *Wood* diffuse-porous (PL. 4, FIG. 21). *Growth rings* indistinct with the naked eye, delimited by smaller vessels

TABLE 1

Species	Growth rings	Vessels	Parenchyma	Xylem rays	Fibres	Traumatic gum canals	Locality	Age
1. *Terminalioxylon naranjo* Schönfeld (1947)		Diffuse, large to medium-sized, t.d. 100-160 μ, solitary, and also in radial groups, elliptical in shape	Abundant; vasicentric (4-seriate), aliform to confluent	Mostly uniseriate, 20-25 cells in height; ray tissue homogeneous	Libriform, non-septate	Absent	Columbia, S. America	Tertiary
2. *Terminalioxylon porosum* Schönfeld (1947)		Diffuse, large to medium-sized, t.d. 150-300 μ, solitary, sometimes in radial groups, oval in shape	Abundant; diffuse and aliform, (2-3 layered), confluent	Mostly uniseriate, 20-40 cells in height; ray tissue heterogeneous	Libriform, non-septate	Absent	Colombia, S. America	Tertiary
3. *Terminalioxylon annamense* Boureau (1950)	Slightly marked	Diffuse, tendency to oblique arrangement, medium-sized to large, t.d. 150-300 μ, usually solitary, rarely in radial groups of 2-3, oval in shape	Vasicentric to aliform (4-seriate) and in apotracheal bands containing vertical canals; cells crystalliferous.	1-2 seriate, 3-20 cells in height; ray tissue nearly heterogeneous	Libriform and non-septate	Vertical arranged in tangential bands, 200-400 μ in diameter	Indo-China	Tertiary (Pliocene)
4. *Terminalioxylon edengense* Boureau (1955)	Delimited by parenchyma bands	Diffuse, usually medium-sized, av. t.d. 100-200 μ, mostly solitary, rarely in pairs and occasionally 3 or 4; intervessel pit-pairs vestured	Abundant; vasicentric to aliform (2-5 seriate) and in apotracheal bands (prob. initial) about 20 cells broad together with 1-3 concentric bands of 3-5 cells thick	Mostly uniseriate, locally biseriate, 8-40 cells high; ray tissue heterogeneous	Libriform with simple pits	Vertical arranged in broad tangential parenchyma bands, very large, 360-1450 μ in diameter	Sahara, North-Africa	Post Eocene
5. *Terminalioxylon felixi* Ramanujam (1956)	Indistinct, delimited by initial parenchyma	Diffuse, medium-sized, 130-250 μ, mostly solitary, occasionally in radial groups of 2-3, circular; intervessel pits fairly large, vestured	Not abundant; initial, diffuse and vasicentric to aliform (1-3 seriate)	Almost exclusively uniseriate, 2-20 cells in height; ray tissue weakly heterogeneous; cells crystalliferous	Libriform, considerably thick walled	Absent	Mortandra, South India	Tertiary (Mio-Pliocene)
6. *Terminalioxylon speciosum* Ramanujam (1956)	Absent	Diffuse, medium to large, 180-270 μ in diameter, solitary, oval to round; intervessel pits-pairs vestured, fairly large	Abundant; diffuse and vasicentric to aliform (2-6 seriate), sometimes confluent	1-2 seriate, with uniseriates predominant and biseriates fairly common, 2-25 cells high; ray tissue weakly heterogeneous	Libriform, non-septate	Absent	Tiruchitambalam and Mortandra, South India	Tertiary (Mio-Pliocene)
7. *Terminalioxylon mortandrense* Navale (1956)	Not visible	Diffuse, medium-sized, 140-170 μ, generally solitary, sometimes in radial groups of 2-3, round; intervessel pit-pairs vestured	Quite abundant; vasicentric to aliform (5-6 seriate), occasionally confluent	Uniseriate, 10-20 cells high; ray tissue homogeneous; cells crystalliferous	Non-libriform, septate	Absent	Mortandra, South India	Tertiary (Mio-Pliocene)
8. *Terminalioxylon sahnii* Navale (1956)	Not visible	Diffuse, medium-sized, 110-140 μ, generally solitary, oval to elliptical; intervessel pit-pairs minute, vestured	Abundant; vasicentric aliform and confluent forming 5-6 layered tangential bands.	Uniseriate, 20-40 cells high; ray tissue homogeneous; cells sometimes crystalliferous	Thick, non-septate	Absent	Mortandra, South India	Tertiary (Mio-Pliocene)
9. *Terminalioxylon fezzanense* Boureau (1958)	Present, delimited by initial or terminal parenchyma bands	Diffuse, medium-sized, av. t.d. 100-200 μ, mostly solitary very rarely in radial groups of 2-3 or even 4-5, oval in shape; intervessel pit-pairs vestured	Quite abundant; vasicentric (upto 4-seriate) to aliform and in initial or terminal parenchyma bands with traumatic gum canals	Mostly uniseriate, very exceptionally biseriate, 26 cells high; ray tissue heterogeneous; cells crystalliferous	Libriform non-septate	Vertical associated with tangential parenchyma bands	Calancho, North Africa	Eocene to Oligocene
10. *Terminalioxylon chowdhurii* Prakash & Navale (1963)	Absent, delimited by terminal parenchyma	Diffuse, medium-sized to large, 171 μ in t.d. solitary as well as in multiples of 2 or more, round to elliptic; intervessel pit-pairs small and vestured	Quite abundant; terminal, diffuse and mostly vasicentric (2-4 seriate) to aliform, sometimes confluent	Mostly uniseriate, sometimes locally bicelled, 2-18 cells high; ray tissue homogeneous; cells crystalliferous	Thin to thick-walled, septate	Absent	Barail Reserve, Cachar Hills, Assam	Middle Tertiary
11. *Terminalia tomentosa* W. & A. (Chowdhury & Tandon, 1964)	Present, delimited by fine bands of initial parenchyma	Diffuse, large, t.d. 272 ± 5 μ, mostly solitary, sometimes in radial groups of 2-3; intervessel pit-pairs vestured	Abundant; initial, diffuse and vasicentric to aliform or confluent	Mostly uniseriate, rarely biseriate; cells sometimes crystalliferous	Non-libriform, non-septate	Absent	Central Burma	Mio-Pliocene
12. *Terminalioxylon tertiarum* Prakash sp. nov.	Not very conspicuous, delimited by smaller vessels and sometimes by terminal parenchyma	Diffuse, large to medium-sized, t.d. 125-270 μ, mostly solitary often in radial multiples, oval to elliptical; intervessel pit-pairs vestured	Not abundant; terminal, diffuse and mostly vasicentric, aliform and occasionally confluent	Mostly uniseriate, sometimes 2-seriate, 2-29 cells high; ray tissue homogeneous; enlarged crystalliferous cells present	Non-libriform often septate	Vertical, arranged in tangential rows, 100-400 μ in size	Deomali, NEFA	Tertiary (Probably Mio-Pliocene)

and narrow line of terminal parenchyma (PL. 4, FIG. 21). *Vessels* appearing as minute dots with the naked eye, the orifices easily distinguishable without a hand lens, large to medium-sized and small, mostly solitary (PL. 4, FIG. 21), sometimes in radial multiples of 2-3 cells, 2-3 or rarely 4 per sq. mm., usually with the rays contiguous on one or both the sides; brownish black contents sometimes seen in the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma mostly aliform sometimes with short wing-like extensions, often confluent joining 2-3 or 4 adjacent vessels (PL. 4, FIG. 21); parenchyma sheath 2-5 seriate round the vessels; apotracheal parenchyma only of terminal type, delimiting the growth rings by forming well-defined narrow lines. *Xylem rays* not visible with the naked eye, somewhat clear with a hand lens, fine, 1-3 (mostly 2) seriate (PL. 4, FIG. 19), very rarely triseriate, 12-48 μ broad, closely spaced, 7-11 per mm.; ray tissue homogeneous (PL. 4, FIG. 18) with rays composed of procumbent cells only; uniseriate rays about 12 μ in width, 2-10 cells and 36-180 μ high; biseriate rays fusiform, 5-16 cells and 112-288 μ high; rays sometimes show tendency towards storied arrangement (PL. 4, FIG. 22). *Fibres* show somewhat radial alignment.

Elements — *Vessels* thin-walled, the walls about 4 μ thick, t.d. 65-210 μ, r.d. 70-320 μ, circular to oval when solitary, those in radial multiples flattened at the places of contact; vessel-members 165-360 μ long with truncate, tapered or slightly tailed ends; perforations simple; inter-vessel pit-pairs vestured (PL. 4, FIG. 20), round to oval, 4-6 μ in diameter, alternate to sub-opposite; vessel-parenchyma pits similar to inter-vessel pitting, many per cell, vessel-ray pits not observed. *Parenchyma* cells thin-walled, t.d. 20-24 μ, height 76-168 μ; crystalliferous strands present (PL. 4, FIG. 18); parenchyma strand 2-4 celled. *Ray cells* thick-walled, the walls about 4 μ thick; procumbent cells variously shaped, t.d. 16-28 μ, r.d. 40-64 μ. *Fibres* moderately thick-walled with big lumina, the walls 4 μ thick, non-septate (PL. 4, FIGS. 19); angular in cross-section; t.d. 10-20 μ, r.d. 12-24 μ; inter-fibre pits could not be seen.

Affinities — Chowdhury, Ghosh & Kazmi (1960) instituted the generic name *Pahudioxylon* to include the fossil woods of the genus *Pahudia*. According to them the wood of *Pahudia* can be distinguished from the woods of *Afzelia* and *Intsia* by the absence of septate fibres. Recently while investigating the present fossil wood, thin sections of the modern woods of the species of *Afzelia*, *Intsia* and *Pahudia*, with whom this fossil showed near resemblance, were examined. This study showed that the secondary xylem is so similar in the genera *Afzelia*, *Intsia* and *Pahudia* that the three genera cannot at present be separated from each other on the wood structure alone. Therefore, the statement of Chowdhury, Ghosh & Kazmi (1960, p. 25) that *Afzelia* and *Intsia* differ from *Pahudia* in having septate fibres is erroneous and seems to be based on the examination of unauthenticated material of the extant wood.

It is to be pointed out here that in 1950 Léonard transferred all the species of the genus *Pahudia* Miq. to the genus *Afzelia* Smith as " the two genera are taxonomically identical and the genus *Afzelia* Smith has priority over *Pahudia* Miq.". Thereforre, only *Afzelia* and *Intsia* occur in the modern flora and these cannot be separated from each other by the anatomical structure of their secondary xylem. In view of this the generic name *Pahudioxylon* is misleading and if the authors had known the publication of Léonard (1950) such mistake would not have occurred. However, we cannot reject this name in view of the Article 62 of the International Code of Botanical Nomenclature (LANJOUW, *et al.*, 1961), which reads, " a legitimate name or epithet must not be rejected merely because it is inappropriate or disagreeable, or because another is preferable or better known, or because it has lost its original meaning ". Therefore, the generic name *Pahudioxylon* Chowdhury, Ghosh & Kazmi should, henceforth, be used for the woods of *Afzelia* and *Intsia* which are inseparable.

The present fossil wood from the bed of the River Namsang of NEFA, resembles *Pahudioxylon sahnii* (GHOSH & KAZMI, 1961) to which it is being assigned here. It, however, shows somewhat shorter xylem rays than *Pahudioxylon sahnii* from Tripura, and this is due to the anatomical variation that usually occurs in the wood of a plant. From a survey of the thin sections of modern woods of *Afzelia* and *Intsia* at the Forest Research Institute, Dehra Dun, it is evident that the fossil wood shows close resemblance

to the wood of *Intsia* (*Afzelia*) *bijuga*. (F. R. I. No. B 103, A 3720.

In India only *Intsia* (*Afzelia*) *bijuga* and *Afzelia retusa* are found. *Intsia bijuga* occurs in the tidal coast forests of Bengal, the Andaman islands and Burma, while *Afzelia retusa* is found in the coast forests of Sunderbans and the Andamans (GAMBLE, 1902).

Besides the present fossil wood, two more fossil woods of the genus *Pahudioxylon* are so far known. These are *P. bankurensis* Chowdhury, Ghosh & Kazmi (1960) from the Tertiary of West Bengal and *P. arcotense* Navale (1963) from the Tertiary (Mio-Pliocene) rocks of the Cuddalore series near Pondicherry. *P. bankurensis* differs from *P. sahnii* in having mostly 2-3 seriate xylem rays which are higher than the fossil wood and in having more often the aliform-confluent type of parenchyma. In *P. sahnii* the xylem rays are mostly biseriate and short and the parenchyma is mostly aliform.

The fossil wood *Pahudioxylon arcotense* described by Navale (1963) differs very widely from the present fossil wood and does not appear to belong to the genera *Afzelia* and *Intsia* at all. The xylem rays of *P. arcotense* are up to 5-seriate and do not show any tendency for storied arrangement as against 1-3 seriate rays found in the genera *Afzelia* and *Intsia*, where the storied tendency is sometimes seen. Also the parenchyma pattern of *P. arcotense* somewhat differs from the parenchyma distribution in *Afzelia* and *Intsia*.

Another fossil wood showing close resemblance to the genus *Afzelia* is assigned to *Leguminoxylon afzelioides* by Boureau (1952) from the South Annam. Although resembling the present fossil wood in some characters, this wood also differs from it mainly in possessing broader, 1-4 (mostly 3) seriate xylem rays which do not show any storied tendency.

As Ghosh & Kazmi (1961) did not give any diagnosis for the species, *Pahudioxylon sahnii*, it is being given below, taking into consideration the details given by them.

SPECIFIC DIAGNOSIS

Pahudioxylon sahnii Ghosh & Kazmi

Wood diffuse-porous. *Growth rings* distinct, delimited by smaller vessels and narrow line of terminal parenchyma. *Vessels* large to medium-sized and small, t.d. 65-210 μ or slightly more, r.d. 70-320 μ, mostly solitary, sometimes in radial multiples of 2-3 cells, circular to oval when solitary, mostly empty, 2-4 per sq. mm.; vessel-members 165-360 μ long with truncate, tapered or slightly tailed ends; perforations simple; intervascular pit-pairs vestured, round to oval, 4-6 μ in diameter, alternate to sub-opposite; vessel-parenchyma pits many per cell and similar to intervessel pitting. *Parenchyma* terminal and mostly aliform with short wing-like extensions, often confluent usually joining 2-3 vessels; parenchyma strands 2-4 celled, crystalliferous strands present. *Xylem rays* fine 1-3 (mostly 2) seriate, 12-48 μ broad, 7-11 per mm.; ray tissue homogeneous with rays composed of procumbent cells only; uniseriate rays 2-10 cells and 36-180 μ high; biseriate rays fusiform, 5-16 or more cells and 112-288 μ or more in height; storied tendency present. *Fibres* moderately thick-waled with big lumina, non-septate, angular in cross-section, t.d. 10-20 μ, r.d. 12-24 μ.

Specimen — B.S.I.P. Museum No. 33745.

Locality — Bed of the River Namsang near Divisional Forest Office at Deomali, in Tirap Frontier Division, NEFA.

Horizon — Most probably washed away from the Tipam sandstones.

Age — Tertiary (Middle Miocene).

DISCUSSION

Modern species of *Calophyllum*, *Terminalia*, *Afzelia* and *Intsia* grow either in the immediate vicinity or at most within a distance of few hundered miles from the fossil locality of Deomali in NEFA. *Calophyllum* is a large genus of trees which occurs in the tropics of both hemispheres but the majority are found in India and South-east Asia. There are about 80 species of trees of which nearly a dozen species are indigenous in the Indian region (India, Pakistan, Burma, Ceylon and the Andamans) but only five species are found in India proper. Best known of the Asiatic species are *C. inophyllum* and *C. tomentosum* while the principal American species is *C. brasiliense* (GREENE, 1932; RECORD & HESS, 1943; WILLIS, 1957; CHOWDHURY & GHOSH, 1958). The genus *Terminalia*, on the other hand, comprising about 200 species of shrubs and medium-size to very large trees, is of

MAP 1 — Geographic distribution of the fossil *Calophylloxylon* (×), *Pahudioxylon* (△) and *Terminalioxylon* (●).

pantropical distribution (RECORD & HESS, 1943). At least 16 species, mostly important trees of large size occur in the Indian region (GAMBLE, 1902). The genera *Afzelia* and *Intsia*, with which one of our fossil wood shows anatomical resemblance, are known to occur in Africa, Asia, Malaysia and Polynesia. A study of the fossil record of the above genera as indicated by their fossil woods (*see* pp. 9, 16, 17 & 22) shows that it conforms more or less the same pattern of distribution (Map 1) as is found in the modern flora.

The existence during the Upper Tertiary of these three genera, characteristically mesophytic forest trees, and their presence in the modern flora of that region, indicates that there appears little or no change in the climatic or ecological conditions of Eastern India since the late Tertiary times. A further study of this flora, which is bound to throw more light on the past vegetation of this region, its trend of migration and a number of other related problems, is in progress and will be dealt with in a subsequent paper when the flora and its ecological significance is more fully known.

ACKNOWLEDGEMENTS

The author wishes to acknowledge his sincere appreciation and thanks to Dr. S. K. Borroah, Director of Geology and Mining, Assam, and Mr. P. B. Kar, Director of Forests, NEFA, who very kindly gave all possible help in the collection of these fossil woods. Thanks are also due to Mr. K. Ramesh Rao, Officer-incharge, Wood Anatomy Branch, F.R.I., Dehra Dun, for sending the photograph of tangential section of *Terminalia tomentosa* and for many facilities given at the Institute.

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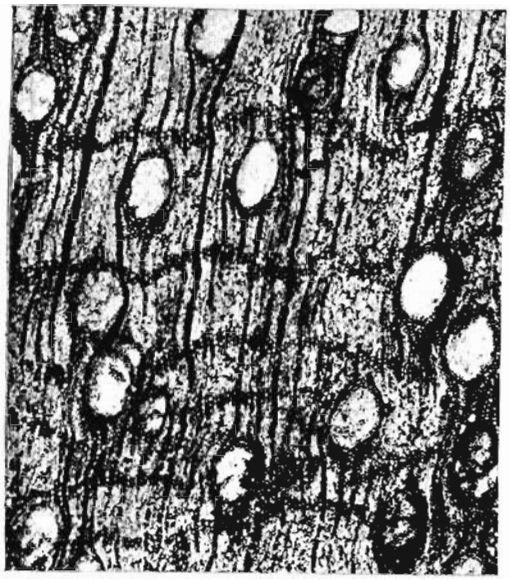

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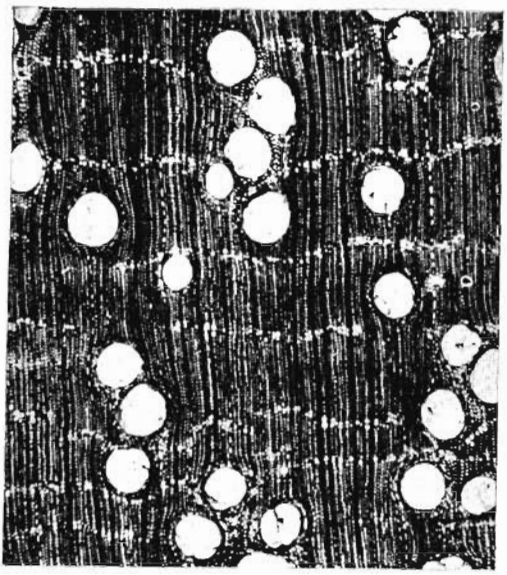

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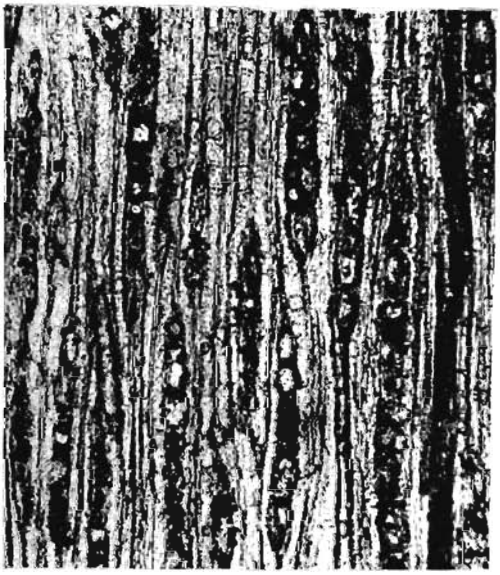

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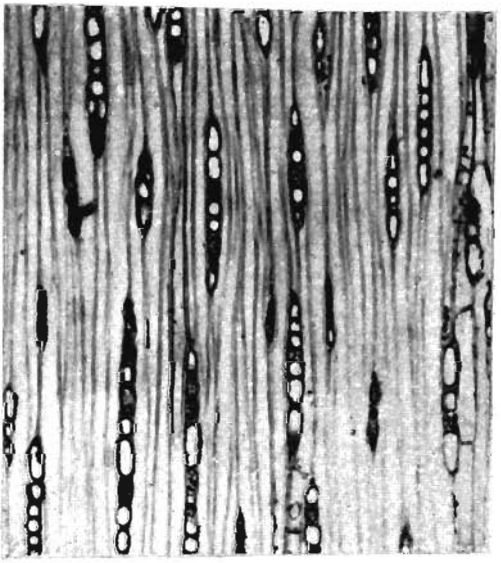

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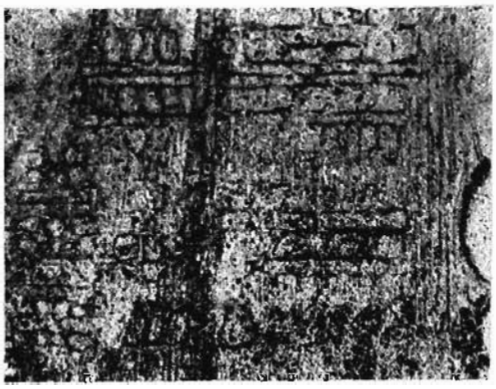

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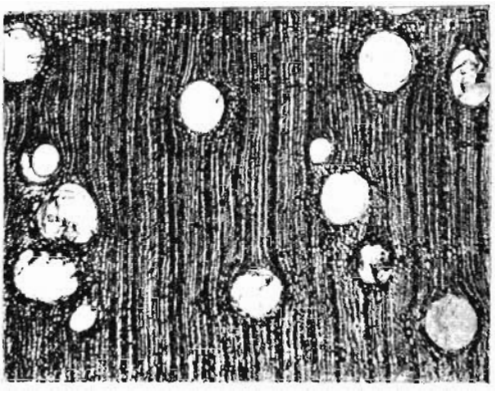

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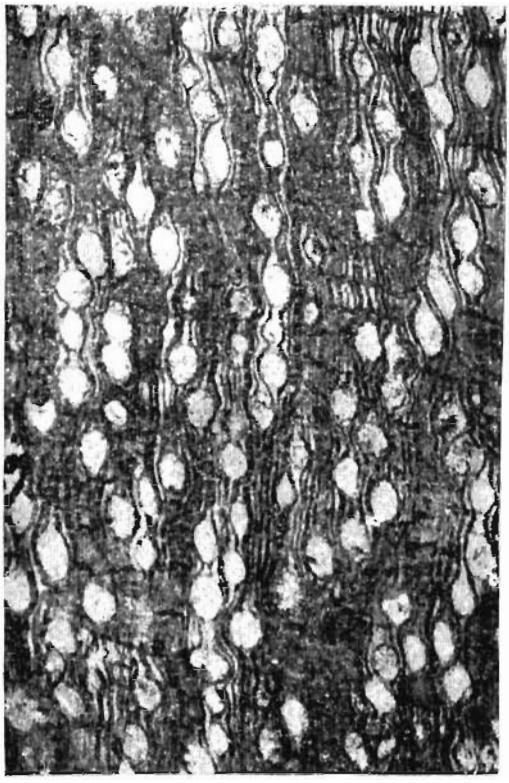

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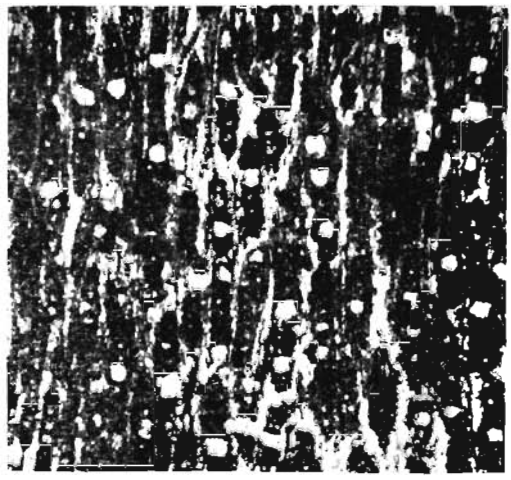

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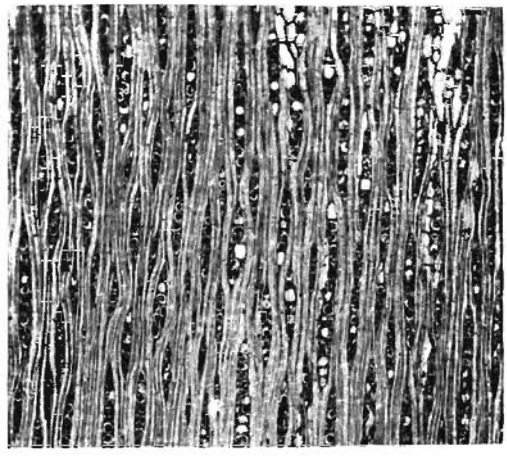

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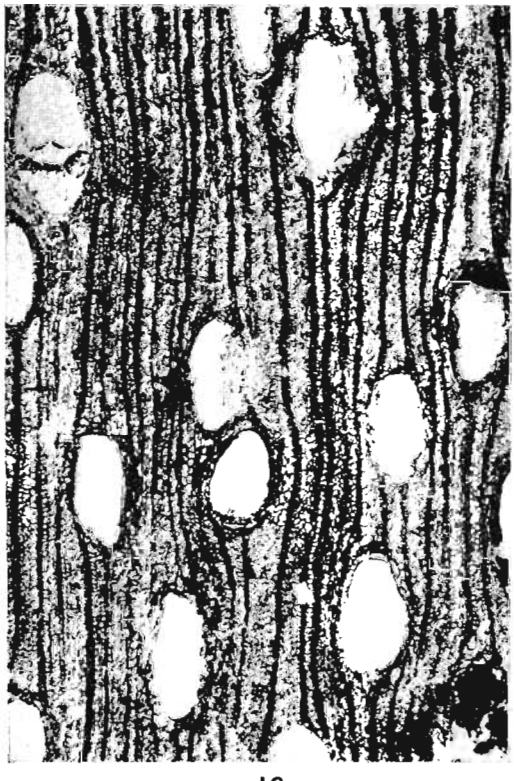

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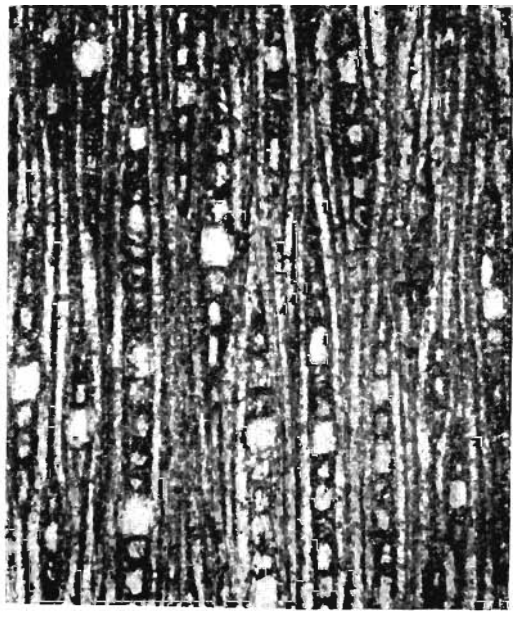

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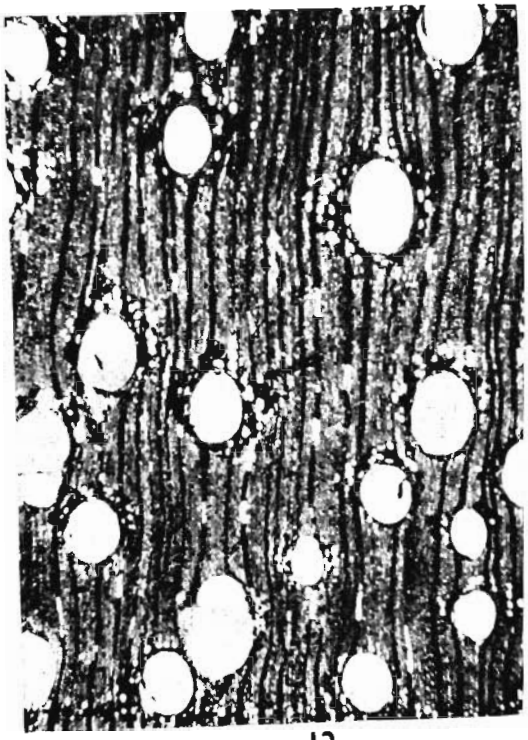

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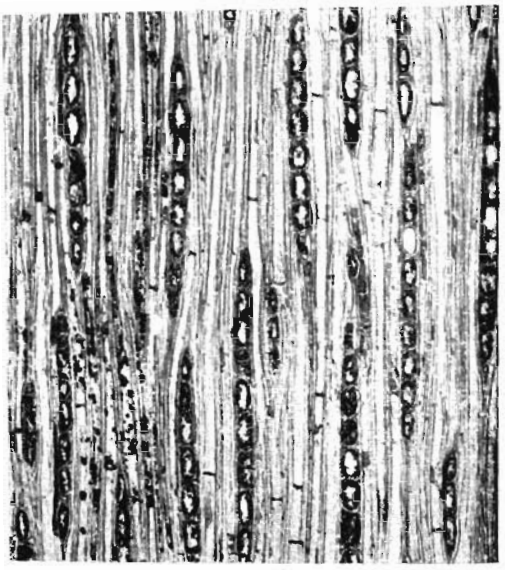

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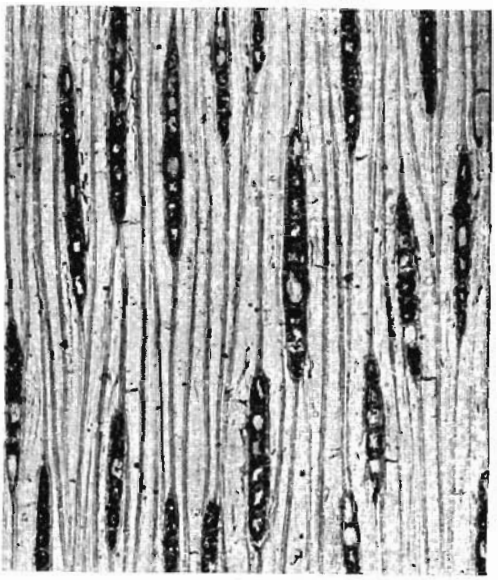

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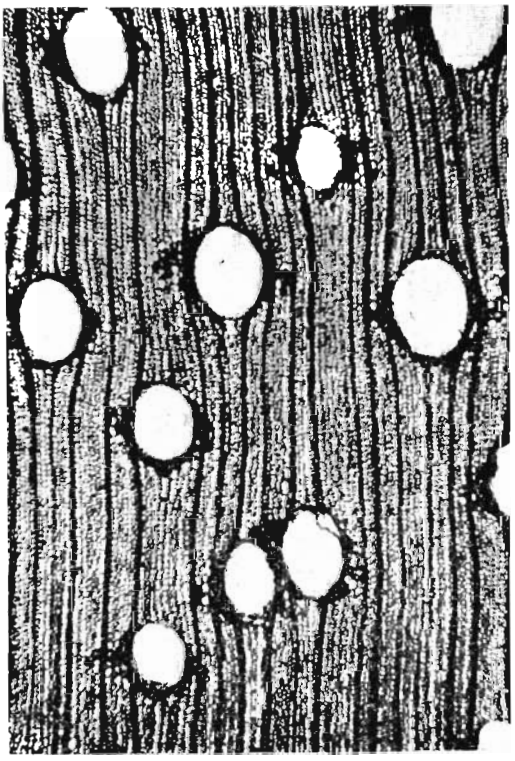

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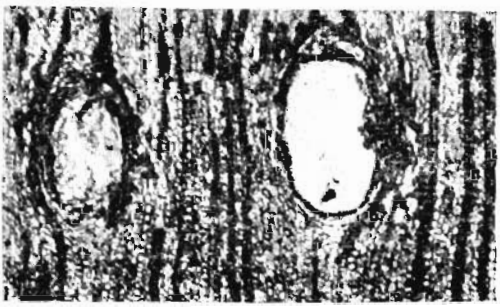

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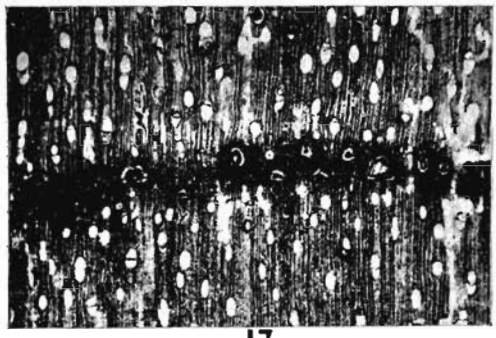

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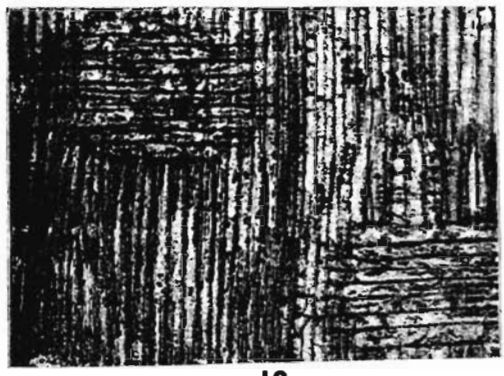

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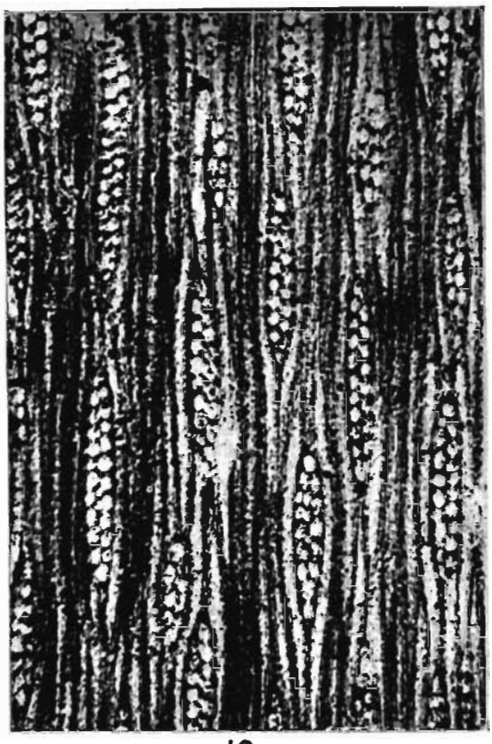

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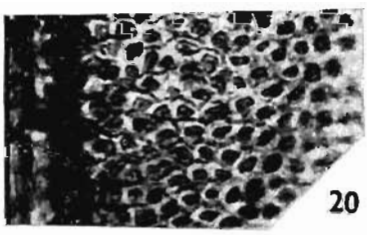

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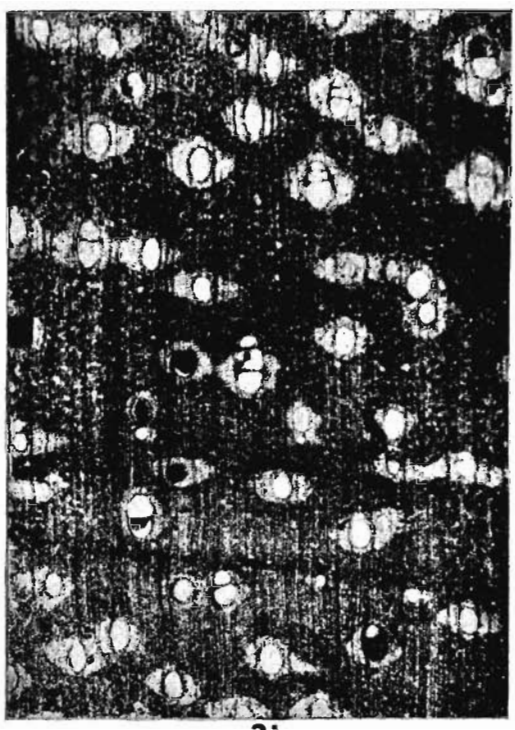

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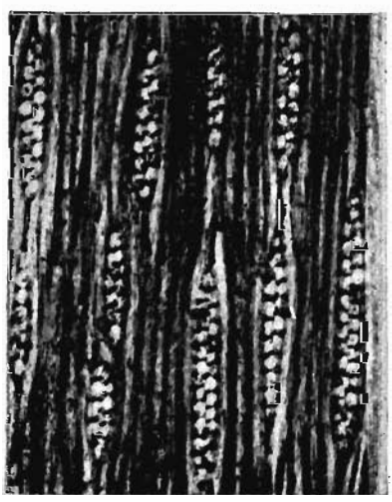

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EXPLANATION OF PLATES

PLATE 1

1. *Calophylloxylon eoinophyllum* sp. nov. Transverse section of the wood. × 28. Note the close agreement in major structural features of the modern wood shown in Fig. 2.

2. *Calophyllum inophyllum*. Transverse section of the wood. × 28.

3. *Calophylloxylon eoinophyllum*. Tangential section of the wood. × 130. Note shape and size of the xylem rays similar to the modern wood shown next.

4. *Calopphyllum inophyllum*. Tangential section of the wood. × 130.

5. *Calophylloxylon eoinophyllum*. Radial section to show the nature of xylem rays. × 80. Note heterogeneous ray tissue.

6. *Calophyllum inophyllum*. Transverse section of the wood. × 28. Note widely spaced tangential parenchyma bands as against closely spaced bands seen in Fig. 2.

PLATE 2

7. *Calophylloxylon eoinophyllum*. Transverse section of the wood in low power. × 15. Note the vessel and parenchyma distributions.

8. *Terminalioxylon tertiarum* sp. nov. Tangential section of the wood. × 60. Note closely placed short xylem rays with crystalliferous cells. A close resemblance between this and the xylem rays of the modern wood of *Terminalia tomentosa* shown in Fig. 9 is quite marked.

9. *Terminalia tomentosa*. Tangential section of the wood to show the rays. × 60.

10. *Terminalioxylon tertiarum*. Transverse section of the wood. × 43. Note similarity in structural features with the modern wood shown in Figs. 12 & 15.

11. *Terminalioxylon tertiarum*. Tangential section of the wood. × 135. Note the xylem rays with crystalliferous cells.

PLATE 3

12. *Terminalia tomentosa*. Transverse section of the wood. × 43.

13. *T. tomentosa*. Another tangential section of the wood. × 135.

14. *Terminalia myriocarpa*. Tangential section of the wood. × 135.

15. *T. myriocarpa*. Transverse section of the wood. × 43.

16. *Terminalioxylon tertiarum*. Transverse section of the wood magnified to show parenchyma distribution. × 60.

PLATE 4

17. *Terminalioxylon tertiarum*. Transverse section of the fossil wood. × 7. Note the vessel distribution and vertical gum canals.

18. *Pahudioxylon sahnii* Ghosh & Kazmi. Radial secion showing nature of the xylem rays. × 100.

19. *P. sahnii*. Tangential section of the wood. × 120. Note the distribution, shape and size of the xylem rays.

20. *P. sahnii*. Vestured intervascular pitting. × 560.

21. *P. sahnii*. Transverse section of the wood in low power. × 17. Note the vessel and parenchyma distribution.

22. *P. sahnii*. Tangential section of the wood showing storied tendency of the xylem rays. × 120.