FOSSIL DICOTYLEDONOUS WOODS FROM THE TERTIARY OF EASTERN INDIA

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ABSTRACT

Fossil woods representing the genera *Elaeocarpus, Mallotus, Afzelia, Bursera, Kayea* and *Terminalia* have been identified from the Tertiary of Tipam sandstones in Assam. Their presence in Eastern India during the Upper Miocene is noteworthy from the standpoint of their palaeographical distribution. The fossil wood of *Bursera* is known for the first time from India and abroad.

INTRODUCTION

FOSSIL woods resembling *Elaeocarpus, Mallotus, Afzelia-Intsia, Bursera, Kayea* and *Terminalia* are described here from the Tipam sandstones near Hailakandi in Cachar District of Assam. A well identified floral assemblage is known now from the Tipam sandstones near Hailakandi in Eastern India based mainly on fossil woods. (Prakash & Tripathi, 1968, 1969ab, 1970ab, 1972, 1974). The modern comparable species of these fossils, viz., *Adenanthera pavonina, Swintonia floribunda, Mangifera indica, Lagerstroemia flosreginae, Terminalia tomentosa, Careya arborea, Kayea assamica, Bursera serrata, Homalium tomentosum, Sterculia villosa, Vitex canescens*, and *Mallotus philippinensis* either grow at the fossil locality near Hailakandi or nearby indicating a somewhat similar vegetational pattern in this region since the Miocene times. However, the presence of *Barringtonia, Afzelia-Intsia*, and a fossil species comparable to *Cynometra ramiflora* in the Tipams near Hailakandi are indicative of a shore-line in this region during the Upper Miocene.

SYSTEMATIC DESCRIPTION

ELAEOCARPACEAE

Ealaeocarpoxylon Prakash & Dayal, 1964 emend.

1. *Elaeocarpoxylon hailakandiense* sp. nov.

The specimen described below is a small piece of petrified wood 3 cm. in diameter and 4 cm. in length. It shows fairly good preservation.

Topography — Wood diffuse-porous (Pl. 1, fig. 1). *Growth rings* absent. *Vessels* very small to medium-sized, mostly solitary or in short radial rows of 2-5, 8-10 per sq. mm., tylosed, sometimes with brownish gummy deposits. *Parenchyma* scanty paratracheal, limited to a few cells around some of the vessels. *Xylem rays* fine to broad, 1-8 cells (Pl. 1, fig. 3) and 12-108 μ in width, 15-25 per mm.; ray tissue markedly heterogeneous (Pl. 1, figs. 3, 5); uniseriate rays 12-24 μ in width, 2-23 cells and 120-1600 μ high, homocellular, consisting of upright cells only; multiseriate rays 2-8 (mostly 4-5) seriate, 32-108 μ in width, 25-54 cells and 848-2175 μ high, heterocellular consisting of procumbent cells in the median thickened portion and with long uniseriate marginal extensions of upright cells at one or both the ends (Pl. 1, fig. 3). *Fibres* aligned in distinct radial rows.

Elements — Vessels thickwalled, the walls about 5-10 μ thick, t.d. 25-190, μ r.d. 53-210 μ, round to oval when solitary, those in radial multiples generally flattened at the places of contact; vessel-members short, 120-240 μ in length with tapered ends; perforations simple; inter-vessel pit-pairs large, 7-10 μ in diameter, bordered, alternate to subopposite, round to oval, sometimes hexagonal due to crowding, with lenticular, horizontal apertures (Pl. 1, fig. 6; Text-fig. 1); vessel-parenchyma and vessel-ray pits not preserved. *Parenchyma cells* thin walled, 100-360 μ in length and 16-52 μ in diameter; cells commonly crystalliferous. *Ray cells* thinwalled with dark infiltration, the walls 1-2 μ thick; procumbent cells round to oval in shape, tangential height 16-48 μ, radial length 60-140 μ; upright cells 48-124 μ in tangential height and 20-40 μ in radial length; ray cells crystalliferous. *Fibres* moderately thick to thickwalled, the walls 6-9 μ thick, septate,

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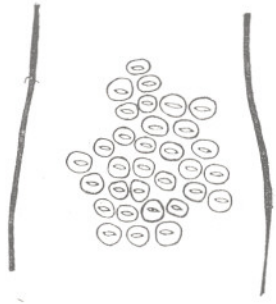


TEXT-FIG. 1 — *Elaeocarpoxylon hailakandiense* sp. nov.— Intervessel pit-pairs. × 330. Slide No. 4620.

angular to oval in cross section, 20-25 μ in diameter, 520-1640 μ in length; interfibre pits not observed.

Affinities — The important anatomical features of the present fossil wood indicate its affinity with the genera *Elaeocarpus* L. and *Echinocarpus* Bl. of the family Elaeocarpaceae (Mohl & Janssonius, 1906, pp. 534-547; Record, 1925, pp. 17-20; Pearson & Brown, 1932, pp. 180-189; Desch, 1957, pp. 153-154; Kukachka & Rees, 1943, pp. 1-70; Metcalfe & Chalk 1950, pp. 262-266; Chowdhury & Ghosh, 1958, pp. 241-247) where a close resemblance with the modern woods of *Elaeocarpus robustus* (F.R.I. slide no. 385/6057) and some species of *Echinocarpus* is seen. This survey included the study of modern woods of thirteen species of *Elaeocarpus* and four species of *Echinocarpus* available at the Xylarium of the Birbal Sahni Institute of Palaeobotany, Lucknow, and the Forest Research Institute, Dehra Dun. Besides, published description and photographs of *Elaeocarpus grandis* F.V.M. (Metcalfe & Chalk, 1950, pp. 264-265, fig. 64C), *E. calomala* (Blanco) Merrill. (Kanehira, 1924, p. 14), *E. dubis* A.DC. (Lecomte, 1926, Pl. 31), *E. robustus* Roxb. (Pearson & Brown, 1932, pp. 183-184, fig. 67; Desch. 1957, pp. 153-154; Chowdhury & Ghosh, 1958, p. 246, Pl. 30, fig. 180), *E. descipiens* Hemsl., *E. japonicus* S. et Z. (Kanehira, 1921, pp. 48-50, Pl. 9, figs. 50-53), *E, oxypyren* Koord. & Valet., *E. pierrei* Koord. & Valet., *E. longifolius* Bl., *E. glaber* Bl., *E. grandiflorus* Sm., *E. petiolatus* Wall., *E. acronodia* Mast., *E. macrophyllus* Bl. *E. leptomishus* Ridl., *E. parvifolius* Wall., *E. obtusus* Bl., *E. stipularis* Bl., *E. subglobosus* Merr., *E. wrayi* King, (Mohl. & Janssonius, 1906, pp. 534-547; Desch, 1957, pp. 153-154) and *Echinocarpus desycarpus* Benth., *E. assamicus* Benth., and *E. sigun* Bl. were also studied (Pearson & Brown, 1932, pp. 180, 181, fig. 66; Chowdhury & Ghosh, 1958, pp. 242, 243, Pl. 30, fig. 177).

A critical and exhaustive study of the modern woods of *Elaeocarpus* and *Echinocarpus* recently undertaken by one of us (Prakash, 1974) has shown that some species of *Elaeocarpus* and *Echinocarpus* are so similar in their structural details that it is not possible to distinguish them by their wood structure alone. On the other hand there are others which can be separated with certainty. Some species of *Elaeocarpus* possess distinct terminal parenchyma delimiting the growth rings, while it is absent from all the species of *Echinocarpus*. However, terminal parenchyma demarcating the growth rings is not a reliable feature in *Elaeocarpus* also as it is present in some specimens but absent from other specimens of the same species (e.g. *Elaeocarpus robustus* F.R.I. slide nos. 385/6065 and A3922/F581; *Elaeocarpus tuberculatus* F.R.I. slide nos. 432/E. 6125 and A3926/B6743) (Chowdhury & Ghosh, 1958, p. 241).

Traumatic gum canals have been reported in *Elaeocarpus* but not in *Echinocarpus* (Record, 1925, pp. 17-20; Desch, 1957, p. 154; Metcalfe & Chalk, 1950, p. 165). However, the presence of traumatic gum canals is also not a reliable feature because these are formed due to injury and may or may not be present in a small piece of wood. (Record, 1925, pp. 17-20). Therefore, the presence of terminal parenchyma and the traumatic gum canals in a specimen of wood, would certainly indicate its affinities with *Elaeocarpus*. But, their absence in the specimens of the same species of *Elaeocarpus* may put them with structurally similar species of *Echinocarpus*.

In some species of *Elaeocarpus* and *Echinocarpus*, the parenchyma distribution is almost similar. They possess scanty paratracheal parenchyma. However, in other species of *Elaeocarpus*, viz., *E. tuberculatus* and two species of *Echinocarpus*, viz., *E. dasycarpus* and *E. tiliaceous*, the parenchyma is quite distinct. These species of *Echinocarpus* can be easily differentiated from *Elaeocarpus* in having diffuse-in-aggregate parenchyma forming distinct uniseriate lines. The presence of broader rays (1-10

seriate) in *Echinocarpus dasycarpus* further separates it from *Elaeocarpus*. Similarly, the presence of diffuse parenchyma, in addition to the paratracheal type, in *Elaeocarpus tuberculatus*, also separates it from other species of *Elaeocarpus* and all the species of *Echinocarpus*.

In other anatomical characters like the vessel distribution, its shape and size, the fibre structure, and the ray type, both the genera show similar structure, and it would be impossible to differentiate them on these characters alone. However, these two genera can be classified into the following three groups as suggested by Prakash (1974).

Group I includes only the species of *Elaeocarpus* possessing diffuse parenchyma in addition to the paratracheal type and also all those species which have terminal parenchyma and/or traumatic gum ducts.

Group II includes only those species of *Echinocarpus* which are quite distinct from *Elaeocarpus* in having diffuse-in-aggregate parenchyma forming distinct, uniseriate lines, e.g. *Echinocarpus dasycarpus, E. tiliaceous*.

Group III includes both *Elaeocarpus* and *Echinocarpus*. Here only those species of *Elaeocarpus* and *Echinocarpus* are included which are difficult to be distinguished and possess scanty paratracheal parenchyma.

In 1964 Prakash & Dayal instituted the form genus *Elaeocarpoxylon* to describe a fossil wood resembling *Elaeocarpus ferrugineus* from the Deccan Intertrappean series of India. Recently Petriella (1972) described another fossil wood from the Early Tertiary of Central Chubut, Argentina, resembling the wood structure of the family Elaeocarpaceae especially with the woods of Group A (Metcalfe & Chalk, p. 263-265) including the genera, *Slonea, Elaeocarpus, Crinodendron, Vallea* and *Aristotelia* (Petriella 1972, pp. 188, 189). As she placed it somewhat near to *Slonea* and emphasized that *Slonea* and *Elaeocarpus* are somewhat similar in wood structure, she amended the diagnosis of the form genus *Elaeocarpoxylon* Prakash & Dayal to include this fossil wood, and named it as *Elaeocarpoxylon sloaneoides*. But the present authors do not agree with her in placing this fossil wood under the form genus *Elaeocarpoxylon* Prakash & Dayal, even after amending the diagnosis, as her fossil wood does not indicate any close affinity either to *Slonea* or to *Elaeocarpus* especially in possessing both simple and scalariform perforation plates. However, it does share the characters of the genera belonging to Group A of the family Elaeocarpaceae (Petriella, 1972, pp. 188, 189; Metcalfe & Chalk, 1950, p. 264). In view of this, it is suggested that a new name *Elaeocarpaceoxylon* after the family Elaeocarpaceae be instituted to include this fossil wood. It is, therefore, named as *Elaeocarpaceoxylon sloneoides* (Petriella) comb. nov.

The present fossil wood from Assam, which resembles *Elaeocarpus robustus* and some species of *Echinocarpus* and falls in Group III as suggested by Prakash (1974) may be included under the form genus *Elaeocarpoxylon* Prakash & Dayal after slightly enlarging its diagnosis as regards the presence of semilibriform to libriform fibres. This name may henceforth be used for all the woods falling under Group III of Prakash (1974) showing wood structure of both *Elaeocarpus* and *Echinocarpus*. However, for all the fossil woods which can be distinctly referred either to *Elaeocarpus* or to *Echinocarpus*, as suggested by Prakash (1974) falling in his Group I or Group II, it is suggested to institute new generic names. Those distinctly belonging to *Elaeocarpus* may be included under the form genus *Euelaeocarpoxylon*, while those belonging to *Echinocarpus* may be referred to *Echinocarpoxylon*.

Only one fossil wood resembling *Elaeocarpus, Elaeocarpoxylon antiquum* Prakash & Dayal (1964) is known so far from India and abroad. However, fruit remains of this genus are known from the Tertiary of Australia. These have been named as *Elaeocarpus mackayi* (F.V.M.) Kirchheimer (1935, p. 179). According to him (Krichheimer, *l.c.*) the fossil remains referred to *Elaeocarpus* from the European Tertiary belonged to the family Cornaceae (see also Gothan & Weyland, 1954, p. 415) and those from the Tertiary of Japan (Natorst, 1893, in Kirchheimer, 1935) do not show definite characters which indicate their unquestioned similarity with *Elaeocarpus*.

Elaeocarpoxylon antiquum Prakash & Dayal (1964) from the Deccan Intertrappean series of India differs from the present fossil wood in the presence of traumatic, vertical gum canals and in having small to medium-sized (r.d. 60-150 μ) vessels, 1-3 seriate xylem rays, and non-crystalliferous fibres. In the present fossil wood,

however, the vessels are 25-190 μ in tangential diameter, 53-210 μ in radial diameter, the xylem rays are 1-8 seriate, the fibres are crystalliferous and the traumatic gum canals are absent. As the present fossil wood markedly differs from *Elaeocarpoxylon antiquum*, it is being referred to a new species and named as *Elaeocarpoxylon hailakandiense*, the specific name is after the town of Hailakandi which is situated near the fossil locality.

The genus *Elaeocarpus* Linn. consists of 200 species (Willis, 1966, p. 395) spread over a wide area, the majority being found in the Indo-Malayan region. It is also represented in Madagascar, Socotra, Cochin-China, the Philippines, Formosa, the Pacific Islands, Abstralia and New Zealand. About 25 species occur in the Indian region. The species *Elaeocarpus robustus* Roxb. with which the present fossil wood shows its resemblance grows in the nearest eastern Himalayas upto 600 m., in Sikkim and North Bengal, and also in Assam, Chittagong, the Andamans and the Malay Peninsula. (Chowdhury and Ghosh, 1958, p. 245). The genus *Echinocarpus* Bl. consists of 10 species (Willis, 1966, p. 390), distributed mostly in South-East Asia and Australia. Five species are known to occur in India. They are found in Bhutan and Sikkim in the eastern Himalayas and throughout Assam (Chowdhury & Ghosh, 1958, pp. 241-242).

GENERIC DIAGNOSIS

Elaeocarpoxylon Prakash & Dayal emend.

Wood diffuse-porous. *Growth rings* present or absent; delineated by thick-walled fibres and/or terminal parenchyma *Vessels* usually small to medium-sized, solitary and in radial multiples; vessel members short to medium-sized or long; perforations simple; intervessel pit-pairs large, bordered, opposite to alternate *Parenchyma* scanty paratracheal, limited to a few cells associated with the vessels; terminal parenchyma absent or present. *Xylem rays* fine to broad, 1-several seritae; ray tissue markedly heterogeneous. *Fibres* non-libriform to libriform, septate. *Gum canals* traumatic, vertical present or absent.

SPECIFIC DIAGNOSIS

Elaeocarpoxylon hailakandiense sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* very small to medium-sized, t.d. 25-190 μ, r.d. 52-210 μ, round to oval, mostly solitary or in short radial rows of 2-5, 8-10 per sq. mm.; perforations simple; intervessel pit pairs large, 7-10 μ in diameter, bordered, alternate to subopposite, round to oval, sometimes hexagonal due to crowding with lenticular, horizontal apertures. *Parenchyma* scanty paratracheal, limited to a few cells around some of the vessels. *Xylem rays* fine to broad, 1-8 cells and 12-103 μ broad, 15-25 per mm.; ray tissue markedly heterogeneous; narrow rays uniseriate, 12-24 μ in width, 2-23 cells and 120-1600 μ high, homocellular, consisting of upright cells only; broader rays 2-8 (mostly 4-5) seriate, 32-103 μ wide, 25-54 cells and 848-2175 μ high, heterocellular, consisting of procumbent cells in the median thickened portion with long uniseriate marginal extensions of upright cells at one or both the ends; ray cells crystalliferous. *Fibres* moderately thick to thickwalled, the walls 6-9 μ thick, septate, angular to oval in cross-section, 20-25 μ in diameter, 520-1640 μ in length.

Holotype B.S.I.P. Museum No. 33913.

Locality — Sultanicherra, near Hailakandi, District Cachar, Assam.

LEGUMINOSAE

Pahudioxylon Chowdhury, Ghosh & Kazmi, 1960

2. *Pahudioxylon assamicum* sp. nov.

The present fossil wood consists of a single specimen of petrified mature secondary xylem measuring 4 cm. in diameter and 6 cm. in length.

Topography — *Wood* diffuse-porous (Pl. 2, fig. 7). *Growth rings* distinct, delimited by terminal parenchyma and smaller vessels (Pl. 2, fig. 7). *Vessels* moderately small to large, majority solitary (Pl. 2, fig. 7), often in short radial rows of 2-4 cells, 3-5 per sq. mm.; tyloses absent, black gummy deposits present (Pl. 2, fig. 7). *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma mostly aliform, sometimes aliform-confluent, joining

2-3 adjacent vessels and forming 3-4 seriate sheath around the pores (Pl. 2, fig. 7); apotracheal parenchyma terminal, delimiting the growth rings and forming well defined, 1-4 (mostly 1-2) seriate lines (Pl. 2, fig. 7). *Xylem rays* 1-4 (mostly 3) seriate (Pl. 2, fig. 9) and 16-64 μ broad, 2-21 cells and 80-300 μ in height 6-7 per mm., sometimes storied; ray tissue homogeneous, rays homocellular, consisting only of procumbent cells (Pl. 2, figs. 9, 11). *Fibres* aligned in radial rows.

Elements — Vessels thinwalled, the walls 4-5 μ thick, t.d. 56-260 μ, r.d. 60-280 μ, round to oval when solitary, those in radial multiples generally flattened at the places of contact; vessel members 150-384 μ long with truncated or tapered ends; perforations simple; intervessel pit-pairs small, 4-6 μ in diameter, vestured (Pl. 2, fig. 12; Text-Fig. 2); vessel-ray and vessel parenchyma pits not preserved. *Parenchyma cells* thin walled, 60-210 μ in length and 18-28 μ in diameter. *Ray cells* thin walled, the walls 2-4 μ thick, procumbent cells 12-24 μ in tangential height, 50-88 μ in radial length. *Fibres* moderately thick-walled with big lumen, the walls 4-5 μ thick, non-septate, 10-20 μ in diameter, 400-1820 μ in length; interfibre pits not preserved.

Affinities — The present fossil wood shows affinity with the modern woods of *Afzelia* and *Intsia* of the family Leguminosae (Metcalfe & Chalk, 1950, pp. 476-535). The genus *Afzelia* includes also all the species of *Pahudia* transferred to it by Leonard (1950). The woods of *Afzelia* and *Intsia* are so similar anatomically that it is not possible to separate them.

In 1960 Chowdhury *et al.* instituted the form genus *Pahudioxylon* which has been redefined and used now for the fossil woods of *Afzelia* and *Intsia* which are inseparable anatomically (Prakash, 1966, p. 231; Müller-Stoll & Mädel, 1967). So far only eight species of *Pahudioxylon* are known from India and abroad (Prakash *et al.*, 1967). These are *Pahudioxylon bankurensis* Chowdhury *et al.* (1960), *P. sahnii* Ghosh & Kazmi (1961), *P. arcotense* Navale (1963), and *P. deomaliense* Prakash (1965), all from the Tertiary of India, *P. afzelioides* (Boureau) Prakash *et al.* (1967) from the Tertiary of South Annam, Indo China, *P. irregulare* (Felix, 1882, 1883) Müller-Stoll & Mädel (1967) from Antigua, *P. pannonicum* (Felix, 1887) Müller-Stoll & Mädel (1967) from Hungary, and *P. kiliani* (Louvet, 1965) Prakash, *et al.* (1967) from the Tertiary of Algeria. The present fossil wood is quite different from all the species listed above. However, it shows somewhat near resemblance to *Pahudioxylon afzelioides* (Boureau) Prakash *et al.* (1967) from the Tertiary of Annam, Indo China and *P. kiliani* (Louvet) Prakash *et al.* (1967) from the Tertiary of Algeria.

Pahudioxylon afzelioides differs from the present fossil wood in having large vessels (t.d. 140-260 μ, r.d. 140-325 μ), and in possessing libriform fibres and vasicentric parenchyma besides aliform and confluent types. However, in the present fossil wood the vessels are small to moderately large (t.d. 56-260 μ, r.d. 60-280 μ), the fibres are moderately thick walled with big lumen and the parenchyma is aliform to aliform-confluent. *Pahudioxylon kiliani* (Louvet) Prakash *et al.* (1967) also differs from *P. assamicum* in having large vessels, libriform fibres and in the vasicentric parenchyma.

As the present fossil wood differs markedly from all the known species of the genus *Pahudioxylon* Chowdhury, Ghosh & Kazmi, it is assigned to a new species, *Pahudioxylon assamicum*.

The genus *Afzelia* Sm. consists of 14 species, distributed in tropical Africa and Asia (Willis, 1966, p. 29), while the genus *Intsia* Thou. consists of 9 species mainly distributed in East Africa, Madagascar and tropical Asia (Willis, 1966, p. 578). In India only *Intsia* (*Afzelia*) *bijuga* and *Afzelia retusa* are found. *Intsia* (*Afzelia*) *bifuga* 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, p. 280).

TEXT-FIG. 2 — *Pahudioxylon assamicum* sp. nov. — Intervessel pit pairs. × 330. Slide No. 4623.

SPECIFIC DIAGNOSIS

***Pahudioxylon assamicum* sp. nov.**

Wood diffuse-porous. *Growth rings* distinct, delimited by terminal parenchyma and smaller vessels. *Vessels* moderately small to moderately large, t.d. 56-260 μ, r.d. 60-280 μ, majority solitary, sometimes in short radial rows of 2-4, round to oval when solitary, 3-5 per sq. mm; tyloses absent; vessel-members 150-384 μ long with truncated or tapered ends; perforations simple; intervessel pit-pairs, small, 4-6 μ in diameter, alternate, vestured. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma mostly aliform, sometimes aliform-confluent, joining 2-3 vessels; apotracheal parenchyma delimiting the growth rings by forming well defined, 1-4 (mostly 1-2) cells thick bands. *Xylem rays* 1-4 (mostly 3) seriate and 16-64 μ broad, 2-21 cells and 80-300 μ in height, 6-7 per mm, sometimes storied; ray tissue homogeneous; rays homocellular, consisting only of procumbent cells. *Fibres* polygonal in cross section, moderately thickwalled with big lumen, the walls 4-5 μ thick, non-septate, 10-20 μ in diameter, 400-1820 μ in length; interfibre pits not preserved.

Holotype — B.S.I.P. Museum No. 33920.

Locality — Sultanicherra, near Hailakandi, District Cachar, Assam.

EUPHORBIACEAE

***Mallotoxylon* Lakhanpal & Dayal, 1964**

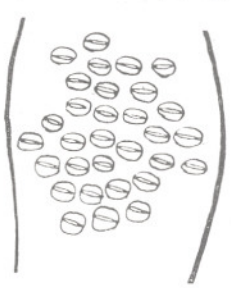
3. *Mallotoxylon assamicum* sp. nov.

The specimen is a single piece of petrified secondary wood measuring 6 cm. in length and 4 cm. in diameter.

Topography — *Wood* diffuse-porous (Pl. 3, fig. 13). *Growth rings* indistinct. *Vessels* very small to medium-sized, solitary as well as in short radial rows of 2-6 (Pl. 3, fig. 13), 8-14 per sq. mm., tylosed, yellowish brown deposits probably gum occasionally present (Pl. 3, fig. 13). *Parenchyma* paratracheal and apotracheal (Pl. 3, fig. 13); paratracheal parenchyma scanty, occurring as 1-2 cells associated with the vessels (Pl. 3, fig. 13); apotracheal parenchyma diffuse occurring as scattered cells and more commonly in short, irregular and interrupted uniseriate lines (Pl. 3, fig. 13). *Xylem rays* fine to medium, 1-4 (mostly 2-3) seriate (Pl. 3, fig. 15), 12-16 per mm; ray tissue markedly heterogeneous (Pl. 3, figs. 15, 17); uniseriate rays 14-20 μ in width, 2-8 cells high, homocellular consisting of upright cells only (Pl. 3, fig. 15); multiseriate rays 2-4 (mostly 2-3) seriate and 40-50 μ in width, 5-38 cells high, heterocellular consisting of procumbent cells in the middle portion and 1-7 rows of upright cells at one or both the ends (Pl. 3, fig. 15); end to end ray fusion frequent. *Fibres* aligned in radial rows.

Elements — *Vessels* thinwalled, the walls 4-6 μ thick, t.d. 36-100 μ, r.d. 44-148 μ, the solitary vessels oval to elliptical in cross-section, those in radial multiples flattened at the places of contact; vessel members 440-960 μ in length, with truncated or tailed ends; perforations simple; intervessel pit-pairs large, 8-10 μ in diameter, bordered, border oval, sometimes hexagonal due to crowding, with lenticular, horizontal apertures (Pl. 3, fig. 18; Text-Fig. 3); vessel-parenchyma and vessel-ray pits not preserved. *Parenchyma cells* thin walled 15-26 μ in diameter, 30-80 μ in length. *Ray cells* thinwalled, procumbent cells 12-20 μ in tangential height, 26-48 μ in radial length; upright cells 30-60 μ in tangential height and 15-20 μ in radial length; ray cells crystalliferous. *Fibres* non-libriform to semilibriform, the walls 4-6 μ thick, non-septate, polygonal in cross-section, 15-20 μ in diameter, 600-1840 μ in length; interfibre pits not preserved.

Affinities — There is a close agreement in almost all the structural details of the present fossil wood with the wood structure of the modern genus *Mallotus* Lour. of the



TEXT-FIG. 3 — *Mallotoxylon assamicum* sp. nov. — Intervessel pit-pairs. × 330. Slide No. 4629.

family Euphorbiaceae. However, the fossil wood also resembles in gross anatomical features with the modern woods of *Diospyros* and *Maba* of the family Ebenaceae and *Mimusops* and *Madhuca* of the family Sapotaceae.

The woods of *Diospyros* and *Maba*, however, differ from the present fossil wood in possessing small to minute inter vessel pit-pairs and in short, mostly uniseriate xylem rays with occasional biseriate parts.

The woods of *Mimusops* and *Madhuca* differ also from the present fossil wood in having vasicentric tracheids, and in possessing small intervessel pit-pairs and thick walled fibres with very small lumen.

A survey of all available woods of the genus *Mallotus* indicates that the nearest affinity of the fossil is with the wood of *Mallotus philippinensis* Muell. Arg. This survey included the study of thin sections of *Mallotus albus* Muell. Arg., *M. philippinensis* Muell. Arg., *M. roxburghianus* Muell. Arg. (Lecomte, 1926, Pl. 26; Pearson & Brown, 1932, pp. 888-890, fig. 27*i*), *M. acuminatus* Muell. Arg. (Metcalfe & Chalk, 1950, p. 1224, fig. 294 I), *M. macrostachyus* Muell. Arg., *M. paniculatus* Muell. Arg., and *M. penangensis* Muell. Arg. (Desch, 1957, p. 162).

Both in the fossil wood and the modern wood of *Mallotus philippinensis* the vessels are very small to medium sized, solitary as well as in short radial rows of 2-6, oval to elliptical in cross-section, the perforations are simple, the intervessel pit-pairs are large, 8-10 μ in diameter, bordered, with lenticular apertures, the parenchyma is scanty paratracheal as well as diffuse and in short, irregular and interrupted, uniseriate lines, the xylem rays are 1-4 (mostly 2-3) seriate with hetrogeneous ray tissue, and the fibres are non-libriform to semilibriform and non-septate.

Because of a close resemblance of the present fossil wood with the wood structure of *Mallotus* Lour., it is assigned to the form genus *Mallotoxylon* Lakhanpal & Dayal (1964). Only one fossil wood of *Mallotus* is known so far from India and abroad. This is *Mallotoxylon keriense* Lakhanpal & Dayal (1964) from the Deccan Intertrappean series of India. *Mallotoxylon keriense* differs from the present fossil wood in possessing slightly smaller vessels and less broader (1-3 seriate) and more higher (225-1500 μ) xylem rays. However, the vessels are slightly bigger, the xylem rays are 1-4 (mostly 2-3) cells broad and 70-960 μ high in the present fossil wood. As the present fossil wood differs distinctly from *Mallotoxylon keriense*, it is referred to a new species *Mallotoxylon assamicum*.

The genus *Mallotus* Lour. consists of 142 species (Willis, 1966, p. 689). It is a large genus of trees and shrubs and is spread over a wide area covering India, Burma, Madagascar, Australia, Tropical Africa, the Philippines, Cochin-China and Malayan Archipelago. About 20 species are found in the Indian flora. *Mallotus philippinensis* Muell. Arg., with which the present fossil wood shows nearest resemblance is a ubiquitous shrub or a small, much branched tree of India and Burma which also extends far afield into Ceylon, the Malayan Peninsula and Archipelago, Australia, China and Formosa (Pearson & Brown, 1932, p. 888). In India this evergreen species occurs in Sub-Himalayan tract and outer hills from the Indus eastwards, ascending occasionally to nearly 1500 metres into the region of *Pinus longifolia* and *Quercus incana*, Chota Nagpur and Indian Peninsula. This is a very common tree in Sal forest and in certain types of mixed and scrub forests (Troup, 1921, p. 837).

SPECIFIC DIAGNOSIS

***Mallotoxylon assamicum*. sp. nov.**

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* very small to medium-sized, t.d. 36-100 μ, r.d. 44-148 μ, solitary as well as in short radial rows of 2-6, the solitary vessels oval to elliptical in cross-section, 8-14 per sq. mm; perforations simple; intervessel pit-pairs large, 8-10 μ in diameter, bordered, border oval, sometimes hexagonal due to crowding, with lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty occurring as 1-2 cells associated with vessels; apotracheal parenchyma diffuse occurring as scattered cells and more commonly as short, irregular and interrupted, uniseriate lines. *Xylem rays* 1-4 (mostly 2-3) seriate, 12-16 per mm.; ray tissue heterogeneous; uniseriate rays 14-20 μ in width, 2-8 cells high, homocellular, consisting wholly of upright cells; multiseriate rays 2-4 (mostly 2-3) seriate, 40-50 μ in width, 5-38 cells high, hetero-

cellular, consisting of procumbent cells in the median thickened portion and 1-7 rows of upright cells at one or both the ends; end to end ray fusion quite frequent; ray cells crystalliferous. *Fibres* non-libriform to semi-libriform, non-septate, polygonal in cross-section, 15-20 μ in diameter, 600-1840 μ in length; interfibre pits not preserved.

Holotype — B.S.I.P. Museum No. 33918

Locality — Sultanicherra near Hailakandi, District Cachar, Assam.

BURSERACEAE

***Burseroxylon* gen. nov.**

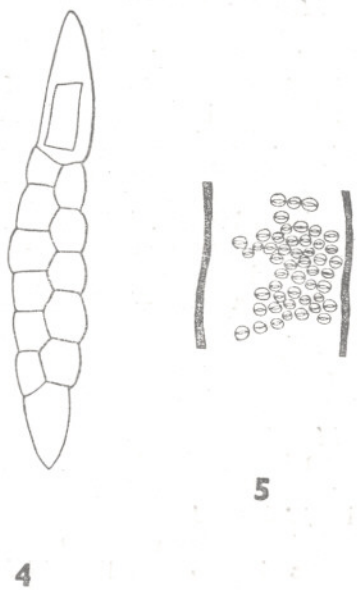
4. *Burseroxylon preserratum* sp. nov.

Fossil wood is represented by a small piece of secondary xylem 10 cm. in length and 4 cm. in diameter showing fine preservation of the structural details.

Topography — Wood diffuse-porous (Pl. 4, fig. 19). *Growth rings* indistinct. *Vessels* moderately small to large, mostly solitary, often in short radial rows of 2-4 (Pl. 4, fig. 19), 12-18 per sq. mm., heavily tylosed (Pl. 4, fig. 19). *Parenchyma* paratracheal, scanty to vasicentric, the latter in 1-2 (mostly 1) cells thick sheath around the vessels (Pl. 4, fig. 23). *Xylem rays* fine to medium, 1-4 (mostly 2-3) seriate (Pl. 4, fig. 21), and 8-10 per mm. in the normal wood, but broader, 1-6 seriate and closely placed in the region full of knots; ray tissue heterogeneous (Pl. 4, fig. 24); uniseriate rays sparse, 2-4 cells and 100-200 μ in height, 16-20 μ in width, homocellular or heterocellular, when homocellular composed only of upright cells, when heterocellular composed of procumbent cells in the middle portion and upright cells at both the ends; multiseriate rays 4-17 cells and 160-480 μ in height, usually 2-4 cells and 50-72 μ in width, heterocellular composed of procumbent cells in the middle portion and upright cells at one or both the ends; end cells enlarged (Pl. 4, figs. 21, 24; Text-fig. 4). *Fibres* mostly aligned in distinct radial rows.

Elements — Vessels thin walled, the walls about 4-6 μ thick, t.d. 80-200 μ, r.d. 160-280 μ, oval to elliptical in shape, those in radial multiples flattened at the places of contact; vessel-members short, 300-640 μ long, with truncated or tailed ends; perforations simple; intervessel pit-pairs large, 8-10 μ in diameter, alternate, bordered, round to oval, angular when crowded, with linear-lenticular, horizontal apertures (Pl. 4, fig. 26; Text-fig. 5); vessel-parenchyma and vessel-ray pits not preserved. *Parenchyma cells* thin walled, 10-12 μ in diameter, 18-40 μ in length. *Ray cells* thinwalled, procumbent cells 15-20 μ in tangential height and 24-40 μ in radial length; upright cells 33-38 μ in tangential height and 21-28 μ in radial length; cells frequently crystalliferous (Text-fig. 4). *Fibres* non-libriform, thin walled, the walls about 2-4 μ thick, septate, angular in cross section, 28-34 μ in diameter, 600-1400 μ in length; interfibre pits not preserved.

Affinities — There is close agreement in almost all the structural details of this wood with those of the modern genus *Bursera* Linn. of the family Burseraceae (Pearson & Brown, 1932, pp. 224-225; Metcalfe & Chalk, 1950, pp. 345-347; Anonymous, 1963, pp. 71-72; Heimsch, 1942, pp. 122-124). However, it also shows superficial resemblance with the modern woods of *Lannea* of the family Anacardiaceae and *Garuga* of the family Burseraceae. The genus *Lannea* differs from the present fossil wood in having mostly large vessels and 1-5 (mostly 3-4) seriate xylem rays



TEXT-FIGS. 4, 5 — Burseroxylon preserratum sp. nov.-4. A biseriate xylem ray with enlarged end cell containing crystal. ×330. Slide No. 4298. 5. Intervessel pit-pairs. × 330. Slide No. 4299.

with horizontal gum canals. The genus *Garuga* can also be differentiated from the present fossil wood in possessing mostly large vessels and 1-7 (mostly 3-4) seriate xylem rays with horizontal gum canals.

In order to find out the nearest comparable species of the genus *Bursera*, thin sections of *Bursera serrata* Wall. ex Coleb., *B. tomentosa* Triana & Planch. and *B. gummifera* Linn. were examined, besides consulting the published description and photographs of *Bursera serrata* Wall. ex Coleb. (Pearson & Brown, 1932, pp. 224-225, fig. 83; Anonymous, 1963, pp. 71-72, Pls. 37-38, figs. 222-223). From this study it is evident that the present fossil wood shows closest resemblance with the modern wood of *Bursera serrata* Wall. ex. Coleb. (F.R.I. slide No. A 1983/B. 6073). In the present fossil wood as well as in the modern wood of *Bursera serrata* the vessels are small to large, mostly solitary, often in short radial rows of 2-4, and heavily tylosed with vessel-members having truncated or tailed ends; the perforations are simple; the intervessel-pit-pairs are large, alternate, with linear-lenticular, horizontal apertures; the parenchyma is scanty paratracheal to vasicentric; the ray tissue is heterogeneous with the xylem rays 1-4 (mostly 2-3) seriate in the normal wood; and the fibres are non-libriform and septate. However, broader, 1-6 (mostly 3-4) seriate, rays are present in the region of knots which are quite common in the present fossil wood. Due to these knots there is abnormal development of the cells in the xylem rays of this region.

It is interesting to note that the modern wood of *Bursera serrata* shows quite a wide range of variation in its anatomical characters as seen from a number of specimens belonging to different regions of a tree. The variations are seen in the presence and absence of growth rings, in the size of the vessels and in the width of the xylem rays. In F.R.I. slide no. 335/6013, the growth rings are distinct, the vessels are small to medium sized and the xylem rays are 1-3 (mostly 2) seriate, while in F.R.I. slide no. A264/B6438, the growth rings are indistinct, the vessls are small to large and the xylem rays are 1-4 (mostly 2-3) seriate. In another slide, F.R.I. no. 1983/B6073 of the same species, the growth rings are indistinct, vessels are small to large and the xylem rays are 1-4 (mostly 2-3) seriate.

Because the present fossil wood resembles the modern wood of *Bursera serrata*, it is assigned to a new form genus *Burseroxylon* and specifically named as *B. preserratum* sp. nov.

So far there is no record of the fossil wood belonging to the genus *Bursera* Linn. However, there are three fossil woods which have been referred to the family Burseraceae. These are *Sumatroxylon mollii* (Krausel) Den Berger (1923) from the Miocene of Sumatra, *Boswellioxylon indicum* Dayal (1964, 1966) and a fossil wood tentatively assigned to Burseraceae by Shallom (1958) from the Deccan Intertrappean series of India. All these woods differ quite distinctly from the present fossil wood. *Sumatroxylon mollii* (Krausel) Den Berger (1923) differs from the present fossil wood in the presence of growth rings, in having broader, 4-8 seriate xylem rays with horizontal gum canals and in the nonseptate fibres.

The fossil wood of Burseraceae described by Shallom (1958) differs from the present fossil wood in having growth rings, in less frequent vessels (5-6 per sq. mm.), and in 2-4 seriate, slightly heterogeneous xylem rays. Lastly, *Boswellioxylon indicum* Dayal (1964, 1966) can also be easily distinguished from the present fossil wood in having small to medium sized (t.d. 60-180 μ, r.d. 74-210 μ) vessels which are solitary and in radial multiples of 2-4 cells and 1-6 (mostly 2-4) seriate xylem rays with horizontal gum canals.

The genus *Bursera* Linn. consists of 80 species widely distributed in tropical America especially in the West Indies, northern South America, Central America and Mexico, and two species extend northward into the United States. *Bursera, serrata* Wall. ex coleb,, with which the present fossil wood resembles closely, is the sole Indian species extending from eastern moist zone of Bengal, Assam, Orissa, Chittagong and tropical forests of Upper and Lower Burma. It also occurs in Rajmahal hills, extending to Eastern ghats especially in valleys and along water courses (Pearson & Brown, 1932, p. 224; Anonymous, 1963, p. 71; Willis, 1966, p. 167).

*Forest Research Institute, Dehra Dun.

GENERIC DIAGNOSIS

***Burseroxylon* gen. nov.**

Wood diffuse-porous. *Growth rings* distinct or indistinct. *Vessels* small to large, solitary and in radial multiples; perforations simple; intervessel pit-pairs large, bordered, alternate, with linear-lenticular orifices. *Parenchyma* paratracheal, scanty to vasicentric. *Xylem rays* fine to medium, 1-5 or more seriate; ray tissue heterogeneous; ray cells frequently crystalliferous. *Fibres* thin to moderately thick, septate.

Genotype — *Burseroxylon preserratum* sp. nov.

SPECIFIC DIAGNOSIS

***Burseroxylon preserratum* sp. nov.**

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* moderately small to large, t.d. 80-200 μ, r.d. 160-280 μ, majority solitary, often in short radial rows of 2-4, 12-18 per sq. mm., heavily tylosed; vessel-segments 300-640 μ in length, with truncated or tailed ends; perforations simple; intervessel pit-pairs large, 8-10 μ in diameter, alternate, bordered, round to oval, border angular, with linear-lenticular, horizontal apertures. *Parenchyma* paratracheal, scanty to vasicentric, the latter in 1-2 (mostly 1) cells thick sheath around the vessels. *Xylem rays* fine to medium, 1-4 (mostly 2-3) seriate in the normal wood, 8-10 per sq. mm.; ray tissue heterogeneous; uniseriate rays few, 2-4 cells and 100-200 μ in height, 16-20 μ in width, homocellular or heterocellular, when homocellular composed only of upright cells, when heterocellular composed of procumbent cells in the middle portion and upright cells at both the ends; multiseriate rays 4-17 cells and 160-480 μ in height, 2-4 cells and 40-72 μ in width, heterocellular, composed of procumbent cells in the middle portion and upright cells at one or both the ends; end cells enlarged and crystalliferous. *Fibres* thin walled, the walls about 2-4 μ thick, non-libriform, septate, angular in cross section, 28-34 μ in diameter, 600-1400 μ in length; interfibre pits not preserved.

Holotype — B.S.I.P. Museum No. 33914.

Locality — Sultanicherra, near the town of Hailakandi, District Cachar, Assam.

GUTTIFERAE

***Kayeoxylon* Chowdhury & Tandon, 1949**

5. *Kayeoxylon assamicum* Chowdhury & Tandon, 1949

Pl. 5, figs. 26, 28

Structural features of the present fossil wood indicate that it is identical to the fossil wood of *Kayeoxylon assamicum* Chowdhury & Tandon (1949) described from the Upper Miocene of Assam.

As the present fossil wood is identical to this species, it is being assigned to it. However, *Kayeoxylon assamicum* of Chowdhury & Tandon differs slightly from the present fossil wood in possessing larger vessels (t.d., 99-133 μ, r.d. 160-190 μ), in having slightly thicker bands of parenchyma, 3-13 (mostly 4-9) cells thick and 1-3 (mostly 1-2) seriate xylem rays which may be due to the anatomical variation that usually occurs in the wood of different parts of a tree.

The genus *Kayea* Wall. consists of 35 species and grows in tropical Asia and Indian Archipelago. *Kayea assamica* Prain with which the present fossil wood resembles most grows only in North Assam in Lakhimpur Division (Pearson & Brown, 1932, p. 55; Willis, 1966, p. 597).

Specimen — B.S.I.P. Museum No. 33910.

Locality — Sultanicherra, near the town of Hailakandi, District Cachar, Assam.

COMBRETACEAE

***Terminalioxyon* Schönfeld, 1947**

6. *Terminalioxylon tertiarum* Prakash, 1966

Pl. 5, figs. 30, 31

Structural features of the present fossil wood indicate that it is identical to *Terminalioxylon tertiarum* Prakash (1966) described from the Tertiary of Deomali in Arunachal Pradesh. Hence, it is assigned to it. However, it differs from the type species in the absence of traumatic, vertical gum canals and in having terminal parenchyma at all the growth rings. These are both variable features.

The genus *Terminalia* Linn. consists of 250 species (Willis, 1966, p. 1107), widely distributed throughout tropical and sub-

tropical regtons in both the hemispheres. *Terminalia tomentosa* Wight et Arn. with which the present fossil wood resembles most, 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 the Punjab, Sind and Rajputana. It occurs all over Burma, except in the North Shan States, Arakan and South Tenasserim, where it is scarce (Pearson & Brown, 1932, p. 519)

Specimen — B.S.I.P. Museum No. 33925.

Locality — Kartikcherra, near the town of Hailakandi, District Cachar, Assam.

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EXPLANATION OF PLATES

PLATE 1

1. *Elaeocarpoxylon hailakandiense* sp. nov.— Cross-section of the fossil wood showing shape, size and distribution of vessels, and the parenchyma pattern. × 35. Slide No. 4619.
2. *Elaeocarpus robustus* — Cross-section showing similar shape, size and distribution of vessels and the parenchyma pattern. × 35.
3. *Elaeocarpoxylon hailakandiense* sp. nov.— Tangential longitudinal section of the fossil wood showing xylem rays. × 60. Slide No. 4620.
4. *Elaeocarpus robustus* — Tangential longitudinal section showing similar type and distribution of xylem rays. × 60.
5. *Elaeocarpoxylon hailakandiense* sp. nov.— Radial longitudinal section of the fossil wood showing heterocellular xylem rays. × 110. Slide No. 4621.
6. *Elaeocarpoxylon hailakandiense* sp. nov.— Magnified intervessel pit-pairs. × 700. Slide No. 4620.

PLATE 2

7. *Pahudioxylon assamicum* sp. nov.— Cross-section of the fossil showing shape, size and distribution of vessels and the parenchyma pattern. × 35. Slide No. 4622.
8. *Intsia bijuga* — Cross-section showing similar shape, size and distribution of vessels and the parenchyma pattern. × 35.
9. *Pahudioxylon assamicum* sp. nov. — Tangential longitudinal section of the fossil showing xylem rays. × 90. Slide No. 4623.
10. *Intsia bijuga* — Tangential longitudinal section showing similar type and distribution of xylem rays. × 90.
11. *Pahudioxylon assamicum* sp. nov. — Radial longitudinal section of the fossil wood showing homogeneous xylem ray tissue × 170. Slide No. 4624.
12. *Pahudioxylon assamicum* sp. nov.— Magnified intervessel pit-pairs. × 400. Slide No. 4625.

PLATE 3

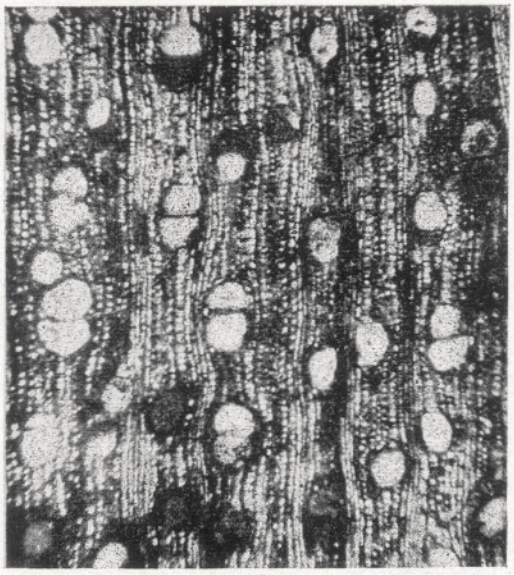
13. *Mallotoxylon assamicum* sp. nov.— Cross-section of the fossil showing shape, size and distribution of vessels and the parenchyma pattern. × 30. Slide No. 4626.
14. *Mallotus philippinensis* — Cross-section of the modern wood showing similar shape, size and distribution of vessels and the parenchyma pattern. × 30.
15. *Mallotoxylon assamicum* sp. nov.— Tangential longitudinal section showing the xylem rays. × 60. Slide No. 4627.
16. *Mallotus philippinensis* — Tangential longitudinal section showing similar type and distribution of xylem rays. × 60.
17. *Mallotoxylon assamicum* sp. nov.— Radial longitudinal section showing heterocellular xylem rays. × 120. Slide No. 4628.
18. *Mallotoxylon assamicum* sp. nov.— Magnified intervessel pit-pairs. × 500. Slide No. 4629.

PLATE 4

19. Cross-section of the fossil wood of *Burseroxylon preserratum* showing vessel distribution and parenchyma pattern. × 30. Slide No. 4297.
20. Cross-section of *Bursera serrata* showing similar vessel distribution and the parenchyma pattern. × 30.
21. Tangential section of the fossil wood of *Burseroxylon preserratum* showing the type of xylem rays and their distribution. × 60. Note the enlarged end cells. Slide No. 4298.
22. Tangential section of *Bursera serrata* showing similar ray type and distribution. × 60.
23. Magnified cross-section of *Burseroxylon preserratum* showing tylosed vessels and the parenchyma pattern. × 45. Slide No. 4299.
24. Radial longitudinal section of *Burseroxylon preserratum* showing heterocellular xylem rays. × 120. Slide No. 4300.
25. Magnified intervessel pit-pairs of *Burseroxylon preserratum*. × 520. Slide No. 4301.

PLATE 5

26. Cross-section of *Kayeoxylon assamicum* showing vessel distribution and the parenchyma pattern. × 30. Slide No. 4302.
27. Cross-section of *Kayea assamica* showing similar vessel distribution and the parenchyma pattern. × 30.
28. Tangential section of *Kayeoxylon assamicum* showing the type of xylem rays and their distribution. × 120. Slide No. 4303.
29. Tangential section of *Kayea assamica* showing similar ray type and distribution. × 120.
30. Cross-section of *Terminalioxylon tertiarum* showing the vessel distribution and parenchyma pattern. × 30. Slide No. 4333.
31. Tangential longitudinal section of *Terminalioxylon tertiarum* showing the type of xylem rays and their distribution. × 100. Slide No. 4334.



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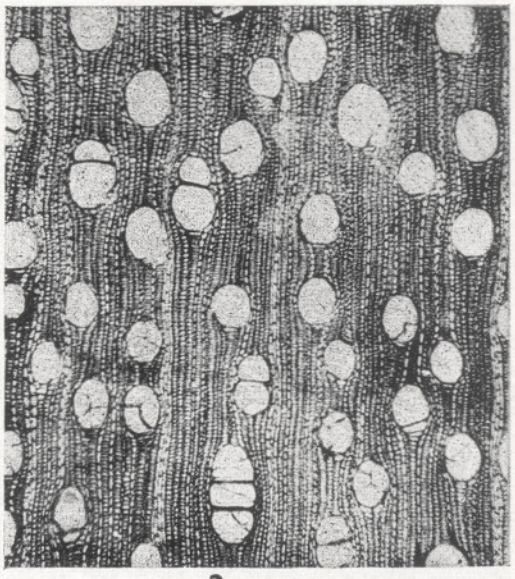

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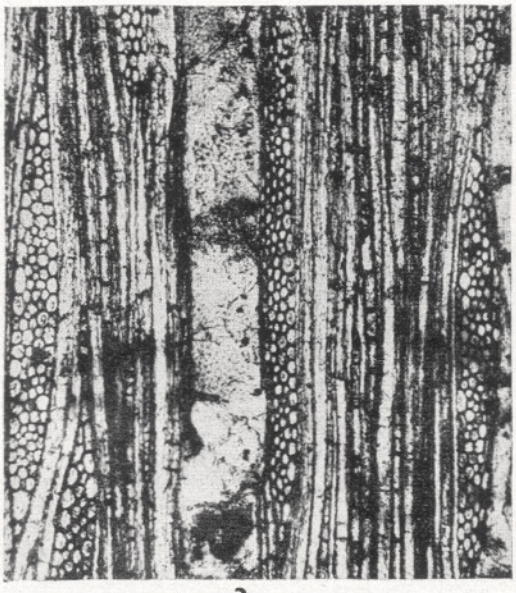

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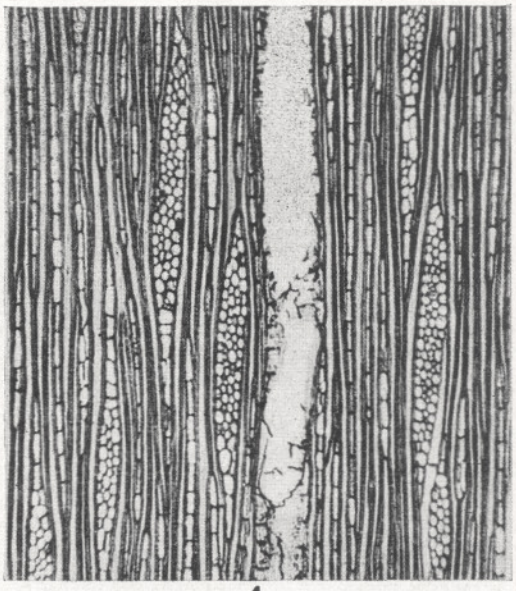

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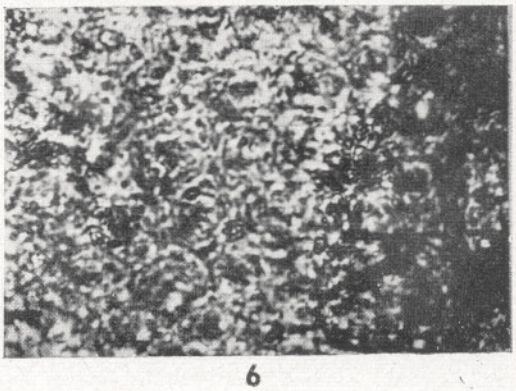

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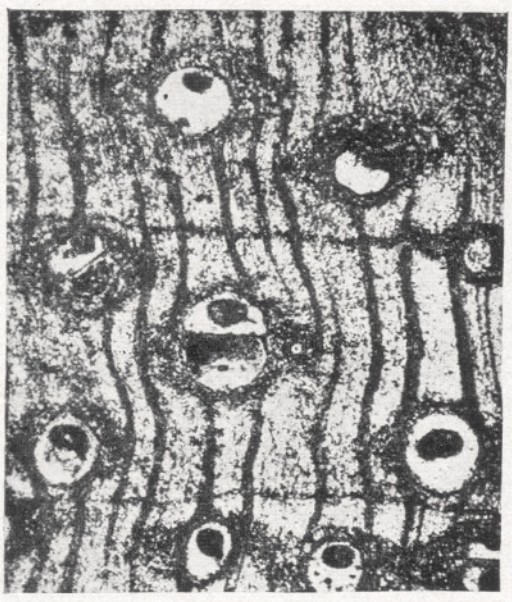

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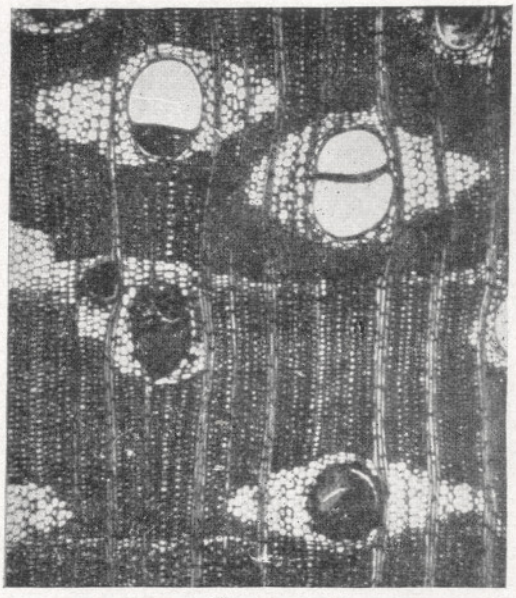

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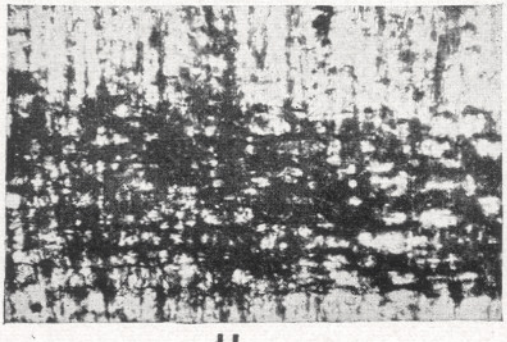

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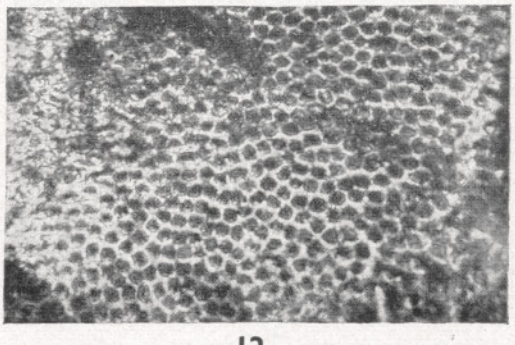

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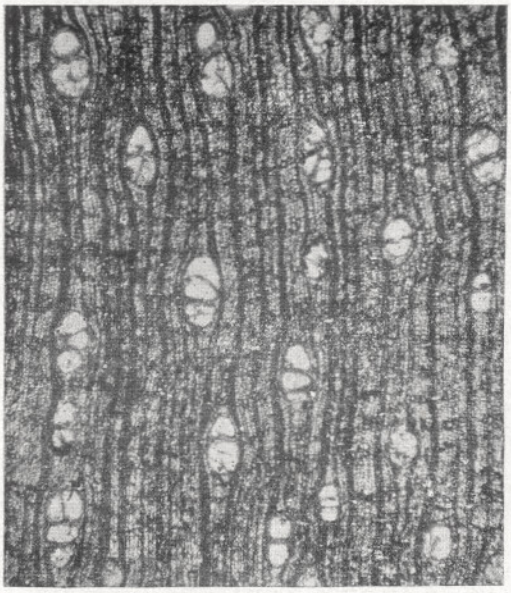

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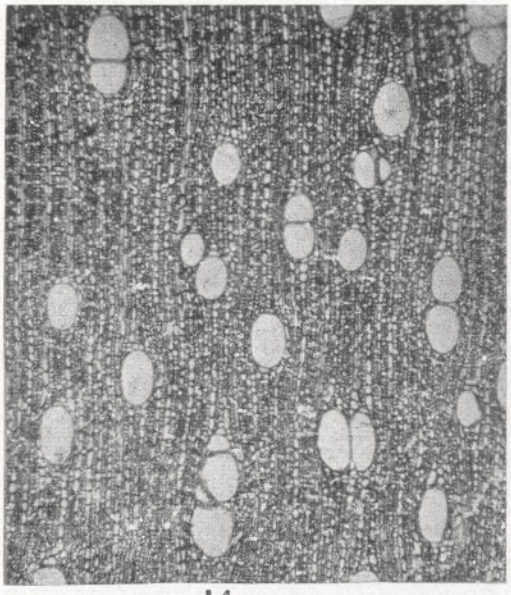

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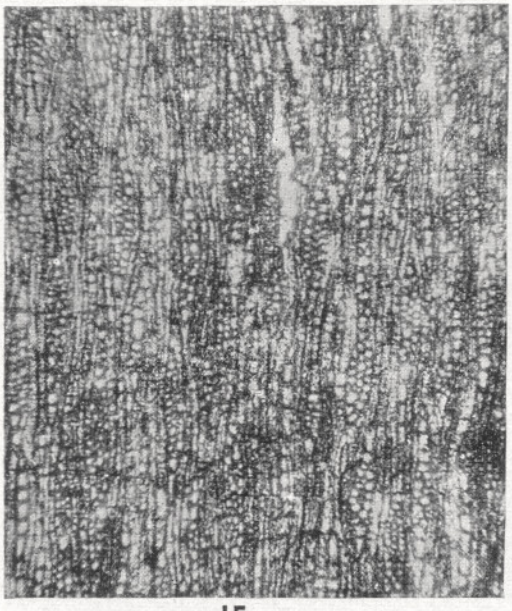

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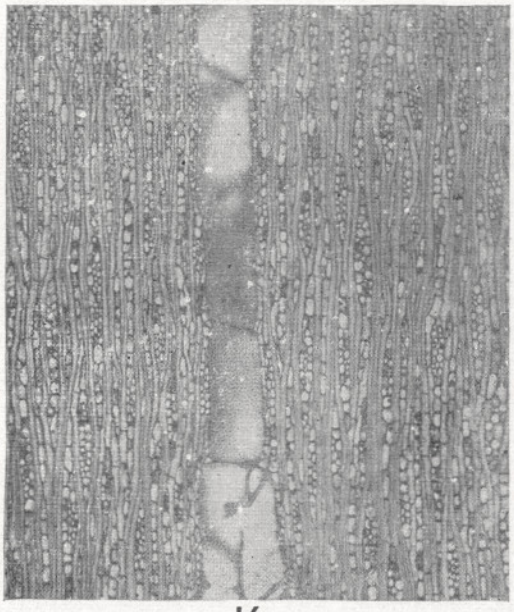

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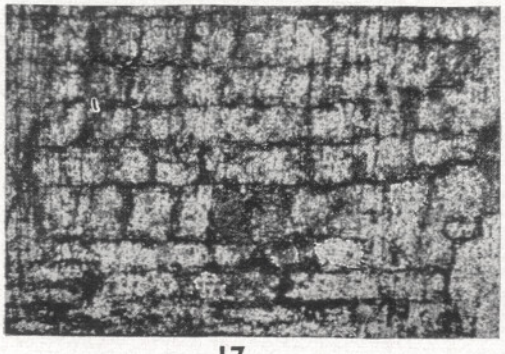

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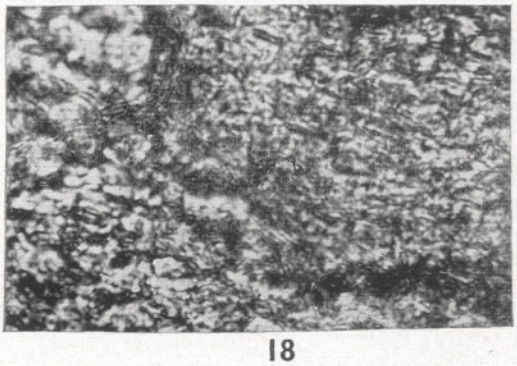

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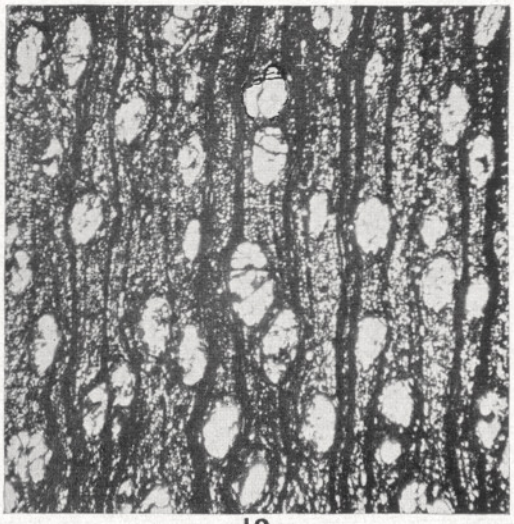

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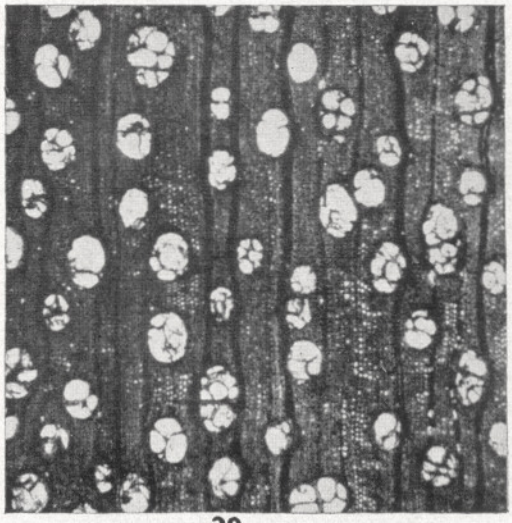

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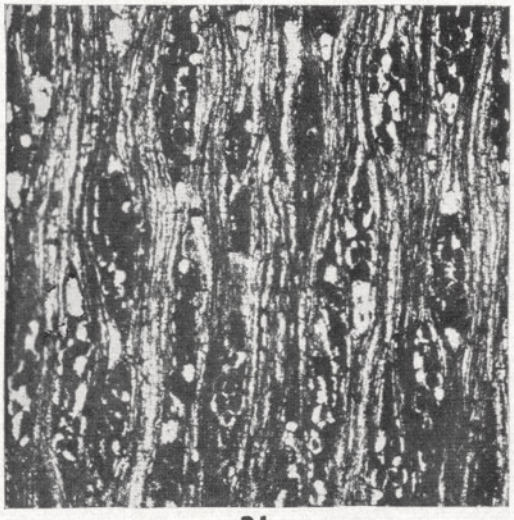

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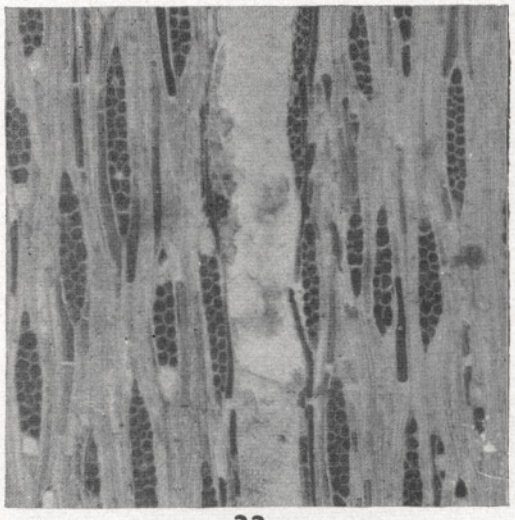

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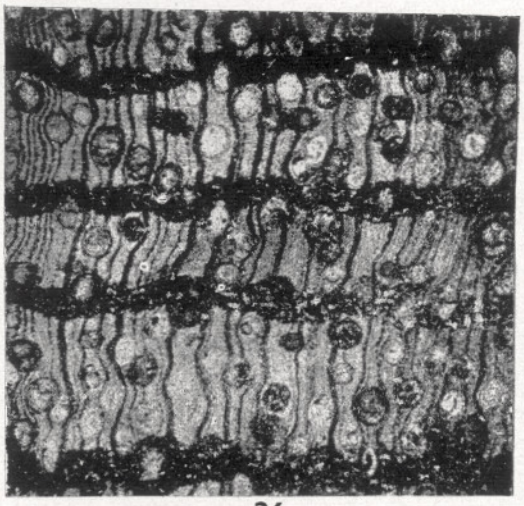

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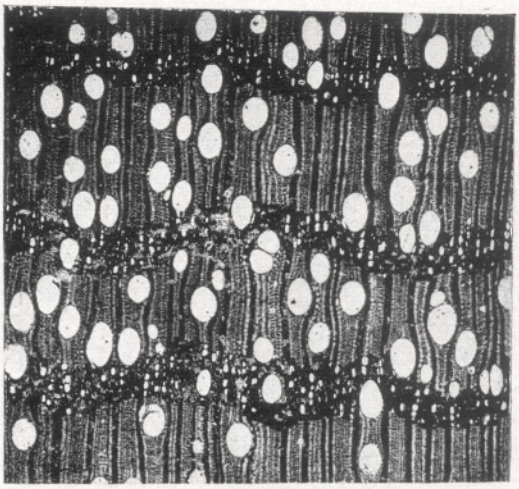

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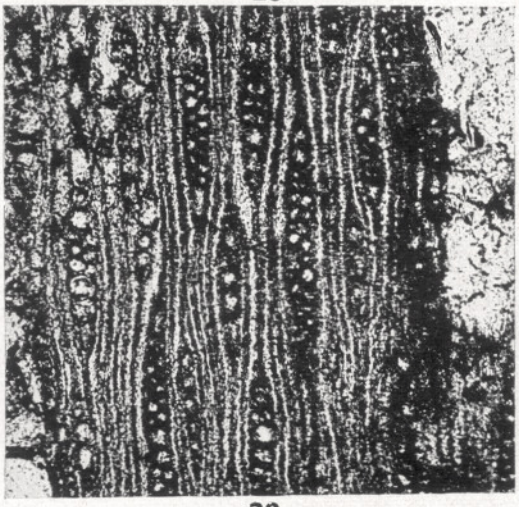

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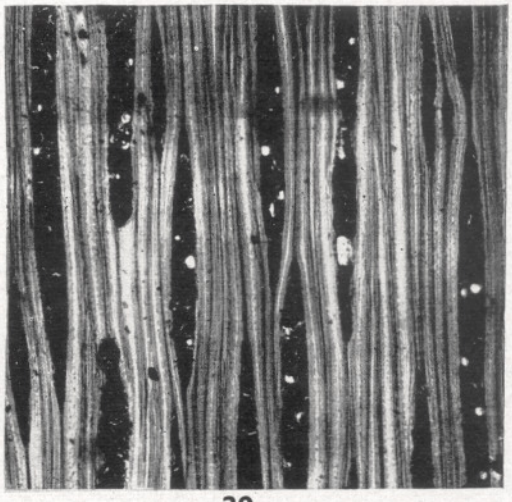

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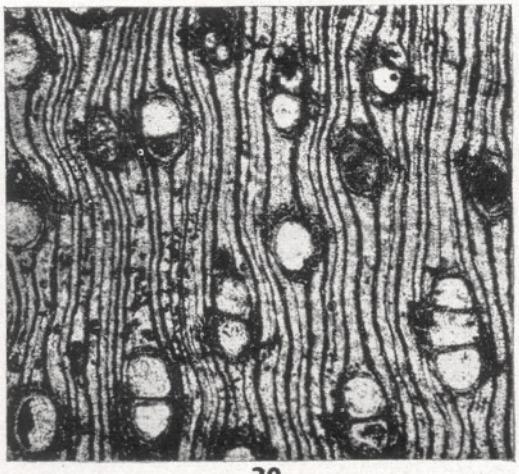

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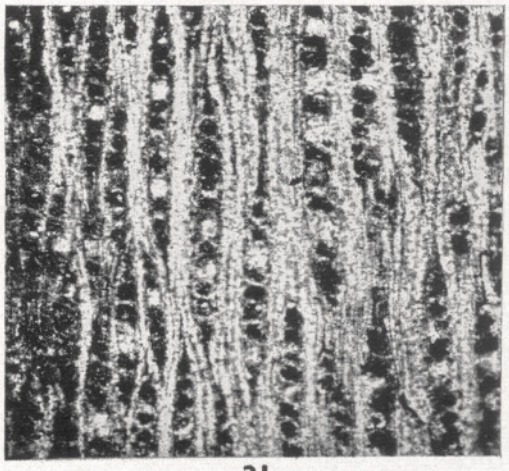

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