FOSSIL WOODS FROM THE TERTIARY OF EASTERN INDIA. 1

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ABSTRACT

Fossil woods of *Shorea, Holigarna, Cassia, Terminalia, Duabanga* and *Sideroxylon* are described here from the Tertiary of Assam and NEFA. They were collected from the beds of Buri-Dehing River near Jaipur and Namsang River at Deomali. Most of the modern equivalents of these fossils are commonly found in the modern forests of Assam and NEFA indicating the occurrence of a somewhat similar type of forest in this region during the Tertiary (Mio-Pliocene) period.

INTRODUCTION

ALTHOUGH the Tertiary rocks of Assam are rich in plant fossils, much work could not be done earlier because almost all the Tertiary outcrops are covered with forests, and the exposures are almost restricted to sections found in the rivers and hillside streams. This together with the lack of transport made the localities inaccessible and the collection difficult. However, with the building of a network of roads and a consequent development of quick transport during the recent years, it has now been possible to reach the fossil localities, and, therefore, the palaeobotanical work has been taken up more vigorously from this region, so far neglected.

With a view to make a systematic study of the fossil woods of Eastern India, a rich collection was made by Drs. R. N. Lakhanpal and M. N. Bose in December 1963 from the beds of Buri-Dehing River near Jaipur (27°16′ N, 95°24′ E) in Assam and Namsang River near the headquaters of the Khonsa Forest Division, at Deomali (TEXT-FIG. 1) in NEFA. From this collection, fossil woods resembling *Calophyllum, Terminalia* and *Afzelia-Intsia* have been described so far by Prakash (1965a, 1966b). The present study is in continuation of this work and deals with the fossil woods belonging to the families Dipterocarpaceae, Anacardiaceae, Leguminosae, Combretaceae, Sonneratiaceae and Sapotaceae.

The present fossil woods are Tertiary in age. Those collected from the bed of Buri-Dehing River at Jaipur might have been derived from the Tipam Series exposed in the vicinity and nearby (TEXT-FIG. 1), indicating an Upper Miocene age. On the other hand, the fossil woods from the bed of Namsang River at Deomali are probably Mio-Pliocene in age supposedly being derived from the Namsang Beds (TEXT-FIG. 1). The presence of fossil woods has already been recorded from the Tipam sandstones and Girujan clay of the Tipam Series and also from the Namsang Beds (KRISHNAN, 1960; PASCOE, 1963).

DIPTEROCARPACEAE

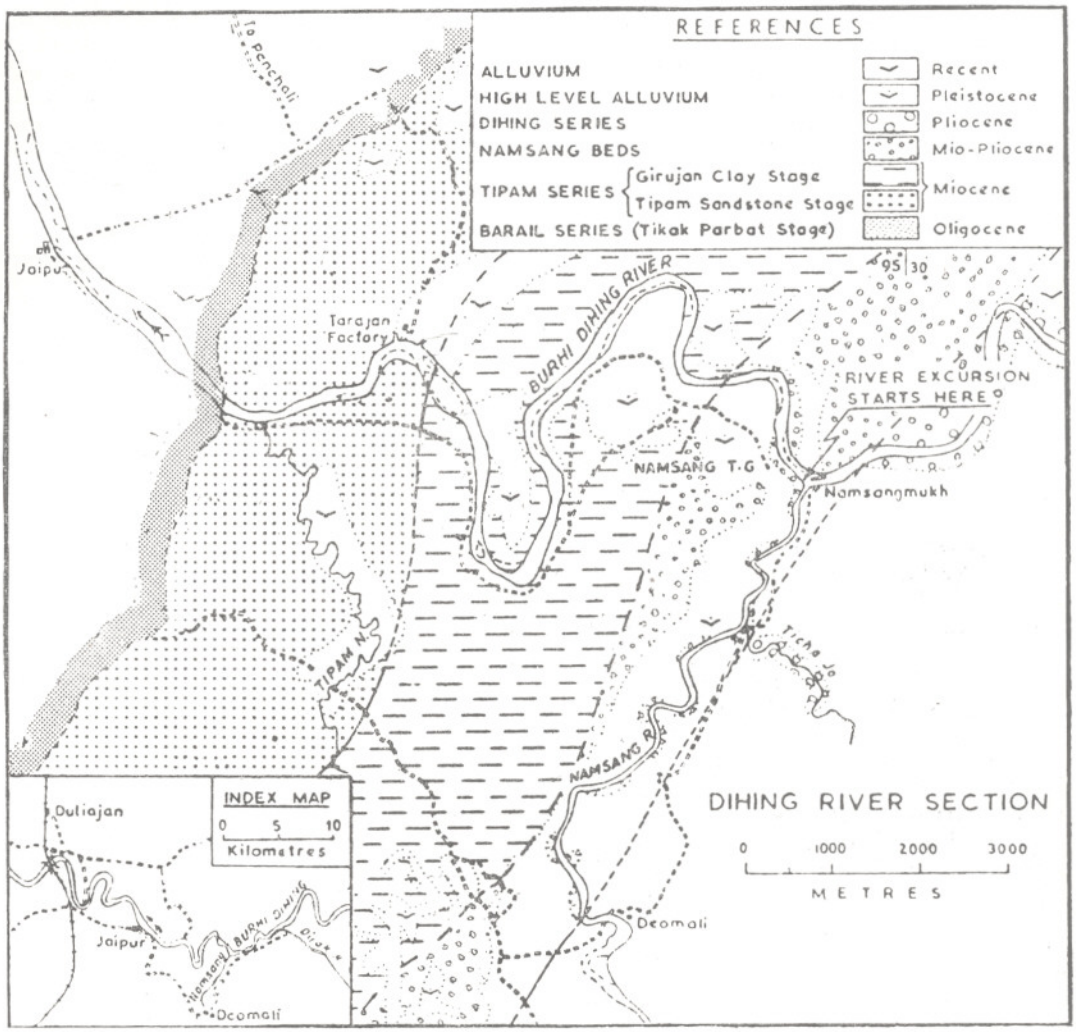
Shoreoxylon Den Berger, 1923

1. *Shoreoxylon tipamense* sp. nov

Pl. 1, Figs. 1-5

The present wood specimen is a single piece measuring about 9 cm. in length and 6 cm. in diameter. The preservation is satisfactory.

Topography — Wood diffuse-porous (PL. 1, FIG. 5). *Growth rings* present, indicated by the presence of larger and crowded vessels in the early wood (PL. 1, FIG. 5). *Vessels* visible to the naked eye, medium to large, mostly solitary, occasionally in radial multiples of 2-3 or rarely more, evenly distributed, those occurring in the inner margin of the ring, crowded (PL. 1, FIG. 5), 3-9 vessels per sq. mm.; tyloses present, thin-walled. *Vasicentric tracheids* not well preserved. *Parenchyma* not easily distinguished from the neighbouring fibres in cross-section, paratracheal, vasicentric to aliform and occasionally aliform-confluent (PL. 1, FIG. 1); diffuse or aggregate parenchyma occasionally present. *Xylem rays* fine to broad, 1-5 seriate (PL. 1, FIG. 3), 5-8 rays per mm., each separated by 4-16 tangential rows of fibres; ray-tissue heterogeneous; rays both homocellular and heterocellular; multiseriate rays heterocellular, consisting of procumbent cells through the median thickened portion and 1-12 marginal rows of upright cells; uniseriate rays both heterocellular and homocellular, the latter are few, consisting wholly



TEXT-FIG. 1. Geological map of Dihing River and adjacent area. (After A. B. Das Gupta, P. Evans, A. K. Metre & S. N. Visvanath, 1964).

of upright cells; sheath cells occasionally present; rays 3-66 cells in height. *Fibres* aligned between two consecutive xylem rays. *Gum canals* normal, vertical, in concentric rings (PL. 1, FIG. 1; PL. 1, FIG. 5).

Elements — Vessels circular to oval, those of radial multiples flattened at the places of contact, t.d. 112-332 μ, r.d. 112-352 μ thin-walled, walls 6-12 μ in thickness; vessel-members 300-600 μ in length, with truncated ends; perforations simple; intervessel pits large, 8-10 μ in diameter, vestured, alternate, circular or orbicular with small circular orifices; vessel-parenchyma and vessel-ray pits almost similar to intervessel pits. *Parenchyma cells* rounded or oval, 20-40 μ in diameter; crystalliferous strands present with usually 4-6 cells, each containing solitary crystal. *Ray cells* both upright and procumbent, thin-walled; upright cells 40-60 μ in tangential height, 10-40 μ in radial length; procumbent cells 16-28 μ in tangential height, 40-120 μ in radial length. *Fibres* round to oval or angular, 12-36 μ in diameter, nonseptate, thin-walled, walls 2-3 μ in thickness; pits not seen. *Gum canals* about 80-160 μ in diameter.

Affinities — Comparison with the modern species: The presence of normal, vertical gum canals in concentric bands in the present fossil wood indicates its affinities with the family Dipterocarpaceae, where all the genera excepting *Monotes* and *Marquesia* possess gum canals. Based on the distribution of gum canals, this family can be divided into two groups. One with resin canals always aligned in long concentric rows, and the other with these canals primarily diffuse. The first group includes genera like *Doona, Hopea, Shorea, Parashorea, Balanocarpus, Dryobalanops* and *Pentacme*, while the other group consists of *Anisoptera, Dipterocarpus, Vateria*, etc. Recently Schweitzer (1958) classified the fossil dipterocarpaceous woods, which have gum canals in tangential bands, into two form genera, viz. *Shoreoxylon* Den Berger (1923) and *Dryobalanoxylon* Den Berger (1923). The genus *Dryobalanoxylon* includes the genera with both libriform fibres and fibre tracheids, while *Shoreoxylon* consists of woods having only libriform fibres. The first category includes only *Dryobalanops*, while the rest, i.e. all those belonging to Shoreae, are put in the second category.

A detailed comparison of the present fossil wood with the modern woods of Dipterocarpaceae showing long, concentric tangential rings of gum canals indicates its affinity with the modern genera of the group Shoreae, especially with *Shorea*. For detailed comparison with the modern species of *Shorea*, thin sections of a number of species were examined, viz. *Shorea argentia* C. E. C. Fischer, *S. assamica* Dyer, *S. farinosa* C. E. C. Fischer, *S. obtusa* Wall., *S. gratissima* Dyer, *S. robusta* Gaertn. f., *S. sericeiflora* C. E. C. Fischer et Hutch., *S. talura* Roxb. and *S. tumbaggaia* Roxb. Besides, it was also compared with published description and figures of a number of other species of *Shorea*. From this detailed comparison it was found that the nearest resemblance of the present fossil wood is with *Shorea assamica* and *S. farinosa*, but more so with the former.

Comparison with the fossil species — The fossil woods of the Shoreae type have been placed under the genus *Shoreoxylon* Den Berger (1923). It consists of a number of species described mostly from the South-East Asia. They are *Shoreoxylon palembangense* (Kräusel) Den Berger (1923) from the Pliocene of South Sumatra, *S. djambiense* Den Berger (1923) from the Tertiary of South Sumatra and Pliocene of West Java (Schweitzer, 1958), *S. moroides* Den Berger (1927) from the Pliocene of Java, *S. swedenborgi* (Schuster) Schweitzer (1958) from the Pliocene of East Indies, *S. asiaticum* Schweitzer (loc. cit.) from the Pliocene of Sumatra, *S. maximum* Schweitzer (loc. cit.) from the Pliocene of Middle Sumatra, *S. parvum* Schweitzer (loc. cit.) from the Pliocene of West Java, *S. multiporosum, S. pulchrum* and *S. posthumi* all described by Schweitzer (loc. cit.) from the Quaternary of Middle Sumatra. From India and Burma, excluding some doubtful ones, there are three species of *Shoreoxylon*, viz. *S. speciosum* Navale (1963) from the Tertiary of South India, *S. evidens* Eyde (1963) from the Tertiary of Garo Hills, Assam, and *S. burmense* Prakash (1965b) from the Tertiary of Burma. After comparing with the above species it has been found that the present fossil wood is quite different from the above species. Therefore, a new specific name, *Shoreoxylon tipamense*, has been proposed for it. The specific name indicates its occurrence in the Tipam sandstones.

The genus *Shorea* includes nearly one hundred species, which are widely distributed throughout the tropical parts of Indo-Malayan region. *Shorea assamica*, with which the present fossil wood resembles closely, is found in Upper Assam, chiefly in Lakhimpur Division, on the north bank, along the foot-hills, in the Nagaland of the Sibsagar Division and in Upper Burma. It also occurs in Lower Burma and Tenasserim (Pearson & Brown, 1932, pp. 106, 119).

Diagnosis

Shoreoxylon tipamense sp. nov.

Wood diffuse-porous. *Growth rings* present, indicated by large and crowded vessels in the early wood. *Vessels* medium to large, t.d. 112-332 μ; r.d. 112-352 μ, mostly solitary, occasionally in radial multiples of 2-3; vessel-members 300-600 μ in length, with truncated ends; perforations simple; tyloses present, thin-walled; intervessel pits and pits leading to contiguous tracheids, large, 8-10 μ in diameter, alternate, circular or orbicular, vestured. *Tracheids* vasicentric, preservation lacking. *Parenchyma* paratracheal, vasicentric to aliform and aliform-

confluent; diffuse or aggregate parenchyma occasionally present; cells 20-40 μ in diameter; crystalliferous strands present containing solitary crystals. *Xylem rays* fine to broad, 1-5 seriate, 5-8 rays per mm.; ray-tissue heterogeneous; rays mostly heterocellular, consisting of procumbent cells through the median thickened portion and 1-12 marginal rows of upright cells at one or both the ends; sheath cells occasionally present; rays 3-66 cells in height. *Fibres* 12-36 μ in diameter, nonseptate, thin-walled, wall thickness 2-3 μ. *Gum canals* normal, vertical, in concentric tangential rows, 80-160 μ in diameter.

Holotype — B.S.I.P. Museum No. 33903.

Locality — Bed of Buri-Dehing River near Jaipur, Assam.

ANACARDIACEAE

Holigarnoxylon gen. nov.

2. *Holigarnoxylon assamicum* sp. nov.

Pls. 1-3, Figs. 6-14

The fossil species, upon which the present description is based, is represented by three small pieces of silicified wood. Their preservation is fairly good.

Topography — Wood diffuse-porous (Pl. 1, Fig. 6). *Growth rings* not seen. *Vessels* small to large (mostly medium-sized), solitary as well as in radial multiples of 2-6, mostly 2 (Pl. 2, Fig. 7), occasionally in double rows, more or less evenly distributed, 5-16 per sq. mm.; tyloses present, thin-walled (Pl. 2, Fig. 7). Parenchyma paratracheal, vasicentric to aliform and aliform-confluent, joining 2-3 neighbouring vessels (Pl. 1, Fig. 6). *Xylem rays* fine, 1-3 (mostly 2) seriate (Pl. 2, Fig. 9; Pl. 3, Fig. 13); ray-tissue heterogeneous; rays heterocellular, consisting of procumbent cells and 1-3 (mostly 1) marginal rows of upright cells at one or both the ends (Pl. 3, Fig. 14); rays up to 20 cells in height, 6-8 per mm. *Fibres* aligned in radial rows between the two consecutive xylem rays.

Elements — Vessels circular to oval, those in radial multiples flattened at the places of contact (Pl. 2, Fig. 7); t.d. 50-256 μ; r.d. 30-240 μ; thick-walled, walls 8-20 μ in thickness; vessel-members 240-640 μ in length, with truncate ends; perforations simple; intervessel pits large, about 8-12 μ in diameter, alternate, oval or orbicular with lenticular apertures; vessel-ray and vessel-parenchyma pits not seen. *Parenchyma cells* about 12-37 μ in diameter, oval or orbicular, those present in the immediate vicinity of the vessels flattened. Upright *ray cells* about 40-160 μ in tangential height, 37-48 μ in radial length, usually swollen and often crystalliferous; procumbent cells 20-40 μ in tangential height, 60-160 μ in radial length. *Fibres* oval to angular (mostly hexagonal), sometimes tangentially flattened, about 8-24 μ in diameter, nonseptate, moderately thick-walled, walls 2-4 μ in thickness.

Affinities — Comparison with the modern woods: Among the modern woods, the above-described anatomical details of the present fossil wood are found in *Holigarna* of the family Anacardiaceae, although it also resembles superficially the wood of the genus *Buchanania* of the same family. However, in *Buchanania* the radial gum canals are occasionally present in the xylem rays, but these are absent in the present fossil wood. In order to find out the nearest modern equivalent of the fossil wood a number of modern species of *Holigarna* were examined critically, viz. *H. arnottiana* Hook. f., *H. beddomei* Hook. f., *H. grahamii* Hook. f., *H. helferi* Hook. f. and *H. longifolia*. Of these, *H. beddomei* is very close to the present fossil wood. Both the fossil and the modern woods show common features such as medium to large vessels, simple perforations, intervessel pits large, alternate, with lenticular apertures; vasicentric to aliform and aliform-confluent parenchyma, joining 2-3 neighbouring vessels, 1-3 (mostly 2) seriate, heterogeneous xylem rays consisting of 1-3 marginal rows of upright cells and procumbent cells through the median thickened portion; upright cells usually smaller containing solitary crystals; and nonseptate fibres.

Fossil woods resembling with those of *Holigarna* are so far unknown, although a number of fossil woods belonging to the family Anacardiaceae have been recorded from India and abroad. From India quite a number of them are known as described by many workers (Chowdhury, 1952; Prakash & Dayal, 1965; Awasthi, 1966; Prakash & Tripathi, 1967, 1968). The present fossil wood, which resembles the genus *Holigarna*, is assigned to a new genus *Holigarnoxylon* and described as *H. assamicum*, the specific name indicating its occurrence in the Tertiary of Assam.

Holigarna is a small genus of large trees, confined to the Indo-Malayan region. Only 9 species are found in India and Burma. *H. beddomei* is a large tree, 24 m. high, found in the hills of Malabar and Travancore in Kerala and Nilgiri and Anamalais in Madras up to 900 m. elevation. In relation to the geographic locale of the fossil, the nearest tree species of *Holigarna* is *H. helferi* Hook. f., which grows in the forests of Chittagong and Burma, chiefly along the streams (GAMBLE, 1902, p. 222).

DIAGNOSES

Holigarnoxylon gen. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small to large, solitary as well as in radial multiples of 2-6 or more, occasionally in double rows, circular to oval; vessel-members truncate; perforations simple; tyloses present, thin-walled; intervessel pits large, usually 8-12 μ in diameter, circular, alternate, with lenticular apertures. *Parenchyma* paratracheal, vasicentric to aliform and aliform-confluent. *Xylem rays* 1-3 seriate; ray-tissue heterogeneous; rays heterocellular, consisting of procumbent cells and 1-3 (mostly 1) marginal rows of upright cells at one or both the ends. *Fibres* nonseptate.

Genotype — *Holigarnoxylon assamicum* sp. nov.

Holigarnoxylon assamicum sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small to large (mostly medium-sized), solitary as well as in radial multiples of 2-6 (mostly 2), sometimes also in double rows, t.d. 50-256 μ; r.d. 30-240 μ; vessel-members 240-640 μ in length, with truncate ends; perforations simple; tyloses present, thin-walled; intervessel pits large, 8-12 μ in diameter, alternate, circular, with lenticular apertures. *Parenchyma* paratracheal, vasicentric, forming 2-3 seriate sheath around the vessels, aliform to confluent, joining 2-3 neighbouring vessels. *Xylem rays* 1-3 (mostly 2) seriate, heterogeneous; rays heterocellular, consisting of procumbent cells through the median thickened portion and 1-3 (mostly 1) marginal rows of upright cells, up to 20 cells in height, 6-8 per mm.; upright cells swollen containing solitary crystals. *Fibres* 8-24 μ in diameter, nonseptate, moderately thick-walled, walls 2-4 in thickness.

Holotype — B.S.I.P. Museum No. 33904.

Locality — Bed of Buri-Dehing River near Jaipur, Assam.

LEGUMINOSAE

Peltophoroxylon Müller-Stoll & Mädel, 1967

3. *Peltophoroxylon cassioides* sp. nov.

Pls. 3-4, Figs. 15-21

The present species is based on a single piece of silicified wood measuring 8 cm. in length and 6 cm. in diameter. The preservation is satisfactory.

Topography — *Wood* diffuse-porous (PL. 4, FIG. 21). *Growth rings* not clearly seen. *Vessels* visible to the naked eye in cross-section, small to large, mostly medium-sized, solitary as well as in radial multiples of 2-6, mostly 2-3 (PL. 3, FIG. 16; PL. 4, FIG. 21), 4-12 per sq. mm.; tyloses absent. *Parenchyma* paratracheal, mostly aliform to aliform-confluent, joining few to many vessels, anastomosing frequently (PL. 3, FIG. 16; PL. 4, FIG. 21); terminal parenchyma not seen due to bad preservation. *Xylem rays* 1-3 (mostly 2-3) seriate (PL. 4, FIG. 18); ray-tissue homogeneous; rays homocellular, consisting of procumbent cells only (PL. 3, FIG. 15), 4-24 cells in height, 6-9 rays per mm. *Fibres* aligned in radial rows between the consecutive rays.

Elements — *Vessels* circular to oval, those of multiples flattened at the places of contact; t.d. 96-240 μ; r.d. 112-320 μ, thin-walled; vessel-members 160-720 μ in length, with truncate ends; perforations simple; intervessel pits large (PL. 4, FIG. 20), 8-10 μ in diameter, vestured, circular or elliptical, alternate, apertures lenticular. *Parenchyma strands* with frequently crystalliferous cells, cells 20-40 μ in diameter. *Ray cells* oval in tangential section, 16-28 μ in tangential height and 40-150 μ in radial length. *Fibres* nonseptate, thick-walled.

Affinities — *Comparison with the modern species*: The characteristic features of this fossil wood are the presence of medium to large vessels, aliform to confluent parenchyma, 1-3 seriate xylem rays, nonseptate fibres and vestured intervessel pits. These features are found in some of the genera of Leguminosae. However, taking into consideration all the anatomical details, the

present fossil shows closest resemblance with the genus *Cassia*. For specific identification thin sections of the woods of the following species were examined at the Forest Research Institute, Dehra Dun. These are *Cassia auriculata* Linn., *C. fistula* Linn., *C. marginata* Roxb., *C. nodosa* Buch.-Ham., *C. siamea* Lam., *C. grandis* Linn., *C. javanica* Linn. and *C. aubrevillei* Pellegr. Besides examining the thin slides of the above species, published description and figures of the following species were also consulted for detailed comparison, namely *C. aubrevillei* Pellegr. (NORMAND, 1950, p. 125, PL. 36), *C. fastuosa* Willd. (KRIBS, 1959, p. 70, FIG. 173), *C. javanica* Linn., *C. timoriensis* DC. and *C. siamea* Lam. (MOLL & JANSSONIUS, 1914, pp. 97-108, FIG. 56; KANEHIRA, 1924, p. 26). Among these species the present fossil wood resembles *Cassia fistula* in all the anatomical details. The species *C. nodosa* is also very near to the present fossil, except that it differs from it in having frequently septate fibres.

In 1882, Felix described a fossil wood from the ? Tertiary of Antigua and named it *Cassioxylon anomalum* as he thought it to resemble the modern wood of *Cassia speciosa*. Since then a few other species were described under this genus. Recently Müller-Stoll and Mädel (1967), while working on the fossil woods of Leguminosae, re-examined the type slides of *Cassioxylon anomalum* and found that this fossil wood does not show any affinities with the genus *Cassia* and may hardly belong to the family Leguminosae. They also pointed out that the modern woods of *Cassia, Peltophorum* and *Xylia* are similar to each other in structural details. Therefore, for the fossil woods showing resemblance with the woods of the genera *Cassia, Peltophorum* and *Xylia*, they proposed the generic name *Peltophoroxylon* Müller-Stoll & Mädel (1967). Consequently, they transferred *Cassioxylon variegatum* Ramanujam (1960) and *Acacioxylon indicum* Ramanujam (1955) to *Peltophoroxylon varie gatum* (Ramanujam) Müller-Stoll & Mädel and *P. indicum* (Ramanujam) Müller-Stoll & Mädel respectively. *Cassioxylon zirkeli* described by Felix (1884) from the Tertiary of Hungary was also examined again by these authors who transferred it to another leguminous form genus, *Dichrostachoxylon* Müller-Stoll & Mädel (1967). In 1966, one of us (PRAKASH) described a fossil wood of *Cassia* from the Tertiary of Assam and named it as *Cassioxylon borooahii*. As the generic name *Cassioxylon Felix* (1882) does not stand for the woods of *Cassia*, for which *Peltophoroxylon* Müller-Stoll & Mädel (1967) is a valid name, the species *Cassioxylon borooahii* Prakash (1966a) is transferred to the genus *Peltophoroxylon* and named as *P. borooahii* (Prakash) comb. nov., Prakash & Awasthi.

While studying the modern woods of *Cassia, Peltophorum* and *Xylia*, thin sections of *Cassia siamea* Lam., *C. fistula* Linn., *C. nodosa* Buch.-Ham., *C. marginata, Peltophorum grande, P. vogelianum* Walp., *Xylia xylocarpa* Taub. and *X. dolobiformis* Benth. and published description and photographs of *Cassia aubrevillei* Pellegr. (NORMAND, 1950, PL. 36) were critically examined. From the study it has been found that the fibres are nonseptate in *Cassia siamea* and *C. fistula*, but septate in other species; and the parenchyma is vasicentric-aliform, often confluent in almost all except *Cassia siamea* (DESCH, 1957, PL. 61, FIG. 1) and *C. aubrevillei* Pellegr. (NORMAND, 1950, PL. 36), where it is usually banded. As in the generic diagnosis of *Peltophoroxylon* given by Müller-Stoll and Mädel (1967, p. 117) the fibres are septate and the parenchyma is vasicentric-aliform, often confluent, therefore, it is amended here so that the genus *Peltophoroxylon* can include all the fossil woods of *Cassia, Peltophorum* and *Xylia*, for which it has been instituted.

Comparison with the fossil species — The present fossil wood, although slightly resembling *Peltophoroxylon indicum*, differs from it in having slightly smaller vessels, less wider xylem rays and nonseptate fibres. *P. variegatum* Ramanujam also differs from the present fossil wood in possessing predominantly confluent parenchyma and septate fibres. *P. borooahii* is also quite distinct from *P. cassioides* in having banded parenchyma, besides differing in many other features.

Since the present fossil wood is quite different from the above-mentioned species of *Peltophoroxylon*, it is being described as a new species, *P. cassioides*, the specific name indicating a close resemblance with the modern wood of *Cassia*, particularly *C. fistula*.

Cassia fistula is one of the most widespread Indian forest trees, occurring throughout the forests of India, Burma and Ceylon.

DIAGNOSES

Peltophoroxylon Müller-Stoll & Mädel (1967) emend.

Wood diffuse-porous. *Vessels* regularly distributed, solitary and in short radial groups; perforations simple; intervessel pits alternate, medium-sized. *Wood parenchyma* vasicentric to aliform, often confluent or banded and initial or terminal. *Xylem rays* homogeneous or weakly heterogeneous with one row of square or upright cells, 1-5 cells broad. *Fibres* libriform, septate or nonseptate.

Peltophoroxylon cassioides sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to large, mostly medium in size, solitary as well as in radial multiples of 2-6 (mostly 2-3); t.d. 96-240 μ; r.d. 112-320 μ; vessel-members 160-720 μ in length with truncate ends; perforations simple; intervessel pits large, 8-10 μ in diameter, vestured; circular or elliptical, alternate, with lenticular apertures, tyloses absent. *Parenchyma* paratracheal, aliform to aliform-confluent, joining few to several vessels, anastomosing frequently; crystalliferous parenchyma strands common with solitary crystal in each locule. *Xylem rays* 1-3 (mostly 2-3) seriate; ray-tissue homogeneous; rays homocellular, consisting wholly of procumbent cells, 2-24 cells in height, 6-9 per sq. mm. *Fibres* nonseptate, thick-walled.

Holotype — B.S.I.P. Museum No. 33905.

Locality — Buri-Dehing River bed near Jaipur, Assam.

COMBRETACEAE

***Terminalioxylon* Schönfeld, 1947**

4. *Terminalioxylon tertiarum* Prakash, 1966

Pl. 4, Figs. 22-23

The specimen being recorded here is a small piece of silicified wood. It is about 5 cm. in length and 4 cm. in diameter. The preservation is fairly good.

Topography and Elements — *Wood* diffuse-porous. *Growth rings* present, delimited by large vessels and thin lines of parenchyma (PL. 4, FIG. 22). *Vessels* small to large, those of early wood large, gradually becoming smaller towards the end of annual rings (PL. 4, FIG. 22), solitary as well as in radial multiples of 2-4, mostly solitary (PL. 4, FIG. 22), 3-5 vessels per sq. mm., circular to oval; t.d. 90-370 μ; r.d. 90-432 μ; vessel-members truncate; perforations simple; intervessel pits large, 6-8 μ in diameter, alternate, vestured. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty to vasicentric, forming 1-3 cells wide sheath around the vessels, occasionally tending to become aliform; apotracheal parenchyma represented by thin lines present at the beginning of growth rings. *Xylem rays* fine, uniseriate (PL. 4, FIG. 23), about 2-22 cells in height; ray-tissue homogeneous, with rays composed wholly of procumbent cells; cells often swollen with solitary crystals. *Fibres* septate, thick-walled.

Affinities — This fossil wood shows all the characters of the modern genus *Terminalia* and is identical to *Terminalioxylon tertiarum* Prakash (1966b) described from Deomali in NEFA. However, the only difference between the present fossil and *T. tertiarum* from NEFA is the absence of traumatic gum canals in the present specimen. The occurrence of this type of gum canals is due to injury and is not a constant feature; hence it may not be present in a small piece of wood.

Holotype — B.S.I.P. Museum No. 33906.

Locality — Burhi-Dehing River bed near Jaipur, Assam.

SONNERATIACEAE

***Duabangoxylon* gen. nov.**

5. *Duabangoxylon tertiarum* sp. nov.

Pls. 5-6, Figs. 24-32

The present species is represented by two pieces of silicified wood. The bigger one measures about 10 cm. in length and 8 cm. in diameter. The preservation is fairly good.

Topography— *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* medium to large or very large (PL. 5, FIGS. 24, 29), solitary as well as in radial multiples of 2-8 (mostly 2), evenly distributed, 2-6 vessels per sq. mm., profusely tylosed (PL. 5, FIG. 24), tyloses thin-walled. *Parenchyma* paratracheal, forming 1-2 seriate sheath around the vessels (PL. 5, FIGS. 24, 26), occasionally

with short lateral extensions. *Xylem rays* fine, uniseriate, occasionally biseriate (PL. 5, FIG. 27; PL. 6, FIG. 31); moderately close, about 7-15 per mm., each separated by 1-7 tangential rows of fibres; ray-tissue heterogeneous; rays homocellular to heterocellular, homocellular rays consisting wholly of procumbent cells, while heterocellular rays consisting of procumbent cells and a few upright cells present at the margin of one or both the ends; rays 3-22 cells in height. *Fibres* aligned in radial rows between the two consecutive xylem rays (PL. 5, FIG. 24).

Elements — Vessels circular to oval, those in radial multiples flattened at the places of contact; t.d. and r.d. 160-432 μ, thin-walled; vessel-members up to 1120 μ in length, with truncate or tailed ends; perforations simple; intervessel pits large, about 8-10 μ in diameter, vestured, alternate, rounded, with linear or lenticular orifices; vessel-ray and vessel-parenchyma pits not seen. *Parenchyma* strands upto 960 μ in length, about 3-4 cells per strand; parenchyma cells 32-40 μ in diameter. *Ray cells* both upright and procumbent, upright cells 48-68 μ in tangential height, 32-48 μ in radial length; procumbent cells 24-32 μ in tangential height, 40-100 μ in radial length; crystals occasionally present. *Fibres* angular, mostly hexagonal, sometimes tangentially flattened, 16-60 μ in diameter, nonseptate, thin-walled, walls 2-3 μ thick; pits not seen.

Affinities — Comparison with the modern woods: The important anatomical features of the present fossil wood are — vessels medium to large or very large, solitary as well as in radial multiples, tylosed, parenchyma paratracheal, rays 1-2 seriate, heterogeneous and fibres nonseptate and thin-walled. These features are found in the woods of the modern genus *Duabanga*, especially in *D. sonneratiodes* of the family Sonneratiaceae. The only other genus *Sonneratia* of this family differs from the present fossil wood in having small to medium-sized vessels, septate fibres and in the absence of parenchyma. The present fossil wood has been assigned to a new genus *Duabangoxylon* and named as *D. tertiara* sp. nov., the specific name indicating its occurrence in the Tertiary beds.

Although the present discovery is the first authentic record of the fossil wood of *Duabanga* from India and abroad, fossil woods of *Sonneratia* have already been described. These are *Sonneratioxylon prambachense* Hofmann (1952) from the Oligocene of Austria, *S. dakshinense* Ramanujam (1957) from the Cuddalore Series of South India and *S. dudukurense* Krishna Rao & Ramanujam (1966) from the Intertrappean beds near Rajahmundry. In addition, Verma (1950) and Shallom (1963) also described fossil woods resembling *Sonneratia* and *Duabanga* and *Sonneratia* respectively from the Deccan Intertrappean Series. However, their identification seems to be doubtful. Recently Awasthi (1969) described a fossil wood resembling *Sonneratia apetala* from the Tertiary of South India.

Duabanga sonneratioides, the only Indian species of the genus *Duabanga*, grows in Eastern Himalaya, ascending to 900 m., Assam and Burma (GAMBLE, 1902).

DIAGNOSES

Duabangoxylon gen. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* medium to large or very large, solitary as well as in radial multiples of 2-8; perforations simple; vessel-members truncate; tyloses present; intervessel pits large, 8-10 μ in diameter, alternate, circular, vestured. *Parenchyma* paratracheal, forming scanty to vasicentric sheath around the vessels, occasionally in short tangential extensions. *Xylem rays* 1-3 seriate; ray-tissue heterogeneous. *Fibres* nonseptate, thin-walled.

Genotype — Duabangoxylon tertiarum sp. nov.

Duabangoxylon tertiarum sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* medium to large or very large, solitary as well as in radial multiples of 2-8 (mostly 2); t.d. and r.d. 160-432 μ, thin-walled; vessel-members up to 1100 μ in length, with truncate or tailed ends, 2-6 vessels per sq. mm.; perforations simple; tyloses present, thin-walled; intervessel pits large, 8-10 μ, circular, vestured. *Parenchyma* scanty vasicentric, forming 1-2 seriate sheath around the vessels, occasionally extending sideways; parenchyma cells 32-60 μ in diameter. *Xylem rays* 1-2 (mostly 1) seriate, heterogeneous, consisting of procumbent cells and 1-2 marginal rows of upright cells at one or both the ends; crystals present, rays 3-22 cells in height. *Fibres*

aligned in radial rows, angular (mostly hexagonal), 16-60 μ in diameter, nonseptate, thin-walled, walls 2-3 μ thick.

Holotype — B.S.I.P. Museum No. 33907.

Locality — Buri-Dehing River bed near Jaipur, Assam.

SAPOTACEAE

***Siderinium* gen. nov.**

6. *Siderinium deomaliense* sp. nov.

Pl. 6, Figs. 33-37

The fossil representing this species is a single piece of silicified wood. It is about 15 cm. in length and 8 cm. in diameter. The preservation is fairly good.

Topography — Wood diffuse-porous (Pl. 6, Fig. 35). *Growth rings* not easily recognizable, close lines of apotracheal parenchyma at some places indicate the presence of growth rings. *Vessels* small to medium-sized, solitary, mostly in radial multiples of 2-8 or more cells, more or less evenly distributed, 15-50 per sq. mm.; tyloses not seen. *Parenchyma* apotracheal, in uniseriate lines, mostly regular, sometimes forming thin bands due to aggregation of cells especially near the beginning of the annual rings, forming reticulum at places (Pl. 6, Fig. 35), about 15-20 lines per mm., each separated by 1-12 radial rows of fibres. *Xylem rays* fine, 1-3 (mostly 2) seriate (Pl. 6, Fig. 33), 11-77 cells in height, close, 10-15 rays per mm., each separated by 1-5 tangential rows of fibres; ray-tissue heterogeneous; rays heterocellular, consisting of procumbent cells in the median portion and 1-3 marginal rows of upright cells at one or both the ends. *Fibres* aligned in radial rows between the two consecutive xylem rays.

Elements — Vessels circular to oval, those of multiples flattened at the places of contact; t.d. 32-176 μ, r.d. 20-192 μ, thick-walled, walls 8-12 μ thick; vessel-members 176-640 μ in length, with truncate ends; perforations simple; intervessel pits minute, 2-4 in diameter, crowded, circular with slit-like apertures; vessel-ray and vessel-parenchyma pits similar to intervessel pits. *Parenchyma cells* rounded, 28-40 μ in diameter. *Ray cells* both upright and procumbent; upright cells 56-84 μ in tangential height, 36-48 μ in radial length; procumbent cells 16-32 μ in tangential height, 40-100 μ in radial length. *Fibres* small, angular (mostly hexagonal), sometimes tangentially flattened, 8-28 μ in diameter, nonseptate, thick-walled, walls 4-6 μ thick.

Affinities — Comparison with the modern woods: The important diagnostic features of the present fossil wood are: (1) vessels small, mostly arranged in radial multiples of 2-8; (2) perforations simple; (3) intervessel pits alternate, minute, crowded, circular with slit-like apertures; (4) parenchyma apotracheal in close, regular, uniseriate lines, often forming reticulum; (5) xylem rays 1-3 seriate, heterogeneous; and (6) fibres thick-walled and nonseptate. A combination of these characters is found in the modern woods of some members of Euphorbiaceae, Rubiaceae, Ebenaceae and Sapotaceae.

In the family Euphorbiaceae, *Cyclostemon* shows many similarities with this fossil wood. However, the wood of *Cyclostemon* differs from the present fossil in having vessels less in radial multiples and in the type of xylem rays which are markedly heterogeneous with several rows of marginal upright cells.

In the family Ebenaceae, the woods of some species of *Diospyros* and *Maba* show some resemblance in the size of vessels, distribution of parenchyma and the xylem rays. However, the present fossil wood differs mainly in having the parenchyma lines closely spaced than in the ebenaceous woods.

In the family Rubiaceae, the type and distribution of parenchyma is quite similar to that of the present fossil wood, but the rubiaceous woods differ in having less vessel multiples and in the type of the intervessel pits and xylem rays.

In Sapotaceae, the genera *Bassia, Chrysophyllum, Mimusops* and *Sideroxylon* show near resemblance with the present fossil wood. However, after a detailed study of the published literature and the thin slides of the modern woods of these genera, it is evident that the genus *Sideroxylon* shows a very close resemblance with the present fossil wood. On examination the thin sections of *Sideroxylon assamicum* Clarke, *S. burmanicum* Coll. & Hemol., *S. longipetiolatum* King & Prain, *S. tomentosum* Roxb. and *S. grandifolium* Wall. revealed a close identity of the fossil wood with *S. grandifolium*.

As far as the authors are aware this is the first record of a fossil wood resembling

the genus *Sideroxylon*. Therefore, it is assigned to a new genus *Siderinium*. It is, however, described as *Siderinium deomaliense* sp. nov. after the name of the locality Deomali.

DIAGNOSES

Siderinium gen. nov.

Wood diffuse-porous. *Growth rings* occasionally present, delimited by apotracheal parenchyma. *Vessels* small to medium, solitary and mostly in radial multiples; vessel-members truncate; perforations simple; tyloses absent; intervessel pits small or minute, crowded, circular, with slit-like apertures. *Parenchyma* apotracheal, usually in regular uniseriate lines, sometimes forming thin bands due to aggregation, at places forming reticulum. *Xylem rays* fine, 1-3 seriate; ray-tissue heterogeneous; rays heterocellular, consisting of procumbent cells through the median portion and 1-several marginal rows of upright cells at one or both the ends. *Fibres* nonseptate, thick-walled.

Genotype — *Siderinium deomaliense* sp. nov.

Siderinium deomaliense sp. nov.

Wood diffuse-porous. *Growth rings* indicated by apotracheal parenchyma. *Vessels* small to medium, solitary (mostly in radial multiples of 2-8), circular to oval; t.d. 32-176 μ, r.d. 20-192 μ, thick-walled, walls 8-12 μ thick, 15-50 per sq. mm.; vessel-members truncate, 176-640 μ in length; perforations simple; intervessel pits small to minute, 2-4 μ in diameter, crowded, circular with slit-like apertures; tyloses absent. *Parenchyma* apotracheal, mostly in regular uniseriate lines, more close near the growth rings, forming reticulum at places, about 15-20 parenchyma lines per mm. *Xylem rays* fine, 1-3 (mostly 2) seriate, 11-77 cells in height, close, 10-15 rays per mm.; ray-tissue heterogeneous; rays heterocellular, consisting of procumbent cells in the median portion and 1-3 marginal rows of upright cells at both the ends. *Fibres* small, angular (mostly hexagonal), flattened, 8-28 μ in diameter, nonseptate, thick-walled, walls 4-6 μ in thickness.

Holotype — B.S.I.P. Museum No. 33908.

Locality — Namsang River bed near Deomali, NEFA.

DISCUSSION

The plants determined generically and described in the present paper comprise modern species of *Shorea, Holigarna, Cassia, Terminalia, Duabanga* and *Sideroxylon*. A study of their modern distribution in India indicates their occurrence either in the immediate vicinity of the fossil locality or at most within a radius of few hundred miles. The genus *Shorea* includes nearly one hundred species of trees which are widely distributed throughout the tropical portions of the Indo-Malayan region. The greatest concentration of species is met with in Borneo, Sumatra and Malay Peninsula. In the Indian region there are ten species of which only four grow in India proper, one in Assam in the east, one in north and central parts of India, and two in south (PEARSON & BROWN, 1932; CHOWDHURY & GHOSH, 1958). The other genus *Holigarna* is indigenous to the tropical evergreen rain forests and strictly Indo-Malayan, ranging from the western coast of Peninsula eastward through the Andamans into Burma and Lower Burma. Nine species are reported to occur in India and Burma (PEARSON & BROWN, 1932). In relation to the geographic locale of the fossil, the nearest tree species of *Holigarna* is *H. helferi* Hook., which grows in the forests of Chittagong and Burma. As regards *Cassia*, over 300 species are known which are widely distributed throughout the warmer regions of the Old and the New World with the exception of Europe. From the standpoint of species, the genus reaches its best development in tropical America, extending southward into Patagonia, and northward into the United States of America. About 20 woody species are found in India. The species *Cassia fistula* which shows close resemblance with the fossil wood is found from the Indus eastwards to the drier forests of Assam, throughout Bihar and Orissa, the Central Provinces, Central India, Khandesh, Gujarat, the Deccan and Carnatic, the east and west coasts and southwards to Ceylon, in most parts of Burma, and introduced in the Andamans (PEARSON & BROWN, 1932). *Terminalia*, on the other hand, comprising about 200 species of shrubs and medium size to very large trees, is of pantropical distribution (RECORD & HESS, 1943). At least 16 species, mostly important trees of large size, occur in the Indian region (GAMBLE, 1902). Some species

of *Terminalia* are quite common in Assam. The genus *Duabanga* consists of two species of large trees. *D. sonneratioides* grows in eastern Himalaya, ascending to 900 m., Assam and Burma (GAMBLE, 1902). Another important genus *Sideroxylon* consists of over 100 species of evergreen, laticiferous trees, sometimes of large size, rarely shrubs. The genus is widely distributed throughout the tropics of both hemispheres and also extends into Australia, New Zealand, Norfolk Island, sourthern Africa and Madeira. At least seven species are known from the Indian flora. *Sideroxylon grandifolium*, which shows nearest affinity with the fossil wood described in the present paper is a large tree of Assam in the Khasia Hills, Sylhet and the hills of Martaban (GAMBLE, 1902; PEARSON & BROWN, 1932).

Besides these, fossil woods of *Dipterocarpus* (GHOSH, 1956) and *Diospyros-Maba* (GHOSH & KAZMI, 1958) are also known from this area. The genus *Dipterocarpus* includes about 80 species, which grow mainly in the Indo-Malayan region. The range of its distribution is from South India and Ceylon in the west to Philippines in the east. About 13 species grow in the Indian region (CHOWDHURY & GHOSH, 1958). The other genus, *Diospyros*, is of about 55 forest trees, some very common, some scarce. They occur chiefly in South India, Ceylon, Burma, Eastern Bengal and Assam, four species only extending to Northern India (GAMBLE, 1902).

The existence of these eight genera during the Upper Tertiary (*Shorea, Dipterocarpus, Terminalia, Cassia, Duabanga, Sideroxylon, Diospyros-Maba*) together with the ones described earlier by one of us (PRAKASH, 1966b), all characteristically mesophytic forest trees, and their presence in the modern flora of that region indicates that there has been little or no change in the climatic or ecological conditions of Eastern India since the Miocene times and whatever little migration has taken place is of local nature.

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EXPLANATION OF PLATES

PLATE 1

1. *Shoreoxylon tipamense* sp. nov. — Cross-section showing shape, size and distribution of vessels, parenchyma and gum canals. × 43.

2. *Shorea assamica* — Cross-section showing similar shape, size and distribution of vessels, parenchyma and gum canals. × 43.

3. *Shoreoxylon tipamense* sp. nov. — Tangential longitudinal section showing xylem rays. × 60.

4. *Shorea assamica* — Tangential longitudinal section showing similar xylem rays. × 60.

5. *Shoreoxylon tipamense* sp. nov.— Another cross-section at low magnification showing nature and distribution of vessels and gum canals. × 12.

6. *Holigarnoxylon assamicum* gen. et sp. nov. — Cross-section under low magnification showing nature and distribution of vessels and parenchyma. × 12.

PLATE 2

7. *Holigarnoxylon assamicum* gen. et sp. nov. — Magnified cross-section showing the type and distribution of vessels and parenchyma. × 43.

8. *Holigarna beddomei* — Cross-section showing vessels and parenchyma similar to fossil. × 43.

9. *Holigarnoxylon assamicum* gen. et sp. nov. — Magnified tangential longitudinal section showing xylem rays. × 135.

10. *Holigarna beddomei* — Tangential longitudinal section showing similar xylem rays. × 135.

11. *Buchanania angustifolia* — Cross-section of the same showing similar vessels and parenchyma as in the fossil. × 43.

12. *Buchanania angustifolia* — Tangential longitudinal section showing similar rays as in the fossil. × 135.

PLATE 3

13. *Holigarnoxylon assamicum* gen. et sp. nov. — Tangential longitudinal section showing xylem rays. × 60.

14. *Holigarnoxylon assamicum* gen. et sp. nov. — Radial longitudinal section showing heterocellular xylem rays. × 100.

15. *Peltophoroxylon cassioides* — Radial longitudinal section showing homocellular xylem rays. × 100.

16. *Peltophoroxylon cassioides* sp. nov.— Cross-section showing type and distribution of vessels and parenchyma. × 43.

17. *Cassia fistula* — Cross-section showing similar vessels and parenchyma. × 43.

PLATE 4

18. *Peltophoroxylon cassioides* sp. nov.— Tangential longitudinal section showing xylem rays. × 135.

19. *Cassia fistula* — Tangential longitudinal section showing similar type of xylem rays. × 135.

20. *Peltophoroxylon cassioides* sp. nov.— Intervessel pits. × 550.

21. *Peltophoroxylon cassioides* sp. nov.— Cross-section showing the general distribution of vessels and parenchyma. × 10.

22. *Terminalioxylon tertiarum* Prakash — Cross-section showing nature and distribution of vessels. × 15.

23. *Terminalioxylon tertiarum* Prakash — Tangential longitudinal section showing xylem rays. × 98.

PLATE 5

24. *Duabangoxylon tertiarum* gen. et sp. nov. — Cross-section showing type and distribution of vessels and parenchyma. × 28.

25. *Duabanga sonneratioides* — Cross-section showing similar type of vessels and parenchyma. × 28.

26. *Duabangoxylon tertiarum* gen. et sp. nov. — Magnified cross-section showing vessels and paratracheal parenchyma. × 70.

27. *Duabangoxylon tertiarum* gen. et sp. nov. — Tangential longitudinal section showing xylem rays. × 135.

28. *Duabanga sonneratioides* — Tangential longitudinal section showing similar xylem rays. × 135.

29. *Duabangoxylon tertiarum* gen. et sp. nov. — Cross-section of another fossil specimen showing nature and distribution of vessels and parenchyma. × 28.

30. *Duabanga sonneratioides* — Cross-section from another specimen showing similar vessels and parenchyma. × 28.

PLATE 6

31. *Duabangoxylon tertiarum* gen. et sp. nov. — Tangential longitudinal section of another fossil specimen showing xylem rays. × 135.

32. *Duabanga sonneratioides* — Tangential longitudinal section from another specimen showing similar xylem rays. × 135.

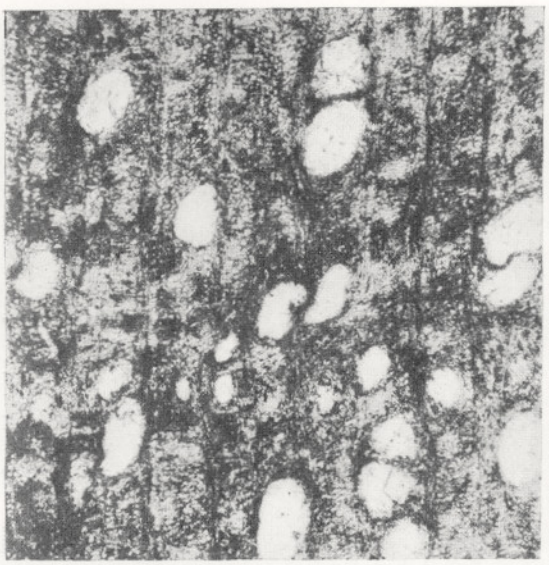
33. *Siderinium deomaliense* gen. et sp. nov. — Tangential longitudinal section showing xylem rays. × 135.

34. *Sideroxylon grandifolium* — Tangential longitudinal section showing similar xylem rays. × 135.

35. *Siderinium deomaliense* gen. et sp. nov. — Cross-section showing nature and distribution of vessels and parenchyma. × 30.

36. *Sideroxylon grandifolium* — Cross-section showing similar type and distribution of vessels and parenchyma. × 28.

37. *Siderinium deomaliense* gen. et sp. nov. — Intervessel pits. × 650.



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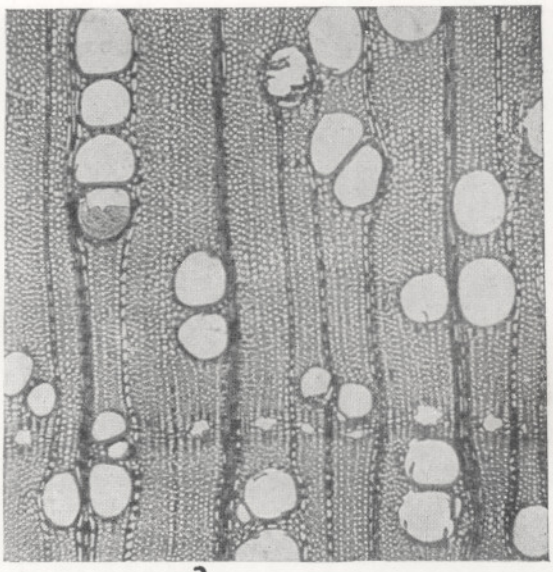

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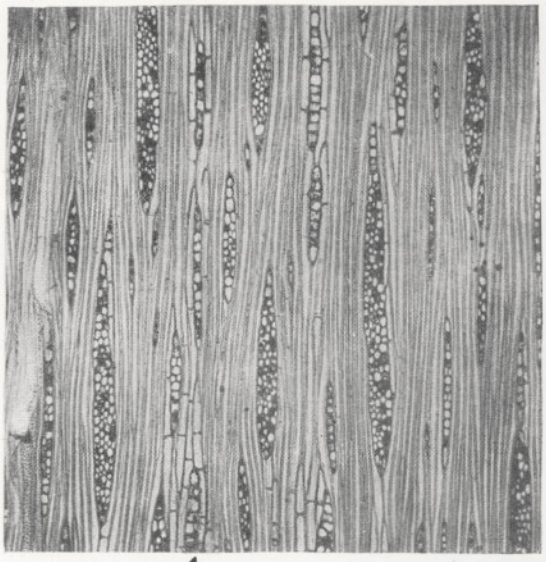

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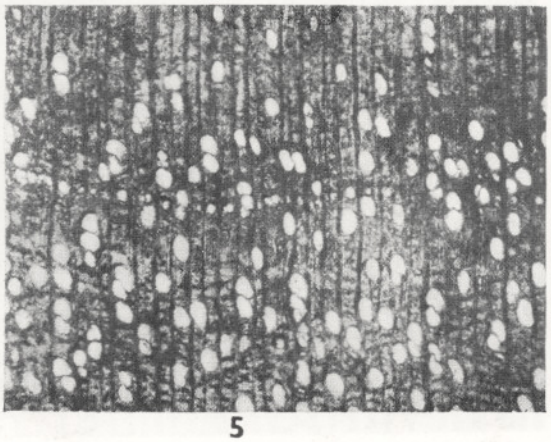

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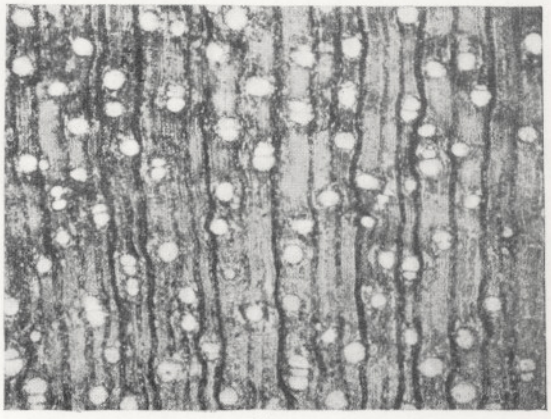

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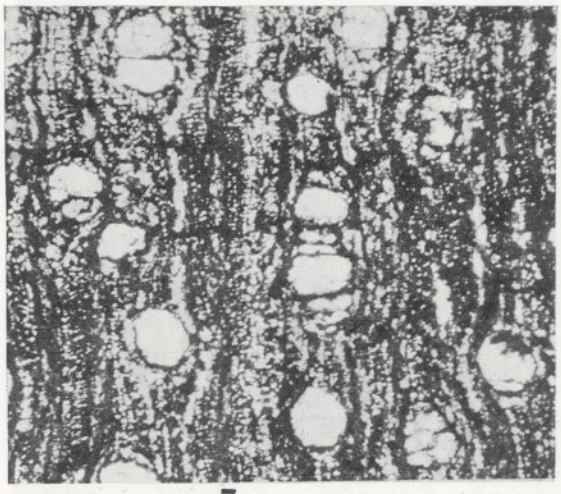

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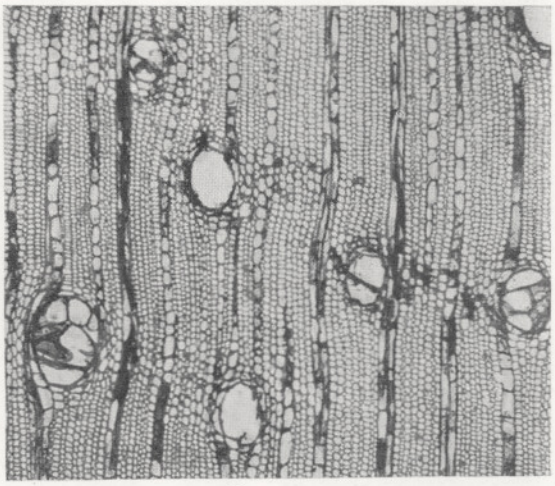

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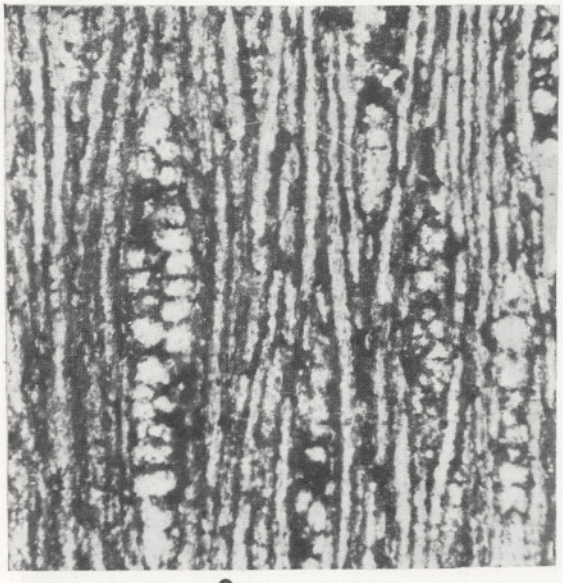

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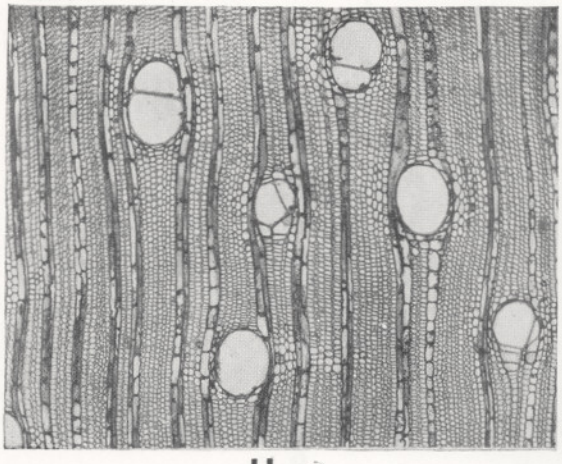

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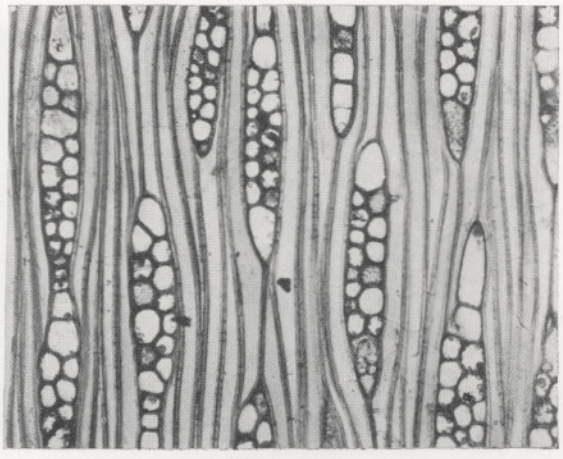

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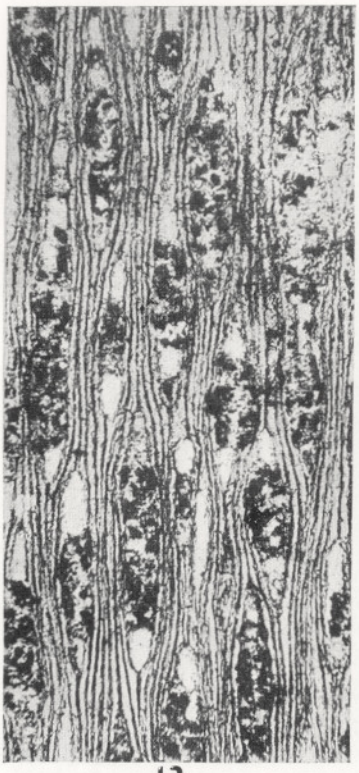

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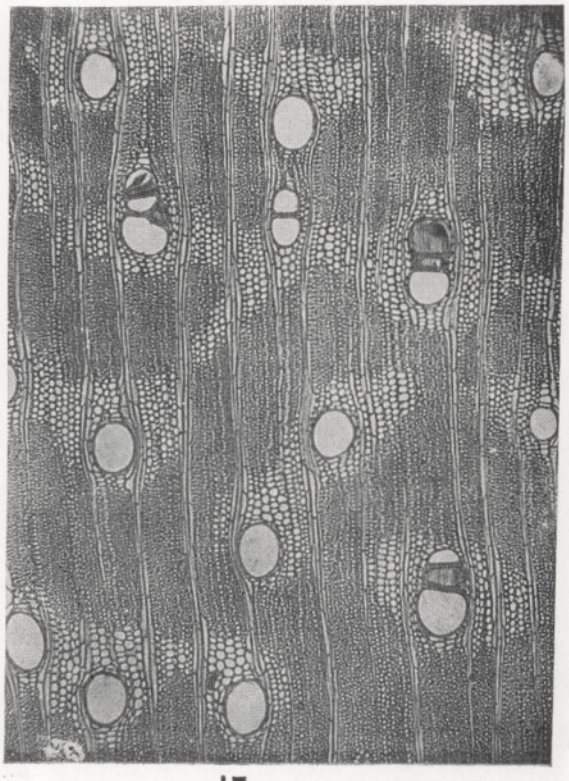

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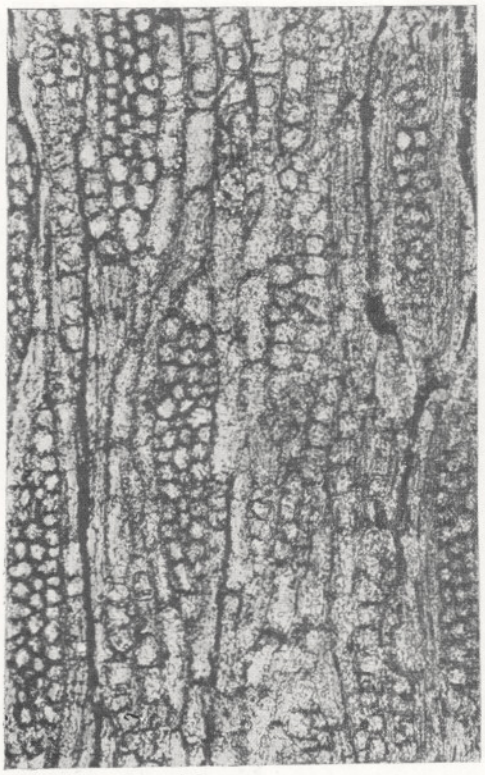

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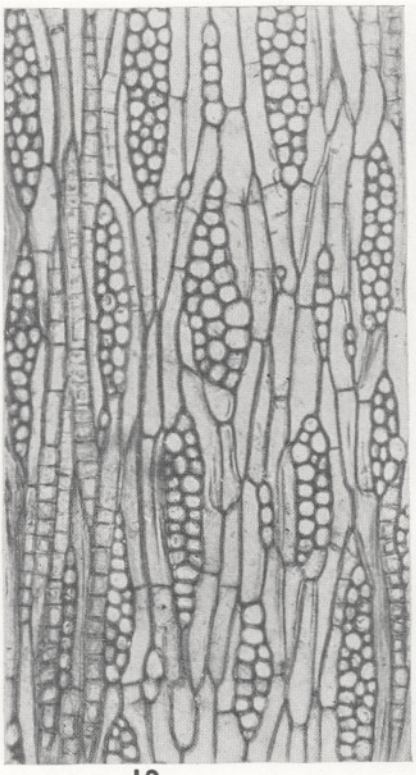

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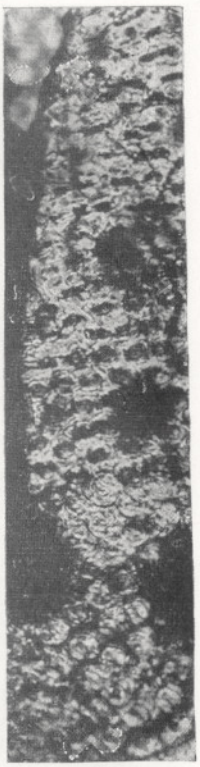

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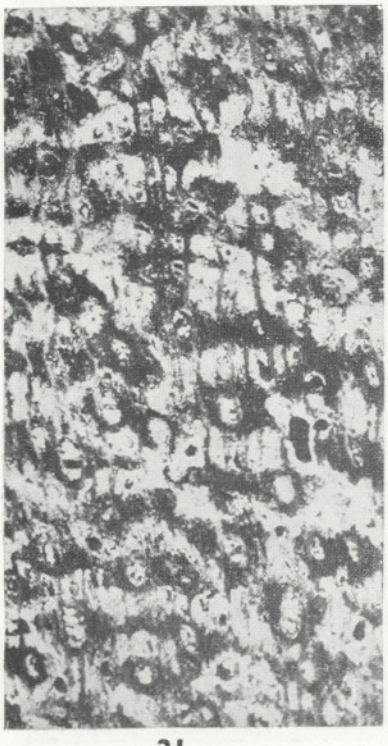

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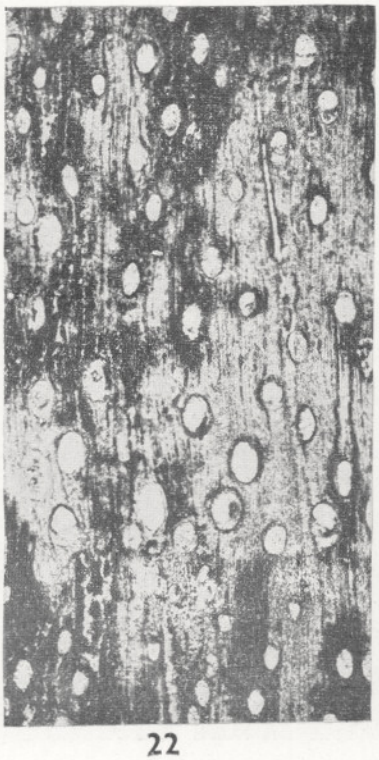

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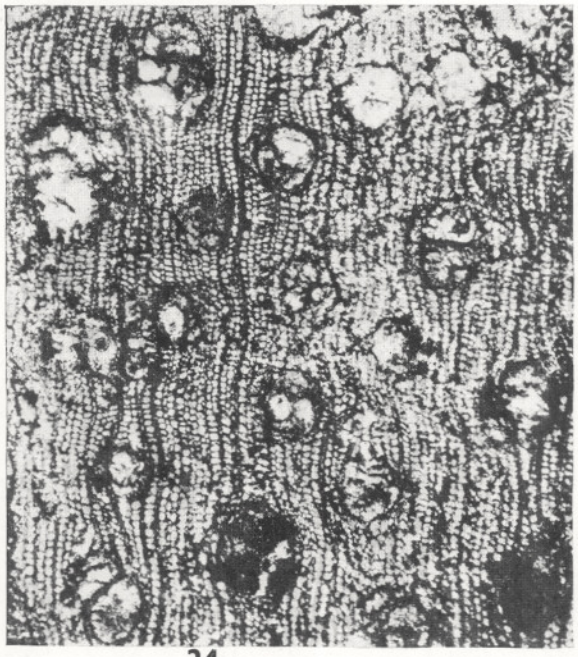

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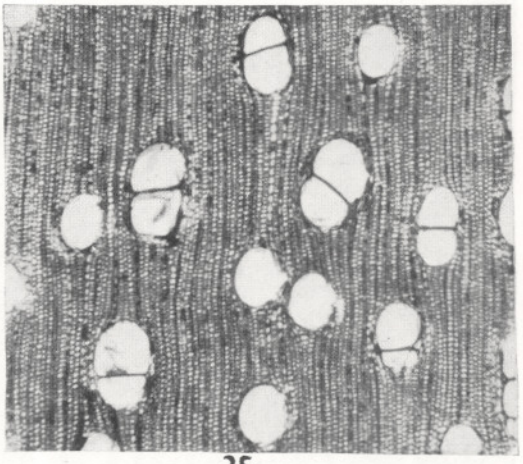

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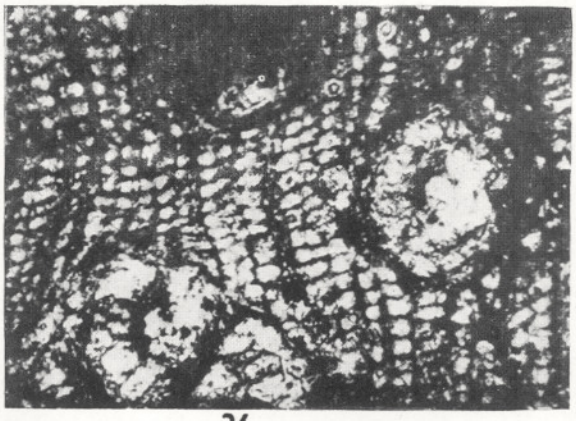

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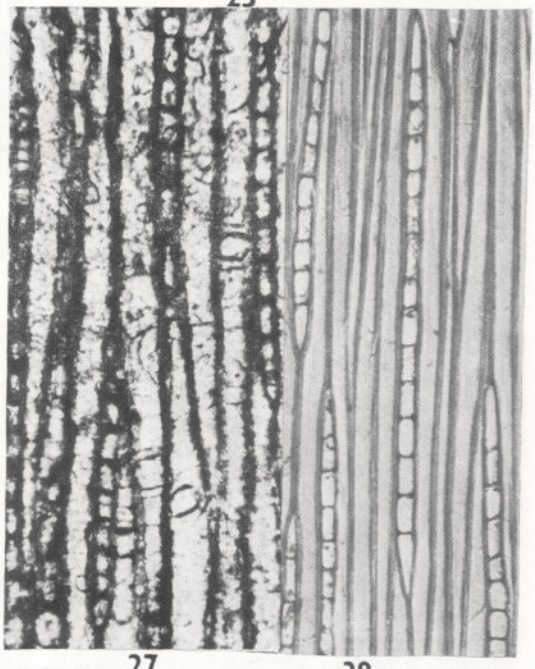

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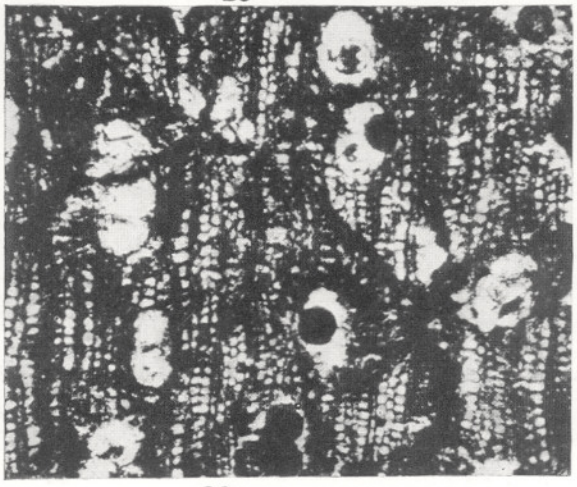

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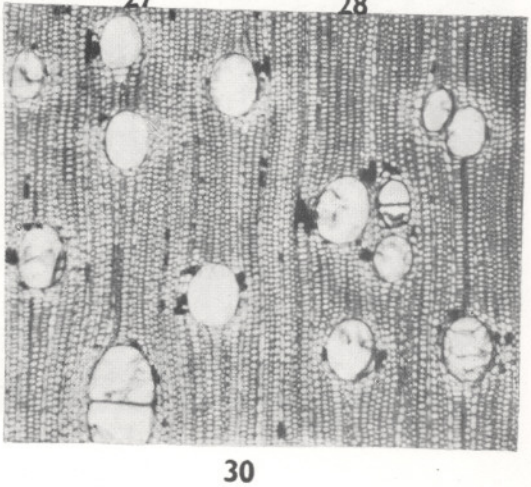

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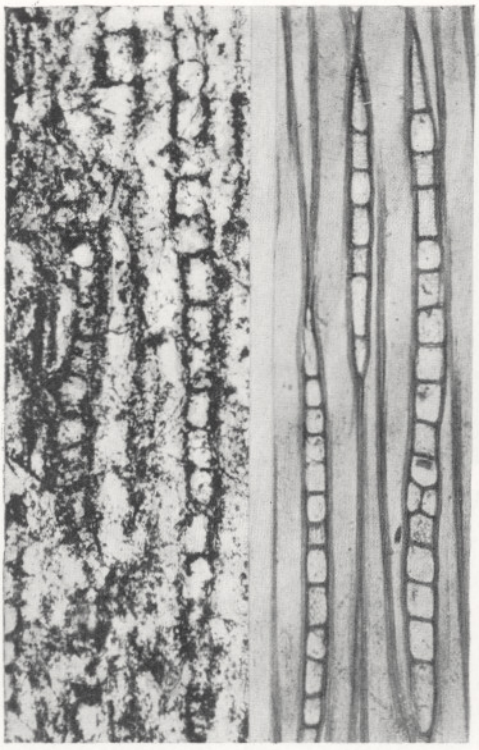

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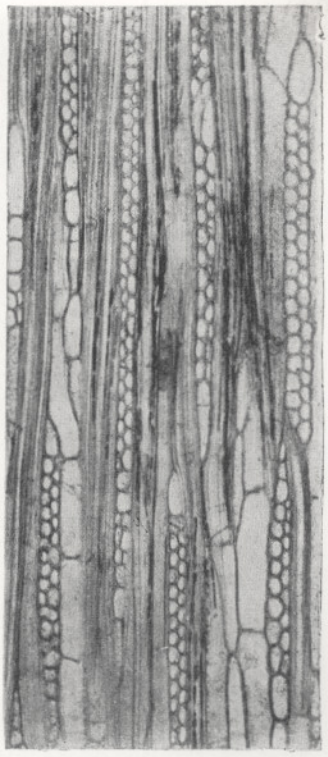

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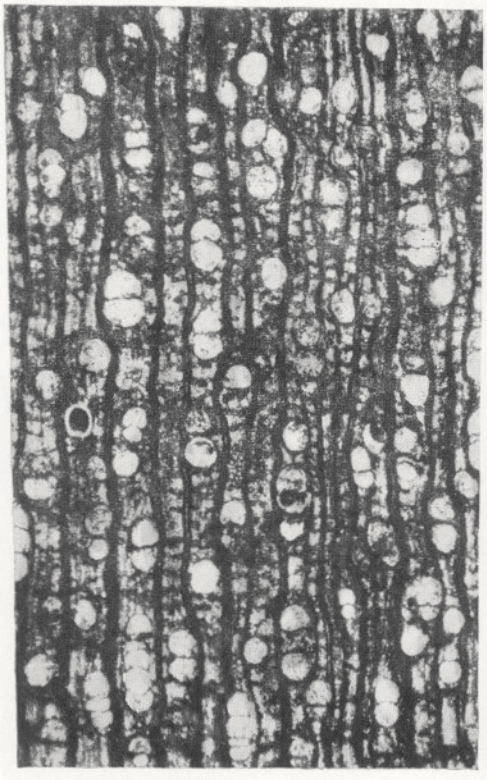

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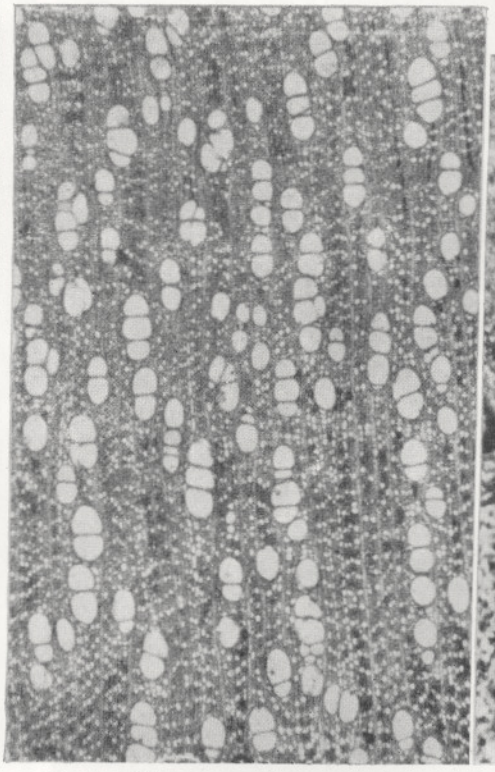

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