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FOSSIL DICOTYLEDONOUS WOODS FROM THE TERTIARY OF THAILAND

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ABSTRACT

Fossil woods of *Pahudioxylon sahnii* Ghosh & Kazmi, *Cynometroxylon parainaequifolium* sp. nov., *Millettioxylon indicum* Awasthi, *Anogeissoxylon thailandicum* sp. nov., and *Dryoxylon siamensis* sp. nov. are described here from the north-east region of Thailand. Although their exact age could not be known, it is most likely that they might belong to Upper Tertiary

Key-words — Fossil dicot woods, Xylotomy, Upper Tertiary (Thailand).

सारांश

थाइलैंड के टरशरी कल्प से द्विबीजपत्री काष्ठाश्म—उत्तम प्रकाश

यहाँ थाइलैंड के उत्तर-पूर्वी क्षेत्र से पहूडियाक्सीलॉन साहनाई घोष एवं काज़मी, साइनोमेट्रॉक्सीलॉन पेराइनइक्वीफोलियम न० जा०, मिलेटियाक्सीलॉन इन्डिकम् अवस्थी, ऐनोगाइसाक्सीलॉन थाइलैंडिकम् न० जा० तथा ड्रायोक्सीलॉन स्यामेन्सिस न० जा० के काष्ठाश्मों का वर्णन किया गया है। यद्यपि इनकी यथार्थ आयु अभी ज्ञात नहीं हो सकी है, लेकिन सम्भवतः ये अपर टरशरी के हो रहे होंगे।

INTRODUCTION

THIS detailed anatomical study is based on a collection of fossil woods sent to us by Mr Swat Nicharat, Chief, National Park Section, Royal Forest Department, Bangkok, Thailand. These woods were collected from the north-east region of Thailand between 15°N and 102°E by Mr Donald Lane of England, while he was working on a F.A.O. forestry project of the Royal Forestry Department of Bangkok.

Most of the fossil woods were found at a level of 1·50 m below the surface, mixed with sandstones and laterites (personal communication). However, nothing has been said about the nature and age of the beds from which these woods were collected in Thailand.

The palaeobotanical studies of the Tertiary flora of Thailand are rather few. Some undeterminable dicotyledons and a legume similar to *Mimosites* are known from the limestone beds of the Upper Tertiary age at Mae Sot (Sethaput, 1956).

The present material consists of six well-preserved specimens of fossil woods, which have been sectioned in transverse, tangential and radial planes and a number of thin sections prepared for study. These have been identified to five modern taxa of the dicotyledons.

SYSTEMATIC DESCRIPTION

Family — LEGUMINOSAE

Genus — *Pahudioxylon* Chowdhury, Ghosh & Kazmi, 1960

1. *Pahudioxylon sahnii* Ghosh & Kazmi, 1961

Pl. 1, figs 1, 3

This species is based on a piece of decorticated secondary wood, measuring about 15 cm in length and 9 cm in diameter.

Topography — Wood diffuse-porous. *Growth rings* delimited by smaller vessels and narrow lines of parenchyma (Pl. 1, fig. 1). *Vessels* usually large to medium-sized, t.d. 105-240 μ, r.d. 150-300 μ, mostly

solitary, sometimes in radial multiples of 2-3 or 4 cells, normally oval but mostly elliptical due to compression during fossilization (Pl. 1, fig. 1); vessel members 150-360 μ long with truncate ends; perforations simple; intervessel pits vestured, alternate to subopposite, 4-6 μ in diameter and round to oval in shape. *Parenchyma* paratracheal and apotracheal (Pl. 1, fig. 1); paratracheal parenchyma mostly aliform (Pl. 1, fig. 1) with short wing-like extensions, sometimes locally confluent joining 3-4 adjacent vessels; parenchyma sheath 2-5-(6) seriate round the vessels; apotracheal parenchyma terminal forming narrow lines (Pl. 1, fig. 1); parenchyma strands sometimes crystalliferous. *Xylem rays* fine, 1-3 (mostly 2) seriate, 4-18 cells high, 8-11 per mm (Pl. 1, fig. 3); ray tissue homogeneous with rays composed of procumbent cells; rays sometimes show tendency towards storied arrangement. *Fibres* nonlibriform, moderately thick-walled and nonseptate.

As the present fossil wood is identical to *Pahudioxylon sahnii* Ghosh & Kazmi (1961), it is assigned to it. It shows a close resemblance to the modern wood of *Afzelia cochinchinensis* (Pierre) J. Leonard (F.R.I. slide no. A 2302) which grows in Siam, Laos, Cambodge and Cochinchine (Lecomte, 1908-1923, pp. 216-217).

Pahudioxylon sahnii is widely known in the Tertiary formations of North-eastern India and Burma and its presence in Thailand further extends its distribution in South-East Asia. It is known from the Miocene (?) of Tripura (Ghosh & Kazmi, 1961), the Late Miocene of Tipam sandstones near Jaipur in Assam (Prakash & Awasthi, 1971), the Mio-Pliocene of Namsang beds near Deomali in Arunachal Pradesh (Prakash, 1966), and the Mio-Pliocene of Irrawaddy Series in Burma (Prakash, 1973).

Specimen — B.S.I.P. Museum no. 35262.

Genus — *Cynometroxylon* Chowdhury & Ghosh, 1946

2. *Cynometroxylon parainaequifolium* sp. nov.

Pl. 2, figs 5, 7

The fossil wood consists of a well-preserved piece of mature secondary xylem measuring 15 cm in length and 14 cm in diameter.

Topography — Wood diffuse-porous (Pl. 2, fig. 5). *Growth rings* not distinct. *Vessels* large to medium-sized and small (Pl. 2, fig. 5), mostly in radial multiples of 2-3 or more, quite often solitary, oval to elliptical in cross section when solitary, about 6-7 per sq mm, with brownish or black deposits. *Parenchyma* apotracheal in concentric tangential bands (Pl. 2, fig. 5) alternating with the fibre bands; bands 4-5 per mm, each 2-5-(7) cells in width. *Xylem rays* 1-2 (mostly 2) seriate (Pl. 2, fig. 7), 13-60 cells in height, heterocellular, consisting of procumbent cells in the middle portion and 1-2 or more marginal rows of upright cells at one or both the ends; end to end ray fusion frequent. *Fibres* not arranged in radial rows.

Elements — Vessels slightly thick-walled, walls about 8 μ thick, t.d. of solitary vessels 75-180 μ, r.d. 75-300 μ, oval to elliptical in shape; vessel members 150-450 μ long with truncate ends; perforations simple; intervessel pits vestured, alternate, 4-6 μ in diameter and oval to orbicular in shape; vessel-parenchyma and vessel-ray pits could not be seen. *Parenchyma cells* thin-walled, 12-20 μ in diameter and 30-105 μ in length. *Ray cells* thin-walled, procumbent cells 8-12 μ in tangential height, 32-48 μ in radial length; upright cells 24-32 in tangential height and 16-20 μ in radial length. *Fibres* libriform, polygonal in cross section, nonseptate, 16-20 μ in diameter and 400-900 μ in length; interfibre pits could not be seen.

Affinities — There is close agreement in almost all details of structure of this wood with that of *Cynometra*. An examination of thin sections of 16 species and published description and photographs of 8 pieces of *Cynometra* reveals that the present fossil wood shows nearest resemblance with the wood structure of *Cynometra inaequifolia* A. Gray (F.R.I. slide no. F 185 & F 224) (Moll & Janssonius, 1914, pp. 149-156; Desch, 1957, pp. 238-268, pl. 61, fig. 2; Metcalfe & Chalk, 1950, pp. 493-494, fig. 110M; Henderson, 1953, p. 39, fig. 183; Kribs, 1959, p. 73, fig. 405; Brazier & Franklin, 1961, p. 46; Normand, 1950, pls 39, 40; Pearson & Brown, 1932, pp. 406-408, fig. 141). The fossil wood resembles the modern wood of *Cynometra inaequifolia* in vessel size and their distribution, in the nature of perforation plates, intervascular pit-pairs, in parenchyma distribution and

in the ray and fibre structure. However, the rays are rarely triseriate in some specimens of the modern wood of *Cynometra inaequifolia*, whereas they are only 1-2 seriate in the fossil wood.

So far only three species of fossil woods showing resemblance with *Cynometra* have been described. These are *Cynometroxylon indicum* from the Tertiary of North Cachar Hills and the Tipam sandstones near Hailakandi in Assam (Chowdhury & Ghosh, 1946; Prakash, 1967; Prakash & Tripathi, 1976), the Namsang beds near Deomali in Arunachal Pradesh (Prakash & Awasthi, 1971), the Lower Siwalik beds near Nalagarh in Himachal Pradesh (Prakash, 1975), the Cuddalore Series in South India (Ramanujam & Rama Rao, 1966), the Irrawaddy Series of Burma (Prakash, 1973) and the microlithic site at Birbhanpur in West Bengal (Ghosh, 1960), *C. dakshinense* from the Cuddalore Series near Pondicherry in South India (Navale, 1959) and *C. schlagintweitti* from Dschaipur in Assam (Müller-Stoll & Mädel, 1967). *Cynometroxylon indicum* differs from the present fossil wood in having small to medium-sized vessels (t.d. 119-131 μ, r.d. 140-156 μ), somewhat broader (3-9 cells thick) parenchyma bands and in 1-3 (mostly 1-2) seriate and less than 40 cells high xylem rays. In the present fossil wood the vessels are usually large to medium-sized (t.d. 75-180 μ, r.d. 75-300 μ), the parenchyma bands are 2-5-(7) cells thick and the xylem rays are 1-2 (mostly 2) seriate and 13-60 cells in height. *Cynometroxylon dakshinense* is also quite distinct from the present fossil wood in having medium-sized (t.d. 108 μ, r.d. 180 μ) vessels and storied xylem rays (seen in type slides). Similarly, *Cynometroxylon schlagintweitii* differs also from *Cynometroxylon parainaequifolium* in possessing somewhat less broad, 2-5 cells thick bands of parenchyma, and in 1-3 (mostly 1) seriate, homocellular xylem rays consisting wholly of procumbent cells.

As the present fossil wood is quite distinct from the other known species of *Cynometroxylon* Chowdhury & Ghosh (1946), it is assigned to a new species, *Cynometroxylon parainaequifolium*, the specific name indicating a near resemblance with the modern wood of *Cynometra inaequifolia*.

The genus *Cynometra* Linn. consists of 60 species (Willis, 1966, p. 321) distributed throughout the tropics of both the hemispheres. In the Old World it is found in Africa and Madagaskar, in the eastward through the Indo-Malayan region to Philippines, Australia and the Pacific islands, while in the New World it ranges into Mexico, Brazil and Columbia. *Cynometra inaequifolia* A. Gray, with which the present fossil wood resembles most, grows in Pūket in Thailand, besides occuring in Philippines and Malayan Peninsula (Craib, 1931, p. 540).

SPECIFIC DIAGNOSIS

Cynometroxylon parainaequifolium sp. nov.

Wood diffuse-porous. *Growth rings* not distinct. *Vessels* large to medium-sized and small, mostly in radial multiples of 2-3 or more, quite often solitary, oval to elliptical, t.d. 75-180 μ, r.d. 75-300 μ, filled with brownish or black deposit, 6-7 per sq mm; vessel segments 150-450 μ long with truncate ends; intervessel pit-pairs vestured, alternate, 4-6 μ in diameter and oval to orbicular in shape. *Parenchyma* in concentric bands alternating with the fibres; bands 2-5-(7) cells thick and 4-5 per mm. *Xylem rays* 1-2 (mostly 2) seriate, 13-60 cells high and heterocellular. *Fibres* libriform, polygonal, non- septate, 16-20 μ in diameter and 400-900 μ in length.

Holotype — B.S.I.P. Museum no. 35263.

Millettioxylon Awasthi, 1967

3. *Millettioxylon indicum* Awasthi, 1967

Pl. 3, figs 9, 11

The specimen consists of a well-preserved piece of petrified secondary wood, 15 cm in length and 9 cm in diameter.

Topography — Wood diffuse-porous. *Growth rings* present. *Vessels* usually small to medium-sized, t.d. 80-180 μ, r.d. 75-240 μ, mostly solitary (Pl. 3, fig. 9), sometimes in radial multiples of 2-3 or 4 cells, round to oval or elliptical in cross section, 4-5 per sq mm, almost always empty; vessel segments storied, 150-390 μ long with truncate ends; perforations simple; intervessel pit-pairs vestured, alternate, 6 μ in diameter. *Parenchyma* apotracheal in thick concentric bands (Pl. 3, fig. 9) alternating with the fibres, generally more or less of equal width as the fibre bands; parenchyma bands 3-9 cells thick;

parenchyma strands storied (Pl. 3, fig. 11); cells sometimes crystalliferous. *Xylem rays* 1-3 (mostly 2) seriate with uniseriates quite frequent, usually storied (Pl. 3, fig. 11), 4-20 cells high, and 9-13 per mm; ray tissue homogeneous with rays composed of procumbent cells. *Fibres* libriform, thick-walled, nonseptate, nonstoried and polygonal in cross section. *Ripple marks* present due to storied parenchyma, xylem rays and the vessel segments.

Because the present fossil wood is identical to *Millettioxylon indicum* Awasthi (1967, 1975) known from the Mio-Pliocene of Cuddalore Series in South India, it is assigned to it. However, it exhibits minor difference with the type material; these are due to variation. It shows close resemblance to the modern wood of *Millettia pendula* Benth. (F.R.I. slide no. A 3296/B 5161) which is a deciduous tree found in savannah forests and dry lower hill forests of Burma, up to 700 m. It also grows in Thailand on mont Sataepat (Teijsmann) and Laos (Lecomte, 1908-1923).

Specimen — B.S.I.P. Museum no. 35264.

FAMILY — COMBRETACEAE

Genus — *Anogeissoxylon* Navale, 1964

syn. *Anogeissuxylon* Louvet, 1965

4. *Anogeissoxylon thailandicum* sp. nov.

Pl. 3, fig. 13; Pl. 4, figs 15, 17

The specimen described here is a small piece of petrified wood 11 cm in diameter and 8 cm in length.

Topography — Wood diffuse-porous. *Growth rings* distinct, delimited by smaller vessels and poorly defined terminal parenchyma (Pl. 4, fig. 15). *Vessels* medium-sized to small or very small (Pl. 4, fig. 15), frequently in radial multiples of 2-3 or 4, sometimes solitary, 24-30 per sq mm, mostly empty; tyloses usually absent. *Parenchyma* terminal and scanty paratracheal to narrow vasicentric forming a thin sheath around the pores, sometimes joining adjacent vessels (Pl. 4, figs 15, 17). *Xylem rays* fine, almost always uniseriate, occasionally locally biseriate (Pl. 3, fig. 13) with addition of 1-2 or few cells, 12-24 μ wide, quite often long, 10-43 cells and 180-900 μ high, closely placed, 18-23 rays per mm; ray tissue heterogeneous, heterogeneity somewhat less pronounced. *Fibres* arranged in radial rows between the consecutive xylem rays.

Elements — Vessels slightly thick-walled, t.d. of solitary vessels 45-120 μ, r.d. 60-135 μ, round to oval but usually irregular due to pressure during fossilization; vessel members 330-690 μ long usually with truncate ends; perforations simple; intervessel pit-pairs orbicular to oval, 4-6 μ in diameter. *Parenchyma cells* thin-walled, 12-20 μ in diameter; crystals wanting. *Ray cells* thin-walled; procumbent cells 12-16 μ in vertical height and 32-40 μ in radial length; upright cells with vertical height 36-40 μ, radial length 14-20 μ; height of ray cells usually 12-24 μ, rarely 28 μ; cells quite often crystalliferous. *Fibres* libriform, thick-walled (appear thin-walled at most places due to cell wall degradation), polygonal in cross section, nonseptate and 10-14 μ in diameter; inter-fibre pits could not be seen.

Affinities — The anatomical characters of the fossil wood most closely resemble the structural features of the combretaceous genus *Anogeissus*, although it also shows near resemblance to the mature secondary xylem of small pored *Terminalia*. The xylem rays of these *Terminalia* are, however, more heterogeneous, and the average height of their ray cells is more than that of *Anogeissus* varying from 22-41 μ or even up to 58 μ in some species. Similar differences in the height of the upright ray cells also exist in the woods of the two genera, the heterogeneity being more pronounced in *Terminalia* than in *Anogeissus* (Ramesh Rao & Purkayastha, 1972, p. 177).

A survey of available woods of the genus *Anogeissus* indicates that the nearest affinity of the fossil is with *Anogeissus acuminata* (F.R.I. slide no. A 2258/B 7019). Our survey included the study of thin sections of woods of *Anogeissus acuminata* (Roxb.) Geuill. et Perr., *A. latifolia* Wall., *A. pendula* Edgew., *A. sericea* Brandis, *A. pierrei*, *A. tonkinensis* and published description of four species (Pearson & Brown, 1932, pp. 537-548, figs 180-182; Metcalfe & Chalk, 1951, pp. 617-619; Ramesh Rao & Purkayastha, 1972, pp. 178-179, pls 89, 90, figs 533-537). The size and distribution of vessels of the fossil wood agree with the distributional pattern in *Anogeissus acuminata*. However, in some wood samples, vessels are slightly bigger in size and sometimes show a tendency towards semi-ring porosity. In both,

perforation plates are simple and the intervascular pit-pairs are small and oval to orbicular in shape.

The distribution of parenchyma appears to be almost identical in both as is the fibre and ray structure. *Parenchyma* is usually terminal and scanty paratracheal to narrow vasicentric, sometimes joining adjacent vessels in both fossil and the living species and the fibres are moderately thick-walled. *Xylem rays* are also similar in nature and size with lot of crystalliferous cells. These are usually uniseriate, sometimes biseriate with the addition of one or two cells. However, such biseriate rays are more frequent in some samples (F.R.I. slide no. A 2089) of *Anogeissus acuminata.*

In 1964, Navale instituted the organ genus *Anogeissusoxylon* for a fossil wood resembling *Anogeissus* from the Cuddalore Series of South India. Subsequently, Louvet (1965) not knowing that an organ genus already existed for the fossil woods of *Anogeissus*, established another genus *Anogeissuxylon* to include his fossil wood from Algeria. As *Anogeissusoxylon* Navale (1964) is published earlier than *Anogeissuxylon* Louvet (1965), *Anogeissusoxylon* Navale (1964) has the priority and is a valid name for the fossil woods of *Anogeissus*, while *Anogeissuxylon* Louvet (1965) becomes its homonym. Recently, Mädel-Angeliewa & Müller-Stoll (1973) amended the diagnosis of *Terminalioxylon* Schönfeld (1947) and included under it *Anogeissusoxylon* Navale (1964) and *Anogeissuxylon* Louvet (1965) as its synonym. They group all the species of *Terminalia* possessing 1 (-2) seriate xylem rays having crystals in the ray cells with *Anogeissus* where a very similar wood structure is found and for these and some *Combretum* they suggest the use of the emended organ genus *Terminalioxylon* Schönfeld. Originally this genus was meant for the fossil woods of all the species of *Terminalia* (Schönfeld, 1947, p. 39) even those possessing broader xylem rays without crystals in the ray cells. Although these authors Mädel-Angeliewa & Müller-Stoll, 1973) also admit that there is slight difference between the modern woods of *Terminalia* and *Anogeissus* and the latter can be differentiated from *Terminalia* in having smaller vessels and usually in the absence of crystals in parenchyma cells, yet they emphasize that these little differences found in the woods of the recent genera *Terminalia* and *Anogeissus* should not be used in separating the fossil genera. Somewhat similar observations have also been made by Kramer (1974, p. 2) who has remarked that although it is rather difficult to distinguish the woods of *Anogeissus* and some *Terminalia*, yet it is not impossible to separate the two genera by their minute anatomical characters. However, he has followed the classification and nomenclature given by Mädel-Angeliewa and Müller-Stoll (1973), and used the genus *Terminalioxylon* in a broader sense including both the genera *Anogeissus* and *Terminalia.* The present author does not agree with their contention and opines that the two fossil genera represented by *Terminalioxylon* Schönfeld (1947) and *Anogeissusoxylon* Navale (1964) should be kept separate and should represent the modern woods of *Terminalia* and *Anogeissus* respectively as there is some anatomical distinction between the two. It is with the small pored *Terminalia* possessing 1(-2) seriate xylem rays and crystalliferous ray cells that the woods of *Anogeissus* resemble most. Even then the two genera can be separated from each other. In *Anogeissus*, the crystals are usually restricted to the rays, while in *Terminalia* they are present both in the rays and in longitudinal parenchyma, a feature which will generally suffice to distinguish the *Anogeissus* woods. Further, the two genera can be distinguished anatomically on the basis of average height of the ray cells. In *Anogeissus*, the average height ranges from 13 to 23 μ, while in *Terminalia* it varies from 21 to 41 μ (up to 58 μ in *Terminalia paniculata*). Similar differences in the height of upright cells also exist between the woods of the two genera, the heterogeneity being more pronounced in *Terminalia* than in *Anogeissus* (Ramesh Rao & Purkayastha, 1972, p. 170). Besides, the large pored *Terminalia* and those with the broader xylem rays and banded parenchyma can also be easily distinguished from *Anogeissus*. Therefore, it is proposed to use the organ genus *Anogeissoxylon* (not *Anogeissusoxylon*) Navale (1964) for *Anogeissus* woods and *Terminalioxylon* Schönfeld (1947) for the woods of all the species of *Terminalia*, whether small or large pored, uni- or multiseriate, and with or without crystals in the rays. An emended diagnosis of the genus *Anogeissoxylon* Navale is given below to incorporate the distin-

guishing generic characters of *Anogeissus* woods and also to accommodate all the species of this genus.

Only two fossil woods have so far been assigned to *Anogeissoxylon* Navale (1964). These are *Anogeissoxylon indicum* (Navale, 1964) from the Mio-Pliocene of the Cuddalore Series in South India, and *Anogeissoxylon bussoni* (Louvet, 1965) from the Lower Eocene of Algeria. Although, their type slides have not been available to me but seeing their description, photographs and the text-figures, especially the type of the xylem rays and absence of crystalliferous parenchyma, both of them appear to belong to *Anogeissus*.

In 1965, Louvet suggested that all the fossil woods of *Evodioxylon* Chiarugi (1933), viz., *Evodioxylon oweni* (Carr.) Chiarugi (1933), *E. primigenium* (Schenk) Kräusel (1939), *E. geinitzii* (Schenk) Kräusel (1939) and *E. intermedium* Kräusel (1939) belong to the family Combretaceae showing a near resemblance to *Anogeissus*. However, Mädel-Angeliewa and Müller-Stoll (1973) transferred three of these to their emended genus *Terminalioxylon* Schönfeld and named them as *Terminalioxylon primigenium* (Schenk) Mädel-Angeliewa & Müller-Stoll, *Terminalioxylon geinitzii* (Schenk) Mädel-Angeliewa & Müller-Stoll, and *Terminalioxylon intermedium* (Kräusel) Mädel-Angeliewa & Müller-Stoll suggesting the affinities of the first two with *Terminalia* and *Anogeissus* respectively. They also suggested that *Evodioxylon oweni* (Carr.) Chiarugi (1933) and *Evodioxylon* sp. Hofmann (1952) belong to *Terminalioxylon*. Recently, Kramer (1974) examined the fossil wood, *Terminalioxylon geinitzii* and indicated its affinities with the modern wood of *Lumnitzera*. Consequently, he transferred it to *Lumnitzeroxylon* and named it as *L. geinitzii* (Schenk) Kramer. As it has not been possible to get the type slides of the above fossil woods, the present author has tried to assess their affinities by studying their description and the figures. *Evodioxylon oweni* (Carr.) Chiarugi (1933) from the Miocene of Somalia appears to belong to *Terminalia* because of the presence of larger vessels and more pronounced heterogeneous xylem rays with bigger upright cells. Similarly, *Terminalioxylon primigenium* (Schenk) Mädel-Angeliewa & Müller-Stoll (1973) is also a fossil wood of *Terminalia* because of the presence of bigger vessels and other anatomical characters of *Terminalia* as suggested earlier. Both the fossil woods, *Terminalioxylon geinitzii* and *T. intermedium*, are most probably similar to *Anogeissus* because of the presence of small pores and less pronounced heterogeneity in the xylem rays, although Kramer (1974) thought that the former belonged to *Lumnitzera*. However, *Lumnitzera* is characterized by long radial chains of vessels and the scanty paratracheal parenchyma.

All these species differ quite distinctly from the present fossil wood. Thus, the fossil wood of *Anogeissoxylon indicum* Navale differs from *Anogeissoxylon thailandicum* in having shorter xylem rays and wider parenchyma sheaths around the vessels, which are small to very small. The parenchyma is vasicentric to aliform. Similarly, *Anogeissoxylon bussoni* Louvet also differs from the present fossil wood in possessing slightly more vasicentric parenchyma in 2-3 rows of cells, frequent long radial vessel multiples, somewhat shorter xylem rays and the secretory canals. The present fossil, however, shows scanty paratracheal to narrow vasicentric parenchyma around the vessels, longer xylem rays and the secretory canals are wanting. As the present fossil wood differs quite distinctly from both the known species, it is described here as *Anogeissoxylon thailandicum* sp. nov.

Anogeissus is confined to the Old World and consists of 8 to 10 species of trees or shrubs with alternate or falsely opposite entire leaves and capitate inflorescence. One species has a wide range in tropical Africa, a second occurs in Arabia, and the remainder are scattered through Southern Asia from Western India and Ceylon to Indo-China (Pearson & Brown, 1932, p. 537). *Anogeissus acuminata* (Roxb.) Geuill. et Perr., with which the present fossil wood compares closely, is a tall tree, frequently found in the teak forests of Burma and also in Chittagong, Bihar and Orissa, Chota Nagpur, the North Circars, Ganjahm to the Godavari usually along the banks of rivers. It also grows in Assam, Laos, Cambodge, Cochinchina and Siam (Craib, 1931, pp. 611, 612) where it occurs in Pāyap, and Mahārāt, common in teak forests. A detailed distribution of all the living species of *Anogeissus* has recently been given by Louvet (1965, p. 297, fig. 4).

GENERIC DIAGNOSIS

Anogeissoxylon Navale, 1964 emend.

Growth rings distinct but inconspicuous, delimited by smaller pores and faint lines of terminal parenchyma; *vessels* medium-sized to very small, solitary as well as in radial multiples; perforations simple, nearly horizontal to oblique; intervessel pit-pairs small, orbicular to oval or angular through crowding. *Parenchyma* terminal, scanty paratracheal to narrow vasicentric, sometimes with lateral extensions occasionally joining adjacent vessels and diffuse. *Rays* fine, 1-3 seriate, heterogeneous with numerous crystalliferous cells, heterogeneity less pronounced; average height of ray cells 13-23 μ. *Fibres* libriform, thick-walled, septate to nonseptate.

SPECIFIC DIAGNOSIS

Anogeissoxylon thailandicum sp. nov.

Wood diffuse-porous. *Growth rings* present, delimited by smaller vessels and poorly defined terminal parenchyma. *Vessels* medium-sized to small or very small, t.d. 45-120 μ, r.d. 60-135 μ, frequently in radial multiples of 2-4, sometimes solitary, 24-30 per sq mm, mostly empty; vessel segments 330-690 μ long, usually truncate; perforations simple; inter-vessel pit-pairs alternate, orbicular to oval, 4-6 μ in diameter. *Parenchyma* terminal and scanty paratracheal to narrow vasicentric, sometimes joining adjacent vessels. *Xylem rays* almost always uniseriate, occasionally locally biseriate, 12-24 μ wide, 10-43 cells or 180-900 μ high, 18-23 per mm; ray tissue heterogeneous, heterogeneity less pronounced; ray cell height usually 12-24 μ, rarely 28 μ; cells quite often crystalliferous. *Fibres* libriform, thick-walled, polygonal in cross section, nonseptate and 10-14 μ in diameter.

Holotype — B.S.I.P. Museum no. 35265.

Genus — *Dryoxylon* Schleiden in Schmid, 1853

5. *Dryoxylon siamensis* sp. nov.

Pl. 4, figs 18-20

The fossil wood is a well-preserved piece of secondary wood measuring 8 cm in length and 11 cm in diameter.

Topography — Wood diffuse-porous to semi-ring-porous (Pl. 4, fig. 19). *Growth rings* distinct. *Vessels* large and somewhat closely spaced in the early wood, gradually decreasing in size towards the outer margin of the ring, usually in radial multiples of 2-3 or 4 cells (Pl. 4, figs 18, 19), sometimes solitary, 4-7 per sq mm, often plugged with tyloses. *Parenchyma* paratracheal and metatracheal; paratracheal parenchyma occurring as few cells in the immediate vicinity of the vessels; metatracheal parenchyma arranged in broken, irregular, tangential lines usually one cell thick (Pl. 4, fig. 19). *Xylem rays* normally 1-3 (mostly 2-3) seriate, 15-45 μ wide, 120-825 μ long, closely placed (Pl. 4, fig. 20), quite often somewhat broad and short and much more aggregated, appearing to be slightly dissected; ray tissue almost homogeneous sometimes with upright cells at the ends. *Fibres* arranged in somewhat irregular rows between the consecutive xylem rays.

Elements — Vessels thick-walled, t.d. of solitary vessels 90-255 μ, r.d. 105-270 μ, oval to elliptical in cross section; vessel members 208-640 μ long with horizontal to slightly oblique end walls; perforations simple; intervessel pit-pairs bordered, alternate to subopposite, 5-7 μ in diameter, orbicular to oval with linear apertures. *Parenchyma cells* thin-walled, t.d. 8-10 μ, height 285-495 μ. *Ray cells* thick-walled, procumbent cells 20-24 μ in vertical height and 36-90 μ in radial length; upright cells with vertical height 36 μ, radial length 20 μ. *Fibres* libriform to semi-libriform, thick-walled, variously shaped, more or less angled in cross section, nonseptate, about 12 μ in diameter; inter-fibre pits could not be seen.

Holotype — B.S.I.P. Museum no. 35266.

Affinities — Although the present fossil wood shows nearest resemblance with the modern wood of *Careya arborea* of the family Lecythidaceae, but because of some differences in the structure of the xylem rays which appear almost homogeneous in the fossil wood, it is proposed now to describe this fossil under the non-committal genus *Dryoxylon* Schleiden (see Schmid, 1853) till its exact affinities are known. *Careya arborea* also grows in Thailand besides occurring in India, Burma and Indo-China. In Thailand, it is found in Pāyap, Prāchinburi, Rāchaburi, Sūrat and Pūket (Craib, 1931, pp. 673-674).

DISCUSSION

Fossil woods of *Pahudioxylon sahnii*, *Cynometroxylon parainaequifolium*, *Millettioxylon indicum*, *Anogeissoxylon thailandicum* and *Dryoxylon siamensis* described here from the north-east region of Thailand, between 15°N and 102°E, are closely comparable to the modern woods of *Afzelia cochinchinensis*, *Cynometra inaequifolia*, *Millettia pendula*, *Anogeissus acuminata* and *Careya arborea* respectively. A study of their present distribution indicated their presence in the modern flora of Thailand; some even growing in the near vicinity of the fossil locality. This suggests a younger age for these fossil plants because from a detailed study of the world floras it has been recognized that in general angiosperm remains from the Late Tertiary horizons can be identified with modern genera and species with considerable degree of confidence. In floras found within this time range we are dealing largely with plants whose modern equivalents may be found in the immediate vicinity or utmost a few hundred miles distant. Consequently, it is assumed that most probably the fossil woods from Thailand might belong to Upper Tertiary. The modern distribution of the living equivalents of the fossil species further indicates that the fossil plants existed under the tropical, mesophytic conditions.

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EXPLANATION OF PLATES

PLATE 1

1. *Pahudioxylon sahnii* Ghosh & Kazmi — Cross section of the fossil wood showing vessel distribution and parenchyma pattern. × 30. Slide no. 35262/ 5132.
2. *Afzelia cochinchinensis* (Pierre) J. Leonard — Cross section of the modern wood showing similar vessel pattern. × 30.
3. *Pahudioxylon sahnii* Ghosh & Kazmi — Tangential longitudinal section of the fossil wood showing ray type and their distribution . × 65. Slide no. 35262/5133.
4. *Afzelia cochinchinensis* (Pierre) J. Leonard — Tangential longitudinal section of the modern wood showing similar ray type and distribution. × 65.

PLATE 2

5. *Cynometroxylon parainaequifolium* sp. nov.— Cross section of the fossil wood showing vessel distribution and parenchyma pattern. × 40. Slide no. 35363/5134.
6. *Cynometra inaequifolia* A. Gray — Cross section of the modern wood showing similar vessel distribution and parenchyma pattern. × 40.
7. *Cynometroxylon parainaequifolium* sp. nov.— Tangential longitudinal section of the fossil wood showing ray type and their distribution. × 65. Slide no. 35263/5135.
8. *Cynometra inaequifolia* A. Gray — Tangential longitudinal section of the modern wood showing similar ray type and distribution. × 65.

PLATE 3

9. *Millettioxylon indicum* Awasthi — Cross section of the fossil wood showing vessel distribution and parenchyma pattern. × 30. Slide no. 35264/5136.
10. *Millettia pendula* Benth.— Cross section of the modern wood showing similar vessel distribution and parenchyma pattern. × 30.
11. *Millettioxylon indicum* Awasthi — Tangential longitudinal section of the fossil wood showing ray type and their distribution. × 65. Note storied arrangement of xylem rays. Slide no. 35264/-5137.
12. *Millettia pendula* Benth.— Tangential longitudinal section of the modern wood showing similar ray type and distribution. × 65. Also note storied arrangement of rays.
13. *Anogeissoxylon thailandicum* sp. nov.— Tangential longitudinal section of the fossil wood showing ray type and their distribution. × 65. Note enlarged crystalliferous cells. Slide no. 35265/5138.
14. *Anogeissus acuminata* (Roxb.) Geuill. et Perr. — Tangential longitudinal section of the modern wood showing similar ray type and their distribution. × 65. Also note enlarged crystalliferous cells.

PLATE 4

15. *Anogeissoxylon thailandicum* sp. nov.— Cross section of the fossil wood showing vessel distribution. × 35. Slide no. 35265/5139.
16. *Anogeissus acuminata* (Roxb.) Geuill. et Perr.— Cross section of the modern wood showing vessel distribution and parenchyma pattern. × 35.
17. *Anogeissoxylon thailandicum* sp. nov.— Cross section magnified to show the parenchyma pattern. × 70. Slide no. 35265/5140.
18. *Dryoxylon siamensis* sp. nov.— Cross section magnified to show the parenchyma distribution. × 70. Slide no. 35266/5141.
19. *Dryoxylon siamensis* sp. nov.— Cross section of the fossil wood under low magnification to show the parenchyma pattern and the vessel distribution. × 30. Slide no. 35266/5142.
20. *Dryoxylon siamensis* sp. nov.— Tangential longitudinal section of the fossil wood showing the type and distribution of xylem rays. × 70. Slide no. 35266/5143.

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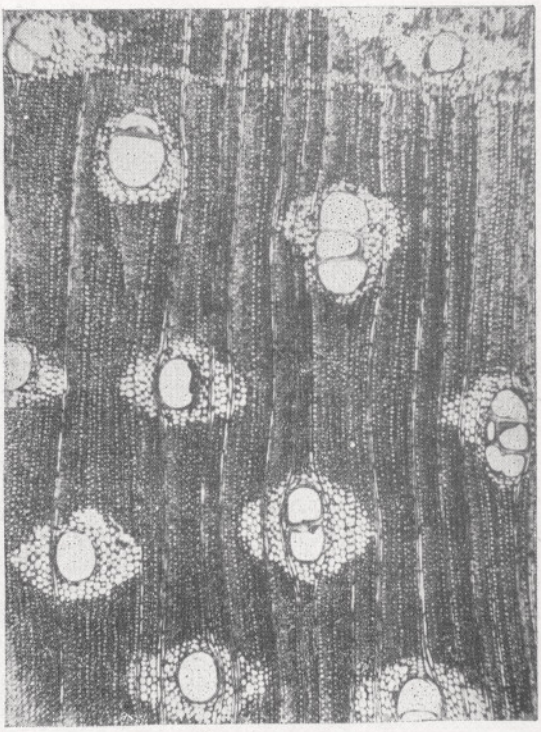

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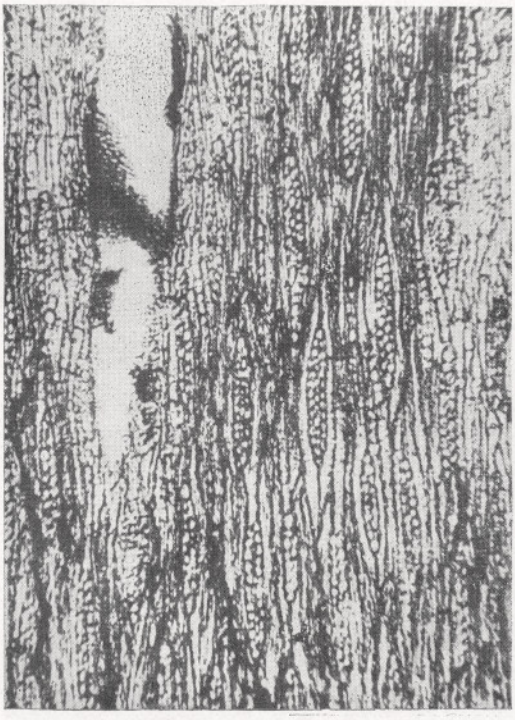

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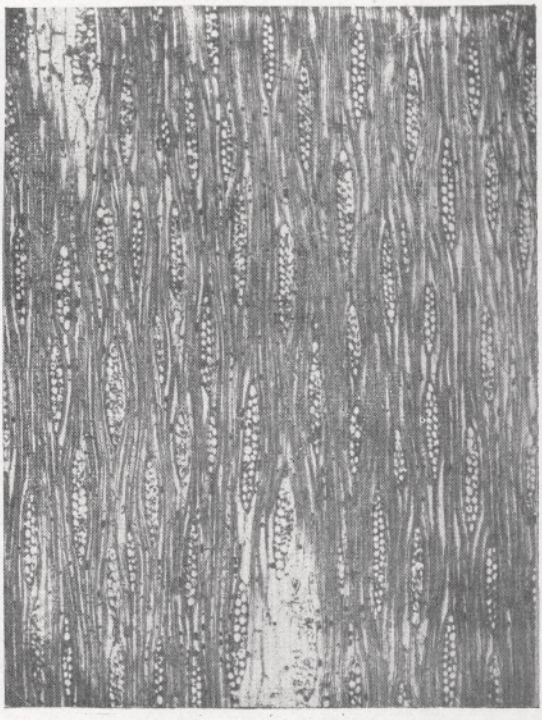

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PLATE 1

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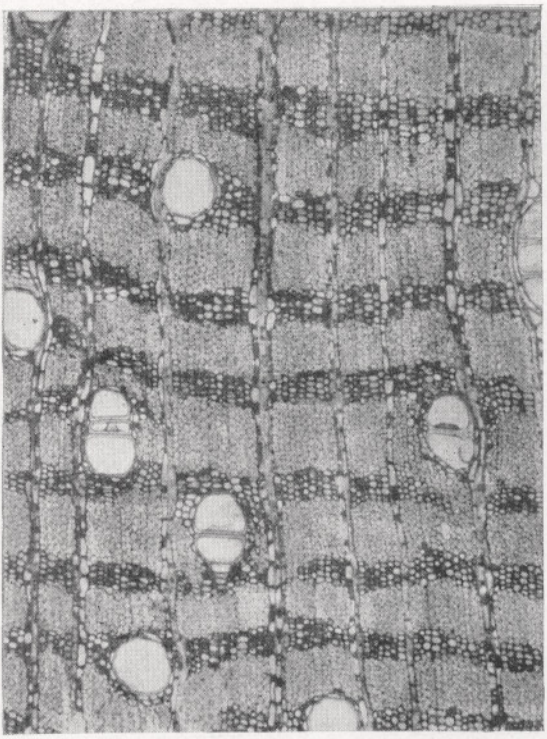

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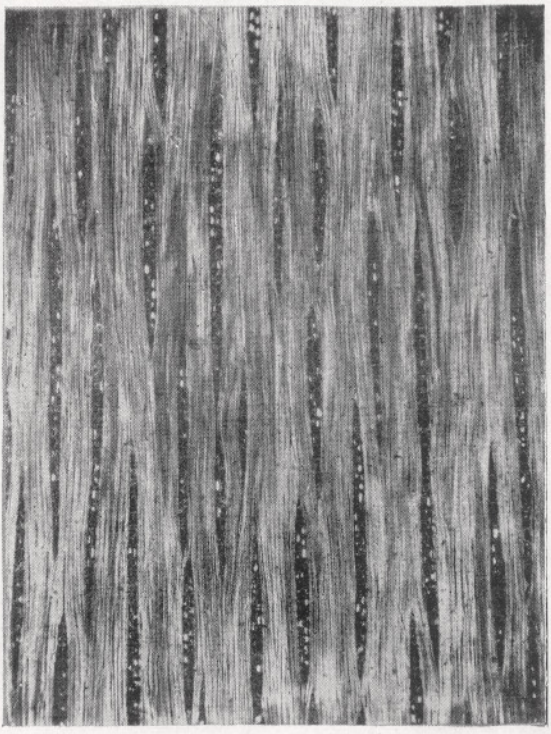

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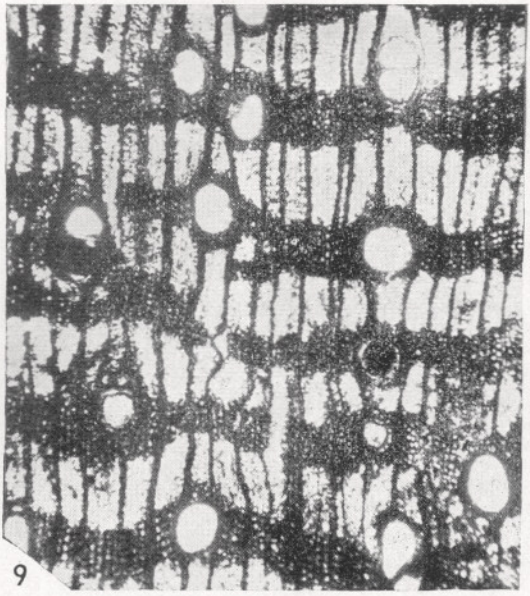

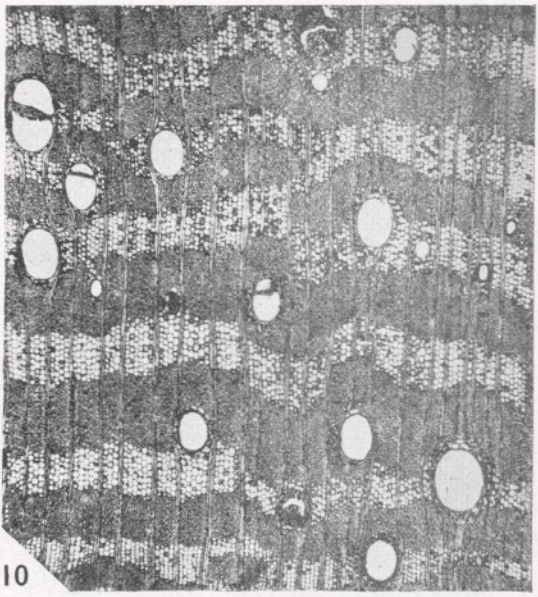

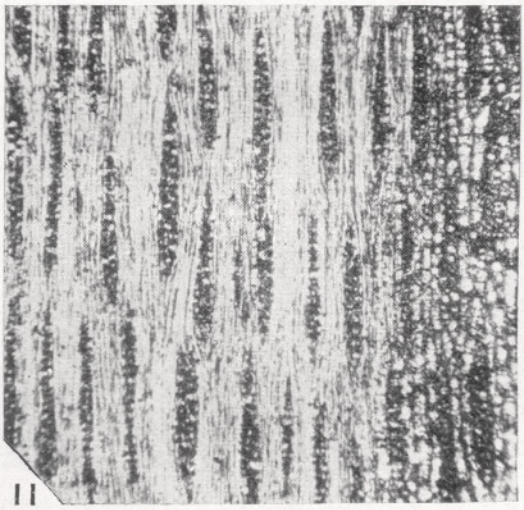

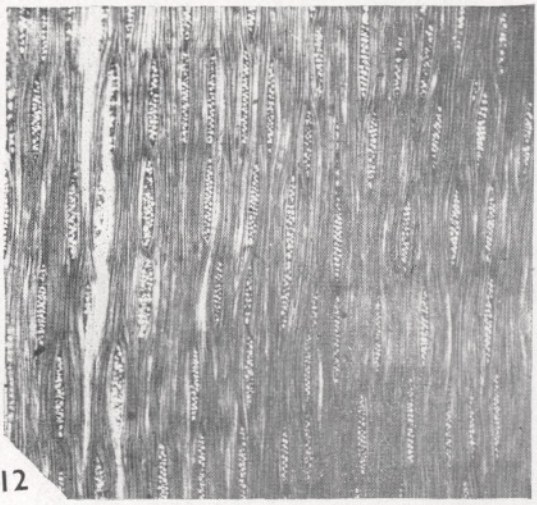

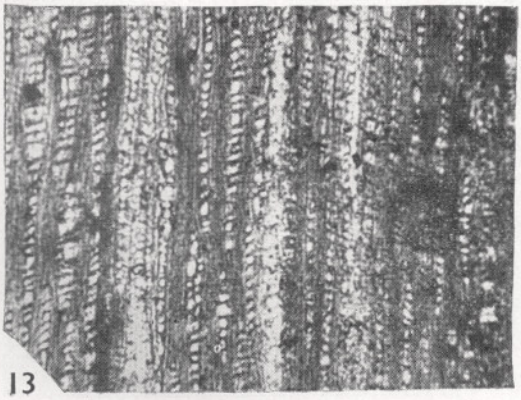

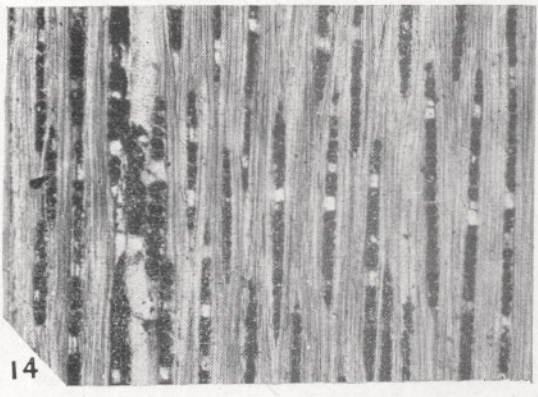

PLATE 3


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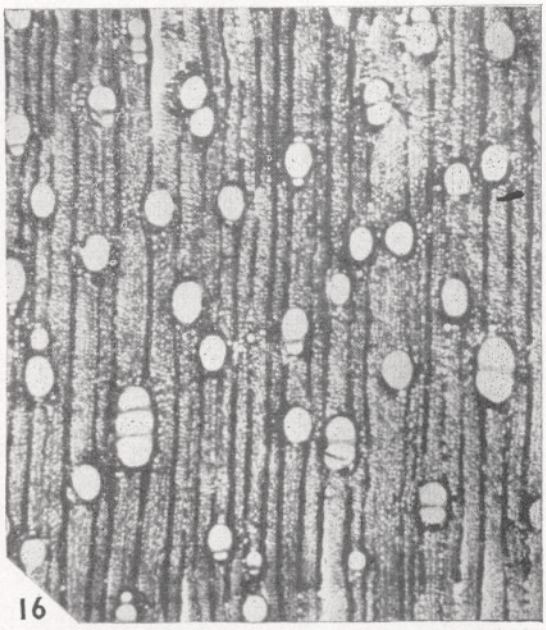
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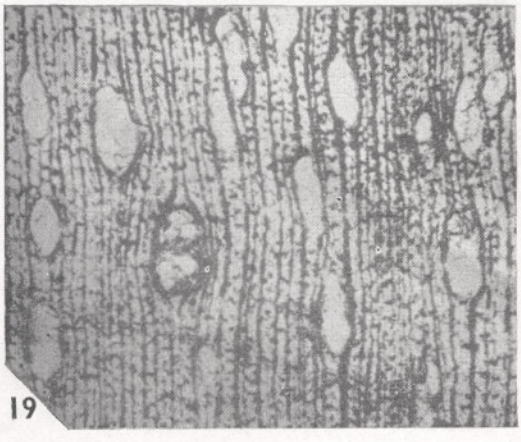
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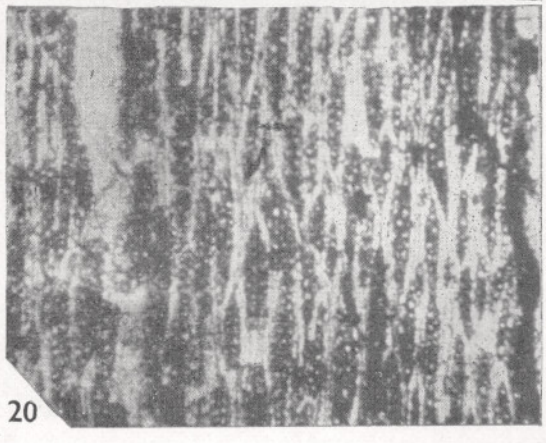
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PLATE 4