The Palaeobotanist, **28-29**: 374-388, 1981.

FURTHER OCCURRENCE OF FOSSIL WOODS FROM THE LOWER SIWALIK BEDS OF UTTAR PRADESH, INDIA

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ABSTRACT

Five taxa of fossil woods are described in detail from the Lower Siwalik beds of Kalagarh in Bijnor District. These are *Dipterocarpoxylon surangei* sp. nov., *Dracontomelumoxylon mangiferumoides* Ghosh & Roy, *Hopeoxylon eosiamensis* sp. nov., *Terminalioxylon palaeomanii* sp. nov., and *Ebenoxylon siwalicus* sp. nov. resembling the extant genera *Dipterocarpus*, *Dracontomelum*, *Sindora*, *Terminalia* and *Diospyros* respectively. All these taxa indicate a more humid climate in the Himalayan foot-hills during the Lower Siwalik period.

Key-words — Xylotomy, Fossil woods, Siwalik beds, Miocene (India).

सारांश

भारत में उत्तर प्रदेश की अधर शिवालिक संस्तरों से और काष्ठाश्म – उत्तम प्रकाश

बिजनौर जनपद में कालागढ़ की अधर शिवालिक संस्तरों से काष्ठाश्मों के पाँच वर्गकों का विस्तृत वर्णन किया गया है। ये क्रमश : डिप्टेरोकार्पस, ड्रेकोन्टोमिलम्, सिन्डोरा, टर्मिनेलिया एवं डायसपायरोस की वर्तमान प्रजातियों से मिलते-जुलते वर्गक, डिप्टेरोकारपॉक्सीलॉन सुरंगॅयाई न० जा०, ड्रेकोन्टोमिलमॉक्सीलॉन मेंजिफेरुमॉयडिस घोष एवं राँय, होपिआॅक्सीलॉन ईओस्यामेन्सिस न० जा०, टर्मिनेलिआॅक्सीलॉन पेलिओमेन्नाई न० जा० तथा एॅबीनॉक्सीलॉन शिवालिकस हैं। ये सभी वर्गक अधर शिवालिक काल में हिमालय गिरि-पादों में अधिक आर्द्र जलवायु का होना इंगित करते हैं।

INTRODUCTION

RECENT studies on the fossil woods from the Lower Siwalik beds of Kalagarh in Bijnor District of Uttar Pradesh have shown a rich assemblage of plant taxa in the Himalayan foot-hills of this region during the Middle Miocene times. These consist of fossil woods of *Polyalthia*, *Anisoptera*, *Dipterocarpus*, *Cassia*, *Cynometra* (Prakash, 1978; Trivedi & Ahuja, 1978a), *Millettia*, *Sterculia*, *Gluta-Melanorrhoea* and probably *Parinarium*, *Dysoxylum* and *Pentacme* (Trivedi & Misra, 1977, 1978, 1979; Trivedi & Ahuja, 1978b, 1978c, 1979a, 1979b). Besides, a brief description without illustration has also appeared recording a fossil wood of *Vateria* from Kalagarh (Trivedi & Ahuja, 1979c). The present paper deals with some more fossil woods from the same beds; these have been identified to the modern genera *Dipterocarpus* of Dipterocarpaceae, *Dracontomelum* of Anacardiaceae, *Sindora* of Leguminosae, *Terminalia* of Combretaceae and *Diospyros* of Ebenaceae.

The author wishes to express his gratitude for the kind invitation to contribute a paper for Dr K. R. Surange Commemoration Volume. Thanks are also due to the authorities of the Forest Research Institute, Dehradun for permission and facilities to work at the Wood Anatomy Branch.

SYSTEMATIC DESCRIPTION

FAMILY — DIPTEROCARPACEAE

Genus — *Dipterocarpoxylon* Hold. emend. Den Berger, 1927

1. *Dipterocarpoxylon surangei* sp. nov.

Pl. 1, figs 1, 2

Material — The fossil wood is a small piece of mature secondary xylem mea-

suring 7 cm in length and 4 cm in diameter.

Topography — Wood diffuse-porous (Pl. 1, fig. 1). *Growth rings* absent. *Vessels* visible to the naked eye, mostly large, almost always solitary, 4-6 per sq mm with rays contiguous on one or both the sides; tyloses present. *Vasicentric tracheids* sparse, paratracheal associated with parenchyma cells showing numerous bordered pits. *Parenchyma* mostly apotracheal, the paratracheal being scanty, present around some of the vessels; apotracheal parenchyma abundant (Pl. 1, fig. 1), diffuse to diffuse-in-aggregate, sometimes forming short, uniseriate, rarely 2-seriate lines in the fibrous ground mass; several rows of parenchyma cells usually surround the large gum ducts. *Xylem rays* fine to mostly broad (Pl. 1, fig. 2), 1-7-(8) seriate, usually 5-7 seriate, 16-160 μm wide and about 160-1620 μm high, closely spaced, 3-5 per mm; ray tissue heterogeneous with rays composed of both upright and procumbent cells; broad rays usually with square or upright cells at one or both the ends and procumbent cells in the middle region; sheath cells sometimes present on the flanks. *Fibres* irregularly arranged in between the consecutive xylem rays. *Gum canals* vertical, very large, usually bigger than the vessels, quite common, single or usually in pairs and sometimes in short tangential rows of 3-5.

Elements — Vessels thin-walled, t.d. 128-290 μm, r.d. 128-352 μm, round to oval in cross section; vessel members 320-640 μm long with truncate ends; perforations simple; intervessel pit-pairs could not be seen due to presence of solitary vessels. *Parenchyma cells* thin-walled, t.d. 16-20 μm, height 48-248 μm. *Ray cells* thick-walled; upright cells vertical height 36-48 μm, radial length 24-32 μm; procumbent cells vertical height 16-28 μm, radial length 36-56 μm. *Fibres* libriform, thick-walled, polygonal in cross section, nonseptate, 12-24 μm in diameter and 800-1200 μm in length; interfibre pits could not be seen. *Gum canals* very large, 240-440 μm in diameter, round to oval in shape, encircled by multiseriate parenchymatous sheath.

Affinities — The presence of vertical gum canals usually in pairs sometimes in short tangential rows, vasicentric tracheids, heterocellular xylem rays with some sheath cells on the flanks and abundant, diffuse to diffuse-in-aggregate parenchyma indicates after extensive comparison that the closest affinities of this fossil wood are with the wood of the modern genus *Dipterocarpus* Gaertn. f. in which a near resemblance can be seen with the modern species *Dipterocarpus tuberculatus* (F.R.I. slide nos. A1062/B7159 and A328/B6502). The size and distribution of vessels in *Dipterocarpoxylon surangei* agree with the vessel size and their distribution in *Dipterocarpus tuberculatus*. Besides, the distribution of parenchyma appears to be similar in both (F.R.I. slide no. A328/B6502), as is the fibre and ray structure. The presence of large gum canals are also seen in the modern wood but they are not so frequent as in the fossil.

All the fossil woods resembling the modern wood of *Dipterocarpus* have already been enumerated (Prakash, 1973, table 1, p. 51, 1978, pp. 381-383; Awasthi, 1974, p. 343). Those described from the Tertiary of India are *Dipterocarpoxylon chowdhurii* Ghosh (Ghosh, 1956; Prakash, 1973) and *D. kalaicharparense* Eyde (1963) from Assam, *D. malavii* Ghosh & Ghosh (1959) from Kachchh, *D. pondicherriense* Awasthi (1974) from the Cuddalore sandstones of South India and *Dipterocarpoxylon* sp. Rawat (1964), *D. siwalicus*, *D. nalagarhense*, *D. premacrocarpum* (Prakash, 1975) and *D. parabaudii* Prakash (1978) from the Siwalik beds. All these species differ quite distinctly from present fossil wood in the presence of very large gum canals and type of xylem rays. However, of all the species, *Dipterocarpoxylon chowdhurii* Ghosh (1956), *D. malavii* Ghosh & Ghosh (1959), *D. tertiarum* Prakash (1965, 1973) and *D. nalagarhense* Prakash (1975) are the closest although, different from this Siwalik wood in some or the other important characters. Thus, *Dipterocarpoxylon chowdhurii* differs from the fossil wood in possessing narrower, 1-6 seriate xylem rays, slightly bigger vessels (dia. 160-375 μm) and smaller gum canals (80-160 μm). The vessels are moderately large to medium sized (dia. 128-352 μm), the gum canals are quite large (240-440 μm) and the xylem rays are 1-8 seriate in width in this Siwalik wood. *Dipterocarpoxylon tertiarum* also differs from the present fossil wood in having slightly larger vessels (dia. 135-420 μm), in somewhat broader, 1-9 seriate xylem rays and in smaller gum canals.

D. malavii is distinct from *D. surangei* in possessing smaller gum canals (42-100 μm) and in having 1-5 seriate xylem rays. Lastly, *D. nalagarhense* is also markedly distinct from this fossil wood in having slightly broader, 1-10 seriate xylem rays and smaller gum canals.

Since this fossil wood markedly differs from all the species of *Dipterocarpoxylon* so far known from India and abroad and compares very well with the modern wood of *Dipterocarpus tuberculatus*, it is assigned to the organ genus *Dipterocarpoxylon* Holden emend. Den Berger (1927) and described as a new species, *Dipterocarpoxylon surangei*. The species is named in honour of my renowned teacher, Dr K. R. Surange, former Director of the Birbal Sahni Institute of Palaeobotany. *Dipterocarpus tuberculatus*, which nearly resembles the present fossil wood, grows in Burma, Cochin-China, Thailand and is also reported to be a large tree of Chittagong hill tracts in Bangla Desh (Chowdhury & Ghosh, 1958).

SPECIFIC DIAGNOSIS

Dipterocarpoxylon surangei sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* large to medium-sized, t.d. 128-290 μm, r.d. 128-352 μm, almost always solitary, round to oval in cross section, 4-6 per sq mm, usually tylosed; vessel members 320-640 μm long with truncate ends; perforations simple; intervessel pits could not be seen. *Vasicentric tracheids* paratracheal, sparse associated with the vessels. *Parenchyma* mostly apotracheal, quite abundant, diffuse to diffuse-in-aggregate, forming short, uniseriate rarely biseriate lines; paratracheal parenchyma present around some of the vessels. *Xylem rays* 1-7 (8) (usually 5-7) seriate, 3-5 per mm; ray tissue heterogeneous, rays heterocellular; sheath cells sometimes present on the flanks. *Fibres* libriform, thick-walled, polygonal in cross section, nonseptate, 12-24 μm in diameter and 800-1200 μm in length. *Gum canals* quite common, vertical, single or usually in pairs and sometimes in short tangential rows of 3-5, very large in size usually bigger than the vessels, 240-440 μm in diameter.

Holotype — B.S.I.P. Museum no. 35379.

FAMILY — ANACARDIACEAE

Genus — *Dracontomelumoxylon* Ghosh & Roy, 1979

1979a *Dracontomeloxylon* Prakash, pp. 248, 249, text-figs 1, 2.

2. *Dracontomelumoxylon mangiferumoides* Ghosh & Roy, 1979 (= *Dracontomeloxylon palaeomangiferum* Prakash, 1979a).

Pl. 1, figs 3-5

Material — The fossil consists of a small piece of secondary xylem measuring 8 cm in diameter and 13 cm in length. The preservation of the fossil wood is fairly good.

Wood diffuse-porous. *Growth rings* absent. *Vessels* large to medium-sized or small (Pl. 3, fig. 3), t.d. 64-272 μm, r.d. 154-368 μm, round to oval or elliptical in shape, usually solitary, sometime in radial multiples of 2-3 or rarely 4-5 or even more, 3-5 per sq mm and heavily tylosed; perforations simple; vessel elements 240-880 μm long, usually with truncate ends; intervessel pits bordered, alternate to subopposite, large, 8-12 μm in diameter with linear apertures (Pl. 1, fig. 4). *Parenchyma* narrow, vasicentric (Pl. 1, fig. 3), sometimes joining adjacent pores. *Xylem rays* 1-5 seriate, usually 2-4 seriate (Pl. 1, fig. 5), 5-51 cells high and 6-9 per mm; ray tissue heterogeneous with rays both homocellular and heterocellular; end cells often swollen and crystalliferous. *Fibres* libriform to semi-libriform, profusely septate, oval to angular in cross section and 12-20 μm in diameter.

The present fossil wood resembles closely the modern wood of *Dracontomelum mangiferum* (F.R.I. slide no. A4064/B6405). Recently Ghosh and Roy (1979) described briefly a fossil wood resembling *Dracontomelum mangiferum* from the Tertiary of West Bengal and named it as *Dracontomelumoxylon mangiferumoides*. After a few months, another fossil wood resembling *Dracontomelum mangiferum* was also recorded from the Lower Siwalik beds of Nalagarh in Himachal Pradesh (Prakash, 1979a, 1979b). This was named as *Dracontomeloxylon palaeomangiferum* (Prakash, 1979a). As both the fossil woods belong to *Dracontomelum mangiferum*, the species *Dracontomeloxylon palaeomangiferum*

from the Siwaliks is a later homonym of *Dracontomelumoxylon mangiferumoides* from the Tertiary of West Bengal being recorded a few months later than the West Bengal fossil. Both the fossil woods exhibit some variable features particularly in the parenchyma pattern and the ray width as also seen in the modern wood of *Dracontomelum mangiferum* (Prakash, 1979b).

As the fossil wood from the Lower Siwalik beds of Kalagarh also resembles the modern wood of *Dracontomelum mangiferum*, it is assigned to *Dracontomelumoxylon mangiferumoides* Ghosh & Roy (1979). However, it shows some variable features and differs from West Bengal and Nalagarh fossil woods in size of the vessels.

Dracontomelum mangiferum is a common tree in damp places along the streams in the Andaman and Nicobar Islands. In Burma, it is found in Myitkyiana, Katha and Mergui. It also occurs in Malaya Peninsula (Anonymous, 1963, p. 275).

Specimen — B.S.I.P. Museum no. 35380.

FAMILY — LEGUMINOSAE

Genus — *Hopeoxylon* Navale emend. Awasthi, 1977

1967 *Copaiferoxylon* Müller-Stoll & Mädel, pp. 133, 134.

1974 *Sindoroxylon* Lemoigne, Beauchamp & Samuel, pp. 280-281, pl. 44, figs 1-5.

1975 *Detarioxylon* Boureau & Louvet, pp. 12-22, pls 1-5, text-figs 1-4

3. *Hopeoxylon eosiamensis* sp. nov.

Pl. 2, figs 6-10; Pl. 3, fig. 11

Material — This species is based on a piece of petrified secondary xylem, about 6 cm in length and 4 cm in diameter. The preservation of the fossil is not very satisfactory.

Topography — Wood diffuse-porous. *Growth rings* indistinct, at places delimited by apotracheal parenchyma bands sometimes containing gum canals (Pl. 2, fig. 7). *Vessels* medium sized to large, solitary and in radial multiples of 2-3 (Pl. 2, figs 6, 7, 9), evenly distributed, 2-4 per sq mm; tyloses absent, but dark brown gummy infiltration present. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform and sometimes confluent joining the adjacent vessels (Pl. 2, figs 6, 9); apotracheal parenchyma in narrow, concentric bands enclosing gum canals (Pl. 2, fig. 7); thin apotracheal bands sometimes also present. *Xylem rays* not visible to the naked eye, 1-4 (mostly 3-4) seriate (Pl. 2, fig. 10) with uniseriates quite common, 2-28 cells or 80-960 μm in height, 3-5 per mm; ray tissue weakly heterogeneous with rays composed mostly of procumbent cells, sometimes with 1-2 upright cells at the ends. *Fibres* regularly arranged in radial rows between the consecutive xylem rays. *Gum canals* vertical, arranged in tangential rows forming concentric rings (Pl. 2, figs 7, 8).

Elements — Vessels medium-sized to large, those solitary round to oval in cross section, t.d. 104-224 μm, r.d. 104-216 μm; vessel members 192-464 μm in length usually with truncate ends; perforations simple; intervessel pit pairs vestured (Pl. 3, fig. 11), alternate to subopposite, round to oval in shape, sometimes horizontally elongated, 8-10 μm in diameter, with linear apertures. *Parenchyma cells* 16-24 μm in diameter and 64-96 μm in length; crystalliferous strands present, usually adjacent to rays. *Ray cells* thin-walled, large, usually filled with brownish black contents; procumbent cells round to oval in tangential section, vertical height 12-20 μm, radial length 28-48 μm; upright cells with vertical height 40-56 μm, radial length 28-32 μm. *Fibres* semilibriform, moderately thick-walled, polygonal in cross section, nonseptate, 8-12 μm in diameter and 480-720 μm in length; interfibre pits could not be seen. *Gum canals* vertical, in concentric rings, circular in cross section, 64-128 μm in diameter.

Affinities — The gross structural features of the fossil wood with concentric rings of vertical gum canals indicate a near resemblance of this fossil with the modern woods of *Copaifera*, *Detarium*, *Sindora*, *Eperua* and *Hardwickia* (excluding *Kingiodendron*) of the family Leguminosae. However, the apotracheal parenchyma bands are quite frequent in some of the growth rings of *Hardwickia* unlike those of the fossil wood. Besides, gum canals are normally absent in *Hardwickia*; they are, however, seen in a concentric ring in one specimen of *H. binata* being traumatic in origin (Ramesh Rao & Purkayastha, 1973, p. 80). Similarly,

Eperua has 1-4 rows of upright cells in the multiseriate xylem rays as against 1-2 rows of upright cells in some rays of the fossil wood. A detailed study of all available woods and anatomical description of *Copaifera*, *Detarium* and *Sindora* indicates that the extant woods of all these three genera are so similar in structural details that it may not be possible to separate them anatomically (Lalitha & Prakash, 1980, table 1). However, considering the present geographic distribution of all these genera, the closest affinities of the present fossil wood are with *Sindora*, the other two, *Copaifera* and *Detarium* being native of Africa. A comparison with all available woods and anatomical descriptions of *Sindora* indicates that the closest resemblance of the fossil is with *Sindora siamensis* (F.R.I. slide no. F1035). This survey included the study of thin sections of *Sindora cochinchinensis* Baill., *S. coriacea* Prain, *S. echinocalyx* Benth., *S. intermedia* Baker, *S. irpicina* de Wit, *S. leiocarpa* Backer ex K. Heyne, *S. wallichii* Benth., *S. siamensis* Teysm. ex Miq., *S. supa* Merr. and *S. velutina* Baker and published descriptions of a few other species (Reyes, 1938, pp. 149-152, pl. 22, figs 2-3; Kanehira 1924a, p. 30; Desch, 1957, pp. 295-298; Moll & Janssonius, 1914, pp. 142-149, fig. 163; Henderson, 1953, fig. 234; Kribs, 1959, p. 100, figs 226, 424).

The fossil wood resembles the modern wood of *Sindora siamensis* in the size and distributional pattern of vessels, type of perforation plates and intervascular pitting, parenchyma distribution, and in fibre and ray structure as well as in the presence of concentric rings of gum canals.

As the fossil closely resembles the modern wood of *Sindora siamensis*, it is assigned to the genus *Hopeoxylon* Navale emend. Awasthi, 1977 (syn. *Copaiferoxylon* Müller-Stoll & Mädel, 1967; syn. *Sindoroxylon* Lemoigne, Beauchamp & Samuel, 1974; syn. *Detarioxylon* Boureau & Louvet, 1975), which now stands for the fossil woods of *Copaifera*, *Detarium* and *Sindora*, since these genera are anatomically very similar and can not be separated (Lalitha & Prakash, 1980).

A number of fossil woods showing close resemblance with the wood structure of *Copaifera*, *Detarium* and *Sindora* are known from many parts of the world. These are *Hopeoxylon migiurtinum* (Chiarugi, 1933) Lalitha & Prakash (1980) from the Tertiary of Somali-land in Africa, *Hopeoxylon sindoroides* (Kramer, 1974a) Lalitha & Prakash (1980) from the Tertiary of West Borneo, *Hopeoxylon aethiopicum* (Lemoigne, Beauchamp & Samuel, 1974) Lalitha & Prakash (1980) from the Tertiary (probably Miocene) of Ethiopia, *Hopeoxylon libycum* (Boureau & Louvet, 1975) Lalitha & Prakash (1980) from the Tertiary (probably Eocene) of Libya, *Hopeoxylon indicum* (Navale) Awasthi (1977), *H. speciosum* (Navale) Awasthi (1977) and *H. arcotense* Awasthi (1977) from the Cuddalore Series of South India and *Hopeoxylon assamicum* Lalitha & Prakash (1980) from the Tipam Series of Assam. However, all these differ quite distinctly from the present fossil wood.

Thus, *Hopeoxylon migiurtinum* differs from the Siwalik fossil wood in possessing smaller vessels (diam. 60-120 μm), narrow, usually 2-3 seriate, homogeneous xylem rays and in narrow, vasicentric and apotracheal bands of parenchyma. Nevertheless, the vessels are large (diam. 104-224 μm), the xylem rays are 1-4 seriate and weakly heterogeneous, and the parenchyma is usually aliform, sometimes confluent besides the presence of occasional apotracheal bands other than those containing gum canals in the present wood. *Hopeoxylon aethiopicum* also differs from the present fossil in possessing somewhat smaller vessels (180-200 μm), narrow, 1-3 seriate, heterogeneous xylem rays and usually vasicentric to sometimes aliform parenchyma. *Hopeoxylon sindoroides* is markedly different in having usually aliform parenchyma and in short, spindle-shaped, 2-5 (mostly 3-4) cells broad and homogeneous xylem rays.

Similarly, *Hopeoxylon libycum* is distinct from the present species in having slightly broad, 1-6 seriate, homogeneous xylem rays and in slightly smaller vessels (diam. 45-250 μm). The South Indian species, *Hopeoxylon indicum*, *H. speciosum* and *H. arcotense* are also distinct from this Siwalik wood in a number of characters. The vessels are small to medium about 60-160 μm in diameter and the xylem rays are narrow, 1-3, mostly 2 seriate and heterogeneous in *Hopeoxylon indicum*. The xylem rays are broader, 3-6 seriate and heterogeneous and the apotracheal bands without gum canals are absent in *H. speciosum*. In *Hopeoxylon*

arcotense short, apotracheal bands occur quite frequently in some of the growth rings and the xylem rays are slightly broader, 1-5 (mostly 3) seriate and heterogeneous.

Lastly *Hopeoxylon assamicum*, although resembling very closely the present fossil wood, also differs from it in having slightly broader, 1-5 seriate and largely fusiform xylem rays which are 4-41 cells high as against 2-28 cells high and 1-4 seriate xylem rays in the present fossil. Besides, the vessels are also somewhat larger (diam. 60-255 μm) in *H. assamicum* than in the present fossil (diam. 96-224 μm). Since the present fossil wood is quite distinct from all the species of *Hopeoxylon* so far known, it is described here as a new species, *Hopeoxylon eosiamensis*, the specific name indicating its antiquity and close resemblance with the modern wood of *Sindora siamensis*, which grows in Malayan Peninsula. The genus *Sindora* consists of about 21 species (Willis, 1973) of which only one species is found in tropical Africa and the rest are confined to south-east Asia, Hainan, West Malaysia, Celebes and Moluccas.

SPECIFIC DIAGNOSIS

Hopeoxylon eosiamensis sp. nov.

Wood diffuse-porous. *Growth rings* indistinct, sometimes delimited by lines of apotracheai parenchyma, quite often containing gum canals. *Vessels* large to medium, t.d. 104-224 μm, r.d. 104-216 μm, solitary and in radial multiples of 2-3, round to oval in cross section, 2-4 per sq mm; tyloses absent, dark brown gummy infiltration present; vessel members 192-464 μm long, usually with truncate ends; perforations simple; intervessel pit-pairs vestured, alternate to subopposite, round to oval in shape, sometimes horizontally elongated, 8-10 μm in diameter with linear apertures. *Parenchyma* vasicentric to aliform and sometimes confluent joining adjacent vessels; apotracheal parenchyma in concentric bands enclosing gum canals; narrow apotracheal bands sometimes also present; crystalliferous parenchyma strands present adjacent to xylem rays. *Xylem rays* 1-4 (mostly 3-4) seriate and 2-28 cells high, homocellular to heterocellular consisting either of procumbent cells only or with 1-2 marginal rows of upright cells at one or both the ends; uniseriates quite common. *Fibres* semilibriform, moderately thick-walled, nonseptate, polygonal in cross section, 480-720 μm in length and 8-12 μm in diameter. *Gum canals* vertical in concentric rings, circular, 64-128 μm in diameter, associated with apotracheal bands of parenchyma.

Holotype — B.S.I.P. Museum no. 35381.

FAMILY — COMBRETACEAE

Genus — *Terminalioxylon* Schönfeld, 1947

4. *Terminalioxylon palaeomanii* sp. nov.

Pl. 3, figs 12-15

Material — This species is based on a piece of decorticated secondary wood, measuring about 8 cm in length and 5 cm in diameter. The preservation is poor.

Topography — Wood diffuse-porous with a slight tendency towards semi-ring porosity. *Growth rings* indistinct, appear to be delimited by smaller vessels. *Vessels* medium-sized to small or very small (Pl. 3, fig. 14) mostly in radial multiples of 2-4-(6) or even more, sometimes solitary, mostly empty. *Parenchyma* scanty paratracheal with few cells associated with the vessels (Pl. 3, fig. 15). *Xylem rays* fine, mostly uniseriate, occasionally biseriate (Pl. 3, fig. 13), 12-24 μm wide, quite often long, 5-24 cells and 100-560 μm high and closely placed; ray tissue heterogeneous, heterogeneity somewhat more pronounced. *Fibres* arranged between the xylem rays.

Elements — Vessels usually irregular due to pressure during fossilization, those solitary and less deformed appear round to oval in shape; vessel members 144-480 μm long usually with truncate ends; perforations simple; intervessel pit-pairs vestured, alternate, small, 4-8 μm in diameter with linear apertures (Pl. 3, fig. 12). *Parenchyma cells* thin-walled. *Ray cells* thin-walled; procumbent cells 16-24 μm in vertical height and 32-52 μm in radial length; upright cells with vertical height 32-48 μm, radial length 24-32 μm; cells quite often crystalliferous. *Fibres* libriform, thick-walled, polygonal in cross section, septate, 8-12 μm in diameter; interfibre pits could not be seen.

Affinities — The structural features of the fossil most closely resemble those of

the combretaceous genus *Terminalia*, although it also shows a near resemblance to the mature secondary xylem of *Anogeissus acuminata* in having small pores, scanty paratracheal parenchyma and a number of other characters. However, it can be differentiated from *Anogeissus* in having more pronounced heterogeneity in xylem rays and in the presence of crystalliferous longitudinal parenchyma. Besides, the average height of the ray cells is distinctly more in *Terminalia* than in *Anogeissus* (Ramesh Rao & Purkayastha, 1972, p. 177; Pearson & Brown, 1932, p. 539). A survey of the available woods of the genus *Terminalia* indicates that the nearest affinity of the fossil is with *Terminalia manii* (F.R.I. slide no. 65/B5780). Our survey included the study of thin sections of woods of sixteen Indian species and about a dozen foreign species of *Terminalia* (see list in Prakash, 1966, p. 227). Besides, published descriptions of these and seven other species of *Terminalia*, viz., *Terminalia nitens* Presl., *T. oocarpa* Merrill, *T. calamansanai* Rolfe, *T. januarensis* D.C., *T. guyanensis* Eich., *T. javanica* Miq., *T. teysmannii* Koord et Valet. were also consulted (Moll & Janssonius, 1914, pp. 368-378, figs 187, 188; Kanehira, 1924a, pp. 32, 33, 1924b, pp. 11, 12, fig. 4; Chowdhury, 1932, pp. 14, 15, pls 23-25, 1939, pl. 4, figs 1-4, 1945, p. 20, pl. 9; Pearson & Brown, 1932, pp. 497-537, figs 168-179; Henderson, 1953, figs 65-72; Kribs, 1959, pp. 28-31, figs 103-107, 109-111, 354; Normand, 1960, pp. 291-293, pl. 126).

The fossil wood shows strong resemblance with the modern wood of *Terminalia manii* in the size and distribution pattern of vessels, in parenchyma distribution, and the fibre and ray structure. However, the parenchyma appears to be slightly more in the modern wood than the present fossil, where it is not very clear due to bad preservation.

In 1947, Schönfeld instituted the organ genus *Terminalioxylon* for the fossil woods resembling *Terminalia* from the Tertiary of Colombia. Recently Mädel-Angeliewa and Müller-Stoll (1973) amended the genus *Terminalioxylon* Schönfeld to include the fossil woods of both *Terminalia* and *Anogeissus*, although they admit that there are some differences between the modern woods of *Terminalia* and *Anogeissus*. It has been seen that the woods of *Terminalia* can be distinguished from *Anogeissus* in having smaller vessels and usually in the presence of crystals in parenchyma cells. Besides, small pored *Terminalias* which, are very close to *Anogeissus*, can also be differentiated in possessing comparatively more heterogeneous xylem rays with the average height of ray cells more in *Terminalia* (22-41 μm, even up to 58 μm) than in *Anogeissus* (13-23 μm). As such I have maintained the organ genus *Terminalioxylon* Schönfeld (1947) for the fossil woods of *Terminalia* and *Anogeissoxylon* Navale emend. Prakash (1979c) for the petrified woods of *Anogeissus* (Prakash, 1979c, p. 54).

A large number of fossil woods belonging to *Terminalia* are known from India and abroad. These have been listed by Prakash (1966, pp. 229-230) and Mädel-Angeliewa and Müller-Stoll (1973, pp. 128-133). Besides, Serra (1966) also described a fossil wood, *Terminalioxylon kratiense*, from the Tertiary of Indo-china and Kramer (1974b) further reported fossil woods of *Terminalioxylon tertiarum* Prakash, *T. burmense* Mädel-Angeliewa & Müller-Stoll and *T. densiporosum* Kramer from the Tertiary of Indonesia. Out of these, *Terminalioxylon geinitzii* (Schenk) Mädel-Angeliewa & Müller-Stoll (1973) has been found to belong to *Lumnitzera* by Kramer (1974b) and *T. intermedium* (Kräusel) Mädel-Angeliewa & Müller-Stoll (1973) appears to show more affinities with *Anogeissus* than *Terminalia* (Prakash, 1979c, p. 55).

All these species differ quite markedly from the present fossil wood in having larger vessels and in possessing more parenchyma which is usually vasicentric to aliform-confluent. However, the vessels are smaller and the parenchyma is scanty paratracheal in this Siwalik wood. As the present fossil wood is closely comparable to *Terminalia manii* and is quite distinct from all the species of *Terminalioxylon* Schönfeld (1947) known so far, it is assigned to a new species, *Terminalioxylon palaeomanii*, the specific name indicating its relationship with the modern wood of *Terminalia manii*.

Terminalia is a large genus of about 250 species of very large trees widely distributed in the tropics of the world. The species *Terminalia manii*, with which the fossil wood resembles closely, occurs in the

Andaman and Nicobar Islands (Ramesh Rao & Purkayastha, 1972, p. 188).

SPECIFIC DIAGNOSIS

Terminalioxylon palaeomanii sp. nov.

Wood-diffuse-porous with a slight tendency towards semi-ring porosity. *Growth rings* indistinct. *Vessels* medium-sized to small or very small, t.d. 64-160 μm, r.d. 96-192 μm, usually in radial multiples of 2-4-(6) or more cells, irregular in shape due to pressure during fossilization, those solitary and not deformed appear round to oval in shape; tyloses absent; vessel members 144-480 μm long, usually with truncate ends; perforations could not be seen; intervessel pit-pairs vestured, alternate, small, 4-8 μm in diameter with linear apertures. *Parenchyma* scanty paratracheal with a few cells associated with some of the vessels. *Xylem rays* mostly uniseriate, occasionally biseriate and 5-24 cells high; ray tissue heterogeneous with pronounced heterogeneity; ray cells often crystalliferous. *Fibres* libriform, thick-walled polygonal in cross section, septate and 8-12 μm in diameter.

FAMILY — EBENACEAE

Genus — *Ebenoxylon* Felix, 1882

5. *Ebenoxylon siwalicus* sp. nov.

Pl. 4, figs 16-20

Material — A small piece of petrified wood, black in colour, measuring 5·5 cm in length and 3·5 cm in diameter. The preservation is not very satisfactory.

Topography — Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium-sized, usually in radial multiples of 2-4 or more cells, sometimes solitary, 8-11 per sq mm, mostly filled with black contents (Pl. 4, fig. 16). *Parenchyma* mostly apotracheal, the paratracheal being scanty; apotracheal parenchyma diffuse to diffuse-in-aggregate, forming concentric, irregular, 1-2 (usually 1) seriate lines in the fibrous ground tissue (Pl. 4, fig. 18). *Xylem rays* 1-3 (Pl. 4, fig. 17), usually uni- and biseriate, 32-48 μm broad, 3-18 cells and 80-640 μm high and 7-12 per mm; ray tissue heterogeneous (Pl. 4, fig. 20) with uniseriates composed only of upright cells, while multiseriates are made up of procumbent cells in the median thickened portion and 1-10 marginal rows of upright cells usually at both the ends. *Fibres* somewhat irregularly arranged.

Elements — Vessels thin-walled, t.d. 64-128 μm, r.d. 64-176 μm, solitary vessels round to oval in shape, those in radial multiples flattened at the places of contact; vessel elements short, 112-480 μm long, usually truncate, sometimes with inclined or tailed ends; perforations simple; intervessel pit-pairs bordered (Pl. 4, fig. 19), alternate, small, 4-6 μm in diameter with linear-lenticular apertures. *Parenchyma cells* thin-walled, 16-20 μm in diameter, 28-72 μm in length. *Ray cells* thin-walled, procumbent cells 8-20 μm in tangential height, 24-64 μm in radial length and upright cells 32-64 μm in tangential height, 28-32 μm in radial length; upright cells often swollen and crystalliferous. *Fibres* libriform to semilibriform, usually thin-walled due to degradation, polygonal in cross section, nonseptate and 10-16 μm in diameter; interfibre pits not seen.

Affinities — Structural features of the present fossil wood indicate after extensive comparison that its closest affinities are with the ebenaceous genus *Diospyros* Linn. (= *Maba* Forst.), in which a near resemblance can be seen with the woods of *Diospyros brandisiana* (F.R.I. slide no. A678/B6449). Our survey included the study of thin sections of 40 species of *Diospyros* and 3 species of *Maba* available at the Forest Research Institute, Dehradun. Besides, the published descriptions and figures of several species of *Diospyros* and *Maba* were also consulted for comparison (Kanehira, 1924a, pp. 40-42, fig. 10; Lecomte, 1926, pl. 61; Pearson & Brown, 1932, pp. 693-697, 700-708, figs 224, 225, 227-229; Chowdhury, 1945, pl. 29; Metcalfe & Chalk, 1950, pp. 883-885, figs 204A, B, C, 99; Desch, 1957, pp. 150, 151, pl. 46, fig. 1, table 25; Kribs, 1959, pp. 37, 38, figs 127-129, 358; Normand, 1960, pls 143-145; Brazier & Franklin, 1961, pp. 34, 38, 39, fig. 359)

The fossil resembles the modern wood of *Diospyros brandisiana* in vessel distribution and the parenchyma pattern with similar irregular 1 rarely 2 seriate, closely placed lines of parenchyma, in moderately thick-walled, nonseptate fibres and 1-3 seriate homo to heterocellular xylem rays with

quite often swollen, crystalliferous cells. Besides, the perforation plates and the intervascular pit-pairs are similar in both the fossil and the modern wood. However, the vessels are slightly smaller in the modern wood in comparison to the present fossil.

In view of a close resemblance with the woods of *Diospyros*, it is assigned to the organ genus *Ebenoxylon* Felix (1882). Fossil woods belonging to *Diospyros* (= *Maba*) have already been enumerated by Prakash and Tripathi (1970, p. 185, table 1) and Prakash (1978, pp. 385, 386). Recently, Prakash (1978) described another fossil wood, *Ebenoxylon miocenicum*, from the Lower Siwalik beds of Kalagarh. All these species differ quite markedly from the present fossil wood. Thus, *Ebenoxylon indicum* Ghosh & Kazmi (1958) from the Tertiary of Arunachal Pradesh differs from this Siwalik wood in possessing homogeneous xylem rays and large vessels (t.d. 85-225 μm, r.d. 164-328 μm). However, the vessels are somewhat smaller (t.d. 64-128 μm, r.d. 64-176 μm) and the xylem rays are 1-3 (mostly 1-2) seriate and heterocellular with swollen cells in the present fossil wood. Similarly, *Ebenoxylon kartikcherrense* Prakash & Tripathi (1970) from the Tipam sandstones of Assam is also distinct from this fossil in having mostly 1-seriate xylem rays without swollen cells and slightly larger vessels (t.d. 80-180 μm, r.d. 92-240 μm). *Ebenoxylon arcotense* Awasthi (1970) from the Cuddalore Series of South India also differs markedly from *Ebenoxylon siwalicus* in having only uniseriate lines of apotracheal parenchyma and in the xylem rays with only 1-2 marginal rows of upright cells at one or both the ends as against 1-2 seriate, irregular lines of parenchyma and 1-3 seriate, heterocellular xylem rays with 1-10 marginal rows of upright cells which are often swollen in the present fossil. Lastly, *Ebenoxylon miocenicum* Prakash (1978), recently described from the same beds in Kalagarh, is also quite different from the present fossil in possessing usually uniseriate, heterocellular xylem rays unlike this fossil wood, where the xylem rays are usually 1-2, rarely 3 seriate with the end cells often swollen and crystalliferous and the median thickened portion composed of procumbent cells. As the present Siwalik wood differs quite distinctly from all the known species of *Ebenoxylon* Felix (1882), it is described here as a new species, *Ebenoxylon siwalicus*.

The genus *Diospyros* (= *Maba*) consists of about 100 species in the Indian region. The species *Diospyros brandisiana* with which the fossil wood shows nearest resemblance is an evergreen tree of Tenasserim and Upper Burma (Gamble, 1902, p. 463).

SPECIFIC DIAGNOSIS

Ebenoxylon siwalicus sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium-sized, round to oval, solitary and usually in radial multiples of 2-4 or more cells, t.d. 64-128 μm, r.d. 64-176 μm, 8-11 per sq mm, plugged with dark contents; vessel members 112-480 μm in length usually with truncate ends; perforations simple; intervessel pit-pairs bordered, alternate, oval, small, 4-6 μm in diameter with linear-lenticular apertures. *Parenchyma* scanty paratracheal and in 1-2 (mostly 1) seriate, irregular, concentric, closely placed lines. *Xylem rays* 1-3 (usually 1-2) seriate, 3-18 cells high and 7-12 rays per mm; ray tissue heterogeneous with uniseriates composed of upright cells only, while multiseriates with procumbent cells in the median thickened portion and 1-10 rows of upright cells usually at both the ends; cells quite often swollen and crystalliferous. *Fibres* libriform to semi-libriform, appear thin-walled due to degradation, nonseptate and 10-16 μm in diameter.

Holotype — B.S.I.P. Museum no. 35383.

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EXPLANATION OF PLATES

PLATE 1

1. *Dipterocarpoxylon surangei* sp. nov.— Cross section in low power showing vessel distribution and the parenchyma pattern. × 30; slide no. 6165.
2. *D. surangei* sp. nov.— Tangential longitudinal section showing xylem rays. × 45; slide no. 6166.
3. *Dracontomelumoxylon mangiferumoides* Ghosh & Roy — Cross section in low power showing vessel distribution and the parenchyma pattern. × 30; slide no. 6167.
4. *D. mangiferumoides* Ghosh & Roy — Magnified intervessel pit-pairs. × 150; slide no. 6168.
5. *D. mangiferumoides* Ghosh & Roy — Tangential longitudinal section showing xylem rays. × 80; slide no. 6168.

PLATE 2

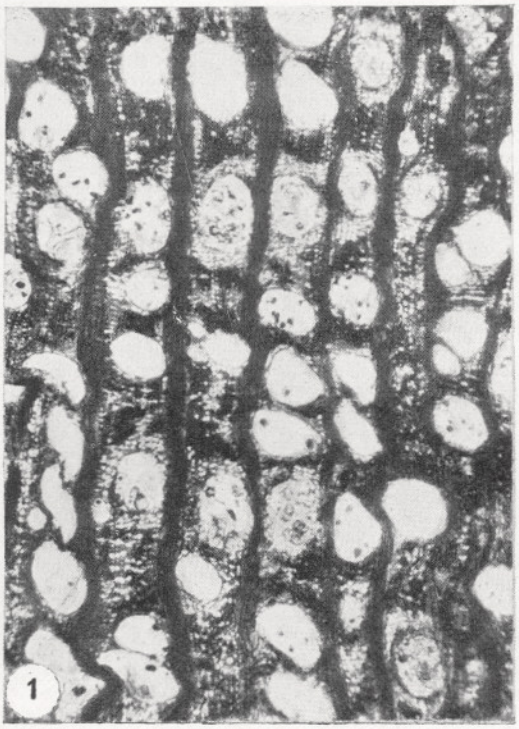
6. *Hopeoxylon eosiamensis* sp. nov.— Cross section in low power showing vessel distribution and parenchyma pattern. × 30; slide no. 6169.
7. *H. eosiamensis* sp. nov.— Another cross section showing vessels and concentric rings of vertical gum canals. × 30; slide no. 6170.
8. *H. eosiamensis* sp. nov.— Another cross section showing parenchyma pattern and a concentric row of vertical gum canals. × 30; slide no. 6171.
9. *H. eosiamensis* sp. nov.— Cross section slightly magnified to show parenchyma distribution. × 45; slide no. 6172.
10. *H. eosiamensis* sp. nov. — Tangential longitudinal section showing xylem rays. × 100; slide no. 6173.

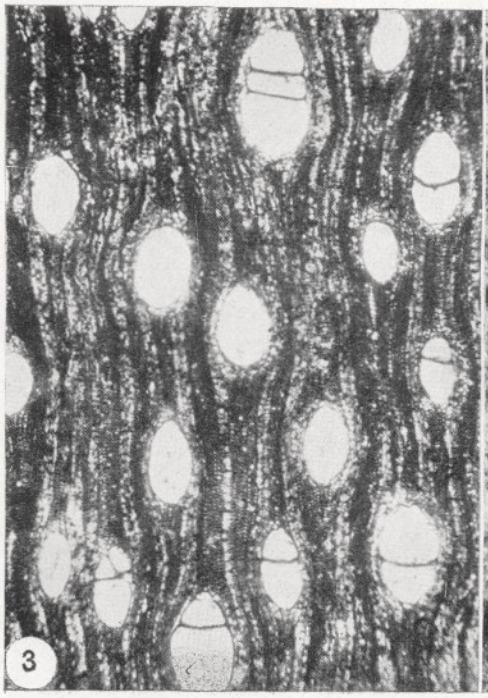
PLATE 3

11. *Hopeoxylon eosiamensis* sp. nov.— Magnified intervessel pit pairs. × 200; slide no. 6173.
12. *Terminalioxylon palaeomanii* sp. nov.— Magnified intervessel pit-pairs. × 300; slide no. 6174.
13. *T. palaeomanii* sp. nov.— Tangential longitudinal section showing xylem rays. × 75; slide no. 6175.
14. *T. palaeomanii* sp. nov.— Cross section of the fossil wood in low power showing vessel distribution. × 30; slide no. 6176.
15. *T. palaeomanii* sp. nov.— Cross section slightly magnified. × 75; slide no. 6177.

PLATE 4

16. *Ebenoxylon siwalicus* sp. nov.— Cross section in low power showing vessel distribution. × 40; slide no. 6178.
17. *E. siwalicus* sp. nov.— Tangential longitudinal section showing xylem rays. × 85; slide no. 6179.
18. *E. siwalicus* sp. nov.— Cross section slightly magnified to show the parenchyma distribution. Note diffuse-in-aggregate parenchyma forming lines. × 120; slide no. 6180.
19. *E. siwalicus* sp. nov.— Magnified intervessel pit-pairs. × 400; slide no. 6179.
20. *E. siwalicus* sp. nov. — Radial longitudinal section showing the nature of xylem rays. × 70; slide no. 6181.





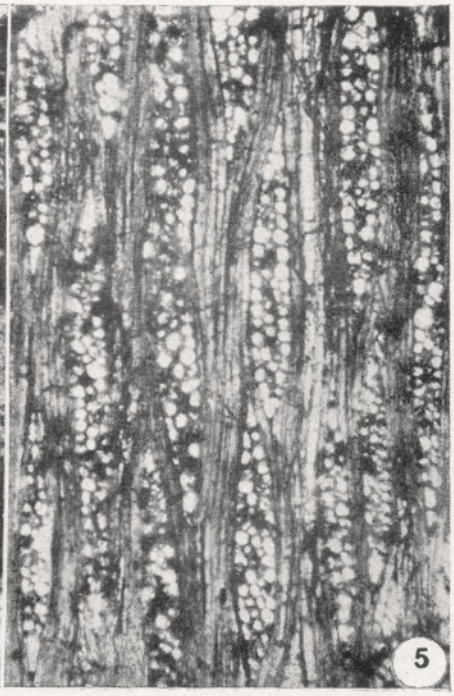
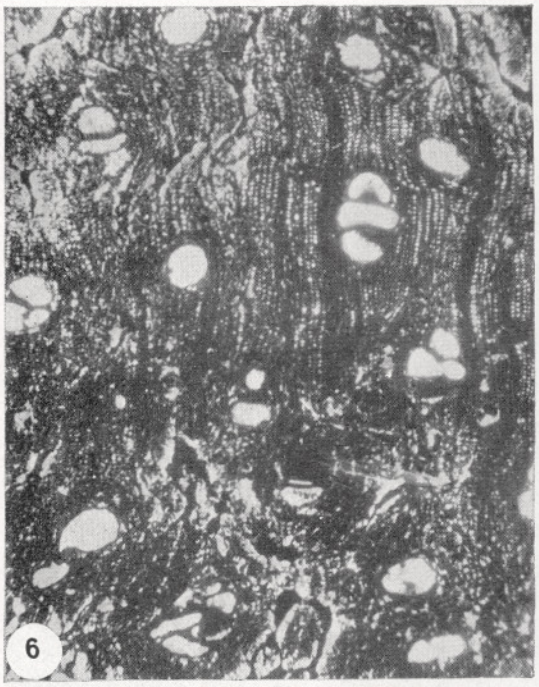
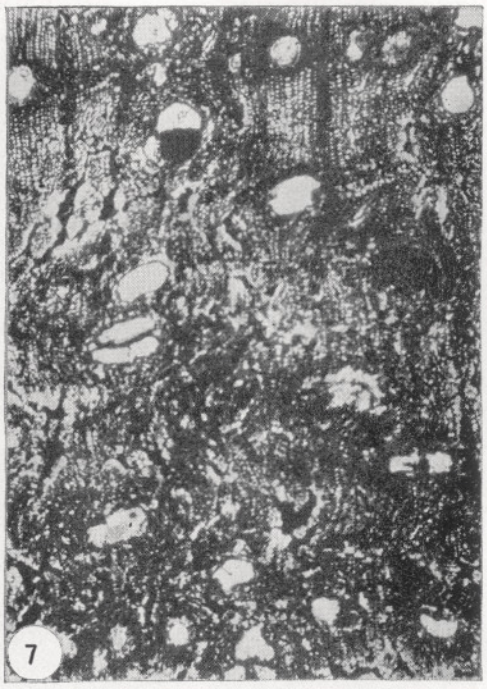
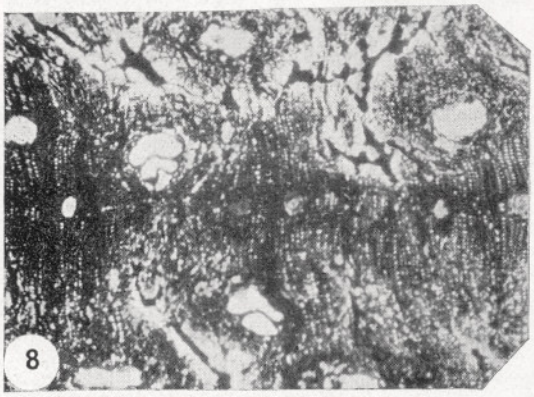


PLATE 1







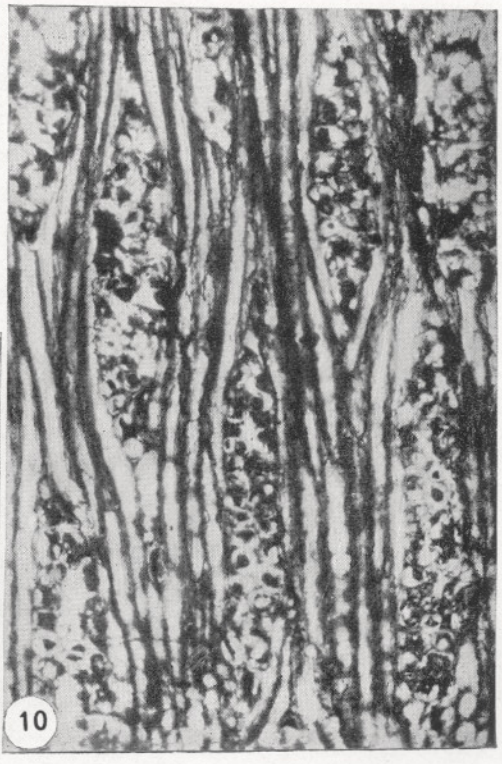
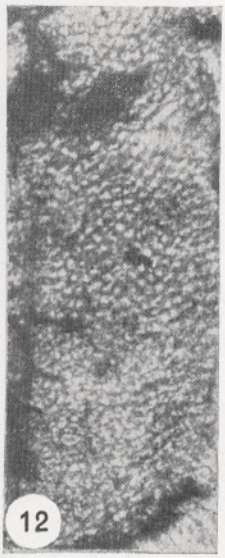
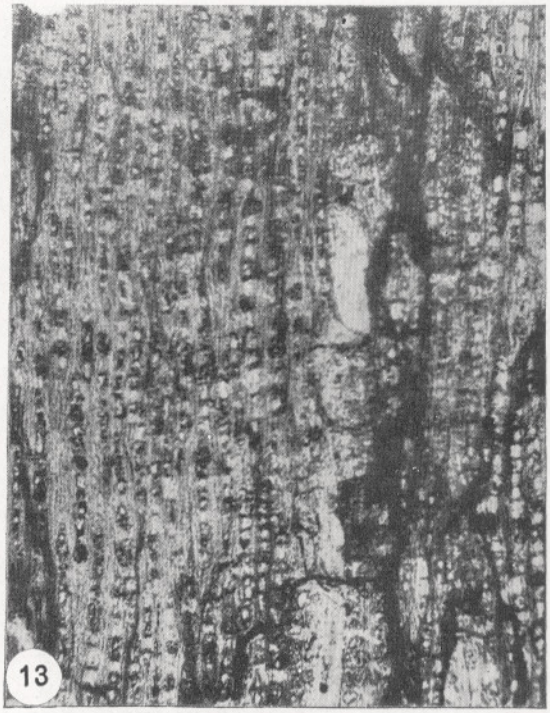
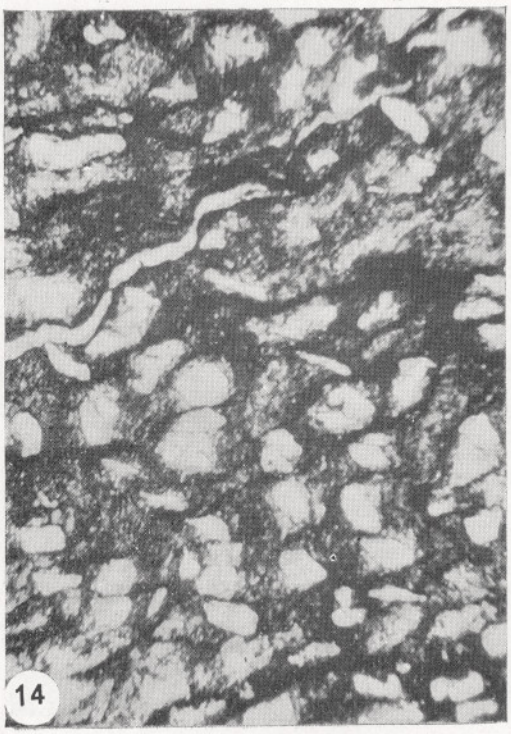


PLATE 2







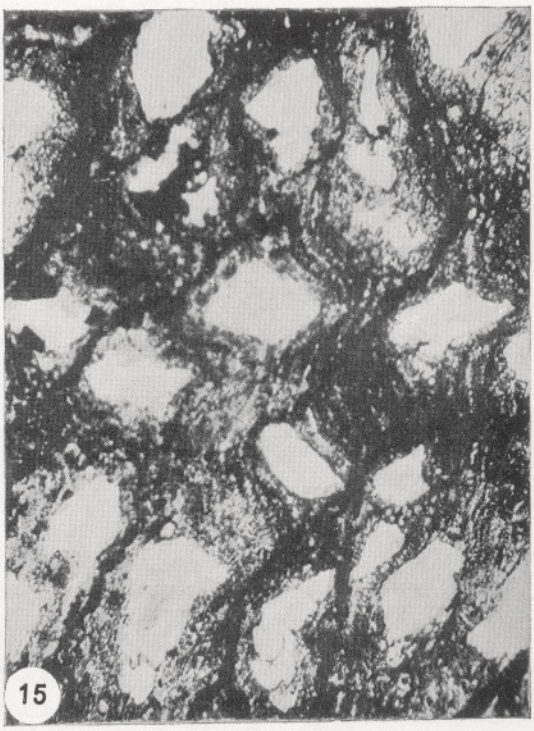
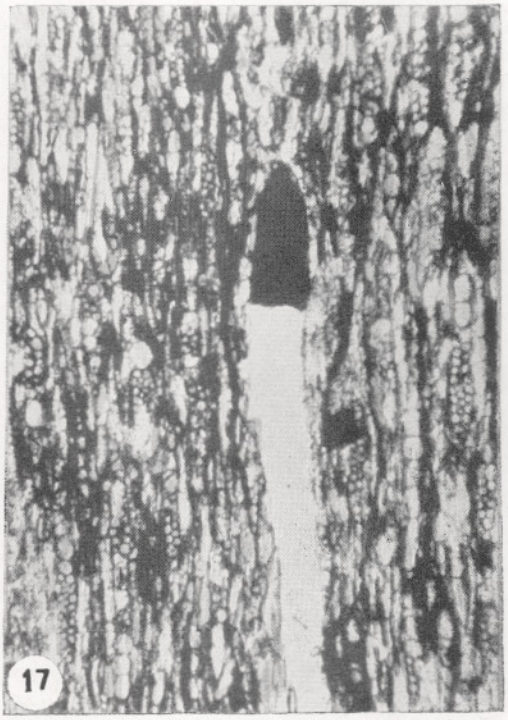


PLATE 3



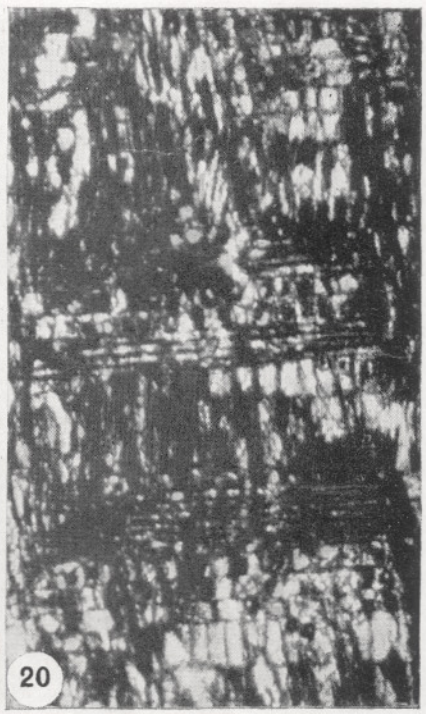


PLATE 4