*The Palaeobotanist*, **28-29**: 338-352, 1981.

# FOSSIL WOODS OF ANACARDIACEAE FROM THE TERTIARY OF WEST BENGAL, INDIA

S. K. ROY
Botany Department, University of Burdwan, Burdwan-713 104, India
&
PRADIP K. GHOSH
Botany Department, Vivekananda College, Burdwan-703 104, India

## ABSTRACT

Four species of fossil woods belonging to the family Anacardiaceae and referable to *Buchananioxylon indicum* gen. et sp. nov., *Dracontomelumoxylon mangiferumoides* Ghosh & Roy, *Melanorrhoeoxylon garbetaense* sp. nov. and *Mangiferoxylon assamicum* Prakash & Tripathi have been described. The occurrence of fossil woods resembling *Buchanania* Spreng., *Melanorrhoea* Wall., and *Mangifera* L. is described here for the first time from the Tertiary rocks of the Birbhum and Midnapur districts of West Bengal.

*Key-words* — Anacardiaceae, Fossil woods, Xylotomy, Miocene (India).

## सारांश

भारत में पश्चिम बंगाल के टरशरी से ऍनाकार्डिएसी कुल के काष्ठाश्म – ऍस० के० रॉय एवं प्रदीप कुमार घोष

ऍनाकार्डिएसी कुल से संबद्ध तथा बुकनानिआ॓क्सीलॉन इंडिकम् नव प्रजाति न नव जाति, ड्रेकोन्टोमिलमॉक्सीलॉन मेंजिफेरुमॉयडिस घोष एवं रॉय, मिलॅनोरोहिआ॓क्सीलॉन गर्बेटायेन्सिस न० जा० एवं मेंजिफ़ेरॉक्सीलॉन असमिकम् प्रकाश एवं त्रिपाठी से निरूपणीय काष्ठाश्मों की चार जातियाँ वर्णित की गई हैं। पश्चिम बंगाल के बीरभूम एवं मिदनापुर जनपदों की टरशरी कालीन चट्टानों से बुकनानिआ स्प्रेंग ; मिलॅनोरोहिआ वाल० एवं मेंजिफ़ेरा ऍल० से मिलती-जुलती काष्ठाश्मों का इस शोध-पत्र में पहली बार वर्णन किया गया है।

## INTRODUCTION

THE sedimentary deposits of the continental origin belonging to the Tertiary period occur widely in India. Plant megafossil and microfossil taxa of almost all the major groups of the Plant Kingdom have been described so far from these deposits. The petrified woods are the commonest form of megafossils found in these deposits. Fossil woods belonging to Anacardiaceae, described so far from India, are referable to *Glutoxylon burmense* (Holden) Chowdhury (Chowdhury, 1934, 1936, 1952; Chowdhury & Tandon, 1952; Ghosh, 1958, 1960; Ghosh & Taneja, 1961; Awasthi, 1966; Prakash & Awasthi, 1971; Prakash & Tripathi, 1969; Roy & Ghosh, 1979a, d; *G. cuddalorense* Awasthi, 1966; *Anacardioxylon semecarpoides* Prakash & Dayal, 1965; *A. shardai* Prakash & Tripathi, 1974; *A. mangiferoides* Ramanujam, 1960; *Mangiferoxylon scleroticum* Awasthi, 1966; *M. assamicum* Prakash & Tripathi, 1970; *Melanorrhoeoxylon cacharense* Prakash & Tripathi, 1976; *Swintonioxylon hailakandiense* Prakash & Tripathi, 1968; *Holigarnoxylon assamicum* Prakash & Awasthi, 1970; and *Lanneoxylon grandiosum* Prakash & Tripathi (1967, 1969). *Glutoxylon burmense* (Chowdhury & Tandon, 1952; Roy & Ghosh, 1979a) and *Dracontomelumoxylon mangiferumoides* (Ghosh & Roy, 1979b) are the two anacardiaceous fossil wood taxa described earlier from the Tertiary of West Bengal. In addition to these anacardiaceous woods, *Pahudioxylon bankurensis* Chowdhury *et al.* (1960), *Anisopteroxylon bengalensis* (Ghosh & Kazmi, 1958), *Cynometroxylon indicum*

(Ghosh, 1960), wood of *Albizia* (Ghosh, 1960), *Millettioxylon pongemiensis* Prakash, (Roy & Ghosh, 1978), *M. bengalensis* Ghosh & Roy (1979a) of Leguminosae, *Terminalioxylon* Deb & Ghosh (1974) of Combretaceae, *Canarioxylon indicum* Ghosh & Roy (1978) of Burseraceae, *Shoreoxylon bengalensis* Roy & Ghosh (1979); *Dipterocarpoxylon bolpuriense* Ghosh & Roy (1979), *D. bolpurense* Ghosh & Roy (1979c) of Dipterocarpaceae, *Chisochetonoxylon bengalensis* Ghosh & Roy (1979d) of Meliaceae, and *Calophylloxylon bengalense* Ghosh & Roy (1979e) are the other fossil woods described from the Tertiary deposits of West Bengal.

The fossil woods described here were collected from the outcrops of the Miocene laterite occurring in Labpur in the Birbhum District and in the beds of Silabati River near Garbeta in Midnapur District. The angular surface configuration of these fossil woods suggests that these have not been drifted very far from the place of their actual occurrence. The floristic significance of the occurrence of these anacardiaceous taxa in the Tertiary of West Bengal is also discussed here.

## Family — Anacardiaceae

**Genus —*Buchananioxylon* gen. nov.**

*Buchananioxylon indicum* sp. nov.

Pl. 1, figs 1-5

The fossil wood is a piece of mature secondary xylem about 4 cm in length and 2 cm in diameter and grey to brownish-grey in colour.

*Topography — Wood* diffuse-porous. *Growth rings* absent. *Vessels* visible to the naked eye, evenly distributed, solitary or in radial multiples of 2-3 (Pl. 1, fig. 1), less frequently in long multiples; round to oval in shape, t.d. 99-233 μm, r.d. 133-233 μm, open or frequently filled with tyloses. Vessels 2-8 per sq mm, vessel members short, 333-666 μm in length; perforation plate simple with truncate end; intervessel pit pairs large, alternate, 7-10 μm in diameter. *Parenchyma* paratracheal, forming a thin sheath around the vessel or vessel groups, vasicentric to aliform sometimes confluent, joining 2-3 neighbouring vessels (Pl. 1, fig. 1). *Xylem rays* fine, 1-3 (mostly 2) seriate (Pl. 1, fig. 3), 5-15 cells in height, 133-465 μm in length, 26-39 μm broad; ray tissue heterocellular, 1-2 marginal rows of upright cells at one or both the ends (Pl. 1, fig. 3); ray cells are thin-walled, procumbent cells 18-30 μm in tangential diameter and 76-130 μm in radial diameter. *Intercellular canals* horizontal, normal, confined to the xylem rays (Pl. 1, fig. 3), 99-166 μm in diameter. *Fibres* aligned in more or less distinct radial rows between the two consecutive xylem rays; thick-walled, septate, non-libriform, and 10-12 μm in diameter.

*Affinities & Comparisons* — The most important anatomical feature of the fossil wood is the presence of normal gum-canals in the fusiform rays. Among the dicotylendons there are only 24 families and about 152 genera which possess normal horizontal gum canals in the xylem rays (Metcalfe & Chalk, 1950). These families are: Anacardiaceae, Apocynaceae, Araliaceae, Burseraceae, Cactaceae, Cochlospermaceae, Compositae, Crypteroniaceae, Dipterocarpaceae, Euphorbiaceae, Guttiferae, Hamamelidaceae, Julianiaceae, Loganiaceae, Moraceae, Myrtaceae, Rosaceae, Rubiaceae, Rutaceae, Sapindaceae, Solanaceae, Thymelaeaceae, Ulmaceae and Umbelliferae. Besides the presence of normal gum canals in the fusiform rays, the fossil also shows some other important anatomical features, viz., the presence of large to medium size vessels with tyloses, 3-4 seriate heterocellular xylem rays with 1-2 rows of upright cells and moderately thick-walled septate fibres.

All the above important anatomical features of the fossil wood indicate its affinities with the family Anacardiaceae (Metcalfe & Chalk, 1950; Anonymous, 1963; Desch, 1957; Pearson & Brown, 1932; Record, 1925) The family Anacardiaceae has a number of genera characterized by the presence of radial canals. These are *Melanorrhoea* Wall, *Gluta* Linn., *Swintonia* Griff, *Bouea* Meisen, *Lannea*, *Parishia* Hook, *Pistacia* Linn., *Mangifera longipes*, *Rhus* Linn., *Spondias* Linn., *Buchanania* Roxb., (Anonymous, 1963; Pearson & Brown, 1932; Metcalfe & Chalk, 1950). In an extensive study of the thin sections of modern woods of these genera it has been found that *Melanorrhoea*, *Gluta*, *Swintonia* and *Bouea* can be easily distinguished from the fossil

in having abundant apotracheal parenchyma occurring as thin or thick tangential bands. Various species of *Rhus* and *Pistacia* are distinctly ring-porous. In *Spondias* the vessels are very large to medium sized, parenchyma paratracheal and diffuse and gum canals are comparatively small. It is with the wood structure of *Buchanania* that the fossil wood shows closest affinity, specially with *B. latifolia* Roxb. The size, shape and distribution of vessels in the present fossil wood is similar to the distributional pattern in the modern species of *Buchanania latifolia*. Both in the fossil wood and in *B. latifolia*, the vessels are small to medium in size, solitary as well as in radial multiples of 2-3 and the intervessel pit pairs are large, alternate, bordered with linear to lenticular apertures. In the amount and distribution of the parenchyma and also in the nature and distribution of xylem rays as well as in the presence of radial canals and the nature of fibres are basically similar in both the fossils and those of *Buchanania latifolia* Roxb. The fossil wood also resembles superficially the modern wood of the genus *Holigarna* of the same family. However, the fossil wood differs markedly in having radial gum canals in the xylem rays. Since the present fossil wood shows resemblance with the wood structure of *Buchanania*, it has been assigned as a new genus *Buchananioxylon*. It is specifically named *Buchananioxylon indicum*.

There is no record of fossil *Buchanania* from India and abroad up till now and thus this is the first record of the fossil wood of *Buchanania* from the Tertiary of West Bengal.

*Present Distribution of Buchanania Roxb.* — The genus *Buchanania* Roxb. consists of about 25 species of trees and shrubs distributed in tropical Asia, Australia and the Pacific Islands. About four species are reported to occur in India and Burma. *Buchanania latifolia* Roxb., a large evergreen tree, is found in dry deciduous forests throughout India from the Sutlez eastwards to Nepal ascending in the sub-Himalayan tract to a height of 900 m. It is found in the forest of Uttar Pradesh, Bihar, Bengal, Orissa, Madhya Pradesh, Andhra Pradesh, Mysore, Tamil Nadu and Kerala. It is also been reported from all over Burma in dry deciduous forest alongwith *Dipterocarpus* (Anonymous, 1963).

## GENERIC DIAGNOSIS

### *Buchananioxylon* gen. nov.

*Wood* diffuse porous. *Growth rings* indistinct. *Vessels* mostly large and distinctly visible to the naked eye, very few to moderately few (2-4 per sq mm), evenly distributed, solitary or in radial multiples of 2-3, round to oval or somewhat angular in outline, open or frequently filled with tyloses. *Parenchyma* scanty, in thin sheath round the vessels, sometimes forming inconspicuous eyelets. *Rays* rather fine, closely spaced. *Fibres* septate or nonseptate. *Gum canals* horizontal, irregularly distributed; sometimes canals are visible under hand lens as dark spots in broader rays on the tangential surface.

*Genotype* — *Buchananioxylon indicum* sp. nov.

## SPECIFIC DIAGNOSIS

*Buchananioxylon indicum* sp. nov.

*Wood* diffuse porous. *Growth rings* absent. *Vessels* visible to the naked eye, evenly distributed solitary or in radial multiples of 2-3, small to medium sized; vessels round to oval in shape, t.d. 99-233 μm; r.d. 133-233 μm; frequently filled with tyloses. Vessel members short, 333-666 μm in length; perforation plates simple with truncate end; intervessel pit pairs large, alternate, 7-10 μm in diameter. *Parenchyma* paratracheal, vasicentric, forming a thin sheath around the vessels. *Xylem rays* fine, 1-3 (mostly 2) seriate, 5-15 cells in height, 133-465 μm in length, 26-39 μm broad; ray tissue heterocellular, 1-2 marginal rows of upright cells at one or both the ends. *Fibres* aligned in more or less distinct radial rows between the two consecutive xylem rays; angular, thick-walled, septate. *Intercellular canals* horizontal, normal, confined to the xylem rays, 99-166 μm in diameter.

*Holotype* — No. $P_{286}$ Palaeobotanical Collection, Department of Botany, Burdwan University, West Bengal.

*Locality* — Labpur, 16 miles east from Suri, Birbhum District, West Bengal.

*Horizon & Age* — Tipam Series; Miocene.

**Genus — *Dracontomelumoxylon* Ghosh & Roy, 1979**

*Dracontomelumoxylon mangiferumoides* Ghosh & Roy, 1979

Pl. 2, figs 6-11

The material is a single piece of secondary xylem about 6 cm in length and 4 cm in diameter. The preservation is satisfactory.

*Topography — Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* hardly visible to the naked eye, but quite distinct with a hand lens, large to medium-sized, 1-6 per mm, evenly distributed, solitary or in short radial multiples of 2-4 (Pl. 2, figs 6, 7); round to oval in outline, t.d. 99-260 μm, r.d. 133-432 μm, vessel segments short to medium-sized, 333-1065 μm in length; perforation plates simple with abruptly tailed at one or both ends; intervascular pit pairs alternate, circular to oval with 1 lenticular apertures, 7-10 μm in diameter (Pl. 2, fig. 11); vessels often filled with tyloses. *Parenchyma* distinct, thin sheaths round the vessels, predominantly paratracheal, vasicentric; 2-4 cells thick; parenchyma cells oval, 13-26 μm in diameter, thick-walled, filled with dark contents. *Xylem rays* moderately fine to broad; broad rays rather widely spaced and uniformly dtstributed; rays 1-4 (mostly 2-3) seriate (Pl. 2, figs 8, 9), 6-9 per mm, 6-45 cells in height, 199-999 μm in length; uniseriate rays are few, 8-10 cells in height and 260-333 μm in length; multiseriate rays are 26-66 μm in width and 6-45 cells in height and 199-999 μm in length; ray tissue heterocellular composed of upright and square cells (Pl. 2, fig. 10); upright ray cells 39-91 μm in tangential height and 26-66 μm in radial length. *Fibres* oval to angular, somewhat radially arranged in cross section, thick-walled, 7-14 μm in diameter; septate; libriform; interfibre pits are simple, small, mostly confined to radial walls.

*Affinities & Comparisons — Wood* diffuse-porous; *vessels* are large to medium in size, solitary or in radial multiples of 2-4; the intervessel pit-pairs are large, alternate with lenticular apertures; *parenchyma* paratracheal; *xylem rays* are 1-4 (mostly 2-3) seriate, heterocellular and fibres are libriform. A combination of all these features indicates a close resemblance with the wood structure of some genera of the family Anacardiaceae and Burseraceae. In the family Burseraceae the genus *Canarium* shows some superficial resemblance with our fossil but differs from it in having somewhat smaller vessels, scanty paratracheal parenchyma, short xylem rays and semi-libriform fibres. Thus the fossil wood indicates its affinities with the modern woods of *Mangifera*, *Anacardium* and *Dracontomelum* of the family Anacardiaceae. The genus *Mangifera* can be distinguished from the fossil wood in having apotracheal parenchyma bands, short rays and non-septate or rarely septate fibres. The fossil wood differs from *Anacardium* in having large vessels, 2-3 seriate long xylem rays and septate fibres. Therefore the wood closely resembles in almost all the structural details with the wood structure of the extant genus *Dracontomelum*.

A large number of fossil woods belonging to the family Anacardiaceae are known from India and abroad, but those supposed to show affinities with *Mangifera* and *Anacardium* are *Anacardioxylon mangiferoides* Ramanujam (1960) from the Tertiary of South India, *A. semecarpoides* Prakash & Dayal (1965) from the Deccan Intertrappean Series of India, *Mangiferoxylon scleroticum* Awasthi (1966) from Pondicherry and South India, and *Mangiferoxylon assamicum* (Prakash & Tiwari, 1970a) from Hailakandi, Assam. *Mangiferoxylon scleroticum* differs from our fossil wood in having terminal and apotracheal parenchyma, abundant sclerotic tyloses and 1-2 (mostly 1) seriate and less frequent (1-2 per mm) xylem rays. *M. assamicum* also differs from the fossil wood in having apotracheal and vasicentric to aliform sometimes aliform-confluent paratracheal parenchyma, homocellular to heterocellular, short 1-3 (mostly 2) seriate xylem rays, non-libriform and rarely septate fibres. From the description and figures of the fossil wood referred to *Anacardioxylon mangiferoides*, it does not appear to show any affinities with the family Anacardiaceae. *Mangifera* and *Anacardium*, to which the fossil wood shows its relationship, do not possess homocellular xylem rays as described in Ramanujam's fossil wood. The present fossil wood also differs from *Anacardioxylon semecarpus* in having tyloses in vessels and septate fibres.

*Present Distribution — Dracontomelum* Blume is a small genus of trees, scattered

throughout south-east Asia, from the Andamans Islands and Burma in the West to the Philippines in the north and the Fiji Islands in the south (Brandis, 1906). *Dracontomelum mangiferum* Blume, the only Indian species of the genus *Dracontomelum* showing similarity with our fossil, is a large evergreen tree found in the tropical and upper mixed forest of the Andaman and Nicobar islands (Anonymous, 1963).

*Specimen* — No. $P_{205}$ Palaeobotanical Collection, Department of Botany, University of Burdwan, West Bengal.

*Locality* — Labpur, Birbhum District, West Bengal.

*Horizon & Age* — Tipam Series; Miocene.

**Genus — *Mangiferoxylon* Awasthi, 1966**

*Mangiferoxylon assamicum* Prakash & Tripathi, 1970a

Pl. 3, figs 18, 19; Pl. 4, figs 20-22

The fossil wood is represented by a single piece of mature secondary xylem measuring 9 cm in length and 4 cm in diameter. Preservation is fairly good.

*Topography — Wood* diffuse-porous. *Growth rings* distinct. Vessels visible to the naked eye, small to large solitary as well as in radial multiples of mostly 2-6 (Pl. 3, figs 18, 19); 2-7 vessels per sq mm, circular to oval in cross section, solitary vessel t.d. 66-199 μm and r.d. 66-239 μm; multiple vessels t.d. 66-292 μm and r.d. 199-532 μm; vessel members short to medium; 66-332 μm in length with truncate ends; perforation plates simple; intervessel pit pairs large, alternate, circular to oval with lenticular aperture, 7-10 μm in diameter (Pl. 4, fig. 22). *Parenchyma* paratracheal and apotracheal (Pl. 3, fig. 19); paratracheal parenchyma forming 2-3 cells wide vasicentric sheath, sometimes with fine wing like extension forming eyelets with the vessels (Pl. 3, figs 18, 19); apotracheal parenchyma represented by thin bands of 2-3 cells width, usually delimiting the growth rings, 1-2 bands per mm (Pl. 3, fig. 19), parenchyma cells thin-walled, about 35-150 μm in length and 6-14 μm in diameter. *Xylem rays* fine, 1-3 (mostly 2) seriate (Pl. 4, fig. 20); 4-20 cells high and 199-465 μm in length; 26-52 μm in width; ray tissue heterocellular (Pl. 4, fig. 21); upright ray cells 39-106 μm in tangential diameter and 39-52 μm in radial length; procumbent cells 26-52 μm in tangential height and 39-98 μm in radial length. *Fibres* aligned in radial rows between two consecutive xylem rays, oval to angular, non-septate, thick-walled, 6-14 μm in diameter. *Tyloses* present.

*Specimen* — No. $P_{559}$ Palaeobotanical Collection, Department of Botany, University of Burdwan, West Bengal.

*Locality* — Labpur, Birbhum District, West Bengal, India.

*Horizon & Age* — Tipam Series; Miocene.

*Affinities & Comparison — Wood* diffuse porous; *vessels* solitary and also in radial multiples of mostly 2-3, intervessel pit pairs are large with lenticular aperture; *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma vasicentric to aliform; apotracheal (terminal) parenchyma usually delimiting the growth rings; 1-3 seriate heterocellular xylem rays, fibres libriform and non-septate. All these features of the fossil wood indicate its close resemblance with the wood of *Mangifera* of the family Anacardiaceae (Pearson & Brown, 1932; Heimsch, 1942; Metcalfe & Chalk, 1950; Brazier & Franklin, 1961; Anonymous, 1963). Besides *Mangifera*, the fossil wood also shows many anatomical features similar to *Anacardium*. However, the genus *Anacardium* differs from the fossil wood in the absence of terminal parenchyma and the sclerotic tyloses. Detailed comparisons of the fossil wood has been made with the woods of *Mangifera indica* Linn., *M. altissima* Blanco, *M. longipes* Griff., *M. zeylanica* Hook., *M. sylvatica* Roxb., *M. caloneura* and *M. odorata* Griff. Comparisons were also made with the published description and figures of *M. indica*, *M. sylvatica*, *M. lauirina* Blume, *M. longipes* Griff., *M. foetida* Lour., *M. altissima* Blance (Pearson & Brown, 1932; Moll & Janssonius, 1908; Brazier & Franklin, 1961; Kribs, 1959; Anonymous, 1963). This study, however, showed that the fossil wood reveals its close similarity with the wood structure of *Mangifera indica* Linn. The fossil wood and the wood of *M. indica* are identical in shape, size and distributional pattern of the vessels, in the nature of intervascular pitting, parenchyma distribution and in the fibre and ray structure.

Awasthi (1966) instituted the genus *Mangiferoxylon* for the fossil woods showing

similarities with the wood of living genus *Mangifera*. Only three fossil woods resembling *Mangifera* are known so far from India and abroad. These are *Anacardioxylon mangiferoides* Ramanujam (1960), *Mangiferoxylon scleroticum* Awasthi (1966), and *M. assamicum* Prakash & Tripathi (1970a). From the description and figures of the fossil wood referred to *Anacardioxylon mangiferumoides* it does not appear to show any affinity with the family Anacardiaceae. *Mangiferoxylon scleroticum* differs from the fossil wood in having abundant sclerotic tyloses and mostly uniseriate and less frequent xylem rays. Nevertheless, the fossil wood exhibits near resemblance to *Mangiferoxylon assamicum*, although there are some minor differences between the two which may be due to the anatomical variations occurring in a single individual or in different individuals of the same species growing under different environmental conditions. As the differences are not very marked; it is being referred to *Mangiferoxylon assamicum* Prakash & Tripathi (1970a).

*Present Distribution* — *Mangifera* is a large genus consisting of 41 species of large to very large evergreen trees confined mainly to the Indo-Malayan region. *Mangifera indica*, very close to the fossil wood, occurs widely in the Himalayas, Hills of Eastern and Western Ghats, Ceylon, forests of central India, Orissa, Bihar, Bengal and Assam and extends through Chittagong Hill Tracts in Bangla Desh to Burma, Thailand, Vietnam and the Malay Peninsula (Anonymous, 1963).

**Genus — *Melanorrhoeoxylon* Prakash & Tripathi, 1969a**

*Melanorrhoeoxylon garbetaense* sp. nov.

Pl. 4, figs 23-27

The specimen is a piece of secondary wood measuring 5 cm in length and 3 cm in diameter. Preservation is very good.

*Topography* — *Wood* diffuse-porous (Pl. 4, fig. 23). *Growth* rings indistinct. *Vessels* small to medium sized, solitary, sometimes in radial rows of 2-3 (Pl. 4, fig. 23), 1-2 sq mm, thin-walled, the walls about 2-4 μm thick, vessels 39-196 μm in tangential diameter, and 133-266 μm in radial diameter round to oval in cross section, those in groups flattened at the places of contact; vessel-members are long with truncate ends; perforation plates simple, intervessel pit pairs large, 7-10 μm in diameter, alternate, bordered, lenticular apertures profusely tylosed. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty to vasicentric forming 1-3 cells thick sheath around the vessels, apotracheal parenchyma usually forming short, broken, thick tangential bands (Pl. 4, fig. 26). *Xylem rays* fine consisting both of simple and fusiform rays with gum canals; simple rays very fine, 1-2 (mostly 1) seriate (Pl. 4, figs 24, 25), 6-17 cells high and 79-425 μm in length; fusiform rays (Pl. 4, figs 24, 25) with horizontal gum canals, 59-70 μm broad, 14-23 cells high and 266-465 μm in length; 10-12 rays per mm, ray tissue homocellular consisting wholly of procumbent cells (Pl. 4, fig. 27); ray cells thick-walled, procumbent ray cells 20-39 μm in tangential height and 52-91 μm in radial length. *Fibres* aligned in radial rows, interrupted by the parenchyma bands; non-libriform to semi-libriform; non-septate, walls 2-4 μm thick, angular in shape, 15-20 μm in diameter. *Intercellular canals* normal, horizontal, small confined to fusiform xylem rays, gum canals 21-45 μm in diameter; epithelial cells present in a row round the gum ducts (Pl. 4, fig. 25).

*Affinities & Comparison* — The characteristic features of the wood are the presence of solitary as well radial multiple vessels, thick bands of apotracheal parenchyma, homocellular xylem rays with normal radial gum canals. These characters are of the wood of Anacardiaceae. In this family there are a number of genera which are characterised by the presence of radial gum canals (Pearson & Brown, 1932; Anonymous, 1963; Metcalfe & Chalk, 1950). Amongst these, the Indian genera with radial gum-canals are *Buchanania*, *Gluta*, *Lannea*, *Melanorrhoea*, *Parishia*, *Pistacia*, *Mangifera* (*M. longipes*), *Rhus*, *Spondius* and *Swintonia*. But *Gluta* and *Melanorrhoea* show remarkable close resemblance with our fossil wood (Metcalfe & Chalk, 1950; Anonymous, 1963). In order to find out the nearest modern equivalent of the fossil it was compared with the woods of these two genera. A detailed study of thin sections of woods of these two genera, viz., *Melanorrhoea apetra* King, *M. curtisii* Oliver, *M. torquata* King, *M. malayana* Corner,

*M.* sp., *Gluta renghas* Linn., *G. tavoyana* Hook, *G. coarctata* Hook, *G. travancorica* Bedd. reveals that the nearest affinity of the fossil wood is with the genus *Melanorrhoea*, especially with *M. usitata* Wall. Prakash and Tripathi (1969a) instituted the form genus *Melanorrhoeoxylon* and separated it from *Glutoxylon* on the basis of the nature of apotracheal parenchyma bands, ray tissues and gum canals. The genus *Melanorrhoeoxylon* includes those species of *Melanorrhoea* which have thick bands of apotracheal parenchyma, 1-10 (usually 3-7 or 8) seriate and the gum canals are comparatively smaller than *Glutoxylon* (Pearson & Brown, 1932).

In view of its closest resemblance with the modern woods of *Melanorrhoea* the fossil wood is designated as *Melanorrhoeoxylon* and named as *Melanorrhoeoxylon garbetaense*, the specific name indicates its occurrence in the locality. The only fossil wood resembling *Melanorrhoea* is *M. cacharense* (Prakash & Tripathi, 1976) described from the Tertiary of Assam. Nevertheless the fossil wood differs from *M. cacharense* in having smaller vessels distributed very sparsely. The vessels are radial multiples and comparatively less number of parenchyma bands.

*Present Distribution* — Genus *Melanorrhoea* Wall. consists of 20 species (Willis, 1966) restricted to the Indo-Malayan region. Two species are indigenous to Burma, one of which *Melanorrhoea usitata* Wall. grows in the drier forest of Burma up to 1,200 m elevation and extends up to Manpur in India, while *M. glabra* Wall. is found in the forests of Tenassium, and Tary and Mergui regions of Burma.

## SPECIFIC DIAGNOSIS

*Melanorrhoeoxylon garbetaense* sp. nov.

*Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* moderately small to medium size; solitary and also radial multiples of 2 or more; oval to elliptical in outline, t.d. 10-106 μm, r.d. 133-266 μm; 1-2 per sq mm, heavily tylosed; vessel members long with truncate ends; perforation plates simple; intervessel pit-pairs large, 7-10 μm in diameter, alternate, bordered, oval to angular through crowding. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty to vasicentric, apotracheal parenchyma bands usually in continuous sometimes broken tangential bands, 1-7 (mostly 3-4) cells thick, closely spaced, 2-8 bands per mm. *Xylem rays* are both simple and fusiform with gum canals; simple rays 1-2 (mostly 1) seriate, 6-17 cells high and 79-425 μm in length; fusiform rays 59-70 μm broad, 14-23 cells high and 266-465 μm in length; rays 10-16 per mm, ray tissue homocellular consisting wholly of procumbent cells. *Fibres* non-libriform to semi-libriform, non-septate, angular 4-8 μm in diameter. *Intercellular canals* normal, horizontal, 21-45 μm in diameter; epithelial cells present in a row round the ducts.

*Holotype* — No. $P_{239}$ Palaeobotanical Collection, Department of Botany, University of Burdwan, West Bengal.

*Locality* — Garbeta, Midnapur District, West Bengal.

*Horizon & Age* — Tipam Series; Miocene.

### Genus — *Lanneoxylon* Prakash & Tripathi, 1967

*Lanneoxylon grandiosum* Prakash & Tripathi, 1967

Pl. 3, figs 12-17

The fossil wood is represented by a single piece of mature secondary xylem measuring 6 cm in length and 3 cm in diameter. It shows satisfactory preservation.

*Topography — Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* small to moderately large, solitary as well in radial multiples of 2-3, evenly distributed, heavily occluded with tyloses (Pl. 3, fig. 13); vessels thin-walled, oval to elliptical in outline, 66-199 μm in tangential diameter; 93-332 μm in radial diameter; walls 4-6 μm thick; vessel members 133-399 μm in length with truncate ends, perforation plates simple intervessel pit pairs large, 4-6 μm in diameter, bordered, alternate, angular due to crowding with lenticular apertures. *Parenchyma* paratracheal, scantily occurring as few cells about the vessels (Pl. 3, fig. 13), parenchyma cells thin-walled. *Xylem rays* very fine to moderately broad, 1-5 (mostly 3-4) seriate (Pl. 3, figs 14, 15) and 26-80 μm broad, 5-25 cells in height and 133-692 μm in length, heterocellular, composed of procumbent cells and upright cells (Pl. 3, fig. 17); ray cells thin-walled, occasionally crystalliferous; pro-

cumbent cells 20-30 μm in tangential diameter, 66-159 μm in radial diameter; upright cells 39-66 μm in tangential diameter and 26-53 μm in radial length; xylem rays with horizontal gum canals (Pl. 3, fig. 16), gum canals small, surrounded by epithelial cells, 26-52 μm in diameter. *Fibres* aligned in more or less distinct radial rows between the two consecutive xylem rays, thick-walled with big lumina, angular in cross section, 4-6 μm in diameter, septate.

*Specimen* — No. $P_{11}$ Palaeobotanical Collection, Department of Botany, University of Burdwan, West Bengal.

*Locality* — Labpur, Birbhum District, West Bengal.

*Horizon & Age* — Tipam Series; Miocene.

*Affinities & Comparisons* — Normal, horizontal gum canals are present in the fossil wood which is a characteristic feature limited to 24 families and about 152 genera listed by Metcalfe and Chalk (1950). These families are: Anacardiaceae, Apocynaceae, Araliaceae, Burseraceae, Cactaceae, Cochlospermaceae, Compositae, Crypteroniaceae, Dipterocarpaceae, Euphorbiaceae, Guttiferae, Hamamelidaceae, Julianiaceae, Loganiaceae, Moraceae, Myrtaceae, Rosaceae, Rubiaceae, Rutaceae, Sapindaceae, Solanaceae, Thymelaeaceae, Ulmaceae and Umbelliferae.

Besides the presence of normal gum canals in the fusiform rays, the fossil also shows some other important anatomical features, viz., presence of large vessels (t.d. 66-199 μm, r.d. 93-322 μm); profusely occluded with tyloses; scanty paratracheal parenchyma; 1-6 (mostly 3-4) seriate heterocellular xylem rays and moderately thick-walled septate fibres. These anatomical features indicate the affinity of the fossil wood with some genera of the family Burseraceae and Anacardiaceae (Metcalfe & Chalk, 1950; Desch, 1957; Pearson & Brown, 1932; Heimsch, 1942; Record, 1925).

In the family Burseraceae, there are about nine genera having radial gum canals found in the fusiform xylem rays. These are — *Balsamodendron*, *Boswellia*, *Bursera*, *Canarium*, *Dacryodes*, *Elaphrium*, *Garuga*, *Protium* and *Santiria*. Amongst the Indian genera, radial gum canals which are occasionally visible under hand lense have been observed in *Balsamodendron*, *Boswellia* and *Garuga* (Moll & Janssonius, 1908, pp. 87-109; Pearson & Brown, 1932, pp. 217-233; Heimsch, 1942, pp. 122-124; Metcalfe & Chalk, 1950, pp. 345-347; Anonymous, 1963; Record, 1935, pp. 19, 20). Of these only two genera, viz., *Garuga* and *Boswellia* are near comparable with our fossil wood. The wood of *Garuga* can be distinguished from our wood in possessing larger pores and rays with enlarged end cells containing crystals. The only Indian species *Garuga pinnata* can be separated by the presence of large and frequent gum canals. It also be noted that the intercellular radial canals are absent and rays have oil cells in *Garuga floribunda* (Reyes, 1938). Though *Boswellia* is nearer in structural details to the fossil wood than *Garuga* but differs from the fossil wood in having more frequent larger radial gum canals in the xylem rays (Pearson & Brown, 1932).

Similarly, in the family Anacardiaceae out of about 65 genera only about 33 show normal horizontal gum canals (Metcalfe & Chalk, 1950) in the xylem rays. Out of these only 10 Indian genera, viz., *Buchanania*, *Gluta*, *Lannea*, *Mangifera longipes*, *Melanorrohoea*, *Parishia*, *Pistacia*, *Rhus*, *Spondias* and *Swintonia* possess such type of gum canals (Pearson & Brown, 1932; Anonymous, 1963; Desch, 1957; Metcalfe & Chalk, 1950).

From an extensive study of the thin sections of modern woods of these genera it has been found that the fossil wood indicates its closest affinity with the modern genus *Lannea* A. Rich, especially *L. coromandelica* (Houtt) Merr. [Syn. *Lannea grandis* (Dennst.) Engler; *Odina wodier* Roxb., *L. Wodier* (Roxb.) Adelb.) (Raizada, 1958)] Thus the fossil wood resembles the modern wood of *Lannea coromandelica* (Houtt) Merr. in size, shape and distributional pattern of the vessels, nature of intervascular pitting in parenchyma distribution and the fibre and ray structure.

Prakash and Tripathi (1967) instituted the organ genus *Lanneoxylon* for the fossil woods showing structural features of *Lannea* and described the species *Lanneoxylon grandiosum* from Dimapur Diphy Road in Mikir Hills, Assam. As the present fossil wood is identical to this species, it is assigned to it.

*Present Distribution* — The genus *Lannea* A. Rich consists of about 15 species of small to large deciduous trees distributed in tropical Africa and Asia. The only species found in the Indian region is *Lannea*

*coromandelica* (Houtt) Merr. (Syn. *L. grandis* Engler) found in the dry forests of all states except parts of Punjab, Rajasthan and Saurashtra. It is also found in the Sub-Himalayan tract and the lower Himalayas from the Indus eastwards ascending to 1,200 m; common in Siwaliks, Dehradun and Saharanpur forests, throughout the area of Oudh, Gorakhpur and Bundelkhand of Uttar Pradesh but not so common in Bengal and Assam and scattered in Bihar and Orissa. It is also common in Travancore and in the deciduous forests of Mysore and Madras. It occurs also in Andamans, Burma and Ceylon (Anonymous, 1963).

## DISCUSSION

About a dozen of taxa of fossil woods belonging to family Anacardiaceae have already been described from the Tertiary deposits of India and Burma (Awasthi, 1966, 1970; Chowdhury, 1934, 1936, 1938, 1950, 1952; Chowdhury & Tandon, 1952; Ghosh, 1958; Ghosh & Taneja, 1961; Ghosh & Roy, 1979; Prakash & Dayal, 1965; Prakash & Awasthi, 1970, 1971; Prakash & Tripathi, 1967, 1968, 1969a, 1969b, 1969c, 1970a, 1976; Ramanujam, 1960; Roy & Ghosh, 1979c). Among these, *Anacardioxylon semecarpoides* is the only record of the wood of Anacardiaceae from the Palaeogene of India. The other taxa, *Glutoxylon burmense*, *G. cuddalorense*, *Anacardioxylon shardai*, *A. mangiferumoides*, *Mangiferoxylon scleroscoticum*, *M. assamicum*, *Melanorrheoxylon cacharense*, *Swintonioxylon hailakandiense*, *Holigarnoxylon assamicum*, *Lanneoxylon grandiosum* and *Dracontomelumoxylon mangiferumoides* have been described from the Neogene of India. Of these, *Glutoxylon cuddalorense*, *Anacardioxylon mangiferumoides* and *Mangiferoxylon scleroscoticum* occur only in the Cuddalore Series (Miocene) of South India. Rest of the Indian Neogene records are either from the Tipam Series of north-eastern India or eastern India. Considering this aspect, it is evident that Anacardiaceae occurred widely during the Neogene. In the Tertiary flora of West Bengal, this family is fairly well represented and indicates that these Tertiary deposits also belong to Neogene.

The fossil woods belonging to Anacardiaceae have also been recorded from abroad (Edwards, 1931; Edwards & Wonnacott, 1935; Felix, 1882, 1894; Kruse, 1954; Platen, 1908; Schönfeld, 1947). Most of these records are from the Tertiary deposits.

The extant counterparts of the fossils described here occur in either dry deciduous forests (*Buchanania latifolia* Roxb.; *Melanorrhoea usitata* Wall., *Lannea grandis* Engl.) of India and Burma or in the evergreen forests of Andaman Islands, Burma and Phillipines (*Dracontomelum mangiferum* Blume) (see Brandis, 1906; Gamble, 1902; Anonymous, 1963). *Mangifera indica* Linn. is found in almost all the forests in the plains of India. Thus, the Tertiary flora in West Bengal consists of those elements which now grow widely in the tropical and sub-tropical forests of Burma, Malaysia, Hills of eastern India and Eastern and Western Ghats. The forest vegetation was predominantly constituted by dry-deciduous elements with a few evergreen types.

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## EXPLANATION OF PLATES

### PLATE 1

*Buchananioxylon indicum* gen. et sp. nov.

1. Cross section of the fossil wood showing type and distribution of vessels and vasicentric parenchyma. × 75.
2. Cross section of *Buchanania latifolia* Roxb. showing the same pattern of distribution of vessels and parenchyma. × 75.
3. T.L.S. of the fossil wood showing xylem rays with horizontal gum canals. × 100.
4. T.L.S. *Buchanania latifolia* Roxb. × 100.
5. R.L.S. of the fossil wood showing heterocellular xylem rays. × 50.

### PLATE 2

*Dracontomelumoxylon mangiferumoides* Ghosh & Roy, 1979

6. Cross section of the fossil wood showing vessels, parenchyma and other elements. × 20.
7. A sector of the above magnified showing vessels and vasicentric parenchyma. × 50.
8. T.L.S. of the fossil wood showing rays, vessel members with oblique end wall. × 120.
9. T.L.S. × 50.
10. R.L.S. showing heterocellular rays with procumbent and upright cells. × 120.
11. T.L.S. showing intervessel pitting. × 500.

### PLATE 3

*Lanneoxylon grandiosum* Prakash & Tripathi, 1967

12. Cross section of the fossil. × 12.
13. Cross section of the fossil further magnified showing the vessels and parenchyma. × 25.
14. T.L.S. of fossil showing xylem ray with a radial gum canal. × 50.
15. T.L.S. showing vessel members with end wall and xylem rays. × 50.
16. Radial gum canal magnified. × 300.
17. R.L.S. showing heterocellular rays. × 50.

*Mangiferoxylon assamicum* Prakash & Tripathi, 1970a

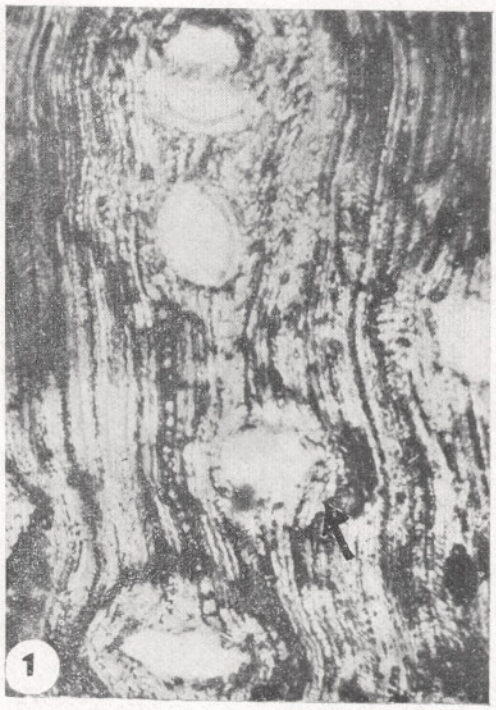
18. Cross section of the fossil wood showing the distribution of parenchyma and vessels. × 50.
19. Cross section of the fossil showing terminal parenchyma. × 50.

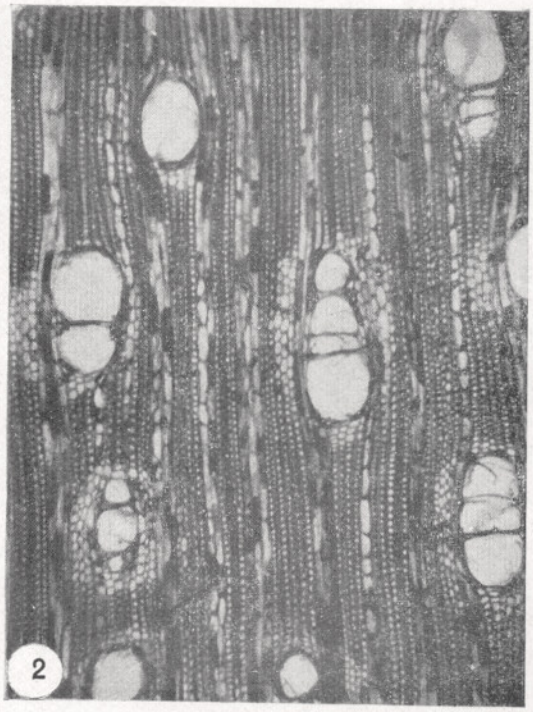
### PLATE 4

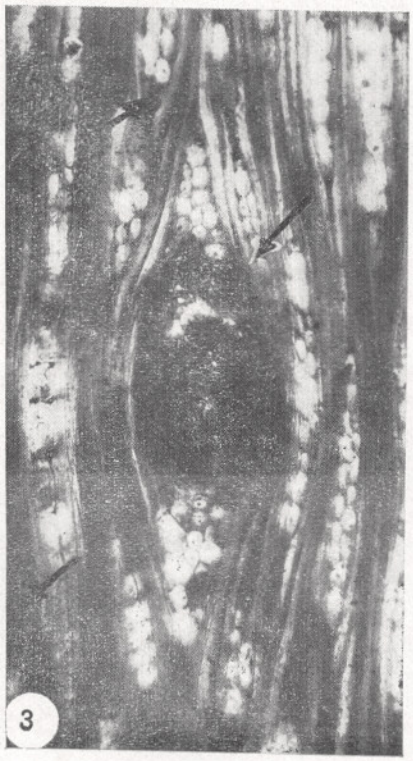
20. T.L.S. of fossil wood. × 100.
21. R.L.S. showing heterocellular rays. × 200.
22. T.L.S. showing intervessel pitting. × 500.

*Melanorrhoeoxylon garbetaense* sp. nov.

23. Cross section of the fossil wood. × 25.
24. T.L.S. showing uniseriate xylem rays and radial gum canal. × 75
25. Magnified radial gum canal. × 100.
26. Magnified view of the apotracheal parenchyma and vessel. × 50.
27. R.L.S. showing homocellular rays. × 50. Arrow marks in the photographs indicate characteristic features.





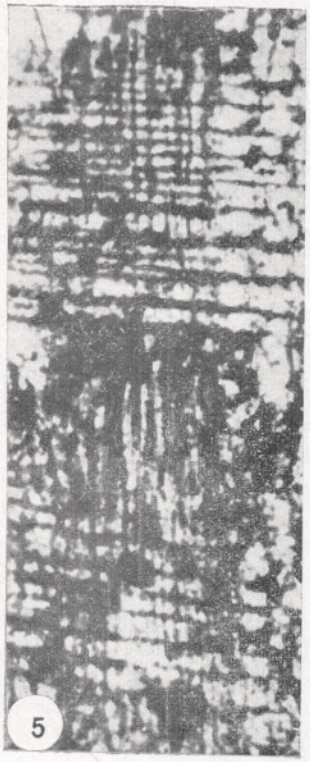
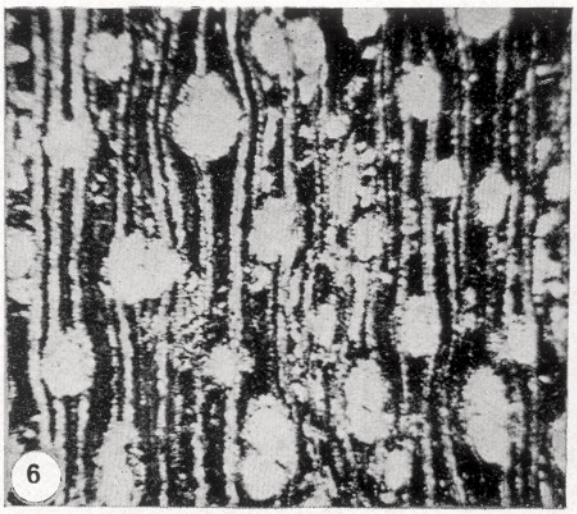
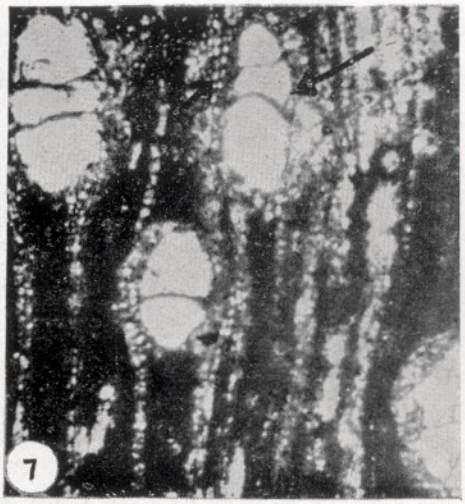
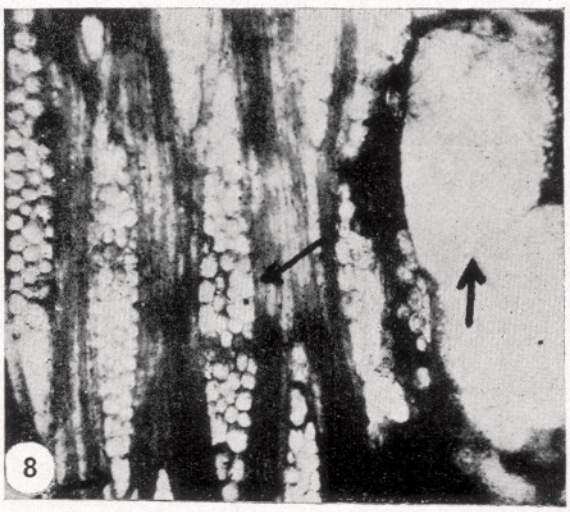
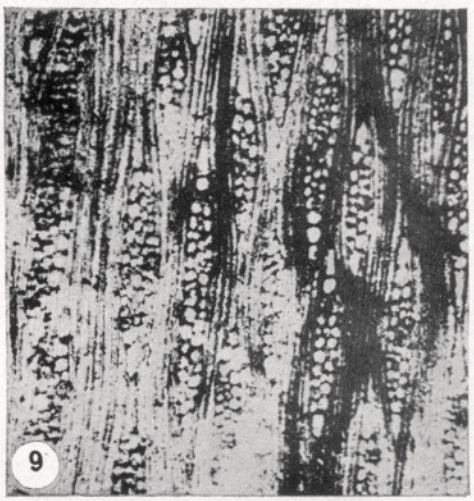


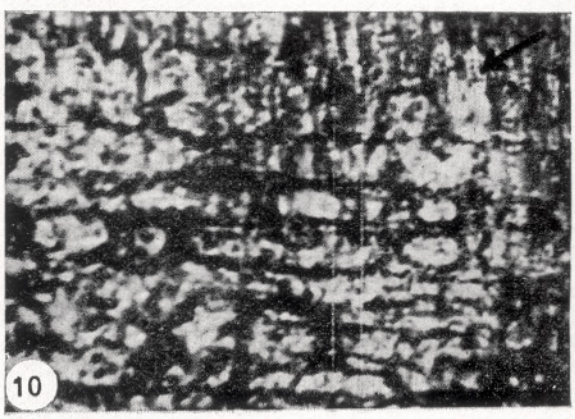

PLATE 1



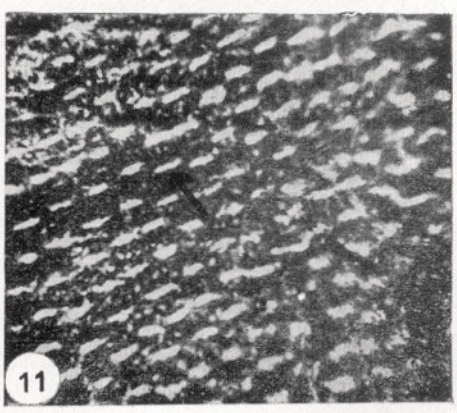
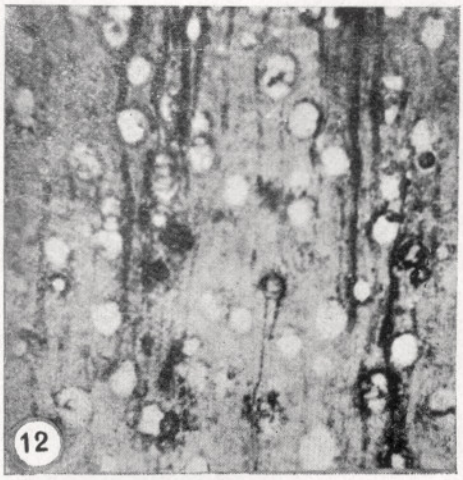
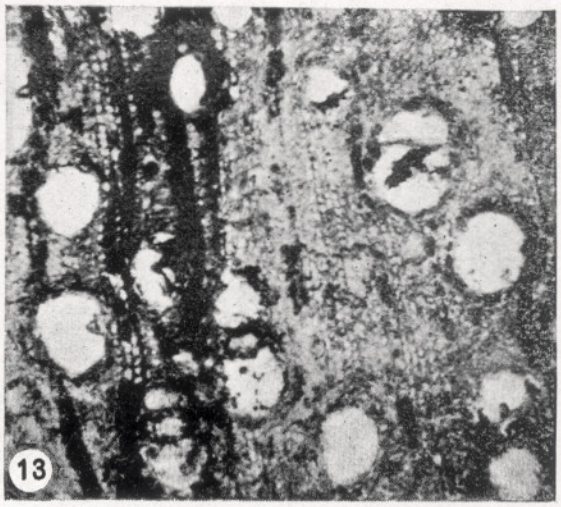
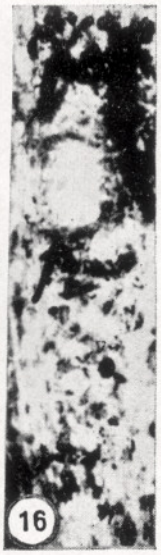



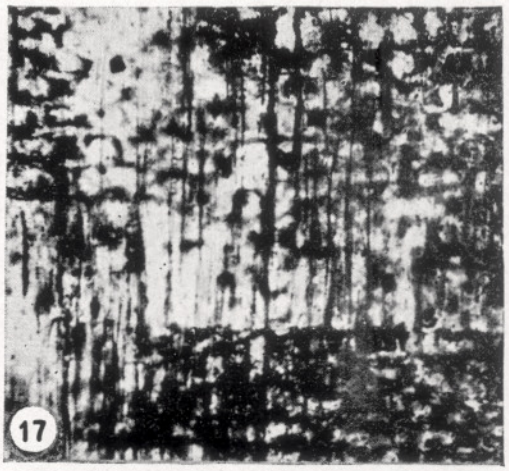

PLATE 2

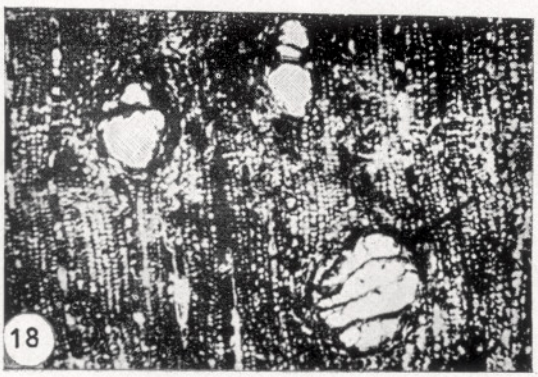




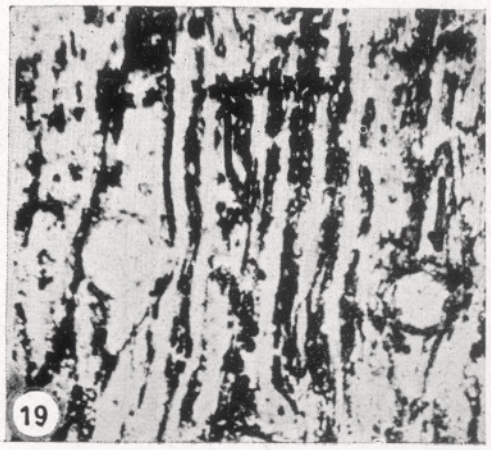
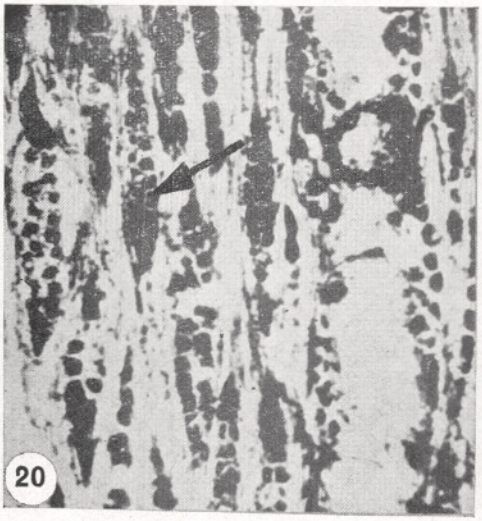
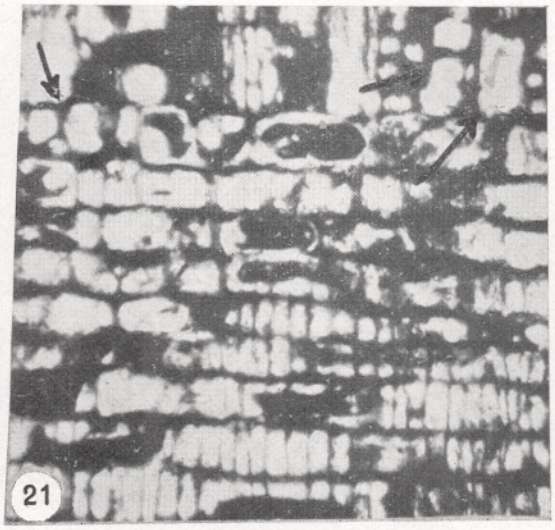
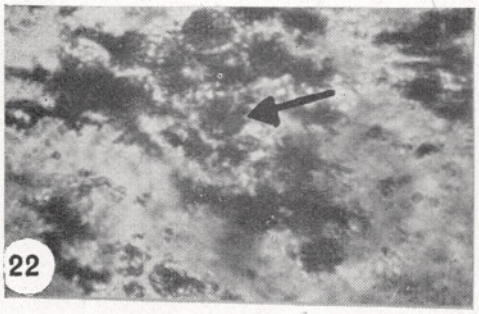
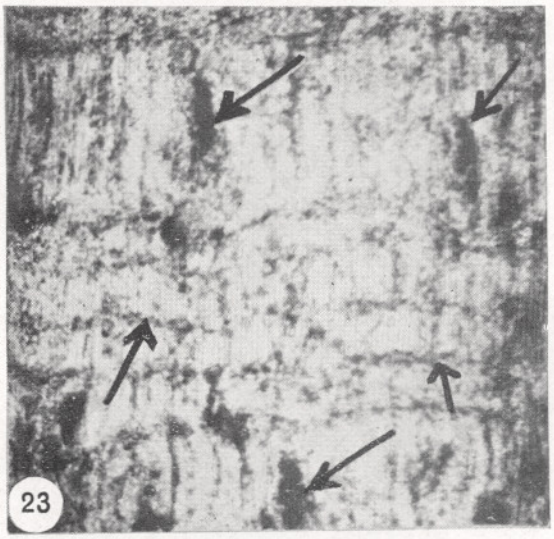




PLATE 3

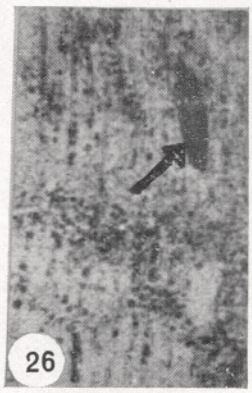




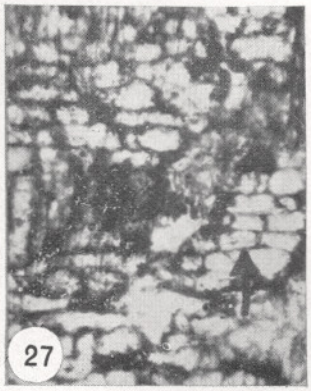




PLATE 4