ADDITIONS TO THE NEOGENE FLORA OF KERALA COAST, INDIA

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Abstract

Six dicotyledonous genera, viz., *Shorea* Roxb. (Dipterocarpaceae), *Fagara* L. (Rutaceae), *Cassia* Tourn ex L. (Fabaceae), *Anisophyllea* R. Br., *Carallia* Roxb. ex R. Br. (Rhizophoraceae) and *Careya* Roxb. (Lecythidaceae), are reported from the Neogene sediments (Warkalli beds) of Kerala coast, based on the study of carbonised woods. These are inhabitants of the tropical evergreen forest of Indo-Malayan region. Occurrence of *Shorea*, *Anisophyllea* and several other evergreen taxa reported earlier from Warkalli beds indicates prevelence tropical climate with excessive humid condition in this part of southern India during Middle Miocene.

Introduction

The Neogene sediments of Kerala coast, classified as Warkalli beds overlying the Quilon beds, are well known for rich deposits of carbonised woods. The anatomical study of carbonised woods carried out in recent years by Awasthi and Ahuja (1982), Awasthi and Panjwani (1984), and Awasthi and Srivastava (1989, 1990) has revealed an assemblage of dicotyledonous taxa belonging to Flacourtiaceae, Ampelidaceae, Clusiaceae, Dipterocarpaceae, Burseraceae, Anacardiaceae, Fabaceae, Combretaceae, Ebenaceae, Sapotaceae, Thymeleaceae and Lauraceae. In order to build-up the database for precise reconstruction of the Neogene floristics of Kerala Coast and to decipher the palaeoecology and phytogeography of the region, more carbonised woods were subjected to detailed study. Out of a number of them studied from Padappakara and Payangadi clay mines, six have been identified with the extant taxa and are described here in detail.

Systematic description

Family—DIPTEROCARPACEAE

Genus —*SHOREOXYLON* Den Berger

Shoreoxylon arcotense Awasthi, 1974

Pl. 2, figs 1-3

Description—Wood diffuse-porous. *Growth rings* not seen. *Vessels* mostly solitary and rarely in multiples of 2 (Pl. 2, fig. 1), small to medium, t.d. 64-160 μm, r.d. 64-180 μm, evenly distributed, 6-10 vessels per sq. mm, thin-walled, heavily tylosed; perforations simple; vessel-members 240-350 μm high with truncate ends; intervessel pits medium to large, 8-12 μm in diameter, alternate, vestured with linear aperture. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma scanty, a few cells occurring around vessels; apotracheal parenchyma forming 3-5 cells wide tangential bands associated with gum canals (Pl. 2, figs. 1,2). *Vasicentric tracheids* intermingled with paratracheal parenchyma. *Rays* 1-3 seriate, heterogeneous, consisting of procumbent cells in the centre and 1-3 rows of upright or square cells at one or both the ends (Pl. 2, fig 3), 25-45 cells or upto 800 μm high; upright cells 20-28 μm in tangential height and 16-24 μm in radial length; procumbent cells 16-20 μm in tangential height and 36-40 μm in radial length. *Fibres* aligned in radial rows, nonseptate, thin-walled. *Gum canals* vertical, occurring in concentric rings, t.d. 80-148, μm, r.d. 100-160 μm (Pl. 2, fig. 2).

Affinities—The above anatomical characters indicate that the carbonised wood belongs to the genus *Shorea* Roxb. and shows close resemblance with that of *Shorea acuminata*. Among the known species of *Shoreoxylon* the present carbonised wood is quite similar to *Shoreoxylon arcotense* Awasthi (1974), described from the Cuddalore Sandstone near Pondicherry, and hence it is being placed in the same species.

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Specimen no.—B.S-I.P. 36655

Locality—Payangadi Super Clay Mine, Kannur District

Family—RUTACEAE

Genus—*FAGAROXYLON* gen. nov.

Fagaroxylon acronychioides sp. nov.

Pl. 1, figs 1-5

Description—Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium, t.d. 48-112 μm, r.d. 80-144 μm, solitary and in radial multiples of 2-3, rarely upto 5 (Pl. 1, figs 1,2), evenly distributed, about 12-18 vessels per sq. mm; vessels filled with dark brownish contents; perforations simple; vessel-members upto 340 μm high with truncate ends; intervessel pits minute, alternate, 4-6 μm in diameter with circular aperture. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma sparse, a few cells associated with vessels; apotracheal parenchyma forming lines of 1-3 (mostly 1-2) cells or 8-16 μm wide occurring at regular intervals, continuous to discontinuous, 8-11 per cm (Pl. 1, figs 1,2). Rays 1-3 (mostly 2) seriate; uniseriate rays homocellular, consisting of upright cells, upto 11 cells or 220 μm high; multiseriate rays made up of procumbent cells in the middle portion and upright cells at both the ends, upto 40 cells or 880 μm high and 32 μm broad (Pl. 1, figs 3,4). *Fibres* radially aligned, semilibriform, nonseptate.

Affinities—In all the anatomial features the carbonised wood is comparable to those of *Fagara* (=*Zanthoxylum*) and *Acronychia* of the family Rutaceae. Comparison with the woods of extant species of these genera from their thin sections as well as published descriptions and photographs (Desch, 1954; Metcalfe, & Chalk, 1950; Miles, 1978; Moll & Janssonius, 1988; Negi, 1963; Normand, 1955; Pearson & Brown, 1932) has revealed that the present carbonised wood shows close resemblance with those of *Fagara rhetsa* (=*Zanthoxylum rhetsa*) and *Acronychia pedunculata* (=*A. laurifolia*). In having narrow apotracheal parenchyma lines it is very close to *Fagara* than *Acronychia* in which the parenchyma lines are somewhat confluent. While in the width and length of xylem rays it shows better resemblance with *Acronychia*.

Comparison with fossil species—There is no record of fossil wood comparable to *Fagara* and *Acronychia*. However, a few fossil woods assigned to other rutaceous genera are known from India and abroad. From India, all the fossil woods described so far are from the Deccan Intertrappean beds, viz., *Atlantioxylon indicum* Lakhanpal et al. (1978) from Parapani, Mandla District, *Evodinium intertrappeum* Shete & Kulkarni (1982) and *E. indicum* Bande & Prakash (1984) from Nawargaon, Wardha District and a wood of uncertain affinity from Mahurzari, Nagpur District (Chitaley & Shallam, 1962). Those described from outside India are *Rutoxylon corneti* Boureau (1952) from Tertiary of Africa, *Citrusoxylon pairisiense* and *C. grandiporosum* Prive-Gill (1981) from Paris Basin, France. These woods are different from our specimen in the nature and distribution pattern of parenchyma and the width and hight of rays.

Because of its close resemblance with the wood structure of *Fagara*, the carbonised wood has been named *Fararoxylon* gen. nov. Its specific name, *F. acronychioides* sp. nov., indicates its resemblance with *Acronychia* also.

GENERIC DIAGNOSIS

FAGAROXYLON gen. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium, solitary and in radial multiples, perforations simple, intervessel pits minute. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma sparse, apotracheal parenchyma represented by continuous or discontinuous lines. *Rays* 1-3 seriate, uniseriate rays homocellular, multiseriate rays homocellular to weakly heterocellular. *Fibres* radially aligned, semilibriform, non-septate.

Genotype—Fagaroxylon acronychioides sp. nov.

Holotype—B.S.I.P. 36656

Locality—Payangadi Super Clay Mine, Kannur District

Family—RHIZOPHORACEAE

Genus—*CARALLIOXYLON* Awasthi

Carallioxylon indicum Awasthi, 1984

Pl. 2, figs 4; Pl. 3, figs 1-3

Description—Wood diffuse-porous. *Growth rings* indistinct *Vessels* small to medium, t.d. 64-160 μm, r.d. 48-192 μm, solitary and in radial multiples of 2-4, rarely upto 6 (Pl. 3, figs 1-3), circular to oval when solitary and those in radial multiples flattend at places of contact, 8-13 vessels per sq. mm; perforations simple; vessel-members 120-960 μm long with oblique ends, inter-vessel pits small, 4-6 μm in diameter, alternate with linear aperture; tyloses occasionally present. *Parenchyma* abundant, paratracheal and apotracheal; paratracheal 1-3 cells wide, sheathing the vessels, apotracheal parenchyma diffuse to diffuse-in-aggregate, forming 2-4 seriate lines (Pl. 2, fig. 4), cells 80-140 μm in length and 42 μm in diameter. *Rays* two types, narrow and broad; narrow rays few, 1-2 seriate, 10-15 cells or 200-350 μm high, consisting of upright cells only; multiseriate rays very broad, 3-38 (mostly 10-20) seriate or 180-680 μm broad and very high, heterocellular consisting of procumbent cells in the centre and upright cells at both the ends (Pl. 3, fig. 5); cells thin-walled; upright cells 32-48 μm in vertical height and 28-35 μm in radial length; procumbent cells 28-35 μm in vertical height and 32-80 μm in radial length (Pl. 3, fig. 6). *Fibres* radially aligned, 16-20 μm in diameter, thick-walled, nonseptate.

Affinities—The carbonised fossil wood shows similarity with the woods of *Anisophyllea*, *Carallia* and *Combretocarpus* of the family Rhizophoraceae, particularly in possessing exceptionally very broad and high rays, which are even higher and broader than in some of the members of Lecythidaceae and Sterculiaceae (Desch, 1954; Henderson, 1953; Kribs, 1959; Lecomte, 1926; Metcalfe & Chalk, 1950; Miles, 1978; Normand, 1960; Purkayastha & Nigam, 1972). Regarding the nomenclature of fossil woods of the family Rhizophoraceae, Awasthi (1984) instituted the genus *Carallioxylon* to include the fossil woods showing similarity with those of *Anisophyllea*, *Carallia*, *Combretocarpus*, *Crossostylis* and *Gynotroches* which are more or less similar to each other in wood structure. However, on critical examination of wood slides as well as going through the published anatomical descriptions and photographs of these genera, it was found that *Anisophyllea* and some species of *Combretocarpus* can be differentiated from the remaining genera in the distribution pattern of parenchyma and rays. In *Carallia*, *Crossostylis*, *Gynotroches* and some species of *Combretocarpus* the parenchyma bands are paratracheal confluent while in *Anisophyllea* and in some species of *Combretocarpus*, the bands are regular, apotracheal in nature. Although, Desch (1954, pp. 468) doubted its apotracheal nature and observed that "paratracheal confluent type of parenchyma bands may separate into several narrow layers giving appearance of apotracheal bands, but as they originate from the vicinity of vessels, it would seem that they should be regared as paratracheal and not apotracheal parenchyma".

There is considerable variation in the thickness and frequency of xylem rays. In *Anisophyllea* and some species of *Combretocarpus* uniseriate and biseriate rays are scarce while in *Carallia* and other genera they are very frequent in comparison to broad rays (Desch, 1954, table 92). Thus, it is quite evident that the carbonised wood displaying the above features is very similar to *Anisophyllea* (*A. zelanica* in particular).

Carallioxylon indicum Awasthi (1984) described from Neyveli lignite is the only known fossil wood of Rhizophoraceae from India. It was shown to resemble the wood of *Carallia brachiata* (Lour.) Merr. On further examination of its type slides as well as thin sections of the woods of the extant genera it was found that *Carallioxylon indicum* shows better resemblance with *Anisophyllea* than to *Carallia*. Hence, *Carallioxylon indicum* should now be treated as a fossil wood of *Anisophyllea*. The generic circumscription of *Carallioxylon* which was instituted to designate the fossil woods resembling the above genera of Rhizophoraceae however remains unchanged.

The present cabonised wood from Kerala shows all the characters as exhibited by *Carallioxylon indicum* Awasthi. Therefore, it is placed in the same species.

Specimen no.—B.S.I.P. 36657

Locality—Varkala cliff section, Thiruvananthapuram District

Carallioxylon miocenicum sp. nov.

Pl. 3, figs 4-6

Description—Wood diffuse-porous. *Growth rings* indistinct. *Vessels* small to medium, t.d. 64-240 μm, r.d. 48-160 μm, solitary and

in radial multiples of 2-3, shape and size not clearly discernible, tangentially flattend due to compressions (Pl. 3, fig. 4); 6-8 vessels per sq. mm; vessel-members upto 500 μm high with oblique ends; perforations simple; intervessel pits not seen; tyloses present. *Parenchyma* abundant, paratracheal, vasicentric to aliform, aliform extensions joining those of neighbouring vessels forming narrow, 1-3 seriate lines, extending beyond several rays (Pl. 3, fig. 5). *Rays* two types, uniseriate and multiseriate (Pl. 3, fig. 5); uniseriate rays frequent, 1-25 cells or upto 720 μm long, composed wholly of upright cells; multiseriate rays 2-10 cells or 180 μm broad and upto 4 mm long, heterocellular, consisting of procumbent cells in the centre and upright cells at both the ends (Pl. 3, fig. 6); ray cells thin-walled, upright cells 32-40 μm in vertical height and 24-32 μm in radial length; procumbent cells 24-28 μm in verical height and 22-38 μm in radial length *Fibres* aligned in radial rows, small, angular, thick-walled, nonseptate.

Affinities—In all the anatomical characters the carbonised wood resembles that of *C. brachiata* (Lour.) Merr. However, it differs from *Carallioxylon indicum* Awasthi (1984) in the nature and distribution pattern of parenchyma and length and width of rays. In the present carbonised wood the parenchyma is paratracheal, confluent, forming fine lines and the xylem rays are relatively less in width, i.e. upto 10 cells as against 38 (usually 25) in *C. indicum* and the uniseriate rays are more frequent than the multiseriate rays. Therefore, it is assigned to a new species *Carallioxylon miocenicum.*

Holotype—B S.I.P. no. 36658.

Locality—Payangadi Supper Clay Mine, Kannur District

Family—FABACEAE

Genus—*CASSINIUM* Prakash

Cassinium prefistulai Prakash, 1975

Pl. 4, figs 1-2

Description—Wood diffuse-porous. *Growth rings* indistinct. *Vessels* solitary and in radial multiples of 2-3 (rarely 4), small to medium, t.d. 64-220 μm, r.d. 80-270 μm, round to oval when solitary and flattend at the places of contact when in multiples, 5-8 per sq. mm (Pl 4, fig. 1), filled with dark contents; perforations simple; vessel-members 160-350 μm high with transverse or oblique septa; intervessel pits alternate, hexagonal due to crowding, 8-10 μm in diameter, vestured with linear aperture (Pl. 4, fig. 2). *Parenchyma* abundant, paratracheal, aliform, forming 3-4 cells wide sheath around vessels, confluent parenchyma forming narrow to undulating bands joining adjacent vessels (Pl. 4, fig. 1); cells 16-20 μm in diameter and 48-80 μm in length. *Rays* 1-3 (Mostly 2-3) seriate, homocellular, composed of procumbent cells only (Pl. 4, fig. 2), 8-28 cells or 160-600 μm high and 30-65 μm broad; cells 16-20 μm in tangential height and 32-86 μm in radial length. *Fibres* aligned in radial rows, 20-30 μm in diameter, semilibriform, nonseptate.

Affinities—The present carbonised wood show close resemblance with that of the genus *Cassia* For naming the fossil woods of *Cassia*, the genus *Cassinium* was instituted by Ptakash (1975). Uptil now six species of *Cassinium* have been described from the Neogene sediments of India, Myanmar and Ethiopia. These are: *C. arcotense* Awasthi (1979) from Pondicherry; *C. ballavpurense* Ghosh & Roy (1981) from Birbhum District, West Bengal; *C. borooahii* (Prakash) Prakash (1975) from Mikir Hills, Assam (Prakash, 1967); Lower Siwalik, Kalagarh, Uttar Pradesh (Prakash, 1978) and from Santiniketan, Bolpur District, West Bengal (Bande & Prakash, 1980); *C. cassioides* (Prakash & Awasthi) Prakash (1975) from Buri Dihing River Bed near Jaipur, Assam (Prakash & Awasthi, 1970); *C. prefistulai* Prakash (1975) from the Lower Siwalik sediments near Nalagarh, Himachal Pradesh; *Cassioxylan variegatum* (Ramanujam) Prakash from Pondicherry (Ramanujam, 1960); *C. cassinodosum* (Prakash) Prakash from Myanmar and *C. ethiopicum* Prakash *et al.* (1982) from Ethiopia. Among these the present fossil wood is very similar to *Cassinium prefistulai*, and hence it is placed in the same species.

Specimen—B.S.I.P. no. 36659

Locality—Padappakara, Kollam District

Family—LECYTHIDACEAE

Genus—*CARETOXYLON* Awasthi

Careyoxylon pondicherriense Awasthi, 1970

Pl. 4, figs. 3-5

1970—*Careyoxylon pondicherriense* Awasthi, p. 70, pl. 2, figs 6, 8; text-figs 6-10.

1972—*Careyoxylon kuchilense* Prakash & Tripathi, p. 155, pl. 1, figs 1,3,5,6; text-fig. 1

Description—Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, mostly medium, t.d. 80-175 μm, r.d. 80-224 μm, solitary and in radial multiples of 2-3, evenly distributed, about 8-12 vessels per sq. mm, heavily tylosed (Pl. 4, fig. 3); perforations simple, vessel-members 208-350 μm high with transverse or oblique septa; intervessel pits alternate, 9-10 μm in diameter with linear aperture. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty, a few cells touching some vessels; apotracheal parenchyma abundant, diffuse to diffuse-in-aggregate, forming irregular net-like pattern with rays (Pl. 4, fig. 3). *Rays* 1-5 (mostly 3-5) seriate, heterogeneous; uniseriate rays 3-15 cells or 80-400 μm high, composed either of upright or square cells or of procumbent cells; multiseriate rays 2-5 seriate or 30-80 μm broad and 15-45 cells or 160-960 μm high, composed mostly of procumbent cells, a few upright or square cells interspersed among them and also 1-2 cells at one or both the ends (Pl 4, figs 4-5); ray cells small, procumbent cells 25-30 μm in tangential height and 12-16 μm in radial length; upright or square cells 28-32 μm in tangential height and 28-40 μm in radial length. *Fibres* aligned in radial rows between two consecutive rays, 12-16 μm in diameter, thick-walled, nonseptate.

Affinities—In all the anatomical features the carbonised wood shows close similarity with that of the extant *Careya arborea* Roxb. of the family Lecythidaceae. The fossil woods of *Careya* recorded so far are *Careyoxylon pondicherriense* from the Cuddalore Sandstone near Pondicherry (Awasthi, 1970); Siwalik sediments, Nalagarh, Himachal Pradesh (Prakash, 1979) and Tertiary of Burma (Prakash & Bande, 1980) and *C. kuchilense* Prakash & Tripathi, 1972) from Kuchila, near Hailakandi, Cachar District, Assam. Regarding their affinities with extant taxa, both the fossil species have been compared with a single taxon *Careya arborea*.

In order to compare the present carbonised wood the type slides of both the species of *Careyoxylon* were critically exmined and it was found that there is hardly any difference between the two in their anatomical characters. Therefore, it is most appropriate to merge *Careyoxylon kuchilense* Prakash and Tripathi with *Careyoxylon pondicherriense* Awasthi which has priority. The present carbonised wood is also placed in it.

Specimen no.—B.S.I.P. 36660

Locality—Varkala cliff section, Thiruvananthapuram District

Discussion

The genus *Acronychia* Forst. consists of 20 species, distributed in tropical Asia, China, Japan, Australia and Pecific Islands (Willis, 1973). The only species of the genus occurring in India is *A. pedunculata* (L.) Miq. It is distributed in sub-Himalayan tract from Dehradun to Assam at an elevations of about 1200 m. In southern India, it occurs in Karnataka, Tamil Nadu and in the Western Ghats ascending upto 2,100 m. In also occurs in Andaman, Myanmar (Burma), Sri Lanka and several Southeast Asian countries (Negi, 1963). *Fagara* Duhan. (=*Zanthoxylum* L) is a large genus of about 150 species distributed in tropical America, Africa, East Indies, Malaysia, Indo-China, Australia and Formosa. About 11 species occur in India and Myanmar. *F. rhetsa*, with which the fossil wood closely resembles, is found in Eastern and Western Ghats from North Kanara and Konkan southwards to Travancore. In Assam, it is scattered throughout the State (Negi, 1963).

Shorea accuminata. Dyer. is found in Malacca in Malaysia (Index Kewensis). *Cassia fistula* is widely distributed throughout India and Myanmar. It is also found in Sri Lanka (Pearson & Brown, 1932).

Anisophyllea R. Br. is a tropical genus consisting of 30 species, found in Africa, Asia and South America (Willis, 1973). *A. apetala* Scort. and *A. distica* are found in Malaysia (Desch, 1954) while *A. zeylanica* Benth. occurs in low moist country of Sri Lanka upto 1000 m elevation (Gamble, 1972). The genus *Carallia* Roxb. consists of

10 species, distributed in Madagascar, Indo-Malaysian region, N. Australia and Philippines. The Indian species *C. brachiata* (Lour.) Merr. *C. lucida* Roxb. is distributed in Madhya Pradesh, semi-evergreen forest of sub-Himalaya and also in Bengal, Assam, Khasi and Chittagong Hills, Chota Nagpur, rain forests of Konkan and Western Ghats, Andaman Island and Burma (Pearson & Brown, 1932). *Careya* Roxb. consists of 4 species, distributed in Indo-Malaysian region. *C. arborea* has a wide distribution throughout India including west coast and Myanmar.

Occurrence of *Shorea Anisophyllea* and several other evergreen taxa reported earlier from Warkalli beds (Awasthi & Ahuja, 1982; Awasthi & Panjwani, 1984; Awasthi & Srivastava, 1989, 1990) indicates prevalence of tropical climate with excessive humid condition in this part of southern India during Middle Miocene.

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Explanation of plates

Plate-1

Fagaroxylon acronychioides gen. et sp. nov.

1. Cross section showing type and distribution of vessels and parenchyma, x 40. B.S.I.P. Slide no. 36656-I.
2. Cross section magnified to show the details of vessels, parenchyma and fibres, x 100; B.S.I.P. Slide no. 36656-I.
3. Tangential longitudinal section showing rays, x 40. B.S.I.P. no. 36656-II.
4. Xylem rays magnified, x 100. B.S.I.P. Slide no. 36656-II.
5. Radial longitudinal section showing heterocellular rays, x 100. B.S.I.P. Slide no. 36656-III.

Plate-2

Shoreoxylon arcotense Awasthi

1. Gross view of wood block showing vessels and parenchyma, x 150, B.S.I.P. no. 36655.
2. Another cross view showing gum canals, x 150, B.S.I.P. wood block no. 36655.
3. Tangential longitudinal view of wood block showing rays, x 150. B.S.I.P. Wood block no. 36655.

Carallioxylon indicum Awasthi

4. Cross view of wood block showing nature and distribution of vessels and parenchyma, x 150, B.S.I.P. Wood block no. 36657.

Plate-3

Carallioxylon indicum Awasthi

1,2. Tangential longitudinal view of wood block showing rays, x 250, B.S.I P. Wood block no. 36657.
3. Radial longitudinal view of wood block showing heterocellular rays, x 250. B.S.I.P. Wood block no. 36657.

Carallioxylon miocenicum sp. nov.

4. Cross view of wood block showing nature and distribution of vessels and parenchyma, x 150. B. S.I.P. Wood block no. 36658.
5. Tangential longitudinal view of wood block showing uniseriate and multiseriate rays, x 150. B.S.I.P. Wood block no. 36658.
6. Radial longitudinal view of wood block showing heterocellular rays, x 150. B.S.I.P. Wood block no. 36658.

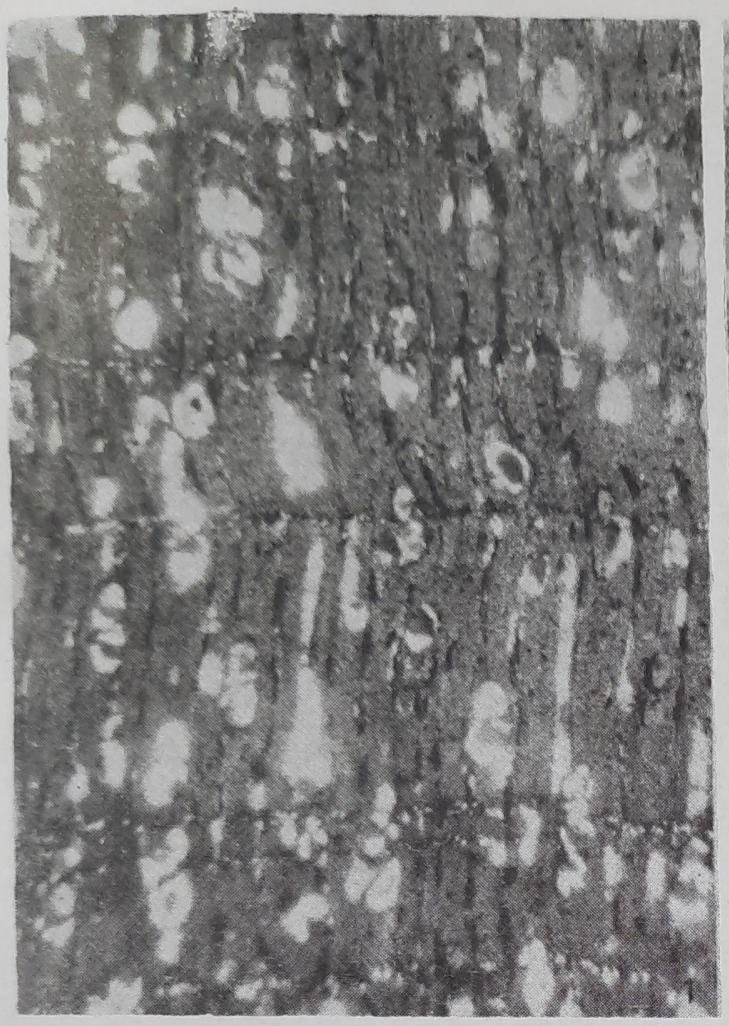
Plate-4

Cassininm prefistulai Prakash

1. Cross section showing type and distribution of vessels and parenchyma, x 100. B.S.I.P. Slide no. 36659-I.
2. Tangential longitudinal section showing rays, x 100. B.S.I.P. Slide no. 36659-II.

Careyoxylon pondicherriense Awasthi

3. Cross section showing nature and distribution of vessels and parenchyma, x 100. B.S.I.P. Slide no. 36660-I.
4. Tangential longitudinal section showing rays, x 100. B S.I.P. Slide no. 36660-II.
5. Tangential longitudinal view of wood block showing rays, x 250. B.S.I P. Wood block no. 36660.



Awasthi & Srivastava—Plate 1