SOME SILICIFIED DIPTEROCARPACEOUS WOODS FROM TERTIARY BEDS OF THE CUDDALORE SERIES NEAR PONDICHERRY, INDIA

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ABSTRACT

The paper deals with the anatomical studies and identifications of four new fossil woods of Dipterocarpaceae. Fossil specimens resemble the modern woods of *Dipterocarpus, Anisoptera, Shorea* and *Hopea*. The new fossil woods are named as *Dipterocarpoxylon cuddalorense* sp. nov., *Anisopteroxylon coromandelense* sp. nov., *Shoreoxylon speciosum* sp. nov. and *Hopeoxylon indicum* gen. et. sp. nov.

INTRODUCTION

RECENTLY two important contributions to our knowledge of living and fossil woods of Dipterocarpaceae (CHOWDHURY & GHOSH, 1958); SCHWEITZER, 1958) have been published. The above authors have given a key to the genera of living and fossil woods of Dipterocarpaceae which can well be adopted for identifications.

The present paper describes the anatomical structures and identifications of some new fossil woods of Dipterocarpaceae from Tertiary rocks of the Cuddalore series near Pondicherry, South India.

DESCRIPTION

DIPTEROCARPOXYLON HOLDEN EMEND. DEN BERGER

1. *Dipterocarpoxylon cuddalorense* sp. nov.

Anatomy

This species is represented by a small piece of fossil wood measuring 6×12 cm. in size. It is deeply stained due to ferruginous substance.

The fossil wood shows the diffuse porous type of structure (PL. 1, FIG. 1).

Growth-rings are not clearly visible.

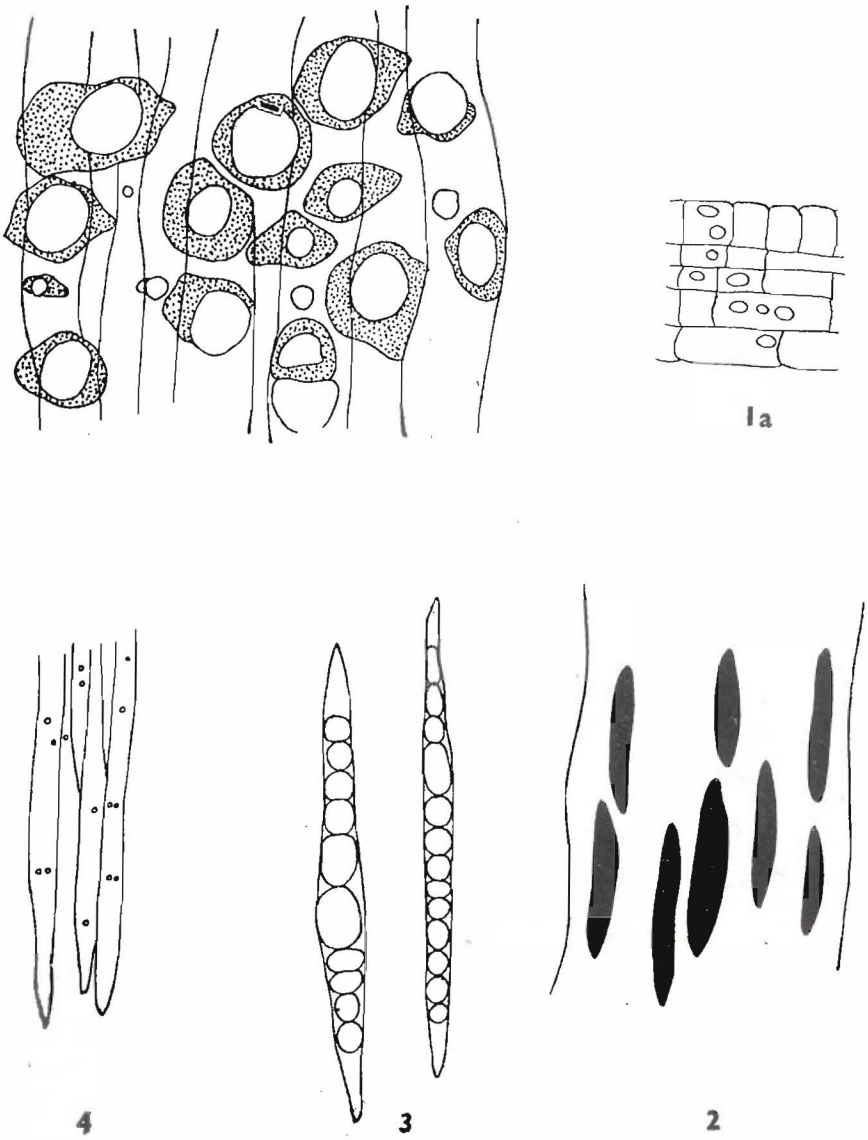
Vessels are seen clearly as round pores even without the help of the microscope. They are numerous and scattered without any definite type of arrangement (PL. 1, FIG. 1; TEXT-FIG. 1). Vessels are large in size, solitary or sometimes seen in groups of two (PL. 1, FIG. 3; TEXT-FIG. 1). Shape of the individual vessel is round to slightly oval, thin-walled, often filled with tyloses and other contents (PL. 1, FIG. 3; TEXT-FIG. 1). Vessel segments are medium in length and the intervessel pits are small, circular and alternate (PL. 1, FIG. 2). Vessel-ray pits are few, not well preserved but can be seen as simple, round to oval pits (TEXT-FIG. 1a).

Parenchyma is distributed around the vessels in patches (PL. 1, FIG. 1; TEXT-FIG. 1). It is mostly paratracheal vasicentric and composed of few layers around the vessels (PL. 1, FIG. 3; TEXT-FIG. 1). Cells of the parenchyma are not well preserved. However, they are seen as small cells, slightly elongated in transverse section (PL. 1, FIG. 3). Also incipient apotracheal parenchyma is associated with the resin canals which are diffuse in the ground mass of the wood (PL. 1, FIGS. 1, 3).

Rays are hardly visible without the aid of the microscope. They are not preserved uniformly. Only at some places they are recognizable due to the stain in the fossil specimen (PL. 1, FIG. 4; TEXT-FIG. 2). Rays are mostly uniseriate, 6-15 cells high and heterogeneous (PL. 1, FIG. 4; TEXT-FIG. 3). Cells of the rays are filled with contents and stained due to ferruginous substance. They are made up of both vertical and procumbent cells (PL. 1, FIG. 4; TEXT-FIG. 3).

Fibres are libriform and arranged in regular rows. Fibre cells are seen as small, round and thick-walled in cross-section (PL. 1, FIG. 3). They are medium in length and non-septate (PL. 1, FIG. 4). Fibre pits could not be observed clearly due to heavy inner contents. They appear to be simple (TEXT-FIG. 4).

Resin canals are scattered in the ground mass of the wood. They are solitary, sometimes in groups, small and diffused (PL. 1, FIG. 1; TEXT-FIG 1). Resin canals are often



Dipterocarpoxylon cuddalorense sp. nov.

TEXT-FIGS. 1-4 — 1, cross-section showing the distribution of vessels, parenchyma, rays and resin canals (small, oval cells). ×*ca.* 75. 1a, vessel ray pits. ×*ca.* 400. 2, distribution of rays in tangential section. ×*ca.* 121. 3, ray cells and their nature. ×*ca.* 150. 4, fibre pits. ×*ca.* 360.

associated with apotracheal parenchyma (PL. 1, FIG. 3). They are arranged in vertical plane. Resin canals consist of a layer of epithelial cells which are rounded to elongated and protrude out on the inner side of the cavity. Often small vessels with contents, show a false appearance resembling resin cavities but a careful examination gives the true nature of the structure without any doubt.

Affinities and Discussion

Presence of the medium-sized to bigger, solitary or radially arranged vessels with alternate, round, small, intervessel pits;

incipient, vasicentric, parenchyma in addition to thin apotracheal parenchyma in the vicinity of resin cavities; uniseriate, heterogeneous rays; non-septate, libriform fibres; and the characteristic presence of vertical canals lead one to compare the present fossil specimen with the woods of the families Caesalpineae, Cornaceae, Simarubaceae, and Dipterocarpaceae. In the family Caesalpineae, woods of *Copaifera, Daniella, Detarium, Eperua, Gossweilerodendron, Kingeodendron, Oxystigma* and *Pterygopodium* possess also normal vertical resin canals (METCALFE & CHALK, 1950; MOLL & JANSSONIUS, 1906) but these woods can be easily discarded as they generally have abundant parenchyma in various forms, unlike the fossil where parenchyma is incipient and only limited to few cells round the vessels. Also, woods mentioned above have broad rays whereas in the present fossil specimen they are few and usually uniseriate. *Cornarus* and *Mastixia* of Cornaceae contain vertical canals in the wood (METCALFE & CHALK, 1950) but they differ from the fossil in the nature of vessels which are very small and rays which are homogeneous. In the family Simarubaceae, *Simaruba* and others show vertical arrangement of canals (METCALFE & CHALK, 1950; MOLL & JANSSONIUS, 1906) but they differ in the nature of rays, vessels and fibres. Comparing the fossil with the family Dipterocarpaceae, many anatomical characters are found to agree with the modern woods of this family (METCALFE & CHALK, 1950; PEARSON & BROWN, 1932; GAMBLE, 1906; REYS, 1923; DESCH, 1936; CHOWDHURY & GHOSH, 1958). The resembling features are, the vertical resin canals; medium-sized solitary or radial type of vessels having alternate, simple, round, intervessel pits; paratracheal parenchyma along with apotracheal parenchyma and uniseriate rays of heterogeneous cells.

Brandis divides this family into following tribes including 15 genera (GAMBLE, 1902):

(i) Dipterocarpae — *Dipterocarpus, Anisoptera*

(ii) Shorae — *Shorea, Hopea, Doona, Pentacme, Balanocarpus, Parashorea.*

(iii) Vaticeae — *Vatica, Cotylelobium*

(iv) Vaterieae — *Vateria, Monoporanda, Stemonoporous*

Anatomically the family Dipterocarpaceae can be divided into two groups on the basis of the arrangement of resin canals. One group of woods namely *Shorea, Hopea, Parashorea, Pentacme* and *Balanocarpus* have resin canals always in tangential rows of many concentric bands. The other group consists of *Anisoptera, Dipterocarpus, Vatica* and *Vateria* wherein resin canals are diffuse. The present fossil specimen possesses resin canals in diffused condition and obviously on the basis of above classification, it falls in the second group. Woods of Vaterieae and Vaticeae of the second group have parenchyma which is abundant, diffused and paratracheal to metatracheal and thus do not agree with the fossil. Even the rays of the above woods do not match as they are very high and multiseriate. It is with the woods of *Dipterocarpus* that the fossil shows close resemblance. Comparison with the wood sections of the modern specimens and published literature (GAMBLE, 1902; MOLL & JANSSONIUS, 1906; PEARSON & BROWN, 1932; METCALFE & CHALK, 1950; CHOWDHURY, 1938; CHOWDHURY & GHOSH, 1958; SOLEREDER & HENDERSON, 1953, and others) have been made for structures similar to those in the fossil specimen. It was found that the fossil agrees well with the anatomical details of *Dipterocarpus* woods. *D. pilosus, D. obtiusifolius* and *D. turbinatus* resemble closely with little variation in the arrangement of rays.

Dipterocarpoxylon garoense (CHOWDHURY, 1938), *D. indicum* (RAMANUJAM, 1955), *D. chowdhurii* (GHOSH, 1956) and *D. malavii* (GHOSH & GHOSH, 1959) are somewhat resembling fossil genera with the present fossil specimen. Species of *Shoreoxylon* do not compare with my fossil as they have resin canals in tangential rows with regular concentric zones. Also, species of *Anisopteroxylon* need no comparison as they differ in the nature and arrangement of resin canals and rays. *Dipterocarpoxylon garoense* from Assam resembles the modern woods of *Anisoptera* to a large extent. In this species grouping of vessels are very common and rays are wide having 5-6 seriate cells whereas in my fossil they are mostly solitary, rarely radial and rays are generally uniseriate. *Dipterocarpoxylon indicum* from South India also differs from my fossil in having multiseriate rays consisting of 10-30 cells in height; non-septate, round fibre cells, smaller vessels of high

frequency and parenchyma of both apotracheal and paratracheal type, the latter having tangential strips of parenchyma cells apart from being vasicentric. *D. chowdhurii* and *D. malavii* can be separated as they possess thick layer of parenchyma around the large-sized resin ducts and multiseriate rays.

Large number of fossil woods described in this family from other countries by Kräusel (1922, 1925, 1926), Den Berger (1923, 1927), Pfeffer & Van Heurn (1928), Edwards (1931), Bancroft (1933), Chiraugi (1933), Gupta (1935), Boureau (1952) and Schweitzer (1958) have been tabulated by Ramanujam and Schweitzer (1955, 1958). Among them, *Dipterocarpoxylon africanum, D. somalense, D. kraeuseli, D. javanicum, D. goepperti* and *D. schenki* are comparable with the present fossil and the rest of the fossil woods described in this family do not compare with the Indian specimen. *Dipterocarpoxylon africanum* (BANCROFT, 1933) resembles my specimen in many respects except in the nature of vessels which are rather small and the parenchyma which is apotracheal and banded. Similarly *Dipterocarpoxylon somalense* is also comparable with my fossil but it differs in having larger resin canals and tangential bands of metatracheal parenchyma. *D. kraeuseli* although agrees in many gross features, it differs in having broad rays, resin ducts often in one or two groups, having abundant parenchyma enclosing the resin ducts. Likewise *D. goepperti* does not resemble in the nature of rays and parenchyma which are abundant and broadly spaced. *D. javanicum* can be differentiated by its abundant tracheids in the ground mass of the wood, broad rays and smaller vessels. *D. schenki* also can be separated as it possess smaller vessels, broad rays and resin ducts in groups of two or three, enclosed by patches of parenchyma often uniting each other.

The fossil specimen resembles the modern woods of *Dipterocarpus* of the family Dipterocarpaceae in its internal structures. It is, therefore, included under the genus *Dipterocarpoxylon* in its restricted sense as advanced by Den Berger (1927). My specimen shows certain distinct features differing from the hitherto described species of the genus *Dipterocarpoxylon* as discussed above and hence it has been separated into a new species.

Dipterocarpoxylon cuddalorense sp. nov.

Diagnosis

A diffuse porous type of wood.

Growth-rings indistinct.

Vessels large, scattered, 220-330 μ in diameter, solitary also radial, tylosed, usually 2 per sq. mm., vessel segments medium height, perforation simple, inter-vessel pits small, alternate, circular, ray-pits indistinct.

Parenchyma limited, paratracheal, vasicentric, few layers round the vessels, also apotracheal, in association with resin canals, faint, circular to oval in shape, often with contents, 2 μ in diameter.

Rays uniseriate, 6-15 cells in height and 180 μ in diameter, ray fusion not uncommon, heterogeneous, stained due to ferruginous matter and often filled with contents.

Fibres medium, non-septate, imperfectly preserved, circular in cross-section, 12 μ in diameter, thick, pits indistinct.

Resin canals vertical type, diffuse, solitary or in groups, 100 μ broad, rarely associated with apotracheal parenchyma, epithelial cells present, round, often protruded inside the vessels.

Holotype — No. 1061, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Kashikoppam, near Pondicherry, South India.

Horizon — Tertiary.

ANISOPTEROXYLON GHOSH & KAZMI 1958

2. *Anisopteroxylon coromandelense* sp. nov.

Anatomy

Two small pieces of variegated petrified wood represent the present fossil specimen. The diagnostic internal structures of the fossil wood are fairly clear, although the material lacks uniform preservation. The fossil wood is greyish yellow in colour.

Growth rings are not well indicated in the specimen.

Vessels are visible as small pores without the help of the microscope. They are medium to large-sized and closely distributed more or less uniformly without showing any pattern or arrangement (PL. 2, FIG. 5; TEXT-FIG. 5). Vessels are solitary, rarely radial, circular in shape and sometimes aligned in oblique lines (PL. 2, FIG. 5). Vessel cavities are often plugged with dark

deposits and tylotic out-growths. Vessel segments are medium in height, truncate and thick-walled (PL. 2, FIG. 7). Perforation is simple and the intervessel pits are abundant, lacking good preservation, medium sized, alternate and bordered (TEXT-FIG. 6). Vessel-ray pits and other details are not seen due to imperfect preservation.

Parenchyma is of two types, namely paratracheal and the apotracheal. The paratracheal parenchyma is very scanty. It is vasicentric and the cells are small, oval in shape and form few cells around the pores (PL. 2, FIG. 5; TEXT-FIG. 5). The apotracheal parenchyma is abundantly diffused as small scattered or aggregate cells (PL. 2, FIG. 5; TEXT-FIG. 5). Also apotracheal parenchyma encloses the resin ducts in the wood (PL. 2, FIG. 6).

Rays are moderately numerous, and more or less uniformly distributed (PL. 2, FIG. 7; TEXT-FIG. 7). They are moderately broad and medium in height (PL. 2, FIG. 8; TEXT-FIG. 7). Rays are mostly heterogeneous. A row of upright cells simulating sheath cells form the outer boundary of the rays and the inner portion is constituted by procumbent cells (PL. 2, FIG. 8; TEXT-FIG. 8). Procumbent cells are irregularly placed and invariably have no preservation (PL. 2, FIG. 8). The pits and the other details were not seen due to the bad preservation.

Fibres are irregularly arranged and can be seen in higher magnification (PL. 2, FIG. 6). Cells of the fibres are angular to polygonal in shape and arranged radially in cross-section (PL. 2, FIG. 6). Fibres are libriform, thick-walled and non-septate.

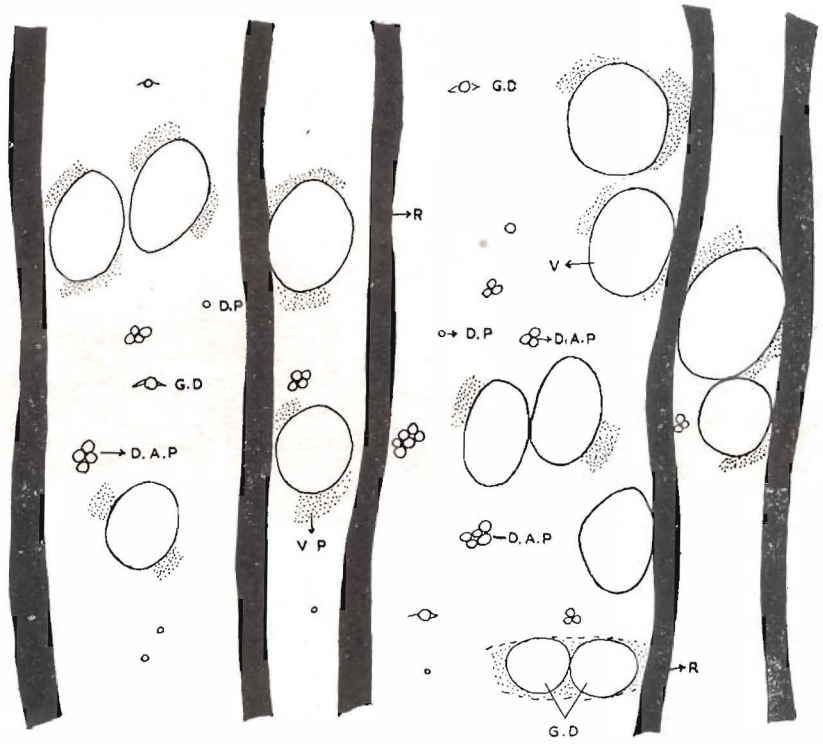
Tracheids are hardly visible under the low power. But on careful examination in high magnification they are seen in close vicinity of the vessels. They are made up of one or few cells, flattened and are intercepted by parenchyma cells.

Gum ducts are not abundant, diffused, sometimes paired (PL. 2, FIGS. 5, 6; TEXT-FIG. 9). Cells are small, circular and enclosed by parenchyma cells (PL. 2, FIG. 6; TEXT-FIG. 9). They are made up of one layer of epithelial cells which are not well preserved (TEXT-FIG. 9). Often the resin ducts are confused with the vessels but the true nature can be made out on close examination.

Affinities and Discussion

The internal structures of the fossil specimen, especially the possession of distinct vertical resin ducts, at once give clue to its identification. Also it can be seen that the other characters of the fossil are somewhat similar to those of the previous woods described here. Therefore, the comparisons with the modern members are limited only to genera having vertical resin canals; limited, heterogeneous rays; and mostly medium-sized to large, solitary vessels. It has been already mentioned earlier that the different genera in Caesalpineae, Cornaceae, Simarubaceae and Dipterocarpaceae possess vertical resin ducts. Considering the comparable members of Caesalpineae they can all be eliminated for they have abundant differences in the amount of the parenchyma, rays and in the arrangement of resin ducts. Similarly, *Cornaris*, *Mastixia* (Cornaceae) and *Simaruba* (Simarubaceae) differ distinctly in the nature of rays. Some woods of the family Dipterocarpaceae indicate a closer comparison with the fossil by having many similar anatomical characters.

In the woods of the tribe Shorae of *Dipterocarpaceae* resin ducts are characteristically in more or less regular tangential lines. Thus it is apparent that the present fossil does not agree with the tribe Shoreae (*Shorea*, *Hopea*, etc.) as they have banded resin ducts. Woods of the tribes Vaterieae, Vaticeae and Dipterocarpeae are comparable with the fossil specimen in the nature of resin ducts and other features and, therefore, considered for closer comparison. Considering the woods of Vaterieae, the fossil agrees in overall features but a closer comparison indicates many differences. Members of Vaterieae possess conspicuously abundant, diffuse parenchyma, the cells of which are even seen without the help of the microscope as small diffuse cavities of pores. Also, a conspicuous variation in vessel size is found between the two. Similarly, woods of Vaticeae differ with the present fossil specimen in the detailed anatomical features in spite of the fact that the two resemble in one or two characters. It is with the tribe Dipterocarpeae that the fossil shows agreement in a very large number of features. According to the classification given by Schweitzer (1958) and Chowdhury & Ghosh (1958), the genera *Dipterocarpus* and *Anisoptera* are differentiated on the basis of the distribution and size of resin canals parenchyma and rays. In *Anisoptera* resin canals are small, diffused; parenchyma is mostly



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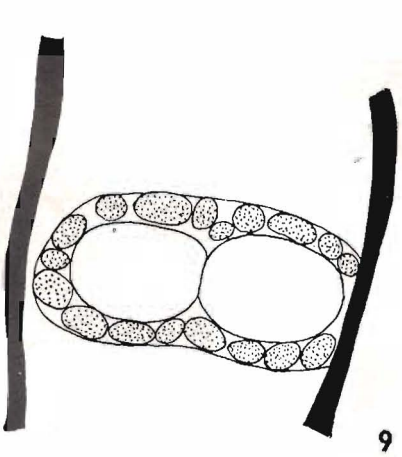

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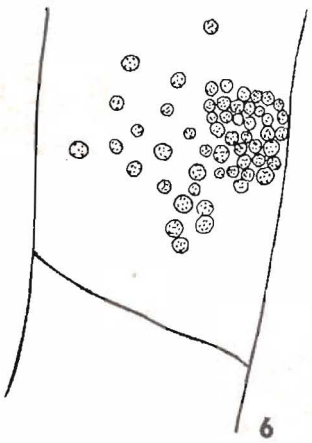
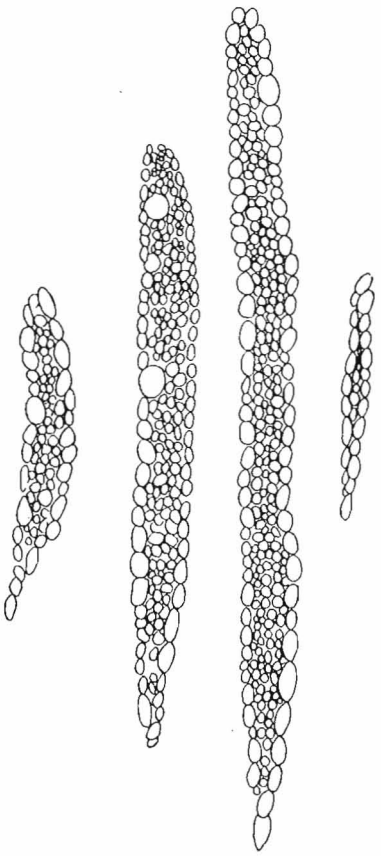


6

Anisopteroxylon coromandelense sp. nov.

TEXT-FIGS. 5, 6, 9 — 5, cross-section showing the distribution of vessels, parenchyma, rays and resin canals. × *ca.* 120. (V, vessel; R, Rays; D.P.,-diffuse parenchyma; D.A.P. diffuse aggregate parenchyma V.P. Vasicentric parenchyma; G.D. gum ducts.). 6, inter-vessel pits. × *ca.* 240. 9, resin canals and their structure. × *ca.* 240.



Anisopteronylon coromandelense sp. nov.

TEXT-FIGS. 7-8 — 7, distribution of rays. × *ca.* 120. 8, ray cells and their nature. Note the sheath cells. × *ca.* 240.

diffused to diffused aggregate; rays are broad with upright sheath cells at the perifery and procumbent cells in the middle; whereas in *Dipterocarpus* resin canals are distributed singly or in rows; parenchyma is mostly vasicentric, rays are limited and heterogeneous. Comparative anatomical studies with the above two genera, namely *Anisoptera* and *Dipterocarpus* reveal that, my specimen is more closer to the genus *Anisoptera*.

During recent years, a number of fossil woods belonging to this family have been recorded from India. Among these, closely resembling woods are *Dipterocarpoxylon indicum* (RAMANUJAM, 1955), *D. cuddalorense* sp. nov., *D. garoense* (CHOWDHURY, 1938), *D. chowdhurii* (GHOSH, 1956), *D. malavii* (GHOSH & GHOSH 1960), *Anisopteroxylon bengalensis* (GHOSH & KAZMI 1958), *A. jawalamukhi* (GHOSH & GHOSH 1958) and *A. cuddalorense* (RAMANUJAM, 1960).

Comparing with *D. indicum*, my specimen differs in the nature of vessels, rays and parenchyma. *D. indicum* possesses large-sized vessels, 1-4 seriate rays and 1-4 cells of vasicentric sheaths. Similarly *D. cuddalorense* sp. nov. does not agree with the present one due to very large-sized vessels, limited paratracheal parenchyma, and uniseriate heterogeneous rays. *D. garoense* and the present fossil have anatomical characters much in common between them as regards the vessels, parenchyma, fibres and ducts. However, the distinct differences exist in the nature of the rays and the size of the vessels. In *D. garoense*, vessels are smaller and the rays are made up of three types, namely the uniseriate, biseriate, and multiseriate, whereas in my specimen mostly multiseriate rays are seen. *D. chowdhurii* also differs in having large-sized solitary vessels and limited, uniseriate to few seriate rays and scanty parenchyma. *Anisopteroxylon bengalensis* and *A. jawalamukhi* although agree in the nature and distribution of resin canals, parenchyma, yet the size of the pores and the nature and distribution of rays differ. *A. cuddalorense* differs in having abundant tyloses, short strip of apotracheal parenchyma and in the nature of ray cells.

Comparing with the large number of species of *Dipterocarpoxylon* recorded from outside India (*see* page 69), only *D. africanum*, *D. somalense*, *D. gracile*, *D. perforatum* and *D. anisopteroides* are considered here because the others differ very markedly in the

nature and distribution of gum ducts and other features. *Dipterocarpoxylon africanum* (BANCROFT, 1933) is comparable with the present fossil in the nature of resin ducts but other features show many differences. Similarly, *D. somalense* agrees with the arrangement of resin ducts, but the nature of parenchyma and rays do not resemble. *D. gracile* can be differentiated from the present fossil in the nature of vessels (small vessels), rays (both uniseriate and broad rays present) and resin ducts (distinctly enclosed by broad patches of parenchyma). *D. perforatum* fairly compared with my specimen but the nature of rays, the arrangement and distribution of resin ducts, frequency of vessels and their distribution are some of the important differences. Similarly, *D. anisopteroides* agrees with my specimen in overall features but distinctly differs in having abundant, diffuse fibre tracheids and homogeneous broad and high rays.

The fossil specimen has been referred to the fossil genus *Anisopteroxylon* (GHOSH & KAZMI, 1958) as it shows close resemblances with the modern woods of *Anisoptera*. Also it has been assigned to a new species for it differs from the known forms of the genus.

Anisopteroxylon coromandelense sp. nov.

Diagnosis

A diffuse porous type of wood.

Growth-rings not visible.

Vessels 180-215 μ in diameter, ranges 3-4 vessels per sq. mm., solitary, often in radial groups of two; intervessel pits small, alternate and bordered; vessel-ray pits and other details are not seen due to the bad preservation.

Parenchyma paratracheal and apotracheal; paratracheal type scanty, vasicentric, few cells around the vessels; the cells 36-48 μ broad; apotracheal cells abundant, small, 24 μ broad, diffuse to diffuse aggregate, often enclosing groups of resin ducts.

Rays 3-6 seriate, rarely uniseriate, 12-35 cells high, ray cells heterogeneous, vertical cells 12 μ broad, along the margin, simulating sheath cells, procumbents crowded, irregularly arranged in the middle and not preserved well.

Fibres libriform, non-septate, 48 μ in diameter, angular and arranged in rows.

Tracheids scanty, one or few layered, thick-walled 36 in diameter.

Gum ducts circular in cross-sections 36-48 μ in diameter, solitary or in pair, epithelial cells, oval to elongated, scattered.

Holotype — No. 19417, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Usteri, near Pondicherry, South India.

Horizon — Tertiary.

SHOREOXYLON DEN BERGER 1927

3. *Shoreoxylon speciosum* sp. nov.

Anatomy

The fossil specimen is represented by a single piece of wood measuring 8×5 cm. in size. The material is blotched with coloured patches here and there. Only secondary xylem is present with the internal structures well preserved.

The fossil wood shows the diffuse porous type of structure.

Growth-rings are not found in the fossil specimen, however the resin ducts are arranged in tangential lines simulating the growth mark (PL. 3, FIG. 9).

Vessels are recognized as small pores to the naked eye. They are more or less uniform and diffused in the ground mass of the wood (PL. 3, FIG. 9). Vessels are medium to large in size, mostly in groups of 3-5 and also solitary (PL. 3, FIG. 10; TEXT-FIG. 10). Tyloses and other deposits are seen in many vessels (PL. 3, FIG. 10). Vessel segments are truncated, and have abundant intervessel pits which are medium, alternate and angular in outline (PL. 3, FIG. 12). Vessel-ray pits are also recognizable and are small and 3-5 per cells (TEXT-FIG. 11).

Tracheids are not abundant and difficult to differentiate in the fossil specimen.

Parenchyma is distinct and limited. It can be seen as dark patches encircling the vessels, even by the naked eye. Paratracheal parenchyma is confined to the region of the vessels (PL. 3, FIG. 9; TEXT-FIG. 10). It is mostly vasicentric and sometimes extending laterally, but never forming bands (PL. 3, FIG. 10). Parenchymatous cells are small, round to oval and are in 2-3 layers around the vessel (PL. 3, FIG. 10). These cells are filled with dark substances. Apotracheal parenchyma is distinctly associated with the resin ducts and forms tangential bands (PL. 3, FIG. 9; TEXT-FIG. 10). Two

or three layers of apotracheal cells are seen along with the resin ducts (PL. 3, FIG. 10; TEXT-FIG. 10). Cells of the apotracheal parenchyma are faint, elongated and limited (PL. 3. FIG. 10).

Rays are scarcely visible without the help of the microscope. Ray cells are often stained due to ferruginous substance. They are evenly distributed (PL. 3, FIG. 10; TEXT-FIG. 12), multiseriate, being 3-6 cells broad and 30-40 cells in height (PL. 3, FIG. 11; TEXT-FIG. 13). Rays are mostly homogeneous having procumbent cells (PL. 3, FIGS. 11, 13; TEXT-FIG. 13). Ray pits are few, small and circular.

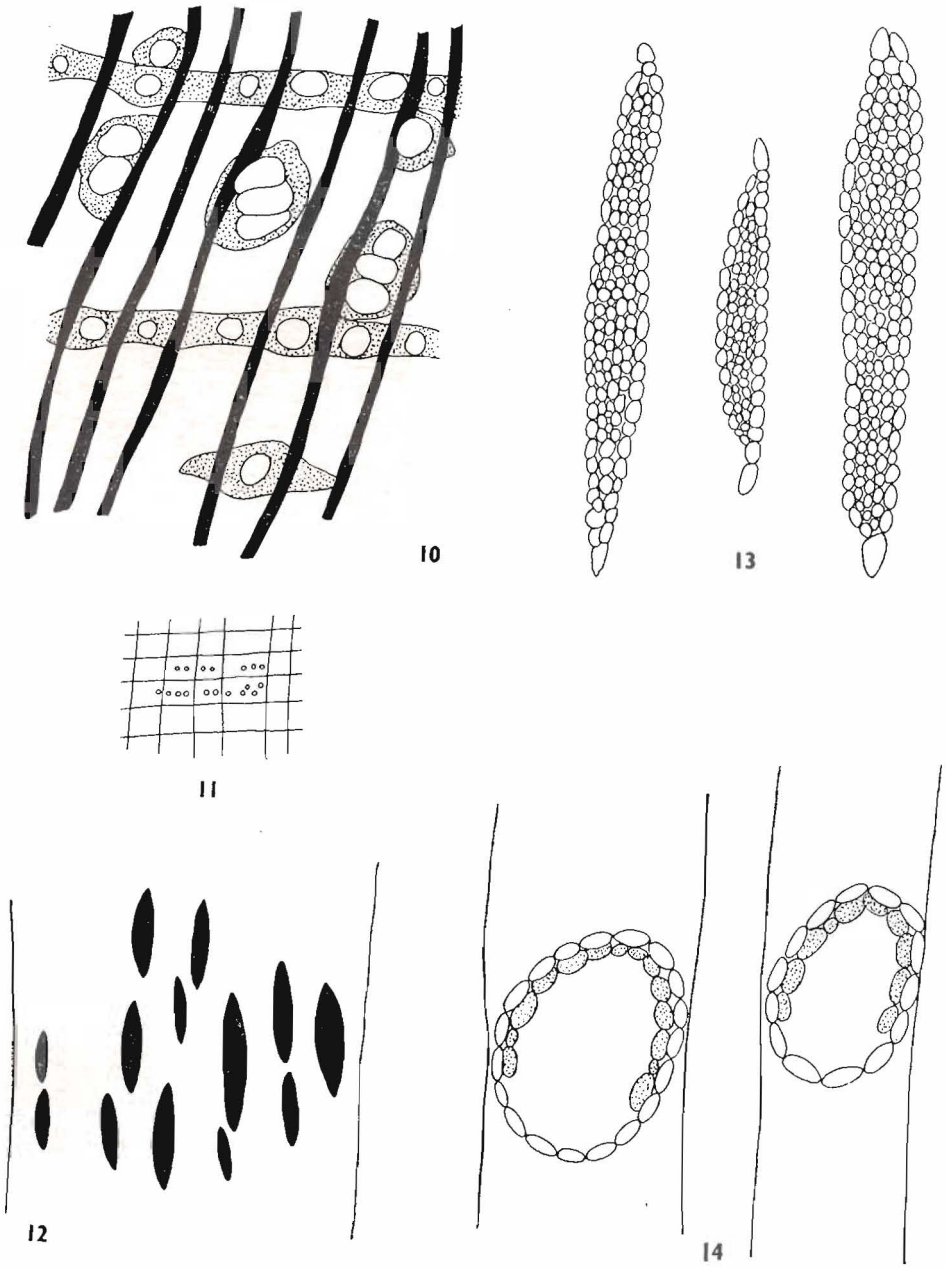
Resin canals are vertical and embedded in the tangential bands (PL. 3, FIG. 10; TEXT-FIG. 10). They are small to medium in size and arranged in tangential, successive rows (PL. 3, FIG. 9; TEXT-FIG. 10). The size of the canals ranges from 80 to 150 μ and usually smaller than the vessels, although few, almost equal to or more than the size of the vessels (PL. 3, FIG. 10). Often resin cells are compressed due to lateral compression. Epithelium is clearly visible sometimes only in part of the canal and the epithelial cells are small, round and often filled with contents (PL. 3, FIG. 10; TEXT-FIG. 14).

Fibres are libriform, thick and medium in length (PL. 3, FIG. 11). They are septate (PL. 3, FIG. 11), round in cross-section (PL. 3, FIG. 10) and form extensive tracts between vessels and the rays (PL. 3, FIG. 11). The fibre pits are small, simple and few.

Affinities and Discussion

The chief diagnostic characters of the fossil specimen are vertical resin canals, homogeneous xylem rays, and limited parenchyma which characterize the woods of Dipterocarpaceae. While dealing with *Dipterocarpoxylon cuddalorense*, it was mentioned that the family Dipterocarpaceae may be broadly grouped into two groups, one with woods having resin canals in concentric rows and the other with woods having diffused resin canals. The first group includes the tribe Shoreae and the second group embraces tribes Dipterocarpeae, Vaterieae and Vaticeae. The present fossil specimen by possessing resin canals in concentric rows compares with the tribe Shoreae in which the genera *Hopea*, *Shorea*, *Parashorea* and *Pentacme* are members. Considering the genus *Parashorea*, although it agrees in the nature of vertical canals, rays and fibres yet it differs markedly with the fossil as its vessels are very large, ranging up to 350 μ and parenchyma is abundant, whereas the fossil possesses medium-sized vessels and rays and limited parenchyma. The genus *Pentacme*, resembles the fossil in the nature of vessels, rays and other characters but abundant presence of tracheids, diffuse, besprinkled, metatracheal parenchyma among fibres and successive single or double rows of resin canals are very distinctive features of this genus unlike my fossil. Comparing with genera *Shorea* and *Hopea*, the fossil agrees with them in most of the features. Recently Chowdhury & Gosh (1958) have given a key to the genera Dipterocarpaceae. According to the key, the present fossil can be referred to the genus *Shorea*. The genus *Shorea* is distinguished by presence of large vessels (more than 200 μ), abundant multiseriate rays and fibres. In *Hopea* vessels are typically small (less than 100 μ) with distinct contours, and rays are short, and two to three seriate unlike *Shorea*. Also detailed anatomical studies of the living woods of *Shorea* and *Hopea* were made in order to find out the genus resembling most to the fossil. Among the two genera, *Shorea* compares well with my specimen. In *Shorea*, similar to my fossil, vessels are large, solitary or radial, the intervessel pits are small, round and alternate, parenchyma is both apotracheal and paratracheal and limited in distribution, rays are multiseriate, homogeneous, made up of procumbent cells, fibres are libriform and thick, resin canals are many, distinct and distributed in tangential rows.

Among the Indian fossil woods described in the family Dipterocarpaceae *Shoreoxylon mortandrense* and *Shoreoxylon holdeni* (RAMANUJAM, 1955) and *S. megaporosum* (RAMANUJAM, 1960) are comparable with the present fossil. Other fossils described (*Dipterocarpoxylon indicum*, *D. garoense*, *D. chowdhurii* and *D. malavii*) are discarded for the purposes of comparison with the present fossil because they have resin canals in diffused condition. Comparing with *Shoreoxylon holdeni*, my fossil resembles in the nature of resin canals and pits. However, *S. holdeni* differs in having conspicuously larger vessels ranging up to 280 μ in size, abundant tracheids and parenchyma, and in the



Shoreoxylon speciosum sp. nov.

TEXT-FIGS. 10-14 — 10, cross-section showing the nature and distribution of vessels, rays, parenchyma and resin canals. ×*ca.* 75. 11, vessel-ray pits in radial section. ×*ca.* 360. 12, distribution of rays in tangential section. ×*ca.* 75. 13, ray cells and their nature. ×*ca.* 240. 14, resin canals and their structure. Note the epithelial cells. ×*ca.* 240.

rays which are characteristically spindle shaped, heterogeneous and more or less having uniseriate and biseriate types altering with each other. The other fossil species *S. mortandrense* does not compare with the present fossil in the nature of rays and

fibres although other characters resemble to a certain extent. *S. megaporosum* differs in having very large-sized solitary vessels and heterogeneous rays.

Among the fossil woods described from other countries (RAMANUJAM, 1955, TABLE 1), following species were considered for comparison as they approached nearest to the fossil wood under consideration. *Shoreoxylon palembangense* (DEN BERGER, 1923), *Drybalanoxylon javanense* (DEN BERGER, 1923), *D. tobleri* (DEN BERGER, 1923), *Shoreoxylon swedenborgii* (SCHWEITZER, 1958), *D. scebelianum* and *D. gibuense* (CHIARUGI, 1933). The present fossil wood shows many features resembling the above fossils although it differs in specific details. *D. gibuense* and *D. scebelianum* have generally solitary vessels, short rays of one or two rows, and often tangential bands of parenchyma along the vessels, whereas my specimen generally possesses radial vessels of 3-4 groups, rays of medium size and tangential bands of parenchyma always associated with resin ducts. *Shoreoxylon swedenborgii* and *S. palembengensis* differ from fossil under consideration in having larger vessels, and very high and broad rays apart from abundant metatracheal parenchyma. Comparing with the present fossil, *Drybalanoxylon tobleri* shows similarities in the nature of vessels, rays and fibres. However, it differs in having very incipient parenchyma, bigger vessels and resin canals which are not always associated with tangential bands of parenchyma. *D. javanense* resembles my fossil wood in many characters such as having radial vessels, rays of 10-40 cells high and the nature of resin canals, although certain differences exist between them. In the former, parenchyma is very limited and rays are very few seriate, mostly two to three, and highly heterogeneous. The fossil woods described by Schweitzer (1958) *Shoreoxylon maximum* and *S. posthumi* are closely comparable. The detailed comparison shows that *S. maximum* differs well in having very large mostly solitary vessels, abundant vasicentric to aliform parenchyma, very high rays ranging up to 85 cells and smaller resin ducts when compared to the South Indian fossil. The other fossil, namely *S. posthumi* agrees in a good number of features. However, the noticeable differences are that vessels are very frequent 5 to 10 per sq. mm., large sized, ranging up-300 μ; rays are higher than my fossil and the parenchyma is abundantly diffused in the ground mass of the wood.

Anatomical structures of the fossil wood clearly indicate that its affinities are stronger with the genus *Shorea* enabling its inclusion in *Shoreoxylon* constituted by Den Berger in 1927 for the fossil woods resembling the woods of *Shorea*. A new species has been created as this wood differs from all the known fossil woods.

Shoreoxylon speciosum sp. nov.

Diagnosis

A diffuse porous wood.

Growth-rings indistinct.

Vessels evenly distributed, not crowded, 175-230 μ in diameter, 2-3 per sq. mm., solitary, mostly radial, 2-3 in groups, circular to oval in shape, frequently tylosed, vessel segments medium, truncate, perforation simple, pits abundant, alternate, round and crowded.

Tracheids very limited, difficult to differentiate from parenchyma.

Parenchyma distinct, paratracheal and apotracheal, paratracheal 3-4 layered, vasicentric, often extended to aliform type; apotracheal in tangential bands, along with the resin ducts; few layered and also diffused.

Rays numerous, 3-6 seriate, 3-5 per sq. mm., 40 cells high, mostly homogeneous having procumbent cells, contiguous on either side of the vessel.

Fibres libriform, thick, septate, 16 μ broad, round in cross-section, medium in height and forming extensive tracts between the vessel and rays.

Resin canals distinct, vertical, in tangential bands, small or medium-sized, 80-150 μ, distinctly enclosed by apotracheal parenchyma, epithelial cells round to elongated, without contents, often protruding inside the vessel.

Holotype – No. 26372, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Bangalamod, near Pondicherry, South India.

Horizon — Tertiary.

HOPEOXYLON GEN. NOV.

4. *Hopeoxylon indicum* sp. nov.

Anatomy

The material is represented by two small pieces of fossil woods which are similar in

anatomical features. The fossil specimen under investigation measures 8×4 cm. in size. Often patches of stains are seen in the material due to ferruginous and other substances. The preservation of the secondary xylem is satisfactory, revealing fairly well the internal details of the wood. In one of the specimens pith is also visible.

Growth-rings are not seen by the naked eye or with the help of the microscope but the characteristic occurrence of parenchyma in tangential rows along with the resin ducts which are also in tangential rows appear as growth marks (PL. 4, FIG. 14; TEXT-FIG. 15).

Vessels are hardly visible without the aid of microscope. They are conspicuously small, diffuse, and have uniform distribution (PL. 4, FIGS. 14, 16; TEXT-FIG. 15). Vessels are solitary as well as radial in groups of 2-4, and usually filled with dark substances (PL. 4, FIG. 16). Vessel segments are some-what truncated, 80-90 μ broad, and medium in length. Intervessel pits are small, crowded, alternate to opposite and circular in shape with angular outline (PL. 4, FIG. 17). Vessel-ray pits are hardly visible due to lack of preservation.

Tracheids are not recognizable but when present, difficult to differentiate from the parenchymatous cells.

Parenchyma is limited and distinct (PL. 4, FIG. 16; TEXT-FIG. 15). It is visible with the help of the handlens as light coloured patches in the immediate vicinity of vessels (PL. 4, FIG. 14). Paratracheal parenchyma is made up of 3-4 cells which are small, circular, often filled with dark substances and always distributed in the vicinity of vessels (PL. 4, FIG. 16; TEXT-FIG. 15). It is vasicentric and also sometimes aliform extending on either sides (PL. 4, FIG. 16; TEXT-FIG. 15). Tangential parenchyma is distinct and usually associated with resin canals forming bands (PL. 4, FIG. 14). These bands are made up of 3-4 layers of cells which are small and filled with dark substances (PL. 4, FIG. 16). Parenchymatous cells are distributed all along the resin ducts which are characteristically in successive rows (PL. 4, FIG. 16; TEXT-FIG. 15).

Rays are hardly visible to the naked eye. They are short and distributed uniformly in regular rows (PL. 4, FIG. 15; TEXT-FIG. 16). Rays are uniseriate to biseriate but rarely more than triseriate (PL. 4, FIG. 15; TEXT-FIG. 17). Biseriate rays are most common being 4-25 cells in height. Rays mostly homogeneous to weakly heterogeneous (PL. 4, FIG. 18; TEXT-FIG. 17). Procumbent cells which mostly constitute the rays are usually filled with dark contents (PL. 4, FIG. 18).

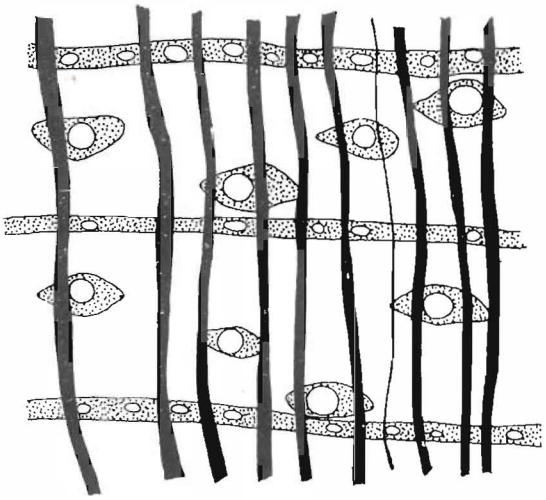
Fibres are libriform, fairly thick and circular in cross-section (PL. 4, FIG. 16). They are non-septate, medium in height and form the ground mass of the wood (PL. 4, FIG. 16).

Resin canals are embedded in the parenchymatous cells (PL. 4, FIG. 14). They are small, circular in shape and often filled with contents (PL. 4, FIG. 16; TEXT-FIG. 18). Resin ducts are always vertical, and tangentially distributed in successive rows more or less regularly (PL. 4, FIG. 16). The cells of the epithelium are small, somewhat elongated in shape and often with dark substances (PL. 4, FIG. 16; TEXT-FIG. 18).

Affinities and Discussion

The fossil specimen is characterized by the presence of resin canals distributed in vertical tangential rows, small to medium sized vessels, limited parenchyma and weakly heterogeneous rays indicating very clearly its affinities with the group Shoreae of Dipterocarpaceae (*see* page 68).

Among the woods of *Shorea*, *Hopea*, *Parashorea* and *Pentacme*, of the group Shoreae, the latter two have generally large vessels and rays, and diffused parenchyma among the fibres, whereas the present fossil is very distinct in having smaller vessel and rays, and limited parenchyma. Comparing with *Shorea* the fossil shows many features in common, although it differs in few other characters. As mentioned earlier the genera *Shorea* and *Hopea* can be differentiated by using the key to genera given by Chowdhury & Ghosh (1958). In *Shorea*, vessels are always more than 200 μ, usually with tyloses and vessel contours are not distinct. Rays are broader, more than 3-4 seriate and made up of 40-50 cells which are heterogeneous in nature. On the other hand in the genus *Hopea*, vessels are typically small to medium, punctate and have distinct vessel contours. Parenchyma is limited, paratracheal, vasicentric to aliform and tangential layers along with resin ducts. Rays are short, 2-3 seriate, 25 cells high and weakly heterogeneous. Resin canals are small, tangential, embedded in the parenchyma, (CHOWDHURY & GHOSH, 1958; METCALFE & CHALK, 1950; PEARSON & BROWN,



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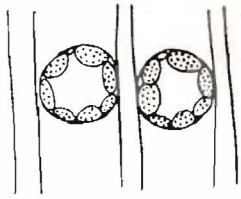

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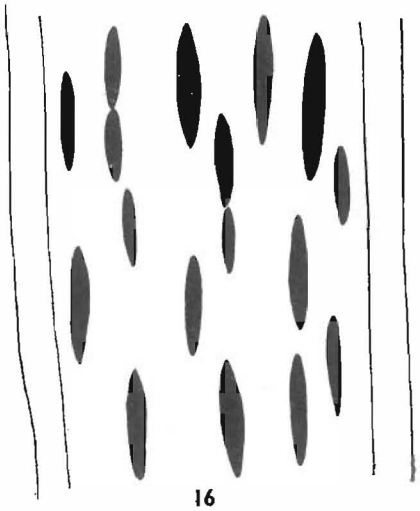

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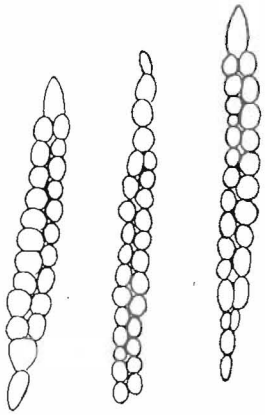

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Hopeoxylon indicum gen. *et* sp. nov.

TEXT-FIGS. 15-18 — 15, cross-section showing the distribution of vessels, parenchyma, rays and resin canals. × *ca.* 120. 16, distribution of rays in tangential section. × *ca.* 120. 17, ray cells and their nature. × *ca.* 240. 18, resin canals and their structure. Note the epithelial cells. × *ca.* 240.

1932 and GAMBLE, 1920). Among the large number of wood sections and references to literature studied during the investigation of the fossil wood shows similarities with the genus *Hopea*.

The fossil specimen shows many comparative features with *Shoreoxylon holdeni*, *S. mortandrense* (RAMANUJAM, 1954), *S. megaporosum* (RAMANUJAM, 1960) and *S. speciosum* sp. nov. among the fossil woods described from India. *Shoreoxylon holdeni* differs with the fossil under consideration in having solitary vessels of 200-280 μ diameter, indistinct parenchyma, and abundant tracheids whereas my fossil is distinct in having very small vessels, limited parenchyma though not abundant and indistinct tracheids. Rays of *S. holdeni* are distinctly

different in having typically spindle shaped cells and made up of regular uniseriate and biseriate rays. Comparing with *S. mortandrense*, the present fossil differs as in the previous case in the nature of vessels, parenchyma and rays. Vessels are bigger being 200-300 μ in diameter, rays and parenchyma are abundant and of many cells. But in the present fossil, rays are very limited, usually biseriate and never more than triseriate. Also resin canals are smaller in size as compared to *S. mortandrense*. *S. megaporosum* differs in having very large vessels and broad heterogeneous rays. *S. speciosum* sp. nov. shows differences with the present fossil in having multiseriate rays of high frequency, bigger vessels and resin canals, in contrast to the fossil under consideration which is characterized by small vessels, limited rays and smaller resin ducts.

Few fossil woods; among the Dipterocarpaceous woods described outside this country can be compared with the fossil under investigation. *Dipterocarpoxylon gibuense* (CHIARUGI, 1933) resembles in the nature of rays and resin canals which are small and short as in the case of my fossil but its vessels are bigger and usually solitary and also possess distinct metatracheal bands which are absent in the Indian fossil. *D. scebelianum* (CHIARUGI, 1933) agrees with the fossil under consideration in the nature of rays and resin canals and other features, yet the presence of metatracheal bands and usually solitary vessels of very big size are distinct differences. *D. swedenborgii* (SCHUSTER, 1910) differs with the present fossil in having broad metatracheal bands, multiseriate rays and large vessels whereas in my fossil the vessels are small, radial and metatracheal bands are absent. *Shoreoxylon palembangense* (DEN BERGER, 1923) can also be differentiated easily from the Indian material as it possesses large-sized vessels, and abundant parenchyma as metatracheal bands. *Drybalanoxylon tobleri* agrees in many features in spite of the fact that it distinctly differs in having bigger vessels, incipient parenchyma and multiseriate rays. *D. javanense* shows certain features resembling well with the present fossil. However, my fossil differs in having very narrow rays with limited number of cells; distinct parenchyma which is vasicentric to aliform whereas in *D. javanense*, parenchyma is incipient, rays are a bit broader with distinct heterogeneous cells. *D. perforatum* Schweitzer (1958) compares well with my fossil in overall features, yet the size of the vessels, resin canals, and the nature of rays differ. In *D. perforatum* vessels range between 125 and 200 μ in diameter, resin ducts are 50-125 μ in size and rays are heterogeneous. From the above comparisons it can be seen that my fossil although shows some resembling characters with those of *D. javanense*, *D. tobleri* and particularly with *D. perforatum* yet it differs from these in certain distinct features.

The fossil under consideration shows most of its anatomical features resembling well with *Hopea*. Therefore, based on the anatomical studies and on the key to genera of Indian dipterocarps recently outlined by Chowdhury & Ghosh (1958), a new form genus *Hopeoxylon* is created to accommodate this fossil. The new genus is a distinct form in having typically small vessels with vessel contours, limited vasicentric, aliform parenchyma, 2-3 weakly heterogeneous, short rays having up to 25 cells high and small resin canals in tangential bands. As opposed, the genus *Shoreoxylon* Den Berger is distinguished by having larger vessels usually more than 200 μ in diameter, abundant aliform parenchyma, broad rays having up to 50 cells high and sizable resin canals in tangential bands.

Hopeoxylon gen. nov.

Diagnosis

diffuse porous wood.

Vessels typically very small, solitary or radial; intervessel pits small, alternate.

Parenchyma very limited, paratracheal scanty and vasicentric, apotracheal along the resin duct.

Rays limited, uniseriate to biseriate, not more than triseriate, typically short, Homogeneous to weakly heterogeneous.

Resin canals typically very small, arranged in tangential bands.

Fibres libriform to semi-libriform.

Hopeoxylon indicum sp. nov.

Diagnosis

A diffuse porous wood.

Growth-rings not visible but tangential bands of parenchyma enclosing the resin ducts look like growth marks.

Vessels-small, solitary, radial, 80-90 μ in diameter, filled with dark substances,

vessel segments medium, intervessel pits small, circular, alternate and fairly crowded.

Tracheids hardly visible and difficult to differentiate from parenchyma.

Parenchyma distinct, limited; paratracheal, vasicentric, sometimes aliform, 3-4 rows of cells in the vicinity of vessels; apotracheal, tangentially banded along with the resin canals, 4-5 layered in tangential rows.

Rays uniseriate, mostly biseriate, rarely more than triseriate; 4-25 cells high, 5-10 per sq. mm., mostly homogeneous, having procumbent cells.

Resin canals typically small, 30 μ, arranged in successive rows in tangential thin bands.

Fibres libriform, non-septate, forming extensive tracts between the vessel and rays, circular and 16 μ in cross-section, fibre pits small, poorly preserved, many per cell.

Resin canals small, circular in shape, arranged in tangential concentric rows, epithelial cells small with fillings.

Holotype — No. 26382, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Kashikoppam, near Pondicherry, South India.

CONCLUSION

The fossiliferous localities near Pondicherry of South India abundantly represent the fossil Dipterocarpaceous woods. The study of the present day-distribution of Dipterocarps (GAMBLE, 1902; PEARSON & BROWN, 1932; CHOWDHURY & GHOSH, 1958 and CHAMPION, 1936) shows that the modern woods of Dipterocarpaceae are dominant in tropical moist deciduous forests of India. This gives a possible clue that during the tertiary times the fossil area might have had the same climate and vegetation similar to the present-day areas of tropical moist deciduous forests of India.

Ghosh & Ghosh (1958) have indicated the possiblity of the migration of Dipterocarpaceous woods to Africa, from Northern route of India from the evidence of their record of *Anisoptera* from Siwaliks. But the present investigation reveals the presence of Dipterocarpaceous woods in South India and this indicates the possibility of the migration from southern route also, as suggested by Ramanujam (1954).

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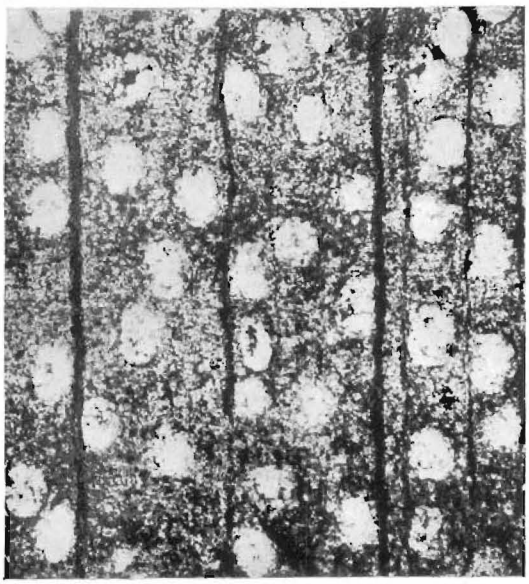

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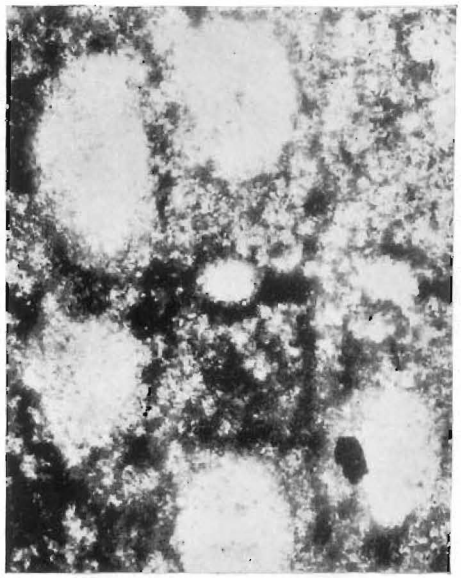

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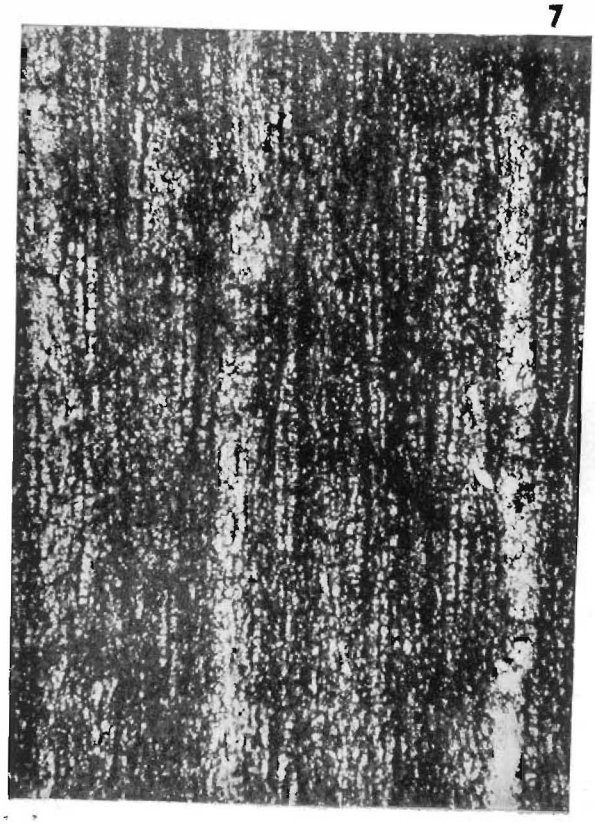

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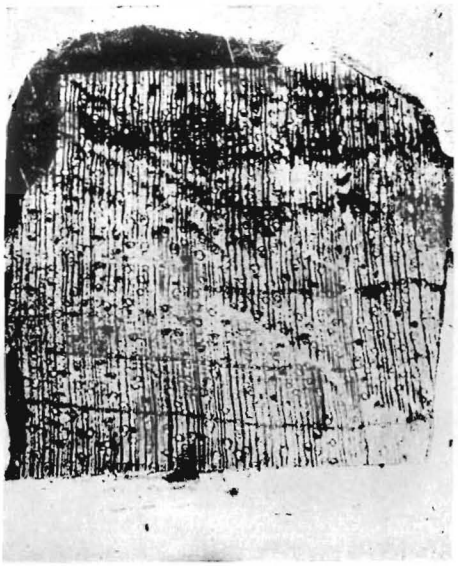

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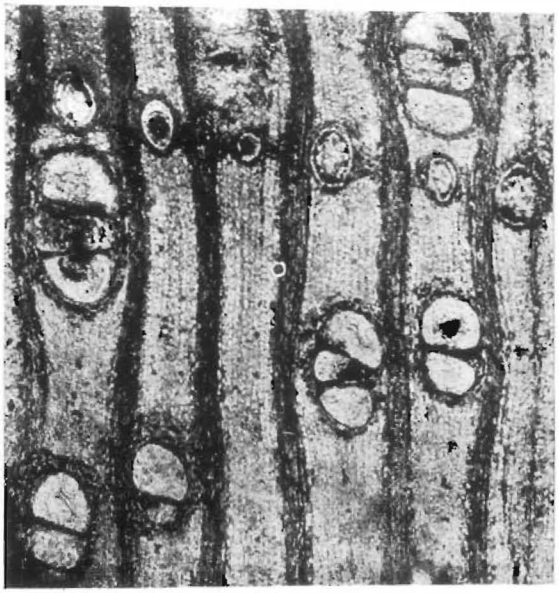

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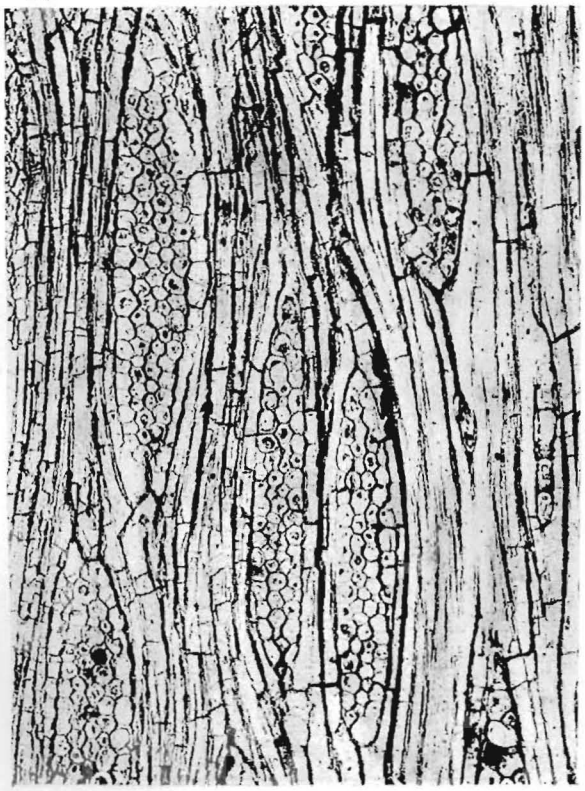

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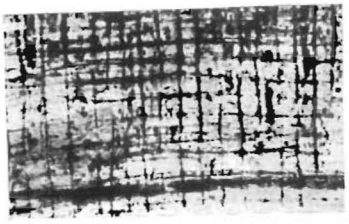

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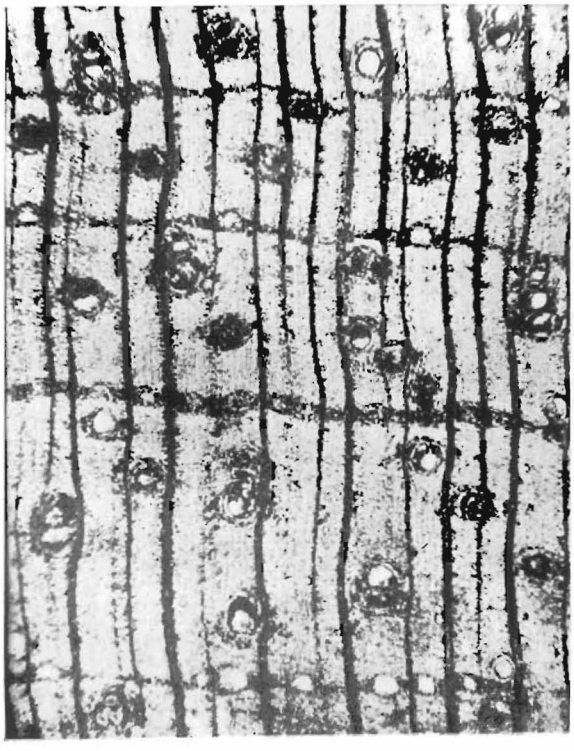

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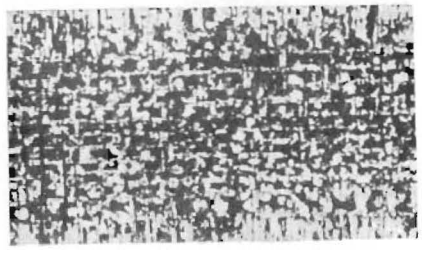

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EXPLANATION OF PLATES

PLATE 1

Dipterocarpoxylon cuddalorense sp. nov.

1. Cross-section showing the distribution of vessels, parenchyma and resin canals. × 3.
2. Tangential section showing the nature of pits. × 100.
3. Another cross-section magnified showing the nature and contents of vessels, the distribution of parenchyma and resin canals. × 75.
4. Tangential section showing the distribution and the nature of rays. × 900.

PLATE 2

Anisopteroxylon coromandelense sp. nov.

5. Cross-section showing the distribution of vessels, parenchyma and resin canals. × 35.
6. Another cross-section magnified showing a pair of resin ducts and diffused parenchyma. × 100.
7. Tangential section showing the distribution of rays. × 35.
8. Another tangential section to show the multiseriate heterogeneous rays. Note the sheath cells along the margin. × 100.

PLATE 3

Shoreoxylon speciosum sp. nov.

9. Cross-section to show the general structure. Note the tangential lines of resin canals and the distribution of vessels. × 3.
10. Another cross-section magnified to show the nature of vessels, parenchyma, resin canals and fibre cells. × 35.
11. Tangential section showing the nature, distribution of rays and fibres. × 35.
12. Tangential section of a portion of the vessel showing intervessel pits. × 100.
13. Radial section to show the nature of rays. × 100.

PLATE 4

Hopeoxylon indicum gen. et sp. nov.

14. Cross-section showing the gross general features. Note the distribution of resin canals, parenchyma and vessels. × 3.
15. Tangential section showing the distribution of rays, the nature of ray cells and fibres. × 35.
16. Another cross-section magnified to show the nature and arrangement of vessels, parenchyma, resin canals and fibre cells. × 35.
17. A portion of a vessel segment in tangential section showing the pits. × 250.
18. Radial section to show the nature of rays. × 100.