FOSSIL WOODS OF DIPTEROCARPACEAE FROM THE TERTIARY OF SOUTH ARCOT DISTRICT, MADRAS

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ABSTRACT

The paper describes three new species of fossil woods of Dipterocarpaceae, from the Tertiary rocks of Mortandra, in South Arcot district. They resemble very strongly the extant species of *Shorea* and *Dipterocarpus*. The fossils are named as *Shoreoxylon Holdeni*, *Shoreoxylon mortandranse* and *Dipterocarpoxylon indicum*.

INTRODUCTION

THE present paper deals with three new species of fossil woods belonging to Dipterocarpaceae, collected by the author from near Mortandra (Murttanqi), a village 5 miles W.N.W. of Pondicherry. From the same locality the author has previously reported (RAMANUJAM, 1953, 1954a) woods belonging to various families like Guttiferae, Celastraceae, Anacardiaceae, Leguminosae, Sonneratiaceae and Euphorbiaceae, and has very recently (RAMANUJAM, 1954b) described in detail the anatomy of two Leguminous woods. All the specimens collected are found partially buried in the Cuddalore sandstones which is believed to range from Eocene to Pliocene (SAHNI, 1931). Krishnan (1949) regards the Cuddalore series to be Miocene and according to Wadia (1953) a greater part of this series is Pliocene. The fossils range in colour from light grey to reddish brown. Their preservation is very satisfactory and consists of only the secondary wood.

GENERAL DESCRIPTION

In the nomenclature of the fossil Dipterocarpaceous woods no regular practice seems to have been followed. Kräusel (1922, 1925, 1926), Edwards (1931) and Bancroft (1933) have used the name *Dipterocarpoxylon* in a broad sense to represent all the fossil woods showing resemblances with the Dipterocarpaceae. Chowdhury (1938) has also followed the same system, but he has taken care to indicate the specific affinities of his fossil in the description. Den Berger (1923, 1927) followed by Pfeiffer and Van Heurn (1928), however, restricted the term *Dipterocarpoxylon* only to the woods agreeing with the tribe Dipterocarpeae which includes two living genera *Dipterocarpus* and *Anisoptera*. They refer the other specimens to new genera like *Shoreoxylon* and *Drybalanoxylon*. The present author feels that Den Berger's mode of nomenclature is not only more natural but also convenient to follow. In fact in cases where the resemblances are unmistakable with the present-day genera like *Shorea* and *Drybalanops*, the retention of these fossils in the genus *Dipterocarpoxylon* would be unfortunate.

Genus — *Shoreoxylon* Den Berger

Shoreoxylon Holdeni sp. nov.

Pl. 1, Figs. 1-7; Text-figs. 1-7

The material consists of a dozen pieces of petrified wood, the biggest of which measures 16×8 cm.

The wood does not possess growth-rings. Concentric bands of vertical resin canals simulating growth marks are seen with the naked eye (PL. 1, FIG. 1), but under the microscope their true nature becomes clear.

The vessels are diffuse and clearly visible to the naked eye. In cross-section they are circular, either solitary or in radial groups of 2-3, somewhat flattened at the points of contact. They are medium to large and very frequently occluded with tyloses which often contain some black deposit (PL. 1, FIG. 2). The form of the individual tyloses varies greatly. Generally the tyloses take the form of thin-walled, more or less globose sacs, which at low magnifications appear somewhat iridescent. Intervessel pitting is abundant; the pits being small, alternate, rounded or slightly flattened with lenticular apertures (PL. 1, FIG. 3). The vessel-segments are medium to long and truncate. The perforations are simple and horizontal or slightly inclined. The vessel-tracheid pitting is the same as the intervessel pitting,

but the pits are slightly larger. The vessel-ray pits are bordered, small, rounded and several per cell (TEXT-FIG. 2). The vessel-parenchyma pitting is not observed.

Tracheides are of very common occurrence in the fossil wood. They always occur in association with the parenchyma in the immediate vicinity of the vessels (PL. 1, FIG. 4). The tracheids are very thick walled and appear rounded or slightly angular in cross-section. The pits on the tracheids are distinctly preserved; they are bordered and oval to circular with rounded to often elliptical apertures (TEXT-FIG. 3).

The fibres are typically libriform and usually of considerable thickness. They are squarish to rounded in cross-section and aligned in regular radial rows. They are all aseptate and usually of medium length and having numerous small simple or narrowly bordered circular pits (TEXT-FIG. 4). The pits are clearly seen both in tangential and radial sections.

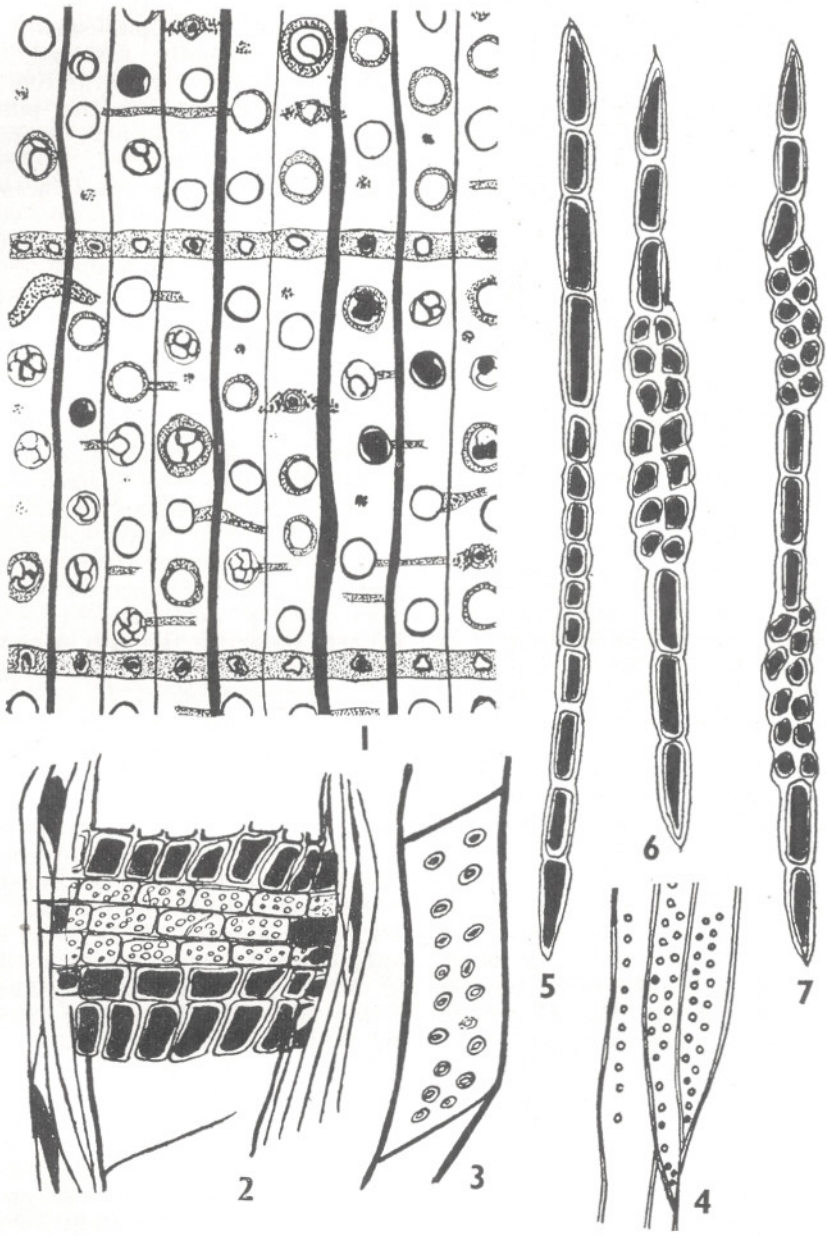
The xylem parenchyma is limited in quantity, but is distinctly seen with a hand lens as light coloured patches. Both paratracheal and apotracheal types of parenchyma are represented (PL. 1, FIG. 5; TEXT-FIG. 1). The former is vasicentric, sometimes with a slight tendency towards the aliform type. Of the apotracheal type there are three kinds: the first is in short tangential strips, 2-3 cells thick and distributed irregularly; the second type is the long tangential bands associated with the resin canals; the third type is represented by diffuse cells or cell groups bordering the rays or embedded in the fibres themselves. The cells of the parenchyma are usually circular, sometimes flattened, with many simple rounded pits. More often than not the parenchymatous cells are plugged with some black substance.

The outline of the rays may be seen with the naked eye on the polished transverse and tangential surfaces of the wood as more or less fine lines. They are fairly numerous and evenly distributed. The rays are 1-4 seriate and 7-40 cells (usually 15-28 cells) high (PL. 1, FIG. 6). Although uniseriate and biseriate rays are frequent, the majority of the rays are 3-4 seriate; these are often spindle-shaped when seen in tangential section and gradually taper towards the ends. Sometimes the rays taper rather abruptly. The rays are always markedly heterogeneous with 2-5 marginal rows of upright cells (TEXT-FIGS. 5, 6, 7) which show best in radial sections (PL. 1, FIG. 7). In some cases the upright cells are intercalated between the procumbent cells. At many places the rays fuse end to end resulting in the formation of rays of great heights. The ray cells are usually heavily impregnated with a dark coloured deposit. Pitting on the tangential walls of the ray cells is seen occasionally; the pits being invariably simple, rounded and many per cell.

Even a cursory glance at the polished cross-surface of the fossil wood will not fail to reveal the vertical resin canals aligned regularly in long concentric rows (PL. 1, FIG. 1). These canals are invariably embedded in the xylem parenchyma. Scattered resin canals also occur here and there, but they are by no means of common occurrence. As seen in cross-section the resin canals are circular and always smaller than the vessels varying little in shape and size. They are either empty or filled with a dark coloured deposit. The wood does not possess any horizontal resin canals or idioblasts.

Comparison with the Living Species — The presence of normal resin canals in the fossil wood indicates affinity with the Dipterocarpaceae and with some genera of the Caesalpineae. But for two African genera, *Monotes* and *Marquesia* the family Dipterocarpaceae is characterized by the possession of vertical resin canals. Other characters of this family which are also met with in the fossil wood are: vessels usually medium sized, solitary or in radial groups of 2-3; perforations simple, intervessel pitting alternate; parenchyma limited, both paratracheal and apotracheal; rays mostly 2-6 cells broad, heterogeneous; vasicentric tracheids common (REYS, 1923; PEARSON & BROWN, 1932; DESCH, 1936; METCALFE & CHALK, 1950).

Dipterocarpaceae is generally divided into two main groups based on the mode of the distribution of the resin canals. In the first group, which includes genera like *Doona, Hopea, Shorea, Parashorea* and *Pentacme*, the resin canals are always aligned in long concentric rows; while in the other group, consisting of *Anisoptera, Dipterocarpus, Vateria*, etc., the distribution of the canals is primarily diffuse. It is then obvious that the South Indian fossil finds a place in the first group. From a detailed comparison with the members of this group it is seen that the fossil has greatest similarity with the genus



TEXT-FIGS. 1-7 — *Shoreoxylon Holdeni* sp. nov. 1, semi-diagrammatic cross-section to show the distribution of xylem parenchyma and resin canals. × 70. 2, vessel-ray pitting. × 300. 3, pits to a tracheid. × 300. 4, pits to the fibres. × 300. 5, uniseriate ray with marginal vertical cells. × 300. 6, biseriate ray with marginal vertical cells. × 300. 7, end to end ray fusion. × 300.

Shorea. In size and form, and distribution of the vessels, in the nature of the rays and the fibres, in the size and arrangement of the resin canals, and lastly in the nature and distribution of the parenchyma the fossil wood from South India shows its closest affinity with this genus.

In the Caesalpineae genera like *Copaifera*, *Detarium* and *Eperua* also possess resin canals in concentric rows as in our fossil, but all

these genera differ very greatly from the present fossil in most of the other important features.

Comparison with the Fossil Species — In 1916 Holden described a fossil wood from the Irrawady series (Tertiary) of Burma under the name *Dipterocarpoxylon*. This was later renamed by Gupta (1935a) as *Irrawadioxylon burmense*. Bancroft (1933) and Chowdhury (1938) were of the opinion that Holden's species might not represent any Dipterocarpaceous wood. *Dipterocarpoxylon burmense* (HOLDEN, 1916) differs fundamentally from our fossil, in the absence of resin canals.

Another Dipterocarpaceous wood, *Dipterocarpoxylon Holdeni* has been described by Gupta (1935b) from the Tertiary of Burma. Gupta's species also differs fundamentally from the South Indian wood in the absence of vertical resin canals.

Dipterocarpoxylon garoense (CHOWDHURY, 1938) described from the Tertiary strata in the Garo Hills of Assam resembles the modern species of *Anisoptera*. There are several differences between this fossil and the one from South India, the most important of which is the distribution of the resin canals; in *D. garoense* the resin canals are solitary and scattered, while in our specimen they are arranged in regular concentric bands.

Out of the many interesting species described from outside India *Shoreoxylon palembangense*, described from the Tertiary of Sumatra (DEN BERGER, 1923) shows great similarity with the fossil wood under study. Superficially both look alike, but there are some differences in details. In *Shoreoxylon palembangense* the vessels are much bigger, the rays are broader, and the vasicentric tracheids are very few; moreover in this case the paratracheal parenchyma is absent.

In the case of the fossil wood from South India the resemblances with *Shorea* are sufficiently strong to enable its inclusion in Den Berger's *Shoreoxylon*. It is specifically named as *Shoreoxylon Holdeni* sp. nov., after Holden.

Diagnosis — Growth-rings absent.

Vessels evenly distributed, 8-10 per sq. mm., medium to large, 160-250 μ in diam., generally solitary or in radial groups of 2-3, circular to oval in cross-section, abundantly tylosed: vessel-segments medium to long, measuring 400-850 μ in length and truncate; perforations simple, horizontal or slightly inclined; intervessel pits small, alternate, rounded or slightly flattened, apertures lenticular; vessel-tracheid pitting same as intervessel pitting, but the pits slightly larger; vessel-ray pits small, several per cell, bordered and rounded.

Tracheids very common, vasicentric, 280-450 μ in length, 35 μ in diam., very thick-walled; pits bordered, oval to round, pore rounded to often elliptical.

Fibres libriform, medium, 1,350-1,500 μ in length, 15 μ in diam., aseptate, squarish to rounded in cross-section, arranged regularly in radial rows; pits numerous, simple or narrowly bordered, circular.

Parenchyma limited, distinctly seen with a hand lens, paratracheal and apotracheal; paratracheal in 1-2 layered vasicentric sheaths, often extending laterally; apotracheal type seen (a) as many short irregularly distributed tangential strips, (b) long tangential bands containing the vertical resin canals, and (c) scattered cells or groups of 1-3 cells bordering the rays or embedded in the fibres; cells circular or flattened; pits many, simple, rounded.

Rays numerous, 8-13 per mm., evenly distributed, markedly heterogeneous with 2-5 marginal rows of upright cells, 1-4 seriate, 7-40 cells high; most of the rays 3-4 seriate; end to end ray fusions common; ray cells profusely filled with a dark coloured deposit; pits to the end walls of these cells often seen, being small, simple and rounded.

Resin canals vertical, aligned in concentric rows simulating growth marks; rarely scattered, 80-110 μ in diam.; mostly filled with a dark coloured deposit, or sometimes empty; canals always embedded in bands of apotracheal parenchyma.

Collection — Holotype No. 4968 of the Birbal Sahni Institute of Palaeobotany Museum.

Shoreoxylon mortandranse sp. nov.

Pl. 1, Fig. 8; Pl. 2, Figs. 9-11; Text-Figs. 8-10

The fossil is represented by a single block measuring 10×15 cm. It is greyish in colour with light yellow patches here and there. The wood is similar in general characters to the one previously described but differs in certain important features of specific value.

The fossil does not possess growth-rings, but the resin ducts are arranged in concen-

tric lines simulating growth marks (PL. 1, FIG. 8).

The vessels are diffuse and appear to the naked eye as well-defined dots against the greyish background of the fossil. They are either solitary, which represents the general case or in radial groups of 2-3, flattened at the places of contact, sometimes extremely so. They are medium to large. Generally only a few vessels are tylosed. Most of the vessels, however, are filled with a crystalline matrix, and it is possible that the tyloses here are not usually seen because of this. The vessel-segments are medium and truncate. Intervessel pitting is abundant; the pits are small to sometimes medium, alternate, typically bordered and rounded to slightly flattened with lenticular apertures. The perforations are horizontal. The vessel-tracheid pitting is not observed. The vessel-ray pits are bordered or sometimes simple, small, rounded, and several per cell. The vessel-parenchyma pitting is not preserved.

The tracheids in contrast with *Shoreoxylon Holdeni* are very rare and seen perfectly only at a few places. They are, however, typically vasicentric. They are very thick-walled and appear rounded to polygonal in cross-section.

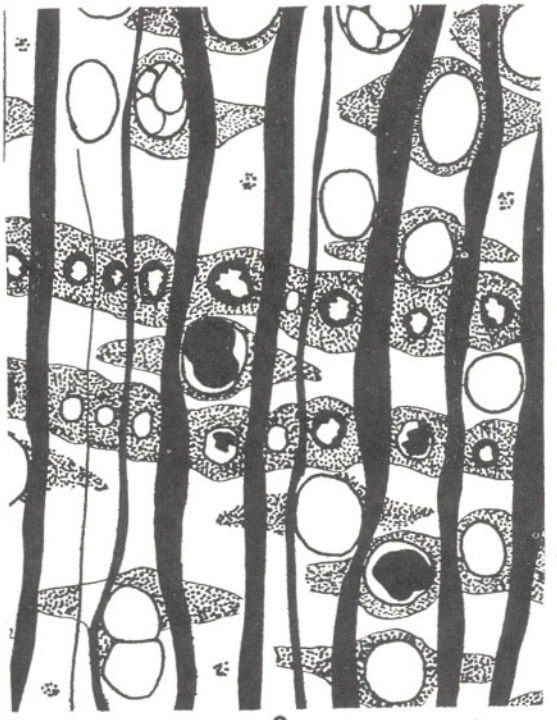
The fibres are libriform to semi-libriform. They are squarish to polygonal in cross-section and are very thick-walled. They are all aseptate and usually of considerable length. The pits to the fibres are numerous, simple or narrowly bordered and rounded to flattened.

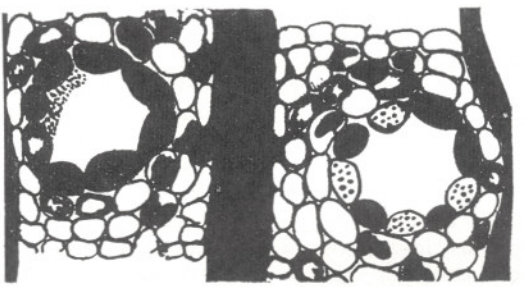
The xylem parenchyma is abundant. It is both paratracheal and apotracheal. The former is predominant and can be seen distinctly with the naked eye as light coloured patches in the immediate vicinity of the vessels. It is represented mostly by aliform sheaths, 1-5 cells thick, often becoming locally confluent (TEXT-FIG. 8; PL. 2, FIG. 9). The apotracheal parenchyma occurs as long tangential bands in association with the resin canals, and as short tangential strips irregularly distributed. The cells of the parenchyma are usually rounded or oval, or sometimes tubular and filled with a dark substance. Pitting when seen consists of simple pits which are very minute and rounded.

The outlines of the xylem rays can be clearly seen with the naked eye on transverse as well as longitudinal surfaces of the fossil wood. They are evenly distributed. They are 1-6 seriate. The uniseriate rays are very rare, biseriate and triseriate are occasional while the majority of them are 4-6 seriate (PL. 2, FIG. 10). The rays are 10-80 cells high and are distinctly heterogeneous. They have both upright and procumbent cells, but in the majority of the rays the vertical cells are confined to the sides as seen in tangential sections (TEXT-FIG. 9); in some of the rays the vertical cells also occur on the margins, but as a rule these marginal vertical cells are 1-2. This is quite different from the previous species in which the vertical cells are entirely marginal and are in 1-5 rows. The ray cells usually contain some dark substance. Pits to the tangential walls of these cells are seen frequently; these are simple, circular to oval and many per cell.

The resin canals are vertical and distinct to the naked eye. They occur as regular, closely spaced concentric lines which are sometimes broken. Generally 6-8 of these concentric lines can be counted radially per inch, but at some places there are as many as 12-15 per inch. The individual resin canals vary much in shape and size even in the same row. They are oval to rounded, often tangentially compressed, and usually smaller in size than the vessels. The canals in between the two neighbouring xylem rays are sometimes radially compressed to a great extent. Rarely the resin canals also occur in scattered condition. No horizontal canals are present. The canals are mostly empty. They are always embedded in concentric bands of apotracheal parenchyma, 1-3 cells thick. The epithelium of the canals consists of a single layer of cells lining the resin cavity. The epithelial cells are usually filled up with a dark coloured substance. In cross-section the epithelial cells are oval or rounded, and somewhat bulged or arched on the side facing the cavity of the canal (TEXT-FIG. 10). Whenever these cells are without contents, the pitting on the transverse walls (end walls) can be seen very clearly. The pits are very minute, simple, circular and many per cell. There are no idioblasts in the fossil wood.

Comparison with the Fossil Species — The present specimen differs greatly from that of *Shoreoxylon Holdeni* in the following characters: (1) the presence of abundant aliform parenchyma, (2) apotracheal parenchyma confined mainly in the vicinity of the resin canals, (3) rare occurrence of tracheids,





TEXT-FIGS. 8-10 — *Shoreoxylon mortandranse* sp. nov. 8, semi-diagrammatic cross-section to show the distribution of xylem parenchyma and resin canals. × 70. 9, heterogeneous ray. × 300. 10, vertical resin canals under high power to show the pits to the epithelial cells. × 300.

(4) rays broader and higher, with a different arrangement of vertical cells.

Dipterocarpoxylon tobleri, described from the Miocene of South Sumatra (KRÄUSEL, 1922) resembles the present specimen to a great extent in the size, shape and distribution of the vessels, in the intervessel pitting, in the structural details of the fibres, and vertical resin canals. But in the nature and distribution of the xylem parenchyma the Sumatran species is easily distinguishable from the South Indian fossil wood. In *Dipterocarpoxylon tobleri* the parenchyma in general is very scanty, particularly the paratracheal type, which is vasicentric but not aliform. The xylem rays in this species although heterogeneous, possess upright cells usually on the margins. Besides, the presence of vasicentric tracheids is a very common feature in *D. tobleri*.

Shoreoxylon palembangense, described from the Miocene of Sumatra (DEN BERGER, 1923), although agreeing in the general features with our fossil can, however, be easily distinguished in the possession of low rays and very scanty parenchyma.

The present specimen, because of its differences from the hitherto described species of Dipterocarpaceae woods, has been given a new specific name, *Shoreoxylon mortandranse*, after the locality Mortandra from where it was collected.

Diagnosis — Growth-rings absent.

Vessels diffuse, medium to large, 180-280 μ in diam., solitary or in radial groups of 2-3, circular when solitary, flattened at the places of contact when in radial groups, sparsely tylosed, vessel-segments medium, 250-500 μ long, truncate; perforations simple, horizontal; intervessel pitting abundant; pits small to medium, alternate, typically bordered, rounded to slightly flattened with lenticular apertures; vessel-ray pits bordered or simple, small, rounded, several per cell.

Tracheids very rare, in groups of 1-4, 320-420 μ in length, 35 μ in diam., very thick-walled, rounded or polygonal in cross-section.

Fibres medium to long, 1,550-1,900 μ in length, 18 μ in diam., libriform to semi-libriform, aseptate, squarish to polygonal in cross-section; pits numerous, simple or narrowly bordered, round to flattened.

Parenchyma abundant, visible to the naked eye as light coloured patches in the immediate vicinity of the vessels, both paratracheal and apotracheal; paratracheal type aliform to locally confluent, 1-5 cells thick; apotracheal type in 1-4 layered concentric bands associated with the resin canals, and as short tangential strips; cells rounded or oval, or sometimes tubular, usually with dark contents; 18-30 in diam.; pits simple, very minute, rounded.

Rays evenly distributed; 1-6 seriate; uniseriate rays very rare, biseriate and triseriate rays occasional, majority of them 4-6 seriate; 10-80 cells high; heterogeneous, the vertical cells mostly confined to the lateral sides of the rays as seen in the tangential sections; when marginal the vertical cells never in more than 1-2 rows; ray cells usually filled with dark contents; pits on the tangential walls simple, circular to oval and many per cell.

Resin canals of vertical type, arranged in regular closely spaced concentric lines, 95-160 μ in diam., very rarely diffuse; pits to the epithelial cells simple, very minute, circular and many per cell.

Collection — Holotype No. 4982 of the Birbal Sahni Institute of Palaeobotany Museum.

Genus — *Dipterocarpoxylon* Holden

Dipterocarpoxylon indicum sp. nov.

Pl. 2, Figs. 12-14; Text-figs. 11-14

The species is represented by two silicified pieces of wood, the bigger one of which measures 10×8 cm. The wood does not show growth-rings either to the naked eye or under the microscope.

The vessels are uniformly distributed. They are medium, sometimes large, mostly solitary and only at times in radial groups of 2-3, which are usually flattened at the places of contact. Tyloses are of common occurrence and show great variation in their size and shape. The vessel-segments are medium and truncate or tailed. The perforations are simple and horizontal. The intervessel pits are small, crowded and distinctly bordered. When not crowded the pits are alternate. They are circular with oval to elliptical apertures. At some places the border and the apertures are not distinct. Vessel-ray pits are simple, small, circular and several per cell. Occasionally these pits are also bordered, and when so the apertures are oval to elliptical.

The fossil does not possess any tracheids. Rarely tracheid-like cells (fibre tracheids ?) are met with in the immediate vicinity of the vessels. Pits to these cells are bordered, circular with round to oval apertures.

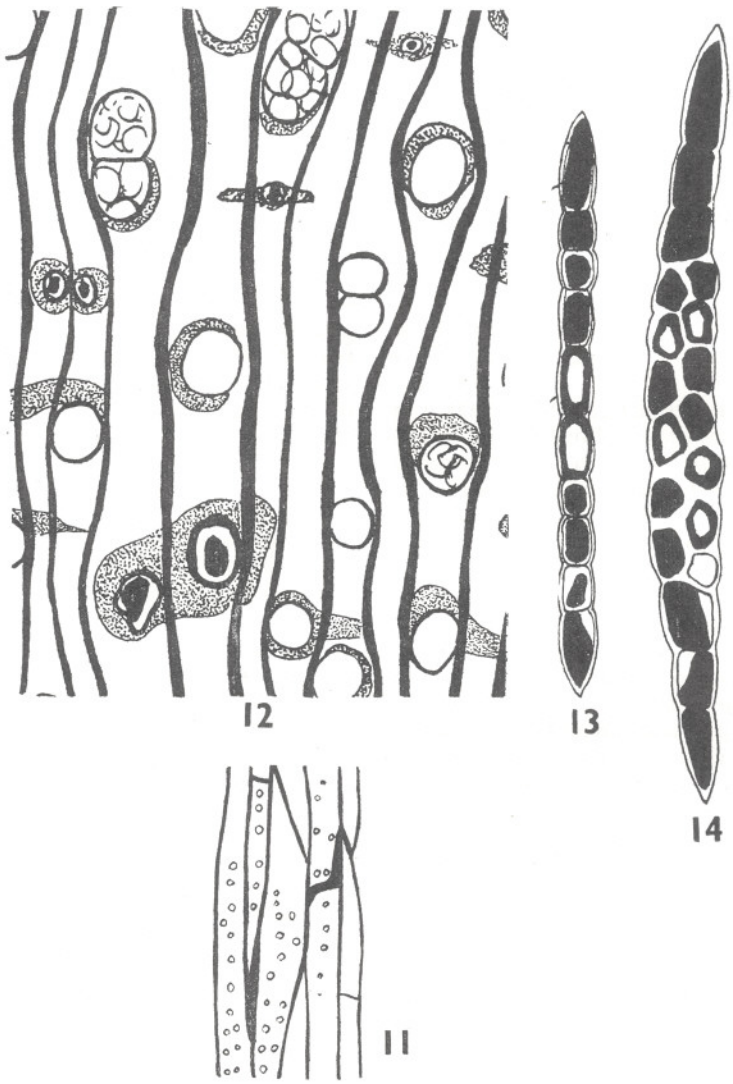
The fibres are libriform. They are arranged regularly in radial rows. They are squarish to polygonal in cross-section. In general the fibres are of medium in length. They are thickwalled, unseptate and possess numerous small, circular, simple or sometimes narrowly bordered pits (TEXT-FIG. 11).

The parenchyma is limited, but distinctly seen with a hand lens as buff-coloured patches here and there. It is paratracheal as well as apotracheal. The former is of two types: (1) vasicentric, 1-4 layered sheaths usually incompletely surrounding the vessels, (2) 1-3 layered, short, irregular tangential strips (TEXT-FIG. 12; PL. 2, FIG. 12). The apotracheal parenchyma is present only in association with the resin canals. It is usually 1-4 cells thick. The cells of the parenchyma

in cross-section are circular or slightly elongated radially. They are often filled with a dark coloured substance. The pitting of the parenchyma cells is not observed.

The rays are fairly visible under the hand lens on both the transverse as well as longitudinal surfaces of the fossil. They are evenly distributed and heterogeneous. The rays are 1-4 seriate and 10-30 cells high (PL. 2, FIG. 13). Uniseriate rays are fairly common, but the majority of them are triseriate. The vertical cells in the heterogeneous rays are usually marginal in 2-3 rows, but are sometimes intercalated between the procumbent cells (TEXT-FIGS. 13, 14). The heterogeneous condition of the rays is best seen in the radial sections (PL. 2, FIG. 14). The ray cells are, as a rule, heavily plugged with a dark coloured substance. End to end ray fusions are not uncommon.

The fossil wood possesses vertical resin canals the distribution of which is principally diffuse. They are, as a rule, solitary but occasionally the canals are seen in groups of



TEXT-FIGS. 11-14 — *Dipterocarpoxylon indicum* sp. nov. 11, pits to the fibres. × 300. 12, semi-diagrammatic cross-section to show the distribution of xylem rays and resin canals. × 70. 13, 14, heterogeneous xylem rays. × 300.

2-3. When they are in groups, the canals are always arranged tangentially in contradistinction to the radial grouping of the vessels. The canals are invariably embedded in a sheath of xylem parenchyma, 1-4 cells thick (PL. 2, FIG. 12). The canals are smaller than the vessels and are either empty or filled with a dark resinous matter. The epithelium consists of a single layer of cells which are oval to rounded and are bulged or arched towards the side facing the interior of the cavity. Some of the vessels filled with dark contents also look like resin canals; however, a closer examination always points out beyond doubt their true nature.

Comparison with the Living Species — The presence of vertical resin canals, the heterogeneous xylem rays evenly distributed, and lastly the limited amount of the xylem parenchyma indicate in no uncertain manner that the fossil under investigation belongs to the modern family Dipterocarpaceae.

While dealing with *Shoreoxylon* species it was mentioned (*see* page 2) that the living genera of Dipterocarpaceae are divided into two categories; the one in which the secretory canals are aligned in concentric rows, and the other in which the secretory canals are primarily diffuse in their distribution. The second category to which our present fossil obviously belongs, embraces genera like *Dipterocarpus, Anisoptera, Vateria* and *Vatica* (Dipterocarpeae, Vaterieae and Vaticae).

The vessels in Vaterieae and Vaticae are small when seen in cross-section and the parenchyma is mostly diffuse in its distribution. The members of Dipterocarpeae, on the contrary, normally have medium-sized vessels (there are many species with large to very large vessels, but none with small vessels, i.e. less than 100 μ in diam.). The parenchyma in the Dipterocarpeae varies greatly in its distribution, often even in the same species (REYS, 1923). As the South Indian fossil has vessels averaging 170 μ in diam., paratracheal parenchyma and scattered secretory canals, it compares easily with the Dipterocarpeae. The comparison also holds good in the nature of the rays and the structural details of the fibres.

A comparison with the two genera *Dipterocarpus* and *Anisoptera* shows that our fossil is nearer to the former. It differs from *Anisoptera* in its narrower rays and in the fact that the vessels do not tend so frequently to form radial groups as in the case of *Anisoptera*. Besides, the vasicentric tracheids in *Anisoptera* are generally of common occurrence.

Comparison with the Fossil Species — A study of the hitherto described species of the Dipterocarpaceous woods (KRÄUSEL, 1922, 1925, 1926; DEN BERGER, 1923, 1927; PFEIFFER & VAN HEURN, 1928; EDWARDS, 1931; BANCROFT, 1933; CHIARUGI, 1933; GUPTA, 1935; CHOWDHURY, 1938; BOUREAU, 1952) has indicated that the present fossil can easily be compared with *Dipterocarpoxylon africanum* (BANCROFT, 1933) from the Miocene of East Africa, *Dipterocarpoxylon somalense* (CHIARUGI, 1933) from the Plio-Pleiostocene of Somaliland, and *Dipterocarpoxylon garoense* (CHOWDHURY, 1938) from the Tertiary of Garo Hills, Assam.

The East African *D. africanum* resembles the timbers of the modern *Dipterocarpus*. The resemblances between it and the South Indian specimen are, therefore, quite marked. But *D. africanum* can be easily distinguished from the present specimen in possessing comparatively smaller vessels, very scanty parenchyma (which except in the immediate vicinity of the resin ducts is negligible), and in the comparatively more common occurrence of short tangential rows of resin canals.

Dipterocarpoxylon somalense is comparable with our fossil in the general features. It, however, differs in possessing very large resin canals, long tangential bands of metatracheal parenchyma, and only 1-2 seriate xylem rays.

Dipterocarpoxylon garoense from Assam, according to Chowdhury (1938), resembles the modern woods of *Anisoptera* to a very great extent. The Assam species differs from the South Indian specimen in the more frequent grouping of the vessels in radial rows, wider rays (5-6 seriate), presence of distinct tracheids, and lastly in the presence of narrow to wide bands of apotracheal parenchyma. But, in the distribution and structural details of the vessels, resin ducts and fibres *D. garoense* resembles our fossil to a very great extent.

The present fossil is described under the genus *Dipterocarpoxylon* in its restricted sense as advocated by Den Berger (1923). As it possesses several features which distinguish it from the hitherto described species, the new specific name *Dipterocarpoxylon indicum* has been proposed for it.

Diagnosis — Growth-rings absent.

Vessels diffuse, medium to sometimes large, 155-225 μ in diam., mostly solitary, radial groups of 2-3 vessels seen only at times, commonly tylosed, 10-14 per mm.; vessel-segments medium, 275-470 μ long, truncate or tailed; perforations simple, horizontal; intervessel pits small, crowded, distinctly bordered, circular with oval to elliptical apertures; often pits alternate; vessel-ray pits small, simple, circular, several per cell; these pits occasionally bordered, border circular, apertures oval to elliptical.

Tracheids absent; rarely tracheid-like cells (fibre tracheids?) found in the immediate vicinity of the vessels; pits bordered, circular, apertures round to oval. Fibre tracheids(?) 400-900 μ long.

Fibres libriform, medium, 1,200-1,550 μ in length, 15 μ in diam.; aseptate, squarish to polygonal in cross-section, arranged in regular radial rows, thick walled; pits numerous, small, simple to sometimes narrowly bordered, circular.

Parenchyma limited, but distinct with a hand lens as buff-coloured patches, paratracheal and apotracheal; paratracheal type of two kinds (1) in 1-4 cells vasicentric sheaths, (2) in 1-3 layered short tangential strips in contact with the vessels; apotracheal type always in association with the resin canals, 1-4 cells thick; cells circular or slightly elongated radially, often filled with a dark coloured substance.

Rays moderately numerous, 6-10 per mm.; uniformly distributed; 1-4 seriate, uniseriate rays fairly common, majority 3 seriate, 10-30 cells high; heterogeneous, with 2-3 marginal rows of vertical cells, vertical cells sometimes intercalated between the procumbent cells; end to end ray fusions not uncommon; ray cells heavily plugged with a dark coloured substance.

Resin canals of vertical type present; distribution principally diffuse, solitary, occasionally in tangential groups of 2-3, very small, 50-85 μ in diam., either empty or filled with a dark resinous substance.

Collection — Holotype No. 4964 of the Birbal Sahni Institute of Palaeobotany Museum.

DISCUSSION

Members of Dipterocarpaceae like *Dipterocarpus, Shorea, Vateria, Vatica*, etc., are more or less well represented in the modern flora of South India (GAMBLE, 1922; PEARSON & BROWN, 1932). The occurrence of Dipterocarps in South India during the Tertiary period is of some significance in connection with the distribution and the routes of migration of the Dipterocarpaceae. The present-day members of this distinctly tropical family are confined mainly to Asia (MERILL, 1923; REYS, 1927; BANCROFT, 1933). Outside this region the family is represented by a single species *Vateriopsis scychellarum* in the Scychelles (SUMMERHEYES, 1931) and by

TABLE 1 — DISTRIBUTION OF THE WOODS OF DIPTEROCARPACEAE KNOWN IN THE FOSSIL CONDITION AND THEIR AGE

SPECIES	COUNTRY	GEOLOGICAL AGE
Bredaea moroides, Goeppert, 1854 *Dipterocarpoxylon moroides*, Kräusel, 1926 *Shoreoxylon moroides*, Den Berger, 1927	Java	Tertiary
Naucleoxylon spectabilie, Crie, 1888 *Dipterocarpoxylon spectabilie*, Kräusel, 1926 *Drybalanoxylon spectabilie*, Den Berger, 1927	Java	Tertiary
Grewioxylon swedenborgii, Schuster, 1910 *Dipterocarpoxylon swedenborgii*, Schuster, 1910	East Indies	Tertiary
Dipterocarpoxylon tobleri, Kräusel, 1922 *Drybalanoxylon tobleri*, Den Berger, 1923 *Dipterocarpoxylon* sp., Kräusel, 1923 *Shoreoxylon djambiense*. Den Berger, 1923 *Dipterocarpoxylon djambiense*, Edwards, 1931	South Sumatra	Tertiary
Dipterocarpoxylon sp., Kräusel, 1922 *Shoreoxylon Krauseli*, Den Berger, 1923 *Dipterocarpoxylon Krauseli*, Edwards, 1931	South Sumatra	Tertiary
Caesalpinioxylon Palembangense, Kräusel, 1922 *Shoreoxylon Palembangense*, Den Berger, 1923	Sumatra	Miocene
Dipterocarpoxylon javanense, Kräusel, 1922 *Drybalanoxylon Javanense*, Den Berger, 1927	Java	Tertiary
Dipterocarpoxylon Goepperti, Kräusel, 1926	Java	Tertiary
Drybalanoxylon sp., Pfeiffer & Van Heurn, 1928	Java	Plio-Pleistocene
Dipterocarpoxylon sp., Pfeiffer & Van Heurn, 1928	Java	Plio-Pleistocene
Shoreoxylon sp., Pfeiffer & Van Heurn, 1928	Java	Plio-Pleistocene
Dipterocarpoxylon Scabelianum, Chiarugi, 1933	Italian Somaliland	Plio-Pleistocene
Dipterocarpoxylon somalense, Chiarugi, 1933	Italian Somaliland	Plio-Pleistocene
Dipterocarpoxylon giubense, Chiarugi, 1933	Italian Somaliland	Plio-Pleistocene
Dipterocarpoxylon africanum, Bancroft, 1933	East Africa	Tertiary
Dipterocarpoxylon garoense, Chowdhury, 1938	Assam, India	Tertiary
Dipterocarpoxylon khmerinum, Boureau, 1952	Indo-China	Tertiary
Shoreoxylon Holdeni, Ramanujam	South India	Tertiary
Shoreoxylon mortandranse, Ramanujam	South India	Tertiary
Dipterocarpoxylon indicum, Ramanujam	South India	Tertiary

two genera, *Monotes* and *Marquesia*, in tropical Africa (BANCROFT, 1933, 1935). The bulk of the Dipterocarpaceae is found in the Malayan Archipelago. Incidentally most of the fossil species also come from this region. Table 1 lists the fossil Dipterocarpaceous woods described so far from various countries. According to Bancroft (1933) the typical members of this family had a much wider distribution during the Plio-Pleiostocene times than at present. Bancroft (loc. cit., pp. 88, 89) suggests two possible routes of migration of the Dipterocarps from South-eastern Asia to Africa, (1) along the present north-western land connection of the Asiatic continent with Africa, (2) a southern route, through South India and Madagascar. The present discovery of Dipterocarps in the Tertiary rocks of South India lends support to the theory of the latter route. It is, however, to be remembered that no Dipterocarps, living or fossil, are found in Madagascar and this leaves a gap in the route of migration. If some fossil Dipterocarps were to be discovered in Madagascar, they will definitely serve to bridge this gap.

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EXPLANATION OF PLATES

PLATE 1

1-7 *Shoreoxylon Holdeni* sp. nov.

1. Polished transverse surface of the wood under low magnification to show the general structure. Note the tangential lines of resin canals. × 3.
2. Tylosed vessels. × 95.
3. Intervessel pitting. × 200.
4. Cross-section showing the vasicentric tracheids. × 95.
5. Cross-section to show the distribution of the vertical canals and xylem parenchyma. × 35.
6. Tangential section showing the general features of the heterogeneous xylem rays. × 50.
7. Radial section showing the marked heterogeneous nature of the rays. × 50.
8. *Shoreoxylon mortandranse* sp. nov. Polished transverse surface of the wood under low magnification to show the general structure. Note the concentric lines of resin canals. × 2.

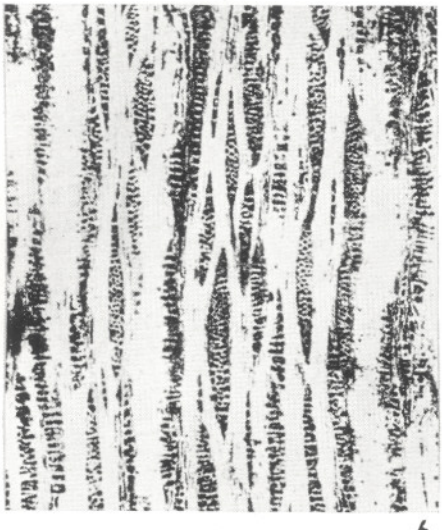
PLATE 2

9-11 *Shoreoxylon mortandranse* sp. nov.

9. Cross-section showing the distribution of the parenchyma. × 35.
10. Tangential section showing the xylem rays. × 150.
11. Radial section to show the heterogeneous nature of the rays. × 200.

12-14 *Dipterocarpoxylon indicum* sp. nov.

12. Cross-section showing the nature and distribution of the vessels, resin canals and the xylem parenchyma. × 35.
13. Tangential section showing the general structure of the rays. × 50.
14. Radial section showing the markedly heterogeneous rays. × 150.



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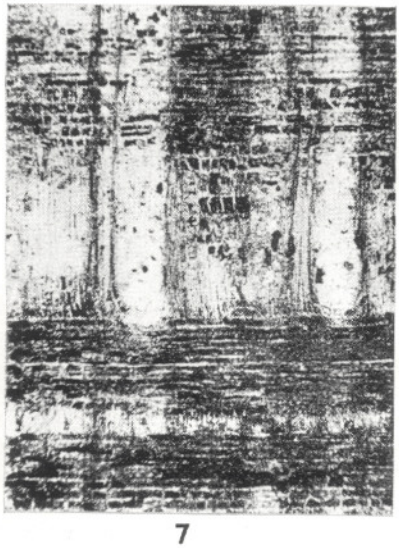

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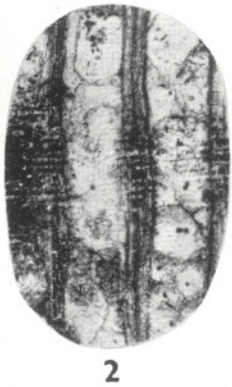

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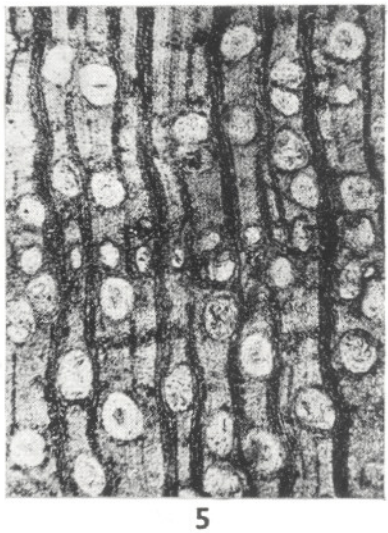

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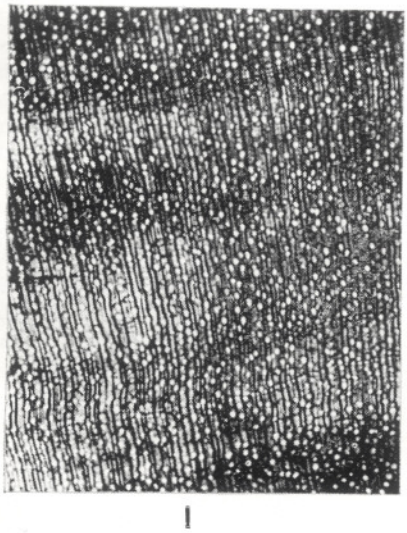

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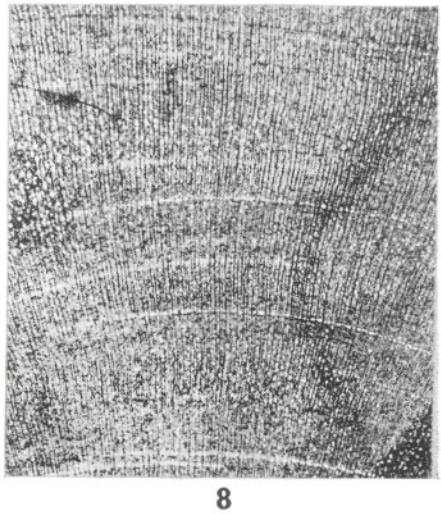

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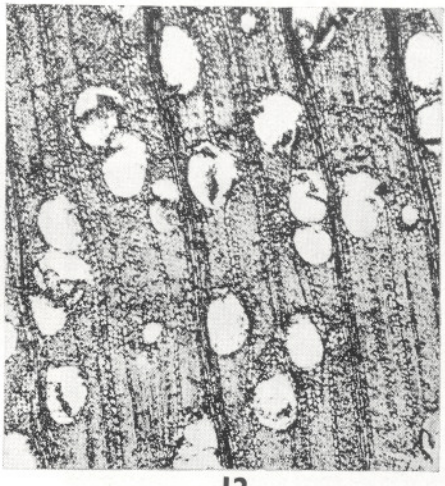

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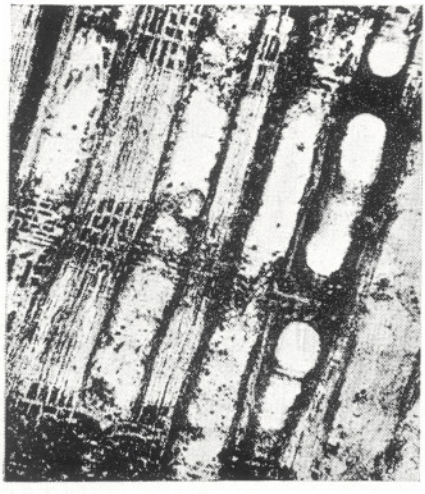

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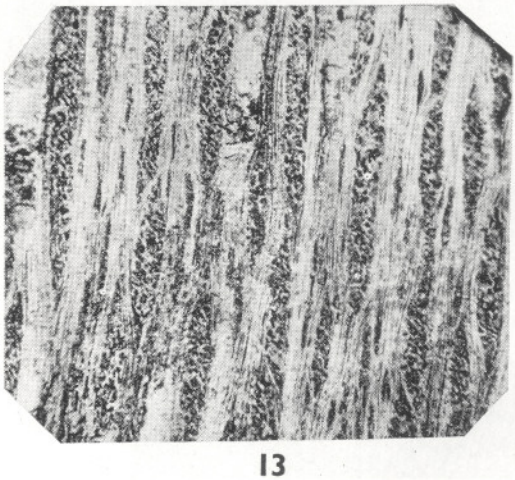

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