OCCURRENCE OF SOME DIPTEROCARPACEOUS WOODS IN THE CUDDALORE SERIES OF SOUTH INDIA

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ABSTRACT

Dipterocarpaceous woods are very common in the Cuddalore Series of South India near Pondicherry. Investigations have revealed the occurrence of three more new species of dipterocarpaceous woods from this area. One of them, showing closest resemblance with the genus *Dipterocarpus*, has been named as *Dipterocarpoxylon pondicherriense*. Of the remaining two, one compares with some species of *Shorea, Parashorea* and *Pentacme*, while the other shows affinities with *Shorea acvminata* Dyer and many other Malayan shoreas. They have been described as *Shoreoxylon indicum* and *S. arcotense* respectively.

INTRODUCTION

OF all the Tertiary deposits of India the Cuddalore sandstones exposed near Pondicherry in the South Arcot district, Tamil Nadu is the richest in dipterocarpaceous woods. Earlier Ramanujam (1956, 1960), Ramanujam and Rao (1967, 1969), and Navale (1963) described quite a large number of them as *Dipterocarpoxylon indicum D. cuddalorense, Shoreoxylon holdeni, S. mortandrense, S. megaporosum, S. speciosum, S. kraeuseli, Anisopteroxylon cuddalorense, A. coromandelense* and *Hopeoxylon indicum*. However, based on the study of the modern woods of Dipterocarpaceae, Awasthi (1971) revised the affinities of many of these; consequently *Dipterocarpoxylon indicum* Ramanujam was renamed as *Dryobalanoxylon indicum* (Ramanujam) Awasthi, and *Shoreoxylon holdeni* Ramanujam, *S. mortandrense* Ramanujam, *S. megaporosum* Ramanujam and *Anisopteroxylon cuddalorense* Ramanujam were found identical to each other and placed under another new species of *Dryobalanoxylon*, viz., *D. holdeni* (Ramanujam) Awasthi. Awasthi (MS) also reinvestigated *Dipterocarpoxylon cuddalorense* Navale and found it identical to *Terminalioxylon grandisporosum* Ramanujam (1966), described from the same locality. Revised account of this together with other such woods will be published in due course.

Further investigation of the woods collected from the same area has yielded three new species belonging to the family Dipterocarpaceae. One of these closely resembles the wood of *Dipterocarpus*, and out of the remaining two one shows affinities with some species of *Shorea, Parashorea* and *Pentacme*, while the other with those of Malayan shoreas.

SYSTEMATIC DESCRIPTION

Family — DIPTEROCARPACEAE

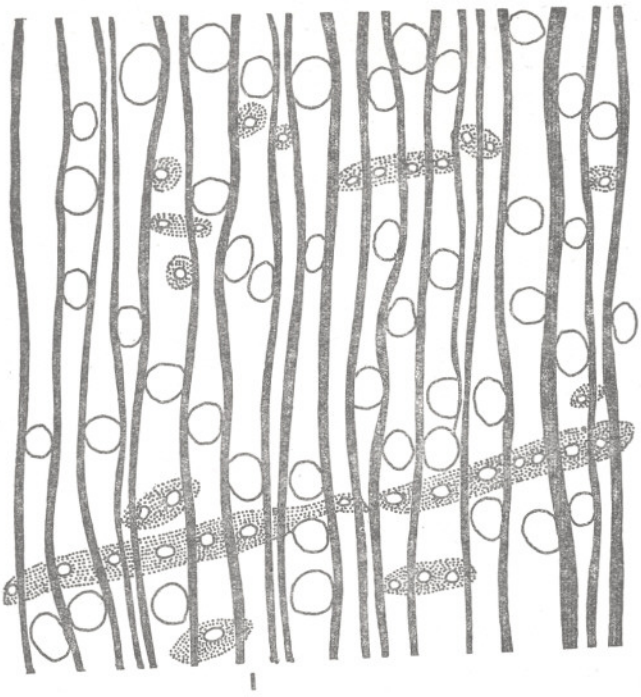
Genus — *Dipterocarpoxylon* Holden emend. Den Berger, 1927

1. *Dipterocarpoxylon pondicherriense* sp. nov.

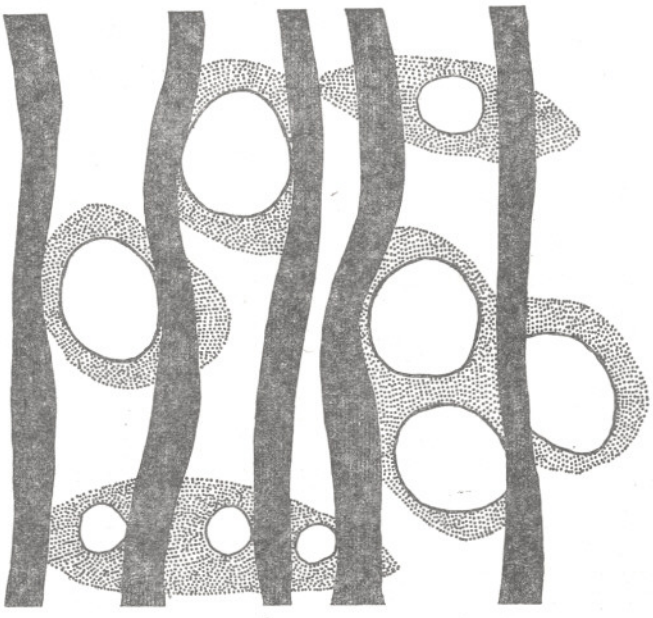
Pl. 1, Figs. 1, 3; Pl. 2, Figs. 5-6; Text-figs. 1-6

Material — Three small pieces of well preserved silicified wood. The colour is yellowish brown.

Topography — Wood diffuse-porous. *Growth-rings* absent. *Vessels* visible to the naked eye as white dots in cross-section, medium to large, forming prominent vessel lines along the grain, exclusively solitary (Pl. 1, Fig. 1,Text-Fig. 1), evenly distributed, 3-8 vessels per sq. mm., tylosed (Pl. 1, Fig. 1). *Tracheids* sparse, intermingled with paratracheal parenchyma, forming a narrow (1-2 seriate) interrupted sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma relatively sparse, intermingled with vasicentric tracheids, forming narrow sheath around the vessels, occasionally aliform, enclosing 2-3 vessels (Pl. 2, Fig. 5; Text-fig. 2); apotracheal parenchyma associated with vertical gum canals (Pl. 1, Fig. 1; Text-fig. 1), frequently extending laterally uniting with those of neighbouring gum canals, forming 3-6 (mostly 3-4) seriate bands reaching across a number of rays (Pl. 1, Fig. 1; Text-fig. 1); diffuse cells occasionally seen. *Xylem rays* fine to moderately broad,



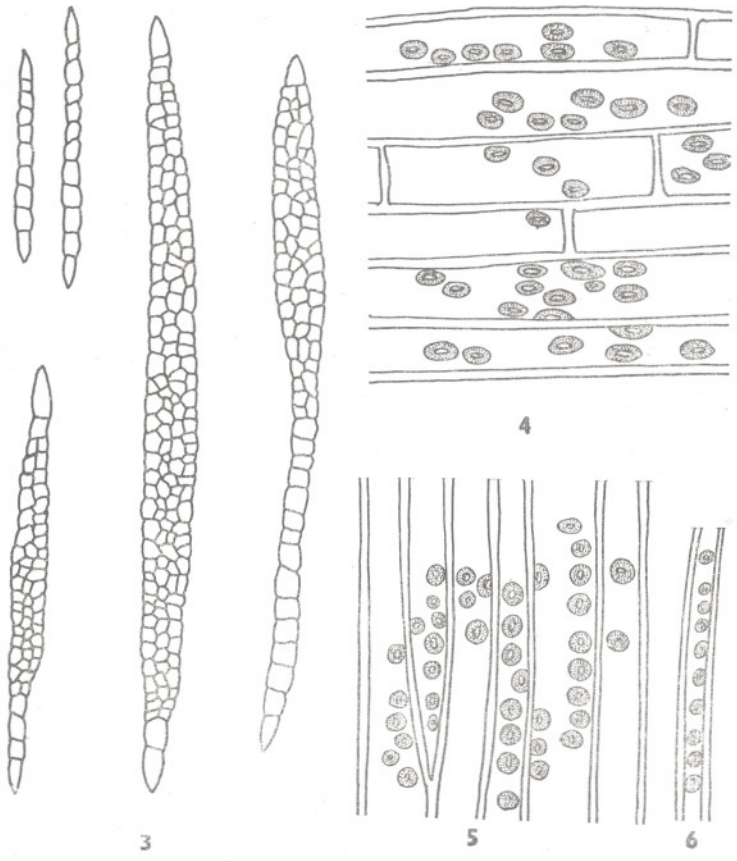
TEXT-FIG. 1 — Cross-section showing nature and distribution of gum canals. × 25.



TEXT-FIG. 2 — Another cross-section magnified to show vessels gum canals and parenchyma (stippled). × 70.

1-5 (mostly 3-4) seriate; ray tissue heterogeneous; uniseriate rays homocellular as well as heterocellular, consisting of upright cells as well as both upright and procumbent cells (Pl. 1, Fig. 3; Text-fig. 3), mostly 4-10 cells in height; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-several (mostly 1-5) uniseriate marginal rows of upright cells (Pl. 1, Fig. 3; Text-fig. 3), about 10-50 cells in height; sheath cells occasionally present. *Fibres* aligned in radial rows between the two consecutive xylem rays. *Gum canals* frequent, vertical, diffuse, enclosed by parenchyma, solitary and mostly in pairs as well as in short tangential rows of 3-8 (Pl. 1, Fig. 1; Text-fig. 1), occasionally upto 10, small, 5-10 per sq. mm.

Elements — *Vessels* circular to oval in cross-section, thin-walled, t.d. 120-370 μ, r.d. 150-345 μ; vessel-members 300-750 μ in length, with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows (Pl. 2, Fig. 6; Text-fig. 5), medium to large, 6-10 μ in diameter, vestured, aperture linear to lenticular; pits leading to contiguous ray cells oval, variable in shape and size, horizontally oriented, bordered, (Text-fig. 4), occasionally confluent, with wide aperture; vessel-parenchyma pits similar to vessel-ray pits; vessels filled with tyloses and crystalliferous contents. *Tracheidal cells* oval or peripherally flattened, 16-56 μ in diameter, nearly as long as fibres. *Parenchyma cells* those of paratracheal peripherally flattened, those associated with gum canals oval to angular, 80-120 μ in length; infiltration dark. *Ray cells* upright and procumbent; upright cells 48-80 μ in tangential height, 40-60 μ in radial length; procumbent cells 16-30 μ in tangential height, 48-100 μ in radial length. *Fibres* angular, mostly hexagonal in cross-



TEXT-FIGS. 3-6 — 3. Xylem rays. × 70. 4. Vessel-ray pits. × 300. 5. Vessel-tracheid pits. × 300. 6. Fibre with bordered pits. × 300.

section, 16-38 μ in diameter, nonseptate, thick-walled, with narrow lumen, common walls 6-10 μ in thickness, pits small, 2-3 μ in diameter, bordered, with circular or slit-like aperture (Text-fig. 6). *Gum canals* circular, upto 120 μ in diameter.

Affinities

Comparison with the modern woods: The important and the characteristic features of the present fossil wood are the presence of normal vertical and diffuse gum canals, exclusively solitary vessels, vasicentric tracheids, paratracheal and apotracheal parenchyma, 1-5 seriate heterocellular xylem rays and fibres with small bordered pits. These features indicate its affinities with the woods of *Dipterocarpus Anisoptera, Vatica* and *Vateria* of the family Dipterocarpaceae. However, on the basis of the size and arrangement of vessels and the size and frequency of gum canals *Vatica* and *Vateria* can be easily differentiated from the present fossil wood. The wood of *Anisoptera* also differs from it in having almost continuous rows of sheath cells in the rays, and moreover, the gum canals in *Anisoptera* are usually small and solitary. It is the genus *Dipterocarpus* with which it shows close similarity in all anatomical details. Detailed comparison of this fossil wood was made with the available thin sections and with the published description and illustrations of many species of *Dipterocarpus* (Moll & Janssonius, 1906, pp. 348-360; Desch, 1941, pp. 62-75, pl. 23-32 Reyes, 1938, pp. 280-296, Figs. 49-54). From this it was found that the present fossil wood shows closest resemblance with that of *Dipterocarpus indicus* Bedd., and hence placed under the genus *Dipterocarpoxylon* Holden emend. Den Berger. Since it is quite different from hitherto known species of *Dipterocarpoxylon* as discussed below, a new specific name *D. pondicherriense* is given to it. The specific name indicates its occurrence near Pondicherry.

Comparison with the fossil species — The genus *Dipterocarpoxylon* was instituted by Holden (1916) to include the fossil woods showing resemblance with those of Dipterocarpaceae. Since then several earlier workers (Kräusel, 1922a, 1922b, 1925, 1926; Edwards, 1931; Chiarugi, 1933) used this generic term in a comprehensive sense to include all the fossil woods of the Dipterocarpaceae, though most of them expressed their doubts about the accuracy of Holden's identification of the fossil wood upon which the genus *Dipterocarpoxylon* was based, because it did not possess the anatomical characters of the family Dipterocarpaceae. Later, Chowdhury (1952) examined the slides of *Dipterocarpoxylon burmense* Holden prepared from the original specimen, and found it very similar to those of *Gluta* and *Melanorrhoea* of the family Anacardiaceae. Therefore, he transferred it to the genus *Glutoxylon* Chowdhury. Earlier, Den Berger (1927) emended the diagnosis of *Dipterocarpoxylon*, retaining this term for the fossil woods resembling those of *Anisoptera* and *Dipterocarpus* of the Dipterocarpeae. In 1958 Ghosh and Kazmi instituted another genus, *Anisopteroxylon* to designate the fossil woods resembling that of *Anisoptera*, and since then the generic term *Dipterocarpoxylon* is used to assign only those fossil woods which show resemblance with those of the genus *Dipterocarpus*. Recently Prakash and Tripathi (1970) transferred *Anisoptera* type of fossil wood described by Chowdhury (1938) as *Dipterocarpoxylon garoense* to *Anisopteroxylon* Ghosh and Kazmi, and named it *Anisopteroxylon garoense* (Chowdhury). The following is a upto date list of the species referred to *Dipterocarpoxylon* described from India and abroad. This list includes the fossil woods resembling *Dipterocarpus* as well as some of *Anisoptera* type of woods placed under *Dipterocarpoxylon* by the earlier workers.

All these species posses a number of anatomical features similar to our fossil wood, *Dipterocarpoxylon pondicherriense*. However, these differ from it in some significant features. *Dipterocarpoxylon porosum, D. geopperti* differ in having broad rays, and less frequent solitary gum canals. In *D. kraeuseli, D. gracile, D. resiniferum* and *D. javanicum* the rays are homogeneous. *D. anisopteroides* being closely allied to *Anisoptera* differs in the possession of abundant diffuse parenchyma and moreover, the gum canals are exclusively solitary and few than in the present species. In *D. perforatum* the vessels are more crowded, i.e. their frequency is much more than in *D. pondicherriense*. In *D. africanum* the gum canals are large, their shape and size being almost the same as in *D. pondicherriense*. However, it differs from the latter in having the vessels in multiples of 3-4.

List of the fossil woods referred to *Dipterocarpoxylon* with their locality and age

	Name	*Locality*	*Age*
1.	*Dipterocarpoxylon porosum* (Stopes) Kräusel, 1922a	England	Aptian ?
	Schweitzer, 1958	Bedfordshire, Woburnsands, England	Lower Greensand?
2.	*D. kraeuscli* (Den Berger) Edwards, 1931	South Sumatra	Tertiary
	Schweitzer, 1958	W. Java	Pliocene
3.	*D. goepperti* Kräusel, 1926	Java	Tertiary
	Schweitzer, 1958	W. Java	Tertiary
4.	*D. africanum* Bancroft, 1933, Syns. 1935; Schweitzer, 1958	East Africa	Tertiary
	D. scevelianum Chiarugi, 1933		
	D. somalense Chiarugi, 1933	East Africa	Plio Pleistocene
	D. giubense Chiarugi, 1933		
5.	*D. schenki* (Felix) Schweitzer, 1958	Java	Tertiary
6.	*D. resiniferum* Schweitzer, 1958	W. Java	Pliocene
7.	*D. javanicum* (Hofmann) Schweitzer, 1958	North West of Java	Tertiary
8.	*D. gracile* Schweitzer, 1958	W. Java	Pliocene
9.	*D. perforatum* Schweitzer, 1958	Middle Sumatra	Quaternary
10.	*D. anisopteroides* Schweitzer, 1958	W. Java	Pliocene
11.	*D. chowdhurii* Ghosh, 1956	Assam, India	Tertiary
12.	*D. kalaicharparense* Eyde, 1963	Garo Hills, Assam, India	Tertiary
13.	*D. malavii* Ghosh & Ghosh, 1959	Kutch, India	Pliocene
14.	*D. tertiarum* Prakash, 1965b	Burma	Tertiary
15.	*Dipterocarpoxylon* sp. Rawat, 1964	Mohand near Dehra Dun, India	Middle Miocene

D. schenki can also be distinguished from *D. pondicherriense* in having smaller vessels and somewhat different distribution of gum canals.

Of the Indian species, *D. chowdhuri* and *D. malavii* differ from the present species in having abundant diffuse parenchyma and the sheath cells being more prominent. In *D. kalaicharparense* the gum canals are mostly solitary or occasionally in pairs, while in *D. pondicherriense* they are solitary, paired as well as in short tangential rows of 3-8 or rarely up to 10.

Dipterocarpoxylon sp. Rawat (1964) is also quite different from the present species, especially in having large gum ducts. In having abundant diffuse parenchyma *D. tertiarum* can also be differentiated from *D. pondicherriense*.

DIAGNOSIS

Dipterocarpoxylon pondicherriense sp. nov.

Wood diffuse-porous. *Growth-rings* absent. *Vessels* medium to large, t.d. 120-370 μ, r.d. 150-345 μ, exclusively solitary, about 3-7 vessels per sq. mm.; perforations simple; pits leading to contiguous tracheids vestured with linear to lenticular orifices, vessel-parenchyma and vessel-ray pits horizontally oriented, bordered, occasionally confluent; tyloses present. *Tracheids* intermingled with paratracheal parenchyma, forming a narrow sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma intermingled with tracheids, forming 1-2 seriate sheath around the vessels, occasionally aliform or tending to enclose 2-3 neighbouring vessels; apotracheal parenchyma associated with the gum canals, diffuse cells occasionally present *Xylem rays* 1-5 (mostly 1-4) seriate; ray tissue heterogeneous; multiseriate rays heterocellular, consisting of procumbent cells and 1-5 uniseriate marginal rows of upright cells at both the ends; sheath cells occasionally present; rays about 10-50 cells in height. *Fibres* nonseptate, thickwalled, pits small, bordered, with slit-like aperture. *Gum canals* frequent, diffuse, solitary, and in paired as well as in short tangential rows of 3-8, occasionally up to 10, 80-120 μ in diameter.

Holotype — B.S.I.P. Museum No. 33695
Locality — Between Murattandichavadi, Tiruchitambalam and Pattanur, 8-10 km. N.W. of Pondicherry.

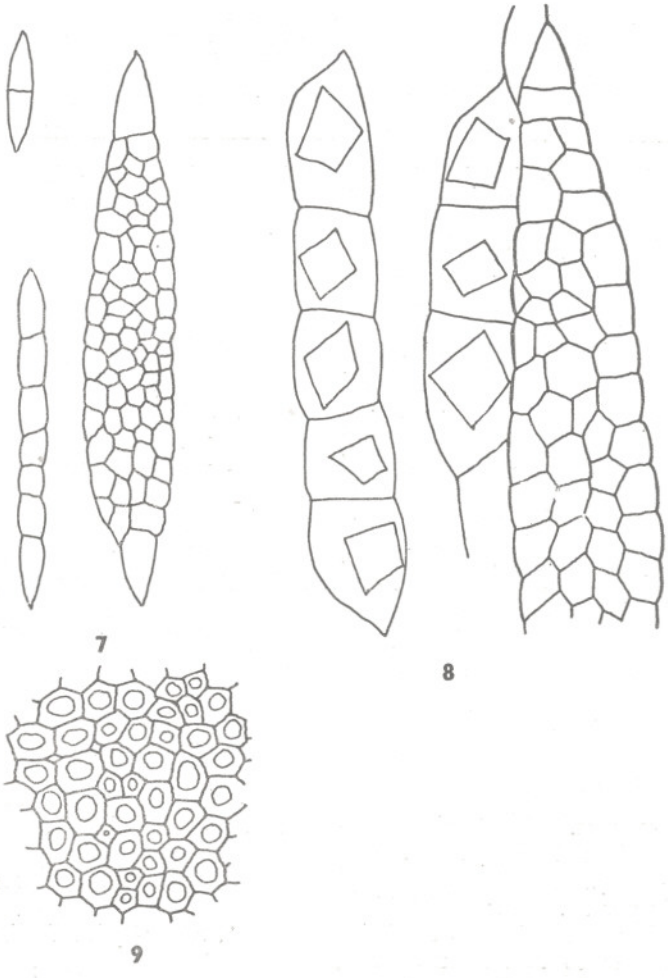
Genus *Shoreoxylon* Den Berger, 1923

2. *Shoreoxylon indicum* sp. nov.

Pl. 2, Figs. 7-11; Text-figs. 7-9

Material — Six pieces of well preserved silicified secondary wood.

Topography — *Wood* diffuse-porous. *Growth rings* indistinct, however, at places wide gap between two parenchyma bands indicates the presence of growth rings. *Vessels* visible to the naked eye, mostly medium to large, solitary and in radial multiples of 2-4 (Pl. 2, Figs. 8, 9), mostly solitary, vessel lines distinct along the grain, evenly distributed, 5-10 vessels per sq. mm., tyloses present (Pl. 2, Fig. 9). *Tracheids* vasicentric, intermingled with paratracheal parenchyma, difficult to distinguish in cross-section. *Parenchyma* abundant, paratracheal and apotracheal; paratracheal parenchyma vasicentric, aliform to aliform-confluent, often with numerous fine to broad and loose aliform-confluent bands (Pl. 2, Fig. 9), apotracheal parenchyma diffuse, usually forming 1-2 seriate irregular lines (Pl. 2, Fig. 9). *Xylem rays* fine to moderately broad, 1-6 seriate (Pl. 2, Fig. 10, Text-fig. 7); ray tissue heterogeneous; uniseriate rays few, homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells; multiseriate rays heterocellular, consisting of procumbent cells and 1-2 marginal rows of upright cells at one or both the end (Pl. 2, Figs. 10, 11; Text-fig. 7); rays up to 60 cells in height, 5-9 per mm. *Fibres* aligned in radial rows between two consecutive rays. *Gum canals* vertical, occurring in regular, concentric tangential rings, embedded in parenchyma bands (Pl. 2, Figs. 8, 9).



TEXT-FIGS. 7-9 — 7. Xylem rays. × 190. 8. Crystalliferous parenchyma strand. × 300. 9. Fibres in cross-section. × 300.

Elements — Vessels circular to oval (Pl. 2, Figs. 8, 9), t.d. 45-240 μ, r.d. 45-300 μ, thickwalled, common walls 8-16 μ in thickness; vessel-members short, 150-450 μ in length, with truncated ends; perforations simple; intervessel pits and pits leading to contiguous tracheids, parenchyma and ray cells large (Pl. 2, Fig. 7), 8-10 μ in diameter, circular to oval, bordered, vestured, apertures circular or lenticular (Pl 2, Fig. 7). *Tracheidal cells* oval to orbicular or peripherally flattened, 32-44 μ in diameter, 375-400 μ in length, pits similar to intervessel pits. *Parenchyma cells* 3-5 per strand, usually angular or oval in cross-section, those associated with gum canals tangentially flattened, 8-28 μ in diameter, 40-80 μ in length; crystalliferous parenchyma strands present with solitary crystal in each cell (Text-fig. 8); infiltration dark. Procumbent *Ray cells* circular in tangential section, 16-24 μ in tangential height, 52-120 μ in radial length, upright cells 40-60 μ in tangential height, 20-48 μ in radial length; infiltration dark. *Fibres* circular to oval, (Text-fig. 9), t.d. 8-20 μ, r.d. 8-18 μ, non-septate, thickwalled (Text-fig. 9), common walls 4-10 μ in thickness; pits simple. *Gum canals* circular, 40-120 μ in diameter.

AFFINITIES

Comparison with the modern woods: The above anatomical features of the fossil wood indicate its affinities with the woods of Dipterocarpaceae. In this family the concentric rings of gum canals are found in the woods of *Shorea, Doona, Hopea, Isoptera, Parashorea, Pentacme, Balanocarpus, Dryobalanops* and *Dioticarpus*. From a comparative study of the present fossil wood with the available thin-sections and published anatomical data of these genera (Desch, 1941, 1957; Kribs, 1959; Chowdhury & Ghosh, 1958; Henderson, 1953; Metcalfe & Chalk, 1950; Pearson & Brown, 1932; Moll & Janssonius, 1906; Reyes, 1938) it has been found that the fossil wood approaches to *Shorea, Parashorea* and *Pentacme*. Out of the species of *Parashorea* and *Pentacme*, the fossil wood shows somewhat similar anatomical details as exhibited by *Parashorea stellata* and *Pentacme sauvis*. *Parashorea stellata* and the present fossil, both possess vessels solitary as well as in radial multiples; vasicentric tracheids; parenchyma vasicentric and aliform, aliform-confluent to confluent, forming bands, often in regular, uniseriate to biseriate lines; rays 1-5 seriate, heterogeneous; fibres thick walled, non-septate, with simple pits, gum canals arranged in several concentric rings. Similarly, *Pentacme sauvis* has also many features common with the present fossil. Besides other characters, both have even similar type of crystalliferous parenchyma strands closely associated with xylem rays. Among the woods of *Shorea* it resembles *Shorea obtusa* in almost all the structural details. Thus our fossil wood has got close resemblance with *Shorea obtusa, Parashorea stellata* and *Pentacme sauvis*. In view of this, it is placed under the genus *Shoreoxylon* Den Berger and named as *S. indicum* sp. nov.

Comparison with the fossil species — So far a large number of fossil woods have been described under *Shoreoxylon* from India and abroad as listed below.

From a detailed comparison with the above species of *Shoreoxylon* it has been found that the present species (*S. indicum*) is quite different from them. It is characterized by abundant, diffuse, loosely banded parenchyma, so much of parenchyma is not present in any of the hitherto known species. Of the Indian species, *S. kraeuseli* described by Ramanujam and Rao (1969) from the same area resembles the present fossil in most of the features. However, it differs from *S. kraeuseli* in having heterocellular rays consisting of 1-2 marginal rows of upright cells at one or both the ends.

DIAGNOSIS

Shoreoxylon indicum sp. nov.

Wood diffuse-porous. *Growth-rings* indistinct, however, at places wide gap between two parenchyma bands indicates the presence of growth rings. *Vessels* mostly medium to large, t.d. 45-240 μ, r.d. 45-300 μ, solitary and in radial multiples of 2-5 (mostly 2-3); perforations simple; intervessels pits and pits leading to contiguous tracheids, parenchyma and rays usually large, 8-10 μ in diameter, circular to oval, bordered with circular or lenticular, horizontal to oblique orifices; tyloses present. *Tracheids* vasicentric, forming 1-2 seriate sheath around the vessels. *Parenchyma* abundant, paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform,

List of the fossil woods referred to *Shoreoxylon* with their locality and age

	Name	*Locality*	*Age*
1.	*Shoreoxylon palembangense* (Kräusel) Den Berger, 1923	South Sumatra	Pliocene
2.	*S. djambiense* Den Berger, 1923	South Sumatra	Tertiary
	Schweitzer, 1958	West Java	Pliocene
3.	*S. moroides* Den Berger, 1927	Java	Pliocene
4.	*S. swedenborgi* (Schuster) Schweitzer, 1958	East Indies	Pliocene
5.	*S. asiaticum* Schweitzer, 1958	Sumatra	Pliocene
6.	*S. maximum* Schweitzer, 1958	Middle Sumatra	Pliocene
7.	*S. parvum* Schweitzer, 1958	W. Java	Pliocene
8.	*S. multiporosum* Schweitzer, 1958	Middle Sumatra	Quaternary
9.	*S. pulchrum* Schweitzer, 1958	Middle Sumatra	Quaternary
10.	*S. posthumi* Schweitzer, 1958	Middle Sumatra	Quaternary
11.	*Shoreoxylon* cf. *posthumi* Schweitzer, 1958	Sumatra	Tertiary
11.	*S. speciosum* Navale, 1963	South India	Miocene-Pliocene
12.	*S. evidens* Eyde, 1963	Garo Hills, Assam	Miocene
13.	*S. burmense* Prakash, 1965a	Burma	Tertiary
14.	*S. kraeuseli* Ramanujam & Rao, 1967, 1969	Pondicherry, India	Miocene-Plicoene
15.	*S. tipamense* Prakash & Awasthi, 1970	Jaipur, Assam, India	Miocene-Plicoene
16.	*S. deomaliense* Prakash & Awasthi, 1971	Deomali, NEFA, India	Miocene-Plicoene

aliform-confluent or in regular bands; apotracheal parenchyma abundant, diffuse, usually forming 1-2 seriate lines. *Xylem rays* 1-6 seriate; ray tissue heterogeneous; rays homocellular to heterocellular, consisting of procumbent cells and 1-2 marginal rows of upright cells at one or both the ends, rays up to 60 cells in height. *Fibres* small, 8-20 μ in diameter, nonseptate, thick-walled, common walls 4-10 μ in thickness. *Gum canals* vertical, occurring in regular, concentric rings, circular, 40-120 μ in diameter.

Holotype — B.S.I.P. Museum No. 33696.

Locality — Between Murattandichavadi and Kasipalaiyam, about 8-10 km. N.W. of Pondicherry.

3. *Shoreoxylon arcotense* sp. nov.

Material — Single piece of well preserved secondary wood measuring 22 cm. in length and 14 cm. in diameter.

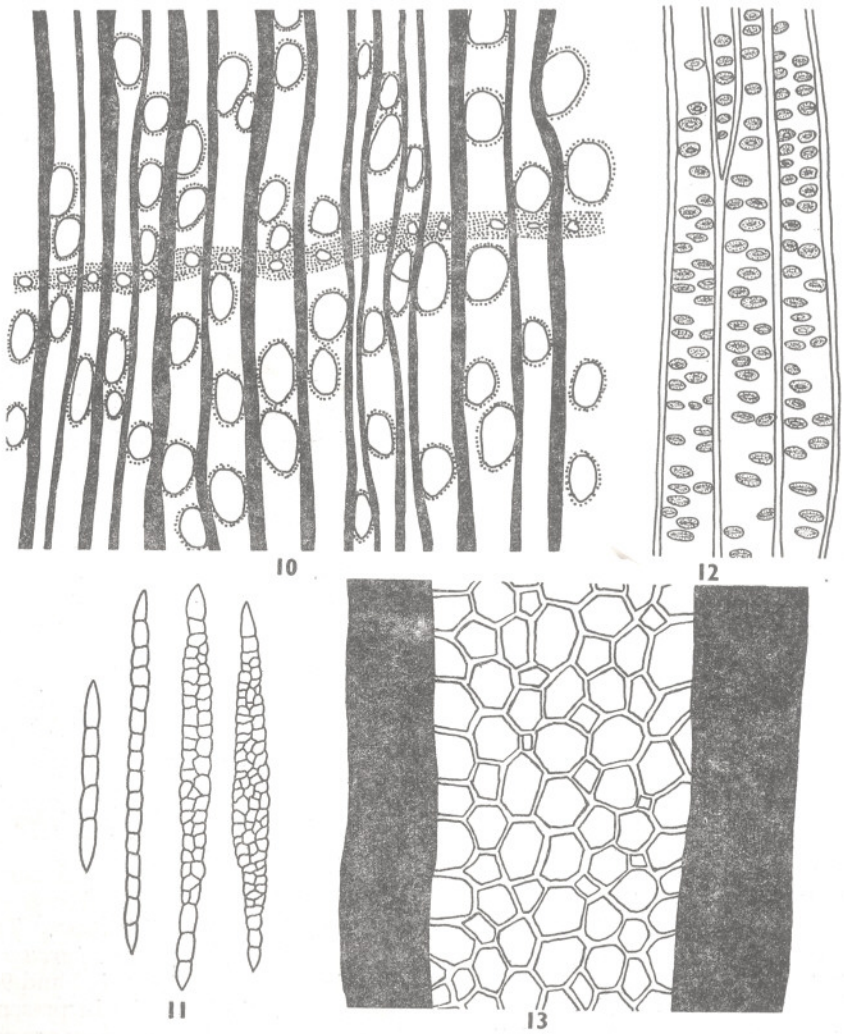
Topography — Wood diffuse-porous. *Growth rings* not seen. *Vessels* visible to the naked eye as small dots, small to medium (mostly medium) in size, almost exclusively solitary (Pl. 3, Figs. 12, 13), very rarely in multiples of two, evenly distributed; about 15-20 vessels per sq. mm., tyloses present. *Tracheids* not distinguishable in cross-section from paratracheal parenchyma, forming 1-2 seriate sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, sometimes indistinguishable in cross-section from the neighbouring fibrous cells and vasicentric tracheids; however, strands seen in tangential longitudinal section, forming 1-2 seriate vasicentric sheath intermingled with tracheids; apotracheal parenchyma associated with gum canals, forming concentric, tangential lines (Pl. 3, Figs. 12, 13), each 2-4 cells wide. *Xylem rays* fine to moderately broad, 12-60 μ wide, 1-4 (mostly 2-3) seriate (Pl. 3, Fig. 14); ray tissue heterogeneous; uniseriate rays frequent, homocellular to heterocellular, consisting wholly of upright cells or both upright and procumbent cells (Text-fig. 11); multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-6 marginal rows of upright cells at one or both the ends (Pl. 3, Figs. 14-15; Text-fig. 11); uniseriate rays 2-15 cells in height, multiseriate rays about 12-40 cells in height. *Fibres* aligned in radial rows between two consecutive xylem rays. *Gum canals* vertical, occurring in concentric, regular tangential rings, embedded in apotracheal parenchyma bands (Pl. 3, Figs. 12-13; Text-fig. 10).

Elements — Vessels circular to oval in cross-section, t.d. 45-165 μ, r.d. 45-195 μ, thinwalled, 4-6 μ in thickness; vessel-members 300-675 μ in length, with truncated or slightly tapered ends; perforations simple; pits leading to contiguous tracheids large, bordered, about 8-10 μ in diameter, vestured, with linear to lenticular aperture (Pl. 3, Fig. 16); pits leading to contiguous parenchyma and rays similar to vessel-tracheid pits, sometimes confluent; crystalliferous

content present in the vessels. *Tracheidal cells* small, oval to orbicular, 16-24 μ in diameter; pits similar to vessel-tracheid pits (Text-fig. 12). *Parenchyma cells* circular to oval, diameter nearly same as of tracheids, those associated with gum canals rectangular to squarish. Upright *Ray cells* 48-80 μ in tangential height, 32-48 μ in radial length; procumbent cells 20-24 μ in tangential height, 40-75 μ in radial length. *Fibres* angular or hexagonal (Text-fig. 13), 12-24 μ in diameter, non-septate, thin-walled, common walls 2-3 μ in thickness; pits simple. *Gum canals* circular, 40-60 μ in diameter.

AFFINITIES

Comparison with the modern woods — The above anatomical features of the present fossil wood indicate its affinities with the woods of the family Dipterocarpaceae. As it has already been mentioned in the forgoing account that the concentric ring of gum canals are found in *Shorea, Doona, Dryobalanops, Parashorea, Pentacme, Balanocarpus* and *Dioticarpus* (*Hopea*). Considering other anatomical details as well, most of these genera can be easily eliminated from comparison with the present fossil wood. It is the only genus *Shorea* with which the fossil wood



TEXT-FIGS. 10-13 — 10. Cross-section showing the nature and distribution of vessels and parenchyma (stippled). × 45. 11. Xylem rays. × 70. 12. Vessel-tracheid pits. × 300. 13. Fibres in cross-section. × 300.

has been found to resemble most. In order to find out the nearest modern equivalent of the present fossil wood the author examined the thin-sections of woods of the following species of *Shorea* available at the xylarium of the Forest Research Institute, Dehra Dun and at the Birbal Sahni Institute of Palaeobotany, Lucknow.

1. *Shorea argentea* C.E.C. Fischer
2. *S. buchananii* C.E.C. Fischer
3. *S. ciliata* King
4. *S. dealbata* Foxw.
5. *S. feguetiana* Heim.
6. *S. farinosa* C.E.C. Fischer
7. *S. gibbosa* Brand.
8. *S. gratissima* Dyer
9. *S. guiso* Bl.
10. *S. hypoleuca* Meijer
11. *S. lamellata* Foxw.
12. *S. macroptera* Dyer
13. *S. mindanensis* Foxw.
14. *S. minor*
15. *S. oblongifolia* Thw.
16. *S. obtusa* Wall.
17. *S. oleosa* Meijer
18. *S. ovalis* Bl.
19. *S. plagata* Foxw.
20. *S. polita* Vidal
21. *S. robusta* Roth.
22. *S. scrobiculata* Burck
23. *S. seminis* V. Stooten
24. *S. superba* Sym.
25. *S. talura* Roxb.
26. *S. tumbuggaia* Roxb.
27. *S. almon* Foxw.
28. *S. assamica* Dyer
29. *S. acuminata* Dyer
30. *S. agsaboensis* W.L. Stern
31. *S. fallax* Meijer
32. *S. gysbertsiana* Burck
33. *S. kalunti* Merr.
34. *S. leprosula* Miq.
35. *S. leptoclados* Sym.
36. *S. palosopsis* Merr.
37. *S. negroscensis*
38. *S. parvifolia* Dyer
39. *S. pauciflora* King
40. *S. philippinensis* Brand.
41. *S. polysperma* Merr.
42. *S. serieciflora* C.E.C. Fischer & Hutch.
43. *S. stipularis* Thw.
44. *S. squamata* Benth. & Hook.
45. *S. smithiana* Sym.
46. *S. teysmaniana* Dyer
47. *S. waltonii* G.H.S. Wood ex Meijer
48. *Shorea* sp. (F.M.S.)
49. *Shorea* sp. (Java)

Of these, the first 26 species can be easily eliminated from comparison with the present fossil as they possess very thick to thick-walled fibres with narrow lumen which seems one of the distinctive features of these species. Since in the present fossil wood the fibres are thin-walled its modern allies can be searched out from the remaining 23 species having similar thin-walled fibres with wide lumen. However, considering other important anatomical features such as the shape, size, distribution of vessels, parenchyma and the xylem rays there is a close agreement in all the anatomical details between the present fossil wood and *Shorea acuminata* Dyer *Shorea* sp. F.M.S. (F.R.I., Dehra Dun slide No. F. 51).

It has been seen that none of the Indian shoreas shows a close similarity with the present fossil wood. *Shorea assamica*, which grows in Assam, resembles the fossil in having thin-walled fibres with wide lumen; however, it differs in several details, such as in the size, shape and the distribution of vessels and parenchyma. In view of its close similarity with the genus *Shorea* it has been placed under the genus *Shoreoxylon* Den Berger and named as *Shoreoxylon arcotense* sp. nov., after South Arcot district. It differs from hitherto known species of *Shoreoxylon* as discussed below.

Comparison with the fossil woods — All the species of *Shoreoxylon* listed on page 346 resembles the present species in several anatomical features. However, they differ from it in some important features. *Shoreoxylon asiaticum* is different in possessing horizontal gum canals in the rays besides the concentric rings of vertical canals. Moreover, the vessels in *S. asiaticum* are large, with t.d. 200-350 μ, r.d. up to 375 μ. The vessels in *S. maximum*, *S. multiporosum*, *S. djambiense*, *S. speciosum*, *S. palembangense* and *S. moroides* are large to very large while in *S. arcotense* they are small to medium-sized. In *S. evidens* the vessels are usually in multiples and the fibres are thick-walled. In *S. posthumi* the rays are 1-5 seriate and short, 20-30 cells in height, and the fibres are thick-walled with 3-8 μ in thickness. The xylem rays in *S. pulchrum* and *S. parvum* are very high, i.e. they are up to 100 and 94 cells in height respectively, while in present species they are not so high (i.e. they are only up to 45 cells in height). *S. swedenborgi* is quite different from it in having broad tangential

band of parenchyma consisting of double rings of gum canals. In *S. burmense* the xylem rays are comparatively broad than in *S. arcotense*. In *S. speciosum* the paratracheal parenchyma is more than in the present species. The xylem rays in *S. speciosum* are also different in having usually single row of marginal upright cell at both the ends, whereas in *S. arcotense* they are more than one in a row. *S. indicum* (described in the preceding pages) and *S. kraeuseli* also differ from the present species particularly in having abundant paratracheal and apotracheal parenchyma.

DIAGNOSIS

***Shoreoxylon arcotense* sp. nov.**

Wood diffuse-porous. *Vessels* small to medium (mostly medium) in size, t.d. 45-165 μ, r.d. 45-195 μ, exclusively solitary, rarely in multiples of 2, 15-20 vessels per sq. mm., perforations simple; pits leading to contiguous tracheids 8-10 μ in diameter, bordered, vestured with lenticular apertures; pits leading to contiguous parenchyma and ray cells slightly more in horizontal diameter; tyloses present. *Vasicentric tracheids* forming 1-2 seriate sheath around the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, only a few cells associated with the vessels, intermingled with vasicentric tracheids; apotracheal parenchyma represented by thin bands enclosing the concentric rings of gum canals, each 2-4 cells in width. *Xylem rays* 1-4 seriate; ray tissue heterogeneous; uniseriate rays frequent, homocellular to heterocellular; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-5 marginal rows of upright cells at one or both the ends; rays 4-40 cells in height; sheath cells occasionally present. *Fibres* 12-24 μ in diameter, nonseptate, thinwalled, common walls 2-3 μ in thickness; pit simple, minute. *Gum canals* vertical, in concentric rings, 40-60 μ in diameter.

Holotype — B.S.I.P. Museum No. 33697.

Locality — Between Murattandichavadi and Kasipalaiyam, about 8-10 km. N.W. of Pondicherry.

DISCUSSION

The genus *Dipterocarpus* Gaertn, f. consists of about 80 species (Willis, 1966 p. 222), distributed throughout the Indo-Malayan region, having maximum development in Borneo, Malay Peninsula and Sumatra. The range of its distribution is from South India and Ceylon in the West to Philippines in the east. About 13 species grow in the Indian region (India, Bangladesh, Ceylon and Andamans), which are large to very large trees of commercial value. In south India only 2 species occur, viz. *Dipterocarpus indicus* Bedd. and *D. bourdilloni* Brand. *Dipterocarpus indicus* Bedd. with which the present fossil wood of *Dipterocarpus* resembles most is one of the chief elements of the evergreen tropical rain forests, occurring in the Western Ghats from Kanara Southwards, Malabar and Travancore, common in South Kanara at the foot of the Hills elevation up to 900 m., especially in south Travancore. *Pentacme* A.D.C. is a small genus consisting of 3 species (Willis, *l.c.*, p. 844), with a very irregular distribution in South-East Asia. *Pentacme sauvis* A.D.C. grows in Burma, Indochina, Thailand and Malay Peninsula, while *P. contorta* (Vidal) Merr. et Roelfe and *P. mindanensis* Foxw. occur in Philippines. The genus *Parashorea* is represented by 11 species (Willis, *l.c.*, p. 833), occurring over a wide area from Burma, Western limit to Borneo and the Philippines in the east. Only one species, i.e. *P. stellata* occurs in Burma. None of these two genera (*Pentacme* and *Parashorea*) is found in India proper. *Shorea* Foxb. is comparatively a large genus consisting of about 180 species (Willis, *l.c.*, p. 1036), distributed throughout sourth-East Asia, starting from Ceylon and India on the West and throughout Burma and other countries of the South-East Asia. However, the greatest concentration of the species is met within Borneo, Sumatra, and Malay Peninsula. There are about 10 species occurring in the Indian region, of which *Shorea robusta* Roxb., *S. assamica* Dyer, *S. talura* Foxw. and *S. tumbuggaia* Roxb. are found in India proper. Those shoreas which have been shown to be the nearest modern equivalents of the fossil woods described in the present paper are confined to the Malayan region. Besides these, Awasthi (1970) also identified another Malayan genus *Dryobalanops*, collected from the same area of Pondicherry. Unlike *Dipterocarpus* and *Shorea* the present distribution of *Dryobalanops* is very restricted. It occurs only in the tropical rain forests of West Malaya, Sumatra and Borneo.

Among the Dipterocarpaceae the genus *Dipterocarpus* is one which has been found so far in almost all the Neogene deposits of India, indicating undoubtedly the existence of tropical rain forest over a large part of the country during the Miocene-Pliocene epochs. On the basis of the occurrence of fossil dipterocarps alone it may also be imagined that along the eastern coast of South India, at least around Pondicherry, the physical conditions under which the plants grew during that time were somewhat similar to the present physical conditions prevailing in the Western coast (Kanara, Malabar and Travancore) of South India, and in the Malayan region since the modern equivalents of the fossil dipterocarps of the Cuddalore series of Pondicherry are chiefly confined to the tropical rain forests of these regions. Detailed account regarding the palaeoecology, phytogeography and other related aspects of the Tertiary flora of India with special reference to the flora of the Cuddalore series and the significance of the occurrence of Malayan dipterocarps and other Malayan plants in the Cuddalore series will be published later separately when this flora is completely worked out.

ACKNOWLEDGEMENT

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REFERENCES

AWASTHI, N. (1971). Revision of some dipterocarpaceous woods previously described from the Tertiary of South India. *Palaeobotanist.* **18**(3): 226-233, 1969.

Idem (MS). Revision of some dicotyledonous woods from the Tertiary of South India.

BANCROFT, H. (1933). A contribution to the geological history of the Dipterocarpaceae. *Geol. För. Stockh. Förh.* **55** (1): 59-100.

Idem (1935). Some fossil dicotyledonous woods from Mount Elgon, East Africa. I. *Am. J. Bot.* **22** (2): 164-183.

CHIARUGI, A. (1933). Legni Fossili della Somalia Italiana. *Palaeontographica Ital.* 32(1): 97-167.

CHOWDHURY, K. A. (1938). Two fossil dicotyledonous woods from the Garo Hills, Assam. *Rec. geol. Surv. India.* **73** (II): 247-266.

Idem (1952). Some more fossil wood of *Glutoxylon* from South-east Asia. *Ann. Bot. N.S.* **16**(63): 73-78.

CHOWDHURY, K. A. & GHOSH, S. S. (1958). Indian Woods **1**. *Dehra Dun.*

DEN BERGER, L. C. (1923). Fossils houtsoorten nit het Tertiair van Zuid-Sumatra. *Verh. geol mijnb. Genoot. Ned.* **7**: 143-148.

Idem (1927). Unterscheidungsmerkmale von rezenten und fossilen Dipterocarpaceengattungen. *Bull. Jard. bot. Buitenz.* (Ser. 3). **8**: 495-498.

DESCH, H. E. (1941) Dipterocarp timbers of the Malay Peninsula. *Malay For. Rec.* **14**

Idem (1957). Manual of Malayan timbers. **1**. *Malay For. Rec.* **15**: 1-328.

EDWARDS, W. N. (1931). Dicotyledones (Ligna). *Foss. Cat.* II (Plantae). **17**: 1-96.

EYDE, R. H. (1963). *A Shoreoxylon* and two other Tertiary woods from the Garo Hills, Assam. *Palaeobotanist.* **11**(1-2): 115-121, 1962.

GHOSH, S. S. (1956). On a fossil wood belonging to the genus *Dipterocarpus. Sci. Cult.* **21**: 691-692.

GHOSH, S. S. & GHOSH, A. K. (1959). *Dipterocarpoxylon malavii* sp. nov. a new fossil record from the Pliocene of Kutch. *Ibid.* **25**: 328-332.

GHOSH, S. S. & KAZMI, M. H. (1958). *Anisopteroxylon bengalensis* gen. et sp. nov. — a fossil wood from Microlithic site of West Bengal. *Ibid.* **23** (9): 485-487.

HENDERSON, F. Y. (1953). An atlas of end-grain photomicrographs for the indentification of hardwoods. *Bull. Forest Prod. Res. Lond.* **26**: 1-87.

Holden, R. (1916). A fossil wood from Burma. *Rec. geol. Surv. India.* **47**: 267-272.

KRÄUSEL, R. (1922a). " Uber einen fossilen Baumstamm von Bolang (Java), ein Beitrag zur Kenntnis der fossilen Flora Niederlandisch-Indiens ". *Proc. Sect. Sci.* **25**: 9-14.

KRÄUSEL, R. (1922b). Fossil Holzer aus dem Tertiar von Dud-Sumatra. *Verh. geol mijnb. Genoot. Ned.* **5**: 231-281.

Idem (1925). Derstand unserer Kenntnisse vonder Tertiar flora Niederlandisch-Indiens. *Ibid.* 8: 329-349.

Idem (1926). Uber einige fossile Holzer aus Java. *Leidsche Geol. Med.* **2** (1): 1-6.

KRIBS, D. A. (1959). Commercial foreign woods on the American market. *Pennsylvania.*

METCALFE, C. R. & CHALK, L. (1950). Anatomy of the dicotyledons. **1**: *Oxford.*

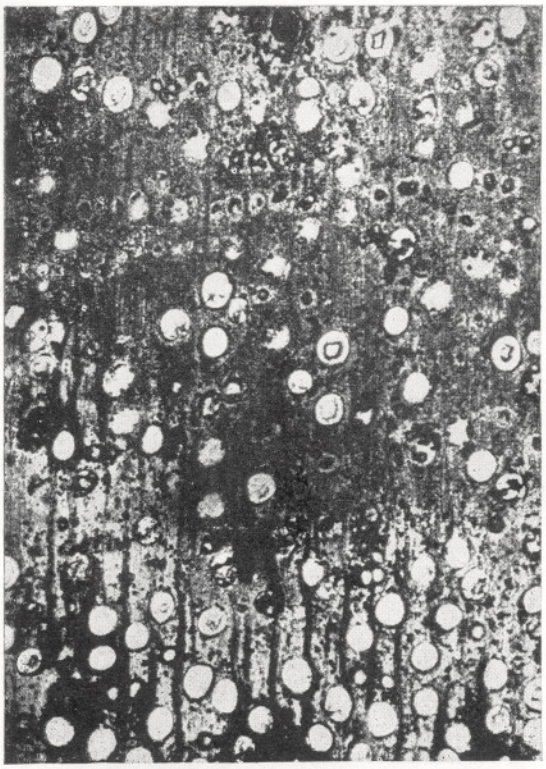
MOLL, J. W. & JANSSONIUS, H. H. (1906). Mikrographie des Holzer der auf Java Vorkommenden Baumarten. **1**: *Leiden.*

NAVALE, G. K. B. (1963). Some silicified dipterocarpaceous woods from Tertiary beds of the Cuddelore series near Pondicherry, India. *Palaeobotanist.* **11**(1-2): 66-81, 1962.

PEARSON, R. S. & BROWN, H. P. (1932). Commercial timbers of India. **1**. *Calcutta.*

PRAKASH, U. (1965a). Fossil wood of Dipterocarpaceae from the Tertiary of Burma. *Curr. Sci.* **34**(6): 181-182.

Idem (1965b). *Dipterocarpoxylon tertiarum* sp. nov., a new fossil wood from the Tertiary of Burma *Ibid.* **34**(8): 254-255.



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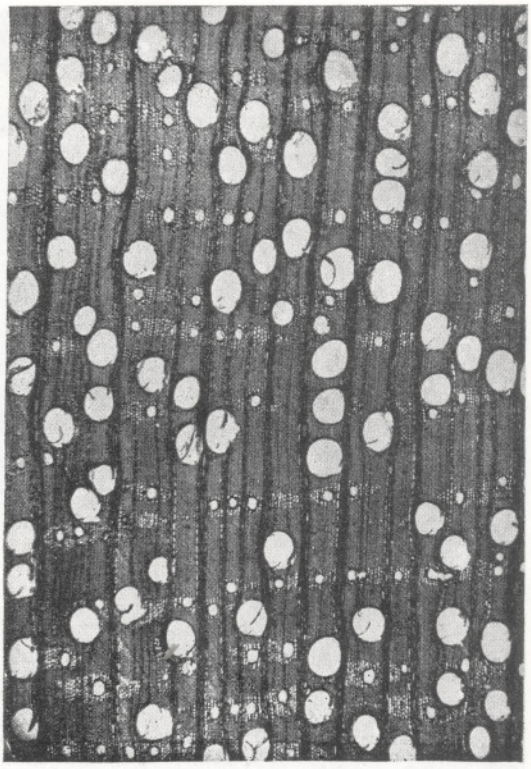

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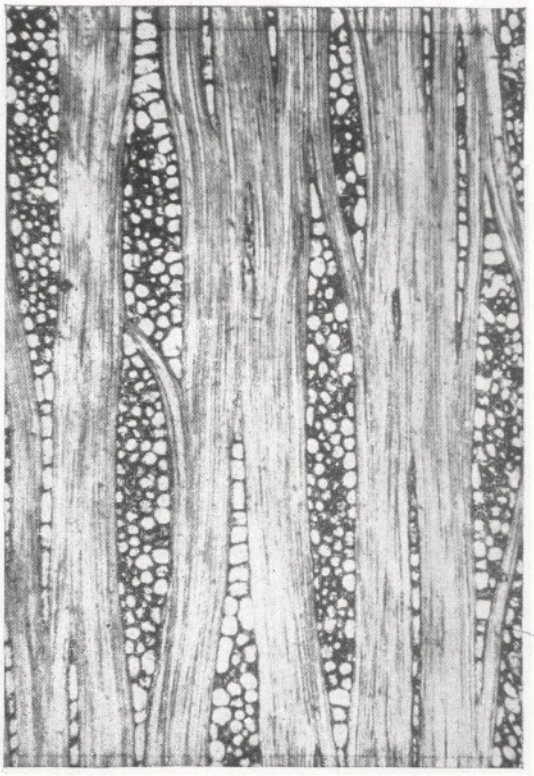

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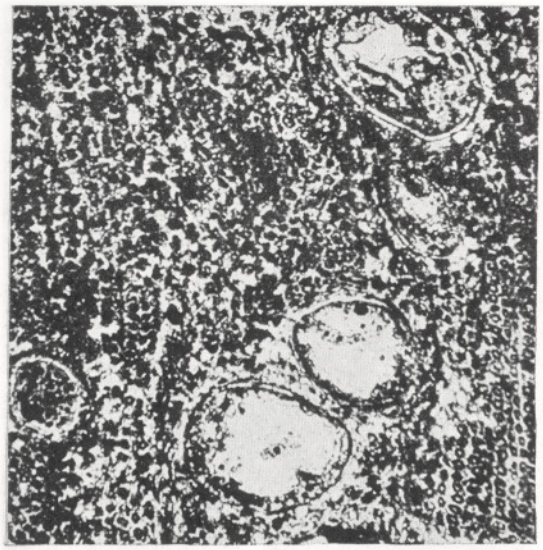

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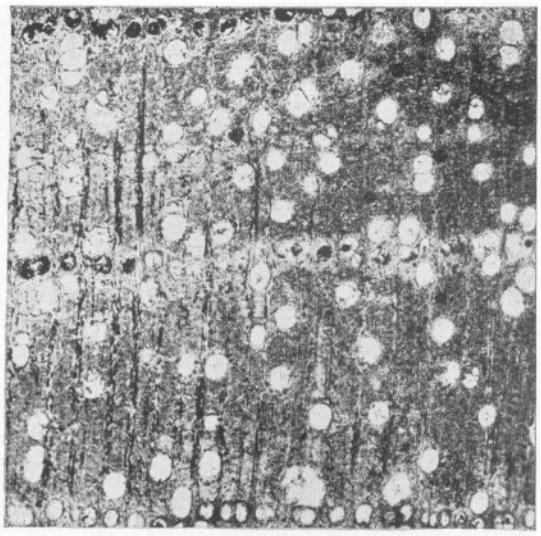

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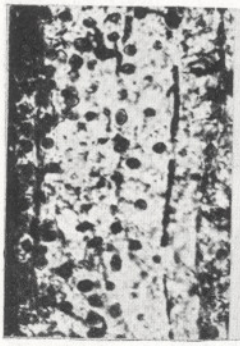

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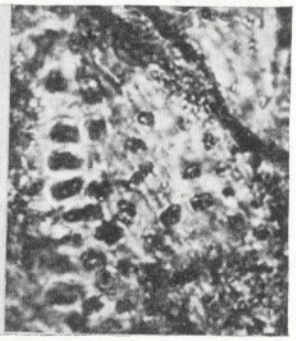

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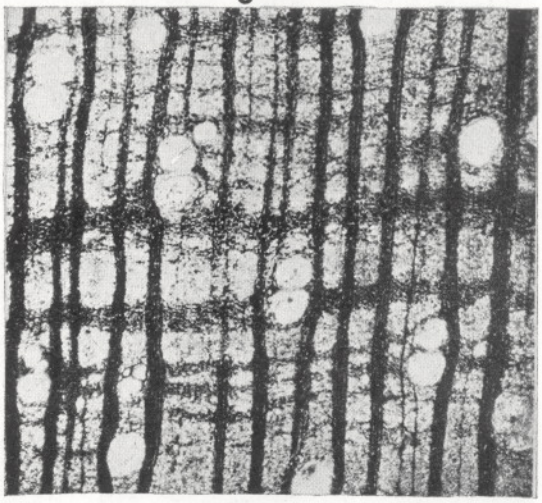

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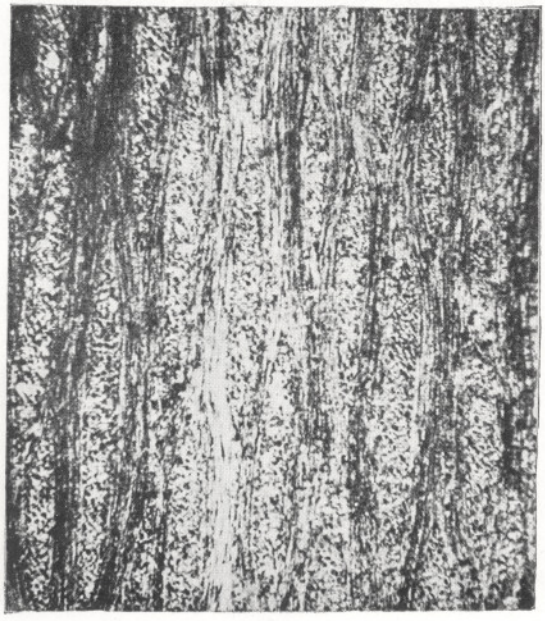

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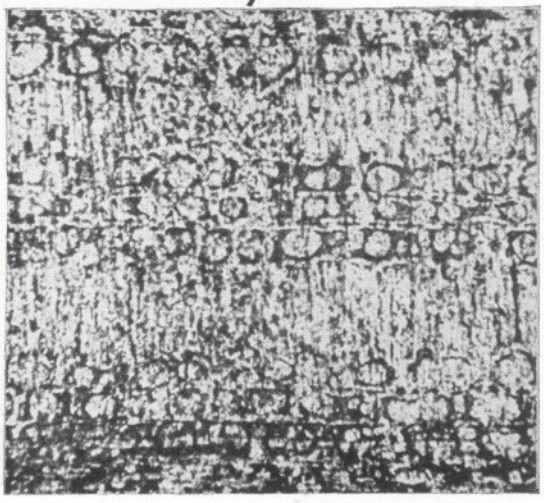

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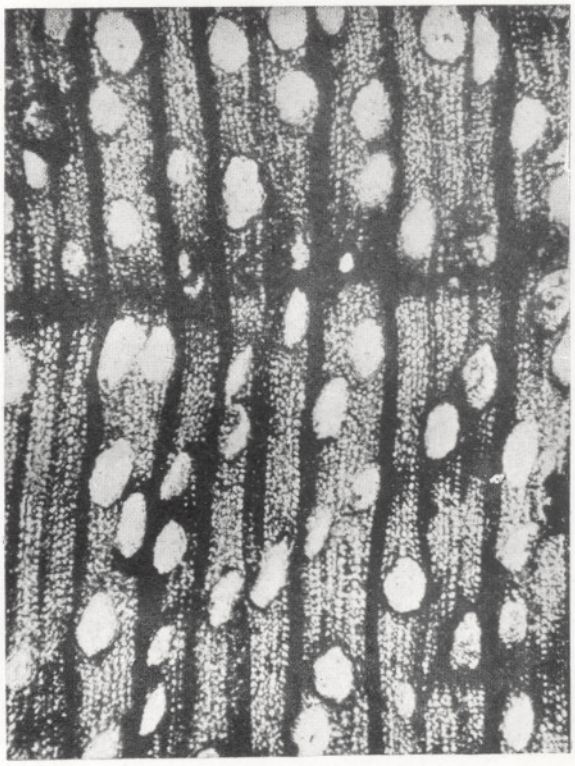

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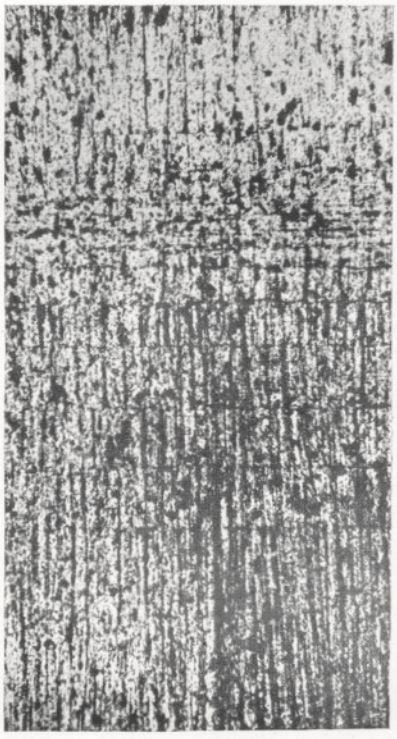

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16

PRAKASH, U. & AWASTHI, N. (1970). Fossil woods from the Tertiary of Eastern India. 1. *Palaeobotanist.* **18**(1): 32-44, 1969.

Idem (1971). Fossil woods from the Tertiary of Eastern India 11. *Ibid.* **18**(3): 219-225, 1969.

PRAKASH, U. & TRIPATHI, P. P. (1970). Fossil woods from the Tipam Sandstones near Hailakandi, Assam. *Ibid.* **18**(2): 183-191.

RAMANUJAM, C. G. K. (1956). Fossil woods of Dipterocarpaceae from the Tertiary of South Arcot District, Madras. *Ibid.* **4**: 45-56, 1955.

Idem (1960). Silicified woods from the Tertiary rocks of South India. *Palaeontographica.* **106B**: 99-140.

Idem (1966). A further investigation of the ligneous fossils of Combretaceae from South India *Palaeobotanist.* **14**(1-3): 246-255, 1965.

RAMANUJAM, C. G. K. & RAO, M. R. R. (1967). A new species of *Shoreoxylon, S. kraeuseli* sp. nov. from the Tertiary of South India, *Curr. Sci.* **36** (16): 439-441.

Idem (1969). *Shoreoxylon kraeuseli* sp. nov. a new dipterocarpaceous wood from the Cuddalore Series of South India. In *J. Sen. Memorial Volume,* Bot. Soc. Beng. Calcutta: 253-258.

RAWAT, M. S. (1964). A new species of *Dipterocarpoxylon* from Siwalik formation of Uttar Pradesh. *Sci. Cult.* **30**: 337-338.

REYES, L. J. (1938). Philippine woods. *Tech. Bull. Dep. Agric. Philipp. Is,* 7:

SCHWEITZER, H. J. (1958). Die fossilen Dipterocarpaceen-Holzer. *Palaeontographica.* **105B**: 1-66.

WILLIS, J. C. (1966). A dictionary of the flowering plants and ferns. *Cambridge.*

EXPLANATION OF PLATES

PLATE 1

1. *Dipterocarpoxylon pondicherriense* sp. nov. Cross-section showing nature and distribution of vessels and xylem rays. × 15. B.S.I.P. Museum. Slide No. 4462.

2. *Dipterocarpus indicus* Bedd. Cross-section showing similar type and distribution of xylem rays × 15.

3. *Dipterocarpoxylon pondicherriense* sp. nov. Tangential longitudinal section showing xylem rays. × 72. B.S.I.P. Museum Slide No. 4464.

4. *Dipterocarpus indicus* Bedd. Tangential longitudinal section showing similar type of xylem rays. × 72.

PLATE 2

5. *Dipterocarpoxylon pondicherriense* sp. nov. Magnified cross-section showing paratracheal parenchyma and vasicentric tracheids. × 70. B.S.I.P. Museum Slide No. 4463.

6. *Dipterocarpoxylon pondicherriense* sp. nov. Vessel-tracheid pits. × 240. B.S.I.P. Museum Slide No. 4464.

7. *Shoreoxylon indicum* sp. nov. Intervessel pits. × 680. B.S.I.P. Museum Slide No. 4466.

Shoreoxylon indicum sp. nov.

8. Cross-section showing nature and distribution of vessels and gum canals. × 15. B.S.I.P. Museum slide No. 4465.

9. Another cross-section showing nature and distribution of vessels and parenchyma. × 28. B.S.I.P. Museum Slide No. 4465.

10. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. Museum Slide No. 4466.

11. Radial longitudinal section showing heterocellular xylem rays. × 55. B.S.I.P. Museum Slide No. 4467.

PLATE 3

Shoreoxylon arcotense sp. nov.

12. Cross-section under low magnification to show the nature and distribution of vessels and gum canals. × 8. B.S.I.P. Museum Slide No. 4468.

13. Another cross-section showing vessels and gum canals. × 50. B.S.I.P. Museum Slide No. 4468.

14. Tangential longitudinal section showing xylem rays. × 100. B.S.I.P. Museum Slide No. 4469.

15. Radial longitudinal section showing heterocellular xylem rays. × 100. B.S.I.P. Museum Slide No. 4470.

16. Vessel-tracheid pits. × 600. B.S.I.P. Museum Slide No. 4471.