FOSSIL WOODS OF LEGUMINOSAE FROM TERTIARY ROCKS OF THE CUDDALORE SERIES NEAR PONDICHERRY, INDIA

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ABSTRACT

The present paper describes the structural details of the three new fossil woods collected near Pondicherry. The fossil woods show affinities with the modern woods of the family Leguminosae. The new forms are *Acacioxylon bharadwajii* sp. nov., *Pahudioxylon arcotense* sp. nov. and *Caesalpinioxylon felexii* sp. nov.

INTRODUCTION

THE fossil assemblage in the Tertiary beds near Pondicherry comprises of many silicified dicotyledonous woods (RAMANUJAM, 1953-1960; NAVALE, 1955-1960). Further investigations in the area have shown the occurrence of few more new fossil woods showing affinities with the living woods of the family Leguminosae. The geological formation of the area is composed of rocks of the Cuddalore series. The age of the series is believed to be Eocene to Pliocene (KRISHNAN, 1949; WADIA, 1953). The descriptions of the area, topography and other details are given in my earlier papers (NAVALE, 1955-1960).

DESCRIPTION

ACACIOXYLON SCHENK 1888

1. *Acacioxylon bharadwajii* sp. nov.

Anatomy

The fossil under investigation is represented by two small pieces of highly silicified woods. The preservation of the specimen is not uniform, yet the details are easily seen due to the distinct pattern of tissues in the fossil wood.

The fossil specimen is a diffuse porous wood.

Growth rings are indistinct. The presence of initial parenchyma often delimits the regions in the wood.

Vessels are recognized even without the help of the microscope. They are numerous, small to medium in size, oval to elliptical in shape and distributed uniformly without any pattern (PL. 1, FIG. 1; TEXT-FIG. 1). Vessels are solitary, also in radial groups of two to three and usually enclosed by irregular patches of parenchyma (PL. 1, FIG. 2; TEXT-FIG. 1). Vessel segments are short, medium in height, solitary, thick-walled and abruptly truncate or tailed at the ends. Vessels are generally filled with dark gummy deposits (PL. 1, FIG. 2) and sometimes rays are seen contiguous on either side (PL. 1, FIG. 2). Perforation is simple and intervessel pits are small, angular in shape and numerous (TEXT-FIG. 2). The vessel-ray pits are not preserved.

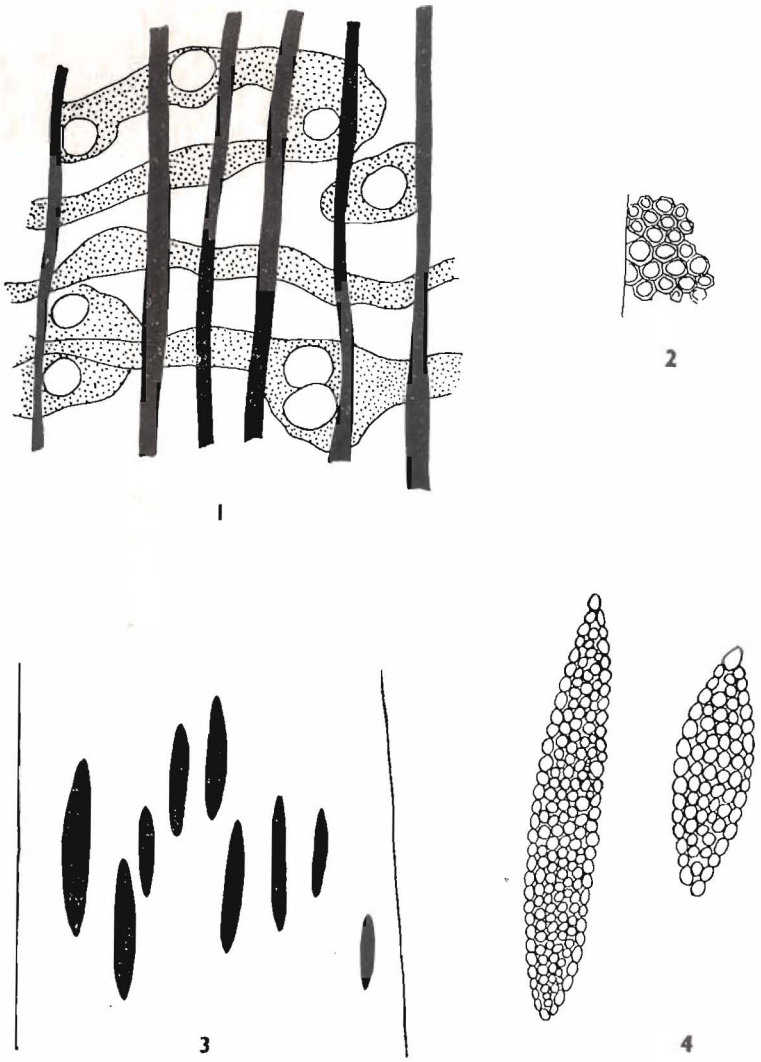
Parenchyma is conspicuous and abundant. It is seen by the naked eye as light coloured patches with irregular bands. The paratracheal parenchyma is dominant and occupies the bulk of the space in the wood (PL. 1, FIG. 1; TEXT-FIG. 1). It is vasicentric, aliform and banded (PL. 1, FIG. 2; TEXT-FIG. 1). Frequently parenchyma forms reticulate pattern around the vessels and often bands are seen bifurcating to end blindly (PL. 1, FIG. 2; TEXT-FIG. 1). The irregular tangential bands are 3-6 cells broad (PL. 1, FIG. 2). Cells of the parenchyma are small, circular and filled with dark contents (PL. 1, FIG. 2). The terminal parenchyma is scanty, but seen as narrow stripes of 1-2 rows of thin cells which are very small and filiform in cross-section (PL. 1, FIG. 1). The metatracheal parenchyma is sparse. Parenchymatous pits are minute, circular and many per cell. The storied arrangement of cells or any tendency towards it is absent.

Rays are visible to naked eye in cross-section. They are numerous, closely spaced (PL. 1, FIG. 3; TEXT-FIG. 3), 4-6 seriate, 10-35 cells high (PL. 1, FIG. 3; TEXT-FIG. 4). Rays are homogeneous and constituted by procumbent cells (PL. 1, FIGS. 3, 4; TEXT-FIG. 4). Ray cells are small, circular and filled with dark contents. The pittings are not visible due to the lack of preservation and the specimen does not show storied arrangement of rays.

Fibres are libriform and medium in height. They are small, usually filled with dark contents, angular and arranged in radial rows in cross-section (PL. 1, FIG. 2). The fibres are non-septate and the pittings are not preserved.

Affinities and Discussion

The combination of the anatomical features of the fossil specimen described above indicate its resemblances with the modern woods of Meliaceae, Combretaceae, Urticaceae, Anacardiaceae, Sapindaceae and Leguminosae. The genera *Gaurea* and *Cedrela* of Meliaceae show similarities with the fossil in the nature and arrangement of vessels, fibres and in having abundant parenchyma. But the wood of *Gaurea* differs in having uniseriate rays (DADSWELL & ECKERSLY, 1939 and METCALFE & CHALK



Acacioxylon bharadwajii sp. nov.

TEXT-FIGS. 1-4 — 1, cross-section of the wood showing the nature and distribution of vessels, parenchyma and rays. × *ca.* 75. 2, portion of a vessel segment showing the nature of the intervessel pits. × *ca.* 950. 3, tangential section of the wood showing the distribution of rays. × *ca.* 75. 4, ray cells and their nature. × *ca.* 240.

1950). *Cedrela* can also be differentiated as it possesses ring-porous type of arrangement and large pits with coalescent apertures.

Terminalia of Combretaceae agrees with the fossil in having medium sized vessels, and abundant parenchyma of paratracheal vasicentric arrangement. However, conspicuous differences are seen in the nature of rays and intervessel pits. Rays are usually uniseriate and homogeneous with chambered crystals in each cell and the vestured pits are very characteristic.

Woods of Urticaceae resemble the fossil specimen in many respects, such as the nature and arrangement of vessels, parenchyma and fibres. But, from careful comparisons they are easily differentiated. Urticaceous woods, generally, have large vessels, extremely abundant parenchyma with lignified cells and multiseriate rays being 10-12 cells in width. Woods of Anacardiaceae and Sapindaceae differ in the nature of parenchyma and rays. Considering the family Leguminosae, its woods show a high range of variation in anatomical characters. Vessels show a diverse nature and arrangement. They may be solitary, large, medium or small; few and scattered or numerous and crowded; uniform in size and distribution or ring-porous arrangement; tyloses may or may not be present. Parenchyma is abundant ranging from narrow vasicentric type to banded form and reticulate pattern. Rays may be fine, broad, uniseriate or multiseriate; homogeneous or heterogeneous. Ripple marks and storied arrangement may or may not be present. Although the family is comprised of woods with diverse anatomical characters yet certain distinct types can be recognized. Gamble (1902) has defined types of wood primarily on the basis of the distribution of parenchyma. Foxworthy (1909) as quoted by Pearson and Brown (1939) has also followed Gamble with one modification. The following is the classification of the anatomical types suggested by Foxworthy (*loc. cit.*).

Type I — Vessels are large to moderately large, scattered, distinctly fringed with parenchyma which forms patches or eyelets, e.g. all Albizzia species, *Acacia catachu*, *A. modesta*, *Acrocarpus* species and *Ougeinia dalbergioides*.

Type II — Vessels are enclosed in irregular patches of wood parenchyma which is often in reticulate pattern, e.g. *Cassia* species, *Acacia leucophloea* and other species.

Type III — Vessels are ringed scantily; parenchyma bands are narrow, wavy, punctate, one or two-layered, e.g. all *Dalbergia* and *Pterocarpus* species.

Type IV — Parenchyma is in the form of bands, numerous, broad, wavy, regularly distributed, e.g. all *Bauhinia*, *Pongamia* and *Milletia* species.

Type V — Vessels are scattered, not enclosed by parenchyma and the bands are not present, e.g. *Acacia ferruginea*, *A. modesta*, *A. senegal*, and *Hardwickia* species.

Type VI — Vessels are large, scanty, unequal and irregular. Alternate bands of parenchyma and fibres are in regular rows, e.g. *Butea frondosa*, *Cynometra* and *Erythrina* species.

It is only with a few members of Leguminosae that the fossil can be compared to a large extent. This family possess well-known woody genera with certain distinct anatomical types of characters. So, according to the grouping proposed by Foxworthy, the fossil can be conveniently referred to the group II because of its nature of parenchyma and vessels. The parenchyma is abundant, conspicuous in having irregular patches of short bands of paratracheal cells enclosing vessels. The detailed and extensive comparisons of the fossil specimen, with large number of sections of modern woods prepared and the references to the literature, show the similarities of the fossil with the woods of *Tamarindus*, *Pahudia Afzelia*, *Pterocarpus*, *Delbergia*, *Albizzia*, *Prosopis*, *Indigofera*, *Cassia* and *Acacia*. *Tamarindus* and *Afzelia* can be eliminated because of the characteristic presence of storied arrangement of rays and parenchymatous cells although they agree in many respects. *Pterocarpus* and *Dalbergia* differ in having ripple marks, and in lacking the abundant bands of paratracheal parenchyma although fine tangential lines of parenchymatous cells are seen in the wood. Also the fossil cannot be matched well with *Albizzia* and *Pahudia* species as they do not have that type of parenchyma distribution and the nature of the vessels as in the fossil. In *Albizzia*, vessels are large, usually solitary and parenchyma is limited to paratracheal vasicentric type forming eyelets. The fossil appears to match with some species of *Acacia* (*A. leucophloea?*).

Among the Indian fossil species, *Acacioxylon indicum* (RAMANUJAM 1954) shows certain similarities in the gross features of

the vessels, parenchyma and rays. But it differs markedly in the distribution of parenchyma, fibres and the size of the vessels. Parenchyma is vasicentric, aliform type, but never in the form of tangential oblique bands which are very commonly seen in the present fossil. Vessels are usually bigger in size and solitary, rays are short and limited, and fibres are typically septate. *Albizioxylon sahnii* (RAMANUJAM, 1960) differs in having solitary vessels and typically aliform parenchyma. Also *Cassioxylon variegatum* (RAMANUJAM, 1960) does not compare with my fossil as it possesses septate fibres and storied alignment of rays. *Tamarindoxylon antiquum* (RAMANUJAM, 1960) differs in the nature of parenchyma and rays. The other fossil woods, *Cynometroxylon indicum* (CHOWDHURY & GHOSH, 1940), *Pahudioxylon bankurensis* (CHOWDHURY, GHOSH & KAZMI, 1960), *C. dakshinense* (Navale, 1958) and the species of *Caesalpinioxylon* (RAMANUJAM, 1954 & 1960) can be easily discarded for they differ in most of the anatomical features.

A careful and detailed comparison of the present fossil wood with the foreign species from the available literature shows its similarities with *Leguminoxylon menchikoffii*, *L. schoelleri*, *Pterocarpoxylon arambourgii* (BOUREAU, 1951 & 1953), *L. edwardsii* and *L. acaciae* (KRAUSEL, 1939), *Acacioxylon antiquum* and *A. vegae* (SCHENK, 1888). *L. edwardsii* can be easily separated as it shows distinct differences in the nature and arrangement of parenchyma and rays. Parenchyma although abundant, paratracheal, vasicentric yet it lacks the irregular, short, oblique, band formation found in the Indian species. Also rays are limited and heterogeneous. *L. menchikoffii* agrees with the present specimen in gross general features but differs in many diagnostic features such as the possession of limited parenchyma of vasicentric, aliform type; the initial bands and short and limited rays. *L. ersanense* also differs in having abundant multiple vessels, limited parenchyma and well-marked initial parenchyma. *L. acaciae* matches well with present fossil wood in the nature and arrangement of vessels and parenchyma, but the presence of abundant, diffuse, metatracheal parenchyma and bigger vessels are marked differences. *L. schoelleri* differs in having multiple vessels, diffuse, aliform, and metatracheal parenchyma and heterogeneous rays. *Acacioxylon antiquum* and *A. vegae* resemble my species in many anatomical features. However, a careful and detailed comparison shows many differences. In *A. antiquum* vessels are small and solitary; parenchyma is very heavily banded with irregular, long, tangential stripes and without initial bands and also rays are very broad. Similarly *A. vegae* differs in having limited, smaller vessels, often in groups, very broad and high rays, and irregular parenchyma having abundant aliform, initial and metatracheal bands.

The anatomical characters of the present fossil specimen and its extensive comparison with the modern woods distinctly indicates its affinities with some woods of Leguminosae. In particular some species of *Acacia* show similar combination of characters like the fossil. Therefore, the present specimen has been referred to the genus *Acacioxylon* Schenk (1888) as it closely agrees with the genus. However the fossil specimen has been referred into a new species as it differs from the hitherto described forms of the genus *Acacioxylon*.

Acacioxylon bharadwajii

Diagnosis

A diffuse porous wood.

Growth rings not distinct in the specimen, however, initial bands of parenchyma simulate growth marks.

Vessels numerous, distributed uniformly without any pattern; small to medium, 108-162 μ in tangential diameter, 162-234 μ in radial diameter; elliptical to oval in shape, solitary or radial groups of two to three; vessel segments short, abruptly truncate, 270-350 μ in length, thick-walled, filled with gummy deposits; perforation simple, intervessel pits small, numerous, alternate and circular; vessel deposits common.

Parenchyma abundant, conspicuous, always enclosing vessels; paratracheal, vasicentric, characteristically forming short irregular bands; parenchyma cells small, circular 9-18 μ broad, 3-10 rows wide; terminal parenchyma limited, distributed in tangential lines, filiform, thin, 1-2 rows of cells, cells 9 μ in size; parenchyma pits very small, many; storied arrangement or any tendency to it absent.

Rays numerous, uniform in distribution, 4-6 seriate, 45-60 μ broad, 15-35 cells high,

350-500 μ in length; homogeneous with procumbent cells; ray cells small, 9 μ in size, oval in shape, filled with contents; storied arrangement absent.

Fibres libriform, medium, 700-900 μ high; fibre cells small, angular, arranged in radial rows; 9 μ broad in cross-section; cell contents common, typically non-septate.

Holotype — No. 4988, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Bangalamod, near Pondicherry, South India.

Horizon — Tertiary.

PAHUDIOXYLON CHOUDHURY, GHOSH & KAZMI, 1960

2. *Pahudioxylon arcotense* sp. nov.

Anatomy

The fossil material is represented by 4 pieces of petrified woods, the largest measuring 14×6 cm. in size. The ground mass of the fossil wood is not well preserved. However, the other details are easily seen, as light dark patches against the white background.

The fossil specimen is a diffuse porous wood.

The presence of initial bands of parenchyma appear as growth marks (PL. 1, FIG. 5). The fossil wood does not show ring-porous or semi ring-porous type of arrangement.

Vessels are visible even without the help of the microscope. They are medium to large in size and distributed uniformly without any distinct pattern (PL. 1, FIG. 5; TEXT-FIG. 5). Vessels are usually solitary, sometimes in pairs and always surrounded by patches of parenchyma (PL. 2, FIG. 8; TEXT-FIG. 5). Vessels are thick-walled, more or less circular and filled with dark contents (PL. 2, FIG. 8). The intervessel pits are not preserved although at some places small, minute, alternate pits are faintly visible which appear to be vestured (PL. 1, FIG. 6; TEXT-FIG. 6). Vessel-ray pits are very small, circular, many per cell (PL. 2, Fig. 9; TEXT-FIG. 7).

Parenchyma is abundant and can be easily seen by the naked eye as dark-coloured patches around the vessels. It is mostly paratracheal and occasionally apotracheal type (PL. 1, FIG. 5). The paratracheal parenchyma is conspicuous, typically vasicentric, aliform to confluent, sometimes uniting with adjacent vessel parenchyma and forming small patches (PL. 2, FIG. 8; TEXT-FIG. 5). The cells of the paratracheal parenchyma are small, circular and filled with contents and are in 3-5 rows in the wood (PL. 2, FIG. 8). The initial parenchyma is limited and seen as fine tangential lines (PL. 1, Fig. 5) consisting of extremely small cells which are in one or two thin rows in the matrix. The parenchymatous pits are minute, round in shape, many per cell and arranged in rows.

Rays are scarcely visible to the naked eye. They are moderately numerous, 1-3 seriate, mostly 2-3 seriate (PL. 1, FIG. 7; TEXT-FIG. 8). Rays are homogeneous, 5-35 cells in height (PL. 1, FIG. 7; TEXT-FIG. 9). They show tendency for radial alignment. Ray cells are small, round, thin-walled and have usually short procumbent cells (PL. 1, FIG. 7; PL. 2, FIG. 9).

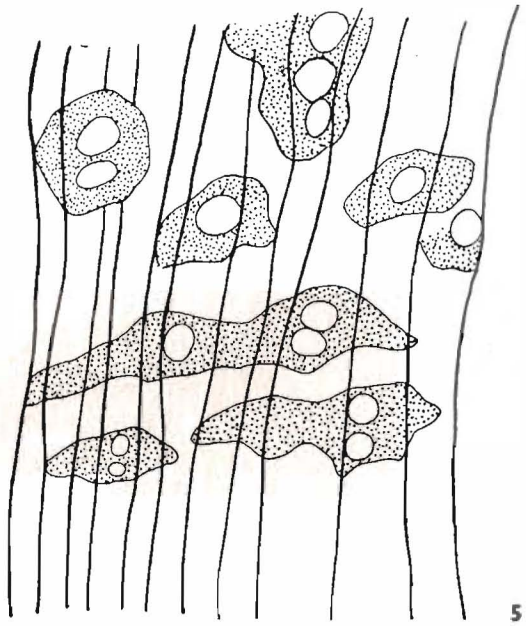
Fibres which form the ground tissue of the fossil are not well preserved. However, in some sections the nature and distribution of fibre cells could be seen. Fibres are non-septate, non-libriform and the cells of the fibres are small, thin and circular in cross-section (PL. 2, FIG. 8).

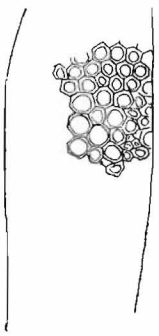
Affinities and Discussion

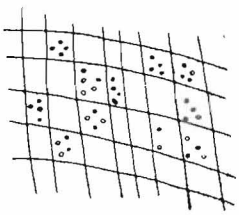
The anatomical characters which help the identification are the solitary or radial groups of vessels with uniform distribution; abundant paratracheal vasicentric parenchyma, forming dark patches; homogeneous, 3-4 seriate rays and non-septate fibres. All these features of the fossil under investigation are more or less similar to *Acacioxylon bharadwajii* sp. nov. and, therefore, indicates similarities with some genera of Leguminosae.

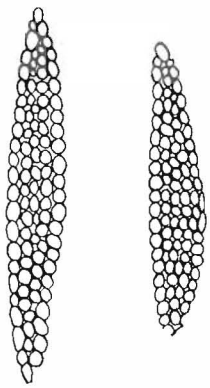
The gross structure of the fossil under investigation shows that it belongs to Type I or II according to the grouping proposed by Foxworthy (refer page 56).

The other minute anatomical characters of the fossil and its extensive comparison with the modern woods of the family as given by Pearson and Brown (1939), Metcalfe & Chalk (1950), Gamble (1902), Boureau (1950), Moll & Janssonius (1924), Dadswell & Ekersely (1938), Chowdhury (1946), Kanehira (1926) indicates its affinities with certain









Pahudioxylon arcotense sp. nov.

TEXT-FIG. 5-9 — 5, cross-section showing the nature and distribution of vessels, parenchyma and rays. × *ca.* 75. 6, portion of the vessel segment showing intervessel pits. × *ca.* 950. 7, vessel ray pits in radial section. × *ca.* 8, tangential section showing the distribution of rays. × *ca.* 75. 9, ray cells and their nature. × *ca.* 240.

woods of *Ougeinia, Tamarindus, Cassia, Afzelia, Albizzia* and *Pahudia* species. Genera *Tamarindus* and *Ougeinia* can be separated from the fossil as they have distinct ripple marks and storied arrangement of parenchyma and rays. The present fossil closely agrees with some species of the genera *Afzelia, Albizia* and *Pahudia*. Woods of *Albizia* and *Afzelia* have septate fibres (CHOWDHURY, GHOSH & KAZMI, 1960) which are lacking in the present fossil specimen. The fossil under investigation can be grouped with the woods of *Pahudia* which possess similar combination of characters (CHOWDHURY, GHOSH & KAZMI, 1960).

During recent years few fossil woods of Leguminosae have been described in India. *Cynometroxylon indicum* (CHOWDHURY & GHOSH, 1946) distinctly differs from the present fossil as it has apotracheal and fibre bands of equal width regularly alternating with each other. *C. dakshinense* (NAVALE, 1958) does not show any resemblances with the present fossil as the nature of the parenchyma and rays are entirely different. Ramanujam described *Caesalpinioxylon sitholeyi* (1954) and *C. feistmantalii* (1960) from the same area. But they differ with the present fossil in having storied arrangement of rays and parenchyma and also heterogeneous rays. *Acacioxylon indicum* (RAMANUJAM, 1954) agrees with the fossil in the nature and arrangement of parenchyma and vessels. However, the differences are in rays and fibres. Ray cells are very short, thick-walled, prominent, visible to the naked eye having no tendency towards radial alignment and the fibres are typically angular and septate. Also the parenchyma is mostly aliform type. *Cassioxylon variegatum* (RAMANUJAM, 1960) differs in having libriform septate fibres and short heterogeneous rays. *Tamarindoxylon antiquum* (1960) can be separated as it differs in the nature of parenchyma and rays. The present fossil compares with *Pahudioxylon bankurensis* (CHOWDHURY, GHOSH & KAZMI 1960) in many characters. However, *P. bankurensis* differs in having smaller vessels, fairly thick-walled, widely spread clear shorter rays and in fibres showing radial alignment. Similarly, *P. sahnii* (1961) can be separated as it possesses distinct growthrings, mostly solitary vessels and biseriate rays.

Large number of fossil leguninous woods have been described from other countries. Few of them *Leguminoxylon acaciae* and *L. edwardsi* (KRÄUSEL, 1939), *Acacioxylon antiquum* and *A. vegae* (SCHENK, 1888), *Leguminoxylon piptadeniae* (HOFFMANN, 1952), *L. menchikoffii, L. ersanense, L. schoelleri* (BOUREAU, 1953) are considered here for comparison with the present fossil specimen as they are agreeable in many gross features. *Leguminoxylon edwardsi* resembles in the nature and arrangement of vessels and parenchyma but distinctly differs in having uniseriate and heterogeneous rays. *L. acaciae* shows similarities with my specimen in size, shape and distribution of vessels and fibres but can be easily separated as it does not have initial bands of parenchyma and possesses very narrow rays. *Acacioxylon antiquum* although matches well in some features with the fossil under investigation, it differs distinctly in having many smaller vessels, banded parenchyma and narrow rays. *A. vegae* also possesses many resembling characters but at the same time differs distinctly in the arrangement of parenchyma which is metatracheal and irregularly banded vessels which are small and in many groups. *Leguminoxylon piptadeniae* agrees in many details with South Indian fossil but differs markedly by lacking apotracheal parenchyma and possessing distinct heterogeneous rays. *L. menchikoffii* compares with the fossil under investigation in having abundant parenchyma and limited rays. But it differs conspicuously in having smaller vessels of many radial groups and fibres which are septate and libriform. Also distribution of parenchyma is of different type. *L. ersanense* closely resembles the fossil in the nature and arrangement of parenchyma, fibres and other features although it can be easily separated due to the differences in vessels which are usually in radial groups of 2-5 in number and rays which are distinctly short and heterogeneous. *L. schoelleri* differs in having abundant bands of parenchyma and radial vessels.

The fossil under investigation clearly indicates its affinities with the genus *Pahudia* and, therefore, the fossil wood has been assigned in the genus *Pahudioxylon* constituted by Chowdhury, Ghosh & Kazmi (1960) for fossil woods having affinities with the modern woods of *Pahudia*. The fossil specimen has been assigned into a new species as it differs from the only other known species *Pahudioxylon*.

Pahudioxylon arcotense sp. nov.

Diagnosis

A diffuse porous wood.

Growth ring not distinct, initial bands of parenchyma appear as if growth marks.

Vessels distinctly visible to the naked eye; uniformly distributed without any pattern; medium to large in size and 135-225 μ in diameter; solitary or in pairs; vessel segments 1200 μ, thick-walled and filled with deposits; intervessel pits appear to be vestured; vessel-ray pits many, simple, round and arranged in rows.

Parenchyma abundant, conspicuously paratracheal, typically vasicentric, aliform, also forming patches in reticulate pattern; 3-5 layered; parenchymatous cells small, round, 30 μ in diameter; initial parenchyma limited, fine filiform, forms tangential lines, cells very small and circular; parenchyma pits small, many, arranged in rows; storied arrangement absent.

Rays indistinct, scarcely visible with the hand lens; 1-3, mostly 2-3 ray cells, 36 μ broad, homogeneous, 5-35 cells high; ray cells thin, 270 μ in length, procumbent in nature; uniseriate rays very rare.

Fibres short to medium in height, 900-1175 μ; non-libriform, non-septate, thin, circular in cross-section; pits indistinct.

Holotype — No. 19400, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Kashikoppam, near Pondicherry, South India.

Horizon — Tertiary.

CAESALPINIOXYLON SCHENK 1888

3. *Caesalpinioxylon felixii* sp. nov.

Anatomy

The fossil material is represented by three small pieces of petrified woods. They are blotched with light coloured patches. The preservation is not good.

Growth rings are not recognized but occasional aggregation of vessels and parenchyma cells simulate growth differentiation.

The specimen is a diffuse porous wood.

Vessels are visible without the aid of microscope. They are small to medium in size and distributed uniformly without showing any particular arrangement (PL. 2, FIG. 11; TEXT-FIG. 10). Vessels are solitary or in pairs, circular to oval in shape and slightly thick-walled (PL. 2, FIG. 10; TEXT-FIG. 10). Vessel segments are short to medium in height and the contents in the vessels are not common. The perforation and the intervessel pits are indistinct due to poor preservation, still, small, circular, alternate pits are sometimes visible (TEXT-FIG. 11). Vessel-ray pits are very minute, circular and many per cell (PL. 2, FIG. 13; TEXT-FIG. 12).

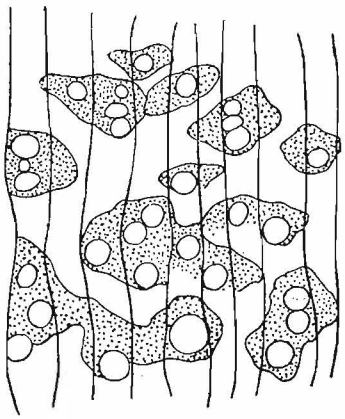
Parenchyma is scanty yet distinct, always in the vicinity of vessels. Parenchyma is paratracheal and vasicentric forming narrow patches around the vessels (PL. 2, FIG. 10; TEXT-FIG. 10). Unlike the previous fossil this specimen neither shows confluent, paratracheal bands nor initial parenchyma. Parenchymatous cells are distinct, small, more or less round and limited to 2-3 cells wide near the vessels (PL. 2, FIG. 10). Parenchyma-pits are also small, numerous and arranged in rows. The parenchyma does not show storied arrangement nor any tendency towards the same.

Rays are limited, hardly visible to the naked eye but in tangential surface they are seen as fine lines with definite, storied pattern of arrangement (PL. 2, FIG. 12; TEXT-FIG. 13). They are 2-3 cells broad, short, with 12-15 cells in height (PL. 2, FIG. 12; TEXT-FIG. 14). Rays are mostly homogeneous. They are made up mostly of procumbent cells. Sometimes few heterogeneous cells are seen in radial section (PL. 2, FIGS. 12, 13; TEXT-FIG. 14). Ray cells are small, more or less round and filled with contents (PL. 2, FIG. 12).

Fibres are poorly preserved. They are mediumly thick-walled, small, squarish to angular in cross-section with contents (PL. 2, FIG. 10). They are non-septate, weakly libriform and medium in height. Pits are not visible due to bad preservation.

Affinities and Discussion

Considering the important assemblage of characters, namely the solitary or paired, medium-sized vessels; scanty, distinct, vasicentric parenchyma in the vicinity of vessels and limited homogeneous to weakly heterogeneous rays with characteristic storied arrangement, restrict the comparison with few modern woods of Meliaceae, Combretaceae, Rutaceae, Spindaceae and Caesalpinae. Meliaceous woods (*Cedrela*, *Gaurea*, etc.) show many similarities in



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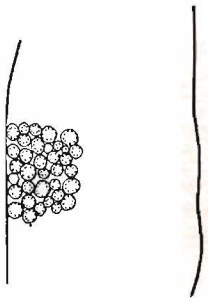

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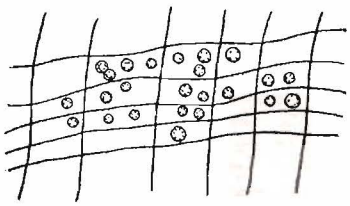

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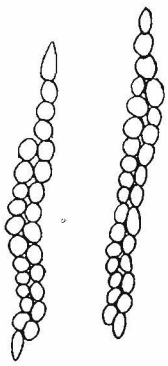

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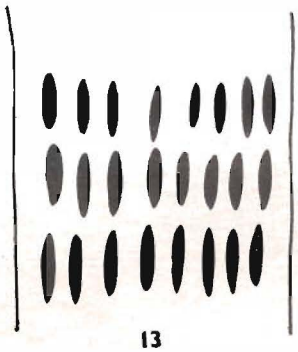

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Caesalpinioxylon felixii sp. nov.

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

having solitary to radial vessels, limited rays but conspicuously differ in having abundant parenchyma. *Terminalia* of Combretaceae does not agree with the fossil for it totally lacks the storied arrangement of rays, scanty parenchyma and simple pits. Woods of Rutaceae although resemble in having limited rays with storied arrangement and incipient parenchyma, yet differ in the nature of rays which are homogeneous and uniseriate. They also differ in having vertical gum canals. The modern woods of Sapindaceae can be separated easily from the fossil as they show marked differences in the nature of parenchyma and rays in spite of the fact that they agree in having

limited rays with storied arrangement, and medium-sized, solitary or paired vessel. They have very scanty parenchyma and rays are uniseriate and homogeneous.

The woods of family Caesalpineae show resemblances with the fossil in the arrangement of vessels, rays and parenchyma. A careful comparison with the large number of sections of modern woods and the published information (*see* page 56) shows that the woods of *Ougeinia*, *Afzelia*, *Cassia*, *Acacia*, *Caesalpinia* and *Tamarindus* agree in many anatomical features with the fossil under consideration. Among these, *Ougeinia*, *Tamarindus* and *Afzelia* differ in having abundant, vasicentric parenchyma and also distinct initial parenchyma as well as vessels with very limited frequency. The fossil under investigation does not match with the woods of *Cassia* and *Acacia* as they generally possess abundant parenchyma with reticulate pattern with initial parenchyma and large vessels, and rays. It is with the genus *Caesalpinia* that the present specimen agrees closely in largest number of anatomical characters such as having limited paratracheal parenchyma, 2-3 seriate rays having storied structure.

Closely comparable fossil species among the Indian fossil specimens are *Caesalpinioxylon feistmantalii*, *C. sitholeyi*, *Acacioxylon indicum*, *Cassioxylon variegatum* (RAMANUJAM, 1954-1960), *Pahudioxylon bankurensis* (CHOWDHURY, GHOSH & KAZMI, 1960), *Acacioxylon bharadwajii* sp. nov. and *Pahudioxylon arcotense* sp. nov. described here. Although woods of *Acacioxylon* agree in gross anatomical features but distinctly differ by having usually broad, medium height, homogeneous rays without storied arrangement and abundant parenchyma, always enclosing the vessels in patches, often forming short irregular bands without showing any storied arrengement. Similarly, *Pahudioxylon bankurensis* and *P. arcotense* sp. nov. differ in having homogeneous rays and aliform confluent parenchyma. As compared to *C. variegatum* the fossil under investigation shows similarities in the nature and arrangement of rays and fibres but the parenchyma and vessels differ distinctly. In *C. variegatum*, parenchyma is both paratracheal and apotracheal. The paratracheal type is abundant forming confluent patches of reticulate type and apotracheal type is in the form of distinct, thin bands of 2-3 rows. Initial parenchyma is also present. Vessels are large, solitary and limited. The present fossil specimen agrees with *C. sitholeyi* in many features but this also can be differentiated by careful and detailed comparisons. In *C. sitholeyi*, parenchyma is abundant, forms distinctly narrow, aliform, confluent patches with distinct storied arrangement, and rays are numerous, homogeneous and not distinctly storied. But in the present fossil specimen, parenchyma is scanty, confined to the vicinity of vessels, forming only paratracheal and vasicentric narrow patches, neither having irregular aliform and confluent patches nor storied arrangement and the rays show distinctly storied arrangement and tend towards heterogeneous condition. Similarly, *C. feistmantalii* can be separated as it possesses abundant parenchyma having storied arrangement and lacking the distinct radial alignment of rays.

Comparing the fossil woods described outside India, *Leguminoxylon afzelioides*, *L. ersanese*, *L. menchikoffii* (BOUREAU, 1950, 1952, 1953, 1954), *L. albizziae* (KRÄUSEL, 1939), *Caesalpinioxylon nathorsti* (SCHÜSTER, 1910), *C. migiurtinum*, *C. Ducis aprutii* and *C. zaccarinii* (CHIARUGI, 1938) and *C. magadaense* (BOUREAU) are only considered for comparison as they show near resemblances. All these species agree in many features yet there are conspicuous differences in one or two diagnostic characters. Taking into consideration one by one *L. afzelioides* may be eliminated because of the presence of abundant paratracheal parenchyma with distinct apotracheal bands and homogeneous rays without storied arrangement. *L. ersanese* can be separated as it possesses bigger vessels, broad and high rays and diffuse metatracheal parenchyma. *L. menchikoffii* disagrees with the present fossil in having abundant vasicentric confluent patches of parenchyma and homogeneous rays without storied structure. *L. albizziae* differs distinctly in having uniseriate homogeneous rays without having any storied arrangement. *Caesalpinioxylon nathorsti* markedly differs in having scanty vessels and totally lacks the storied arrangement of rays. *C. migiurtinum* can be easily discarded because of the presence of distinct vertical gum ducts in it although it shows many other similarities with the specimen. In *C. Ducis aprutii*, the absence of storied arrangement of rays and homo-

geneous nature of rays separate the two. *C. zaccarinii* can be differentiated as the nature of parenchyma and rays is distinctly different. Parenchyma is prominently diffuse and metatracheal and rays are homogeneous with no storied arrangement. *C. magadaense* does not match with the fossil for it possesses larger vessels, and homogeneous rays.

The detailed comparisons with the modern and fossil species distinctly show that the present fossil resembles in many features with certain wood of Caesalpineae, in particular the genus *Caesalpinia*. Schenk (1889) grouped, the fossil woods having resemblance with the woods of the family Caesalpineae, in the genus *Caesalpinioxylon*. As the present fossil also shows affinities with Caesalpinaceous woods, it is assigned to the genus *Caesalpinioxylon*. Also the present specimen distinctly differs from the hitherto described fossil species of *Caesalpinioxylon* and hence is separated into a new species.

Caesalpinioxylon felixii sp. nov.

Diagnosis

A diffuse porous wood.

Growth rings not distinct, early and late wood differentiation absent, occasional aggregation of vessels appear to show some differentiation.

Vessels diffuse, 108 μ in transverse diameter, 255 μ in radial diameter, solitary or paired, round to oval in shape, slightly thick-walled; intervessel pits indistinct, small, alternate, round; vessel-ray pits small crowded, round; many per cell.

Parenchyma scanty, paratracheal, vasicentric; cells of the parenchyma in 2-3 rows, 18 μ in diameter, thick-walled; aliform sheaths or bands and also storied arrangement absent.

Rays uniform, limited in distribution, 2-3 seriate, 12-16 cells high; 27-45 μ in breadth, 225 μ in height; homogeneous to weakly heterogeneous; distinctly storied, cells filled with dark deposits.

Fibres not well preserved, squarish to angular in cross-section, non-septate, libriform; pits not seen due to the lack of preservation.

Holotype — No. 4994, Museum, Birbal Sahni Institute of Palaeobotany.

Locality — Usteri, near Pondicherry, South India.

Horizon — Tertiary.

CONCLUSION

Tertiary rocks of the Cuddalore series near Pondichery appear to possess largest number of fossil Leguminous woods. Out of the 150 Angiospermous woods studied by me, 50 belonged to the family Leguminosae, 40 to the family Dipterocarpaceae, 35 to the family Combretaceae and 25 to the other different families. It is, therefore, reasonable to assume that the fossiliferous area cherished a luxuriant forest, dominated by woody members of Leguminosae during the Tertiary period.

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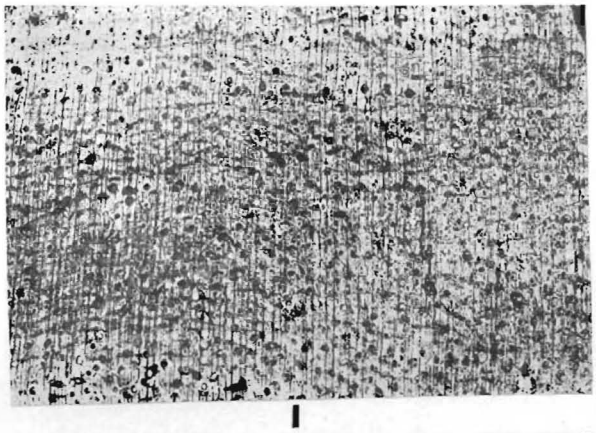

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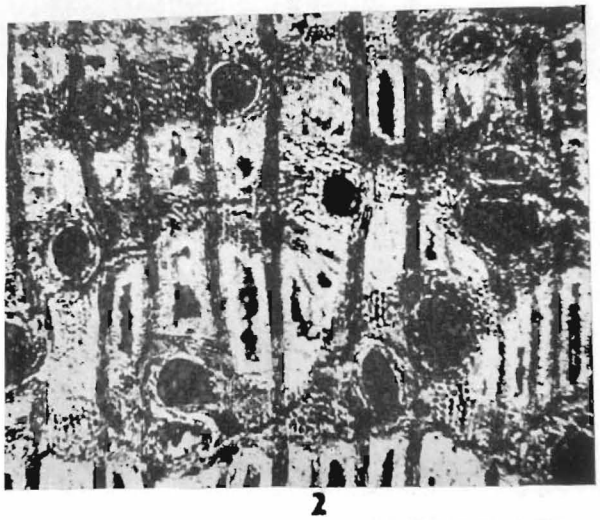

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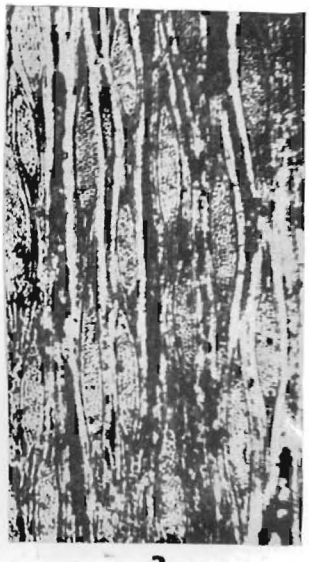

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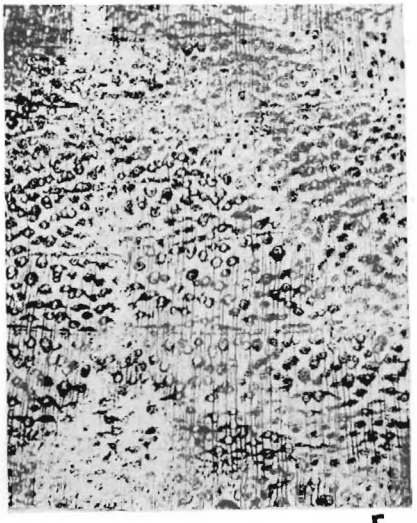

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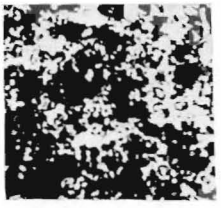

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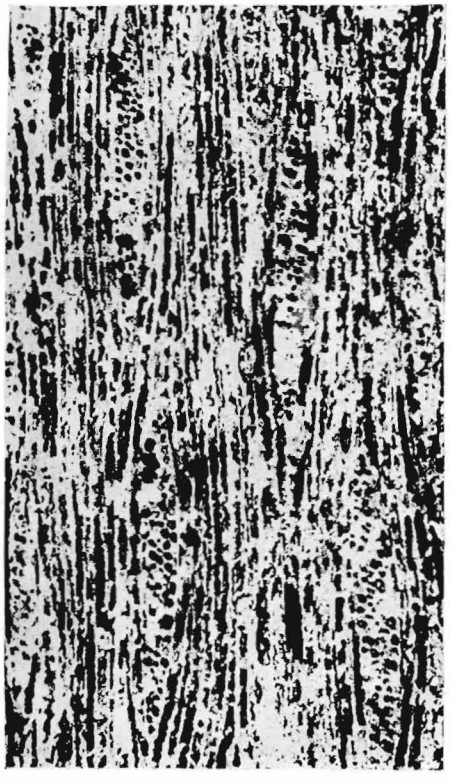

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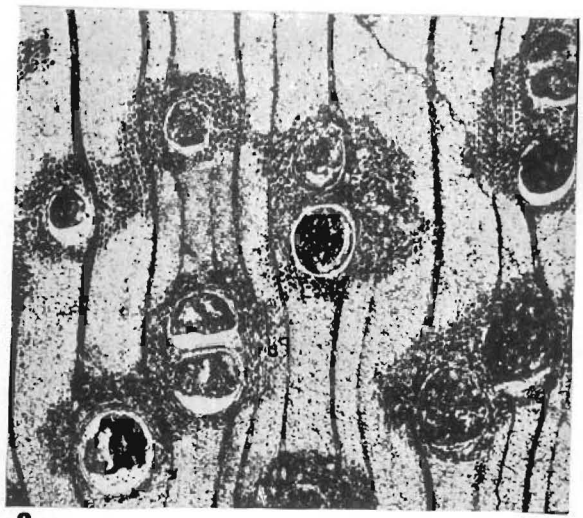

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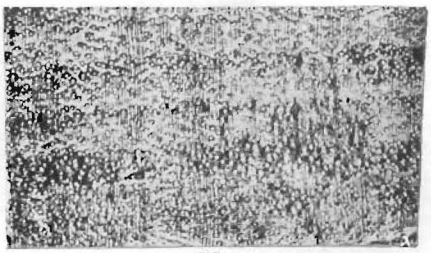

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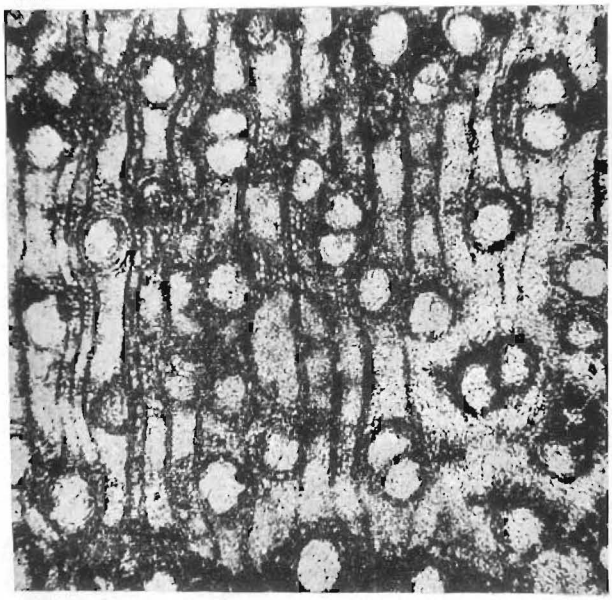

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EXPLANATION OF PLATES

PLATE 1

Acacioxylon bharadwajii sp. nov.

1. Cross-section showing the general structure of the wood. Note the irregular distribution of parenchyma. × 3.

2. Another cross-section to show the nature of vessels, parenchyma and its distribution. × 50.

3. Tangential section showing the nature and distribution of rays and fibres. × 35.

4. Radial section to show the nature of rays. × 50

Pahudioxylon arcotense sp. nov.

5. Cross-section of the wood to show the general structure. × 3.

6. A portion of the vessel-segment showing intervessel pits. × 100.

7. Tangential section showing the nature and distribution of rays and fibres. × 100.

PLATE 2

8. Cross-section magnified to show the nature of vessels, parenchyma and ground cells. × 100.

9. Radial section to show the nature of rays. × 100.

Caesalpinioxylon felixii sp. nov.

10. Cross-section showing the nature of vessels, parenchyma and fibres. × 35.

11. Cross-section in low magnification to show the gross features of the wood. × 3.

12. Tangential section showing the storied arrangement of rays and their distribution. × 35.

13. Radial section showing the nature of rays. × 250.