

Fossil woods from Neogene of Warkalli beds of Kerala Coast and their palaeoecological significance*

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Five carbonised angiospermous woods, viz., *Poeciloneuron palaeoindicum* sp. nov., *Adenantheroxylon pavoninum* Prakash & Tripathi, *Koompassioxylon keralaensis* sp. nov., *Parinarioxylon cuddalorensis* Awasthi and *Bischofia palaeojavanica* Awasthi are described from the Warkalli beds (Middle Miocene) exposed along Kerala Coast. They show close resemblance with the woods of *Poeciloneuron indicum* (Clusiaceae), *Adenanthera pavonina* and *Koompassia excelsa* (Fabaceae), *Parinari corymbosum* (Chrysobalanaceae) and *Bischofia javanica* (Bischofiaceae) respectively.

All these taxa are the main constituents of tropical wet evergreen to semi-evergreen forests of Western Ghats, Myanmar, Thailand, Malaysia, Sri Lanka, Indonesia, Philippines, which also provide evidence of the prevalence of tropical humid conditions with heavy rainfall in the area at the time of deposition of the Warkalli beds. Occurrence of Malaysian taxa, namely, *Koompassia excelsa* and *Parinari corymbosum* provide further evidence of phytogeographical linkage between Indian subcontinent and southeast Asia. Their absence in the present flora of Western Ghats leads to infer that there has been a gradual change in the vegetation pattern and climate since Neogene.

Key-words —Carbonised woods, Angiosperm, Warkalli beds, Middle Miocene, India.

INTRODUCTION

THE Neogene sediments occurring along Kerala Coast are classified as Quilon and Warkalli beds. They are exposed in cliff sections and clay mines at several places from Thiruvananthapuram District in the South to Kasaragod District in the North (Map 1). The Warkalli beds contain rich deposits of carbonised woods, occurring in lignite beds overlain by carbonaceous clays, variegated clays and sandstones. From these beds a large number of carbonised woods, few leaves and a fruit have already been reported belonging to several tropical dicotyledonous families viz. Clusiaceae, Dipterocarpaceae, Sterculiaceae, Ampelidaceae, Sapindaceae, Anacardiaceae, Fabaceae, Combretaceae, Ebenaceae, Lauraceae, Thymelaeaceae, Burseraceae, Flacourtiaceae, Sapotaceae, Rutaceae, Rhizophoraceae and Lecythidaceae (Awasthi & Ahuja, 1982; Awasthi & Panjwani, 1984; Awasthi & Srivastava 1989, 1990, 1992a, 1992b; Srivastava & Awasthi, 1994). With a view to update the flora for reconstruction of palaeoclimate and phytogeography of the region further work is carried

out on carbonised woods from Kerala Coast. Amongst the woods studied those showing close resemblance with the woods of extant *Poeciloneuron*, *Adenanthera*, *Koompassia*, *Parinari* and *Bischofia* are described in the present paper.

SYSTEMATIC DESCRIPTION

Family - Clusiaceae

Genus - *Poeciloneuron* Bedd.

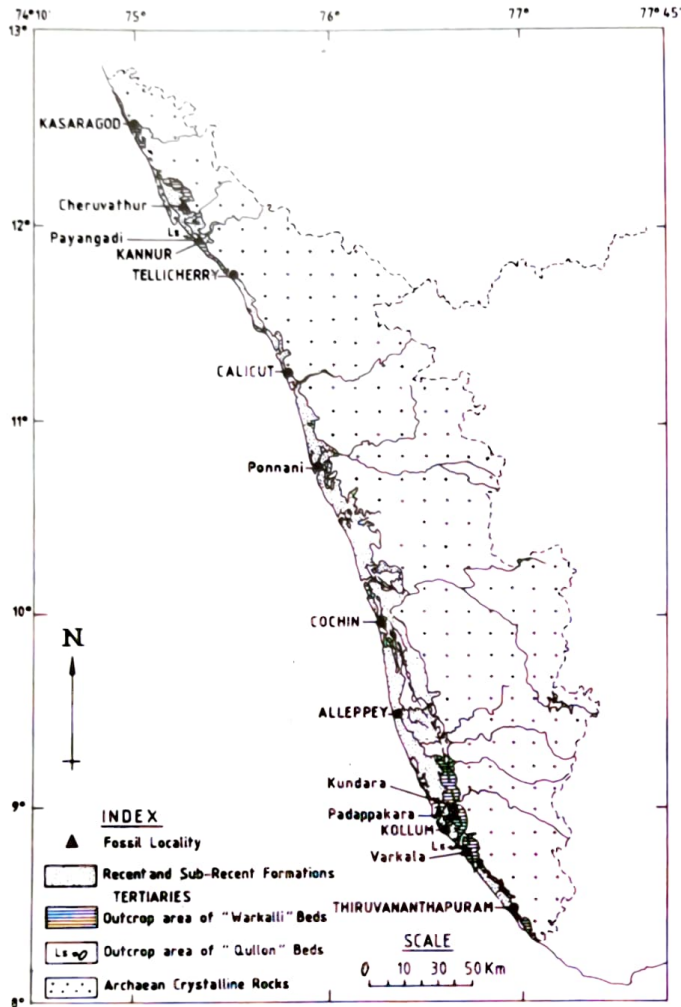
Poeciloneuron palaeoindicum sp. nov.

Pl. 1, figs 1-3, 6, 8

The species is based on three pieces of carbonised woods, two from well cutting at Cheruvathur, in Kasaragod District and one from Payangadi Super Clay Mine, Kannur District.

Description- Wood diffuse porous. Growth rings not seen. Vessels exclusively solitary or rarely in multiples of 2; obliquely arranged, small to medium sized, 40-150 µm in tangential diameter and 50-175 µm in radial diameter; 10-18 vessels per sq. mm; round to oval; open

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Map 1: Geological map of Kerala showing Tertiary formations and fossil localities (redrawn from Poulose & Narayanaswamy, 1968).

or plugged with tyloses (Pl. 1, figs 1,2); perforations simple; vessel-members 150-550 μm long with truncate or abruptly tailed ends; intervessel pits not seen. Parenchyma paratracheal, vascentric to aliform, intermingled with vascentric tracheids, forming 1-4 seriate sheath, sometimes with short lateral extensions (Pl. 1, fig. 2); parenchyma cells 20-26 μm in diameter and 44-55 μm in length. Rays 1-3 (mostly 1-2) seriate, 7-10 rays per mm; heterogeneous, 4-40 cells or 40-270 μm long, rays heterocellular made up of procumbent cells with 1-2 marginal rows of upright cells at one or both the ends (Pl. 1, figs. 3,6); ray cells small with gummy infiltration;

procumbent cells 11-17 μm in tangential height and 28-50 μm in radial length; upright cells 30-45 μm in tangential height and 14-28 μm in radial length (Pl. 1, fig. 8). Fibres aligned in radial rows between two consecutive rays; libriform, non-septate; 12-16 μm in diameter; interfibre pits simple, more numerous on tangential walls. Tracheids vascentric, intermingled with parenchyma cells.

Affinities- The important anatomical characters of the wood are : vessels small to medium, obliquely, arranged, tylosed, mostly solitary or rarely in multiples of 2; tracheids vascentric; parenchyma paratracheal, vascentric to aliform and xylem rays 1-3 seriate, heterogeneous. These features collectively indicate its affinities with the genus *Poeciloneuron* Bedd. of the family Clusiaceae (Pearson & Brown 1932; Metcalfe & Chalk 1950; Tandon & Purkayastha 1958; Illic 1991). For further comparison examination of thin sections of the wood of the extant genus has revealed that the carbonised wood is very similar to *Poeciloneuron indicum*.

As far as the authors are aware this is the first record of fossil wood of *Poeciloneuron* and, therefore, it has been described as a new species, *Poeciloneuron palaeoindicum*, the specific name indicates close resemblance of the fossil wood with that of *Poeciloneuron indicum*.

Holotype- BSIP Museum No. 37427

Locality- Well cutting at Cheruvathur village, Kasaragod District, Kerala.

Age- Middle Miocene

Family- Fabaceae

Genus- *Adenanthoxylon* Prakash & Tripathi 1968

***Adenanthoxylon pavoninum* Prakash & Tripathi 1968**

Pl. 1, figs 4, 5, 7

The fossil specimen is represented by a single piece of carbonised wood measuring 3 cm in width and 5.2 cm in length. The preservation is fairly good showing all the anatomical details.

Description- Wood diffuse porous. Growth rings indistinct. Vessels small to medium, rarely large, t. d. 100-

Plate 1

1. *Poeciloneuron palaeoindicum* sp. nov. Transversely sectioned surface to show oblique arrangement of vessels with tyloses. x 40, Block no. BSIP 37427.
2. Same surface magnified to show vessels, paratracheal aliform parenchyma and vascentric tracheid. x 120.
3. Tangential longitudinally sectioned surface showing distribution of rays. x 40; Block no. BSIP 37427.
6. Same surface magnified to show xylem rays. x 120.
8. Radial longitudinally sectioned surface showing heterocel-

- lular xylem rays. x 150; Block no. BSIP 37427.
- Adenanthoxylon pavoninum* Prakash & Tripathi
4. Transversely sectioned surface showing distribution of vessels and parenchyma. x 40; Block no. BSIP 37428.
5. Tangential longitudinally sectioned surface showing xylem rays. x 40; Block no. BSIP 37428.
7. Radial longitudinally sectioned surface showing homocellular xylem rays. 150; Block no. BSIP 37428.

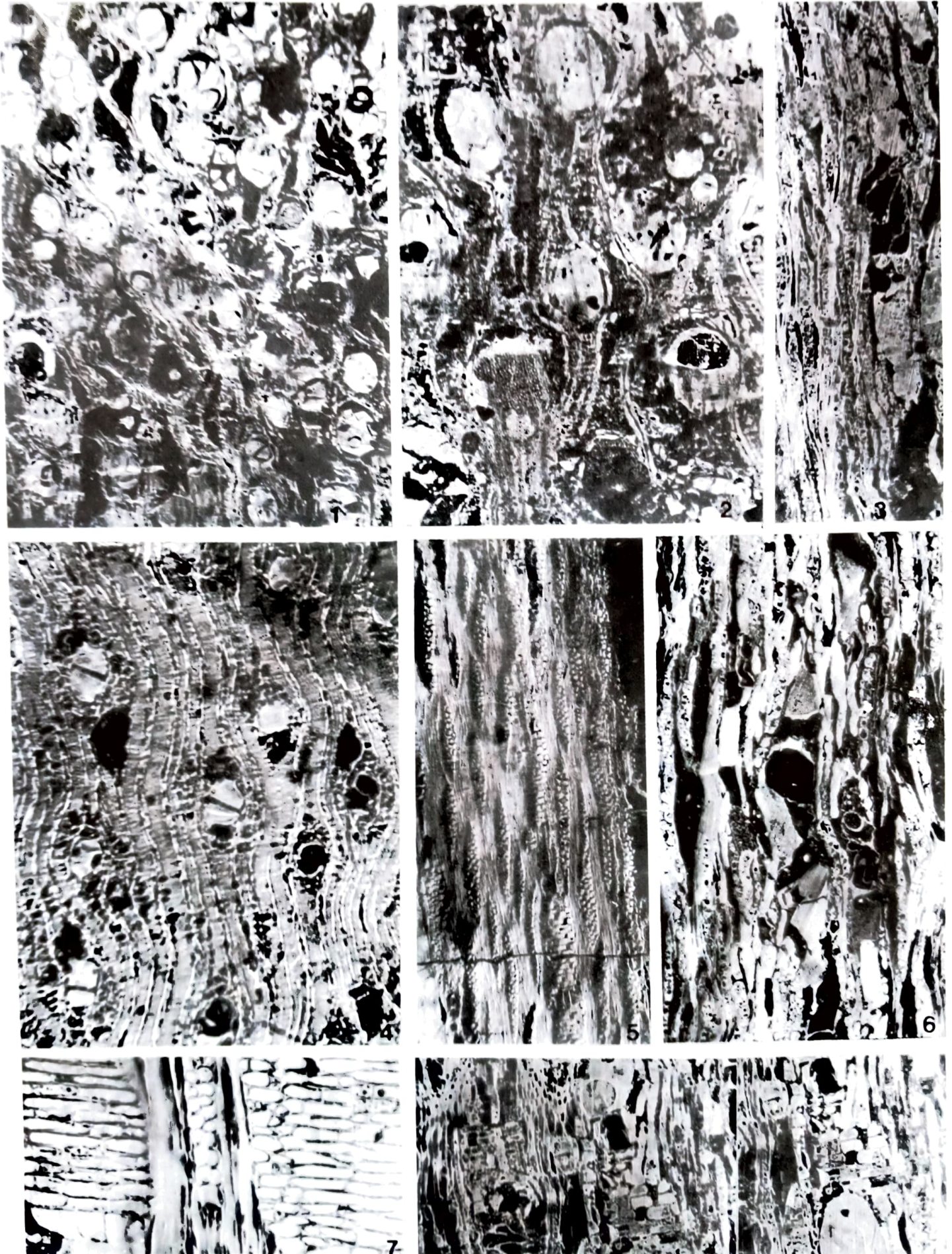


Plate 1

180 μm , r.d. 40-220 μm ; solitary and in radial multiples of 2-5; round to oval when solitary and flattened at the place of contact when in multiples, open or filled with dark contents; 6-9 vessels per sq mm (Pl. 1, fig 4); vessel members 300-550 μm long with truncate ends; perforation simple; intervessel pits bordered, alternate, vested, measuring 6-8 μm in diameter. *Parenchyma* paratracheal and apotracheal; paratracheal mostly vasicentric forming 2-4 seriate sheath round the vessels, rarely aliform with short lateral extensions; apotracheal parenchyma present as diffuse cells among fibres; parenchyma cells filled with dark contents; cells 16-30 μm in diameter and 50-80 μm in length (Pl. 1, fig 4). *Xylem rays* 1-3 (mostly 2-3) seriate, homogeneous, rays homocellular composed only of procumbent cells; uniseriate rare, 4-6 cells or 100-130 μm long; multiseriate 9-25 cells or 250-650 μm long (Pl 1, fig 5); procumbent cells 25-40 μm in tangential height and 80-120 μm in radial length (Pl. 1, fig. 7). *Fibres* aligned in radial rows, semilibriform, non-septate, 16-20 μm in diameter and 400-1000 μm in length, interfibre pits not seen.

Affinities- The carbonised wood shows close similarity with the woods of the genus *Adenanthera* L. of Fabaceae (Moll & Janssonius 1914; Kanehira 1924; Metcalfe & Chalk 1950; Desch 1957; Ramesh Rao *et al.* 1992; Illic 1991).

Thin sections as well as published descriptions and photographs of the woods of *Adenanthera bicolor* Moon, *A. intermedia* Merril, *A. microsperma* Teysm et Binn, *A. pavonina* L. and *A. tamerendifolia* were examined critically in order to further ascertain the affinity of the fossil. It was found that in all anatomical details the carbonised wood shows close similarity with that of *A. pavonina*.

Fossil woods showing resemblance with *A. pavonina* were described as *Adenantheroxylon pavoninum* Prakash & Tripathi (1968, 1969) from Tipam Series of Assam and Siwalik sediments of Nalagarh, Himachal Pradesh (Yadav 1988). Since the present carbonised wood is very similar to *Adenantheroxylon pavoninum*, it is being placed under the same species.

Figured specimen- BSIP Museum No. 37428

Locality- Payangadi Super Clay Mine, Kannur District, Kerala

Genus - *Koompassioxylon* Kramer 1974

Koompassioxylon keralaensis sp. nov.

Pl. 2, figs 1-3,6

The species is based on two well preserved specimens of carbonised wood showing all the anatomical details.

Description- Wood diffuse porous. *Growth rings* not seen. *Vessels* solitary and in radial multiples of 2-3 (sometimes upto 6); oval when solitary and flattened at the place of contact when in multiples: tyloses absent, open or filled with gummy deposits (Pl. 2, fig.1); small to large, t. d. 100-225 μm , r. d. 60-300 μm ; 4-6 per sq mm; perforations simple, vessel members 150-425 μm long with oblique or abruptly tailed ends; intervessel pits alternate, vested with linear or lenticular apertures, 6-8 μm in diameter. *Parenchyma* paratracheal aliform with pointed wings on both sides, sometimes confluent (Pl. 2, fig. 1); parenchyma cells thin walled, 22-30 μm in diameter and 50-100 μm in length, showing storied tendency. *Rays* 1-3 seriate, 5-33 cells or 140-525 μm in length; showing storied tendency at places (Pl. 2, figs 2,3); homocellular to weakly heterocellular made up of procumbent cells only a few with square or slightly enlarged end cells, ray cells large, 14-22 μm in tangential height and 28-70 μm in radial length (Pl. 2, fig.6). *Fibres* radially aligned between rays, polygonal in cross section, libriform, non-septate, 15-20 μm diameter.

Affinities- The important anatomical features of the present carbonised wood, such as paratracheal aliform-to aliform-confluent parenchyma, vested intervessel pits and 1-3 (mostly 2) seriate, homocellular to weakly heterocellular xylem rays with storied tendency indicate its affinities with the woods of the genus *Koompassia* Maing. of the family Fabaceae. Thin sections as well as published description and photographs of all the four species of *Koompassia*, viz., *K. borneensis*, *K. excelsa* Taub., *K. grandiflora* Kostern., and *K. malaccensis* Maing. were studied. It was found that the carbonised wood shows nearest resemblance with *K. excelsa* Taub. (= *K. parviflora*

Plate 2

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| <p><i>Koompassioxylon keralaensis</i> sp. nov.</p> <ol style="list-style-type: none"> 1. Transversely sectioned surface showing distribution of vessels and aliform confluent parenchyma. x 40; Block no. BSIP 37429. 2. Tangential longitudinally sectioned surface showing distribution of xylem rays. x 40; Block no. BSIP 37429. 3. Same surface magnified showing xylem rays with storied tendency. x 150. 6. Radial longitudinally sectioned surface showing homocellular rays, few with end cells slightly enlarged. x 150; Block no. BSIP | <p>37429.</p> <p><i>Parinarioxylon cuddalorensis</i> Awasthi</p> <ol style="list-style-type: none"> 4. Transversely sectioned surface showing distribution of vessels and parenchyma. x 40; Block no. BSIP 37430. 5. Same surface magnified to show vessels and broken parenchyma lines. x 120. 7. Radial longitudinally sectioned surface showing heterocellular xylem rays. x 150; Block no. BSIP 37430. |
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180 μm , r.d. 40-220 μm ; solitary and in radial multiples of 2-5; round to oval when solitary and flattened at the place of contact when in multiples, open or filled with dark contents; 6-9 vessels per sq mm (Pl. 1, fig 4); vessel members 300-550 μm long with truncate ends; perforation simple; intervessel pits bordered, alternate, vested, measuring 6-8 μm in diameter. *Parenchyma* paratracheal and apotracheal; paratracheal mostly vasicentric forming 2-4 seriate sheath round the vessels, rarely aliform with short lateral extensions; apotracheal parenchyma present as diffuse cells among fibres; parenchyma cells filled with dark contents; cells 16-30 μm in diameter and 50-80 μm in length (Pl. 1, fig 4). *Xylem rays* 1-3 (mostly 2-3) seriate, homogeneous, rays homocellular composed only of procumbent cells; uniseriate rare, 4-6 cells or 100-130 μm long; multiseriate 9-25 cells or 250-650 μm long (Pl 1, fig 5); procumbent cells 25-40 μm in tangential height and 80-120 μm in radial length (Pl. 1, fig. 7). *Fibres* aligned in radial rows, semilibriform, non-septate, 16-20 μm in diameter and 400-1000 μm in length, interfibre pits not seen.

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Thin sections as well as published descriptions and photographs of the woods of *Adenanthera bicolor* Moon, *A. intermedia* Merrill, *A. microsperma* Teysm et Binn, *A. pavonina* L. and *A. tamerendifolia* were examined critically in order to further ascertain the affinity of the fossil. It was found that in all anatomical details the carbonised wood shows close similarity with that of *A. pavonina*.

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Figured specimen- BSIP Museum No. 37428

Locality- Payangadi Super Clay Mine, Kannur District, Kerala

Genus - *Koompassioxylon* Kramer 1974

***Koompassioxylon keralaensis* sp. nov.**

Pl. 2, figs 1-3,6

The species is based on two well preserved specimens of carbonised wood showing all the anatomical details.

Description- Wood diffuse porous. *Growth rings* not seen. *Vessels* solitary and in radial multiples of 2-3 (sometimes upto 6); oval when solitary and flattened at the place of contact when in multiples: tyloses absent, open or filled with gummy deposits (Pl. 2, fig.1); small to large, t. d. 100-225 μm , r. d. 60-300 μm ; 4-6 per sq mm; perforations simple, vessel members 150-425 μm long with oblique or abruptly tailed ends; intervessel pits alternate, vested with linear or lenticular apertures, 6-8 μm in diameter. *Parenchyma* paratracheal aliform with pointed wings on both sides, sometimes confluent (Pl. 2, fig. 1); parenchyma cells thin walled, 22-30 μm in diameter and 50-100 μm in length, showing storied tendency. *Rays* 1-3 seriate, 5-33 cells or 140-525 μm in length; showing storied tendency at places (Pl. 2, figs 2,3); homocellular to weakly heterocellular made up of procumbent cells only a few with square or slightly enlarged end cells, ray cells large, 14-22 μm in tangential height and 28-70 μm in radial length (Pl. 2, fig.6). *Fibres* radially aligned between rays, polygonal in cross section, libriform, non-septate, 15-20 μm diameter.

Affinities- The important anatomical features of the present carbonised wood, such as paratracheal aliform-to aliform-confluent parenchyma, vested intervessel pits and 1-3 (mostly 2) seriate, homocellular to weakly heterocellular xylem rays with storied tendency indicate its affinities with the woods of the genus *Koompassia* Maing. of the family Fabaceae. Thin sections as well as published description and photographs of all the four species of *Koompassia*, viz., *K. borneensis*, *K. excelsa* Taub., *K. grandiflora* Kostern., and *K. malaccensis* Maing. were studied. It was found that the carbonised wood shows nearest resemblance with *K. excelsa* Taub. (= *K. parviflora*

Plate 2

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| <i>Koompassioxylon keralaensis</i> sp. nov. | |
| 1. | Transversely sectioned surface showing distribution of vessels and aliform confluent parenchyma. x 40; Block no. BSIP 37429. |
| 2. | Tangential longitudinally sectioned surface showing distribution of xylem rays. x 40; Block no. BSIP 37429. |
| 3. | Same surface magnified showing xylem rays with storied tendency. x 150. |
| 6. | Radial longitudinally sectioned surface showing homocellular rays, few with end cells slightly enlarged. x 150; Block no. BSIP |
| 37429. | |
| <i>Parinarioxylon cuddaloreense</i> Awasthi | |
| 4. | Transversely sectioned surface showing distribution of vessels and parenchyma. x 40; Block no. BSIP 37430. |
| 5. | Same surface magnified to show vessels and broken parenchyma lines. x 120. |
| 7. | Radial longitudinally sectioned surface showing heterocellular xylem rays. x 150; Block no. BSIP 37430. |

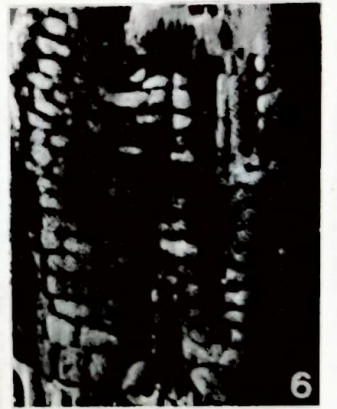
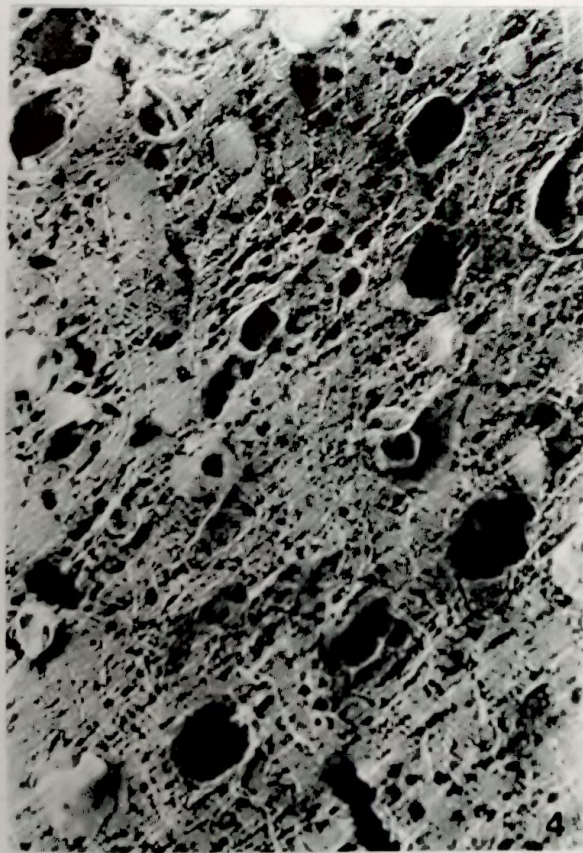
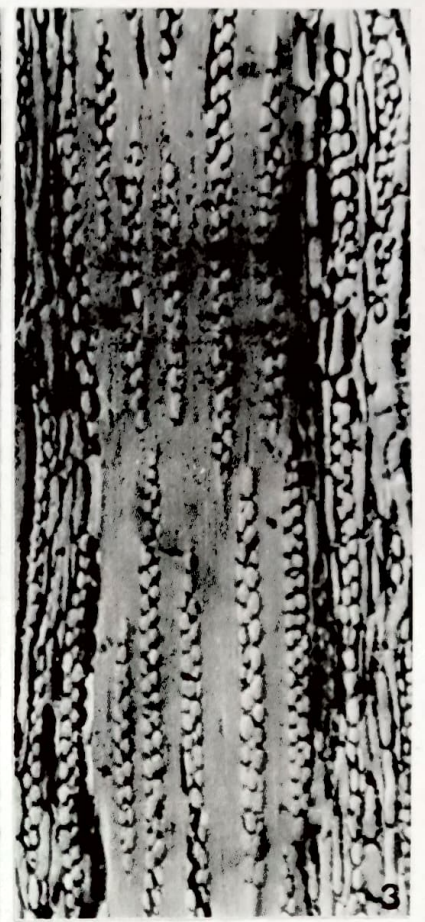
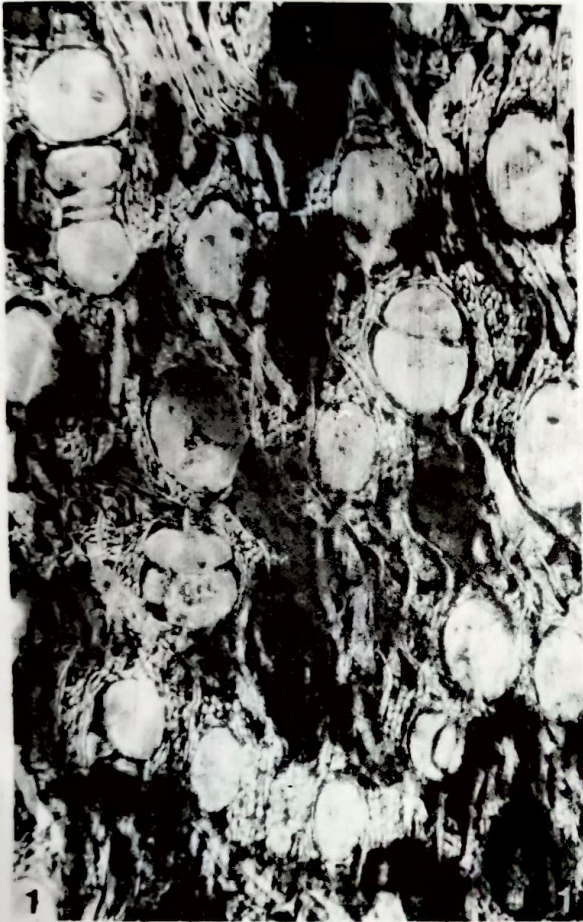


Plate 2

Prain) in having non-storied rays with tendency towards storied arrangement at places in some specimens. However, Desch (1957) reported ripple marks due to storied arrangement of rays and other elements. In *K. grandiflora* and *K. malaccensis* rays and other elements are completely storied.

Koompassioxylon elegans Kramer is the only fossil species showing affinities with *Koompassia malaccensis* which was widely distributed in the past. This species has been reported from south east Asia, West Bengal, Siwalik sediments of Himachal Pradesh and Tipam Sandstone of Assam (Kramer 1974; Bande & Prakash 1980; Yadav 1988; Awasthi & Mehrotra 1990) indicating its wider distribution in the Indo-Malayan region. It differs from the carbonised wood in having distinct ripple marks due to storied arrangement of vessel member, xylem rays and parenchyma strands.

Since the present carbonised wood is different from the only known fossil species, so it is described as *Koompassioxylon keralaensis* sp. nov. indicating its presence in Kerala.

Holotype- BSIP Museum No. 37429

Locality- Kundara Clay Mine, Kollam District, Kerala.

Age - Middle Miocene

Family - Chrysobalanaceae

Genus-Parinarioxylon Pferiffer & Van Heurn 1928

Parinarioxylon cuddaloreense Awasthi 1969

1986-*Parinarioxylon neyveliensis* Awasthi & Agarwal, p-57, pl.1, figs 1-5.

Pl. 2, figs 4, 5, 7; Pl. 3, figs 1,2

The description is based on a single piece of twisted carbonised wood exhibiting satisfactory preservation.

Description- Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to large, t. d. 55-190 µm; r. d. 60-250 µm; exclusively solitary or nearly so; round to oval, few flattened tangentially due to pressure during fossilization; open or filled with dark content; 3-8 vessels per sq mm (Pl. 2, figs 4,5); vessel members 100-450 µm long with oblique or truncate ends; perforations simple, pits leading to fibre tracheids small, about 5 µm in diameter. *Parenchyma* abundant apotracheal, diffuse to diffuse-in-

aggregate forming broken lines among fibres (Pl. 2, figs 4, 5); parenchyma cells 20-25 µm in diameter and 55-110 µm in length. *Rays* very fine, uniseriate, rarely bicelled due to pairing of cells, about 8-46 cells of 150-1400 µm long (Pl. 3, figs 1,2) weakly heterocellular consisting of procumbent cells, sometime with single row of upright or square cells at both the ends; procumbent cells 12-28 µm in tangential height and 40-86 µm in radial length; upright or square cells 30-40 µm in tangential height and 20-40 µm in radial length (Pl. 2, fig 7). *Fibres* aligned in radial rows, 10-14 µm in diameter; distinctly bordered, numerous uniseriate pits on tangential walls; non-septate.

Affinities- The most important anatomical features of the carbonised wood are: vessels exclusively solitary, parenchyma in apotracheal broken lines, rays uniseriate, heterogeneous and fibres non-septate with bordered pits which indicate its affinities with the wood of the genera belonging to the family Chrysobalanaceae (Metcalf & Chalk 1950). Earlier this family was known as Chrysobalanoideae, a sub-family of Rosaceae. The genera of this family are homogeneous in wood structure and can be easily separated from rest of the Rosaceae (Record & Hess 1943; Metcalfe & Chalk 1950). From survey of published literature and photographs of the woods of *Acioa*, *Angelesia*, *Chrysobalanus*, *Couepia*, *Grangeria*, *Hirtella*, *Licania*, *Parastemon* and *Parinari* and examination of their thin sections, it was found that the present wood shows gross resemblance with almost all the genera. However, considering the minor details of the fossil wood, it is closer to *Parinari* in general and *P. corymbosum* and *P. salomonensis* in particular (Desch 1954; Kribs 1959; Normand 1960; Purkayastha & Shahi 1972; Hayashi *et al.* 1973; Miles 1978; Illic 1991).

Three fossil species showing affinities with the woods of *Parinari* are known so far. They are, *Parinarioxylon itersonii* Pfeiffer & Van Heurn (1928) from Tertiary of Java and Ethiopia (Lemoigne, 1978) and two species from India, viz., *Parinarioxylon cuddaloreense* Awasthi (1969) from Cuddalore Sandstones near Pondicherry and *Parinarioxylon neyveliensis* Awasthi & Agarwal (1986) from Neyveli lignite deposits in Tamil Nadu. *P. itersonii* reported from Java differs from the wood under consideration in having large to very large vessels with less frequency (1-2 vessels per sq mm) and

Plate 3

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| <p><i>Parinarioxylon cuddaloreense</i> Awasthi</p> <p>1. Tangential longitudinally sectioned surface showing xylem rays. x 40; Block no. BSIP 37430.</p> <p>2. Same surface magnified to show long uniseriate rays. x 120.</p> <p><i>Bischofia palaeojavanica</i> Awasthi.</p> <p>3. Transverse section showing distribution of vessels. x 45; Slide</p> | <p>no. BSIP 37431-I.</p> <p>4. Same section magnified showing heavily tylosed vessels. x 110.</p> <p>5. Tangential longitudinal section showing xylem rays and fibres. x 110; Slide no. BSIP 37431-II.</p> <p>6. Radial longitudinal section showing heterocellular xylem rays. x 110; Slide no. BSIP 37431-III.</p> |
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Plate 3

uniseriate apotracheal parenchyma lines. The Ethiopian specimen has smaller vessels and paratracheal vascentric aliform parenchyma in addition to apotracheal lines (Lemoigne 1978, p. 217, pl. 8, figs 1-3). The occurrence of vascentric aliform parenchyma in the specimen puts a question mark about its identification as a fossil wood of *Parinari* since in the family Chrysobalanaceae, only apotracheal parenchyma is present as fine continuous lines or bands and vascentric aliform parenchyma is entirely absent (Metcalf & Chalk 1950; Purkayastha & Shahi 1972). *P. neyveli* Awasthi & Agarwal hardly show any anatomical difference from *P. cuddalorensis* Awasthi. Hence it is merged under the same species. Since the anatomical features of the present fossil wood are also in conformity with *P. cuddalorensis* except larger vessel size, it is placed under the same species.

Figured specimen — BSIP Museum No. 37430

Locality—Kundara Clay Mine, Kollam District, Kerala.

Family-Bischofiaceae

Genus-*Bischofia* Bl.

Bischofia palaeojavanica Awasthi 1989

Pl. 3, figs 3-6

The species is based on three pieces of carbonised wood, the largest one measuring 4.2 cm in width and 10.6 cm in length showing fairly good preservation.

Description—Wood diffuse porous. Growth rings indistinct. Vessels mostly solitary and also in radial multiples of 2-3, small to medium sized, t. d. 80-160 μm , r. d. 75-240 μm ; round to oval when solitary and flattened at the place of contact when in multiples; heavily tylosed, often completely occluding the vessels (Pl. 3, figs, 3, 4); 6-8 per sq mm; perforations simple; vessel members 200-360 μm long with truncate or oblique ends; intervesel pits large, alternate, bordered with linear or lenticular apertures, 12-15 μm diameter. Parenchyma very sparse, restricted to one or two cells contiguous to tangential walls of some of the vessels. Rays 1-5 (mostly 1-4) seriate; ray tissue heterogeneous; uniseriate homocellular to heterocellular, either made up of upright cells only or both upright and procumbent cells, 8-16 cell or 240-400 μm long; multiseriate rays heterocellular, made up of procumbent cells in the central part with uniseriate extensions of upright cells at one or both the ends; 18-48 cells or 400-1120 μm long (Pl. 3, fig 5); procumbent cells 20-28 μm in tangential height and 30-40 μm in radial length; upright cells 32-60 μm in tangential height and 30-40 μm in radial length (Pl. 3, fig.6). Fibres aligned in radial rows between two con-

secutive rays, thick walled, septate, 15-20 μm in diameter.

Affinities—The above anatomical characters of the carbonised wood indicate its affinities with that of *Bischofia javanica* Bl. of the family Bischofiaceae (Pearson & Brown 1932; Desch 1957; Illic 1991).

Fossil woods resembling that of *Bischofia javanica* are described as *Bischofia palaeojavanica* Awasthi from the Namsang beds near Deomali, Arunachal Pradesh (Awasthi 1989), Tipam Sandstone, Nagaland (Awasthi & Mehrotra 1990) and Neyveli lignite deposits (Agarwal 1994). The present carbonised fossil wood also exhibits similar features, and therefore, it is placed under the same species.

Figured specimen— BSIP Museum No. 37431

Locality—Varkala Cliff Section, Thiruvananthapuram District, Kerala.

DISCUSSION

The carbonised woods identified as *Poeciloneuron*, *Adenantha*, *Koompassia*, *Parinari* and *Bischofia* furnish additional data for further interpreting palaeoclimate and phytogeography of the region at the time of their deposition. The endemic genus *Poeciloneuron* Bedd. consists of two species indigenous to South India. *P. indicum* the nearest modern counterpart and *P. pauciflorum* are large trees of evergreen forests of Western Ghats from Mysore southwards in Kanara to Travancore (Pearson & Brown 1932; Tandon & Purkayastha 1958). In Western Ghats *Poeciloneuron* is found between 700-800 m, i.e., in a very narrow belt, a little below the crest of the Ghats and is situated wholly on western slope which is exposed to monsoon winds (Pascal 1988). The genus *Adenantha* L. consists of 8 species distributed throughout tropics of Asia, Africa and Australia. *A. pavonina* L., the only Indian species grows in east Himalayas ascending to 1233 m in Sikkim, Assam, Andamans, Western Ghats and parts of Bangla Desh, Sri Lanka, Malaysia, Myanmar, Timor, China and Philippines (Hooker 1879; Gamble 1972; Ramesh Rao *et al.* 1972).

The genus *Koompassia* Maing. is represented by four species, restricted to Malayan Peninsula, Borneo and New Guinea (Willis 1973). *K. excelsa* with which the fossil wood resembles most, is large tree more frequently found in the valleys below 500 meter (Desch 1957).

The genus *Parinari* Aubl. of the family Chrysobalanaceae consists of 60 species of tropical shrubs and trees. Of which 2 species are found in India and 12 in Malaysia occurring chiefly in low land forests (Desch 1954; Purkayastha & Shahi 1972). *P. corymbosum* Miq. found

in Malaysia and Philippines and also found in Tenasserime, Andaman Island and Borneo (Desch 1954). *Bischofia* Bl. is a monotypic genus consists of only species *B. javanica* Bl. distributed in China, Formosa, southeast Asia, Indo-Malaysia and Polynesia (Willis 1973). In India, it is widely distributed from tropical Himalayas, Gorakhpur to Bengal and Assam, in west coast from Konkan to Nilgiris and scarce in Andaman Island (Pearson & Brown 1932; Santapau & Henry 1973).

Of the five taxa described in the present paper, *Poeciloneuron*, *Adenantha*, *Bischofia* and many already reported genera, such as *Calophyllum*, *Euphoria*, *Cassia*, *Cynometra*, *Terminalia*, *Careya*, *Diospyros*, and *Cinnamomum-Litsea* presently grow in semi-evergreen to evergreen forests of Western Ghats indicating that there has not been much change in vegetational pattern and climatic conditions along Kerala coast since Miocene times. However, absence of *Koompassia* and *P. corymbosum* may be considered palaeoecologically and phytogeographically significant. At present these taxa are totally absent from the Indian subcontinent and luxuriantly growing in Malaysian Peninsula. Like *Koompassia*, few other genera namely, *Dryobalanops*, *Anisoptera*, *Gluta*, *Swintonia* and *Gonystylus* reported from Kerala Coast as well as from other Neogene sediments of India are now restricted to tropical wet evergreen forest of Myanmar and Malaysian region. From their total absence in the Palaeogene sediments of India it is quite evident that they are native of Malaysia and after establishment of land connections between India and southeast Asia they had entered India via Myanmar and were luxuriantly growing upto Neogene in the equable warm and humid climate with high precipitation through out the year. Owing to their greater sensitivity to the environmental changes, such taxa failed to regenerate due to considerable decrease in the annual precipitation and also duration of rainy season, because in the tropical region it is mainly rainfall which controls the distribution of plants than atmospheric temperature (Subramanyam & Nayar 1974). The climate of Indian Peninsula and specially Western Ghats is characterised by monsoon regime which superimposes itself over a regime of thermic convectional rainfall linked with zenithal passage of sun (Pascal 1988). Thus, disappearance of several wet evergreen elements from this region is an indication of gradual deterioration of forests since Neogene times.

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