

Holocene woody vegetation and environment of Meenachil River Basin, Kottayam District, Kerala, India

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ABSTRACT

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A few, well preserved, carbonised wood samples (sub-fossils) were collected from Holocene sediments of Mosco and Ponpally areas of Meenachil River Basin, east of Vembanad Lake region in Kottayam District, Kerala. The area is traversed by Meenachil River in the north and its tributary Meenadom Ar in the south. The anatomical study of the woods reveals presence of seven species, belonging to six genera, viz. *Artocarpus* (Family Moraceae), *Calophyllum* (Family Clusiaceae), *Holigarna*, *Lannea* and *Spondias* (Family Anacardiaceae) and *Sonneratia* (Family Sonneratiaceae). No carbonised wood has so far been described from the Kottayam District, Kerala. The assemblage indicates that the area was covered by dense forest and witnessed high rainfall and the prevailing conditions were warm and humid. Occurrence of *Sonneratia*, a mangrove tree that occurs in the tidal creeks and littoral forests, indicates proximity of sea. The sea level was higher at that time and receded since then. Thus, the carbonised woods provide evidence about the prevailing environmental conditions and sea level fluctuations in the area.

Key-words: Carbonised woods, Holocene, environment, sea level fluctuations, Kottayam District, Kerala, India.

INTRODUCTION

The occurrence of Tertiary and Recent deposits as longitudinal outcrops paralleling the western coast of South India has led to the view that morphological evolution of the Kerala Coast was a consequence of alternating transgressive-regressive regime during the Holocene epoch. The pattern of rivers and geomorphological set-up suggest that coastline was extended towards east during the geological past. The present Vembanad Lake and low lying lands marked the eastern limits (Mallick & Suchindan 1984, Nair 2007).

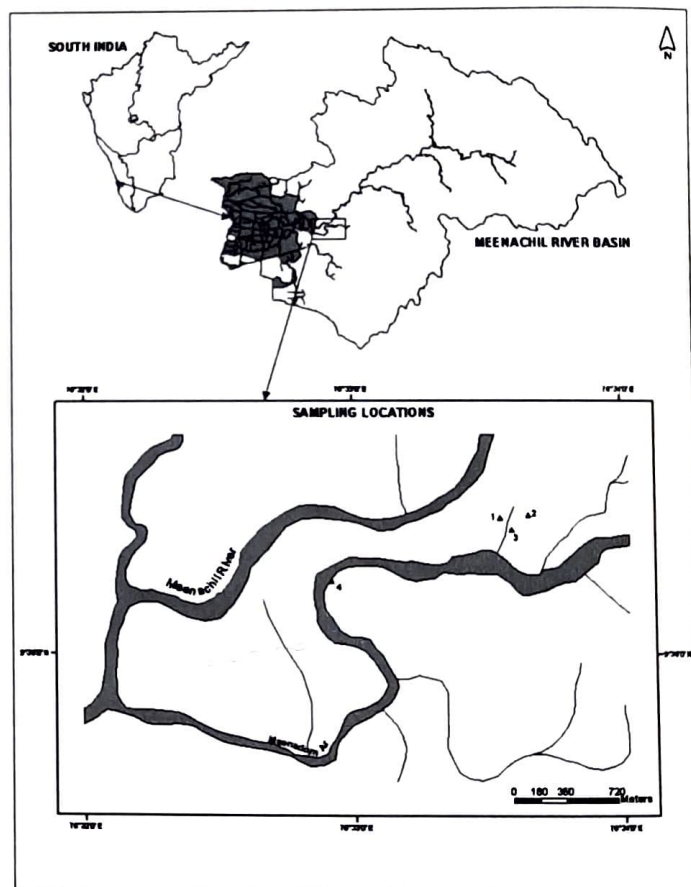
The Quaternary sediments of Kerala consist of alluvium, beach sand deposits, limeshell deposits, red sands, peat beds, calcareous clays with shells which are underlain by laterite in the coastal area marking the

unconformity with the Mio-Pliocene sediments. These sediments are distributed extensively in low lying areas of Kollam, Kottayam, Alleppey, Ernakulum, Trichur, Calicut, Kannur and Kasargod districts (Rajendran et al. 1989). These sediments were provisionally categorized as Recent to Sub-Recent (Paulose & Narayanaswamy 1968). The Quaternary sediments are best developed in Vembanad Lake or lagoonal area and named as Vembanad Formation (Raha et al. 1983, Raha 1996, Najeeb 1999). They have been lately divided into four formations, viz. Guruvayur Formation, Periyar Formation, Viyyam Formation and Kadappuram Formation and range in age from Late Pleistocene to Late Holocene (Nair 2007). The occurrence of peat sequence in the sediments in low lying area around Vembanad in Kottayam District indicates the formation of peat from submerged coastal

forest around 8000 years BP based on the dating of peat and carbonised wood (Power et al. 1983, Rajendran et al. 1989). One of the studied samples from Mosco (39810) was dated at the Radiocarbon Laboratory of the Birbal Sahni Institute of Palaeobotany, Lucknow, assigning a calibrated Radiocarbon age of 6280 years BP (BS No. 2331).

According to Nair (2005), the Kerala Coast witnessed five episodes of marine transgression / regression during the late Holocene. These studies show a drastic change in geomorphology along the Kerala Coast including Vembanad Lake region during the period of marine transgression and regression. Shifts observed in the courses of Meenachil River including its tributaries of lower reaches have been linked to the closure of then existed outlets or formation of new lagoons and also associated with tectonic processes (Narayana et al. 2001, Prakash et al. 2001, Renjith et al. 2007). The present study is an attempt to depict the Holocene changes of Meenachil River at its lower reaches using palaeovegetational analysis. A perusal of the literature shows that no carbonized wood has been described so far from the Kottayam District of Kerala although Tertiary fossil woods have been reported both from North and South Kerala districts of Kasargod, Kannur, Kollam and Thiruvananthapuram (Awasthi & Srivastava 2005). In the present paper a few carbonized woods from the Viyyam Formation sediments of Vembanad Lake region are being described for the first

time, whose occurrence was reported recently in an International Workshop on Climate Change (Guleria et al. 2008). The age of Viyyam Formation is considered to range from Early to Late Holocene (Nair 2007, p. 30).



Text-figure 1. Showing carbonised wood localities in the Meenachil River Basin near Vembanad Lake, Kerala.

Table 1. Details of wood samples and their locations

Sl. No.	Loc. No.	Name of the location	Description of the wood samples		Geographical location
			BSIP Museum No.	Depth from the ground	Latitudes and Longitudes
1	1	Mosco I: Situated about 350m from Meenachil river and 300m from the Meenadom Ar between the two streams	39809	5.5m	09°36'33.7"N 76°33'33.7"E
2			39808	5.5m	
3	2	Mosco II: Situated about 500m from the Meenachil and 450m from the Meenadom Ar	39805	4m	09°36'33.6"N 76°33'41.3"E
4			39808	5m	
5			39804	5m	
5			39810	9m	
6	3	Mosco III: Situated about 500m from the Meenachil and 200m from the Meenadom Ar	39803	4m	09°36'28.4"N 76°33'37.2"E
7			39808	3m	
8			39807	4m	
9	4	Ponpally II: Situated at a distance of 50m from the Meenadom Ar within its meandering loop	39806	4m	09°36'17.5"N 76°32'55.4"E

MATERIAL AND METHOD

The carbonised wood samples were obtained from four terrestrial sand mining sites located at Mosco and Ponpally areas of Meenachil River Basin situated about 15 km inland from the coast near Vembanad Lake in Kottayam District of Kerala. Meenachil River is one of the major rivers that discharge into the Vembanad Lake. The Vembanad Lake is the largest lake in Kerala and is now identified as Ramsar site for conservation (Mohan et al. 2005). The samples were found embedded in sand or clayey sand mostly at a depth of 3m to 6m from the ground level between the northern Meenachil River and southern Meenadom Ar (Text-figure 1, Table 1). The locations are characterized by laterite / laterite soil of ex-situ origin as overburden to a depth 1.5 to 2m, followed by sandstone with a thickness varying from 0.25m to 0.50m followed by loose sand with / without clay layers (2m to 5m) before reaching the crystalline base rock. The woods were sectioned by sliding microtome and structures were studied under high power binocular microscope from their transverse, tangential longitudinal and radial longitudinal sections.

SYSTEMATIC DESCRIPTION

Family: Clusiaceae

Genus: *Calophyllum* Linn.

Calophyllum sp. 1

Plate 1, figures 1-5

Material: A single piece of wood measuring 15.2 cm in length and 5.5 cm in width. The preservation is satisfactory revealing xylotomical details.

Description: Wood diffuse-porous. Growth rings indistinct, demarcated by crowding of vessels. Vessels almost exclusively solitary, arranged in oblique radial lines (Plate 1, figure 1); 8-10 per sq. mm; small to large-sized, tangential diameter 66-286 μm , radial diameter 100-300 μm ; circular to elliptic; occluded with tyloses; lumen filled with red gummy deposits (Plate 1, figure 2); vessel members 385-600 μm in length with truncate or oblique end walls; perforations simple; intervessels pits not seen. Parenchyma abundant, apotracheal, forming 3-6 seriate broken tangential bands among fibres (Plate 1, figure 2); bands distantly placed, 1-2

bands per sq. mm, parenchyma cells 11-14 μm in diameter and 80-110 μm in length, crystalliferous, single large crystal frequently present. Xylem rays exclusively uniseriate, rarely bicelled due to pairing of cells in median portion, closely spaced, 30-40 rays per mm (Plate 1, figure 2); heterocellular made up of both upright and procumbent cells (Plate 1, figure 3); 2-17 (mostly 10-15) cells or 66-620 μm long; single large crystal present in ray cells (Plate 1, figure 5); ray cells distorted due to fungal attack; procumbent cells with tangential height 16.5-27.5 μm and radial length 55-80.5 μm ; upright cells 44-60 μm in tangential height and 27.5-44 μm in radial length. Fibre tracheids aligned between two consecutive rays, angular, 11-33 μm in diameter; nonseptate. Vasicentric tracheids present, circular to oval in cross section, forming 2-3 seriate sheath round the vessels, pits with linear aperture frequently present in vertical rows (Plate 1, figure 3). Wood infected by fungi, fungal spores seen in longitudinal section (Plate 1, figure 5).

Figured Specimen: BSIP Museum No. 39803.

Other Specimen: BSIP Museum No. 39810

Locality: Mosco II, Mosco III.

Affinities: The characteristic features of the fossil wood are: solitary vessels with tyloses arranged in oblique radial lines, vasicentric tracheids, apotracheal parenchyma in broken bands and uniseriate rays. These characters collectively indicate affinities of the wood sample with the extant woods of the genus *Calophyllum* Linn. of the family Clusiaceae (Pearson & Brown 1932, Metcalfe & Chalk 1950, Anonymous 1958, Illic 1991).

The genus *Calophyllum* Linn. is confined to moist tropical regions of the world chiefly in Southeast Asia. About a dozen species occur indigenously in India of these, *Calophyllum inophyllum* Linn., *C. tomentosum* Wight and *C. wightianum* Wall. are found on the banks of rivers and evergreen forests of Kerala and it is difficult to distinguish them xylotomically, hence the sample is assigned to *Calophyllum* sp. *Calophyllum inophyllum* is found along the coast above high water marks (Anonymous 1958). The genus continued to occur in Kerala since Middle Miocene (Awasthi & Srivastava 1992).

***Calophyllum* sp. 2**

Plate 1, figures 6-10

Material: Two pieces of wood measuring 15.5 cm in length and 3.5- 4.0 cm in width. The preservation is satisfactory revealing xylotomical details.

Description: Wood diffuse-porous. Growth rings not seen. Vessels almost exclusively solitary or nearly so, rarely in pairs, arranged in oblique radial lines (Plate 1, figures 6-7); 4-6 per sq. mm; small to large (mostly medium) sized, tangential diameter 80-330 μm , radial diameter 100-286 μm ; circular to elliptic; occluded with tyloses or open (Plate 1, figure 7); vessel members 330-600 μm in length with truncate or oblique end walls; perforations simple; intervessels pits not seen. Parenchyma abundant, apotracheal, forming 2-6 celled broken tangential bands among fibres (Plate 1, figures 6-7); 1-3 bands per sq. mm, parenchyma cells 16.5-31 μm in diameter and 55-110 μm in length, crystalliferous, single large crystal frequently present. Xylem rays exclusively uniseriate, rarely bicelled due to pairing of cells in median portion, closely spaced, 30-40 rays per mm (Plate 1, figure 8); heterocellular made up of both upright and procumbent cells (Plate 1, figure 9); 2-16 cells or 44-450 μm long; single large crystal present in ray cells; procumbent cells with tangential height 16.5-22 μm and radial length 27.5-55 μm ; upright or square cells 33-50 μm in tangential height and 27.5-44 μm in radial length. Fibre tracheids aligned between two consecutive rays, angular, 11-22 μm in diameter; nonseptate. Vasicentric tracheids present, circular to oval in cross section, forming 1-3 seriate sheath round the vessels, pits frequently present in vertical rows, opposite, 4-6 μm in diameter with linear aperture (Plate 1, figure 10). The wood is infected by

fungi, fungal hyphae seen in rays, parenchyma and fibre cells.

Figured Specimen: BSIP Museum No. 39804.

Locality: Mosco II.

Affinities: The specimen shows all the characters of *Calophyllum* and hence it is assigned to the genus *Calophyllum* Linn. It is difficult to differentiate *Calophyllum* sp. anatomically. However, the present specimen shows distinct difference in its structure compared to *Calophyllum* sp. 1, described above. The two differ in frequency of vessels, parenchyma bands and relative length of xylem rays. Frequency of vessels very high, parenchyma bands less and distantly placed and xylem rays are relatively longer in *Calophyllum* sp. 1 as compared to the present specimen, hence, it is assigned to *Calophyllum* sp. 2.

Family: Anacardiaceae

Genus: *Holigarna* Buch.-Ham. ex Roxb.

Holigarna sp.

Plate 2, figures 1-5

Material: A single carbonised wood piece measuring about 8.0 cm in length and 6.5 cm in width. The specimen is well preserved showing all the anatomical details.

Description: Wood diffuse-porous. Growth rings indistinct. Vessels small to large (mostly medium) sized, tangential diameter 55-330 μm , radial diameter 50-400 μm ; evenly distributed, 8-9 vessels per sq. mm; solitary and in radial multiples of 2-3 (Plate 2, figures 1-2); circular to oval when solitary, with flattened contact walls when in multiples; open or filled with tyloses; vessel-members 330-660 μm long with truncate or oblique end walls; perforations simple; inter-vessel pits alternate,

Plate 1

- 1-5. *Calophyllum* sp. 1. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39803-1). 2. Enlarged cross section showing nature and distribution of vessels filled with tyloses and gummy material, distantly placed parenchyma bands and fine rays (BSIP Museum Slide No. 39803-1). 3. Tangential longitudinal section showing uniseriate xylem rays, vessels and vasicentric tracheids (BSIP Museum Slide No. 39803-2). 4. Radial longitudinal section showing heterocellular xylem rays, vessels filled with tyloses (BSIP Museum Slide No. 39803-3). 5. Tangential longitudinal section showing fungal spores, uniseriate rays depicting single large crystals in ray cells and distorted ray cells (BSIP Museum Slide No. 39803-2). 6-10. *Calophyllum* sp. 2. 6. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39804-1). 7. Enlarged cross section showing solitary vessels arranged in oblique fashion filled with tyloses, parenchyma bands and fine xylem rays (BSIP Museum Slide No. 39804-1). 8. Tangential longitudinal section showing short uniseriate xylem rays (BSIP Museum Slide No. 39804-2). 9. Radial longitudinal section showing heterocellular xylem rays (BSIP Museum Slide No. 39804-4). 10. Tangential longitudinal section showing vessels filled with tyloses and vasicentric tracheids (BSIP Museum Slide No. 39804-3).

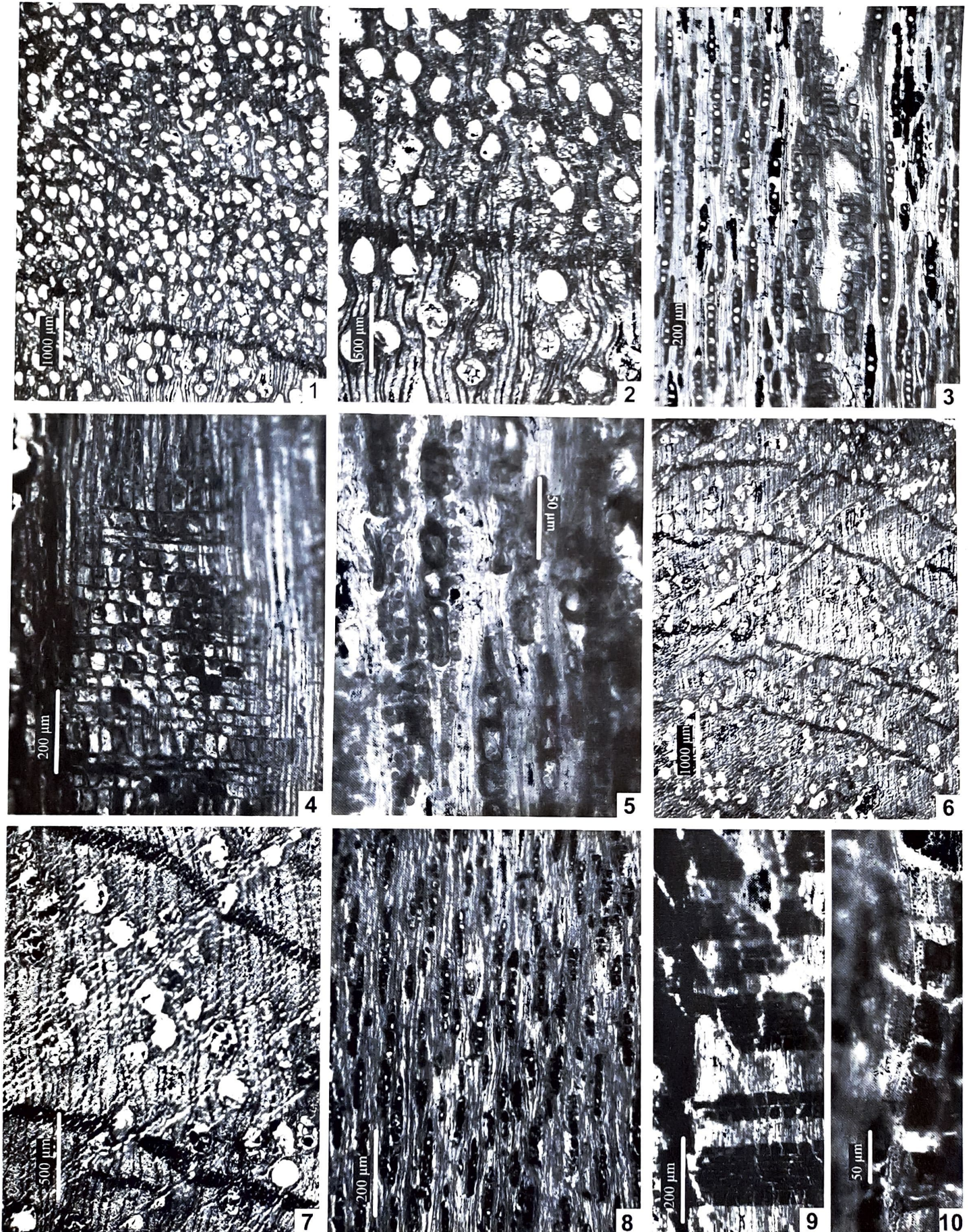


Plate 1

large, bordered, hexagonal with lenticular aperture, 11-12 μm in diameter (Plate 2, figure 5). Parenchyma paratracheal, vasicentric to aliform and aliform-confluent forming 2-4 seriate sheath with wings extending laterally joining 2-3 vessels (Plate 2, figures 1-2); each cells 27.5-37.5 μm in diameter and 66-165 μm in length. Xylem rays 1-4 (mostly 2 - 3) seriate; 11-19 rays per mm; heterocellular (Plate 2, figures 3-4); uniseriate rare, short, 2-20 cells or 110-770 μm long, multiseriate 2-4 seriate, made up of procumbent cells with extensions of 1-3 marginal row of upright cells at one or both the ends; 10-52 cells or 200-1364 μm long; rhomboidal crystals rarely seen in both procumbent and upright cells (Plate 2, figures 3-4); procumbent cells 22-30 μm in tangential height and 50-110 μm in radial length; upright cells 55-115 μm in tangential height and 22-37.5 μm in radial length; vessel-ray pits large, many per cell, half bordered. Fibres aligned in radial rows, polygonal in cross section, libriform, nonseptate; 16.5-28 μm in diameter.

Figured Specimen: BSIP Museum No. 39805.

Locality: Mosco II.

Affinities: In all the above mentioned features the fossil wood shows resemblance with the wood structures of *Buchanania* Sprengel. and *Holigarna* Buch.-Ham. ex Roxb. of the family Anacardiaceae. Of the two genera, *Buchanania* possesses radial gum canals which are absent in *Holigarna* (Ghosh & Purkayastha 1963). The absence of radial gum canals in the present specimen indicates its best resemblance with the woods of genus *Holigarna*.

The genus *Holigarna* is confined to Indo-Malaysian region and about nine species are reported from India and Myanmar (Ghosh & Purkayastha 1963).

The following species occur in evergreen forests of Western Ghats from Konkan to Kerala, viz. *H. arnottiana* Hook.f., *H. beddomei* Hook. f., *H. ferruginea* March., *H. grahamii* (Wight) Kurz and *H. nigra* Bourd. They are, however, anatomically very close and difficult to differentiate (Ghosh & Purkayastha 1963). The fossil may represent any of the species and accordingly named as *Holigarna* sp.

Genus: *Lannea* Richard A.

***Lannea coromandelica* (Houtt.) Merr.**

Plate 2, figures 6-10

Material: The species is based on a single carbonised wood piece measuring about 10 cm in length and 5.5 cm in width. The specimen is well preserved showing all the anatomical details.

Description: Wood diffuse-porous. Growth rings indistinct, demarcated by denser fibres (Plate 2, figures 7-8). Vessels small to large (mostly medium) sized, tangential diameter 110-225 μm , radial diameter 30-190 μm ; evenly distributed, 8-9 vessels per sq. mm; solitary and in radial multiples of 2-3 (Plate 2, figure 8); circular to oval when solitary, with flattened contact walls when in multiples; heavily tylosed (Plate 2, figure 8); vessel members, 275-1100 μm long with truncate or oblique end walls; perforations simple; inter-vessel pits alternate, large, bordered, hexagonal with linear or lenticular aperture, 7.25-13.75 μm in diameter (Plate 2, figure 6). Parenchyma scanty, paratracheal, few cells associated with some of the vessels (Plate 2, figures 7-8); each cells 33-44 μm in diameter and 70-110 μm in length. Xylem rays 1-5 (mostly 2-3) seriate (Plate 2, figure 9); 22-30 rays per mm; heterocellular (Plate 2, figure 10); uniseriate rare, short, 4-10 cells or 220-350 μm long, multiseriate 7-25 cells or 165-1100 μm



Plate 2

- 1-5. *Holigarna* sp. 1. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39805-1). 2. Enlarged cross section showing distribution of vessels, xylem rays and vasicentric to aliform-confluent parenchyma (BSIP Museum Slide No. 39805-1). 3. Tangential longitudinal section showing xylem rays with crystalliferous cells and vessel filled with tyloses (BSIP Museum Slide No. 39805-2). 4. Radial longitudinal section showing heterocellular nature of rays (BSIP Museum Slide No. 39805-3). 5. Intervessel pits in Tangential longitudinal section (BSIP Museum Slide No. 39805-2). 6-10. *Lannea coromandelica* (Houtt.) Merr. 6. Intervessel pits in TLS showing xylem rays (BSIP Museum Slide No. 39806-2). 7. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39806-1). 8. Enlarged cross section showing heavily tylosed vessels and scanty paratracheal parenchyma (BSIP Museum Slide No. 39806-1). 9. Tangential longitudinal section showing xylem rays and gum canals in the broad rays (BSIP Museum Slide No. 39806-2). 10. Radial longitudinal section showing heterocellular xylem rays with fungal spores and frequently septate fibres (BSIP Museum Slide No. 39806-3).

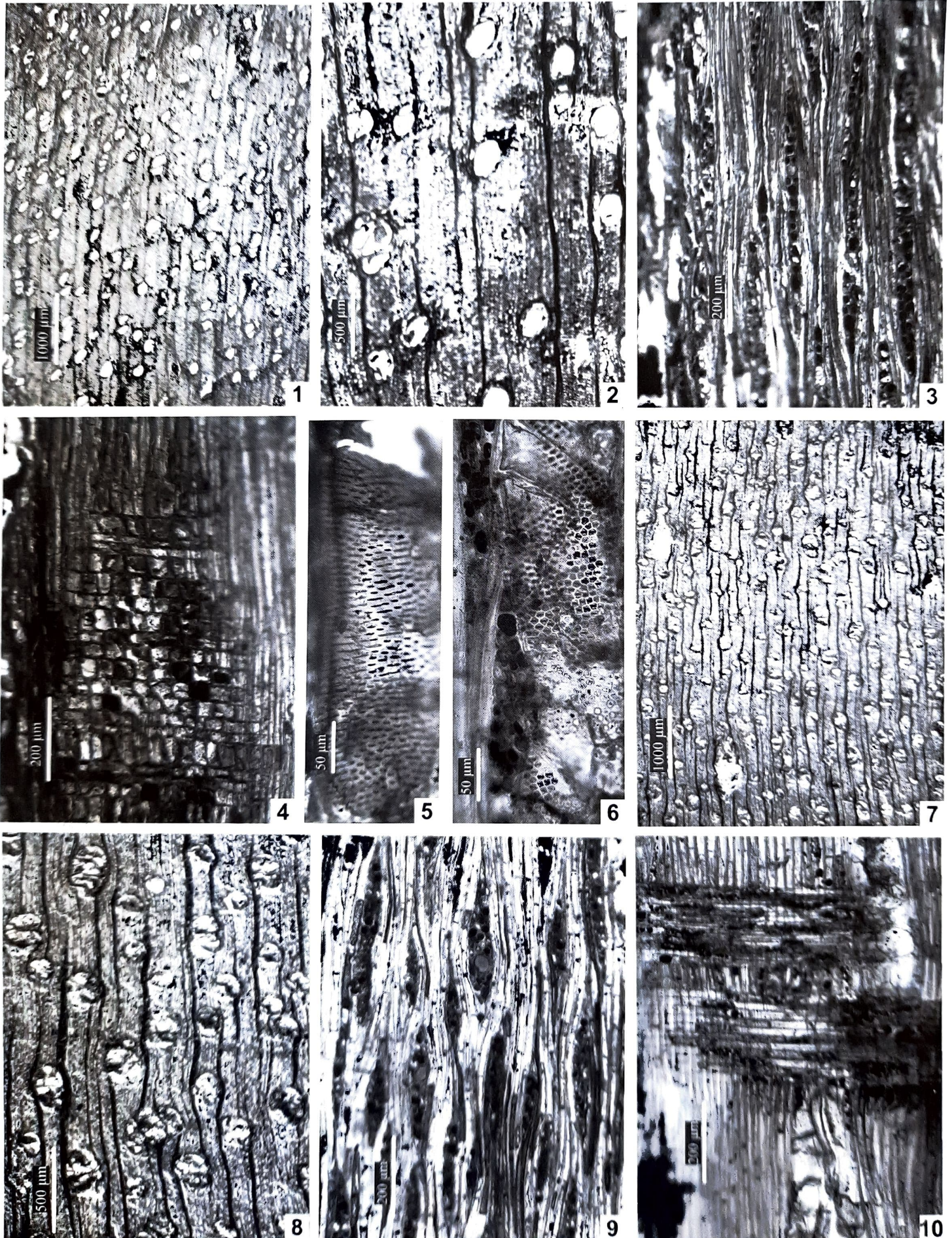


Plate 2

long, few with radial gum canals; made up of procumbent cells in the centre and upright cells at one or both ends; rhomboidal crystals rarely seen in both procumbent and upright cells, fungal spores seen in ray cells (Plate 2, figure 10); silica inclusions present in ray cells; procumbent cells 16.6-28 μm in tangential height and 99-165 μm in radial length; upright cells 82.5-110 μm in tangential height and 22-28 μm in radial length; vessel-ray pits large, many per cell. Gum canals radial, frequently present in multiseriate rays (Plate 2, figure 9), large, single per ray, 55 - 82 μm in diameter; encircled by single layered epithelial lining (Plate 2, figure 9). Fibres aligned in radial rows, polygonal in cross section, semilibriform, frequently septate; 22-28 μm in diameter (Plate 2, figures 7-8).

Figured Specimen: BSIP Museum No. 39806.

Locality: Ponpally II.

Affinities: The important anatomical features of the present wood are: Growth rings indistinct, vessels small to medium in size, solitary and in radial multiples of 2-3, profusely tylosed, parenchyma scanty, paratracheal; rays 1-5 mostly 2-3 seriate, ray tissue heterocellular, crystals present in ray cells, radial gum canals present and fibres thick walled and septate. In all the above characters the fossil wood shows close resemblance with the woods of family Anacardiaceae (Ghosh & Purkayastha 1963). On preliminary examination the sample was considered to belong to genus *Canarium* of the family Burseraceae on account of occurrence of gum canals in its xylem rays (Guleria et al. 2008). Subsequently on detailed investigation it was found that epithelial lining of radial gum canals in the present fossil is one cell thick and crystals are confined to ray cells only. On the basis of all the above mentioned features it was found that the fossil shows

closest anatomical similarity with the modern wood of genus *Lannea* A. Rich., viz. *L. coromandelica* (Houtt.) Merr., the only species found in India (Chauhan & Dayal 1990, Srivastava & Guleria 2004).

The genus *Lannea* A. Rich consists of about 15 species of small to large deciduous trees and is found in tropical Africa and Asia (Mabberely 1997). *Lannea coromandelica* (Houtt.) Merr. (syn. *L. grandis* Engl.), the only Indian species is fairly wide in its distribution and is found in dry forests of all states except parts of Punjab, Rajasthan and Saurashtra. It is very common in Travancore and in the deciduous forests of Mysore and Tamil Nadu. In the Andamans, the tree grows frequently in damp places along streams (Ghosh & Purkayastha 1963).

Genus: *Spondias* Linn.

Spondias sp.

Plate 3, figures 1-5

Material: A single carbonised wood piece measuring about 12 cm in length and 5 cm in width. The specimen is well preserved showing all the anatomical details.

Description: Wood diffuse-porous (Plate 3, figures 1-2). Growth rings indistinct, faintly demarcated by denser fibres. Vessels small to medium-sized, tangential diameter 82.5-177 μm , radial diameter 70-177 μm ; evenly distributed, 8-9 vessels per sq. mm; solitary as well as in radial multiples of 2-3 (Plate 3, figure 2), circular to oval when solitary, with flattened contact walls when in multiples; open or partially filled with tyloses (Plate 3, figure 2); vessel-members 275-450 μm long with truncate or oblique end walls; perforations simple; inter-vessel pits alternate, large, bordered, hexagonal with linear aperture, 8.25-11 μm

Plate 3

1-5. *Spondias* sp. 1. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39807-1). 2. Enlarged cross section showing distribution of vessels, xylem rays and scanty paratracheal parenchyma (BSIP Museum Slide No. 39807-1). 3. Tangential longitudinal section showing xylem rays with gum ducts and tylosed vessel (BSIP Museum Slide No. 39807-2). 4. Radial longitudinal section showing heterocellular nature of xylem rays (BSIP Museum Slide No. 39807-3). 5. Intervessel pits as seen in TLS (BSIP Museum Slide No. 39807-2). 6-10. *Sonneratia apetala* Buch- Ham. 6. Vestured intervessel pits seen in Radial longitudinal section (BSIP Museum Slide No. 39808-3). 7. Cross section showing nature and distribution of vessels and fine xylem rays (BSIP Museum Slide No. 39808-1). 8. Enlarged Cross Section showing distribution of vessels, xylem rays and absence of parenchyma (BSIP Museum Slide No. 39808-1). 9. Tangential longitudinal section showing fine rays (BSIP Museum Slide No. 39808-2). 10. Radial longitudinal section showing heterocellular rays (BSIP Museum Slide No. 39808-3).

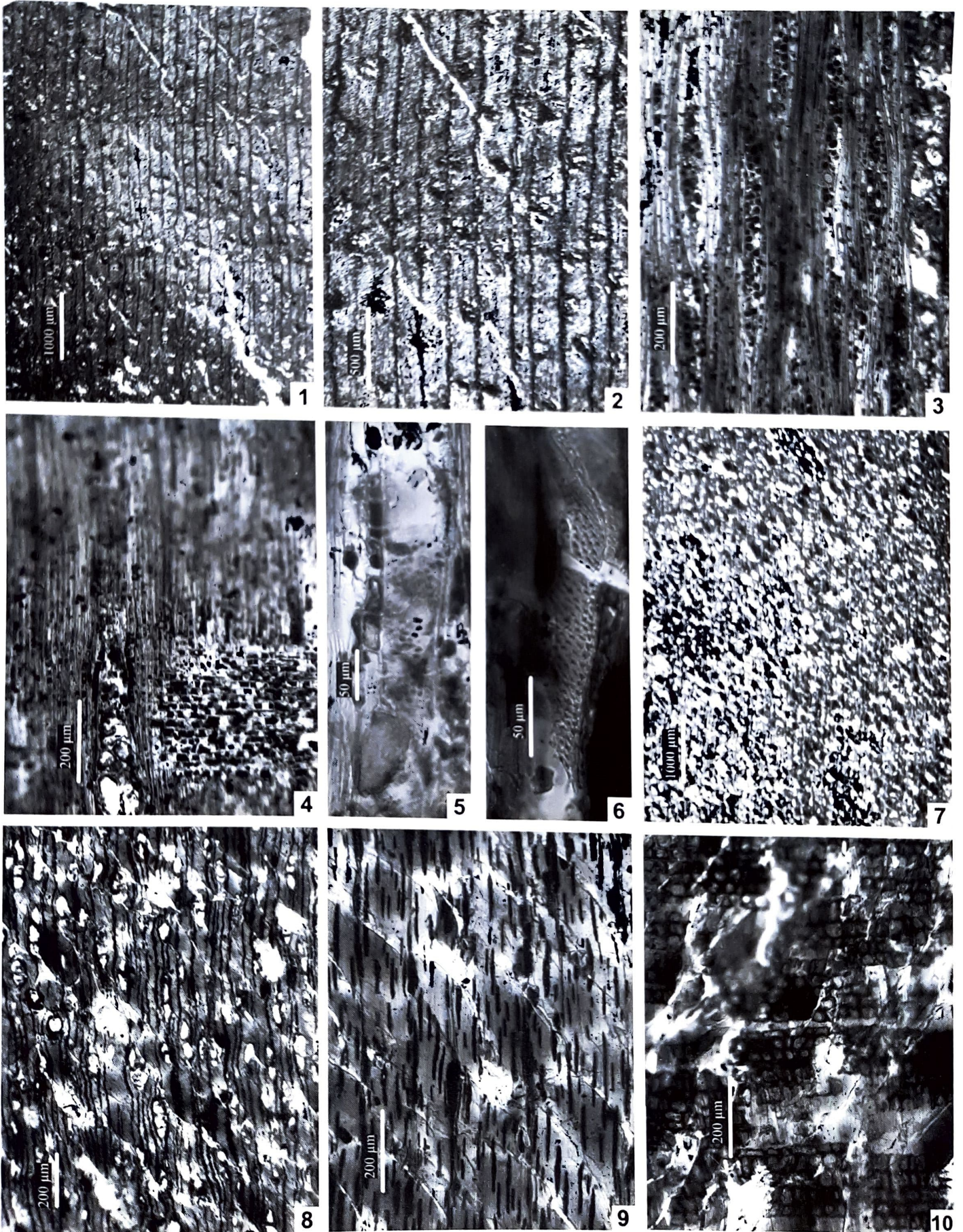


Plate 3

in diameter (Plate 3, figure 5). Parenchyma scanty, paratracheal, few cells associated with vessels, rarely 1-2 seriate sheath round some of the vessels (Plate 3, figure 2); each cells 16.5-27.5 μm in diameter and 55-124 μm in length. Xylem rays 1-5 (mostly 3) seriate (Plate 3, figure 3), 18-22 rays per mm; heterocellular (Plate 3, figure 4); uniseriate rare, made up of upright cells only, 8-20 cells or 330-660 μm long, multiseriate 10-30 cells or 275-700 μm long, few with radial gum canals (Plate 3, figure 3); made up of procumbent cells in the centre with the extensions of 1-3 upright cells at one or both ends; procumbent cells 16.5-28 μm in tangential height and 38.5-66 μm in radial length; upright cells 27.5-44 μm in tangential height and 11.5-22 μm in radial length (Plate 3, figure 4). Gum canals radial, frequently present in multiseriate rays (Plate 3, figure 3), small, single per ray, 33-55 μm in diameter; encircled by single layered epithelial lining. Fibres aligned in radial rows, polygonal in cross section, semilibriform, nonseptate; 22-28 μm in diameter.

Figured Specimen: BSIP Museum No. 39807.

Locality: Mosco III.

Affinities: In having anatomical features such as small to medium vessels, solitary and in radial multiples of 2-3 open or partially filled with tyloses, scanty vasicentric parenchyma, fine to broad xylem rays, presence of radial gum canals and nonseptate fibres, the present wood indicates its close resemblance with the extant wood of *Spondias* Linn. of the family Anacardiaceae.

The genus *Spondias* Linn. consists of 10 species of small to large trees widely distributed in the tropics of Old and New World. Three species of the genus are said to be indigenous to India, namely, *Spondias axillaris* Roxb., *S. acuminata* Roxb. and *S. mangifera* Willd (Anonymous 1963). Among the three species, *S. axillaris* possesses ring porous wood, hence is different from the present sub fossil. The woods of remaining two species, namely, *S. acuminata* and *S. mangifera* which are found in the present day flora of Kerala are difficult to distinguish anatomically from each other. Hence, it is described as *Spondias* sp. As far as the authors are aware this is the first record of ancient wood of *Spondias* Linn.

Family: Sonneratiaceae

Genus: *Sonneratia* Linn.

Sonneratia apetala Buch-Ham.

Plate 3, figures 6-10, Plate 4, figure 1

Material: Two pieces of carbonised woods measuring 7.0 cm x 5 cm and 11 x 2.5 cm, respectively. One of the samples is twisted. The specimens are fairly well preserved.

Description: Wood diffuse-porous (Plate 3, figure 7). Growth rings not seen. Vessels evenly distributed, small to medium (mostly small), tangential diameter 38-93 μm , radial diameter 44-100 μm , solitary and in radial multiples of 2-3 (rarely up to 5), circular to oval when solitary, those in radial multiples are flattened at the place of contact; open or filled with brown-black deposits and a few tylosed (Plate 3, figure 8); vessel-members 220-440 μm , long with truncate or oblique end walls; perforations simple; inter vessel pits alternate, hexagonal, vestured, 6-6.8 μm , in diameter (Plate 3, figure 6). Parenchyma absent. Xylem rays fine, uniseriate, rarely bicelled due to pairing of cells (Plate 3, figure 9), heterocellular, made up of procumbent cells with interspersed upright or square cells; short, 2-7 cells or 37-175 μm long (Plate 3, figure 10); ray cells crystalliferous, solitary large crystal found in upright cells; procumbent cells 50-77 μm in radial height and 27.5-38.5 μm in tangential length; upright or square cells 38-42 μm in tangential height and 27-5-40 μm in radial length (Plate 3, figure 10). Fibres aligned in radial rows between two consecutive rays; septate, septa rarely seen, 14-20 μm , in diameter. Wood infected by fungi, fungal hyphae visible (Plate 4, figure 1).

Figured Specimen: BSIP Museum No. 39808.

Locality: Mosco I, Mosco III.

Affinities: The combination of characters of the wood, namely, diffuse porous wood, small to medium sized vessels, vestured intervessel pits, absence of parenchyma, uniseriate rays and septate fibres are the important characters of family Sonneratiaceae (Pearson & Brown 1932, Metcalfe & Chalk 1950, Vijendra Rao et al. 1987). Woods of two genera of the family, viz. *Duabanga* Buch-Ham and *Sonneratia* Linn., can easily be distinguished particularly in the presence and

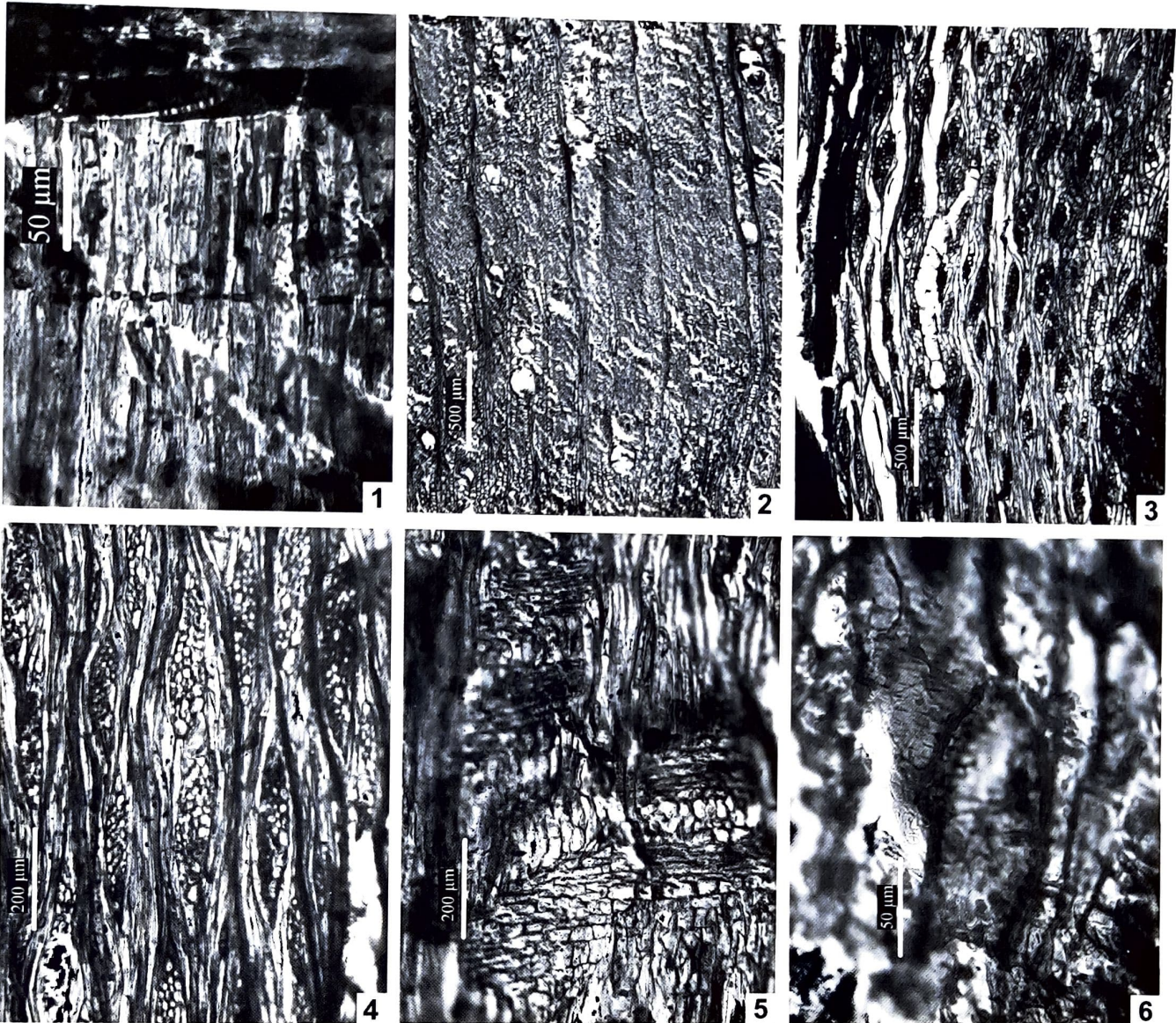


Plate 4

1. *Sonneratia apetala* Buch- Ham. Radial longitudinal section showing fungal hyphae and spores (BSIP Museum Slide No. 39808-4).
 2-6. *Artocarpus* sp. 2. Cross section showing nature and distribution of vessels, parenchyma and xylem rays (BSIP Museum Slide No. 39809-1). 3. Tangential longitudinal section showing fine and broad xylem ray (BSIP Museum Slide No. 39809-2). 4. Tangential longitudinal section showing distribution of vessels, xylem rays and parenchyma (BSIP Museum Slide No. 39809-2). 5. Radial longitudinal section showing heterocellular nature of xylem rays (BSIP Museum Slide No. 39809-3). 6. Large intervessel pits as seen in TLS (BSIP Museum Slide No. 39809-2).

absence of parenchyma, low and high frequency of vessels, tangential diameter of vessels and in the absence and presence of septa in fibres (Purkayastha 1982, Vijendra Rao et al. 1987). In view of the absence of parenchyma and presence of septate fibres, the wood belongs to the genus *Sonneratia* Linn. The genus *Sonneratia* consists of 4-5 species of trees and occurs in mangrove swamps of East Africa, SE Asia and warmer parts of Australia. Three species have been reported from India, viz. *Sonneratia alba* J. Smith, *S. apetala* Buch-Ham and *S. caseolaris* (Linn.) Engler

and all of them are anatomically very similar (Purkayastha 1982, pp. 40-41). Out of the three species, *S. apetala* is common on western coast south of Konkan. The fossil most likely represents the wood of *S. apetala* and is placed under the same species. It is a moderate sized tree attaining a height of about 15m and is found in littoral forests.

Family: Moraceae

Genus: *Artocarpus* Forster & Forster f.

Artocarpus sp.

Plate 4, figures 2-6

Material: A single carbonised wood piece measuring about 15 cm in length and 3.7 cm in width. The specimen is well preserved showing all the anatomical details.

Description: Wood diffuse-porous. Growth rings not seen. Vessels evenly distributed, small to medium sized, tangential diameter 77-220 μm , radial diameter 55-165 μm ; 8-9 vessels per sq. mm; solitary as well as in radial multiples of 2-3 (Plate 4, figure 2), circular to oval when solitary, those in multiples flattened at the place of contact; open or partially filled with tyloses; vessel members 165-440 μm long with oblique end walls; perforations simple; inter-vessel pits alternate, bordered, hexagonal with linear aperture, 7-10 μm in diameter (Plate 4, figure 6). Parenchyma abundant, paratracheal vasicentric to aliform forming 3-4 seriate sheath round the vessels which extend laterally to form wings, rarely confluent forming 3-4 seriate bands at places (Plate 4, figure 2); each cell 22-44 μm in diameter and 55-132 μm in length. Xylem rays 1-5 (mostly 3-5) seriate (Plate 4, figures 3-4); 10-18 rays per mm; heterocellular (Plate 4, figure 5); uniseriate rare, made up of upright cells or both upright cells and procumbent cells, 8-20 cells or 330-660 μm long, multiseriate 10-30 cells or 275-700 μm long, few with radial gum canals; sheath cells occasionally present on the flanks; made up of procumbent cells in the centre with the extensions of 1-4 upright cells at one or both ends; procumbent cells 16.5-28 μm in tangential height and 38.5-66 μm in radial length; upright cells 27.5-44 μm in tangential height and 11.5-22 μm in radial length (Plate 4, figure 5). Gum ducts radial, frequently present in multiseriate rays, small, single per ray, 33-55 μm in diameter; encircled by single layered epithelial lining. Fibres aligned in radial rows, polygonal in cross section, semilibriform, nonseptate; 22-28 μm in diameter.

Figured Specimen: BSIP Museum No. 39809.

Locality: Mosco I.

Affinities: The important characters of the present fossil are: vessels mostly solitary or in radial multiples of 2-4 with abundant tyloses; inter-vessel pits large, parenchyma paratracheal mostly vasicentric to aliform-confluent, xylem rays mostly broad, heterogeneous with

occasional radial ducts and septate fibres. The above anatomical features of the specimen indicate its close similarity with the modern woods of the genus *Artocarpus* Forster & Forster f. of the family Moraceae (Pearson & Brown 1932, Metcalfe & Chalk 1950, Hayashi et al. 1973). About 7-8 species of *Artocarpus* are said to occur in India, out of which *A. heterophyllus* Lamk., *A. hirsutus* Lamk. and *A. lacucha* Buch-Ham. are distributed in the moist evergreen forests of Western Ghats. The last two species are found in west coast of Kerala (Raturi et al. 2001). In view of their close anatomical similarity the fossil may belong to *A. hirsutus* / *A. lacucha*. The history of the genus is well known in India (Guleria et al. 1996) and the genus has continued to occur on the Kerala coast since Middle Miocene, i.e. about 15 million years ago (Srivastava 1998, Guleria et al. 2004).

DISCUSSION

The assemblage, represented by the woods of *Artocarpus*, *Calophyllum*, *Holigarna*, *Lannea*, *Sonneratia* and *Spondias*, indicates that the area was covered by dense forest and witnessed high rainfall and the prevailing conditions were warm and humid. Similar results have also been deduced on the basis of pollen studies in the South Kerala Sedimentary Basin during 10-4 Ky BP by Jayalakshmi et al. (2005) and Kumaran et al. (2005).

Calophyllum, *Spondias* and *Sonneratia* are inhabitant of coastal area and indicate near-shore conditions, particularly the last one. *Sonneratia* is a mangrove tree that occurs in the tidal creeks and littoral forests. Mangroves occupy the tropical coasts and are considered to be prolific producers of peat. *Calophyllum inophyllum*, a comparable species, is found all along the coast above high water mark and in the evergreen forests of Western Ghats along the river banks. *Artocarpus*, *Holigarna* and *Lannea* are found in the evergreen to semi-evergreen forests of Western Ghats, including Kerala. The fungal infection in most of the woods further substantiates existence of warm and humid conditions. There appears no significant or drastic difference in the present day climatic conditions of coastal Kerala as compared to the same at the time of deposition of these woods.

Occurrence of *Sonneratia* indicates proximity of sea and indicates that the sea level was much higher at that time and receded since then. The assemblage indicates continental to lagoonal or marginal marine environment. Thus the carbonised woods provide evidence about the prevailing environmental conditions and sea level fluctuations in the area. The Kerala Coast attained the present form through a series of transgressions and regressions during the Holocene. The present work provides independent evidence supporting the views of many workers (Narayana et al. 2001, Pandarinath et al. 2001, Soman 2002, Nair 2007, and others) that Kerala Coast has been modified due to sea level fluctuations at periodic intervals during Holocene epoch. It is important to mention here that the change in sea level is of great concern to those living in coastal regions and the fate of occupants of coastal areas, among other things, depends on the rise and fall of sea level.

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