STUDIES ON SOME CARBONISED WOODS FROM THE NEYVELI LIGNITE DEPOSITS, INDIA

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ABSTRACT

Six carbonised woods showing close resemblance with those of the extant genera, viz., *Hopea*, *Gluta*, *Carallia*, *Diospyros-Maba* and *Cordia* have been described from the Neyveli Lignite. They have been named as *Hopenium neyveliensis* sp. nov., *Glutoxylon burmense* (Hold.) Chowdhury, *Carallioxylon indicum* gen. *et* sp. nov., *Ebenoxylon arcotense* Awasthi and *Cordioxylon multiseriatum* gen. *et* sp. nov. respectively. Excepting *Carallia* and *Cordia* the other genera are already known from the Cuddalore Sandstone near Pondicherry. These taxa are mostly inhabitants of the tropical evergreen forests of Western Ghats and elsewhere in Southeast Asia which indicate somewhat similar climatic conditions around Neyveli at the time of their deposition.

INTRODUCTION

The Neyveli Lignite in South Arcot district, Tamil Nadu, being the largest deposit of lignite in the Indian sub-continent, has received the attention of geologists, palaeobotanists and mining engineers since early thirties of this century when perhaps the first bore core was drilled in the vicinity of the village Neyveli. Their main interest has been to understand the physical nature, composition, source material and depositional environment of the lignite because of its proven commercial and industrial potential. The lignite is about 18 m in thickness, overlain by clays and sandstones and underlain by clays and sands (Text-fig. 1). The lignite contains almost all the botanical entities, such as pollen and spores, algal and fungal bodies, impressions and compressions of leaves, and carbonised woods, twigs, shoots, fruits, etc.

The palynofossils and fungal and algal bodies from the lignite have been studied by several workers (Navale, 1961; 1968b, 1972; Navale & Misra, 1979; Thiergart & Frantz, 1962; Ramanujam, 1963a, 1963b, 1966a, 1966b, 1966-67, 1982; Ramanujam & Ramachar, 1963; Deb, 1972; Bakshi *et al.*, 1979; Ramanujam *et al.*, 1980; Reddy *et al.*, 1980; Ambwani, 1983; Ambwani *et al.*, 1981; Bande & Ambwani, 1982). As a result, a fairly good number of taxa are known though exact affinities of some of the microfossils with the modern ones are yet to be ascertained. On the contrary, the megafossils have received little attention and so far only a few preliminary reports have been made. In an abstract published in the Proceeding of the Indian Science Congress, Singh and Mathew (1954) reported leaves and dicotyledonous plants besides pollen grains and algal and fungal remains. In another abstract appeared in the proceeding of the International Botanical Congress, Jacob and Jacob (1954) have mentioned the occurrence of leaves and leaf cuticles of angiosperms, some of which were provisionally placed in the family Oleaceae. Chatterjee and Bhattacharya (1965) described a compressed bark/leaf-sheath of a palm-like tree and some shoots with crown of leafy bracts/leaves which they suggested to be either certain young shoots of palm-like tree or some other morphological

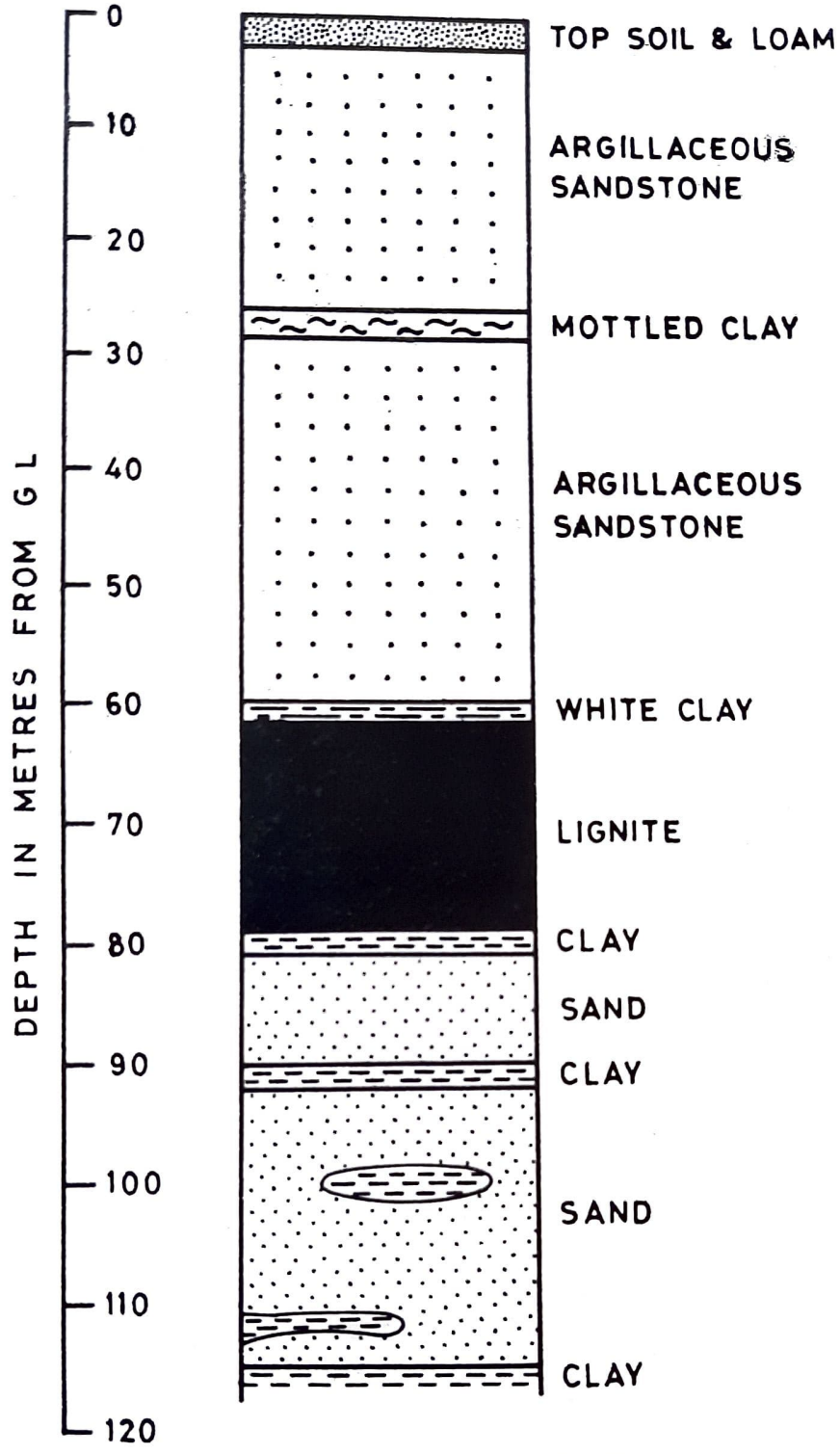

Fig. 1. Vertical section of lignite-bearing formation (after Ramanujam, 1982, p. 59, fig. 2)

organs of related groups of palm. Recently, AMBWANI (1982) described a small shoot with leaf-bases showing its anatomical similarity with that of *Dracaena* of the family Agavaceae. This stem is quite similar in its external features to the shoots reported earlier by CHATTERJEE AND BHATTACHARYA (1965). Earlier, in 1956 LAKSHMANAN AND LEVY briefly described a lignitized wood showing general features of the Sapotaceae.

During the study of lignite pellets NAVALE (1968a, 1974) observed woody structures of *Diospyros-Maba, Dipterocarpus-Anisoptera, Mesua-Calophyllum, Cassia-Acacia, Ter-*

minalia, Phyllanthoideae group of Euphorbiaceae and palm, and cuticular structures of Gramineae. These determinations may be considered tentative because other important features of the wood, such as the nature and distribution of rays, fibres etc., are not known.

In order to reconstruct the palaeo-vegetation constituting the vast lignite deposit and to decipher palaeoecology and palaeo-phytogeography of this region at the time of its deposition it was deemed necessary to undertake systematic study of plant megafossils of the Neyveli lignite.

The material for the present study comprises carbonised woods collected from the Neyveli lignite mine I. The woods were sectioned with Reichert Sliding Microtome. The fragile material was, however, sectioned after embedding in paraffin wax. While sectioning, liquid colloidion was smeared on the surface of the block of wood to be cut to prevent the sections from distortion. The sections were thoroughly washed in pure xylol to remove the paraffin wax and then mounted in canada balsam.

Out of several carbonised woods studied, those showing resemblance with the modern species of *Hopea*, *Carallia*, *Gluta*, *Diospyros-Maba* and *Gordia* are described in this paper.

SYSTEMATICS

Family—Dipterocarpaceae

Genus—**Hopenium** Awasthi, 1980

Hopenium neyveliensis sp. nov.

Pl. 1, Figs 1, 3, 5,

Description—Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, rarely large, majority solitary, occasionally in multiples of 2-3 (Pl. 1, Fig. 1) or in groups of small vessels, circular to oval, about 40-180 μm in diameter, about 30-50 vessels per sq. mm; tylosed; perforations simple; vessel-members 150-450 μ in length, truncate; intervessel pits and pits leading to contiguous tracheids medium to large, 8-10 μm in diam., vestured, with linear to lenticular apertures. *Vasicentric Tracheids* sparse, not easily recognisable in cross-section, seen in the tangential longitudinal section due to presence of bordered pits, intermingled with parenchyma occurring around vessels or vessel groups, diameter nearly same as of parenchyma. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, usually forming incomplete sheath, intermingled with tracheids, frequently interrupted by rays; apotracheal parenchyma diffuse or diffuse-in-aggregate or cells scattered irregularly without definite noticeable pattern (Pl. 1, Fig. 1), parenchyma occurring around gum canals forming 3-6 seriate tangential bands usually closely placed (Pl., 1, Fig. 1); cells about 20-32 μm in diameter. *Rays* 1-4 seriate (Pl. 1, Fig. 3), mostly 3-4, about 6-8 per mm in cross-section, 15-60 cells in height; ray tissue heterogeneous; rays heterocellular, consisting of procumbent cells and 1-4 or sometimes more uniseriate marginal rows of upright or square cells (Pl. 1, Figs 3, 4); upright cells usually interspersed among procumbent cells and sometimes also occurring in the flanks, mostly crystalliferous (Pl. 1, Fig. 3), 32-52 μm in tangential height and 20-32 μm in radial length; procumbent cells 16-24 μm in tangential height and 28-140 μm in radial length; *Fibres* small, angular, 16-28 μm in diameter, thick-walled, walls

4-6 μm, nonseptate; pits not clearly seen. *Gum canals* normal, vertical, aligned in tangential rows foming concentric rings, mostly bigger than vessels (Pl. 1, Fig. 1), circular to oval, 120-450 μm in diameter.

Comparison—The important features of the fossil are: vessels small to medium, tylosed; tracheids vasicentric; parenchyma paratracheal, diffuse-in-aggregate or scattered among fibres and also occurring around gum canals;xylem rays 1-4 seriate, heterogeneous; fibres nonseptate, thick-walled and gum canals vertical in concentric rings. These features collectively indicate its affinities with the woods of tribe Shoreae of the family Dipterocarpaceae Beside the above mentioned features, the fossil is further characterized in having xylem rays with crystalliferous upright or square cells interspersed among the procumbent cells. Such rays are mostly found in *Hopea* of Shoreae.

A critical examination of thin-sections of the woods of *Hopea* has revealed that the present fossil wood is closer to some of the Indian hopeas as well as *Hopea plagata*, especially in having large to very large gum canals and smaller vessels. *Hopea plagata* Vidal is known to occur in Philippines.

So far, only one species of fossil wood of *Hopea*, viz., *Hopenium pondicherriense* Awasthi (1980), is known from the Cuddalore Series near Pondicherry. The present fossil differs from it in having large to very large gum canals (240-450 μm in diam. as against 40-100 μm) and further, in being more frequent in their distribution. Therefore, the present fossil wood is assigned to a new species—*Hopenium neyveliensis*. The specific name is after the locality—Neyveli.

DIAGNOSIS

Hopenium neyveliensis sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, majority solitary, occasionally in multiples of 2-3 or aligned in small radial groups, 40-150 μm in diameter, tylosed, about 30-40 per sq. mm; intervessel pits or pits leading to tracheids large, 6-8 μm, vestured; tyloses present. *Tracheids* vasicentric, intermingled with paratracheal parenchyma. *Parenchyma* paratracheal and apotracheal. paratracheal parenchyma vasicentric to occasionally aliform, apotracheal parenchyma diffuse-in-aggregate, or cells scattered among fibres, parenchyma associated with gum canals forming 3-6 seriate tangential bands. *Rays* 1-4 seriate, heterogeneous, consisting of 1-4 or more uniseriate marginal rows of upright or square cells and procumbent cells in the medium portion, crystalliferous square or upright cells interspresed among procumbent cells and also present in the flanks; rays 15-60 cells in height. *Fibres* small, angular, 16-28 μm in diameter, thick-walled, nonseptate, *Gum canals* abundant, normal, vertical, in concentric rings, closely spaced, large to very large in size, 225-450 μm in diameter.

Holotype—B. S. I. P. Museum No. 35728

FAMILY-ANACARDIACEAE

Genus-**Glutoxylon** Chowdhury, 1936

Glutoxylon burmense (Hold.) Chowdhury; Pl. 2, Figs 6, 7

Description—*Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to large, mostly medium (Pl. 2, Fig. 6), solitary and in radial multiples of 2-6, rarely more,

circular to oval in cross-section, t.d. 60-240 μm, r.d. 60-180 μm, walls 8-10 μm, uniformly distributed, about 12-25 vessels per sq. mm; tyloses abundant, sometimes completely occluding the vessels; vessels-members truncate to attenuately tailed, perforations simple; intervessel pits large, 8-12 μm in diameter, alternate, oval to orbicular, bordered, with lenticular apertures. *Parenchyma* paratracheal and apotracheal (Pl. 2, Fig. 6). paratracheal parenchyma scantly to vasicentric, forming narrow sheath around the vessels, occasionally aliform: apotracheal parenchyma represented by fine to moderately broads lines or bands, each 2-5 cells in width; 1-4 per mm., straight to wavy, continuous or broken; cells mostly angular to squarish, those of paratracheal slightly bigger and peripherally flattened. *Rays* two types : (1) simple, uniseriate, occasionally biseriate (Pl. 2, Fig. 7), homocellular, consisting of procumbent cells only, about 2-17 cells high and (2) fusiform, 4-6 seriate, homocellular, consisting of procumbent cells and solitary radial gum duct in the centre (Pl. 2, Fig. 7), about 17-30 cells high; procumbent cells 24-40 μm in tangential height and 40-100 μm in radial length. *Gum canals* horizontal, occurring in fusiform rays (Pl. 2, Fig. 7). *Fibres* aligned in radial rows between two consecutive rays in cross-section, rectangular to squarish, small, 8-20 μm in diameter, nonseptate, moderately thick-walled.

Comparison—In all its anatomical features the carbonised wood clearly show close resemblance with that of *Gluta* and hence is being placed under the genus *Glutoxylon* (Hold.) Chowdhury (1936). Fossil woods of *Gluta* are known from almost all the Neogene deposits of India, Burma and Southeast Asia (Chowdhury, 1934, 1936, 1952; Awasthi, 1966; Prakash & Tripathi, 1969; Prakash & Awasthi 1971; Kramer, 1974; Trivedi & Ahuja, 1978, Awasthi & Ahuja, 1982). The present carbonised wood of *Gluta* is quite different from atleast one of the species of *Glutoxylon*, namely, *G. cuddalorense* Awasthi (1966) in which the frequency of parenchyma bands is more. The other species *Glutoxylon burmense* (Hold.) Chowdhury appears somewhat similar to it in all the structures and hence the present fossil wood is placed under the same species. This species has already been reported as silicified wood from the Cuddalore Sandstone near Pondicherry (Awasthi, 1966).

Neyveli Specimen—B. S. I. P. No. 35729

Family—Rhizophoraceae

Genus—**Carallioxylon** gen. nov.

Carallioxylon indicum sp. nov.

Pl. 2, Figs 8-9; Pl. 3, Figs 10-12; Text-fig. 2

Description—*Wood* diffuse-porous, *Growth rings* not seen. *Vessels* mostly compressed exhibiting no definite shape and size (Pl. 2, Figs 8, 9), however, at some places a few vessels appearing as solitary or in radial multiples of 2-3 (Text-fig. 1), medium to large, seemingly uniformly distributed on both the sides of broad rays, about 10-15 vessels per sq. mm, about 95-300 μm in diameter, thin-walled; perforations simple, oblique; vessel-members about 400-1000 μm long; inter-vessel pits large, 8-10 μm, oval to orbicular or angular through crowding, alternate, bordered, linear to lenticular apertures; pits leading to parenchyma and ray-cells large, about 8-12 μm in diameter; tyloses present. *Parenchyma* paratracheal, apotracheal; paratracheal parenchyma vasicentric to aliform, alifom extensions often joining to those of neighbouring

vessels forming narrow, 1-3 seriate lines or bands extending beyond several rays (Pl.2, Figs 8-9; Text-fig. 2); apotracheal parenchyma occurring as diffuse or scattered cells or occasionally in short, 1-2 seriate tangential lines (Pl. 1, Figs 8-9). *Rays* uniseriate and multiseriate, uniseriate rays short to long, composed wholly of upright cells; multiseriate rays broad (Pl. 3, Figs. 10-11), upto 500 μm wide, 10-25 seriate and several hundred cells in height, occupying appreciable volume of the wood, heterocellular, consisting of procumbent cells and uniseriate marginal rows of upright cells (Pl, 3, Fig. 12); upright cells 24-48 μm in vertical height, 16-32 μm in radial length; procumbent cells 16-34 μm in tangential height, 40-160 μm in radial length; crystals present. *Fibres* small, angular, 16-40 μm in diameter, thick-walled, walls 6-10 μm in thickness, nonseptate: pits present, probably brodered.

Text-fig. 1. Cross-section of *Carallioxylon indicum* gen. *et* sp. nov. showing type and distribution of vessels, parenchyma and rays. ×30.

Comparison—The above anatomical features particularly the type and distribution of parenchyma and broad and tall rays indicate similarity of this carbonised wood with some of the members of the family Sterculiaceae (*Sterculia* and *Cola*) and Rhizophoraceae. However, considering other anatomical characters, such as the presence of tyloses and tall multiseriate rays *Sterculia*, *Cola* and other sterculiaceous wood can be differentiated from the present carbonised wood. Moreover, in the

present fossil the low and narrow rays, parenchyma strands and vessel-members do not show any tendency towards storied arrangement.

In the family Rhizophoraceae there are five genera, viz., *Anisophyllea, Carallia, Combretocarpus, Crossastylis* and *Gnotroches* which are more or less similar to each other in xylotomy. After going through the available xylotomical data, i.e. descriptions and photographs (Desch, 1954, p. 470, pl. 93; Henderson, 1953, p. 61, figs. 316, 318; Kribs, 1959, p. 133, figs. 286, 448; Lecomte, 1926, pl. 61; Metcalfe & Chalk, 1950, p. 605, fig. 134; Miles, 1978, p. 166; Normand, 1960, p. 283, pl. 122; Pearson & Brown, 1932, p. 492, fig. 167; Ramesh Rao & Purkayastha, 1972, p. 170, pl. 88, figs. 527-528) as well as thin sections of a few woods it was found that the present carbonised wood show similarity in gross features with the above genera of Rhizophoraceae. However, taking into consideration all the anatomical details it was also found that there is a great similarily between the present fossil wood and the wood of *Carallia*, particularly *C. lucida* (=*C. brachiata*).

To accommodate the present carbonised wood a new genus—*Carallioxylon*, is instituted. This genus should also be used to designate all those fossil woods which show close similarity with the above mentioned four genera because some of their species perhaps overlap to each other in the xylotomical characters. The present fossil is specifically named as *Carallioxylon indicum* sp. nov.

Diagnosis

Carallioxylon gen. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to large, solitary as well as in radial multiples of mostly 2-3; perforations simple; intervessel pits large, alternate, bordered; tyloses often present. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma aliform to confluent, forming fine to modertely broad bands extending beyond several rays; apotracheal parenchyma diffuse, or diffuse-aggregate, also forming short lines. *Rays* uniseriate and multiseriate; uniseriate rays frequent, mostly tall and composed wholly of upright cells; multiseriate rays broad, upto 25 cells in width, extremely tall, heterocellular, consisting of procumbent cells and several uniseriate marginal rows of upright cells. *Fibres* thin-walled, nonseptate, pits simple to bordered.

Genotype—Carallioxylon indicum sp. nov.

Carallioxylon indicum sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to large, solitary and in radial multiples of 2-3, uniformly distributed, 10-15 vessels per sq mm; intervessel pits large, 8-10 μm in diameter, alternate, bordered with lenticular aperture; tyloses present. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, aliform to confluent confluent, bands fine, extending beyond several rays; apotracheal parenchyma diffuse-in-aggregate, sometimes in 1-2-seriate short tangential lines. *Rays* uniseriate and multiseriate; uniseriate rays short, composed wholly of upright cells, multiseriate rays extremely broad, upto 25 cells; in width, extremely tall, heterocellular, consisting of procumbent cells and 1-several uniseriate marginal rows of upright cells at both the ends. *Fibres* thick-walled, nonseptate, pits probably bordered.

Holotype—B. S. I. P. Museum No. 35730

FAMILY—EBENACEAE
Genus—**Ebenoxylon** Felix

Ebenoxylon arcotense Awasthi, 1970
Pl. 3, Figs 13-15, Pl. 4, Fig. 16

Description—Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium or large, solitary and in radial multiples of 2-6, mostly 2-4 (Pl. 3, Fig. 13), round to oval, t. d. 140-250 μm, r. d. 60-320 μm, walls 6-12 μm in thickness, arranged slightly in oblique radial lines, about 10-20 vessels per sq mm; perforations simple; intervessel pits medium to large, 6-10 μm in diameter, angular, bordered, alternate, with linear to lenticular orifices; vessel-parenchyma and vessel-ray pits slightly bigger than intervessel pits; tyloses not seen. *Parenchyma* paratracheal and apotracheal; paratractual parenchyma very sparse, apotracheal parenchyma occurring in narrow, 1-2 seriate regular and straight as well as wavy lines undulating the vessels (Pl. 3, Figs. 13-14), about 9-11 per mm; cells small to medium, 20-32 μm in diameter; crystals present. *Rays* fine, 1-2 seriate (Pl. 3, Fig. 15), mostly uniseriate, about 16-18 per mm in cross-section, mostly upto 15 cells, rarely upto 24 cells in height; heterocellular, consisting of procumbent cells and 1-3 marginal rows of square or upright cells at one or both the ends (Pl. 4, Fig. 16), upright or square cells 60-100 μm in tangential height and 50-75 μm in radial length, procumbent cells 16-30 μm in tangential height and 40-160 μm in radial length. *Fibres* aligned in radial rows between two consecutive rays, small, angular to rectangular, about 8-20 μm in diameter, thick-walled, nonseptate.

Comparison—The hitherto described anatomical features of the fossil wood clearly show its close similarity with the woods of xylotomically indistinguishable genera *Diospyros* and *Maba* of the family Ebenaceae. In order to identify the fossil upto specific level it was compared with the thin-sections of about 50 species of *Diospyros* and *Maba*, out of which *Diospyros assimilis* is the one found to be very similar to the fossil in all the structural details, such as shape, size, number of vessel multiples and their frequency, width and frequency of parenchyma lines, width and height of xylem rays.

Among the fossil woods of Ebenaceae known so far from the Upper Cretaceous onwards from different parts of the world listed by AWASTHI (1971), PRAKASH AND TRIPATHI (1971) and AWASTHI AND AHUJA (1982), *Ebenoxylon arcotense*, described by AWASTHI (1971) from the Cuddalore Series near Pondicherry appears to be identical with the present carbonised wood. Incidentally both the fossils are closely comparable to *Diospyros assimilis* which is still found in the evergreen forests of Western Ghats.

Neyveli specimen—B. S. I. P. Nos. 35731, 35732

FAMILY—BORAGINACEAE
Genus—**Cordioxylon** gen. nov.

Cordioxylon multiseriatum sp. nov.
Pl. 4, Figs 17-21

Description—Wood diffuse-porous. *Growth rings* not clearly seen. *Vessels*

visible to the naked eye, medium to large and also small, solitary as well as in radial multiples of 2-4 (Pl. 4, Fig. 17), sometimes in clusters or groups of small vessels (Pl. 4, fig, 18), bigger vessels upto 260 μm in tangential diameter and upto 280 μm in radial diameter, normal vessels about 10-18 per sq. mm, and those in clusters upto 75 per sq. mm.; perforations simple, nearly horizontal; vessel-members usually short, upto 450 μm in length; intervessel pits medium to large, 6-8 μm in diameter, bordered, apetures circular to lenticular (Pl. 4, Fig. 21); pits leading to ray and parenchyma cells somewhat similar to intervessel pits; tyloses occasionally present. *Parenchyma* paratracheal, vasicentric to aliform, also forming fine to aliform-confluent bands, interrupted by xylem rays (Pl. 4, Fig. 17-18); cells upto 44 μm in diameter; strands 2-4 celled, some with fusiform (substitute) fibres. *Rays* quite distinct to naked eye, appearing fairly broad with hand lens making appreciable volume of the wood (Pl. 1, Figs 17-18), 3-4 per mm in cross-section, each 200-240 μm wide, upto 12 or 14 seriate, height upto 4800 μm; ray tissue heterogeneous; rays heterocellular, consisting of procumbent cells and 1-several marginal rows of upright cells forming more or less continuous row along the flank (Pl. 1, Figs 19-20); procumbent cells 16-40 μm in tangential height and 32-200 μm in radial length. *Fibres* banded, alternating with parenchyma bands or lines, libriform, oval to angular in cross-section, medium in size, 16-24 μm in diameter, nonseptate, thick-walled.

Comparison—The most characteristic features of the present fossil wood are: vessel large solitary or in multiples or in clusters, parenchyma aliform, confluent, confluent bands being of irregular nature; xylem rays broad, high, with sheath cells and substitute fibres (fusiform parenchyma). A combination of these features is met with in the woods of the family Sterculiaceae, Boraginaceae and Moraceae. The woods of Sterculiaceae and Moraceae usually possess banded parenchyma of variable width and rays mostly broad and upto 20 cells in width. Besides, the fossil is further characterised by the presence of clusters of vessels usually associated with bigger vessels which are not so common in the wood of Sterculiaceae and Moraceae. Considering the hitherto described features collectively the fossil shows close resemblance with the woods of *Cordia* of the family Boraginaceae. Among the species of *Cordia*, thin sections of the woods of. *C. myxa* Linn., *C. fragrantissima* Kurz, *C. grandis* Roxb. and *C. macleodii* Hook. f. and could be available for comparison. Besides, it was also compared with the photomicrographs of *Cordia abyssinica* R. Br. (Syn. *C. holstii* Gurke), *C. alliodora* (R. & P.) Cham., *C. goeldiana* Huber, *C. millenii* Bak., *C. platythyrsa* Bak. and *C. trichotoma* Allab. (Miles, 1978, pp. 22-24). Taking into consideration the size and frequency of vessels, absence or presence of tyloses, width of parenchyma bands and height and width of rays *Cordia myxa* shows better resemblance with the fossil. The other species, however, differ from it in some significant characters. In *Cordia fragrantissima* and *C. macleodii* the tyloses are abundant and the rays are not that much tall as in the fossil and, moreover, in *C. fragrantissima* the rays are upto 8 seriate only. *Gordia grandis* also shows some differences from the fossil in having relatively broader parenchyma bands occupying enormous space of the wood. In the above remaining species the xylem rays are not so much broad as in the fossil.

Since the fossil shows close similarity with the wood of *Cordia*, it is placed under a new genus *Cordioxylon* and named *Cordioxylon multiseriatum* sp. nov.; the specific name signifies multiseriate rays of the fossil.

Diagnosis

Cordioxylon gen. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to large, solitary as well as in radial multiples, sometimes very small or in clusters associated with bigger vessels, few to many vessels per sq mm; perforations simple; intervessel pits medium to large, bordered; tyloses sometimes present. *Parenchyma* paratracheal, vasicentric, aliform, aliform-confluent to banded, bands fine to broad, sometimes fusiform (with substitute fibres). *Xylem rays* multiseriate, moderately broad to broad, tall, heterogeneous; sheath cells often present. *Fibres* often banded, alternating with parenchyma bands, thick-walled, nonseptate.

Genotype—Cordioxylon multiseriatum sp. nov.

Cordioxylon multiseriatum sp. nov.

Wood—diffuse-porous. *Growth rings* not seen. *Vessels* small to large, solitary and in radial multiples of 2-4, sometimes several small vessels associated with bigger vessels, bigger vessels upto 280 μm in diameter; perforations simple; vessel-members upto 450 μm in length; intervessel pits about 6-8 μm in diameter, bordered; tyloses occasionally present. *Parenchyma* paratracheal, vasicentric to aliform or aliform-confluent, forming fine to broad bands, strand sometimes fusiform (substitute fibres). *Rays* upto 14-seriate, uniseriates few, moderately long; heterocellular, consisting of procumbent cells, 1-several marginal rows of upright cells, sheath cells, present. *Fibres* thick-walled, nonseptate.
Holotype— B. S. I. P. No. 35733

DISCUSSION

Of the five plant taxa recovered from the Neyveli lignite deposits, *Gluta*, *Hopea* and *Diospyros* are already known as silicified woods from the Cuddalore Sandstone near Pondicherry whereas *Carallia* and *Cordia* are being reported for the first time. The genus *Gluta* consists of about 20 species (Ding Hou, 1978) of which only *G. travancorica* is found in India in dense evergreen forest of Travancore Hills and Tinnevely Ghats ascending to 1200 m. *Hopea* and *Diospyros* are also among the important genera of the evergreen to semi-evergreen forests. About 5 species of *Hopea* and 24 species of *Diospyros* are known to occur in Western Ghats and Travancore Hills. The genus *Carallia* includes 10 species (Willis, 1973, p. 201), distributed in tropical Asia, Australia and Madagascar. The only species occurring in India is *C. lucida* Roxb. *Syn.* [*C. brachiata* (Lour.) Merr.], distributed in the evergreen and swamp forest of the sub-Himalayan tract extending to Dehra Dun, but very scarce, common in the Western Ghats from Konkan southward. It is also known to occur in the Andaman Islands, Chittagong, Bangladesh, Hills of Pegu and Martaban in Burma, Malay peninsula and Island to the south and Australia (Gamble, 1972, p. 335). *Cordia* is a fairly large genus consisting of 250 species of trees and shrubs, distributed in the warmer parts of the world (Willis, 1973, p. 290). About 13 species are known to be evenly distributed in India. *Cordia myxa* with which the wood from Neyveli resembles most is a moderate-sized tree found throughout India and Sri Lanka. The other closely allied species is *C. octandra*, a small tree, occurring in Travancore (Gamble, 1972).

From the above account of the distribution of modern counter-parts of carbonised woods it is quite evident that tropical climate with high precipitation prevailed along the eastern coast of South India during the Miocene-Pliocene. Based on rich assemblage of pollen and spores and epiphyllus fungus, RAMANUJAM (1982) also made similar inferences regarding the palaeoclimate around the site of deposition. Only under such conditions the luxuriant growth of evergreen elements constituting the tropical evergreen to semi-evergreen forests is possible and without which certainly there would have not so much of plant material to be deposited and transformed into lignite. Since further studies on plant megafossils is in progress this aspect will be taken up in due course of time when substantial data are available.

Regarding the age of the Neyveli lignite WADIA (1966), KRISHNAN (1968) and BALASUNDER (1968) considered the Cuddalore Sandstones and the lignite embedded in them to be Miocene. On the basis of palynological assemblage RAMANUJAM (1966, 1982) also considered lignite deposit as Miocene in age, while VENKATACHALA (1973) and DEB *et al.* (1973) are of the opinion that because of some palynological similarities with Palaeogene microfossil assemblages of Assam and Kachchh the Neyveli lignite should be dated as Eocene. However, the occurrence of *Hopea* and *Gluta*, being typical elements of the Neogene flora of India, strongly supports the view that the age of the lignite deposits is Miocene.

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EXPLANATION OF PLATES

PLATE 1

Hopenium neyveliensis sp. nov.

1. Cross-section showing the nature and distribution of vessels, parenchyma and gum canals. × 32. BSIP slide no. 35728-I.

Hopea plagata

2. Cross-section showing similar nature and distribution of vessels, parenchyma and gum canals as in fossil shown in fig. 1. ×32.

Hopenium neyveliensis sp. nov.

3. Tangential longitudinal section showing rays with upright cells occurring in the flanks as well as interspersed among procumbent cells. ×80., BSIP slide no. 35728-II.

Hopea plagata

4. Tangential longitudinal section showing similar rays with upright cells occurring in the flanks as well as interspersed among procumbent cells. ×80.

Hopeninium neyveliensis sp. nov.

5. Radial longitudinal section showing heterocellular rays. ×80. BSIP slide no. 35728-III.

PLATE 2

Glutoxylon burmense (Hold.) Chowdhury

6. Cross-section showing vessels and apotracheal parenchyma bands. ×35. BSIP slide no. 35729-I.
7. Tangential longitudinal section showing simple uniseriate rays and multiseriate fusiform rays with radial gum canal. ×140. BSIP. slide no. 35729-II

Carallioxylon indicum gen. *et* sp. nov.

8. Cross-section showing parenchyma, rays and compressed vessels. ×30. BSIP slide no. 35730-I.
9. Another cross-section showing rays, aliform confluent parenchyma and compressed vessels. ×30. BSIP slide no. 35730-II.

PLATE 3

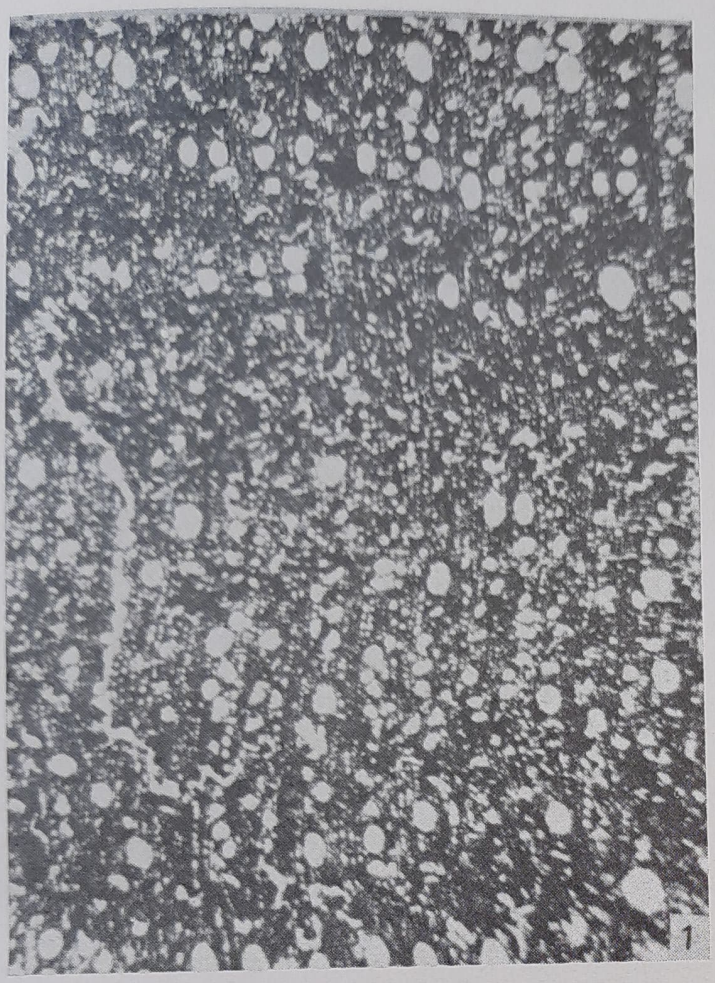
Carallioxylon indicum gen. *et* sp. nov.

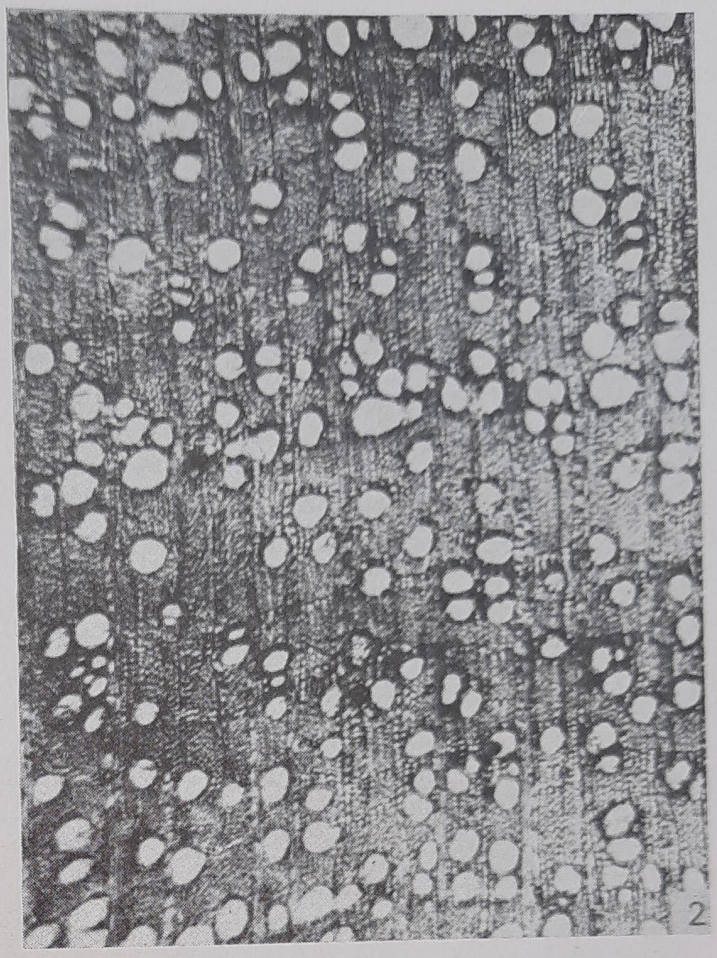
10, 11. Tangential longitudinal section showing rays, both multiseriate and fine uniserate. ×100. BSIP slide nos. 35730-II, III.

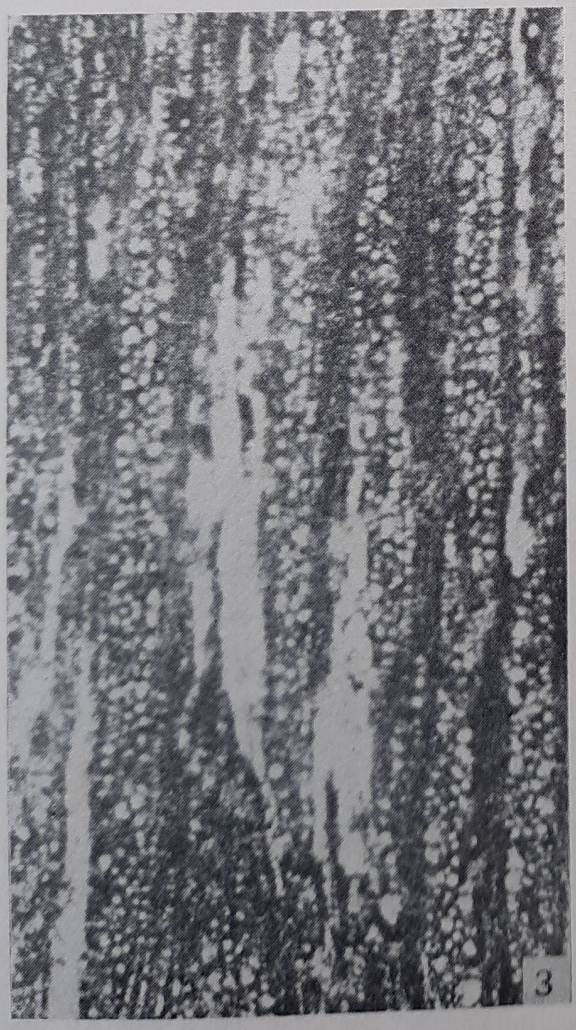
12. Radial longitudinal section showing heterocellular rays. ×100. BSIP slide no. 35730-IV.

Ebenoxylon arcotense Awasthi

13. Cross-section showing the nature and distribution of vessels and parenchyma. ×35. BSIP. slide no. 35731-I.





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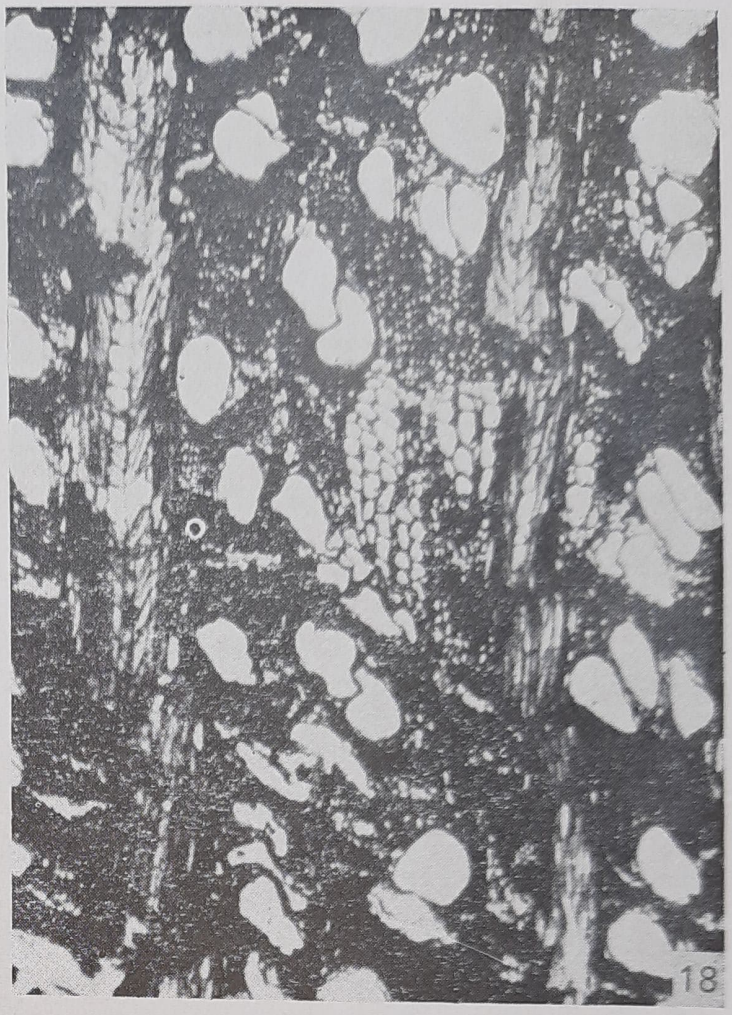
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14. Another cross-section enlarged showing apotrocheal parenchyma lines. ×90. BSIP slide no. 35732-I.
15. Tangential longitudinal section showing rays. × 90. BSIP. slide no. 35731-II.

PLATE 4

Ebenoxylon arcotense Awasthi

16. Radial longitudinal section showing heterocellular rays. ×90. BSIP slide no. 35731-III.

Cordioxylon multiseriatum gen. *et* sp. nov.

17. Cross-section showing the nature and distribution of vessels, parenchyma, fibres and rays. ×35. BSIP slide no. 35733-I.
18. Another cross-section showing vessels in clusters. × 35. BSIP slide no. 35733-I.
19. Tangential longitudinal section showing rays. × 35. BSIP slide no. 35733-I.
20. Radial longitudinal section showing heterocellular rays. ×60. BSIP slide no. 35733-III.
21. Intervessel pits. ×500. BSIP slide no. 35733-II.