BOTANICAL RESOLUTION OF SOME MICROSTRUCTURES OF NEYVELI LIGNITE, SOUTH INDIA

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ABSTRACT

Futher studies on the microscopic composition of Neyveli lignite, South-India have revealed that some microstructures show affinities to certain angiosperm taxa such as Guttiferae, Dipterocarpaceae, Leguminosae, Combretaceae, Euphorbiaceae, Palmae and Gramineae. The present paper records the xylotomical features of the newly recognized biostructures as seen in the polished surface sections, and their affinities to modern genera.

INTRODUCTION

NEYVELI lignite, the largest known brown Coal deposit in India occurs beneath the coastal plains near Cuddalore, South-India in association with the Tertiary rocks (believed to be of Upper Miocene age, Subramanyam 1969) known as Cuddalore Series. The following is the sequence of rock formations met with the lignite deposit.

Recent		Soils, alluvium, laterite, Kankar, blown sands
Tertiary	Upper Miocene (Cuddalores)	Argillaceous sandstones, Pebble bearing sandstones, grits, clays and lignites
	Probable unconformity	
	Eocene	Black clays, shales, grey sandstones, calcareous sandstones, limestones with fossils
Mesozoic	Cretaceous	Shell limestones, Silaceous limestones etc
Archaean		Dolerite, Pegmatites and Quartz

The lignite deposit is found associated with the Cuddalore sandstones and clays. The sandstones contain layers of soft water-logged sand, grits and clays and contain lot of miosture which makes lignite soft and suitable for excavation. The lignite occurs in different forms each of them appearing to merge with one another. Some of the common types are woody, attrital and brown coal types each having characteristic features (Navale 1968b, 1971a). Woody lignites have been formed from lignified wood. It is hard, compact and blocky. The xylotomical features of some biostructures recognized in the lignite show affinities to modern woods.

XYLOTOMICAL DESCRIPTION OF BIOSTRUCTURES

The identification of woody structures of the lignite has been made mainly on the basis of cross-sectional view as seen in the lignite pellets prepared by polished surface technique (Navale 1968b). The other sectional views (radial or longitudinal) could not be prepared as it is not possible to isolate organic and inorganic entities from the general ground mass of the lignite. However the cross-sectional views as seen in the general ground mass of the lignite have given sufficient data to determine the botanical affinities. The diagnostic characters of the resembling taxa are given herewith.

GUTTIFERAE

Topography — Wood diffuse porous (Pl. 1, Fig. 1); *Growth rings* absent; *Vessels* numerous, medium to large in size, solitary, arranged in radial lines in cross-section (Pl. 1, Fig. 1); *Parenchyma* arranged in fine concentric tangential bands, apotracheal bands slightly wavy, interrupted by xylem rays (Pl. 1, Fig. 1); *Tracheids* paratracheal (Pl. 1, Fig. 1); *Xylem rays* fine, distinct, closely placed, mostly uniseriate, separated by many rows of fibres (Pl. 1, Fig. 1); *Fibres* arranged in radial rows in cross-section interrupted by parenchyma bands (Pl. 1, Fig. 1).

Elements — *Vessels* thickwalled, 10 μ, oval to squarish in cross-section, transverse diameter 84-100 μ, radial diameter 100 μ-140 μ, filled with contents; *Tracheids* cells oval to polygonal in cross-section, 12×20 μ; *Parenchyma* cells mostly round in cross-section, 20 μ in size; *Xylem rays* uniseriate; *Fibres* circular in cross-section, slightly flattened, 10 μ in width.

Affinities — The diagnostic structural features of the woody lignite are (1) Vessels

solitary, arranged in oblique radial lines, (2) tracheids paratracheal (3) parenchyma apotracheal, tangential bands (4) rays uniseriate. The combination of the above characteristic features of the lignite show resemblance to the woods of *Callophyllum* or *Mesua* of the family Guttiferae (Metcalfe and Chalk 1950, Pearson and Brown 1932, Chowdhury and Tandon 1949, Lakhanpal and Awasthi 1963, 1964). However the exact affinity to the above genera could not be established due to the limited sectional view as seen in the polished surface of the pellet. Lakhanpal and Awasthi (1963, 1964) recognized both the fossil woods of *Mesua* and *Callophyllum* in the Cuddalore Series from the neighbouring locality. In view of their findings, it is reasonable to expect the above genera in the lignite also, which is associated with the Cuddalore sandstones.

Remarks — Fossil woods belonging to the family Guttiferae (*Garcinia, Mesua, Kayea*) have been described from the Tertiaries of South-Arcot, Tamilnadu and Assam (*loc. cit.*). *Kayea, Mesua* and *Callophyllum* are genera of evergreen moist deciduous forests of Assam and western ghats.

DIPTEROCARPACEAE

Topography — Wood diffuse porous (Pl. 1, Fig. 2); *Growth rings* not recognizable; *Vessels* medium to large in size, solitary, rarely radial, filled with tyloses (Pl. 1, Fig. 2); *Parenchyma* paratracheal or apotracheal (Pl. 1, Fig. 2), Paratracheal parenchyma vasicentric, 1-3 layered, incompletely surrounding the vessels, short, irregular often in tangential strips, apotracheal parenchyma continuous 1-4 cells thick; *Resin Canals* diffuse, solitary, covered by xylem parenchyma, Canals smaller than vessels (Pl. 1, Fig. 2); wood rays fine, close, one to four seriate, uniseriate common (Pl. 1, Fig. 2); *Fibres* form the ground mass of the tissue, aligned in radial rows in cross-section (Pl. 1, Fig. 2).

Elements — *Vessels* thickwalled, pore size 150-220 μ in transverse diameter, solitary, tylosed, 10-14 per mm; *Tracheids* absent; *Parenchyma* limited, paratracheal vasicentric type, one to four cells, small, round in cross-section, 10 μ in size, apotracheal type one to four cells thick, associated with resin Canals, 8 μ in size; *Resin Canals* cells smaller than vessels, 50-60 μ in size filled with resinous substance, epithelium cells small, 5 μ in size; *Woodrays* one to 4 celled rays, one celled rays common, 3 celled rays abundant and 4 celled rays rare, filled with substances; Fibres squarish to polygonal cells, 30 μ in size in cross-section.

Affinities — The presence and the nature of resin canals as described above, paratracheal and apotracheal types of parenchyma and uniseriate to multiseriate wood rays of the lignite biostructure suggests its affinities to the woods of Dipterocarpaceae. The genera belonging to Dipterocarpaceae are anatomically divisible into 2 categories, one with secretary canals aligned in concentric rows (*Shorea, Hopea* etc.) and the other with diffuse resin canals (*Dipterocarpus, Anisopteris* etc.). Genera *Vateria* and *Vatica* (Vateriae and vaticae) differ from the microstructure under consideration in having smaller vessels and diffuse parenchyma. It is only with the genera *Dipterocarpus* or *Anisopteris* the lignite microstructure shows close similarities. Among these two genera, the material resembles more with *Dipterocarpus* than *Anisopteris* as the latter has narrow rays and vasicentric tracheids.

Remarks — Large number of fossil woods belonging to the family Dipterocarpaceae from the rocks of the Cuddalore series have been catalogued (Ramanujam 1968, Awasthi 1972). It is probable that these woods were existing during the peat formation.

LEGUMINOSAE

Topography — Diffuse porous wood (Pl. 1, Fig. 3); *Growth rings* — not conspicuous; *Vessels* — abundant, uniformly distributed, small to medium in size, solitary or in radial rows of 2 to 4, filled with gummy deposit (Pl. 1, Fig. 3); *Parenchyma* conspicuous, paratracheal, vasicentric, forming eyelets, paratracheal Zonate parenchyma anastomose forming tangential strips or bands (Pl. 1, Fig. 3); *Wood rays* distinct, 2-5 seriate, separated by large tracts of fibres (Pl. 1 Fig. 3); *Fibres* distinct, thick celled, forming the ground mass of the wood (Pl. 1, Fig. 3).

Elements — *Vessels* thickwalled, 9 μ in size, vessel pore tangential diameter 130-200 μ, radial diameter 165-300 μ, shape oval in cross-section, filled with deposit; *Parenchyma* cells small, 18 μ in cross-section, paratracheal parenchyma 3 to 4 celled,

aliform type, reticulate, 3-4 layered; *Wood-rays* 2-5, ray cells small (scarcely visible under hand lens), circular, 30 μ wide; *Fibres* cells small, angular, arranged in radial rows 9 μ broad in cross-section.

Affinities — Solitary or radial groups of vessels with uniform distribution, abundant paratracheal, vasicentric parenchyma anastomosing into few layers, multiseriate rays suggest affinities to the wood of Leguminosae. This family presents a great variation in almost all characters of the wood (nature of vessels, parenchyma, rays and fibres). However certain anatomical types have been made on the broad structural features (Gamble 1902) which are as follows:

1. *Ougeinia — Albizzia* type
2. *Acacia — Cassia* type
3. *Dalbergia* type
4. *Bahunia* type
5. *Hardwickia* type
6. *Erythrina* type

The microstructure of the lignite shows affinities with *Acacia-Cassia* type which is characterized by paratracheal parenchyma forming eyelets or zonate type anastomosing to form tangential strips, medium sized solitary or radial vessels and limited multiseriate rays.

Remarks — Cassia-Acacia type of woods have already been reported by Ramanujam (1954) and Navale (1958 and 1962) from the Cuddalore Series of South-Arcot. In the lignite, both wood and pollen of this genus have been identified (Ramanujam 1966) to support the present, identification.

COMBRETACEAE

Topography — Diffuse porous Wood (Pl. 1, Fig. 4); *Growth rings* absent; *vessels* medium to large size, solitary or in multiples of two, filled with tyloses (Pl. 1, Fig. 4); *Parenchyma* both paratracheal and apotracheal, paratracheal parenchyma vasicentric to aliform, apotracheal parenchyma diffused scattered in the ground mass of the wood (Pl. 1, Fig. 4); *Wood rays* uniform, contiguous, uniseriate, crystals present in each cell (Pl. 1, Fig. 4); *Fibres* round to oval in cross-section, arranged in radial rows, cells thick walled (Pl. 1, Fig. 4).

Elements — *Vessels* thick walled, 10 μ, vessel pore round in cross-section, small, size (tangential × radial) 50 × 50 μ-60 μ; Density of the pores 5 to 13 per mm.^{2}; *parenchyma* associated with vessels, paratracheal cells form contour around vessels, thinly aliform, 4 cells, size of the cells 30 μ, apotracheal parenchyma 10 cells thick, size of the cells 20 × 25 μ along the radial direction of the bands, the apotracheal bands include secretary bands; *Wood rays* one celled, exceptional cases two celled, homogeneous, crystals present in ray cells.

Affinities — The general microscopic structural features show affinities with the woods of Leguminosae, Anacardiaceae, Sapindaceae, Combretaceae. Yet certain diagnostic structural features particularly diffuse, solitary or radial vessels with tyloses, paratracheal, vasicentric parenchyma forming eyelets, diffuse apotracheal cells, unsiseriate rays with crystal content in ray cells strongly indicate resemblance to *Terminalia* of Combretaceae.

Remarks — Large number of fossil *Terminalia* woods have been recognized (Ramanujam 1956a, Navale 1955) in the neighbouring areas of the Cuddalore Series in which the Neyveli lignite is also associated.

EUPHORBIACEAE

Topography — Diffuse porous wood (Pl. 1, Fig. 5); *Growth rings* not distinct; vessels small to medium in size, arranged in radial rows of 2 to 5, rarely solitary, tyloses occasionaly present (Pl. 1, Fig. 5); *Parenchyma* apotracheal, diffused (Pl. 1, Fig. 5); *Wood rays* 2 to 5 seriate, sinuate, separated by fibres (Pl. 1, Fig. 5); *Fibres* — cells round to oval in cross-section, thickwalled aligned in radial rows.

Elements — *Vessel* pore size 80 μ-120 μ, Density 4-5 per sq. mm., multiples of 2-5, thick walled, size 20 μ, round when solitary, flattened when radial; *parenchyma* common, apotracheal, cells diffused, scattered, round to polygonal, size of the cells 35 μ in cross-section; *Wood rays* 1-4 cells broad, 10 to 50 cells high, small dissected rays intermingle with large rays, linkage in rays common, *Fibres* arranged in radial rows, more or less round in cross-section, fibre cells 10 μ diameter.

Affinities — Lack of any diagnostic characters as mentioned above necessitates a comparison with large number of families. However by evaluating on the basis of combination of characters and by process of elimination, the nearest taxa that the microstructure under consideration resembles is Euphorbiaceae. Even this family has diver-

gent structural details of the wood. Yet on the basis of xylotomic principles, the family Euphorbiaceae may be classified into Phyllanthoidae group and Crotonoidae group (Metcalfe and Chalk 1950). The present material does not compare with Crotonoidae group. It is with the Phyllanthoidae group the wood structure shows its affinities. Although the Phyllanthoidae group is again subdivided into *Aporosa* type (abundant apotracheal parenchyma etc.) and *Glochidion* type (limited parenchyma etc.), the present material could not be assigned to the above types due to the overlapping of some characters, nevertheless, the microstructure resembles the woods of Phyllanthoidae group in general.

Remarks — Large number of fossil woods of Euphorbiaceae have been identified in the associated rocks of Cuddalore Series near Neyveli (Ramanujam 1956b, Navale 1960). It is reasonable to expect the woods of Euphorbiaceae in the lignite also. Recognition of euphorbiaceous pollen further supports the identification.

PALMAE

Topography — Central-zone preserved; *Fibrovascular bundles* scattered, irregular, orbicular to reniform, circular vessels lie side by side; *xylem parenchyma* preserved; *Phloem* not present; *Ground tissue* narrow, rectangular cells, meshes closely fitted with conspicuous intercellular spaces (lacunae).

Elements — Fibrovascular bundles in the central region scattered 20 to 25 per cm.^{2}, F/v-ratio 2: 1, bundle size 170 μ, lacunae size 0·2 to 0·3 mm.

Affinities — The nature of the scattered bundles, narrow ground tissue with inter cellular spaces and other characters observed in the lignite structure undoubtedly place the woody tissue in palmae group. The limited microstructural features as revealed by the lignite and absence of any system of classification of the palms leave no alternative but to place it in the general group of this family. It may be mentioned here some palm woods and pollen are known from South-Arcot and Neyveli lignite (Ramanujam 1968, Navale 1972).

Remarks — Very few fossil Palms are known in the Tertiary rocks of the Cuddalore Series (Ramanujam 1953, 58, Sahni 1931) which is otherwise rich in dicotyledonous forms. Even in the lignite, mostly dicotyledonous xyloidal structures are common (Navale 1968a, 1971 and 1972).

GRAMINEAE

Apart from xyloidal structures, the lignite is composed of number of cuticles, dispersed tissues, spores and pollen (Navale 1968 b). Although studies have been made to know the botanical affinities of spores and pollen Navale 1961, 1971 Ramanujam 1966a, b) no attempt has been made to resolve the cuticles and other tissues due to lack of any diagnostic characters, however, some cuticles have been assigned to certain taxa (Jacob, K. & Jacob, C) and now probably a graminaceous type of cuticle has been identified.

Topography — Epidermis cells regular, rectangular, outer walls thick, *Mesophyll* no differenciation between palisade and spongy tissues, assimilatary cells appear in cross-section to be oriented in radial manner around the vessels, *Vascular bundles* small, widely spaced, surrounded by sheath.

Elements — *Cuticular cells* thick, 10 μ in size, shape round to rectangular, *Mesophyll cells* small to medium size, round to oval in shape, size 30 μ in cross-section *Vascular bundles* small, scattered 10 to 20 per cm^2., bundle size 70 μ-100 μ, sheath cells round to oval 3 μ in size.

Affinities — The chlorenchyma unlike that in the leaves of dicotyledonous leaves shows no differentiation into contrasting palisade and spongy tissues, and the nature of vascular bundles as described above are suggestive of graminaceous affinity of the material under study.

Remarks — Pollen grains of this family have also been recovered from the Neyveli lignite (Navale 1972, Ramanujam, 1966a.).

DISCUSSION

It is apparent from the above studies, and from the already known data that the Neyveli lignite has been formed from a recent angiospermic vegetation. The woody lignite is constituted by a diversified woody taxa. Some of the known genera are *Mesua* or *Callophyllum* (Guttiferae), *Dipterocarpus* (Dipterocarpaceae), *Cassia* or *Acacia* (Leguminosae), *Terminalia* (Combretaceae), *Diospyros* or *Maba* (Ebenaceae), *Bassia* (Sapotaceae), *Phyllanthinium* (Euphorbiaceae) and palms (Palmae). These genera must have formed part of the vegetation during the

peat formation because of the presence of woody portions in the lignite although many of the pollen belonging to the above taxa are not known. This may probably be due to the lack of diagnostic characters for the generic identification of dispersed pollen and spores which are grouped under artificial forms like *tricolpites* or *triporites* etc., or pollen might have corroded or produced in small amount.

It is evident from the information so far accumulated that the Neyveli lignite was formed during Tertiary period as the angiospermic vegetation predominated in the composition. Further, abundance of some fossil genera such as *Dipterocarpus, Terminalia, Cassia, Cynometra* which are considered to be of upper Miocene times suggest the age of the Neyveli lignite deposit to be of upper Miocene.

A perusal of the present day vegetation in our country reveals that the taxa so far recorded in the lignite, grow in rain forest type of vegetation (Warm, humid, monsoon-type of climatic conditions) of Assam and W. Ghats. It is, therefore, reasonable to presume that the lignite might have been formed under tropical humid, rain forest type of climatic conditions in Neyveli during the Upper Miocene times of the Tertiary period.

CONCLUSION

Woody lignites form an important constituent of the Neyveli lignite deposit. They are formed from diversified angiospermic taxa, some of which are described in the present study. Further investigations on xyloidal portions of the lignite may supplement a good deal of information in establishing the extant vegetation of the source material that formed the Neyveli lignite.

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EXPLANATION OF PLATE 1

PLATE 1

1. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Mesua* or *Callophyllum* of the family Guttiferae. × 15.

2. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Dipterocarpus* of the family Dipterocarpaceae. × 35.

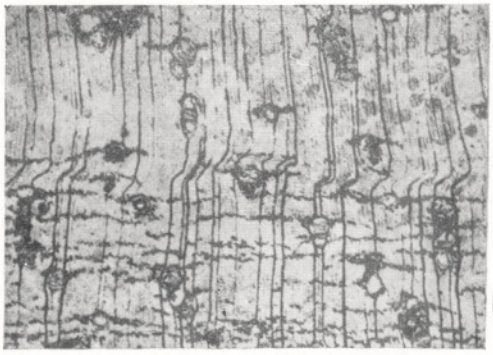
3. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Cassia* or *Acacia* of the family Leguminosae. × 3.

4. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Terminalia* of the family Combretaceae. × 50.

5. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Phyllanthoidae* group of the family Euphorbiaceae. × 75.

6. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of the woods of *Palmae*. × 10.

7. Cross-sectional view of the polished portion of a lignite showing the microstructures resembling the anatomical features of a monocot leaf. × 240.



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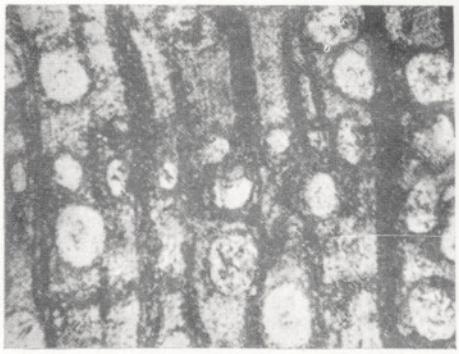

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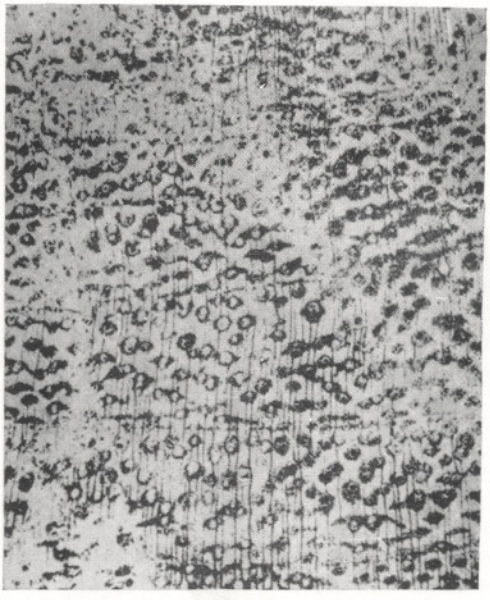

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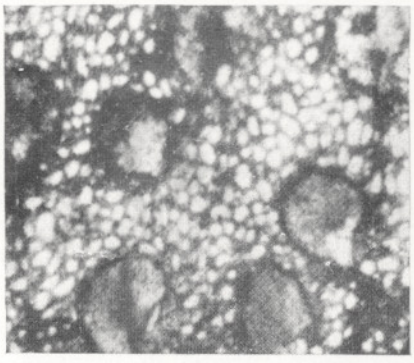

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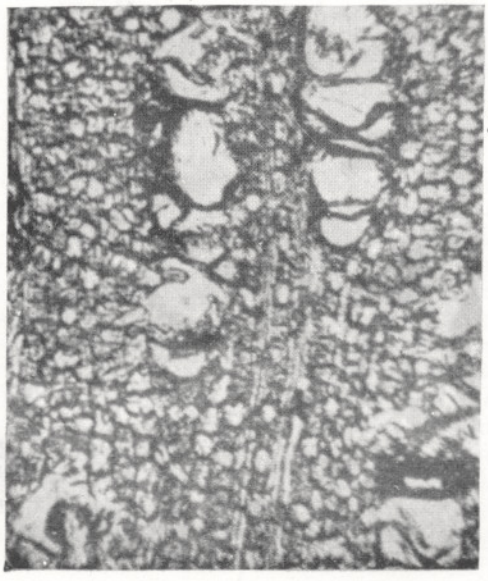

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