SOME CONTRIBUTION TO THE PALAEOBOTANY OF NEYVELI LIGNITE, SOUTH INDIA*

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ABSTRACT

A comparative analysis of the dispersed plant remains consisting of woody and nonwoody tissues, pollen grains and spores from the Tertiary lignite of Neyveli, South India, has revealed that the lignite has been formed from a predominantly angiospermous vegetation. The affinities of the fossil material represented either by pollen grains or other organic tissues show a large assemblage of dicotyledonous taxa. After a critical study of the hitherto known fossil flora from the deposit, the characteristic families which form the source vegetation of the lignite are Leguminosae, Meliaceae, Euphorbiaceae, Sapotaceae, Ebenaceae, Guttiferae, Dipterocarpaceae, Combretaceae, Gramineae, Palmae and some aquatic taxa (probably belonging to Nymphaeaceae, Lentibulariaceae, Lecythidaceae and Potamogetonaceae). Apart from the above taxa, ferns and fungi represented by miospores, microstructures and microplanktons also occur in the lignite. The evidences provided by the fossil material and by the petrologic nature of the lignite suggest the existence of a warm humid, tropical to subtropical climatic condition during the formation of the deposit. The occurrence of fresh water forms coupled with mangrove elements indicate the formation of the lignite probably at the confluence of the river with the sea during the Tertiary period.

INTRODUCTION

LIGNITE or brown coal seams consist of inumerable fragments of fossilized plant material. These fossilized plant fragments can be recognized as remnants of a plant of some particular family, genus or species. Such palaeobotanical resolutions help in obtaining information on the vegetation existing at the time when the source peat was formed. The data thus obtained are of much help in determining the composition and nature of the lignites apart from palaeogeographic and palaeoclimatic conditions.

A general knowledge concerning the geology, physical and chemical characteristics of Neyveli lignite is available from the literature (Balasunder, 1968; Rao, 1955; Navale 1961, 67a, b and 70; Thiergart & Frantz, 1963; Ramanujam, 1963, 1966; C.F.R.I. report 1954). It is desirable nevertheless to obtain specific information concerning the source material and its composition. The palaeobotanical resolutions of some biostructures and fossil pollen and spores made here unravel the nature of the source material, its origin and composition. Such knowledge on compositional changes must be known if the maximum benefit is to be obtained from this important fuel resource of South India.

GEOLOGICAL ASPECTS

Neyveli lignite, the single largest brown coalfield so far known in India lies in Tamilnadu (Madras) State. The total deposit of the lignite is estimated to comprise over 3000 million tons spread beneath an area of 300 sq. kms. in seams having an average thickness of 23m. The most favourable and economical reserves of the lignite of about 200 million tons occur within an area of 14 sq. Km. in the northern side of the Coalfield (Fig. 1). Another location in the south has also proved to have 380 million tons over an area of about 33 sq. Km. (Balasunder, 1968).

The lignite bed is found associated with Tertiary (probably Miocene-Pliocene) Cuddalore sandstones and clays. The lignite seam of 15 meters thick occurs underneath the Cuddalore sandstones. One major seam extends throughout the basin. But in the area south of the basin the seam splits into more than one. The lignite does not crop out anywhere on the surface and seems to pinch out towards the boundaries of the field. There are three distinct clay beds above the lignite which are fairly continuous and extensive. The lignite is sandwiched between high pressure aquifers which are intercorrelated and confined below the lignite seam.

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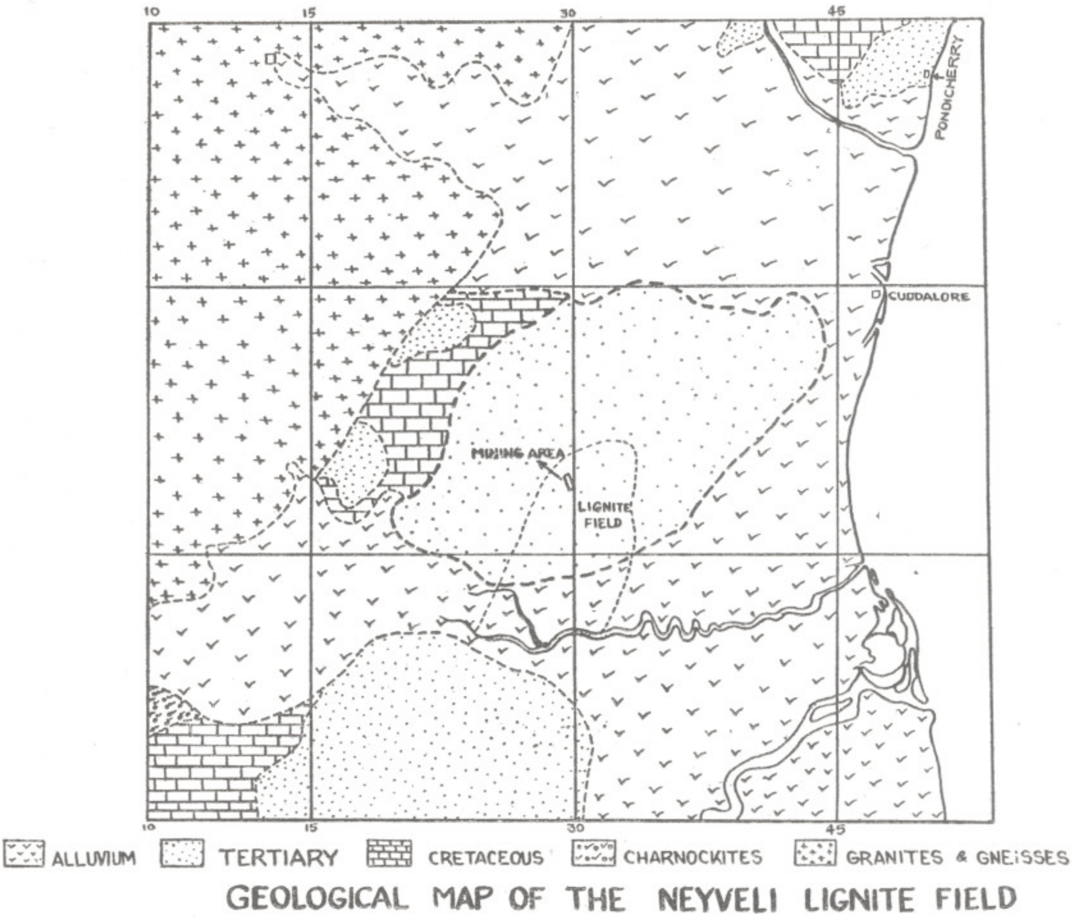

TEXT-FIG. 1

PHYSICAL COMPOSITION OF THE LIGNITE

Megascopically, the lignite is non banded, massive and compact in appearance. There is not much of variation in the physical characteristics among the material studied. The lignite appears to be either woody, amorphous or coaly. Microscopically, well preserved and recognizable entities are mainly woody and non-woody tissues of different plants, spore-pollen exines, cuticles of leaves, resins, fungal spores and sclerotia (Navale, 1968). The spores and pollen of the lignite, the most indestructible and longest lasting having their own characteristic size and ornamentation, play a much smaller part in the composition probably because of the woody nature of the lignite. On the other hand, cuticles, plant tissues, resins, fungal spores and sclerotia are of common occurrence. Anthrocologically the physical components (organic and inorganic) may be grouped under *Huminite* (woody and non woody tissues, detritus and gel); *Liptinite* (spores, pollen, cuticles, resins, etc.); and *Inertinite* (fusinized organic substances) an artificial classification (Navale, 1969) evolved to facilitate the resolution of the physical composition of lignites.

THE LIGNITE WOODY STRUCTURES AND THEIR AFFINITIES

While investigating the physical constituents of the lignites, some woody microstructures revealed characteristic diagnostic features referable to modern angiosperm woods. It may be mentioned here, that in all cases identification of the wood has been made only on the basis of cross-sectional view of biostructures as seen in the lignite pellets during their preparation for the study of the physical composition (Navale, 1970). As it is difficult to separate the woody or as a matter of fact any organic or inorganic entities from the general ground mass of the lignite, the other sectional views (radial or longitudinal) could not be prepared to support the information derived from cross-sectional view as seen in the pellets. Nevertheless the latter surface has given sufficient diagnostic information so as to enable me to determine with reasonable accuracy their affinities to modern families. While evaluating, a careful analysis and comparison with the known flora from the Cuddalore Series and other Tertiaries, and also phytogeographical considerations were kept in view.

Guttiferae (Genus : *Mesua* or *Callophyllum*)

The microstructural features of the lignite woody tissue show resemblance to the woods of *Mesua* or *Callophyllum* belonging to the family Guttiferae by having some of the diagnostic characters such as obliquely arranged radial vessels, paratracheal tracheids, apotracheal parenchyma bands, uniseriate rays and thick walled fibres. However, the exact affinity to the above genera could not be shown due to limited sectional view (only cross section) seen under polished surface. Lakhanpal and Awasthi (1963, 65) recognized the fossil woods of *Mesua* and *Callophyllum* in the Cuddalore sandstones from the neighbouring locality. These findings support the recognition of such woods in the lignite also, which is associated with the rocks of Cuddalore Series. Fossil woods of *Kayea* belonging to this family have been reported from the Tertiary of Assam (Chowdhury and Tandon, 1948). The living representatives of the fossils (*Mesua*, *Callophyllum*, and *Kayea*) are part of the present day deciduous rain forests of Assam, and South-India.

Dipterocarpaceae (Genus *Dipterocarpus*)

The diagnostic characteristics of the lignite woody tissue such as paratracheal or apotracheal parenchyma, the former being vasicentric, 1-3 layered, incompletely surrounding the vessels, short, irregular, often in tangential strips, the latter (apotracheal) being continuous, 1-4 cells thick; resin canals diffuse, solitary, covered by xylem parenchyma; wood rays close, 1-4 seriate are suggestive of resemblance to the woods of *Dipterocarpus*. Although *Anisopteris* closely compares with the present microstructure, the wood may be distinguished from the nature of vessels and resin canals. To corroborate this finding, a large number of fossil woods belonging to the genus *Dipterocarpus* have also been described from the Cuddalore sandstones and from Assam Tertiaries (Ramanujam, 1968; Awashti, 1971 Ms). Thus it is reasonable to presume that this family formed a common element in the source material of the lignite as it occurs both in fossil wood state and in the lignite itself.

Leguminosae (*Cassia* or *Acacia* type)

The woods of this family present a great variation in almost all anatomical characters (nature of vessels, parenchyma, rays and fibres). Yet it has shown certain typical anatomical types (Gamble, 1902), such as (1) *Ougenia-Albizzia* type (2) *Acacia-Cassia* type (3) *Dalbergia* type (4) *Bauhinia* type (5) *Hardwickia* type (6) *Erythrina* type.

The lignite microstructure shows affinities with *Acacia-Cassia* type which is characterized by paratracheal parenchyma forming zonate type anastomosing to form tangential strips, and medium sized vessels. These woods have already been described in fossil condition from the Cuddalore sandstones and in Tertiaries of Assam (Ramanujam 1968, Awasthi 1971 Ms). Also pollen showing affinities to the above genera have been recorded from the same deposit (Ramanujam, 1966).

Combretaceae (*Terminalia*)

The combinations of the characters such as diffused solitary as well as multiples of 2 or 3 vessels filled with tyloses, paratracheal vasicentric to aliform parenchyma forming sheaths around the pores; uniseriate rays containing crystals in each cell, leave no doubt for assigning the lignite microstructure to the genus *Terminalia* (Navale, 1971). It may also be mentioned here that large number of fossil woods of *Terminalia* have been recognized in the neighbouring region from the Cuddalore sandstones

(Ramanujam, 1968; Awasthi, 1971 Ms), supporting the common occurrence in the lignite deposit.

Sapotaceae (*Bassia* or *Mimusops*)

The microstructure resembling either the woods of *Bassia* or *Mimusops* has been diagnosed from Neyveli deposit (Navale, 1970). Microstructurally it is rather difficult to distinguish the woods of the family Ebenaceae and Sapotaceae. However, by negative approach to identification (i.e. elimination method), affinities to the above family and genera may be shown. Recognition of this family is supported by the presence of fossil pollen.

Ebenaceae (*Diospyros*)

Some woody portions of the lignite microstructure shows affinities either to the woods of *Diospyros* or *Maba* from the anatomical features as these genera cannot be differentiated from microscopic characters alone. Nonetheless the microstructure appears to resemble the wood structure of *Diospyros*, in view of the existing evidences from the already known fossils of this genus in the Cuddalore series. Fossil woods of *Diospyros* have been reported in the Cuddalore sandstones (Awasthi, 1971 Ms) from South Arcot, Madras, which corroborate the identification of this tissue in the lignite.

Euphorbiaceae (*Phyllanthus*?)

The fossil woody tissue has been assigned to the family Euphorbiaceae on the basis of the combination of characters, and by a process of elimination of noncomparable families due to the lack of any diagnostic characteristics as revealed by the microstructure. Even this family has a varied structural detail in its wood structure. On the basis of wood anatomy, the family Euphorbiaceae is divided into Phyllanthoidae and Crotonoidae group (Metcalfe and Chalk, 1950). It is with the former group members, that the wood structure of the lignite shows its affinities (Navale, 1971). Quite a few fossil woods of this family have been described under artificial genera like *Paraphyllanthoxylon, Phyllanthinium, Euphorbioxylon, Glochidioxylon* from the Cuddalore sandstones to support the present identification (Ramanujam, 1968; Awasthi, 1971 Ms).

Palmae

The nature of the scattered bundles, narrow ground tissue with intercellular spaces and other anatomical characters observed in the lignite structure undoubtedly place some woody tissues in Palmae group. However, limited microstructural features as revealed from the woody tissue and absence of any system of classification of the palms, leave no alternative but to place it in the general group of this family. Some palm woods and pollen are known from South Arcot and Neyveli lignite (Ramanujam, 1968; Navale, 1971) which is otherwise rich in dicotyledonous forms.

Gramineae

The microscopical characters of some Gramineae seen in the lignite suggest resemblances to mesophyllous structure of grass by having chlorenchyma unlike that in the leaves of most dicotyledonous forms without any sharp differentiation into contrasting palisade and spongy portions. The assemilatory tissue cells appear in transverse section to be oriented in a radial manner around the vessels. Vascular bundles are seen as small, scattered, and surrounded by sheath. The presence of this family is supported by many pollen grains in the deposit.

FOSSIL POLLEN AND SPORES AND THEIR AFFINITIES

In recent years, considerable interest has been shown to the microfossil content of the Neyveli lignite by some authors and they have attempted to show natural affinities of the dispersed fossil spore and pollen on the basis of morphological characters (Jacob & Jacob, 1950; Rao, 1955; Navale, 1961; Thiergart & Frantz, 1962; Ramanujam, 1966; and Nair, 1966). Ramanujam (1966) gave a detailed list of the families recognized in the deposit. However, in the present studies which consist of original findings and a reassessment of the recorded data, particular attention has been paid to various factors which determined the composition, and based on these considerations the following families which might have formed part of the vegetation during Miocene-Pliocene period in the area have been considered.

NYMPHAEACEAE

The pollen grains, bearing a large operculate pore or monosulcate apertures, and smooth exine show close resemblance to that of *Nymphaea*. Ramanujam (1966) related some *Monosulcites neyveliense*, having monosulcate apertures, to *Nymphaea*. In the present day plants both the monosulcate (elongate) and operculate (spheroidal) forms are reported for the same species (Singh *et al.*, 1969). The genus *Nymphaea* occurs in fresh water lakes in India and has been reported from other Indian Tertiary strata.

CRUCIFERAE

The grains of Cruciferae described under *Tricolpites* (Navale, 1961) characterized by 3-colpi and reticulate ornamentation is an important constituent of the herbaceous assemblage of the Neyveli lignite flora. The family is stenopalynous, and represented by hundreds of species occurring in a variety of climates and habitats, including water logged areas. This family is so far known from the microfossil representatives alone.

LEGUMINOSAE

Some 3 colporate grains described under *Margocolporites* and *Palaeocaesalpiniaceaepites* (Ramanujam, 1966) resemble very closely the grains of *Caesalpinia* by having pseudocolpoid-margins and retipilate exine surface. Similarly, the fossil genus in *Polyadopollenites* (Ramanujam, 1966) is mimosoid in affinity. There are also other 3 colporate (*Retitricolporites*; Genus *Tricolpites* — Ramanujam, 1966) and 3 porate (*Retitriporites* — Ramanujam, 1966) with unconfirmed generic affinity but probably belonging to Leguminosae. Megafossils belonging to this family have also been reported from the lignite to support the occurrence of the family.

MELIACEAE

Grains described under *Tetracolporites* (*T. quandrangularis* Ramanujam, 1966; Navale, 1961) characterized by 4-colporate apertures and thicker nexine by which they resemble the grains of *Azadirachta* of Meliaceae have been commonly found in the lignite deposit. Similar grains are shown to occur in other Indian lignites.

POTAMOGETONACEAE

Grains described under the genus *Retipilanapites* (Ramanujam, 1966), are characteristically inaperturate and retipilate resembling closely the grains of *Potamogeton* (Rao, 1955). Presently the genus occurs in fresh water lakes of India and particularly in the tropics.

LECYTHIDACEAE

A synaperturate grain, with well formed aspides in the region of ora, resembling the characteristic grains of *Barringtonia*, was recovered from Neyveli lignite. The genus is a typical mangrove plant of Indian tropics and the occurrence of its pollen indicates that the lignite deposit was formed under backwater conditions. Megafossil record of *Barringtonia* from Cuddalore rocks support the findings.

LENTIBULARIACEAE

Grains having 8-11 ill-defined colpi and smooth exine and described under the name *Neyvelipollenites psilatus* (Ramanujam, 1966) resembling those of *Utricularia* indicate the existence of another fresh water aquatic constituent in the Neyveli lignite. The plant is very characteristic of the lakes and ponds of tropical and subtropical waters and particularly occurs along with *Nymphaea*, *Potamogeton* and *Myriophyllum* as represented in the Neyveli lignite.

EUPHORBIACEAE

Grains having 6-colpate aperture, and faintly reticulate exine, recovered from the lignite resemble that of *Phyllanthus* and apart from this, some sporae dispersae of 3-colporate aperture might have euphorbiaceous affinity. The family is represented by several genera and species and is world wide in distribution. Fossil wood structures resembling *Phyllanthus* and other genera occur in the lignite.

LABIATAE

Grains described under *Hexacolpites* (Navale, 1961), *Hexaradiatus indicus* (Thiergart & Frantz, 1962, Ramanujam, 1966) with 6 colpi and reticuloid exine surface ornamentation indicate the occurrence of Labiaceous plants in Neyveli lignite. Such grains have been reported from the lignites of other Indian Tertiary localities providing evidence of wide occurrence of these plants during that time.

PALMAE

Monocolpate grains described under the genera *Arecipites*, *Palmaepollenites* (Ramanujam, 1966) and characterized by their comparatively small size, single colpi lying end to end on the long axis and the ornamentation varying from foveolate to spinose forms, provide evidence for the occurrence of Palmae during the Tertiary. This fact is amply supported by tissue structure and reflects a tropical to subtropical climate during that time (Rao, 1965).

GRAMINEAE

Palynologically, Gramineae is stenopalynous and is characterized by monoporate and operculate pollen grains and described earlier under the name *Graminidites* sp. (Ramanujam, 1966). Grains varying in general size, and diameter of pores occur in the lignite giving evidence of the occurrence of more than one graminaceous genera in the Neyveli flora.

OTHER PROBABLE TAXA

There are a number of dispersed grains with 3-colporate apertures described under *Sapotaceaoidaepollenites* and *Tricolporites* (Ramanujam, 1966) with varied botanical affinities; being possibly related to the Sapotaceae, Leguminosae or Euphorbiaceae. Similarly, the grains of aquatic taxa such as *Haloragacidites mameatus*, *H. neyveli*, and *Jacobipollenites magnificus* have possible affinities to Haloragaceae and Sparganiaceae respectively. Further, other colpate forms with highly reticulate exine surface as the one described under *Liliacidites* provide evidence of the occurrence of liliaceous element in the Neyveli flora.

FERN SPORES

The pteridophytic flora in Neyveli lignites is not so predominant as angiospermous microflora. Spores of Schizaeaceae and Polypodiaceae are common apart from reported occurrence of spores showing affinities with Gleicheniaceae, Lycopodiaceae and Hymenophyllaceae (Ramanujam, 1966-67). Conspicuous presence of fern spores in association with abundant angiospermic elements suggest warm, humid environmental conditions during the peat deposition.

FUNGAL SPORES AND SCLEROTIA

Although no efforts have been made here to study fungal spores and sclerotia, Ramanujam (1963a) has shown their not uncommon presence by recording many dispersed spores and thyriothecia comparable to *Notothyrites*, *Microthyriacites* of Microthyriaceae and *Plochmopeltinites* of Micropeltaceae. Later he and Ramachar (1963b) described a few rust fungi (Uredinales) comparable to urediospores of *Melesia*, teliospores of *Puccinia*, *Triphragmium*, *Uromyces*, *Xenedochus* and telial heads of *Ravenelia*. Chandra (1954) and Navale (1967, 70) have also shown by polished surface method, the common occurrence of teleutospores, and few species of sclerotia (*S. brandonianus*, *S. crassitesta*, *S. multicellulatus* and *Coronasclerotes africanus*) from Neyveli lignite. The common occurrence of such extensive fungal remains in lignites probably suggest warm humid environmental conditions.

DISCUSSION

Analysis and composition — The lignite microstructures reveal a diversified woody flora. The wood structures which show affinities to modern genera are *Mesua*, *Dipterocarpus*, *Cassia* or *Acacia*, *Terminalia*, *Diospyros*, *Bassia* or *Mimusopsis*, *Phyllanthus*, palms and grasses belonging to the families of Guttiferae, Dipterocarpaceae, Leguminosae, Combretaceae, Ebenaceae, Sapotaceae, Euphorbiaceae, Palmae, and Gramineae respectively.

Few pollen and spores showing affinities to some modern families were reported by Rao (1955), Navale (1961) and Thiergart & Frantz (1962). Later, Ramanujam (1966) gave a detailed list of the families represented by pollen and spores, after his extensive studies on the Neyveli lignite. Among these families, Nymphaeaceae, Leguminosae, Meliaceae, Potamogetonaceae, Lentibulariaceae, Labiatae, Sapotaceae, Palmae, Liliaceae and Gramineae could be confirmed on the basis of the present pollen study apart from some newly added families such as Lecythidaceae, Cruciferae, and Euphorbiaceae.

A comparison of the lists of woody and nonwoody tissues and pollen (Table 1) reveals a number of similarities and differences. It is obvious from the table, that mostly dictyledonous families are represented both in wood and pollen genera. Among these families, some are represented by both pollen and woody or nonwoody tissues while the rest are represented either by pollen or by tissues only. The families represented by both pollen and tissues are Leguminosae, Sapotaceae, Euphorbiaceae, Palmae and Gramineae while the families represented by pollen and spores only are Olacaceae, Araliaceae, Nyssaceae, Aquifoliaceae, Labiatae, Myricaceae, Potamogetonaceae, Cruciferae, Liliaceae, Myrsinaceae, Fagaceae, Rhamnaceae, Caprifoliaceae, Santalaceae, Hippocrateaceae, Symplocaceae, Rubiaceae, Oleaceae, Meliaceae, Lecythidaceae, Sparganiaceae, Ulmaceae, Juglandaceae, Haloragaceae, Thymelaeaceae, and Ericaceae. It may be mentioned here that many of the above families need further confirmation. The families represented by wood only are Combretaceae, Guttiferae and Dipterocarpaceae.

Before interpreting the differences and similarities between pollen and wood lists, it would be appropriate to consider the effects of the factors that influence the dispersal and preservation of pollen and wood. Van Der Burgh (1967) after considering the role of wind, water, insects and corrosion, states that (1) when only pollen and no wood is found of a particular plant, there are two possibilities, (a) either the plant occurred outside the bog and there has been no wood belonging to it inside the bog at all or (b) the wood totally decayed. In both cases plant remains must be used to check which of the alternative is applicable. (2) If only wood and no pollen was found, the species must have formed part of the local vegetation. (3) Much pollen and little of wood, the plant formed part of vegetation, either a large part or alternatively a small part with huge pollen production. (4) Much of wood and little of pollen, the species had a large part in the vegetation and pollen partly disappeared, corroded or was produced in small amount.

Keeping the above facts in mind, the interpretation of differences and composition of the lignite has been made on the basis of available data which is still very meagre on lignite wood structure and the botanical affinities of the majority of pollen types. The genera belonging to the families Leguminosae, Euphorbiaceae, Sapotaceae, Palmae and Gramineae must have been part of the vegetation of the bog as both pollen and wood are present. As regards members of Combretaceae, Dipterocarpaceae and Guttiferae, the latter also must have formed part of the vegetation as much wood is found. It is probable that some plants with tricolporate grains may also belong to these families. The remaining families are known only by pollen. It is reasonable to expect that xyloidal elements must have been dissentegrated due to their herbaceous nature. Even after eliminating all doubtful taxa, some of the characteristic members of the extant vegetation at the time the source peat was formed, are *Mesua* (Guttiferae), *Dipterocarpus*, *Shorea* (Dipterocarpaceae), *Cassia* and *Acacia* (Leguminosae), *Terminalia* (Combretaceae), *Azadirachta* (Meliaceae), *Diospyros* (Ebenaceae), *Mimusops* (Sapotaceae), *Barringtonia* (Lecythidaceae), *Nymphaea* (Nymphaeaceae), *Utricularia* (Lentibulariaceae), *Potamogeton* (Potamogetonaceae), *Borassus* (Palmae) and grasses (Gramineae) apart from ferns and fungal remains of different Taxa (Ramanujam, 1963, 1966). Conspicuously, gymnosperms are absent.

Stratigraphy and Correlation — It is evident from the above list, that the lignite formation took place during the Tertiary period as the angiosperms were very predominant in the composition. Some of the fossil genera such as *Dipterocarpus*, *Shorea* and *Terminalia* are of middle or upper Miocene period and hence suggest the age of the deposit to be of middle or upper Miocene which is also supported by fossil animal evidences (Foraminifers and Molluscan remains are considered to be upper Miocene).

Precise and accurate correlation of inter- and intra-Tertiary lignite basins is rather difficult to determine with the limited data available on the palaeobotanical composition and particularly the vegetational distribution in relation to lithological details. Nevertheless, some broad comparisons may be made with the present status of our knowledge. The Neyveli flora closely

TABLE 1 — COMPARATIVE LIST OF THE FOSSIL POLLEN AND SPORES, AND ORGANIC TISSUES KNOWN FROM NEYVELI LIGNITE

	NATURAL ORDER	SPOROMORPH	ORGANIC TISSUES	REMARKS
Dicots				
	Nymphaeaceae	P (*Nymphaea*)	P (*Petiole* ?)	
	Cruciferae	P	X	
	Guttiferae	X	P (*Mesua*) Wood (*Calophyllum*)	
	Dipterocarpaceae	X	P (*Dipterocarpus*) Wood (*Shorea*)	
	Tiliaceae	P (*Tilia* ?)	X	?
	Meliaceae	P (*Melia*) (*Azadirachta*)	X	
	Hippocrateaeceae	P	X	,,
	Aquifoliaceae	P	X	,,
	Rhamnaceae	P	X	,,
	Leguminosae (Papilionaeae) (*Caesalpineae*) (Mimoseae)	P (*Erythrina*) (*Cassia*) (*Acacia*)	P (*Cassia*) Wood (*Acacia*	
	Haloragidaceae	P (*Haloraghis* (*Myriophyllum*)	X	,,
	Lecythidaceae	P (*Barringtonia*	X (Present, as fossil wood associated with Cudalore sand stone near Pondichery	
	Combretaceae	X	P (*Terminalia*) Wood	
	Araliaceae	P	X	?
	Nyssaceae	P	X	
	Rubiaceae	P (*Coprosma*)	X	,,
	Caprifoliaceae	P (*Viburnum*)	X	,,
	Ericaceae	P	X	,,
	Myrsinaceae	P	X	,,
	Sapotaceae	P	P (*Mimusops*) Wood	
	Ebenaceae	X	P (*Diospyros*)° Wood	
	Symplocaceae	P	X	
	Oleaceae	P (*Fraxinus*)	X	,,
	Lentibulariaceae	P (*Utricularia*)	X	
	Labiatae	P	X	
	Chenopodiaceae/ Amaranthaceae	P (*Amaranthus* ?)	X	
	Thymelaeaceae	P (*Wikstroemia*)	X	,,
	Olacaceae	P	X	,,
	Santalaceae	P (*Santalum*) (*Exocaria*)	X	,,
	Euphorbiaceae	P (*Phyllanthus*)	P (*Phyllanthus*) Wood	
	Ulmaceae	P	X	
	Juglandaceae	P (*Engelhardtia*) (*Pterocarya*) (*Carrya*)	X	,,
	Myricaceae	P	X	
	Fagaceae	P (*Nothofagus* ?) (*Quercus* ?)	X	,,
	Betulaceae	P (*Betula* ?) (*Carpinus* ?)	X	,,
Monocots				
	Liliaceae	P	X	
	Commelinaceae	P	X	
	Palmae	P (*Borassus*) (*Phoenix*)	X (Wood)	,,
	Potamogetonaceae	P	P	
	Sparganiaceae	P		
	Gramineae	P	P (Leaf)	,,

Continued

TABLE 1—COMPARATIVE LIST OF THE FOSSIL POLLEN AND SPORES, AND ORGANIC TISSUES KNOWN FROM NEYVELI LIGNITE — *Continued*

	NATURAL ORDFR	SPOROMORPH	ORGANIC TISSUBS	REMARKS
Gymnospermae				
	Podocarpaceae	P	X	
Pteridophytes				
	Polypodiaceae	P	X	
	Schizaeaceae	P	X	
	Osmundaceae	P	X	
	Hymenophyllaceae	P	X	
	Gleicheniaceae	P	X	
	Lycopodiaceae	P	X	
Fungi				
	Mycrothyriaceae	P	P (Sclerotia)	
	Micropeltaceae	P	X	
	and Rust fungi (uredinales)	P	P (Teliospores)	
Algae				
	Botryococcus		P	

Index: P=Present; X=Absent; ?=Affinities doubtful.

compares with Warkalli fossil pollen and spore assemblage by having a large number of common taxa (Ramanujam, 1966) but with the other neighbouring lignite deposit namely Cannanore, the present flora does not agree as the Cannanore mioflora as known, is conspicuous by having *Cannanoropollis* and *Limitipollis* miospores which is completely different from others. It may be mentioned here that a reappraisal of the source material and botanical affinities may limit many differences and probably bring out a uniform picture of South-Indian lignite floral composition. As regards Kutch and Palana (Sah & Kar, 1971 Ms), the composition of mioflora is entirely different as they are dominated by pollen showing affinities to Proteaceae, Onagraceae (*Epilobium* type), Leguminosae (*Caesalpinia*), Meliaceae (*Meliapollis*), Lecythidaceae (*Barringtonia*).

In general, it may be reasonable to say that Neyveli, Warkalli and Cannanore deposits might have had a common source material from the vegetation of middle or upper Miocene age as discussed in this paper while that of Kutch and Palana lignites derived from an entirely different source material of lower Eocene vegetation (Sah & Kar, 1971 Ms).

Palaeogeography and Climatic Conditions — After comparing the lignite flora of India on the basis of information then available, Rao (1955) generalized the existence of a warm humid type of climate during Tertiary period. A similar conclusion was reached by Ramanujam (1966) after his extensive palynological studies of South Arcot lignite and also by me (1970) based on the physical composition of the lignite. The present detailed investigation indicates a fairly large representation of aquatic flora composed of *Nymphaea, Utricularia, Potamogeton, Haloragis* along with salt water loving *Barringtonia* apart from terristrial woody tropical angiosperms among which may be mentioned *Dipterocarpus, Terminalia, Mesua, Caesalpinia* and some members of Oleaceae and Palmae which suggests an admixture of aquatic and terrestrial woody flora.

Both Rao (1958) and Ramanujam (1966) observed an admixture of warm climatic and cold climatic elements (*Nothophagus, Pterocarpus*) in the lignite flora, of which temperate elements do not form a part of the present day flora of those localities but are confined to as far as the Himalayas. Even after presuming that the affinities of the fossil pollen are correct, does it mean the extinction of these temperate elements from the localities of their original occurrence; if so what are the factors that contributed to the extinction of upland plants when lowland plants continue to exist till today. A detailed investigation of mioflora and a reappraisal of botanical affinities after a clearer understanding of pollen morphology of the present day flora may alone solve the riddle.

Inspite of the absence of a complete knowledge of the Neyveli lignite flora, the common occurrence of taxa like *Potamogeton*, *Nymphaea*, *Utricularia*, *Azadirachta*, *Dipterocarpus*, *Shorea*, *Terminalia*, *Phyllanthus*, *Diospyros*, *Mesua*, Gramineae and Palmae, coupled with ferns and fungal organic remains indicate clearly that by and large the deposition took place in fresh water lakes probably closer to the sea or estuaries as evident from the occurrence of *Barringtonia* and *Sonneratia* (recognized in the Cuddalore rocks) and the climate during the peat formation was subtropical to rain forest type having warm humid palaeoenvironmental conditions.

Genesis and Utilization — It is reasonable to assess from the evidences provided by the microstructure and microfossil contents of the lignite that arborial, aquatic and brackish vegetation contributed largely to the peat formation. Thus the substances derived are mainly composed of woody, attrital and huminite material. Frequent occurrence of fusinized tissues in the lignite suggest open water conditions during the formation of the lignite. It is probable that some of the accumulated peat was above the water level rendering aerobic decomposition of the peat. As such fungal organisms seem to have played an important role in the decomposition. The different lithological layers (Huminoid, Attrital, woody and Fusinized substances) suggest variable formation due to probable changes in water level (transgression or regression of water) during the formation. Separation of substances derived from the above material either for carbonization or extraction, would be judicious for selective utilization.

CONCLUSION

Efforts have been made, after correlating wood and pollen data of Neyveli lignite, to evaluate with reasonable accuracy the picture of extant vegetation. The information thus obtained were considered for elucidating floristic constitution, climatic conditions, the age, nature and formation of the lignite deposit. It may be mentioned here, only broad generalization on geobotanical significance of the material could be made at present, with the limited data. More significant information is bound to come when relationship between sediment type and depositional environment is established by analysis and correlating the rock type (lithotype and microlithotype), pollen and spores and residual maceration entities.

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