Tertiary palynology of Kerala Basin—An overview

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In Kerala Basin the Tertiary sedimentary sequence is represented by Quilon and Warkalli formations. Palaeoassociations of upland, lowland, fresh-water, sandy beach and mangrove vegetations have been figured out. Composition of the palynological assemblages indicates the existence of tropical rain forests with a high degree of rainfall. Dinoflagellate cysts and pollen grains of *Barringtonia, Rhizophora, Nypa* and *Calamus* suggest deposition under brackish water mangrove swamps. The sandy beach conditions are indicated by *Palmidites, Palmaepollenites* and *Quilonipollenites*. Divergent views on the age of Quilon and Warkalli formations have been reconsidered on the basis of new palynological evidences.

Key-words—Palaeopalynology, Kerala Basin, Tertiary (India).

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साराँश

केरल द्रोणी का तृतीयक युगीन परागाणविक अध्ययन : एक पुनरीक्षण

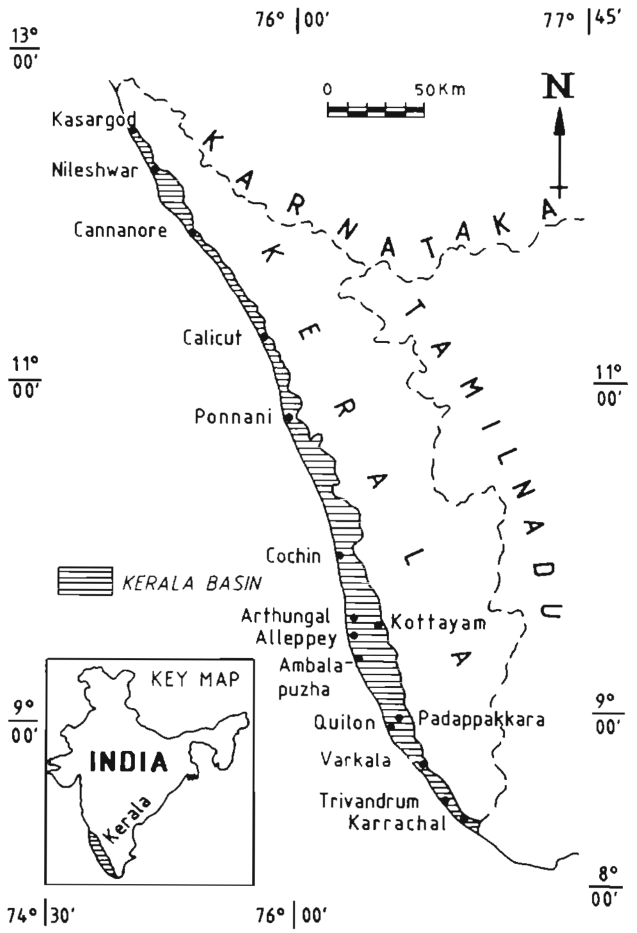
हरिपाल सिंह एवं मुलागलापल्ली रामचन्द्र राव

केरल द्रोणी में तृतीयक युगीन अवसादीय अनुक्रम क्वीलन एवं वरकली शैल-समूहों से निरूपित है। उपरिभूमि, निम्नभूमि, स्वच्छ जल, बलुई तट एवं मैंग्रोव वनस्पति के पुरासाहचर्य अभिलिखित किये गये हैं। परागाणविक समुच्चयों के पारस्परिक साहचर्य से अत्यधिक वर्षा वाले उष्णकटिबन्धीय वनों का होना इंगित होता है। घूर्णीकशाभ पुटीयाँ तथा **बैरिंग्टोनिया, राइजोफ़ोरा, नाइपा** एवं **कैलेमस** के परागकण खारे जल युक्त मैंग्रोव दलदली परिस्थितियों के अन्तर्गत निक्षेपण प्रस्तावित करते हैं। **पाल्मीडाइटिस, पाल्मीपोलिनाइटिस** एवं **क्वीलोनीपोलिनाइटिस** की उपस्थिति के कारण बलुई तट वाली परिस्थितियाँ व्यक्त होती हैं। नये परागाणविक प्रमाणों के आधार पर क्वीलन एवं वरकली शैल-समूहों की आयु पर उल्लिखित विभिन्न दृष्टिकोणों पर पुनर्विचार किया गया है।

MOST of the palynological studies on the Quilon and Warkalli formations (Kerala Basin) have not been related to stratigraphically located samples. They are confined only to a meagre number of grab samples. Thus the accrued palynological evidence cannot be considered authentic to draw a successional picture of the vegetational history though Ramanujam (1982) opined that the two formations pertain to a single time transgressive unit, being Early to Middle Miocene in age.

In the recent past, Raha, Rajendran and Kar (1987) and Rao (1989) have systematically studied palynology from the bore-holes of Ambalapuzha and Arthungal (Alleppey District, Kerala), respectively (Map 1). They have used palynology as the basis for assigning Eocene to Early Miocene age to the successions studied.

The present paper reassesses the available palynological data from the Tertiary sediments of Kerala Basin in the light of recent palynological advances made in this area, with a view to identify ecologically and stratigraphically significant palynotaxa as related to habitat and time. An attempt has also been made to reconstruct vegetation of the past so as to understand its possible impact on the evolution of the modern flora. Some important contributions made on the Tertiary palynology of Kerala Basin are: Rao and Vimal (1952), Vimal (1953), Potonié and Sah (1960), Ramanujam (1960, 1966, 1972, 1977, 1982, 1987), Ramanujam and Rao (1971, 1977, 1978), Jain and Kar (1979), Ramanujam and Srisailam (1978), Ramanujam, Srisailam and Reddy (1981), Rao and Ramanujam (1978, 1982), Kar and Jain (1981), Varma and Patil (1985), Varma,



Map 1—Kerala Basin showing localities of Tertiary exposures.

Ramanujam and Patil (1986), Raha, Rajendran and Kar (1987), Varma (1987) and Rao (1989).

GEOLOGY

The Tertiary sediments of Kerala coast are well known as Warkalli and Quilon formations. These rocks were first described by King (1882) and Foote (1883). The Quilon Formation consists of limestones with intercalations of calcareous clays, carbonaceous clays and sand whereas the Warkalli Formation comprises variegated sandstones interbedded with white plastic and variegated clays, carbonaceous clays and seams of lignite or peaty lignite. The Tertiary sequence rests unconformably over the Archean crystalline complex. It is succeeded by recent to subrecent marine and estuarine sediments (Poulose & Narayanaswami, 1968). A recent study of the lithology based on some bore-hole information resulted in the institution of a third formation, viz., Vaikom Formation, underlying the Quilon Formation (Rao, 1975; Rao *et al.*, 1975). These beds are similar to Warkalli Formation but are more arenaceous and coarse-grained.

PALYNOLOGY

The Quilon and Warkalli palynological assemblages consist of 135 genera and 165 species. Pteridophytic spores and angiospermous pollen constitute an important part of the assemblage. Dinoflagellate cysts and fungal remains are also commonly met with. On the basis of the morphological similarities, botanical affinities of some Quilon and Warkalli palynofossils have been tagged with modern families, as tabulated below:

Pteridophytes

Verrucosisporites	Lycopodiaceae (*Lycopodium*)
Foveosporites	Ophioglossaceae (*Ophioglossum*)
Cibotiidites	Dicksoniaceae
Lygodiumsporites	Schizaeaceae
Crassoretitriletes	Schizaeaceae
Schizaeoisporites	Schizaeaceae
Gleicheniidites	Gleicheniaceae (*Gleichenia*)
Striatriletes	Parkeriaceae
Intrabaculisporis	Schizaeaceae
Cyathidites	Cyatheaceae
Alsophilidites	Cyatheaceae
Osmundacidites	Osmundaceae
Biretisporites	?Hymenophyllaceae
Lycopodiumsporites	Lycopodiaceae
Pteridacidites	Pteridaceae (*Pteris*)
Laevigatosporites	Polypodiaceae
Polypodiaceaesporites	Polypodiaceae
Polypodiisporites	Polypodiaceae

Angiosperms

Monocotyledons

Retipilonapites	Potamogetonaceae (*Potamogeton*)
Palmaepollenites	Arecaceae
Arecipites	Arecaceae
Clavapalmaedites	Arecaceae (*Oncosperma*)
Langapertites	Arecaceae
Spinizonocolpites	Arecaceae (*Nypa*)
Quilonipollenites	Arecaceae (*Eugeissonia*)
Dicolpopollis	Arecaceae (*Calamus*)
Trilatiporites	Arecaceae (*Sclerosperma*)
Paravuripollis	Arecaceae (*Salaca*)

Iridacidites	Iridaceae
Liliacidites	Liliaceae

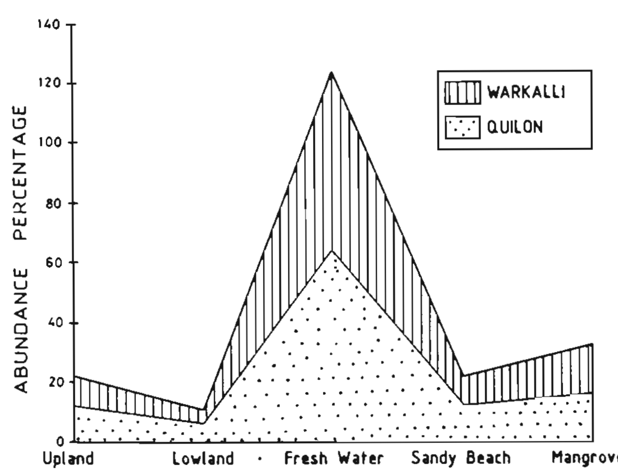
Dicotyledons

Crotonoidaepollenites	Euphorbiaceae
Crototricolpites	Euphorbiaceae
Retitricolporites	
Dipterocarpoides	Dipterocarpaceae
Retitricolpites (some spp.)	Oleaceae
Heterocolpites	Combretaceae
Psilatricolpites	Ebenaceae
Loranthipites	Loranthaceae (*Loranthus*)
Gothanipollis	Loranthaceae
Palaeocoprosmadites	Rubiaceae (*Coprosma*)
Talisiipites	Sapindaceae
Cupaniedites	Sapindaceae
Araliaceoipollenites	Araliaceae (*Aralia*)
Symplocoipollenites	Symplocaceae (*Symplocoa*)
Zonocostites	Rhizophoraceae (*Rhizophora*)
Bombacacidites	Bombacaceae
Hippocrateaceaedites	Hippocrateaceae (*Hippocratea*)
Cauveripollis	Caprifoliaceae
Compositoipollenites	Asteraceae
Ctenolophonidites	Ctenolophonaceae (*Ctenolophon*)
Polycolpites	Lamiaceae
Retistephanocolpites	Lamiaceae
Meliapollis	Meliaceae
Sapotaceoidaepollenites	Sapotaceae
Myricipites	Myricaceae
Casuariniidites	Casuarinaceae (*Casuarina*)
Verrutriporites	Sonneratiaceae
Proteacidites	Proteaceae
Haloragracidites	Haloragaceae (*Myriophyllum*)
Triorites	Onagraceae
Anacolosidites	Olacaceae (*Anacolosa*)
Clavaperiporites	Thymeliaceae
Ornatetradites	Droseraceae
Droseridites	Droseraceae (*Drosera*)
Trisyncolpites	Caesalpiniaceae
Lakiapollis	Bombacaceae (*Durio*)
Sonneratiopollis	Sonneratiaceae
Malvacearumpollis	Malvaceae
Chenopodipollis	Chenopodiaceae
Polyporina	Chenopodiaceae
Caryophyllidites	Caryophyllaceae
Umbelliferoipollenites	Apiaceae
Neyvelipollenites	Lentibulariaceae
Myricaceoipollenites	Myricaceae
Cricotriporites	Rubiaceae
Lacrimapollis	Tiliaceae
Clavatricolporites	Aquifoliaceae
Warkallipollenites	Plumbaginaceae

PALAEOECOLOGICAL ANALYSIS

Rao and Ramanujam (1982) and Varma (1987) brought out ecological significance of palynofossils from Quilon Formation and Tonakkal clays (Kerala State), respectively. The proposed ecological groups seem to be far more in number than necessary. We have fed the available data to the computer and prepared an area graph (Text-fig. 1). The qualitative aspect of palynological data and palaeogeographical locale of the Tertiary sequence of sediments of Kerala Basin in the Indian subcontinent do not confirm the presence of montane elements (Rao & Ramanujam, 1982; Varma, 1987). The terrestrial elements represented by upland (relief) and lowland floras rapidly merge with the fresh water elements which lose hold towards the vicinity of tidal mud flats and coastal shore-line.

Palynological data was thoroughly combed and ecologically significant palynotaxa were selected and segregated for identifying various habitats. The palynoflora of Quilon and Warkalli formations has been segregated under the following different ecological groups such as upland, lowland, fresh-water, sandy beach and mangrove.



Text-figure 1—Distribution of different ecological group of plants in Quilon and Warkalli formations.

Upland elements

Umbelliferoipollenites	Apiaceae
Symplocoipollenites	Symplocaceae (*Symplocoa*)
Hippocrateaceaedites	Hippocrateaceae
Proteacidites	Proteaceae
Palaeocoprosmadites	Rubiaceae (*Coprosma*)
Clavaperiporites	Thymeliaceae
Compositoipollenites	Asteraceae

Lowland elements

Lakiapollis	Bombacaceae (*Durio*)
Tricolporopollis	Euphorbiaceae
Favitricolporites	Rubiaceae

Fresh water elements

Lycopodiumsporites	Lycopodiaceae (*Lycopodium*)
Lygodiumsporites	Schizaeaceae (*Lygodium*)
Crassoretitriletes	Schizaeaceae (*Lygodium*)
Schizaeoisporites	Schizaeaceae (*Schizaea*)
Pteridacidites	Pteridaceae (*Pteris*)
Polypodiisporites	Polypodiaceae (*Polypodium*)
Polypodiaceaesporites	Polypodiaceae (*Polypodium*)
Laevigatosporites	Polypodiaceae
Striatriletes	Parkeriaceae (*Ceratopteris*)
Liliacidites	Liliaceae
Marginipollis	Lecythidaceae (*Barringtonia*)
Psilatricolpites	Ebnaceae
Ctenolophonidites	Ctenolophonaceae (*Ctenolophon*)
Neyvelipollenites	Lentibulariaceae
Margocolporites	Caesalpiniaceae (*Caesalpinia*)
Trisyncolpites	Caesalpiniaceae
Sapotaceoidaepollenites	Sapotaceae
Meliapollis	Meliaceae
Triporopollenites	Moraceae
Anacolosidites	Olacaceae (*Anacolosa*)
Ornatetradites	Droseraceae (*Drosera*)
Retipilonapites	Potamogetonaceae
Araliaceoipollenites	Araliaceae
Haloragacidites	Haloragaceae
Cupaniedites	Sapindaceae (*Cupania*)

Sandy Beach elements

Palmaepollenites	Arecaceae
Quilonipollenites	Arecaceae (*Eugeissonia*)
Longapertites	Arecaceae
Dicolpopollis	Arecaceae
Paravuripollis	Arecaceae
Spinizonocolpites	Arecaceae (*Nypa*)

Mangrove elements

Meliapollis (some spp.)	Meliaceae
Intratriporopollenites	Tiliaceae
Rhoipites	Anacardiaceae
Alangipollis	Alangiaceae (*Alangium*)
Zonocostites	Rhizophoraceae (*Rhizophora*)
Retitricolporites	Verbenaceae
Heterocolpites	Combretaceae
Verrutricolporites	Lythraceae

The palms generally tend to remain away from the storm tide and dominate the sandy beach flora. The mangrove swamps are confined to littoral regions between low tide and high tide all along the estuaries of rivers and on low mud flats of the sea coast. The fresh-water elements are conspicuous and may be representing the lowland and upland elements of the flora. They dominate the assemblages at all levels characteristic of tropical rain forests.

The spores of Schizaeaceae, Parkeriaceae, Osmundaceae, Polypodiaceae and pollen of Arecaceae, Rhizophoraceae, Verbenaceae, Hippocrateaceae, Caesalpiniaceae, Combretaceae, Sapotaceae, Dipterocarpaceae, Meliaceae, Ctenolophonaceae, Oleaceae, Moraceae and Anacardiaceae in the palyno-assemblage of Quilon and Warkalli formations clearly indicate the prevalence of tropical climate at the time of deposition.

The presence of fungal remains, viz., *Phragmothyrites, Notothyrites, Parmathyrites, Multicellaesporites, Pluricellaesporites,* fern spores and tropical rain forest elements belonging to the families Ctenolophonaceae, Oleaceae, Dipterocarpaceae, Moraceae and Alangiaceae confirm high degree of rainfall.

Similar palaeoclimatic derivations have been made by Awasthi and Ahuja (1982) on the basis of fossil woods, viz., *Calophyllum, Drybalanops, Gluta, Swintonia, Terminalia, Diospyros, Litsea,* *Cynometra, Gonystylus* and *Leea* reported from the Neogene of Varkala in Kerala Coast.

Dinoflagellate cysts (*Operculodinium, Achomosphaera* and *Thalassiphora*) and pollen of *Barringtonia, Rhizophora, Lumnitzera, Nypa, Calamus,* Araliaceae, Sapindaceae, Meliaceae and Droseraceae indicate the existence of brackish water mangrove swamps. Pollen comparable to Potamogetonaceae, Haloragaceae and Droseraceae indicate the presence of fresh water lakes or ponds, dotting the inland landscape, away from the mangrove belt. The sandy beach conditions have been inferred by the presence of palm pollen (*Palmidites, Palmaepollenites* and *Quilonipollenites*).

AGE OF QUILON AND WARKALLI FORMATIONS

On the basis of foraminifera, ostracod and mollusca evidences, the Quilon Formation is assigned an Early to Middle Miocene age (Jacob & Sastry, 1952; Dey, 1962). The Warkalli Formation overlying the Quilon Formation is considered to be Late Miocene to Pliocene in age (Poulose & Narayanaswami, 1968).

Ramanujam (1982) opined that a striking similarity exists between the assemblages of both the formations. He concluded (on the basis of surface and subsurface palyno-assemblages) that the entire Tertiary sequence of Kerala Basin constitutes a single time transgressive group being Early to Middle Miocene in age.

Raha, Rajendran and Kar (1987) on subsurface palynological data from Ambalapuzha, Alleppey District, Kerala, suggested Eocene to Early Miocene age to the sediments. Palynofossil taxa *Proxapertites, Polycolpites, Meliapollis, Verrutricolporites, Proteacidites* and *Striacolporites* with some palm pollen are suggestive of Eocene age. Oligocene age has been inferred by the presence of *Crassoretitriletes, Trisyncolpites* and *Bombacacidites.* The occurrence of *Malvacearumpollis, Hibisceaepollenites* and *Quilonipollenites* suggests Early Miocene age.

Recent palynological study of Arthungal bore-hole, Alleppey District, Kerala by one of us (Rao, 1989 *in this volume*) also provides cogent evidence that the palynoflora of Warkalli and Quilon formations may vary from Eocene to Early Miocene in age. The Arthungal bore-hole palynofloral succession has been divided into three distinct cenozones, viz., *Malvacearumpollis bakonyensis* Cenozone (Early Miocene), *Crassoretitriletes vanraadshooveni* Cenozone (Oligocene) and *Triangulorites bellus* Cenozone (Eocene). Each cenozone contains age definitive and ecologically important palynofossils, the details of which are given in the above mentioned paper. It is quite obvious from this palynological data that the Arthungal bore-hole penetrates through strata ranging in age from Eocene to Early Miocene.

Thus, on the basis of subsurface Arthungal palynofossils it is suggested that the entire Tertiary sequence of Kerala Basin may have to be restudied palynologically both from the surface and subsurface for finer resolution of the age before a tangible conclusion can be made.

DISCUSSION

The Quilon and Warkalli formations of Kerala have yielded a variety of pteridophytic spores and angiospermous pollen (Table 1). Dinoflagellate cysts and fungal remains are also present whereas the gymnospermous pollen are poorly represented.

Table 1

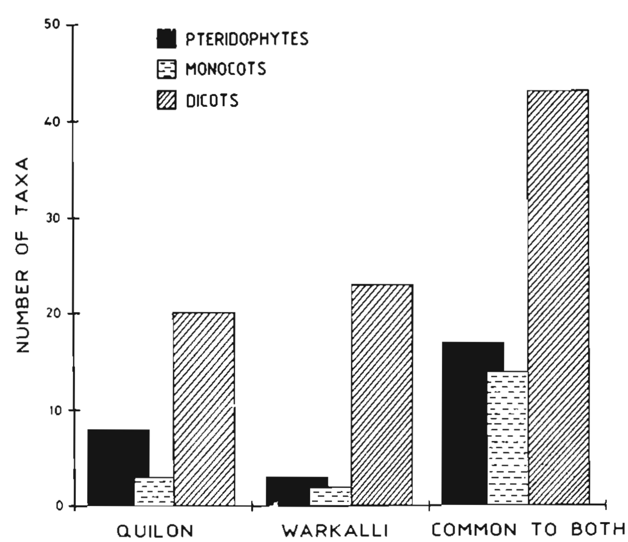
Palynotaxa	Quilon Formation	Warkalli Formation	Common genera between two formations
Lygodiumsporites	+		
Intrabaculisporis	+		
Gleicheniidites	+		
Eximospora	+		
Foveotriletes	+		
Cingulatisporites	+		
Cibotiidites	+		
Laevigatosporites	+		
Spinainaperturites	+		
Clavainaperturites	+		
Crotonisulcites	+		
Monoporopollenites	+		
Spinamonoporites	+		
Crotonoidaepollenites	+		
Foveotricolpites	+		
Crototricolpites	+		
Punctatricolpites	+		
Bacubrevitricolpites	+		
Clavasyncolpites	+		
Meyeripollis	+		
Costatipollenites	+		
Talisiipites	+		
Foveostephanocolporites	+		
Padappakkarapollis	+		
Polybrevicolporites	+		
Triorites	+		
Casuarinidites	+		
Echitriporites	+		
Tetrapollis	+		
Inaperturotetradites	+		
Haloragacidites	+		

Contd.

Parsonsidites	+		
Biretisporites	–	+	
Neyvelisporites	–	+	
Polypodiaceaesporites	–	+	
Iridacidites	–	+	
Disulcipollis	–	+	
Warkallipollenites	–	+	
Stephanocolpites	–	+	
Clavatricolpites	–	+	
Rhoipites	–	+	
Lacrimapollis	–	+	
Myrtaceidites	–	+	
Psilastephanocolporites	–	+	
Diporites	–	+	
Retitriporites	–	+	
Florschuetzia	–	+	
Myricaceoipollenites	–	+	
Trilatiporites	–	+	
Caryophyllidites	–	+	
Polyporina	–	+	
Ranunculacidites	–	+	
Clavatricolpites	–	+	
Intratriporopollenites	–	+	
Subtriporopollis	–	+	
Pseudonothofagidites	–	+	
Farsonsidites	–	+	
Periporopollenites	–	+	
Chenopodipollis	–	+	
Sparganiaceaepollenites	–	+	
Lycopodiumsporites	–	–	+
Osmundacidites	–	–	+
Cyathidites	–	–	+
Intrapunctisporis	–	–	+
Alsophilidites	–	–	+
Dandotiaspora	–	–	+
Seniasporites	–	–	+
Cicatricosisporites	–	–	+
Scantigranulites	–	–	+
Verrucosisporites	–	–	+
Foveosporites	–	–	+
Crassoretitriletes	–	–	+
Pteridacidites	–	–	+
Monolites	–	–	+
Cheilanthoidspora	–	–	+
Polypodiisporites	–	–	+
Schizaeoisporites	–	–	+
Retipilonapites	–	–	+
Palmaepollenites	–	–	+
Arecipites	–	–	+
Verrumonocolpites	–	–	+
Neocouperipollis	–	–	+
Palmidites	–	–	+
Proxapertites	–	–	+
Clavapalmaedites	–	–	+
Spinizonocolpites	–	–	+
Paravuripollis	–	–	+
Liliacidites	–	–	+
Longapertites	–	–	+
Quilonipollenites	–	–	+
Dicolpopollis	–	–	+
Retitricolpites	–	–	+
Retibrevitricolpites	–	–	+
Loranthipites	–	–	+
Marginipollis	–	–	+
Retistephanocolpites	–	–	+
Ctenolophonidites	–	–	+
Polycolpites	–	–	+
Lakiapollis	–	–	+
Tricolpites	–	–	+
Palaeosantalaceaepites	–	–	+
Psilatricolporites	–	–	+
Heterocolpites	–	–	+
Retitricolporites	–	–	+
Cauveripollis	–	–	+
Araliaceoipollenites	–	–	+
Zonocostites	–	–	+
Compositoipollenites	–	–	+
Bombacacidites	–	–	+
Hippocrateaceaedites	–	–	+
Palaeocoprosmadites	–	–	+
Symplocoipollenites	–	–	+
Margocolporites	–	–	+
Gothanipollis	–	–	+
Cupaniedites	–	–	+
Sapotaceoidaepollenites	–	–	+
Meliapollis	–	–	+
Polygalacidites	–	–	+
Triporopollenites	–	–	+
Myricipites	–	–	+
Maculoporites	–	–	+
Verrutriporites	–	–	+
Graminidites	–	–	+
Jandufouria	–	–	+
Ornatriporites	–	–	+
Proteacidites	–	–	+
Thomsonipollis	–	–	+
Haloragacidites	–	–	+
Clavaperiporites	–	–	+
Anacolosidites	–	–	+
Ornatetradites	–	–	+
Droseriidites	–	–	+
Podocarpidites	?	+	–

The distribution of different plant groups in Quilon and Warkalli formations alongwith the common elements between the two is given in Text-figure 2.

1. Ecological analysis of the Tertiary palynofossils



Text-figure 2—Distribution of different plant groups in Quilon and Warkalli formations.

from the Kerala Basin identifies upland, lowland, fresh water, sandy beach and mangrove elements occurring as constituents of tropical rain forests of semi-evergreen type. The terrestrial elements of upland relief flora and lowland vegetation tend to merge with the fresh water constituents and dominate the total assemblage. Luxuriant growth of palms seems to have been supported by the sandy beaches. Mangrove vegetation thriving on the tidal mud flats and dinocysts in the estuaries have also been richly contributing to the past vegetation.

2. The bore-holes penetrating through the Tertiary sediments of Kerala Basin have yielded palynological evidences which assign Eocene to Early Miocene age to the successions studied. In view of this newly emerged palynological information, concerted efforts are required to systematically restudy the entire sequence from the stratigraphically located samples. Therefore the contention of Ramanujam (1982) that the entire Tertiary sequence of Kerala Basin is a single time transgressive unit, being Early to Middle Miocene in age, needs to be confirmed.

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