Palynological investigations of Tertiary lignite and associated sediments from Cannanore, Kerala Basin, India

M. R. Rao & C. P. Rajendran

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The palynoflora recovered from the Tertiary lignite and associated sediments exposed along Cannanore and adjoining area of Kerala Basin consists of 50 genera and 73 species . Of these, 13 genera and 20 species are represented by pteridophytic spores and 36 genera and 52 species to angiospermous pollen. Ten species have been proposed as new. Some significant constituents of the assemblage are —*Lygodiumsporites, Dictyophyllidites, Crassoretitriletes, Intrapunctisporis, Cheilanthoidspora, Polypoditisporites, Retimonosulcites, Quilonipollenites, Lakiapollis, Tricolpites, Gemmatricolpites, Tricolporopollis, Dermatobrevicolporites, Margocolporites, Retitrescolpites, Meliapollis, Ctenolophonidites, Myricipites, Triporopollenites, Clavaperiporites* and *Malvacearumpollis*. Quantitative dominance of angiospermous pollen is a conspicuous feature of the assemblage. Ecological analysis of the assemblage identifies several palaeoassociations of low-land, fresh water swamp and water edge, sandy beach, montane and back - mangrove vegetation. The recoered palynological assemblages indicate the prevalence of wet semi-evergreen type of vegetation with warm and humid tropical climate and plenty of rainfall during sedimentation. The brackish-water environment of deposition is indicated by back-mangrove elements (*Palaeosantalaceaepites, Malvacearumpollis*) and dinoflagellate cysts. On the basis of comparison of the present assemblage with the known Indian Tertiary palynoassemblages, Miocene age has been assigned.

Key-words —Palynology, Palaeoecology, Miocene, Kerala Basin (India).

M. R. Rao, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

C.P. Rajendran, Centre for Earth Science Studies, Arkonam, Trivandrum 695 031, India.

सारांश

केरल द्रोणी मे कन्नानौर से तृतीयक लगुडांगार एवं सहयुक्त अवसादों का परागाणविक अन्वेषण

मुलागलापल्ली रामचन्द्र राव एवं सी. पी. राजेन्द्रन

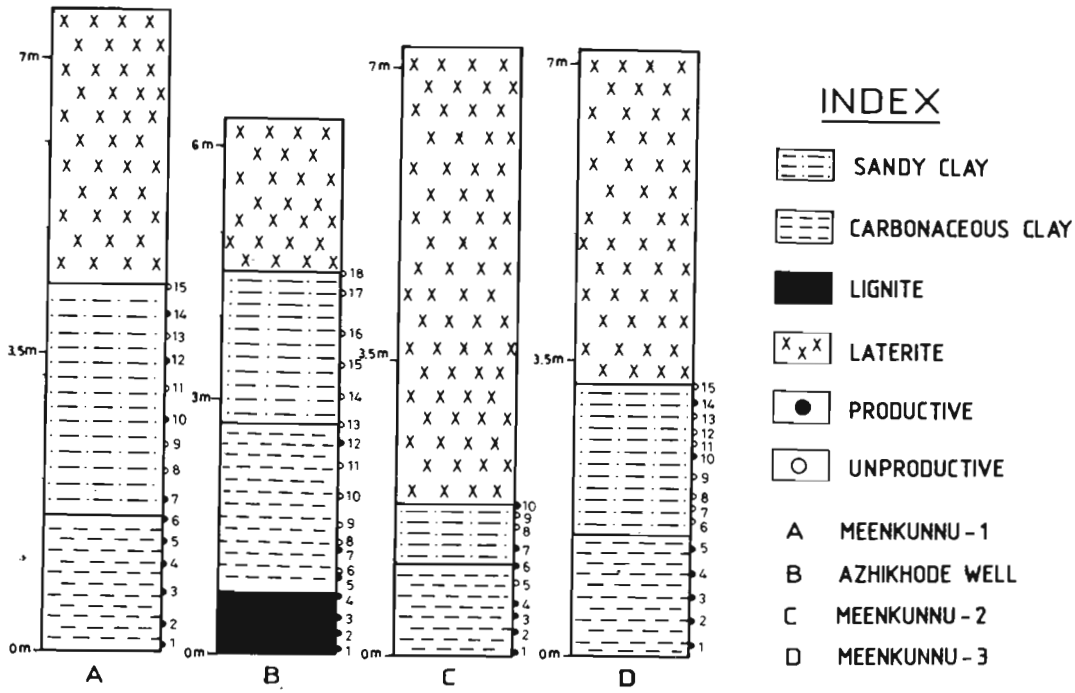
केरल द्रोणी के कन्नानौर एवं आस-पास के क्षेत्र में अनावरित तृतीयक युगीन लगुडांगार एवं सहयुक्त अवसादों से उपलब्ध परागाणु वनस्पतिजात में 50 प्रजातियाँ एवं 73 जातियाँ विद्यमान हैं। इनमें से 13 प्रजातियाँ एवं 20 जातियाँ टेरीडोफाइटी बीजाणुओं की तथा 36 प्रजातियाँ एवं 52 जातियाँ आवृतबीजी परागकणों की हैं। पूरे उपलब्ध वनस्पतिजात में 10 जातियाँ नई प्रस्तावित की गई हैं। इनमें *लाइगोडियमस्पोराइटिस, डिक्टियोफिल्लिडाइटिस, क्रेसोरेटिट्राइलिटीस, इन्ट्रापंकटिस्पोरिस, चीलेन्थोयडस्पोरा, पोलिपोडाइस्पोराइटिस, रेटिमोनोसल्काइटिस, क्विलोनिपोलिनाइटिस, लकियापोलिस, ट्राइकॉल्पाइटिस जेमाट्राइकॉल्पाइटिस, ट्राइकाल्पोरोपॉलिस, डर्मेटोब्रेविकॉल्पोराइटिस, मार्गोकॉल्पोराइटिस, रेटिट्रेस्कॉल्पाइटिस, मिलियापॉलिस, टीनोलोफोनीडाइटिस, मिरिसीपाइटिस, ट्राइपोरोपोलिनाइटिस, क्लेवापेरिपोराइटिस* एवं *माल्वेसियॅरमपॉलिस* नामक कुछ विशिष्ट अवयव हैं। आवृतबीजी परागकणों की बाहुल्यता इस समुच्चय की विशिष्टता है। पुरापारिस्थितिकीय विश्लेषण के आधार पर इस समुदाय में कई परागाणविक साहचर्य प्रेक्षित किये गये हैं। उपलब्ध समुच्चयों से अवसादन के संमय अति वर्षा के साथ-साथ उष्ण, आर्द्र कटिबन्धीय जलवायु तथा नम अर्ध सदाहरित वनस्पति का होना इंगित होता है। मैंग्रोव अवयवों एव घूर्णीकशाभ पुटीयों की उपस्थिति खारे जलवाली परिस्थितियों की द्योतक है। वर्तमान समुच्चय की अन्य तृतीयक युगीन भारतीय परागाणु समुच्चयों से तुलना के आधार पर इस समुच्चय की मध्यनूतन आयु प्रस्ताि वत की गई है।

PALYNOLOGICAL studies on the Quilon and Warkali formations (Kerala Basin) have been carried out for systematic palynology, palaeoecological interpretations and dating of sediments. The studies are based

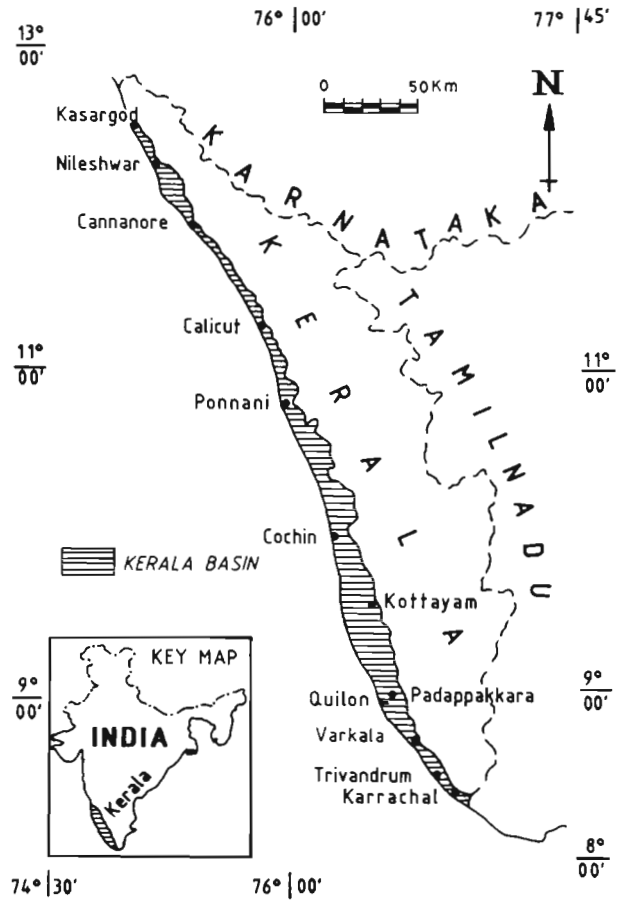
on the grab samples and not stratigraphically measured sections. The sediments have been assigned Early to Middle Miocene age. However, the recent palynological studies reveal the existence of subsurface Palaeogene sediments in the area (Raha *et al.*, 1987; Rao, 1990, 1995). In view of this newly emerged palynological information, it is envisaged to restudy and analyse the entire palynological data in a comprehensive manner in order to fill the gap on the existing divergent views. With the above objectives, a project has been taken up to study the entire extent of Tertiary Kerala Basin with the collaboration of Center for Earth Science Studies and Central Ground Water Board, Trivandrum. The authors made a detailed collection of clay and lignite samples from the ares of Meenkunnu, Payangadi, Nileswar, Karyankod, Pilicode and Azhikhode. Meenkunnu and Karyankod are outcrops; Payangadi and Nileswar are mine sections and Pilicode and Azhikhode are well sections. The samples collected from Nileswar, Karyankod and Pilicode were found to be barren and the palynostratigraphic study of Payangadi section will be taken up later. The present paper exclusively deals with the Cannanore lignite and associated sediments exposed along Meenkunnu and adjoining areas and Azhikhode well, Cannanore District, Kerala (Map 1).

The cliff section at Cannanore is sampled at Meenkunnu, 6 km north of the Cannanore guest house on the Cannanore-Azhikhode road. The lithology consists of mainly thick band of sandstone intercalated with clay underlain by carbonaceous clay. The base is not seen. The top of the section is covered by laterite. In some part of the section a sequence of ball clay with carbonaceous clay is developed in between sandstone and lignite. The lithological-details of the different sections have been given in Text-figure 1.

The Tertiary sediments of Kerala are well known as Warkalli and Quilon formations from type localities (King, 1882; Foote, 1883). The Quilon Formation consistsof limestones with intercalations of calcareous clays, carbonaceous clays and sand whereas the Warkalli ormation comprises variegate sandstones interbedded with white plastic and variegated clays, carbonaceous clays and seams of lignite or eaty lignite. The Tertiary sequence rests unconformably over the Archaean crystalline complex and is succeeded byrecent to subrecent marine andestuarine sediments (Poulose & Narayana-swami 1968). A recent study of the lithology based on soe bore-hole inormation resulted in the institution of a third formation, viz., Vaikom Formation, underlying the Quilon formation (Rao, 1975; Rao *et al.*, 1975).



Text-figure 1—Lithological details of Cannanore lignite and associated sediments of Kerala Basin.



Map 1— Geological map of Kerala showing area of investigation.

These beds are similar to Warkalli Formaion but are more arenaceous and coarse grained. The recent lithtratigraphic classification based on overall analysis of surface and subsurface samples and their relationships, the entire Cenozoic sequence of Kerala has been designated as the Malabar Supergrou, encompassing the Quaternary and Tertiary groups. A laterite horizon marks a distinct unconformity between Vembanad Formation and Warkalli Group. The Warkalli Group consists of Ambalapuzha, Quilon and Mayyanad formations. The Ambalapuzha and Mayyanad formations are terrigenous whereas Quilon Formation is marine (Raha *et al.*, 1983).

Extensive palynological studies were made by different palynologists to establish time-stratigraphic relation between the marine Quilon Formation and the continental Warkalli Formation. Rao and Vimal (1953) have recorded pteridophytic spores from the lignite of Warkalli beds. Potonié and Sah (1960) have reported a good number of angiospermous pollen fom Cannanore. Detailed palynological studies on the out crops of Tertiary sediments of Kerala have been done by Ramanujam (1977, 1987), Ramanujam and Rao (1973), Ramanujam *et al.* (1991), Rao and Ramanujam (1978, 1982), Kar and Jain (1981), Varma and Patil (1985), Varma *et al.* (1986) and Varma (1987). They have recorded variety of fungal elements, pteridophytic spores and angiospermous pollen and assigned an Early Miocene to Middle Miocene age to the Quilon and Warkalli formations. In the recent past, Raha, Rjendran and Kar (1987) and Rao (1990, 1995) have systematically studied palynology from the bore-holes of Ambalapuzha, Arthungal, Kalarkod and Nirkunnam respectively, Alleppey District, Kerala and recorded a full succession of Early Eocene through Oligocene to Miocene.

MATERIAL AND METHOD

A total number of 58 samples of carbonaceous clay, sady clay and lignite were collected from Meenkunnu and adjoining areas and Azhikhode well. In order to get a rich and complete assemblage, samples were collected laterally and also all precautions have been taken to avoid contamnation.

Samples were treated with HCL, HF and HNO_3 followed by 5 per cent solution of KOH . The slides were prepared in polyvenyl alcohol an mounted in Canada Balsam. Olypus microscope BH2 has been used for the study and photomicrography. The material, slides and negatives of figured specimens ave been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

LIST OF PALYNOTAXA

Taxa with asterisk(*) mark have been either described or commented in the text.

Pteridophytic spores

Cyathidites australis Couper 1953 (Pl. 1, fig. 4).
Todisporites major Couper 1958
Lygodiumsporites lakiensis Sah & Kar 1969
L. eocenicus Dutta & Sah 1970 (Pl. 1, fig. 6).
L. padappakkarensis Rao & Ramanujam 1978 (Pl. 1, fig. 7)
Intrapunctisporis intrapunctis Krutzsch 1959

I. harudiensis Kar 1978 (Pl. 1, fig. 5)
**Dictyophyllidites cannanorensis* sp. nov. (Pl. 1, figs 1- 2)
**Surmaspora karii* sp. nov. (Pl. 1, figs 24-26)
Crassoretitriletes vanraadshooveni Germeraad *et al.* 1968
Cheilanthoidspora monoleta Sah & Kar 1974
C. mioceneca Kar & Jain 1981
Neyvelisporites bolkhovitinae (Ramanujam) Ramanujam 1972 (Pl. 1, fig. 8)
**Neyvelisporites* sp. (P. 1, fig. 9)
Polypodiaceaesporites chatterjii Kar 1979
Laevigatosporites ovatus Wilson & Webster 1946 (Pl. 1, fig. 13)
Polypodiisporites favus Potonié 1934
P. ornatus Sah 1967 (Pl. 1, fig. 12)
P. tuberculensis Rao & Singh 1987 (Pl 1, fig. 11)
Pteridophytic spore - 1 (Pl. 1, fig. 3)

Angiospermous pollen grains

Verrualetes assamicus Singh & Saxena 1984 (Pl. 3, fig. 12)
* *Verrualetes cannanorensis* sp. nov. (Pl. 3, fig. 7)
**Assamiapollenites* sp. (Pl. 1, figs 16-17)
**Grimsdalea* sp. (Pl. 3, fig. 8)
Crotonoidaepollenites euphorbiodes Rao & Ramanujam 1982 (Pl.1, fig. 10)
Retipilonapites delicatissimus Ramanujam 1966
Palmaepollenites kutchensis Venkatachala & Kar 1969
Neocouperipollis kutchensis Kar & Kumar 1987
Quilonipollenites sahnii Rao & Ramanujam 1978 (Pl. 1, fig. 15)
**Crotomonosulcites* sp. (Pl. 1, fig. 14)
Retimonosulcites ovatus (Sah & Kar) Kar 1985
**Retimonosulcites ramanujamii* sp. nov. (Pl. 3, figs 18-19)
Proxapertites emendatus (Sah & Dutta) Kar & Kumar 1986
Tricolpites reticulatus Cookson ex Couper 1953
T. crassireticulatus Dutta & Sah 1970
T. matanomadhensis Saxena 1979
Dipterocarpuspollenites retipilatus Kar 1985 (pl. 1, fig. 20)
Plumbaginacipites neyvelii Navale & Misra 1979
**Gemmatricolpites saxenii* sp. nov. (Pl. 2, figs 10-12)
**Gemmastephanocolpites* sp. (Pl. 3, fig. 6)
**Tribrevicolporites duttae* sp. nov. (Pl. 1, figs 21-22)
**Tribrevicolporites sarkarii* sp. nov. (Pl. 3, figs 3-4)
**Tribrevicolporites* sp. (Pl. 1, fig. 23)
Paleosantalaceaepites minutus Sah & Kar 1970
Lakiapollis ovatus Venkatachala & Kar 1969 (Pl. 1, fig. 19; Pl. 3, fig. 10)
Tricolporopollis decoris Dutta & Sah 1970
T. matanamadhensis (Venkatachala & Kar) Tripathi & Singh 1985
**Tricolporopollis cannanorensis* sp. nov. (Pl. 2, figs 6-8)
**Tricolporopollis alleppeyensis* sp. nov. (Pl. 3, figs 1- 2, 17)
Pellicieroipollis langenheimii Sah & Kar 1970
Retitrescolpites indicus Rao & Ramanujam 1982 (Pl. 2, fig. 19)
Dermatobrevicolporites dermatus (Sah & Kar) Kar 1985
Favitricolporites magnus Sah 1967
Margocolporites tsukadae Ramanujam 1966 (Pl. 2, fig. 5)
Meliapollis quadrangularis (Ramanujam) Sah & Kar 1970
M. ramanujamii Sah & Kar 1970
Striacolporites striatus Sah & Kar 1970
S. cephalus Sah & Kar 1970
Ctenolophonidites costatus (van Hoeken Klinkenberg) van Hoeken-Klinkenberg 1966 (Pl. 2, figs 17-18)
**Psilodiporites* sp. (Pl. 2, fig. 9)
Subtriporopollis rotundis Sah 1967
**Subtriporopollis* sp. (Pl. 3, fig. 5)
Triporopollenites robustus Kar & Jain 1981
**Triporopollenites meenkunnuensis* sp. nov. (Pl. 2, figs 1-3)
Proteacidites truncatus Cookson 1950 (Pl. 2, fig. 16)
Proteacidites triangulus Kar & Jain 1981 (Pl. 2, fig. 15)
Myricipites singhii Rao 1995 (Pl. 3, fig. 11)
**Malvacipollis* sp. (Pl. 3, fig. 16)
**Polybrevicolporites* sp. (Pl. 3, fig. 9)
Clavaperiporites jacobii Ramanujam 1966 (Pl. 2, figs 13-14)
Malvacearumpollis bakonyensis Nagy 1962 (Pl. 3, figs 13-15)
M. grandis Sah 1967

Incertae-sedis

*Archela sp. (Pl. 1, fig. 8)

SYSTEMATIC DESCRIPTION

Genus—*Dictyophyllidites* Couper 1958

Type species—*Dictyophyllidites harrisii* Couper 1958

Dictyophyllidites cannanorensis sp. nov.

Pl. 1, figs 1-2

Holotype—Pl. 1, fig. 1, size 46x42 µm, slide no. BSIP 11124.

Type locality—Meenkunnu phase-I, Cannanore District, Kerala.

Diagnosis—Miospores sub-triangular, apices broadly rounded, interapical margins straight to convex. Size range 40-46 x 38-42 µm. Trilete mark distinct, laesurae straight, accompanied by a thickened, raised kyrtome. Exine up to 3 µm thick associated with folds. Distal surface showing foveolate ornamentation.

Comparison—*Dictyophyllidites harrisii* Couper 1958 is distinguished from the present species by its bigger size (up to 56 µm) and longer Y- rays, extending up to equator. *D. pectinataeformis* (Bolkhovitinae) Dettmann 1963 is different by its granulose exine. *D. cymbatus* Venkatachala & Goczan 1964 possessing kyrtomic folds, is not comparable. *D. granulatus* Saxena 1978 is different by having thicker exine (5 µm) and granulose ornamentation. *D. indicus* Rao & Singh 1987 is different by its larger size (up to 85 µm) and laevigate exine.

Occurrence— Meenkunnu phase-I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Surmaspora* Singh & Rao 1984

Type species— *Surmaspora sinuosa* Singh & Rao 1984

Surmaspora karii sp. nov.

Pl. 1, figs 24-26

Holotype—Pl. 1, figs 24-25, size 53x52 µm, slide no. BSIP 11429.

Type locality—Meenkunnu phase-II, Cannanore District, Kerala.

Diagnosis—Miospores triangular to sub-triangular with broadly rounded apices. Trilete, trilete mark extends up to 3/4 radius, surrounded by thick labra having globular thickenings at the ray ends. Exine 5 µm thick, verrucate, verrucae thick laterally fused with pseudoreticulate ornamentation on the distal side. In between verrucae, finely punctate ornamentation present.

Comparison—*Surmaspora sinuosa* Singh & Rao 1984 is distinct from the present species by the presence of ribbon-like labra and sparsely placed verrucae.

Occurrence—Meenkunnu phase - II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Neyvelisporites* (Ramanujam) Ramanujam 1972

Type species— *Neyvelisporites bolkhovitinae* Ramanujam 1972

Neyvelisporites sp.

Pl. 1, fig. 9

Description—Miospore oval in shape. Size 62 x 50 µm. Monolete, distinct. Exine 2.5 µm thick. Distal surface showing foveo-reticulate ornamentation.

Occurrence—Meenkunnu phase - I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Unknown

Pteridophytic spore- I

Pl. 1, fig. 3

Description—Miospore subtriangular, apices broadly rounded, interapical sides convex. Size 50x48 m. Trilete, open, reaching to the apices. Exine 2 µm thick. Distal surface showing scrobiculate ornamentation.

Occurrence—Meenkunnu phase - I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Unknown.

Genus—*Grimsdalea* Germeraad, Hopping & Muller 1968

Type species—*Grimsdalea magnaclavata* Germeraad, Hopping & Muller 1968

Grimsdalea sp.

Pl. 3, fig. 8

Description—Pollen grain spherical in polar view. Size 54 x 53 µm. Inaperturate. Exine 4 µm thick, intectate, baculate, bacula parsely placed, 5 µm long, 4 µm wide, blunt tips. Surface showing scabrate ornamentation.

Comparison—*Grimsdalea* sp. is closely comparable with the type species *G. magnaclavata* Germeraad *et al.* 1968 by its general characters but the latter can be distinguished by its scatterly placed clava and thinner exine.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus — *Verrualetes* Singh & Saxena 1984

Type species — *Verrualetes assamicus* Singh & Saxena 1984

Verrualetes cannanorensis sp. nov.

Pl. 3, fig. 7

Holotype—Pl. 3, fig. 7, size 58 x 46 µm, slide no. BSIP 11448.

Type locality—Meenkunnu phase- II, Cannanore District, Kerala.

Diagnosis—Pollen grains sub-circular in polar view. Size range 53-58 x 40-46 µm. Inaperturate, central depression present. Exine 3.5 µm thick, verrucate, verrucae 6-8 µm long, 4-7 µm in diameter, variable sizes, sparsely placed. Ornamentation in between verrucae laevigate.

Comparison—*Verrualetes assamicus* Singh & Saxena 1984 comparable by its inaperturate and verrucate ornamentation but can be distinguished from the present species by having robustly built and densely placed verrucae giving pseudoreticulate ornamentation on surface view.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Assamiapollenites* (Singh) Singh & Saxena 1984

Type species— *Assamiapollenites browni* (Biswas) Singh 1975

Assamiapollenites sp.

Pl. 1, figs 16-17

Description—Pollen grain oval in shape. Size 41 x 38 µm. Inaperturate, central depression present. Exine 3 µm thick, perforated,ornamented with gemma, spines alternate with bacula. Surface showing finely fitted ornamentation.

PLATE 1 ⟶

(All photomicrographs are enlarged *ca.* x 500, unless otherwise mentioned. Coordinates of the specimens refer to the stage of BH2 Olympus microscope no. 217267).

1. 2. *Dictyophyllidites cannanorensis* sp. nov., slide nos. BSIP 11124, coordinates 3.0x132.5; 11415, coordinates 18.0x135.5.
3. Pteridophytic spore 1, slide no. BSIP 11416, coordinates 11.8x131.0
4 *Cyathidites australis* Couper, slide no. BSIP 11418, coordinates 14.0x162.0
5. *Intrapunctisporis barudiensis* Kar, slide no.BSIP 11419, coordinates 11.4x121.0
6. *Lygodiumsporites eocenicus* Dutta & Sah, slide no. BSIP 11418, coordinates 14.0x161.5.
7. *L. padappakkarensis* Rao & Ramanujam, slide no. BSIP 11420, coordinates 10.0x161.0.
8. *Neyvelisporites bolkhovitinae* Ramanujam, slide no. BSIP 11427, coordinates 10.0x 145.2.
9. *Neyvelisporites* sp., slide no. BSIP 11438, coordinates 15.6x163.0.
10. *Crotonoidaepollenites euphorbioides* Rao & Ramanujam, slide no. BSIP 11443, coordinates 5.0x132.5.
11. *Polypodiisporites tuberculensis* Rao & Singh, slide no. BSIP 11423, coordinates 18.0x161.2.
12. *Polypodiisporites ornatus* Sah, slide no. BSIP 11426, coordinates 8.2x132.4.
13. *Laevigatosporites ovatus* Wilson & Webster, slide no.BSIP 11424, coordinates 15.5x132.4.
14. *Crotomonosulcites* sp., slide no. BSIP 11435, coordinates 14.4x141.0.
15. *Quilonipollenites sahnii* Rao & Ramanujam, slide no. BSIP 11422, coordinates 13.8x 152.0.
16-17. *Assamiapollenites* sp., slide no. BSIP 11435, coordinates 19.2x161.2.
18. *Archella* sp., slide no. BSIP 11438, coordinates 9.0x172.6.
19. *Lakiapollis ovatus* Venkatachala & Kar, slide no. BSIP 11453, coordinates 12.5x132.0.
20. *Dipterocarpuspollenites retipilatus* (Kar & Jain) Kar, slide no. BSIP 11422, coordinates 13.7x125.0.
21-22. *Tribrevicolporites duttae* sp. nov., slide nos. BSIP 11454, coordinates 13.6x139.1 (Holotype); 11420, coordinates 12.3x124.0.
23. *Tribrevicolporites* sp., slide no. BSIP 11437, coordinates 16.0x148.0.
24-26 *Surmaspora karii* sp. nov., slide nos. BSIP 11429, coordinates 8.0x145.5 (Holotype); 11430, coordinates 6.5x150.7 (x 750).

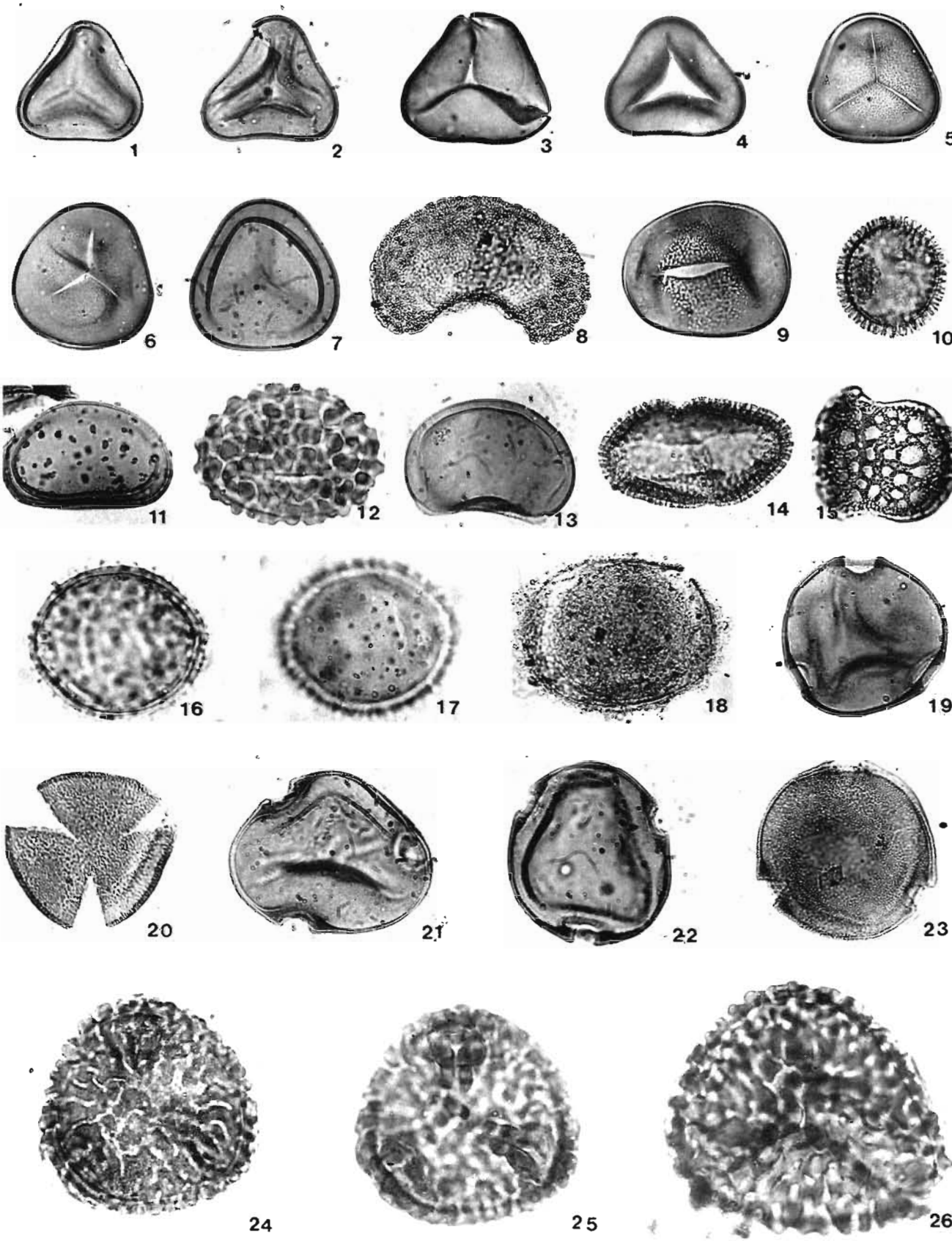


PLATE 1

Comparison—*Assamiapollenites browni* (Biswas) Singh 1975 is distinct by the presence of bacula on the exine. *A. chandleri* distinguished in having a circular opercular attachment near the equator. *A. potamogetonaceaeformis* (Biswas) Singh & Saxena 1984 is distinct by having densely pilate exine. *A. ghoshii* Singh & Saxena 1984 is distinct by its bigger size and robustly built bacula.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Retimonosulcites* Kar 1985

Type species— *Retimonosulcites (Liliacidites) ellipticus* (Venkatachala & Kar) Kar 1985

Retimonosulcites ramanujamii sp. nov.

Pl. 3, figs 18 - 19

Holotype—Pl. 3, fig. 19, size 155 x 110 µm, slide no. BSIP 11423.

Type locality—Meenkunnu phase- I, Cannanore District, Kerala.

Diagnosis—Pollen grains oval-elliptical in shape with broad ends, sometimes ends unequally broad. Size range 100-160 x 75-110 µm. Monosulcate, sulcus mostly tappering at the ends and broadest in middle region. Exine up to 3 µm thick, smooth. Surface showing distinct inframicroreticulate ornamentation.

Comparison—*Retimonosulcites ellipticus* (Venkatachala & Kar) Kar 1985 is closely comparable with the present species by its monosulcate nature and inframicroreticulate condition but the latter can be differentiated by its smaller size (30-42 x 25-28 µm) and thinner exine. *Retimonosulcites ovatus* Kar 1985 is different by its funnel-shaped sulcus, smaller size range and weakly microreticulate ornamentation.

Occurrence— Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Crotonisulcites* Rao & Ramanujam 1978

Type species—*Crotonisulcites grandis* Rao & Ramanujam 1978

Crotonisulcites sp.

Pl. 1, fig. 4

Description—Pollen grain oval-elongate, ends rounded, constricted in the center. Size 69 x 39 µm. Monosulcate, sulcus reaching poles, 50 µm long, wide at the centre and narrow at the ends. Exine 6.5 µm thick, nexine thicker than sexine, sexine 3 µm thick, intectate, baculate, nexine 4 µm thick, finely fitted. Surface showing crotonoid type of reticulation.

Comparison—Crotonisulcites sp. is closely comparable with *Crotonisulcites grandis* in all characters but the latter can be distinguished by its smaller size and pila-clavate exine.

Occurrence—Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Liliaceae.

Genus—*Gemmatricolpites* Pierce 1961

Type species—*Gemmatricolpites gemmatus* Pierce 1961

Gemmatricolpites saxenii sp. nov.

Pl. 2, figs 10 - 12

Holotype—Pl. 2, fig. 10, size. 39 x 33 µm, slide no. BSIP 11424.

Type locality—Meenkunnu phase- I, Cannanore District, Kerala.

Diagnosis—Pollen grains sub-circular in polar view. Size range 40-46 x 32-44 µm. Tricolpate, colpae 9 µm wide. Exine up to 4 µm thick, perforated, sexine thicker than nexine, sexine 3 µm thick, baculate, gemma, spinules scatterly present in between, nexine 1 µm thick, smooth. Finely fitted reticulate ornamentation on distal side.

Comparison—*Gemmatricolpites saxenii* closely resembles the type species *G. gemmatus* Pierce 1961 by its gemmate character and tricolpate condition but the latter can be differentiated by its smaller size (15 x 18.5 µm) and sparcely placed gemma.

Occurrence—Meenkunnu phase-I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

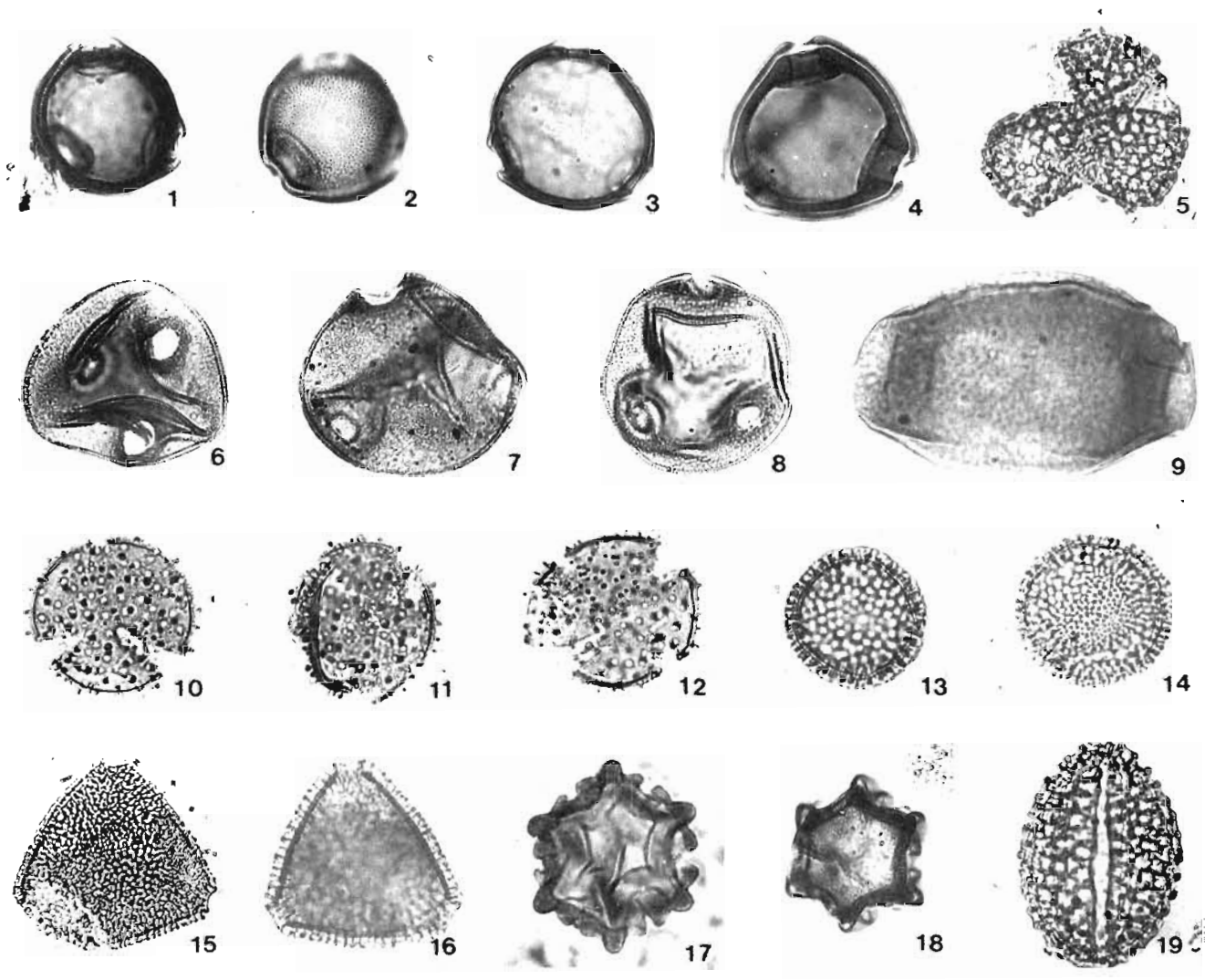


PLATE 2

(All photomicrographs are enlarged *ca.* x 500, unless otherwise mentioned. Coordinates of the specimens refer to the stage of BH2 Olympus microscope no. 217267).

1-3. *Triporopollenites cannanorensis* sp. nov., slide nos. BSIP 11431, coordinates 16.0x159.3 (Holotype); 11432, coordinates 2.2x150.5.

4. *Dermatobreviculporites dermatus* Kar, slide no. BSIP 11433, coordinates 8.5x 152.3.

5. *Margocolporites tsukadae* Ramanujam, slide no. BSIP 11424, coordinates 4.0x143.2.

6-8. *Tricolporopollis cannanorensis* sp. nov., slide nos. 11432, coordinates 20.5x128.0.; 11435, coordinates 8.0x143.0 (Holotype); 11452, coordinates 11.2x139.2.

9. *Psilodiporites* sp., slide no. BSIP 11455, coordinates 18.5x144.5.

10-12. *Gemmatricolpites saxenii* sp. nov., slide nos. BSIP 11124, coordinates 20.8x131.0 (Holotype); 11419, coordinates 10.0x156.0; 11124, coordinates 10.5x141.2.

13-14. *Clavaperiporites jacobii* Ramanujam, slide nos. BSIP 11442, coordinates 14.0x142.0; 11419, coordinates 12.0x 129.1.

15. *Proteacidites triangulus* Kar & Jain, slide no. BSIP 11415, coordinates 8.0x143.0.18-19.

16. *P. truncatus* Cookson, slide no. BSIP 11439, coordinates 12.0x128.0.

17-18. *Ctenolophonidites costatus* (van Hoecken-Klinkenberg) van Hoecken klinkenberg, slide nos. BSIP 11440, coordinates 12.0x157.0; 11423, coordinates 16.4x144.5.

19. *Retitrescolpites indicus* Rao & Ramanujam, slide no. BSIP 11457, coordinates 16.0x156.0.

Genus— *Gemmastephanocolpites* van der Hammen & de Mutis 1965

Type species— *Gemmastephanocolpites gemmatus* van der Hammen & de Mutis 1965

Gemmastephanocolpites sp.

Pl. 3, fig. 6

Description—Pollen grain subcircular in polar view. Size 65 x 58 µm. Tetracolpate, colpi 8-10 µm diameter. Exine 3.5 µm thick, sexine thicker than nexine, 3 µm thick, intectate, baculate, gemma sparsely placed in between, nexine 0.5 µm thick, smooth, surface showing pitted reticulate ornamentation.

Comparison—*Gemmastephanocolpites gemmatus* van der Hammen & de Mutis (1965) is different by its smaller size (33.5 µm) and closely placed gemma.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus— *Tribrevicolporites* Kar 1985

Type species— *Tribrevicolporites eocenicus* Kar 1985

Tribrevicolporites duttae sp. nov.

Pl. 1, figs 21-22

Holotype—Pl. 1, fig. 22, size 64 x 58 µm, slide no. BSIP 11454.

Type locality—Meenkunnu phase- I, Cannanore District, Kerala.

Diagnosis—Pollen grains sub-triangular in polar view associated with folds. Size range 55-75 x 50-65 µm; tribrevicolporate. Colpi, 5-7 µm wide, pores distinct, slightly thickened, 3-5 µm in diameter. Exine 2-3.5 µm thick, sexine as thick as nexine, finely reticulate, meshes appearing as pits in surface view.

Comparison—*Tribrevicolporites duttae* sp. nov. closely comparable with *T. eocenicus* Kar 1985 by its shape and tribrevicolporate condition but is distinguished from the latter in its smaller size (46 x 44 µm) and distinct reticulate ornamentation.

Occurrence— Meenkunnu phase-I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Tribrevicolporites sarkarii sp. nov.

Pl. 3, figs 3-4

Holotype—Pl. 3, fig. 3, size 63 x 58 µm, slide no. BSIP 11446.

Type locality—Meenkunnu phase- II, Cannanore District, Kerala.

Diagnosis—Pollen grains subtriangular to subcircular associated with folds. Size range 60-54 x 53-58 µm. Tricolporate to tetracolporate, mostly subtriangular grains. Colpi 6-8 µm in diameter. Pore 6 µm wide, pore surrounded by thick annulus. Exine 4.5 µm thick, nexine thicker than sexine, sexine 2 µm thick, finely punctate, nexine 2.5 µm thick, scabrate. Surface showing finely scabrate ornamentation.

Comparison—*Tribrevicolporites eocenicus* Kar 1985 is closely comparable by its tribrevicolporate condition but is distinguished from the present species by having distinct reticulate ornamentation *Tribrevicolporites duttae* sp. nov. is distinct by its finely reticulate ornamentation.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Tribrevicolporites sp.

Pl. 2, fig. 23

Description—Pollen grain sub-circular in polar view. Size 65 µm. Tribrevicolporate. Colpi 11 µm wide, pore 9 µm in diameter. Exine 3 µm thick, sexine thicker than nexine, sexine 2 µm thick, nexine 1 µm thick. Surface showing distinct reticulum.

Comparison—*Tribrevicolporites* sp. is closely comparable with the type species by its tribrevicolporate nature but can be distinguished by its bigger size and fine reticulate ornamentation on the distal side.

Occurrence— Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus— *Tricolporopollis* Dutta & Sah 1970

Type species— *Tricolporopollis decoris* Dutta & Sah 1970

Tricolporopollis cannanorensis sp. nov.

Pl. 1, figs 6 - 8

Holotype— Pl. 1, fig. 7, size. 55 x 56 µm, slide no. BSIP 11435.

Type locality—Meenkunnu phase- I, Cannanore District, Kerala.

Diagnosis—Pollen grains oval-subcircular, associated with folds. Size range 45-65 x 40-60 µm. Tribrevicolporate, brevicolpate, colpi 3-4.5 µm wide, apertural end thickened. Exine 2-3.5 µm thick, sexine and nexine not differentiated. Surface showing pitted reticulate ornamentation.

Comparison—Tricolporopollis cannanorensis sp. nov. closely compares with the *T. decoris* Dutta & Sah 1970 by its shape and tricolporate condition but the latter can be distinguished by its smaller size, thinner exine and fine reticulate ornamentation. *T. rubra* is distinct by the presence of distinct foveolate ornamentation. *T. globosa* is differentiated by its smaller size (up to 38 µm) and coarsely reticulate sculpture. *T. matanamadhensis* (Venkatachala & Kar) Tripathi & Singh 1985 is distinct by its thicker exine (4 µm) and reticulate ornamentation formed by pila and bacula.

Occurrence—Meenkunnu Phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Euphorbiaceae

Tricolporopollis alleppeyensis sp. nov.

Pl. 3, figs 1-2, 17

Holotype—Pl. 3, fig. 1, size 61x60 µm, slide no. BSIP 11444.

Type locality—Meenkunnu phase- II, Cannanore District, Kerala.

Diagnosis—Pollen grains rounded triangular associated with folds, some specimens showing triradiate scar. Size range 57-65 x 54-60 µm. Tricolporate, brevicolpate, pore 8-10 µm in diameter, apertural end thickened. Exine up to 3.5 µm thick, sexine and nexine sometimes not differentiated, sexine up to 3.5 µm thick, perforated, nexine 1 µm thick. Surface showing finely pitted reticulation.

Comparison—Tricolporopollis alleppeyensis sp. nov. is closely comparable with the type species by its brevicolporate condition but the latter can be distinguished by having thinner exine and fine reticulate ornamentation. *T. cannanorensis* sp. nov. is different by its smaller size and distinct fine reticulate ornamentation.

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Unknown.

Genus— *Psilodiporites* Varma & Rawat emend. Venkatachala & Rawat 1972

Type species—*Psilodiporites hammenii* Varma & Rawat 1963

Psilodiporites sp.

Pl. 2, fig. 9

Description—Pollen grain cylindrical in shape. Size 100 x 60 µm. Diporate, pore elliptical in shape, distinct. Exine thin, surface finely scabrate.

Occurrence— Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Unknown.

Genus— *Triporopollenites* Pflug emend. Potonié 1960

Type species—*Triporopollenites coryloides* Thomson & Pflug 1953

Triporopollenites meenkunnuensis sp. nov.

Pl. 2, figs 1 - 3

Holotype—Pl. 2, figs 1-2, size 48 x 45 µm, slide no. BSIP 11431.

Type locality—Meenkunnu phase- I, Cannanore District, Kerala.

Diagnosis—Pollen grains subtriangular in polar view. Size range 45-52 x 40-45 µm. Triporate, anguloaperturate, pore up to 8 µm wide, surrounded by thick annulus, 5 µm thick. Exine 4 µm thick, sexine thicker than nexine, sexine 3 µm thick, intectate, perforated, nexine 1 µm thick, smooth. Distal surface showing distinct fine reticulate ornamentation.

Comparison—Triporopollenites coryloides Thomson & Pflug 1953 is comparable with the present species by its general shape and triporate nature but the former can be distinguished by its thinner exine and is not distinctly stratified. *Triporopollenites parvus* Sah 1967 is distinct by smaller size (29 µm) and obscure to faintly granulate ornamentation. *T. triangularis* Sah 1967 possesses distinctly reticulate exine, hence, not comparable. *Triporopollenites robustus* Kar & Jain 1981 is distinguished by its laevigate exine. *T. verrucatus* Kar & Jain 1981 is distinct by its smaller size range (18-25 µm) and

verrucose-granulose ornamentation. *T. minutus* Rao & Ramanujam 1982 is differentiated by its smaller size (up to 16.5 µm) and smooth to finely granular ornamentation.

Occurrence— Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Subtriporopollis* Sah 1967

Type species—*Subtriporopollis tenuis* Sah 1967

Subtriporopollis sp.

Pl. 3, fig. 5

Description—Pollen grain subtriangular in polar view, apical sides concave. Size 62 x 58 µm. Triporate, pore distinct, 8 µm in diameter. Exine 3 µm thick, sexine thicker than nexine, perforated. Surface showing distinct foveo-reticulate ornamentation.

Comparison—Subtriporopollis tenuis Sah 1967 is distinct from the present species in having thinner and retipilariate exine. *S. rotundis* Sah 1967 is different by the presence of dense pila on the sexine and surface view showing finely pitted reticulate ornamentation.

Occurrence—Meenkunnu phase- III, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Rubiaceae.

Genus—*Malvacipollis* Harris 1965

Type species—*Malvacipollis diversus* Harris 1965

Malvacipollis sp.

Pl. 3, fig. 16

Description—Pollen grain subcircular in polar view. Size 42 x 41 µm. Porate, pores not distinct due to closely placed coni. Exine 4 µm thick, conate/spinulate, very closely placed.

Comparison—Malvacipollis diversus Harris 1965 is distinct by its distinct zoniporate condition and smaller size range (22-32 µm)

Occurrence— Meenkunnu phase- I, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

Genus—*Polybrevicolporites* Venkatachala & Kar 1969

Type species— *Polybrevicolporites cephalus* Venkatachala & Kar 1969

Polybrevicolporites sp.

Pl. 3, fig. 9

Description—Pollen grain subcircular in polar view. Size 44 x 40 µm. Pentacolporate, brevicolpate, 10 µm long, 6 µm in diameter, pores well developed. Exine 3 µm thick, perforated. Surface showing pitted reticulation.

Comparison—Polybrevicolporites sp. is closely comparable with *P. cephalus* Venkatachala & Kar 1969 by its pentacolporate condition but the latter is distinguished by its intrabaculate exine.

PLATE 3 ⟶

(All photomicrographs are enlarged *ca.* x 500, unless otherwise mentioned. Coordinates of the specimens refer to the stage of BH2 Olympus microscope no. 217267).

1-2,17. *Tricolporopollis alleppeyensis* sp. nov., slide nos. BSIP 11444, coordinates (Holotype), 19.5x 157.2; 11433, coordinates 12.4x 136/0; 11445, coordinates 10.5x 160.0 (X750).

3-4. *Tribrevicolporites sarkarii* sp. nov., slide nos. BSIP 11446, coordinates 9.0x 161.0 (Holotype); 11447, coordinates 11.0x 151.0.

5. *Subtriporopollis* sp., slide no. BSIP 11445, coordinates 15.0x152.4.

6. *Gemmastephanocolpites* sp., slide no. BSIP 11445, coordinates 8.4x165.5.

7. *Verrualetes cannanorensis* sp. nov., slide no. BSIP 11448, coordinates 19.0x135.0 (Holotype).

8. *Grimsdalea* sp., slide no. BSIP 11449, coordinates 18.0x165.0.

9. *Polybrevicolporites* sp., slide no. BSIP 11450, coordinates 14 0x152.4.

10. *Laktapollis ovatus* Venkatachala & Kar, slide no. BSIP 11434, coordinates 8.1x 139.2.

11. *Myricipites singhii* Rao, slide no. BSIP 11434, coordinates 18.5x 165.0.

12. *Verrualetes assamicus* Singh & Saxena, slide no. BSIP 11451, coordinates 14.0x137.0.

13-15. *Malvacearumpollis bakonyensis* Nagy, slide nos. BSIP 11443, coordinates 8.3x155.0; 11452, coordinates 16.5x167.0.; 11445, coordinates 10.5x169.5.

16. *Malvacipollis* sp., slide no. BSIP 11448, coordinates 6.4x143.0.

18-19. *Retimonosulcites ramanujamii* sp. nov., slide nos. BSIP 11423, coordinates 9.0x141.4 (Holotype); 11453, coordinates 16.0x163.2

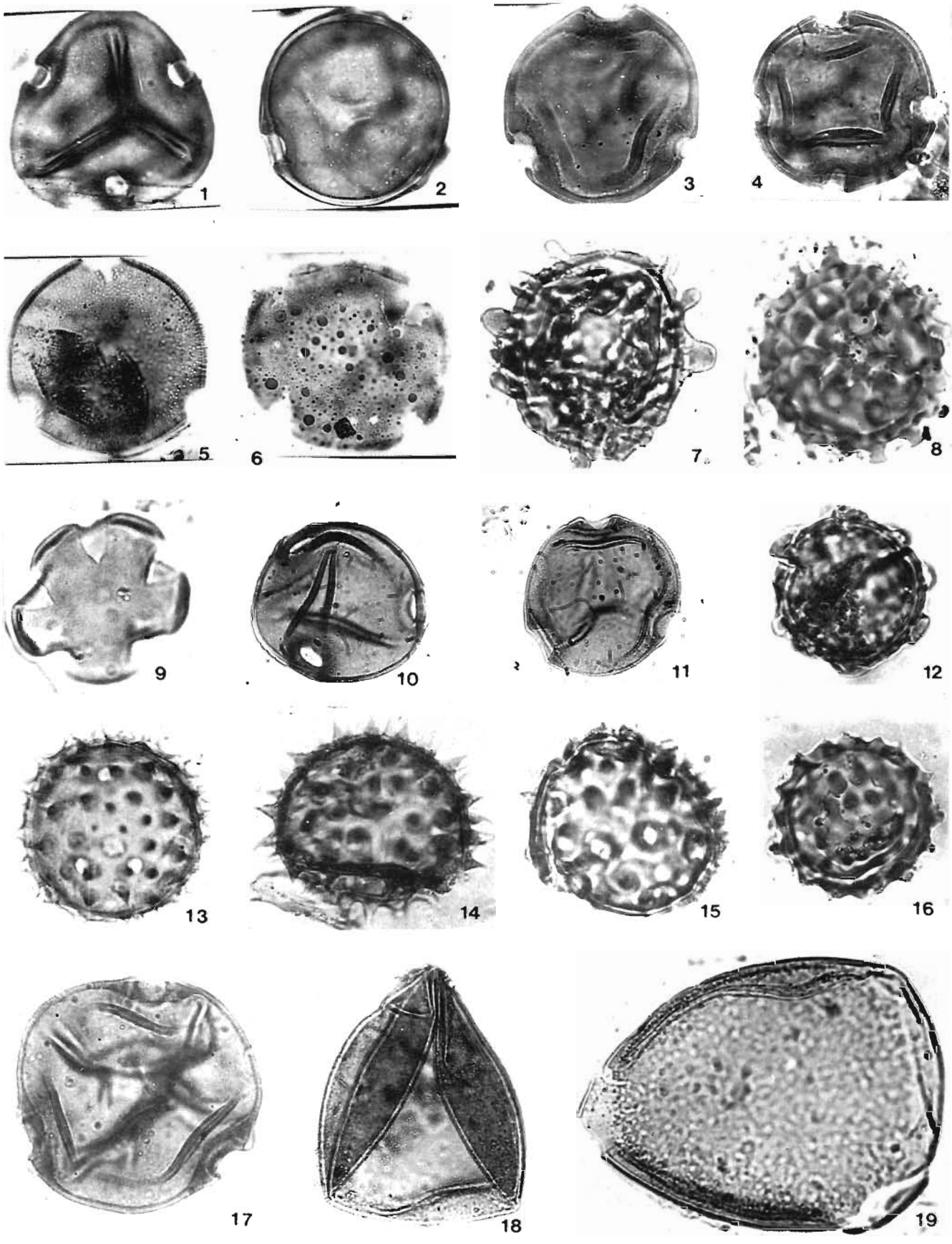


PLATE 3

Occurrence—Meenkunnu phase- II, Cannanore District, Kerala (Quilon Formation, Miocene).

Affinity— Unknown.

Incertae sedis

Genus—*Archella*

Archella sp.

Pl. 1, fig. 18

Description—Algal spore oval in shape with circular operculum. Size 28 x 23 µm. Operculum 20 µm in diameter. Spore wall 1.5 µm thick, hair like structures present. Body wall showing fine reticulate ornamentation.

Occurrence—Meenkunnu phase- I, Cannanore district, Kerala (Quilon Formation, Miocene).

Affinity—Unknown.

DISCUSSION

Palynoflora recovered from the sediments of Meenkunnu and adjoining areas of Kerala have yielded a variety of pteridophytic spores and angiospermous pollen. Dinoflagellate cysts and fungal remains have also been recorded.

The total assemblage consists of 50 genera and 73 species of pteridophytic spores and angiospermous pollen. Of them, 10 species have been proposed as new, viz., *Dictyophyllidites cannanorensis, Surmaspora karii, Verrualetes cannanorensis, Retimonosulcites ramanujamii, Gemmatricolpites saxenii, Tribrevicolporites duttae, T. sarkarii, Tricolporopollis cannanorensis, T. alleppeyensis* and *Triporopollenites meenkunnuensis*. The genera like *Proxapertites emendatus, Neocouperipollis kutchensis, Tricolpites reticulatus* and *Striacolporites* spp. recovered from the above sediments have been considered as reworked. Qualitative and quantitative analyses of the palynoflora reveal the dominance of angiospermous pollen over pteridophytic spores.

Qualitative Analysis

The possible botanical affinities of various palynotaxa and present day distribution of various families are given in Table 1.

TABLE 1

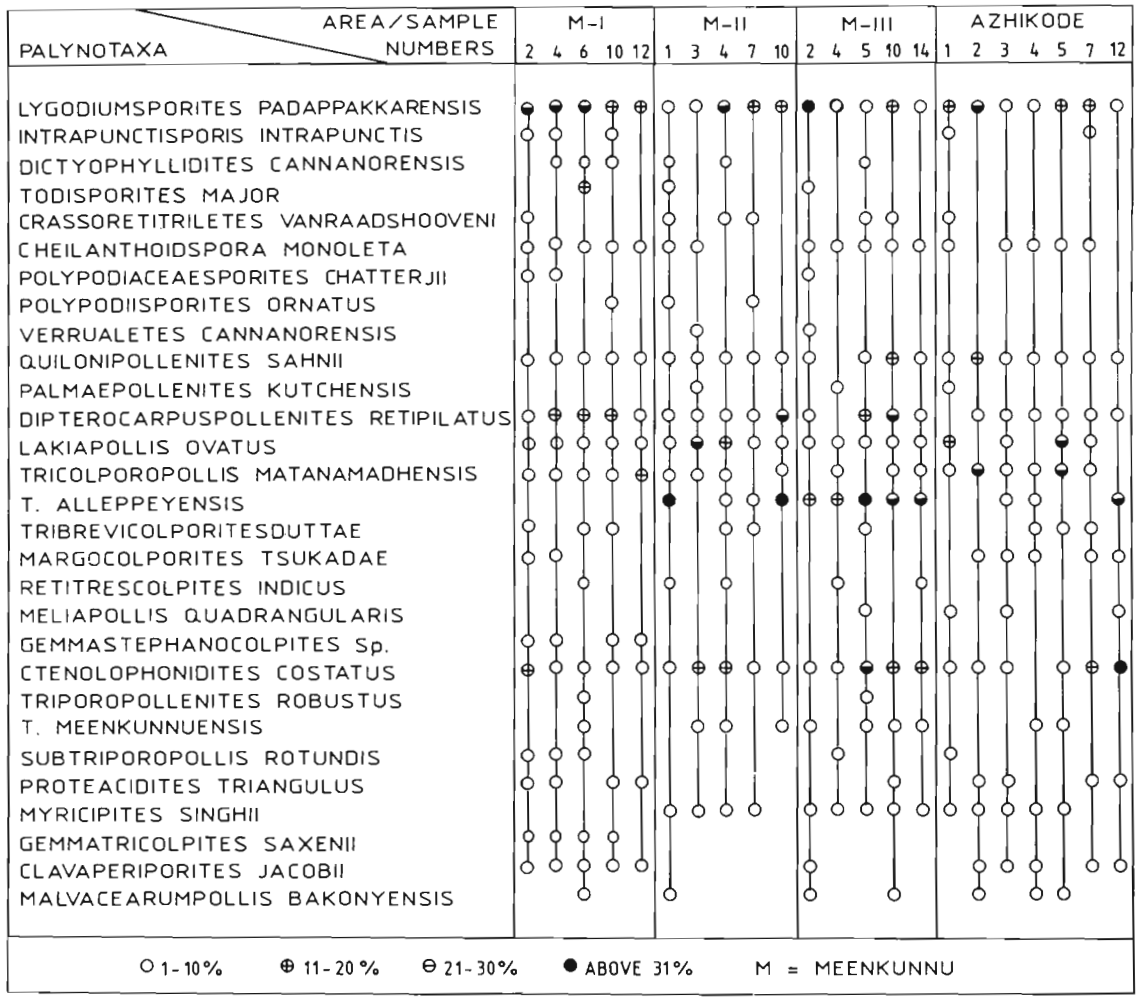
Family	Palynotaxa	Present day distribution of family
Arecaceae	*Palmaepollenites kutchensis* *Neocouperipollis kutchensis* *Quilonipollenites sahnii*	Tropical-subtropical
Bombacaceae (*Durio*)	*Lakiapollis ovatus*	Tropical-subtropical
Caesalpiniaceae (*Caesalpinia*)	*Margocolporites tsukadae*	Tropical subtropical
Clusiaceae	*Meliapollis quadrangularis* *M. ramanujamii*	Tropical
Cytenolophonaceae (*Ctenolophon*)	*Ctenolophonidites costatus*	Tropical
Cyatheaceae	*Cathidites australis*	Tropical-subtropical
Dicksoniaceae	*Dictyophyllidites cannanorensis*	Tropical-subtropical
Dipterocarpaceae	*Dipterocarpuspollenites retipilatus*	Tropical- subtropical
Euphorbiaceae	*Tricolporopollis matanamadhensis*	Cosmopolitan
Gunneraceae	*Tricolpites reticulatus*	Cosmopolitan
Lycopodiaceae	*Lycopodiumsporites* sp.	Tropical- subtropical
Malvaceae	*Malvacearumpollis bakonyensis* *M. grandis*	Tropical temperate
Moraceae	*Triporopollenites robustus*	Tropical-subtropical
Myricaceae	*Myricipites singhii*	Cosmopolitan
Oleaceae	*Retitrescolpites indicus*	Cosmopolitan
Osmundaceae	*Todisporites major*	Cosmopolitan
Polypodiaceae (*Polypodium*)	*Polypodiaceaesporites chatterjii* *Polypodiisporites rarus* *P. ornatus* *P. tuberculensis*	Cosmopolitan
Potamogetonaceae	*Retipilonapites delicatissimus*	Cosmopolitan
Proteaceae	*Proteacidites truncatus* *P. triangulus*	Tropical
Rubiaceae	*Subtriporopollis rotundis* *Subtriporopollis* sp.	Tropical-subtropical
Schizaeaceae	*Lygodiumsporites lakiensis* *L. eocenicus* *L. padappakkarensis*,	Tropical-subtropical
Thymeliaceae (*Wilkstroemia*)	*Clavaperiporites jacobii*	Temperate-tropical

Quantitative Analysis

The quantitative analysis has been done on the basis of frequency of various palynotaxa in a count of 200 specimens per sample. The pteridophytic spores are represented by 13 genera and 20 species constituting 25 per cent of the assemblage. The significant pteridophytic spores of all the four as-

semblages are : *Lygodiumsporites, Crassoretitriletes, Todisporites, Dictyophyllidites, Intrapunctisporis, Cheilanthoidspora, Polypodiaceaesporites* and *Polypodiisporites.* The angiospermous pollen are represented by 36 genera and 52 species and constitute 75 per cent of the assemblage. The dominant genera are: *Quilonipollenites, Retimonosulcites, Lakiapollis, Tricolpites, Retitrescolpites, Tribrevicolporites, Meliapollis, Margocolporites, Tricolporopollis, Ctenolophonidites, Myricipites, Triporopollenites, Proteacidites, Clavaperiporites* and *Malvacearumpollis.* Meenkunnu Phase-I assemblage consists of 37 genera and 44 species, in which 10 genera and 16 species belong to pteridophytic spores and 27 genera and 28 species to angiospermous pollen. Meenkunnu Phase-II is represented by 26 genera and 27 species in which, 10 genera and 10 species are of pteridophytic spores and 16 genera and 17 species of the angiospermous pollen. Meenkunnu Phase-III comprises 29 genera and 36 species, amongst them 7 genera and 8 species belong to pteridophytic spores and 22 genera and 28 species to angiospermous pollen. Azhikhode bore-well consists of 21 genera and 24 species, out of them, 6 genera and 7 species belong to pteridophytic spores and 15 genera and 17 species to angiospermous pollen, one genus and 1 species to algal spores.

For the percentage frequency, only 30 species of different genera from four assemblages have been selected and plotted in the Text-figure 2. The palynofloral frequency chart reveals that *Lygodiumsporites padappakkarensis, Intrapunctisporis* spp., *Cheilanthoidspora monoleta, Crassoretitriletes vanraadshooveni, Polypodiaceaesporites chatterjii* and *Polypodiisporites* spp. are important pteridophytic genera in all the four assemblages.



Text-figure 2—Percentage frequency of palynotaxa in Meenkunnu I-III and Azhikhode well.

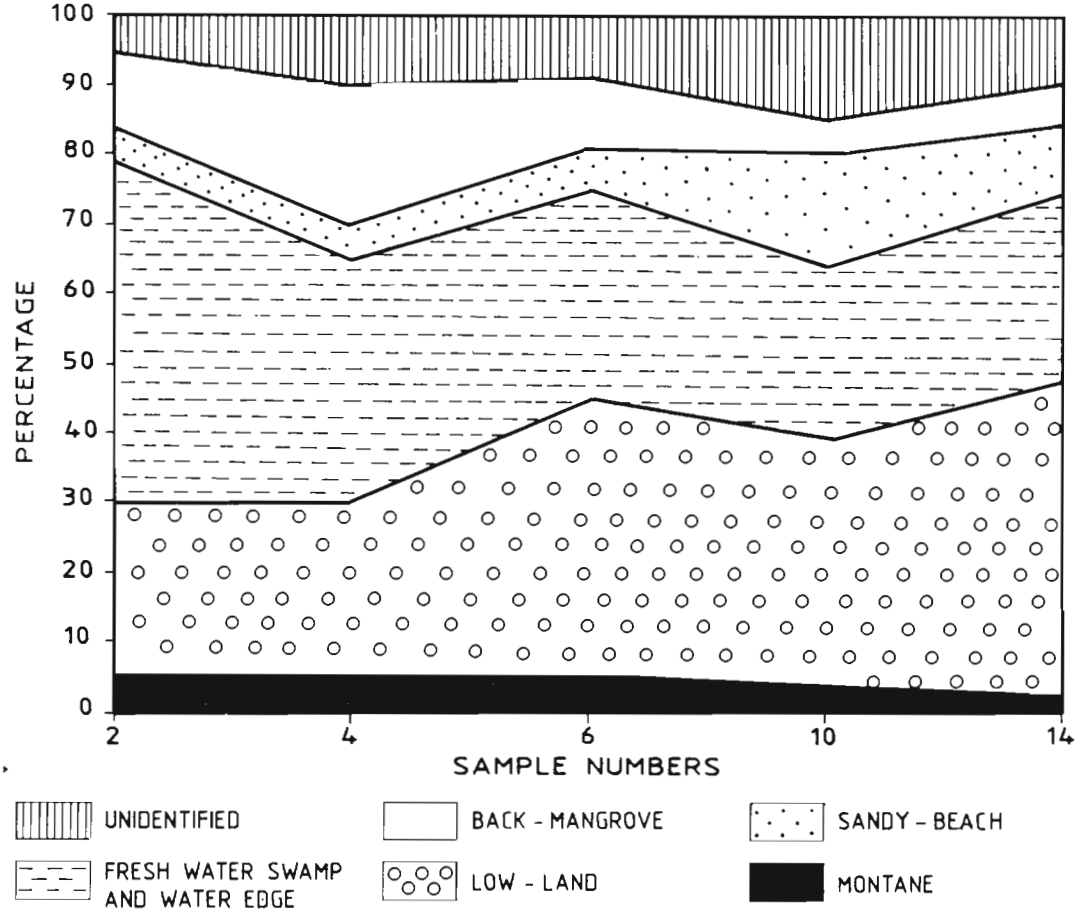
Lygodiumsporites padappakkarensis is dominant throughout the assemblage followed by *Intrapunctisporis*, *Crassoretitriletes* and polypodiaceous spores. *Polypodiisporites ornatus* is restricted to M-I to M-II whereas *Verrualetes cannanorensis* is present only in the M-II and M-III assemblages. *Gemmatricolpites saxenii* sp. nov. is restricted to Meenkunnu-I, whereas *Meliapollis quadrangularis* is present in M-III and Azhikhode well. The frequency of *Quilonipollenites sahnii* is low in all the assemblages. The percentage frequency of *Proteacidites* spp., *Subtriporopollis* spp., *Clavaperiporites jacobii* and *Malvacearumpollis* spp., are low (up to 10%). *Lakiapollis, Dipterocarpuspollenites, Tricolpites, Tricolporopollis, Ctenolophonidites, Triporopollenites* and *Myrcipites* are dominant throughout the assemblages.

PALAEOCLIMATE

The palynofossils recovered from Meenkunnu I-III and Azhikhode well have affinities with 23 extant families. Of these, 9 families are restricted to tropical-subtropical, 3 families pertain to tropical-temperate, 7 families to cosmopolitan and 3 families are restricted to tropical climate (Table 1). The prevalence of tropical-subtropical climate with heavy rainfall during the sedimentation of Meenkunnu and Azhikhode well of Cannanore District, Kerala is evident from the composition of the assemblage and present day distribution of the nearest extant families. The representation of fungal remains also supports the above view.

ENVIRONMENT OF DEPOSITION

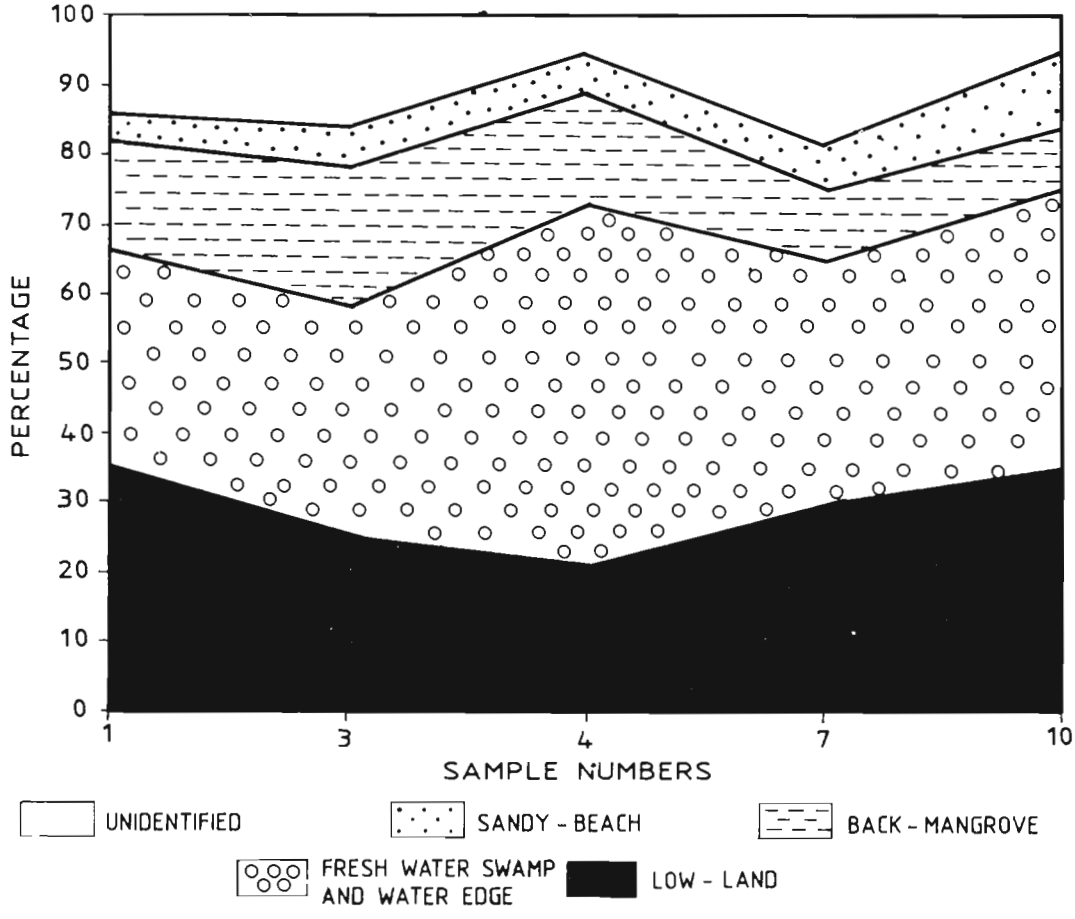
The palynofossils recovered from the above samples are very rich and diversified. The present palynoflora contains elements belonging to various ecological groups, viz., montane, low-land, fresh water swamp and water edge, back-mangrove and sandy beach elements. The frequencies of different ecological groups of Meenkunnu I to III and Azhikhode well are given in Text-figures 3-6.



Text-figure 3—Representation of different ecological groups in Meenkunnu-I.

Montane Elements	-	
Clavaperiporites	-	Thymeliaceae
Proteacidites	-	Proteaceae
Low-land	-	
Margocolporites	-	Caesalpiniaceae
Lakiapollis	-	Bombacaceae
Favitricolporites	-	Rubiaceae
Subtriporopollis	-	Rubiaceae
Tricolporopollis	-	Euphorbiaceae
Myricipites	-	Myricaceae
Fresh water swamp and water edge plants		
Lygodiumsporites	-	Schizaeaceae
Crassoretitriletes	-	Schizaeaceae
Neyvelisporites	-	Schizaeaceae
Todisporites	-	Osmundaceae
Lycopodiumsporites	-	Lycopodiaceae
Polypodiaceaesporites	-	Polypodiaceae
Polypodiisporites	-	Polypodiaceae
Ctenolophonidites	-	Ctenolophonaceae
Meliapollis	-	Clusiaceae
Retipilonapites	-	Potamogetonaceae
Proxapertites	-	Arecaceae
Back-mangrove		
Malvacearumpollis	-	Malvaceae
Paleosantalaceaepites	-	Rhizophoraceae
Sandy beach elements		+
Palmaepollenites	-	Arecaceae
Quilonipollenites	-	Arecaceae
Neocouperipollis	-	Arecaceae

An analysis of ecological groups of Meenkunnu I-III and Azhikhode well reveals that fresh water swamp and water edge and low-land elements are dominant over montane, back-mangrove and sandy beach elements. The details of each section is mentioned below.



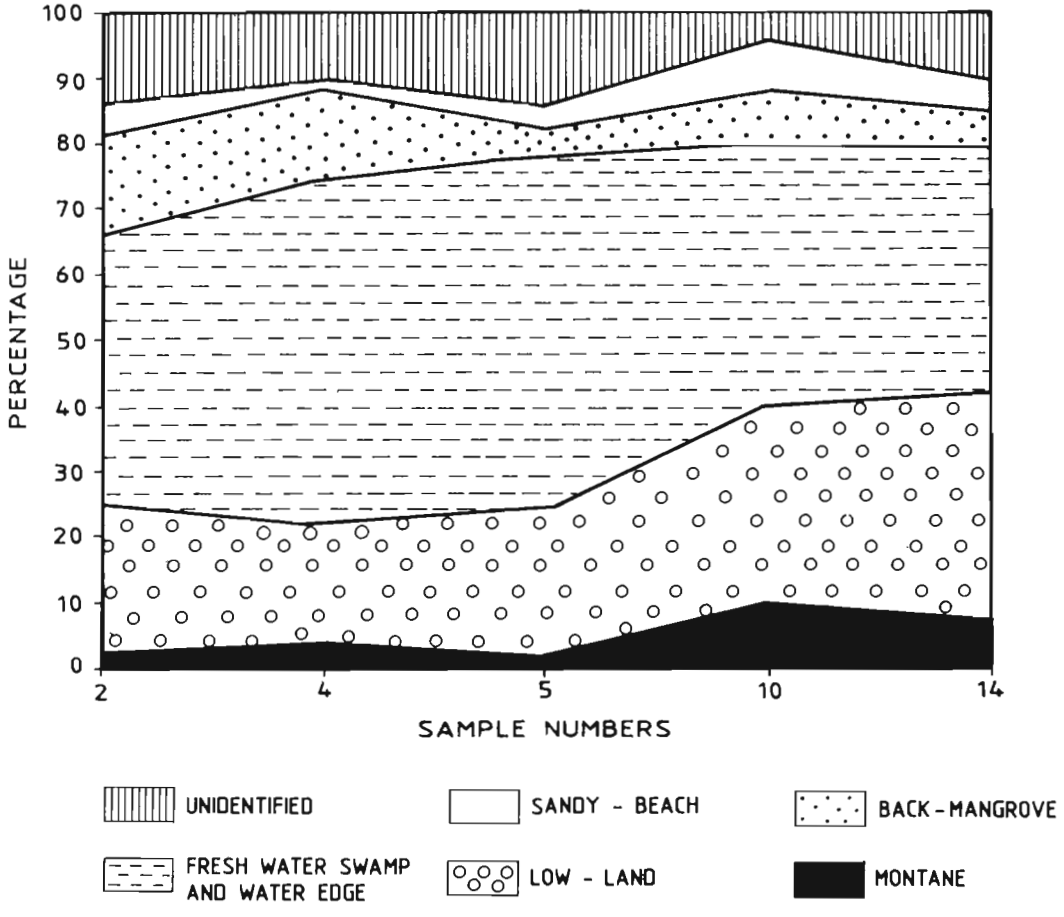
Text-figure 4 — Representation of different ecological groups in Meenkunnu - II

In Meenkunnu-I section, low-land elements are dominant over the fresh water swamps and water edge plants. The frequency of low-land elements is lower in the lower part (30%) and increases at the middle (45%) and decreases in the 10th sample and again increases at the top. The frequency of fresh water swamp and water edge elements is high in the lower part and decreases at the 4th sample and shows increase in the 6th sample. The frequency of the same decreases at the 10th sample and increases at the upper part. Sandy beach elements are low in 2, 4 and 6 samples and frequency of these elements increases in 10th and 14th samples. Back-mangrove elements dominate in 2, 4 and 6 samples whereas they dwindle in 10th and 14th samples. Frequency of montane elements are almost the same in all samples (Text-figure 3).

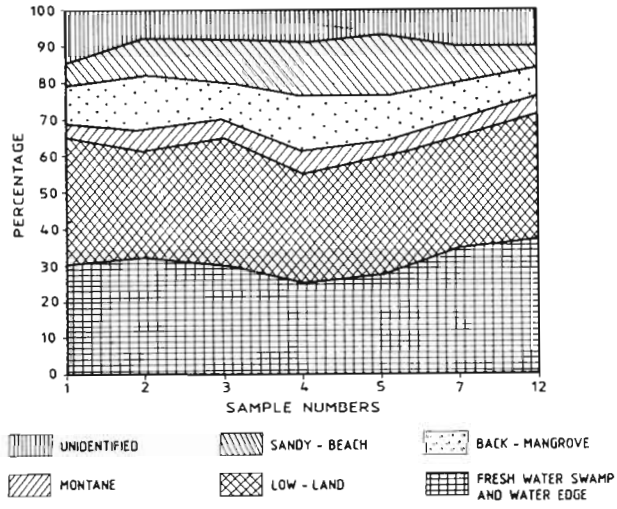
The fresh water swamp and water edge plants are dominant over low-land elements in Meenkunnu-II assemblage. The frequency of sandy beach elements is almost same in all the samples (1-7) but their number increases in the 10th sample. Back-mangrove elements are dominant in 1, 3 and 4 samples and decrease at 7th and 10th samples (Text-figure 4).

In Meenkunnu-III, low-land elements are almost same in all the samples but their higher frequency in the 10th and 14th samples has been observed. Montane elements are very low in 2-5 samples and the frequency increases in 10th and 14th samples. The back-mangrove elements are high in the lower part but decrease in the 5th sample and again increase in 10th and 14th samples. Freshwater swamp and water edge elements are dominant in this assemblage whereas the frequency of sandy elements is low in all the samples (Text-figure 5).

In Azhikhode well, the frequency of low-land and freshwater swamp and water edge elements are same in all the samples. The frequency of sandy elements has also been observed same in all the



Text-figure 5— Representation of different ecological groups in Meenkunnu - III.



Text-figure 6— Representation of different ecological groups in Azhikhode well.

samples. Back-mangrove elements are observed with lower frequency in the lower part (1-3) and their number increases in 4th and 5th samples and again decreases at the 7th and 12th sample (Text-figure 6).

The above discussion reveals that the deposition of sediments could have taken place in the fluctuation of transgressive and regressive phases.

The qualitative analysis of Meenkunnu and Azhikhode assemblages also reveals the presence of *Lygodiumsporites, Todisporites, Intrapunctisporis, Lycopodiumsporites,* and *Polypodiisporites, Polypodiaceaesporites,* which is indicative of fresh water swampy environment. The montane elements belonging to families Thymeliaceae and Proteaceae appear to be derived from long distances. The pollen types of Potamogetonaceae is indicative of fresh water lakes or ponds dotting the landscape. The dominant occurrence of *Lakiapollis* and *Tricolporopollis* indicates the luxuriant growth of wet evergreen forest. The prevailing nearshore conditions have been confirmed by the presence of palm pollen, viz., *Palmaepollenites, Neocouperipollis* and *Quilonipollenites.* The presence of dinoflagellate cysts and the back-mangrove elements (*Paleosantalaceaepites* and *Malvacearumpollis*) suggests the existence of brackish water mangrove swamps.

REFERENCES

Couper RA 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *N. Z. geol. Surv. Palaeontol. Bull.* **22**: 1 -77.

Couper RA 1958. British Mesozoic microspores and pollen - a systematic and stratigraphic study. *Palaeontographica* **B103**: 75-79.

Delcourt AF & Sprumont G 1955. Les spores et grains de pollen du Wealdien du Hainaut. *Mem. Soc Belge. Geol.* **4**: 73.

Dettmann ME 1963. Upper Mesozoic microfloras from south eastern Australia. *Proc. R. Soc. Vict.* **77** (1) : 1-148.

Dutta SK & Sah SCD 1970. Palynostratigraphy of the Tertiary sediments of Assam - 5. Stratigraphy and palynology of south Shillong plateau. *Palaeontographica* **B133** (1-4): 1-72.

Foote RB 1883. On the geology of south Travancore. *Rec. geol. surv India* **16** (1): 20-35.

Germeraad JH, Hopping CA & Muller J 1968. Palynology of Tertiary sediments from tropical areas. *Rev. Palaeobot. Palynol.* **6** (3 & 4): 189 - 348.

Harris WK 1965. Tertiary microfloras from Brisbane, Queensland. *Rep. geol. Surv. Qd.* **10**: 1-7.

Kar RK 1985. The fossil floras of Kutch - 4. Tertiary palynostratigraphy. *Palaeobotanist* **34**: 1 - 279.

Kar RK & Jain KP 1981. Palynology of the Neogene sediments around Quilon and Varkala, Kerala Coast, south India-2. Spores and pollen grains. *Palaeobotanist* **27** (2): 113 -131

King W 1882. The Warkalli beds and associated deposits at Quilon in Travancore. *Rec. geol. Surv. India* **15** (2): 93-102.

Pierce RL 1961. Lower-Upper Cretaceous plant microfossils from Minnesota. *Bull. geol. Surv. Min. Univ.* **42**: 1-86.

Potonié R 1960. Synopsis der Gattungen der *spore disperse* III. Teil: Nachtrage Sporites , Fortsetzung Pollenites mit generalregister Zu Teil I - III. *Beih. geol. Jb.* **39** 1-189.

Potonié R & Sah SCD 1960. *Sporae dispersae* of the lignites from Cannanore beach on the Malabar coast of India. *Palaeobotanist* **7**(2): 121-145.

Poulose KV & Narayanaswami S 1968. The Tertiaries of Kerala. *Mem. geol. Soc. India* **2**: 300-308.

Raha PK, Rajendran CP & Kar RK 1987. Record of Early Tertiary deposits in Kerala, India and its palaeogeographic significance. *Geophytology* **17** (2): 209-218.

Raha PK, Roy SK & Rajendran CP 1983. A new approach to the lithostratigraphy of the Cenozoic sequence of Kerala. *J. geol. Soc.* **24**: 325-342.

Rajendran CP, Raha PK & Kar RK 1989. Palynological assemblage from Neogene outcrops f Kerala Coast, India. *Indian Minerals* **43**(1): 39-46.

Ramanujam CGK 1972. Revision of pteridophytic spores from the Warkall lignite of south India. *Proc. Sem Palaeopalynol Indian Stratigr Calcutta*: 248-254.

Ramanujam CGK 1977. A palynological approach to the study of Warkalli deposits of Kerala in south India. *Geophytology* **2**: 160-164.

Ramanujam CGK 1987. Palynology of the Neogene Warkalli beds of KeralaState in south India. *J. Palaeont. Soc. India* **32**: 25-46.

Ramanujam CGK & Rao KP 1973. A study of pollen grains of *Ctenolophonidites* from the Warkalli deposits of south India with a note on the geological history of *Ctenolophon*. *Palaeobotanist* **20**: 211-215.

Ramanujm CGK, Reddy PR & Rao GM 1991. Palynoassemblages of the subsurface Tertiary strata at Pattanakad, Alleppey District, Kerala State. *J. palaeont. Soc. India* **36**: 51-58.

Rao AR & Vimal KP 1953. Preliminary observations on the microfossil content of some lignites from Warkalli in Travancore. *Curr Sci* **21**: 210-215.

Rao KP & Ramanujam CGK 1978. Palynology of the Neogene Quilon beds of Kerala State in south India-1. Spores of pteridohytes and pollen of monocotyledons. *Palaeobotanist* **25**: 397-427

Rao KP & Ramanujam CGK 1982. Palynology of the Quilon beds of Kerala State in south India 2. Pollen o dicotyledons and discussion. *Palaeobotanist* **30**: 68-100.

Rao KVR 1975. Ground water exploration and long term aquifer management, Kerala. *In: Symp. Mineral Resources in Kerala and their utilization. Geosci. technol. Assoc., Kerala*: 1-7.

Rao KVR, Subramanian P, Kurien J & Murthy MK 1975. Hydrolic parameters and preliminary resources evolution of coastal sandstone aquifer system in Kerala State (India). *Proc. natn. Symp. hydrol. Roorkee Univ., Roorkee*: 40-44.

Rao MR 1990. Palynological investigation of Arthungal bore-hole, Alleppey District, Kerala. *Palaeobotanist* **38**: 243 - 255.

Rao MR 1995. Palynostratigraphic zonation and correlation of the Eocene-Early Miocene sequence in Alleppey District, Kerala, India. *Rev. Palaeobot. Palynol.* **86**: 325-348.

Rao MR & Singh HP 1987. Palynology of Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road section, Jaintia Hills (Meghalaya) and Cachar (Assam). Part-III. Pteridophytic spores. *Palaeobotanist* **35** (3): 267-280.

Sah SCD 1967. Palynology of an Upper Neogene profile from Rusizi Valley (Burundi). *Annals. Mus. r. Afr. Cent.* ser. **B57**: 1-73.

Saxena RK 1978. Palynology of the Matanomadh Formation in the type area, north western Kutch, India (Part I). Systematic description of pteridophytic spores. *Palaeobotanist* **25**: 448-456.

Saxena RK 1979. Palynology of Matanomadh Formation in type area, north western Kutch, India (Part II). Systematic description of gymnospermous and angiospermous pollen grains. *Palaeobotanist* **26** (2): 130-143.

Singh HP & Rao MR 1984. *Surmaspora*, a new pteridophytic spore genus recovered from the Tertiary sediments of Meghalaya and Assam. *Curr. Sci.* **52** (15): 803-805.

Singh HP & Saxena RK 1984. Palynology f the Neogene sediments of Jorajan well-3, Upper Assam. *Prof. A. K. Ghosh. Commem. Vol.* 613-631.

Singh RY 1975. Morphological study of the *Retialetes* complex from Indian Tertiaries. *Geophytology* **5** (1): 98- 104.

Thomson PW & Pflug H 1953. Pollen und sporen des Mittele-uropaischen Tertiars. *Palaeontographica* **94**: 1-138.

Tripathi SKM & Singh HP 1985. Palynology of the Jaintia Group (Palaeocene - Eocene) exposed along Jowai-Sonapur road, Meghalaya, India (Part 1). Systematic palynology. *Geophytology* **15** (2): 164-187.

van der Hammen T & de Mutis G 1965. The Palaeocene flora of Colombia. *Lied. Geol. Meded.* **35**.

Varma YNR 1987. Palynomorphs of ecological significance from Tonakkal Tertiary clays of Kerala State. *Indian. J. Bot.* **10** (2): 163-168.

Varma YNR & Patil RS 1985. Fungal remains from the Tertiary carbonaceous clays of Tonakkal area, Kerala. *Geophytology* **15** (2): 151-158.

Varma YNR, Ramanujam CGK & Patil RS 1986. Palynoflora of Tertiary sediments of Tonakkal area, Kerala. *J. Palynol.* **22**: 39-53.

Varma CP & Rawat MS 1963. A note on some diporate grains recovered from Tertiary horizons of India and their potential maker value. *Grana Palynol.* **4**: 130-139.

Venkatachala BS & Goczan F 1964. The spore-pollen flora of Hungarian "Kossen Facies" *Acta geol. lilloana* **8** (1-4): 203- 228.

Venkatachala BS & Kar RK 1969. Palynology of the Tertiary sediments of Kutch-1. Spores and pollen from bore-hole no. 14. *Palaeobotanist* **1**: 157- 178.

Venkatachala BS & Rawat MS 1972. Palynology of the Tertiary sediments in Cauvery Basin-1. Palaeocene-Eocene palynoflora from the subsurface. *In:* Ghosh AK *et al. (Editors)— Proc. Sem. Palaeopalynol. Indian Stratigr., Calcutta (1971)*: 292-334.