JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 32, 1987, P P 26 — 46

PALYNOLOGY OF THE NEOGENE WARKALLI BEDS OF KERALA STATE IN SOUTH INDIA

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ABSTRACT

The paper records 63 genera and 86 species of the palynomorphs referable to pteridophytes and angiosperms from the terrigenous Warkalli beds in the type locality Varkalai, and Alleppey and Cannanore beach areas of Kerala, Schizaeaceae (*Schizaeoisporites, Neyvelisporites*, and *Crassoretitriletes)* and Polypodiaceae (*Polypodiisporites*, and *Laevigatosporites)* are the predominent elements of the pteridophytes.

The monocotyledons are represented by Potamogetonaceae, Iridaceae, Palmae, Agavaceae and Gramineae, of which Palmae is the predominent family. The dicotyledons constituting the bulk of the palynoflora are referable to various tropical families. The following are the more significant taxa of the angiospermous pollen viz. *Retipilonapites, Palmaepollenites, Paravuripollis, Dicolpopollis, Quilonipollenites, Ctenolophonidites, Psilatricolporites, Retitrocolporites, Clavatricolporites, Lacrimapollis, Heterocolpites, Compositoipollenites, Margocolporites, Bombacacidites, Myrtaceidites, Sapotaceoidaepollenites, Loranthipites, Retitriporites, Verrutriporites, Trilatiporites, Clavaperiporites, Ornatetradites* and *Polyporina,*

Palynologically the continental Warkalli beds show a remarkable similarity with the marine Quilon beds, which is considered to be floristic and stratigraphic significance. It is considered that both the Quilon and Warkalli formations were laid down during the same time span i.e., Early to Middle Miocene, although under different environmental scenarios.

The palynoflora of the Warkalli Formation highlights the prevalence of a coastal vegetational complex under tropical humid climate with heavy precipitation, during the Miocene of Kerala.

INTRODUCION

The Tertiary deposits of the Kerala state extend all along its coast in a north-south linear basin. Because of the extensive lateritic and alluvial cover, coupled with the presence of several estuarine and lagoonal water bodies, the Tertiary exposures are very much obscured and seen only as discontinuous patches in the southern and northern parts of the Kerala coast. The Tertiary deposits are succeeded by the Recent to Sub-recent marine and estuarine deposits. The Kerala Tertiary includes 1. The Quilon Formation (Quilon beds) comprising fossiliferous limestones, calcareous clays, carbonaceous and sandy clays and sands, and 2. the Warkalli Formation (Warkalli beds) of variegated sands, white plastic clays, carbonaceous clays and associated seams or lenticles of lignite (King, 1882, Poulose & Narayanaswami, 1968; Dutta, 1981). A third formation, viz., Vaikom Formation, underlying the Quilon Formation has been instituted recently (Raghava Rao, 1975; Raghava Rao *et-al.*, 1975). The Vaikom beds are similar to the Warkalli beds but are more arenaceous and coarse-grained.

Desikachary (1976) identified four formations in the Tertiary sequence of Kerala, which in the ascending order are 1. Mayyanad Formation, 2. Azheekal Formation, 3. Ambalapuzha Formations and 4. Kainakari Formation. Azheekal and Ambalapuzha Formations are more or less equivalent to the Quilon and Warkalli Formations , respectively. Nair and Rao (1980) in a recent stratigraphic analysis of the Kerala basin have recognized, particularly in the southern part of Kerala, five lithio units numbered in the ascending order as I, II, III, IIIA and IV.

Raha *et al.* (1983) in a recent lithostratigraphic classification of the Caenozoic sediments of Kerala have included all the Tertiary deposits under a single category, viz., Warkalli Group comprising Ambalapuza, Quilon and Mayyanad formations from top to bottom. The Ambalapuzha and Mayyanad formations are essentially basin margin fluviatile and deltaic facies with sandstones, clays and lignites, while the Quilon Formation constitutes the calcareos platform facies. The purely terrigenous sediments in the southern and eastern margins of the basin which cannot be definitely placed either in Ambalapuzha or Mayyanad formations (as the designated as the Warkalli Formation. The Quaternary-Holocene sequences comprising peat beds, beach sands, alluvium etc., are designated by these authors as the Vembanad Formation. The entire Caenozoic sequence of the Kerala coast comprising the Vembanad Formation and the Warkalli Group is designated as the Malabar Super Group (see Table I).

Warkalli Formation: As early as 1882, King described the type section of the Warkalli Formation (Warakalli beds of King) in the sea cliff at Warakalli (Varkalai) in the southern part of Kerala. Poulose and Narayanaswamy (1968) showed that the Warakalli beds extend all along the Kerala coast, though in between Kottayam and Cannanore, these beds are much obscured by the recent sediments. The best sections of the Warkalli (Varkalai)

Table I - A comparative study of the recent schemes of Lithostratigraphy of the Caenozoic sediments of Kerala.

Desikachar (1976)	Nair & Rao (1980)	Raha, Roy & Rajendran (1983)
Kainakari Fm. Alluvium, beach sand, peaty clays and peat.	*Uni IV* Beach sand and alluvial clays	*Vembanad Fm.* Beach sand, sand clay with peat beds. Alluvium and gravel beds.
Ambalapuzha Fm. Arkosic sand, sandy clays, black clays and peat	*Unit III A* Laterite, ferrugenous sandstone and clay.	*Ambalapuzha Fm.* Fluvial sandstone clays and lignite.
	Unit III Arkosic sand, clays and lignite.	
Azheekal Fm. Limestones, calcareous clays and sands.	*Unit II* Limestone with sand and clays.	*Quilon Fm.* Limestone, calcareous clays and sands.
Mayyanad Fm. Sandstones, sandy clays, clays and peat.	*Unit I* Pebbly sands, sandy clays, black clays, lignite.	*Mayyanad Fm.* Fluvial sandstone Clay and lignite.

and Vettur are in the China-clay mine at Kundara in southern Kerala and in the sea cliffs at Cannanore and quarry cuttings at Palayangadi, Payyar, Nileshwar and Kalanad in northern Kerala.

In the present paper, the concept of Warkalli formation as understood by such earlier workers as Poulose and Narayaswamy (1968), Raghava Rao (1975), Dutta (1981) and others is followed, pending a detailed palynological study of the newly instituted Ambalapuzha and Mayyanad formations. It is, however, pertinent to note that the continental facies developed in the Varkalai type locality from which numerous samples have been collected for the present study, is also referable to the Warkalli Formation of Raha *et al. (1983).*

Information available to date on the spore and pollen complex of the Warkalli Formation is of limited nature. As early as 1953 Vimal recorded a few spore and pollen types from the Warkalli lignite. No binomial nomenclature of the palynomorphs was, however, adopted in this study. Later on, Potonie and Sah (1958) described *sporae dispersae* from the Cannanore beach area. Ramanujam (1960, 1972) studied some pteridophytic sporomorphs and brought to light the dominance of Schizaeaceae and polypodiaceae. Ramanujam (1967) recorded the occurrence of myrtaceous pollen in the peaty lignite of Alleppey area. Ramanujam and Rao (1973b) studied the pollen of *Ctenolophonodites)* from the Warkalli beds and commented upon the geological history of *Ctenolophon.* Ramanujam and Rao (1977) furnished a check-list of the spore and pollen taxa recovered by them from the Warkalli Formation. Kar and Jain (1981) in their palynological study of the Kerala Tertiary deposits provided descriptions of some spore and pollen taxa referable to pteridophytes and angiosperms, respectively from the type area of the Warkalli Formation. More recently, Srisailam and Ramanujam (1982) studied the diverse pollen types referable to Palmae from the Warkalli beds of the Cannanore beach area.

The present communication provides for the first time a detailed playnological study of the warkalli formation from both the southern and northern areas of Kerala. Further, the paper also incorporates the relevance of playnology to the overall floristics, stratigraphy and palaeoenvironmental considerations at the time of the deposition of the terrigenous warlalli sediments.

MATERIAL AND METHODS

The material investigated includes many (Fifty Seven) samples of clay, carbonaceous clay and lighnite from Warkalli (Varkalai), Tamaraikulam and Pathirapally (well sections) in the vicinity of Alleppey, and Cannanore beach areas (for location of fossil areas see Ramanujam & Rao, 1978; Ramanujam, 1982).

Warkalli (Varkalai) area. The Warkalli beds seen in the sea cliffs edging the seashore about 12 miles south of Quilon are upto about 45.5 m thick and show the following lithic succession.

Laterite (with sandstone masses)
Sandy clays (or lithomarge)
Sandy clays with sandstone bands
Alum clays
Lignite beds

The bottom lignite beds rest upon loose white sand and no information is available of the strata underlying the white sand. Thirty samples of lignite and blackish clay were collected from the above sequence. The lignite is dark brown, easily breakable and particularly rich in plant debris.

Alleppey area. Near Tamaraikulam and Pathirapally of the Alleppey area, many well sections show fairly thick bands of carbonaceous clays interbedded with discontinuous seams. Fifteen samples of carbonaceous clay and lignite were collected from these places. The clay samples are with greyish detritus and the lignite is brownish black and pliable.

Cannanore beach area. Some lignite beds along with dark or greyish black clay pockets are seen in the Cannanore beach area as part of the Warkalli beds. Overlying the clay and lignite is a thick bed (9.1 m) of laterite. Numerous lignified pieces of wood are seen embedded in the clays. At the base of the laterite one may find locally and cream coloured mottled clay overlying the lignite bands. The cannanore lignite is hard, dull grey-coloured and nodular in appearance with silica in varying proportions. The lithic sequence in the Cannanore beach area is as follows:-

Laterite
Mottled clay
Lignite
Bands of greyish black clay

Twelve samples were collected from the lignite and greyish black clay from the above sequence.

Customary methods of maceration were employed for the recovery of the palynofossils from the clay and lignite samples (see Rao & Ramanujam, 1978).

The size given for each taxon, unless otherwise mentioned represents the average of ten specimens and excludes measurement of sculptural elements. The location of the Holotype is given uniformly by mentioning first the sample code, the number of the sample, followed by the slide number and the coordinates of the microscope stage. The size of the Holotype is given in parenthesis at the end.

The following are the codes for the samples studied.

WL - Samples from Warkalli type area

AL - Samples from Alleppey area

CN - Samples from Cannanore beac

All the slide preparations (with Holotypes and other figured specimens) and the remaining samples are preserved in the palaeobotanical collection, at the Department of Botany, Post Graduate College of Science, Osmania University, Saifabad, Hyderabad.

SYSTEMATIC DESCRIPTION

Genus *Pteridacidites* SAH 1967

Type species: *P. africanus* SAH 1967

Pteridacidites rotundus SAH 1967

(PlateI-1)

Remarks: *Gangasporites* from the Late Miocene-Pliocene of the Bengal basin (Mathur & Chopra, 1982), though cingulate is verrucate on the proximal side and vermiculate on the distal side. *Pteridacidites rotundus* shows striking resemblance with the spores of *Pteris* of pteridaceae (Santa Devi, 1977).

Genus *Neyvelisporites* RAMANUJAM 1972

Type species: N. bolkhovitinai RAMANUJAM 1972

(Plate I — 2, 3)

Remarks: The fossil taxon is referable to Schizaeaceae and shows particularly significant resemblance with the spores of *Schizaea pennula* and *S. germanni* (Selling, 1944; Bolkhovitina, 1961; Murillo & Bless. 1978).

Genus *Schizaeoisporites* POTONIE 1951

Type species : S. eocenicus SELLING 1944

Schizaeoisporites phaseolus DELCOURT & SPRUMONT 1953

(Plate I — 4)

Remarks: The fossil spore shows resemblance with the spores of *Schizaea laevigata* (Bolkhovitina, 1961).

Genus *Polypodiisporites* POTONIE 1956

Type species: P. favus POTONIE 1934

Polypodiisporites turbinatus SAH 1967

(Plate I — 8)

Remarks: The spores of this taxon are commonly encountered in the lignite from the Cannanore beach area.

Polyodiisporites impariter POTONIE & SAH 1958

(Plate I — 5, 7)

Remarks: This species is characterized by its peculiar sculpture which consists of coni intermingled with verrucae. It is a characteristic element of the Warkalli beds.

Polypodiisporites ratnami (RAMANUJAM 1966-67) RAMANUJAM 1978

(Plate I — 6)

Spinascent Monolete Spores

(Plate I — 9-10)

Description : Spores brownish-yellow, concave-convex laterally, oblong to ovoidal proximally, 40-46 x 25-31 μm, monolete, laesura long, lens-shaped, prominently lipped, exosporium 3-4 μm thick, spinose; spines upto 2.5 μm long, slender, often bristle-like, occasionally showing a tendency towards local grouping.

Remarks: The spinascent monolete spores have been encountered in almost all the samples studied. Monolete spores with slender spines are known to occur in some members of polypodiaceae, such as *Drynaria* and *Crpsinus* (Nayar, 1964; Nayar & Santa Devi, 1964; Santa Devi, 1977). Our specimens compare favourably with the spores of *Drynaria propinqua* and *Crpsinus taeniatus*. The sports of *Cyclogramma* which are also spinascent, have longer and more densely placed spines (Nayar & Santa Devi, 1964).

The check-list provided at the end shows the other pteridophytic spores recorded from the Warkalli beds.

Genus *Retipilonapites* RAMANUJAM 1966

Type species: *R. arcotense* RAMANUJAM 1966

Retipilonapites tertiaris RAO & RAMANUJAM 1978

(Plate I — 11)

Remarks: This was recorded from the Quilon beds. The possession of large-meshed reticulum with free bacula in the lumina is the distinctive feature of this taxon.

The fossil pollen is related to *Potamogeton* of Potamogetonaceae.

Genus : *Palmaepollenites* POTONIE) 1951

Type species : P. tranquillus (POTONIE) POTONIE 1951

Palmaepollenites kutchensis VENKATACHALA & KAR 1969

(Plate I — 12)

Genus *Arecipites* WODEHOUSE 1933

Type species: *A. punctatus* WODEHOUSE 1933

Arecipites magnus n. sp.

(Plate I — 13)

Holotype: Pl.1, Fig. 13; WL 2-6; 6.0 X 8.6 (41.5 X 32 μm).

Diagnosis: pollen grains heteropolar, amb broadly oval, 39.5-43.0 X 31-33 um, monosulcate, sulcus long, uniformally, broad with rounded ends and incrassate margin. Exine upto 2 um thick, punctitectate, columella fine, surface finely punctate.

Remarks: Arecipites punctatus Wodehouse (1933) is much smaller. *A. indicus* from the Palaeocene of the Cauvery basin is smaller and with a narrow tenuimarginate sulcus (Venkatachala & Rawat, 1972). The fossil pollen is related to *Areca* of Palmae.

Type locality: Cliff Section, Warkalli
Age: Miocene

Genus *Iridacidites* n. gen.
Type Species: *Iridacidites warkalliensis*

Diagnosis: Pollen grains heteropolar, amb elongate-ellipsoidal, monosulcate, longisulcate, surface foveorugulate to foveoreticulate.

Remarks: The new taxon is easily distinguishable from the other monosulcate fossil pollen. *Neyveli-pollenites* recorded recently from the Neyveli lignite has prominently lipped sulcus and finely reticulate exine. (Sarma *et al.*, 1984). Matanomadhiasulcites from the Palaeocene of Kutch (Kar, 1985) is distinguishable in its much larger size (63-205 x 38-145 um) and very broad sulcus. *Retimonosulcites* from the Eocene of Kutch (Kar, 1985) is microreticulate. *Quilonipollenites* described earlier from the Miocene Quilon beds of Kerala (Rao & Ramanujam, 1978) possesses an extended sulcus and coarsely reticulate sculpture.

Iridacidites warkalliensis n.sp.
(Plate I — 14-15)

Holotype: Pl.1, Fig. 14.15; WL 4-6; 22.6 X 89.2 (68.5 x 27.5 μm)

Diagnosis:Pollen grains heteropolar, amb elonagate-ellipsoidal, 65-75 x 23-29 μm, monosulcate, sulcus long, extending entire length of grain, narrow, tenuimarginate; exine 2.5 um thick, subtectate, surface prominently foveorugulate to locally foveoreticulate, lumina irregular.

Remarks: Monosulcate grains of this characteristic type have been encountered frequently in the Warkalli type area. In their size, shape and sculpture they show striking resemblances with the pollen of *Watsonia* of Iridaceae (Sharma, 1968). The pollen of *Gladiolus* another member of Iridaceae, while agreeing with the fossil pollen in the size and shape, is distinguishable in its granulose-foveolate exine.

Type locality:Cliff section, Warkalli
Age:Miocene

Iridacidites plicatus n.sp.
(Plate I — 16)

Holotype: *Pl.1, Fig. 16; WL 4-6; 23.3 x 85.6 (66.5 x 26.5 μm)*

Diagnosis: Pollen grains heteropolar, amb elongate-ellipsoidal, 64-75 x 25-27 um, monosulcate, sulcus narrow, extending all along length of grain, bordered on either side by prominent plica (folds). sulcus tenuimarginate; exine 2.5 um thick, subtectate, foveorugulate to locally foveoreticulate.

Remarks: This is distinguishable from the type species, *Iridacidites warkalliensis* in the possession of plica bordering the sulcus.

Type locality:Cliff section, Warkalli
Age:Miocene

Monosulcate Plicate pollen type
(Plate I — 17-18)

Description: Pollen grains heteropolar, amb ellipsoidal, 23.5-32.5 x 20-22 um, monosulcate, longisulcate, two prominent plica (folds) regularly seen bordering the sulcus; exine upto 2 μm thick, punctitectate, columella fine, surface finely pitted, pits in linear series parallel to sulcus.

Remarks: Similar grains were earlier recorded from the Quilon sediments (Rao & Ramanujam, 1978). The fossil pollen is referable to Palmae.

Genus *Liliacidites* COUPER 1953
Type species: L. kaitangataensis COUPER 1953
Liliacidites magnus n. sp.
(Plate I — 19)

Holotype: Pl. 1, Fig. 19; WL 1-13; 14.8 x 85.6 (69.5 x 48.0 μm)

Diagnosis: Pollen grains heteropolar, amb ovoidal-ellipsoidal, 58-75 x 42-55 μm, monosulcate, sulcus of medium size, tenuimarginate; exine upto 2.8 um thick, subtectate, surface reticulate, heterobrochate, brochi polygonal, curvimurate, muri simplibaculate, locally with beaded look, lumina irregular; reticulum faint locally.

Remarks : Liliacicdites major from the Mikir Formation (Lower Tertiary) of Assam (Mehrotra, 1983) is larger with vermiculate ornamentation. *Liliacidites magnus* is referable to Agavaceae and shows striking resemblance with the pollen of *Agave* (Sharma, 1968; Nair & Sharma, 1965; Lozano-Garcia, 1979).

Type locality : Cliff Section, Warkalli
Age: Miocene

Genus Paravuripollis RAO & RAMANUJAM 1978
Type speices: *P. Mulleri* RAO & RAMANUJAM 1978
(Plate II — 20)

Remarks: The fossil pollen is referable to Palmae and is particularly related to *Salacca,* a palm of swamp and evergreen forests (Thanikaimoni, 1970).

Genus *Clavapalmaedites* RAO & RAMANUJAM 1978
Type species: *C. hammenii* RAO & RAMANUJAM 1978
(Plate I — 21-22)

Remarks: This was originally recorded from the type

locality (padappakkara) of the Quilon Formation. The fossil pollen shows striking similarities with the pollen of *Oncosperma* and *Ceroxylon* of Palmae (Thanikaimoni, 1970).

Genus Longapertities HOEKEN-KLINKERBERG 1964
Type Species: L. Marginatus HOEKEN-KLINKENBERG
Longapertites hammeni RAO & RAMANUJAM 1978
(Plate II—23-24)

Genus Spinizonocolpites MULLER 1968
Type species: S. echinatus MULLER 1968
Spinizonocolpites spinulosus n. sp.
(Plate II—25)

Holotype: Pl. 2, Fig. 25; WL 2-6; 7.3 x 89.9 (26 x 16.5 μm)

Diagnosis: Pollen grains ellipsoidal, 23-28.5 x 14.5-18 μm, zonosulcate, sulcus extending all around the grain, dividing it into two halves; exine upto 1.8 μm thick, structure not distinct, surface spinulate, surface between spinules microreticulate.

Remarks: In its smaller size and spinulose nature *Spinizonocolpites spinulosus* differs from *S. echinatus* Muller (1968). The affinities of this pollen are with Nypoidae of Palmae. Kulkarne and Phadtare (1981) recently recorded pollen referable to *Nypa* from the lignite beds of Ratnagiri district, Maharashtra.

Type locality: Cliff section, Warkalli
Age: Miocene

Genus Disulcipollis KRUTZSCH 1970
Type species: D. cuddalorense (RAMANUJAM) KRUTZSCH 1970
(Plate II—-20)

Remarks: Dicolpopollis (Pflanz) Potonie (1960) is differentiated from *Disulcipollis* in the possession of reticulate sculpture. The affinities of this fossil pollen are with *Metroxylon* of palmae (Thanikaimoni, 1970).

*Genus: Dicolpopollis (*PFLANZ)POTONIE 1960
Type species: D. koekeli (PFLANZ) POTONIE 1960
Dicolpopollis elegans RAO & RAMANUJAM 1978
(Plate II—27)

Remarks: The fossil pollen is referable to *Calamus* of palmae (Thanikaimoni, 1970; Muller, 1979).

Genus Warkallipollenities RAY & RAMANUJAM 1984
Type species: W. erdtmanii RAO & RAMANUJAM 1984
Warkallopollenites thanikaimonii n. sp
(Plate II—32-34)

Holotype: P 1.2, Fig. 32-34; WL 4-3; 12.0 x 91.6 (45.5 μm).

Diagnosis: Pollen grains isopolar, amb more or less subcircular to three-lobed, sides convex, 45-55 μm, tricolpate, longicolpate, colpi gaping at equatorial margin, colpus margin ragged, fringed with sculptureal elements; exine upto 5 μm thick (including sculpture), crassisexinous, intectate, prominently clavate-baculate, processes upto 4 μm long, densely placed in a distinct radiating pattern from polar region as seen in polar view, radial rows of bacules simple or borked, heads of processes generally pentagonal in surface view.

Remarks: In the type species *Warkallipollenites erdtmanii* the sculptural elements represented by clavae are not aligned in distinct radiating pattern, and further they are surmounted by 3 or 4 spinules (Thanikaimoni *et al.*, 1984). The heads of the clavate-baculate processes of the present species seem to be rugged under high magnification (Oil immerssion), but no distinct spinules could be seen on them. The fossil pollen is referable to *Plumbaginaceae* and shows striking resemblance with the pollen of *Aegialitis rotundifolia. Plumbaginacipites neyveli* from the Neyveli lignite of Tamil Nadu is tectate with the surface granular to microreticulate (Navale & Mishra, 1979).

The specific name is in honour of the late Dr. G. Thanikaimoni whose contributions to the Indian palynology are well known.

Type locality: Cliff section, Warkalli
Age: Miocene

Genus: Loranthiipites RAO& RAMANUJAM 1982
Type species: L. elegans RAO & RAMANUJAM 1982
Loranthipites elegans RAO& RAMANUJAM 1982
(Plate III—65-66)

Remarks: Our specimens are slightly larger (30.5 x 45.5 um) than the ones recorded earlier form the Quilon sediments (Rao & Ramanujam, 1982). The fossil pollen is referable to Loranthaceae and shows remarkable resemblances with the pollen of *Dendrophthoe* (Erdtman, 1952; Rao & Shukla, 1975; Vasanthy, 1976).

Loranthipites sp .
(Plate III—67)

Description: Pollen grains with prominently 3-armed amb, sides concave and sweeping like an arc, angles truncate and arched, 42-55 μm, equatorial view rarely encountered, prominently oblate, tricolpate, longicolpate, colpi faint, almost meeting with each other at polar area, particular on one side; exine upto 2.2um thick, tectate, surface psilate; each mesocolpial area with a prominent fold.

Remarks: This type is larger than *Loranthipites elegans* and with conspicuous mesocolpial folds.

Genus Stephanocolpites HAMMEN emend. POTONIE 1960
Stephanocolpites arcotense RAMANUJAM 1966
(Plate II—35)

Genus: Ctenolophonidites HOEKEN-KLINKENBERG 1966
(Plate II—36-37)

Remarks: This is a common element of the Warkalli palynoflora (see Ramanujam & Rao, 1973). It has been earlier encountered in the Quilon Formation and also, the Neyveli lignite (Rao & Ramanujam, 1982; Ambawani

et al., 1981; Ramanujam & Reddy, 1984). The affinities of the fossil pollen are with *Ctenolophon engleri* of Ctenolophonaceae, which is now confined to tropical Africa (Hoeken-Klinkenberg, 1966; see also Germeraad *et al.*, 1968). Muller (1981) mentions that *Ctenolophon* type of pollen disappeared in India in the post-Eocene. The common occurrence of *Ctenolophonidites* in the Quilon and Warkalli sediments all along the Kerala coast, clearly indicates that the extinction of this taxon took place in India after the Miocene age (Ramanujam & Rao, 1973; Kar & Jain, 1981; Rao & Ramanujam, 1982).

Genus Retistephanocolpites LEIDELMEYER 1966
Type species: R. angeli LEIDELMEYER 1966
Retistephanocolpites neogenicus n. sp.
(Plate II — 38-40)

Holotype: Pl.2, Fig. 39,40; WL4-; 11.3 x 81.4 (30.5 μm)
Paratype: Pl.2, Fig. 38; WL-5.

Diagnosis: Pollen grains isopolar, amb rounded, 28-35 μm, stephanocolpate, hexacolpate (occasionally 5-colpate), colpi short, narrow, tenuimarginate; exine upto 2.5 μm thick, subtectate, surface reticulate to locally striato-reticulate, brochi angular to almost rounded, medium to fine, decrease in size towards poles, lumina psilate.

Remarks: Retistephanocolpites angeli from the Lower Eocene of Guyana is larger and with a finer reticulum (Leidelmeyer, 1966). *R. williamsi* Gemeraad *et al.*(1968) is larger and with a fine foveoreticulate sculpture imparting a spongy look to the pollen wall. The fossil pollen is referable to Labiatae.

Type locality: Cliff section, Warkalli
Age: Miocene

Genus Hetrocolpites (HAMMEN) HAMMEN. & GARCIA DE MUTIS
Type species: H. palaeocenicus HAMMEN & GARCIA DE MUTIS 1965
Heterocolpites combretoides RAO RAMANUJAM 1982
(Plate II — 41,42)

Remarks: The affinities of the fossil pollen are with *Lumnizera*. a mangrove member of Combretaceae (Leopold Estella, 1969; Blasco & Caratini, 1973). *Lumnitzera* is seen associated with *Bruguiera, Sonneratia, Rhizophora* and *Avicennia* in the littoral (mangrove) vegetation of India. The pollen of some species of *Terminalia* is also comparable to some extent with the fossil pollen.

Genus Psilatricolporites HAMMEN 1956
Type species. H. operculatus HAMMEN & WYMSTRA 1964
Psilatricolporites operculatus HAMMEN & WYMSTRA 1964
(Plate II-28)

Remarks: Similar pollen grains from the Neogene of Barundi were described as *Rananculacidites communis* (Sah, 1967). The author considers *R. communis* (Sah, 1967) as a junior synoym of *Psilatricolporites operculatus*. Tricolporate operculate pollen are encountered in some Euphorbiacea (*Alchornea, Hevea),* Rosaceae (*Rosa, Hagenia* etd.) and Capparidaceae (*Cadaba)* (see Erdtman, 1952; Bonnfille, 1971 a, 1971 b; Martin, 1974). The affinities of *Psilatricolporites operculatus* are with *Alochornea,* a pantropical genus of Euphorbiaceae. In India *Alchornea* is represented by trees and shrubs in the moist tropical forest of Assam and Khasi hills (Brandis, 1921). Germeraad *et al.* (1968) recorded this pollen type from the Lower Tertiary of Carribbean and Nigeria and the Neogene of Borneo. *Alchornea* pollen was also recorded from the Lower Tertiary of New South Wales, Australia (Martin, 1974) and the Oligocene-Lower Miocene of Cameroun (Salard-Cheboldaeff, 1978).

Psilatricolporites truncatus n. sp.
(Plate III— 43)

Holotype: Pl.3, Fig. 43; CN-9; 7.3 x 76.9 (26.5 μm)

Diagnosis: Pollen grains isopolar, amb six-sided, sides flattened, angles truncate, 25-37.5 um, tricolporate, longicolpate, colpi funnel-like and gaping at equatorial margin in polar view, tenuimarginate, oralalongate with nexinous thickenings, exine: 2.2.μm thick, tectate, surface psilate.

Remarks: The truncate angles and the lalongate with nexinous thickenings are the distinguishable features of this taxon.

Type locality; Cannanore beach area
Age: Miocene

Psilatricolporites sp.
(Plate III— 51)

Description: Pollen grains isopolar, subprolate to prolate, 19.5-26 x 16.5- 20.5 um, tricolporate, longicolpate, colpi sharply bent at equator, ends pointed, ora prominently lalongate; exine 1.8 um thick, tectate, sexine slightly thicker than nexine, columella fine, surface psilate to finely flecked.

Genus: Clavatricolporites LEIDELMEYER 1966
Type species: C. laticiae LEIDELMEYER 1966
Clavatricolporites brevicolpatus n. sp.
(Plate II— 29-31)

Holotype: Pl.2, Fig. 29-31; WL 4-7; 16.1 x 79.0 (28.5 μm)

Diagnosis: Pollen grains isopolar, amb subtriangluar 25-32 μm, tricolporate, colpi broad, brevicolpate, colpal margins infolded, ends rounded, ora rounded, with thickened margin; exine upto 4μm thick (inclusive of processes), intectate, surface-pilte; calva and pila of various sizes. Usually 2.5 μ high, slighly smaller at mesocolpia, heads rounded to irregular.

Remarks: *Ilexpollenites* Thiergart (1937) is longicolpate and the claval heads are essentially angular in surface view, imparting a pebbly look to the surface. The fossil pollen resembles the pollen of some species of *Ilex* of Aquifolia ease (Bonnefille, 1971 a)

Type locality: Cliff section, workalli
Age: Miocene

Genus: *Rhoipites* WODEHOUSE 1933)
Rhoipites sp.
(Plate II — 44)

Description: Pollen grains isopolar, subprolate spheroidal, 22.5 x 19.5 μm, tricolporate, longicolpate, colpi bent at polar areas, ora-lalongate; exine 1.8 μm thick, tectate, surface finely punctate.

Rhoipites anacardioides n. sp.
(Plate II, 45—47)

Holotype: Pl.3, Fig. 45,46; AL-3; 26.9 x 102.8 (34.5 x 24.5 μm)

Paratype: Pl.3, Fig. 47; AL-3.

Diagnosis: Pollen grains essentially isopolar, amb subtriangular, equatorial view prolate to subprolate, 30-36 x 22-26 um, tricolporate, longicolpate, colpi extending upto polar region, constricted at equator, bracket-shaped, ora distinct, lalongate; exine upto 2.5 um thick, sexine thicker than nexine, tectate, columella fine, surfaced finely reticulate to locally straie-reticulate (reticulate-ridged), brochi very fine, narrow, irregular, more or less meridionally aligned, and locally parallely aligned.

Remarks: In its long bracket-shaped colpi, finely reticulate sculpture with locally striate-reticulate condition, the present species differs from the rest of the species of *Rhoipites* (Pocknall, 1982; Pocknall & Crosbie, 1982). The botanical affinities of the various species of *Rhoipites* are diverse. *Rhoipites anacardioides* is clearly referable to Anacardiaceae and shows affinities with *Gluta* and *Melanorrhoea* (Baksi, 1976), more impressively with the latter.

Type locality: Well-section, Alleppey area
Age: Miocene

Genus: *Retitricolporites* HAMMEN & WYMSTRA 1964
Retitricolporites rhombicus n. sp.
(Plate III — 48-49)

Holotype: Pl.3, Fig. 48.49; WL2-13; 25.9 x 81.3 (25 x 21 Y μm)

Diagnosis: Pollen grains isopolar, prolate, more or less rhomboidal, 26-31 x 20-25 μm, tricolporate, longicolpate, colpi slightly constricted at equator; ora some what rounded, exine 2.5 μm thick, tectate, columella distinct, surface reticulate, brochi rather smaller towards poles, polygonal, muri simplibaculate, lumina pailate.

Remarks: The rhomboidal shape and the longicolpate nature are the distinguishable features of this species. The fossil pollen shows resemblances with the pollen of *Fagaropsis* of Rutaceae (Bonnefille, 1971 a).

Type locality: Cliff section, Warkalli
Age: Miocene

Retitricolporites sp.
(Plate III — 52)

Description: Pollen grains isopolar, amb rounded-triangular, distinctly three-lobed, 28-36 μm, prolate spheroidal, in equatorial view, tricolporate, ora faint, somewhat lolongate; exine upto 2.6 μm thick, surface prominently reticulate, brochi towards colpi smaller than those at other parts, muri simplibaculate, lumina psilate.

Remarks: The fossil pollen is related to *Avecennia* of Avicenniaceae (Blasco & Caratini, 1973).

Retitricolporites operculatus n. sp.
(Plate III — 53)

Holotype: P1.3, Fig. 53; CN 12; 23.9 x 79.4 (28.5 μm)

Diagnosis: Pollen grains isopolar, amb 3-lobed, 26.5-32.5 μm, tricolporate, longicolpate, operculate, gaping at equatorial margin, ora faint; exine 2.6 μm thick, subtectate, sexine as thick as nexine, surface reticulate, heterobrochate, brochi polygonal decreasing in size towards colpi, locally with discontinuous muri imparting a vermiculate look to exine, curvimurate, lumina irregular, psilate.

Remarks: *Retitricolporites operculatus* differs from *Psilatricolporites operculatus* in the possession of reticulate exine. The affinities of this fossil pollen are with some species of *Cissampelos* and *Cocculus* of Menispermaceae (Thanikaimoni, 1984).

Type locality: Cannanore beach area
Age: Miocene

Retitricolporites variabilis n.sp.
(Plate III — 54-55)

Holotype: Pl.3, Fig. 54-55; WL 4-10; 14.6 x 91.6 (35.5 μm)

Diagnosis: Pollen grains isopolar, amb triangular, 33-38 μm, angulaperturate, tricolporate, longicolpate, colpi crassimarginate, ends pointed, ora rounded to lalongate exine 2.2 μm thick, subtectate, columella distinct, surface reticulate, heteronbrochate, brochi hexa-to polygonal, decrease in size and almost disappear towards polar area, lumina smooth.

Remarks: *Retitricolporites annulatus* from the Oligocene to Lower Miocene of Cameroun is similar to the present taxon, but is smaller and with prominently crassimarginate ora (Salard-Cheboldeeff, 1978). The fossil pollen is referable to Vitaceae and resembles the pollen of *Leea*.

Type locality: Cliff section, Warkalli
Age: Miocene

Retibrevitricolporate pollen type
(Plate III — 50)

Description: Pollen grains isopolar, amb rounded, 32-38 μm, tricolporate, brevicolpate, ora somewhat lalongate; exine 1.8 μm thick, subtectate, surface finely reticulate, homobrochate, brochi polygonal, lumina psilate.

Retitricolporate curvimura pollen type
(Plate III—56-57)

Description: Pollen grains isopolar, amb rounded, 22.5 -36 μm, tricolporate, ora faint; exine upto 3.5 μm thick, subtectate, surface retipilate, heterobrochate, brochi hexa to polygonal, curvimurate, lumina sinuous with few piloid processes.

Remarks: The fossil pollen is referable to Oleaceae and shows affinities with *Ligustrum* (Vasanthy, 1976). Only few grains were encounted.

Genus: *Compositoipollenites* POTONIE. 1951
Type species: *C. rhizophorus* POTONIE 1951
Compositoipollenites miniums n. sp.
(Plate III—58-60)

Holotype: Pl. 3, Fig. 58,59; AL-10; 14.2 x 95.9 (16.5 μm)
Paratype: Pl.3, Fig. 60; AL-10.

Diagnosis: Pollen grains isopolar, amb subcircular, 15.5-20.5 μm. fossaperturate, tricolporate, colpi not prominent, ora faint; exine 3-3.5 μm thick (including processes). tectate, prominently echinate, spines densely placed upto 3μm long, base slightly bulbous, tips pointed.

Remarks: *Compositoipollenites tricolporatus* from the Oligocene of Kutch (Kar, 1985) is more rounded and larger. *Acanthotricolpites bulbospinosus* from the Lower Eocene of Kutch (Kar, 1985) is much larger with grana and bacules in the interspinal areas. The fossil pollen is referable to Compositae.

Type locality:1 Well section, Alleppey area
Age: Miocene

Genus: *Symplocoipollenites* POTONIE 1951
Type species: *S. Vestibulus* POTONIE 1951
Symplocoipollenites baksii n. sp.
(Plate III—61)

Holotype: P1.3, Fig. 61; WLZ-10; 18.1 x 96.7 (26.5 μm)

Diagnosis: Pollen grains isopolar, amb triangular, 24-29 μm. angulaperturate, tricolporate, colpi very short, narrow streak-like, ora lalongate; exine 1.8 μm thick, tectate, surface punctate to microreticulate.

Remarks: In the nature of its sculpture, the present taxon is distinguishable from *Symplocoipollenites indicus* Ramanujam (1966), from Neyveli lignite. *S. kutchensis* and *S. minutus* from the Eocene of Kutch are much smaller. *S. constrictus* Sah and Kar (1970) has scrobiculate exine. Mathur and Jain (1980) recently instituted a new taxon *Drasipollenites* for fossil Symplocaceae pollen with reticulate exine and included. *S. indicus*. *S. Kutchensis* and *S. minutus* under this new taxon.

The species is named in honour of the late Dr. S.K. Basksi of Jadhavapur University, Calcutta.

The fossil pollen is referable to Symplocaceae and shows strong resemblance with the pollen of *Symplocos alata* (Meijden, 1970; Gupta & Sharma, 1977).

Type locality: Cliff section, Warkalli
Age: Miocene

Genus *Lacrimapollis* (VENKATACHALA & RAWAT)
Type species:L. pilosus VENKATACHALA & RAWAT 1984
Lacrimapollis brownlowioides n. sp.
(Plate III—62-63)

Holotype: Pl.3, Fig. 62,63; AL-3; 22.9 x 101.7 (42.5 μm)

Diagnosis: Pollen grains isopolar, amb subcircular, 36-45 μm, suboblate to oblate equatorially, tricolporate, brevicolpate, colpi with rounded ends, margins and ends of colpi infolded, ora large, faint rounded to lalongate with incrassate margins; exine upto 4.5 μm thick, crassisexinous, perfotectate, columella very prominent, upto 3 μm long, many of them forked, surface finely reticulate, brochi angular.

Remarks: *Lacrimapollis pilosus* from the Lower Miocene of the Cauvery basin is smaller and with much finer sculpture (Venkatachala & Rawat, 1973).

The fossil pollen shows remarkable resemblances with the pollen of *Brownlowia, Pentace* and *Diplodiscus* of Tiliaceae (Muller, 1964; Sharma, B.D., 1969; Barre de Cruz, 1982; Thanikaimoni *et al.*, 1984). The similarities of the fossil taxon with the pollen of *Brownlowia,* particularly *B. tersa, B. Peltata* and *B. elmeri* are very impressive.

The genus *Brownlowia* is mangrove member of Tiliaceae confined to South-East Asia.

Type locality: Well section, Alleppey area
Age: Miocene

Genus *Margocolporites* RAMANUJAM ex SRIVASTAVA
Margocolporits tsukadai RAMANUJAM 1966
(Plate III—64)

Remarks: The fossil pollen is referable to Caesalpiniaceae and shows remarkable resemblances with the pollen of *Caesalpinia, Peltophorum* and *Mazoneuron* (Tsukada, 1963; Mittre & Sharma, 1962; Smith, 1964).

Genus: Myrtaceidites COOKSON & PIKE 1954
Type species: *M. eugenioides* COOKSON & PIKE 1954
(Plate III—68-70)

Remarks: The triangular amb, small size (12-15 um), tricolporate and parasyncolpate condition are the characteristic features of *Myrtaceidites*. The fossil pollen is referable to Myrtaceae and shows striking resemblances with the pollen of *Eugenia* and *Syzigium*

(Cookson & Pike, 1954; pike, 1956; Tsukada, 1984; Rao & Shukla, 1975). Ramanujam (kalmun 1964) Rao & Shukla. 1975). Ramanujam (1967) earlier recorded myrtaceous pollen from the Alleppey area.

Genus :Cupaniedites COOKSON & PIKE 1954
Type species: *C. orthoteichus* COOKSON & PIKE 1954

Cupaniedites cooksonii n.sp.
(Plate III — 71-72)

Holotype: P1.3, Fig. 71, 72; AL-12; 21.8x85.1 (23.5 μm)

Diagnosis: Pollen grains isopolar, amb triangular, sides convex, 20-25.5 μm, angulaperturate, tricolporate, syncolpate, colpal margins incrassate, ora lalongate; exine upto 2 μm thick, tectate, surface coarsely granular to locally microreticulate.

Remarks: This has been encountered in the samples from the Alleppey area. *Cupaniedites orthoteichus* from the Tertiary of Australia has straight-sided amb and a reticulate exine (Cookson & Pike. 1954). *C.decoratus* from the Neogene of Cauvery basin is punctate-reticulate (Venkatachala & Rawat, 1973).

The species is named in honour of the late Miss Isabel Cookson of Australia.

The fossil pollen is referable to Sapindaceae and shows affinities with *Cupania.*

Type locality: Well section, Alleppy area
Age: Miocene

Genus: *Sapotaceoidaepollenites* POTONIE, THOMSON & THIERGART 1950
Sapotaceoidaepollenites africanus SAH 1967
(Plate IV — 73-74)

Remarks : This is a common element of the palyno-flora. The fossil pollen is referable to Sapotaceae and shows particular resemblances with the pollen of *Madhuca latifolia.*

Sapotaceoidaepollenites neyveliensis RAO & RAMANUJAM 1982
(Plate IV — 75-76)

Remarks: The affinities of this taxon are with *Manilkara* of Sapotaceae.

Genus: *Meliapollis* SAH & KAR 1970
Type species: *M.ramanujamii*SAH & RAMANUJAM 1982

(Plate IV — 77)

Remarks: The affinities of the fossil pollen are with Meliaceae. Some of the Guttiferae members, however, also show resemblance with this pollen type.

Genus: *Psilastephanocolporites* LEIDELMEYER 1966
Type species: *P. fissilis* LEYDELMEYER 1966
Psilastephanocolporites keralensis n. sp.
(Plate IV — 78)

Holotype:Pl.4, Fig. 78; WL 2-15; 8.0 x 84.3 (41 μm)

Diagnosis: Pollen grains isopolar, amb rounded and lobed, 36-45 μm, stephanocolporate, colpi 8 to 10, short to medium, leaving a large apocolpial area (upto 20 μm in diam), colpal margins incrassate, infolded, ora seem to be lalongate; exine 1.8 μm thick, punctitectate, columella fine, surface punctate.

Remarks: Psilastephanocolporites fissilis from the Eocene of Guyana (Leidelmeyer, 1966) is psilate and more prominent ora. The fossil pollen is referable to Polygalaceae and shows resemblances with *Xantho-phyllum* (Thanikaimoni *et al., (1984).*

Type locality: Cliff section, Warkalli
Age: Miocene

Genus Diporites HAMMEN 1954
Type species : D. grandiporosus HAMMEN
Diporites crassiporatus n. sp.
(Plate--79)

Holotype: Pl. 4, Fig. 79; WL2-13; 19.9 x 90.8 (39 x 30 um)

Diagnosis:Pollen grains barrel-shaped, 34-42 x 29-33 um, diporate, pores vestibulate, rounded to subcircular, 6.5 um in diam., pore margin prominently thickened (annulate); exine 1.8 μm thick, structure indistinct, surface finely granular.

In its crassiporate condition this taxon differs from the other *Diporites* species. The fossil pollen is referable to Apocyanaceae.

Type locality: Cliff section, Warkalli
Age: Miocene

Diporate verrucate pollen type
(Plate IV —80-81)

Description: pollen grains barrel-shaped, 14.5-19.5 x 18.5-23 μm, diporate, pores upto 3.5 μm in diam., with conspicuous annulus; exine 1.8 μm thick, surface verrucate, verrucae of low height, not prominent.

*Genus Retitriporites (*HAMMEN) MULLER 1968
Type species: *R. aspidopori* MULLER 1968
Retitriporites quilonensis n. comb
(Plate IV —82)

Maculoporites quilonensis Rao & Ramanujam 1982, Pl. 4, Fig. 64-66) Descrption and Holotype as in Rao and Ramanujam (1982).

Remarks: This pollen type was originally recorded from the Quilon Formation of Kerala as *Maculoporites quilonensis* (Rao & Ramanujam, 1982.) However, the genus *Maculoporites* described earlier by Venkatachala and Rawat (1973) as triporate pollen has been recently shows to be tricolporate and accordingly the type species of *Maculoporites, M. reticulatus* has been included under *Coneopollis* Venkatachala and Rawat (1$973) as *C. reticulatus* (see Thanikaimoni *et al., 1984).* This obviously has necessitated a restudy of the Kerala species *Maculcporites quilonensis,* and it has been

confirmed by the author that it is a triporate pollen as originally described. In view of this the above pollen type is now included under *Retitriporites* and a new combination *R. quilonensis* is made.

The fossil pollen is referable to Rubiaceae and shows striking resemblance with the pollen of *Randia* (Guinet, 1962; Sharma, 1969). Fossil pollen referable to *Randia* has been recorded earlier from the Miocene of Australia, New Zealand and Cameroun (see Muller, 1981).

Retitriporites sp.

(Plate IV—83)

Description: pollen grains isopolar, amb subcircular, 21.5 μm, triporate; exine 1.8 μm thick, tectate, columella distinct, surface rugulate-reticulate, brochi frequently discontinuous.

Genus *Verrutriporites* MULLER 1968
Type species: *V. lunduensis* MULLER 1968
(Plate IV—84)

Verrutriporites perverrucatus RAO & RAMANUJAM 1982
(Plate IV—85)

Remarks: The fossil pollen is related to *Duabanga moluccana* of Sonneratiaceae (Thanikaimoni & Jayaweera, 1960).

Genus *Haloragacidites* COUPER 1953
Type species: *H. trioratus* COUPER 1953
Haloragacidites sp.
(Plate IV—86, 90)

Description: Pollen grains iso to sub-isopolar, oblate to suboblate spheroidal, 14.5-18.5 μm, triporate (occasionally tetraporate), pores aspodote, upto 3 μm in diam. pore margin pouting; exine 1.8 μm thick, faintly verrucate, verrucae small.

Remarks: The fossil pollen is referable to Haloragaceae and shows affinities with *Myriopyllum* (Praglowskii, 1970)

Genus *Florschuetzia* GERMERAAD, HOPPING & MULLER 1968
Type species: *F. trilobata* GERMERAAD, HOPPING & MULLER 1968
Florschuetzia sp. cf. *F. levipoli* GERMERAAD, HOPPING & MULLER 1968
(Plate IV—87-88)

Description: Pollen grains isopolar, prolate to subprolate, equatorial region bulging, polar caps clearly demarcated, 32-36 x 18-22 μm, triporate, pores upto 3.5 μm in diam., with a thickened and protruding rim, equidistantly placed; exine 2.2 μm thick, sexine as thick as nexine, tectate, columella fine, surface finely rugulate-verrucate at and around equatorial region, psilate at polar areas.

Remarks: Florschuetzia levipoli from the Neogene of Borneo (Germeraad *et al.*, 1968) resembles the South Indian specimens in many respects but is larger and with more prominent verrucate-areolate sculpture at the equatorial region. *Sonneratiopollis bellus* Venkatachala and Kar (1969), according to Muller (1978, 1981), is not related to Sonneratiaceae. In a recent publication, Kar (1985), however, reiterated the affinities of *Sonneratiopollis* with the pollen of *Sonneratia*. Phadtare and Kulkarni (1984) recroded recently *Florschuetizia semilobata* and *F. levipoli* from the Ratnagiri lignite in Maharashtra. The South Indian fossil pollen shows resemblances with the pollen of *Sonneratia alba* (Germeraad *et al.*, 1968; Muller, 1978; Barre-de Cruz, 1982). *Iugopollis tetraporites* from the Eocene of Cauvery basin (Venkatachala & Rawat, 1972), according to Muller (1978, 1981), is a brevicolporate pollen and hence not related to Sonneratiaceae. *Florschuetzia minutus* from the Kadi Formation of the Cambay basin (Rawat, Mukherjee & Venkatachala, 1977) has also not been considered a Sonneratiaceae taxon (Muller, 1981).

Genus *Triporopollenites* (PFLUG) THOMSON & PFLUG 1953
Type species: T. coryloides THOMSONH & PFLUG 1953
Triporopollenites minutus RAO & RAMANUJAM 1982
(Plate IV—89)

Remarks: The fossil pollen is referable to Moraceae and shows impressive resemblances with the pollen of *Artocarpus*.

Genus *Cricotriporites* LEIDELMEYER 1966
Type Species: *C. guianensis* LEIDELMEYER 1966
Cricotriporites camerouensis SALARD 1980
(Plate IV—93)

Description: Pollen grains isopolar, amb subcircular, 28-35 μm, triporate, pores upto 3 μm in diam., with distinct annulus; exine 1.8 μm thick, tectate, surface finely punctate to locally scabrate, often with few folds.

Remarks: The affinities of this pollen are with *Randia (R. uliginosa)* of Rubiaceae (Salard, 1980).

Genus *Myricaceoipollenites* POTONIE 1951
Type species: *M. megagranifer* POTONIE 1951
Myricaceoipollenites sp.
(Plate IV—94)

Description: Pollen grains isopolar, amb triangular, 26-34 μm, angulaperturate, triporate, pores upto 3 μm in diam., margins slightly incrassate; exine 1.8 μm thick, tectate, surface psilate.

Remarks: Only few specimens of this pollen type were encountered in our preparations.

Genus *Trilatiporites* RAMANUJAM 1966
Type species: *T. erdtmanii* RAMANUJAM 1966
Trilatiporites truncatus SARMA, REDDY & SRISAILAM 1984

(Plate IV—91)

Remarks: The affinities of Trilatiporites are with *Sclerosperma* of Palmae (Erdtman & Singh, 1957; Bande & Ambawani, 1982).

Trilatiporites sp.
(Plate IV—92)

Description: Pollen grains heteropolar, suboblate, amb rounded to rounded-triangular, 30-45 um, triporate, latiporate, all three pores on one hemisphere only, pores upto 3.5 um in diam., elevated on a thickened rim; exine 1.8 um thick, subtectate, columella distinct, surface reticulate, brochi polygonal.

Remarks: Only few specimens of this pollen type were encountered in our preparations.

Genus *Caryophyllidites* COUPER 1960
Type Species: *C. polyporatus* COUPER 1960
Caryophyllidites warkalliensis n. sp.
(Plate IV—95-96)

Holotype: Pl.4, Fig. 95.96; WL2-4; 19.7 x 79.1 (54.5 μm)

Diagnosis: Pollen grains isopolar, spheroidal, and circular, 52-60 μm, patoporate (periporate), pores 16-18, upto 3 μm in diam, margins distinct, not equidistantly placed; exine 2.2 μm thick, sexine as thick as nexine, punctitectate, columella distinct, surface puncti-granulate.

Remarks: Calystegiopollis Krutzsch (1966) is with pores irregular in contour and densely placed spinules. *Magnaperiporites* Gonzalez (1967) is much larger and spinulate (see Salard Cheboldaeff, 1975). *Periporopollenites reticulatus* from the Eocene of South-Eastern Nigeria is with less number of pores and distinctly reticulate exine (Jan Du Chene *et al.*, 1978). Caryophyllaceae Type 3 pollen from the continental Miocene of central Afghanisthan (Lang & Meon Vilain, 1976) is fairly comparable with the present taxon but for its much smaller size. The oldest record of *Caryophyllidites* is from the Middle Oligocene of New Zealand (see Muller, 1981).

The fossil pollen is referable to Caryophyllaceae and shows affinites with *Arenaria* and *Silene* (Selling, 1946; Mittre & Gupta, 1964).

Type locality: Cliff section, Warkalli
Age: Miocene

Genus *Polyporina* (NAUMOVA) POTONIE 1960
Type species: *P. multistigmosa* PONTOIE 1960
Polyporina globosa SAH 1967
(Plate IV—97-98)

Remarks: The fossil pollen is related to Amaranthaceae-Chenopodiaceae complex. The affinities with Chenopodiaceae seem to be likely. This pollen type is known to occur from the Oligocene onwards in India (Kar, 1985).

Genus *Clavaperiporites* RAMANUJAM 1966
Type species: *C. jacobi* RAMANUJAM 1966
(Plate IV—99)

Remarks: Thymelaepollis Sah and Kar (1970) and *Buxaceaepollenites* Sah (1967) may constitute junior synonyms of *Clavaperiporites*. Crotonoid pattern of sculpture is mostly encountered in Thymeliaceae, Buxaceae and some members of Euphorbiaceae. In Euphorbiaceae, the polleng types with crotonoid pattern are inaperturate (Erdtman, 1952; Bonnefille, 1971 a, b). The fossil pollen shows affinities with *Wikstroemia* of Thymeliaceae (Selling, 1947).

Genus *Ornatetradites* RAO & RAMANUJAM 1982
Type species: *O. droseroides* RAO & RAMANUJAM 1982
(Plate IV—100)
Ornatetradites droseroides RAO & RAMANUJAM 1982
Ornatetradites chandge RAO & RAMANUJAM 1982
(Plate IV—101-102)

Remarks: The fossil pollen is referable to Drosera of Droseraceae (Chanda, 1965; Raj, 1970). This pollen type has been encountered in various samples from the Warkalli and Cannanore areas. The pores usually obscured by the sculptural element may be seen clearly in Fig. 100.

Genus *Droseridites* (COOKSON) POTONIE
Droseridites spinosa COOKSON 1947
(Plate IV—103)

Remarks: The tetrads are in the size range of 45-60 μm, with the individual grains 25-28 x 30-35 μm. No distinct apertures could be seen. *Droseridites parvus* from the Tertiary of Assam (Dutta & Sah, 1970) is much smaller with sparsely distributed spinules.

The fossil pollen is referable to Droseraceae.

In addition to the above palynomorphs, the author has also recorded in the present study the following spore and pollen taxa. Some of these taxa, however, were already reported from the Warkalli beds in an earlier study by Ramanujam (1972) and Srisailam and Ramanujam (1982).

Pteridophytes:

Verrucosisporites dakshinensis, Crassoretitriletes van-raadshooveni, Microfoveolatosporis polyaperturata, Schizaeoisporites digitation digitatoides, S. minutus, S. grandiformis, S. grandistriatus, Foveosporites miocenicus, and P. perverrucatus.

Angiosperms:

Spinizonocolpites quilonensis, Longa-pertites klinkenbergii, Quilonipollenites sahnii, Q. ornatus, Dicolpopollis microreticulatus, Warkallipollenites erdtmanii,

Retitricolpites dipterocarepoides, Bacubrevitricolpites rotundus, Marginipollis kutchensis, Bombacacidites minutus, Compositoipllenites argutus, Hippocrateaceaedites quilonensis, Paliaeocoprosmadites keralensis, Margocolporites oligobrochatus, Sapotaceoidae pollenites ratnami, Trilatiporites erdtmanii, Anacolosidites luteoides, and Monoporopollenites sp.

DISCUSSION

Floristic analysis: The palynoflora of the Warkalli sediments recorded in the present study consists of 63 genera and 86 species. Of these, 10 genera and 20 species constitute the pteridophytes and 53 genera and 66 species, the angiosperms. Among the angiosperms, 13 genera and 19 species are referable to the monocotyledons, of which one genus and three species are newly established. The dicotyledonous pollen types are represented by 40 genera and 47 species, of which the newly established taxa include 15 species. There is also one new combination. The author has not encountered any gymnospermous pollen (saccate or non-saccate) in any of the numerous samples studied. Similarly no marine phytoplanktonic elements such as dinocysts or acritarchs were encountered in any of the samples.

The following list enumerates the known botanical affinities of the various spore and pollen taxa of the Warkalli sediments:-

Palynotaxa	Botanical affinities
PTERIDOPHYTES:	
Verrucosisporites	— Lycopodiaceae *(Lycopodium)*
Pteridacidites	— Pteridaceae *(Pteris)*
Crassoretitriletes	— Schizaeaceae *(Lygodium)*
Neyvelisporites	— Schizaeaceae *(Schizaea)*
Schizaeoisporites	— Schizqeaceae *(Schizaea)*
Laevigatosporites	— Polypodiaceae
Polypodiisporites	— Polypodiaceae
ANGIOSPERMS: (Monocotyledons)	
Retipilonapites	— Potamogetonaceae *(Potamogeton)*
Iridacidites	— Iridaceae *(Watsonia)*
Liliacidites magnnus	— Agavaceae
Palmaepollenites	— Palmae
Arecipites	— Palmae
Clavapalmaedites	— Palmae *(Oncosperma, Ceroxylon)*
Paravuripollis	— Palmae *(Salaca)*
Longapertites	— Palmae
Spinizonocolpites	— Palmae *(Nypa)*
Quilonipollenites	— Palmae *(Eugeissona)*
Disulcipollis	— Palmae *(Metroxylon)*
Dicolpopollis	— Palmae *(Calamus)*
Trilatiporites	— Palmae *(Sclerosperma)*
Monoporopollenites	— Graminae
ANGIOSPERMS: (Dicotyledons)	
Warkallipollenites	— *Plumbaginaceae*
Ctenolophonidites	— *Ctenolophonaceae (Ctenolophon)*
Heterocolpites	— Combretanceae *(Lumnitzera)*
Retistephanocolpites	— Labiatae
Clavatricolporites	— Aquifolianceae *(Ilex)*
Rhoipites anacardioides	— Anacardiaceae *(Melanorrhoea)*
Psilatricolporites operculatus	— Euphorbiaceae *(Alchornea)*
Retitricolporites operculatus	— Menispermaceae *(Cissampelos, Cocculus)*
Clavatricolporites brevicolpatus	— Aquifoliaceae *(Ilex)*
Retitricolporites variabills	— Vitaceae *(Leea)*
Retitricolporites rhombicus	— Rutaceae *(Fagaropsis)*
Compositoipollenites	— Compositae
Hippocrateaceaedites quilonensis	— Hippocrateaceae
Symplocoipollenites	— Symplocaceae *(Symplocos)*
Lacrimapollis	— Tiliaceae *(Brownlowia)*
Margocolporites	— Caesalpiniaceae *(Caesalpinia, Peltophorum)*
Palaeocoprosmadites	— Rubiaceae *(Coprosma)*
Loranthipites	— Loranthaceae *(Dendrophthoe)*
Bombacacidites	— Bombacaceae
Myrtaceidites	Myrtaceae *(Eugenia Sizygium)*
Sapotaceoidaepollenites	— Sapotaceae *(Madhuca, Manilkara)*
Psilastephanocolporites keralensis	— Polygalaceae *(Xanthophyllum)*
Diporites orassiporatus	— Apocyanaceae
Retitiriporites quilonensis	— Rubiaceae *(Randia)*
Verrutriporites perverrucatus	— Sonneratiaceae *(Duabanga)*
Haloragacidites	— *Haloragaceae (Myriophyllum)*
Florschuetzia of F.levipoli	— Sonneratiaceae *(Sonneratia)*
Triporopollenites minutus	— Moraceae *(Artocarpus)*
Cricotriporites	— Rubiaceae
Myricaceoipollenites	— Myricaceae
Anacolosidites	— Olacaceae *(Anacolosa)*
Caryophyllidites	— Caryophyllaceae
Polyporiba	— Chenopodiaceae
Clavaperiporites	— Thymeliaceae *(Wikstroemia)*
Ornatetradites	— Droseraceae *(Drosera)*
Droseridites	— Droseraceae

The following may be considered as the characteristic spore and pollen taxa of the terrigenous Warkalli beds viz., *Polypodiisporites, Neyvelisporites, Schizaeoisporites, Retipilonapites, Palmaepollenites, Paravuripollis, Dicolpopollis, Quilonipollenites, Warkallipollenites, Ctenolophonidites, Psilatricolporites, Retitricolporites, Clavatricolporites, Lacrimapollis, Compositoipollenites, Margocolporites, Bombacacidites, Myrtaceidites, Sapotaceoidaepollenites, Heterocolpites, Retitriporites, Verrutriporites, Trilatiporites, Ornatetradites, and Polyporina.*

PALYNOASSEMBLAGE OF QUILON AND WARKALLI FORMATIONS- A COMPARATIVE STUDY

During the recent years detailed palynological studies were made on the outcrops of the Quilon Formation at Padappakkara, Paravur and Edva localities in the southern part of Kerala (Rao & Ramanujam, 1975, 1978, 1982; Ramanujam, Srisailam & Reddy, 1981; Kar & Jain, 1981; Ramanujam, 1982). These studies resulted in the documentation of numerous floristically, stratigraphiccaly and palaeoenvironmentally significant spore and pollen taxa of pteridophytes and angiosperms. In addition to these, the Quilon beds also yielded many fungal sporomorphs (Ramanujam & Rao, 1976). As the marine Qui-

lon and fluviatile and lacustrine Warkalli beds constitute the lithic sequence of the Kerala Tertiary (Miocene), a comparison of their palynoassemblages would be highly desirable in evaluating the palynological and concomitantly the stratigraphic kinship of these beds.

A critical comparison of the microfloral assemblages of the Quilon and Warakalli formations indicates in no uncertain manner the remarkable similarity between them, which incidentally highights the prevalence of the same floristic complex at the time of the deposition of the Quilon and Warakalli sequence of beds.

Listed below are the various genera and species common to both the Quilon and Warakalli formations.

Pteridophyte :

Verrucosisporites dakshinensis, Pteridacidites, Crassoretitriletes, Foveosporites miocenius, Microfoveolatosporis polyaperturata, Schizaeoisporites minimus, S. grandiformis, S. grandistriatus, S. digitatoides, Laevigatosporites ovatus, Polypodiiporites impariter, P. ratnami, P. ornatus, P. miocenicus and *P. perverrucatus.*

Angiosperm :

Retipilonapites tertiaris, Palmaepollenites neyveliensis, Arecipites, Paravuripollis mulleri, Clavapalmaedites hammenii, Longapertites hammenii, L. klinkenbergii, Spinizonocolpites quilonensis, Quilonipollenites sahnii, Q. ornatus, Dicolpopollis elegans, D. microreticulatus, Retitricolpites dipterocarpoides, Bacubrevitricolpites rotundus, Marginipollis kutchensis, Psilatricolporites, Retitricolporites, Ctenolophonidites costatus, Heterocolpites combretoides, Compositoipollenites argutus, Bombacacidites minutus, Hippocrateaceaedites quilonensis, Margocolporites tsukadai, M. oligobrochatus, Symplocolpollenites, Sapotaceoidaepollenites africanus, S. neyveliensis, Meliapollis quilonensis, Palaeocoprosmadites keralensis, Lorathipites elegans, Cupaniedites, Retitriporites quilonensis, Verrutriporites perverrucatus, Triporopollenites minutus, Haloragacidites, Anacolosidites luteoides, Myricaceoipollenites, Clavaperiporites jacobi, Ornatetradities droseroides, O. chandae and *Droseridites.*

The stratigraphically important (Miocene) elements common to both the Quilon and Warkalli formations are viz., the heavily ornamented *Polypodiisporites* (common), *Crassoretitriletes, Pteridacidites, Quilonopollenites, Compositoipollenites, Retitriporites, Retitricolpites dipterocarpoides, Bombacacidites, Hippocrateacedites,* and *Monoporopollenites.* Kar and Jain (1981) recently recorded the species of *Striatriletes (= Magnastriatites)* and the pollen of *Jandufouria,* which are also of stratigraphic importance. To these may be added the common occurrence of the pollen of Caesalpiniaceae, Sapotaceae and Rubiacae. Palynology indicates an Early to Middle Miocene age to both the Quilon and Warakalli deposits (see Ramanujam, 1982).

It is only in the relative frequency of some palynomorphs that there are some minor differences between the Quilon and Warakalli formations. Thus, the frequently of palm pollen is found to be higher in the Quilon than in the Warkalli beds. It may be noted pertinently that dinocysts and acritarchs copious in a number of calcareous samples of the quilon formation were not encountered in any of the Warkalli sediments. One may justifiably conclude that both the Warkalli and Quilon formations are characterized by essentially the same palynoflora which incidentally testifies to more or less the same geological age of both these. As mentioned earlier by the author (Ramanujam, 1982), the difference between these formations is more of a facies expression than of a temporal significance. Dutta (1981) states that the Quilon and Warkalli formations seem to record a continuous sequence of sedimentation and so can be regarded as constituting one group. The overall palynoflora of the Quilon Formation reflects the transgressive phase, while that of the Warkalli Formation, suggests the regressive phase of the oscillatory movements of the sea along the kerala coast.

COMPARISON WITH NEYVELI MICROFLORA OF TAMIL NADU

The Neyveli lighnite deposit of the South Arcot district, Tamil Nadu has yielded a rich and well preserved assemblage of a variety of palynomorphs and fungal remains (Thiergart & Frantz, 1962, Ramanujam, 1963, 1966, 1966-67; Deb, 1972; Navale & Mishra, 1979; Ramanujam, Srisailam & Reddy, 1981; Ramanujam, Reddy & Sarma, 1984; Sarma Reddy & Srisoilam, 1984). Ramanujam and Reddy (1984) recently provided an analysis of the Neyveli palynoflora,

The predominance of Schizaeaceae and polypodiaceae spore types among the pteridophytic elements is shared by both the Neyveli and Warkalli palynofloras. In both these palynofloras, the gymnospermous elements are conspicuous by their absence. A number of fruit bodies referable to the epiphyllous microthriaceous complex viz., *Callimothallus, Parmathyrites, Paramicrothallites, Haplopeltis, Euthyrites, Plochmopeltinites* and *Trichopeltinites* are common to both the Neyveli and Warkalli deposits (Ramanujam & Rao, 1973 a; Rao & Ramanujma, 1976; Reddy, 1981; Reddy, Ramanujam & Srisailam, 1982). Further, there are an appreciable number of angiospermous pollen types common to both these deposits. The following are the more significant taxa in this connection:-

Retipilonapites, Quilonipollenites, Clavapalmaedites, Disulcipollis, Paravuripollis, Trilatiporites, Retitricolpites dipterocarpoides, Palaeocoprosmadites, Warkallipollenites, Marginipollis, Ctenolophonidites, Heterocolpites, Hippocrateaceaedites, Margocolporites, Symplocoipollenites, Lacrimapollis (= Intratriporopollenites), Bombacacidites, Retitriporites, Haloragacidites, Anacolosidites, Polyporina, Clavaperiporites and

Ornatetradites.

The above comparison clearly highlights an imposing degree of palynological similarity between the Neyveli and Warkalli deposits, which the author considers, an unequivocal expression of temporal congruity and stratigraphic correlatability of these deposits.

PALAEOENVIRONMENTAL CONSIDERATIONS.

The palynoflora of the Warkalli sediments clearly points towards a tropical humid climate with heavy precipitation during the Lower to Middle Miocene of Kerala. The recognition of the spore and pollen types of the following families is meanigful in this connection, viz., Schizaeaceae, Polypodiaceae, Pteridaceae, Palmae, Sonneratiaceae, Bombacaceae, Sapotaceae, Spindaceae, Anacardiaceae, Caesalpiniaceae. Combacaceae, Hippocrateaceae, Ctenolophonaceae, Dipterocarpaceae, Olacaceae, Myrtaceae and Moraceae. The abundance of ferns such as Schizaeaceae and Polypodiaceae and the occurrence of pollen referable to Dipterocarpaceae (*Retitricolpites dipterocarpoides,), Ctenolophonaceae (Ctenolophonidites), Anacolosa of* Olacaceae *(Anacolosidites), Artocarpus* of Moraceae *(Triporopollenites minutus),* Melanorrhoea of Anacardiaceae *(Retitricolporites anacardioides), Duabanga* of Sonneratiaceae (*Verrutriporites perverrucatus),* and *Alchornea* of Euphorbiaceae (*Psilatricolporites operculatus)* particularly point towards heavy precipitation. The earlier record of various epiphyllous microthyriaceous fungi (Ramanujam & Rao, 1973 a; Rao & Ramanujam, 1976) is again indicative of heavy rainfall. The present day climate of Kerala is also of tropical humid type with heavy precipitation. We are, therefore, prompted to visualize that since the Miocene age the same climatical pattern prevailed in this region.

The flora unravelled shows that it was essentially confined to the depositional basin and its immediate vicinity. The few pollen types of the subtropical families such as Aquifoliaceae, Myricaceae, Thymeliaceae and Symplocaceae could possibly have had their source in the mountainous terrain near by.

The record of pollen referable to *Nypa, Brownlowia, Sonneratia, Avicinnia* and *Lumnitzera* indicates the prevalance of mangrove swamps. The earlier record of fungal spores related to the modern brackish (to marine) hyphomycetous taxon *Cerrenalia* from the Cannanore area (Ramanujam & Srisailam, 1978) lends credence to the occurrence of a few local pockets of brackish influence during the deposition of the Warkalli sediments.

The occurrence of spore and pollen types related to the freshwater swamp and water edge elements such as *Schizaea, Potamogeton, Myriophyllum, Ctenolophon, Anacolosa* and Plumbaginaceae shows the presence of ponds, lakes, streams and other fresh water expansions away from the mangrove belt. The palynological studies indicate clearly that the Warkalli beds constitute the continental and locally brackish equivalents of the marine Quilon beds.

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EXPLANATION OF PLATES

(Unless otherwise mentioned all Figs. x 1000)

PLATE I

1. *Pteridacidites rotundus*
2,3. *Neyvelisporites bolkhovitinai*
4. *Schizaeoisporites phaseolus* X 750
5,7. *Polypodiisporites impariter*
6. *P. ratnami*
8. *P. turbinatus*
9,10. Spinascent monolete spore type x 750
11. *Retipilonapites tertiaris*
12. *Palmaepollenites kutchensis*
13. *Arecipites magnus* n. sp.
14,15. *Iridacidites warkalliensis* n. Gen., n. sp. (Holotype)
16. *I. plicatus* n. sp. (Holotype)
17,18. Monosulcate plicate pollen type
19. *Liliacidites magnus* n. sp. (Holotype)

PLATE II

20. *Paravuripollis mulleri*
21,22. *Clavapalmaedites hammenii*
23,24. *Longapertites hammenii*

25. *Spinizonocolpites spinulatus* n. sp. (Holotype)
26. *Disulcipollis cuddalorense*
27. *Dicolpopollis elegans*
28. *Psilatricolporites operculatus*
29-30. *Clavatricolporites brevicolpatus* n. sp. (Holotype)
32-34. *Warkallipollenites thanikaimonii* n. sp. (Holotype)
35. *Stephanocolpites arcotense*
36,37. *Ctenolophonidites costatus*
38-40. *Retistephanocolpites neogenicus* n. sp. (Holotype Fig. 39,40)
41,42. *Heterocolpites combretoides*

PLATE III

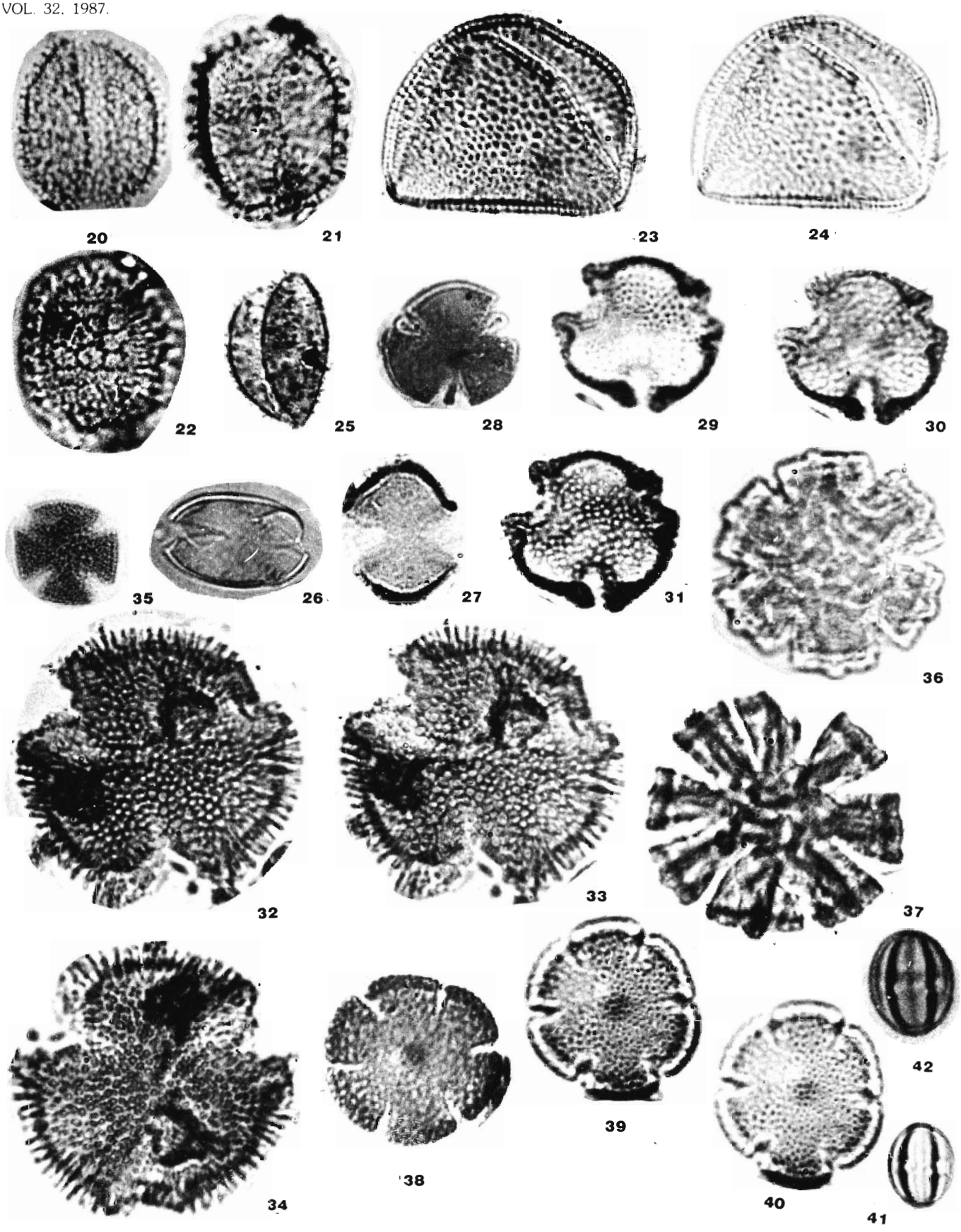
43. *Psilatricolporites truncatus* n. sp. (Holotype)
44. *Rhoipites* sp.
45-47. *Rhoipites anacardioides* n. sp. (Holotype Fig. 45,46)
48,49. *Retitricolporites rhombicus* n. sp. (Holotype)
50. Retibrevitricolporate pollen type.
51. *Psilatricolporites* sp.
52. *Retitricolporites* sp.
53. *Retitricolporites operculatus* n. sp.(Holotype)
54,55. *Retitricolporites variabilis* n. sp. (Holotype)
56,57. Retitricolporate curvimurate pollen type
58-60. *Compositoipollenites minimus* n. sp. (Holotype Fig. 58,59)
61. *Symplocolpollenites baksii* n. sp. (Holotype)
62,63. *Lacrimapollis brownlowioides* n. sp. (Holotype)
64. *Margocolporites tsukadai*
65,66. *Loranthipites elegans*
67. *Loranthipites* sp.
68-70. *Myrtacidites eugenioides*
71,72. *Cupaniedites cooksonii* n. sp. (Holotype)

PLATE IV

73,74. *Sapotaceoidaepollenites africanus*
75,76. *S. neyveliensis*
77. *Meliapollis quilonensis.*
78. *Psilastephanocolporites keralensis* n. sp. (Holotype)
79. *Diporites crassiporatus* n. sp. (Holotype)
80,81. Diporate verrucate pollen type
82. *Retitriporites quilonensis* n. comb.
83. *Retitriporites* sp.
84. *Verrutriporites lunduensis*
85. *V. perverrucatus*
86,90 *Haloragacidites* sp.
87,88. *Florschuetzia* sp. cf. *F. levipoli*
89, 90. *Triporopollenites minutus*
91. *Trilatiporites truncatus*
92. *Trilatiporites* sp.
93. *Cricotriporites camerouensis*
94. *Myricaceoipollenites* sp.
95,96. *Cryophyllidites warkalliensis* n. sp. (Holotype) x 750
97,98. *Polyporina globosa* x 750
99. *Clavaperiporites jacobii*
100. *Ornatetradites chandae*
101,102. *Ornatetradites droseroides*
103. *Droseridites spinosa.*

Plate I

RAMANUJAM.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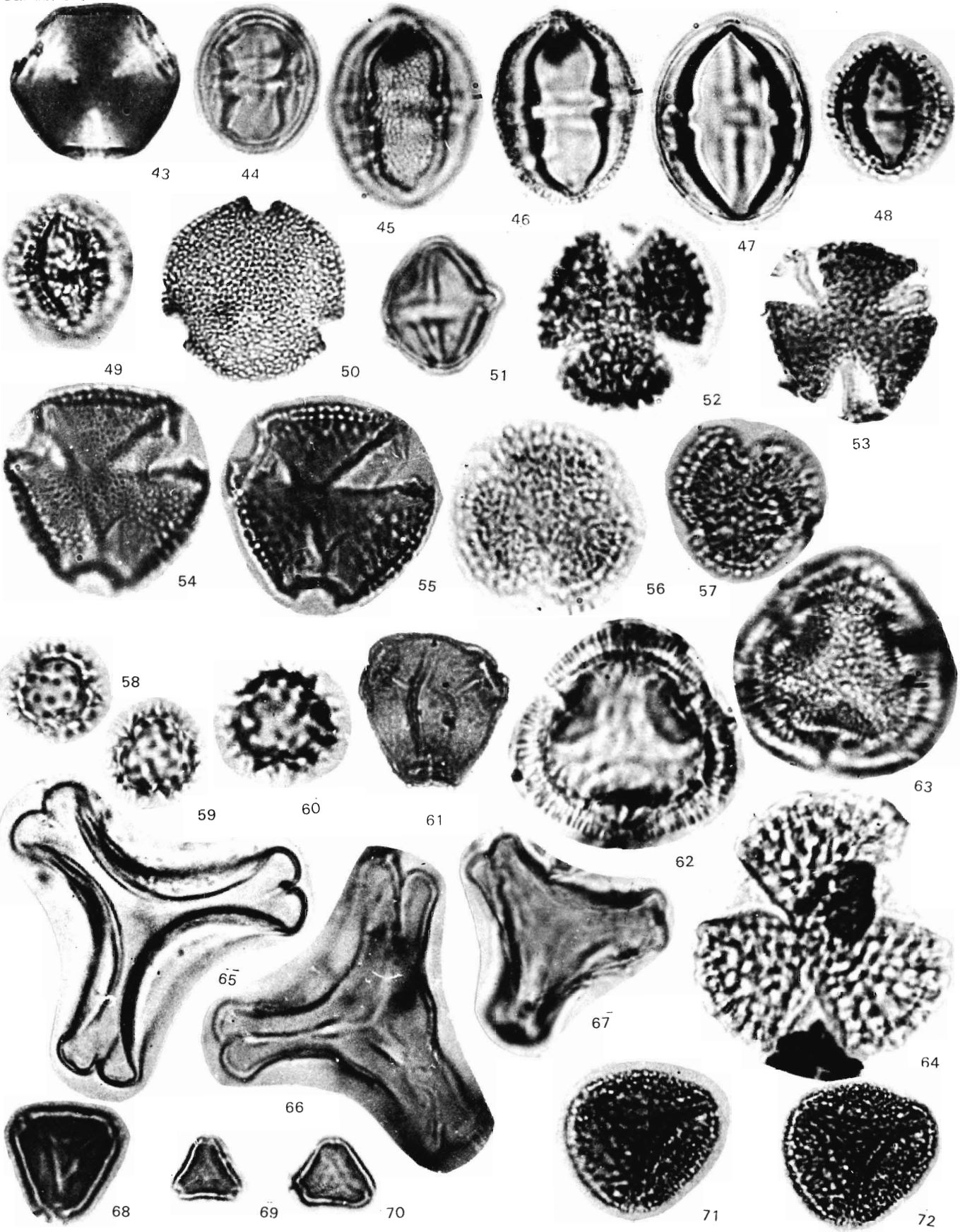
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