Palynological investigation of Arthungal bore-hole, Alleppey District, Kerala

M. R. Rao

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Palynological assemblage from the Arthungal bore-hole (Alleppey District, Kerala) consists of 49 genera and 65 species of pteridophytic spores and angiospermous pollen. Dinoflagellate cysts and fungal remains have also been reported. *Liliacidites keralaensis* and *Jacobipollenites arthungalensis* have been established as new species. The palynological succession has been divided into three cenozones, viz., *Triangulorites bellus* Cenozone, *Crassoretitriletes vanraadshooveni* Cenozone and *Malvacearumpollis bakonyensis* Cenozone. Palynological data depict a warm and humid tropical climate with plenty of rainfall during the time of deposition. Palynofossils belonging to lowland, fresh water swamp and water edge, back mangrove and coastal floras have been identified. Palynological succession ranges from Eocene-Early Miocene in age.

Key-words—Palaeopalynology, Palaeoecology, Eocene-Early Miocene (India).

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

सारांश

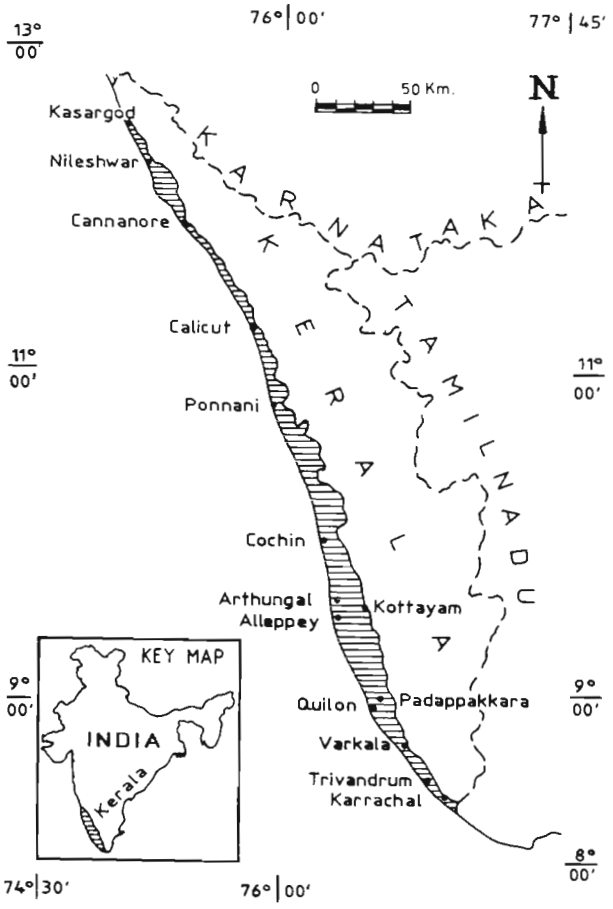
केरल में अॅलेप्पी जनपद में आरथुंगल वेधछिद्र का परागाणविक अन्वेषण

मुलागलापल्ली रामचन्द्र राव

आरथुंगल वेध-छिद्र (अॅलेप्पी जनपद, केरल) से प्राप्त परागाणविक समुच्चय में टेरीडोफाइटी बीजाणुओं एवं आवृतबीजी परागकणों की 49 प्रजातियाँ एवं 65 जातियाँ मिली हैं। **लिलिएसीडाइटिस केरलायेन्सिस** एवं **जेकबिपोलिनाइटिस आरथुंगलेन्सिस** नामक नई जातियाँ बनाई गई हैं। परागाणविक अनुक्रम तीन नवमंडलों में विभक्त किया गया है। ये **ट्राइएंगुलोराइटिस बैल्लस** नवमंडल, **क्रेसोरेटिट्राइलिटीस वानराडशूवेनाई** नवमंडल एवं **माल्वेसियरमपॉलिस बेकॉनयेन्सिस** नवमंडल हैं। उपलब्ध परागाणविक आँकड़े निक्षेपण के समय अत्याधिक वर्षा के साथ-साथ उष्ण एवं नम उष्णकटिबन्धीय जलवायु प्रदर्शित करते हैं। निम्नभूमि, स्वच्छ जल वाली दलदल, पश्च मैंग्रोव एवं तटीय वनस्पतिजात के अश्मित परागकण अभिनिर्धारित किये गये हैं। उपलब्ध परागाणविक अनुक्रम आदिनूतन से प्रारम्भिक मध्यनूतन काल तक विस्तृत है।

PALYNOFOSSILS have been recovered from Arthungal (9° 39″ 32 : 76° 17″ 50) bore-hole (440.70 m depth) in Alleppey District, Kerala (Map 1) The area is covered by coastal alluvium composed of sand and sandy clay. This is underlain by a sequence of alternating beds of clays and sandstones with band of lignite. The lithological details of the samples are as follows:

	Depth/range in m	Lithology
1	430.70-442.70	Carbonaceous sand
2.	418.70-430.70	Clayey sand
3.	412.70-418.70	Clayey sand
4.	409.70-412.70	Clayey sand
5.	379.70-409.70	Clayey sand
6.	322.70-379.70	Carbonaceous sand
7	274.70-322.70	Coarse carbonaceous sand
8.	271.70-274.70	Clayey sand
9.	268.70-271.70	Lignite
10.	241.70-268.70	Carbonaceous sandy clay
11	205.70-241.70	Carbonaceous sandy clay
12.	157.70-205.70	Sandy clay
13.	151.70-157.70	Sandy clay
14.	142.70-151.70	Clayey sand
15.	124.70-142.70	Clayey sand
16.	100.70-124.70	Clayey sand
17	91.70-100.70	Clayey sand
18.	76.70- 91.70	Clayey sand
19.	46.70- 76.70	Sand
20.	31.70- 46.70	Clayey sand
21.	22.70- 31.70	Carbonaceous clayey sand
22.	16.70- 22.70	Sand
23.	7.70- 16.70	Sandy clay
24.	0.00- 7.70	Coarse sand



Map 1—Localities of Tertiary exposures in Kerala Basin.

The Tertiary sediments of Kerala coast are known as Warkalli and Quilon beds; they were first described by King (1882) and Foote (1883). The Quilon beds consist of fossiliferous limestones with intercalations of calcareous clays, carbonaceous clays and sands, while the Warkalli beds include variegated sandstone interbedded with white plastic and variegated clays, carbonaceous clays and seams of lignite or peaty lignite. The Tertiary sequence rests unconformably over the Archean crystalline complex and is succeeded by recent to subrecent marine and estuarine sediments (Poulose & Narayanaswami, 1968).

Palynological studies of the Tertiary sediments of Kerala have been done by Rao and Vimal (1953), Potonié and Sah (1960), Ramanujam (1977), Ramanujam and Rao (1971), Rao and Ramanujam (1978, 1982), Kar and Jain (1981), Varma, Ramanujam and Patil (1986) and Varma (1987). Raha, Rajendran and Kar (1987) for the first time reported Eocene-Early Miocene palyno-assemblages from 600 metres deep bore-hole near Ambalapuzha in Alleppey District, Kerala.

Out of 24 samples, 18 are productive. The palynofossils include 49 genera and 65 species of pteridophytic spores and angiospermous pollen. Dinoflagellate cysts and fungal remains are also present. The slides and negatives are deposited at the Birbal Sahni Institute of Palaeobotany, Lucknow.

The following spore-pollen species are present

PLATE 1 →

(All photomicrographs *ca.* × 500; Coordinates on Olympus Microscope no. 217267, BH. 2).

1, 2. *Liliacidites keralaensis* sp. nov., Slide no. BSIP 9909; Coordinates: 15.5 × 162.9 (Holotype); 19.3 × 136.5.
3. *Retipilonapites arcotense* Ramanujam, Slide no. BSIP 9910; Coordinates: 15.7 × 163.6.
4. *Longapertites hammenii* Rao & Ramanujam, Slide no. BSIP 9911; Coordinates: 8.5 × 143.8.
5. *Palmaepollenites kutchensis* Venkatachala & Kar, Slide no. BSIP 9912; Coordinates: 20.0 × 130.6.
6. *Palmaepollenites eocenicus* (Biswas) Sah & Dutta, Slide no. BSIP 9913; Coordinates: 8.8 × 145.2.
7. *Polypodiaceaesporites intrapunctis* Rao & Ramanujam, Slide no. BSIP 9914; Coordinates: 20.5 × 151.5.
8. *Laevigatosporites ovatus* Wilson & Webster, Slide no. BSIP 9915; Coordinates: 16.4 × 165.2.
9. *Clavainaperturites clavatus* v.d. Hammen & Wijmstra, Slide no. BSIP 9916; Coordinates: 8.5 × 163.6.
10. *Palmidites maximus* Couper, Slide no. BSIP 9913; Coordinates: 6.5 × 126.5.
11, 12. *Cheilanthoidspora monoleta* Sah & Kar, Slide nos. BSIP 9917; Coordinates: 8.5 × 127.8; 9918, coordinates 12.0 × 138.1
13. *Cheilanthoidspora mioceneca* Kar & Jain, Slide no. BSIP 9919; Coordinates: 20.0 × 141.2.
14. *Inaperturopollenites* sp. cf. *I. punctatus* Saxena & Bhattacharyya, Slide no. BSIP 9911; Coordinates: 10.1 × 133.7
15. *Palmaepollenites keralensis* Rao & Ramanujam, Slide no. BSIP 9920; Coordinates: 11.5 × 129.6.
16. *Quilonipollenites sahnii* Rao & Ramanujam, Slide no. BSIP 9921; Coordinates: 6.0 × 138.6.
17. *Polypodiisporites ratnamii* Rao & Ramanujam, Slide no. BSIP 9922; Coordinates: 11.2 × 135.0.
18. *Polypodiisporites miocenicus* Rao & Ramanujam, Slide no. BSIP 9923; Coordinates: 10.0 × 162.8.
19. *Crassoretitriletes vanraadshooveni* Germeraad *et al.*, Slide no. BSIP 9924; Coordinates: 18.5 × 152.3.
20, 21. *Lygodiumsporites padappakkarensis* Rao & Ramanujam, Slide nos. BSIP 9913; Coordinates: 10.0 × 138.6, 9916; Coordinates: 8.7 × 133.0.
22. *Intrapunctisporis intrapunctis* Krutzsch, Slide no. BSIP 9925; Coordinates: 21.5 × 163.4.
23. *Osmundacidites kutchensis* Sah & Kar, Slide no. BSIP 9913; Coordinates: 19.0 × 161.7.
24. *Verrucosisporites* sp., Slide no. BSIP 9926; Coordinates: 18.0 × 158.0.
25, 26. *Neocouperipollis (Couperipollis) kutchensis* (Venkatachala & Kar) Kar & Kumar, Slide nos. BSIP 9927; Coordinates: 15.5 × 164.5; 9925; Coordinates: 19.0 × 157.5.
27. *Foveotriletes* sp., Slide no. BSIP 9925; Coordinates: 8.7 × 167.7.
28. *Striatriletes susannae* v.d. Hammen emend. Kar, Slide no. BSIP 9928; Coordinates: 21.4 × 141.4.

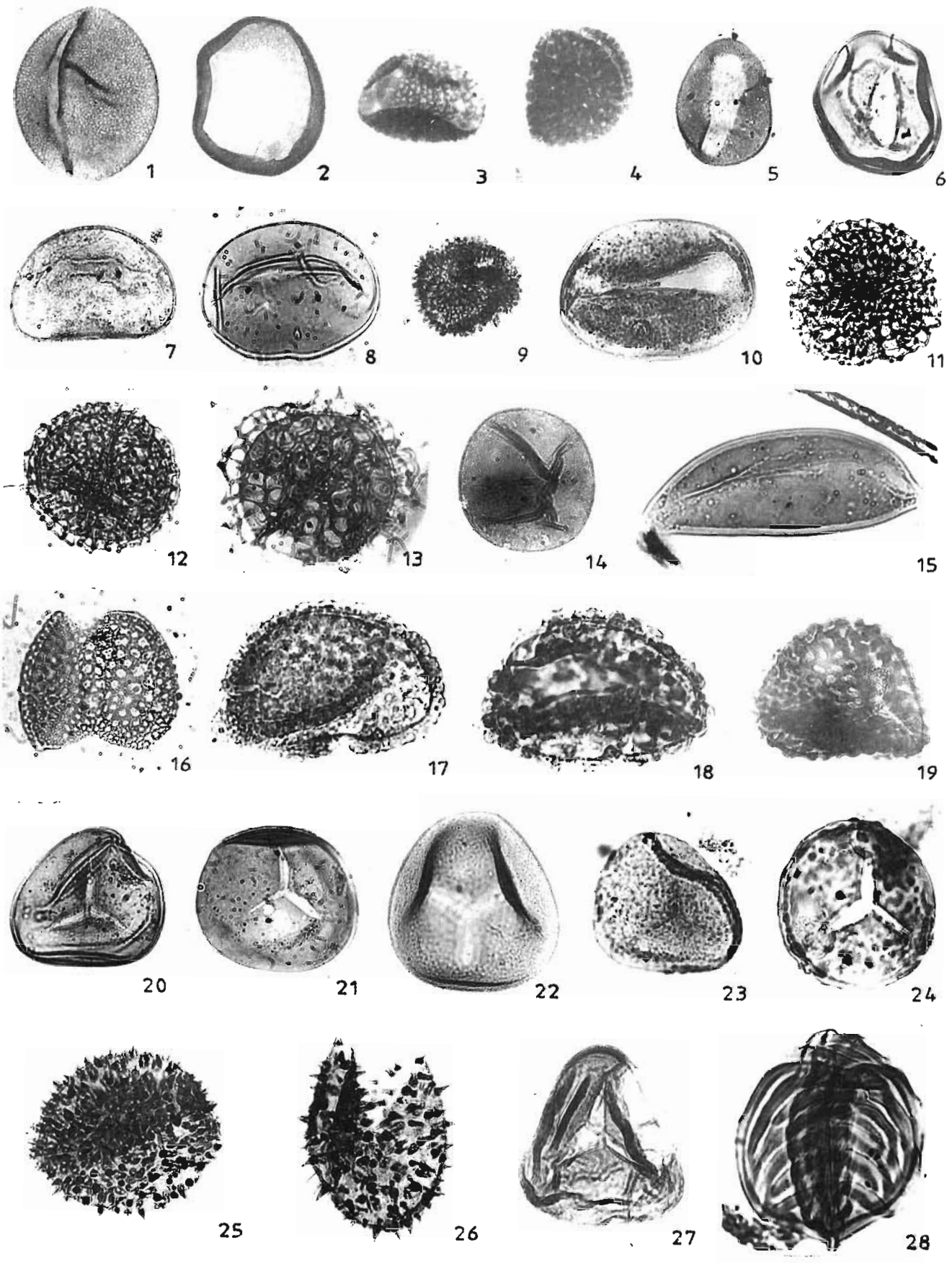


PLATE 1

in the assemblage Palynotaxa marked with asterisks (*) are described in the text. The botanical affinities of the spore-pollen are given below:

Schizaeaceae—Lygodiumsporites padappakkarensis Rao & Ramanujam 1978 (Pl. 1, figs 20, 21), *Crassoretitriletes vanraadshooveni* Germeraad, Hopping & Muller 1968 (Pl. 1, fig. 19, Pl. 3, fig. 26).

Osmundaceae—Osmundacidites kutchensis Sah & Kar 1969 (Pl. 1, fig. 23).

Parkeriaceae—Striatriletes susannae van der Hammen emend. Kar 1979 (Pl. 1, fig. 28).

Polypodiaceae—Laevigatosporites ovatus Wilson & Webster 1946 (Pl. 1, fig. 8), *Polypodiaceaesporites intrapunctis* Rao & Ramanujam 1978 (Pl. 1, fig. 7), *Polypodiisporites miocenicus* Rao & Ramanujam 1978 (Pl 1, fig. 18), *P ratnamii* Rao & Ramanujam 1978 (Pl. 1, fig. 17).

Potamogetonaceae—Retipilonapites arcotense Ramanujam 1966 (Pl. 1, fig. 3), *Clavainaperturites clavatus* van der Hammen & Wijmstra 1964 (Pl 1, fig. 9).

Palmae—Palmidites maximus Couper 1953 (Pl. 1, fig. 10), *Palmaepollenites eocenicus* (Biswas) Sah & Dutta 1966 (Pl. 1, fig. 6), *P kutchensis* Venkatachala & Kar 1969 (Pl. 1, fig. 5), *P. keralensis* Rao & Ramanujam 1978 (Pl. 1, fig. 15), *Longapertites hammenii* Rao & Ramanujam 1978 (Pl. 1, fig. 4), *Neocouperipollis kutchensis* (Venkatachala & Kar) Kar & Kumar 1987 (Pl 1, figs 25, 26), *Quilonipollenites sahnii* Rao & Ramanujam 1978 (Pl. 1, fig. 16; Pl. 2, fig. 22), *Trilatiporites noremi* Ramanujam 1966 (Pl. 3, figs 2, 3).

*Liliaceae—*Liliacidites keralaensis* sp. nov. (Pl 1, figs 1, 2).

Oleaceae—Retitrescolpites singularis Rao & Ramanujam 1982 (Pl. 2, fig. 13).

Ctenolophonaceae—Ctenolophonidites costatus van Hoeken Klinkenberg 1966 (Pl. 2, figs 18, 19).

Bombacaceae—Lakiapollis ovatus Venkatachala & Kar 1969 (Pl. 2, fig. 29; Pl. 3, fig. 16).

Euphorbiaceae—Tricolporopollis decoris Dutta & Sah 1970 (Pl. 2, fig. 15).

Meliaceae—Meliapollis ramanujamii Sah & Kar 1970 (Pl. 2, fig. 28), *M. quadrangularis* (Ramanujam) Sah & Kar 1970 (Pl. 2, fig. 3).

Caesalpiniaceae—Margocolporites tsukadai Ramanujam 1966 (Pl. 2, fig. 27), *M. sahnii* Ramanujam 1966 (Pl. 2, figs 5, 6), *Trisyncolpites ramanujamii* Kar 1979 (Pl. 2, fig. 20).

Rubiaceae—Retitricolporites crassioratus Rao & Ramanujam 1982 (Pl. 2, fig. 7), *Favitricolporites magnus* Sah 1967 (Pl. 2, fig. 8).

Polygalaceae—Polybrevicolporites karii Rao & Ramanujam 1982 (Pl. 3, fig. 9).

Apocynaceae—Psilodiporites hammenii Varma & Rawat 1963 (Pl. 3, fig. 5).

PLATE 2 →

(All photomicrographs *ca.* × 500; Coordinates on Olympus microscope no. 217267 : BH2)

1, 2. *Sastriipollenites trilobatus* Venkatachala & Kar, Slide nos. BSIP 9929; Coordinates: 6.0 × 160.4; 9930; Coordinates: 17.5 × 129.0.

3. *Meliapollis quadrangularis* (Ramanujam) Sah & Kar, Slide no. BSIP 9922; Coordinates: 6.0 × 171.0.

4. *Verrutricolpites* sp., Slide no. BSIP 9931; Coordinates: 12.0 × 135.0.

5, 6. *Margocolporites sahnii* Ramanujam, Slide no. BSIP 9932; Coordinates: 16.0 × 139.3.

7. *Retitricolporites crassioratus* Rao & Ramanujam, Slide no. BSIP 9930; Coordinates: 9.3 × 146.0.

8. *Favitricolporites magnus* Sah, Slide no. BSIP 9933; Coordinates: 6.4 × 168.0.

9. *Tricolporopollis rubra* Dutta & Sah, Slide no. BSIP 9919; Coordinates: 14.0 × 154.4.

10. *Polycolpites* sp., Slide no. BSIP 9921; Coordinates: 8.5 × 148.5.

11. *Retistephanocolpites* sp., Slide no. BSIP 9924; Coordinates: 20.0 × 140.2.

12. *Dermatobrevicolporites (Triorites) dermatus* (Sah & Kar) Kar, Slide no. BSIP 9934; Coordinates: 12.3 × 151.0.

13. *Retitrescolpites singularis* Rao & Ramanujam, Slide no. BSIP 9935; Coordinates: 11.0 × 131.5.

14. *Tricolpites retipilatus* Kar & Jain, Slide no. BSIP 9936; Coordinates: 8.3 × 161.5.

15. *Tricolporopollis decoris* Dutta & Sah, Slide no. BSIP 9921; Coordinates: 8.5 × 156.5.

16. *Tricolporopollis* (Venkatachala & Kar) *matanamadhensis* Tripathi & Singh, Slide no. BSIP 9928; Coordinates: 18.0 × 167.0.

17. *Gemmatricolpites* sp., Slide no. BSIP 9926; Coordinates: 16.0 × 130.6.

18, 19. *Ctenolophonidites costatus* (van Hoeken-Klinkenberg) Slide nos. BSIP 9916; Coordinates: 11.0 × 138.5; 9937; Coordinates: 18.5 × 158.4.

20. *Trisyncolpites ramanujamii* Kar, Slide no. BSIP 9915; Coordinates: 10.0 × 136.8.

21. *Tricolpites crassireticulatus* Dutta & Sah, Slide no. BSIP 9916; Coordinates: 9.0 × 155.2.

22. *Quilonipollenites sahnii* Rao & Ramanujam, Slide no. BSIP 9925; Coordinates: 9.0 × 155.2.

23. *Tricolpites retibaculatus* Saxena, Slide no. BSIP 9913; Coordinates: 20.3 × 164.0.

24, 25. *Triangulorites bellus* (Sah & Kar) Kar, Slide nos. BSIP 9929; Coordinates: 4.2 × 147.4; 9923; Coordinates: 14.5 × 137.2.

26. *Tricolpites matanomadhensis* Saxena, Slide no. BSIP 9924; Coordinates: 15.0 × 142.0.

27. *Margocolporites tsukadai* Ramanujam, Slide no. BSIP 9919; Coordinates: 11.6 × 156.9.

28. *Meliapollis ramanujamii* Sah & Kar, Slide no. BSIP 9930; Coordinates: 11.4 × 148.0.

29. *Lakiapollis ovatus* Venkatachala & Kar, Slide no. BSIP 9924; Coordinates: 14.4 × 165.0.

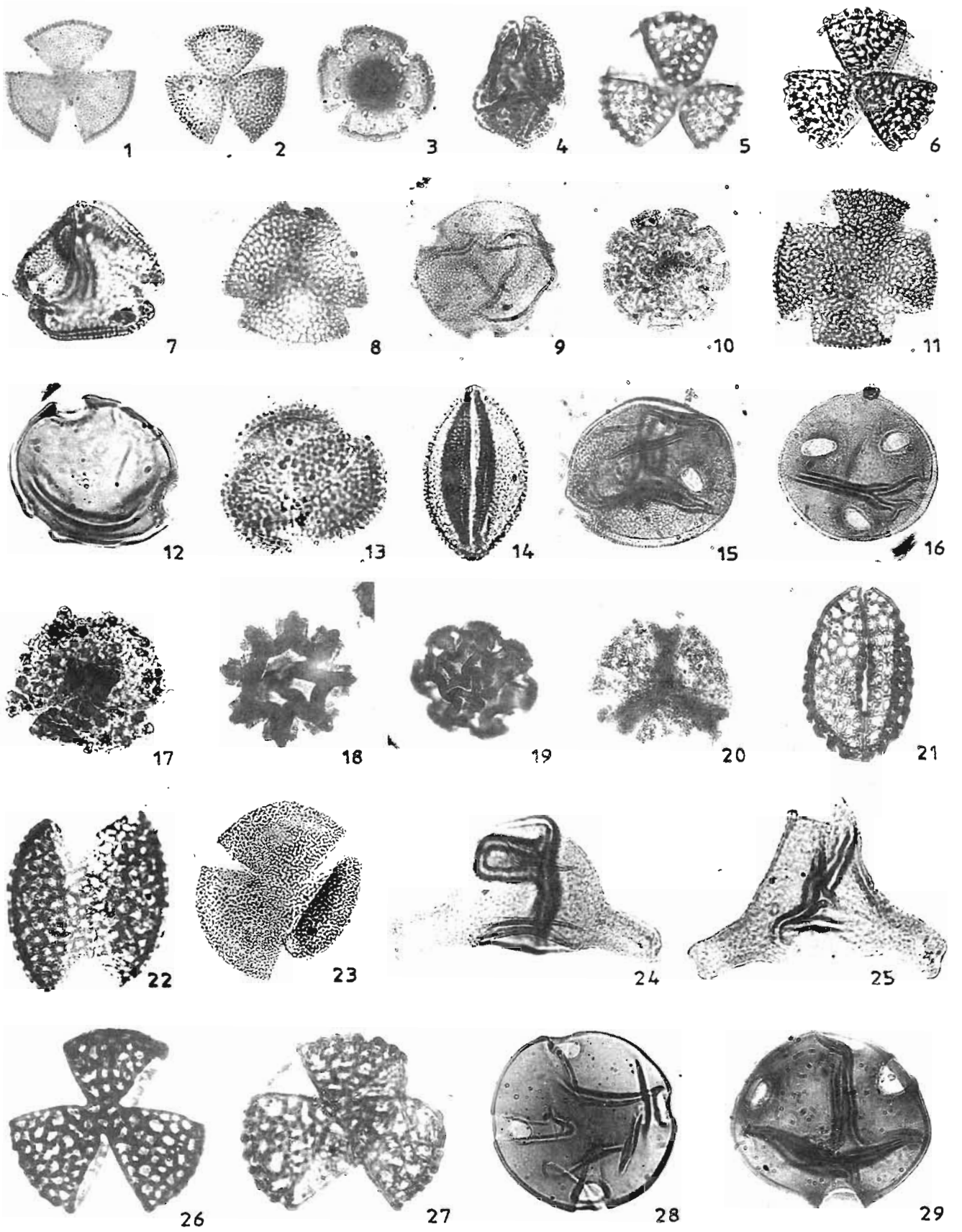


PLATE 2

Moraceae—Triporopollenites minutus Rao & Ramanujam 1982 (Pl. 3, fig. 4).

Proteaceae—Proteacidites triangulus Kar & Jain 1981 (Pl. 3, figs 17, 18), *P truncatus* Rao & Ramanujam 1982 (Pl. 3, fig. 7).

Chenopodiaceae—Chenopodipollis miocenica Kar & Jain 1981 (Pl. 3, fig. 6).

Malvaceae—Malvacearumpollis bakonyensis Nagy 1962 (Pl. 3, figs 22, 23).

Uncertain affinity—Intrapunctisporis intrapunctis Krutzsch 1959 (Pl. 1, fig. 22), *Foveotriletes* sp. (Pl. 1, fig. 27), *Verrucosisporites* sp. (Pl. 1, fig. 24), *Cheilanthoidspora monoleta* Sah & Kar 1974 (Pl. 1, figs 11, 12), *C. mioceneca* Kar & Jain 1981 (Pl. 1, fig. 13), *Inaperturopollenites* sp. cf. *I. punctatus* Saxena & Bhattacharyya 1987 (Pl. 1, fig. 14), *Tricolpites crassireticulatus* Dutta & Sah 1970 (Pl. 2, fig. 21), *T. retibaculatus* Saxena 1979 (Pl. 2, fig. 23), *T matanomadhensis* Saxena 1979 (Pl. 2, fig. 26), *T. retipilatus* Kar & Jain 1981 (Pl. 2, fig. 14), *Tricolpites* sp. (Pl. 3, fig. 21), *Verrutricolpites* sp. (Pl. 2, fig. 4), *Gemmatricolpites* sp. (Pl. 2, fig. 17), *Retistephanocolpites* sp. (Pl. 2, fig. 11), *Polycolpites* sp. (Pl. 2, fig. 10), *Tricolporopollis rubra* Dutta & Sah 1970 (Pl. 2, fig. 9), *T matanamadhensis* Tripathi & Singh 1985 (Pl 2, fig. 16), *Sastriipollenites trilobatus* Venkatachala & Kar 1969 (Pl. 2, figs 1, 2), *Dermatobrevicolporites dermatus* (Sah & Kar) Kar 1985 (Pl. 2, fig. 28), *Retitricolporites* sp. (Pl. 3, fig. 29), *Striacolporites ovatus* Sah & Kar 1970 (Pl. 3, fig. 28), *S. cephalus* Sah & Kar 1970 (Pl. 3, fig. 10), *Verrucolporites verrucus* Sah & Kar 1970 (Pl. 3, fig. 8), **Jacobipollenites arthungalensis* sp. nov. (Pl. 3, figs 11, 24), *Verrutriporites* sp. (Pl. 3, fig. 19), *Triangulorites bellus* (Sah & Kar) Kar 1985 (Pl. 2, figs 24, 25), *Polyporina multiporosa* Kar 1985 (Pl. 3, fig. 1) and *Ornatetradites droseroides* Rao & Ramanujam 1982 (Pl. 3, fig. 27).

The taxa designated as 'sp.' in the check list are distinct and hence could not be assigned to any of the known species. Detailed morphological study of these taxa will be carried out later.

Genus—*Liliacidites* Couper 1953

Type species—*Liliacidites kaitangataensis* Couper 1953

Liliacidites keralaensis sp. nov.
Pl. 1, figs 1, 2

Holotype—Pl. 1, fig. 1, size 65 μm; Slide no. BSIP 9909.

Type locality—Arthungal bore-hole, Alleppey District, Kerala, depth range 322.70-377.70 m.

Diagnosis—Pollen oval-elliptical, size range 60-70 × 34-50 μm, monosulcate, sulcus distinct, 6 μm long, 4 μm wide extending from one end to other; exine up to 3.5 μm thick, sexine ca 2.5 μm, nexine

PLATE 3 →

(All photomicrographs *ca.* × 500; Coordinates on Olympus microscope no. 217267. BH-2)

1. *Polyporina multiporosa* Kar; Slide no. BSIP 9938; Coordinates: 17.0 × 132.2.
2, 3. *Trilatiporites noremi* Ramanujam, Slide no. BSIP 9934, Coordinates: 16.6 × 135.0.
4. *Triporopollenites minutus* Rao & Ramanujam, Slide no. BSIP 9937; Coordinates: 8.0 × 148.1.
5. *Psilodiporites hammenii* Varma & Rawat, Slide no. BSIP 9930; Coordinates: 10.5 × 150.3.
6. *Chenopodipollis miocenica* Kar & Jain, Slide no. BSIP 9939; Coordinates: 15.0 × 156.1.
7. *Proteacidites truncatus* Rao & Ramanujam, Slide no. BSIP 9940; Coordinates: 11.4 × 169.0.
8. *Verrucolporites verrucus* Sah & Kar, Slide no. BSIP 9914; Coordinates: 4.0 × 160.0.
9. *Polybrevicolporites karii* Rao & Ramanujam, Slide no. BSIP 9931; Coordinates: 9.3 × 160.0.
10. *Striacolporites cephalus* Sah & Kar, Slide no. BSIP 9913; Coordinates: 17.4 × 160.0.
11, 24. *Jacobipollenites arthungalensis* sp. nov., Slide no. BSIP 9936; Coordinates: 15.0 × 165.0; 9941; Coordinates: 8.6 × 159.0 (Holotype).
12. *Operculodinium* sp., Slide no. BSIP 9911; Coordinates: 6.3 × 158.0.
13. *Heliospermopsis hungaricus* Nagy, Slide no. BSIP 9937; Coordinates: 7.0 × 165.4.
14. *Lirasporis intergranifer* Potonié & Sah emend. Kar & Jain, Slide no. BSIP 9928; Coordinates: 19.5 × 127.0.
15. *Collumosphaera* sp., Slide no. BSIP 9919; Coordinates: 19.5 × 127.0.
16. *Lakiapollis ovatus* Venkatachala & Kar, Slide no. BSIP 9911; Coordinates: 18.0 × 149.5.
17-18. *Proteacidites triangulus* Kar & Jain, slide no. BSIP 9910; Coordinates: 16.0 × 168.2.
19. *Verrutriporites* sp., Slide no. BSIP 9909; Coordinates: 11.0 × 149.0.
20. *Achomosphaera* sp., Slide no. BSIP 9916; Coordinates: 7.5 × 134.0.
21. *Tricolpites* sp., Slide no. BSIP 9933; Coordinates: 21.5 × 143.6.
22-23. *Malvacearumpollis bakonyensis* Nagy, Slide no. BSIP 9939; Coordinates: 5.0 × 162.0.
25. *Thatlasiphora* sp., Slide no. BSIP 9941; Coordinates: 17.5 × 160.6.
26. *Crassoretitriletes vanraadshooveni* Germeraad *et al.*, Slide no. BSIP 9942; Coordinates: 10.5 × 164.0.
27. *Ornatetradites droseroides* Rao & Ramanujam, Slide no. BSIP 9934; Coordinates: 4.0 × 147.8.
28. *Striacolporites ovatus* Sah & Kar, Slide no. BSIP 9930; Coordinates: 14.0 × 133.0.
29. *Retitricolporites* sp., Slide no. BSIP 9943; Coordinates: 8.5 × 139.0.

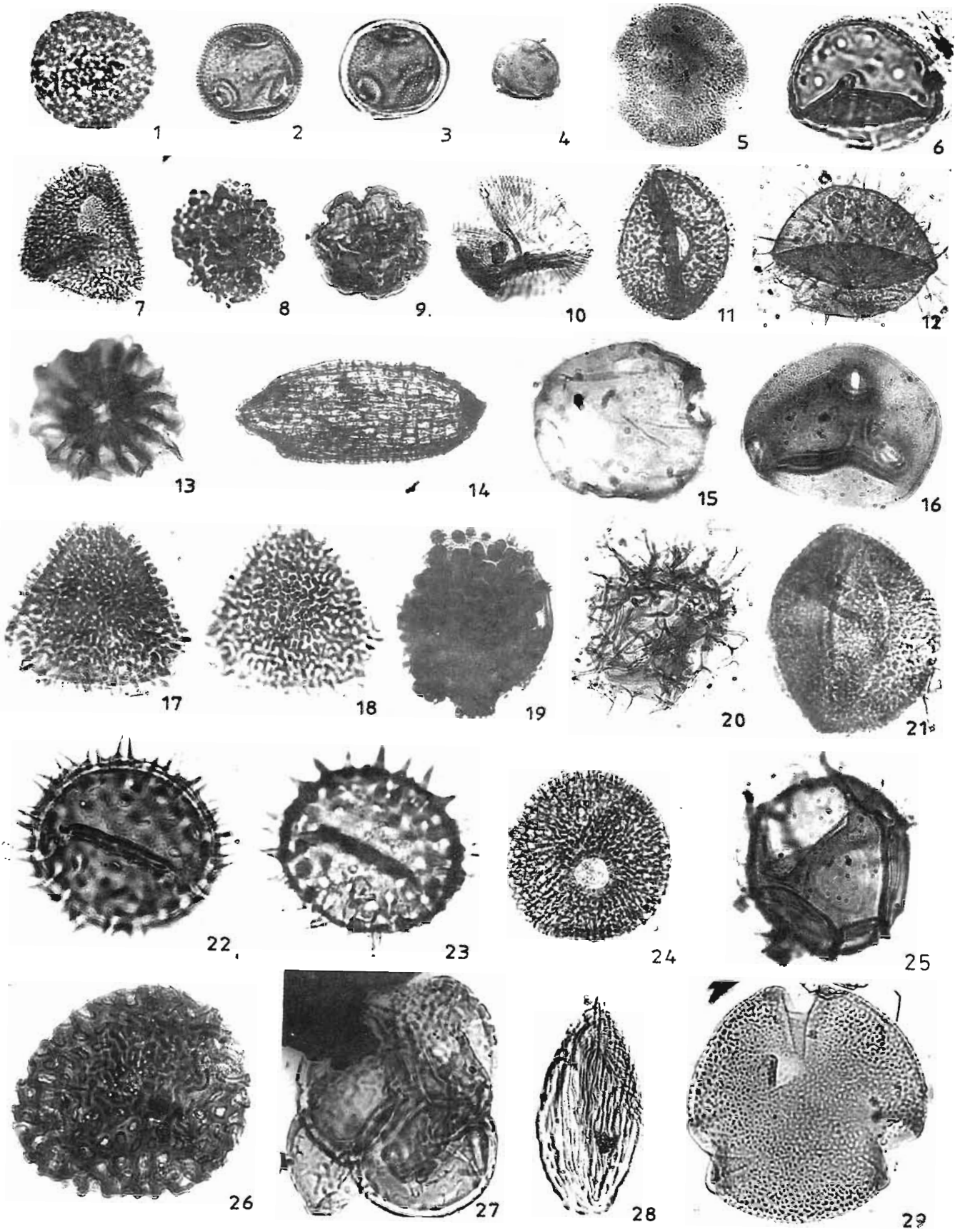
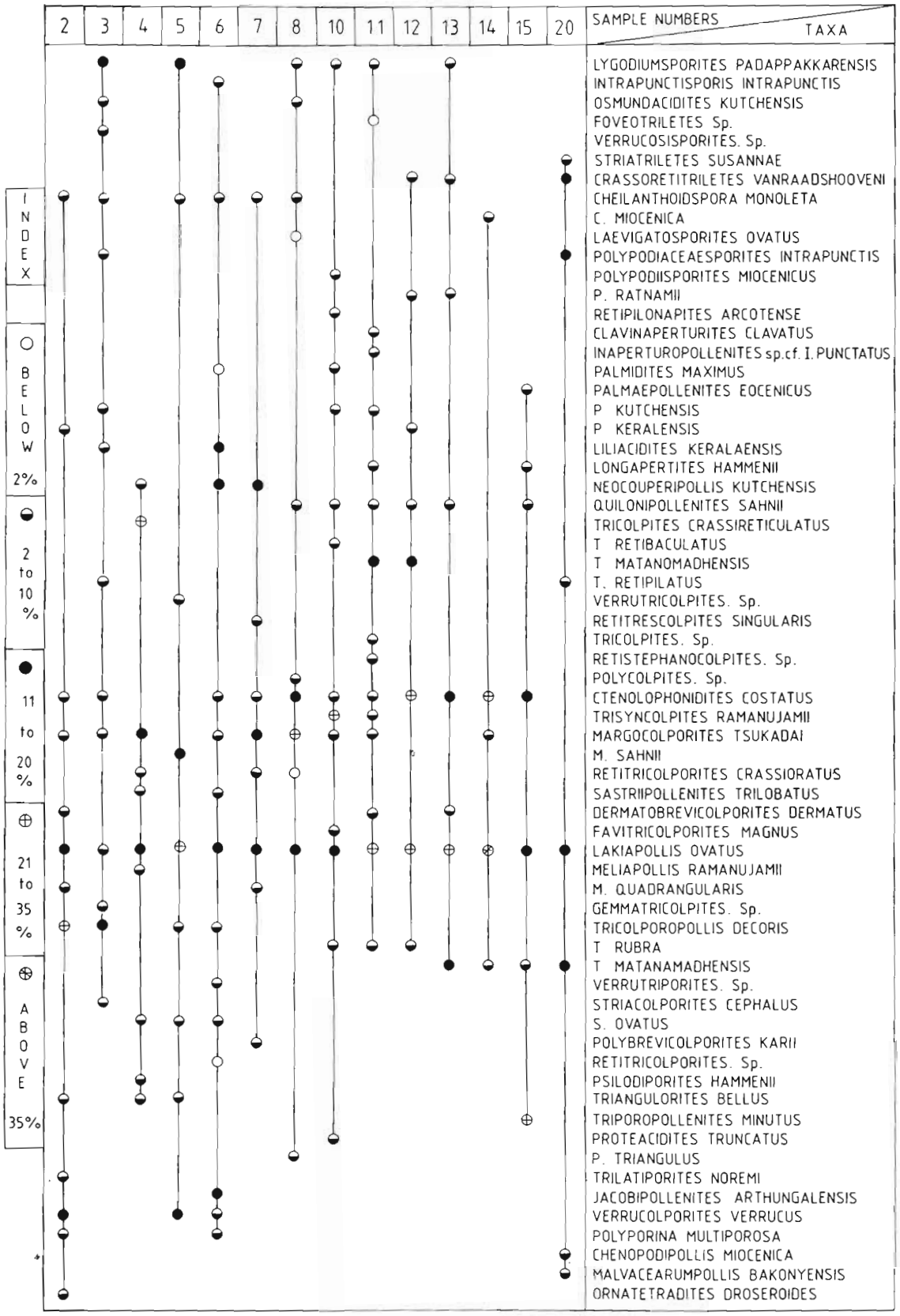


PLATE 3



Text-figure 1—Percentage frequency of palynotaxa in Arthungal bore-hole (frequency chart is based on samples where more than one hundred specimens could be counted).

ca 1 μm thick; surface finely reticulate, reticulum homobrochate, brochi up to 1 μm.

Comparison—*Liliacidites keralaensis* sp. nov. compares well with *L. kaitangataensis* Couper (1953) in its organization but the latter can be distinguished by its differential ornamentation pattern of the reticulate exine (lumina 5 μm at equator and 1 μm at poles). *L. baculatus* Venkatachala & Kar 1969 is distinguished by its funnel-shaped sulcus and intrabaculate exine. *L. ellipticus* Venkatachala & Kar 1969 is distinct by its boat-shaped sulcus and finely intrareticulate exine. *L. magnus* Jain, Kar & Sah 1973 is closely comparable by its ornamentation but the present species is differentiated by its tectate exine. *Liliacidites microreticulatus* Dutta & Sah 1970 is bigger in size (89 μm) and has differential ornamentation.

Affinity—Liliaceae.

Genus—*Jacobipollenites* Ramanujam 1966

Type species—*Jacobipollenites magnificus* Ramanujam 1966.

Jacobipollenites arthungalensis sp. nov.
Pl. 3, figs 11, 24

Holotype—Pl. 3, fig. 24; size 60 μm; Slide no. BSIP 9941.

Type locality—Arthungal bore-hole, Alleppey District, Kerala, depth range 322.70-377.70 m.

Diagnosis—Pollen spheroidal, size 55-60 × 45-55 μm; monoporate, pore distinct, 10-12 μm wide, thick annulus present around pore; exine up to 4 μm thick, retipilate, surface showing retipilariate ornamentation.

Comparison—*Jacobipollenites arthungalensis* sp. nov. is closely comparable with *J. magnificus* Ramanujam 1966 in its general characters but the latter can be distinguished in having coarse reticulum and absence of annulus around pore.

Affinity—Unknown.

PALYNOSTRATIGRAPHY

The three cenozones established are given below in ascending order (Text-fig. 2):

iii) *Malvacearumpollis bakonyensis* Cenozone

ii) *Crassoretitriletes vanraadshooveni* Cenozone

i) *Triangulorites bellus* Cenozone

Triangulorites bellus Cenozone

Type section—Depth range 440.70-272.70 m.

Lithology—Mainly composed of sand and clayey sand, thickness 168 m.

Nature of contact—This cenozone constitutes the lowest biostratigraphic unit in the bore-hole. The sediments are conformably overlain by those which contain *Crassoretitriletes vanraadshooveni* Cenozone.

Species restricted to this cenozone—*Cheilanthoidspora monoleta, Liliacidites keralaensis, Neocouperipollis kutchensis, Tricolpites crassireticulatus, Polycolpites* sp., *Sastriipollenites trilobatus, Meliapollis ramanujamii, M. quadrangularis, Tricolporopollis decoris, Striacolporites cephalus, S. ovatus, Polybrevicolporites karii, Triangulorites bellus, Jacobipollenites arthungalensis* and *Verrucolporites verrucus.*

Characteristic palynofossils—*Ctenolophonidites costatus, Lakiapollis ovatus, Cheilanthoidspora monoleta, Liliacidites keralaensis, Neocouperipollis kutchensis, Polycolpites* sp., *Sastriipollenites trilobatus, Meliapollis ramanujamii, M. quadrangularis, Tricolporopollis decoris, Striacolporites cephalus, S. ovatus, Polybrevicolporites karii, Triangulorites bellus, Jacobipollenites arthungalensis* and *Verrucolporites verrucus.*

Remarks—The significant features of this cenozone are the restricted and common occurrence of *Tricolporopollis decoris* (20%), *Jacobipollenites arthungalensis* (18%), *Liliacidites keralaensis* (15%), *Neocouperipollis kutchensis* (11%) and restricted but rare representation of *Triangulorites bellus* (8%) and *Verrucolporites verrucus* (8%). *Lakiapollis ovatus* (25%) is the dominant taxon. *Tricolporopollis decoris* is abundant (26%) in the lower part but rare towards top (3%).

Crassoretitriletes vanraadshooveni Cenozone

Type section—Depth range 271.70-151.70 m.

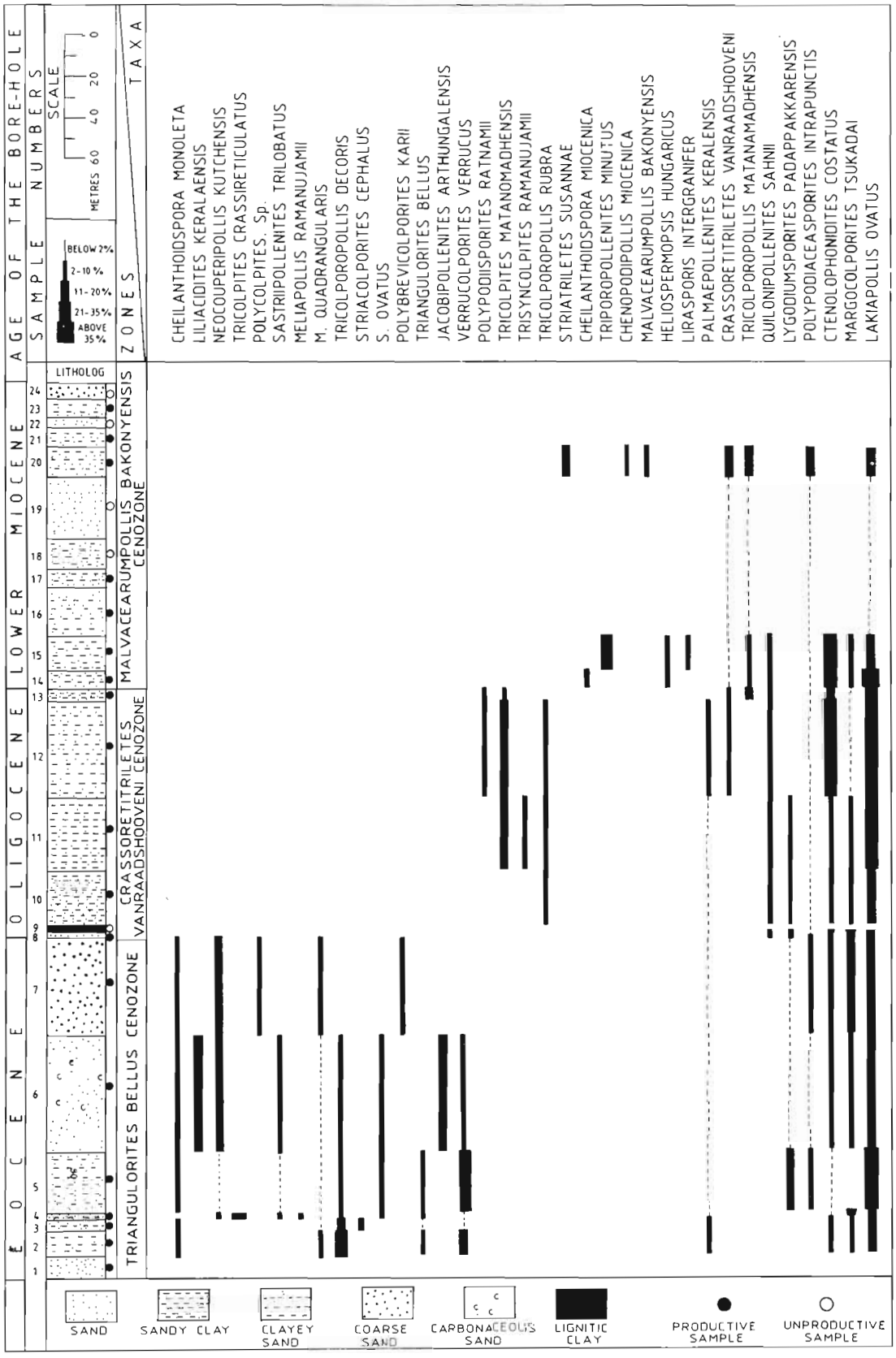
Lithology—Mainly sandy clay with a band of lignite; thickness 120 m.

Nature of contact—The upper part of the sediments which contains this cenozone is composed of sandy clay. It is conformably overlain by the clayey sand of *Malvacearumpollis bakonyensis* Cenozone.

Species restricted to this cenozone—*Polypodiisporites ratnamii, Tricolpites matanomadhensis, Tricolporopollis rubra* and *Trisyncolpites ramanujamii.*

Characteristic palynofossils—*Crassoretitriletes vanraadshooveni, Polypodiisporites ratnamii, Lygodiumsporites padappakkarensis, Polypodiaceaesporites intrapunctis, Ctenolophonidites costatus, Margocolporites tsukadai, Lakiapollis ovatus* and *Trisyncolpites ramanujamii.*

Remarks—The appearance of *Crassoretitriletes*



Text-figure 2—Palynostratigraphic zonation in Arthungal bore hole.

and *Trisyncolpites* is significant in these sediments. *Trisyncolpites* is restricted to this cenozone only. *Ctenolophonidites costatus* (49%) and *Lakiapollis ovatus* (25%) are the abundant taxa in this cenozone. *Lygodiumsporites padappakkarensis* (10%) is rare in the lower part and gradually decreases towards the top of the cenozone. Extinction of *Lakiapollis* and *Ctenolophonidites* at the post Eocene terminal event has been reported (Venkatachala *et al.*, 1989). However, their dominant occurrence in the Arthungal bore-hole (Eocene-Early Miocene) has been observed. The post Eocene appearance may be surmised either to reworking or to their continuation beyond Eocene.

Malvacearumpollis bakonyensis Cenozone

Type section—Depth range 151.70-7.70 m.

Lithology—Mainly clayey sand, upper part sandy clay alternating with sand, thickness 144 m.

Nature of contact—These sediments are overlain by carbonaceous sand and are devoid of palynofossils.

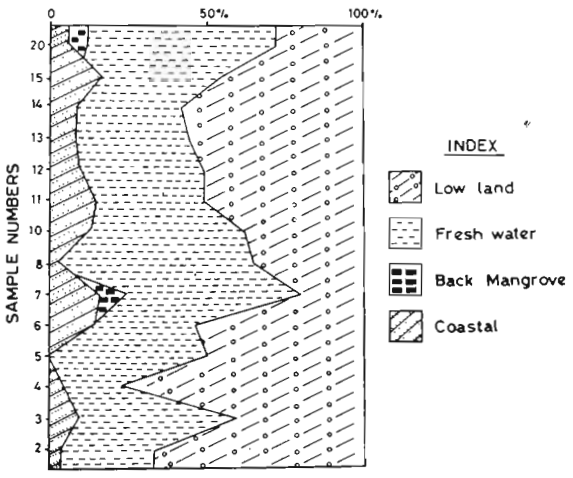
Species restricted to this cenozone—Striatriletes susannae, Cheilanthoidspora mioceneca, Triporopollenites minutus, Chenopodipollis miocenica, Malvacearumpollis bakonyensis, Heliospermopsis hungaricus and *Lirasporis intergranifer.*

Characteristic palynofossils—Crassoretitriletes vanraadshooveni, Quilonipollenites sahnii, Polypodiaceaesporites intrapunctis, Ctenolophonidites costatus, Striatriletes susannae, Cheilanthoidspora mioceneca, Chenopodipollis miocenica, Malvacearumpollis bakonyensis, Heliospermopsis hungaricus, Lirasporis intergranifer and *Lakiapollis ovatus.*

Remarks—This cenozone is characterized by the predominance of *Lakiapollis ovatus* (30%). *Malvacearumpollis bakonyensis* and *Chenopodipollis miocenica* appeared for the first time whereas *Lygodiumsporites padappakkarensis* and *Palmaepollenites keralensis* are absent. The relative increase in *Crassoretitriletes* and *Polypodiaceaesporites* has been recorded. *Ctenolophonidites costatus* is present only in the lower part of the cenozone and absent towards the top.

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

The bore-hole assemblage is rich and diversified. These palynofossils can be divided into different ecological groups such as low-land, fresh-water swamp and water-edge, back-mangrove and coastal. The dinoflagellate cysts indicate shallow marine conditions. The frequency of different ecological groups has been given in Text-fig. 3.



Text-figure 3—Representation of different ecological groups in Arthungal bore-hole.

Low-land flora

Favitricolporites	Rubiaceae
Psilodiporites	?Apocynaceae
Tricolporopollis	Euphorbiaceae
Lakiapollis	Bombacaceae

Fresh-water swamp and water-edge flora

Lygodiumsporites	Schizaeaceae (*Lygodium*)
Crassoretitriletes	Schizaeaceae (*Lygodium*)
Laevigatosporites	Polypodiaceae
Polypodiaceaesporites	Polypodiaceae
Polypodiisporites	Polypodiaceae
Striatriletes	Parkeriaceae (*Ceratopteris*)
Liliacidites	Liliaceae
Ctenolophonidites	Ctenolophonaceae
Margocolporites	Caesalpiniaceae (*Caesalpinia*)
Trisyncolpites	Caesalpiniaceae
Meliapollis	Meliaceae
Triporopollenites	Moraceae
Ornatetradites	Droseraceae
Retipilonapites	Potamogetonaceae
Clavainaperturites	Potamogetonaceae
Chenopodipollis	Chenopodiaceae

Back-mangrove flora

Meliapollis	Meliaceae
Malvacearumpollis	Malvaceae

Coastal flora

Trilatiporites	Palmae (*Sclerosperma*)
Palmaepollenites	Palmae

Quilonipollenites	Palmae (*Eugeissonia*)
Longapertites	Palmae
Neocouperipollis	Palmae

On the basis of the presence of spore/pollen of Schizaeaceae, Parkeriaceae, Osmundaceae, Liliaceae, Caesalpiniaceae, Meliaceae, Ctenolophonaceae, Oleaceae, Rubiaceae and Polygalaceae in the assemblage it has been inferred that the climate at the time of deposition was tropical.

The presence of fungal remains (*Phragmothyrites, Notothyrites, Multicellaesporites*, etc.) and the occurrence of ferns and representatives of tropical rain forest elements belonging to the families Ctenolophonaceae, Oleaceae and Moraceae confirm high degree of rainfall Thus, a humid and tropical climate with high rainfall has been inferred.

The presence of dinoflagellate cysts has been observed in the middle part (151.70-271.70 m) of the bore-hole which indicates that the sequence was deposited under shallow marine condition. The dinoflagellate cysts (*Operculodinium, Achomosphaera* and *Thallasiphora*) and the back mangrove flora suggest the existence of brackish water mangrove swamps The pollen types comparable to Potamogetonaceae (*Retipilonapites, Clavainaperturites*) and Droseraceae (*Ornatetradites*) are indicators of fresh-water lakes or ponds dotting the landscape. The prevailing near-shore conditions have been confirmed by the presence of palm pollen (*Palmidites, Palmaepollenites, Neocouperipollis* and *Quilonipollenites*).

AGE OF THE SEDIMENTS

The *Triangulorites bellus* Cenozone ranges from 440.70 to 272.70 m. The genera restricted to this cenozone are usually found associated with the Eocene assemblages (Sah & Kar, 1970; Sah & Dutta, 1966; Dutta & Sah, 1970; Kar, 1985; Raha *et al.*, 1987). Hence this assemblage has been dated as Eocene.

The *Crassoretitriletes vanraadshooveni* Cenozone encompasses depth levels from 271.70-151.70 m. Germeraad, Hopping and Muller (1968) critically studied the occurrence and distribution of *Crassoretitriletes* in pantropical areas suggesting that this form appears for the first time in the Lower Oligocene sediments. In addition, Kar (1979) reported *Trisyncolpites ramanujamii* from the Oligocene sediments of Kutch and considered it a age-definitive. The first appearance of *Crassoretitriletes* and *Trisyncolpites* intermixed with the dominant elements like *Lygodiumsporites, Polypodiisporites, Margocolporites* and *Lakiapollis*, suggests Oligocene age.

The *Malvacearumpollis bakonyensis* Cenozone has been found to be distributed at depth levels ranging from 151.70-7.70 m. The genera are usually associated with the Miocene assemblages (Rao & Ramanujam, 1978, 1982; Kar & Jain, 1981; Venkatachala & Rawat, 1973; Rao *et al.*, 1985; Kar, 1985).

Malvacearumpollis is considered important for suggesting Early Miocene age. This genus occurs as a dominant element in the Khari Nadi Formation, Kutch (Kar, 1985) and Surma Group, Meghalaya and Assam (Rao *et al.*, 1985) though it is poorly represented in Kerala Basin. The first appearance of *Heliospermopsis* and *Lirasporis* and the predominance of *Crassoretitriletes* and *Quilonipollenites* coupled with *Striatriletes, Cheilanthoidspora mioceneca* and *Chenopodipollis miocenica* dates this assemblage as Early Miocene. From the above palynological data, it is inferred that the Arthungal bore-hole palynological succession ranges from Eocene to Early Miocene in age.

CONCLUSIONS

1. The angiospermous pollen are qualitatively and quantitatively dominant elements of the Arthungal palynoflora.

2. The palynosequence in Arthungal bore-hole can be divided into three cenozones, viz., *Triangulorites bellus* Cenozone, *Crassoretitriletes vanraadshooveni* Cenozone and *Malvacearumpollis bakonyensis* Cenozone.

3. The palynoflora suggests a humid and tropical climate with plenty of rainfall during the deposition of these sediments.

4. The environment of deposition has been inferred as brackishwater mangrove swamps.

5. On the basis of palynological data, the sequence studied has been assigned Eocene-Early Miocene age

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