Palynological investigation of the Boldamgiri Formation (Early Miocene) in type area, Garo Hills, Meghalaya*

R. K. Saxena & M. R. Rao

Birbal Sahni Institute of Palaeobotany, Lucknow - 226 007, India

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A rich palynofloral assemblage has been recorded from the Boldamgiri Formation (Early Miocene) exposed in the type area - Boldamgiri, on Adugiri - Purakhasia Road in West Garo Hills District, Meghalaya. The assemblage is dominated by pteridophytic spores, both trilete and monolete, followed by gymnospermous and angiospermous pollen. Besides, a good number of dinoflagellate cysts and fungal remains have also been recorded. The important palynotaxa of the assemblage are: *Lygodiumsporites, Biretisporites, Intrapunctisporis, Striatriletes, Foveotriletes, Cheilanthoidspora, Polypodiaceaesporites, Pinuspollenites, Abiespollenites, Pinjoriapollis, Meyeripollis, Echistephanocolpites, Polyadopollenites, Chenopodipollis* and *Malvacearumpollis*. Based on palynofossils distribution, the studied sequence is divisible into two palynozones- the lower and the upper, which can be distinguished by means of their characteristic and restricted palynofossils. Present day distribution of various plant families represented in the assemblage and abundance of pteridophytic spores and fungal remains indicate tropical-subtropical (warm-humid) climate. The palynoflora indicates a coastal marine depositional environment having fresh water connections with swamps and ponding conditions nearby.

Key-words—Palynology, Boldamgiri Formation, Early Miocene, Garo Hills, Meghalaya (India).

INTRODUCTION

THE lithostratigraphic unit 'Boldamgiri Formation' was instituted by Chakraborty (1972) after the village Boldamgiri (Lat. 25° 24′ 00" N : Long. 90° 06′ 00" E) on Adugiri-Purakhasia Road in West Garo Hills District, Meghalaya where good exposures of this formation can be observed along the road. Chakraborty and Baksi (1972) further elaborated the description of this formation and also published a geological map of Garo Hills and western part of Khasi Hills. The Boldamgiri Formation, in the Boldamgiri area, consists of coarse grained and gritty, feldspathic, ferruginous sandstone with thin beds of greyish black carbonaceous shale. According to Chakraborty and Baksi (1972), the Boldamgiri Formation is a probable equivalent of the Bhuban Subgroup of Surma Group developed in the eastern part of Meghalaya and Assam.

While a considerable amount of palynological and palynostratigraphical work has been carried out on the Palaeocene-Eocene sediments of Garo Hills, only a few papers have been published on the palynological studies of the post-Eocene sediments of this area (Baksi, 1962; Banerjee, 1964; Salujha *et al.*, 1973; Nandi & Sharma, 1984).

The present work is an attempt to study palynoflora from the Boldamgiri Formation in the type area (West Garo Hills) and to utilize the same in palaeoecological and stratigraphical interpretations. A brief account of the stratigraphic setting of the area is given below.

STRATIGRAPHY

The Boldamgiri Formation, unconformably overlying the Kherapara Formation and underlying the Angartoli Formation, occupies a large area in West Garo Hills. Traversing southwards from Tura, along Tura-Dalu Road, good development of the Tura Formation can be observed. Further downdip, it is unconformably overlain by a few metres thick Siju Limestone consisting of yellow, fossiliferous, arenaceous limestone. The Siju Limestone is overlain by the Rewak Formation. Both the contacts, viz., Tura/Siju and Siju/Rewak, can be seen in a stream cutting between 9 and 10 km from Tura. Near Kherapara, on Tura-Dalu Road, the Rewak Formation is overlain by the Kherapara Formation. On Adugiri -

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Purakhasia Road, which runs south-west from Adugiri, the Rewak Formation is developed up to 9 km from Adugiri where it is overlain by the Kherapara Formation. In both, Tura-Dalu and Adugiri-Purakhasia, road sections only a narrow belt of Kherapara Formation is exposed. The Kherapara Formation is unconformably succeeded by the Boldamgiri Formation. While the contact between the two formations is clearly seen in Tura-Dalu Road section, the same in Adugiri-Purakhasia Road Section is covered by thick vegetation. The unconformable nature of the Kherapara/Boldamgiri contact is evident by the abrupt appearance of feldspathic, coarse grained sandstone with grits and even pebbles of basement granite near the base and also by highly ferruginous nature of the sandstone overlying fine grained sediments of the Kherapara Formation.

The Boldamgiri Formation consists of coarse to very coarse, gritty, feldspathic, occasionally current bedded sandstone interbedded with black carbonaceous shales. In the Boldamgiri area, the shale beds are thin, constituting a subordinate lithology. However, towards east, near Baghmara (Lat. 25° 11′ 15" N : Long. 90° 38′ 50" E), the shales considerably increase in thickness. Further downdip, the Boldamgiri Formation is overlain by the Angartoli Formation which is made up of non-feldspathic sandstones, bluish siltstone and sandy shales. The stratigraphic succession in the West Garo Hills is summarized below:

Age	Stratigraphic unit	Lithology
Late Miocene to Pliocene	Post-Angartoli (Bilkona, Rangapani and Dalu formations)	
	----------Disconformity----------	
	Angartoli Formation	Fine-grained, nonfeldspathic, micaceous sandstone, bluish siltstone and sandy shales.
Miocene	----------	
	Boldamgiri Formation	Coarse-grained, gritty, feldspathic, ferruginous sandstones with carbonaceous shale.
	----------Unconformity----------	
Oligocene	Kherapara Formation	Finely bedded alternations of shale and fine-grained sandstone. The lower part contains thick sandstones whereas upper part is largely argillaceous.
Palaeocene to Eocene	Pre-Kherapara (Tura, Siju and Rewak formations)	
	----------Unconformity----------	
Precambrian	Basement complex	Granite and granite gneisses.

MATERIAL

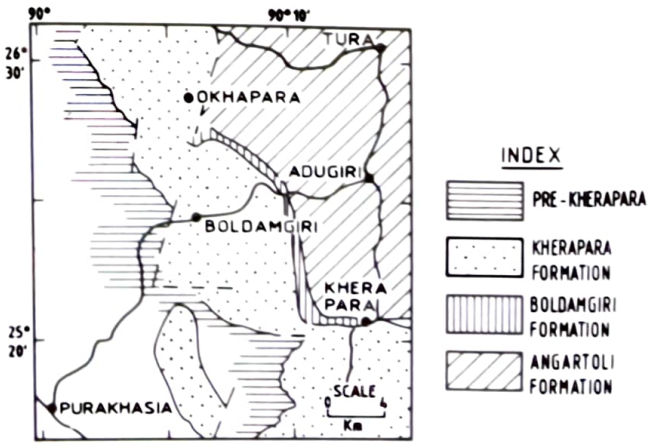
The samples for the present study were collected from the Boldamgiri Formation exposed along Adugiri-Purakhasia Road between Boldamgiri and a spot 23 km from Adugiri (Text-fig. 1). Altogether, twentyfour samples were collected from the carbonaceous shale beds of this formation. Of these, 14 samples yielded palynofossils. Samples were collected at a stratigraphic interval of 0.5 to 1 metre. The stratigraphic position of the samples is shown in Text-fig. 2. All the slides and negatives of the figured specimens are stored in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

PALYNOFLORAL ASSEMBLAGE

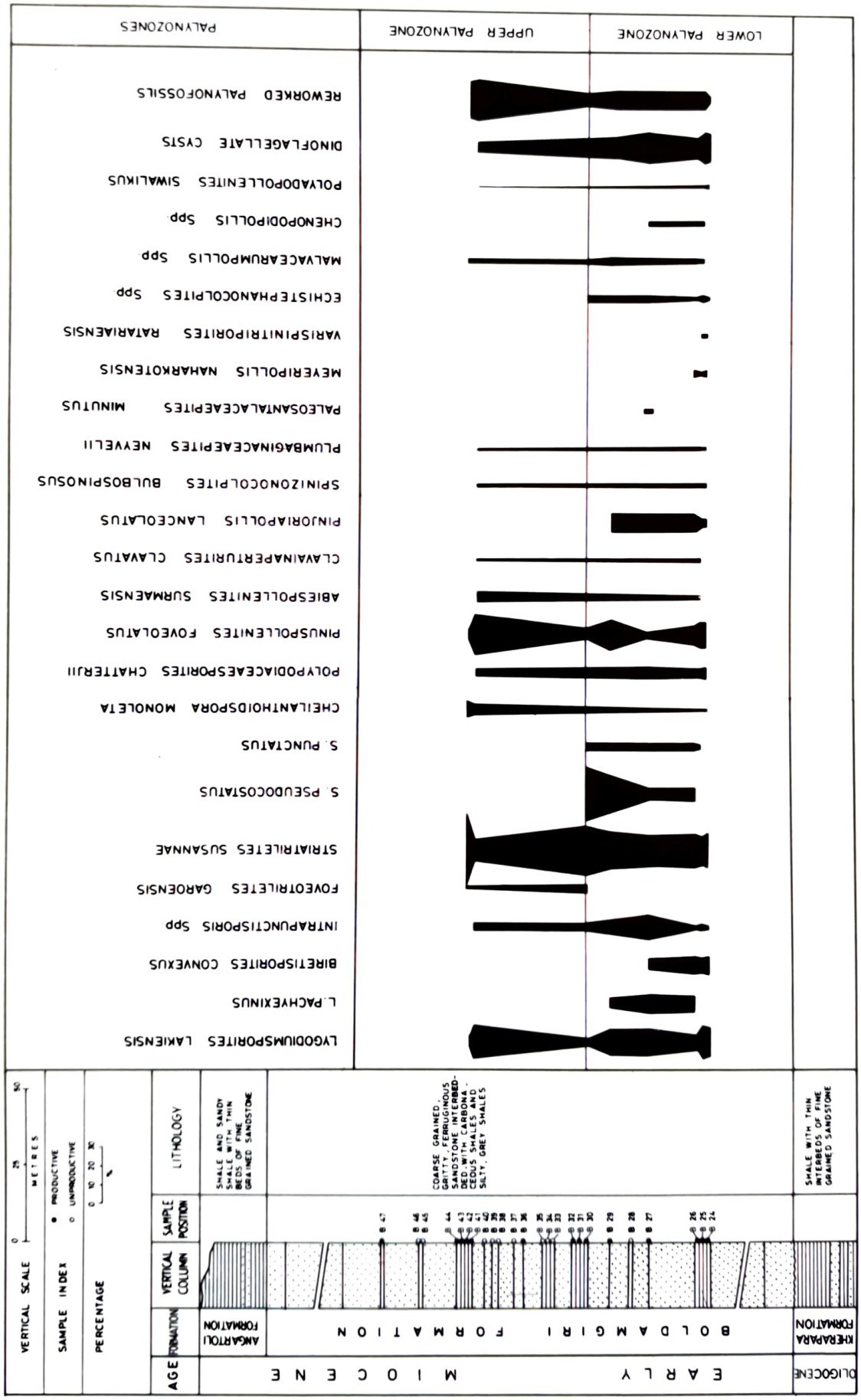
Algal remains

Achomosphaera sp.

Polysphaeridium subtile Davey & Williams emend. Bujak *et al.*, 1980



Text-fig. 1. Locality map showing area of study.



Text-fig.2. Percentage of palynotaxa belonging to various ecological groups, Boldamgiri Formation, Gora Hills, Meghalaya.

Polysphaeridium sp. (Pl.3, fig. 11)

Spiniferites sp.

Tuberculodinium vancampoae (Rossignol) Wall, 1967

Algal Spore Type-1

Fungal remains

Dicellaesporites minutus Kar & Saxena, 1976 (Pl. 3, fig. 17)

Dicellaesporites sp. (Pl. 3, fig. 8)

Diporisporites ankleshvarensis (Varma & Rawat) Elsik, 1968

Inapertisporites sp. (Pl. 3, fig. 16)

Kutchiathyrites eccentricus Kar, 1979

Lirasporis intergranifer Potonie' & Sah emend. Jain & Kar, 1979

Meliola sp.

Multicellaesporites sp. (Pl. 3, fig. 12)

Parmathyrites ramanujamii Singh *et al.*, 1986

Phragmothyrites eocaenica Edwards emend. Kar & Saxena,1976

Pluricellaesporites sp.

Trichothyrites setiferus (Cookson) Saxena & Misra, 1990

Fungal spore tetrad (Pl.3, fig.21)

Pteridophytic spores

Biretisporites convexus Sah & Kar, 1969 (Pl.1, fig.3)

Cheilanthoidspora monoleta Sah & Kar, 1974 (pl.1, fig.10.

Cyathidites australis Couper, 1953

C. minor Couper,1953 (Pl.1, fig.1)

**Foveotriletes garoensis* sp. nov. (Pl.1, figs 9, 11)

**Foveotriletes* sp. (Pl. 1, fig. 12)

Intrapunctisporis harudiensis Kar, 1978 (Pl.1, fig. 4)

**Intrapunctisporis plicatus* sp. nov. (Pl.1, figs 5-6)

Lycopodiumsporites bellus Sah & Kar,1969 (Pl.1, fig. 2)

Lygodiumsporites lakiensis Sah & Kar, 1969 (Pl.1, fig. 7)

L. pachyexinus Saxena, 1978

Neyvelisporites bolkhovitinae Ramanujam, 1972 (Pl.1, fig.22)

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

Pilamonoletes excellensus Kar, 1991 (Pl. 1, fig. 23)

Polypodiaceaesporites chatterjii Kar, 1979 (Pl.1, fig. 21)

Polypodiisporites speciosus Sah & Dutta, 1968 (Pl.1, fig. 15)

**Pteridacidites* sp. (Pl.1, fig. 13)

Striatriletes pseudocostatus Singh & Tripathi, 1983

**S. punctatus* sp. nov. (Pl.1, figs 16-17)

S. susannae van der Hammen emend. Kar, 1979 (Pl. 1, figs 18-19)

**Verrutriletes* sp. (Pl.1, fig. 14)

*Tetrad Spore Type-1 (Pl.1, fig. 20)

Gymnospermous pollen

Abiespollenites surmaensis Rao, 1986 (Pl.2, fig. 5)

Pinuspollenites foveolatus Rao, 1986 (Pl.2, figs 1-3)

Angiospermous pollen

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

**Chenopodipollis* sp. (Pl.2, fig. 22)

Clavainaperturites clavatus Ramanujam, 1966

Dermatobrevicolporites dermatus (Sah & Kar) Kar, 1985

**Echistephanocolpites boldamgiriensis* sp. nov. (Pl.2, figs 14-15)

PLATE-1

(All photomicrographs are enlarged *ca* x 600. Coordinates of the specimens refer to the stage of the BH2 Olympus microscope no. 217267).

1. *Cyathidites minor* Couper, slide no. 11652/13 (18.0x163.0).
2. *Lycopodiumsporites bellus* Sah & Kar, slide no. 11653/4 (7.5x 154.0).
3. *Biretisporites convexus* Sah & Kar, slide no. 11653/7 (18.8x151.5).
4. *Intrapunctisporis harudiensis* Kar, slide no. 11653/11 (3.0x 162.0).
5-6. *Intrapunctisporis plicatus* sp. nov., slide nos. 11668 (3.0x140.0) - Holotype; 11654/1 (19.0x138.0).
7. *Lygodiumsporites lakiensis* Sah & Kar, slide no. 11655/3 (14.0x141.0)
8. *Osmundacidites* sp., slide no. 11656/8 (18.0x127.0).
9, 11. *Foveotriletes garoensis* sp. nov., slide nos. 11657/7 (19.0x 135.0) - Holotype; 11657/3(14.5x162.5).
10. *Cheilanthoidspora monoleta* Sah & Kar, slide no. 11658/2 (13.2x 134.0).
12. *Foveotriletes* sp., slide no. 11654 (12.0x141.5).
13. *Pteridacidites* sp., slide no. 11659/4 (18.0 x 142.5).
14. *Verrutriletes* sp., slide no. 11657/3 (19.2x 144.0).
15. *Polypodiisporites speciosus* Sah, slide no. 11660/2 (18.0x 137.3).
16-17. *Striatriletes punctatus* sp. nov., slide nos. 11658/5 (14.0x 150.0); 11661/5 (21.8x163.6) - Holotype.
18-19. *Striatriletes susannae* van der Hammen emend. Kar, slide nos. 11657/4 (13.5x151.0); 11662/2 (8.0x137.0).
20. Tetrad Spore Type-1, slide no. 11663/1 (9.5x165.0).
21. *Polypodiaceaesporites chatterjii* Kar, slide no. 11662/7 (19.9x 165.5).
22. *Neyvelisporites bolkhovitinae* Ramanujam, slide no. 11659 (10.0x136.0).
23. *Pilamonoletes excellensus* Kar, slide no. 11664/1 (8.7x137.2).

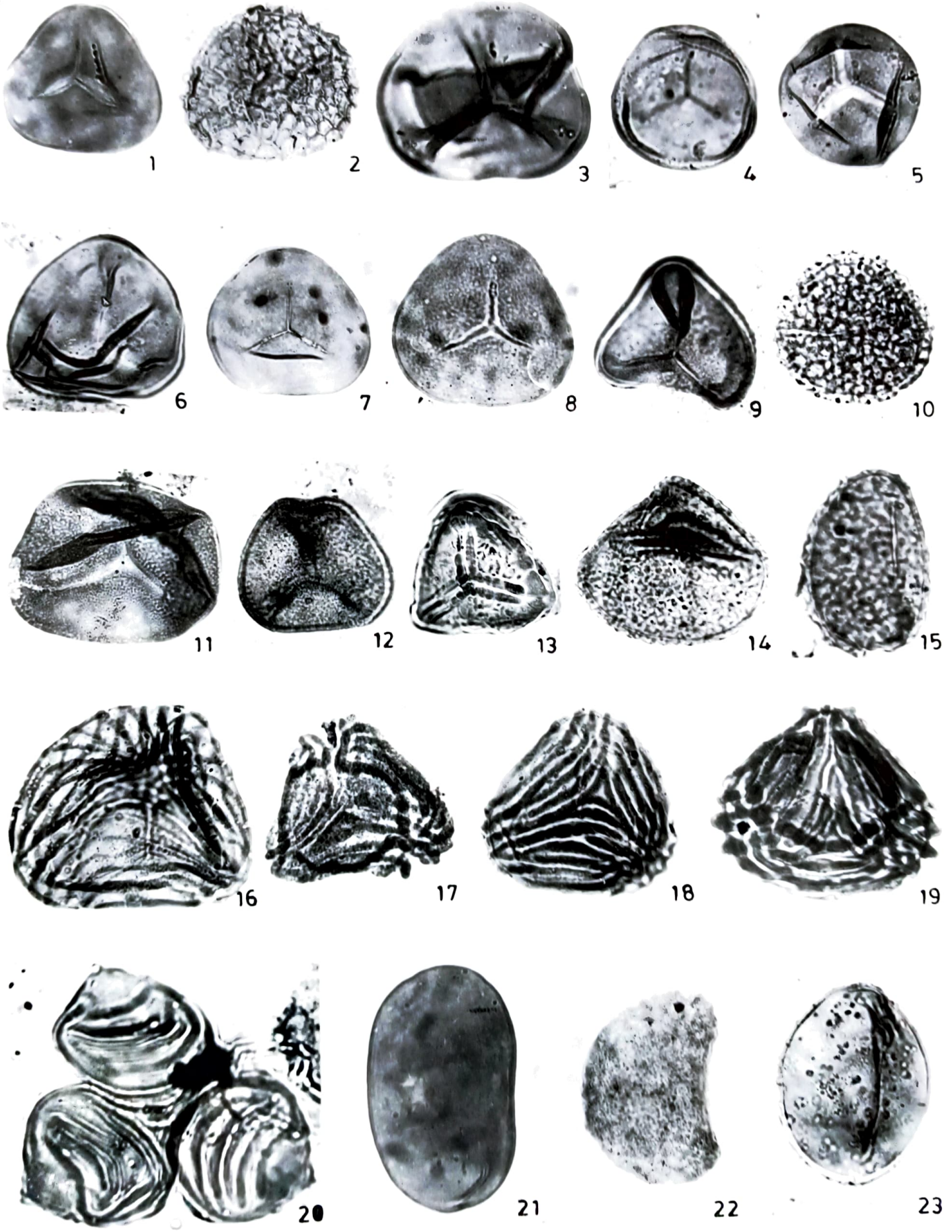


Plate 1

E. meghalayaensis Raol *et al.*, 1985 (Pl.2, fig. 13)

Favitricolporites magnus Sah, 1967 (Pl.3, fig. 4)

Malvacearumpollis bakonyensis Nagy, 1962 (Pl.3, figs 1-2)

**Malvacearumpollis* sp. (Pl.2, fig. 10)

Meyeripollis naharkotensis Baksi & Venkatachala, 1970 (Pl.2, fig.11)

**Myricipites* sp. cf. *M. harrisii* (Couper) Dutta & Sah, 1970 (Pl. 3, fig. 13)

Paleosantalaceaepites minutus Sah & Kar, 1970 (Pl. 2, fig. 17)

Pinjoriapollis lanceolatus Saxena & Singh, 1981 (Pl.2, fig. 12)

Plumbaginacipites neyvelii Navale & Misra, 1979 (Pl.2, figs 8-9)

Polyadopollenites siwalikus Saxena & Singh, 1982 (Pl.3, figs 5-6)

Proteacidites triangulus Kar & Jain, 1981 (Pl.2, fig. 18)

Retipilonapites cenozoicus Sah, 1967 (Pl.2, fig. 21)

Spinizonocolpites bulbospinosus Singh, 1990 (Pl.2, fig.6)

Tricolpites reticulatus Cookson ex Couper, 1953 (Pl.3, fig.10)

Triporopollenites robustus Kar & Jain, 1981(Pl.2, fig. 19)

Varispinitriporites ratariaensis (Kar & Saxena) Kar, 1985 (Pl. 2, figs 4, 16)

Verrutriporites lundensis Muller, 1968 (Pl.2, fig. 20)

**Warkallipollenites* sp. (Pl. 2, fig. 7)

Reworked palynofossils

Callialasporites trilobatus (Balme) Dev, 1961 (Pl. 3, fig. 14)

Parasaccites sp. (Pl. 3, fig. 15)

Plicatipollenites sp. (Pl. 3, fig. 18)

Rouseisporites sp. (Pl. 3,fig. 9)

Striatopodocarpites sp. (Pl. 3, figs 19-20)

Incertae-sedis

Heliospermopsis ankleshvarensis (Srivastava) Saxena & Misra, 1990 (Pl. 3, fig. 7)

Palynotaxa marked with an asterisk (*) have been described below. Plate and figure numbers given in the above list in parentheses refer to the illustrations of the present paper.

DESCRIPTION

Genus-*Intrapunctisporis* Krutzsch, 1959

Type species-Intrapunctisporis intrapunctis Krutzsch, 1959

Intrapunctisporis plicatus sp. nov.
Pl.1, figs 5-6

Holotype- Pl. 1, fig. 5, slide no. 11668 (3.0x140.0).

Type locality, horizon and age- Adugiri. Purakhasia Road near Boldamgiri, West Garo Hills, Meghalaya; Boldamgiri Formation; Early Miocene.

Diagnosis- Miospores subspherical. Size range 40-55 µm. Trilete, rays distinct with bifurcated and thickened ends, reaching upto 2/3 radius. Exine 2 µm thick, intrapunctate, folded around the trilete mark.

Comparison- The present species is closely comparable with *I. intrapunctis* Krutzsch (1959) in its general organization but the latter is distinguished by its two layered, densely intrapunctate exine. *Intrapunctisporis harudiensis* Kar (1978) is bigger in size and has thicker exine. *Intrapunctisporis densipunctis* Tripathi & Singh (1985) is distinguished by its bigger size (80-85 µm) and thinner and densely intrapunctate exine. *In-*

PLATE-2

1-3. *Pinuspollenites foveolatus* Rao, slide nos. 11663/13 (20.0x170.0); 11665/4 (18.3x154.5); 11666/4 (8.0x154.0).
4, 16. *Varispinitriporites ratariaensis* (Kar & Saxena) Kar, slide nos. 11667/3 (6.4x149.0); 11652/1 (11.0x148.2).
5. *Abiespollenites surmaensis* Rao, slide no. 11658/10 (17.3x170.0).
6. *Spinizonocolpites bulbospinosus* Singh, slide no. 11658/1 (10.5x135.3).
7. *Warkallipollenites* sp., slide no. 11668/4 (18.4x152.5).
8-9. *Plumbaginacipites neyvelii* Navale & Misra, slide nos. 11669/5 (18.7x146.4); 11670/4 (20.5x157.4).
10. *Malvacearumpollis* sp., slide no. 11654/4 (20.5x166.4).
11. *Meyeripollis naharkotensis* Baksi & Venkatachala, slide no. 11671/10 (20.5x154.0).
12. *Pinjoriapollis lanceolatus* Saxena & Singh, slide no. 11659/11 (18.0x 169.2).
13. *Echistephanocolpites meghalayaensis* Rao *et al.*, slide no. 11672/6 (9.0x147.2).
14-15. *Echistephanocolpites boldamgiriensis* sp. nov., slide nos. 11658/3 (15.7x 156.2); 11673/9 (15.4x144.0)- Holotype.
17. *Paleosantalaceaepites minutus* Sah & Kar, slide no. 11666/10 (15.5x 143.0).
18. *Proteacidites triangulus* Kar & Jain, slide no. 11670/2 (18.7x 142.0).
19. *Triporopollenites robustus* Kar & Jain, slide no. 11674/1 (9.5x 132.5).
20. *Verrutriporites lundensis* Muller, slide no. 11675/2 (14.0x140.0).
21. *Retipilonapites cenozoicus* Sah, slide no. 11659/1 (10.5x135.3).
22. *Chenopodipollis* sp., slide no. 11672/5 (14.0x151.0).

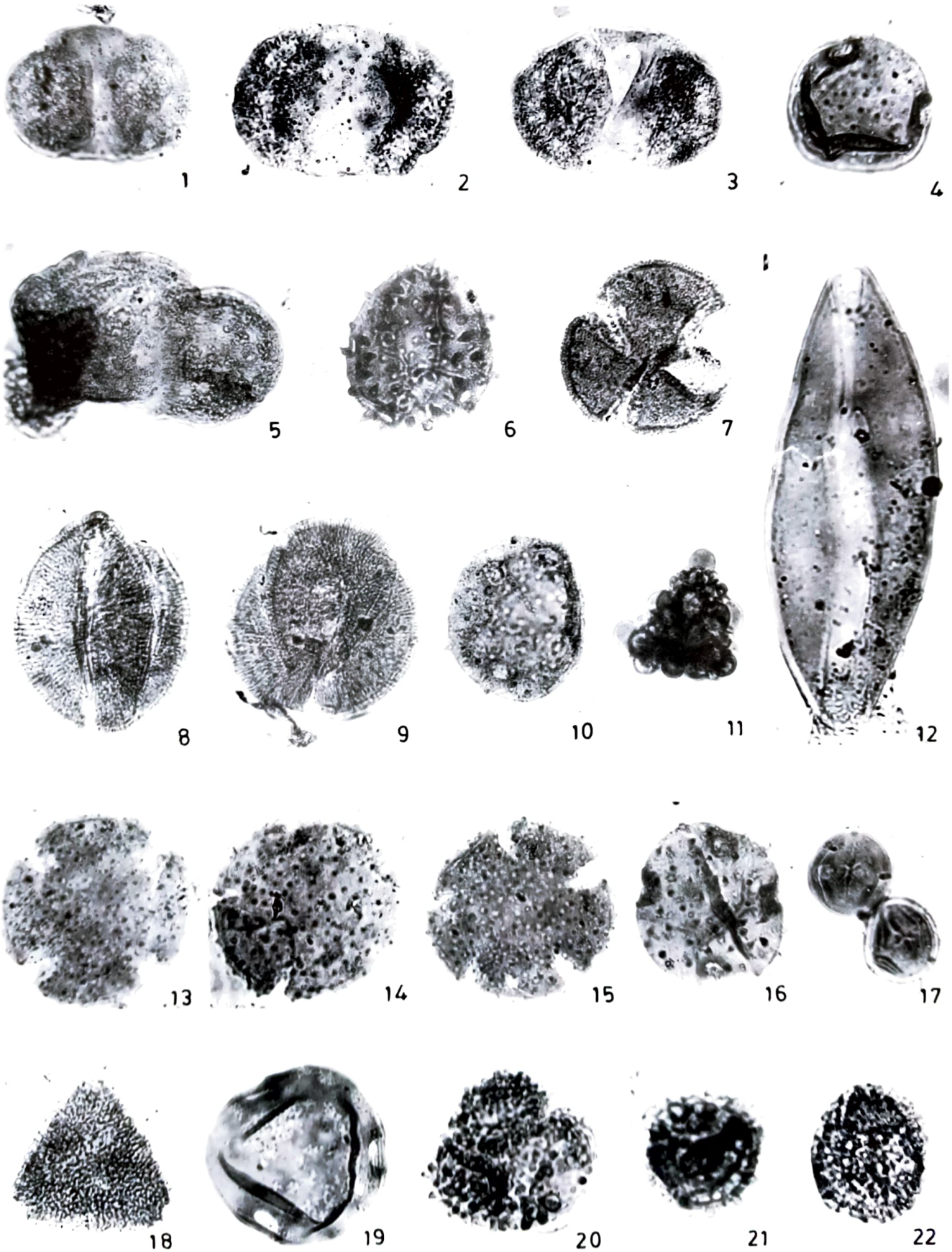


Plate 2

trapunctisporis giganticus Kar & Kumar (1986) is different in its bigger size and closely intrapunctate exine.

Genus-*Osmundacidites* Couper, 1953

Type species-Osmundacidites wellmanii Couper, 1953

***Osmundacidites* sp.**
Pl.1, fig. 8

Description- Miospore subtriangular. Size 56x54 µm. Trilete, rays reaching 3/4 radius. Exine 2 µm thick, granulate, folds present.

Comparison- Osmundacidites sp. differs from *Osmundacidites wellmanii* Couper (1953) which has thinner, granulate- papillate exine. Moreover, in the latter, sculpture is reduced to finely granulate in contact area.

Genus-*Foveotriletes* van der Hammen ex Potonie' 1956

Type species-Foveotriletes scrobiculatus (Ross) Potonie', 1956

***Foveotriletes garoensis* sp. nov.**
Pl.1, figs 9,11

Holotype- Pl.1, fig. 9, slide no. 11657 (19.0x135.0).

Type locality, horizon and age- Adugiri - Purakhasia Road near Boldamgiri, West Garo Hills, Meghalaya; Boldamgiri Formation; Early Miocene.

Diagnosis- Miospores subtriangular with rounded apices. Size range 60-75 X 55-67 µm. Trilete mark distinct, reaching 2/3 radius. Exine upto 1.5 µm thick.

Comparison- The present species closely compares with *Foveotriletes scrobiculatus* (Ross) Potonie' (1956) in having foveolate exine but the latter can be distinguished by its smaller size (upto 48 µm) and thicker exine (2.5 µm). *Foveotriletes microreticulatus* Couper (1958) differs by its raised commissures. *Foveotriletes parviretus* (Balme) Dettmann (1963) differs from the present species by its straight sides and simple laesurae. *Foveotriletes miocenicum* Ramanujam (1967) possesses an ill-developed trilete mark and smaller size (48.5 µm), hence not comparable. *Foveotriletes bifurcatus* Rao & Ramanujam (1978) is distinguished by its smaller size.

Affinity- Unknown.

***Foveotriletes* sp.**
Pl.1, fig. 12

Description- Miospore subtriangular with broadly rounded apices. Size 54x51 µm. Trilete mark distinct. Exine 3 µm thick, thickened along the trilete rays, foveoreticulate.

Comparison- Foveotriletes sp. closely compares with *F. scrobiculatus*, (Ross) Potonie', (1956) in having foveolate exine but the former can be distinguished by its smaller size and thickening along the trilete mark.

Genus Pteridacidites Sah, 1967

Type species-Pteridacidites africanus Sah, 1967

***Pteridacidites* sp.**
Pl.1, fig. 13

Description- Miospore subtriangular with broadly rounded apices. Size 58x52 µm. Trilete, rays prominent, reaching up to the equator, ray margins covered with distinct verrucae. Cingulate, cingulum upto 5 µm thick. Exine upto 3.5 µm thick, verrucate.

Comparison- Pteridacidites africanus Sah (1967) is comparable to the present species in its well defined zona but the former is distinguished by its distinctly triangular body and verrucae covering most of the distal surface.

Genus-*Striatriletes* van der Hammen emend. Kar, 1979

Type species-Striatriletes susannae van der Hammen emend. Kar, 1979

***Striatriletes punctatus* sp. nov.**

Pl. 1, figs 16-17

PLATE-3 →

1-2. *Malvacearumpollis bakonyensis* Nagy, slide nos. 11669/5 (12.0x 160.0); 11677/2 (20.4x141.0).
3. *Chenopodipollis miocenica* Kar & Jain, slide no. 11675/3 (18.4x141.6).
4. *Favitricolporites magnus* Sah, slide no. 11657/6 (13.5x157.0).
5-6. *Polyadopollenites siwalikus* Saxena & Singh, slide nos. 11667/7 (11.0x165.4); 11662/7 (6.0x156.0).
7. *Heliospermopsis ankleshvarensis* (Srivastava) Saxena & Misra, slide no. 11659/3 (20.5x138.0).
8. *Dicellaesporites* sp., slide no. 11676/1 (12.0x136.4).
9. *Rouseisporites* sp., slide no. 11652/13 (14.0x167.0).
10. *Tricolpites reticulatus* Cookson ex Couper, slide no. 11659/2 (16.5x 138.4).
11. *Polysphaeridium* sp., slide no. 11668/9 (11.0x159.0).
12. *Multicellaesporites* sp., slide no. 11663/2 (11.4x130.0).
13. *Myricipites* sp. cf. *M. harrisii* (Couper) Dutta & Sah, slide no. 11672/3(21.0x146.0).
14. *Callialasporites trilobatus* (Balme) Dev, slide no. 11677/7 (11.0x153.0).
15. *Parasaccites* sp., slide no. 11667/5 (7.5x150.6).
16. *Inapertisporites* sp., slide no. 11663/9 (13.5x 145.4).
17. *Dicellaesporites minutus* Kar & Saxena, slide no. 11678/3 (3.5x 137.0).
18. *Plicatipollenites* sp., slide no. 11660/5 (9.3x 151.0).
19-20. *Striatopodocarpites* sp., slide nos. 11660/5 (8.5x 152.5); 11658/1 (9.5x 160.5).
21. Fungal spore tetrad, slide no. 11656/1 (18.0x127.0).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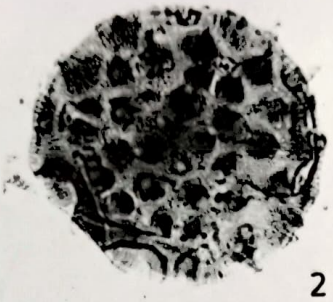
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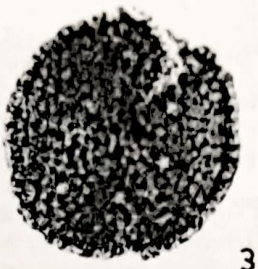
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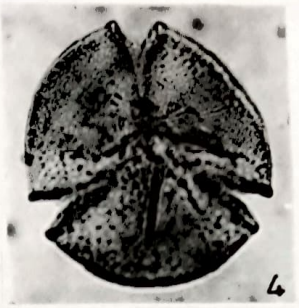
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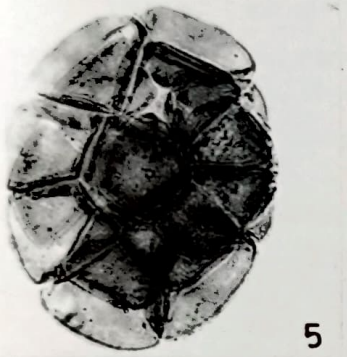
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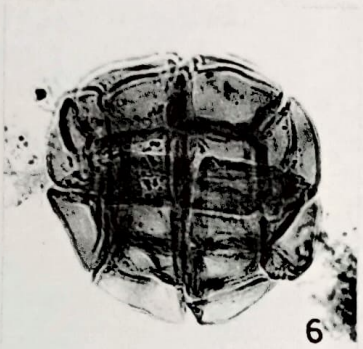
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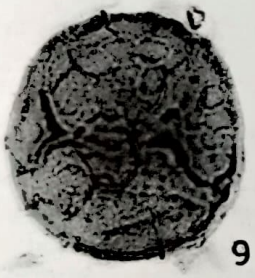
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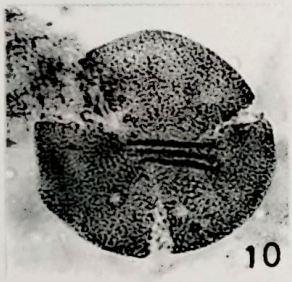
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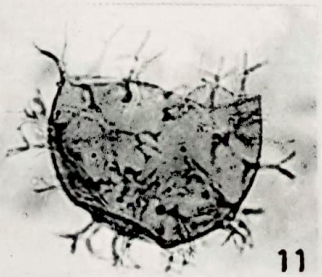
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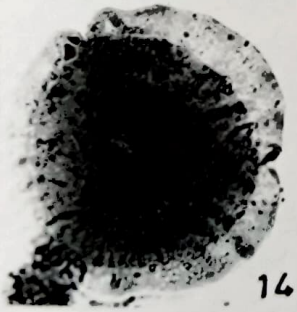
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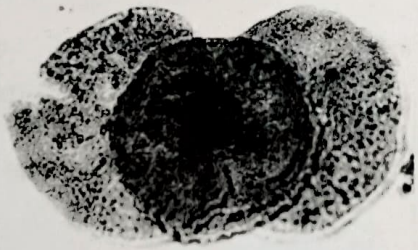
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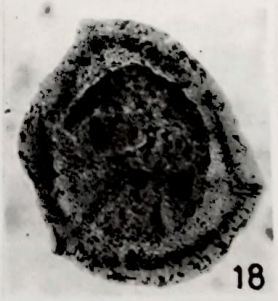
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Plate 3

Holotype- Pl.1, fig. 17, slide no. 11661 (21.8x163.6).

Type locality, horizon and age- Adugiri - Purakhasia Road near Boldamgiri, West Garo Hills, Meghalaya; Boldamgiri Formation; Early Miocene.

Diagnosis- Miospores subtriangular. Size range 65-75x55-70 µm. Trilete. Exine striate, ridges arise at ray ends, six in each concentric ring, sparsely placed. Ridges and intervening furrows ornamented with puncta.

Comparison- Striatriletes susannae van der Hammen emend. Kar (1979) is distinguished from *S. punctatus* sp. nov. by its bigger size (77-113 µm) and laevigate ridges and furrows. *Striatriletes microverrucosus* Kar & Saxena (1981) possesses microverrucate ridges, hence not comparable. *Striatriletes pseudocostatus* Singh & Tripathi (1983) is distinct by its ill- developed, flat and unevenly wide ridges. *Striatriletes sinuosus* Rao & Singh (1987) is differentiated from the present species by its strongly built and tapering trilete mark and laevigate ridges and furrows.

Genus -*Verrutriletes* van der Hammen ex Potonie' 1956

Type species-Verrutriletes compositipunctatus

(Dijkstra) Potonie',1956

***Verrutriletes* sp.**

Pl. 1, fig. 14

Description- Miospore subtriangular with rounded apices. Size 72x60 µm. Trilete mark reaching 2/3 radius. Exine 4.5 µm thick, verrucate, verrucae closely placed, forming negative reticulum.

Comparison- Verrutriletes sp. is closely comparable with *V. compositipunctatus* Potonie', (1956) by its verrucate exine but the latter is distinguished by having numerous hemispherical papillae on distal face.

Tetrad Spore Type - 1

Pl. 1, fig. 20

Description- Spore tetrad subtriangular. Size range 110-120x 76-86 µm. Individual spore subtriangular with broadly rounded apices and convex sides, 50-72 x 48-70 µm, trilete, exine striate, ridges sparsely placed, ridges and furrows laevigate.

Remarks- Tetrad Spore Type-1 appears to be a tetrad of *Striatriletes* spores.

Genus-*Warkallipollenites* Ramanujam & Rao in Thanikaimoni *et al.*, 1984

Type species - Warkallipollenites erdtmanii Ramanujam & Rao in Thanikaimoni *et al.*, 1984

***Warkallipollenites* sp.**

Pl.2, fig. 7

Description- Pollen grain subcircular. Size 63x 62 µm. Tricolpate, longicolpate. Exine 4.5 µm thick, sexine 3.5 µm thick, clavate, clava closely placed with free ends, surface showing negative reticulum.

Comparison- Warkallipollenites sp. closely resembles with *W. erdtmanii* Ramanujam & Rao in Thanikaimoni *et al.* (1984) in its general characters but the latter is distinguished by densely placed clava surmounted by 3-4 spinules.

Genus-*Echistephanocolpites* Wijmstra, 1971

Type species-Echistephanocolpites echinatus Wijmstra, 1971

***Echistephanocolpites boldamgiriensis* sp. nov.**

Pl. 2, figs. 14-15

Holotype- Pl. 2, fig. 15, slide no. 11673 (15.4x144.0).

Type locality, horizon and age- Adugiri - Purakhasia Road near Boldamgiri, West Garo Hills, Meghalaya; Boldamgiri Formation; Early Miocene.

Diagnosis- Pollen grains subspherical. Size range 60-65x 55- 60 µm. Pentacolpate, colpi 5-8 µm wide in the centre. Exine up to 4 µm thick, sexine thicker than nexine, conate, coni sparsely placed, exine between coni pitted- reticulate.

Comparison- Echistephanocolpites boldamgiriensis sp. nov. is closely comparable with *Echistephanocolpites echinatus* Wijmstra (1971) but the latter can be distinguished by its compactly placed coni. *Echistephanocolpites meghalayaensis* Rao *et al.* (1985) differs in possessing 4 colpi and sparsely placed coni.

Genus-*Myricipites* Wodehouse, 1933

Type species-Myricipites dubius Wodehouse, 1933

Myricipites* sp. cf. *M. harrisii (Couper) Dutta & Sah, 1970

Pl. 3, fig. 13

Description- Pollen grain subtriangular. Size 50 x 45 µm. Triporate, pore 11 µm in diameter. Exine 3 µm thick, psilate to scabrate, folded, sexine and nexine not differentiated.

Comparison- The present specimen is closely comparable to *Myricipites harrisii* (Couper) Dutta & Sah (1970) by its triporate and laevigate exine but the latter is distinguished by its smaller size (18-35 mm) and thinner exine (upto 2 µm).

Genus-*Chenopodipollis* Krutzsch, 1966

Type species - Chenopodipollis multiplex (Weyland & Pflug) Krutzsch, 1966

***Chenopodipollis* sp.**

Pl. 2, fig. 22

Description- Pollen grains subspherical. Size range 45-57 x 42-44 µm. Polyporate, periporate. Exine up to 4 µm thick, sexine thicker than nexine, tectate, surface showing negative reticulum.

Comparison- *Chenopodipollis multiplex* (Weyland & Pflug) Krutzsch (1966) is comparable with the present species by its periporate condition and reticulate exine but the former is smaller in size (up to 30 µm) and has thinner exine (2 µm).

Genus-*Malvacearumpollis* Nagy, 1962

Type species-Malvacearumpollis bakonyensis Nagy, 1962

***Malvacearumpollis* sp.**
Pl. 2, fig. 10

Description- Pollen grains subspherical. Size range 55-72 x 48- 60 µm. Polyporate, 4-5 pores distinct. Exine upto 1.5 µm thick, sexine and nexine not differentiated, spinulate, spinule 4-6 µm long, 2-3 µm wide, sparsely placed, surface finely pitted-reticulate.

Comparison- *Malvacearumpollis* sp. is closely comparable with *M. bakonyensis* Nagy (1962) in its general characters but the latter is distinguished in having large spines (6-12 in number) and bulging (5- 6 µm) bases.

QUANTITATIVE ANALYSIS

The palynoflora recorded here from the Boldamgiri Formation contains 52 genera and 63 species. Of these, 4 genera and 5 species belong to dinoflagellate cysts, 11 genera and 12 species to fungal remains, 15 genera and 21 species to pteridophytic spores, 2 genera and 2 species to gymnospermous pollen and 20 genera and 23 species to angiospermous pollen. Besides, reworked Permian and Cretaceous palynofossils and salt glands of mangrove plants (*Heliospermopsis* spp.) have also been recovered.

Quantitative analysis of the assemblage has been done on the basis of frequencies of palynotaxa in a count of 200 or more specimens per sample and from such counts, percentage of each palynotaxon or group of palynotaxa was calculated. Dinoflagellate cysts and reworked palynofossils were counted as groups whereas fungal remains were kept away from the counting (Text-fig.2).

The most dominant palynotaxa of the assemblage, occurring throughout the sequence, are: *Striatriletes susannae* (average 20%) *Pinuspollenites foveolatus* (average 12%) and *Lygodiumsporites lakiensis* (average 10%). *Striatriletes susannae* ranges from 11 percent to 38 percent in individual samples. Other important palynotaxa are: *Biretisporites convexus* (8% in the Lower Palynozone), *Meyeripollis naharkotensis* (4% in the Lower Palynozone), *Polypodiaceaesporites chatterjii* (4%) and *Cheilanthoidspora monoleta* (5% in the Upper Palynozone).

Vertical distribution of the palynotaxa clearly indicates that the studied sequence is divisible into two palynozones-the lower and the upper. Palynotaxa restricted to the Lower Palynozone (with their average percentages in parentheses) are: *Lygodiumsporites pachyexinus* (5%), *Biretisporites convexus* (8%), *Striatriletes pseudocostatus* (8%), *S. punctatus* (4%), *Pinjoriapollis lanceolatus* (6%), *Paleosantalaceaepites minutus* (1.5%), *Meyeripollis naharkotensis* (4%), *Varispinitriporites ratariaensis* (1%), *Echistephanocolpites* spp. (3%) and *Chenopodipollis* sp. (1%).

On the other hand, *Foveotriletes garoensis* (2.5%), *Osmundacidites* sp., *Pilamonoletes excellensus*, *Triporopollenites robustus*, *Favitricolporites magnus* and *Pteridacidites* sp. are restricted to the Upper Palynozone. *Abiespollenites surmaensis* and *Cheilanthoidspora monoleta*, occurring throughout the sequence, increase in frequency in the Upper Palynozone.

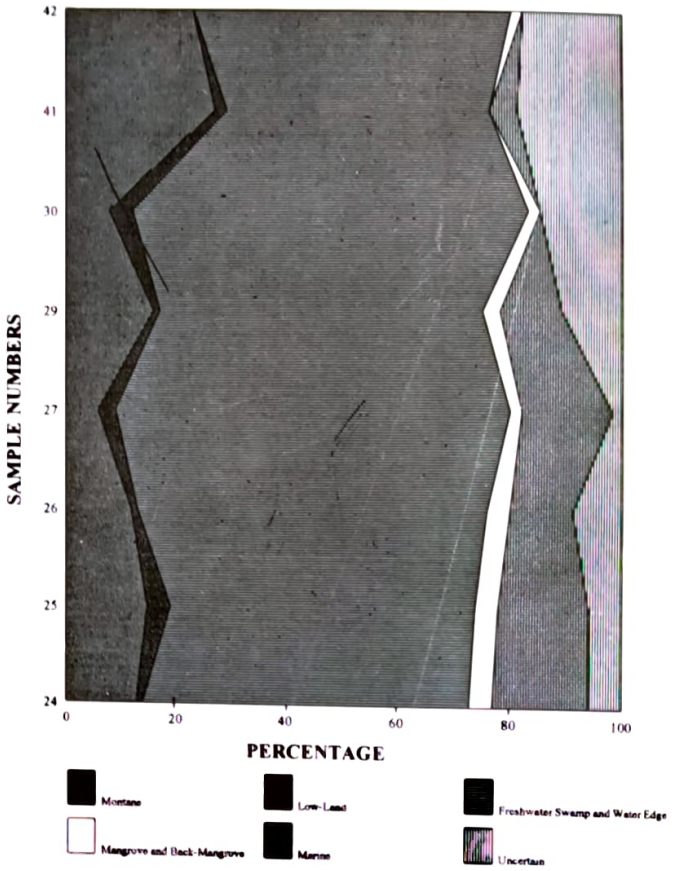
Dinoflagellate cysts and reworked Permian and Cretaceous palynofossils have also been recorded. Dinoflagellate cysts are more dominant in the Lower Palynozone (average 15%) than in the Upper Palynozone (average 5%). Contrary to this, the frequency of reworked palynofossils is less in Lower Palynozone (average, 5%) than that in the Upper Palynozone (average 14%).

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

The Boldamgiri palynoassemblage contains dinoflagellate cysts, fungal fruiting bodies and spores, pteridophytic spores and gymnospermous and angiospermous pollen. The pteridophytic, gymnospermous and angiospermous palynotaxa of the assemblage are assignable to 22 families. These are: Cyatheaceae, Lycopodiaceae, Schizaeaceae, Hymenophyllaceae, Osmundaceae, Parkeriaceae, Pteridaceae, Polypodiaceae, Pinaceae, Magnoliaceae, Arecaceae, Potamogetonaceae, Thymelaeaceae, Rhizophoraceae, Rubiaceae, Plumbaginaceae, Mimosaceae, Proteaceae, Myricaceae, Malvaceae, Chenopodiaceae and Gunneraceae. Of these, 10 families, viz., Cyatheaceae, Schizaeaceae, Parkeriaceae, Magnoliaceae, Arecaceae, Rhizophoraceae, Rubiaceae, Mimosaceae, Proteaceae, Myricaceae, have their present day distribution restricted to tropical (-subtropical) regions, whereas others are cosmopolitan in distribution. The temperate elements assignable to Magnoliaceae and Pinaceae appear to be derived from the upland areas in the north. The pteridophytic ele-

ments generally favour moist and shady habitat. *Ceratopteris*, richly represented by *Striatriletes*, is a water fern growing in tropical region. Rich representation of fungal fruiting bodies and spores is also indicative of warm and humid climate. The overall vegetational pattern indicate a tropical- subtropical, humid climate during the sedimentation of the Boldamgiri Formation.

Presence of *Lygodiumsporites* and *Striatriletes* is indicative of fresh water swamps and ponding conditions near the site of deposition. Fresh water conditions are indicated by *Retipilonapites* belonging to Potamogetonaceae. The assemblage is, in fact, dominated by fresh water swamps and water edge elements (Text-fig.3). Pollen belonging to Chenopodiaceae (*Chenopodipollis*) are salt loving and occur near sea coast. Mangrove and back mangrove elements (*Paleosantalaceaepites, Heliospermopsis, Malvacearumpollis*) and dinoflagellate cysts (*Tuberculodinium, Polysphaeridium, Achomosphaera* and *Spiniferites*) have been found in almost throughout the sequence. These elements are well represented in the lower part of the sequence and gradually decline upwards which may possibly be related to gradual regression of the sea. Chakraborty and Baksi (1972) opined that the Boldamgiri Formation was deposited in a shallow basin and noticed frequent occurrence of deltaic channel - fills in the very coarse grained sediments of this formation. The coastal and shore-line elements are represented by arecaceous pollen (*Spinizonocolpites*). The gymnospermous pollen appear to be derived from the upland areas in the north. It may therefore be inferred that the Boldamgiri Formation was deposited in a coastal marine environment having fresh water connections with swamps and ponding conditions nearby and that the coast was bordered by mangroves and other coastal elements.



Text-fig. 3. Vertical distribution of palynotaxa in the Boldamgiri Formation, Garo Hills, Meghalaya.

PALYNOFLORAL COMPARISON

A comparison of the present assemblage with the known Boldamgiri/Bhuban (Early Miocene) assemblages is discussed below :

Baksi (1962, 1974) recorded palynofossils from the Tertiary sediments of Simsang River Section, Meghalaya and recognized four palynozones. Of these, Zone-IV is assigned to Early Miocene age. The palynofossil genera common to the present assemblage and the Zone-IV of Simsang River Section are: *Striatriletes* (=*Schizaeaceaesporites* and *Parkeriaceaesporites*), *Polypodiaceaesporites* and *Tricolpites*. Besides, coniferous pollen (= *Pinuspollenites* and *Abiespollenites*), spinose pollen (= *Spinizonocolpites*), gemmate syncolpate pollen (= *Meyeripollis*), dinoflagellate cysts and fungal remains are also shared by these two assemblages. Palynotaxa present in the Zone-IV of Simsang River Section but absent from the present assemblage are: *Bauhinia burdwanensis, Leiotriletes, Tetradopites, Tricolpopites, Polygonaceaepites* and *Densexinosporites*. On the other hand, the following palynotaxa of the present assemblage are absent from the Zone-IV of Simsang River Section: *Cyathidites, Lygodiumsporites, Biretisporites, Foveotriletes, Lycopodiumsporites, Intrapunctisporis, Osmundacidites, Verrutriletes, Cheilanthoidspora, Neyvelisporites, Pilamonoletes, Retipilonapites, Clavainaperturites, Pinjoriapollis, Paleosantalaceaepites, Favitricolporites, Plumbaginacipites, Warkallipollenites, Dermatobrevicolporites, Echistephano colpites, Varispinitriporites, Proteacidites, Triporopollenites, Malvacearumpollis, Chenopodipollis* and *Polyadopollenites*. The comparative study reveals that the dominant elements, viz., *Pinuspollenites/Abiespollenites* (= coniferous pollen), *Striatriletes* and *Meyeripollis* (= gemmate-syncolpate pollen) are present in both the assemblages showing close resemblance between them.

Banerjee (1964) published a few palynotaxa from the Surma sediments (Miocene) of Simsang River Section, Meghalaya. The following palynotaxa of this as-

semblage have also been recorded in the present assemblage: *Polypodiaceaesporites* (= *Psilasmonoletes*), *Neyvelisporites* (= *Foveomonoletes*), *Polypodiisporites* (= *Verrumonoletes*), *Lygodiumsporites* (= *Psilatriletes*), *Lycopodiumsporites* (= *Retitriletes*), *Pinuspollenites/ Abiespollenites* (= *Saccites*), *Pinjoriapollis* (= *Monocolpites*), *Echistephanocolpites* (= *Stephanocolpites*), *Striatriletes* and *Tricolpites*. The above comparison indicates that the assemblage recorded by Banerjee (1964) closely resembles with the present assemblage.

Salujha *et al.* (1973) reported palynoassemblages from the Bhuban and Bokabil formations developed along the southern edge of Shillong Plateau and attempted to distinguish the two formations on the basis of palynofossils. The genera common between the present assemblage and that from the Bhuban Formation of South Shillong Front are: *Striatriletes* (= *Magnastriatites*), *Polypodiaceaesporites*, *Polypodiisporites*, *Tricolpites*, *Favitricolporites*, *Paleosantalaceaepites* and *Triporopollenites*. The palynoassemblage described by Salujha *et al.* (1973) is broadly comparable with the present one.

Nandi and Sharma (1984) reported a rich palynofloral assemblage from the Boldamgiri Formation (Early Miocene) of Damalgiri area in Garo Hills, Meghalaya. The following taxa of this assemblage have also been recorded from the present assemblage: *Cyathidites*, *Lygodiumsporites*, *Foveotriletes*, *Striatriletes* (= *Cicatricosisporites/ Magnastriatites*), *Polypodiaceaesporites*, *Polypodiisporites* (= *Polypodiidites*), *Pinuspollenites*, *Tricolpites*, *Echistephanocolpites* (=*Stephanocolpites*), *Favitricolporites*, *Meyeripollis*, *Myricipites* and *Chenopodipollis*. Detailed comparative study indicates that *Lygodiumsporites*, *Leiotriletes*, *Striatriletes*, *Polypodiaceaesporites*, *Pinuspollenites*, *Meyeripollis*, *Echistephanocolpites* and *Chenopodipollis* are dominant in both the assemblages, hence, the two assemblages are closely comparable.

Saxena *et al.* (1987) made a detailed palynostratigraphic study of the Barail (Oligocene) and Surma (Early Miocene) sediments exposed along Sonapur-Badarpur Road Section in Jaintia Hills (Meghalaya) and Cachar (Assam) and divided the sequence into 5 palynological cenozones. Of these, the third and fourth palynozones, viz., *Striatriletes sinuosus* Cenozone and *Pinuspollenites foveolatus* Cenozone, respectively within the Bhuban Formation (Early Miocene) are comparable with the present assemblage. The following genera are common to the above palynozones and the present assemblage: *Cyathidites*, *Lygodiumsporites*, *Lycopodiumsporites*, *Biretisporites*, *Striatriletes*, *Polypodiaceaesporites*, *Polypodiisporites*, *Pinuspollenites*, *Abiespollenites*, *Echistephanocolpites*, *Malvacearumpollis* and *Polyadopollenites*. The above comparison shows that the present assemblage is largely comparable with that from the Bhuban Formation of Sonapur- Badarpur Road Section.

Kar (1991) published palynoassemblages from the Oligocene to Pliocene sediments of Assam and Tripura. Following palynotaxa recorded from the Early Miocene sediments (*Striatriletes susannae* Cenozone) by Kar (1991) are common to the present assemblage: *Striatriletes*, *Osmundacidites*, *Lycopodiumsporites*, *Lygodiumsporites*, *Pilamonoletes*, *Paleosantalaceaepites* and *Pinuspollenites*:

CONCLUSIONS

The palynoassemblage from the Boldamgiri Formation of the type area is rich and diversified containing algal (dinoflagellate cysts) and fungal (ascostromata and spores) remains, pteridophytic spores and gymnospermous and angiospermous pollen. The assemblage is dominated by pteridophytic spores (*Striatriletes* spp., *Lygodiumsporites* spp., *Intrapunctisporis* spp., *Biretisporites convexus*, *Polypodiaceaesporites chatterjii*, etc.) and coniferous pollen (*Pinuspollenites foveolatus* and *Abiespollenites surmaensis*). Interpretation of the palynofossil taxa and their distribution permit to draw the following conclusions.

1. The studied sequence is divisible into two palynozones which can be distinguished by their characteristic and restricted palynotaxa.
2. The distribution of the families represented in the assemblage indicates that the area enjoyed a tropical-subtropical (warm and humid) climate during the sedimentation of the Boldamgiri Formation.
3. The Boldamgiri Formation was deposited in a coastal marine environment having fresh water connections with swamps and ponding conditions nearby. The later period of sedimentation witnessed a regressive phase.
4. The assemblage is closely comparable to and hence homotaxial with the known Boldamgiri/ Bhuban (Early Miocene) assemblages of Meghalaya.

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