Palynostratigraphy and palaeoecology of Early Eocene palynoflora of Rajpardi lignite, Bharuch District, Gujarat

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The palynoflora recovered from carbonaceous clay, shale and lignite samples of Rajpardi lignite mine is represented by angiospermic pollen belonging to palms and arborescent dicotyledons, pteridophytic spores and fungal fruiting bodies. In all, 35 genera and 46 species are recorded which are dominated by dicotyledonous pollen. The present assemblage also comprises some significant taxa, viz., *Matanomadhiasulcites maximus, Retimonosulcites ovatus, Lakiapollis ovatus, Tribrevicolporites eocenicus, Tricolporopilites robustus, Dermatobrevicolporites dermatus, Laevigatopolycolpites rotatus* and *Lanagiopollis* spp., etc., in which some of the palynotaxa have been assigned to various extant families. On the basis of similarity with modern taxa, it is envisaged that these fossil palynotaxa were the representatives of tropical to subtropical vegetation belonging to swamp habitat. This assemblage is correlated with Naredi Formation, Kutch as well as other contemporaneous deposits of India and an Early Eocene age has been assigned. The stratigraphic significance and botanical affinity of the palynoflora have also been discussed.

Key-words—Palynostratigraphy, Palaeoecology, Early Eocene, Gujarat (India).

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साराँश

गुजरात में भड़ौंच जनपद में राजपार्डी लगुडांगार से प्राप्त प्रारम्भिक आदिनूतन कालीन परागाणुवनस्पतिजात का परागाणुस्तरविन्यास तथा पुरापारिस्थितिकी

माधव कुमार

राजपार्डी लगुडांगार खान की कार्बनमय मिट्टी, शेल एवं लगुडांगार के नमूनों से उपलब्ध परागाणुवनस्पतिजात में ताड़ों एवं वृक्षीय द्विबीजपत्रीयों के परागकण, टेरीडोफाइटी बीजाणु एवं कवकीय फलनकायें विद्यमान हैं। वर्तमान समुच्चय में *मातानोमढ़ि यासल्काइटिस मेक्सिमस, रेटिमोनोसल्काइटिस ओवेटस, लकियापॉलिस ओवेटस, ट्राइब्रेविकॉल्पोराइटिस ईओसेनिकस, ट्राइकॉल्पोरोपाइलाइटिस रोबस्टस, डर्मेटोब्रेविकॉल्पोराइटिस डर्मेटस, लेविगेटोपोलिकॉल्पाइटिस रोटेटस एवं लानाजिओपॉलिस* जाति आदि नामक कुछ विशिष्ट वर्गक विद्यमान हैं। इनमें से कुछ वर्गकों को विभिन्न वर्तमान कुलों से भी सम्बद्ध किया गया है। वर्तमान वर्गकों के आधार पर यह प्रस्तावित किया गया है कि ये अश्मित परागाणुवर्गक दलदली स्थानों में उष्णकटिबन्धीय से उपोष्णकटिबन्धीय वनस्पति का निरूपण करते हैं। इस समुच्चय की कच्छ में नरेडी शैल समूह तथा देश के अन्य समकालीन निक्षेपों से इसकी तुलना की गई है तथा इसकी प्रारम्भिक आदिनूतन आयु आँकी गई है। उपलब्ध परागाणु वनस्पतिजात के स्तरिक महत्व तथा इसकी वनस्पतिक सजातीयता की भी विवेचना की गई है।

THE lignite bearing sediments of Gujrat show a diversified assemblage of palynofossils. Venkatachala and Kar (1969a), Sah and Kar (1970), Kar (1985), Bhattacharyya (1987), Phadtare and Thakur (1990), and Kar and Bhattacharya (1992) contributed on the palynological studies of Early Tertiary sediments of Panandhro, Akrimota, Gujradam and some subsurface rocks of Naredi Formation of Kutch and Rajpardi lignite mine of south Cambay Basin. Guleria (1991, 1994) studied the megafossils recovered from the area. The Rajpardi lignite, situated at southern part of Gujarat, is generally considered as part of Tarkeshwar Formation (Kathiara, 1969; Kathiara & Bhatt, 1969) which is exposed on the eastern fringe around Jhagadia-Tarkeshwar area in Bharuch District. The age of this lignite has been a controversial topic since

the work of Blanford (1869). Many workers have proposed different ages of Tarkeshwar Formation using various geological parameters.

In contrast to the geological knowledge, not much is known about the floristic composition and palaeoecology of the Rajpardi lignite. Therefore the present detailed study of the Rajpardi lignite has been carried out.

MATERIAL AND METHODS

A total of 145 samples including lignite, carbonaceous clay and carbonaceous shale were collected from two freshly exposed vertical pit sections at a regular stratigraphic interval of 20 cm. About 30 gm of each sample was chemically processed using conventional method. The slides were prepared with smearing the macerals in polyvinyl alcohol on cover slips and mounted in canada balsam. For quantitative analysis 200 specimens were counted from each productive sample. The slides of figured specimens have been deposited at the Repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

GEOLOGY OF THE AREA

The Rajpardi lignite mine is situated at about 35 km east on Ankleshwar-Rajpipla road toward south of Rajpardi Village, Bharuch District, between Lat. 21°43'-21°40' N and Long. 73°13'- 73°15' E. It covers an area of about 3.5 sq km. The lignite mine is bounded by three villages namely Bhuri, Amod and Muljipura (Map 1). The area looks slightly hilly due to Babaguru Hills (height about 118 m) otherwise the general topography of the area is flat.

Tectonically, the Cambay Basin is located on the north western fringe of Deccan Trap (Upper Cretaceous). The Tertiary rocks in the south of Cambay Basin are exposed on eastern margin around Jhagadia-Tarkeshwar area. Chandra and Chowdhary (1969), Kathiara (1969), Kathiara and Bhatt (1969), Sudhakar and Basu (1973), and Koshal and Uniyal (1986) studied the stratigraphy of the Cambay Basin in detail. According to them the generalised sequence of the stratigraphy of the area is as follows :

Table 1

Age	Formation (thickness in m approx.)	Lithology
Pleistocene to recent	Alluvium	Sands of various colour, soils and kankars
Pliocene to Middle Miocene	Jhagadia (304)	Light coloured sandstone, marls, limestone and conglomerates
Early Miocene	Kand (452)	Limestone, marls, clay and sandstone, bands of agate bearing conglomerate
Earliest Miocene	Babaguru (152)	Ferruginous sandstone, agate bearing conglomerate and varied clay, grey sandstone and white sand
Oligocene to Late Eocene	Tarkeshwar (152)	Grey, yellow and brown friable sandstone with lenses of bentonitic clay with lignite beds and lenses of carbonaceous clays, sandstone and lignite
Late to Early Eocene	Numulitic (122)	Numulitic limestone clays and lenses of sandstone
Early Eocene to Palaeocene	Vagadkhol (304)	Bentonitic clays, friable sandstone and conglomerate
----------	UNCONFORMITY	----------
Upper Cretaceous	Deccan Traps	Basalts with basic intrusions

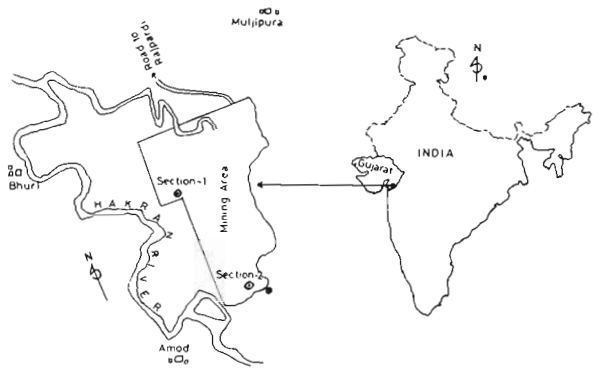
In the Rajpardi mine area, the rocks of Vagadkhol, Tarkeshwar and Babaguru formations are exposed.

Vagadkhol Formation

On the eastern side of the lignite field the rocks of Vagadkhol Formation are exposed unconformably overlying the Deccan Traps. The richly fossiliferous formation consists of argillaceous and arenaceous limestone, marls and clay. The contact between Deccan Traps and Vagadkhol Formation is distinguished by the matrix supported by conglomerate containing pebbles of quartz, agate and basalt. The lower most part of trap consists of varied coloured clays near Bhuri Village.

Tarkeshwar Formation

The Tarkeshwar Formation conformably overlies the Vagadkhol Formation around Rajpardi. Kathiara and Bhatt (1969) divided it into two lithosomes. The lower lithosome, consisting of grey clay with varying thickness, is overlain by carbonaceous shale with bands of lignite on the upper part. One meter thick sequence of clay, shale and 4-5 m thick seam of lignite



Map 1—Showing the location of area.

is the characteristic feature of the upper part. This band also contains ferruginous sandstone, sand and silica. The upper lithosome consists of only ferruginous sandstone and sand.

Babaguru Formation

The Babaguru Formation conformably overlies the Tarkeshwar Formation. Here the rocks comprise sandstone, loose sand, grey clay, quartz, pebbles and conglomerate, but are unfossiliferous.

There are two sections, I and II in the Tarkeshwar Formation studied and the palynoflora recovered from them is as under :

Taxa	Sections I	II
Pteridophytic spores		
Biretisporites sp.	+	+
Cheilanthoidspora sp.	+	
Lygodiumsporites lakiensis Sah & Kar 1969	+	+
Polypodiisporites repandus Takahasi 1964		+
Polypodiisporites sp.		+
Angiosperms		
Arecipites intrapunctatus Kar & Saxena 1981	+	+
Arengapollenites ovatus Kar & Bhattacharya 1992	+	+
Liliacidites baculatus Venkatachala & Kar 1969		+
Matanomadhiasulcites maximus Kar 1985	+	+
Neocouperipollis ankleshwarensis Kar & Bhattacharya 1992	+	+
Palmaepollenites indicus Ramanujam 1966	+	+
Palmidites plicatus Singh 1975	+	+
Proxapertites assamica Singh 1975		+
Retimonosulcites ovatus Kar 1985	+	
Clavaperiporites jacobii Ramanujam 1966	+	+
C. clavatus Ramanujam 1966	+	+
Dermatobrevicolporites dermatus Kar 1985	+	+
D. exaltus Kar 1985	+	+
Laevigatopolycolpites rotatus Kar & Bhattacharya 1992		+
Lakiapollis ovatus Venkatachala & Kar 1969	+	+
Lanagiopollis cambayensis sp. nov.	+	+
L. retsmae Phadtare & Thakur 1990	+	+
L. rugularis Morley 1982	+	+
L. ruguloverrucatus Morley 1982	+	+
L. tetracolporatus sp. nov.	+	
Lanagiopollis sp.	+	+
Nyssapollenites incertus Dutta & Sah 1970	+	
Polygalacidites sp.	+	
Psilatricolporites cassoides Ramanujam 1966	+	
Retipollenites confusus Gujman 1967		+
Retistephanocolporites sp.		+
Retitribrevicolporites matanomadhensis Kar 1985	+	
Sastripollenites trilobatus Venkatachala & Kar 1969		+
Scrobiculatricolporites undulatus Singh & Misra 1991	+	
Striatricolpites semistriatus Gujman 1967	+	

Contd. ⟶

PLATE 1

(All photographs are magnified ca. x 500).

1. *Lygodiumsporites lakiensis* Sah & Kar, slide no. BSIP 11563 Q36/3.
2. *Retitribrevicolporites matanomadhensis* Kar, slide no. BSIP 11530 P9/4.
3. *Retistephanocolporites* sp., slide no. BSIP 11531 K38.
4. *Clavaperiporites jacobii* Ramanujam, slide no.BSIP 11530 G39.
5. *Tricolpites reticulatus* Cookson, slide no. BSIP 11533 D21/1.
6. *Arengapollenites ovatus* Kar & Bhattacharya, slide no.BSIP 11532 U5/4.
7. *Lakiapollis matanomadhensis* Kar, slide no. BSIP 11542 J25/3.
8, 9. *Clavaperiporites clavatus* Navale & Misra, slide no. BSIP 11531 E55/4.
10. *Striatricolpites semistriatus* Gujman, slide no. BSIP 11557 X33/2.
11. *Tricolpites retipilatus* Kar & Jain, slide no. BSIP 11552 K12.
12. *Lanagiopollis tetracolporatus,* slide no. BSIP 11540 N45.
13,14. *Lanagiopollis rugularis* Morley, slide no. BSIP 11535 T25.
15. *Sastripollenites trilobatus* Venkatachala & Kar, slide no. BSIP 11554 T55/3.
16. Pollen Type A, slide no. BSIP 11531 G39.
17, 18. *Tricolporopollis rubra* Dutta & Sah, slide nos BSIP 11531 D43/4 and 11529 O52.
19, 23. *Retitribrevicolporites matanomadhensis* Kar, slide nos BSIP 11557, F34, 11555 V21.
20. Pollen Tetrad Type A, slide no. BSIP 11529 P49/2.
21, 22. *Lanagiopollis cambayensis* sp. nov., slide no. BSIP 11529 P13.
24. *Lakiapollis ovatus* Sah & Kar, slide no. BSIP 11531 H36/4.
25, 26. *Lanagiopollis ruguloverrucatus* Morley, slide no. BSIP 11552 N43.
27. *Lanagiopollis rugularis* Morley, slide no. BSIP 11565 H15/1.
28. *Proxapertites assamica* (Dutta & Sah) Singh, slide no. BSIP 11556 S19/3.

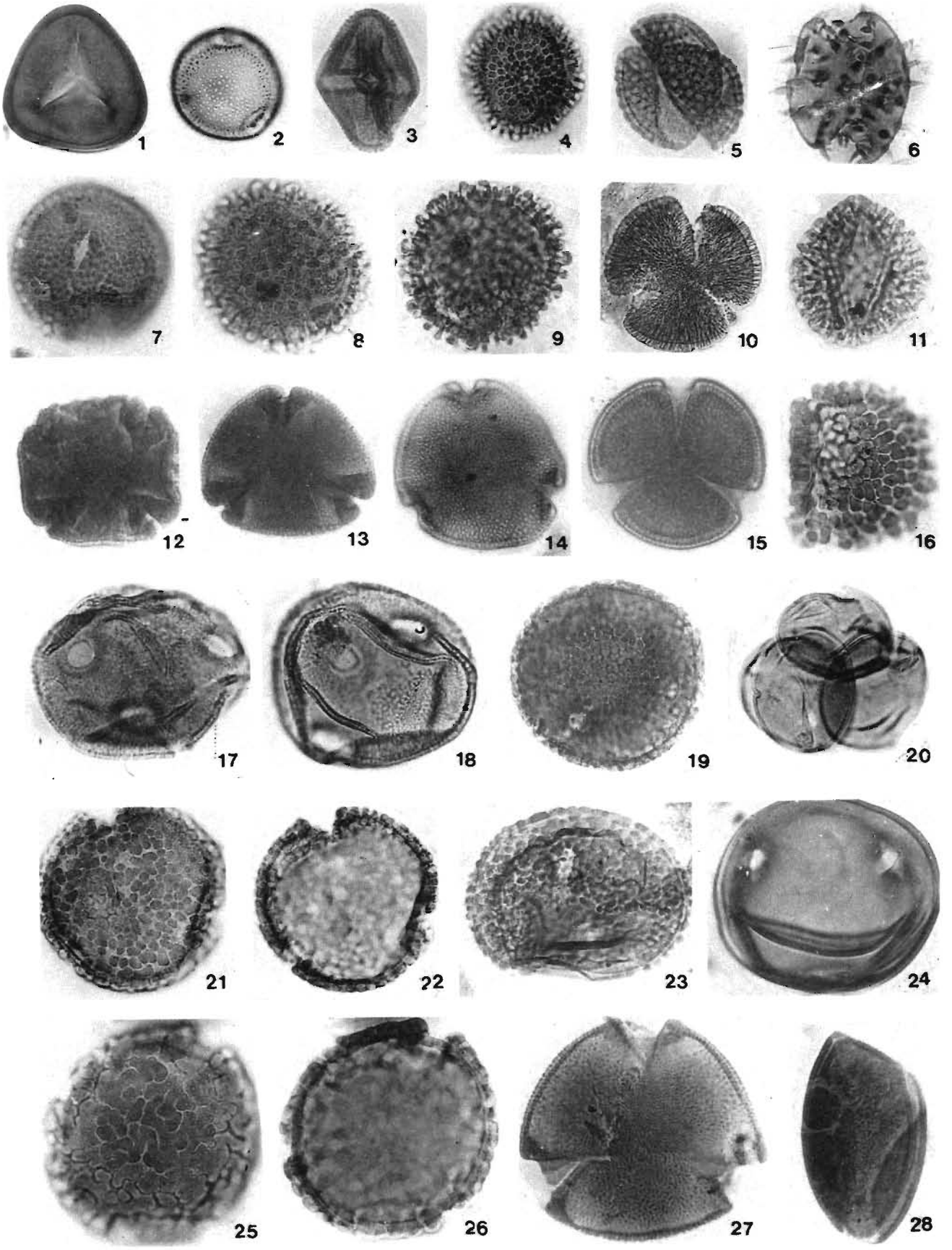


PLATE 1

Taxa	Sections	I	II
Tribrevicolporites eocenicus Kar 1985			+
Tricolpites reticulatus Cookson 1947		+	
T. retipilatus Kar & Jain 1981		+	
Tricolpites sp.		+	
Tricolporocollumelites pilatus Kar 1985			+
Tricolporopilites robustus Kar 1985		+	+
Tricolporopollis sp.		+	+
Pollen Tetrad type A		+	+
Pollen tetrad type B		+	
Fungi			
Inapertusporites kedvesii Elsik 1968		+	+
Phragmothyrites eocenicus Edward 1922			+
Notothyrites setiferous Cookson 1947		+	+
Trichothyrites sp.			+

SYSTEMATIC STUDY

Genus—*Lanagiopollis* Morley 1982

Type species—*Lanagiopollis rugularis* Morley 1982.

Lanagiopollis cambayensis sp. nov.

Pl. 1, figs 21, 22; Pl. 2, figs 11, 12

Holotype—Pl. 2, figs 11, 12, slide no. BSIP 11548 T39.

Isotype—Pl. 1, figs 21, 22, slide no. BSIP 11529 P13.

Type locality and horizon—Rajpardi Lignite, Tarkeshwar Formation, Gujarat; Early Eocene.

Diagnosis—Pollen grains subcircular in shape, tricolporate, colpi long, pores circular to oval, lalongate. Exine 4-5 m thick, verrucate, verrucae free or fused.

Description—Pollen grains subcircular in shape, 60-70 µm. Tricolporate, colpi long, pore circular to oval, lalongate. Exine 4.0-5.0 µm thick, verrucate, verrucae 3.0-3.5 µm high, densely placed, verrucae heads various shaped, free, sometimes fused, beset with microgranulate sculptures. Nexine up to 1 µm thick.

Comparison—This species is comparable with *Lanagiopollis ruguloverrucatus* Morley 1982 but differs by the absence of rugulae and brevicolpi. *L. rugulatus* Phadtare & Thakur 1990 differs in having costate rugulae.

Affinity—*Alangium barbatum* (Reitsma, 1970) of the family Alangiaceae.

Derivation of name—The name of species is derived by its occurrence in Cambay Basin.

Lanagiopollis tetracolporatus sp. nov.

Pl. 1, fig. 12; Pl. 2, fig. 16

Holotype—Pl. 2, fig. 16, slide no. BSIP 11539 U26.

Type locality and horizon—Rajpardi Lignite, Tarkeshwar Formation, Gujarat; Early Eocene.

Diagnosis—Pollen grains quadrangular in shape. Tetracolporate, colpi long, pore margin thickened, ora protruded. Exine 2.0-2.5 µm thick, microreticulate, lumina various shaped, muri up to 1 µm thick.

Description—Pollen grains quadrangular in shape, 68-73 X 75-85 µm. Tetracolporate, colpi 20-35 µm long, open; pore circular, 10-12 µm in diameter, margin thickened, ora protruded. Exine 2.0-2.5 µm thick, pilate, pila heads fused to form microreticulate

PLATE 2 ⟶

(All photographs are magnified ca. x 500).

1. *Polypoditsporites repandus*, Takahasi, slide no. BSIP 11560 M14/3.
2. Tetracolpate pollen, slide no. BSIP 11564 G29/2.
3. *Dermatobrevicolporites exaltus* Kar, slide no. BSIP 11552 H28/3J25/3.
4, 20. *Nyssapollenites incertus* Dutta and Sah, slide no. BSIP 11532 K10 and 11533 V23/3.
5. *Laevigatopolycolpites rotatus* Kar & Bhattacharya, slide no. BSIP 11530 W16/2.
6. *Palmaepollenites indicus* Ramanujam, slide no. BSIP 11538 G48/2.
7. *Laevigatopolycolpites rotatus* Kar & Bhattacharya, slide no. BSIP 11534 P54/38.
8. Pollen tetrad Type B, slide no. BSIP 11552 J28.
9. *Retipollenites confusus* Guzman, slide no.BSIP 11545 V6, V7/3.
10. *Notothyrites setiferus* Cookson, slide no. BSIP 11544 R35/2.
11,12. *Lanagiopollis cambayensis* sp. nov., slide no. BSIP 11548 T39.
13. *Lanagiopollis* sp., slide no. BSIP 11539 R39.
14. *Arecipites intrapunctatus* Kar & Saxena, slide no. BSIP 11529 W48.
15. cf. *Lanagiopollis rugularis* Morley, slide no. BSIP 11553 G52/4.
16. *Lanagiopollis tetracolporatus* sp. nov., slide no. BSIP 11539 U30/1.
17. *Neocouperipollis ankleshwarensis* Kar & Bhattacharya, slide no. BSIP 11561 M47/3.
18, 19. *Phragmothyrites eocenicus* Edwards, slide nos. BSIP 11559 J41/3 and 11546 L44.
21. *Laevigatopolycolpites rotatus* Kar & Bhattacharya, slide nos. BSIP 11529 V26.
22. *Matanomadhiasulcites maximus* (Saxena) Kar, slide no. BSIP 11549 R3/1.

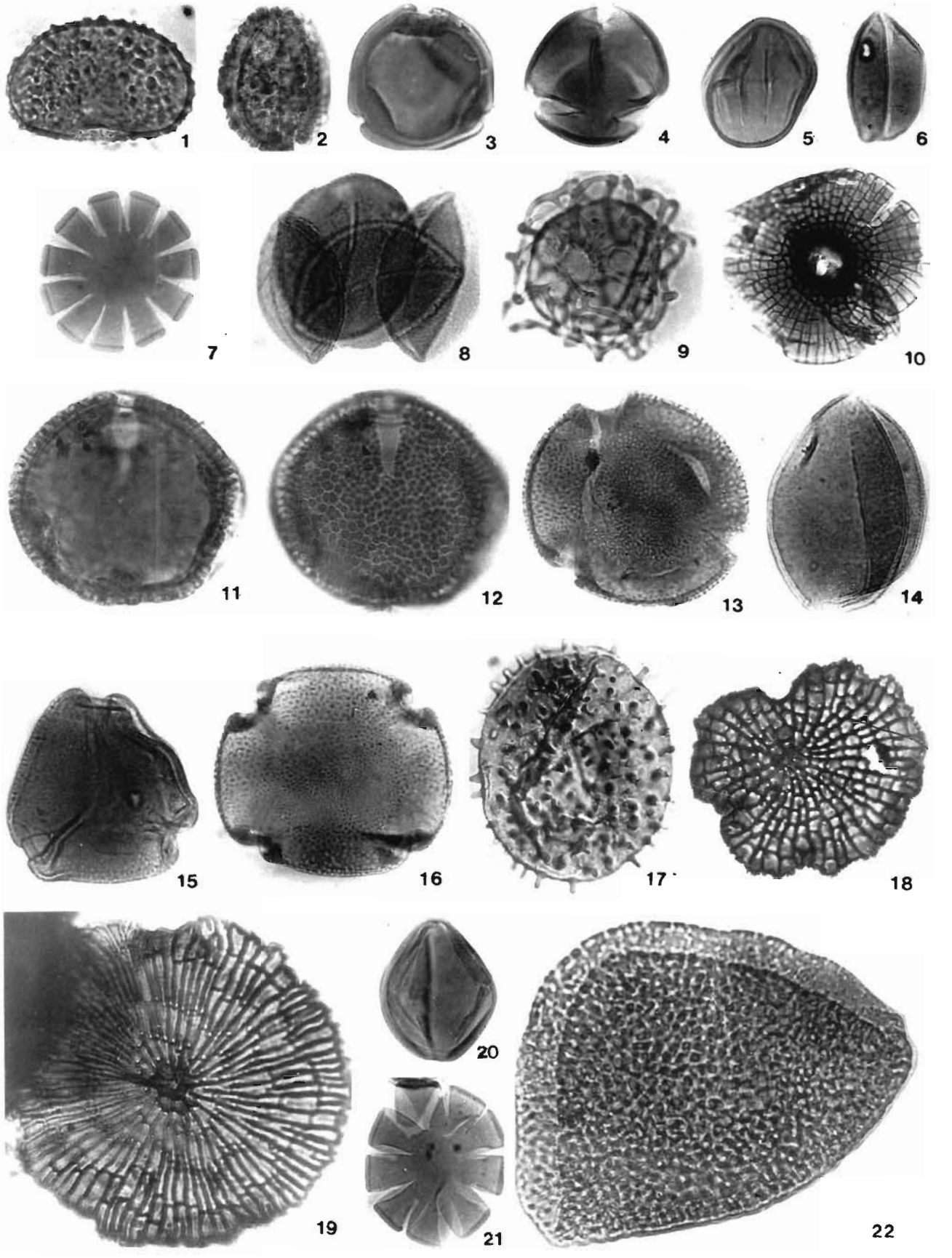


PLATE 2

ornamentation. Lumina various shaped, comparatively smaller near the poles and broader towards the equator; muri up to 1 µm thick. Nexine 0.5 µm thick.

Comparison—This species differs from other recorded species of *Lanagiopollis* by its tetracolporate aperture.

Affinity— *Alangium barbatum* (Alangiaceae).

Lanagiopollis sp.

Pl. 2, fig. 13

Description—Pollen grains subtriangular in shape, 75-85 µm. Tricolporate, pseudocolpate, colpi 20-25 µm long, pores circular to oval, 12-18 µm in diameter, margin thickened. Pseudocolpi 18-20 µm long, open crescent shaped, muri around furrow slightly thickened. Exine 1.5-2.0 µm thick, pilate, pila heads fused to form microreticulate ornamentation; lumina irregular in shape. Nexine up to 1 µm thick.

Comparison—*Lanagiopollis* sp. distinctly differs from other recorded species of the genus by its pseudocolpate aperture near the poles.

Pollen tetrad Type A

Pl. 1, fig. 20

Description—Pollen grains subtriangular in shape, size 50-65 µm. Individual grains subcircular in shape, 30-35 µm in diameter, showing simple cohesion. Exine up to 1.0 µm thick, laevigate to scabrate. Aperture monocolpate, colpus long extended to the poles.

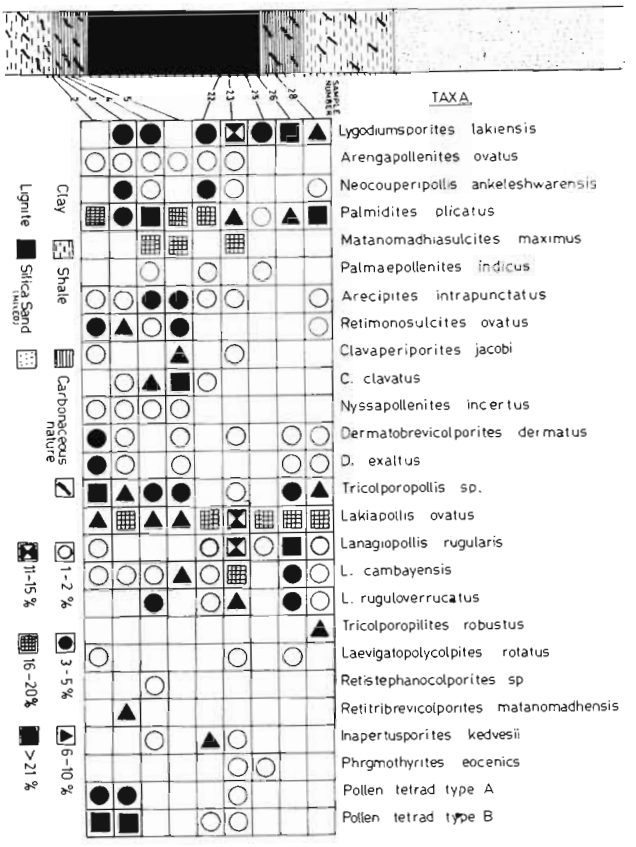
Remarks—The occurrence of monosulcate grains in fossil tetrad pollen is very rare. The tetrad with laevigate exine are the distinguishable characters of this type.

Pollen tetrad Type B

Pl. 2, fig. 8

Description—Pollen grains various shaped, 60-75 µm in size. Individual grains elliptical to oval in shape, 40-50 X 28-40 µm, showing simple cohesion in a tetrad. Exine up to 1.5 µm thick, nexine as thick as sexine, microreticulate to intrastructured. Monosulcate, sulcus meet at proximal face in a tetrad.

Comparison—The present specimen shows irregular pattern of cohesion of individual grains in tetrad. The presence of microreticulate exine distinguishes it from Pollen tetrad Type A.



Text-figure 1—Histogram showing percentage distribution of palynotaxa in section I of the Rajpardi lignite.

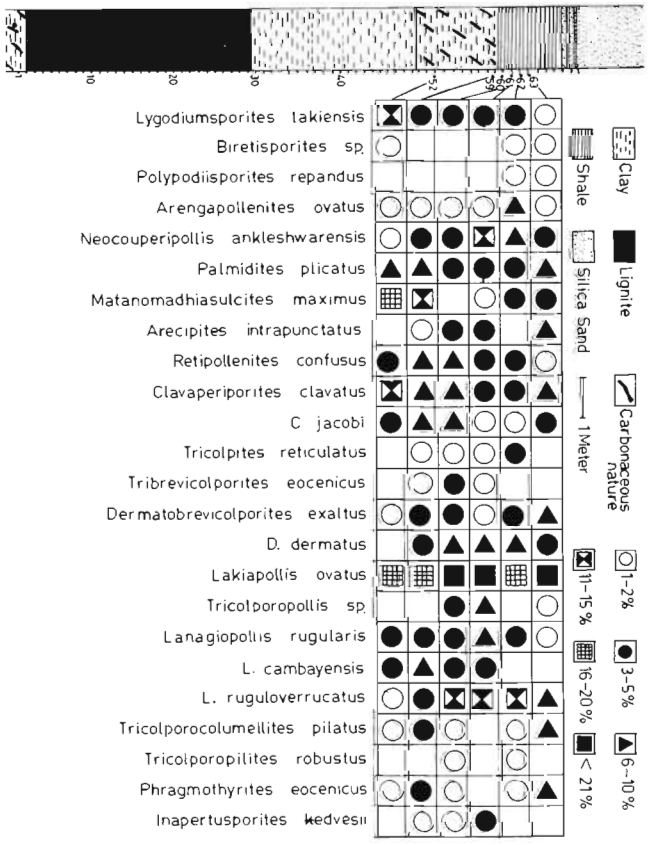
QUANTITATIVE AND QUALITATIVE ANALYSES

The palynoassemblage of Rajpardi lignite is well-preserved and rich which shows marked diversity in composition and species abundance (Text-figures 1, 2).

In overall palynoassemblage the angiosperm pollen are very common. The pteridophytic spores show relatively low frequency followed by fungal fruiting bodies. The assemblage comprises 36 genera and 46 species, in which angiosperm pollen are represented by 28 genera and 37 species, pteridophytic spores by 4 genera and 5 species and fungal fruiting bodies by 4 genera and 4 species. The gymnosperm pollen have not been observed in the assemblage.

Among fungal fruiting bodies *Inapertusporites kedvesii* represents 2 per cent in lower part and 3-6 per cent in the upper part in both the sections. The

pteridophytic spores constitute 3-22 per cent while *Polypodisporites repandus* is only 2 per cent in Section II. *Arengapollenites ovatus* and *Palmaepollenites indicus* are represented by 2 per cent each and *Neocouperipollis ankleshwarensis* and *Arecipites intrapunctatus* by 2-5 per cent. A good frequency of *Palmidites plicatus* has been observed in both the sections. *Retimonosulcites ovatus* shows up to 10 per cent in the lower part and decreases up to 2 per cent in the upper part of Section I and looses its abundance in Section II. *Matanomadhiasulcites maximus* represents about 20 per cent in upper to lower part of section I and 11-15 per cent in the lower part, while 2-5 per cent in the upper part of Section II. The most dominating taxa in overall assemblage is *Lakiapollis ovatus* (up to 20 per cent in Section I and more than 21 per cent in Section II. *Lanagiopollis cambayensis, L. rugularis, L. ruguloverrucatus* and *Tricolporopilites robustus*, etc. contribute 14 per cent in Section I and 18 per cent in section II. *Tricolporopollis* occurs 6-10 per cent and 2 per cent in the upper part of both the sections. *Nyssapollenites incertus* and *Laevigatopollenites rotatus* occurs only 2 per cent in Section I. The other common genera, e.g., *Clavaperiporites* observed more than 21 per cent in Section I and up to 15 per cent in section II. *Dermatobrevicolporites dermatus* and *D. exaltus* shows 1-5 per cent in Section I and up to 10 per cent in Section II.



Text-figure 2—Histogram showing percentage distribution palynotaxa in section II of the Rajpardi lignite.

List of palynotaxa attributed to various families:

Alangiaceae—*Lanagiopollis* spp.
Nyssaceae—*Nussapollenites incertus*
Bombacaceae—*Lakiapollis ovatus.*
Linaceae—*Clavaperiporites jacobi* and *C. clavatus.*
Arecaceae—*Palmidites plicatus, Palmaepollenites indicus, Arecipites intrapunctatus, Retimonosulcites ovatus, Neocouperipollis ankleshwarensis* and *Arengapollenites ovatus.*
Microthyriaceae—*Notothyrites setiferous, Phragmothyrites eocenicus, Inapertusporites kedvesii*, etc.

PALYNOSTRATIGRAPHY

As already discussed in this paper the palynoflora comprises angiospermic pollen, pteridophytic spores and fungal fruiting bodies. Text-figures 1 and 2 show the occurrence of spore-pollen taxa recovered from both the sections of Rajpardi lignite. In both the sections the palynoflora is dominated by *Lakiapollis ovatus* and therefore *Lakiapollis ovatus* Cenozone has been established.

Besides, *Palmidites plicatus, Neocouperipollis ankleshwarensis, Lanagiopollis verrucatus, L. rugularis, Tricolporopollis rubra, Lygodiumsporites lakiensis* and *Retitribrevicolporites matanomadhensis*. are the subdominant taxa in Section I. While *Lanagiopollis ruguloverrucatus, L. cambayensis, Clavaperiporites clavatus, Retipollenites confusus, Palmidites plicatus* and *Neocouperipollis ankleshwarensis* are the subdominant taxa in Section II of Rajpardi lignite.

CORRELATION OF PALYNOFLORA

Kutch Basin

The present palynofossil assemblage is comparable with Naredi Formation (Early Eocene) of

Table 2—Some significant pollen taxa from Rajpardi lignite and their stratigraphic range in other Tertiary deposits of India

Palaeocene	Eocene			Oligocene	Miocene	Taxa
	Early	Middle	Late			
	•••••					*Arengapollenites ovatus*
	•••••					*Neocouperipollis ankleshwarensis*
•••••••••	•••••	•••••		•••••••••	•••••••	*Palmidites plicatus*
•••••••••	•••••				•••••••	*Proxapertites assamica*
•••••••••	•••••					*Matanomadhiasulcites maximus*
•••••••••	•••••	•••••	••••			*Arecipites intrapunctatus*
•••••••••	•••••					*Retimonosulcites ovatus*
	•••••	•••••			•••••••	*Clavaperiporites clavatus*
•••••••••	•••••					*Nyssapollenites incertus*
	•••••					*Dermatobrevicolporites dermatus*
	•••••					*D. exaltus*
•••••••••	•••••	•••••	••••			*Lakiapollis ovatus*
	•••••	•••••				*Lanagiopollis rugularis*
	•••••	•••••				*L. ruguloverrucatus*
•••••••••	•••••	•••••				*Tricolporopollis rubra*
•••••••••	•••••					*Retitribrevicolporites matanomadhensis*
	•••••					*Retipollenites confusus*
•••••••••	•••••				•••••••	*Tribrevicolporites eocenicus*
	•••••	•••••				*Tricolporopilites robustus*
	•••••	•••••				*Tricolporocollumelites pilatus*

bore-core no. 14 near Matanomadh, Jhularai, Baranda and bore-core no. 1 and 2 near Lakhpat, Akri lignite and Gujra Dam section, Kutch (Venkatachala & Kar, 1969a; Sah & Kar, 1970; Kar, 1985; Kar & Bhattacharya, 1992).

The taxa like *Lygodiumsporites lakiensis, Matanomadhiasulcites maximus, Retimonosulcites ovatus, Lakiapollis ovatus, Tricolpites reticulatus, Sastripollenites trilobatus, Dermatobrevicolporites dermatus, D. ovatus, Clavaperiporites clavatus* and *Inapertusporites kedvesii* have been found common both in the Naredi Formation and Rajpardi lignite. Similarly, *Lygodiumsporites lakiensis, Liliacidites baculatus, Lakiapollis ovatus, Tricolpites reticulatus* and *Inapertusporites kedvesii* have also been found common in Akri lignite and Gujra Dam section (Kar & Bhattacharya, 1992) and the Rajpardi lignite assemblage.

Cambay Basin

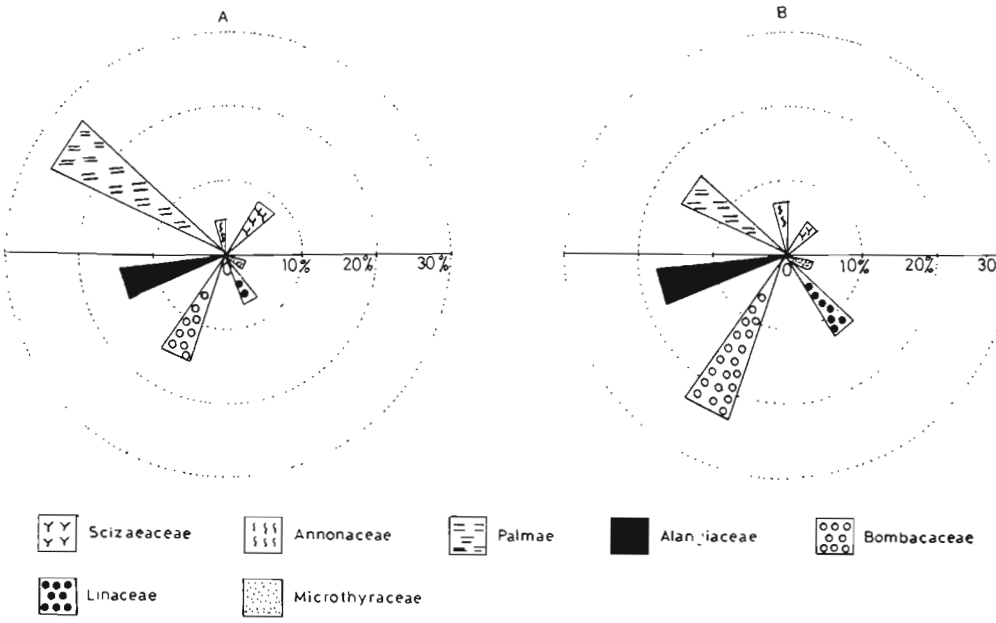
The present palynofossil assemblage also shows similarity with the palynoflora of Cambay Basin. *Retipollenites confusus* Guzman reported by Rawat *et al.* (1977) from Cambay Basin and observed by Venkatachala *et al.* (1989) as well as many other morphologically similar monosulcate pollen grains (quoted with different names) have been found common in the Rajpardi palynoassemblage.

Rajasthan Basin

The knowledge of palynoflora of the Lower Tertiary sediments of Rajasthan Basin is very little. The limited available data through the work of Sah and Kar (1974), Naskar and Baksi (1978) and Tripathi (1994) are mostly based on the morphological study of some pollen. So it is not possible to correlate the present palynoassemblage with Rajasthan Basin.

AGE OF RAJPARDI LIGNITE

Kathiara (1969) opined that the Rajpardi lignite constitutes the lower part of Tarkeshwar Formation and assigned a Late Eocene to Oligocene age to these sediments. Chandra and Chowdhary (1969) and Sud-



Text-figure 3—Diagram showing percentage of palynotaxa in the palynoassemblage attributed to different families (A = section I, B = section II).

hakar and Basu (1973) lithologically correlated the Tarkeshwar Formation with other equivalent formations and assigned Upper Eocene-Miocene age.

In Rajpardi area, the Vagadkhol Formation unconformably overlies Deccan Traps. It is worth mention that the Numulitic Formation is not developed here (Table 1). So the Tarkeshwar Formation unconformably overlies Vagadkhol Formation. Kathiara (1969) and Kathiara and Bhatt (1969) stated that the Tarkeshwar Formation is divisible into two lithosomes in which the upper lithosome comprises ferruginous sandstone and coarse sand, while the lower lithosome consists of carbonaceous clay/shale and lignite. They (Kathiara & Bhatt, 1969) also opined that the lower lithosome might have deposited in swampy conditions. In the present study, most of the palynoflora (Text-figures 1, 2, 3) is derived from the carbonaceous shale, carbonaceous clay and lignite. Stratigraphically important or marker taxa occuring in Rajpardi palynoassemblage and other Early Eocene horizon of India are: *Lakiapollis ovatus, Matanomadhiasulcites maximus, Dermatobrevicolporites dermatus, D. exaltus, Retimonosulcites ovatus, Proxapertites assamica, Retitribrevicolporites matanomadhensis, Tricolporopollis rubra, Tribrevicolporites eocenicus* and different species of *Alangium* pollen.

Guleria (1992) on the basis of study of fossil woods proposed Eocene age, while Bhattacharya (1987) and Kar and Bhattacharya (1992) assigned Early Eocene age to these lignites. The present detailed study also supports this veiw. Therefore, in Rajpardi and adjacent area the age limit of Vagadkhol Formation should be Middle-Late Palaeocene, and upper lithosome having conformable contact must be older than that proposed earlier by Chandra and Chowdhary (1969), Kathiara and Bhatt (1969), and Sudhakar and Basu (1973).

PALAEOECOLOGY AND DEPOSITIONAL ENVIRONMENT

The quantitative distribution of stratigraphically and ecologically important palynotaxa observed from base to top of the section reveals that during deposition these plants enjoyed subtropical to tropical climate.

The cratonic Deccan trap basalt provided the base for Early Tertiary sedimentary deposits in Rajpardi area. With the gap in sedimentation the basement rock is overlain by Vagadkhol Formation where there is no trace of plant entities (fragments). This indicates that during the deposition of rocks of the Vagadkhol Formation the area was topographically

uneven or tectonically unstable. After an interval of time a restricted depression was created by tectonic disturbances and become favourable site for further sediment accumulation. Sudhakar and Basu (1973) opined that the Tarkeshwar Formation represents a depositional site of a regressive phase and a series of shallow inland locked basin where the sediments were frequently subjected to subaerial exposures in an extensive area. This extensive depression or lake received heavy tropical precipitation which became favourable for plant growth. The change in lithofacies from carbonaceous clay and carbonaceous shale to lignite is also substantiated by a frequency counts of palynofossils derived from these samples. Some reduction in the frequency of pteridophytic spores and gradual enhancement of shruby and woody land elements, e.g., *Matanomadhiasulcites maximus, Retimonosulcites ovatus, Proxapertites assamica, Arecipites intrapunctatus, Retipollenites confusus, Retitribrevicolporites matanomadhensis, Tribrevicolporites eocenicus, Tricolporopilites robustus, Lanagiopollis* spp. etc. have also been observed. The stratigraphic distribution of these taxa supports the view that these species were deposited in Rajpardi area during Early Eocene (Ypresian). The occurrence of some important palynotaxa and their affinity attributed to various extant taxa with their ecological relationship explains that these plants were the representatives of swampy habitat.

The occurrence of *Lakiapollis ovatus* Cenozone in Rajpardi lignite palynoassemblage is an example of typical marshy flora. The fresh induction of many other dicot taxa explains gradual change of swamp to marshy habitat. Further, it also reveals that these plants were spreading in entire area during the period when the sediments were deposited.

The occurrence of a good number of pollen grains of the families Arecaceae (Palmae), Bombacaceae and Alangiaceae indicates that these plants had luxurient growth and helped in making a rich vegetation in the area during sedimentation. After a periodic seasonal covering with water the area became rich on humic material and after a steep rise in landscape a good number of woody plants (including Alangiaceae, Bombacaceae and Palmae) were flaunted. The absence of dinoflagellate cysts and mangrove pollen in the palynoassemblage indicates that there was no influx of brackish water during deposition. No abrupt floral changes have been observed from base to top of the section. These facies (carbonaceous clay/shale and lignite) show a distinct parallel lamination in Rajpardi lignite mine area indicating that the deposition took place in calm water condition in quiet environment or permanent water body existed in close vicinity of depositional site where edaphic moisture was supplemented, or there was a fresh water influx having rich organic matters and nutrients from nearby flowing large water body accumulated near the swamp. Regarding polycolporate grains Venkatachala and Chowdhary (1977) opined that they mostly occur in coal and shale samples which provide a clue to assess their relationship with swampy vegetation.

The microthyriaceous fruiting bodies, e.g., *Inapertusporites kedvesii, Phragmothyrites eocenicus*, etc. are typical epiphyllous fungi and their occurrence in the palynoassemblage indicates the existence of a characteristic terrestrial plant ecosystem generally thrived in mesophytic thick forest of warm and humid condition and heavy rainfall. Their presence also supports the swampy habitat during deposition.

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REFERENCES

Bhattacharya M 1987. Fungal remains from the Rajpardi Lignite, Broach District, Gujarat. *Geophytology* **17**(1): 120.

Blanford WT 1869. On the geology of Tapti and Lower Harbuda valleys and some adjacent districts. *Mem. geol. Surv. India* **6** : 163-394.

Chandra PK & Chowdhary LR 1969. Stratigraphy of the Cambay Basin. *Bull. Oil & Natural Gas Commission* **6** (2) : 37-50.

Dutta SK & Sah SCD 1970. Palynostratigraphy of the Tertiary sedimentary formations of Assam: 5. Stratigraphy and palynology of South Shillong Plateau. *Palaeontographica* **131B**(1-4) : 1-62.

Guleria JS 1991. On the occurrence of carbonized woods resembling *Terminalia* and *Sonneratia* in Palaeogene deposits of Gujarat, western India. *Palaeobotanist* **39**(1) : 1-8.

Guleria JS 1994. Fossil leaf of *Terminalia* from the Rajpardi Lignite mine, district Bharuch, Gujarat, India. *Geophytology* **24**(1): 55-58.

Guzman AEG 1967. A palynological study on the Upper Los Cuervos and Mirador formations (Lower and Middle Eocene; Tibu area, Colombia). *Leiden, E. J. Brill*: 1-68.

Jain KP & Gupta RC 1970. Some fungal remains from the tertiaries of Kerala Coast. *Palaeobotanist* **18** : 177-182.

Kar RK 1985. The fossil floras of Kachchh - IV. Tertiary palynostratigraphy. *Palaeobotanist* **34** : 1-280.

Kar RK & Bhattacharya M 1992. Palynology of Rajpardi Lignite, Cambay Basin, Gujra Dam and Akri Lignite, Kutch Basin. *Palaeobotanist* **39**(2) : 250-263.

Kar RK & Saxena RK 1981. Palynological investigation of a bore core near Rataria, southern Kutch, Gujarat. *Geophytology* **11**(2) : 103-124.

Kathiara RS 1969. Lignite deposit in Bhuri area, Broach District, Gujarat. *Mineral Wealth* **4**(4) : 1-5.

Kathiara RS & Bhatt BK 1969. Sedimentology of Bhuri Lignite area, Broach District, Gujarat. *Mineral Wealth* **4**(4) : 12-16.

Koshal VN & Uniyal SN 1986. Palynostratigraphy of the Cenozoic succession of Cambay Basin, Gujarat. *Bull. geol. Min. Metall. Soc. India* **54** : 208-226.

Morley RJ 1982. Fossil pollen attributed to *Alangium* Lamarck (Alangiaceae) from the Tertiary of Malaysia. *Rev. Palaeobot. Palynol.* **36** : 65-94.

Naskar P & Baksi SK 1978. Palynological investigation of Akri lignite, Rajasthan, India. *Palaeobotanist* **25** : 314-329.

Phadtare NR & Thakur B 1990. Fossil pollen of *Alangium* from the Eocene lignite of Gujarat, India with comments on its stratigraphic antiquity. *Rev. Palaeobot. Palynol.* **63** : 281-297.

Ramanujam CGK 1966. Palynology of the Miocene lignite from South Arcot District, Madras, India. *Pollen Spores* **8** : 149-203.

Rawat MS, Mukherjee J & Venkatachala BS 1977. Palynology of the Kadi Formation, Cambay Basin, India. *Proc. IV Colloq. Indian Micropalaeontol. Stratigr., Dehradun* : 179-192.

Reitsma TJ 1970. Pollen morphology of the Alangiaceae. *Rev. Palaeobot. Palynol.* **10** : 249-332.

Sah SCD & Dutta SK 1974a. Palynostratigraphy of the Tertiary formations of Assam: 3. Biostratigraphic zonation of Cherra Formation of South Shillong Plateau. *Palaeobotanist* **21**(1) : 42-47.

Sah SCD & Dutta SK 1974b. Palynostratigraphy of the sedimentary formations of Assam, India : 4. Age of the Laitryngew-Mawkma coal-bearing sandstone and their relationship with Cherra Formation. *Palaeobotanist* **21**(1) : 48-51.

Sah SCD & Kar RK 1970. Palynology of the Laki sediments in Kutch - 3. Pollen from the bore-holes around Jhulrai, Baranda and Panandhro. *Palaeobotanist* **18**(2) : 127-142.

Sah SCD & Kar RK 1974. Palynology of the Tertiary sediments of Palana, Rajasthan. *Palaeobotanist* **21**(2) : 163-188.

Singh A & Misra BK 1991. Review of some Tertiary pollen genera and species. *Rev. Palaeobot. Palynol.* **67** : 205-215.

Sudhakar R & Basu DN 1973. A reappraisal of the Palaeocene stratigraphy of the southern Cambay Basin. *Bull. Oil & Natural Gas Commission* **10**(1-2) : 55-76.

Tripathi SKM 1994. New angiosperm pollen from subsurface Early Palaeogene sediments of Barmer District, Rajasthan, India. *Palaeobotanist* **42**(1) : 61-65.

Venkatachala BS, Caratini C, Tissot C & Kar RK 1989. Palaeocene Eocene marker pollen from India and tropical Africa. *Palaeobotanist* **37**(1) : 1-25.

Venkatachala BS & Chowdhary LR 1977. Palaeoecology of the Kadi Formation, Cambay Basin, India. *Proc. 4th Colloq. Indian Micropalaeontol. & Stratigr.* : 259-277.

Venkatachala BS & Kar RK 1969a. Palynology of the Tertiary sediments of Kutch-1. Spores and pollen from Bore-hole no. 14. *Palaeobotanist* **17**(2) : 157-178.

Venkatachala BS & Kar RK 1969b. Palynology of the Tertiary sediments in Kutch-2. Epiphyllous fungal remains from Bore-hole no. 14. *Palaeobotanist* **17**(2) : 179-183.