Palynology of Rajpardi lignite, Cambay Basin and Gujra Dam and Akri lignite, Kutch Basin

R. K. Kar & M. Bhattacharya

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The fossil assemblage consists of 42 species belonging to 38 genera. On the basis of abundance, Rajpardi palynological assemblage has been divided into three cenozones in ascending order: *Polygalacidites rhomboidus* Cenozone, *Inapertusporites kedvesii* Cenozone and *Arengapollenites achinatus* Cenozone. The assemblages recovered from the Gujra Dam Section cutting and Akri lignite have been correlated with *Lygodiumsporites lakiensis* Cenozone. It has been postulated that the lower part of Rajpardi lignite was deposited above the storm tide zone and the upper level of the lignite was perhaps deposited between equinoctial to storm tide zones.

Key-words—Palynology, Stratigraphic correlation, Rajpardi lignite, Akri lignite, Lower Eocene (India)

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सारांश

कैम्बे द्रोणी एवं गुजरा बाँध में राजपार्डी लगुड़ांगार तथा कच्छ द्रोणी में अकरी लगुड़ांगार का परागाणविक अध्ययन

रंजीत कुमार कर एवं मृदुला भट्टाचार्य

इस समुच्चय में 38 प्रजातियों से सम्बद्ध 42 जातियाँ विद्यमान हैं। बाहुल्यता के आधार पर राजपार्डी परागाणविक समुच्चय को आरोही क्रम में तीन नवमंडलों में विभाजित किया गया है जो **पोलिगेलेसीडाइटिस रॉम्बॉयडस** नवमंडल, **इनऐपर्टसपोराइटिस कैडवेसाई** नवमंडल एवं **अरेंगापोलिनाइटिस ऐंकाइनेटस** नवमंडल हैं। गुजरा बाँध की कटान एवं अकरी लगुड़ांगार से उपलब्ध समुच्चय की तुलना **लाइगोडियमस्पोराइटिस लाकीयेन्सिस** नवमंडल से की गई है। यह प्रस्तावित किया गया है कि राजपार्डी लगुड़ांगार का निचला भाग तूफ़ानी ज्वारभाटा मंडल के पहले तथा इसका ऊपरी भाग संभवतः तूफ़ानी ज्वारभाटा एवं विषुवीय काल के मध्य निक्षेपित हुए थे।

THE material was collected from Rajpardi, Gujra Dam Section cutting and Akri in Gujarat State, western India. Rajpardi is near Jhagadia in the district of Broach (Lat. 21°43′N : Long. 73°9′E) on Ankeleshwar-Rajpipla Road. The lignite is about 10 m thick and is overlain by about 15 m of clay. In all, 46 samples were collected, out of which 35 samples yielded palynofossils.

Gadekar (1980) placed the Rajpardi lignite and claystones in the Tarakeshwar Formation and assigned Oligocene age. Desikachar (1984) designated them to Kadi Formation assigning a Lower Oligocene-Upper Eocene age. The Gujra Dam Section in Kutch is near the type locality of the Naredi Formation of Biswas and Raju (1971, 1973) and Akri is a village near Panandhro lignitefield. Both these localities belong to Naredi Formation (Lower Eocene, Biswas & Raju, 1971). In all, 10 samples were collected from Gujra Dam Section and of them, only four samples yielded palynofossils while from Akri, six samples were collected and all proved barren.

The slides are deposited to the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

The geology and stratigraphy worked out by Desikachar (1984) is comprehensive and has been followed in this paper.

Previous palynological work in Rajpardi area—Palynological investigation in this area is rather scanty. Ghosh, Srivastava and Sen (1963) described some polycolpate pollen from this region. Sen (1966) recorded some microthyriaceous ascostromata and Srivastava (1967) recovered *Oudkusumites*. Varma and Rawat (1963) noted some diporate pollen grains. Varma and Srivastava (1965) described *Pediastrum delicatites*. Rawat, Mukherjee

and Venkatachala (1977) recorded 85 genera and 135 species of palynotaxa from the subsurface sediments representing Kadi Formation in North Cambay Basin. They assigned a Lower Eocene age for the assemblage. Venkatachala and Chowdhary (1977) deciphered the palaeoecological condition of deposition of Kadi Formation and postulated that this formation was deposited as a tongue within the Cambay Black Shale in a fluctuating marine and non-marine environment.

Biswas (1971), Biswas and Deshpande (1970), Biswas and Raju (1971, 1973) and Hardas and Biswas (1973) have extensively worked out the stratigraphy of the Kutch Basin which is also followed here.

PALYNOFOSSILS FROM RAJPARDI

Pteridophytic spores

Biswasiaspora sp.
Polypodiaceaesporites chatterjii Kar 1979a

Angiospermic pollen

Palmaepollenites kutchensis Venkatachala & Kar 1969a
P. ovatus Sah & Kar 1970
P. magnus Sah & Kar 1970
Dracaenoipollis circularis Sah & Kar 1970
Arecipites bellus Sah & Kar 1970
Neocouperipollis achinatus (Sah & Kar) Kar & Kumar 1986
N. ankeleshwarensis sp. nov.
Arengapollenites achinatus Kar 1985
A. ovatus sp. nov.
Retimonosulcites ovatus (Sah & Kar) Kar 1985
R. ellipticus (Venkatachala & Kar) Kar 1985
R. longus sp. nov.
Matanomadhiasulcites maximus (Saxena) Kar 1985
M. kutchensis (Saxena) Kar 1985
Spinizonocolpites echinatus Muller 1968
Sastriipollenites trilobatus Venkatachala & Kar 1969a
Laevigatopolycolpites rotatus sp. nov.
Retistephanocolpites kutchensis Saxena 1979
R. flavatus (Sah & Kar) Kar 1985
Cupuliferoipollenites ovatus Venkatachala & Kar 1969a
Ratariacolporites plicatus Kar 1985
Pellicieroipollis langenheimii Sah & Kar 1970
Triangulocolporites triangulus Kar 1985
Angulocolporites microreticulatus Kar 1985
Margocolporites tsukadai Ramanujam 1966
Tricolporocolumellites pilatus Kar 1985
Retitribrevicolporites matanomadhensis (Venkatachala & Kar) Kar 1985
Polygalacidites rhomboidus sp. nov.
Thymelaepollis crotonoides Sah & Kar 1970
Thymelaepollis sp.

Fungi

Phragmothyrites eocaenicus Edwards emend. Kar & Saxena 1976
Parmathyrites robustus Jain & Gupta 1970
Notothyrites setiferus Cookson 1947
Kutchiathyrites eccentricus Kar 1979
Inapertusporites kedvesii Elsik 1968
Inapertusporites sp. A
Inapertusporites sp. B
Pluricellaesporites planus Trivedi & Verma 1969

PALYNOFOSSILS FROM GUJRA DAM SECTION AND AKRI LIGNITE

Pteridophytic spores

Lygodiumsporites lakiensis Sah & Kar 1969
L. pachyexinus Saxena 1978
Todisporites major Couper 1958
T. kutchensis Sah & Kar 1969
T. minor Couper 1958
Intrapunctisporis apunctis Krutzsch 1959
Intrapunctisporis sp.
Alsophilidites sp.
Dandotiaspora plicata (Sah & Kar) Sah, Kar & Singh 1971
Osmundacidites sp.
Laevigatosporites lakiensis Sah & Kar 1969
Polypodiaceaesporites strictus Kar & Saxena 1981
Polypodiaceaesporites sp.
Schizaeoisporites sp. A
Schizaeoisporites sp. B

Gymnospermic pollen

Callialasporites sp.

Angiospermic pollen

Palmaepollenites kutchensis Venkatachala & Kar 1969a
P. nadhamunii Venkatachala & Kar 1969a
Palmidites naviculus Kar & Saxena 1981
Palmidites sp. A
Palmidites sp. B
Neocouperipollis rarispinosus (Venkatachala & Kar) Kar & Kumar 1986
N. kutchensis (Venkatachala & Kar) Kar & Kumar 1986
Liliacidites sp.
Proxapertites microreticulatus Jain, Kar & Sah 1973
P. reticulatus (Kar & Saxena) Kar 1985
Tricolpites reticulatus Cookson 1947
Intrareticulites brevis (Sah & Kar) Kar 1985

Acanthotricolpites bulbospinosus Kar 1985
Psilastephanocolpites sp.
Symplocoipollenites constrictus Sah & Kar 1970
Araliaceoipollenites matanomadhensis Venkatachala & Kar 1969a
Rhoipites sp.
Margocolporites dubius Ramanujam 1966
M. sahnii Ramanujam 1966
Lakiapollis ovatus Venkatachala & Kar 1969a
Pseudonyssapollenites kutchensis (Venkatachala & Kar) Kar 1985
Minutitricolporites minutus Kar 1985
Pellicieroipollis langenheimii Sah & Kar 1970
Meliapollis ramanujamii Sah & Kar 1970
M. navalei Sah & Kar 1970
M. meloides (Ramanujam) Sah & Kar 1970
Verrucolporites verrucus Sah & Kar 1970
Retitetrabrevicolporites globatus (Venkatachala & Kar) Kar 1985
Polybrevicolporites cephalus Venkatachala & Kar 1969a
Triporopollenites simplex Ramanujam 1966
Proteacidites protrudus Sah & Kar 1970
Trilatiporites kutchensis Venkatachala & Kar 1969a
Tripilaorites triangulus (Sah & Kar) Kar 1985
Triporopollenites sp.
Pseudonothofagidites kutchensis Venkatachala & Kar 1969a
P. cerebrus Venkatachala & Kar 1969a
Ctenolophonidites sp.
Kielmeyerapollenites eocenicus Sah & Kar 1974

Fungi

Inapertusporites kedvesii Elsik 1968
Monoporisporites sp.
Diporisporites sp.

DESCRIPTION OF NEW TAXA

Rajpardi

Biswasiaspora Kar & Saxena 1981

Type species—*Biswasiaspora baculata* Kar & Saxena 1981.

Biswasiaspora sp.
Pl. 1, fig. 25

Description—Spore oval, 70-82 × 52-58 μm. Monolete open, extending about half along longer axis. Exine less than 2 μm thick, conied-granulose.

Comparison—*Biswasiaspora baculata* Kar & Saxena 1981 is distinctly baculate, whereas in *B. pseudoreticulata* Kar & Saxena 1981 bacula provide pseudoreticulate appearance in surface view.

Neocouperipollis Kar & Kumar 1986

Type species—*Neocouperipollis kutchensis* (Venkatachala & Kar) Kar & Kumar 1986.

Neocouperipollis ankeleshwarensis sp. nov.
Pl. 1, fig. 34

Diagnosis—Pollen grains oval, 58-84 × 44-62 μm. Monocolpate, colpus long, distinct, stretching almost from end to end. Spinose, spines well-built with bulbous base and pointed tip, 4-8 μm long, 2-4 μm broad at base, interspinal exine more or less laevigate.

Comparison—*Neocouperipollis kutchensis* (Venkatachala & Kar) Kar & Kumar 1986 has spines with bulbous base and pointed tip but subcircular in shape. *N. achinatus* (Sah & Kar) Kar & Kumar 1986 is much smaller in size than the present species and the exine is spinose-baculate. *N. wodehousei*

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PLATE 1

(All photomicrographs are enlarged *ca.* × 500 unless otherwise mentioned).

1. *Cyathidites minor* Couper, Slide no. G4/2/3.
2,4. *Lygodiumsporites lakiensis* Sah & Kar, Slide no. Akri 7/1/3, Akri 8/2/2.
3,5, 18,28. *Dandotiaspora plicata* (Mathur) Sah, Kar & Singh, Slide nos. Akri 8/4/8, Akri, 8/3/4, Akri 7/2/4.
6,10. *Thymelaepollis crotonoidis* Sah & Kar, Slide no. RP/2/1/6, RP/2/3/1.
7,16. 17,22,27. *Laevigatopolycolpites rotatus* gen. et sp. nov., Slide nos. 9085/5/5, B 56; 9082/3/1, J 38/2; 9079/1/8, V 61/4; 9084/3/2, O 38/3; 9083/3/3, N 33.
8. *Proteacidites protrudus* Sah & Kar, Slide no. G 10/1/17.
9. *Lakiapollis ovatus* Venkatachala & Kar, Slide no. RP/2/2/6.
11,24. *Thymelaepollis* sp., Slide nos. 9086/1/6, J 58/4; 9087/2/2, M 43/4.
12. *Pellicieroipollis langenheimii* Sah & Kar, Slide no. RP/38/3/2.
13. *Psilastephanocolpites* sp., Slide no. G. 10/3/3.
14. *Alsophilidites* sp., Slide no. 9089/7/10, L 65/2.
15. *Osmundacidites* sp., Slide no. 9089/7/9, W 59/4.
19. *Arecipites bellus* Sah & Kar, Slide no. RP 4/1/8.
20. *Palmidites* sp. A, Slide no. 9092/4/1, P 36/1.
21. *Monoporisporites* sp., Slide no. 9095/6/3, O 29.
23,33. *Retimonosulcites longus* sp. nov., Slide nos. 9081/2/10, T 62/3, 9103/4/8, M 38/3.
25. *Biswasiaspora* sp., Slide no. 9079/1/5, O 45/2.
26. *Schizaeoisporites* sp. A, Slide no. 9090/3/9, W 49/1.
29. *Callialasporites* sp., Slide no. 9091/5/2, N 35/2.
30. *Palmidites* sp. B, Slide no. 9094/8/13, S 54.
31. *Intrapunctisporis* sp., Slide no. 9088/1/9, E 32/4.
32. *Ctenolophonidites* sp., Slide no. 9083/6/4, O 59.
34. *Neocouperipollis ankeleshwarensis* sp. nov., Slide no. 9080/1/7, L 45/4.

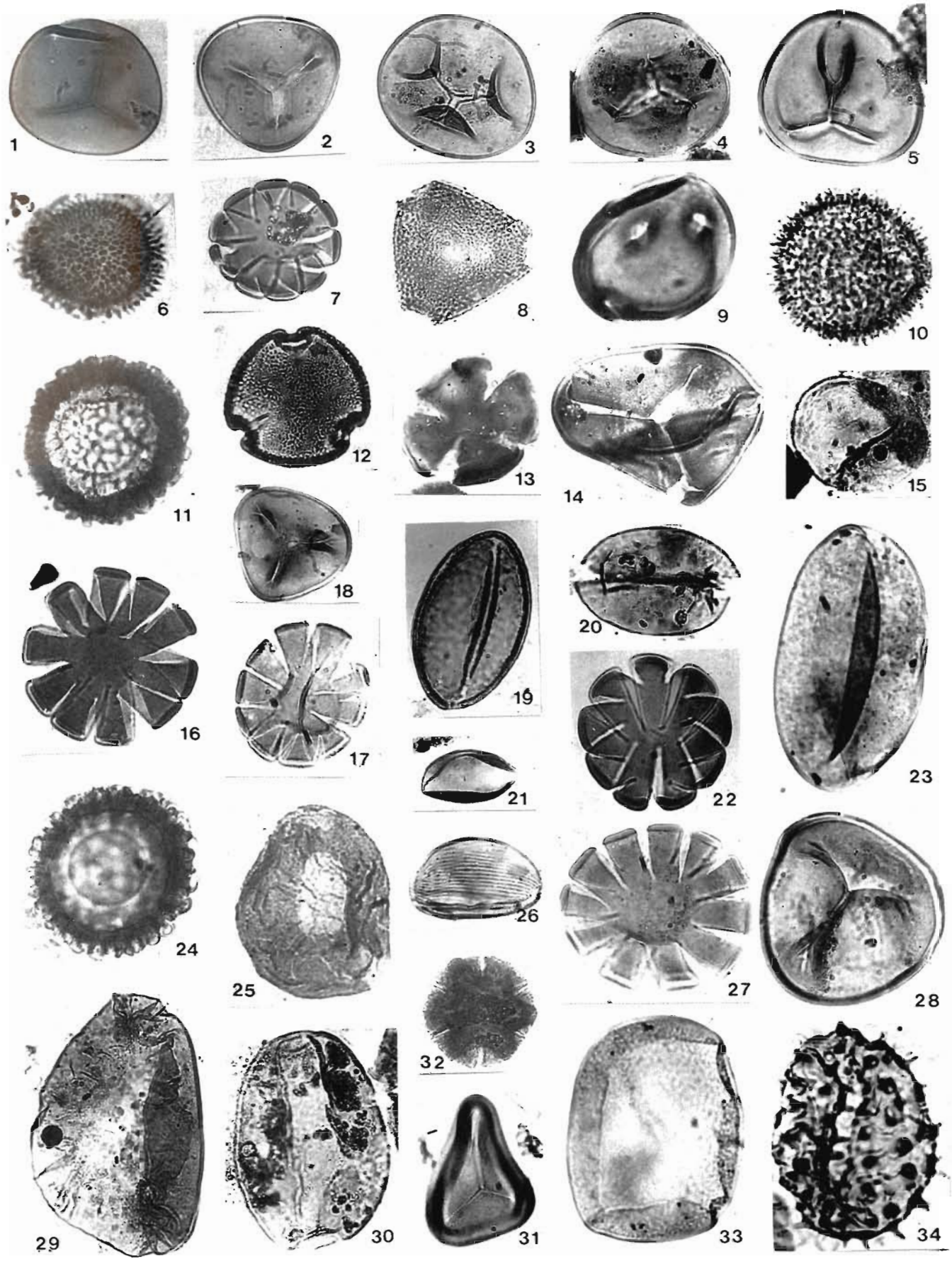
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PLATE 1

(Biswas) Kar & Kumar 1986 is subcircular in shape and ornamentation baculate-spinose.

Holotype—Pl. 1, fig. 34; size 80 × 62 μm; Slide no. BSIP 9080/1/7.

Type locality—Rajpardi lignite mine, Rajpardi, Lower Eocene, Gujarat.

Arengapollenites Kar 1985

Type species—*Arengapollenites achinatus* Kar 1985.

Arengapollenites ovatus sp. nov.
Pl. 2, figs 29, 30

Diagnosis—Pollen generally oval, sometimes circular, 40-59 × 34-54 μm, colpus distinct, extending from end to end. Exine up to 2 μm thick, spinose, spines sparsely placed, in apertural region spines arranged in alternate fashion in a manner of sharply toothed jaws, interspinal space laevigate.

Comparison—*Arengapollenites achinatus* Kar 1985 is comparable to the present species in general organisation but the present one is more broad than the type species.

Holotype—Pl. 2, fig. 30; size 45 × 43 μm; Slide no. BSIP 9083/3/5.

Type locality—Rajpardi lignite mine, Rajpardi, Lower Eocene, Gujarat.

Retimonosulcites Kar 1985

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

Retimonosulcites longus sp. nov.
Pl. 1, figs 23, 33

Diagnosis—Pollen grains monosulcate, 104-130 × 42-54 μm, sulcus traceable from one end to other, sometimes closed or boat-shaped. Exine up to 2 μm thick, microreticulate.

Comparison—*Retimonosulcites ellipticus* (Venkatachala & Kar) Kar 1985 resembles present species in microreticulate ornamentation and oval-elliptical shape but is much smaller in size (30-42 × 25-28 μm) than the present species. *R. ovatus* (Sah & Kar) Kar 1985 has funnel-shaped sulcus and is also smaller in size range as compared to present species.

Holotype—Pl. 1, fig. 23; size 130 × 44 μm; Slide no. BSIP 9081/2/10.

Type locality—Rajpardi lignite mine, Rajpardi, Lower Eocene, Gujarat.

***Laevigatopolycolpites* gen. nov.**

Type species—*Laevigatopolycolpites rotatus* sp. nov.

Generic Diagnosis—Pollen grains subcircular in polar view, polycolpate, colpi 9-12, distinct, long, extending almost pole to pole. Exine laevigate, sometimes weakly intrastructured.

Description—Pollen grains generally found in polar view, 44-70 × 40-65 μm, sometimes partially tilted specimens also observed; proximo-distally fully flattened specimens due to well-developed colpi provide the appearance of a wheel. Colpi well-developed, equidistantly placed, 10 colpi found in

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PLATE 2

(All photomicrographs are enlarged *ca.* × 500 unless otherwise mentioned).

1. *Intrareticulitis brevis* (Sah & Kar) Kar, Slide no. G 10/6/6.
2. *Arengapollenites achinatus* Kar, Slide no. RP/2/4/6.
3. *Triporopollenites* sp., Slide no. 9089/7/7, H 48/4.
4, 7. *Minutitricolporites minutus* (Sah & Kar) Kar, Slide no. 9104/3/17, V 63.
5, 8. *Polybrevicolporites cephalus* Venkatachala & Kar, Slide no. G 9/4/2, G 9/1/2.
6. *Retistephanocolpites kutchensis* Saxena, Slide no. RP4/1/4.
9. *Pseudonyssapollenites kutchensis* (Venkatachala & Kar) Kar, Slide no. G 10/2/5.
10, 24. *Polypodiisporites repandus* Takahashi, Slide nos. G 9/7/2; 9101/2/5, F 63/2.
11, 16. *Tripilaorites triangulus* (Sah & Kar) Kar, Soide no. G 10/1/8, G 10/1/10.
12, 17. 21. *Tricolpites reticulatus* Cookson, Slide nos. RP/8/1/4, RP/22/1/4, RP/9/1/4.
13. *Palmaepollenites kutchensis* Venkatachala & Kar, Slide no. Akri 8/4/7.
14, 15. *Pseudonothofagidites kutchensis* Venkatachala & Kar, Slide nos. G 9/2/3, G 9/7/8.
18. *Liliacidites* sp., Slide no. 9099/2/4, F 41.
19. *Meliapollis ramanujamii* Sah & Kar, Slide no. G 10/8/3.
20. *Tricolporocolumellites pilatus* Kar, Slide no. RP 4/2/8.
22. *Schizaeoisporites* sp. A, Slide no. 9090/3/5, G 43/3.
23. *Rhoipites* sp., Slide no. 9094/8/6, J 43/4.
25, 26, 28. *Polygalacidites rhomboidus* sp. nov., Slide nos. 9097/1/6, R 56; 9080/1/2, G 26/4; 9107/3/6, N 39/3.
27. *Neocouperipollis rarispinosus* (Sah & Dutta) Kar & Kumar, Slide no. 9106/1/1, W 40/4.
29, 30. *Arengapollenites ovatus* sp. nov., Slide nos. 9083/3/5, G 29/2; 9096/2/1, S 34.
31. *Polypodiaceaesporites* sp., Slide no. 9098/1/15, M 61.
32. *Angulocolporites microreticulatus* Kar, Slide no. 9100/4/6, E 34/4.
33. *Pellicieroipollis langenheimii* Sah & Kar, Slide no. 9082/3/2, N 45/3.
34. *Retitribrevicolporites matanomadhensis* (Venkatachala & Kar) Kar, Slide no. 9103/4/4, H 34.
35. *Matanomadhiasulcites maximus* (Saxena) Kar, Slide no. 9086/1/1, O 31/2.
36. *Retimonosulcites ovatus* (Sah & Kar) Kar, Slide no. 9102/3/6, G 29/3.
37. *Kutchiathyrites eccentricus* Kar, Slide no. 9105/2/1, J 33/1.

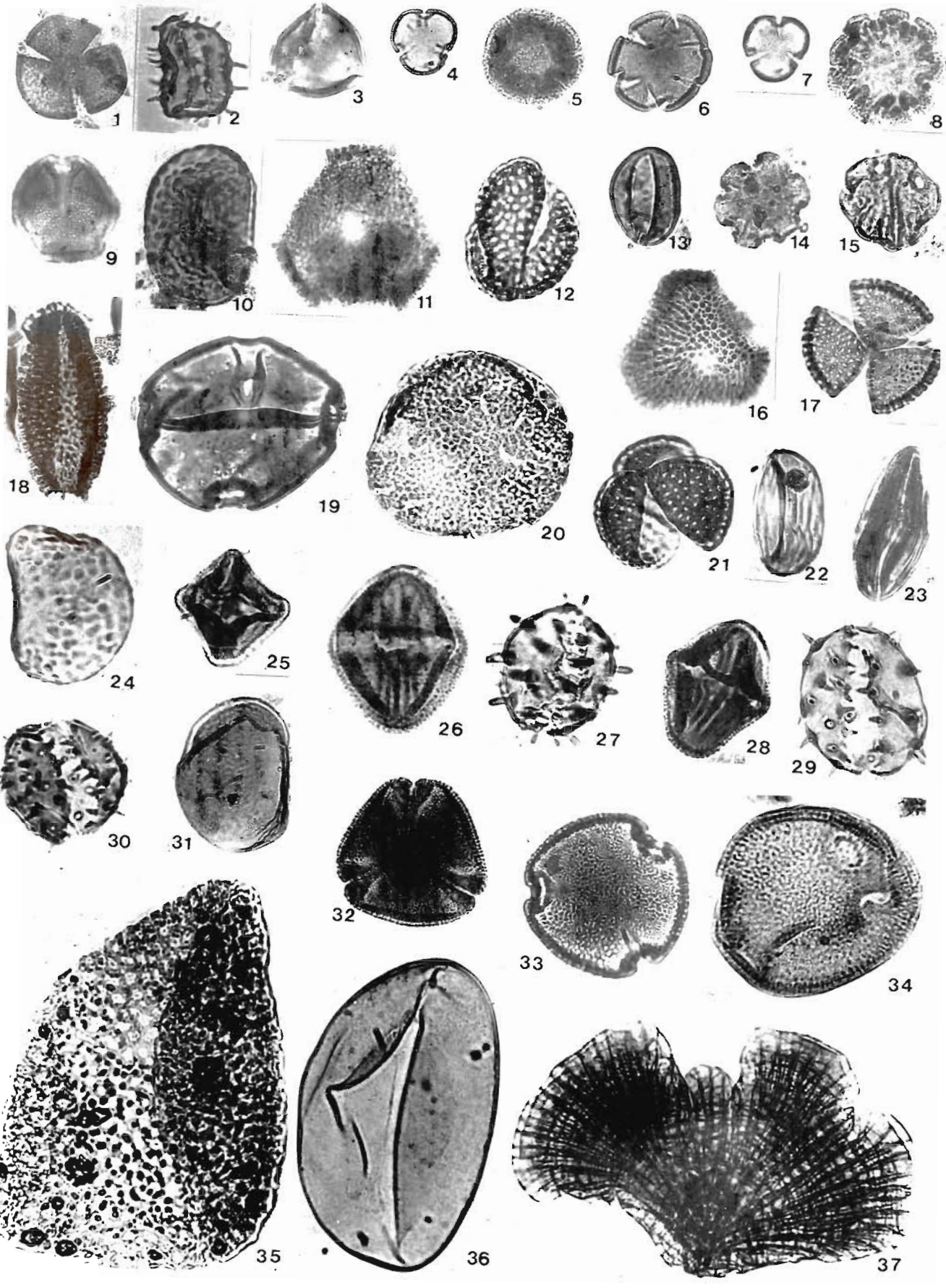
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PLATE 2

most specimens, colpi while open appear as funnel-shaped in polar view. Exine 2-4 μm thick, nexine thicker than sexine, laevigate in most specimens, nature of intrastructure while present not decipherable.

Comparison—*Psilastephanocolpites* Leidelmeyer 1966 comes close to the present genus in the presence of laevigate exine but is distinguished by its more or less square shape and tetracolpate condition. *Scabrastephanocolpites* van der Hammen & Mutis 1965 is subcircular but the exine is scabrate. *Polycolpites* Couper 1953 has long colpi, subcircular shape but the exine is clavate. *Ctenolophonidites* van Hoeken-Klinkenberg 1966 is laevigate and polycolpate but has prominent exinal thickening. *Ghoshiacolpites* Sah & Kar 1970 has 5-9 colpi and thickened ridge in the middle. *Retistephanocolpites* Leidelmeyer 1966 is reticulate, foveoreticulate or foveolate.

Laevigatopolycolpites rotatus sp. nov.
Pl. 1, figs 7, 16, 17, 22, 27

Diagnosis—Pollen grains subcircular in polar view, 44-68 × 40-65 μm. Polycolpate, colpi long, distinct, stretching almost pole to pole, colpi 9-12, but generally 10, open colpi look like a wheel. Exine 2.4 μm thick, sexine thicker than nexine, laevigate, sometimes weakly intrastructured.

Holotype—Pl. 1, fig. 16; size 68 × 65 μm; Slide no. BSIP 9082/3/1.

Type locality—Rajpardi lignite mine, Rajpardi, Lower Eocene, Gujarat.

Polygalacidites Sah & Dutta 1966

Type species—*Polygalacidites clarus* Sah & Dutta 1966

Polygalacidites rhomboidus sp. nov.
Pl. 2, figs 25, 26, 28

Diagnosis—Pollen grains more or less rhomboidal in equatorial view, 42-62 × 40-55 μm, 5-7 colporate, pores large, joining together to form synorate condition, colpi long, distinct, extending almost from one end to other in equatorial view. Exine 1.5-2.5 μm thick, retipilate.

Comparison—*Polygalacidites clarus* Sah & Dutta 1966 has got sculptureless exine, 5-6 apertures. Size ranges from 22-27 μm. *P. gujaratensis* Kar 1985 is also 5-6 colporate, synorate but exine is laevigate to weakly intrastructured.

Holotype—Pl. 2, fig. 26; size 62 × 50 μm; Slide no. BSIP 9080/1/2.

Type locality—Rajpardi lignite mine, Rajpardi, Lower Eocene, Gujarat.

Thymelaepollis Sah & Kar 1970

Type species—*Thymelaepollis crotonoidis* Sah & Kar 1970

Thymelaepollis sp.
Pl. 1, figs 11, 24

Description—Pollen grain subcircular, 68 × 66 μm, polyporate, pores generally not distinct due to strongly developed sculptural elements. Exine about 3 μm thick, very closely pilate, pila 6-10 μm long, 4-6 μm broad at end.

Comparison—*Thymelaepollis crotonoidis* Sah & Kar 1970, the type species of the genus, resembles the present specimens in shape and polyporate nature but the latter is distinguished by its bigger size and heavily built sculptural elements.

Gujra Dam and Akri Lignite

Intrapunctisporis Krutzsch 1959

Type species—*Intrapunctisporis intrapunctis* Krutzsch 1959

Intrapunctisporis sp.
Pl. 1, fig. 31

Description—Spore subcircular 52 × 51 μm. Trilete distinct, rays extending more than three-fourths radius, bifurcate at ends. Exine approximately 2 μm thick, laevigate and intrapunctate.

Comparison—*Intrapunctisporis intrapunctis* Krutzsch 1959 is distinguished from the specimen described here by its triangular-subtriangular shape and bigger size range. *I. apunctis* Krutzsch 1959 is slightly bigger in size range and weakly intrapunctate.

Alsophilidites (Cookson) ex Potonié 1956

Type species—*Alsophilidites kerguelensis* Cookson 1947

Alsophilidites sp.
Pl. 1, fig. 14

1969 *Alsophilidites* sp. Sah & Kar, p. 110, pl. 1, fig. 3.

Description—Spore generally triangular, apices rounded, interapical margin more or less straight, trilete extending up to three-fourths radius, exine 2 μm thick, laevigate.

Comparison—*Alsophilidites* sp. described by Sah and Kar 1969 resembles the present specimen in size and extension of the haptotypic mark up to equator. The exine is, however, more thick as compared to the present specimen studied.

Osmundacidites Couper 1953

Type species—*Osmundacidites wellmanii* Couper 1953

Osmundacidites sp.
Pl. 1, fig. 15

Description—Spore subcircular, 45 × 43 μm. Trilete indistinct, exine about 1-2 μm thick, granulose, conied, sculptural elements less than 0.5 μm high, closely placed.

Comparison—*Osmundacidites wellmanii* Couper 1953 is more or less of same size range of the present species but is distinguished by its extension of trilete up to margin.

Polypodiaceaesporites Thiergart 1937

Type species—*Polypodiaceaesporites haardti* Thiergart 1937

Polypodiaceaesporites sp.
Pl. 2, fig. 31

Description—Spore bean-shaped, 58 × 41 μm. Monolete extending up to three-fourths along longitudinal axis. Exine 1.5 μm thick, slightly verrucose.

Comparison—*Polypodiaceaesporites* sp. described by Sah and Kar (1969) closely resembles the present one in shape and size but is distinguished by its weakly infrastructured exine.

Schizaeoisporites Potonié 1951

Type species—*Schizaeoisporites eocaenicus* (Selling) Potonié 1956

Schizaeoisporites sp. A
Pl. 1, fig. 26; Pl. 2, fig. 22

Description—Spore oval 42-48 × 25-32 μm. Monolete generally distinct reaching up to three-fourths along longitudinal axis. Exine up to 2 μm thick, costate, costi well-developed, closely placed, parallel to each other.

Comparison—*Schizaeoisporites* sp. A described by Sah and Kar (1969) is bean-shaped and the monolete extends only half of the longitudinal axis.

Callialasporites Dev 1961

Type species—*Callialasporites trilobatus* (Balme) Dev 1961

Callialasporites sp.
Pl. 1, fig. 29

Description—Pollen grain monosaccate, 100 μm long, 60 μm broad due to folding. Central body ill-defined, saccus well-developed, radially folded along attachment zone.

Remarks—This pollen grain seems to be reworked and deposited from the Mesozoic sediments.

Palmidites (Chitaley) Couper 1953

Type species—*Palmidites maximus* Couper 1953

Palmidites sp. A
Pl. 1, fig. 20

Description—Pollen grain elliptical, 60 × 40 μm, monocolpate, colpi long, stretching from pole to pole. Exine about 1.5 μm thick, laevigate.

Comparison—*Palmidites maximus* Couper 1953 comes close to the size of the present specimen but in the former the colpus does not extend from one end to other.

Palmidites sp. B
Pl. 1, fig. 30

Description—Pollen grain broadly oval, 82 × 58 μm. Colpus uniformly broad, stretching from pole to pole. Exine about 2 μm thick, laevigate.

Comparison—*Palmidites* sp. A is of much smaller in size and less broad than the specimen described here.

Liliacidites Couper 1953

Type species—*Liliacidites kaitangataensis* Couper 1953

Liliacidites sp.
Pl. 2, fig. 18

Description—Pollen grain elliptical 72 × 32 μm, sulcus distinct, open unequally, reaching from one end to other. Exine about 2 μm thick, retipilate, pila 3-6 μm long, closely placed.

Comparison—*Liliacidites baculatus* Venkatachala & Kar 1969a resembles present species in shape but is much smaller in size with baculate ornamentation.

Psilastephanocolpites Leidelmeyer 1966

Type species—*Psilastephanocolpites maia* Leidelmeyer 1966

Psilastephanocolpites sp.
Pl. 1, fig. 13

Description—Pollen grain subcircular 49 × 46 μm, tetracolpate, colpi long, funnel-shaped. Exine about 2 μm thick, psilate.

Comparison—*Psilastephanocolpites maia* Leidelmeyer 1966 is more or less squarish in shape and the colpi are not so long as in the present species.

Rhoipites Wodehouse 1933

Type species—*Rhoipites bradleyi* Wodehouse 1933

Rhoipites sp.
Pl. 2, fig. 23

Description—Pollen grain elliptical in equatorial view, 59 × 28 μm, colporate, colpi distinct, stretching almost one end to other, pores indistinct. Exine about 1.5 μm thick, laevigate and weakly intrastructured.

Comparison—*Rhoipties kutchensis* Venkatachala & Kar 1969a is much smaller in size than the present specimen with easily recognizable pores and finely intramicroreticulate exine.

Triporopollenites (Pflug) Thomson & Pflug 1953

Type species—*Triporopollenites coryloides* Pflug 1953

Triporopollenites sp.
Pl. 2, fig. 3

Description—Pollen grain triangular 34 × 32 μm, triporate, anguloaperturate, pore distinct, slightly protruding, interapertural margin convex. Exine about 1.5 μm thick, laevigate.

Comparison—*Triporopollenites coryloides* Pflug 1953 is smaller in size than the specimen described here.

Ctenolophonidites van Hoeken-Klinkenberg 1966

Type species—*Ctenolophonidites costatus* van Hoeken-Klinkenberg 1966

Ctenolophonidites sp.
Pl. 1, fig. 32

Description—Pollen grain subcircular 42 × 40 μm, hexacolpate, colpi distinct, narrow, appearing as slit in polar view. Exoexinal thickening distinct, also present in mesocolpial region. Exine laevigate and weakly intrastuctured.

Comparison—*Ctenolophonidites palaeoparvicolpus* Kar & Jain 1981 resembles present specimen in shape and size. However, *C. palaeoparvicolpus* Kar & Jain 1981 is generally septacolpate, whereas the present one is only hexacolpate.

Monoporisporites van der Hammen 1954

Type species—*Monoporisporites burgli* van der Hammen 1954

Monoporisporites sp.
Pl. 1, fig. 21

Description—Spore elliptical, 36 × 19 μm, monoporate, pore about 3 μm in diameter, spore coat approximately 1 μm thick, laevigate, folded at margin.

Comparison—*Monoporisporites burgli* van der Hammen 1954 resembles the present species in shape but is easily distinguishable by its bigger size.

DISCUSSION

Palynological assemblage from Rajpardi—The palynofossils recovered from the Rajpardi lignite are represented by fungal bodies, spores and hyphae, pteridophytic spores and angiospermic pollen grains. They have been assigned to 38 spores-pollen genera and 42 species. Of them, fungal elements are represented by 7 genera and 6 species, pteridophytic spores by 7 genera and 4 species and angiospermic pollen by 24 genera and 32 species. The fungal elements and the angiospermic pollen are well represented. The pteridophytic spores are generally not common except in some samples (Text-fig. 1).

Eighteen samples from the Rajpardi lignite have been assessed quantitatively. *Inapertusporites kedvesii, Lygodiumsporites lakiensis, Arengapollenites achinatus* and *Neocouperipollis achinatus* are almost consistently found in all the samples. *Thymelaepollis crotonoides, Polygalacidites rhomboidus, Laevigatopolycolpites rotatus* and microplanktons are sporadic in representation in the assemblage.

On the basis of quantitative representation, the assemblage is divided into *Polygalacidites rhomboidus* Cenozone, *Inapertusporites kedvesii* Cenozone and *Arengapollenites achinatus* Cenozone in ascending order.

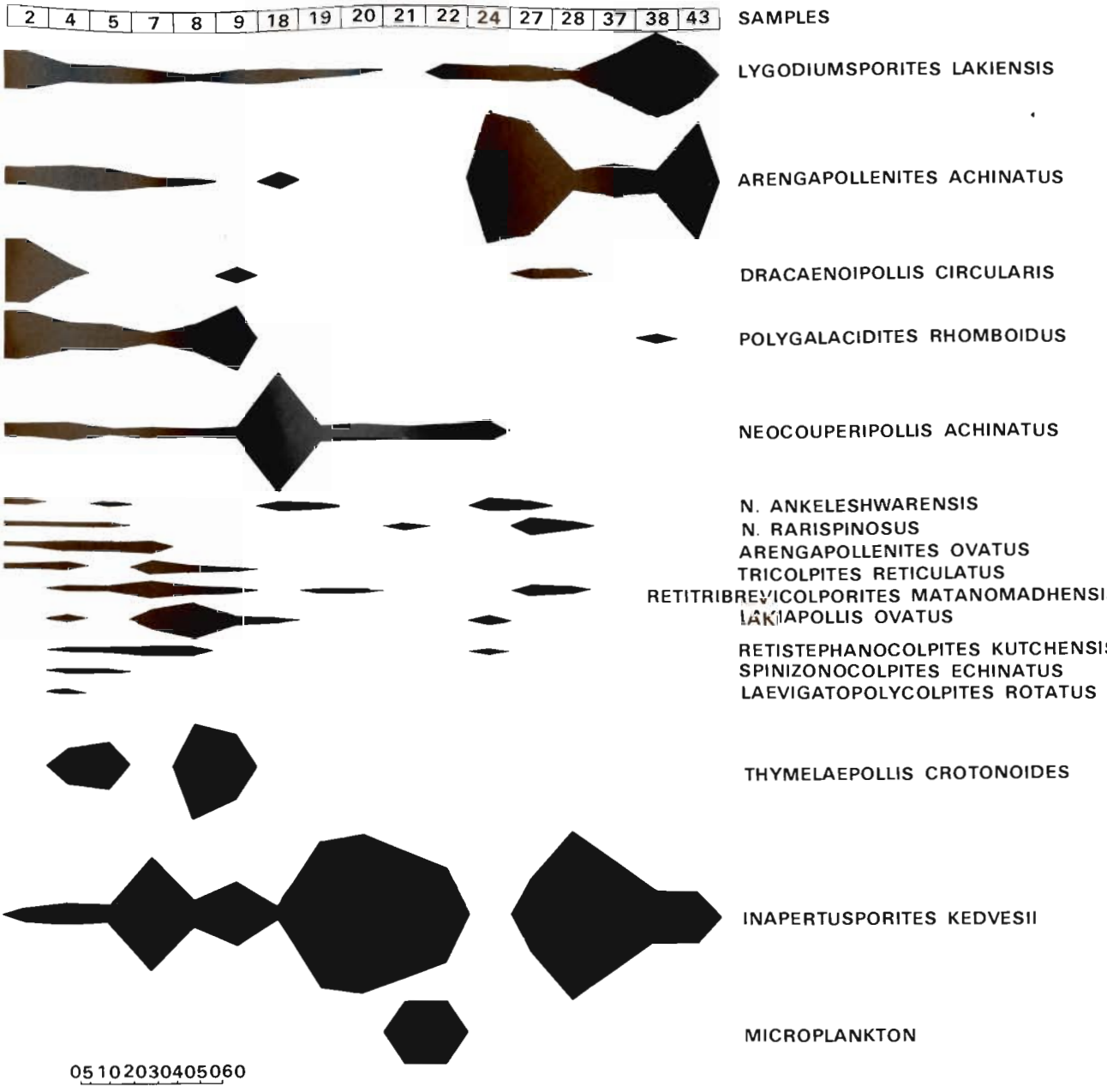
Polygalacidites rhomboidus Cenozone

Lithology—This zone consists of lignite of about 6 m thick and is recognised by sample nos. 2 to 9.

Lower contact—The lower contact comprises lignite at the base of the mine.

Upper contact—The upper contact also consists of lignite below the *Inapertusporites kedvesii* Cenozone.

Significant species of this cenozone—*Thymelaepollis crotonoides, Dracaenoipollis circularis, Inapertusporites kedvesii, Lygodiumsporites lakiensis, Arengapollenites achinatus,*



Text-figure 1—Showing the percentage of different taxa in Rajpardi lignite.

Arengapollenites ovatus, Lakiapollis ovatus, Tricolpites reticulatus and *Palmaepollenites ovatus.*

Inapertusporites kedvesii Cenozone

Lithology—This zone comprises lignite of about 4.5 m thick and persists from sample nos. 18-22.

Lower Contact—The lower contact consists of lignite above the *Polygalacidites rhomboidus* Cenozone.

Upper Contact—The upper contact is also made up of lignite below the *Arengapollenites achinatus* Cenozone.

Significant species of this cenozone—*Neocouperipollis achinatus, Palmaepollenites ovatus, Arengapollenites achinatus, Lygodiumsporites lakiensis, Thymelaepollis* sp., *Palmaepollenites magnus, Pluricellaesporites planus* and microplankton.

Arengapollenites achinatus Cenozone

Lithology—This zone is characterized by the lignite of about 8 m thick.

Lower contact—The lower limit of this zone consists of lignite which rests on the

Inapertusporites kedvesii Cenozone.

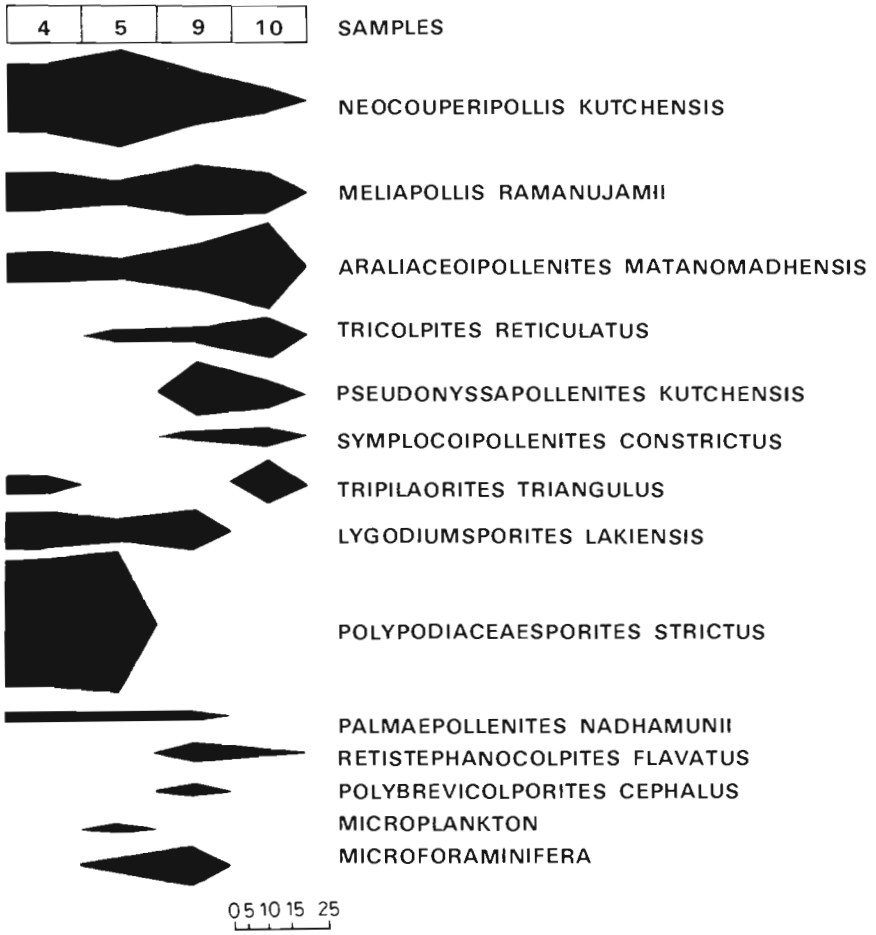
Upper contact—The upper limit consists of lignite below the grey clay/shale.

Significant species of this Cenozone—*Inapertusporites kedvesii, Lygodiumsporites lakiensis, Dandotiaspora plicata, Neocouperipollis achinatus, Neocouperipollis ankeleshwarensis, Laevigatopolycolpites rotatus, Palmaepollenites ovatus* and *Phragmothyrites eocaenicus.*

Comparison with Kadi Formation assemblage—The palynology of Kadi Formation which was deposited as a tongue within Cambay Black Shale in a fluctuating marine and nonmarine environment was worked out by Venkatachala and Chowdhary (1977). In this area, palms in general outnumber other groups and are mostly represented by *Clavainaperturites, Palmaepollenites, Liliacidites, Arecipites, Maurtiidites (Spinainaperturites), Spinizonocolpites,* cf. *Racemonocolpites, Retimonocolpites, Proxapertites, Dicotetradites* and *Disulcites.* The polycolpate and polyporate pollen found in the assemblage are: *Stephanocolpites, Retistephanocolpites, Polycolpites, Polygalacidites, Pseudonothofagidites, Stephanoporites/Wadiapites.* The nonmangrove angiosperm genera are: *Tricolpites, Retitricolpites, Striatricolpites, Kurtzipites, Umbelliferoipollenites, Rhoipites, Hippocrateaceaedites, Sapotaceoidaepollenites, Myrtaceidites, Trisyncolpites, Foveotriporites, Proteacidites, Caryapollenites, Engelhardioidites* and *Droseridites.* The pteridophytic spores in the assemblage are: *Lycopodiumsporites, Lycopodites, Lygodiumsporites, Biretisporites, Polypodiaceoisporites, Cicatricosisporites,* cf. *Osmundacidites, Polypodiisporites, Polypodiaceaesporites, Laevigatosporites, Verrucatosporites* and *Schizaeoisporites.*

The dominant genera in the assemblage are: *Clavainaperturites, Maurtiidites, Spinizonocolpites, Proxapertites, Disulcites, Psilodiporites, Palaeocaesalpiniaceaepites, Palaeocoprosmadites, Margocolporites, Retibrevitricolpites, Anacolosidites, Iugopollis, Stephanocolpites, Retistephanocolpites, Polycolpites, Polygalacidites, Pseudonothofagidites, Stephanoporites, Striatricolpites, Umbelliferoipollenites* and *Araliaceoipollenites.*

Venkatachala and Chowdhary (1977) assigned a



Text-figure 2—Showing the percentage of different taxa in Gujra Dam.

Lower Eocene age for the Kadi palynological assemblage. They also observed that this assemblage is closely comparable to the *Psilodiporites hammenii* Zone recovered from the Cauvery Basin by Venkatachala and Rawat (1970).

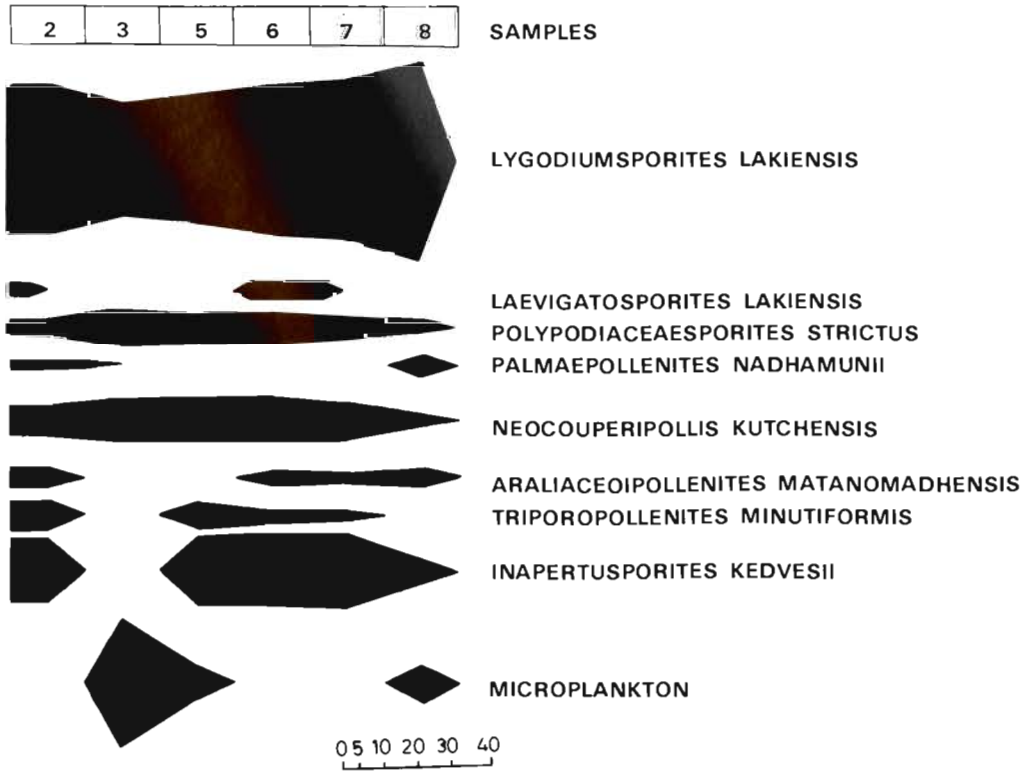
The Rajpardi palynological assemblage closely resembles the Kadi assemblage by the dominance of palm pollen. Besides, polycolpate genera listed by Venkatachala and Chowdhary (1977) are also mostly found in Rajpardi lignite. However, some of the mangrove genera, e.g., *Psilodiporites, Retibrevitricolpites, Lacrimapollis, Palaeocaesalpiniaceaepites, Palaeocoprosmadites, Favitricolporites, Psilatricolporites, Verrutricolporites, Zonocostites, Cupanieidites, Marginipollis, Annutriporites, Myricaceoipollenites, Anacolosidites, Iugopollis* and *Tetrapollis* recorded by Rawat, Mukherjee and Venkatachala (1977) and Venkatachala and Chowdhary (1977) from Kadi Formation do not occur in Rajpardi lignite which can be attributed to different palaeoecological settings from that of Kadi area.

Gujra Dam Section—Out of 10 samples macerated, only 4 samples were fossiliferous. Pteridophytic spores and angiospermic pollen are well represented. *Lygodiumsporites lakiensis, Neocouperipollis kutchensis, Meliapollis ramanujamii, Tricolpites reticulatus, Araliaceoipollenites matanomadhensis* and *Pseudonyssapollenites kutchensis* are more or less consistently found in all the 4 samples (Text-fig. 2).

The assemblages recovered from Gujra Dam section and Akri are correlatable with the *Lygodiumsporites lakiensis* Cenozone as this species is presented in both assemblages in significant percentage. Besides, *Dandotiaspora plicata, Neocouperipollis kutchensis* and *Inapertusporites kedvesii* are found in appreciable percentage in these assemblages.

Comparison of Rajpardi with other Kutch assemblages—Rajpardi, Gujra Dam and Akri palynological assemblages have the following common taxa *Dandotiaspora plicata, Lygodiumsporites lakiensis, Intrapunctisporis* sp., *Polypodiaceaesporites repandus, Palmaepollenites kutchensis, Tricolpites reticulatus, Lakiapollis ovatus, Pellicieroipollis langenheimii, Polybrevicolporites cephalus, Retistephanocolpiles flavatus, Angulocolporites microreticulatus, Inapertusporites kedvesii, Diporisporites* sp. and microplankton (Text-fig. 3).

Besides, *Retitribrevicolporites matanomadhensis, Tricolporocolumellites pilatus, Arecipites bellus, Thymelaepollis crotonoides, Retistephanocolpites kutchensis, Arengapollenites achinatus, Inapertusporites kedvesii, Pluricellaesporites planus,*



Text-figure 3—Showing the percentage of different taxa in Akri lignite.

Notothyrites amorphous, Phragmothyrites eocenicus, Triangulorites triangulus, Parmathyrites robustus, Matanomadhiasulcites maximus, Matanomadhiasulcites kutchensis, Retimonosulcites ellipticus, Retimonosulcites ovatus, Palmaepollenites kutchensis, Dracaenoipollis circularis, Palmaepollenites magnus, Cupuliferoipollenites ovatus, Neocouperipollis achinatus, Spinizonocolpites echinatus and *Ratariacolporites plicatus* are those taxa in Rajpardi assemblage which have been found common to other various Lower Eocene localities of Kutch (Kar, 1985). This assemblage also resembles the Lower Eocene assemblages of Kutch described by Venkatachala and Kar (1969a, 1969b) and Sah and Kar (1969, 1970). *Laevigatopolycolpites* which has been recorded from Rajpardi is, however, absent in Kutch. *Inapertusporites kedvesii* and *Arengapollenites achinatus* cenozones of Rajpardi lignite are broadly correlatable with *Lakiapollis ovatus* Cenozone of Kutch by the well represen tation of *Lakiapollis ovatus, Inapertusporites kedvesii, Lygodiumsporites lakiensis* and *Neocouperipollis achinatus.*

Age of Rajpardi lignite—Gadekar (1980) assigned Oligocene age to the Rajpardi lignite, while Desikachar (1984) included the lignite in Kadi Formation of Lower Oligocene-Upper Eocene age. Rawat, Mukherjee and Venkatachala (1977) and Venkatachala and Chowdhary (1977) assigned a Lower Eocene for the Kadi Formation on the basis of palynofossils. The palynological assemblage of Rajpardi lignite closely resembles *Lakiapollis ovatus* Cenozone of Kutch, which is assigned a Lower Eocene age (Kar, 1985). Thus it is tenable to assign a Lower Eocene age for the Rajpardi lignite.

Palaeoecology of Rajpardi lignite

Rajpardi lignite as a whole exhibits the dominance of fungal spores, palm pollen and pteridophytic spores. The upland angiospermic pollen are comparatively more in the lower part and the mangrove pollen are more or less absent throughout the assemblage. The assemblage suggests that the lignite was deposited in a deltaic condition rich in terrigenous detritus where the fungal elements thrived (vide Scull *et al.*, 1966).

Dansereau (1957) studied the vegetational pattern from estuary to high land. He found that the mangroves are restricted from low to equinoctial tide and after that the ferns are found from equinoctial to storm tide. The palms are found above the storm tide zone and after the palm zone the other upland vegetation starts. The dominance of palm pollen in the lower level represented by *Arecipites bellus, Arengapollenites echinatus, A. ovatus, Palmaepollenites kutchensis, P. magnus, Dracaenoipollis circularis, Neocouperipollis achinatus, N. ankeleshwarensis, N. rarispinosus, Spinizonocolpites echinatus* and *Palmaepollenites ovatus* indicates that the lignite was deposited above the storm tide zone. The absence of microplankton in most of the samples also corroborates this assumption that the lignite was more or less free from marine influence. The common occurrence of polycolpate and polycolporate pollen like *Laevigatopolycolpites rotatus* and *Polygalacidites rhomboidus* indicates that these plants could thrive in marshy condition.

In the upper level of the lignite (sample nos. 37-43), the qualitative and quantitative representation of palm pollen comparatively dwindles down and the pteridophytic spores are well represented by *Lygodiumsporites lakiensis* and *Dandotiaspora plicata.* It probably indicates that the basin was gradually subsiding and the sedimentation took place in between equinoctial to storm tide zones where the pteridophytes flourished. The level of water increased gradually allowing no room for the development of plants and instead of lignite, fine clastics were deposited.

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