
Indian Tertiary angiosperm pollen : A critical assessment

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More than 400 genera and 1000 species of angiosperm pollen are known from the Tertiary sediments of India. It has been observed that large number of these taxa are based on one or few specimens and meagre morphological differentiation. Thus, their usefulness is limited. Thanikaimoni *et al.* (1984) and Venkatachala *et al.* (1989), in an effort to distinguish important stratigraphic and environmental markers, selected several taxa and illustrated, discussed and compared them with the African pollen. In continuation, holotypes, paratypes and other specimens of selected species available at the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow have been restudied, critically evaluated and their morphological limits circumscribed to make them more useful and applicable for age determination and stratigraphic correlation as well as for palaeoenvironmental interpretation with emphasis on their affinity with extant taxa.

Key-words —Palynology, Angiospermous pollen, Tertiary (India).

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सारांश

भारतीय तृतीयक युगीन आवृतबीजी परागकण: एक विशेष मूल्यांकन

बेंगलूर श्रीनिवासा वेंकटाचाला, रमेश कुमार सक्सेना, हरिपाल सिंह, रंजीत कुमार कर, सूर्यकान्तमणि त्रिपाठी, माधव कुमार, समीर सरकार, जगन्नाथ प्रसाद मंडल, मुलागलापल्ली रामचन्द्र राव, रमा शंकर सिंह, भगवानदास दोमाजी मंडावकर एवं कृष्ण अम्बवानी

भारत के तृतीयक युगीन अवसादों से आवृतबीजी परागकणों की 400 प्रजातियों एवं 1000 जातियों से भी अधिक ज्ञात हैं। ऐसा प्रेक्षित किया गया है कि इनमें से बहुत से वर्गक एक अथवा कुछ प्रादर्शों तथा कुछेक आकारिकीय लक्षणों पर ही आधारित किये गये हैं। अतएव इनका उपयोग सीमित है। मुख्य स्तरिकीय एवं वातावरणीय सूचक जातियों का अभिनिर्धारण करने के लिए थनिकेमोनी इत्यादि (1984) और वेंकटाचाला (1989) ने अनेक वर्गकों का चित्रांकन, विवेचना एवं अफ्रीकी वर्गकों से तुलना की थी। इसी अध्ययन के आधार पर बीरबल साहनी पुरावनस्पतिविज्ञान संस्थान, लखनऊ के संग्रहालय में उपलब्ध कुछ विशेष जातियों के प्रादर्शों का पुनः अध्ययन पुनर्मूल्यांकन तथा आकारिकीय परिसीमन किया गया है जिसके आधार पर इनका उपयोग आयुनिर्धारण, स्तरिकीय सहसम्बन्धन तथा वर्तमान वर्गकों से इनकी सजातीयता तथा पुरापर्यावरण सुनिश्चित करने में किया जा सकता है।

THE Tertiary sediments of India are overwhelmingly rich in a diverse variety of angiospermous pollen and more than 400 genera and 1000 species of these pollen have been described. However, many of these taxa are not tenable as they are not properly circumscribed and their diagnoses overlap with those of others. This limits their application. It was therefore

felt necessary to restudy the holotypes and other specimens of the pollen taxa for their character assessment and relationship with extant taxa. With the above objective, Thanikaimoni *et al.* (1984) restudied, described, illustrated and discussed selected Indian and African Tertiary pollen taxa. In continuation to this, Venkatachala *et al.* (1989) restudied 11

pollen taxa which are markers of Palaeocene-Eocene sediments of India and tropical Africa. The present paper is yet another attempt in the same direction. Holotypes, paratypes and other specimens of some selected pollen taxa, available at the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow have been restudied and critically evaluated and their morphological limits circumscribed. Efforts have also been made to suggest their extant relationship.

A list of palynotaxa studied is given in Table 1.

DESCRIPTION

Genus—*Acanthotricolpites* Kar 1985

Type species — *Acanthotricolpites bulbospinosus* Kar, 1985

Original diagnosis (Kar, 1985, p. 72) — Pollen grains subcircular in polar view. Tricolpate, colpi long. Exine spinose, spines with bulbous base and pointed tip, interspinal space densely covered with grana and bacula.

Emended diagnosis (Singh & Misra, 1991, p. 224) — Pollen circular, isopolar; usually folded; tri- to tetraporate; pores medium to large, \pm circular, unthickened, difficult to recognize due to heavy ornamentation and multiple exinal folds rendering sulcate (false sulcus) nature to the grains; exine thin, spinose; spines broad based, long, vary in shape and size and shed off easily leaving scars, gemmae occasionally present interspersed with spines; exine columellate, nexine usually indistinct; interspinal area microreticulate, appears to be microgranulate in different foci.

Species studied :

Acanthotricolpites bulbospinosus Kar 1985

Pl. 4, figs 1-2; Pl. 7, figs 7-8

Holotype—Kar, 1985, pl. 11, fig. 4, slide no. 3357/1; Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Bore core no. 13 near Baranda, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Kar, 1985, p. 73) — Pollen grains subcircular in polar view, 42-55 x 40-53 μ m. Tricolpate, colpi generally indistinct, broad. Exine 1-2 μ m thick, sexine as thick as nexine, spinose, spines strongly built, 5-8 μ m long, 1-2 μ m broad at base,

spines gradually taper to form pointed tip, spines sparsely placed, generally 4-8 μ m apart. Interspinal space densely granulate-baculate.

Redescription (Singh & Misra, 1991, p. 224) — Pollen grains isopolar, 40-65 μ m, usually folded; 3-4 porate; pores 10-16 μ m, unthickened margins; exine 1-2 μ m thick (excluding spines), spinose, spines (1-3 μ m broad x 3-9 μ m long) gradually tapering from base to apex, straight or curved, shed off leaving scars; exine columellate (columellae up to 1 μ m long), nexine usually indistinguishable; interspinal area microreticulate.

Number of specimens studied — 38.

Description :

Symmetry and form : Isopolar; subtriangular in polar view, always preserved in polar view.

Dimension : 40-71 μ m (including spines).

Aperture : Triporate, rarely tetraporate, pores equatorially elongated, 15-20 μ m in diameter, pore margin thin, devoid of spines.

Exine : 3 μ m thick, tectate, spinose.

Sexine : Tectum between spines granulate, spines supracteal, with bulbous base and acute tips, 4-9 x 1.5-4 μ m in size and 4-13 μ m apart, infractum columellate, columellae closely placed, 0.5 x 1.3 μ m.

Nexine : Not clearly distinguishable.

Occurrence—Naredi Formation (Early Eocene), Kutch (Kar, 1985); Lakadong Sandstone (Palaeocene), Meghalaya (Mandal, 1987); Kopili Formation (Late Eocene), Meghalaya (Trivedi, pers. com.); Neyveli Formation (Eocene), Tamil Nadu (Singh & Misra, 1991).

Affinity—The sculpture of exine is close to that of *Nypa* suggesting its affinity to Arecaceae. However, it could not be compared with any extant taxa.

Remarks—The holotype is tectate and has three equatorially placed, big pores instead of colpi. The interspinal exine is scabrate.

Genus — *Alangiopollis* Krutzsch 1962

Type species—*Alangiopollis barghoornianus* (Traverse, 1955) Krutzsch 1962.

Original diagnosis (Krutzsch, 1962, p. 279) — Large tricolporate pollen with relatively short polar axis; figure spherical or oval-lenticular; amb approx. circular; exocolpi usually widely gapping, not very long, narrowing towards the poles to a V-shape, hardly depressed in the equatorial region; endopores

large (up to over 10 μm diameter) round to somewhat oval, cavernae variously thickened; structure and sculpture variable, in part very strongly reticulate-striate; structured part of the wall (especially along the side) thicker than the smooth inner wall layer(s).

Species studied :

Alangiopollis arcotensis Navale & Misra 1979

Pl. 10, figs 1-2

Holotype — Navale and Misra, 1979, pl. 1, fig. 18, slide no. 10996, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Neyveli Lignitefield, South Arcot District, Tamil Nadu; Neyveli Formation; Eocene.

Original diagnosis (Navale & Misra, 1979, p. 230) — Pollen grain isopolar, rounded triangular, subcircular to circular in polar view, 70-120 x 70-120 μm in size. Tri- to tetracolporate, colpi distinct, length varying from medium to short, 20-35 μm deep, bordered by thickened margo, colpi membrane psilate, ends acute to rounded. Pore distinct, lalongate, circular or rarely lalongate, pore margin thinned. Exine 2.5-5 μm thick, sexine thicker than or equal to nexine, surface tegillate, reticulate, retipilate, simplicolumellate, capita more or less rounded, columellae short and thin, lumina small of varying shapes, smaller near colpi margins.

Number of specimens studied — 11.

Description :

Symmetry and form : Isopolar, rounded triangular, subcircular to circular.

Dimension: 70-120 μm .

Aperture: Tri- to tetracolporate; ectoaperture distinct, 20-25 μm deep, bordered by thick margo; endoaperture lalongate, margin thin.

Exine : Semitectate, 2.5 μm thick, sexine thicker than nexine.

Sexine : Reticulate, retipilate, simplicolumellate, capita \pm rounded, columellae short and thin; lumina vary in shape and size, smaller towards margin.

Nexine : Evenly thick, continuous.

Occurrence — Neyveli Formation (Eocene), Tamil Nadu (Navale & Misra, 1979).

Affinity — *Alangium* (Alangiaceae).

Alangiopollis gemmatus Navale & Misra 1979

Pl. 8, figs 4-9

Holotype — Navale & Misra, 1979, pl. 1, fig. 17, slide no. 200/5/4, Repository — BSIP, Lucknow.

Type locality, horizon and age — Neyveli Lignite field, South Arcot District, Tamil Nadu; Neyveli Formation; Eocene.

Original diagnosis (Navale & Misra, 1979, p. 230) — Pollen grain isopolar, subtriangular, size 63 x 60 μm . Tricolporate, angulaperturate, colpi short(?) faintly visible, pore simple, distinct, pore diameter 3-3.5 μm . Exine 3-4.7 μm (including surface ornamentation) thick. Surface provided with wart-like projections-gemmae, gemmae of various sizes, 1.5-3 μm , irregularly distributed, exine area between gemmae microgranulate.

Number of specimens studied — 9.

Description :

Symmetry and form : Isopolar, subtriangular.

Dimension : 50-70 μm .

Aperture : Tricolporate, angulaperturate; ectoaperture small; endoaperture distinct, almost circular, 3-3.5 μm across.

Exine : 2.5-3 μm thick; sexine as thick as nexine.

Sexine : Tectate, gemmate, gemmae 1.5-3 μm in size, irregularly distributed; intergemmal area microgranulate.

Nexine : Evenly thick.

Occurrence — Neyveli Formation (Eocene), Tamil Nadu (Navale & Misra, 1979).

Affinity — *Alangium villosum* (Alangiaceae).

Genus — *Angulocolporites* Kar 1985

Type species — *Angulocolporites microreticulatus* Kar 1985

PLATE 1 →

(All photographs are enlarged x1000)

- 1-3. *Plicatiperturites retipilatus* Kar. Slide no. BSIP 6373/4
 4-6. *Polyporina multiporosa* Kar. Slide no. BSIP 8248/3.
 7-13. *Trisyncolpites ramanujamii* Kar. Slide nos. BSIP 5099/6, BSIP 5099/5, BSIP 5092/3 and BSIP 5094/2.

14. *Cruciferopollenites elongatus* Navale & Misra. Slide no. BSIP 10991.

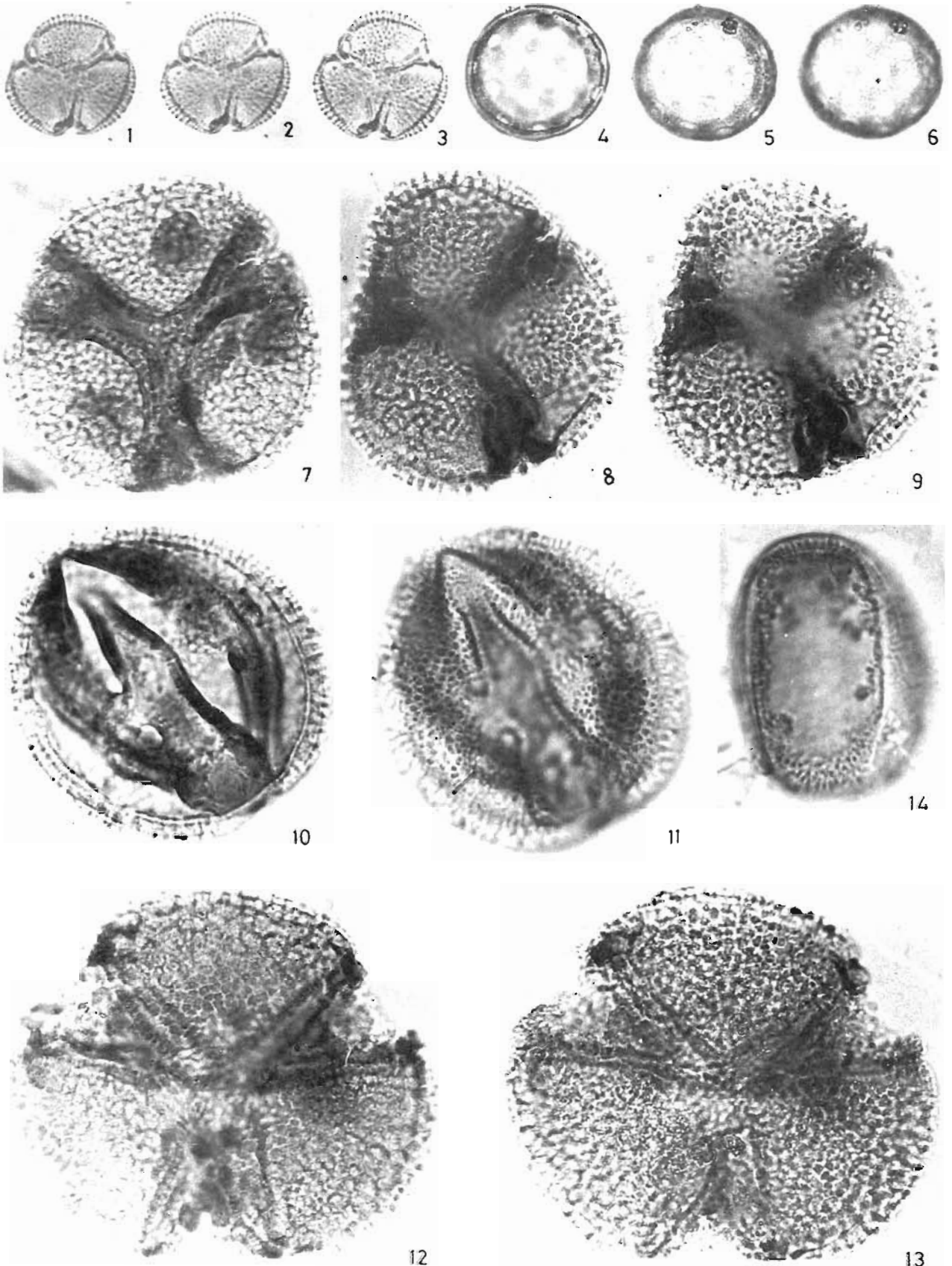


PLATE 1

Original diagnosis (Kar, 1985, p. 76) — Pollen grains triangular-subtriangular in polar view. Tricolporate, angulaperturate, colpi long, pores distinct-indistinct. Exine microreticulate.

Remarks—Generic diagnosis of *Angulocolporites* Kar 1985 is very similar to that of *Foveotricolporites* Pierce 1961. A detailed study of both these genera is therefore recommended.

Species studied :

Angulocolporites microreticulatus Kar 1985

Pl. 6, figs 1-3; Pl. 9, figs 10-11

Holotype — Kar, 1985, pl. 16, fig. 8, slide no. 3353/6. Repository—B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no.13 (depth 20 m), Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Kar, 1985, p. 76) — Pollen grains triangular-subtriangular in polar view, 30-45 x 29-44 μm . Tricolporate, angulaperturate, colpi long, funnel-shaped, pores generally indistinct, margin not thickened. Exine 1.5-2.5 μm thick, sexine thicker than nexine, laevigate and microreticulate.

Number of specimens studied — 9.

Description :

Symmetry and form : Isopolar, triangular-subtriangular.

Dimension : 40-50 x 30-35 μm .

Aperture : Tricolporate, angulaperturate; ectoaperture long, funnel shaped; endoaperture distinct, lalongate, 4-8 μm in diameter.

Exine : About 1 μm thick, sexine thicker than nexine.

Sexine : Microreticulate; meshes about 1 μm in diameter, muri as thick as lumina, lumina circular to elongated, sexine pattern uniform.

Nexine : Very thin, continuous.

Occurrence — Naredi Formation (Early Eocene), Kutch (Kar, 1985).

Affinity — Not known.

Genus — *Arecipites* Wodehouse 1933

Type species—*Arecipites punctatus* Wodehouse 1933 (designated by Potonié, 1958, p. 97)

Original diagnosis (Wodehouse, 1933, p. 497) — Ellipsoidal, 23-25 μm long, with a single longitudinal furrow which may close tightly throughout its entire length, not gaping at its ends.

Emended diagnosis — (Nichols *et al.*, 1973, p. 248)— Monocolpate pollen, amb elongate - ellipsoidal; colpus tapered, not expanded or gaping at ends. Exine tectate in structure, but exine stratification often obscure; sometimes exhibiting columellae in optical section. Exine psilate to finely foveolate or scrobiculate, diameter of foveolae about 0.5 μm . Size variable in different species, *ca.* 20-50 μm .

Species studied :

Arecipites bellus Sah & Kar 1970

Pl. 4, fig. 8; Pl. 6, figs 4-5

Holotype— Sah and Kar, 1970, pl. 1, fig. 19, slide no. 3367/8, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 15, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Sah & Kar, 1970, p. 128-129) — Pollen grains oval, 58-66 x 48-55 μm . Monocolpate, colpus extending end to end. Exine punctate.

Number of specimens studied — 12.

Description :

Symmetry and form : Heteropolar, oval.

Dimension : 85-66 x 48-55 μm .

Aperture : Monosulcate, sulcus extending up to equator.

Exine : 1-2 μm thick; sexine slightly thicker than nexine.

Sexine : Tectate, reticulate, tectum columellate, muri of the reticulum much thicker than lumina, lumina mostly circular but may also be elongated.

PLATE 2

(All photographs are enlarged x1000)

1-7. *Parumbelliferopollentis dulcis* Kar. Slide no. BSIP 3258/1, BSIP 3256/9.

8-11. *Cruciferopollenites elongatus* Navale & Misra. Slide no. BSIP 10991.

12-13. *Plumbaginactites neyvelit* Navale & Misra. Slide no. BSIP 10992

14-16. *Dakshinipollenites tripakshi* Navale & Misra. Slide no. BSIP 10993.

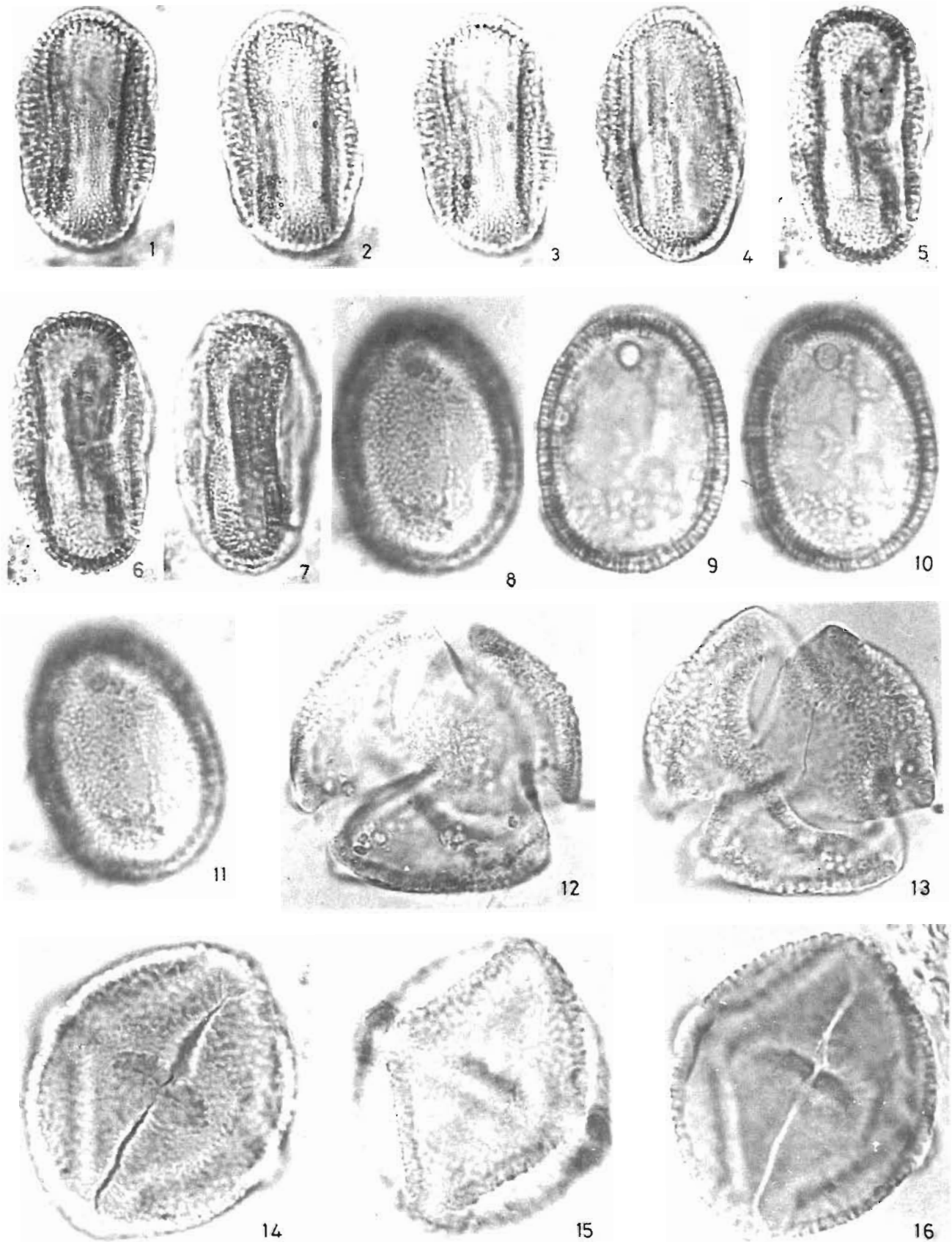


PLATE 2

Nexine: 0.5-1 μm thick, continuous.

Occurrence—Naredi Formation (Early Eocene), Kutch (Sah & Kar, 1970; Kar, 1978, 1985); subsurface Middle - Late Eocene sediments, Kutch (Kar & Saxena, 1981; Kar, 1985); Lakadong Sandstone (Palaeocene), Meghalaya (Kar & Kumar, 1986).

Affinity— This type of pollen are produced by palms and several other monocotyledons (Thanikaimoni, 1969, 1970)

Genus — *Arengapollenites* Kar 1985

Type species— *Arengapollenites achinatus* Kar 1985

Original diagnosis (Kar, 1985, p. 70)—Pollen grains monocolpate, oval-subcircular in shape, achinate, spines so arranged on margins of colpus that they interlock the aperture on invagination, interspinal exine laevigate.

Species studied :

Arengapollenites achinatus Kar 1985

Pl. 9, fig. 3

Holotype —Kar, 1985, pl. 7, fig. 9, slide no. 8236/2, Repository—B.S.I.P., Lucknow.

Type locality, horizon and age — Panandhro Lignite mine, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Kar, 1985, p. 71) — Pollen grains monocolpate, colpus distinct, extending end to end, equally broad, oval-subcircular in shape, spinose, spines with broad base and pointed tip, sparsely placed except in apertural region where they are closely placed on two margins in alternate fashion so as to close the aperture on invagination. Exine 1-2 μm thick, interspinal exine laevigate.

Number of specimens studied — 21

Description :

Symmetry and form : Heteropolar, oval - subcircular.

Dimension: 42-53 x 28-36 μm (excluding spines).

Aperture : Monosulcate, sulcus extended.

Exine : 1-2 μm thick, sexine as thick as nexine.

Sexine. Tectate, tectum smooth, spinose, spines with broad base and pointed tips, 3-5 μm long.

Nexine. Evenly thick, continuous.

Occurrence—Naredi Formation (Early Eocene), Kutch (Kar, 1985; Kar & Bhattacharya, 1992).

Affinity— *Arenga* (Arecaceae).

Genus — *Bombacacidites* Couper 1960

Type species—*Bombacacidites bombaxoides* Couper 1960

Original diagnosis (Couper, 1960, p. 53)—Isopolar, tricolporate, colpi short, planaperturate (apertures midway between sides of grains in polar view); peroblate, triangular in polar view, clearly sculptured.

Emended diagnosis (Krutzsch, 1970, p. 278) — Shape flat lenticular to spheroidal, equatorial outline typically over-round, in part subcircular or convexly triangular. Three equatorial geminals, in the over-round forms in centre of the sides, in other aspects in part also apparently displaced towards the corners. Exocolpi short, perpendicular and symmetrical with respect to the equator. Endopore distinctly thickened or only weakly so. Surface always clearly reticulate, but in the corner regions often with finer meshes. Sometimes (secondarily) with fine sculpture such as spinules, granulate, pilate, etc. Small to medium-large in size, rarely large forms.

Species studied :

Bombacacidites triangulatus Kar 1985

Pl. 3, figs 8-9

Holotype — Kar, 1985, pl. 30, fig. 1, slide no. 8242/2; Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Kaiyari, Kutch District, Gujarat; Maniyara Fort Formation; Oligocene.

Original diagnosis (Kar, 1985, p. 137)—Pollen grains triangular in polar view, 56-80 x 55-79 μm .

PLATE 3

(All photographs are enlarged x1000)

- | | |
|---|---|
| 1-6. <i>Verrucolporites verrucus</i> Sah & Kar. Slide no. BSIP 3351/8, BSIP 3367/2. | 10-11. <i>Racemonocolpites thanjnatensis</i> Mandal. Slide no. BSIP 9580/3. |
| 7. <i>Thymelaepollis crotonoidis</i> Sah & Kar. Slide no. BSIP 3372/12. | 12-13. <i>Neocouperipollis kutchenis</i> (Venkatachala & Kar) Kar & Kumar. Slide no. BSIP 3315/, V 34 |
| 8-9. <i>Bombacacidites triangulatus</i> Kar. Slide no. BSIP 8250/3. | |

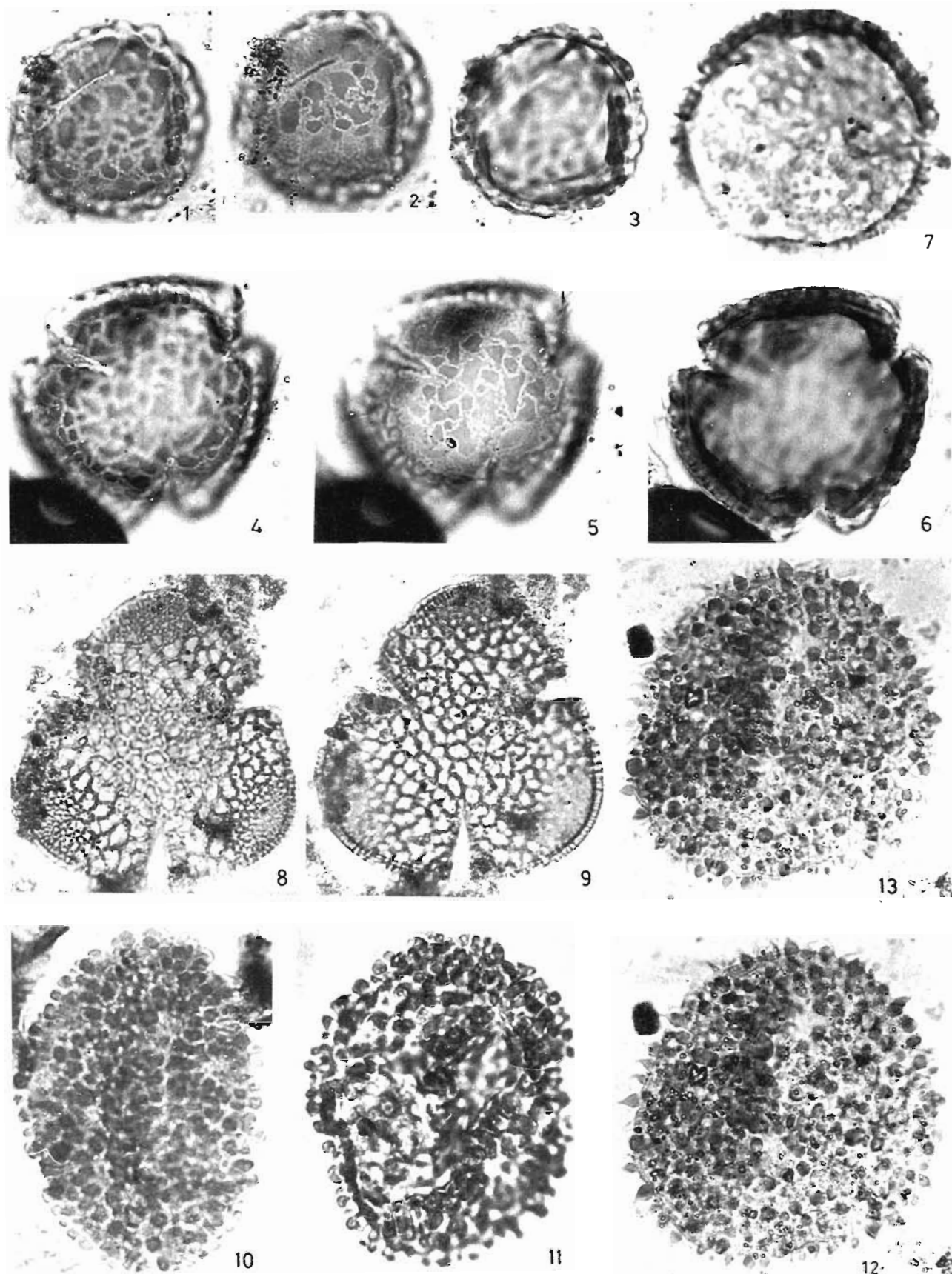


PLATE 3

Tricolpate, colpi situated midway between sides, margin thickened, brevicolpate, pores not traceable. Exine 1.5-2.5 μm thick, sexine thicker than nexine, reticulate, reticulum broader in middle and shorter at apices.

Number of specimens studied — 10.

Description :

Symmetry and form : Isopolar, triangular.

Dimension : 60-80 x 55-70 μm .

Aperture : Tricolporate; ectoaperture small, margin thickened; endoaperture indistinct.

Exine : 1.5-2.5 μm thick; sexine thicker than nexine.

Sexine : Semitectate, reticulate, lumina 1-2.5 μm in diameter, smaller at apices; sexine thick around ectoaperture.

Nexine : Evenly thick, continuous.

Occurrence—Maniyara Fort Formation (Oligocene), Kutch (Kar, 1985); Oligocene sediments, Kerala (Raha *et al.*, 1987).

Affinity—Bombacaceae.

Genus — *Calophyllumpollenites* Sah & Kar 1974

Type species — *Calophyllumpollenites rotundus* Sah & Kar 1974

Original diagnosis (Sah & Kar, 1974, p. 172) — Pollen grains subcircular-circular with three constriction due to apertures. Tricolporate, colpi long, pore margin \pm thickened. Exine thick, \pm laevigate-finely reticulate.

Species studied:

Calophyllumpollenites rotundus Sah & Kar 1974

Pl. 9, fig. 12

Holotype—Sah & Kar, 1974, pl. 2, fig. 47, slide no. 4360/25; Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Palana, Bikaner District, Rajasthan; Palana Lignite; Early Eocene.

Original diagnosis (Sah & Kar, 1974, p. 173)— Pollen grains subcircular-circular in polar view, 36-48

μm , 3 colporate, colpi long, pore margin thickened. Exine thick, laevigate to finely reticulate.

Number of specimens studied — 9.

Description :

Symmetry and form : Isopolar, subcircular-circular.

Dimension : 50-60 x 45-50 μm .

Aperture : Tricolporate, ectoaperture long, wide, margin thickened, endoaperture distinct with uniformly thickened margin, circular.

Exine : 2-2.5 μm thick; sexine thicker than nexine or equally thick.

Sexine : Tectate, perforate.

Nexine : 0.5-1 μm thick; uniform.

Occurrence—Palana Lignite (Early Eocene), Rajasthan (Sah & Kar, 1974).

Affinity—Not known.

Genus — *Compositoipollenites* Potonié 1951 ex Potonié 1960

Type species — *Compositoipollenites rhizophorus* (Potonié, 1934) Potonié 1960.

Original diagnosis (Potonié, 1960, p. 105)— Spherical pollen; 3 pores (and colpi ?); exine all over ornamented with spinae which are often \pm irregular and often bent; spinae 3-4 μm in holotype, at their bases separated by a negative reticulum.

Species studied :

Compositoipollenites tricolporatus Kar 1985

Pl. 4, figs 5-7; Pl. 5, fig. 12

Holotype — Kar, 1985, pl. 30, fig. 3, slide no. 8243/10, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Nala cutting on the eastern side of the village Kaiyari, Kutch District, Gujarat; Maniyari Fort Formation; Oligocene.

Original diagnosis (Kar, 1985, p. 137) — Pollen grains more or less subcircular both in polar and equatorial views, 20- 28 x 18-26 μm . Tricolporate, colpi pore distinct, lologate. Exine up to 2 μm thick,

PLATE 4

(All photographs are enlarged x1000)

- 1-2. *Acanthotricolpites bulbospinosus* Kar. Slide no. BSIP 10997.
3-4. *Verrupolyporites globosus* Kar. Slide no. BSIP 8247/4.
5-7. *Compositoipollenites tricolporatus* Kar. Slide no. BSIP 8246/9.

8. *Arecipites bellus* Sah & Kar. Slide no. BSIP 6369/1.
9-12. *Ratariacolporites plicatus* Kar. Slide nos. BSIP 6365/4 and BSIP 6368/19.

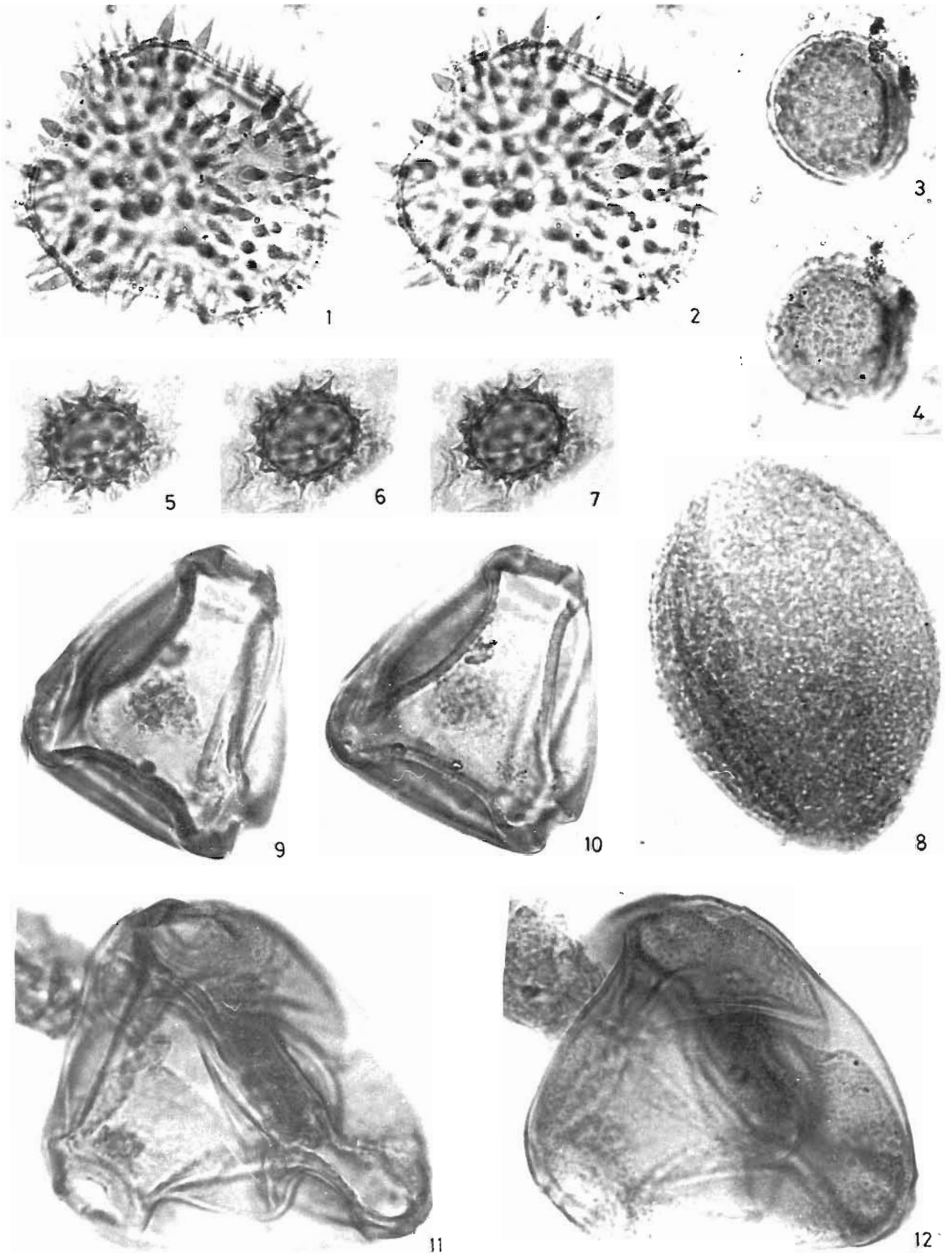


PLATE 4

spinose, spines robustly built with bulbous base and pointed tip, base of spines pilate, rest part of the exine also pilate.

Number of specimens studied — 12.

Description :

Symmetry and form : Isopolar, spheroidal.

Dimension : 18-28 x 16-28 μm .

Aperture : Tricolporate; colpi long, endoaperture lalongate, 2 μm in diameter.

Exine : 1-2 μm thick, sexine thicker than nexine.

Sexine : Spinose, spines robust, sharply tapering, 3-4 μm long, 1.5-3 μm at the base, spine ends pointed.

Nexine : Uniformly thick, continuous.

Occurrence—Maniyara Fort Formation (Oligocene), Kutch (Kar, 1985).

Affinity—Asteraceae.

Remarks—This group of pollen is stratigraphically important in post-Eocene sediments.

Genus — *Cruciferoipollenites* Navale & Misra 1979

Type species—*Cruciferoipollenites elongatus* Navale & Misra 1979

Original diagnosis (Navale & Misra, 1979, p. 226) — Pollen grain isopolar, prolate, size range 47-120 x 33-110 μm . Tricolpate to tricolporoidate, colpi long, generally uneven, distinct and extending almost up to the poles. Exine 3-4 μm thick, sexine thicker than nexine. Surface tegillate, granulate to microreticulate, grana comparatively denser at the poles.

Species studied :

Cruciferoipollenites elongatus Navale & Misra 1979

Pl. 1, fig. 14; Pl. 2, figs 8-11

Holotype — Navale and Misra, 1979, pl. 1, fig. 1, slide no. 10991, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Neyveli lignitefield, South Arcot District, Tamil Nadu; Neyveli Formation; Eocene

Original diagnosis (Navale & Misra, 1979, p. 227) — Isopolar pollen grain, prolate, mostly seen in equatorial compression while in polar compression they are seldom intact. Size range 47-56 x 33-54 μm . Tricolpate to tricolporoidate, colpi quite long, margins generally uneven, distinct, extending up to the pole, mesocolpi convex towards periphery. Exine 3.5-4 μm thick, thinning gradually towards colpi, sexine nearly double the thickness of nexine, tegillate, surface structure finely microreticulate, lumina of varying shapes.

Number of specimens studied — 9.

Description :

Symmetry and form : Elliptical in equatorial view

Dimension : 47-67 x 33-54 μm .

Aperture : Tricolpate, colpi 30 μm long, narrow, margin uneven due to ornamentation.

Exine : 4-6 μm thick, tectate, sexine thicker than nexine.

Sexine : 3.5-4 μm thick, tectum perforated with perforations of irregular shapes and sizes, infratectum columellate, columellae 2.2 μm long, irregularly shaped.

Nexine : 1.5-2 μm thick, uniformly thick, continuous.

Occurrence — Neyveli Formation (Eocene), Tamil Nadu (Navale & Misra, 1979).

Affinity — Not known.

Genus — *Dakshinipollenites* Navale & Misra 1979

Type species—*Dakshinipollenites tripakshi* Navale & Misra 1979

Original diagnosis (Navale & Misra, 1979, p. 229) — Pollen grain isopolar, triangular to subtriangular (in polar view), subprolate to suboblate (equatorial view); 48-70 x 48-66 μm in size. Tricolporate, angulaperturate, colpi long, narrow and deep, apocolpi small. Ora faint to indistinct, lalongate, slit-like. Exine thin (1.5 μm) in the middle part of the mesocolpi where it is projected out like a hump; gradually thickens laterally, being thickest (3-4.5 μm) on the

PLATE 5

(All photographs are enlarged x1000)

1-4. *Hippocrateaceaedites constrictus* Sah & Kar. Slide no. 4354/9.

5-7. *Ligulifloraedites plicatus* Kar. Slide no. BSIP 8240/3

8-10. *Polycolporites indicus* Mehrotra. Slide nos. BSIP 9446, Y 49; BSIP 9444, F 49; BSIP 9392, V 30/2.

11. *Dermatobrevicolporites dermatus* (Sah & Kar) Kar. Slide no. BSIP 6360/5

12. *Compositoipollenites tricolporatus* Kar. Slide no. BSIP 8243/10

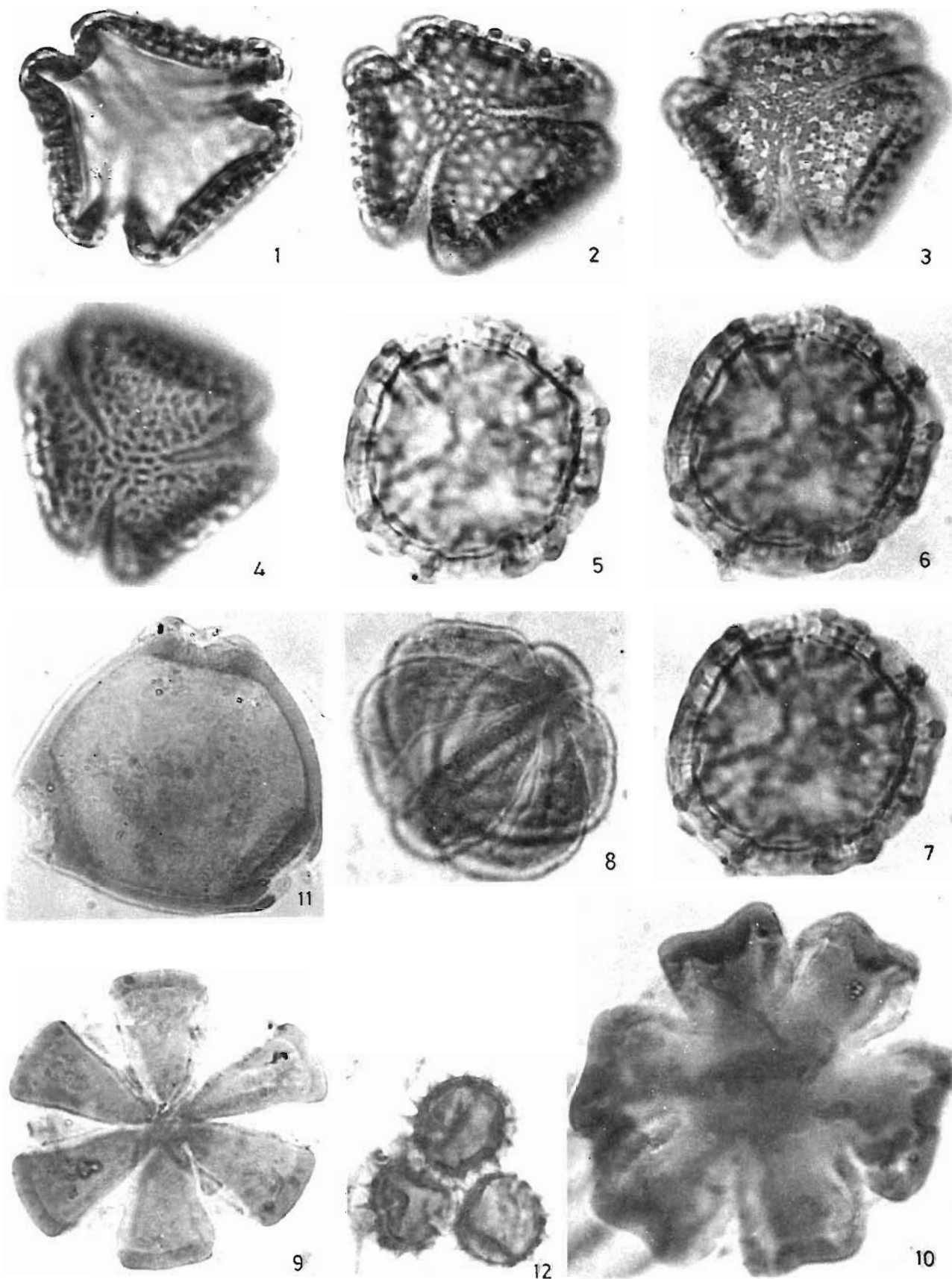


PLATE 5

colpi margins. Surface microgranulate to granulate, granulation more prominent towards colpi margins.

Species studied :

Dakshinipollenites tripakshi Navale & Misra 1979

Pl. 2, figs 14-16

Holotype—Navale and Misra, 1979, pl. 1, fig. 13, slide no. 10995, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Neyveli lignite field, South Arcot District, Tamil Nadu; Neyveli Formation; Miocene.

Original diagnosis (Navale & Misra, 1979, p. 229) —Isopolar pollen grain, subprolate to suboblate in equatorial view, triangular to subtriangular in polar view. Size range 48-70 x 48-66 μm . Tricolpate, angulaperturate, longicolpate, colpi deep and narrow, extending quite upto the poles, apocolpium small. Pore obscure, lalongate, like a slit. Exine thin (1.5-2 μm) in the middle part of the mesocolpi (clearly visible in the polar view) projecting outwards like a hump, gradually thickening laterally, being thickest (3-4.5 μm) at the colpi margins. Microgranulate to granulate, granulation becoming more prominent towards colpi margins.

Number of specimens studied—12.

Description :

Symmetry and form : Isopolar, subprolate to oblate in equatorial view, triangular to subtriangular in polar view.

Dimension : 48-70 x 48-66 μm .

Aperture : Tricolporate; ectoaperture long, narrow, endoaperture lalongate, obscure.

Exine : 1.5-2 μm thick in the middle part of the mesocolpi and 3- 4.5 μm thick at ectoapertural margins; sexine thicker than nexine.

Sexine : Intectate, baculate, pilate; pila heads up to 1 μm wide, free.

Nexine : Evenly thick, continuous.

Occurrence—Neyveli lignite (Miocene), Tamil Nadu (Navale & Misra, 1979).

Affinity—Not known.

Genus — *Densiverrupollenites* Tripathi & Singh 1984

Type species—*Densiverrupollenites eocenicus* Tripathi & Singh 1984

Original diagnosis (Tripathi & Singh, 1984, p. 154) —Pollen grains spheroidal to subspheroidal in polar view, tricolporate, apertures subequatorially placed, brevicolpate, ora circular to slightly lalongate; exine ornamentation verrucae beset with gemmae.

Species studied :

Densiverrupollenites eocenicus Tripathi & Singh 1984

Pl. 10, figs 5-6

Holotype—Tripathi and Singh, 1984, pl. 1, fig. 3. slide no. 6958, Repository—B.S.I.P., Lucknow.

Type locality, horizon and age—At 133 km from Shillong on Shillong Badarpur road, Jaintia Hills, Meghalaya; Kopili Formation; Late Eocene.

Original diagnosis (Tripathi & Singh, 1984, p. 155) —Pollen grains spheroidal to subspheroidal; tricolporate, brevicolpate; apertures subequatorially placed; exine 1.5-2.5 μm thick, sexine as thick as nexine, verrucate to gemmate, verrucae and gemmae very closely placed.

Number of specimens studied—17.

Description:

Symmetry and form : Spheroidal to subspheroidal.

Dimension : 70-95 x 65-75 μm .

Aperture: Tricolporate, ectoaperture small, lalongate, 8-10 μm long; endoaperture circular to slightly lalongate with thickened margin.

Exine : Intectate, 1.5-2.5 μm thick, sexine as thick as nexine.

Sexine : Gemmate, verrucate; gemma 1-2 μm high, 2-3 μm wide, closely placed.

Nexine : Uniform.

PLATE 6

(All photographs are enlarged x1000)

1-3. *Angulocolporites microreticulatus* Kar. Slide no. BSIP 4359/10.

4-5. *Arecipites bellus* Sah & Kar. Slide no. BSIP 3367/8.

6-7. *Plicatiaperturites retttilatus* Kar. Slide no. BSIP 6373/5.

8-9. *Sastriipollenites trilobatus* Venkatachala & Kar. Slide no. BSIP 9419. N 43/4.

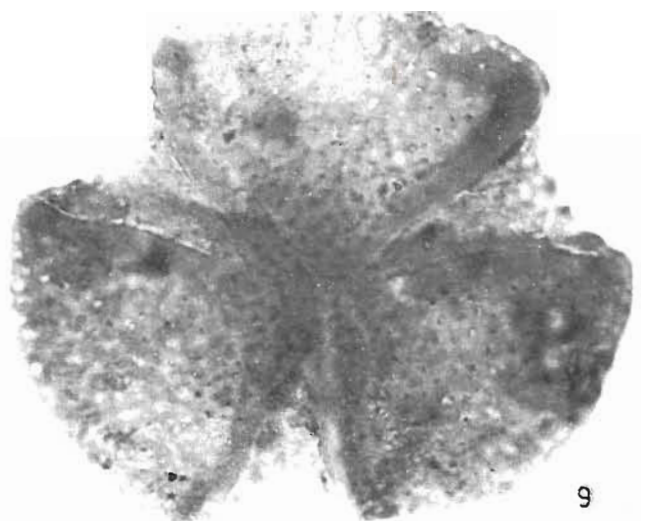
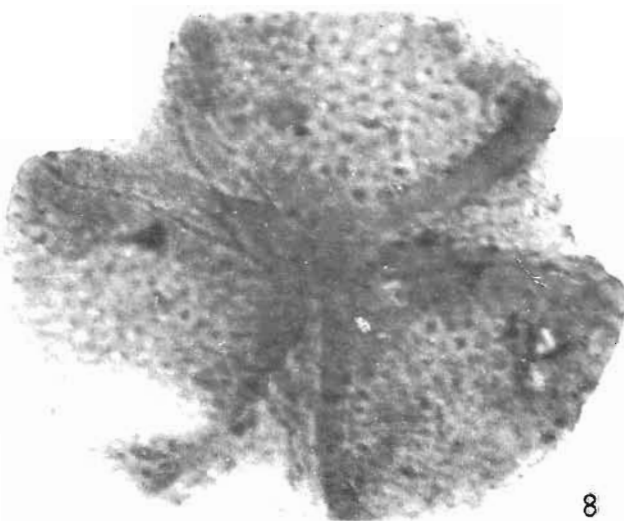
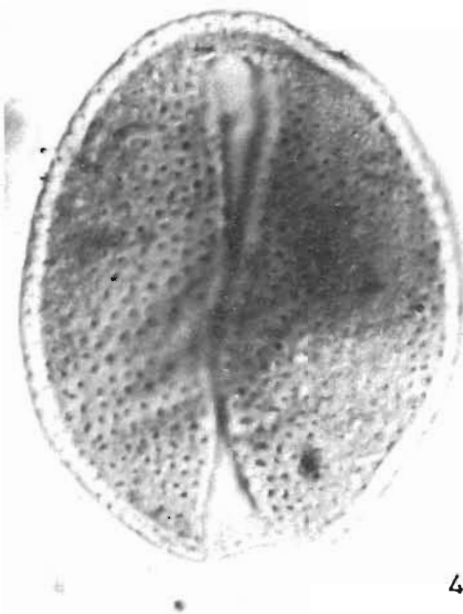
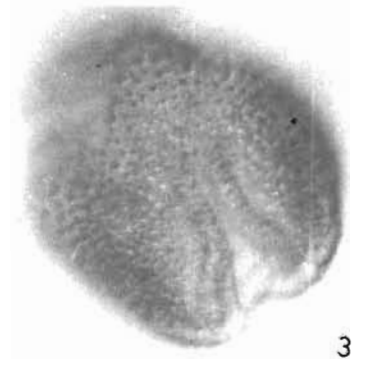
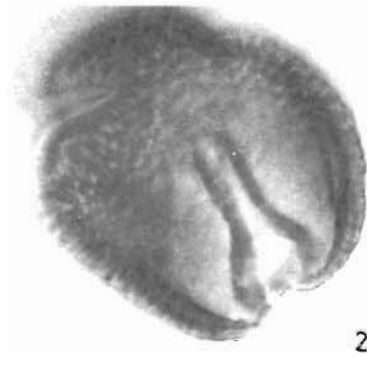


PLATE 6

Occurrence—Kopili Formation (Late Eocene), Meghalaya (Tripathi & Singh, 1984).

Affinity—Alangiaceae.

Genus — *Dermatobrevicolporites* Kar 1985

Type species —*Dermatobrevicolporites dermatus* (Sah & Kar, 1970) Kar, 1985

Original diagnosis (Kar, 1985, p. 89)—Pollen grains triangular-subtriangular, tricolporate, brevicolpate, pore large, margin thickened, exine thick, laevigate-finely intrastriated.

Species studied :

Dermatobrevicolporites dermatus (Sah & Kar, 1970) Kar 1985

Pl. 5, fig. 11, Pl. 8, figs 1-2

Holotype—Sah and Kar, 1970, pl. 2, fig. 49, slide no. 3365/20, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Bore core no. 15 near Baranda and Panandhro (depth 7 m), Kutch District, Gujarat; Naredi Formation, Early Eocene.

Original diagnosis (Sah & Kar, 1970, p. 140)—Pollen grains subtriangular-subcircular, 30-38 x 28-35 μ , 3-orate, ora with thickened margin. Exine thick, \pm laevigate-finely intrastriated.

Restated diagnosis (Kar, 1985, pp. 89-90)—Pollen grains triangular-subtriangular, 30-38 x 28-35 μ m, always found in polar view, tricolporate, colpi short, 10-15 μ m in length, pore well developed, 5-10 μ m in diameter. Exine 2-4 μ m thick, sexine thicker than nexine, more or less psilate or sometimes weakly intrastriated.

Number of specimens studied—9.

Description :

Symmetry and form : Isopolar, triangular to subtriangular in polar view.

Dimension : 30-45 x 28-35 μ m.

Aperture : Tricolporate; ectoaperture 10-15 μ m long, endoaperture 5-10 μ m in diameter, slightly protruded, margin thickened.

Exine : 1.5-3.5 μ m thick, undifferentiated.

Occurrence—Naredi Formation (Early Eocene), Kutch (Sah & Kar, 1970); Miocene sediments, Kerala (Raha *et al.*, 1986).

Affinity—Not known.

Genus — *Echimonoporopollis* Saxena *et al.* 1991

Type species—*Echimonoporopollis grandiporus* Saxena *et al.* 1991

Original diagnosis (Saxena *et al.*, 1991, p. 46)—Pollen grains spherical, subspherical or ovoidal, small to medium sized. Monoporate. Exine generally thin, spinose, spines vary in shape and size.

Species studied :

Echimonoporopollis grandiporus Saxena *et al.* 1991

Pl. 9, figs 1-2, 4-5

Holotype—Saxena *et al.* 1991, pl. 1, fig. 1, slide no. 9945a. *Repository*—B.S.I.P., Lucknow.

Type locality, horizon and age—Jayamkondacholapuram well-12 (depth 142.3 m from ground level), Tiruchirapalli District, Tamil Nadu, Neyveli Formation (lower part), Palaeocene.

Original diagnosis (Saxena *et al.* 1991, p. 48)—Pollen grains spherical to subspherical in shape. Size range 30-42 x 29-40 μ m (excluding spines). Monoporate, pores distinct, circular to oval, *ca.* 7-13 μ m in diameter, pore margin unthickened. Exine up to 1.5 μ m thick, sexine as thick as nexine, spinose. Spines 3-6 μ m long, evenly distributed, bases of spines bulbous, tips of spines mostly pointed but may also be blunt. Interspinal area psilate, punctate or microreticulate.

Number of specimens studied—14.

PLATE 7

(All photographs are enlarged x1000)

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|--|---|
| 1-4. <i>Icacinoipollenites spinulatus</i> Navale & Misra. Slide no. BSIP 10994. | 7-8. <i>Acanthotricolpites bulbospinosus</i> Kar. Slide nos. BSIP 10998 and BSIP 10999. |
| 5-6. <i>Tribrevicolporites eocenicus</i> Kar. Slide nos. BSIP 3362/2, 11-12. BSIP 3372/7 | 9. <i>Thymelaepollis crotonoidis</i> Sah & Kar. Slide no. BSIP 3372/12. |
| | 10. <i>Plicatiaperturites retipilatus</i> Kar. Slide no. BSIP 6373/5. |

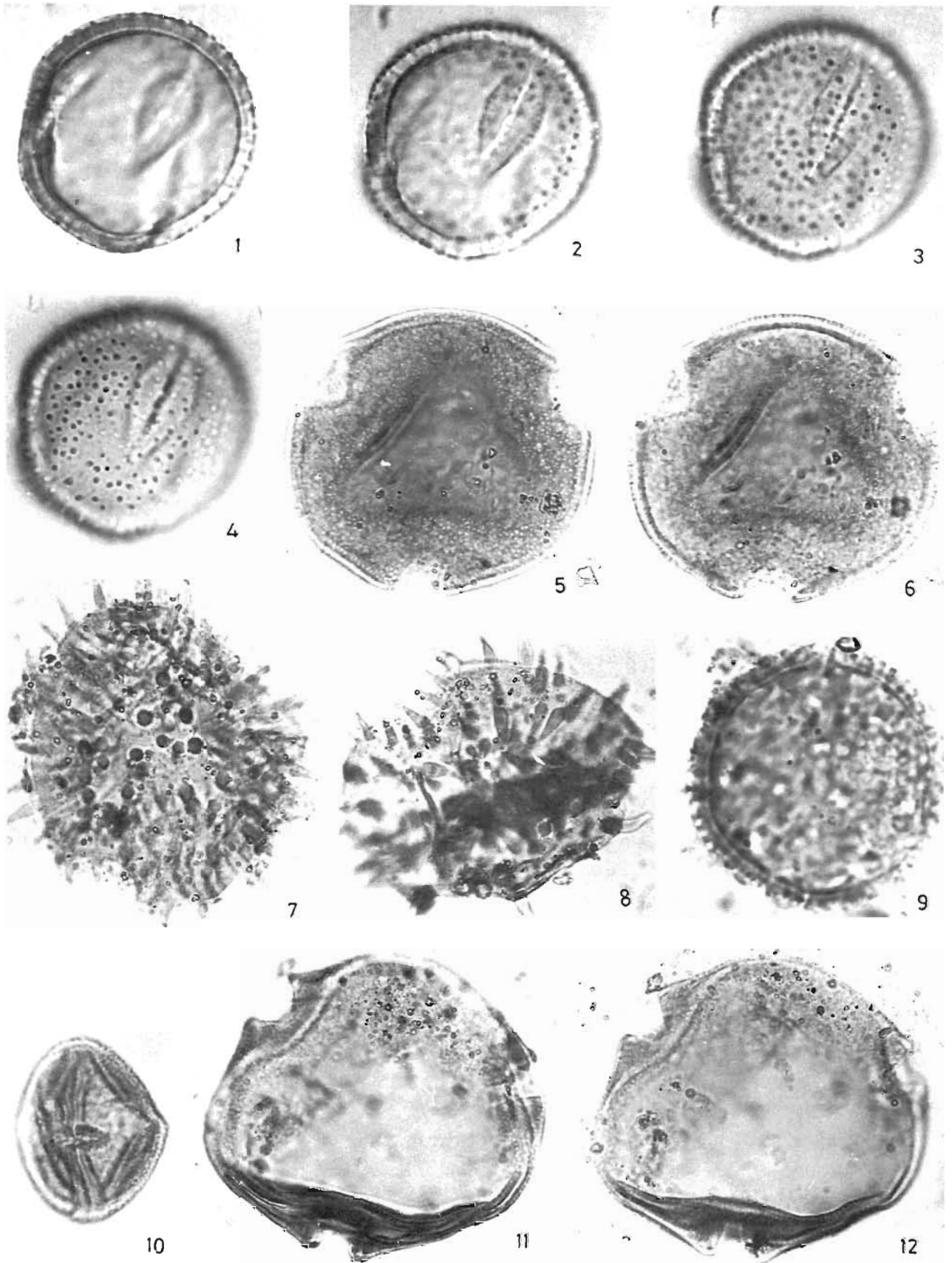


PLATE 7

*Description :**Symmetry and form :* Spherical to subspherical.*Dimension :* 28-47 x 26-41 μm (excluding spines)*Aperture :* A single distal pore, circular to oval, 8-13 μm in diameter, margin not thickened.*Exine :* Spinose.*Sexine :* 1 μm thick, spines 4-7 μm long, broader and bulbous at base and pointed towards tip, evenly distributed, interspinal area psilate, punctate, or microreticulate.*Nexine :* As thick as sexine, smooth.*Occurrence*—Neyveli Formation (Palaeocene), Tamil Nadu (Saxena *et al.*, 1991).*Affinity*—Not known.*Echimonoporopollis neyveliensis* Saxena *et al.* 1991

Pl. 9, figs 8-9

Holotype—Saxena *et al.*, 1991, pl. 1, fig. 6, slide no. 9944, Repository — B.S.I.P., Lucknow.*Type locality, horizon and age*—Jayamkondacholapuram well-12 (depth 144.0 m from ground level), Tiruchirapalli District, Tamil Nadu; Neyveli Formation, Palaeocene.*Original diagnosis*—(Saxena *et al.*, 1991, p. 48) — Pollen grains spherical to ovoidal in shape. Size range 41-46 x 38-45 μm (excluding spines). Monoporate, pore distinct, circular, 10-14 μm in diameter, pore margin unthickened. Exine 0.5-1.0 μm thick, sexine as thick as nexine, spinose. Spines uniformly distributed, robustly built, broad at base and gradually taper towards the tip, spine bases not bulbous, length of spines 6.2-9.6 μm. Interspinal area punctate - microreticulate.*Number of specimens studied* — 13.*Description :**Symmetry and form :* Spherical to subspherical.*Dimension :* 40-48 x 36-46 μm (excluding spines).*Aperture :* A single distal pore, circular, 8-14 μm in diameter, pore margin not thickened.*Exine :* Spinose.*Sexine :* 0.5 μm thick, spines evenly distributed, broad at base, and tapers towards the tip, 6.2-9.6 μm long, interspinal area punctate-microreticulate.*Nexine :* As thick as sexine, smooth.*Occurrence*—Neyveli Formation (Palaeocene), Tamil Nadu (Saxena *et al.*, 1991).*Affinity*—Not known.**Genus—*Foveotricolporites* Pierce 1961**Type species—*Foveotricolporites rhombohedrals* Pierce 1961*Original diagnosis* (Pierce, 1961, p. 52) — Foveolate, tricolporate pollen.*Species studied :**Foveotricolporites reticuloidus* Kar 1985

Pl. 9, figs 6-7

Holotype—Kar, 1985, pl. 15, fig. 6, slide no. 3364/13, Repository — B.S.I.P., Lucknow.*Type locality, horizon and age* — Bore core no. 15 near Baranda and Panandhro (depth 3 m), Kutch District, Gujarat; Naredi Formation, Early Eocene.*Original diagnosis* (Kar, 1985, p. 79)—Pollen grains oval in equatorial view, 36-44 x 34-41 μm, tricolporate, colpi long, pore distinct, lalongate. Exine 2-3 μm thick, sexine much thicker than nexine, tectate, reticuloid, reticulate appearance being formed by pila.*Number of specimens studied* — 10.*Description :**Symmetry and form :* Isopolar, oval in equatorial view.*Dimension :* 36-44 x 34-41 μm.*Aperture :* Tricolporate; ectoaperture long; reaching to the pole; endosperture distinct, large (4-5 μm) lalongate, bordered by thick costae.**PLATE 8**

(All photographs are enlarged x1000)

- | | |
|--|--|
| 1-2. <i>Dermatobrevicolporites dermatus</i> (Sah & Kar) Kar. Slide no. BSIP 3377/12. | 10-12. <i>Varisptnitriporites rotariensis</i> Kar. Slide nos. BSIP 6353/8 and BSIP 6352/8. |
| 3. <i>Thymelaepollis crotonoidis</i> Sah & Kar. Slide no. BSIP 3372/12. | 13. <i>Racemonocolpites thanjinathensis</i> Mandal. Slide no. BSIP 9581. L 54/3. |
| 4-9. <i>Alangiopollis gemmatus</i> Navale & Misra. Slide no. BSIP 10995; BSIP 10993. | |

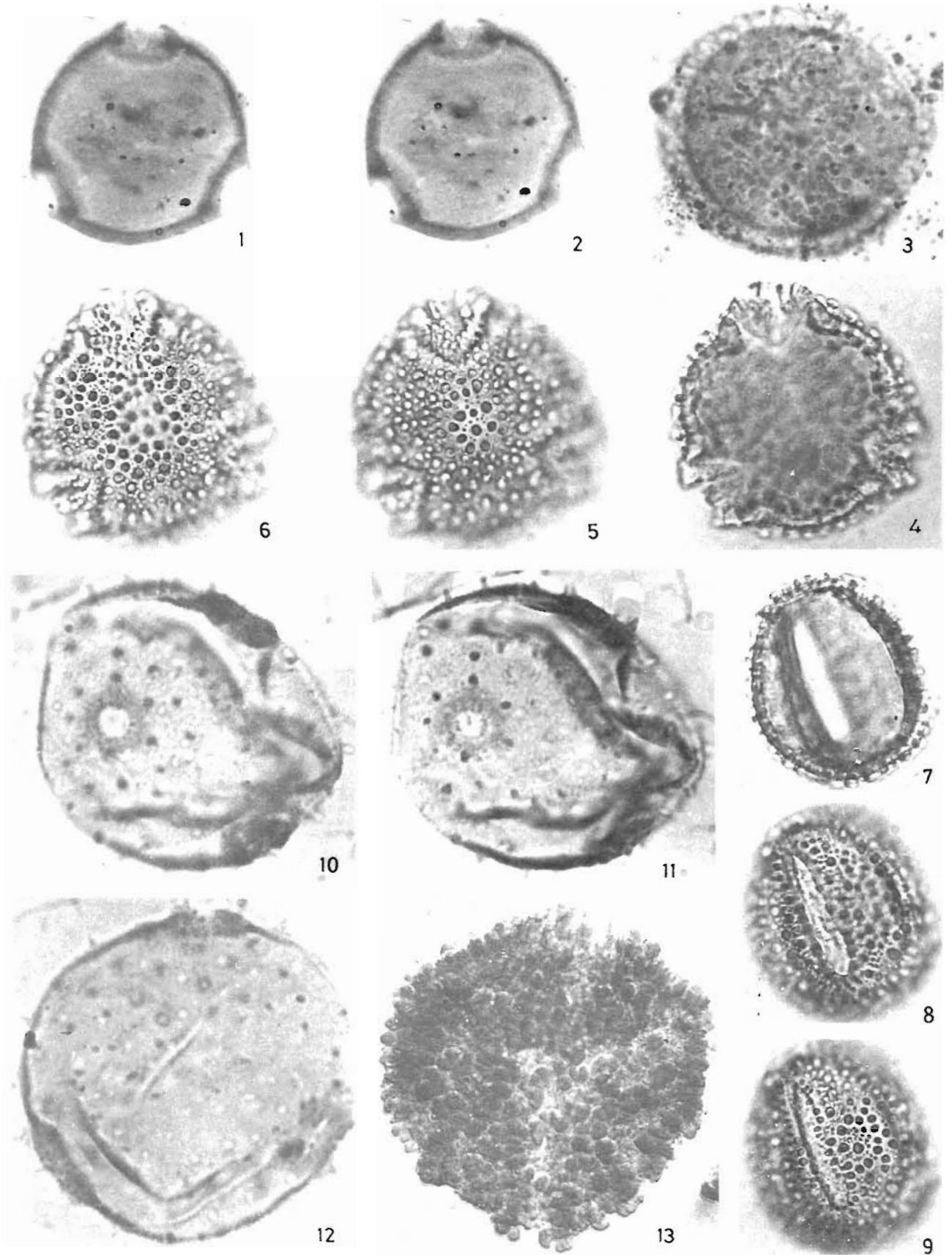


PLATE 8

Exine: 2-3.5 μm thick, sexine much thicker than nexine.

Sexine: Irregularly baculate, 2-2.5 μm thick.

Nexine: Up to 1 μm thick, uniform.

Occurrence—Naredi Formation (Early Eocene), Kutch (Kar, 1985).

Affinity—*Dodonaea* (Sapindaceae).

Genus — *Hippocrateaceaedites* Ramanujam 1966

Type species — *Hippocrateaceaedites vancampoeae* Ramanujam 1966

Original diagnosis (Ramanujam, 1966, p. 170)— Pollen grains isopolar, oblate to suboblate, 3-zonicolporate. Amb subtriangular. In polar view the sexine of each lobe is prolonged into characteristic knob-like process on either side of colpus. Colpi broad at equator suddenly narrowing towards poles, surrounded by a thickened exine, longicolpate, ora prominent, rounded with a thick annulus interrupted at equator. Exine punctitegillate.

Emended diagnosis (Rao & Ramanujam, 1982, p. 77) — Pollen grains oblate to suboblate, amb triangular to subtriangular, tricolporate, longicolpate, in polar view sexine prolonged into characteristic knob-like processes on either side of colpus. Colpal margin thickened, ora prominent, rounded to lalongate with a thickened rim interrupted at equator. Exine punctitectate to finely reticulate.

Species studied :

Hippocrateaceaedites constrictus Sah & Kar 1974

Pl. 5, figs 1-4

Holotype— Sah and Kar, 1974, pl. 2, fig. 46, slide no. 4354/9, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Palana lignitefield, Bikaner District, Rajasthan; Palana Lignite; Early Eocene.

Original diagnosis (Sah & Kar, 1974, p. 170) — Pollen grains triangular with marked constriction at

apices, 3 colporate, pore margin thickened. Exine pilate - reticulate.

Number of specimens studied — 11.

Description :

Symmetry and form : Isopolar, triangular to subtriangular.

Dimension : 40-50 μm .

Aperture : Tricolporate; ectoaperture long with thickened margin, endoaperture 3-5 μm in diameter, margin thickened.

Exine : 3-5 μm thick, sexine as thick as nexine.

Sexine : Intectate, reticulate, reticulum formed of pila, pila 3-4 μm long, closely placed.

Nexine : Thin, uniformly wide, continuous.

Occurrence — Palana Lignite (Early Eocene), Rajasthan (Sah & Kar, 1974).

Affinity—Hippocrateaceae.

Genus — *Icacinoipollenites* Navale & Misra 1979

Type species — *Icacinoipollenites spinulatus* Navale & Misra 1979

Original diagnosis (Navale & Misra, 1979, p. 228) — Pollen grain isopolar, subprolate to oblate, size range 41-68 x 30-56 μm . Tricolpate, brevicolpate, colpi slit-like, surrounded by lip-like thickening. Exine 2.5-5.5 μm thick, crassisexinous, tegillate, spinulate, spinules very small (1 μm). Surface microgranulate.

Species studied :

Icacinoipollenites spinulatus Navale & Misra 1979

Pl. 7, figs 1-4

Holotype— Navale and Misra, 1979, pl. 1, fig. 8, slide no. 10994, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age— Neyveli lignite field, South Arcot District, Tamil Nadu; Neyveli Formation; Eocene.

PLATE 9

(All photographs are enlarged x1000)

- 1-2,4-5. *Echimonoporopollis grandiporus* Saxena *et al.* Slide no. BSIP 9945.
3. *Arengapollenites achinatus* Kar. Slide no. BSIP 8236/2.
6-7. *Foveotricolporites reticulooidus* Kar. Slide no. BSIP 3364/13.

- 8-9. *Echimonoporopollis neyveliensis* Saxena *et al.* Slide no. BSIP 9944.
10-11. *Angulocolporites microreticulatus* Kar. Slide no. BSIP 3353/6.
12. *Calophyllumpollenites rotundus* Sah & Kar. Slide no. BSIP 4360/25.

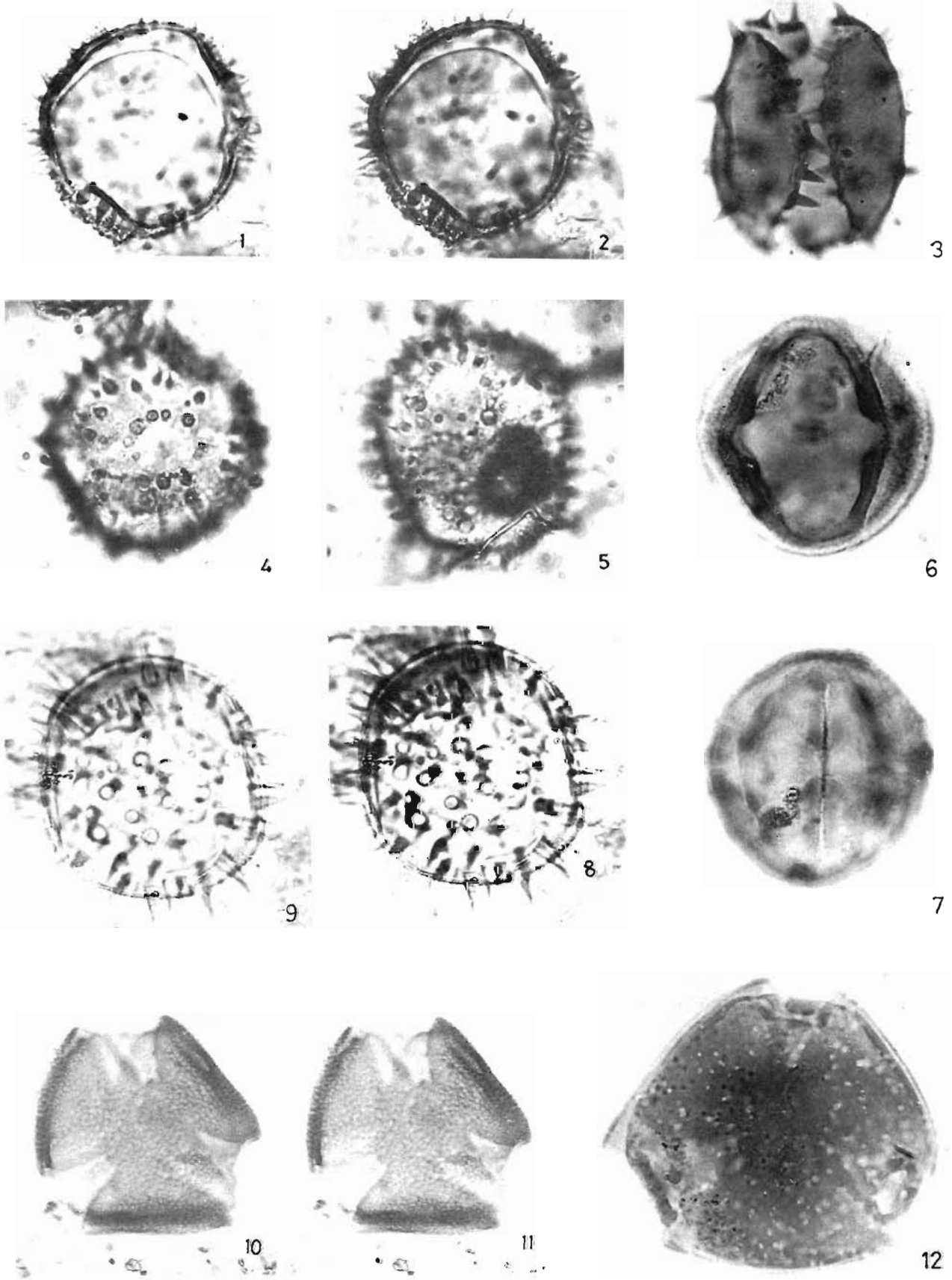


PLATE 9

Original diagnosis (Navale & Misra, 1979, p. 228) — Isopolar pollen grain, subprolate to oblate (in equatorial view) 41-68 x 38-56 μm in size. Tricolpate, brevicolpate, slit-like colpi surrounded by lip-like thickening about 2.5-3 μm thick. Exine 3.5-4.5 μm thick, crassisexinous, sexine nearly 3-4 times thicker than nexine, tegillate, spinulate, spinules very small (1 μm long) but their bases are distinctly seen in the surface view, surface microgranulate.

Number of specimens studied — 8.

Description :

Symmetry and form : Spheroidal in equatorial view.

Dimension : 41-68 x 38-62 μm .

Aperture : Tricolpate, colpi 12 μm long, narrow, margin uneven accompanied by lip-like raised structure on either side.

Exine : 4-5 μm thick, tectate, spinulose.

Sexine : Crassisexinous, sexine 3.5-4.5 μm thick; columella very closely placed, 3.5-4 μm long; spinules suprategal, 1-2.5 μm long, 3-7 μm apart, regularly present on colpi margin; interspinal areas granulate, infrategum distinctly columellate.

Nexine : 0.5 μm thick, continuous.

Occurrence — Neyveli Formation (Eocene), Tamil Nadu (Navale & Misra, 1979).

Affinity — According to Navale and Misra (1979), the pollen grains resemble *Desmostachys preussii* of the family Icacinaceae. However, this affinity needs rechecking.

Remarks — While describing this species, Navale and Misra (1979) spelled the genus as *Icacinacipollenites* instead of *Icacinoipollenites*. This has been considered a typographic error, hence corrected.

Genus — *Ligulifloraedites* Kar 1985

Type species — *Ligulifloraedites pilatus* Kar 1985

Original diagnosis (Kar, 1985, p. 91) — Pollen grains generally subcircular, radially symmetrical, apertures indistinct, probably tricolpate - tricolporate. Exine thick, roughly differentiated into a pat-

tern of intectate lacunae and tectate-columellate cristae, columellae bearing pila.

Species studied :

Ligulifloraedites pilatus Kar 1985

Pl. 5, figs 5-7

Holotype — Kar, 1985, pl. 7, fig. 18, slide no. 8230/3, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Panandhro lignitefield, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Kar, 1985, pp. 91-92) — Pollen grains radially symmetrical, subcircular with slight undulated margin, 45 x 54 - 44 x 53 μm . Apertures not distinct, seem to be tricolpate-tricolporate. Exine 5-7 μm thick, sexine much thicker than nexine, differentiated into a pattern of intectate lacunae and tectate-columellate cristae, columella 4-6 μm broad, bearing single row of pin-headed pila, pila robustly built.

Number of specimens studied — 7.

Description :

Symmetry and form : Radially symmetrical; spheroidal in polar view.

Dimension : 45-65 x 44-65 μm .

Aperture : Tricolporate.

Exine : 6-7 μm thick, tectate, pila-reticulate.

Sexine : Pila robust, 3.5 - 6.5 x 1-3.5 μm , pila head occasionally fused, up to 4 μm broad; on one surface pila are arranged in single row and form irregular reticulum, lumina 3.5 - 13 μm , on the other side pila are in 2-3 rows forming very thick bands, bands join to form irregular reticulum; muri 3.5-9 μm wide, lumina 3-15 μm ; infrategum distinctly columellate.

Nexine : 1.5 μm thick, continuous.

Occurrence — Naredi Formation (Early Eocene), Kutch (Kar, 1985).

Affinity — This species closely resembles the pollen of some members of Caesalpinaceae, e.g., *Delonix* and *Peltophorum*.

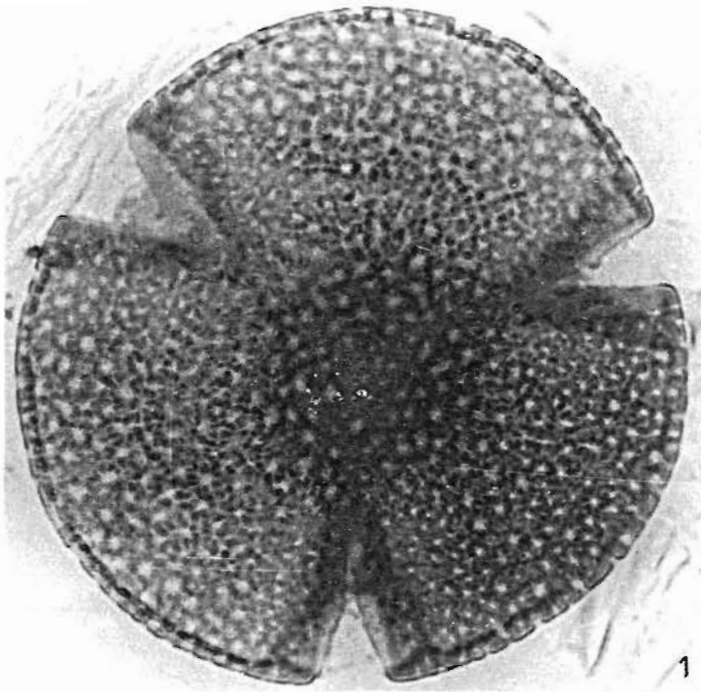
PLATE 10

(All photographs are enlarged x1000)

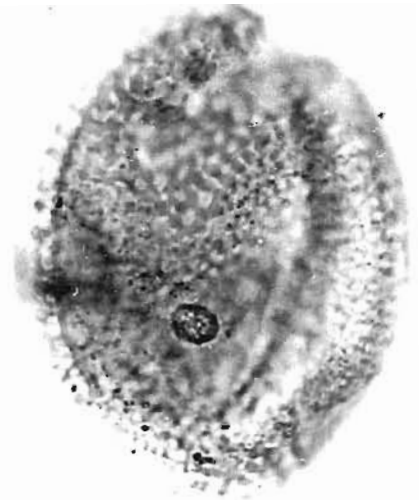
1-2. *Alangiopollis arcotensis* Navale & Misra. Slide no. BSIP 10996.

3-4. *Liliacidites baculatus* Venkatachala & Kar. Slide no. BSIP 3312.

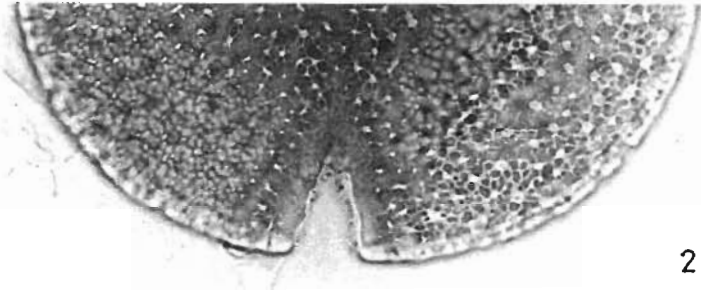
5-6. *Densiverrupollenites eocenicus* Tripathi & Singh. Slide no. BSIP 6958/1.



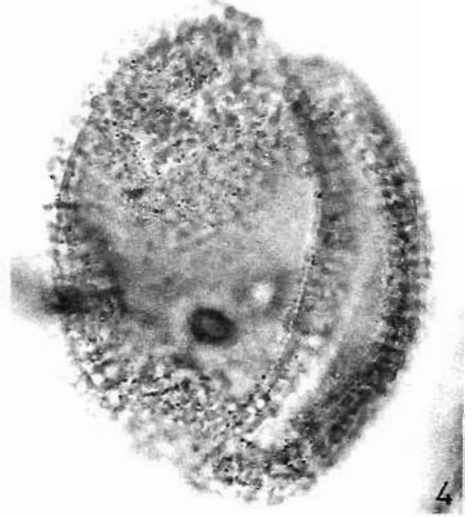
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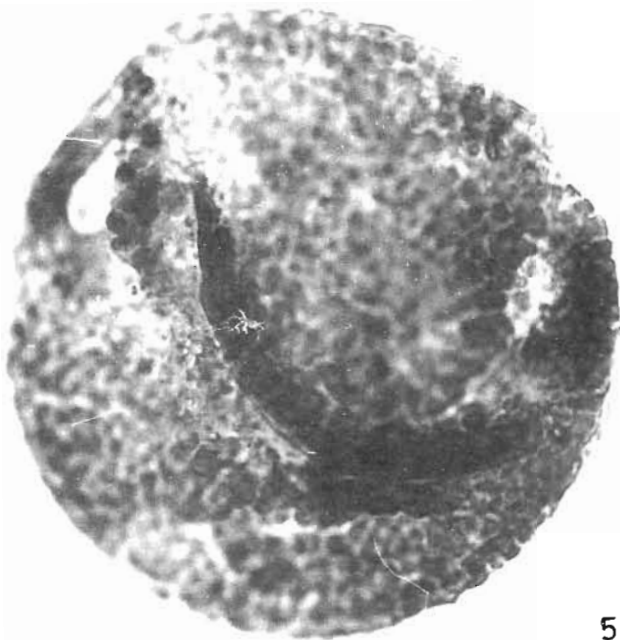
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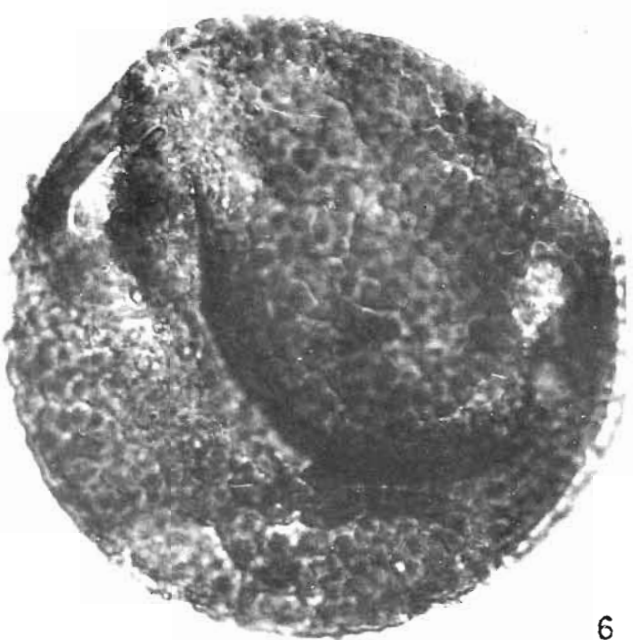
2



4



5



6

PLATE 10

Genus — *Liliacidites* Couper 1953

Type species — *Liliacidites kaitangataensis* Couper 1953

Original diagnosis (Couper, 1953, p. 56) — Free anisopolar, bilateral, monosulcate, occasionally trichotomosulcate; sulcus long, broad; grain usually elongate; exine clearly reticulate, lumina of reticulum variable in size; clavate, baculate in optical section (muri composed of baculae or clavae).

Emended diagnosis (Krutzsch, 1970, p. 30) — Monosulcate (abnormally also trichotomosulcate) pollen with coarsely reticulate exine, muri underlain by a distinct columellae or baculae layer, the components of which in part may protrude freely to the exterior as clavae. Medium sized to large forms.

Species studied :

Liliacidites baculatus Venkatachala & Kar 1969

Pl. 10, figs 3-4

Holotype — Venkatachala and Kar 1969, pl. 1, fig. 17, slide no. 3312, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 14 (depth 45 m), Matanomadh, Kutch District, Gujarat; Naredi Formation, Early Eocene.

Original diagnosis (Venkatachala & Kar, 1969, p. 160) — Pollen grains oval-elliptical in shape, 45-65 x 30-45 μm . Colpus well-developed, funnel shaped. Exine intrabaculate forming negative reticulum in surface view.

Number of specimens studied — 8.

Description :

Symmetry and form : Heteropolar, oval to elliptical.

Dimension : 45-65 x 30-45 μm .

Aperture : Monosulcate, sulcus extended.

Exine : 3-4 μm thick, sexine much thicker than nexine.

Sexine: Tectate, reticulate, retipilate, pila 2.5-3 μm long.

Nexine: Continuous, about 1 μm thick.

Occurrence — Naredi Formation (Early Eocene), Kutch (Venkatachala & Kar, 1969).

Affinity — This species is closely comparable to the pollen of *Eugetissona insignis*.

Remarks — *Liliacidites baculatus* was transferred to *Matanomadbiasulcites* by Kar (1985). *Liliacidites baculatus* Venkatachala & Kar 1969 has extended sulcus hence does not come under the generic circumscription of either *Liliacidites* or *Matanomadbiasulcites* Thanikaimoni *et al.* (1984) suggested resemblance of this species with Quilonipollenites.

Genus — *Neocouperipollis* Kar & Kumar, 1987

Type species — *Neocouperipollis kutchensis* (Venkatachala & Kar, 1969) Kar & Kumar 1987

Original diagnosis (Kar & Kumar, 1987, p. 172) — Pollen grains more or less elliptical in polar view, monosulcate, echinate, sulcus extending from one end to the other along the longest axis, spines pointed with nexinal thickening at the base, exine more or less smooth between the spines.

Remarks — The genus *Couperipollis* was designated by Venkatachala and Kar (1969) with a view to maintain homogeneity in *Monosulcites* Erdtman 1947. *Monosulcites*, originally proposed to accommodate laevigate, monocolpate pollen, was emended by Couper (1953) and monocolpate, spinose forms were also included in it. Considering this emendation untenable, Venkatachala and Kar (1969) proposed *Couperipollis* designating *Monosulcites perspinosus* Couper 1953 as its type species. Later, it was found that holotype of *Monosulcites perspinosus* is not traceable in the slides prepared by Couper (Norris, 1962; Pocknall & Mildenhall, 1984). The type locality, from where Couper's material was collected, has been eroded by sea (Pocknall & Mildenhall, 1984). To overcome this problem, Kar and Kumar (1987) proposed *Neocouperipollis*, designating *N. kutchensis* (Venkatachala & Kar, 1969) Kar & Kumar 1987 as its type species.

Species studied :

Neocouperipollis kutchensis (Venkatachala & Kar, 1969) Kar & Kumar 1987

Pl. 3, figs 12-13

Holotype — Venkatachala and Kar, 1969, pl. 1, fig. 16, slide no. 3314, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore hole no. 14, Matanomadh, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Venkatachala & Kar, 1969, p. 161)—Pollen grains subcircular in shape, 35-65 x 30-60 μm . Monosulcate, sulcus ill-developed, hardly discernible, extending from one end to other. Exine spinose, spines with bulbous base and pointed tip.

Emended diagnosis (Kar & Kumar (1987, p. 173) — Pollen grains more or less subcircular to oval in shape, 35-65 x 30-60 μm . Monosulcate, exine spinose, spines strongly built with bulbous base and pointed tip, interspinal space more or less laevigate to granulose.

Number of specimens studied — 26.

Description :

Symmetry and form : Heteropolar, subcircular to oval.

Dimension : 35-65 x 30-60 μm .

Aperture : Monosulcate, sulcus long, obscured by spines.

Exine : 1.5-2 μm thick, not clearly differentiated, spinose, spines with bulbous base and pointed tip, 5-8 μm long, 4-7 μm wide at base; interspinal area laevigate to granulate, 1.5-2 μm thick.

Occurrence — Matanomadh, Naredi and Harudi formations (Palaeocene - Eocene), Kutch (Venkatachala & Kar, 1969; Kar, 1978, 1985; Saxena, 1979); Palana Lignite (Early Eocene), Rajasthan (Sah & Kar, 1974); subsurface middle-Late Eocene sediments of Kutch (Kar & Saxena, 1981); Lakadong Sandstone (Palaeocene), Meghalaya (Kar & Kumar, 1986; Mandal, 1990).

Affinity — Arecaceae.

Genus — *Parumbelliferoipollis* Kar 1978

Type species — *Parumbelliferoipollis dulcis* Kar 1978

Original diagnosis (Kar, 1978, p. 168) — Pollen grains elliptical in equatorial view. Tricolpate, colpi distinct to indistinct. Exine thick, rugulate to scrobiculate; sexine as thick as nexine at poles, but much thicker than nexine at equator.

Species studied :

Parumbelliferoipollis dulcis Kar 1978

Pl. 2, figs 1-7

Holotype — Kar, 1978, pl. 1, fig. 20, slide no. 3254/13, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Harudi, Kutch District, Gujarat; Harudi Formation; Middle Eocene.

Original diagnosis (Kar, 1978, p. 169) — Pollen grains only found in equatorial view, elliptical, without any marked constriction in middle region. Tricolpate, colpi long, distinct to indistinct, extending up to three-fourths along longer axis. Exine 2-5 μm thick at polar region, 6-10 μm broad at equator; sexine as thick as nexine at equator; pila closely placed and fused to form rugulate to scrobiculate structure.

Number of specimens studied — 15.

Description :

Symmetry and form : Elliptical in equatorial view.

Dimension : 40-60 x 26-35 μm .

Aperture : Tricolpate, colpi 23-35 μm long, narrow.

Exine : 3-5 μm thick, tectate, reticulate.

Sexine : Much thicker than nexine at equator, pila heads fuse to form reticulum; lumina 1 μm in diameter, pila 1.5 x 0.5 μm ; infratectum columellate.

Nexine : 1-1.5 μm thick, thinner at equator.

Occurrence — Harudi Formation (Middle Eocene), Kutch (Kar, 1978, 1985).

Affinity — Kar (1978) doubtfully assigned this genus to Apiaceae. The present study reveals that in its sexine structure the pollen are also comparable to some members of Acanthaceae. However, pollen of these two families always bear endoapertures.

Genus — *Plicatiaperturites* Kar 1985

Type species—*Plicatiaperturites retipilatus* Kar 1985

Original diagnosis (Kar, 1985, p. 124) — Pollen grains subcircular in polar and oval in equatorial views. Tricolporate, pore distinct, margin thickened, colpi long with thickened margin. Exine 1.5-2.5 μm thick, retipilate-reticulate, ornamentation more in mesocolpial than in apertural region.

Species studied :

Plicatiaperturites retipilatus Kar 1985

Pl. 1, figs 1-3; Pl. 6, figs 6-7; Pl. 7, fig. 10

Holotype — Kar & Saxena, 1981, pl. 3, fig. 61, slide no. 6373/4, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 27 (depth 30 m), Rataria, Kutch District, Gujarat; subsurface; Middle-Late Eocene sediments.

Diagnosis — (Kar, 1985, p. 124) — Pollen grains subcircular in polar and oval in equatorial views, 20-30 x 18-28 μm . Tricolporate, pores distinct, margin thickened, pores alongate in equatorial view. Colpi distinct, long, bordered by exinal thickening on both sides. Exine up to 2.5 μm thick, sexine thicker than nexine, retipilate-reticulate ornamentation more on mesocolpial than in apertural region.

Number of specimens studied — 11.

Description.

Symmetry and form : Isopolar, subcircular in polar view, oval in equatorial view.

Dimension : 20-30 x 18-20 μm .

Aperture : Tricolporate, ectoaperture long, extending up to 2/3 of the polar axis, endoaperture circular, costate.

Exine : Tectate; 2 - 3 μm thick, thicker in intercolpium; sexine thicker than nexine.

Sexine : Retipilate, pila forming reticulate pattern; pila smaller near aperture; pila heads up to 1 μm in diameter.

Nexine : Up to 1 μm thick, uniform.

Occurrence — Subsurface Middle-Late Eocene sediments, Kutch (Kar, 1985).

Affinity — *Haldina* (Rubiaceae) produces pollen having same type of apertures and exine pattern.

Genus — *Plumbaginacipites* Navale & Misra 1979

Type species — *Plumbaginacipites neyvelii* Navale & Misra 1979

Original diagnosis (Navale & Misra, 1979, p. 227) — Pollen grain isopolar, oblate, suboblate to spheroidal. Size ranges from 60-95 x 60-70 μm . Tricolpate, colpi simple, long and deep, do not reach the poles, mesocolpi rounded. Exine always thick (5-7 μm), sexine thicker than nexine, sexine with distinct rod layer, rods are long, papillate to clavate showing a granular to microreticulate surface pattern.

Species studied :

Plumbaginacipites neyvelii Navale & Misra 1979

Pl. 2, figs 12-13

Holotype — Navale and Misra, 1979, pl. 1, fig. 4, slide no. 10992, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Neyveli lignitefield, South Arcot District, Tamil Nadu; Neyveli Formation; Eocene.

Original diagnosis (Navale & Misra, 1979, p. 227) — Isopolar pollen, oblate to spheroidal, 60-95 x 60-70 μm in size. Tricolpate, colpi longicolpate, deep but do not reach the poles, mesocolpi are rounded at the periphery. Exine 5-7 μm thick, sexine thicker (2-3 times) than nexine, gradually thinning towards the colpi margins. Distinct rod layer is present in the sexine, rods are long, papillate to clavate forming granulate to finely micro-reticulate surface structure.

Number of specimens studied — 9.

Description :

Symmetry and form : Spheroidal in polar view.

Dimension : 60-95 x 60-80 μm .

Aperture : Tricolpate; colpi 25 μm long with rounded ends.

Exine : 6.5 μm thick, tectate, ornamented with varying sculptural elements (bacula, clava).

Sexine : Thicker than nexine, 4-5 μm thick, tectum perforated; sculptural elements 0.5-1 μm apart, 0.5-1.2 x 3-4 μm in size; heads of the elements occasionally fused; thin near colpi margin, infratectum columellate, columellae 5 x 1 μm , shorter near the colpi.

Nexine : 1-1.5 μm , uniformly thick.

Occurrence — Neyveli Formation (Eocene), Tamil Nadu (Navale & Misra, 1979, pl. 1, figs 4-6); subsurface Pleistocene sediments, Bengal Basin (Mathur & Chopra, 1987).

Affinity — According to Navale and Misra (1979) this species has affinity with *Plumbaginae zeylanica* of family Plumbaginaceae described by Selling (1947).

Genus — *Polycolporites* Mehrotra 1983

Type species — *Polycolporites indicus* Mehrotra 1983

Original diagnosis (Mehrotra, 1983, p. 15) — Pollen grains circular-subcircular, polycolporate, colpi long, reaching up to radius; exine ornamentation scabrate.

Remarks — Stephanocolporate pollen with long ectoaperture, distinct apertural membrane and laevigate-pitted exinal pattern are accommodated in

this genus. *Polymargocolporites* Kar & Kumar 1986 has similar morphological characters. *Polymargocolporites* Kar & Kumar 1986 is therefore a junior synonym of *Polycolporites* Mehrotra (1983).

Species studied :

Polycolporites indicus Mehrotra 1983

Pl. 5, figs 8-10

Holotype — Mehrotra, 1983, pl. 4, fig. 2, slide no. 6481, Repository — Palynology Laboratory, O.N.G.C., Dehradun.

Type locality, horizon and age — Kopili-Kharkor River section, Garampani, North Cachar Hills, Assam; Mikir Formation, Palaeocene.

Original diagnosis (Mehrotra, 1983, p. 15) — Pollen grains circular; size range 44-52 μm , hexacolporate, colpi reaching upto the radius, pores distinct, 5-6 μm wide, elongate; exine 2 μm thick, scabrate.

Number of specimens studied — 19.

Description :

Symmetry and form : Subcircular-lobate in polar view, oval in equatorial view.

Dimension : Equatorial axis 52-60 μm , polar axis 48-55 μm .

Aperture : Penta- to hexacolporate, ectoaperture reaching almost up to poles, elliptic with tapering ends, endoapertures elliptic, 4-5 x 3-4 μm , apertural membrane present except at endoapertures.

Exine : 2-3 μm thick, sexine thinner than nexine.

Sexine : 0.5-1 μm thick, laevigate -pitted, reticulum irregular, lumina 0.5-1 μm in diameter; infratectum columellate.

Nexine : 1.5 - 2 μm thick.

Occurrence—Mikir Formation (Palaeocene), Meghalaya (Mehrotra, 1983), Lakadong Sandstone (Palaeocene), Meghalaya (Kar & Kumar, 1986).

Affinity — ? Rubiaceae.

Remarks — *Polymargocolporites mawlensis* Kar & Kumar (1986, p. 204, pl. 10, figs 2-4, 6-8, 12) is identical to *Polycolporites indicus*, hence is considered its junior synonym. The margo structure not described by Mehrotra (1983), is distinct in the illustrations.

Genus — *Polyporina* Naumova ex Potonié 1960

Type species — *Polyporina multistigmata* (Potonié, 1931) Potonié 1960

Original diagnosis (Potonié, 1960, p. 134) — With numerous foveae, more or less closely spaced, distinctly recessed, with double contours, exine between the circular foveae more distinctly granulate than in the foveae.

Species studied :

Polyporina multiporosa Kar 1985

Pl. 1, figs 4-6

Holotype — Kar, 1985, pl. 30, fig. 13, slide no. 8248/3, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Nala cutting on the eastern side of the village Kaiyari, Kutch District, Gujarat; Maniyara Fort Formation; Oligocene.

Original diagnosis (Kar, 1985, p. 138) — Pollen grains subcircular-circular, more or less radially symmetrical, 27-35 x 26-34 μm , polyporate, pores subcircular 25-35 in number, 2-4 μm in diameter, 6-10 μm apart, evenly distributed. Exine 1-2 μm thick, sexine as thick as nexine, interporal space \pm microreticulate.

Number of specimens studied — 12.

Description :

Symmetry and form : Spheroidal.

Dimension : 25-35 μm .

Aperture : Periporate, pores numerous (more than 24 in number), circular, 2-2.5 μm in diameter, margin thickened, 1.5 μm in width, pores evenly distributed, 6-7 μm apart.

Sexine : Tectum 1.5 μm thick, infratectum columellate, columellae 0.5-1 μm .

Nexine : 1 μm thick, psilate.

Occurrence — Maniyara Fort Formation (Oligocene), Kutch (Kar, 1985); Mayyanad Formation (Eocene), Kerala (Raha *et al.*, 1986).

Affinity — Not known.

Remarks — This pollen type is common to several families (Muller, 1981).

Genus — *Racemonocolpites* Van der Hammen 1954 ex González Guzmán 1967

Type species — *Racemonocolpites racematus* Van der Hammen 1954 ex González Guzmán 1967
Original diagnosis (González Guzman, 1967, p. 50) — Monocolpate pollen grains with gemmate-baculate-clavate sculpture.

Species studied :

Racemonocolpites thanjinathensis Mandal 1990

Pl. 3, figs 10-11; Pl. 8, fig. 13

Holotype — Mandal, 1990, pl. 1, fig. 5, slide no. 9580/5, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Thanjinath, Meghalaya; Sylhet Limestone, Lakadong Sandstone Member; Palaeocene.

Original diagnosis (Mandal, 1990, p. 326) — Pollen grains elliptical in polar view; monosulcate, sulcus distinct, extending up to margin. Exine sculptured with closely placed clava, bacula and gemmae, intersculptural exine granulose/ microbaculose.

Number of specimens studied — 14.

Description :

Symmetry and form : Heteropolar, elliptical.

Dimension : 50-82 x 42-56 μm .

Aperture : Monosulcate, sulcus extending up to equator.

Exine: Up to 1.5 μm thick, intectate, covered with dense clavae, bacula and gemmae; clavae 3-5.5 μm long and 2.5-3 μm broad, bacula 2-4.4 μm long and 1-3.2 μm broad, gemmae 3-5.2 μm broad; intersculptural area granulate to microbaculate.

Occurrence — Lakadong Sandstone (Palaeocene), Meghalaya (Mandal, 1990).

Affinity — *Iriartia* (Arecaceae).

Genus — *Ratariacolporites* Kar 1985

Type species — *Ratariacolporites plicatus* Kar 1985

Original diagnosis (Kar, 1985, p. 123) — Pollen grains triangular-subtriangular in polar view. Tribrevicolporate, apertures situated at angles,

generally associated with folds, exine \pm laevigate to intrastructured.

Species studied :

Ratariacolporites plicatus Kar 1985

Pl. 4, figs 9-12

Holotype — Kar and Saxena, 1981, pl. 4, fig. 73, slide no. 6368/19, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 27 (depth 34 m), Rataria, Kutch District, Gujarat; subsurface Middle-Late Eocene sediments.

Original diagnosis (Kar, 1985, p. 123) — Pollen grains triangular-subtriangular in polar view, 50-60 x 48-58 μm . Tricolporate, brevicolpate, colpi 10-18 μm , colpi generally indistinct, pore circular-oval. Exine 1-2.5 μm thick, more or less laevigate, sometimes weakly granulose, feebly intrastructured. Exine folded regularly in interapertural region, folds originate in one apertural region and end in other, \pm run parallel to margin.

Number of specimens studied — 12.

Description :

Symmetry and form : Isopolar, subtriangular to triangular in polar view.

Dimension : 60-80 x 55-70 μm .

Aperture : Tricolporate; ectoaperture 10-18 μm long; endoaperture circular to oval.

Exine : Tectate; 1-2 μm thick; sexine as thick as nexine.

Sexine : Laevigate, sometimes weakly granulose; feebly intrastructured.

Nexine : Up to 1 μm thick, inner part granular.

Occurrence — Subsurface Middle-Late Eocene sediments, Kutch (Kar & Saxena, 1981; Kar, 1985); subsurface Eocene sediments, Kerala (Raha *et al.*, 1986).

Affinity — Not known.

Genus — *Sastriipollenites* Venkatachala & Kar 1969

Type species — *Sastriipollenites trilobatus* Venkatachala & Kar 1969

Original diagnosis (Venkatachala & Kar, 1969, p. 169) — Pollen grains tricolporate, margocolporate, three-lobed; colpi long, funnel shaped, ora distinct to indistinct. Exine granulose to intrabaculate.

Species studied :

Sastriipollenites trilobatus Venkatachala & Kar 1969

Pl. 6, figs 8-9

Holotype - Venkatachala & Kar, 1969, pl. 3, fig. 69, slide no. 3321/18, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 14, Matanomadh, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Venkatachala & Kar, 1969, p. 169) — Pollen grains isopolar, trilobed in equatorial view. Tricolporate, margocolpate, colpi well developed, invaginated inwards. Ora distinct to indistinct. Exine up to 2 µm thick, intrabaculate.

Number of specimens studied - 15.

Description :

Symmetry and form: Isopolar, subcircular, trilobed in equatorial view.

Dimension: 30-40 x 28-36 µm.

Aperture: Tricolporate; margocolpate; ectoaperture long, extending up to poles, invaginated inwards; endoaperture distinct, lolongate.

Exine: Tectate; 1.5-2.5 µm thick; sexine thicker than nexine.

S_{exine}: Punctate, puncta up to 1 µm across.

N_{exine}: Up to 1 µm thick, uniform.

Occurrence — Naredi Formation (Early Eocene), Kutch (Venkatachala & Kar, 1969; Kar, 1978, 1985); Mayyanad Formation (Eocene), Kerala (Raha *et al.*, 1986); Lakadong Sandstone (Palaeocene), Meghalaya (Kar & Kumar, 1986).

Affinity — Unknown.

Remarks — Kar (1985, p. 8) observed *Sastriipollenites trilobatus* to be tricolpate. However, our study on the type material (slide no. 3320/18, Venkatachala & Kar, 1969) shows it to be tricolporate.

Genus — *Thymelaepollis* Sah & Kar 1970

Type species — *Thymelaepollis crotonoidis* Sah & Kar 1970

Original diagnosis (Sah & Kar, 1970, p. 140) — Pollen grains circular-subcircular. Polyporate, pores uniformly distributed. Exine thick, baculate-spinose, sometimes with excrescences on top.

Species studied :

Thymelaepollis crotonoidis Sah & Kar 1970

Pl. 3, fig. 7; Pl. 7, fig. 9; Pl. 8, fig. 3

Holotype — Sah and Kar, 1970, pl. 2, fig. 71, slide no. 3372, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 15, depth 23 feet, Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Sah & Kar, 1970, p. 140) — Pollen grains circular-subcircular, 42-54 x 40-53 µm. Polyporate. Exine 2-4 µm thick, mostly baculate, some times with excrescences at top.

Number of specimens studied — 10.

Description :

Symmetry and form : Spheroidal - oblate spheroidal.

Dimension : 50-53 µm.

Aperture : Periporate, pores numerous, circular, 2-2.5 µm in diameter, pore margin thin.

Exine : Intectate, 3-5 µm thick (including sculpturing elements)

Sexine : Columellate, Columellae 3 µm long, top of the tectum scabrate.

Nexine : 1.5 µm thick, continuous.

Occurrence — Naredi Formation (Early Eocene), Kutch (Sah & Kar, 1970).

Affinity — Not known.

Genus — *Tribrevicolporites* Kar 1985

Type species — *Tribrevicolporites eocenicus* Kar 1985

Original diagnosis (Kar, 1985, p. 80) — Pollen grains subtriangular in polar view, tribrevicolporate. pore margin not thickened. Exine finely reticulate to scabrate.

Species studied :

Tribrevicolporites eocenicus Kar 1985

Pl. 7, figs 5-6, 11-12

Holotype — Kar, 1985, pl. 13, fig. 9, slide no. 3362/2, Repository - B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 15 (depth 6.5 m), Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Kar, 1985, p. 80) — Pollen grains subtriangular-triangular in polar view, tribrevicolporate, colpi 10-20 μm long, pores distinct, 4-10 μm in diameter, margin not appreciably thickened. Exine 2 - 3 μm thick, sexine as thick as nexine, finely reticulate, meshes appearing as pits in surface view.

Number of specimens studied - 12.

Description

Symmetry and form : Isopolar, subtriangular to triangular in polar view.

Dimension : 40-55 x 36-50 μm .

Aperture : Tricolporate; ectoaperture 10-20 μm long; endoaperture 4-10 μm in diameter, margin slightly thickened.

Exine : Tectate; 2.5 - 3.5 μm thick; sexine as thick as nexine.

Sexine : Columellate, columella closely placed, intramicroreticulate; sexine 2 - 2.5 μm thick.

Nexine : 1 - 1.5 μm thick; uniform.

Occurrence—Naredi Formation (Early Eocene), Kutch (Kar, 1985); Lakadong Formation (Palaeocene), Meghalaya (Kar & Kumar, 1986; Mandal, 1987); Mayyanad Formation (Early Miocene), Kerala (Raha *et al.*, 1987).

Affinity—Not known.

Genus—*Trisyncolpites* Kar 1979

Type species — *Trisyncolpites ramanujamii* Kar 1979

Original diagnosis (Kar, 1979, p. 28) — Pollen grains trisynmargocolporate, margocolpi broad, thickened, providing the appearance of triradiate ridge in equatorial view. Exine pilate-baculate, sometimes retipilate-retibaculate, nexine very much thicker than sexine, intrapunctate.

Species studied

Trisyncolpites ramanujamii Kar 1979

Pl. 1, figs 7-13

Holotype — Kar, 1979, pl. 2, fig. 33, slide no. 5099/6. Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Barkhana nala cutting near the village Sarangwara, Kutch District, Gujarat; Maniyara Fort Formation; Oligocene.

Original diagnosis (Kar, 1979, p. 29) — Pollen grains subcircular in polar and elliptical in equatorial view, 51-87 μm . Trisynmargocolporate, margocolpi broad, thickened, united to provide a pseudo-triradiate ridge like pattern. Exine pilate-baculate, in some specimens retipilate-retibaculate, nexine almost double than sexine, intrapunctate. Pores lologate.

Number of specimens studied—9.

Description :

Symmetry and form : Isopolar, subcircular in polar view and \pm elliptical in equatorial view.

Dimension : 50-65 μm .

Aperture : Trisynmargocolporate, ectoaperture broad, thickened at margin; endoaperture lologate.

Exine : Intectate; 3 - 5 μm thick; nexine thicker than sexine.

Sexine. Clavate - baculate: clavae and baculae ends free.

Nexine : Uniform; 2 - 2.5 μm thick.

Occurrence—Maniyara Fort Formation (Oligocene). Kutch (Kar, 1979, 1985)

Affinity—Not known.

Genus—*Varispinitriporites* Kar 1985

Type species — *Varispinitriporites ratariensis* (Kar & Saxena, 1981) Kar 1985

Original diagnosis (Kar, 1985, p. 125) — Pollen grains subcircular-circular. Triporate, pore margin thickened, exine ornamented with two kinds of spines, bigger one sparsely placed, smaller one closely placed.

Species studied .

Varispinitriporites ratariensis (Kar & Saxena 1981) Kar 1985

Pl. 8, figs 10-12

Holotype — Kar and Saxena, 1981, pl. 4, fig. 75, slide no. 6352/8, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age—Bore core no. 27 (depth 27 m), Rataria, Kutch District, Gujarat; Middle-Late Eocene.

Original diagnosis (Kar & Saxena, 1981, p. 114) — Pollen grains subcircular, 55 - 62 x 50 - 60 μm , triporate, pore margin thickened. Exine up to 2 μm thick, baculate, interbacular space granulose.

Restated diagnosis (after Kar, 1985, p. 126) — Pollen grains subcircular, 55-62 x 50-60 μm . Triporate, pore distinct, 8-15 μm , equally spaced, margin thick, spinose, spines of two types, bigger one 3-6 μm long, 2-3 μm broad, tips somewhat pointed, spines placed 8-12 μm apart, smaller spines 2-3 μm long, about 1 μm broad, very closely placed.

Number of specimens studied — 14.

Description :

Symmetry and form : Isopolar, subspheroidal.

Dimension : 55-66 x 50-61 μm .

Aperture : Triporate, pores distinct, equally spaced, 8-12 μm in diameter, pore margin thickened, 4-5.5 μm thick; few long and curved, spines present on pore margin.

Exine : Tectate, sexine thicker than nexine.

Sexine : Echinata, 2-2.5 μm thick, two types of spines present, short spines less than 1.5 μm in length and ± 1 μm in width closely placed, long spines 3-6 μm in length and 2-2.5 μm in width, sparsely distributed, 8-10 μm apart.

Nexine : 1-2 μm thick, smooth, continuous.

Occurrence — Middle-Late Eocene sediments, Kutch (Kar & Saxena, 1981).

Affinity— *Pterospermum* (Sterculiaceae).

Genus — *Verrucolporites* Sah & Kar 1970

Type species — *Verrucolporites verrucus* Sah & Kar 1970

Original diagnosis (Sah & Kar, 1970, p. 132) — Pollen grains oval-elliptical in equatorial and subcircular in polar view. 3 colporate, colpi long, pore generally indistinct. Exine thick, verrucose.

Species studied :

Verrucolporites verrucus Sah & Kar 1970

Pl. 3, figs 1-6

Holotype — Sah & Kar, 1970, pl. 2, fig. 33, slide no. 3351/8, Repository — B.S.I.P., Lucknow.

Type locality, horizon and age — Bore core no. 13 (depth 48'), Kutch District, Gujarat; Naredi Formation; Early Eocene.

Original diagnosis (Sah & Kar, 1970, p. 133) — Pollen grains oval-elliptical in equatorial and subcir-

cular in polar view. 30-50 x 25-44 μm , 3-colporate. colpi long, pore indistinct. Exine strongly verrucose.

Number of specimens studied - 16.

Description :

Symmetry and form : Isopolar, oval to elliptical in equatorial view, subcircular in polar view.

Dimension : 30-50 x 25-44 μm .

Aperture : Tricolporate; ectoaperture long, extending up to poles; endoaperture obscured by ornamentation.

Exine : Intectate, 3 - 5 μm thick; sexine thicker than nexine.

Sexine : 1.5-3 μm thick, verrucose, verrucae 4-8 μm high, closely placed; appearing as negative reticulum in surface view.

Nexine : 1 — 2 μm thick ; uneven.

Occurrence — Naredi Formation (Early Eocene), Kutch (Sah & Kar, 1970).

Affinity — Not known.

DISCUSSION

The Indian Tertiary angiospermous pollen flora is much diversified. The palynoflora of north-eastern and western India, particularly in the Early Tertiary, exhibit broad similarities. Certain important palynotaxa occur for the first time in the two regions at more or less the same time. In general, *Matanomadhiasulcites maximus*, *Triangulorites pachyexinus*, *Recemonocolpites thanjinathensis*, *Echimonoporopollis grandiporus* and *Echimonoporopollis neyveliensis* are common to both Palaeocene and Early Eocene sequences.

The luxuriant vegetation in the Palaeocene and Eocene epochs resulted into the deposition of coal in north-eastern and lignite in western India. The angiospermous pollen are better represented in the Eocene. The following 33 species are restricted to the Eocene: *Clavaperiporites clavatus*, *Ctenolophonidites neyveliensis*, *Septacolpites radiatus*, *Palaeomalvacipollis rudis*, *Meliapollis tamilii*, *M. pachydermis*, *M. simplex*, *Ornatetradites droseroides*, *Pseudonothofagidites cerebrus*, *Retipollenites confusus*, *Cryptopolyporites cryptus*, *Tripilaorites triangulus*, *Tricolporopilites robustus*, *Tricolporocolumellites pilatus*, *Cruciferoipollenites elongatus*, *Icacinoipollenites spinulatus*, *Ligulifloraedites pilatus*, *Parumbelliferoipollenites dulcis*, *Plumbaginacipites neyvelii*, *Arengapollenites*

achinatus, *Liliacidites baculatus*, *Alangiopollis arcotensis*, *A. gemmatus*, *Angulocolporites microreticulatus*, *Calophyllumpollenites rotundus*, *Densiverrupollenites eocenicus*, *Dermatobrevicolporites dermatus*, *Foveotricolporites reticuloides*, *Plicatiapertura retipilatus*, *Thymelaepollis crotonoides*, *Varispinitripolites ratariensis*, *Hippocrateaceaedites constrictus* and *Dakshinipollenites tripakshi*

The frequency of angiospermous pollen decreases in the Oligocene sequence. However, *Bombacacidites triangulus*, *Compositoipollenites tricolporatus*, *Coneopollis decorus*, *C. reticulatus*, *Lacrimapollis pilosus*, *Meyeripollis nabarkotensis* and *Trisyncolpites ramanujamii* appear for the first time. Of these, *Bombacacidites triangulatus* and *Compositoipollenites tricolporatus* are confined to the Oligocene whereas the remaining species extend into the Miocene.

The Miocene palynoflora is impoverished and is characterized by the presence of *Crototricolpites densus*, *Tricolpopollis kockeli*, *Loranthipites elegans*, *Paravuripollis mulleri* and *Warkallipollenites erdtmanii* (Table 1).

Table 1—Stratigraphic ranges of important palynotaxa from the Tertiary sediments of India

Taxa	Palaeo- cene	Eocene	Oligo- cene	Miocene
<i>Matanomadbiasulcites maximus</i>				
<i>Triangulorites pachyexinus</i>				
<i>Racemonocolpites thanjinathensis</i>				
<i>Echimonoporopollis grandiporus</i>				
<i>Echimonoporopollis neyueliensis</i>				
<i>Neocouperipollis achinatus</i>				
<i>Ctenolophonidites stellatus</i>				
<i>Iugopollis tetraporites</i>				
<i>Kielmeyerapollenites eocenicus</i>				
<i>Lakiapollis ovatus</i>				
<i>Retitribrevicolporites matanomadhensis</i>				
<i>Longapertites vaneedenbergii</i>				
<i>Meliapollis neyuelii</i>				
<i>Pellicteroiipollis langenheimii</i>				
<i>Polycolpites flavatus</i>				
<i>Polycolpites pedaliaceoides</i>				
<i>Proxapertites assamicus</i>				
<i>Proxapertites cursus</i>				
<i>Proxapertites operculatus</i>				
<i>Psilodiporites hammenii</i>				
<i>Psilodiporites erdtmanii</i>				
<i>Psilodiporites bengalensis</i>				
<i>Retistephanocolpites williamsii</i>				
<i>Striacolporites cephalus</i>				
<i>Striacolporites striatus</i> ,				
<i>Matanomadbiasulcites kutchensis</i>				
<i>Proteacidites protrudus</i>				
<i>Triangulorites bellus</i>				
<i>Polycolporites mawlensis</i>				
<i>Tribrevicolporites eocenicus</i>				
<i>Arecipites bellus</i>				
<i>Acanthotricolpites bulbospinosus</i>				
<i>Neocouperipollis kutchensis</i>				
<i>Ghoshiacolpites globatus</i>				
<i>Striacolporites ovatus</i>				
<i>Verrucolporites verrucus</i>				
<i>Anacolosidites luteoides</i>				
<i>Neocouperipollis rarispinosus</i>				
<i>Ctenolophonidites costatus</i>				
<i>Dicolpopollis kalewensis</i>				
<i>Marginipollis kutchensis</i>				
<i>Marginipollis concinnus</i>				
<i>Margocolporites tsukadae</i>				
<i>Meliapollis ramanujamii</i>				
<i>Meliapollis quadrangulata</i>				
<i>Palmaepollenites kutchensis</i>				
<i>Palmaepollenites nadhamunii</i>				
<i>Palmaepollenites ovatus</i>				
<i>Palmaepollenites eocenicus</i>				
<i>Polybrevicolporites cephalus</i>				
<i>Polycolpites granulatus</i>				
<i>Pseudonothofagidites kutchensis</i>				
<i>Tricolpites reticulatus</i>				
<i>Clavaperiporites clavatus</i>				
<i>Ctenolophonidites neyueliensis</i>				
<i>Septacolpites radiatus</i>				
<i>Palaeomalvaceapollis rudis</i>				
<i>Meliapollis tamilii</i>				
<i>Meliapollis pachydermis</i>				
<i>Meliapollis simplex</i>				
<i>Ornatetradites droseroides</i>				
<i>Pseudonothofagidites cerebrus</i>				

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