Indian Tertiary angiosperm pollen: A critical assessment


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).

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, ± 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; exine sometimes present interspersed with spines; exine colomellate, nexine usually indistinguishable; interspinal area microreticulate.

*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 × 40-53 μm. Tricolpate, colpi generally indistinct, broad. Exine 1-2 μm thick, sexine as thick as nexine, spinose, spines strongly built. 5-8 μm long, 1-2 μm broad at base, spines gradually taper to form pointed tip, spines sparsely placed, generally 4-8 μm apart. Interspinal space densely granulate-baculate.

*Redescription* (Singh & Misra, 1991, p. 224) — Pollen grains isopolar, 40-65 μm, usually folded; 3-4 porate; pores 10-16 μm, unthickened margins; exine 1-2 μm thick (excluding spines), spinose, spines (1-3 μm broad x 3-9 μm long) gradually tapering from base to apex, straight or curved, shed off leaving scars; exine colomellate (colomellae up to 1 μm 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 μm (including spines).

**Aperture** — Triporate, rarely tetraporate, pores equatorially elongated, 15-20 μm in diameter, pore margin thin, devoid of spines.

**Exine** — 3 μm thick, tectate, spinose.

**Sexine** — Tectum between spines granulate, spines supratectal, with bulbous base and acute tips, 4-9 x 1.5-4 μm in size and 4-13 μm apart, infratectum colomellate, colomellae closely placed, 0.5 x 1.3 μm.

**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**


*Original diagnosis* (Krutzhc, 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 arctotensis* Navale & Misra 1979

Holotype — Navale and 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. 2) — 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, colunnellae 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 ± rounded, colunnellae short and thin; lumina vary in shape and size, smaller towards margin.

Nexine: Evenly thick, continuous.


Affinity — *Alangium* (Alangiaceae).

*Alangiopollis gemmatus* Navale & Misra 1979

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. 2) — 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-gemmas, 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.


Affinity — *Alangium villosum* (Alangiaceae).

Genus — *Angulocolporites* Kar 1985

Type species — *Angulocolporites microreticulatus* Kar 1985

PLATE 1

(All photographs are enlarged x1000)

1-3. *Plicataperturrites retipilatus* Kar. Slide no. BSIP 6373/4


**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.

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**Genus — Arecipites** Wodehouse 1953

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

**Original diagnosis** (Wodehouse, 1933, p. 497) — Ellipsoidal, 23-25 μ 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


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


**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 columnellate, muri of the reticulum much thicker than lumina, lumina mostly circular but may also be elongated.

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**PLATE 2**

(All photographs are enlarged x1000)


**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 a perputural 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.

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

**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 lenticulate to spheroidal, equatorial outline typically over-rounded, in part subcircular or convexly triangular. Three equatorial germinals, in the over-rounded 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.

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**PLATE 3**

(All photographs are enlarged x1000)

1-6. **Verrucolporites verrucus** Sah & Kar. Slide no. BSIP 3351/8, BSIP 3367/2.

7. **Thymelarapollis crotonoides** Sah & Kar. Slide no. BSIP 3372/12.


10-11. **Racemomacolpites thanjinaibensis** Mandal. Slide no. BSIP 9580/3

12-13. **Neocoupertapollis kutchensis** (Venkatachala & Kar) Kar & Kumar. Slide no. BSIP 3315/3, V 34
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 ± thickened. Exine thick, ± 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, laevesate 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 ± 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** — Nalac 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, lolongate. Exine up to 2 μm thick,

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**PLATE 4**

(All photographs are enlarged x1000)

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: Tricolpate; colpi long, endoaperture elongate, 2 μm in diameter.
Exine: 1-2 μm thick, sexine thicker than nexine.
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 or 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 lignite field, 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.
Nexine: 3.5-4 μm thick, tectum perforated with perforations of irregular shapes and sizes, infratetum columellate, columellae 2.2 μm long, irregularly shaped.

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. Tricolpate, angulaperturate, colsi long, narrow and deep, apocolpi small. Ora faint to indistinct, lalongate, slit-like. Exinolaminar (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
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 up to 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 suboblate 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, baculately, pilate; pila heads up to 1 μm wide, free.

Nexine: Evenly thick, continuous.


Affinity — Not known.

Genus — Densiverrupollentes Tripathi & Singh 1984

Type species — Densiverrupollentes 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 verruca beset with gemmae.

Species studied:

Densiverrupollentes 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, verruca 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, verruca; gemma 1-2 μm high, 2-3 μm wide, closely placed.

Nexine: Uniform.

PLATE 6

(All photographs are enlarged x1000)

4-5. Arecipites bellus Sah & Kar. Slide no. BSIP 33657X.
6-7. Plicataperturites retipilatus Kar. Slide no. BSIP 6373/5.
Occurrence—Kopili Formation (Late Eocene), Meghalaya (Tripathi & Singh, 1984).

Affinity—Alangiaceae.

**Genus——** *Dermatobrevicolpites* Kar 1985

Type species——*Dermatobrevicolpites 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 intrastructured.

**Species studied:**

*Dermatobrevicolpites 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 Panandrho (depth 7 m), Kutch District, Gujarat; Naredi Formation, Early Eocene.


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

**Number of specimens studied** — 9.

**Description**:

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

**Dimension** : 30-45 x 28-35 μm.

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

**Exine** : 1.5-3.5 μm thick, undifferentiated.

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

**Affinity**—Not known.

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

Type species——*Echimonopropolis 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**:

*Echimonopropolis 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 μm (excluding spines). Monoporate, pores distinct, circular to oval, ca. 7-13 μm in diameter, pore margin unthickened. Exine up to 1.5 μm thick, sexine as thick as nexine, spinose. Spines 3-6 μm 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.

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**PLATE 7**

(All photographs are enlarged x1000)


5-6. *Tricolarpullenites ecovicus* Kar. Slide nos. BSIP 3362/1, 11-12 BSIP 3372/7


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.

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 Panandho (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; endospore distinct, large (4-5 μm) lalongate, bordered by thick costae.

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PLATE 8

(All photographs are enlarged x1000)

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 vancampae Ramanujam 1966

*Original diagnosis* (Ramanujam, 1966, p. 170) — Pollen grains isopolar, oblate to suboblate, 3-zonocolporate. Amb subtriangular. In polar view the sexine of each lobe is prolonged into characteristic knoblike 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 punctitectilate.

*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 knoblike 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 — *Icacinopollenes* Navale & Misra 1979

Type species — *Icacinopollenes 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, crassiseinous, tegillate, spinulate, spinules very small (1 μm). Surface microgranulate.

Species studied:

*Icacinopollenes 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.
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, teggillate, 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 supratectal, 1-2.5 μm long, 3-7 μm apart, regularly present on colpi margin; interspinal areas granulate, infratectum distinctly columellate.
Nexine: 0.5 μm thick, continuous.

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 Icacinopolles. 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 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, pilate-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; infratectum 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 Caesalpiniaeae, e.g., Delonix and Peltophorum.

PLATE 10

(All photographs are enlarged x1000)

3-4. Lilacites bacalata Venkatachala & Kar. Slide no. BSIP 3312.
5-6. Denstwurzellitenites eocenicus Tripathi & Singh. Slide no. BSIP 6958/1.
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 columnellae 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.


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 *Eugeissona insignis*.

Remarks — *Liliacidites baculatus* was transferred to *Matanomadabisulcites* by Kar (1985). *Liliacidites baculatus* Venkatachala & Kar 1969 has extended sulcus hence does not come under the generic circumscription of either *Liliacidites* or *Matanomadabisulcites* 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 nesinal 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, obscure 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 granulose, 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—Parumbelliferolpollis Kar 1978

Type species—Parumbelliferolpollis dulcis Kar 1978

Original diagnosis (Kar, 1978, p. 168)—Pollen grains elliptical in equatorial view. Tricolpate, colpi distinct to indistinct. 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 columnellate.
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—Plicatiaperitrites Kar 1985

Type species—Plicatiaperitrites retipilatus Kar 1985

Original diagnosis (Kar, 1985, p. 124)—Pollen grains subcircular in polar and oval in equatorial views. Tricolporate, 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:

Parumbelliferolpollis 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 — 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 elongate in equatorial view. Colpi distinct, long, bordered by exinal thickening on both sides. Exine up to 2.5 μm thick, sexine thicker than nexine, retipulate-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: Retipulate, 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, infractectum columnate, columnellae 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 Plumbaginacipites 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

**Species studied:**

*Polycolporites indicus* Mehrotra 1983

*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 up to 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.

**Nexine** — 0.5-1 µm thick, laevigate -pitted, reticulum irregular, lumina 0.5-1 µm in diameter; infratectum columellate.

**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 Potonie 1960**

*Type species* — *Polyporina multistigmosa* (Potonie, 1931) Potonie 1960

*Original diagnosis* (Potonie, 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

*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 ± 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.

**Exine** — 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 — *Racionalcolpites* Van der Hammen 1954 ex González Guzmán 1967

*Type species — Racionalcolpites racematus* Van der Hammen 1954 ex González Guzmán 1967

*Original diagnosis* (González Guzmán, 1967, p. 50) — Monocolpate pollen grains with gemmate-baculate-clavate sculpture.

*Species studied:

**Racionalcolpites tanjinatbensis** 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 area granulate/microbaculate.

*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* (Areceaceae).

Genus — *Ratariacolporites* Kar 1985

*Type species* — *Ratariacolporites plicatus* Kar 1985

*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, ± 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 — *Sastrilpollonites* Venkatachala & Kar 1969

*Type species* — *Sastrilpollonites 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, lollongate.

**Exine**:
- Tectate; 1.5-2.5 μm thick; sexine thicker than nexine.
- Sexine: Punctate, puncta up to 1 μm across.
- Nexine: Up to 1 μm thick, uniform.

**Occurrence** - Naredi Formation (Early Eocene), Kutch (Venkatachala & Kar, 1969); Maryanad 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, 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**:
- Tectate, 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 - 3 μm thick, sexine as thick as nexine.

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

**Nexine**: Uniform; 1 - 1.5 μm thick.

**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 lobogate.

*Number of specimens studied* — 9.

**Description**

**Symmetry and form**: Isopolar, subcircular in polar view and ± elliptical in equatorial view.

**Dimension**: 50-65 μm.

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

**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**


*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.

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: 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, 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


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: Intactate, 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, Triangularites pachyexinus, Recemoscolpites 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, Cenolophidites neyveliensis, Septacolpites radiatus, Palaeomalvaipollis rudis, Meliapollis tamili, M. pachydermis, M. simplex, Ornatetradites aroseroides, Pseudonothofagidites cerebrus, Retipollinites confusus, Cryptopolypporites cryptus, Tripliaorites triangulus, Tricolparopollites robustus, Tricolporocolumellitites pilatus, Cruciferoipollenites elongatus, Icacinipollenites spinulatus, Ligulisfloraedites pilatus, Parmelliferopollenites dulcis, Plumbaginacipites neyveli, Arangapolles
achinatus, Litiacidites baculatus, Alangipollis arco
cotensis, A. gemmatus, Angulocolpites micro
ereticulatus, Calophyllumpollenites rotundus, Dens
terrapollenites eocenicus, Dermatobrevicolpites
dermatus, Foveotricolpites reticuloides, Plicaliaperturites retipilatus, Thymelaepollis
crotonoides, Varispiniripetrites rataniensis, Hip

crataceaepollites constriactus and Dakshinipollenites
tripalsh

The frequency of angiospermous pollen
decreases in the Oligocene sequence. However, Bombacacidites triangulus, Compositoipollentes
tricolporatus, Coneopollis decorus, C. reticulatus,
Lacrimopollis pilosus, Meyeripollis nabarko
tensis and Trisyncolpites ramanujamii appear for the first
time. Of these, Bombacacidites triangulus and
Compositoipollentes 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 den
sus, Tricolpopollis kockeli, Loranthipollites elegans,
Parauripollis mulleri and Warkallipollenites endmanii (Table 1).

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

<table>
<thead>
<tr>
<th>Taxa</th>
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<th>Eocene</th>
<th>Oligocene</th>
<th>Miocene</th>
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