PALYNOSTRATIGRAPHY OF THE NAREDI (LOWER EOCENE) AND THE HARUDI (MIDDLE EOCENE) FORMATIONS IN THE DISTRICT OF KUTCH, INDIA

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ABSTRACT

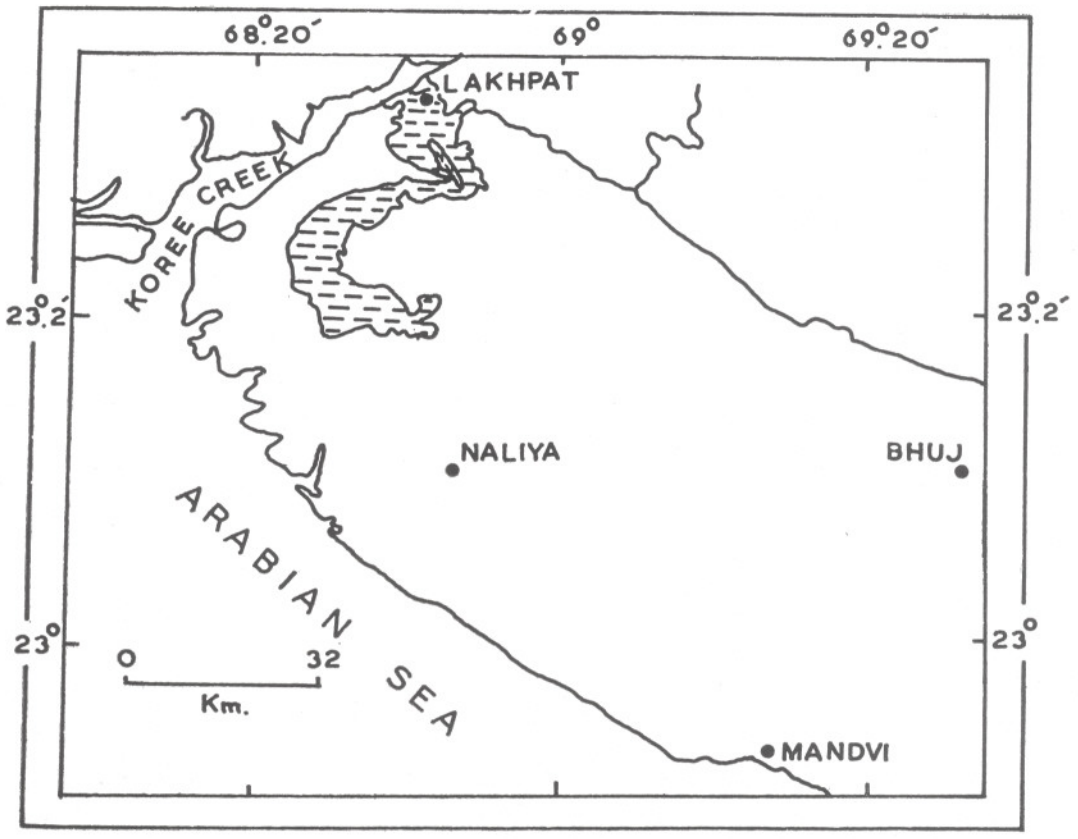
The palynological assemblage from the Naredi Formation (Lower Eocene) comprises 65 spore-pollen genera and 92 species, while that of the Harudi (Middle Eocene) has only 26 genera and 30 species. *Triorites triangulus* Cenozone is proposed for the lower Gypseous Shale Member of the Naredi Formation. This cenozone is characterized by the abundance of *Cupuliferoipollenites ovatus, Tricolpites reticulatus, Lakiapollis ovatus* and *Cyathidites minor*. For the lower part of the Harudi Formation, *Proxapertites microreticulatus* Cenozone is proposed where *Palmaepollenites kutchensis, Scantigranulites sparsus* and *Couperipollis kutchensis* are also found as significant taxa. The cenozones have been compared with the other Lower Tertiary cenozones of India.

INTRODUCTION

THE Tertiary sediments in Kutch are well-known for their invertebrate fossils since Sowerby (1840) and Grant (1840) mentioned some of them. Wynne (1872) wrote a memoir on the geology of Kutch and noted the stratigraphic importance of Tertiary *Nummulites*. Blanford (1876) correlated the Tertiary *Nummulites* of Kutch with those of Sind. Nuttal (1926) studied the larger foraminifera in detail. Among later workers, Tewari (1952, 1957), Tewari and Singh (1969), Poddar (1959, 1964), Sen Gupta (1959, 1964, 1965), Nagappa (1959), Tandon (1962, 1971), Dutta (1965), Biswas (1965, 1971), Biswas and Deshpande (1970), Biswas and Raju (1971, 1973), Pant and Mathur (1968), Mohan and Soodan (1970) and Raju (1974) have done commendable work towards the understanding of geology and biostratigraphy of the Tertiary sediments in Kutch. Palynological fossils from these sediments have been studied by Mathur (1963, 1966), Venkatachala and Kar (1968, 1969a, 1969b), Sah and Kar (1969, 1970, 1972), Kar (1978) and Kar and Saxena (1976).

The Eocene rocks in Kutch, in the opinion of Biswas and Raju (1971, 1973), can be divided into three lithostratigraphic units, viz., Naredi Formation, Harudi Formation, and Fulra Limestone. The Naredi Formation is called after the village Naredi (23° 34′30″; 68°39′00″) and is on the side of Nalia — Narayansarovar Road. This formation is well exposed in the cliffs along the river Kakdi and is divisible into three members. The lower Gypseous Shale Member is about 25 m thick and consists of grey-brown clay and shale occasionally with bands of lignite. The gypsum is found occasionally as thin layers in these shales. Besides, calcareous concretions are also frequently met with in this member. The middle *Assilina* Limestone Member is approximately 6 m thick and is very rich in *Assilina*. The upper Ferruginous Claystone Member is about 11 m thick and is characterized by grey-brown claystone with gypseous layers and ferruginous laminae. The various microfauna reported from this formation favour a Lower Eocene age (Ypresian) (Map 1).

The Harudi Formation is not more than 15 m thick and is named after the village Harudi (23°30′30″; 68°41′10″). This formation is exposed to the north-west of the village about 2 km north-west on the Nalia-Narayansarovar Road. The formation comprises grey shale with yellow limonitic partings in the lower part. Occasional thin lignitic layers are also found within it. The upper part consists of calcareous claystone and siltstone with occasional layers of gypsum. In the opinion of Biswas and Raju (1971, 1973) a ferruginous, gypseous clayey marlite studded with *Nummulites* is the marker bed of this formation. Planktonic foraminifera have been worked out by Mohan and Soddan (1970) from these rocks and they have ascribed a Middle Eocene age (Lutetian) to this formation.



MAP 1 — Outline map of Western Kutch showing the Eocene exposures.

Fulra Limestone is well observed in the southern scarp of Babia Hill about 1·7 km south-west of Fulra (23°42′30″: 68°47′12″). The entire formation is made up of yellow to dirty white foraminiferal limestone. This formation is full of macro- and microfauna which indicate a Middle Eocene (Upper Lutetian) age.

MATERIAL AND METHOD

The surface samples from Naredi Formation were collected for number of years from Akri, Panandhro, Matanomadh, Naredi, Jhulrai, Baranda, Wagapathar and Umarsar in the district of Kutch. Besides, number of bore-hole cores were also studied belonging to the lower Gypseous Shale Member of this formation drilled around Matanomadh, Baranda, Jhulrai, Panandhro and Akri villages. These samples were kindly supplied by the Directorate of Geology and Mining, Government of Gujarat. The samples were macerated from all the three members of this formation but only the Gypseous Shale Member proved productive.

The samples from Harudi Formation were collected from the escarpment beside a nala about 2 km north-west of Harudi — the type locality of this formation. The limonitic partings with occassional very thin lignitic layers in the lower part only yielded palynological fossils. All the slides have been deposited to the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

The following 65 spore-pollen genera and 92 species have been encountered in the different exposures and subsurface samples from the Naredi Formation:

Cyathidites minor Couper, 1953; *Cyathidites* cf. *C. minor* Couper, 1953; *Alsophili-*

dites sp.; *Gleicheniidites* sp.; *Biretisporites bellus* Sah & Kar, 1969; *B. convexus* Sah & Kar, 1969; *Todisporites kutchensis* Sah & Kar, 1969; *Todisporites flavatus* Sah & Kar, 1969; *Dandotiaspora plicata* (Sah & Kar) Sah, Kar & Singh, 1971; *Lygodiumsporites lakiensis* Sah & Kar, 1969; *Intrapunctisporis apunctis* Krutzsch, 1959; *Deltoidospora* sp.; *Dictyophyllidites* sp.; *Foveosporites* sp.; *Osmundacidites kutchensis* Sah & Kar, 1969; *Leptolepidites* sp.; *Lakiasporites triangulus* Sah & Kar, 1969; *Lycopodiumsporites parvireticulatus* Sah & Dutta, 1966; *L. bellus* Sah & Kar, 1969; *Trilobosporites* sp.; *Laevigatosporites lakiensis* Sah & Kar, 1969; *L. cognatus* Sah & Kar, 1969; *Laevigatosporites* sp.; *Monolites* sp.; *Polypodiaceaesporites* sp.; *Polypodiisporites* sp.; *Schizaeoisporites* sp.; *Seniasporites verrucosus* Sah & Kar, 1969; *S. minutus* Sah & Kar, 1969; *Callialasporites lenticularis* (Döring) Dev, 1961; *C. trilobatus* (Balme) Dev, 1961; *Podocarpidites ellipticus* Cookson, 1947; *Podocarpidites* sp.; *Laricoidites kutchensis* Venkatachala, Kar & Raza, 1969; *Araucariacites australis* Cookson, 1947; *Clavatipollenites cephalus* Sah & Kar, 1970; *Arecipites bellus* Sah & Kar, 1970; *Palmaepollenites kutchensis* Venkatachala & Kar, 1969a; *P. nadhamunii* Venkatachala & Kar, 1969a; *P. ovatus* Sah & Kar, 1970; *P. plicatus* Sah & Kar, 1970; *P. magnus* Sah & Kar, 1970; *Proxapertites microreticulatus* Jain, Kar & Sah, 1973; *Dracaenoipollis circularis* Sah & Kar, 1970; *Liliacidites ellipticus* Venkatachala & Kar, 1969a; *L. baculatus* Venkatachala & Kar, 1969a; *Couperipollis perspinosus* (Couper) Venkatachala & Kar, 1969a; *C. rarispinosus* (Sah & Dutta) Venkatachala & Kar, 1969a; *C. kutchensis* Venkatachala & Kar, 1969a; *C. achinatus* Sah & Kar, 1970; *Couperipollis brevispinosus* (Biswas) Venkatachala & Kar, 1969a; *Tricolpites reticulatus* Cookson, 1947; *T. brevis* Sah & Kar, 1970; *T. minutus* Sah & Kar, 1970; *T. levis* Sah & Dutta, 1966; *Tricolpites* sp.; *Retitricolpites robustus* Sah & Kar, 1970; *Marginipollis kutchensis* (Venkatachala & Kar) comb. nov.; *Umbelliferoipollenites ovatus* Venkatachala & Kar, 1969a; *U. constrictus* Venkatachala & Kar, 1969a; *Ailanthipites* sp.; *Araliaceoipollenites matanamadhensis* Venkatachala & Kar, 1969a; *Cupuliferoipollenites ovatus* Venkatachala & Kar, 1969a; *Rhoipites kutchensis* Venkatachala & Kar, 1969a; *Symplocoipollenites kutchensis* Venkatachala & Kar, 1969a; *S. minutus* Venkatachala & Kar, 1969a; *S. constrictus* Venkatachala & Kar, 1969a; *Nyssapollenites kutchensis* Venkatachala & Kar, 1969a; *Palaeocoprosmadites arcotense* Ramanujam, 1966; *Hippocrateaceaedites* sp.; *Margocolporites tsukadai* Ramanujam, 1966; *M. sitholeyi* Ramanujam, 1966; *M. sahnii* Ramanujam, 1966; *Lakiapollis ovatus* Venkatachala & Kar, 1969a; *L. matanamadhensis* Venkatachala & Kar, 1969a; *Sastriipollenites trilobatus* Venkatachala & Kar, 1969a; *Verrucolporites verrucus* Sah & Kar, 1970; *Pellicieroipollis langenheimii* Sah & Kar, 1970; *Meliapollis ramanujamii* Sah & Kar, 1970; *M. raoi* Sah & Kar, 1970; *M. navalei* Sah & Kar, 1970; *M. quadrangularis* (Ramanujam) Sah & Kar, 1970; *M. melioides* (Ramanujam) Sah & Kar, 1970; *Striacolporites striatus* Sah & Kar, 1970; *S. ovatus* Sah & Kar, 1970; *S. cephalus* Sah & Kar, 1970; *Paleosantalaceaepites primitiva* Biswas, 1962; *P. ellipticus* Sah & Kar, 1970; *P. minutus* Sah & Kar, 1970; *Stephanocolpites globatus* Venkatachala & Kar, 1969a; *S. granulatus* Venkatachala & Kar, 1969a; *S. flavatus* Venkatachala & Kar, 1969a; *Polybrevicolporites cephalus* Venkatachala & Kar, 1969a; *P. antiquum* (Ramanujam) Venkatachala & Kar, 1969a; *Polycolpites granulatus* Sah & Kar, 1970; *P. flavatus* Sah & Kar, 1970; *Ghoshiacolpites globatus* Sah & Kar, 1970; *Monoporopollenites* sp.; *Trilatiporites kutchensis* Venkatachala & Kar, 1969a; *T. minutus* Sah & Kar, 1969; *Sonneratioipollis bellus* Venkatachala & Kar, 1969a; *Proteacidites protrudus* Sah & Kar, 1970; *Triorites triangulus* Sah & Kar, 1970; *T. minutus* Sah & Kar, 1970; *T. bellus* Sah & Kar, 1970; *T. dermatus* Sah & Kar, 1970; *Pseudonothofagidites kutchensis* Venkatachala & Kar, 1969a; *P. cerebrus* Venkatachala & Kar, 1969a; *Thymelaepollis crotonoidis* Sah & Kar, 1970; *Cryptopolyporites cryptus* Venkatachala & Kar, 1969a.

The spores-pollen genera and species recovered from the Harudi Formation have been systematically described as follows.

SYSTEMATIC PALYNOLOGY

Anteturma — *Sporites* H. Potonié, 1893
Turma — *Triletes* (Reinsch) Potonié & Kremp, 1954
Subturma — *Azonotriletes* Luber, 1935

Infraturma — *Laevigati* (Bennie & Kidston) Potonié, 1956

Genus — *Cyathidites* Couper, 1953

Type Species — *Cyathidites australis* Couper, 1953.

Cyathidites australis Couper, 1953

Pl. 1, figs. 1-2

Remarks — The specimens assigned to this species in the present material are generally infected by some bacteria or fungi providing various pseudo-ornamentational pattern. One type is very minute in size, looks like a pin head and when closely placed seems cursorily to be punctate (Pl. 1, fig. 1). Another type is more or less subcircular in shape and looks like blotches on the surface (Pl. 1, fig. 2). It may be mentioned here that Dettmann (1963) also noted some bacteria/fungi on the exine of some spores (Dettmann, 1963, pl. 1, fig. 3) assigned to *Cyathidites australis* Couper (1953) from the Upper Mesozoic sediments of South-eastern Australia. She, however, thought this was due to corrosion of the exine.

Cyathidites minor Couper, 1953

Remarks — This species is well-known in Jurassic and Cretaceous sediments of the world. In Palaeogene, it is also quite common in India. Sah and Kar (1969) reported this species from Naredi Formation (Lower Eocene) of Kutch while Kar (1978) referred some specimens comparable to this species from Oligocene of Kutch. Dutta and Sah (1970) described the same species from Palaeocene-Lower Eocene of Assam.

Genus — *Dandotiaspora* Sah, Kar & Singh, 1971

Type Species — *Dandotiaspora dilata* (Mathur) Sah, Kar & Singh, 1971.

Dandotiaspora plicata (Sah & Kar) Sah, Kar & Singh, 1971

Remarks — The crescent-shaped fold on the distal side opposite to the ray ends are not well developed in the specimens studied here. The fold is found either at one or two ray ends. The other characters are, however, very much similar to *D. plicata* (Sah & Kar) Sah, Kar & Singh (1971).

Genus — *Intrapunctisporis* Krutzsch, 1959

Type Species — *Intrapunctisporis intrapunctis* Krutzsch, 1959.

Intrapunctisporis harudiensis sp. nov.

Pl. 1, figs. 3-5

Holotype — Pl. 1, fig. 3, size 44 μ. Slide no. 3254/7.

Type Locality — Harudi, Harudi Formation (Middle Eocene), Kutch, India.

Diagnosis — Spores triangular, 41-64 μ. Trilete, rays well-developed, extending mostly upto equator. Exine 1-2·5 μ thick, intrapunctate, apices rounded, interapical margin generally convex.

Comparison — *Intrapunctisporis* sp. described by Kar (1978) from the Oligocene of Kutch is distinguished from the present species by its bigger size range and narrow apices. *Intrapunctisporis intrapunctis* Krutzsch (1959) is bigger in size range and is more intrapunctate than the present species.

Genus — *Lygodiumsporites* (Potonié, Thomson & Thiergart) Potonié, 1956

Type Species — *Lygodiumsporites adriensis* (Potonié & Gelletich) Potonié, Thomson & Thiergart, 1950.

Remarks — Potonié, Thomson and Thiergart (1950) instituted *Lygodiumsporites* to accommodate, trilete, triangular spores with laevigate and intrastructured exine. The rays in this genus do not extend more than half of the radius. They selected *Punctatisporites adriensis* Potonié & Gelletich (1933) as the type species of the genus.

Dettmann (1963) placed *Lygodiumsporites adriensis* (Potonié & Gelletich) Potonié, Thomson & Thiergart: Bolkhovitina (1961) into *Cyathidites minor* Couper (1953). In

the opinion of Potonié (1956), *Lygodiumsporites* can be distinguished from *Deltoidospora* (Miner) Potonié (1956), *Cyathidites* Couper (1953) and *Gleicheniidites* (Ross) Delcourt & Sprumont (1955) by its distinctly shorter haptotypic mark. By its mostly intrapunctate structure of the exine *Lygodiumsporites* also comes close to *Intrapunctisporis* Krutzsch (1959) but the former is again demarcated by its shorter trilete rays.

Lygodiumsporites lakiensis Sah & Kar, 1969

Genus — *Todisporites* Couper, 1958

Type Species — *Todisporites major* Couper, 1958.

Todisporites kutchensis Sah & Kar, 1969

Infraturma — *Apiculati* (Bennie & Kidston) Potonié, 1956

Genus — *Osmundacidites* Couper, 1953

Type Species — *Osmundacidites wellmanii* Couper, 1953.

Osmundacidites kutchensis Sah & Kar, 1969

Genus — *Scantigranulites* gen. nov.

Type Species — *Scantigranulites triangulus* sp. nov.

Generic Diagnosis — Spores triangular-subtriangular. Trilete, rays extending half of radius to equator. Exine generally thick, granulose, grana sparsely placed, scattered all over spore coat.

Description — Spores generally triangular with bluntly rounded apices and straight-convex interapical margin. Trilete distinct, rays narrow, uniformly broad; commissure well recognizable, sometimes folds found in association with trilete rays. Exine 1-3 μ thick, grana about 1 μ high, intergranular space laevigate.

Comparison — *Granulatisporites* (Ibrahim) Potonié & Kremp (1954) compares well with the present genus in possessing triangular shape and granulose ornamentation. But the former genus is easily distinguished by its closely placed grana hardly leaving any intergranular space in between them. *Intertriletes* Anderson (1960) has triangular shape but is ornamented with fine reticulum on the contact area. *Nevesisporites* de Jersey & Paten (1964) is variously sculptured on the proximal side and is also cingulate. *Osmundacidites* Couper (1953) is sparsely granulose but is distinguished from the present genus by its circular-subcircular shape. *Eximispora* Sahujha, Kindra & Rehman (1972) is generally triangular-subtriangular shape but is conspicuous by its presence of large tubercles. *Scantigranulites* proposed here is differentiated from all the trilete genera by its triangular-subtriangular shape and sparsely placed grana, uniformly distributed all over the surface.

Scantigranulites triangulus sp. nov.

Pl. 1, figs. 6-7

Holotype — Pl. 1, fig. 6, size 65 μ. Slide no. 3260/3.

Type Locality — Harudi, Harudi Formation (Middle Eocene), Kutch, India.

Diagnosis — Spores mostly subtriangular, with bluntly rounded apices and convex interapical margin; 59-74 μ. Trilete distinct, rays extending upto three-fourths radius. Exine 2-3 μ thick, granulose, grana 1 μ high, sparsely placed, uniformly distributed.

Scantigranulites sparsus sp. nov.

Pl. 1, figs. 8-11

Holotype — Pl. 1, fig. 8, size 44 μ. Slide no. 3262/2.

Type Locality — Harudi, Harudi Formation (Middle Eocene), Kutch, India.

Diagnosis — Spores triangular with straight-convex interapical margin, 35-55 μ. Trilete distinct, rays extending upto three-fourths radius. Exine 1-2·5 μ thick, granulose, grana scantily spread.

Comparison — *Scantigranulites triangulus* resembles the present species in shape and ornamentational pattern but the former is distinguished by its bigger size range.

Turma — *Monoletes* Ibrahim, 1933
Subturma — *Azonomonoletes* Luber, 1935
Infraturma — *Psilamonoleti* van der Hammen, 1955

Genus — *Laevigatosporites* (Ibrahim) Schopf, Wilson & Bentall, 1944

Type Species — *Laevigatosporites vulgaris* Ibrahim, 1933.

Laevigatosporites cognatus Sah & Kar, 1969

Remarks — The specimens assignable to *Laevigatosporites* is very rare in the present material.

Laevigatosporites sp.

Pl. 1, fig. 12

Description — Spore subcircular, 30 μ. Monolete open, extending less than half along longitudinal axis. Exine 1 μ thick, laevigate, irregularly folded.

Comparison — *Laevigatosporites cognatus* Sah & Kar (1969) and *L. lakiensis* Sah & Kar (1969) are easily distinguished from the present specimen by their bigger size range and elliptical shape.

Infraturma — *Sculptatomonoleti* Dybová & Jachowitz, 1957

Genus — *Seniasporites* Sah & Kar, 1969

Type Species — *Seniasporites verrucosus* Sah & Kar, 1969.

Seniasporites verrucosus Sah & Kar, 1969

Remarks — Specimens have mostly globular verrucae. They are well-developed and closely placed only on the distal side of the exine providing pseudoreticulate ornamentation in surface view.

Genus — *Polypodiisporites* Potonié, 1934

Type Species — *Polypodiisporites favus* Potonié, 1934.

Polypodiisporites constrictus Kar, 1978

Pl. 1, fig. 13

Remarks — The specimens studied here are not much constricted. The verrucae are well-developed on both sides and they have flattened base and pointed tip.

Genus — *Schizaeoisporites* Potonié, 1951

Type Species — *Schizaeoisporites phaseolus* Delcourt & Sprumont, 1955.

Schizaeoisporites sp.

Pl. 1, fig. 14

Description — Spore elliptical, 65 × 40 μ. Monolete distinct, straight, extending upto three-fourths radius. Costae prominent, parallel to each other, intercostate exine laevigate.

Comparison — The present species comes near to *Schizaeoisporites palanacnsis* Sah & Kar (1974) reported from the Palana lignites (Lower Eocene) of Rajasthan by its shape and general organization but is separated by its larger size. *Schizaea pusilla* Pursh: Ghosh, Jacob & Lukose (1964) has punctate exine. *S. crassimurus* Dutta & Sah (1970) has very stout costae and is mostly subcircular in shape. *S. eocaenicus* (Selling) Potonié (1956) described by Dutta and Sah (1970) is more broad than the present specimen.

Infraturma — *Sphaerozonisulcates* Venkatachala & Kar, 1969a

Genus — *Proxapertites* (van der Hammen) van der Hammen, 1956

Type Species — *Proxapertites operculatus* (van der Hammen) van der Hammen, 1956.

Proxapertites microreticulatus Jain, Kar & Sah, 1973

Pl. 1, figs. 15-16

Remarks — This species is quite common in the present material. The overall shape of the specimens is mostly subcircular with a pronounce suture at the margin; completely detached specimens are, however, rare. The microreticulation is mostly well-developed and the exine is, sometimes, irregularly folded.

Turma — *Plicates* (Naumova) Potonié, 1960

Subturma — *Monocolpates* Iversen & Troels-Smith, 1950

Genus — *Palmaepollenites* Potonié, 1951

Type Species — Palmaepollenites tranquillus (Potonié) Potonié, 1951.

Remarks — Palmaepollenites is well represented in the assemblage. The pollen grains are generally elliptical and their size range varies from 26-51 × 18-40 μ. The following species are generally met with.

Palmaepollenites kutchensis Venkatachala & Kar, 1969a

P. ovatus Sah & Kar, 1970

P. plicatus Sah & Kar, 1970

Genus — *Dracaenoipollis* Sah & Kar, 1970

Type Species — Dracaenoipollis circularis Sah & Kar, 1970.

Dracaenoipollis circularis Sah & Kar, 1970

Remarks — The size range of the specimens studied is almost same as has been observed by Sah and Kar (1970) from the Lower Eocene sediments of Kutch. The operculum is distinct and the exine is weakly granulose.

Besides *Dracaena*, some of the modern genera of Palmae, particularly *Cocos* also resembles *Dracaenoipollis*.

Genus — *Arecipites* Wodehouse, 1933

Type Species — Arecipites punctatus Wodehouse, 1933.

Remarks — Arecipites was instituted by Wodehouse (1933) to accommodate monocolpate, elliptical pollen with puncta. He assumed that this genus shows close affinity to the extant pollen grains of *Phoenix dactilifera* of the family Palmae. Besides *Phoenix*, it seems that this genus also shows similarity to the pollen grains of *Calamus* also of Palmae.

Arecipites bellus Sah & Kar, 1970

Remarks — This species is very rare. The colpus is distinct and extends from one end to the other. The puncta is distinct, closely placed and provides pseudoreticulate ornamentation in surface view.

Genus — *Couperipollis* Venkatachala & Kar, 1969a

Type Species — Couperipollis perspinosus (Couper) Venkatachala & Kar, 1969a.

Couperipollis brevispinosus (Biswas) Venkatachala & Kar, 1969a

Remarks — The colpus is traceable in most of the specimens. Interspinal exine is distinctly intrapunctate. This structure is also visible at the base of the bulbous spines.

Couperipollis kutchensis Venkatachala & Kar, 1969a

Pl. 1, fig. 17

Remarks — The colpus is indistinct and even hardly traceable in some specimens. The spines are closely placed, interspinal exine is intrapunctate.

Subturma — *Triptyches* (Naumova) Potonié, 1960

Genus — *Tricolpites* (Erdtman) Potonié, 1960

Type Species — Tricolpites reticulatus Cookson, 1947.

Tricolpites levis Sah & Dutta, 1966

Remarks — The specimens are subcircular in polar view. Three colpi are distinct and extending almost from pole to pole.

Tricolpites sp. cf. *T. mataurаensis* Couper, 1953

Pl. 1, fig. 18

Description — Pollen grains mostly found in polar view, 32-36 μ, colpi distinct, broad. Exine upto 4 μ thick, retipilate, lumen broad.

Remarks— The specimens are distinguished from *T. matauraensis* Couper (1953) by its broadly retipilate nature; other characters closely resemble each other.

Tricolpites sp.

Pl. 1, fig. 19

Description — Pollen grains subcircular, 56-63 μ. Tricolpate, colpi distinct. Exine 4-6 μ thick, sexine much thicker than nexine, retipilate.

Comparison — The present species is distinguished from *Tricolpites levis* Sah & Dutta (1966) by its well-developed retipilate ornamentation. *T. reticulatus* Cookson (1947) is distinctly reticulate.

Genus — *Marginipollis* Clarke & Frederiksen, 1968

Type Species — *Marginipollis concinnus* Clarke & Frederiksen, 1968.

Marginipollis kutchensis (Venkatachala & Kar) comb. nov.

Pl. 1, fig. 26

1968 *Rostriapollenites kutchensis* Venkatachala & Kar, p. 336, pl. 1, figs. 9-11.

1969a *Rostriapollenites kutchensis* Venkatachala & Kar: Venkatachala & Kar, p. 161, pl. 1, figs. 19-21a-c.

Remarks — Venkatachala and Kar (1968) instituted *Rostriapollenites* to accommodate fossil *Barringtonia* type of pollen grains from the Lower Eocene of Kutch. But Clarke and Frederiksen (1968) also published *Marginipollis* to accommodate the same. Since *Marginipollis* has been published earlier, it has got nomenclatural priority over *Rostriapollenites*.

Marginipollis kutchensis is distinguished from *M. concinnus* Clarke & Frederiksen (1968) by its tegillate sexine with irregular thickenings of the tegillum providing areoloidate appearance. Besides, *M. concinnus* is also granulose whereas *M. kutchensis* is laevigate.

Genus — *Parumbelliferoipollis* gen nov.

Type Species — *Parumbelliferoipollis dulcis* sp. nov.

Generic Diagnosis — 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.

Description — Pollen grains always found in equatorial view, known size range 38-49 × 20-30 μ. Colpi generally narrow, sometimes hardly discernible, extending upto three-fourths along longitudinal axis. Exine 2-5 μ broad at poles, thickened upto 10 μ at equator. Pila closely placed, 6-10 μ long, mostly fused together to form rugulate to scrobiculate structure. Sexine in some specimens considerably thickened at equator forming a pseudocolpate appearance in surface view.

Comparison — The present genus is closely comparable to *Umbelliferoipollenites* Venkatachala and Kar (1969a) described from the Lower Eocene sediments of Kutch in general organization but the latter is dicolporate and usually constricted at equator. *Ailanthipites* Wodehouse (1933) resembles *Parumbelliferoipollis* in elliptical shape and ornamentational pattern but differs in being distinctly tricolpate. *Caprifoliipites* Wodehouse (1933), *Cupuliferoipollenites* Potonié (1951) and *Castaneoidites* Potonié, Thomson & Thiergart (1950) are also tricolporate. *Cornaceoipollenites* Potonié (1950), *Platanoidites* Potonié, Thomson & Thiergart (1950) and *Tricolpites* (Erdtman) Couper (1953) approximate *Parumbelliferoipollis* in tricolpate condition but the latter is easily distinguished by its much thicker sexine at equator.

Remarks — *Parumbelliferoipollis* instituted here resembles the extant pollen grains of Umbelliferae worked out by Cerceau-Larrival (1959, 1962, 1965), Ting (1961), Rossingnol (1962), Maurizio and Louveaux (1964), Joshi and Raghuvansi (1966) and others in overall shape, size range, ornamentational pattern and much thickened sexine at equator. But the pollen grains of Umbelliferae are either di- or tricolporate and generally they are constricted at the equator in equatorial view. In none of the specimens studied here, has colporate condition and thus they are easily separated

from the known modern pollen of Umbelliferae.

Some of pollen grains of Araliaceae also resemble *Parumbelliferoipollis* in overall shape and general organization but in the former, the pollen grains are mostly tricolporate and the nexine is much thicker than sexine at equator in some of the species.

The pollen grains of *Heliotropium* of the family Boraginaceae described by Gupta (1972) also somewhat resemble the present genus in elliptical shape without any marked constriction at the equator. But the eight species described by him are generally colporate or colporoidate. *Heliotropium zeylanicum* Lamt. in the opinion of Gupta (1972), is tricolpate but the exine is almost psilate.

Pollen grains of Cornaceae are also usually tricolporate and the pore is quite distinct in most of the species.

The present genus proposed here is not exactly comparable to any of the families but it comes closer to the pollen grains of Umbelliferae in general shape, size range and peculiar thickened sexine at equatorial region.

Parumbelliferoipollis dulcis sp. nov.

Pl. 1, figs. 20-24

Holotype — Pl. 1, fig. 20, size 42×23 μ. Slide no. 3254/13.

Type Locality — Harudi, Harudi Formation (Middle Eocene), Kutch, India.

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

Remarks — *Strobilathidites kundavaensis* Sah (1967) described from Neogene of Rusizi Valley resembles the present species in shape and somewhat in size range but is distinctly porate. The apparent presence of colpi in *S. kundavaensis* is due to the alternation of crassisexinous with crassisexinous parts. This is the characteristic feature of the pollen grains of *Strobilanthes* belonging to the family Acanthaceae.

Genus — *Verrucolporites* Sah & Kar, 1970

Type Species — *Verrucolporites verrucus* Sah & Kar, 1970.

Remarks — Pollen grains are smaller in size range (20-26 μ) than those previously described by Sah and Kar (1970). The pores are ill-defined. Verrucae are well-developed, inter-verrucose exine is granulose.

Subturma — *Polyptyches* (Naumova) Potonié, 1960

Genus — *Stephanocolpites* (van der Hammen) Potonié, 1960

Type Species — *Stephanocolpites constatus* van der Hammen, 1954.

Stephanocolpites globatus Venkatachala & Kar, 1969a

Remarks — This species is rare. The specimens are found only in polar view. Four colpi are short; the exine is about 4 μ thick and seems to be scrobiculate.

Stephanocolpites nadhamunii Venkatachala & Kar, 1969a

Remarks — The colpi are small but distinct. The exine is upto 4 μ thick, sexine is thicker than nexine and is scrobiculate. In this respect, the pollen grains of the present material differ from those described by Venkatachala and Kar (1969a) because they are finely intrabaculate.

Genus — *Polycolpites* Couper, 1953

Type Species — *Polycolpites clavatus* Couper, 1953.

Polycolpites flavatus Sah & Kar, 1970

Remarks — The specimens recovered here have almost similar size range and same ornamentation pattern noted by Sah and Kar (1970) for the Lower Eocene pollen grains from Kutch.

Genus — *Palaeosantalaceaepites* Biswas, 1962

Type Species — *Palaeosantalaceaepites primitiva* Biswas, 1962.

Palaeosantalaceaepites minutus Sah & Kar, 1970

Remarks — Pollen grains are not so broad in the present material as has been reported by Sah and Kar (1970). The pores are comparatively less developed and the colpi extend more than three-fourths along longer axis. The exine is not more than 2 μ thick and is laevigate.

Genus — *Symplocoipollenites* Potonié, 1957

Type Species — *Symplocoipollenites vestibulum* Potonié, 1957.

Symplocoipollenites minutus Venkatachala & Kar, 1969a

Turma — *Poroses* (Naumova) Potonié, 1960
Subturma — *Diporines* (Naumova) Potonié, 1960

Genus — *Diporites* van der Hammen, 1954

Type Species — *Diporites grandiporus* van der Hammen, 1954.

Diporites sp.

Pl. 1, fig. 25

Description — Pollen grain elliptical, diorate, 38 × 30 μ. Ora distinct, margin thickened. Exine 3 μ thick, scrobiculate.

Comparison — *Diporites* spp. described by Sah and Kar (1970, 1974) are distinguished from the present specimen by their non-thickened pore margin.

Subturma — *Polyporines* (Naumova) Potonié, 1960

Genus — *Pseudonothofagidites* Venkatachala & Kar, 1969a

Type Species — *Pseudonothofagidites kutchensis* Venkatachala & Kar, 1969a.

Pseudonothofagidites kutchensis Venkatachala & Kar, 1969a

Remarks — The pollen grains are 5-porate, pore margin is not much thickened and the exine is sparsely granulose.

POLLEN POLYAD — TYPE 1

Pl. 1, fig. 27

Description — Pollen grains found in polyad, most probably 16 pollen attached together. Aperture not traceable; exine upto 3 μ thick, spinose, interspinal space seems to be intrapunctate.

Comparison — *Droseridites* Cookson (1947) resembles the present specimens in the presence of spines but the former is always found in tetrad. *Polyadopollenites* Thomson & Pflug (1953) approximates the present type in possessing 16 pollen clustered together but is distinguished by its granulose exine. *Ericipites* Wodehouse (1933) is always found in tetrad and the exine is laevigate-granulose.

MICROPLANKTON — TYPE 1

Pl. 1, fig. 28

Description — Microplanktons subcircular, 56-70 μ. Wall upto 2 μ thick, wrinkled, granulose-warty. Subcircular operculum present on one side.

Comparison — *Psilosphaera* Sah & Kar (1974) comes close to this type in shape and nature of operculum but is distinguished by its smooth wall.

MICROPLANKTON — TYPE 2

Pl. 1, fig. 29

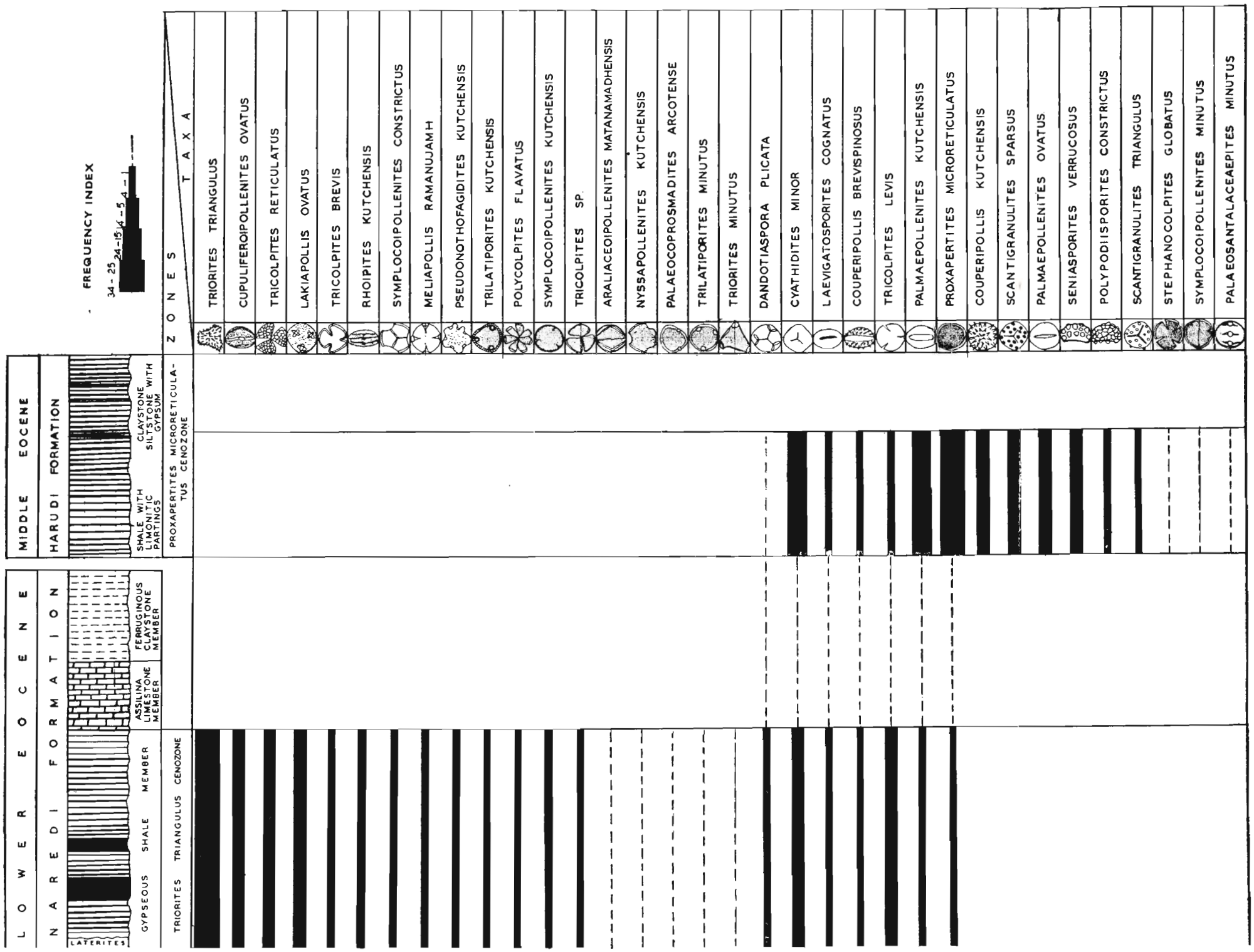
Description — Microplankton oval, 68 μ. Wall 3 μ thick, laevigate, few plates discernible.

Comparison — *Octaplata* Sah & Kar (1974) resembles the present species in shape and size but is readily differentiated by the presence of distinct 8 plates.

Genus — *Phragmothyrites* (Edwards) Kar & Saxena, 1976

Type Species — *Phragmothyrites eocaenica* (Edwards) Kar & Saxena, 1976.

PALYNOSTRATIGRAPHIC ZONATION OF EOCENE SEDIMENTS IN KUTCH



TEXT-FIG. 1 — Note that the stratigraphic column shown in the Text-figure is not to the scale. Where palynological information is not known, the space against the stratigraphic column has been kept blank.

Phragmothyrites sp.

Pl. 1, fig. 30

Description — Ascostromata subcircular, 72 μ, non-ostiolate. Radial hyphae well-developed, radiating, transverse hyphae not traceable. Ascostromata seems to be one-celled thick, pores not observed.

Comparison — *Phragmothyrites eocaenica* (Edwards) Kar & Saxena (1976) is distinguished from the present species by the possession of well-developed transverse hyphae to form pseudoreticulate appearance in conjunction with the radial ones.

PALYNOLOGICAL ZONATION

Naredi Formation — The Gypseous Shale Member is quite rich in spores and pollen grains and in all 65 genera and 92 species have been recovered so far. Out of these, *Callialasporites lenticularis* (Döring) Dev, 1961; *Podocarpidites ellipticus* Cookson, 1947; *Podocarpidites* sp.; *Laricoidites kutchensis* Venkatachala, Kar & Raza, 1969; and *Araucariacites australis* Cookson, 1947 seems to be reworked species. It may be recalled here that all these species have been earlier reported from the Upper Jurassic and Lower Cretaceous sediments of Kutch.

While samples from Akri, Panandhro, Naredi and other places were counted (200 specimens) for quantitative analysis, it was observed that the following 25 species are generally observed within the counted specimens:

Cyathidites minor Couper, 1953; *Dandotiaspora plicata* (Sah & Kar) Sah, Kar & Singh, 1971; *Laevigatosporites cognatus* Sah & Kar, 1969; *Palmaepollenites kutchensis* Venkatachala & Kar, 1969a; *Proxapertites microreticulatus* Jain, Kar & Sah, 1973; *Couperipollis brevispinosus* (Biswas) Venkatachala & Kar, 1969a; *Tricolpites levis* Sah & Dutta, 1966; *T. brevis* Sah & Kar, 1970; *T. reticulatus* Cookson, 1947; *Tricolpites* sp.; *Araliaceoipollenites matanamadhensis* Venkatachala & Kar, 1969a; *Cupuliferoipollenites ovatus* Venkatachala & Kar, 1969a; *Rhoipites kutchensis* Venkatachala & Kar, 1969a; *Symplocoipollenites constrictus* Venkatachala & Kar, 1969a; *S. kutchensis* Venkatachala & Kar, 1969a; *Nyssapollenites kutchensis* Venkatachala & Kar, 1969a; *Palaeocoprosmadites arcotense* Ramanujam, 1966; *Lakiapollis ovatus* Venkatachala & Kar, 1969a; *Meliapollis ramanujamii* Sah & Kar, 1970; *Polycolpites flavatus* Sah & Kar, 1970; *Trilatiporites kutchensis* Venkatachala & Kar, 1969a; *T. minutus* Sah & Kar, 1970; *Triorites triangulus* Sah & Kar, 1970; *T. minutus* Sah & Kar, 1970; *Pseudonothofagidites kutchensis* Venkatachala & Kar, 1969a.

Of all these taxa, *Triorites triangulus* is most common and so the cenozone is proposed after the name of this species.

Triorites triangulus Cenozone

Reference Localities — Naredi Section, Panandhro and Akri Sections.

Lithology — Grey gypseous shale, brown and grey clay with occasional bands of lignites and carbonaceous shales.

Lower Contact — This member rests unconformably on the trap and its derivatives. At Naredi, it rests on the laterites, at Akri on the altered trap and at Panandhro on the lithomargic clay.

Upper Contact — The *Assilina* Limestone Member overlies this cenozone.

Characteristic species of the Cenozone — *Cupuliferoipollenites ovatus, Tricolpites reticulatus, Lakiapollis ovatus, Cyathidites minor, Tricolpites levis, T. brevis, Rhoipites kutchensis, Symplocoipollenites constrictus, Meliapollis ramanujamii and Pseudonothofagidites kutchensis.*

Cenozone Indicator — The good percentage of *Triorites triangulus* is a good indicator for this cenozone.

Harudi Formation — The miospore assemblage consists of 26 genera and 30 species. Out of these, 17 species are found in all the samples within the counted specimens:

Cyathidites minor Couper, 1953; *Dandotiaspora plicata* (Sah & Kar) Sah, Kar & Singh, 1971; *Scantigranulites triangulus* sp. nov.; *S. sparsus* sp. nov.; *Laevigatosporites cognatus* Sah & Kar, 1969; *Seniasporites verrucosus* Sah & Kar, 1969; *Polypodiisporites constrictus* Kar (Ms.); *Proxapertites microreticulatus* Jain, Kar & Sah, 1971; *Palmaepollenites kutchensis* Venkatachala & Kar, 1969a; *P. ovatus* Sah & Kar, 1970; *Couperipollis brevispinosus* (Biswas) Venkatachala & Kar, 1969a; *C. kutchensis* Venkatachala & Kar, 1969a; *Tricolpites levis* Sah & Dutta, 1966; *Stephanocolpites globatus* Venkatachala & Kar, 1969a; *Polycolpites*

flavatus Sah & Kar, 1970; *Palaeosantalaceaepites minutus* Sah & Kar, 1970; *Symplocoipollenites minutus* Venkatachala & Kar, 1969a.

Amongst these, 7 species, viz., *Dandotiaspora plicata, Cyathidites minor, Laevigatosporites cognatus, Couperipollis brevispinosus, Tricolpites levis, Palmaepollenites kutchensis* and *Proxapertites microreticulatus* are also found in the Naredi Formation.

But this formation is well recognized by its good representation of *Proxapertites microreticulatus, Couperipollis kutchensis, Scantigranulites sparsus* and *Seniasporites verrucosus. Proxapertites microreticulatus* which is found only in 1% in the Naredi Formation contributes 26% in the Harudi Formation. For this reason the cenozone is named after this species (Text-fig. 1).

Proxapertites microreticulatus Cenozone

Reference Locality — Exposure about 2 km north-west of the village Harudi.

Lithology — Mostly grey shale with yellow limonitic partings and occasional thin lignitic bands.

Lower Contact — The shales lie unconformably on the laterites.

Upper Contact — This comprises calcareous claystone and siltstone with thin layers of gypsum.

Characteristic species of the Cenozone — *Palmaepollenites kutchensis, Cyathidites minor, Couperipollis kutchensis, Scantigranulites sparsus, Palmaepollenites ovatus, Seniasporites verrucosus, Laevigatosporites cognatus* and *Tricolpites levis.*

Cenozone Indicator — The cenozone is well marked by the abundance of *Proxapertites microreticulatus, Palmaepollenites kutchensis, Couperipollis kutchensis* and *Scantigranulites sparsus.*

Comparison with Other Palynological Zones

The Bengal palynological zone II comprising Jalangi Formation (Palaeocene-Lower Eocene) proposed by Baksi (1972) is not much comparable to the *Triorites triangulus* Cenozone as the former is characterized by the abundance of *Retialetes* and *Schizosporis* which he thinks should be grouped to *Proxapertites* van der Hammen (1956).

Similarly, *Nymphaeoipollis assamicus* Cenozone proposed by Sah and Singh (1974) for Tura Formation (Lower Eocene) is also quite distinct from the present zone by its presence of *Nymphaeoipollis assamicus, Cicatricosisporites macrocostatus, Stephanocolpites tertiarus* and *Polypodiisporites speciosus.* Only *Meliapollis ramanujamii* is common to both the cenozones.

The Lakadong palynological zone proposed by Dutta and Sah (1970) is also easily distinguished by its occurrence of *Retialetes* and *Biretisporites* in good number.

On the other hand *Proxapertites microreticulatus* Cenozone which has been proposed for Harudi Formation (Middle Eocene) closely resembles the palynological zones described by Baksi (1972) and Sah and Singh (1974) from Lower Eocene of Bengal and Assam respectively by their abundance of *Proxapertites.* As has already been stated, on the basis of *Nummulites* (Biswas & Raju, 1971, 1973) and planktonic foraminifera (Mohan & Soodan, 1970), the Harudi Formation has been dated as Middle Eocene (Lutetian) and so this disparity in age between the Kutch and Assam-Bengal assemblages should be critically examined. The Naredi Formation on the basis of microfauna has also been dated as Lower Eocene (Ypresian) and the Gypseous Shale Member, from which the *Triorites triangulus* Cenozone has been proposed forms the basal member of this formation. The *Psilodiporites hammenii* and the *Anacolosidites trilobatus* palynological zones proposed by Venkatachala and Rawat (1971) for the Lower and Middle Eocene of Cauvery basin respectively are only broadly comparable to the present cenozones as both *Psilodiporites* and *Anacolosidites* are absent in the samples studied here.

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EXPLANATION OF PLATE

(*All photomicrographs are enlarged ca.* × 500)

PLATE 1

1-2. *Cyathidites australis* Couper; Slide nos. 3252/1, 3253/1.

3-5. *Intrapunctisporis harudiensis* sp. nov.; Slide nos. 3254/7, 3255/9, 3256/3.

6-7. *Scantigranulites triangulus* gen. et sp. nov.; Slide nos. 3260/3, 3261/4.

8-11. *Scantigranulites sparsus* sp. nov.; Slide nos. 3262/2, 3263/1, 3261/9, 3264/11.

12. *Laevigatosporites* sp.; Slide no. 3257/17.

13. *Polypodiisporites constrictus* Kar (1978); Slide no. 3253/12.

14. *Schizaeoisporites* sp.; Slide no. 3264/13.

15-16. *Proxapertites microreticulatus* Jain, Kar & Sah; Slide nos. 3263/3, 3265/2.

17. *Couperipollis brevispinosus* (Biswas) Venkatachala & Kar; Slide no. 3257/10.

18. *Tricolpites* sp. cf. *T. matauraensis* Couper; Slide no. 3255/6.

19. *Tricolpites* sp.; Slide no. 3266/1.

20-24. *Parumbelliferoipollis dulcis* gen. et sp. nov.; Slide nos. 3254/13, 3256/9, 3258/1, 3258/4, 3253/11.

25. *Diporites* sp.; Slide no. 3255/5.

26. *Marginipollis kutchensis* (Venkatachala & Kar) comb. nov.; Slide no. 3259/6.

27. Pollen polyad — type-1; Slide no. 3261/5.

28. Microplankton — type-1; Slide no. 3255/8.

29. Microplankton — type-2; Slide no. 3257/2.

30. *Phragmothyrites* sp.; Slide no. 3267/4.

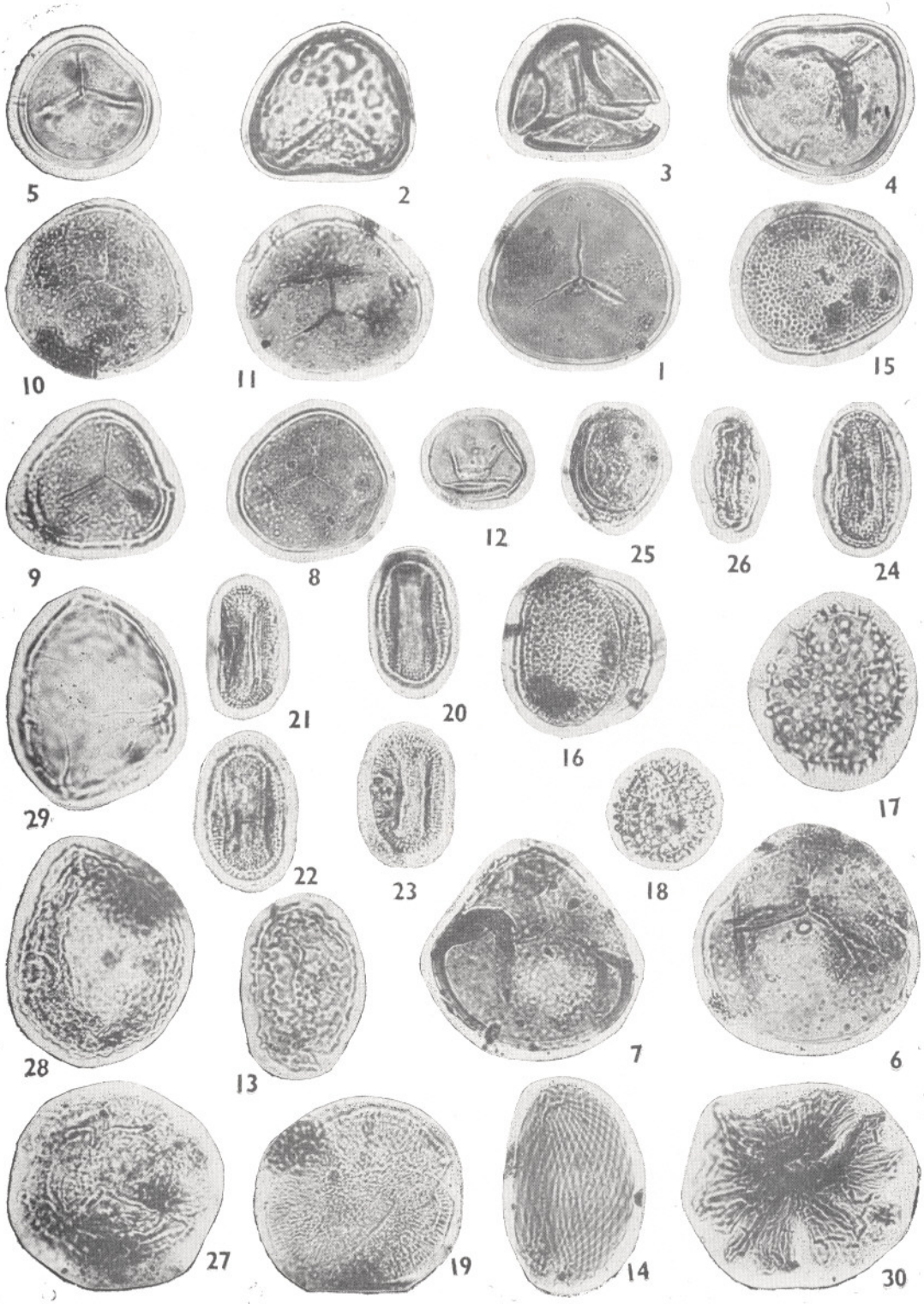
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PLATE 1