LATE EOCENE CALCAREOUS NANNOPLANKTON FROM TARKESHWAR, SURAT-BROACH AREA, GUJARAT

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ABSTRACT

A rich assemblage of the Late Eocene calcareous nannoplankton is recovered from the brownish yellow fossiliferous marl exposed in the vicinity of Tarkeshwar Village. Twenty five species of the calcareous nannoplankton belonging to genera Coelolitihis Schwarz 1894, Eriscocilla Black 1964, Cyclocociliihina Wilcoxon 1970, Reticulofenestra Hay, Mohler and Wade 1966, Thorasphaera Kampnner, 1927, Discoaster Tan Sin Hok, 1927, Heliolitihis Hay and Mohler 1961, Brarudiasphaera Deflandre, 1947, Micrococythinus Deflandre 1930, Triquetrabulbulus Martini 1965, Coccolithids Kampnner, 1953 and Corallinula Stradner, 1962 are described and illustrated. Reticulofenestra diatema-Corallinula germanicus Assemblage-Zone is delineated. The presence of larger and benthonic foraminiferids in abundance in the brownish yellow fossiliferous marl suggests that the marl was deposited in an inner neritic environment. It is generally believed that the calcareous nannoplankton invariably occur in the sediments deposited at deeper depths, but the present study indicates that in the tropical climate the calcareous nannoplankton thrive profusely even in a shallow marine environment.

INTRODUCTION

The writers had collected the samples (T1-T3) from the brownish yellow fossiliferous marl exposed at about 1½ km. south south-east of the Tarkeshwar village in a narrow nala (Fig. 1) for the study of calcareous nannoplankton in the year 1969. The marl is 3 metres thick. In addition to nannofossils, the samples contain larger foraminiferida (Nummulites fabianii and Pellatispira sp.) as well as smaller foraminiferids. The ostracoda, bryzoa and corals are poorly distributed.

Blanford (1867) studied the geology of this region and classified these rocks under “Older Tertiary”. Rao (1941) was the first micropalaeontologist who correctly identified the Late Eocene rocks of this region. Eames (1952) proposed Tapti Series for the Pellatispira bed of the Surat-Broach region. Singh et al. (1972) recorded for the first time the occurrence of nannofossils from the Late Eocene rocks of this region. Singh (1972) reclassified the Tertiary sequence of the present area and described a new subgenus and a new species—Anomalolinella pre-anomalolinella sureshi Singh. The writers consider that the brownish yellow fossiliferous marl is the lateral variation of the Ghalha Clay Member (Late Eocene) of the Bodhan Formation of Singh (1972). Sudhakar and Basu (1973) dealt with the Paleogene stratigraphy of southern Cambay Basin. Roychoudhary et al. (1972) discussed the subsurface stratigraphy of extreme northwestern part of Cambay Basin.

Roth (1973, 1974), Charles et al. (1973), Schlanger et al. (1973) and Bukry (1973) explained about the effect of diagenesis on the calcareous nannoplankton. In the Tarkeshwar area, the discoasters have been very much affected by the diagenesis in form of secondary calcite overgrowth and dissolution. Frequency distribution of the calcareous nannoplankton is shown in Fig. 2.
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**N** = VR (VERY RARE), ONE SPECIMEN PER SLIDE (484 Sq. m.m. area)

**R** = RARE, 2-5 SPECIMENS PER SLIDE (484 Sq. m.m. area)

**C** = COMMON, 6-10 SPECIMENS PER SLIDE (484 Sq. m.m. area)

**F** = FREQUENT, 11-25 SPECIMENS PER SLIDE (484 Sq. m.m. area)

Fig. 2. Showing frequency distribution of calcareous nannoplankton in the brownish yellow fossiliferous marl.
Slides were prepared by using a new mounting medium "BIONAL" and Natural Canada Balsam manufactured by the Chandel Scientific Products, Lucknow.

SYSTEMATIC DESCRIPTION

Family  Coccolithaceae Kampfner, 1928
Genus    Coccolithus Schwarz, 1894
Coccolithus sp. a
(Plate I—1-5, 7-9 ; Fig. 3)

Specimens: Four complete coccoliths, Slide Nos. N.L.U. 44, 60, 61.

Description: Placoliths medium-to-large sized, surrounded to elliptical with two appressed shields and undulating margin. Distal shield broad with unequal segments (16 segments in one of the specimen, Pl. 1, fig. 1, Text fig. 3). Proximal shield consists of small segments vary in number from 8 to 9. Central opening wide and elliptical. In crossed-nicols shows strong birefringence and distinct shields.

Remarks: It differs from Coccolithus gigas Bramlette and Sullivan in not having a 'X' shaped structure in its central opening. This species is distinguished from Coccolithus opealagius (Bramlette and Riedel) by its wider segments of distal shield. Diameter 15 μ—2 μ.

Fig. 3. Coccolithus sp. a, showing the arrangement of two appressed shields along with their segments. Same specimen as shown in Pl. 1, Fig. 3, x2500.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of the Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone; Martini, 1971).

Repository: Geological Museum, Lucknow University.

Coccolithus sp. b
(Plate I—10-18 ; Figs. 4-6)

Specimens: Five complete coccolithus, slide Nos. N.L.U. 30, 34, 54, 55, 64.

Description: Placoliths small-to-large sized, surrounded to subelliptical, with two appressed shields. Distal shield prominent with 14 to 15 subtriangular segments. Proximal plate subelliptical and small with a narrow raised rim (Pl. 1, fig. 10), central region probably consists of small irregular grains of calcite. In crossed-nicols shows strong birefringence, half part of distal shield distinct and proximal shield prominent. Diameter 10.5μ—16.5 μ.

Figs. 4-6. Coccolithus sp. b, showing the arrangement of two appressed shields, segments of distal shield and central region probably consisting of irregular grains of calcite, 2, (Pl. 1, fig. 15), 3 (Pl. 1, fig. 13) and 4 (Pl. 1, fig. 11), x2500.

Remarks: It differs from Coccolithus crassus Bramlette and Sullivan in having a broader distal plate and small proximal plate with a narrow raised rim. It can be demarcated from Coccolithus consuetus Bramlette and Sullivan and Coccolithus californicus Sullivan by the absence of a X-shaped structure in the central region. It resembles Coccolithus sp. a in outline but differs from latter in having a central region which is probably composed of small grains of calcite.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. south south-east of the Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone; Martini, 1971).

Repository: Geological Museum, Lucknow University.

Coccolithus sp. c
(Plate II—1-12, Figs. 7, 8)


Description: Coccoliths medium sized, surrounded to subelliptical, with two appressed shields. Distal shield broad with undulating peripheral margin consisting of 6 to 14 segments united together with distinct sutures, size of segments varies. Proximal shield narrow, elevated in form of collar (Pl. 2, fig. 3, text-fig. 8) and seems to contain a central opening or a depressed area. In
crossed-nicols the proximal shield shows strong birefringence in comparison to distal shield. Diameter 4 $\mu$m — 12 $\mu$m.

Figs. 7-8. Coccolithus sp. e, showing two appressed shields, segments of distal shield, elevated collar of proximal shield and central region probably containing an opening or depressed area; 5 (Pl. 2, fig. 6); 6 (Pl. 1, fig. 9); $\times 2500$.

Remarks: The well formed raised proximal shield having a central opening or depression and different birefringence figures in crossed-nicols of the present species differentiate it from its associated species — Coccolithus sp. a, and Coccolithus sp. b. It differs from Coccolithus crassus Bramlette and Sullivan reported from the Early Eocene of California in having a broader distal shield and a narrow raised proximal shield.

Horizon and locality: Brownish yellow fossiliferous marl; 1 $\frac{1}{2}$ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Coccolithus sp. f

(Plate II—19-21)

Specimen: A complete specimen, Slide No. N.L.U. 71.

Description: Coccolith medium sized, circular, with two appressed shields and a star shaped central region. In crossed-nicols shows strong birefringence. Diameter 9 $\mu$m.

Horizon and locality: Brownish yellow fossiliferous marl; 1 $\frac{1}{4}$ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Coccolithus sp. g

(Plate II—22-24)

Specimen: A complete coccolith, Slide No. N.L.U. 15.

Description: Coccolith medium sized, elliptical, with two appressed plates showing segmentation and probably a central opening. In crossed-nicols shows strong birefringence. Diameter 13.5 $\mu$m.

Horizon and locality: Brownish yellow fossiliferous marl; 1 $\frac{1}{4}$ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus Ericsonia Black, 1964

Ericsonia muiri (Black)

(Plate 1—6; Plate II—25-28; Plate III—1, 2)

Coccolithus muiri Black, 1964, p. 309, pl. 50, figs. 3, 4.

Ericsonia muiri (Black); Roth, 1970, p. 841.

Ericsonia muiri (Black); Iaccarino and Rio, 1972, p. 659, pl. 73, fig. 13.

Ericsonia muiri (Black); Baldo-Bekalandi Baldi, 1974, pl. 7, figs. 1, 2.

Specimens: Two complete placoliths, Slide Nos. N.L.U. 54, 75.

Remarks: It is similar to Ericsonia muiri Black recorded from the Middle Eocene, Muir, Seamount, Atlantic Sea. Coccoliths are large sized and subelliptical, with 30 rays (Pl. 2, fig. 25). The depressed central area of coccolith is composed of small irregular grains of calcite. It shows strong birefringence in the crossed-nicols. Diameter 16.5 $\mu$m.

Distribution: Iaccarino and Rio (1972)—Marine di M. Piano Formation (Late Eocene), Milano. Baldo-Bekalandi Baldi (1974)—Zone NP 24, Sphenolithus distensus Zone (Senso Martini) Kessellien (Kessell clay); NP 25, Sphenolithus ciperensis Zone, Triquetorhhabdus carinatus Zone, Egerian, Novaj profile,
Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus: *Cyclococcolithina* Wilcoxon, 1970

*Cyclococcolithina formosa* (Kampptner) (Plate III—3-8)

*Cyclococcolithus formosus* Kampptner, 1963, pp. 163-164, pl. 2, fig. 8, text-fig. 20.

*Coccolithus planispira* Black, 1964, p. 308, pl. 50, figs. 1-2.

*Cyclococcolithus orbis* Gartner and Smith, 1967, p. 4, pl. 4, figs. 1-3.

*Cyclococcolithina formosa* (Kampptner) Wilcoxon, 1970, p. 82.

Specimen: Two complete placioliths, Slide Nos. N.L.U. 15, 88.

Remarks: It resembles *Cyclococcolithina formosa* (Kampptner). Placioliths are medium sized, subrounded and consist of two appressed plates. Diameter 12 μ.

Distribution: Baldi-Beke (1971)—Discoaster lodoensis Zone (Early Eocene)—*Isthmolithus recurvus* Zone (Late Eocene), Bakony Mountains, Hungary. Roth (1973)—Early Eocene—Early Oligocene rocks of the Central Pacific basin. Sadek and Telb (1974)—Mokattam Formation (Middle Eocene), Betty well-l, northwestern desert, Egypt.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus: *Reticulofenestra* Hay, Mohler and Wade, 1966

*Reticulofenestra dictya (Deflandre and Fert) (Plate III—9-16)

*Discococcolithus dictya* (Deflandre and Fert, 1954, pp. 140-141, figs. 15-16.

*Cyclococcolithus dictya* (Deflandre and Fert); Hay and Towe, 1962, p. 503, pl. 5, fig. 4, pl. 7, fig. 1.

*Reticulofenestra dictya* (Deflandre and Fert); Loccker, 1972, p. 761, pl. 8, figs. 1, 2.


Remarks: It is similar to *Reticulofenestra dictya* (Deflandre and Fert). Placioliths are well-preserved and consist of two closely appressed plates having radial sutures and a distinct central opening. Diameter 9μ-10.5μ.


Horizon and Locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village.

Age: Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

*Reticulofenestra placomorpha* (Kampptner and Deflandre) (Plate III—17-20)

*Trimalithus planomorphus* Kampptner, 1948, p. 157, pl. 2, fig. 11.

*Reticulofenestra lacomorpha* (Kampptner and Deflandre); Lockcr, 1972, pp. 762, 763, pl. 8, figs. 7, 8, pl. 17, fig. 5.


Remarks: It closely resembles *Reticulofenestra placomorpha* (Kampptner and Deflandre). However, the surface of the placiolith is not very clear for determining its surface sculpture. Diameter 9μ-10.5μ.


Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

*Reticulofenestra pseudogammation* (Bouche) (Plate III—21-26)

*Coccolithus pseudogammation* Bouche, 1962, p. 85, pl. 1, figs. 19, 20, text-fig. 5.

*Cyclococcolithus neogammation* Bramlette and Wilcoxon, 1967, pl. 1, figs. 1-3, pl. 4, figs. 3-5.

*Reticulofenestra pseudogammation* (Bouche); Lockcr, 1972, p. 763, pl. 6, figs. 17-19.

Specimen: Two complete placioliths, Slide Nos. N.L.U. 10, 18.

Remarks: Lockcr (1972) considered that *Coccolithus bryonalis* Reinhardt, *Cyclococcolithus neogammation* Bramlette and Wilcoxon and *Reticulofenestra laevis* Roth and Hay are the junior synonyms of *Reticulofenestra pseudogammation* (Bouche). Diameter 9μ.

Distribution: Bouche (1962)—Lutetian, Paris. Bramlette and Wilcoxon (1967)—Very common throughout the lower part of the Cipero section up to *Globorotalia fohsi* fohsi Zone, common also in Oligocene and Early Miocene of Europe, Indonesia and Atlantic and Pacific deep sea cores. Baldi-Beke (1971)—Upper part of
**Zygolithus dubius**—*Discaster floraeus* horizon (Middle Eocene).
—*Isthmolithus recurvus* Zone (Late Eocene). Baldi-Beké (1972)—Buda Marl (Late Eocene), Budapest, Hungary.

**Horizon and locality:** Brownish yellow fossiliferous marl; 1½ km. S S E. of Tarkeshwar village in a nala.

**Age:** Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

**Repository:** Geological Museum, Lucknow University.

**Family:** Thoracosphaeraceae, Schiller, 1930.

**Genus:** Thoracosphaera Kampfer, 1927

**Thoracosphaera** sp.

(Plate III—27)

**Specimen:** Incomplete specimen, Slide No. N.L.U. 20.

**Description:** Shell consists of mosaic of interlocking small subsquare to irregular shaped calcite grains. In crossed-nics shows strong birefringence.

**Remarks:** Only a part of shell has been found. It has very close resemblance with shell of *Thoracosphaera deflandrei* Kampfer.

**Horizon and locality:** Brownish yellow fossiliferous marl, 1½ km. south south-east of the Tarkeshwar village in a nala.

**Age:** Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

**Repository:** Geological Museum, Lucknow University.

**Family:** Discoasteraceae Tan Sin Hok, 1927

**Genus:** Discoaster Tan Sin Hok, 1927

**Discoaster barbadiensis** Tan Sin HoK emend. Bramlette and Riedel, 1954

(Plate IV—1-5)

**Discoaster barbadiensis** Tan Sin Hok (in part), 1927, p. 119.

**Discoaster barbadiensis** Tan Sin Hok; Bramlette and Riedel, 1964, p. 398, pl. 39, figs. 5a, b.

**Specimens:** Four complete and one broken discasteros, Slide Nos. N.L.U. 11, 15, 32, 40, 64.

**Remarks:** The present specimens are identical with *Discoaster barbadiensis*. The type species is characterized by the pointed apexes of the rays. Tarkeshwar specimens show a major degree of variation in shape of the rays. Some of the specimens are true representative of *Discoaster barbadiensis* (Pl. 4, fig. 1) whereas some are having rounded apexes of the rays (Pl. 4, figs. 2-5). Due to the diagenesis, the rays became thick and lost their original shape (Pl. 4, fig. 3). Diameter 8 μ—21 μ.


**Horizon and locality:** Brownish yellow fossiliferous marl, 1½ km. S S E. of Tarkeshwar village in a narrow nala.

**Age:** Late Eocene (? NP 19, *Isthmolithus recurvus* Zone, Martini, 1971).

**Repository:** Geological Museum, Lucknow University.

**Discoaster distinctus** Martini

(Plate IV—6)

**Discoaster distinctus** Martini, 1958, p. 363, pl. 4, figs. 17a, b.

**Specimens:** Two discasteros, Slide Nos. N.L.U. 44, 72.

**Remarks:** It resembles *Discoaster distinctus* Martini and contains six rays with bifid apexes. Diameter 10.54μ—16.5 μ.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Discoaster elegans Bramlette and Sullivan

(Plate IV—7)

Discoaster elegans Bramlette and Sullivan, 1961, p. 159, pl. 11, figs. 16a, b.


Remarks: It is similar to Discoaster elegans Bramlette and Sullivan described from the Lodoso Section (Early Eocene and Middle Eocene), Fresno County, Central California, U.S.A., Diameter—16.5 µ.


Horizon and locality: Brownish yellow fossiliferous marl, 1½ km. south south-east of the Tarkeshwar village in a narrow nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Discoaster saipanensis Bramlette and Riedel

(Plate IV—8-11)

Discoaster saipanensis Bramlette and Riedel, 1954, p. 398, pl. 39, fig. 4.

Specimen: Three complete discoasters, Slide No. N.L.U. 11, 17, 37.

Remarks: Bramlette and Riedel (1954) recorded this species from the Densinyama Formation (Late Eocene), north Saipan and remarked that it is very common in the Late Eocene samples from widely scattered localities. Diameter—10.5 µ—15 µ.


Horizon and locality: Brownish yellow fossiliferous marl, 1½ km. S S E of Tarkeshwar village in a narrow nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Discoaster tani Bramlette and Riedel

(Plate IV—12-15)

Discoaster tani Bramlette and Riedel, 1954, p. 397, pl. 39, fig. 1.

Specimens: Three complete discoasters, Slide Nos. N.L.U. 37, 61, 85.

Remarks: Discoasters are medium to large-sized, with five rays. The rays are broad, thick, and joined through 2/3 of their margins. Rays show faint development of lateral nodes (Pl. 4, fig. 13). In crossed-nicols show strong birefringence. Diameter 9µ—15µ.

Distribution: Bramlette and Riedel (1954)—Densinyama formation (Late Eocene), N. Saipan; Hospital Hill marl, San Fernando group (Late Eocene), Trinidad; Waiaareken formation (Late Eocene), west of Oamaru, New Zealand; Oceanic formation (Late Eocene), Bath, Barbados; Gatunckillo formation (Late Eocene), Panama Canal Zone and Ledian blue marl (Late Eocene), Cote des Basques, Biarritz, France. Roth (1973)—Central Pacific basin, Site 167, C. grandis Zone—Discoaster barbadiensis Zone, Middle Eocene—Late Eocene; Site 171, N. fulgens Zone—Chiasmolithus solitius Zone, Middle Eocene.

Horizon and locality: Brownish yellow fossiliferous marl, 1½ km. S S E of Tarkeshwar village in a narrow nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Family: Heliolithecaceae Hay and Mohler, 1967

Genus: Heliolithus Bramlette and Sullivan, 1961

Heliolithus sp. a.

(Plate IV—16-27)


Description: Helioliths small and rounded in shape. Central area thick with a distinct central opening having 1/3 of diameter of heliolith. Thin peripheral area of heliolith consists of 16-17 segments. In crossed-nicols, central area shows strong birefringence whereas, the
peripheral area shows thin rings. Diameter 6 μ—10.5 μ.

Remarks: It differs from Heliolithus riedeli Bramlette and Sullivan described from the Unit 1 (Palaeocene) of the Lodo Section of California in having 16 to 17 petal-like elements and a different bifringence figure in the crossed-nicols.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. south south-east of the Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Family: Braarudosphaeraceae Deflandre, 1947
Genus: Braarudosphaera Deflandre, 1947

Braarudosphaera bigelowi (Gran and Braarud) (Plate V—4-7)

Pontosphaera bigelowi Gran and Braarud, 1933, p. 389, text-fig. 67.
Braarudosphaera bigelowi (Gran and Braarud); Deflandre, 1947, p. 439, text-figs. 1-5.

Specimens: 3 complete pentoliths, Slide Nos. N.L.U. 25, 30, 31, 33, 48, 78 and 82.

Remarks: It is identical with Braarudosphaera bigelowi (Gran and Braarud). Diameter 12 μ—22.5 μ.

Distribution: Bramlette and Sullivan (1961)—Middle Eocene (Lutetian), Ciper formation. Stradner (1969)—Flysch, Marthasterites tribranchiatus Zone (Early Eocene) Hagenbach valley, Austria. Hodson and West (1970)—The British Upper Bracklesham Beds (Eocene), Hampshire. Balidi-Beke (1971)—Horizon poor in nanoplankton (Middle Eocene), Isthmolithus recurvus zone (Late Eocene) Bakony Mountains, Hungary. Black (1972)—Late Eocene, Mississippi; Middle Eocene, Bracklesham Bay, Sussex. Balidi-Beke and Baldi (1974)—Kiscellian Stage, NP 24, Sphenolithus distinctus Zone; Egerian stage, NP 25, Sphenolithus ciperoensis Zone, Triquetrorhabdulus carinatus Zone, Navaj profile, Hungary. Sadak and Teleb (1974)—Thebes Formation (Ypresian), Minia Formation (Middle Eocene; Lutetian) and Mokattam Formation (Late Eocene); of Betty well-1, north-western desert, Egypt.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus: Micrantholithus Deflandre, 1950

Micrantholithus crenulatus Bramlette and Sullivan (Plate IV—29; V—1-3)

Micrantholithus crenulatus Bramlette and Sullivan, 1961, p. 155, pl. 9, figs. 3a, b, 4.


Remarks: It is similar to Micrantholithus crenulatus Bramlette and Sullivan. The photomicrographs (Pl. 4, fig. 29; Pl. 5, fig. 1) of the present specimens are identical with the photomicrographs (Pl. 9, figs. 3a, b, 4) of the type species. The diameter of Tarkeshwar pentolith varies from 12 μ to 16.5 μ whereas, the diameter of the type species varies from 7 μ to 12 μ. In crossed-nicols four segments of the pentalith become bright and fifth segment becomes dark.

Distribution: Bramlette and Sullivan (1961)—Locally rare in Units 2 and 3 (Palaeocene and Early Eocene) and more common in unit 4 (Middle Eocene), Lodo Section, north-western Fresno County, Central California, U.S.A.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. south south-east of the Tarkeshwar village in a nala.

Age: Late Eocene (? NP 19, Isthmolithus recurvus Zone).

Repository: Geological Museum, Lucknow University.

Family: Triquetrorhabdulaceae Lipp, 1969
Genus: Triquetrorhabdulus Martini, 1965

Triquetrorhabdulus inversus Bukry and Bramlette (Plate V—11, 15)

Triquetrorhabdulus inversus Bukry and Bramlette 1969 p. 142, pl. 1, figs. 9-14.

Remarks: It is similar to Triquetrorhabdulus inversus Bukry and Bramlette. Tarkeshwar specimens are well-preserved. Length 16.5 µ—24 µ.

Distribution: Bukry and Bramlette (1969)—Common throughout the Middle Eocene of all three major oceanic provinces, in Lutetian equivalents of south-west France, Trinidad, California and many other areas. Roth (1973)—Restricted to the Middle Eocene and was observed at sites 165, 167, 168 and 171.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus: Coccolithites Kampnert, 1955

Coccolithites ? sp. (Plate IV—28)

Specimen: Complete coccolith, Slide No. N.L.U. 44.

Description: Coccolith medium sized, rounded, and consists of a single round plate with distinct thick r.i.m. In crossed-nicols becomes dark. Diameter 12 µ.

Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

Genus: Coranulus Stradner, 1962

Coranulus germanicus Stradner (Plate IV—30)

Coranulus germanicus Stradner, 1962, p. 366, pl. 1, figs. 21-30

Specimen: A complete specimen, Slide No. N.L.U. 17.

Remarks: It agrees well with the description of the type species—Coranulus germanicus Stradner. Diameter 15 µ.


Horizon and locality: Brownish yellow fossiliferous marl; 1½ km. S S E of Tarkeshwar village in a nala.

Age: Late Eocene (NP 19, Isthmolithus recurvus Zone, Martini, 1971).

Repository: Geological Museum, Lucknow University.

BIOSTRATIGRAPHIC ZONE

Reticulofenestra dictyoda dictyoda—Coranulus germanicus Assemblage-zone: It is confined to the brownish yellow fossiliferous marl (type area—situated at about 1½ km. S S E of Tarkeshwar village in a nala, Fig. 1) which is 3 metres thick. The beds underlying the brownish yellow fossiliferous marl are not exposed. The characteristic nannoplankton of the present zone are Coccolithus sp. a—sp. g, Eriosema muri, Cyclococcolithina formosa, Reticulofenestra dictyoda dictyoda, R. placomorpha, R. pseudogammation, Thoracosphaera sp., Discoaster barbadiensis, D. distinctus, D. elegans, D. saipanensis, D. tani, Heliolithus sp. a, Braudusphaera bigelowi, B. discula-Mierantholithus crenulatus, Triquetrorhabdus inversus ?, Coccolithites? sp. and Coranulus germanicus.

AGE DETERMINATION

The brownish yellow fossiliferous marl has yielded characteristic Late Eocene foraminifers—Nummulites fabiani (Prever) and Pellatispira sp. Only five species of the genus Discoaster Tan Sin Hok have been recorded from this marl. These are Discoaster barbadiensis, D. distinctus, D. elegans, D. saipanensis and D. tani. Martini (1971) has given the range of D. barbadiensis from the NP 12, Marthasterites tribrachiatus Zone (Early Eocene) to NP 20, Sphenolithus pseudoradians Zone (Late Eocene). Peins (1971) recorded the range of D. distinctus from the Early Eocene to early Late Eocene. Discoaster elegans is known to occur in the Early Eocene to Late Eocene. Martini (1971) recorded the range of D. saipanensis from the NP 16, upper part of Discoaster tani nodifer Zone (late Middle Eocene) to NP 20, Sphenolithus pseudoradians Zone (Late Eocene). Baldi-Beke (1971) reported D. saipanensis from the Early Eocene (Discoaster lodoensis Zone) strata of the Bakony Mountains, Hungary. Discoaster tani has a short geological age range varying from the Middle Eocene to Late Eocene (Bramlette and Riedel, 1954, Roth, 1973). Eriosema muri has been recorded from the Middle Eocene (Black, 1964), Late Eocene (Taccarino and Ro, 1972) and from the Oligocene (Baldi-Beke and Baldi, 1973 ; Roth, 1970). Cyclococcolithina formosa ranges in age between the Early Eocene and Early Oligocene (Baldi-Beke, 1971 ; Roth, 1973 ; Sadek and Teleb, 1974). Reticulofenestra dictyoda dictyoda has been reported from the Middle Eocene and Late Eocene strata of the world (Deflandre and Fert, 1954 ; Hay and Towe, 1962 ; Haq, 1968, Baldi-Beke, 1972). Reticulofenestra placomorpha occurs in the Middle Eocene, Late Eocene and Oligocene strata (Baldi-Beke, 1971, 1972 ; Baldi-Beke and Baldi, 1974). Reticulofenestra pseudogammation is known to occur in the Middle Eocene (Bouche, 1962 ; Baldi-Beke, 1971) Late Eocene (Baldi-Beke, 1971, 1972), Oligocene and Early Miocene (Bramlette and Wilcoxson, 1967). Braudusphaera bigelowi is a long ranging form (Cretaceous to Recent). Braudusphaera discula has so far been recorded from the Palaeocene and Eocene of the world (Bramlette and Riedel, 1954 Baldi-Beke, 1971 ; Baldi-Beke and
Baldi, 1973; Sadek and Teleb, 1974). *Micrantholithus crenulatus* seems to be restricted to the Palaeocene and Eocene (Bramlette and Sullivan, 1961). *Triquetrorhabdulus inversus* has been recorded from the Middle Eocene (Bukry and Bramlette, 1969; Roth, 1973). *Coronulus germanicus* has so far been reported from the Late Eocene (Stradner, 1962; Locker, 1973). A form belonging to the genus *Isthmolithus* Deflandre, 1954 has been noticed in a temporary slide but could not be photographed and it differs from the species *Isthmolithus recurvus* Deflandre in having four horizontal bars whereas, *Isthmolithus recurvus* has only two horizontal bars. No characteristic discoasters of the Middle Eocene has been recorded in this marl. In view of the above data, the brownish yellow fossiliferous marl has been referred to Late Eocene (> NP 19, *Isthmolithus recurvus* Zone; Martini, 1971).

**PALAEOEOECOLOGY**

The relative distribution percentage of larger foraminifers is very high in comparison to the smaller bentonic foraminifers. The planktonic foraminifers occur rarely. Ostracoda and corals are poorly distributed. On the basis of above facts, it may be safely concluded that the brownish yellow fossiliferous marl was deposited in the shallower part of inner neritic environment.

**CONCLUSION**

1. Nannoplankton assemblage as well as foraminiferal assemblage suggest a Late Eocene age for the brownish yellow fossiliferous marl.

2. The approximate percentage of different genera in the total calcareous nannoplankton assemblage is as follows: *Coccolithus* Schwarz (40%), *Erisconia* Black (1%), *Cyclococcolithina Wilcoxon (1%)*, *Reticulofenestra* Hay, Mohlar and Wade (10%), *Thoracosphaera* Schiller (1%), *Discocastor Tan Sin Hok* (22%), *Helolithus* Hay and Mohler (5%), *Braarudosphaera* Deflandre (10%), *Micrantholithus* Deflandre (5%), *Triquetrorhabdulus* Martini (5%), *Coccolithites*? Kampiner (1%) and *Coronulus* Stradner (1%).

3. *Reticulofenestra dactyoda*?—*Coronulus germanicus* Assemblage—Zone is proposed.

4. The rich nannoplankton assemblage suggests that the deep water marine environment is not necessary for the profuse growth of nannoplankton in the tropical climate.

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**REFERENCES**


EXPLANATION OF PLATES

PLATE I

1-5, 7-9  Coccolithus sp. a, 1, 4, 5, 7, transmitted light, ×2500; 2, 8, crossed-nicols; 3, 9, long axis 45° to crossed-nicols, ×2600.
10-18  Coccolithus sp. b, 10, 11, 13, 15, 18, transmitted light, ×2500; 17, crossed-nicol; 12, 14, 16 long axis 45° to crossed-nicols, ×2600.

PLATE II

1-12  Coccolithus sp. c, 1, 3, 5, 6, 9, 11, 12, transmitted light, ×2500; 2, 4, 8, 10, crossed-nicols; 7, long axis 45° to crossed-nicols, ×2600.
13-15  Coccolithus sp. d, 13, transmitted light ×2500; 14, crossed-nicols; 15, long axis 45° to crossed-nicols, ×2600.
16-18  Coccolithus sp. e, 16, transmitted light, ×2500; 18, crossed-nicols; 17, long axis 45° to crossed-nicols, ×2600.
19-21  Coccolithus sp. f, 19, transmitted light, ×2500; 20, long axis 45° to crossed-nicols; 21, crossed-nicols; ×2600.
22-24  Coccolithus sp. g, 22, transmitted light, ×2500; 23, long axis 45° to crossed-nicols; 24, crossed-nicols; ×2600.
25-28  Erisosonia muiri (Black) 25, 28, transmitted light, ×2500; 26, long axis 45° to crossed-nicols; 27, crossed-nicols; ×2600.

PLATE III

1,2  Erisosonia muiri (Black) 1, long axis 45° to crossed-nicols; 2, crossed-nicols, ×2600.
3-8  Cyclococcolithina formosa (Kamptner) 3, 6, transmitted light, ×2500; 4, 8, crossed-nicols, ×2500; 5, 7 long axis 45° to crossed-nicols, ×2600.
9-16  Reticolofenestra dicyoda dicyoda (Deflandre and Fert) 9, 11, 14, transmitted light, ×2500; 10, 12, 15, crossed-nicols; 11, 16, long axis 45° to crossed-nicols; ×2600.
17-20  Reticolofenestra placomorpha (Kamptner and Deflandre) 17, 18, transmitted light, ×2500; 19, long axis 45° to crossed-nicols; 20, crossed-nicols, ×2600.
21-26  Reticolofenestra pseudogemmation (Bauche) 21, 24, transmitted light, ×2500; 22, 26, crossed-nicols; 23, 25, long axis 45° to crossed-nicols, ×2600.
27  Thoracosphaera sp.; broken part of a shell, transmitted light, ×2500.

PLATE IV

1-5  Discoaster barbadiensis Tan Sin Hok; transmitted light; 3, 4, 5, showing the effect of dissolution on the rays of discoasters; ×2500.
6  Discoaster distinctus Martini; transmitted light, ×2500.
7  Discoaster elegans Bramlette and Sullivan; transmitted light, ×2500.
8-11  Discoaster saipanensis Bramlette and Riedel; transmitted light; 11, showing the effect of dissolution on the rays of discoaster, ×2500.
12-15  Discoaster tanii Bramlette and Riedel; 12-14, showing different stages of growth and thickening of the rays due to secondary calcite deposit, transmitted light, ×2500; 15, crossed-nicols, ×2600.
16-27  Heisolithus sp., 16, 19, 22-24, 27, transmitted light, ×2500; 17, 20, 25, crossed-nicols; 18, 21, 26, long axis 45° to crossed-nicols, ×2600.
28  Coccolithus sp., transmitted light, ×2500.
29  Micrantholithus cremulatus Bramlette and Sullivan, transmitted light, ×2500.
30  Corallus germanicus Stradner; transmitted light, ×2500.

PLATE V

1-3  Micrantholithus cremulatus Bramlette and Sullivan; 1, 2, transmitted light, ×2500; 3, crossed-nicols, ×2600.
4-7  Braarudosphaera bigelowii (Gran and Braarud); 4, 6, 7, transmitted light, ×2500; 5, crossed-nicols, ×2600.
8-10  Braarudosphaera discors Bramlette and Riedel; 8, 10, transmitted light, ×2500; 9, crossed-nicols, ×2600.
11, 15  Triquetrotubulites inversus; Bukry and Bramlette; transmitted light, ×2500.
12-14  Crystals of calcite showing some resemblance with discoasters; 12, 14, transmitted light, ×2500; 12, crossed-nicols, ×2600.