

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—*Coccolithus* Schwarz 1894, *Ericsonia* Black 1964, *Cyclococcolithina* Wilcoxon 1970, *Reticulofenestra* Hay, Mohler and Wade 1966, *Thoracosphaera* Kamptner, 1927, *Discoaster* Tan Sin Hok, 1927, *Heliolithus* Hay and Mohler 1961, *Braarudosphaera* Deflandre, 1947, *Micrantholithus* Deflandre 1950, *Triquetrorhabdulus* Martini 1965, *Coccolithites* Kamptner, 1955 and *Corannulus* Stradner, 1962 are described and illustrated. *Reticulofenestra dictyoda*-*Corannulus 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, bryozoa 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—*Anomalinella pre-anomalinella 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 north-western 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 effected by the diagenesis in form of secondary calcite overgrowth and dissolution. Frequency distribution of the calcareous nannoplankton is shown in Fig. 2.

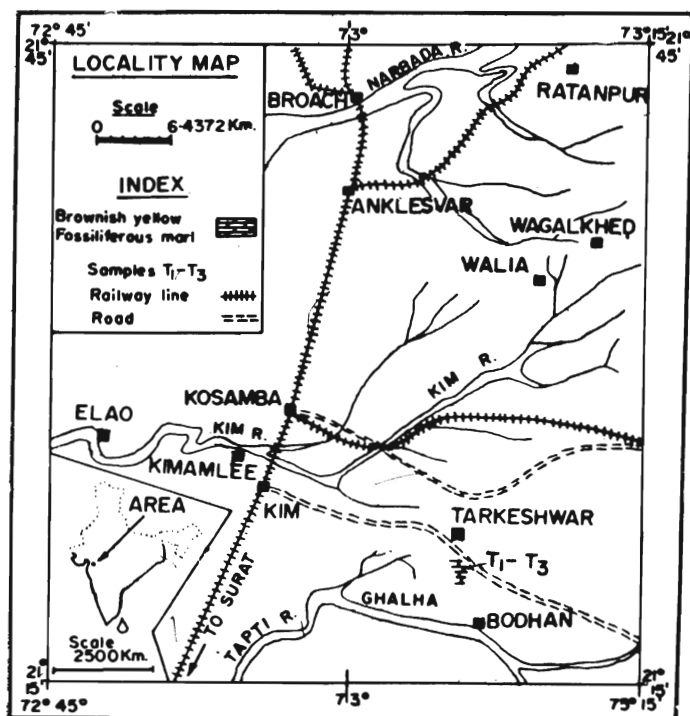


Fig. 1. Locality map of the area.

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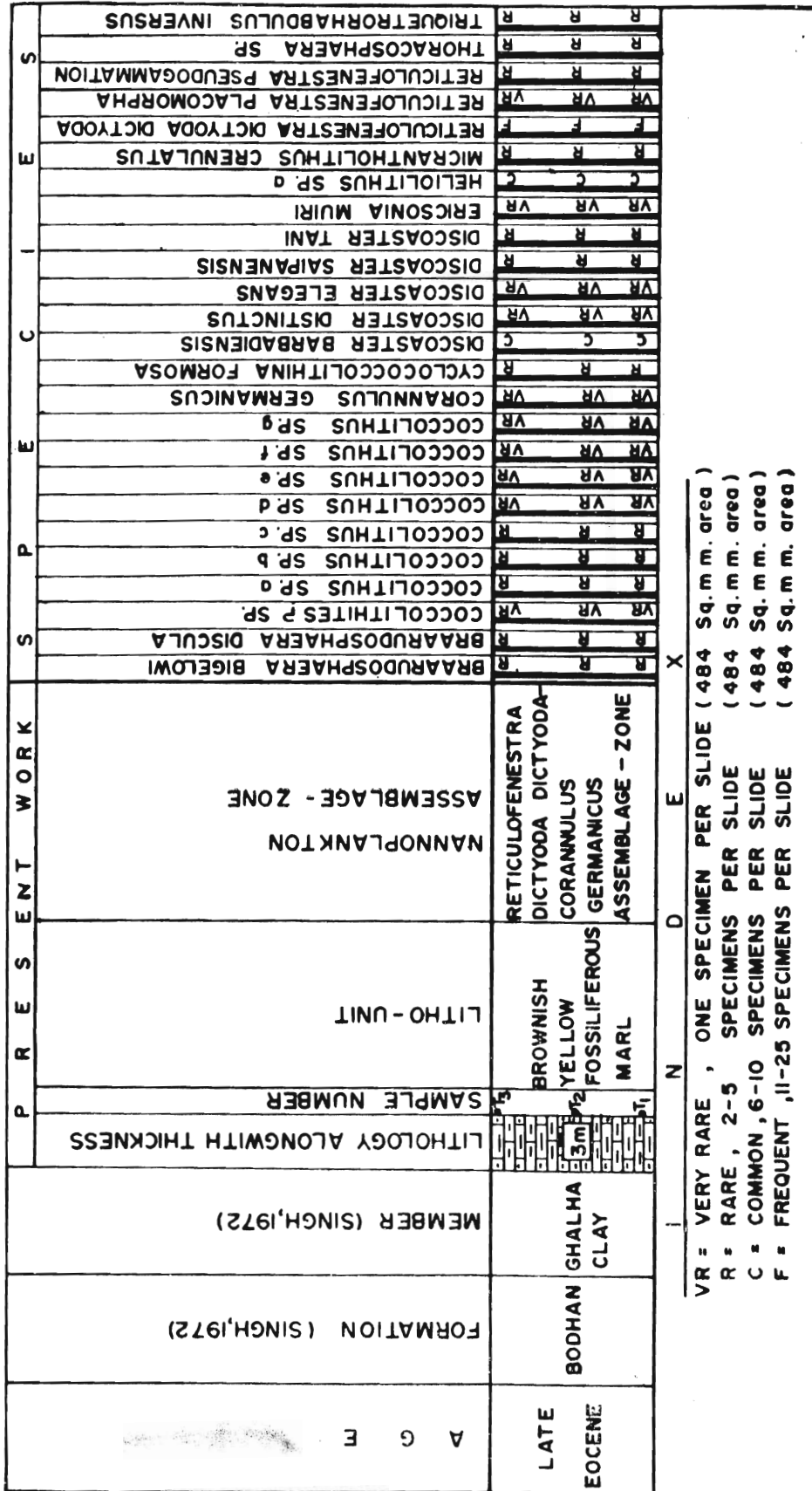


Fig. 2. Showing frequency distribution of calcareous nannoplankton in the brownish yellow fossiliferous marl.

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 Kamptner, 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, subrounded 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 eopelagicus* (Bramlette and Riedel) by its wider segments of distal shield. Diameter $15\ \mu$ — $2\ \mu$.

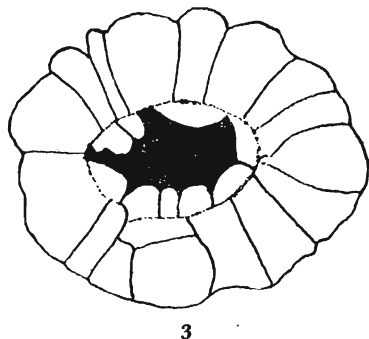


Fig. 3. *Coccolithus* sp. a, showing the arrangement of two appressed shields along with their segments. Same specimen as shown in Pl. 1, Fig. 3, $\times 2500$.

Horizon and locality : Brownish yellow fossiliferous marl ; $1\frac{1}{2}$ 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.

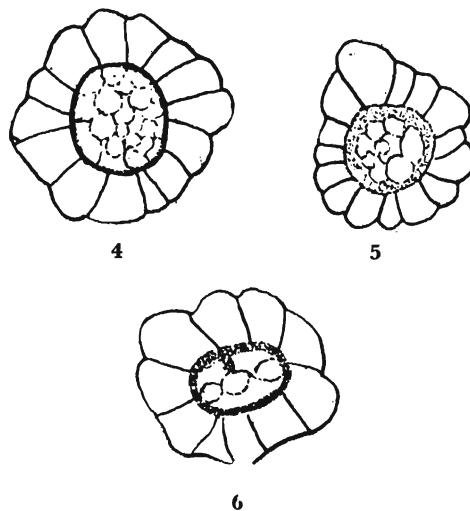
Coccolithus sp. b

(Plate I—10-18 ; Figs. 4-6)

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

Description : Placoliths small-to-large sized, subrounded 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 $10.5\ \mu$ — $16.5\ \mu$.



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), $\times 2500$.

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 ; $1\frac{1}{2}$ 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.

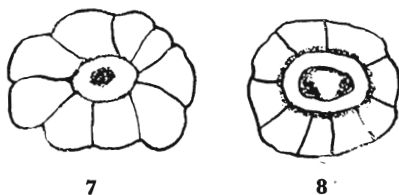
Coccolithus sp. c

(Plate II—1-12, Figs. 7, 8)

Specimens : Eight complete coccoliths, Slide Nos. N.L.U. 16, 17, 43, 59, 68, 73.

Description : Coccoliths medium sized, subrounded 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 $4\ \mu$ — $12\ \mu$.



Figs. 7-8. *Coccolithus* sp. c, 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. 3); $\times 2500$.

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. d

(Pl. II—13-15)

Specimen : A complete coccolith, Slide No. N.L.U. 18.

Description : Coccolith small, circular, with two appressed shields. Distal shield slightly broader than proximal plate and contains about 14 segments. Proximal shield narrow and elevated. Central opening broad, circular and divided by a central bar. In crossed-nicols shows strong birefringence. Diameter $7.5\ \mu$.

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. e

(Pl. II—16-18)

Specimen : A complete coccolith, Slide No. N.L.U. 20.

Description : Coccolith small, circular, with four appressed shields and a small central opening. In crossed-nicols shows birefringence with circular rings. Diameter $7.5\ \mu$.

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 $9\ \mu$.

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. 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 $13.5\ \mu$.

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.

Genus *Ericsonia* Black, 1964

Ericsonia muiri (Black)

(Plate I—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); Baldi-Beke and 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 $16.5\ \mu$.

Distribution : Iaccarino and Rio (1972)—Marne di M. Piano Formation (Late Eocene), Milano. Baldi-Beke and Baldi (1974)—Zone NP 24, *Sphenolithus distentus* Zone (Senso Martini) Kiscellien (Kiscell clay); NP 25, *Sphenolithus ciperoensis* Zone, *Triquetrorhabdulus 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 (Kamptner)
(Plate III—3-8)

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

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

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

Cyclococcolithina formosa (Kamptner) Wilcoxon, 1970, p. 82.

Specimens : Two complete placoliths, Slide Nos. N.L.U. 15, 88.

Remarks : It resembles *Cyclococcolithina formosa* (Kamptner). Placoliths 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 Teleb (1974)—Mokattam Formation (Middle Eocene), Betty well-1, 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 dictyoda dictyoda (Deflandre and Fert)
(Plate III—9-16)

Discolithus dictyodus Deflandre and Fert, 1954, pp. 140-141, figs. 15, 16.

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

Reticulofenestra dictyoda dictyoda (Deflandre and Fert); Locker, 1972, p. 761, pl. 8, figs. 1, 2.

Specimens : Five complete placoliths, Slide Nos. N.L.U. 30, 53, 87, 88.

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

Distribution : Deflandre and Fert (1954)—Middle Eocene, New Zealand (Oligocene d'Oamaru) and France. Hay and Towe (1962)—Middle Eocene of Donzacq (France). Haq (1966)—Late Eocene of Syria. Haq (1968)—Middle Eocene of N.W. Germany. Stradner

and Edwards (1968)—Late Eocene, Oamaru Diatomite, New Zealand. Baldi-Bake (1972)—Bryozoan Marl, Buda Marl and Kiscell clay (Late Eocene), Budapest, Hungary.

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 (Kamptner and Deflandre)
(Plate III—17-20)

Trimalithus placomorphus Kamptner, 1948, p. 157, pl. 2, fig. 11.

Reticulofenestra placomorpha (Kamptner and Deflandre); Locker, 1972, pp. 762, 763 pl. 8, figs. 7, 8, pl. 17, fig. 5.

Specimens : Two complete placoliths, Slide Nos. N.L.U. 30, 31.

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

Distribution : Baldi-Beke (1971)—Middle Eocene, horizon poor in nannoplankton ; Late Eocene, *Isthmolithus recurvus* Zone, Bakony Mountains, Hungary. Baldi-Beke (1972)—Late Eocene, Bryozoan Marl, Buda Marl, Kiscell clay, Budapest, Hungary. Baldi-Beke and Baldi (1974)—Kiscellian, NP 24, *Sphenolithus distentus* Zone, ? *Triquetrorhabdulus carinatus* Zone, Navaj 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.

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

Coccolithus ? pseudogammation Bouche, 1962, p. 85, pl. 1, figs. 19, 20, text-fig. 6.

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

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

Specimens : Two complete placoliths, Slide Nos. N.L.U. 10, 18.

Remarks : Locker (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 9 µ.

Distribution : Bouche (1962)—Lutetian, Paris. Bramlette and Wilcoxon (1967)—Very common throughout the lower part of the Cipro 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

Zygodolithus dubius—*Discoaster floreus* horizon (Middle Eocene)
—*Isthmolithus recurvus* Zone (Late Eocene). Baldi-Beke
(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* Kamptner, 1927

Thoracosphaera sp.

(Plate III—27)

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

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

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

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 discoasters,
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 *Dis-*
coaster 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 .

Distribution : Deflandre (1934)—Oligocene, Haiti.
Bramlette and Riedel (1954)—Late Eocene, near middle
of Oceanic Formation at Bath, Barbades ; Eocene strata
of California, Saipan, New Zealand, several Caribbean
islands and Tunisia. Martini (1958)—Early Eocene
and Late Eocene, northwestern Germany. Bramlette and
Sullivan (1961)—Early Eocene (*Discoaster tribrachiatus*-

zone) to Middle Eocene, Lodo-, Domengine- and Canos-
Formation, California, U.S.A. Stradner (1962)—Eocene
(Middle Eocene), Flysch Von Istrien. Sullivan (1964)—
Palaeocene-Eocene, Lodo Formation, California. Bystricka
(1964)—Early Middle Eocene, Solvakei. Locker (1965,
1968)—Early Late Eocene, Mecklenburg ; Eocene 3
and Eocene 5, northern Germany. Hay (1967)—Middle-
Late Eocene, Oceanic Formation, Barbados, Pant and
Mamgain (1966)—Eocene, Eocene (Kirthar), Kutch,
India. Takayama (1967)—Early to Middle Eocene,
? Late Eocene to Torton, Castell d' Arquato, Italy. Levin
and Joerger (1967)—Late Eocene, Little Stave Creek,
Alabama, U. S. Gartner and Smith (1967)—Late Eocene,
Yazoo Formation, Louisiana, U.S.A. Achuthan and
Stradner (1967) Late Eocene, Wemmelian Stratotype,
Belgium. Hoffmann (1966)—Late Eocene, Bohrung
Salzwedel. Perch-Nielson (1971)—Middle and Late
Eocene, Denmark. Badli-Beki (1971, 1972)—Early
Eocene-Late Eocene, Bakony Mountains, Hungary ; Late
Eocene, Bryozoan Marl, Buda Marl and Kiscell Clay,
Hungary. Bukry (1973)—Late Eocene, *Discoaster barba-*
diensis zone, Leg 16 cores from the East Pacific Rise (*Dis-*
coaster kuepperi zone or subzone to lower part of *Dis-*
coaster barbadiensis zone). Sadek and Teleb (1973)—Eocene
Section of Betty Well-1, northwestern desert, Egypt ; Late
Eocene, Mokattam Formation, *Discoaster barbadiensis* zone,
Ypresian, Early Eocene, Thebes Formation ; and Lutetian
(Middle Eocene), Minia Formation.

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 Univer-
sity.

Discoaster distinctus Martini

(Plate IV—6)

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

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

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

Distribution : Martini (1958)—Below Late Eocene
(Unters Ober-Eozan), NW Germany. Auchthan and
Stradner (1967)—Late Eocene, Wemmelian Stratotype,
Belgium. Edwards (1970)—Wemmelian, Asschian,
Auversian?, middle part of the Hampden Formation in
the Hampden Beach Section. Perch-Nielson (1971)—
Middle and Late Eocene, Denmark. Baldi-Bekc (1971)—
Middle Eocene-Late Eocene, Bakony Mountains, Hungary.
Sadek and Teleb (1973)—Middle Eocene, present through-
out *Discoaster subloadoensis* and *Discoaster barbadiensis* Zones,
Betty well-1, 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.

Discoaster elegans Bramlette and Sullivan

(Plate IV—7)

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

Specimens : Complete discoaster, Slide No. N.L.U. 40.

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

Distribution : Stradner (1969)—Early Eocene, Eocene Flysch, Hagenback Valley (northern Vienna Woods), Austria. Perch-Nielsen (1971)—Eocene, Denmark. Baldi-Beke (1971)—Priabonian, Borehole Balinka—219, 363.3-363.5 m., Hungary. Sadek and Teleb (1973)—Early Eocene, Thebes Formation, Middle Eocene, Minia Formation, and Early Eocene, Mokattam Formation, Betty Well-1, northwestern Egypt.

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.

Distribution : Pant and Mangain (1965)—Middle Eocene (Kirthar) and Oligocene (Nari), Kutch, India. Hay (1967)—Middle-Late Eocene, Oceanic Formation, Barbados. Edwards (1970)—Latest Kaiatan—Early Runangan, Priabonian, upper part of the Kaiato Mudstone, lower part of the Oamaru Diatomite, base of the Totara Limestone, and top of the Burnside Marl, New Zealand. Baumann (1970)—Late Eocene, *Globigerapsis mexicana* zone, Scagila Vairegata Formation, Italy. Perch-Nielsen (1971)—Late Eocene, Denmark. Baldi-Beke (1971, 1972)—Early Eocene—Late Eocene, Bakony Mountains ; Late Eocene, Bryozoan Marl, Buda Marl

and Kiscell Clay, Hungary. Bukry (1973)—Middle Eocene—Late Eocene, *Discoaster mirus* zone, *Chiasmolithus gigas* zone to *Discoaster barbadiensis* zone, Leg 16., cores from the East Pacific Rise. Sadek and Teleb (1973)—Late Eocene, Mokattam Formation, Betty Well-1, north-western desert, Egypt.

Horizons 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 ; Waiareken formation (Late Eocene), west of Oamaru, New Zealand ; Oceanic formation (Late Eocene), Bath, Barbados ; Gatuncillo 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 solitus* 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 : Heliolithaceae Hay and Mohler, 1967

Genus : *Heliolithus* Bramlette and Sullivan, 1961

Heliolithus sp. a.

(Plate IV—16-27)

Specimens : Seven complete helioliths, Slide Nos. N.L.U. 15, 25, 35, 83, 88.

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 $6\ \mu$ — $10.5\ \mu$.

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 birefringence figure in the crossed-nicols.

Horizon and locality : Brownish yellow fossiliferous marl ; $1\frac{1}{2}$ 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, 1935, 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 $12\ \mu$ — $22.5\ \mu$.

Distribution : Bramlette and Sullivan (1961)—Middle Eocene (Lutetian), Cipero formation. Stradner (1969)—Flysch, *Marthasterites tribrachiatus* Zone (Early Eocene) Hagenbach valley, Austria. Hodson and West (1970)—The British Upper Bracklesham Beds (Eocene), Hampshire. Baldi-Beke (1971)—Horizon poor in nannoplankton (Middle Eocene), *Isthmolithus recurvus* zone (Late Eocene) Bakony Mountains, Hungary. Black (1972)—Late Eocene, Mississippi; Middle Eocene, Bracklesham Bay, Sussex. Baldi-Beke and Baldi (1974)—Kiscellian Stage, NP 24, *Sphenolithus distinctus* Zone; Egerian stage, NP 25, *Sphenolithus ciperonensis* Zone, *Triquetrorhabdulus carinatus* Zone, Novaj profile, Hungary. Sadek 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 ; $1\frac{1}{2}$ 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.

Braarudosphaera discula Bramlette and Riedel
(Plate V—8-10)

Braarudosphaera discula Bramlette and Riedel, 1954, p.394, pl.38, fig7.

Specimens : Two pentoliths, Slide Nos. N.L.U. 30, 56.

Remarks : It agrees well with the description of the type species. Diameter $16.5\ \mu$ — $18\ \mu$.

Distribution : Bramlette and Riedel (1954)—Univer-sidad formation (Middle or Early Eocene), Loma Principe, Ave de los Presidentes, Havana, Cuba. Baldi-Beke (1971)—*Reticulofenestra placomorpha*—*Pemma rotundum* horizon (Middle Eocene) to *Zygolithus dubius*—*Discoaster florens* horizon (Middle Eocene), *Isthmolithus recurvus* Zone (Late Eocene), Bakony Mountains, Hungary. Baldi-Beke and Baldi (1974)—NP 25, *Sphenolithus ciperonensis* Zone, Egerian Stage, Navaj profile, Hungary. Sadek and Teleb (1974)—Thebes Formation (Ypresian), Minia Formation (Lutetian), Betty well-1, north-western desert, Egypt.

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.

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.

Specimens : Three complete pentoliths, Slide Nos. N.L.U. 30, 31.

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 pentoliths varies from $12\ \mu$ to $16.5\ \mu$ whereas, the diameter of the type species varies from $7\ \mu$ to $12\ \mu$. In crossed-nicols four segments of the pentolith 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 ; $1\frac{1}{2}$ 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.

Specimens : Five rods, Slide No. N.L.U. 11, 30.

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 ocean, 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.

INCERTAE SEDIS

Genus : *Coccolithites* Kamptner, 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 rim. 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 *Corannulus* Stradner, 1962

Corannulus germanicus Stradner

(Plate IV—30)

Corannulus 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—*Corannulus germanicus* Stradner. Diameter 15 μ .

Distribution : Stradner (1962)—Late Eocene, Steinbrucher Reingrubberhohe bei Bruderndorf, Niederosterreich. Locker (1973)—Late Eocene, Schonewalder Schichten, Sataakow Profilen.

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—*Corannulus 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, *Ericsonia muiri*, *Cyclococcolithina formosa*, *Reticulofenestra dictyoda dictyoda*, *R. placomorpha*, *R. pseudogammation*, *Thoracosphaera* sp., *Discoaster barbadiensis*, *D. distinctus*, *D. elegans*, *D. saipanensis*, *D. tani*, *Heliolithus* sp. a, *Braarudosphaera bigelowi*, *B. discula*-*Micrantholithus crenulatus*, *Triquetrorhabdulus inversus*?, *Coccolithites*? sp. and *Corannulus germanicus*.

AGE DETERMINATION

The brownish yellow fossiliferous marl has yielded characteristic Late Eocene foraminiferids—*Nummulites fabianii* (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). Prins (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). *Ericsonia muiri* has been recorded from the Middle Eocene (Black, 1964), Late Eocene (Iaccarino and Rio, 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 Wilcoxon, 1967). *Braarudosphaera bigelowi* is a long ranging form (Cretaceous to Recent). *Braarudosphaera 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). *Corannulus 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).

PALAEOECOLOGY

The relative distribution percentage of larger foraminiferids is very high in comparison to the smaller benthonic foraminiferids. The planktonic foraminiferids 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%), *Ericsonia* Black (1%), *Cyclococcolithina* Wilcoxon (1%), *Reticulofenestra* Hay, Mohlar and Wade (10%). *Thoracosphaera* Schiller (1%), *Discoaster* Tan Sin Hok (22%), *Heliolithus* Hay and Mohler (5%), *Braarudosphaera* Deflandre (10%), *Micrantholithus* Deflandre (3%), *Triquetrorhabdulus* Martini (5%), *Coccolithites*? Kamptner (1%) and *Corannulus* Stradner (1%).
3. *Reticulofenestra dictyoda dictyoda*—*Corannulus 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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EXPLANATION OF PLATES

PLATE I

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

PLATE II

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

PLATE III

- 1,2 *Ericsonia muiri* (Black) ; 1, long axis 45° to crossed-nicols ; 2, crossed-nicols, $\times 2600$.
 3-8 *Cyclococcolithina formosa* (Kamptner) ; 3, 6, transmitted light, $\times 2500$; 4, 8, crossed-nicols, $\times 2500$; 5, 7 long axis 45° to crossed-nicols, $\times 2600$.
 9-16 *Reticulofenestra dictyoda dictyoda* (Deflandre and Fert) ; 9, 11, 14, transmitted light, $\times 2500$; 10, 12, 15, crossed-nicols ; 13, 16, long axis 45° to crossed-nicols ; $\times 2600$.
 17-20 *Reticulofenestra placomorpha* (Kamptner and Deflandre) ; 17, 18, transmitted light, $\times 2500$; 19, long axis 45° to crossed-nicols ; 20, crossed-nicols, $\times 2600$.
 21-26 *Reticulofenestra pseudogammation* (Bauche) ; 21, 24, transmitted light, $\times 2500$; 22, 26, crossed-nicols ; 23, 25, long axis 45° to crossed nicols, $\times 2600$.
 27 *Thoracosphaera* sp.; broken part of a shell, transmitted light, $\times 2500$.

PLATE IV

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

PLATE V

- 1-3 *Micrantholithus crenulatus* Bramlette and Sullivan ; 1, 2, transmitted light, $\times 2500$; 3, crossed-nicols, $\times 2600$.
 4-7 *Braarudosphaera bigelowi* (Gran and Braarud) ; 4, 6, 7, transmitted light, $\times 2500$; 5, crossed-nicols, $\times 2600$.
 8-10 *Braarudosphaera discula* Bramlette and Riedel ; 8, 10, transmitted light, $\times 2500$; 9, crossed-nicols, $\times 2600$.
 11, 15 *Triquetrorhabdulus inversus* ? Bukry and Bramlette ; transmitted light, $\times 2500$.
 12-14 Crystals of calcite showing some resemblance with discoasters ; 12, 14, transmitted light, $\times 2500$; 12, crossed-nicols, $\times 2600$.

