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EARLY PLIOCENE DIATOMS AND SILICOFLAGELLATES FROM NEILL ISLAND, SOUTH ANDAMAN, INDIA, PART-I

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ABSTRACT

Of thirtyone species of diatoms recovered from the Round Formation of Neill island, three species are described as new. Four species of silicoflagellate are also recorded. The present assemblage of diatoms and silicoflagellates is dated as Early Pliocene with the help of planktonic foraminifers recovered from the same sample. The Round Formation was deposited in the middle to upper bathyal environments.

INTRODUCTION

Prior to the present work, Singh and Vimal (1973a, 1974) studied the planktonic foraminiferids obtained from the Round Formation (Sawai Bay Mudstone ; Sample No. S1) exposed along the northeastern coast of Neill Island (Fig. 1) and noticed the presence of diatoms and silicoflagellates in abundance in sample—S1. With a view to study the assemblage of diatoms and silicoflagellates of sample—S1 in detail, the writers undertook this study which may prove useful elsewhere for precisely dating the sediments and for regional as well as local correlation. Singh and Vimal (1974) dated the sample —S1 as Miocene—Pliocene and referred the planktonic foraminiferal assemblage of this sample to Zone N. 18, *Globorotalia (G.) tumida tumida—Sphaeroidinellopsis subdehiscens paenedehiscens* Partial—range zone (Late Miocene —Early Pliocene, Blow 1969). Berggren (1973) discussed in detail about the Miocene/Pliocene boundary and remarked that "The initial appearance of *S. dehiscens* was recorded[35] about 40 feet above the base of the Miocene/ Pliocene boundary is somewhat older than the N 18/ N 19 boundary. As noted below, it actually lies at the base of Zone N 18 or even slightly lower ; for all practical purposes it may be drawn at the base of Zone N 18". In view of this, the sample S1 (Round Formation) has now been dated as Early Pliocene.

While going through the literature, the writers have noticed that the diatoms are very useful in correlation, in dating the sediments, in making biostratigraphic zones and in deducing palaeoecology. Unfortunately, very little work has so far been carried out on this group in India, though India has a well-developed Tertiary belt

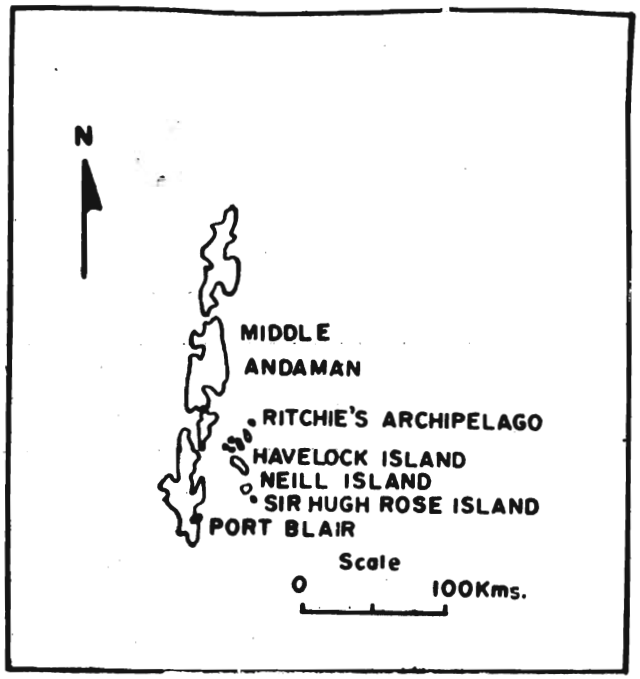

Fig. 1. Showing location of the area.

comprising Murrees and Siwaliks exposed along its northern border. By studying the diatoms from the Murrees and the Siwaliks, one may demarcate different biostratigraphic zones within these formations and may distinguish the Lower Siwalik from the Upper Murree. The writers have re-described some of the poorly described species of diatoms in the present paper.

Chatterjee (1967) suggested the following lithostratigraphic classification for the Archipelago Group of the Andaman Islands :

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Pleistocene and Recent		Swampy mud flats, Coral rags and raised beaches	
		—Unconformity—	
Neogene	Archipelago Group (Mio-Pliocene)	Long clay Formation	— 200'
		Guitar Limestone Formation	—1500'
		—Unconformiy—	
		Round Chalk and Silt Formation	—2000'
		Strait Sandstone Formation	—1700'
		—Unconformity—	
U. Eocene—(?) Oligocene		Port Blair Formation	—25000'

In view of the Preliminary Report on Lithostratigraphic Units (International Subcommission on Stratigraphic Classification, 1970, Canada), the Chatterjee's above lithostratigraphic classification can be amended in the following ways :

		Swampy mud flats Coral rags and raised beaches	
		—Unconformity—	
Neogene	Archipelago Group (Mio-Pliocene)	Long Formation	— 200'
		Guitar Formation	—1500'
		—Unconformity—	
		Round Formation	—2000'
		Strait Formation	—1700'
		—Unconformity—	
U. Eocene—(?) Oligocene		Port Blair Formation	—2500'

The writers have found that the Chatterjee's lithostratigraphic classification is very useful and is applicable to the various formations of Neill Island (Table-1).

In addition to these diatoms, the Round Formation (S1) has also yielded a rich assemblage of benthonic foraminiferds, sponge spicules and radiolaria, with a poor representation of ostracodes. The uppermost part (S2) of the Round Formation (Fig. 2) also contain diatoms, nannoplankton, foraminiferds, radiolaria and sponge spicules in a good number. The appearance of *Sphaeroidinella dehiscens dehiscens* forma *immatura* Blow alongwith *Globoquadrina altispira altispira* (Cushman and Jarvis) in the uppermost part (S2) of the Round Formation suggests an Early Pliocene age (Zone N. 19, *Sphaeroidinella dehiscens dehiscens—Globoquadrina altispira altispira* Partial—range zone, Banner and Blow, 1965 ; Blow, 1969) for it. The detailed study on the diatoms recovered from this part of the Round Formation is in progress and will be published elsewhere.

Ehrenberg (1851, 1854), Ghosh and Maitra (1947), Jacob and Srivastava (1952), Desikachary and Maheshwari (1958) and Mathur (1973) studied the marine diatoms from the Tertiary Formation of the Nicobar, Colebrook and Havelock islands.

This work was carried out in the Department of Geology, University of Lucknow, Lucknow. Hypotypes and specimens of diatoms have been deposited in the Museum, Department of Geology, Lucknow University, Lucknow.

Table 1—Showing stratigraphy of Neill island

Age	Group	Formations (Singh and Vimal (1973c))	Present work (Formations)
Holocene		Neill Island Coral Beds: Bioclastic Limestone Thickness—1.5 m.; Shelly Limestone Thickness—0.30 m.; Coral Beds Thickness—3m.	Neill Island Coral Beds: BioclasticLimestone Thickness—1.5m.; Shelly Limestone Thickness—0.30 m.; Coral Beds Thickness—3m.
————	Archipelago	————Unconformity————	————Unconformity————
Late Pleistocene		Malacca Limestone ; thickness—4m.	Malacca Limestone ; thickness—4m.
.....		.....?.....?.....?....	.....?.....?.....?....
Late Pliocene—Early Pleistocene		Sawai Bay Limestone ; thickness—3.4 m.	Guitar Formation; thickness 3.4 m.
.....		.....Unconformity.....	Unconformity .....
Late Miocene—Early Pliocene		Sawai Bay Mudstone ; thickness—155 m. (Base not exposed)	Round Formation ; thickness—155m. (Base not exposed)

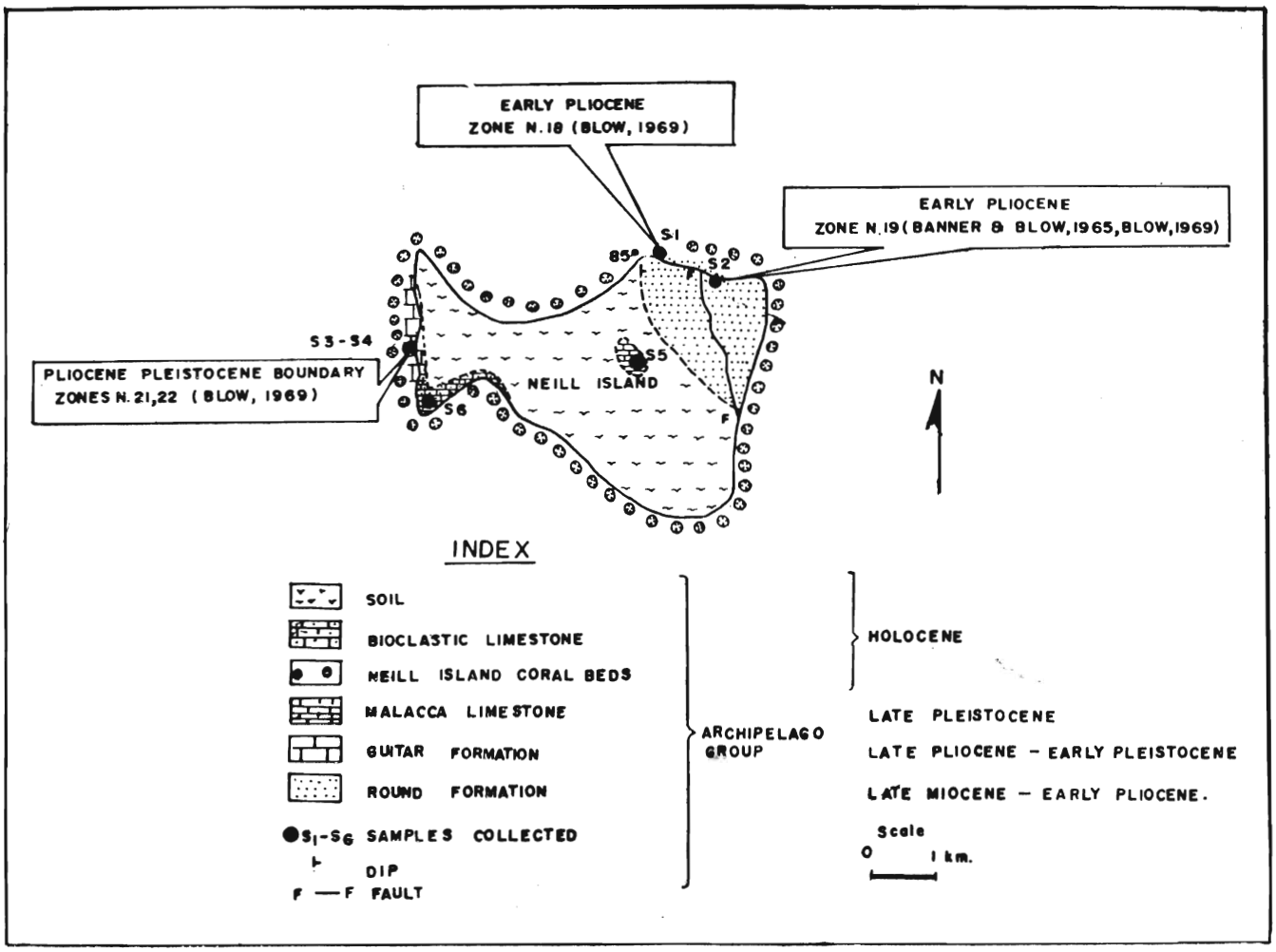

Fig. 2. Showing the location of the samples (Singh and Vimal. 1973c).

Table 2—Showing the frequency distribution of Diatoms and Silicoflagellates in the upper part (S 1) of the Round Formation.

Sl. No.	Species	Frequency distribution
	DIATOMS	
1.	*Actionocyclus ellipticus*	C
2.	*Actinoptychus undulatus* var. *undulatus*	R
3.	*Arachnoidiscus ehrenbergii*	R
4.	*Arachnoidiscus rajui*	R
5.	*Arachnoidiscus sastryi*	R
6.	*Arachnoidiscus talukdari*	R
7.	*Asteromphalus* sp. 1.	VR
8.	*Asteromphalus* sp. 2.	VR
9.	*Asteromphalus ? marylandica*	VR
10.	*? Campylodiscus* sp.	
11.	*Campyloneis* sp.	
12.	*Cladogramma* sp.	
13.	*Cocconeis* sp. 1	VR
14.	*Cocconeis* sp. 2	
15.	*Cocconeis ? punctatissima*	VR
16.	*Coscinodiscus* sp. 1	R
17.	*Coscinodiscus* sp. 2	VR
18.	*Coscinodiscus* sp. 3	VR
19.	*Coscinodiscus asteromphalus*	VR
20.	*Coscinodiscus asteromphalus* var. *omphalantha*	VR
21.	*Coscinodiscus excentricus* var. *leasareolatus*	VR
22.	*Coscinodiscus lineatus*	VR
23.	*Coscinodiscus marginatus*	VR
24.	*Coscinodiscus oculus—irridis*	VR
25.	*Coscinodiscus pacificus*	R
26.	*Coscinodiscus rothii*	R
27.	*Cyclotella* sp.	R
28.	*Diploneis ? crabro*	R
29.	*Navicula ? lyra*	VR
30.	*Triceratium favus*	R
	SILICOFLAGELLATES	
31.	*Dictyocha ausonia*	C
32.	*Dictyocha fibula*	C
33.	*Dictyocha speculum*	C
34.	*Mesocene circulus* var. *apiculata*	R

Index : VR—Very Rare—One specimen per slide. R—Rare—2-5 specimens per slide. C—Common—6-10 specimens per slide.

SYSTEMATIC DESCRIPTION

Genus *Actinocyclus* Ehrenberg, 1938

Antinocyclus ellipticus Grunow

(Pl. I—1-4)

Actinocyclus ellipticus Grunow; Kanaya, 1971, p. 554, pl. 40.5, figs.1-3.

Remarks : The present form agrees with *Actinocyclus ellipticus* Grunow reported from the Late Miocene rocks (cores obtained by Swedish Deep-Sea Expedition 1976) by Kanaya (1971). It shows variation in the shape of the valve from elliptical to oval. Kanaya (1971) considered it as a Late Miocene species in the experimental Mohole section ; Length : 0.0375 mm.—0.0780 mm ; Width : 0.0240 mm.—0.060 mm.

Genus *Actinoptychus* Ehrenberg, 1843

Actinoptychus undulatus (Bailey) Ralfs in Pritchard 1861 var. *undulatus* f. *undulatus*

(Pl. I—5, 6)

Actinoptychus undulatus (Bailey) Ralfs, Hustedt, 1929, p. 475, fig. 264.

Actinoptychus undulatus (Bailey) Rafls, Desikachary and Maheshwari, 1958, p. 32, text-fig. 11.

Remarks : It is identical with the illustration (Text-fig. 11) of *Actinoptychus undulatus* (Bailey) Ralfs given by Desikachary and Maheshwari (1958) who reported it from the Miocene rocks of Colebrook island. Subrahmanyan (1946) recorded it from the sea water of the Madras coast. Cupp (1943, p. 67) considered it : as "Neritic bottom form, frequently found in plankton.... of very wide distribution". Diameter : 0.0270 mm.—0.0600 mm.

Genus *Arachnoidiscus* Deane ex. Pritchard, 1852

Arachnoidiscus ehrenbergii Bailey ex. Ehrenberg, 1849

(Pl. I—7-8, 10-11)

Arachnoidiscus ehrenbergii Bailey; Long, Fuge, and Smith, 1946, p. 95, pl. 13, fig. 6; Wornardt, 1969, fig. 19 (12).

Remarks : Valve rounded and flat. Margin entire, and consists of fine striae arranged parallel to each other in a linear pattern. Radial ribs distinct, originating from the margin and terminating in the central hyaline area ; their number vary from 23 to 25, a short rib present in the centre in between the two corresponding radial ribs at the margin. Areolae distinct, small in size and arranged in concentric slightly undulating rows indefinite in number. Central part of the valve resembles the central region of an umbrella in outline, central hyaline area well-developed.

Long *et al.* (1946) reported this species from the Moreno Shale (Late Cretaceous), California, U.S.A. Wornardt (1969) recorded it from the Early and Middle Pliocene rocks of California. The form described by Long *et al.* (1946) has 20 radial ribs. The specimen illustrated by Wornardt (1969) has 24 radial ribs. Our specimens have been found to contain 23 to 25 radial ribs. It ranges in age from the Late Cretaceous to the Recent. Hendey (1937, p. 267) described the ecology of this species and stated that it "favours tropical and subtropical waters" and is a "littoral diatom ; it probably spends part of its time as a bottom form, epiphyitc often upon red algae and corallines ; sometimes found in large numbers". In Neill Island, it occurs in the Round Formation deposited in middle to upper bathyal environment. Diameter : 0.3300 mm.—0.3600 mm.

Arachnoidiscus rajui sp. nov.

(Pl. I—9, 12)

Etymology : The species is named after Dr. A. T. R. Raju, Deputy Superintending Geologist, Institute of Petroleum Exploration, O. N. G. Commission, Dehra Dun.

Holotype : A. complete valve, Slide No. D.L.U. 1 (Plate I—12)

Paratype : A complete valve, Slide No. D.L.U. 2 (Pl. 1—9).

Description : Valve rounded to subrounded. Margin wavy and consists of small striae arranged in a linear fashion, radial ribs, and small ribs ; a distinct rounded row of areolae present just beneath the margin ; each areola occurs in between the two corresponding small striae at the margin. Radial ribs distinct, originating from the margin and reaching to the centre of the valve ; their number vary from 22 to 23 ; a short rib present in the centre in between the two corresponding radial ribs at the margin, on either side of this short rib three small striae occur. Areolae prominent, rounded to rectangular in shape, arranged in concentric rows ; the size of areolae grows gradually larger from the periphery to the centre, the number of rows of areolae varies from 16 to 17 ; generally eight areolae occur in between the two corresponding radial ribs at the margin. Diameter : 0.1320 mm.—0.1576 mm.

Remarks : The present new species resembles *Arachnoidiscus evanescens* Brown and *A. decorus* Brown in outline but differs from them in having more concentric rows of areolae and different arrangement of fine striae at the margin It can be easily distinguished from he *A. ehrenbergii* Bailey in lacking central hyaline area. It differs from its associated new species. *A. talukdari* in having different type of thearrangement of areolae and radial ribs. It can also be differentiated from *A. indicus* Ehrenberg and *A. manni* Hanna and Grant in having small areolae and larger number of long radial ribs.

Type locality : Northeastern coast of Neill Island.

Type horizon : Round Formation.

Age : Early Pliocene (Zone N. 18, Blow, 1969).

Repository : Museum, Department of Geology, Lucknow University

Arachnoidiscus sastryi sp. nov.

(Pl. II—1-3)

Etymology: The species is named after Sri J. C. V. Sastry, Department of Geology, Nanasa Gangotri, Mysore 6.

Holotype : A complete valve, Slide No. D.L.U. 3.

Description : Valve circular and flat. Margin dentate, small ribs projecting out from the margin. Radial ribs prominent, originating from the margin and terminating at the centre of the valve, 30 in number ; a small rib present in the centre in between the two corresponding radial ribs at the margin, and on either side of this small rib three fine ribs occur. Central hyaline area distinct, several small ribs radiating from its margin. Areolae distinct, circular in shape, arranged in closely placed concentric rows, and indefinite in number ; square to rectangular type of net-work distinct. Diameter : 0.3750 mm.

Remarks : It differs from *A. talukdari* sp. nov., *A. rajui* sp. nov., and *A. ehrenbergii* Bailey in having dentate margin of the valve (pl. 2, fig. 3). It resembles *A. evanescens* Brown in outline but differs from the latter in having a central hyaline area and dentate margin.

Type locality : Northeastern coast of Neill Island.

Type horizon : Round Formation.

Age : Early Pliocene (Zone N. 18, Blow, 1969)

Repository : Museum, Department of Geology, University, Lucknow.

Arachnoidiscus talukdari sp. nov.

(Pl. II—4-6)

Etymology : The species is named after well-known geologist, Sri S. N. Talukdar, Director, Institute of Petroleum Exploration, Oil and Natural Gas Commission, Dehra Dun.

Holotype : A complete valve, Slide No. D.L.U. 4.

Description : Valve rounded and flat. Margin entire, thick and consists of fine small striae arranged parallel to each other in a linear fashion, radial ribs and small ribs. Radial ribs prominent, originating from the margin and terminating in the central part of the valve, 38 in number ; a small rib present in the centre in between the two corresponding radial ribs at the margin ; 3 to 4 small striae occur on either side of this small rib. Areolae distinct, rectangular in shape, arranged in concentric row, closely placed and indefinite in number. Diameter : 0.3225 mm.

Remarks : It closely resembles *A. evanescens* Brown in outline but differs from the latter in having larger number of radial ribs and closely placed concentric rows of areolae. It differs from the *A. rajui* sp. nov., *A. indicus* Ehrenberg, and *A. manni* Hanna in having larger number of radial ribs and closely spaced concentric rows of areolae.

Type locality : Northeastern coast of Neill island.

Type horizon : Round Formation.

Age : Early Pliocene (Zone N. 18, Blow, 1969).

Repository : Museum, Department of Geology, Lucknow University.

Genus *Asteromphalus* Ehrenberg, 1844

Asteromphalus sp. 1

(Pl. II—7, 8)

Description : Valve oval. Margin entire, with thick border. Middle field excentric. Rays distinct,curved, originating from the centre and terminating at the margin, number of rays varies from 7 to 11. Areolae distinct, small and rounded in shape.

Diameter : 0. 0330 mm.—0.0465 mm.

Remarks : Two well-preserved specimens of this species have been found.

Asteromphalus sp. 2

(Pl. II—9)

Description : Valve circular, with radiating rays. Sector line unbranched, twelve sectors distinct. Hyaline rays prominent, twelve in number, long, and slightly curved. Diameter of the central region : 0.0300 mm.

Remarks : The valve of this species is very delicate and fragile. A broken part of the valve representing only the central area has been found.

Asteromphalus ?marylandica (Ehrenberg)

(Pl. II—10)

Asteromphalus marylandica (Ehrenberg); Desikachary and Maheshwari, 1958, p. 32, text fig. 11.

Remarks : The present form agrees with *Asteromphalus marylandica* (Ehrenberg) described by Desikachary and Maheshwari (1958) from the Diatomaceous Earth of Colebrook island. Our specimen has nine rays whereas the form described by Desikachary and Maheshwari (1953) has only eight rays. Diameter of central disc : 0.0300 mm.

Genus *Campylodiscus* Ehrenberg, 1841

? Campylodiscus sp.

(Pl. V—7, 8)

Description : Valve elliptical. Margin entire. Radial ribs distinct, indefinite in number, radiating from the central rounded region. Length : 0.1515 mm.; Width : 0.1200 mm.

Remarks : Only a very-well preserved specimen of this species has been found.

Genus *Campyloneis* Grunow, 1862

Campyloneis sp.

(Pl. II—11, 12)

Description : Valve elliptical, asymmetrical. Margin finely dentate, convex, and with thick borders having fine striae. Ends obtuse, axial area of the medium size, lanceolate in shape. Raphe indistinct. Ribs prominent, 6 to 7 ribs present on each side of the axial area and obliquely arranged, ribs joined with lateral margin of the valve, and at their junctions rounded beads present. Punctae small and rounded in shape, interrib area contains two or more striae and 2 to 4 rows of punctae. Length : 0.0315 mm.—0.0330 mm. ; Width : 0.0180 mm.—0.0210 mm.

Remarks : Ghosh and Maitra (1947) recorded this species from the Diatomaceous Earth exposed in this Nicobar islands.

Genus *Cladogramma* Ehrenberg, 1844

Cladogramma sp.

(Pl. III—7, 10)

Description : Valve circular, small. Margin dentate. Radial ribs distinct, bifurcate into smaller branches. Concentric rows of small punctae distinct. Diameter : 0.0225 mm.—0.0270 mm.

Genus *Cocconeis* Ehrenberg, 1838

Cocconeis sp. 1

(Pl. III—1)

Description : Valve oval. Margin entire. Axial pseudoraphe indistinct. Vertical striae prominent, curved and undulating, indefinite in number. Length : 0.0765 mm.; Width : 0.0645 mm.

Remarks : Only a single well-preserved valve of this species has been found.

Cocconeis sp. 2

(Pl. III—2, 3)

Description : Valve oval. Margin entire. Axial pseudoraphe distinct. Vertical ribs prominent, dentate, and curved ; Sometimes broken transverse striae present, poorly visible. Length : 0.0495 mm.—0.0825 mm ; Width : 0.345 mm.-0.0600 mm.

Remarks : Two well-preserved valves of the present species have been found.

Cocconeis ? *punctatissima* Greville and Karsten

(Pl. III—4)

Cocconeis punctatissima Greville and Karsten; Ghosh and Maitra, 1947. p. 446, pl. 29, fig. 9.

Remarks : Valve elliptical, Margin dentate and convex. Ends obtuse. Raphe distinct, dividing the central nodules into two parts. Central and polar nodules distinct. Punctae distinct, about 40 transverse rows of punctae bending at the poles ; more or less straight in the middle part of the valve. Length : 0.0480 mm. ; Width : 0.0315.

It agrees with the figure (pl. 29, fig. 9) of *Cocconeis punctatissima* Greville and Karasten given by Ghosh and Maitra (1947) who reported it from the Diatomaceous Earth of the Nicobar Islands.

Genus *Coscinodiscus* Ehrenberg, 1838

Coscinodiscus sp. 1

(Pl. III—8)

Description : Valve circular, flat and large. Margin entire, thin and consists of fine vertical striae arranged parallel to each other. Central area occupied by thick, small, subhexagonal areolae arranged irregularly. Diameter 0.0540 mm.

Coscinodiscus sp. 2

(Pl. IV—2)

Description : Valve circular, flat and large. Margin dentate and thin. Central area consists of large hexagonal to subhexagonal areolae which become smaller in size near the margin. Diameter : 0.0067 mm.

Coscinodiscus sp. 3

(Pl. IV—5)

Description : Valve circular, flat and small. Margin entire, thin and consists of fine vertical striae arranged parallel to each other. Central area consists of small, thick, subhexagonal areolae arranged in different patterns ; a rounded large areola present in the centre ; smaller sub-hexagonal areolae constitute the marginal area. Diameter : 0.0045 mm.

Coscinodiscus asteromphalus Ehrenberg

(Pl. III—5, 6)

Coscinodiscus asteromphalus Ehrenberg; Wornardt, 1971, p. 1279, pl. 4, figs. 1-9.

Remarks : The present form is identical with the species *Coscinodiscus asteromphalus* described by Wornardt (1971) from the Sisquoc Formation, Purisima Hills, California. It has also been recorded from the Diatomaceous Earth of Colebrook Island (Desikachary and Maheshwari, 1958), sea water of Madras coast (Subrahmanyan, 1946), and Distomaceous Earth of Oki Island (Okuno, 1967). Hendey (1937, p. 244) remarked on this species that it is "a neritic diatom, favouring a fairly high salinity". He further stated that it "was observed only in material from the Pacific Ocean". Hendey (1964, p. 78) considered it as "A pelagic plankton species with world wide distribution". In Neill Island, it is distributed rarely in the Round Formation deposited in the middle to upper bathyal environments. Diameter : 0.0037 mm.

Coscinodiscus asteromphalus var. *omphalantha* (Ehrenberg) Grunow

(Pl. IV—3)

Coscinodiscus asteromphalus var. *omphalantha* (Ehrenberg) Grunow, Wornardt, 1967b, p. 20, fig. 19.

Remarks : It closely resembles photomicrograph (1967b, fig. 19) of *Coscinodiscus asteromphalus* var. *omphalantha* Grunow published by Wornardt who recorded it from the Monterey Formation (Late Miocene), California, U.S.A.

Coscinodiscus excentricus var. *leasareolatus* Kanaya

(Pl. III—9 ; Pl. IV—4)

Coscinodiscus excentricus var. *leasareolatus* Kanaya in Kanaya & Koizumi Koizumi, 1973, p. 832, pl. 3, 7-10.

Remarks : It is identical to *Coscinodiscus excentricus* var. *leasareolatus* Kanaya. It is distributed in the Late Miocene to the Pliocene rocks. Diameter : 0.0225 mm.—0.0060 mm.

Coscinodiscus lineatus Ehrenberg

(Pl. III—11, 12)

Coscinodiscus lineatus Ehrenberg, Wornardt, 1971, p. 1279, pl. 4, figs. 10, 11, pl. 5, figs. 1-12.

Remarks : Wornardt (1971) studied this species in detail and recorded it from the Monterey Formation (Late Miocene), Lompoc, California. Long *et al.*, (1946) recorded it from the Moreno shale (Late Cretaceous) exposed in the San Joaquin Valley, California. Sournia (1971) reported it from the Indian ocean. Subrahmanyan (1946) recorded it from the sea water of the Madras Coast. Hendey (1937, p. 243) considered it as a truly neritic diatom in temperate and subtropical seas. The present study reveals that it is not confined to neritic as indicated by Hendey (1937) but also occurs in the middle to upper bathyal sediments, e.g. the Round Formation, Neill Island. Kanaya (1959) holds the opinion that "the high frequency of this species in a diatom thanatocoenosis indicates that its accumulation has taken place under the prevalence of tropical or sub-tropical waters, rather than of temperate or cold ones.' 'According to Wornardt (1967b), it ranges in age from the Late Cretaceous to the Recent. Diameter : 0.0037 mm.—0.0075 mm.

Coscinodiscus marginatus Ehrenberg

(Pl. IV—1)

Coscinodiscus marginatus Ehrenberg; Wornardt, 1971, p. 44, pl. 3, figs. 1-5.

Remarks : It is almost identical with those illustrated by Wornardt (1967a) from the late Bickmore Canyon Diatomite (Late Miocene). Wornardt (1967a) has also recorded it from the Pancho Rice Formation (Early Pliocene). Long *et al.*, (1946) reported this species from the Moreno shale (Late Cretaceous). Wornardt (1971) recorded it from the Monterey formation (LateMiocene), Newport Beach, California and re-studied it in detail with the help of Scanning Electron Microscope. Sournia (1971) reported this species from the Indian Ocean. It is known to occur in the Late Cretaceous to the Recent sediments (Wornardt, 1967b). Diameter : 0.0037 mm.

Coscinodiscus ? oculus—irridis Ehrenberg

(Pl. IV—6, 7)

Coscinodiscus oculus—irridis Ehrenberg; Wornardt, 1967a, pp. 50, 51, fig. 7.

Remarks : It tallies with the photomicrograph (Pl. 1, fig. 7) of hypotype of the species *Coscinodiscus oculus—irridis* Ehrenberg given by Wornardt (1967a) who reported it from the Bickmore Canyon Diatomite (Late Miocene, Delmontian), U.S.A., type *Bolivina obliqua* Zone (Late Miocene, Delmontian), Sisquoc Formation (Early to Middle Pliocene), Etchegoin Formation (Early to Late Pliocene) and San Jaoquin Formation (Early to Late Pliocene). Okuno 1967 recorded it from the Diatomaceous earth of Oki island, Japan. Hendey (1937, p. 249 remarks that this is "probably an oceanic species, but in the material examined it was always found as a meroplanktonic form". Hendey (1964, p. 78) considers that "It is an oceanic pelagic species found all over the world". According to Wornardt (1967b), it ranges in age from the Late Eocene to the Recent. Diameter : 0.0106 mm.

Coscinodiscus pacificus Rattray

(Pl. IV—8)

Coscinodiscus pacificus Rattray, Wornardt, 1969, fig. 19(11).

Remarks : It closely resembles the photomicrographs (1969), fig. 19(11) 1967 ; pl. 2, fig. 7) of *Coscinodiscus pacificus* Rattray published by Wornardt who recorded it from the type Monterey Formation (Late Miocene, Delmontian), Sisquoc Formation (Early to Middle Pliocene) and from San Joaquin Formation (Early to Late Pliocene) of U.S.A. It occurs in the Middle Miocene to Recent marine sediments. Diameter : 0.1290 mm.

Concinodiscus rothii Grunow

(Pl. IV—9)

Coscinodiscus rothii Grunow, Wornardt, 1969, fig. 26 (3).

Remarks : It has been reported from the Middle Miocene strata of California, Japan and Java. The illustrated form is identical with the photomicrograph of *Coscinodiscus rothii* Grunow published by Wornardt (1969). Diameter : 0.0270 mm.

Genus Cyclotella Kutzing, 1834

Cyclotella sp.

(Pl. IV,—10-11)

Description : Valve circular. Margin dentate. Punctae distinct, rounded and arranged in two concentric rings. Striae distinct and running towards the centre from the inner margin of the inner concentric ring of punctae. Central part of the valve appears smooth. Diameter : 0.0165 mm.—0.0330 mm.

Genus *Diploneis* Ehrenberg, 1844

Diploneis ? crabro (Ehrenberg) Ehrenberg

(Pl. IV—12)

Diploneis crabro (Ehrenberg) Ehrenberg; Wornardt; 1967b, p.85, fig. 201

Remarks : It resembles the photomicrograph of *Diploneis crabro* (Ehrenberg) Ehrenberg published by Wornardt (1967b) who recorded it from the Monterey formation (Late Miocene). Hendey (1964, p. 225) considered it as "A marine species favouring a high salinity". Length : 0.1245 mm.

Genus *Navicula* Bory, 1822

Navicula ? lyra Ehrenberg

(Pl. V—2)

Navicula lyra Ehrenberg, Ghosh and Maitra, 1947, p. 445, pl. 24, fig. 1.

Remarks : The present form resembles closely the figure (pl. 24, fig. 1) of *Navicula lyra* Ehrenberg given by Ghosh and Maitra (1947) who recorded it from the Diatomaceous Earth of the Nicobar islands. But our form slightly differs from the specimen reported from the Diatomaceous Earth of the Nicobar islands in not having a slightly constricted middle portion of the valve. Length : 0.0480 mm.; Width : 0.0316 mm.

Genus *Triceratium* Ehrenberg, 1840

Triceratium favus Ehrenberg

(Pl. V—1, 12)

Triceratium distinctum Janisch and Karsten, Ghosh and Maitra, 1947, pl. 24; fig. 14.

Triceratium favus Ehrenberg; Wornardt, 1967b, p. 66, fig. 124

Remarks : Valve triangular. Margin entire, slightly convex with thick borders containing small rounded areolae arranged in a linear fashion. Ends angular, angle between the two adjacent sides varies between 69° and 84°. Pores distinct, rounded in shape, three in number, each placed on the corner of the valve. Surface sculptured by medium-sized hexagonal markings and on the lateral margins of the valve half hexagonal markings present. Length of the long axis of the valve : 0.0780 mm.—0.1050 mm.

Ghosh and Maitra (1947) recorded it from the Diatomaceous Earth of the Nicobar islands. It ranges in age from the Late Miocene to the Recent.

Gen. and sp. indet

(Pl. V—3, 6, 10)

Description : Valve circular, and flat. Margin thick, elevated and wavy ; each convex part of the wavy margin contains a peculiar structure consisting of a pair of kidney shaped bodies separated from each other by a median groove and arranged at a regular interval ; a thin rib originates from the back side of the kidney shaped bodies and goes inside the valve ; the margin consists of three parts—outer, middle and inner margins ; the outer margin consists of fine, parallel striae and wavy margin consisting of two to three concave rows of rounded areolae ; the last row of the areolae facing the outer margin contains elongated areolae ; the middle margin consists of slightly elongated radiating areolae ; the inner margin consists of three distinct concentric rows of fine striae, traversed by fine ribs. Areolae distinct, rounded and arranged in a closely placed concentric rows formed by the fine network of concentric and radiating striae. Diameter : 0.3120 mm.

SILICOFLAGELLATES

Genus *Ditcyocha* Ehrenberg, 1839

Dictoyocha ausonia Deflandre

(Pl. V—5, 9, 11 ; Pl. VI—1, 4)

Dictyocha ausonia Deflandre; Wornardt, 1970a, pl. 3, figs. 11-12.

Remarks : It resembles *Dictyocha ausonia* Deflandre reported by Wornardt (1970a, 1971) from the Relizian and Luisian Stages (Middle Miocene), Newport Beach, California and Monterey Formation (Late Miocene), Newport Beach, California. Ling (1971) recorded this species from the Shinzan diatomaceous mudstone member, Onnagawa Formation (Miocene), Northeast Japan. The length of the basal body ring : 0.0300 mm.—0.0450 mm.

Dictyocha fibula Ehrenberg

(Pl. VI—2, 3)

Dictyocha fibula Ehrenberg; Wornardt, 1971, pl.15, figs. 1-9.

Remarks : Wornardt (1971) recorded the present species from the Monterey Formation (Late Miocene), Lompoc, California. Ling (1971) and Ling and Kurihara (1972) reported it from the Shinzan diatomaceous mudstone member, Onnagawa Formation (Miocene), northeast Japan, and the Hayana Group (Early to early Middle Miocene), Kanagawa Prefecture, Japan respectively. Length of the basal body ring : 0.0225 mm.—0.0570 mm.

Genus *Distephanus* Stohr, 1880

Distephanus speculum (Ehrenberg)

(Pl. VI—7-9)

Dictyocha speculum Ehrenberg, 1839, p. 129, p. 13, figs. 5-7; Bachmann, 1964, pp. 99-100. pl. 2, figs. 9-11; Wornardt, 1971, p. 1282, pl. 15, figs. 1-9.

Distephanus speculum (Ehrenberg), Ling and Kurihara, 1972, pp. 35, 36, pl. 1, fig. 17.

Remarks : It is well-preserved and has been reported from the Shinzan diatomaceous mudstone member, Onnagawa Formation (Miocene), northeast Japan (Ling, 1971), Monterey Formation (Late Miocene), Lompoc, California (Wornardt, 1971), and the Hayana Group (Early to early Middle Miocene), Kanagawa Prefecture, Japan (Ling and Kurihara, 1972). Length of the basal body ring : 0.0165 mm.—0.0225 mm.

Genus *Mesocena* Ehrenberg, 1843

Mesocena circulus var. *apiculata* Lemmermann

(Pl. VI—5, 6)

Mesocena circulus var. *apiculata* Lemmermann, 1901, p. 257, pl. 10, figs. 9, 10; Ling, 1971, pp. 692-693, pl. 1, figs. 14-16.

Remarks : It agrees well with description and illustration (Pl. 1, Fig. 14-16) of Ling (1971) who recorded it from the Shinzan diatomaceous mudstone member, Onnagawa Formation (Miocene), northeast Japan. Diameter of the basal body ring: 0.0600 mm.—0.0660 mm.

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EXPLANATION OF PLATES

PLATE I

1-4 *Actinocyclus ellipticus* Grunow, valve views, ×640

5,6 *Actinoptychus undulatus* (Bailey) Ralfs in Pritchard var. *undulatus* f. *undulatus*, valve views, ×640

7,8,10,11 *Arachnoidiscus ehrenbergii* Bailey, 7, 10, valve views, ×110 ; Fig. 8, enlarge view of the central part of the valve, ×370 ; 11, enlarge view of the margin of the valve, ×370

9,12 *Arachnoidiscus rajui* sp. nov., valve views, ×250

PLATE II

1-3 *Arachnoidiscus sastryi* sp. nov., 1, valve view, ×110 ; 2, enlarge view of the central part of the valve, ×370 ; 3, enlarge view of the margin of the valve, ×370.

4-6 *Arachnoidiscus talukdari* sp. nov., 4, valve view, ×110 ; Fig. 5, enlarge view of the central part of the valve, ×370; 6, enlarge view of the margin of the valve, ×370.

7,8 *Asteromphalus* sp., 1, valve views, 7, ×910 ; 8, ×640.

9 *Asteromphalus* sp. 2, valve view, ×640.

10 *Asteromphalus* ? *marylandica* (Ehrenberg), valve view, ×640.

11,12 *Campyloneis* sp., valve views, 11, ×640 ; 12, ×939.

PLATE III

1 *Cocconeis* sp. 1, valve view, ×640.

2,3 *Cocconeis* sp. 2, valve views, ×640.

4 *Cocconeis* ? *punctatissima* Greville and Karsten, valve view, ×640.

5,6 *Coscinodiscus asteromphalus* Ehrenberg, 5, valve view, ×250 ; 6, enlarge view of the valve, ×370.

7,10 *Cladogramma* sp., valve views, 7, ×640, 10, ×444.

8 *Coscinodiscus* sp. 1, valve view, ×640.

9 *Coscinodiscus excentricus* var. *leasareolatus* Kanaya, valve view, ×640.

11,12 *Coscinodiscus lineatus Ehrenberg*, valve views, ×640.

PLATE IV

1 *Coscinodiscus marginatus* Ehrenberg, valve views, ×640.

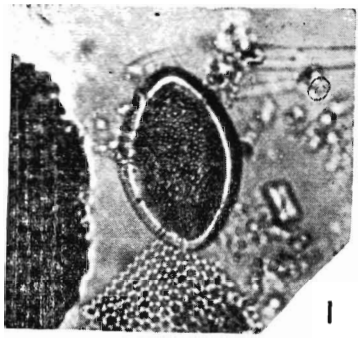
2 *Coscinodiscus* sp. 2, valve view, ×640.

3 *Coscinodiscus asteromphalus* var. *omphalantha* (Ehrenberg) Grunow, valve view, ×640.

4 *Conscinodiscus excentricus* var. *leasareolatus* Kanaya, valve view, ×640.

5 *Coscinodiscus* sp. 3, valve view, ×640.

6,7 *Coscinodiscus*? *oculus-irridis* Ehrenberg, valve views, ×640.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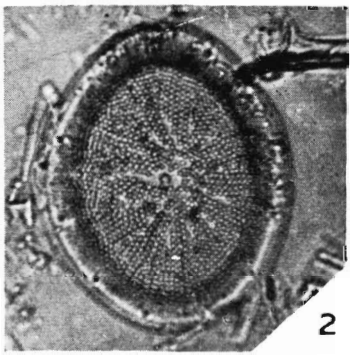
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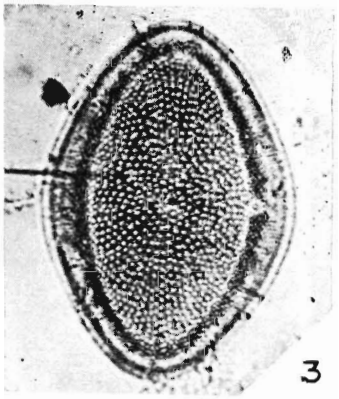
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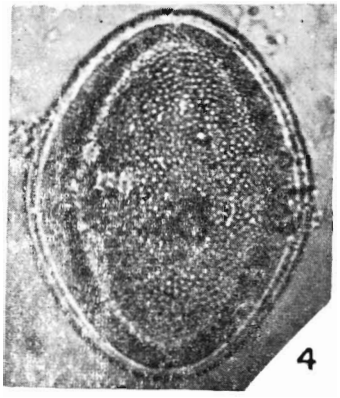
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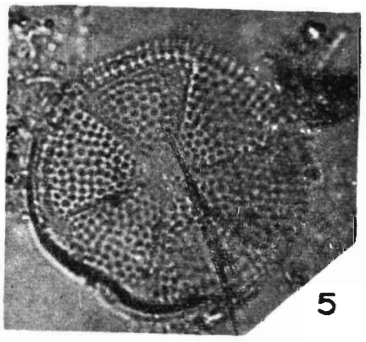
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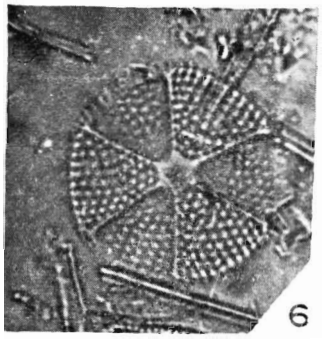
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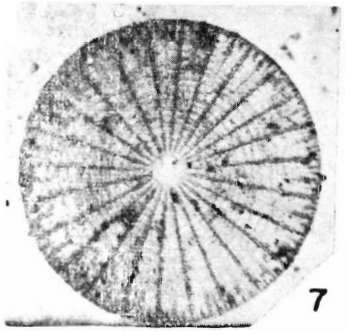
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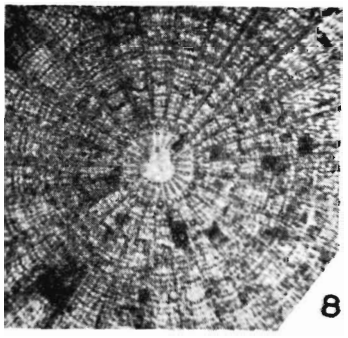
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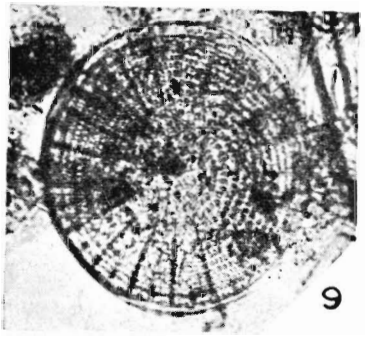
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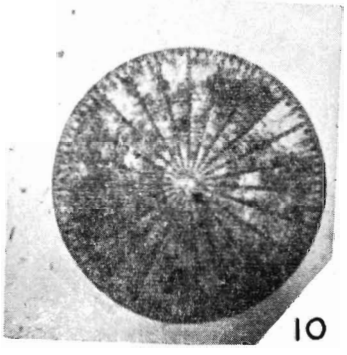
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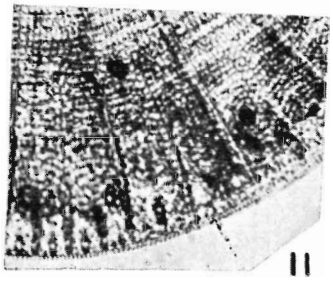
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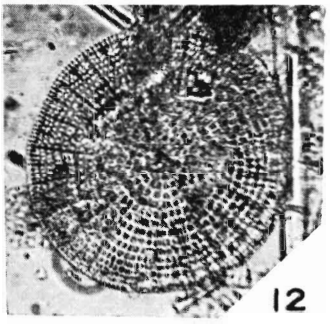
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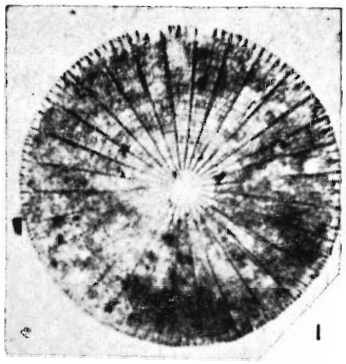
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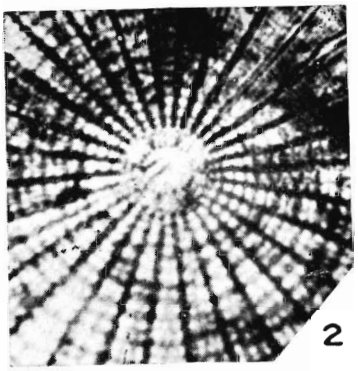
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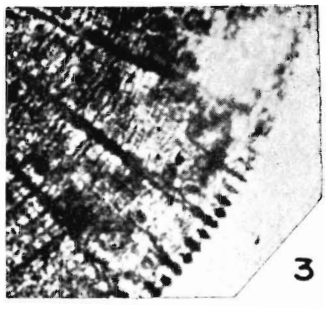
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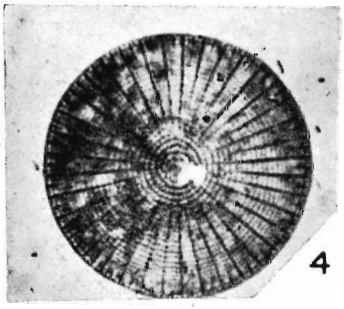
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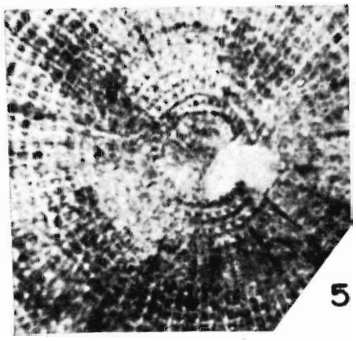
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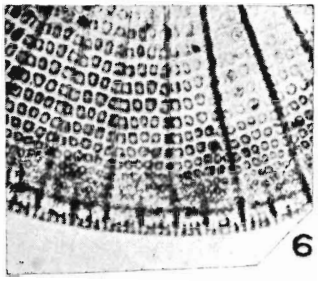
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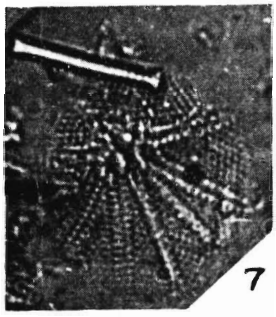
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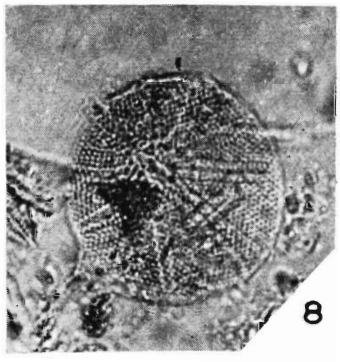
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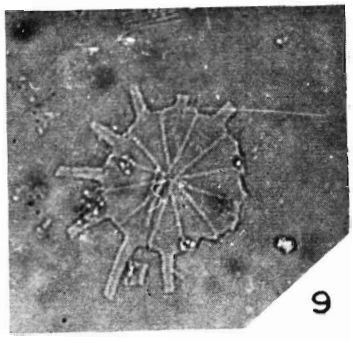
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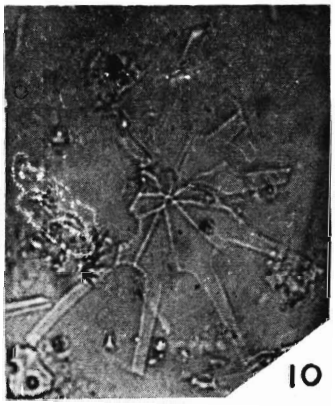
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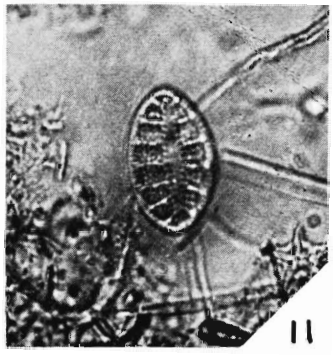
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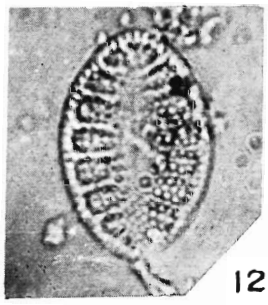
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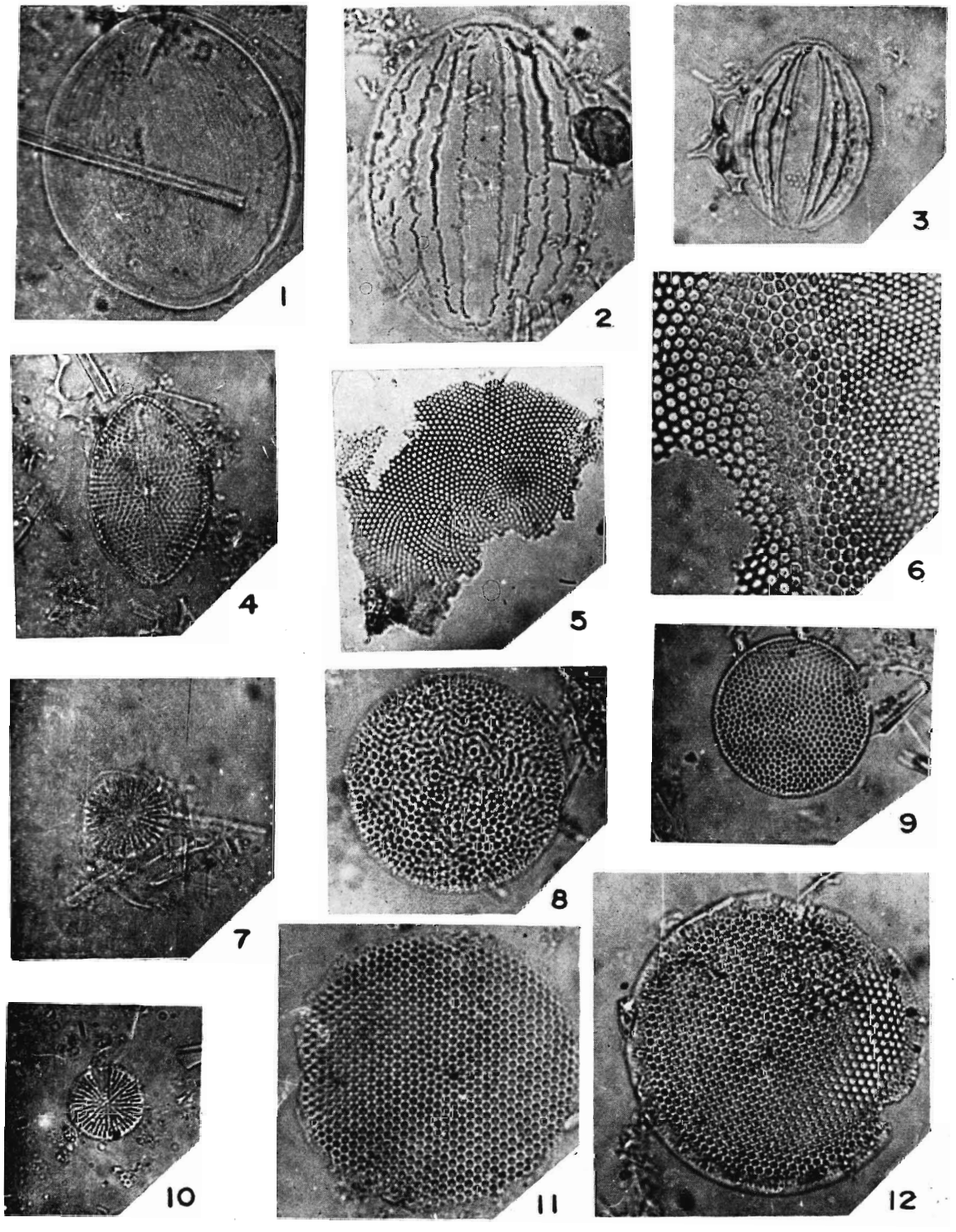
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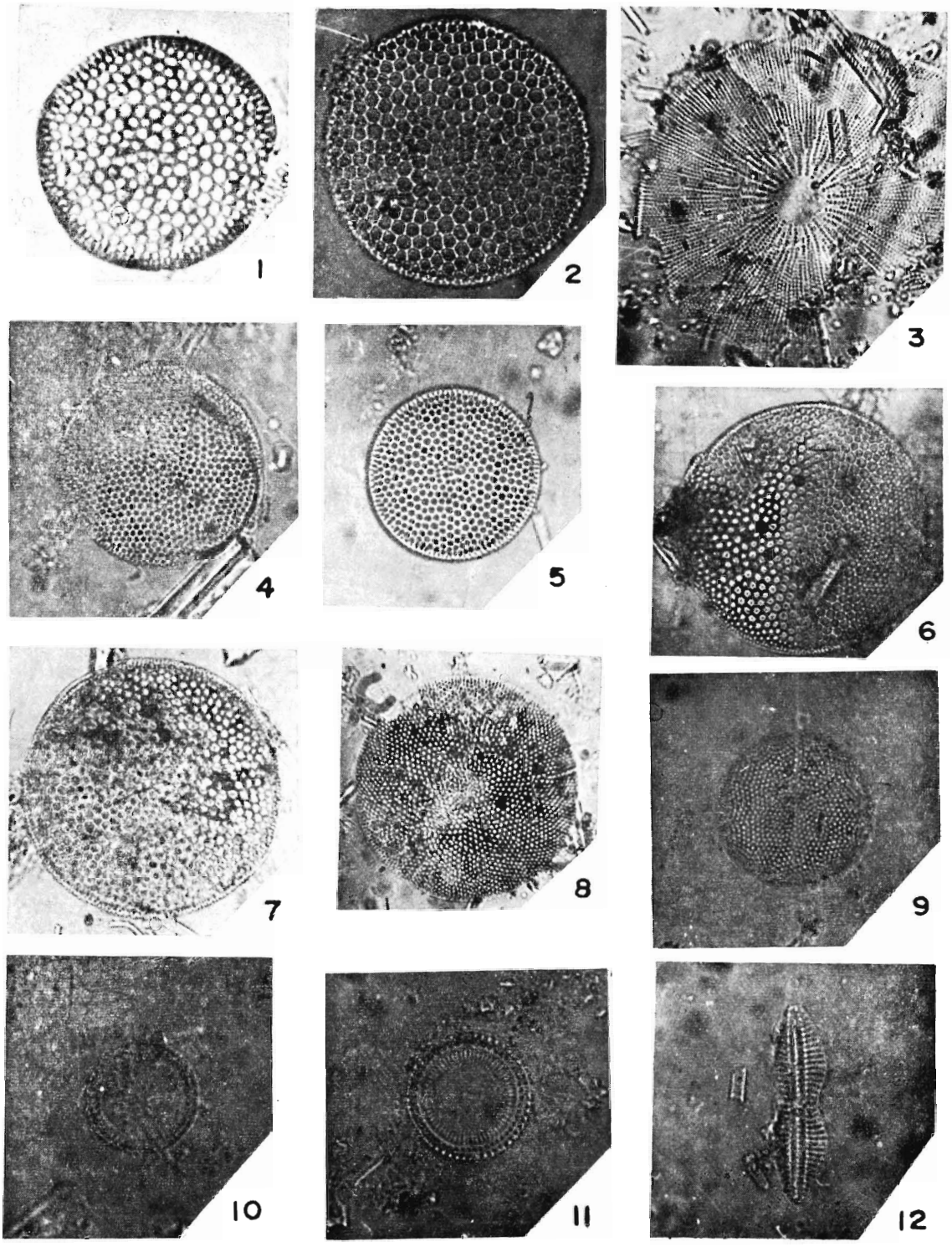
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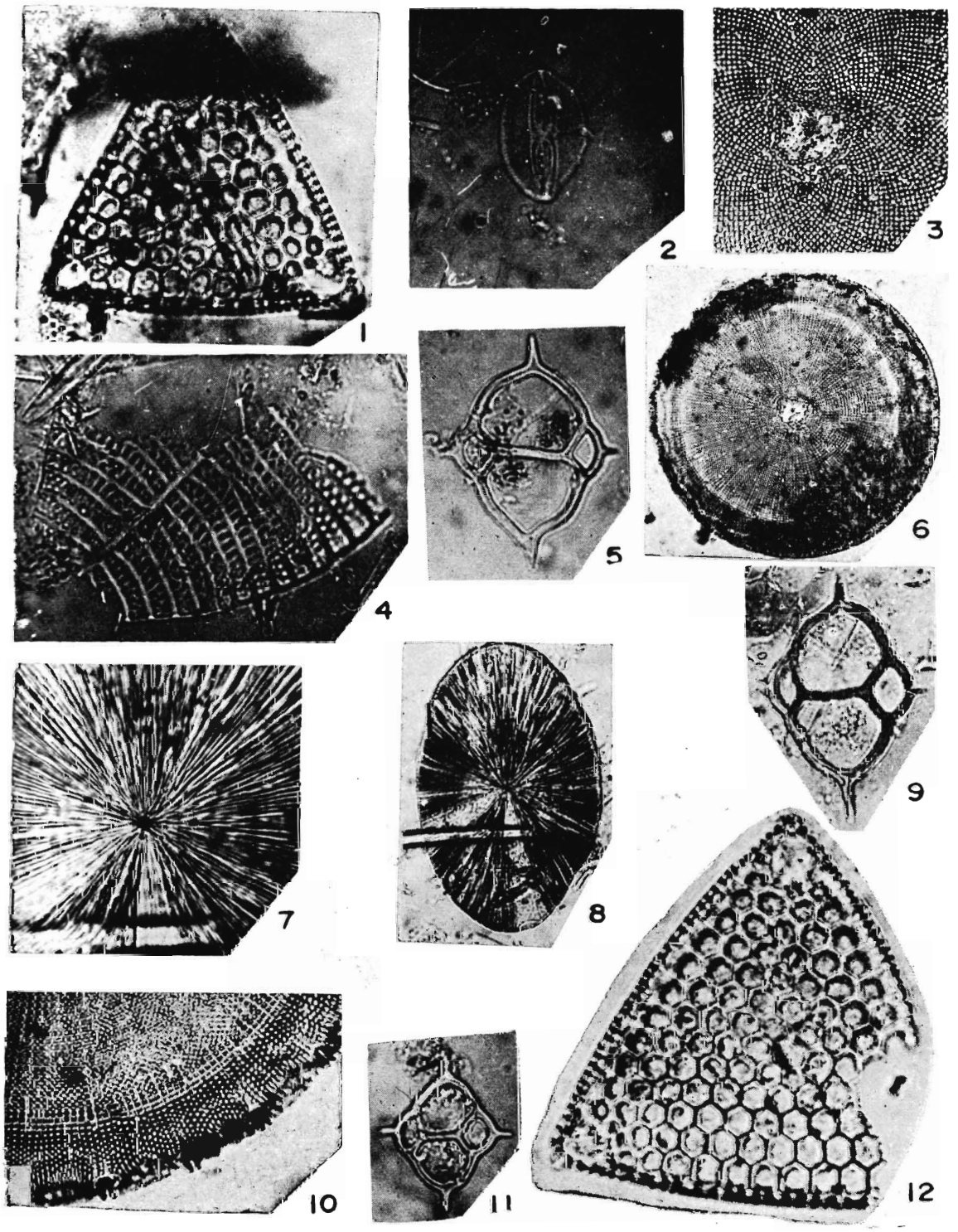
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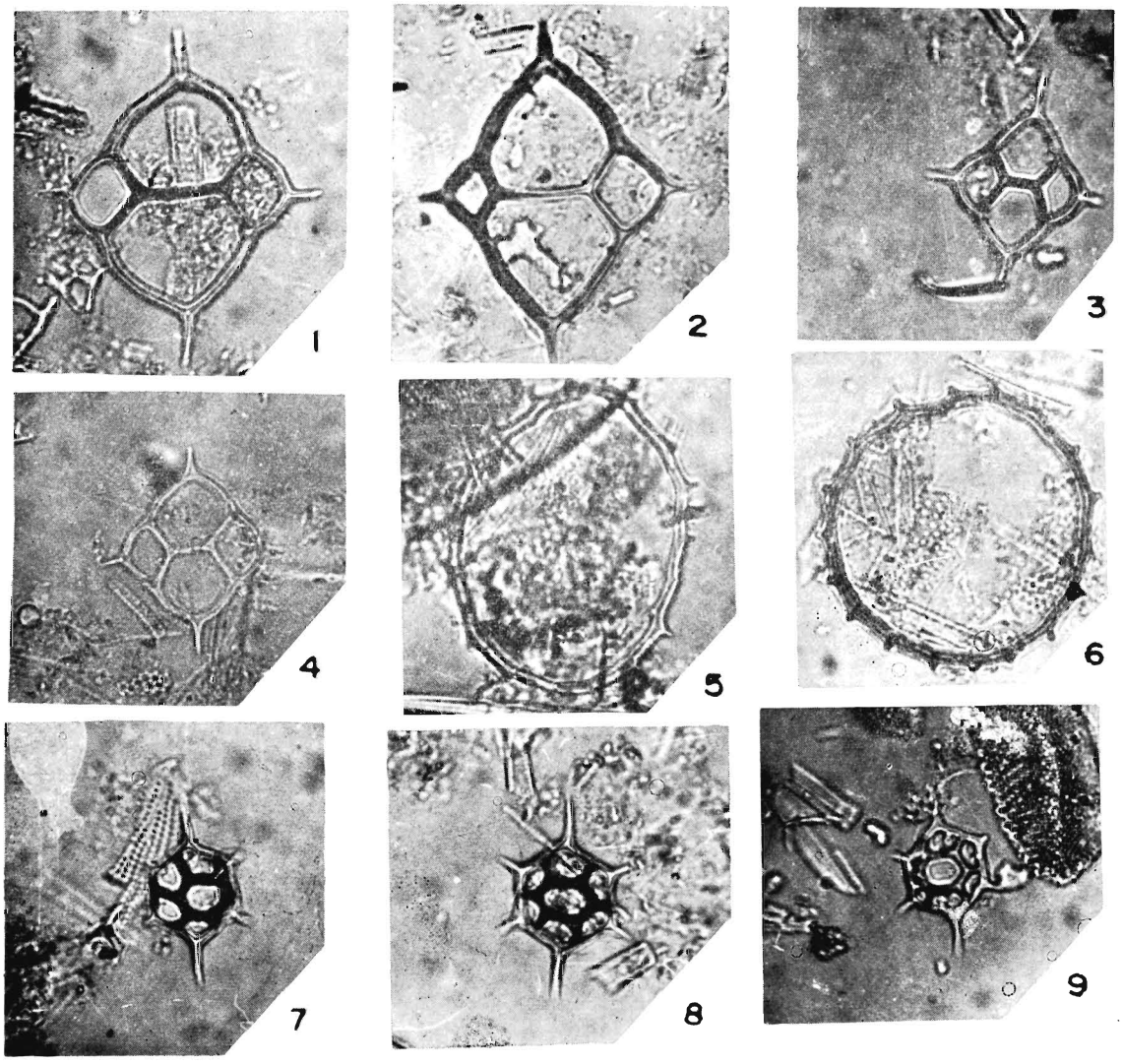
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8 *Coscinodiscus pacificus* Rattray, valve view, ×287.
9 *Coscinodiscus rothii* Grunow, valve view, ×640.
10,11 *Cyclotella* sp., valve view, ×640.
12 *Diploneis*? *crabro* (Ehrenberg) Ehrenberg, valve view, ×640.

Plate V

1,12 *Triceratium favus* Ehrenberg, valve views, ×640.
2 *Navicula*? *lyra* Ehrenberg, valve view, ×640.
3,6,10 Gen. and sp. indt., 3, enlarge view of the central part of the valve showing ornamentation, ×370, 6, valve view, ×150.5 ; Fig. 10, enlarge view of the margin showing kidney shaped bodies arranged at a regular interval, ×370.
4 An unidentified diatom, valve view, ×640.
5,9,11 *Dictyocha ausonia* Deflandre, valve views, ×640.
7,8 ? *Campylodiscus* sp., 7, enlarge view of the central part of the valve, ×370 ; 8, valve view, ×250.

Plate VI

1,4 *Dictyocha ausonia* Deflandre, valve view, ×640.
2,3 *Dictyocha fibula* Ehrenberg, valve views, ×640.
5,6 *Mesocena circulus* var. *asficulata* Lemmermann, valve views, ×617.
7-9 *Distephanus speculum* (Ehrenbreg), valve views, ×640.