31. RADIOLARIA FROM THE NORWEGIAN SEA, LEG 38 OF THE DEEP SEA DRILLING PROJECT

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INTRODUCTION

The high latitudes of the Arctic region were first visited by D/V *Glomar Challenger* in 1974, on Leg 38 of the Deep Sea Drilling Project, to the Norwegian Sea. Seventeen sites were selected, and 17 holes were drilled during this leg (Figure 1, see Table 1 in Chapter 1, this volume)

For radiolarian studies, the Norwegian Sea is a virgin area, as no information is available on either radiolarian stratigraphy or biogeography from pre-Holocene sediments. The distribution of radiolarians in the surface sediments of the Norwegian-Greenland Sea is discussed in only four papers. Stadum and Ling (1969) reported on the recent distribution of phaeodarians and their state of preservation, Petrushevskaya (1969) and Petrushevskaya and Bjørklund (1974) dealt with the distribution of polycystine radiolarians from surface sediments.

Only one paper, Bjørklund and Kellogg (1972) deals with the stratigraphy of Tertiary (late Eocene) sediments, from a site located near the top of one of the diapiric structures on the Vøring Plateau southwest of the Lofoten Peninsula. R/V *Vema* of Lamont-Doherty Geological Observatory has made several cruises (V 23, V27, V 28, and V 30) into the Norwegian-Greenland Sea, taking nearly 200 piston cores. The Tertiary sediments were recovered during the two latter cruises.

Tertiary continental outcrops from northern Europe such as Denmark, North Germany, North Poland, and Franz Josephs Land—Novaja Semlja discussed in Heiberg, 1863; Hustedt (in O. Wetzel, 1935); Schulz, 1927; Grundow, 1884, respectively, are all similar in an absence of radiolarians. However, from other land sections on the USSR eastern territories, radiolarian assemblages of Paleocene and Eocene ages have been described by different Russian authors—Borisenko (1960a, b), Krasheninnikov (1960), Kozlova and Gorbovetz (1966), and Lipman (1950).

DSDP Leg 12 went to the area south of the Norwegian-Greenland Sea, the Labrador Sea, Rockall Basin, and the Bay of Biscay. Here, Benson (1972) reported on radiolarian assemblages with good preservation, recovered from sediments of Pliocene to Oligocene age, while strongly corroded faunas were obtained from Eocene and Paleocene sediments.

Generally no information is available on Tertiary radiolarian stratigraphy in the Norwegian-Greenland Sea. A well-established Quaternary-Tertiary radiolarian stratigraphy has been established by Riedel and Sanfilippo (1970, 1971) for DSDP Legs 4 and 7, respectively, and Moore (1971) for Leg 8 in lower Atlantic and Pacific latitudes. During DSDP Leg 12 to the North Atlantic Ocean, Benson (1972) was able to use the established radiolarian stratigraphy for an age determination of the sediments. Thus, one of the main objectives of this paper was to search out the radiolarian stratigraphy, and see if the already established zonation from lower latitudes could be used with faunal assemblages recovered from the Norwegian Sea.

Based on reports from Russian workers, Lipman (1950), Kozlova and Gorbovetz (1966), and Bjørklund and Kellogg (1972), the present author recognized similarities in the faunal assemblages from Siberia and the Vøring Plateau. Since these faunal assemblages are quite different from the assemblages reported by Benson (1972) and Petrushevskaya and Kozlova (1972), DSDP Legs 12 and 14 from the northern and equatorial Atlantic, respectively, the author concludes that the radiolarian population in the North Atlantic and the Norwegian-Greenland Sea must have somehow been isolated. Most likely this was due to a landbridge, the Iceland-Faeroe Ridge, present during the early phase of the development of the Norwegian-Greenland Sea. Recent data from the Aleutian Islands also lead to the conclusion, that during early Tertiary, the North Pacific was isolated from the Arctic Ocean by a landbridge, due to an elevation of the Aleutian Islands.

The foregoing suggests that the Arctic in the early Tertiary was an isolated ocean, which explains why it is only in the early Tertiary that the Siberian and Vøring Plateau faunas have common species.

Goll and Bjørklund (in press) show that the occurrence of radiolarians in the surface sediment of the Norwegian-Greenland Sea is associated with the high productive areas in the western Norwegian Sea and with the areas in the eastern Norwegian Sea underlying the Norwegian-Atlantic Current (the continuation of the Gulf Stream). The Greenland Sea is barren or very poor in radiolarians. This distribution pattern is not yet fully understood, but the main conclusion must be that the North Atlantic Current passing over the Iceland-Faeroe Ridge, into the Norwegian Sea, greatly influences this distribution pattern, together with dissolution and masking effects.

The main objectives of this study were: to try to establish a radiolarian stratigraphy for the Norwegian-Greenland Sea; to compare the radiolarian fauna recovered in the North Atlantic during DSDP Legs 12 and 14 with that of Leg 38, in an attempt to test the hypothesis that the North Atlantic and the Norwegian-Greenland Sea were not connected in the early Tertiary; to search for the time when the North Atlantic Current swept over the Iceland-Faeroe Ridge, in other words, when did the ridge submerge. Finally, could the results of Leg 38 provide information regarding

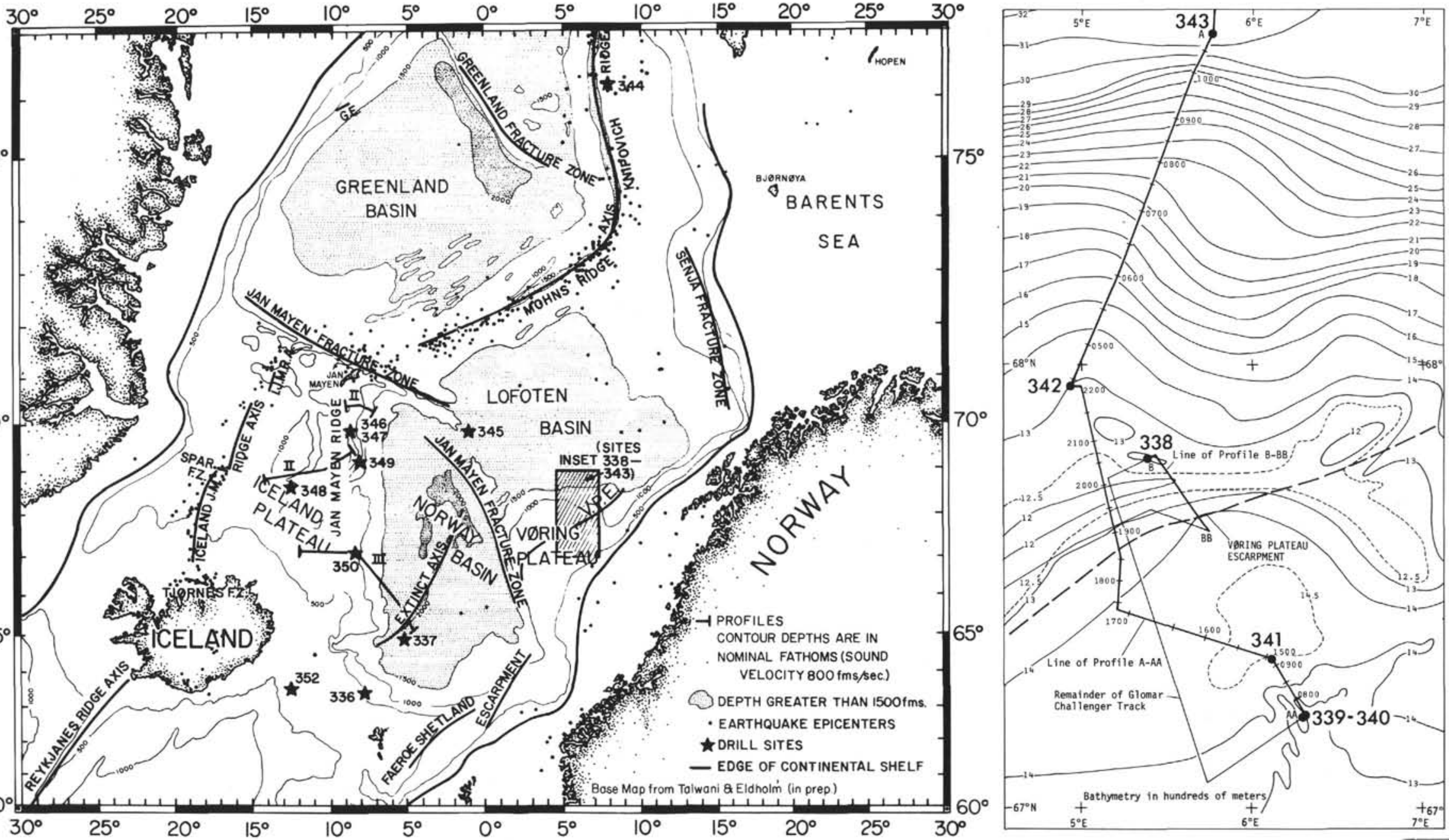


Figure 1. *Location of Leg 38 drilling sites, and bathymetry and structure of the Norwegian - Greenland Sea. (Note: Site 351 was occupied but was not drilled. Its location has not been shown on this map. The inset map shows the track of* Glomar Challenger *between Sites 338 and 343 on the Voring Plateau. Portions between Sites 339 and 343 correspond to line of composite profile illustrated in accompanying diagram. Also shown are position of Voring Plateau Escarpment, and corrected bathymetry of the area, in hundreds of meters, constructed principally from records taken by R/V* Vema *of Lamont Doherty Geological Observatory, supplemented by* Glomar Challenger *data.*

climatic shifts during Pleistocene time, and did the Pleistocene coolings have any influence on the current circulation in the North Atlantic?

MATERIAL AND METHODS

All samples used in this study were cleaned using standard procedures. It is of importance to describe in detail how the samples were processed, because an unknown "microfossil" was frequently found at Sites 338, 344, and 349. In the literature, they are described as Anellotubulates. Recently they have been described as being artifacts, produced by reaction of H_2O_2 with pyrite (Pickett and Scheibnerova, 1974, and Richardson et al., 1973). Perch-Nielsen (1975) reported on and illustrated similar "microfossils." The procedures were as follows:

1) An equal amount of sediment was used for easier observation of fluctuations in the radiolarians per volume units of sediment.

2) Water was brought to the boiling point in a beaker, sample was introduced, then concentrated H_2O_2 and sodium hexametaphosphate (Calgon) was added.

3) The suspension was treated with an ultrasound probe for about 10-15 sec, then sieved on a 44 μm screen.

4) Residue was treated with HCl, and the ultrasound probe was used for 5 sec.

5) The fine fraction of the residue was brought into suspension in the beaker and decanted.. The suspension was allowed to settle out in a clean beaker, and from this fine fraction the fauna slides were made.

6) 0.5 ml was pipetted out and put on a 25 × 50 mm coverslip. Sample was spread out with a toothpick and dried on a hotplate.

7) Caedax (N = 1.56) was put on the slide, a drop or two of xylene was put on the coverslip, which was placed on the slide.

8) Slide was allowed to boil for about 30-45 sec to dry out the Caedax.

9) Slide was put on a cold table to get rid of the gas bubbles faster.

The investigations were carried out with a Zeizz Standard RA microscope, normally using the 25× objective and the 10× wide-angle ocular. All microphotographs were taken with an automatic Leitz Orthomat camera using the 10× objective.

Comments on abundances and the state of preservation of radiolarians have to be very subjective, especially the preservation, as this is a mechanism, which is poorly understood and cannot be measured by any instrument.

Three stages of preservation were used:

P: Poor preservation—when the tests were strongly corroded and fragmented;

M: Moderate preservation—when more than 50% of the tests are fragmented or some corrosion could be observed;

G: Good preservation—when more than 50% of the tests were unbroken, and no corrosion could be observed.

Five stages of abundances were used:

B: Barren—no radiolarians were found on half the slide;

R: Rare—one to five fragments were observed on half the slide;

F: Few—more than five fragments or tests were observed on half the slide;

C: Common—mostly complete tests. 1-30 tests per traverse were observed using the 63× objective;

A: Abundant—mostly complete tests, greater than 30 tests were observed using the 63× objective.

These designations are only of limited value due to the fact that the faunal slides were made in a semiquantitative way. For this study, about 700 samples were processed and examined for radiolarians.

BIOSTRATIGRAPHY

During Leg 38, Cenozoic sediments were cored from the Arctic region for the first time, and as similar material never has been available, it was now possible to do a detailed study on Cenozoic radiolarian stratigraphy and paleoecology. Due to time limitations, the major emphasis of the present contribution is to establish a northern high-latitude radiolarian biostratigraphy. It is hoped the biostratigraphic framework outlined in this paper will be useful for the scheduled IPOD Leg 49.

The radiolarian assemblages recovered during this leg had very few species in common with holes drilled further south in the Atlantic Ocean. As no key fossils, upon which the lower latitude Atlantic and Pacific oceans are based, could be found in sufficient numbers, it was necessary to develop a local Norwegian Sea radiolarian stratigraphy. Again, due to time limitations, the taxonomic chapter will only deal with those species being significant for this local biostratigraphy. However, species of little or no value for the stratigraphy, but of value for information on the faunal assemblages, are illustrated.

No absolute or good age determination of the sediment was possible by radiolarians. Therefore, the radiolarian stratigraphy obtained had to be correlated to a time scale by correlation with diatoms (Recent-middle Miocene) and silicoflagellates (late Miocene-Eocene), as reported elsewhere in this volume by Schrader, and Martini and Müller, respectively.

Species known to be short ranging in equatorial sediments are usually lacking in Cenozoic radiolarian assemblages from latitudes higher than about 45°N in the Atlantic Ocean (compare Benson, 1972). This is most likely due to major changes in the ecological conditions at different latitudes. The recent faunal assemblage in the Norwegian-Greenland Sea surface sediments varies greatly from the assemblage obtained from surface sediments from Rockall Basin. The input of radiolarians transported with the North Atlantic Current are surprisingly low in the Norwegian Sea sediments underlying this major current system. Also, during Neogene time this transportation effect seems to have been negligible. Therefore, the majority of the radiolarians accumulated in the sediments are believed to have been endemic to the Norwegian-Greenland Sea.

Definition of Radiolarian Zones

Sediments ranging in age from Recent to early (?) Eocene were recovered during Leg 38. To put together a radiolarian stratigraphy was difficult, as no one site contained a continuous sediment column, where radiolarians were present throughout the hole. Thus, to obtain a stratigraphy ranging from Recent to early (?) Eocene, data from various sites had to be compiled. Site 338 turned out to be most important for the establishment of the radiolarian stratigraphy, as this site contained radiolarian-bearing sediments ranging from late Miocene to late (?) Eocene. From this site, 10 radiolarian zones were recognized.

Calocyclas talwanii Zone (Samples 338-29, CC to 27-3, 76-78 cm), Late Eocene

Base: Not defined, radiolarians absent below 29, CC.

Top: First appearance of *Lophocorys norvegiensis* and the extinction of *Calocyclas talwanii* and *Phacodiscus testatus.*

General: *Lithomitra* sp. B and *Botryostrobus* sp. P (Petrushevskaya and Kozlova, 1972) are present throughout the zone.

Lophocorys norvegiensis Zone (Samples 338-27-3, 76-78 cm to 25, CC), Late Eocene

Base: Coincident with the top of *Calocyclas talwanii* Zone.

Top: Not well defined, as radiolarians are strongly corroded above 26-3, 76-78 cm.

General: *Lithomitra* sp. B and *Botryostrobus* sp. P (Petrushevskaya and Kozlova, 1972) are present throughout the zone.

Phorticium sp. A Zone (Samples 338-24-3, 62-64 cm to 21, CC), Oligocene

Base: Not well defined, as sediments below 24-3, 62-64 cm are strongly corroded.

Top: Coincident with the first occurrence of *Ceratocyrtis robustus*, *Actinomma* (?) sp. A, and a very characteristic, not identified Nassellaria (only fragments of cephalis and thorax), Nassellaria sp. A.

General: *Ceratocyrtis mashae* present for the first time in 23-3, 72-74 cm.

Ceratocyrtis robustus Zone (Samples 338-21, CC to 19-3, 80-82 cm), Oligocene

Base: Coincident with top of the *Phorticium* sp. A Zone, and the first occurrence of *Ceratocyrtis robustus.*

Top: Extinction of Nassellaria sp. A and *Spongomelissa* sp. Chen, 1975.

Velicucullus oddgurneri Zone (Samples 338-19-3, 80-82 cm to 18, CC), Oligocene

Base: Coincident with the top of the *Ceratocyrtis robustus* Zone.

Top: Extinction of *Phorticium* sp. A and the first occurrence of *Gondwanaria japonica* and *Eucyrtidium* sp.

Gondwanaria japonica Zone (Samples 338-18, CC to 13, CC), Early Miocene

Base: Coincident with the top of the *Velicucullus oddgurneri* Zone.

Top: Extinction of *Ceratocyrtis robustus.*

Cyrtocapsella eldholmi Zone (Samples 338-13, CC to 12, CC), Early Miocene

Base: Coincident with the top of the *Gondwanaria japonica* Zone.

Top: Extinction of *Gondwanaria japonica* and the first occurrence of *Cyrtocapsella eldholmi*, *Hexalonche* sp. B, *Stichocorys biconica*, and *Heteracantha dentata.*

Stichocorys biconica Zone (Samples 338-12, CC to 11-2, 115-117 cm), Early Miocene

Base: Coincident with the top of the *Cyrtocapsella eldholmi* Zone.

Top: Extinction of *Velicucullus oddgurneri.*

Actinomma holtedahli Zone (Samples 338-11-2, 115-117 cm to 10-2, 146-148 cm), Early-middle Miocene

Base: Coincident with the top of the *Stichocorys biconica* Zone, and the first occurrence of *Ceratocyrtis histricosus* and *Hexalonche* sp. A.

Top: Extinction of *Stichocorys biconica*, *Hexalonche* sp. B, *Actinomma holtedahli*, and *Cyrtocapsella eldholmi.*

Lithomelissa stigi Zone (Samples 338-10-2, 146-148 cm to 8-2, 53-55 cm), Middle Miocene

Base: Coincident with the top of the *Actinomma holtedahli* Zone.

Top: Not well defined, as the sediments above 8-2, 53-55 cm have a low radiolarian species diversity and are barren above 7, CC.

A radiolarian assemblage from Site 337 of an early (?) Oligocene age was recovered. *Lithomitra* sp. A was frequently found, and as this species was found in the upper late Eocene, but not in the Oligocene sediments at Site 338, the Site 337 radiolarian assemblage is believed to be stratigraphically between the two assemblages as reported from Site 338. One radiolarian zone was suggested based on the faunal assemblage recovered.

Lithomitra sp. A Zone (Samples 337-9-3, 20-22 cm to 11, CC) Early (?) Oligocene.

Base: Not defined.

Top: Not defined.

A radiolarian assemblage from Site 339 of a middle (?) Eocene age was recovered. As this site was near the top of a diapir, it is questionable how valuable this site will be for stratigraphic purposes. However, one radiolarian zone was suggested based on the faunal assemblage recovered.

Artostrobus (?) quadriporus Zone (Samples 339-12, CC to 9, CC), Middle Eocene

Base: Not defined.

Top: Not defined.

The oldest radiolarian assemblage recovered during this leg was obtained from Site 343. Here, a radiolarian composition quite different from that at Site 339 was recovered. Compared with the faunal assemblages described in Kozlova and Gorbovetz (1966) from Komissarovo, Well 4-K, and from Ingalinsk, Well 1-K, *Archnocalpis* (?) *tumulosa* was frequently found in 5, CC, but was also present in 6, CC. An early Eocene age was based on the recovered silicoflagellate assemblage, and a radiolarian zone is suggested even if the base and top are not defined.

Archnocalpis (?) tumulosa Zone (Samples 343-6, CC to 5, CC), Early Eocene

Base: Not defined.
Top: Not defined.

Late Miocene, Pliocene, and Pleistocene sediments were recovered from Sites 341 and 348, and it was difficult to put this upper zonation together. In Sample 338-7, CC, there was a high concentration of *Hexalonche* sp. A. This species was hardly observed in Sample 338-8-2, 53-55 cm, the latter believed to be close to the middle-late Miocene boundary. The high occurrence of *Hexalonche* sp. A is, therefore, believed to be close to the base of the late Miocene. This species was also found in high numbers at Site 341 (Sample 15-2, 30-32 cm), and Site 348 (Sample 31-5, 17-19 cm). In those sites *Hexalonche* sp. A had a very short time range of mass abundancy, and most likely this species had a "bloom" all over the Norwegian Sea in early late Miocene, and may, therefore, serve as a good time marker. Above this *Hexalonche* sp. A peak at Site 348, a complete sediment column was suggested based on the diatom and silicoflagellate zonations. For Site 348, a radiolarian zonation from late Miocene to Recent could be defined.

Antarctissa whitei Zone, Late Miocene-Pliocene

Base: Coincident with the first occurrence of *Antarctissa whitei.*
Top: Extinction (?) of *Antarctissa whitei.*

Remarks: The *Antarctissa whitei* Zone overlies an unzoned interval at both Sites 341 and 348. This zone may be extended both upwards and downwards, as sediments above and below are characterized by having a low radiolarian diversity of a moderate to poor preservation. However, *Antarctissa whitei* has a very robust test, and have most likely survived dissolution. At this stage, the *Antarctissa whitei* Zone ranges from upper late Miocene to the Pliocene-Pleistocene boundary. The last occurrence of *Antarctissa whitei* at Site 348 is in Sample 5-5, 147-149 cm, and the Pliocene-Pleistocene boundary based on diatoms has been placed within Core 5. (See Schrader, this volume.)

Cycladophora davisiana Zone, Quaternary

Base: Coincident with the top of the *Antarctissa whitei* Zone.
Top: Recent sediments.

Remarks: Generally the "Glacial" sediments recovered during this leg are barren of radiolarians. Only from Sites 336, 341, 348, and 349 were a considerable amount of radiolarians obtained. *Cycladophora davisiana* was present in all "Glacial" samples containing radiolarians at Site 336, but was only scattered throughout the Pliocene-Pleistocene sediments at Site 348. *C. davisiana* seems to occur for the first time in the North Atlantic near the base of the Pliocene. This is in agreement with the studies carried out in the Antarctic during Leg 28 (Chen, personal communication). As the range of *Antarctissa whitei* is not definitely stated, the base of the *Cycladophora davisiana* Zone may not have been correctly placed. However, at this stage, the base is suggested to be near or closely equal to the Pliocene-Pleistocene boundary.

In summary, a list of the Norwegian Sea radiolarian zones is given in Table 1. The zones are listed from younger towards older.

TABLE 1
Norwegian Sea Radiolarian Zones

Cycladophora davisiana Zone
Antarctissa whitei Zone
Unzoned
Lithomelissa stigi Zone
Actinomma holtedahli Zone
Stichocorys biconica Zone
Cyrtocapsella eldholmi Zone
Gondwanaria japonica Zone
Velicucullus oddgurneri Zone
Ceratocyrtis robustus Zone
Phorticium sp. A
Lithomitra sp. A
Lophocorys norvegiensis Zone
Calocyclas talwanii Zone
Artostrobus (?) *quadriporus* Zone
Acronocalpis (?) *tumidula* Zone

SITE DESCRIPTIONS

In the following section, all sites drilled during Leg 38 will be discussed. Sixteen sites were drilled, but only a few were of stratigraphic importance for establishing a radiolarian zonation for the area. Therefore, range tables will be presented for only the selected sites, and generally only radiolarians of stratigraphic significance are included. Tables listing samples studied, but barren of radiolarians are given for each site.

Iceland-Faeroe Ridge

Ruddiman and McIntyre (1973) showed that the polar front during the maximum of the last glaciation was situated almost east-west, along 45°N latitude. This implies that the surface water circulation in the northern Atlantic during glacial periods was different from the present circulation system. During the last glacial period, the North Atlantic Current did not flow into the Norwegian Sea over the Iceland-Faeroe Ridge, but traveled eastward south of 45°N latitude, and turned southward along the Spanish-West African coast. From piston core studies in the Rockall Basin carried out by the author, it was observed that the occurrence of radiolarians fluctuated, being abundant in interglacial, carbonate-rich sediments, and barren in glacial, carbonate-poor sediments. Piston core studies from the Norwegian Sea show that the Recent sediments are relatively rich in radiolarians, but the species diversity is low compared to lower latitudes. It was also observed that, throughout the Norwegian Sea, the radiolarians disappear from the sediments close to the 18 K level, and have, so far, not been obtained from deeper sediments. The questions which arise are: why are radiolarians absent in earlier interglacials in the Norwegian Sea sediments? Is it because of dissolution, masking effect by terrigenous sediments, or lack of production? These complex questions are still not solved, but one of the sites on the Iceland-Faeroe Ridge brought new information on the occurrence of radiolarians in the "glacial" sediments.

Site 336

In the Pliocene-Pleistocene sediments recovered, radiolarians are present in the interglacial periods, normally of a good preservation in the upper half of the sediments, and moderate to poor in the lower part. Radiolarians are absent in the glacial period sediments.

It has been noted that radiolarians from the Norwegian Sea had been found only in the Holocene sediments, and it was still questionable whether radiolarians were present in earlier interglacial periods. Site 336 showed that at the northern flank of the Iceland-Faeroe Ridge a repetition of radiolarian-rich intervals occurred (compare Table 2). These intervals with high radiolarian content and low input of ice-rafted material are believed to reflect better ecological conditions during interglacial periods. The species diversity is much lower than in sediments of the same age from the Rockall Basin, indicating that the North Atlantic Current transported very limited amounts of radiolarians from the North Atlantic into the Norwegian Sea. However, it is of interest to observe the high percentage of *Cycladophora davisiana* (65% and 58% in Samples 1-4, 40-42 cm and 2-1, 92-94 cm, respectively), while *Cycladophora davisiana* only makes up 2%-3% in the surface sediments.

Late (?) Oligocene radiolarian-bearing sediments were recovered from 15-1, 33-35 cm to 19, CC (Figure 2, Table 3). The biogenous silica in this part is generally made up of broken sponge spicules. The radiolarian species diversity is relatively high, with a majority of unidentified *Lithomitra* spp., *Stylodictya* spp., and members of the family Spongodiscidae. *Velicucullus oddgurneri* and *Ceratocyrtis mashae* were present in Samples 15, CC through 17, CC (see Table 3). Siliceous microfossils are lacking in the sediment column from Samples 20-3, 70-72 cm to 40, CC.

Table 4 lists the Glacial-Recent radiolarian species. No attempt was made to observe the stratigraphic range for all the Recent species. Only those sites having a reasonable amount of species are included in Table 4.

Site 352

This site was drilled on the southern flank of the Iceland-Faeroe Ridge. Radiolarians from the Pleistocene section (Samples 1-3, 30-32 cm to 3, CC, Table 5, Figure 3) were recovered, having a rare abundance, and generally a moderate to poor preservation.

Radiolarians were also present in middle(?)-late Oligocene sediments (Samples 352A-1, CC to 3, CC, Table 5, Figure 3).

In Hole 352A, radiolarians were not recognized, as the material was very fragmented and strongly corroded. Also at this site, as at 336, the majority of biogenous silica consisted of broken sponge spicules. One of the main objectives from a paleontological point of view was to compare the faunas on both sides of the

TABLE 2
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 336

Core	Section	Interval (cm)
1	1	49-51
1	1	131-133
1	2	35-37[a]
1	2	45-47[a]
1	2	124-126[a]
1	3	40-42[a]
1	4	40-42[a]
1	5	61-63
1	5	131-133
1		CC
2	1	92-94[a]
2	2	20-22[a]
2	2	88-90
2	3	3-5
2	3	84-86
2	4	64-66
2	4	119-121
2		CC
3	1	76-78
3	1	138-140[a]
3	2	61-63[a]
3		CC
4	1	133-135
4	2	84-86[a]
4		CC[a]
5	1	77-79
5	2	63-65
5	3	53-55
5	4	20-22
5	4	125-127
5	5	70-72[a]
5	5	125-127[a]
5	6	55-57
5	6	130-132[a]
5		CC[a]
6	0	27-29
6	1	40-42[a]
6	2	25-27[a]
6	2	145-147[a]
6	3	33-35
6	3	135-137
6	4	35-37
6	4	145-147[a]
6	5	25-27[a]
6	5	145-147
6	6	35-37
6	6	135-137
6		CC
7		CC
8	1	25-27[a]
8	1	33-35
8	2	35-37[a]
8	2	125-137
8	3	20-22
8	3	115-117
8	4	25-27[a]
8	4	115-117[a]
8	5	50-52[a]
8	5	130-132[a]
8	6	20-22[a]
8	6	90-92
8		CC[a]
9	1	125-127[a]
9	2	30-32
9	2	75-77[a]
9	3	40-42[a]

TABLE 2 – *Continued*

Core	Section	Interval (cm)
9	3	75-77[a]
9	4	10-12
9	4	120-122[a]
9	5	33-35
9	5	135-137
9		CC
10	1	75-77[a]
10	1	135-137
10	2	32-34[a]
10	2	115-117
10		CC[a]
11	1	125-127[a]
11	2	25-27[a]
11	2	105-107[a]
11	3	30-32[a]
11	3	110-112[a]
11	4	30-32
11		CC[a]
12	1	75-77
12	2	55-57
12	2	141-143
12		CC
13		CC

[a]Radiolarians observed.

Iceland-Faeroe Ridge. This was, however, impossible as good radiolarian faunas did not exist.

Conclusion

On both the Atlantic Ocean and the Norwegian Sea sides of the Iceland-Faeroe Ridge, Pliocene-Pleistocene sediments directly overlie sediments of an Oligocene age, more precisely, middle Oligocene in Hole 352A.

As the path of the North Atlantic Current was strongly influenced by the climate during Pliocene-Pleistocene time, the evolution of this current system must also have been strongly affected by the evolution of the Iceland-Faeroe Ridge. The question arises as to when, during Paleogene time, did the North Atlantic Current sweep into the Norwegian Sea, (i.e., when did the ridge submerge?).

Additional information on this problem is given by the radiolarian species *Velicucullus oddgurneri*. Material from Leg 12, Site 116 was received from Dr. R.N. Benson and from the core library at Lamont-Doherty Geological Observatory. By using the data presented by Benson (1972), the radiolarian preservation was observed to be poor during the Oligocene.

Velicucullus oddgurneri is present at both Sites 336 and 338 from the upper part of late Oligocene, is absent at Site 352 [352A], but is present at Site 116 (Leg 12), Samples 18, CC through 12, CC, ranging from the late Oligocene-early Miocene boundary to somewhere in the middle of early Miocene. Using the stratigraphy presented by Benson (1972), it was found that the first occurrence of *V. oddgurneri* at Site 116 is in Sample 18, CC, which is in the late Miocene, but close to the Oligocene-Miocene boundary.

However, since the time for the first occurrence at Sites 338 and 116 is nearly the same, *V. oddgurneri* cannot be considered endemic to the Norwegian Sea, as it

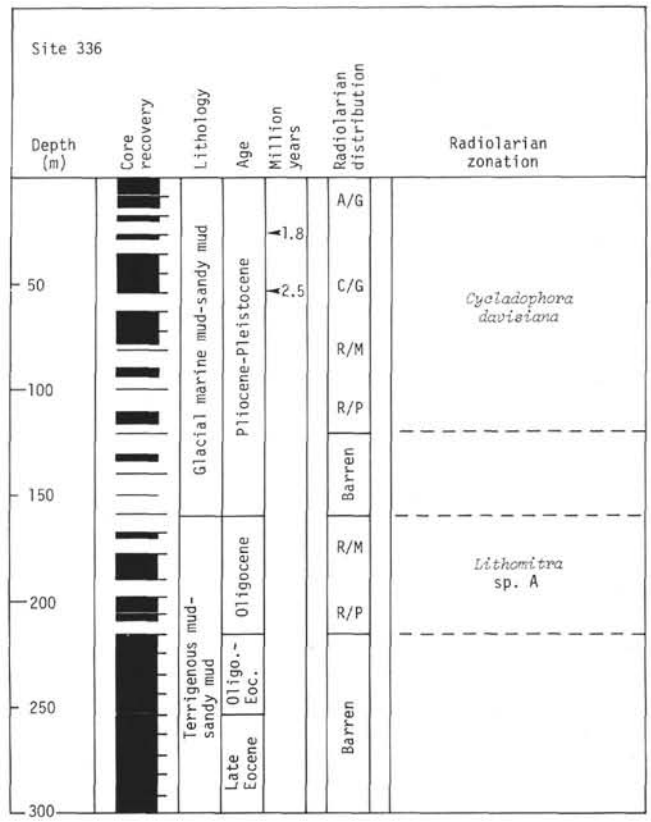


Figure 2. *Site summary - Site 336.*

is also present at Site 116. It is possible that *V. oddgurneri* was present first in the Norwegian Sea, and then migrated south. However, this is not likely as the Iceland-Faeroe Ridge at this time must have been very shallow. Only the North Atlantic Current may have passed over the ridge, as the production of Arctic Bottom Water had not been initiated at this time. However, the conclusion is the same, namely, that during the upper late Oligocene and lower early Miocene, there must have been some kind of water exchange between the North Atlantic and the Norwegian Sea.

Norway Basin

Site 337

This site is located on what are believed to be rift mountains, just east of the "extinct" spreading axis in the Norway Basin. Twenty-eight meters of Pleistocene sediments were recovered, having rare radiolarian occurrences with a moderate preservation (Figure 4, Table 6).

Early-middle Oligocene radiolarian-bearing sediment was obtained from Samples 9-3, 20-22 cm to 11, CC, however, the species diversity was low, with radiolarians moderately to poorly preserved. *Lithomitra* sp. A was observed frequently, and as this species is also found in the late Eocene at Site 338, the recovered Oligocene at Site 337 is believed to be stratigraphically above the Eocene sediments, but below the radiolarian-bearing Oligocene sediments at Site 338. One radiolarian zone is suggested from this site, *Lithomitra* sp. A Zone.

TABLE 3
Pre-Glacial Samples
Studied for
Radiolarians – Site 336

Core	Section	Interval (cm)
15	1	33-35[a]
15		CC[a]
15	3	13-15[a]
16		CC[a]
17		CC[a]
18	3	30-32[a]
18		CC[a]
19	1	130-132[a]
19		CC[a]
20	3	70-72
20		CC
Cores 21-40 core catchers.		

[a]Radiolarians observed.

TABLE 4
Radiolarians Separated from
Upper "Glacial" Sediments

	Sites				
Spumellaria	336	338	346	348	349
Arachnosphaera dichotoma		X			X
Cladococcus viminalis		X		X	X
Cromyechinus borealis	X	X	X	X	X
Drymyomma elegans		X			X
Echinomma leptodermum	X	X	X	X	X
Echinomma sp.	X	X	X	X	X
Hexaconthium enthacanthum		X	X	X	X
Hexaconthium pachydermum		X			X
Larcospira minor		X	X	X	X
Lithelius spiralis		X			X
Phorticium clevei	X	X	X	X	X
Rhizoplegma boreale	X	X	X	X	X
Spongodiscus osculosus	X	X			X
Spongodiscus resurgens	X	X	X	X	X
Spongotrochus glacialis	X		X	X	X
Streblacantha circumtexta	X	X	X	X	X
Stylodictya tenuispina		X			X
Stylodictya validispina					X
Nassellaria					
Amphimelissa setosa	X	X	X	X	X
Androcyclas gamphonycha		X			X
Artostrobus annulatus	X	X	X	X	X
Artostrobus joergenseni	X		X	X	X
Botryostrobus plathycephalus			X	X	X
Botryostrobus tumidulus	X				
Campylacantha cladophora					X
Ceratocyrtis glaeus			X	X	X
Ceratocyrtis histricosus			X	X	X
Ceratospyris hyperboreus					X
Cladoscenium tricolpium		X			X
Corocalyptra craspedota			X		X
Cornutella profunda	X	X			X
Cycladophora davisiana	X	X	X	X	X
Dictyoceras acanthicum		X			
Euscenium (?) *corynephorum*				X	X
Gonosphaera primordialis		X			X
Litharachnium tentorium	X	X			
Lithostrobus cuspidatus	X			X	
Lithomelissa hystrix		X			X
Lithomelissa setosa	X	X	X	X	X
Lithomitra arachnea	X				
Lithomitra lineata	X		X	X	X
Peridium longispinum			X	X	X
Phormacantha hystrix		X			X
Plagiacantha arachnoides	X		X	X	X
Plectacantha trichoides					X
Pseudodictyophimus gracilipes	X		X	X	X
Stichocorys seriatus		X			X
Theocyrtis borealis			X	X	X

Vøring Plateau

The Vøring Plateau is a relatively flat (about 1200 m) submarine plateau. The plateau is a prominent feature of the continental slope off Norway (Figure 1), and its origin and age have been a subject of considerable speculation. Talwani and Eldholm (1972) described the Vøring Plateau Escarpment, which is a buried escarpment with a roughly northeast-southwest trend. This escarpment divides the Vøring Plateau in an outer and an inner part. A considerable thickness of sediments, perhaps up to 8 km, may extend into the Mesozoic or even Paleozoic.

Outer Vøring Plateau

Site 338

This site is located on the inner part of the topographic "high," and was the only site having radiolarian-bearing sediments ranging through most of the late Eocene to late Miocene (Figure 5, Table 7). Miocene and Eocene radiolarians are characterized by good preservation and a high species diversity, while in the Oligocene sediments, the species diversity is low, preservation moderate to poor, with an increase in the Trissocyclidae.

The "Glacial" sediments are generally barren in radiolarians, only in Sample 1-1, 0-2 cm was a rich faunal assemblage recovered, the preservation being good. All the rest of the Pliocene-Pleistocene sediments are barren of radiolarians (Table 8). *Hexalonche* sp. A are abundant in Sample 7, CC, being absent above and rare below this sample. This peak of *Hexalonche* sp. A, based on silicoflagellates, occurs in the late Miocene, but close to the middle-late Miocene boundary. Very few species being key fossils for the lower latitude radiolarian stratigraphy were observed. *Stichocorys diploconus*, *Cyrtocapsella tetrapera*, and *Cannartus violina* were found only at a few horizons. One specimen of *C. violina* was observed in Sample 10, CC, while *C. tetrapera* was found in Sample 17, CC, assumed to be in the lower part of the early Miocene.

The Oligocene sediments (Samples 18-1, 110-112 cm through 24-3, 62-64 cm, Figure 5, Table 8) are characterized by a relatively low species diversity and rare to poor preservation in the lower part. *Phorticium* sp. A is characteristic for the Oligocene sediments.

Eocene radiolarian-bearing sediments (Samples 26-3, 62-64 cm, through 29, CC) do have a high species diversity and good preservation. *Lophocorys norvegiensis*, *Calocyclas talwanii*, *Peripyramus magnifica*, *Lithomitra*

TABLE 5
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 352

Core	Section	Interval
Hole 352		
1		CC
2		CC
4		CC
5		CC
Hole 352A		
1		CC
2		CC
3		CC

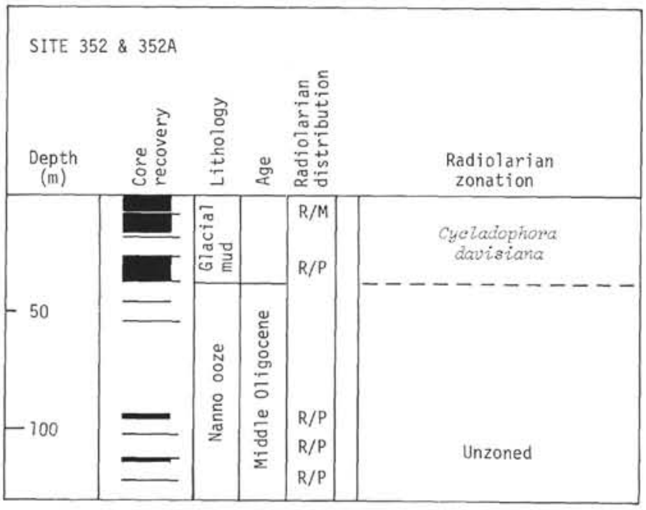


Figure 3. *Site summary - Site 352, Holes 352 and 352A.*

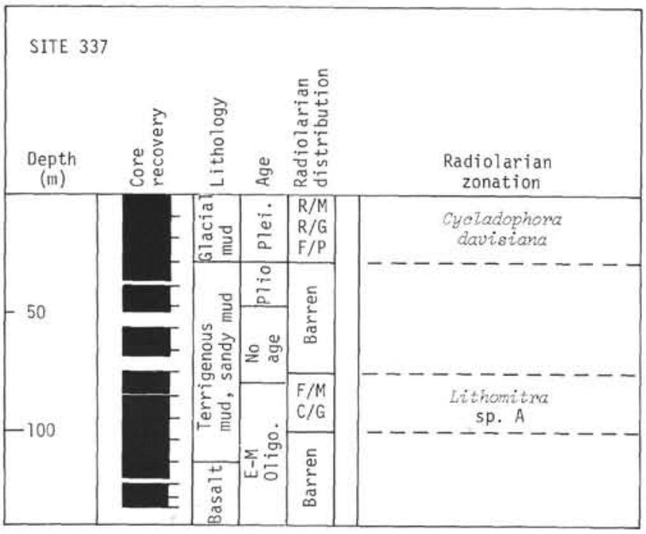


Figure 4. *Site summary - Site 337.*

sp. A, and *Botryostrobus joides* are characteristic species. Older Eocene sediments are barren of siliceous microfossils (Table 9). Ten radiolarian zones were suggested for this site (Figure 5).

TABLE 6
Samples Studied for Radiolarians – Site 337

Core	Section	Interval (cm)
1	3	30-32[a]
1		CC[a]
2	3	100-102[a]
2		CC[a]
3	3	110-112[a]
3		CC[a]
4	3	40-42
4		CC
5	3	80-82
5		CC
6	2	65-67
6		CC
7	3	83-85
7		CC
8	2	20-22
8		CC
9	3	20-22[a]
9		CC[a]
10	3	20-22[a]
10		CC[a]
11	3	25-27[a]
11		CC[a]
12	3	20-22
12		CC

[a]Radiolarians observed.

Site 342

This site is located on the outer part of the topographic "high," and only early Miocene sediments had considerable amounts of radiolarians of a good preservation (Figure 6, Table 10). *Cyrtocapsella tetrapera* (Plate 17, Figures 19, 20) occurred in relatively high numbers in Sample 3, CC, correlated to Site 338 with an upper early Miocene age.

C. tetrapera are not common in the Norwegian Sea sediments, but were reported by Benson (1972) as abundant in upper early Miocene at Site 116, Leg 12. It is worth mentioning that the occurrence of *C. tetrapera* in the Norwegian Sea most likely is a result of transportation by the North Atlantic Current, and is, therefore, taken as evidence for a definite submergence of the Iceland-Faeroe Ridge during the upper late Miocene.

Velicucullus oddgurneri was observed in Sample 6, CC. Basement (?) was recovered directly under these early Miocene sediments, while early Eocene sediments were recovered at Site 338. Both sites are on the same topographic "high," and the difference in age between the two sites may be due to either: (1) that basement is a basalt sill, or (2) that Site 342 had a more effective submarine erosion than Site 338. Two zones, defined at Site 338, were recognized at Site 342 (Figure 6).

Site 343

This site is located at the eastern margin of the Lofoten Basin, at the foot of the Vøring Plateau, and this site yielded the oldest sediments, early Eocene. The sediment is generally terrigenous, and biogenic silica was observed, having a good preservation, only in Samples 5-3, 55-57 cm through 6, CC. However, some

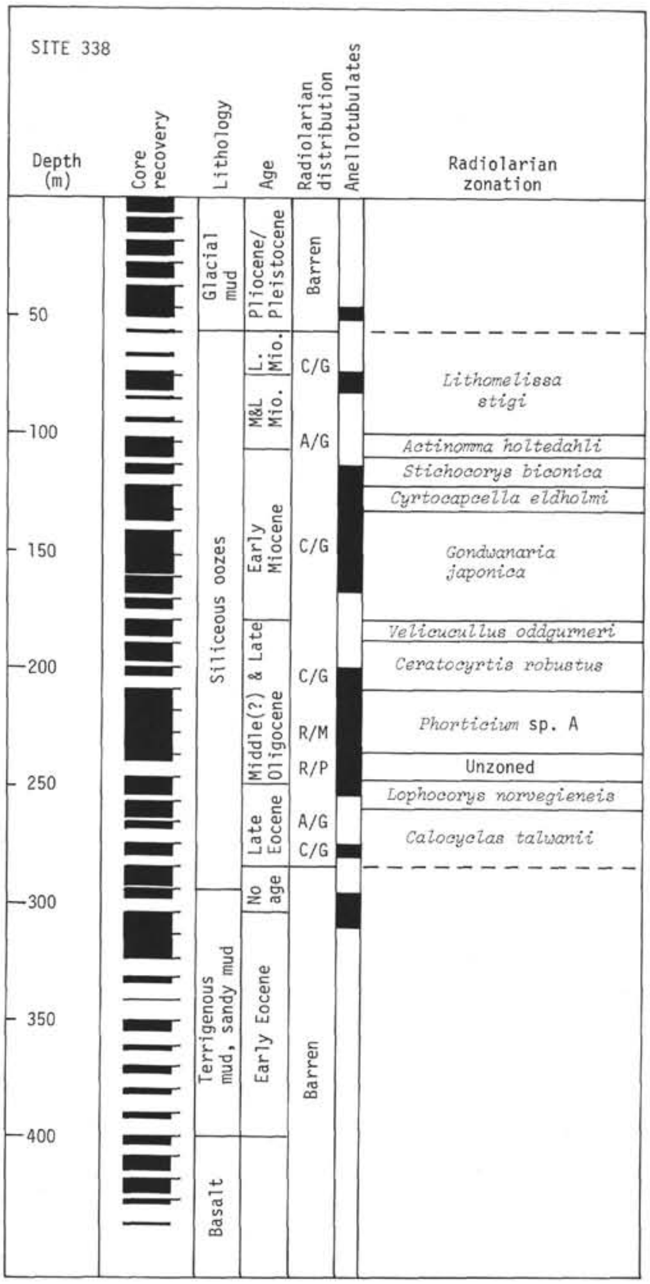


Figure 5. *Site summary - Site 338.*

TABLE 7
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 338

Core	Section	Interval (cm)
1	1	0-2[a]
1	1	84-86
1	1	127-129
1	1	136-138
1	1	143-145
1	2	80-82
1	2	110-112
1	2	130-132
1	2	141-143
1	3	23-25
1	3	69-71
1	3	118-120
1	4	45-47
1	4	93-95
1	4	126-128
1		CC
2	1	77-79
2	1	121-123
2	2	70-72
2	2	127-129
2	3	43-45
2	3	133-135
2	4	10-12
2	4	77-79
2		CC
3	2	52-54
3	2	122-124
3	3	132-134
3	3	136-138
3	4	17-19
3	4	35-37
3	4	102-104
3	4	130-132
3		CC
4	1	116-118
4	2	35-37
4	2	116-118
4	3	96-98
4	4	29-31
4	4	108-110
4		CC
5	2	53-55
5	3	76-78
5	3	135-137
5	4	81-83
5	5	10-12
5	5	78-80
5	6	30-32
5	6	120-122
5		CC

[a]Radiolarians observed.

strongly corroded fragments were found in Samples 12, CC and 13, CC (Figure 7, Table 11). Sediments younger than early Eocene, but older than the "Glacial" are absent, most likely due to submarine erosion.

Conclusion, Outer Vøring Plateau

The best site for biostratigraphic purposes turned out to be Site 338. Radiolarian-bearing sediments were present from late Eocene to lower late Miocene. The Norwegian Sea radiolarian stratigraphy is basically compiled from Site 338, with additional information from a few other sites.

Cyrtocapsella tetrapera in the Norwegian Sea sediments is taken as evidence for a definite submergence of the Iceland-Faeroe Ridge during late early Miocene, as *C. tetrapera* is understood as being transported from the Atlantic by the North Atlantic Current. Substantial submarine erosion is believed to have taken place at Sites 342 and 343.

Inner Vøring Plateau

This part of the plateau is located on the landward side of the Vøring Plateau Escarpment. Basement was not noted on seismic profiles, and the sediment thickness is assumed to be as much as 8 km. It was in these sediments that the prime biostratigraphic site was to be drilled.

Closer to land, the plateau has a very "mountainous" appearance due to a number of diapiric structures. These were drilled in an attempt to find sediments older

TABLE 8
Radiolarian Species Distribution, Abundance and Preservation – Site 338

Sample (Interval in cm)	Abundance and Preservation	Selected Species	*Spongotrochus glacialis*	*Hexalonche* sp. A	*Ceratocyrtis helotholus*	*Lithomelissa stigi*	*Heteracantha dentata*	*Triceraspyris* sp.	*Pseudodictyophimus gracilipes*	*Lipmanella xiphephorum*	*Cyrtocapcella tetrapera*	*Actinomma holtedahli*	*Cannartus violina*	*Lithomelissa* sp.	*Cyrtocapcella* sp.	*Stichocorys biconica*	*Hexalonche* sp.	*Tricolocapsa papillosa*	*Ceratocyrtis mashae*	*Stichocorys* sp.	*Heliodiscus* sp.	*Cyrtocapcella eldholmi*	*Velicucullus oddgurneri*	Trissocyrtidae sp. A	*Gondwanaria japonica*	Trissocyrtidae sp. B	*Spongopyle* sp.	*Ceratocyrtis robustus*	Nassellaria indet.	*Phorticium* sp. A	*Spongomelissa* sp.	*Streblacantha* sp.	*Calocyclas* sp.	*Botryostrobus joides*	*Lithomitra* sp.	*Lophocorys norvegiensis*	*Peripyramis magnifica*	*Theocalyptra tetracantha*	*Phacodiscus testatus*	*Calocyclas talwanii*	*Antarctissa* sp.
7, CC	C/G			A	F																																				
8-2, 53-55	C/G		F	F	F	A	R	C	R	R																															
8-2, 120-122	C/G		F	F	F	A	R	F	R																																
8-3, 45-47	C/G		F	F	F	A	R	F	R	R																															
8-3, 135-137	C/G		R		F	A	R	F		R																															
8-4, 55-57	C/G		R		F	A	R	F																																	
8-4, 145-147	C/G				F	A		F	R																																
8, CC	C/G		R		F	A		F	R	R																															
9-1, 85-87	R/G		R			C		F		R																															
9-1, 145-147	R/G		R	R		C																																			
9, CC	C/G		C			C			R	F																															
10-1, 115-117	C/G		R	R	F	C	R	C	R	F	R																														
10-2, 60-62	C/G		R			F	R	F			R	A			R	R	A																								
10-2, 146-148	A/G		F			R	F		R		R	C		F	R		F	R			R																				
10, CC	A/G						C		R			A	R	F	R		F	R		F																					
11-1, 145-147	C/G		R		F		C	R	R		R	F		C	R	F	F	F	R	R																					
11-2, 115-117	R/G		R				R		R					C	R	F	F	F																							
11-3, 135-137	C/G			C	F		R	R	R					R	R	A	C	R	C	F	R		R	R																	
11, CC	A/G						R	R	R					R	R	F	A		C	R	F		R	R		R															
12-2, 145-147	C/G						R	R						R	R	R	R		C	R	F	R	C	R																	
12, CC	A/G						R								R	R	R		C	R	F		C	R	R																
13-1, 145-147	C/G																		C	R	F		C	R	R	R															
13-3, 145-147	R/G																		C	R	R		C	F	F	R															
13-5, 125-127	A/G								R										F	R	R		R	F	F	R	R														
13, CC	C/G																		R	R	R		R	F	F	F	F														
14-2, 140-142	C/G																		R	R	R		R	C	F	F	R	R													
14, CC	C/G																		R	R	R		R	C	F	F	R														
15-2, 145-147	R/G								R										R	R	R		C	C	R	R	R														
15-4, 130-132	R/G								R										R	R	R		C	C	R	F		R													
15, CC	C/G								R										R	R	R		F	C	R	C		R													
16-2, 60-62	C/G								R										R	R	R		C	F	R	F		R													
16-5, 20-22	C/G								R										R	R			C	F	R			R													
16, CC	C/G								R										R	R			R	F	R	R		R													
17-2, 140-142	C/G								R										R	R			F	F	R	R		R													
17, CC	R/G																		R	R			R	R	R	R		F													
18-1, 110-112	R/G																		R	R	R		R	F	R	F	R	R													
18, CC	R/G								R										R	R			R	R	R	R		R													
19-3, 80-82	R/M																		R				R	R					R	R	R										
19, CC	C/G								R										F										R	C											
20-5, 60-62	R/P																		R										R	F											
20, CC	C/M																		F									R	R	F	R										
21-1, 100-102	C/G																		C					R		R		R	F	C	F	R									
21, CC	C/G																		C					R		R		R	R	C	F	R									
22-4, 79-81	R/M																		R											R	R	R									
22, CC	C/G																		F							C				F	R	R									
23-3, 72-74	C/M																		F					R						F	R	R									
23, CC	R/M																													F		R									
24-3, 62-64	R/M																													R											
24, CC	B																																								
25-1, 134-136	B																																								
25, CC	B																																								
26-3, 67-69	A/G																														R		R	R	A	F	R				
26 CC	C/G																																R	R	F	R	R				
27-3, 76-78	C/G																																R	R	R	R	R	R	R	R	
27, CC	A/G																																R	R	R	R	R	R	R	R	
28-2, 54-56	C/G																																R	R	F	R	R		R	R	
28, CC	C/G																																	R	R		R			R	R
29-1, 148-150	C/G																																	R	R		R		R	R	R
29, CC	C/G																																	R					R	R	R

TABLE 9
Pre-Glacial Age Samples
Barren of Radiolarians-Site 330

Core	Section	Interval (cm)
30	2	42-44
30	4	129-131
30		CC
31	1	89-91
31	2	97-99
31		CC
Cores 32-41, Core-catcher samples		

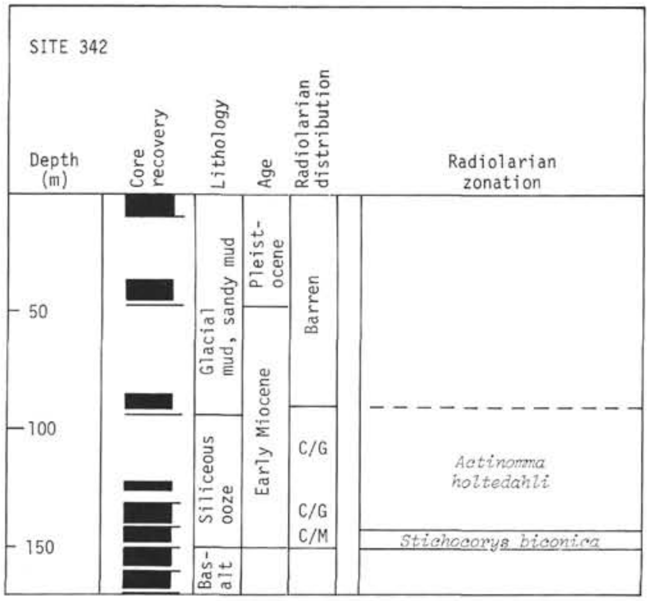


Figure 6. *Site summary - Site 342.*

TABLE 10
Samples Studied for
Radiolarians – Site 342

Core	Section	Interval (cm)
1		CC
2		CC
3	2	50-52[a]
3		CC[a]
4	2	115-117[a]
4		CC[a]
5	2	125-127[a]
5		CC[a]
6	3	130-132[a]
6		CC[a]

[a]Radiolarians observed.

than reported by Bjørklund and Kellogg (1972) from the same area.

Site 339

This site was located on one of the diapirs. Roughly 75 meters of Pliocene-Pleistocene sediments, mostly barren in radiolarians, was recovered, overlying middle Eocene radiolarian-bearing sediments. *Phacodiscus testatus, Cornutella californica* (?), *Peripyramis magnifica, Spongopyle spiralis, Lophocorys norvegiansis* were observed in these middle Eocene sediments (Figure 8, Table 12). All samples, except Core 1, have a well-preserved radiolarian fauna, and the species diversity is high. The sediments are strongly disturbed, most likely by a combination of diapirism and drilling.

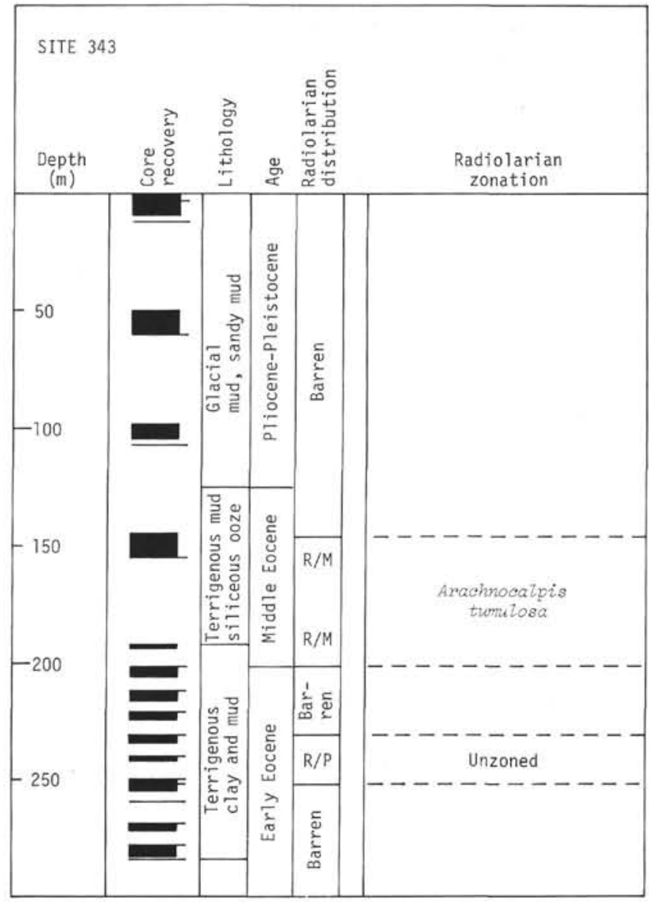


Figure 7. *Site summary - Site 343.*

Site 340

This site is also located on the diapir, but on a topographically steeper part. The Pliocene-Pleistocene sediments, about 10 meters, were nearly barren of radiolarians, but the underlying late Eocene sediments, all contained radiolarians of a good preservation (Figure 9, Table 13). The species diversity is high with *Calocyclas talwanii, Cornutella californica, Peripyramis magnifica, Theocalyptra tetracantha, Stylodictya variabilis, Spongopyle spiralis,* and *Lophocorys norvegiensis* as the dominating species. This site shows a reversed (?) stratigraphy and the sediment is greatly disturbed, perhaps a result of diapirism and coring. This site should not be used for stratigraphic purposes.

Site 341

This site is located northwest of the diapir sites, but southeast of Site 338. The site was drilled in an area of flat-lying beds, and the objective was to obtain a Tertiary biostratigraphy of the Norwegian continental

TABLE 11
Samples Studied for Radiolarians – Site 343

Core	Section	Interval (cm)
1	2	47-49
1		CC
2	3	66-68
2		CC
3	3	80-82
3		CC
4	2	53-55
4		CC
5	3	55-57[a]
5		CC[a]
6	1	145-147[a]
6		CC[a]
7	3	35-37
7		CC
8	2	60-62
8		CC
9	2	45-47
9		CC
10	2	55-57
10		CC
11	2	60-62
11		CC
12	2	80-82
12		CC[a]
13		CC[a]
14		CC
15	2	80-82
15		CC

[a]Occurrence of early Eocene radiolarians.

TABLE 12
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 339

Core	Section	Interval (cm)
1	3	63-65[a]
1		CC[a]
2	3	70-72
2		CC
3	3	90-92
3		CC
4	3	83-85
4		CC
5	2	94-96
6	4	84-86
6		CC
7	3	79-81
7		CC
8	1	23-25
8	1	130-132[a]
8	2	110-112[a]
8	3	80-82[a]
8	4	98-100[a]
8		CC
9		CC[a]
10	2	140-142[a]
10		CC[a]
11	1	117-119[a]
11		CC[a]
12	2	110-112[a]

[a]Radiolarians observed.

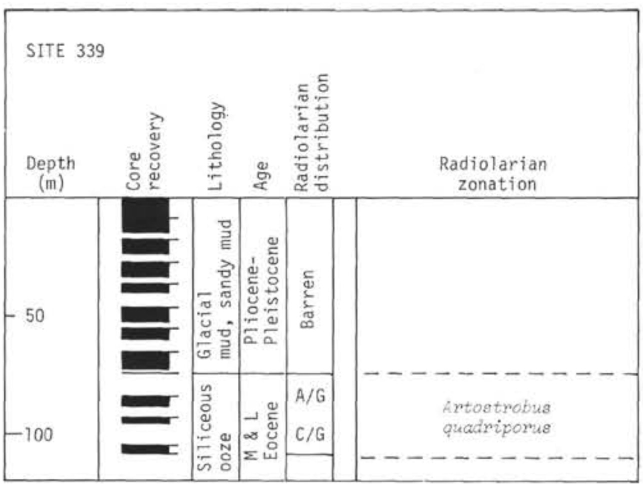


Figure 8. *Site summary - Site 339.*

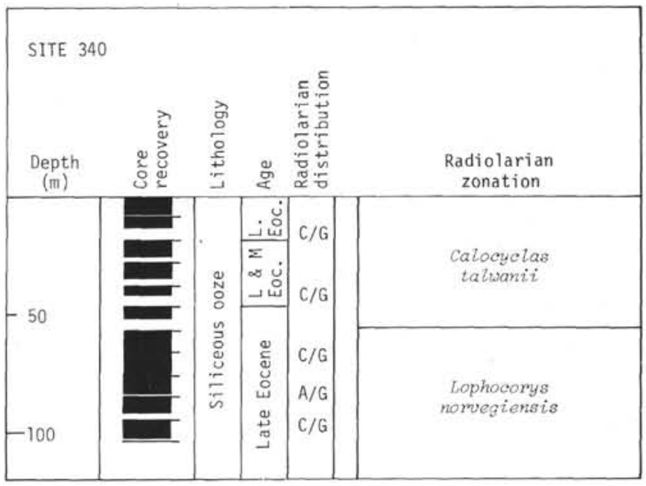


Figure 9. *Site summary - Site 340.*

margin. The hole drilled through a Pliocene-Pleistocene section, nearly five times as thick as at Site 338.

Radiolarians are not generally present in this section. Only in Samples 4-2, 94-96 cm to 7, CC was a reworked radiolarian assemblage of good preservation obtained (Figure 10, Table 14). *Velicucullus oddgurneri*, *Stichocorys biconica*, *Eucyrtidium* sp., and *Hexalonche* sp. A do indicate an upper middle to late Miocene age for these redeposited sediments (Figure 10).

The Pliocene-Pleistocene sequence directly overlying late Miocene sediments has a high radiolarian species diversity, and all siliceous microfossils are of a good preservation (Figure 10, Table 15). *Antarctissa whitei*, *Ceratocyrtis mashae*, *C. compacta*, *Heteracantha dentata*, *Triceraspyris* sp., *Hexalonche* sp. A, *Gondwanaria japonica*, and *Velicucullus oddgurneri* were frequently observed. *Hexalonche* sp. A are abundant in Sample 31-5, 17-19 cm, assumed to correspond to Sample 338-7,

TABLE 13
Late Eocene Samples
Studied for
Radiolarians – Site 340

Core	Section	Interval (cm)
1	3	85-87
1		CC
2	3	30-32
2		CC
3	3	60-62
3		CC
4	3	35-37
4		CC
5	2	45-47
5		CC
6	3	55-57
6		CC
7	4	130-132
7		CC
8	3	45-47
8		CC
9	3	35-37
9		CC
10	3	45-47
10		CC
11	3	45-47
11	3	CC

[a]All samples contain radiolarians, but show a reversed (?) stratigraphy.

CC. Two radiolarian zones were suggested from this site.

Conclusion, Inner Vøring Plateau

Sediments from both Sites 339 and 340 are composed of Tertiary biogenous siliceous oozes, which are believed to be the principal material of the diapir cores.

A principal question is what is causing the relatively thick layer of displaced Tertiary material in the Pliocene-Pleistocene section. Since this site is only a short distance northwest of the diapiric area, and the diapir cores are Tertiary biogenous siliceous oozes, it is assumed that this body of displaced Tertiary material represents the time of principal diapirism. As the Pliocene-Pleistocene sediments are without radiolarians they cannot indicate the time for the onset of the diapirism.

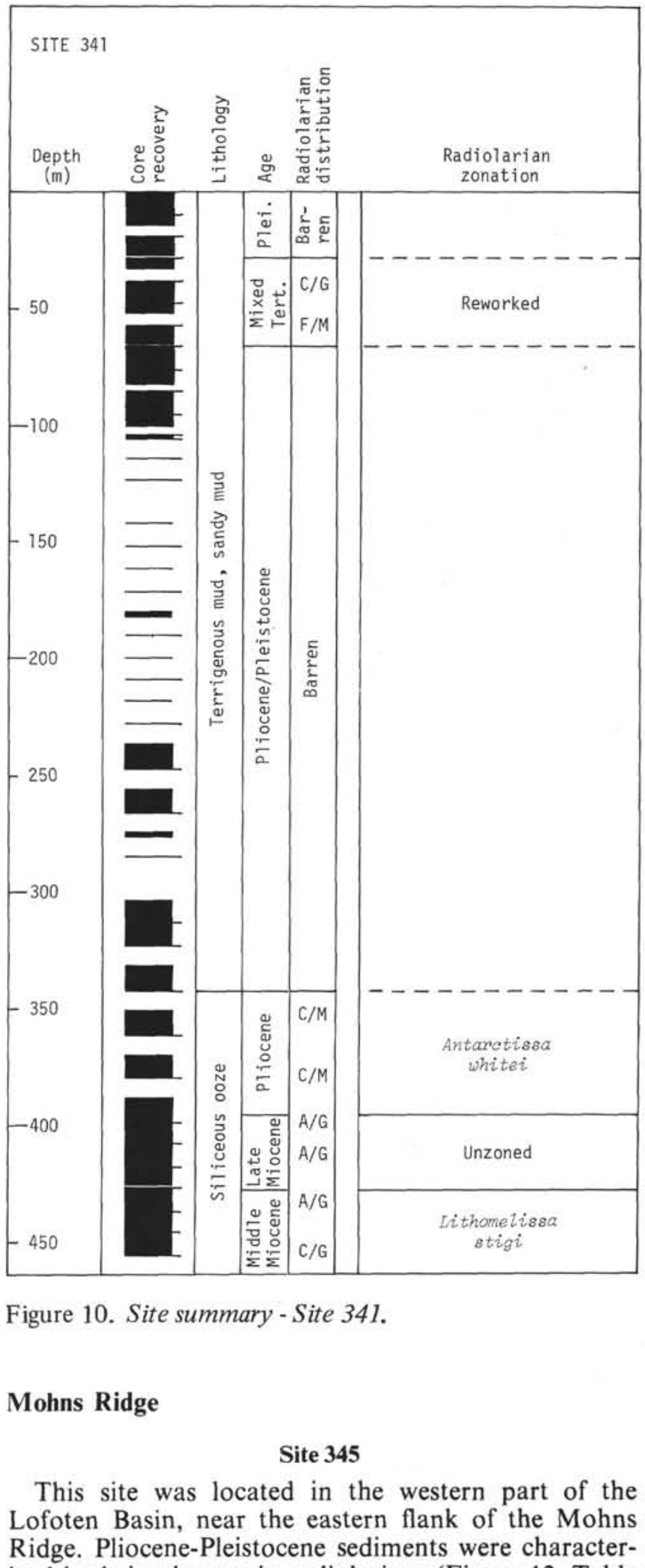


Figure 10. *Site summary - Site 341.*

Knipovich Ridge

Site 344

It was assumed that this site would be of great value from a paleontological point of view, as it was the northernmost site drilled. However, as the sediments were barren of any kind of siliceous microfossils, and the fact that "Glacial" sediments were not penetrated, information on whether the preglacial siliceous oozes were present that far north was not obtained. It will be of great interest to learn whether the Paleogene siliceous oozes, occurring further south in the Norwegian Sea, did extend into the Arctic Ocean. Only core-catcher samples were prepared and studied for radiolarians (Figure 11).

Mohns Ridge

Site 345

This site was located in the western part of the Lofoten Basin, near the eastern flank of the Mohns Ridge. Pliocene-Pleistocene sediments were characterized by being barren in radiolarians (Figure 12, Table 16). Early Miocene radiolarian assemblages were recovered in Samples 6-1, 43-45 cm to 10-5, 30-32 cm (Figure 12, Table 17). Other preglacial sediments were also barren of radiolarians (Figure 12, Table 18). No zonation was done for this site, but the occurrence of *Heteracantha dentata* in Sample 6-1, 43-45 cm may indicate that this sample belongs to the *Stichocorys biconica*

TABLE 14
Samples Studied, Either Barren or Having Displaced Radiolarian Assemblages – Site 341

Core	Section	Interval (cm)
1	3	88-90
1		CC
2	2	64-66
2		CC
3	3	88-90
3		CC
4	2	94-96
4		CC[a]
5	3	88-90[a]
5		CC[a]
6	2	92-94[a]
6		CC[a]
7	3	92-94[a]
7		CC[a]
8	3	83-85
8		CC
9	3	86-88
9		CC
10	3	120-122
10		CC
11	3	100-102
11		CC
12	3	95-97
12		CC
Cores 13-15, Core-catcher samples		
16	1	105-107
16		CC
17	2	70-72
17		CC
18	1	30-32
18		CC
19	1	145-147
19		CC
20	3	95-97
20		CC
21	3	80-82
21		CC
22	1	82-84
22		CC
23	4	51-53
23		CC
24	3	90-92
24		CC

[a]Reworked radiolarians.

Zone. However, the occurrence of *Gondwanaria japonica* and absence of *Ceratocyrtis robustus* indicate that the faunal assemblage belongs to the *Cyrtocapsella eldholmi* Zone. Other key species are not present, thus, this zoning is not too exact.

Jan-Mayen Ridge

Site 346

This site was located on the Jan-Mayen Ridge, and Pliocene-Pleistocene sediments were characterized by being barren in fossils. However, in Sample 1, CC a good modern fauna existed, dominated by *Cycladophora davisiana* and *Amphimelissa setosa*. The preservation was good (Figure 13, Table 19).

Middle Miocene sediments were recovered from Samples 4-2, 95-97 cm to 11, CC. The radiolarian abundance is rare, of a moderate to poor preservation (Figure 13, Table 19). This section is unzoned, but again, as at Site 345, *Heteracantha dentata* are present, indicating a maximum age for Sample 4-2, 95-97 cm of upper early Miocene. However, the age is probably younger. The rare radiolarians and their bad stage of preservation do not allow a more exact date. In addition, *Velicucullus oddgurneri* and *Ceratocyrtis mashae* were observed.

Site 347

This site is located a short distance southwest of Site 346. Only core catchers were studied for radiolarians. An abundant, modern radiolarian assemblage of good preservation was recovered from Sample 1, CC. The rest of the samples were barren of radiolarians (Figure 14).

Site 349

This site is located on the Jan-Mayen Ridge, southeast of Sites 346 and 347. Nearly all core-catchers samples were barren of any kind of siliceous

TABLE 15
Radiolarian Species, Abundances, Preservation – Site 341

Sample (Interval in cm)	Abundance and Preservation	*Lophocorys norvegiensis*	*Lychnocanium grande*	*Antarctissa whitei*	*Ceratocyrtis histricosus*	*Triceraspyris* sp.	*Ceratocyrtis mashae*	*Heteracantha dentata*	*Hexalonche* sp. A	*Ommatartus antepenultimus*	*Lipmanella xiphephorum*	*Lithomelissa stigi*	*Ceratocyrtis* sp.
25-2, 118-120	R/P	R	R	R		R							
25-5, 2-4	A/G			R		R							
25 CC	C/M	R	R	R		R			R				
26-2, 111-113	C/M			R		R			R				
26-5, 54-56	C/M		R	R		R	R	R	R				
26 CC	C/M		R	R		R		R					
27-3, 14-16	C/M			R									
27-5, 82-84	C/M					C							
27, CC	C/M	R				F		R					
28-3, 79-81	C/M					R				R			
28-6, 66-68	F/M				F	R							
28, CC	C/M	R			R	R		R			R		
29-2, 100-102	F/M					R		R					R
29-5, 120-122	A/M												
29, CC	A/G	R				F		R					
30-2, 110-112	F/P												
30-5, 90-92	F/P												
30, CC	C/M												
31-5, 17-19	A/M								A				
31, CC	A/M								A			R	
32-2, 101-103	C/M								F			R	
32-5, 87-89	F/M								F			R	
32, CC	A/M								R			R	
33-2, 92-94	C/M								R			R	
33-5, 110-112	C/M											R	
33, CC	C/G											R	
34-2, 41-43	F/M											R	
34-5, 107-109	F/M											R	
34, CC	C/M											R	

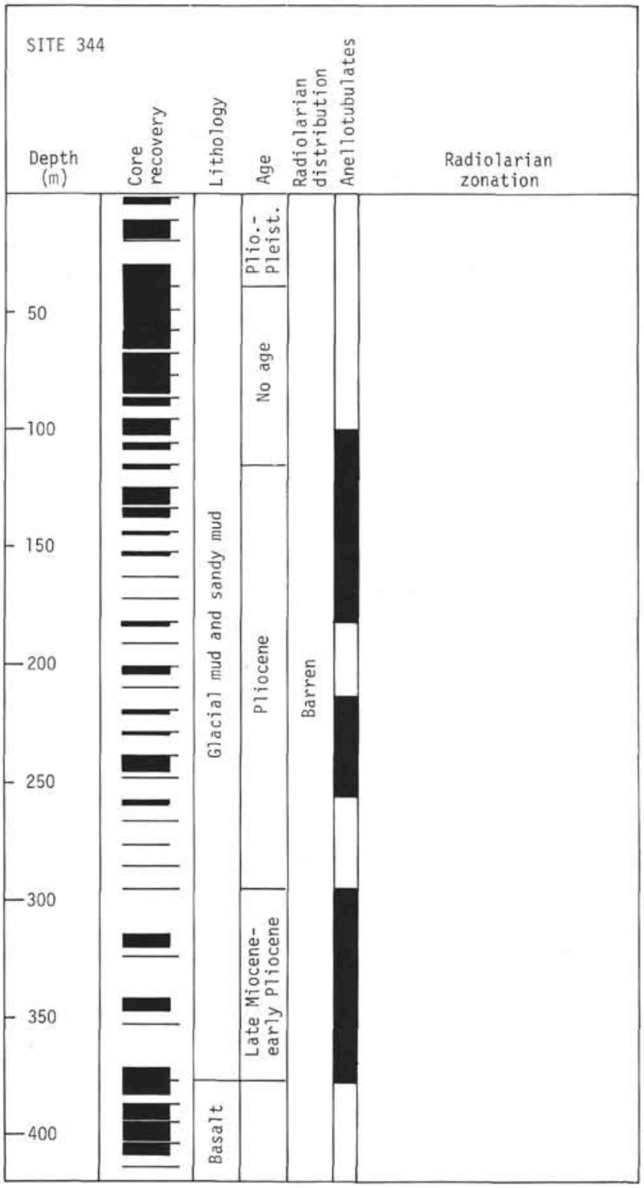


Figure 11. *Site summary - Site 344.*

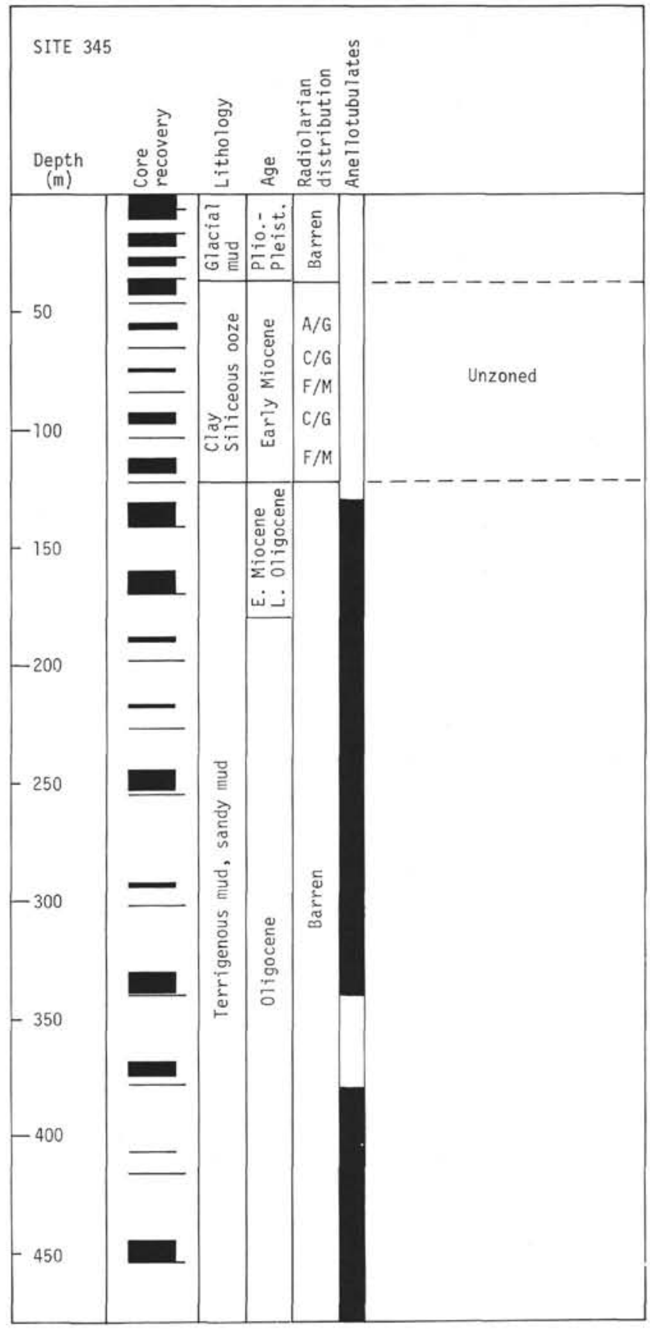


Figure 12. *Site summary - Site 345.*

microfossils. However, Samples 1-1, 10-12 cm and 1, CC had a good, well preserved, modern radiolarian fauna. One specimen of *Amphimelissa* sp. was recognized in Sample 13, CC. This was also found at Site 338, indicating a late Eocene age (Figure 15).

Site 350

This site is the southernmost site on the Jan-Mayen Ridge. All core-catcher samples, except for 1, CC and 3, CC, where few radiolarians of a bad preservation were observed, are barren of any kind of siliceous microfossils (Figure 16). One specimen of *Heteracantha dentata* was present in Sample 3, CC, and using its range from Site 338, this sample may be referred to the upper early Miocene-middle Miocene. However, this is not accurate dating, as all other key species are missing.

Iceland Plateau

Site 348

This site is located west of the Jan-Mayen Ridge and is characterized by having a relatively rich, and well to moderately preserved radiolarian fauna from Recent to middle Miocene (Figure 17, Tables 20 and 21). The abundance and preservation of radiolarians vary greatly throughout this section. However, two zones could be identified, the *Cycladophora davisiana* Zone, ranging throughout the Pleistocene, and the *Antarctissa whitei* Zone, ranging throughout the Pliocene and slightly into

TABLE 16
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 345

Core	Section	Interval (cm)
1	1	0-2
1	1	103-105
1	2	65-67
1	3	52-54
1	4	71-73
1		CC
2	1	49-51
2	1	69-71
2	2	47-49
2	2	94-96
2	3	44-46
2	3	109-111
2		CC
3	1	106-108
3	2	82-84
3	3	39-41
3	3	129-131
3		CC
4	1	60-62
4	2	52-54
		CC

TABLE 17
Selected Radiolarians from Site 345

Sample (Interval in cm)	Abundance	Preservation	*Heteracantha dentata*	*Trissocyclidae* sp. A	*Velicucullus oddgurneri*	*Pterocyrtidium* (?) *reschetnjakae*	*Ceratocyrtis mashae*	*Spongomelissa* (?) sp.	*Peripyramis* sp.	*Eucyrtidium* sp.	*Gondwanaria japonica*	*Ceratocyrtis robustus*	*Phorticium* sp.
6-1, 43-45	R	P	R										
6-1, 80-82	R	P											
6-1, 126-128	F	P		R									
6-2, 17-19	C	G		R	R	F	R						
6-2, 96-98	A	M			A	F	F		F				
6, CC	A	G		R	A	F	F	A	R				
7-2, 88-90	C	G			A	R	F	R	R	R			
7, CC	R	P			R		R						
8-1, 125-127	C	M		R	R	R	R	R	R	R	R		
8-2, 118-120	C	M				F	F	F			R		
8-3, 121-123	F	M				R	R	F					
8-4, 58-60	F	M			R	R	R	F					
8, CC	C	G		R	R	F	R	C		R	F		
9-1, 141-143	R	M		R			R						
9-2, 40-42	F	M		R		R		R					
9-3, 50-52	R	M		R	R	R							
9-4, 40-42	R	P											
9, CC	F	M		R		R							
10-0, 30-32	C	G		R	R	R	R					C	
10-1, 35-37	C	M										C	
10-2, 30-32	F	M			R			R				C	F
10-3, 45-47	F	M										R	F
10-4, 30-32	F	M					R					F	F
10-5, 30-32	F	M					R					F	F

TABLE 18
Pre-Glacial Samples Barren for Radiolarians – Site 345

Core	Section	Interval (cm)
5	1	88-90
5	2	66-68
5	3	35-37
5	4	11-13
5	4	105-107
5		CC
10	6	30-32
10		CC
11	1	30-32
11	2	20-22
11	3	35-37
11	4	30-31
11	5	30-32
11	6	20-22
11		CC
Cores 12-30, Core-catcher samples		

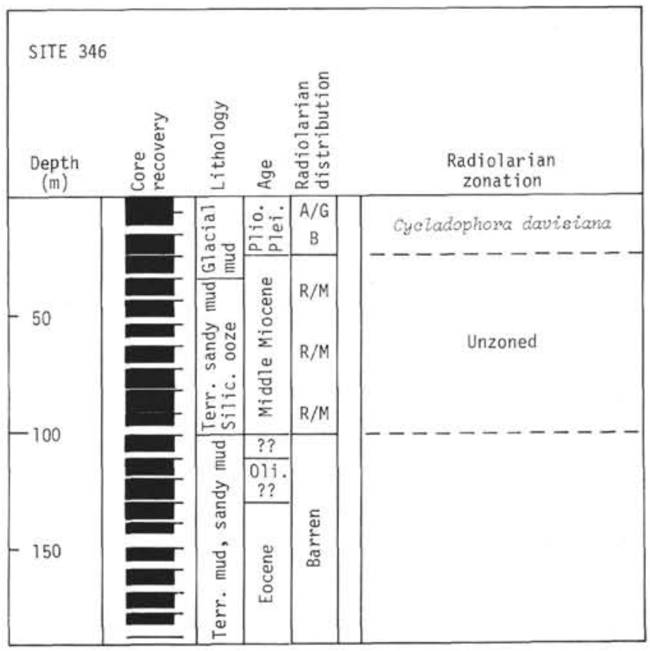


Figure 13. *Site summary - Site 346.*

the late Miocene. From Samples 12, CC to 18, CC there is an unzoned interval, corresponding with a similar unzoned interval at Site 341. The mass occurrence of *Hexalonche* sp. A is believed to be a good time indicator, and is present at Site 338 (Sample 7, CC), Site 341 (Sample 31-5, 17-19 cm), and Site 348 (Sample 15-2, 30-32 cm) of lower late Miocene. This site is also peculiar in having a high occurrence of phaeodarians in Samples 5, CC through 7, CC (Plate 13, Figures 15-21).

Ecological Interpretations

From the site summaries (Figures 2-17), it was seen that the "Glacial" sediments varied considerably in thickness. It is of interest to observe that the "Glacial" sediments are principally barren of radiolarians at sites

TABLE 19
Samples Studied for Radiolarians – Site 346

Core	Section	Interval (cm)
1	1	30-32
1		CC[a]
2	3	10-12
2		CC
3	3	130-132
3		CC
4	2	95-97[a]
4		CC[a]
5	2	60-62[a]
5		CC[a]
6	3	30-32[a]
6		CC[a]
7	3	35-37[a]
7		CC[a]
8	3	25-27[a]
8		CC
9	3	130-132[a]
9		CC[a]
10	3	15-17[a]
10		CC[a]
11	3	95-97[a]
11		CC[a]
12	3	110-112
12		CC
13	3	20-22
13		CC
Cores 14-20, Core-catcher samples		

[a]Radiolarians observed.

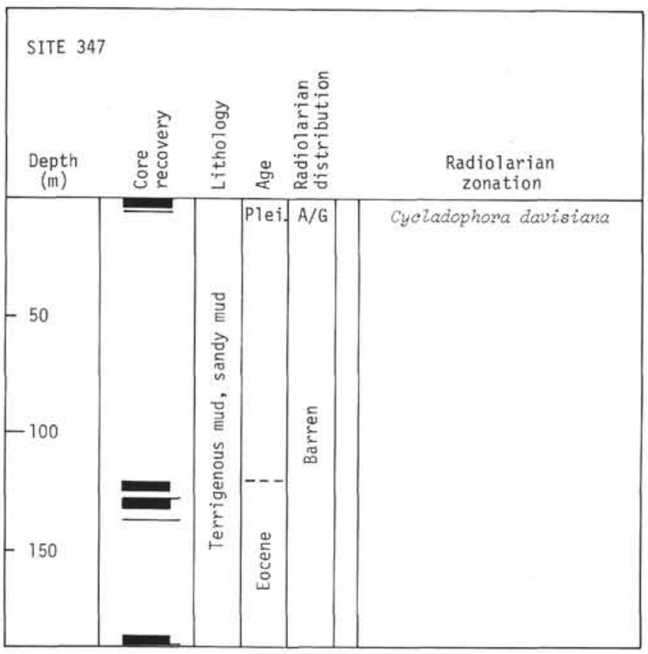


Figure 14. *Site summary - Site 347.*

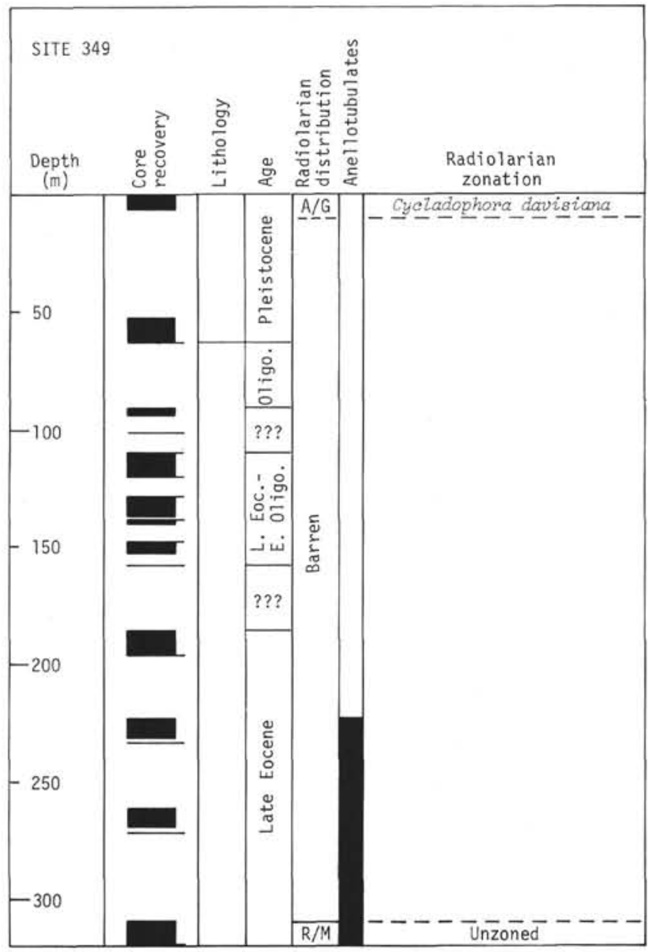


Figure 15. *Site summary - Site 349.*

located in the eastern and in the northern parts of the Norwegian Sea, Sites 341 and 344, having 323 meters and 320 meters of "Glacial" sediments, respectively. However, at most of the sites in the western part of the Norwegian Sea (Sites 346, 347, 348, and 349), the "Glacial" sediments average 50 meters in thickness, varying from 32 to 64 meters at Sites 346 and 348, respectively. The sediments have a relatively rich and well-preserved radiolarian fauna. These radiolarian distribution patterns are most likely explained by a combination of masking, dissolution, and production. For the Jan-Mayen area sites there is no nearby source of terrigenous sediments, assuming that the sediments derived from Greenland are trapped on the western side of the present spreading axis. However, on the Vøring Plateau and at the Knipovich Ridge, the buried Vøring Plateau Escarpment and the Knipovich Ridge have trapped sediments being derived from Norway and the Barents Sea and Spitzbergen, respectively. Therefore, the high influx of glacial-derived terrigenous material at Sites 341 and 344 may be masking the radiolarians. It should also be kept in mind that as a great deal of terrigenous material is put into suspension in the oceanic environment surface production might have been decreased.

For the Jan-Mayen sites, as a consequence of the fact that most of the terrigenous sediments are trapped to the west, the masking effect is less pronounced. The water has less suspended material, allowing a higher production, and therefore generally a better preservation of siliceous microfossils in the sediments.

Antarctissa whitei is generally rare in the eastern Norwegian Sea (Site 341), while it is abundant at Site 348 in the western Norwegian Sea. This might indicate

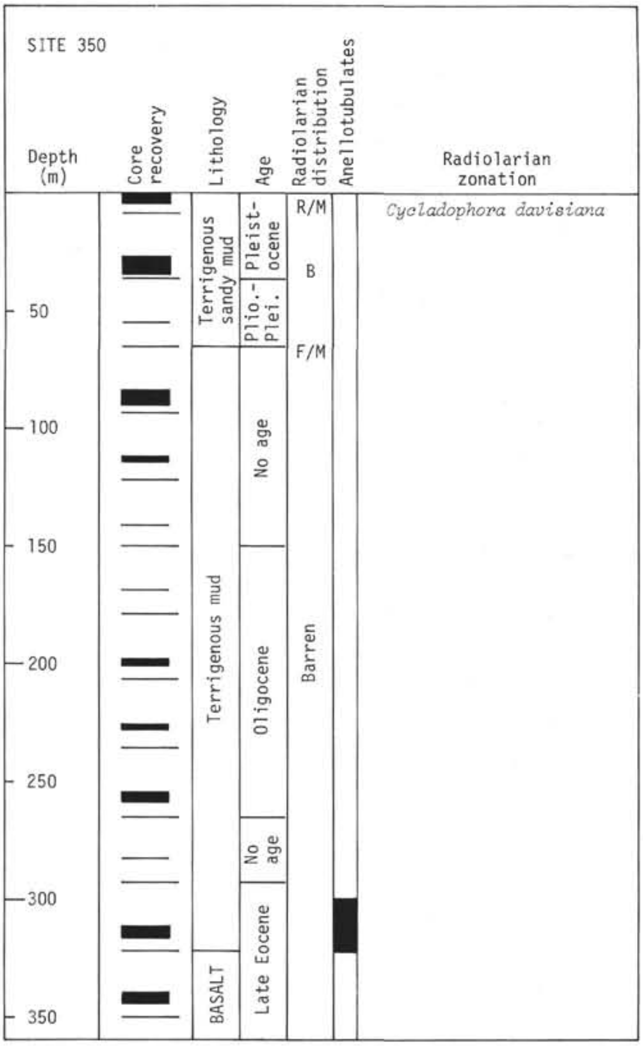


Figure 16. *Site summary - Site 350.*

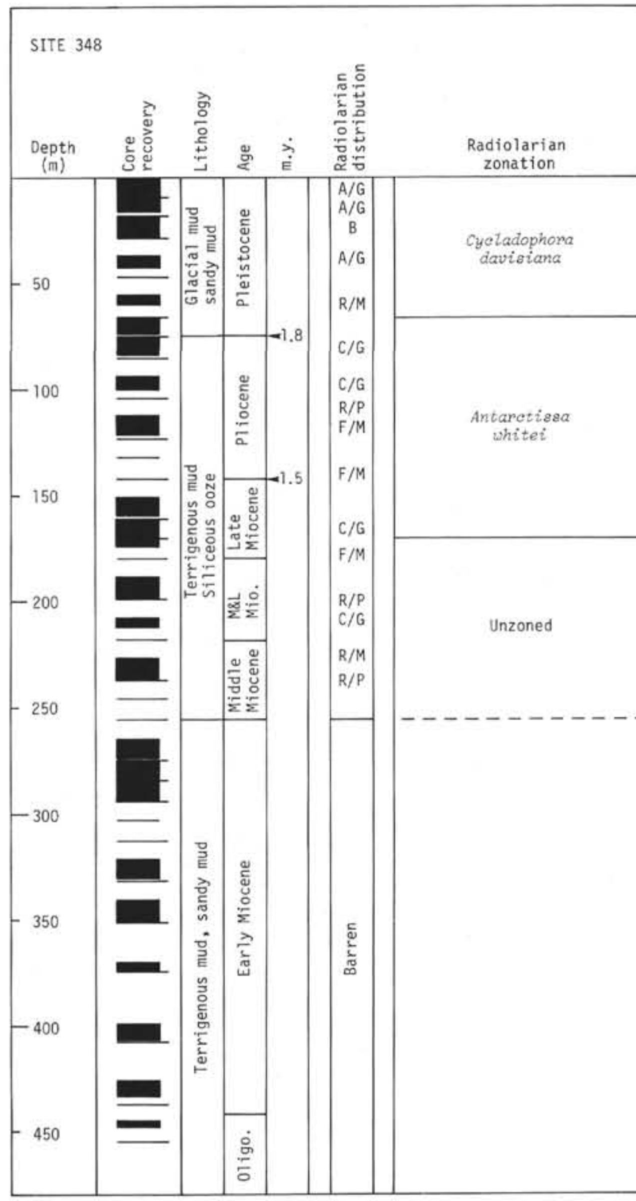


Figure 17. *Site summary - Site 348.*

that *A. whitei* is associated with cold water, and therefore, reflects a cold water current system in the western Norwegian Sea. This system, only to some extent, influences the radiolarian distribution further east in the Norwegian Sea.

The preglacial sediments again show an interesting distribution pattern. All sites in the Icelandic Plateau and Jan-Mayen area are characterized by being almost barren, or by having rare radiolarians of moderate to poor preservation. However, in the Vøring Plateau, preglacial sediments are characterized by rich faunas of a good preservation. This distribution pattern is a result of active spreading and a high input of terrigenous material causing a suspension of loaded water. This, in effect, reduced the productivity in the western Norwegian Sea during most of the Oligocene and Miocene. The eastern Norwegian Sea is receiving limited amounts of terrigenous sediments, and is accumulating biogenic siliceous oozes.

The submergence of the Iceland-Faeroe Ridge is believed to have been definite in the lower early Miocene, as the occurrence of *Velicucullus oddgurneri* and *Cyrtocapsella tetrapera* in the Norwegian Sea sediments is interpreted as a transportation effect from the north Atlantic water-masses which at this time got free access to the Norwegian Sea.

As learned from Sites 338 and 342, only traces of key species of importance for the lower latitude radiolarian zonation were observed. This is taken as evidence that faunal transportation by the North Atlantic Current, from the North Atlantic into the Norwegian Sea, was very limited. Therefore, biogenic siliceous oozes that accumulated in the Norwegian Sea, are concluded to have been produced by a native fauna and flora. The well developed Eocene siliceous oozes on the Vøring Plateau present another problem. What was the circulation system in the Norwegian Sea during the Eocene? There was apparently no connection with the Atlantic Ocean to the south, but fauna similarities between the Vøring Plateau and different wells in Siberia (Kozlova and Gorbovetz, 1966) leads to the conclusion that the

TABLE 20
Pliocene-Pleistocene Samples Studied for Radiolarians – Site 348

Core	Section	Interval (cm)
1	1	65-67[a]
1	2	85-87[a]
1	3	75-77
1	4	70-72[a]
1	5	70-72
1	6	70-72
1		CC
2	1	52-54[a]
2	1	90-92[a]
2	2	100-102
2	3	90-92
2	4	60-62
2		CC
3	1	66-68
3	2	72-74
3	4	70-72
3	5	74-76
3	6	70-72
3		CC
4	1	104-106
4	2	50-52[a]
4	2	106-108
4	3	41-43
4	3	145-147
4		CC
5	1	105-107
5	2	88-90[a]
5	3	11-13[a]
5	3	78-80[a]
5	5	147-149[a]
5		CC[a]
6	3	50-52[a]
6	3	110-112[a]
6		CC[a]
7	3	45-57[a]
7	3	115-117[a]
7		CC[a]
8	3	55-57[a]
8	3	140-142[a]
8		CC[a]
9	3	30-32[a]
9	3	100-102[a]
9		CC[a]
10		CC[a]

[a]Radiolarians observed.

TABLE 21
Radiolarian Species, Abundances and Preservation – Site 348

Sample (Interval in cm)	Abundance and Preservation	*Cephalic structure indet.*	*Artostrobus joergenseni*	*Antarctissa whitei*	*Phaeodaria spp.*	*Ceratocyrtis galeus*	*Ceratocyrtis histricosus*	*Pterocyrtidium reschetnjakae*	*Ceratocyrtis mashae*	*Hexalonche sp. A*
5-1, 105-107	B									
5-2, 88-90	R/M	R								
5-3, 11-13	F/M	R								
5-3, 78-80	C/G	A								
5-5, 147-149	R/M	F								
5, CC	C/M	R	R	C	R	R				
6-3, 50-52	A/G		R	A	R	R				
6-3, 110-112	C/G		R	A	R	R		R		
6, CC	C/G		R	A	A					
7-3, 45-47	C/G		R	C	R					
7-3, 115-117	C/G			C	R					
7, CC	C/M			F	R		R			
8-3, 55-57	C/M			F			R			
8-3, 140-142	F/M						R			
8, CC	R/P									
9-3, 30-32	R/M									
9-3, 100-102	R/M									
9, CC	F/G			R						
10, CC	F/M			R						
11-3, 30-32	C/M		R							
11-3, 120-122	C/G		R	R					R	
11, CC	F/M								R	
12-3, 30-32	C/G		R	R					R	
12-3, 120-122	C/G		R	R					R	
12, CC	C/G		R	R					R	
13-2, 30-32	C/G		R							
13-2, 120-122	R/P									
13, CC	F/M									
14-3, 30-32	F/G									
14-3, 120-122	F/M									
14, CC	R/P									R
15-2, 30-32	C/G									A
15-2, 120-122	F/M									R
15, CC	C/M									R
16-3, 30-32	R/M									R
16-3, 120-122	R/G									
16, CC	R/M									
17, CC	R/M									
18, CC	R/P									
19-3, 45-47	B									
19, CC	B									

Norwegian Sea and the Arctic Ocean did have common radiolarian species. In other words, there must have been some kind of water exchange between the two seas. However, the circulation pattern during Eocene time is still unknown, and the opening and connection of the northern Norwegian Sea with the Arctic Ocean is still not fully understood.

SUMMARY OF THE RADIOLARIAN STRATIGRAPHY

For the 16 sites drilled, radiolarians were recovered from 10 sites (Table 22). Based on the radiolarians from these sites, it was possible to work out a radiolarian zonation, which is suggested in Table 23. It should here be pointed out that the following boundaries are not well defined, and they are indicated with broken lines in Table 23 in the time column to the right: the early-middle Eocene, the middle-late Eocene, the Eocene-Oligocene, and the middle-late Miocene. Several sites had to be used to compile the suggested local Norwegian Sea radiolarian zonation. *Calocyclas talwanii* Zone through *Lithomelissa stigi* Zone was defined from Site 338, except for the *Lithomitra* sp. A Zone of lower Oligocene age which was suggested as a zone based on the fauna obtained from Site 337. A middle Eocene

TABLE 22
Radiolarian Zones, Leg 38 Sites

Age		Radiolarian Zones	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	352
Pleist.		*Cycladophora davisiana*	(1-10)	1-3											1-5-5	1		1-3
Plio.		*Antarctissa whitei*						25-28-3							5-5 12			
Miocene	L	Unzoned			7			28-3-31-5							12-15			
Miocene	M	*Lithomelissa stigi*			8-2 10-2			31-5-34										
Miocene		*Actinomma holtedahli*			10-2-11-3				3-2-5									
Miocene	E	*Stichocorys biconica*			11-3-12				5-6									
Miocene	E	*Cyrtocapsella eldholmi*			12-13													
		Gondwanaria japonica			13-18													
Oligocene		*Velicucullus oddgurneri*			18-19-3													
Oligocene		*Ceratocyrtis robustus*			19-3-21													
Oligocene		*Phorticium* sp. A			21-24-3													
Oligocene		*Lithomitra* sp. A	14-19	9-11														
Eocene	L	*Lophocorys norvegiensis*			25-27-3			7-11										
Eocene	L	*Calocyclas talwanii*			27-3-29			1-7										
Eocene	M	*Artostrobus quadriporus*				10-12												
Eocene	E	*Acronocalpis tumulosa*								4-5								

faunal assemblage was recovered from Site 339, and the *Artostrobus quadriporus* Zone was suggested. An early Eocene fauna assemblage was recovered from Site 343, and the *Arachnocalpis tumulosa* Zone was suggested.

Late Miocene through Pleistocene sediments were recovered from Sites 341 and 348, and an unzoned interval was suggested for the late Miocene, while the *Antarctissa whitei* Zone and the *Cycladophora davisiana* Zone were defined for the Pliocene and Pleistocene, respectively.

TAXONOMY

In previous DSDP reports, the taxonomic sections have been rather substantial. For space reasons, the present author will minimize this section, as the taxonomy for the majority of the illustrated species is dealt with in one or more of the following papers: Cita et al., (1970), Riedel and Sanfilippo (1970, 1971), Moore (1971), Petrushevskaya and Kozlova (1972), Goll (1972), Dumitrica (1972), Kling, (1973), Sanfilippo and Riedel (1973), Petrushevskaya (1975), and Chen (1975). The reader is referred to these papers for specific descriptions, synonymy lists, and general taxonomic remarks.

In the taxonomic section of this paper, only those species which are of importance for the radiolarian zonation will be dealt with. As some of the species used as zone names are new species, a formal description of these species follows. Table 24 contains listing of species encountered in this study.

Order POLYCYSTINA Ehrenberg

Polycystina Ehrenberg, 1838, emend. Riedel 1967.

Suborder SPUMELLARIA Ehrenberg, 1875

Family ACTINOMMIDAE Haeckel, emend. Riedel, 1967

Genus ACTINOMMA Haeckel

Actinomma holtedahli n. sp.
(Plate 20, Figures 8, 9)

Actinomma Haeckel, 1862.

Description: Based on examination of 25 specimens, the test is composed of one (?) spongy medullary shell, 50-75 μm in diameter. Two cortical shells, outer and inner basically of same structure, outer shell, in most cases, a little thinner with smaller pores, 10 μm in diameter than the inner cortical shell with pores about 20 μm in diameter. Diameter of outer cortical shell, 200-250 μm, while the inner is roughly 20-40 μm smaller. The medullar shell is connected to the two cortical shells by numerous (more than 15) thin cylindrical, radial spines, while the two cortical shells are connected with additional bars.

Dimensions of holotype: Outer cortical shell, 250 μm, inner cortical shell, 210 μm, and the medullary shell about 75 μm. Holotype Plate 20, Figure 9. Holotype from Sample 338-15-4, 130-132 cm.

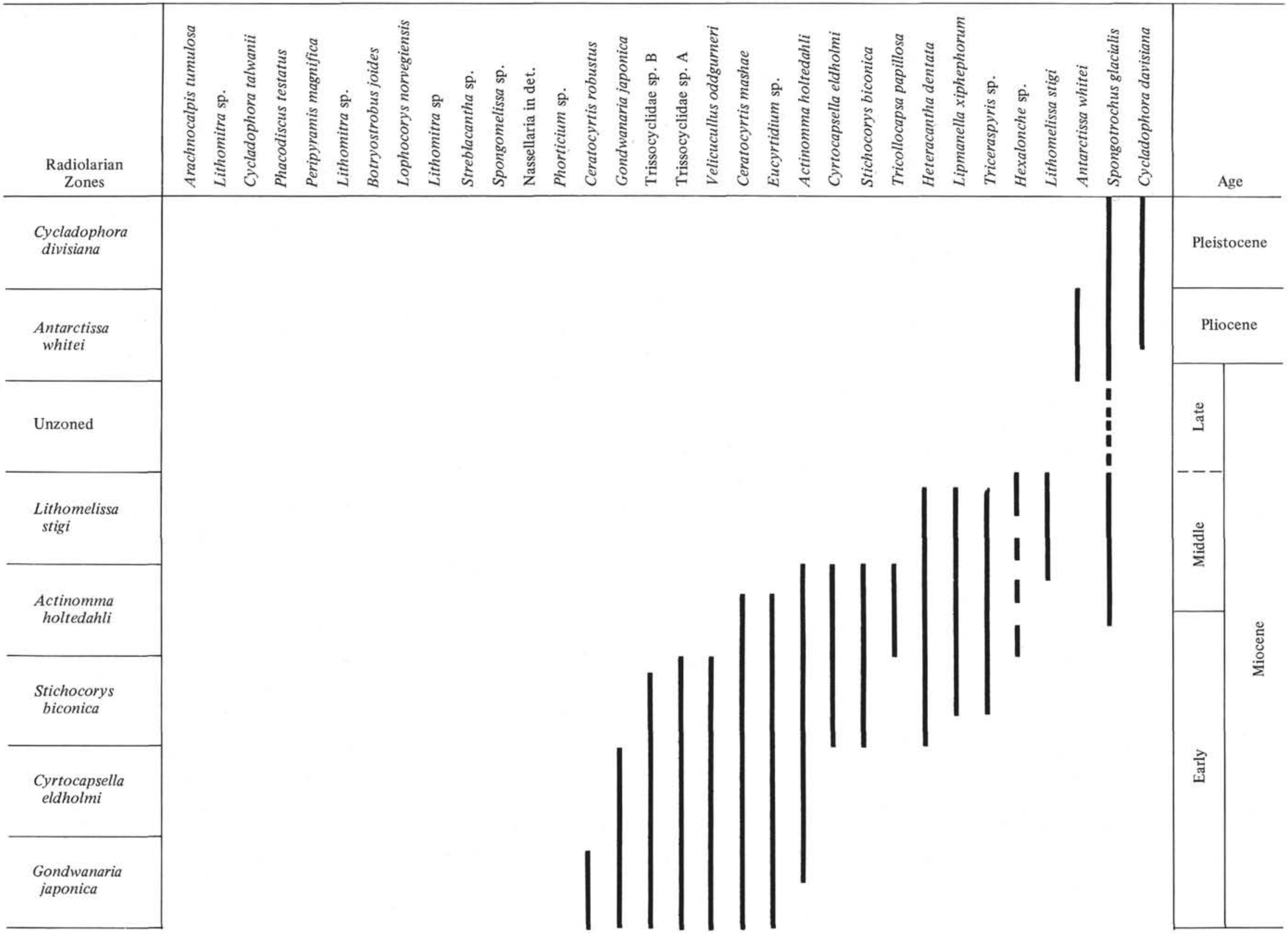
Distribution: Present at Site 338 from Samples 10-2, 146-148 cm through 15-4, 130-132 cm.

The specific name *holtedahli* is in honor of Prof. Dr. phil. Hans Holtedahl, Geological Institute, Dept. B., University of Bergen.

The holotype is stored in the type collection at the Zoological Museum, Bergen, with the journal number 57951.

Remarks: The generic placing of this species is rather questionable, as it was not possible for the observer to state whether the medullar shell consisted of one or two shells, as illustrated in Dumitrica (1972, pl. 7, fig. 4-6), and, consequently, should have been referred to the genus *Rhizosphaera*.

TABLE 23
Radiolarian Zonation, Leg 38



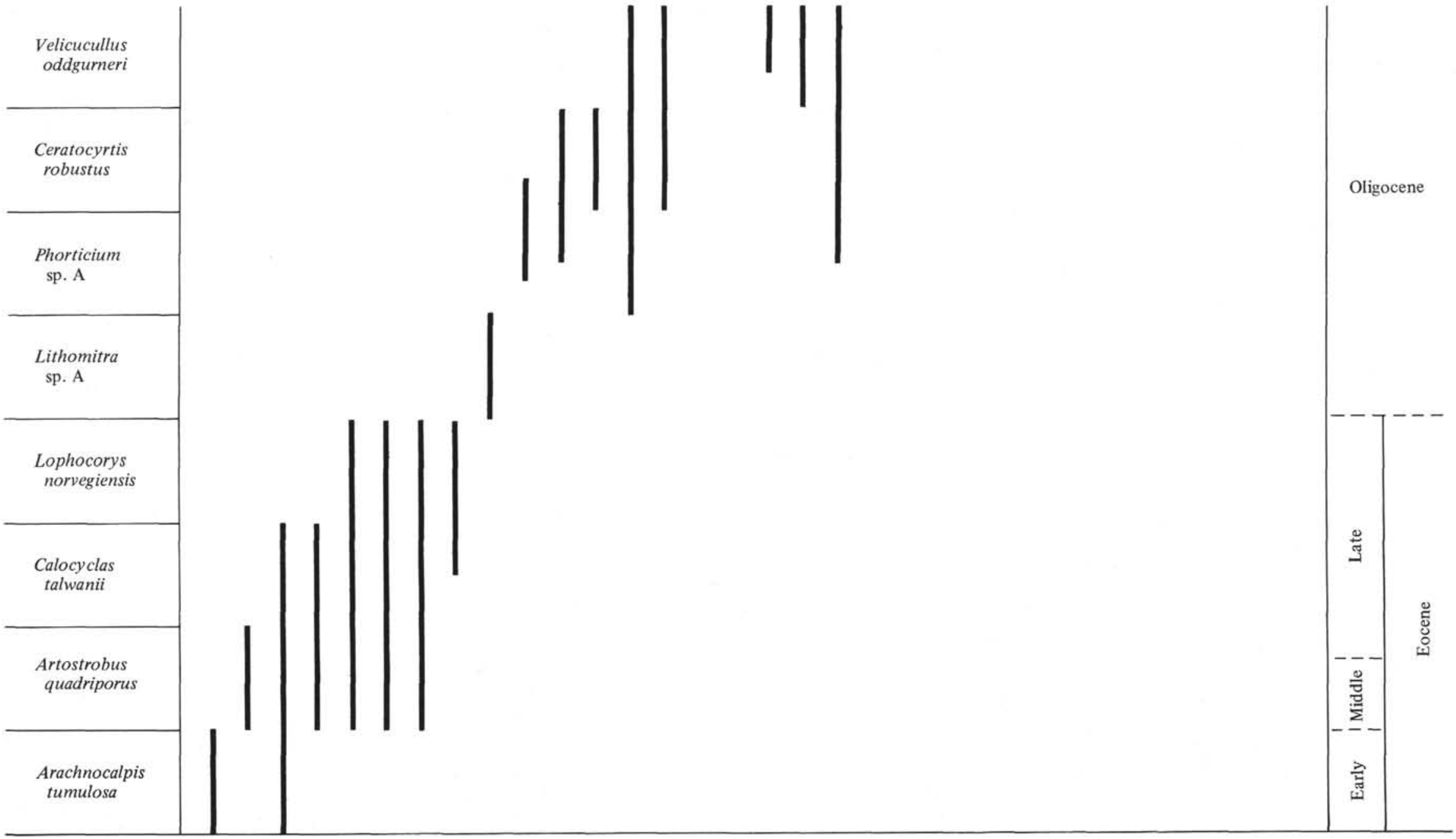

Velicucullus oddgurneri
Ceratocyrtis robustus
Phorticium sp. A
Lithomitra sp. A
Lophocorys norvegiensis
Calocyclas talwanii
Artostrobus quadriporus
Arachnocalpis tumulosa
Oligocene
Late
Middle
Early
Eocene

TABLE 24
Alphabetical Listing of Species Encountered in This Study

Actinomma holtedahli n. sp. (Plate 20, Figures 8, 9)
Actinomma sp. (Plate 20, Figure 7)
Actinomma sp. (Plate 19, Figures 1, 2)
Amphimelissa setosa (Cleve, 1899) (Plate 11, Figures 28-32)
Androcyclas gamphonycha (Jorgensen, 1900) (Plate 10, Figures 2-6)
Antarctissa whitei n. sp. (Plate 13, Figures 9-14)
Antarctissa sp (Plate 13, Figures 1-8)
Arachnocalpis tumulosa Kozlova, 1966 (Plate 24, Figures 6-9)
Arachnosphaera dichotoma Jorgensen, 1900 (Plate 3, Figures 5-9)
Artobotrys borealis (Cleve, 1899) (Plate 11, Figures 24-27)
Artostrobus annulatus (Bailey, 1856) (Plate 11 Figure 14)
Artostrobus joergenseni Petrushevskaya, 1971 (Plate 11, Figures 12, 13)
Artostrobus quadriporus n. sp. (Plate 23, Figures 15-21)
Botryostrobus sp. (Plate 16, Figures 6-8)
Botryostrobus sp. (Plate 16, Figures 9, 10)
Cadium bullatum Stadum and Ling, 1969 (Plate 18, Figure 15)
Cadium melo (Cleve, 1899) (Plate 12, Figure 14)
Calocyclas extensa (Clark and Campbell, 1942) (Plate 21, Figures 4-7)
Calocyclas talwanii Bjorklund and Kellogg, 1972 (Plate 21, Figures 1-3)
Calocyclas sp. (Plate 21, Figures 8-10)
Calocyclas sp. (Plate 22, Figures 1, 2)
Calocyclas sp. (Plate 22, Figures 3, 4)
Calocyclas sp. (Plate 22, Figure 5)
Campylacantha cladophora Jorgensen, 1905 (Plate 6, Figures 1-6)
Ceratocyrtis galeus (Cleve, 1899) (Plate 11, Figures 1-3)
Ceraticyrtis histricosus (Jorgensen, 1905) (Plate 8, Figures 19-24; Plate 11, Figures 4, 5)
Ceratocyrtis sp. aff. *C. histricosus* (Jorgensen, 1905) (Plate 15, Figures 6, 7)
Ceratocyrtis mashae n. sp. (Plate 17, Figures 1-5)
Ceratocyrtis robustus n. sp. (Plate 17, Figures 6-10)
Ceratocyrtis sp. (Plate 15, Figures 1-3)
Ceratocyrtis sp. (Plate 18, Figures 18-21)
Ceratospyris hyperborea Jorgensen, 1905 (Plate 10, Figures 13, 14)
Ceratospyris sp. (Plate 23, Figure 22)
Challengeron diodon Haeckel, 1887 (Plate 12, Figures 8-11)
Challengeron (?) spp. (Plate 13, Figures 15-21)
Cladococcus viminalis Haeckel, 1862 (Plate 1, Figures 10-12)
Cladoscenium tricolpium (Haeckel, 1882) (Plate 7, Figures 5-8)
Cornutella sp. aff. *C. californica* Clark and Campbell, 1942 (Plate 23, Figures 23, 24)
Cornutella profunda Ehrenberg, 1854 (Plate 11, Figure 15)
Cornutella sp. (Plate 15, Figure 23)
Corocalyptra craspedota (Jorgensen, 1900) (Plate 9, Figures 11-15)
Corocalyptra sp. aff. *C. craspedota* (Jorgensen, 1900) (Plate 15, Figure 24)
Cromyechinus borealis (Cleve, 1899) (Plate 2 Figures 7-15)
Cytrocapsella eldholmi n. sp. (Plate 17, Figures 11-13)
Cyrtocapsella japonica (Nakaseko, 1963) (Plate 17, Figures 17, 18)
Cyrtocapsella tetrapera Haeckel, 1887 (Plate 17, Figures 19, 20)
Cyrtocapsella sp. (Plate 17, Figures 14-16)
Cycladophora davisiana Ehrenberg, 1872 (Plate 11, Figures 9-10)
Dictyoceras acanthicum Jorgensen, 1900 (Plate 10, Figure 1; Plate 11, Figure 11)
Drymyomma elegans Jorgensen, 1900 (Plate 3, Figures 1-4)
Echinomma leptodermum Jorgensen, 1900 (Plate 1, Figures 13, 14; Plate 2, Figures 1-6)
Euscenium (?) *corynephorum* Jorgensen, 1900 (Plate 7, Figures 1-4)
Genus et sp. indet. (Plate 22, Figures 11, 12)
Genus et sp. indet. (Plate 24, Figures 1, 2)
Gondwanaria japonica (Nakaseko, 1963) (Plate 18, Figures 22-27)
Gonosphaera primordialis Jorgensen, 1905 (Plate 9, Figures 7-10)
Heliodiscus sp. aff. *H. hexasteriscus* (?) Clark and Campbell, 1942 (Plate 20, Figures 12, 13)
Heliodiscus sp. (Plate 14, Figures 13, 14)
Heteracantha dentata Mast, 1910 (Plate 14, Figures 10-12)
Hexalonche sp. A (Plate 14, Figures 1-5)
Hexalonche sp. B (Plate 14, Figures 7-9)
Hexalonche sp. (Plate 19, Figures 3, 4)
Hexaconthium enthacanthum Jorgensen, 1900 (Plate 1, Figures 1-3)

TABLE 24 – *Continued*

Hexaconthium pachydermum Jorgensen, 1900 (Plate 1, Figures 4-9)
Hexaconthium sp. Pl. 19, Fig. 5
Larcospira minor (Jorgensen, 1900) (Plate 5, Figures 2-8)
Lipmanella xiphephorum sensu Petrushevskaya and Kozlova, 1972 (Plate 16, Figures 11-13)
Litharachnium tenthorium Haeckel, 1862 (Plate 9, Figure 6)
Lithelius spiralis Haeckel, 1860 (Plate 5, Figure 1)
Lithomelissa hystrix Jorgensen, 1900 (Plate 8, Figures 14-18)
Lithomelissa setosa Jorgensen, 1900 (Plate 8, Figures 1-13, Plate 11, Figures 19-23)
Lithomelissa stigi n. sp. (Plate 15, Figures 12-17)
Lithomelissa (?) sp. (Plate 16, Figures 14-16)
Lithomelissa sp. (Plate 15, Figures 9-11)
Lithomitra lineata Ehrenberg, 1838 (Plate 11, Figure 16)
Lithomitra plathycephala (?) (Ehrenberg, 1872) (Plate 11, Figures 17, 18)
Lithomitra sp. (Plate 15, Figures 26-28)
Lithomitra sp. (Plate 23, Figures 1-3)
Lithomitra sp. (Plate 23, Figures 4-6)
Lophocorys biaurita (Ehrenberg, 1875) (Plate 21, Figures 16, 17)
Lophocorys norvegiensis Bjorklund and Kellogg, 1972 (Plate 21, Figure 11)
Lophocorys sp. (Plate 21, Figures 12-15)
Lychnocanium grande Clark and Campbell, 1942 (Plate 15, Figure 5)
Lychnocanium (?) sp. (Plate 23, Figures 10, 11)
Peridium longispinum Jorgensen, 1900 (Plate 7, Figures 9-15)
Peripyramis magnifica Clark and Campbell, 1942 (Plate 22, Figures 13, 14)
Peripyramis sp. (Plate 18, Figure 1)
Phacodiscus testatus Kozlova, 1966 (Plate 20, Figures 10, 11)
Phormacantha hystrix (Jorgensen, 1900) (Plate 6, Figures 12-18)
Phorticium clevei (Jorgensen, 1900) (Plate 4, Figures 6-10)
Plagiacantha arachnoides (Claparede, 1855) (Plate 6, Figure 7)
Plectacantha oikiskos Jorgensen, 1905 (Plate 6, Figures 8-10)
Plectacantha trichoides Jorgensen, 1905 (Plate 6, Figure 11)
Porospathis holostoma (Cleve, 1899) (Plate 12, Figures 12, 13)
Protocystis harstoni (Murray, 1885) (Plate 12, Figures 5-7)
Protocystis tridens (Haeckel, 1887) (Plate 12, Figures 1-3)
Protocystis xiphodon (Haeckel, 1887) (Plate 12, Figure 4)
Pseudodictyophimus gracilipes (Bailey, 1856) (Plate 9, Figures 1-5; Plate 11, Figures 6, 7)
Pseudodictyophimus sp. aff. *P. gracilipes* (Bailey, 1856) (Plate 16, Figures 1-5)
Pterocyrtidium sp. aff. *P. reschetnjakae* Petrushevskaya, 1971 (Plate 24, Figures 3-5)
Pylosphaera (?) sp. (Plate 14, Figure 17)
Spongodiscus sp. (Plate 20, Figure 1)
Spongomelissa sp. sensu Chen, 1975 (Plate 22, Figures 6-9)
Spongotrochus glacialis Popofsky, 1908 (Plate 11, Figure 8; Plate 14, Figure 18; Plate 20, Figures 2, 3)
Stichocorys biconica (Vinassa de Regny, 1900) (Plate 16, Figures 17-21)
Stichocorys seriata (Jorgensen, 1905) (Plate 10, Figures 7-12)
Stichocorys sp. (Plate 18, Figures 2-6)
Streblacantha circumtexta Jorgensen, 1900 (Plate 5, Figures 9-12)
Stylodictya tenuispina Jorgensen, 1900 (Plate 4, Figure 5)
Stylodictya validispina Jorgensen, 1900 (Plate 4, Figure 4)
Stylosphaera sp. (Plate 14, Figures 15, 16)
Theocalyptra tetracantha Bjorklund and Kellogg, 1972 (Plate 22, Figures 15-17)
Tricerospyris sp. (Plate 15, Figures 18-22)
Tricolocapsa papillosa (Ehrenberg, 1872) (Plate 16, Figures 22, 23)
Tripilidium (?) *clavipes adven* Clark and Campbell, 1942 (Plate 22, Figure 10)
Trissospyris sp. A (Plate 18, Figures 7-11)
Trissospyris sp. B (Plate 18, Figures 12-17)
Velicucullus oddgurneri n. sp. (Plate 19, Figures 6-9)

Suborder NASSELLARIA Ehrenberg (1875)

Family EUCYRTIDIIDAE Ehrenberg

Eucyrtidiidae Ehrenberg (1847), Petrushevskaya (1971).

Genus ARTOSTROBUS Haeckel

Artostrobus Haeckel 1887; Campbell, 1954; Petrushevskaya, 1975.

Petrushevskaya (1975) discusses the lineage of *Artostrobus* sp. Cr. through *A. pusillum* to *A. annulatus*. Based on her description of *A.* sp. Cr., and the illustration (pl. 10, fig. 1), it is not possible to determine with certainty if *A.* sp. Cr. is identical with the following description.

Artostrobus quadriporus n. sp.
(Plate 23, Figures 15-21)

Description: Shell consists of cephalis, thorax, and abdomen, with no ring separating the thorax and the abdomen. The 25 specimens examined vary from 40 to 50 μm across the thickest part on the abdomen, with a length varying from 90 to 125 μm. The shell wall is rather thick, and pores on the upper half of the test are round to square, while the test at this part is heavily spiny (Plate 23, Figures 15-17 and 20). The lower part of the test is characterized by being more delicate, the spines are usually missing. The species name is based on the lowermost rows of pores, which are square, or nearly square (Plate 23, Figures 15, 17, and 20).

Dimensions of holotype: The broadest point on the abdomen is 44 μm, while the length of the test is 107 μm (Plate 23, Figure 17). Holotype from Sample 339-11, CC.

Distribution: Present at Site 339 throughout the Tertiary sequence. Holotype stored in the type collection at the Zoological Museum, Bergen, with the journal number 57952.

Family LAMPROMITRIDAE Haeckel, 1881

Genus CERATOCYRTIS Bütschli

Ceratocyrtis robustus n. sp.
(Plate 17, Figures 6-10)

Ceratocyrtis Bütschli, 1882; Petrushevskaya, 1971.

Description: The test is composed of cephalis and thorax, with the hemispherical, small pored cephalis almost incorporated into the thoracic wall. The apical and ventral spines are normally very short, however, sometimes they might be quite obvious features on the cephalis (Plate 17, Figure 8). The thorax is rather thick walled, with rounded to irregularly rounded pores of variable size, 5-25 μm. The outline of the thorax is conical, not tapering towards the oral end (Plate 17, Figures 6 and 8). The apical spine is a pronounced feature (Plate 17, Figure 10), which, in some cases, branches out and almost reaches the lower end of the thorax. The lateral and dorsal spines do not normally pierce the thoracic wall. If they do, they are very hard to define, due to the rough and spiny upper half of the thorax (Plate 17, Figure 8). This description is based on a study of 25 specimens.

Dimensions of holotype: Cephalis is 43 μm wide, and the height about 20 μm, defined from the top of the cephalis, to where the vertical spine pierces the thoracic wall. The greatest width of the thorax is 166 μm, while the height of the test (cephalis and thorax) is 127 μm. Holotype (Plate 17, Figure 8), from Sample 338-17, CC.

The width of the 24 paratypes measured varied between 120 and 180 μm, with an average of 164 μm.

Distribution: At Site 338, this species was observed from Samples 21, CC through 14-2, 140-142 cm, middle Oligocene to lower late Miocene.

The holotype is stored in the type collection in the Zoological Museum, Bergen, with the journal number 57957.

Ceratocyrtis mashae n. sp.
(Plate 17, Figures 1-5)

Description: This species is very similar to the previous one, differing in having a thorax which is tapering towards the oral end, by the more pronounced incorporation of the cephalis into the thoracic wall, and by its smaller size (cephalis and thorax).

Dimensions of holotype: It is not possible to give exact measurements of the cephalis, due to the heavy ornamentation of the test in the junction area of the cephalis and the thorax. The greatest width of the thorax is 125 μm, while the length of the test is 160 μm. Holotype (Plate 17, Figure 1) from Sample 338-11-3, 135-137 cm.

Of the 25 specimens measured, the width of the thorax varied between 112 and 140 μm, with an average of 128 μm.

The specific name *mashae* is in honor of Maria (Masha) G. Petrushevskaya, Zoological Institute, Academy of Sciences, USSR, Leningrad.

Distribution: At Site 338, this species ranges from Samples 23-3, 72-74 cm through 11-2, 115-117 cm, middle Oligocene to lower middle Miocene.

Holotype is stored in the type collection in the Zoological Museum, Bergen, with the journal number 57958.

Remarks: *C. mashae* was observed in the material examined from Site 116 from the North Atlantic. Petrushevskaya and Kozlova (1972) also reported on a *Ceratocyrtis* sp. and *Ceratocyrtis* sp. aff. *C. cucullaris* (Ehrenberg, 1873). The present author believes that the illustrated specimen in Petrushevskaya and Kozlova (1972, pl. 37, fig. 12) is identical with those specimens the author observed from the Site 116 material, and in many of the Norwegian Sea sites, the species here described as *C. mashae.*

Genus ANTARCTISSA Petrushevskaya

Antarctissa whitei n. sp.
(Plate 13, Figures 9-14)

Antarctissa Petrushevskaya, 1967.

Description: The test is very massive, with no distinct junction of cephalis and thorax. The surface looks rather spongy, and it may appear that the pores look funnel-shaped, although, the general appearance is rounded pores, irregularly displaced, with no obvious difference between the cephalic and thoracic pores (Plate 13, Figures 9-14). The internal structures can be seen by observing from below. From the wall, where cephalis and thorax join, bars pierce out towards the center and join a semicircular ring, situated above the medial bar with the vertical, apical, dorsal, and lateral spines (Plate 13, Figure 13). The bars are seldom visible on the surface of the test.

Dimensions of holotype: The widest point of the test is 67 μm, while the length is 84 μm. Twenty-five paratypes were measured varying between 60 and 75 μm of the widest part on the test with a length varying between 58 and 100 μm (Plate 13, Figure 9). Holotype from Sample 348-6-3, 50-52 cm.

The name *whitei* is in honor to Dr. Stan M. White, School of Natural Sciences, California State University at Fresno, California, who acted as editorial representative on Leg 38.

Distribution: Present at Sites 341 and 348, ranging from 25, CC to 28-3, 79-81 cm, and from 5-5, 147-149 cm to 12, CC, respectively.

The holotype is stored in the type collection at the Zoological Museum, Bergen, with the journal number 57953.

Genus LITHOMELISSA Ehrenberg

Lithomelissa stigi n. sp.
(Plate 15, Figures 12-17)

Lithomelissa Ehrenberg, 1847.

Description: Cephalis very small, roughly one-third of the diameter of the thorax, well separated from the latter. Thorax wall campanulate with large rounded pores, 5-8 μm, while the pores on the thorax are larger, 5-15 μm of a more irregular, rounded shape. The vertical and apical spines are cylindrical and well developed, with a length varying from 10 to 60 μm for the apical spine, while the ventral spine is considerably shorter, 5-25 μm. In most cases, the lateral spines do not pierce the thoracic wall, however, the dorsal spine can be very often seen on the outside of the thoracic wall.

Dimensions of holotype: Width of cephalis, 30 μm, height of cephalis, 27 μm, width of thorax, 60 μm, height of test (cephalis and thorax), 70 μm, length of apical spine, 40 μm, and length of vertical spine, 9 μm. Holotype illustrated on Plate 15, Figure 15. From Sample 338-8-2, 120-122 cm. Description is based on examination of 25 specimens.

The name *stigi* is in honor of my son Stig G. Bjørklund. Holotype is stored in the holotype collection at the Zoological Museum, Bergen, journal number 57955.

Family THEOPERIDAE Haeckel, emend. Riedel 1967

Genus CYRTOCAPSELLA Haeckel

Cyrtocapsella eldholmi n. sp.
(Plate 17, Figures 11-13)

Cyrtocapsella Haeckel, 1887.

Description: This species is the largest *Cyrtocapsella* species recovered from the Norwegian Sea sediments. Twenty-five specimens were examined with a width of the third segment varying between 120 and 150 μm, and a height of the three first segments varying between 130 and 160 μm. Cephalis is spherical, furnished with a well-developed apical spine (Plate 17, Figure 11). Thorax is widely campanulated with rounded pores, 5-10 μm, equally distributed, thorax wall thick.

The abdominal, third, segment is separated from the thorax with a well-defined lumbar stricture. The third segment is thick walled with the same pore ornamentation as on the thorax. The abdominal fourth segment, when present, is characterized by its thinner wall and its variable outline, with the two extreme forms shown on Plate 17, Figures 11, 12, between which a series of intermediates exists.

Dimensions of holotype: Width and height of cephalis are equal, 30 μm. Width and height of thorax are 105 μm and 60 μm, respectively. Width and height of the third segment are 133 μm and 63 μm, respectively. The apical spine, 23 μm, and the vertical spine, 13 μm. Holotype (Plate 17, Figure 11) from Sample 338-12-2, 145-147 cm.

The specific name *eldholmi* is in honor of Associate Professor Olav Eldholm, Geological Institute, University of Oslo, who has extensively studied the evolution and the spreading of the Norwegian-Greenland Seas. The holotype is stored in the holotype collection at the Zoological Museum, Bergen, with the journal number 57956.

Remarks: This species is so outstanding both in size and structure, that it should be easy to distinguish from the other *Cyrtocapsella* species (Plate 17, Figures 14-20), present in Norwegian Sea and North Atlantic Ocean sediments.

Family SETHOPHORMIDAE Haeckel, 1882

Genus VELICUCULLUS Riedel and Campbell, 1952

Velicucullus oddgurneri n. sp.
(Plate 19, Figures 6-9)

Definition: The genus is characteristic by its velum on the underside of the flatly expanded or almost discoidal thorax. Because of the great size of this species, and the flat thorax, it is rather difficult to turn the specimens when mounted on the slide and almost all observations were, on the 25 specimens examined, from the apical side. It was, therefore, not possible to observe the velum in side view. There is a shadow of a ring located on the thorax where the thorax wall starts to flatten out. As there is no stricture in this position, this shadow is taken for being the velum (Plate 19, Figures 6-8).

For internal structures, the medial bar with the axial, dorsal, ventral, and lateral bars are recognized. The normal pattern is that these bars are perpendicular to each other (Plate 19, Figure 6). The dorsal spine, however, does, in some cases, furcate so it looks as if five spines are present (Figure 18). In some cases, the spines penetrate the thoracic wall, so they can be seen on the outside. The diameter of the outer edge of the flattened thorax varies between 350 and 450 μm, while the diameter of what is believed to be the velum varies between 180 and 230 μm. The pores on the thorax are irregularly rounded, with an almost uniform size, 8-10 μm, showing a tendency to linear orientation towards the rim (Plate 19, Figure 8).

Dimensions of holotype: Diameter of velum, 210 μm, diameter of the outer rim of thorax, 360 μm. Holotype (Plate 19, Figure 6), from Sample 338-12, CC.

The specific name *oddgurneri* is in honor of my father Odd Gurner Bjørklund, who has shown much interest in my work.

The holotype is stored in the type collection of the Zoological Museum, Bergen, with the journal number 57954.

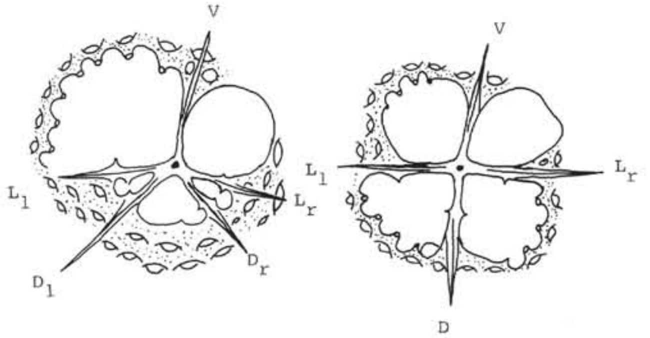


Figure 18. *Internal view of the main spines in* Velicucullus oddgurneri *seen from the apical side. V = ventral spine, D = dorsal spine, L = lateral spine, l and r refer to left and right, respectively.*

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SPECIFIC NOTES CONCERNING THE PLATES

"Glacial" sediments, relatively rich in radiolarians, were recovered from several sites (Table 4). Site 349 is especially rich in radiolarians, and the faunal assemblage recovered from Sample 349-1-1, 10-12 cm is identical with the faunal assemblages obtained from gravity cores from the same area. Instead of illustrating species from Sample 349-1-1, 10-12 cm, the author has chosen to show photographs of species photographed from the radiolarian collection of Jørgensen, which is stored at the Zoological Museum, Bergen. As Jørgensen did not use any photographs in his publications, and as he described quite a number of new species, it is in the interest of all radiolarian taxonomists to have access to this type of material. Jørgensen did not mark his holotypes, but the illustrated specimens on Plates 1-10 have been identified by Jørgensen. Plate 11 illustrates specimens recovered from Sample 349-1-1, 10-12 cm, while the phaeodarians shown on Plate 12 are taken from the Jørgensen and Cleve collections. All specimens illustrated from the Jørgensen collection include in their captions, the sampling locality (not very well defined, only to the specific fjord), and a number (example, 1/4 1900) referring to day, month, and year of sampling. More species are illustrated than shown in Table 4, thus making the Jørgensen collection more complete and valuable for future taxonomic work.

PLATE 1

Scale bar is 100 μm

Figures 1-3	*Hexaconthium enthacanthum* Jørgensen, 1900. 1. Herdlafjorden 20/1-1899. 2,3. Herdlafjorden 24/1-1899.
Figures 4-9	*Hexaconthium pachydermum* Jørgensen, 1900. 4, 5. Same specimen, Kvaenangen 24/1-1899. 6, 7. Same specimen, Kvaenangen 24/1-1899. 8, 9. Herdlafjorden 20/1-1899 and 29/8-1899, respectively.
Figures 10-12	*Cladococcus viminalis* Haeckel, 1862. 10. Storfjorden 1900. 11. Romereimsfjorden 8/9-1901. 12. Herdlafjorden 20/1-1899.
Figures 13, 14	*Echinomma leptodermum* Jørgensen, 1900. Both from Kvaenangen 24/1-1899.

PLATE 1

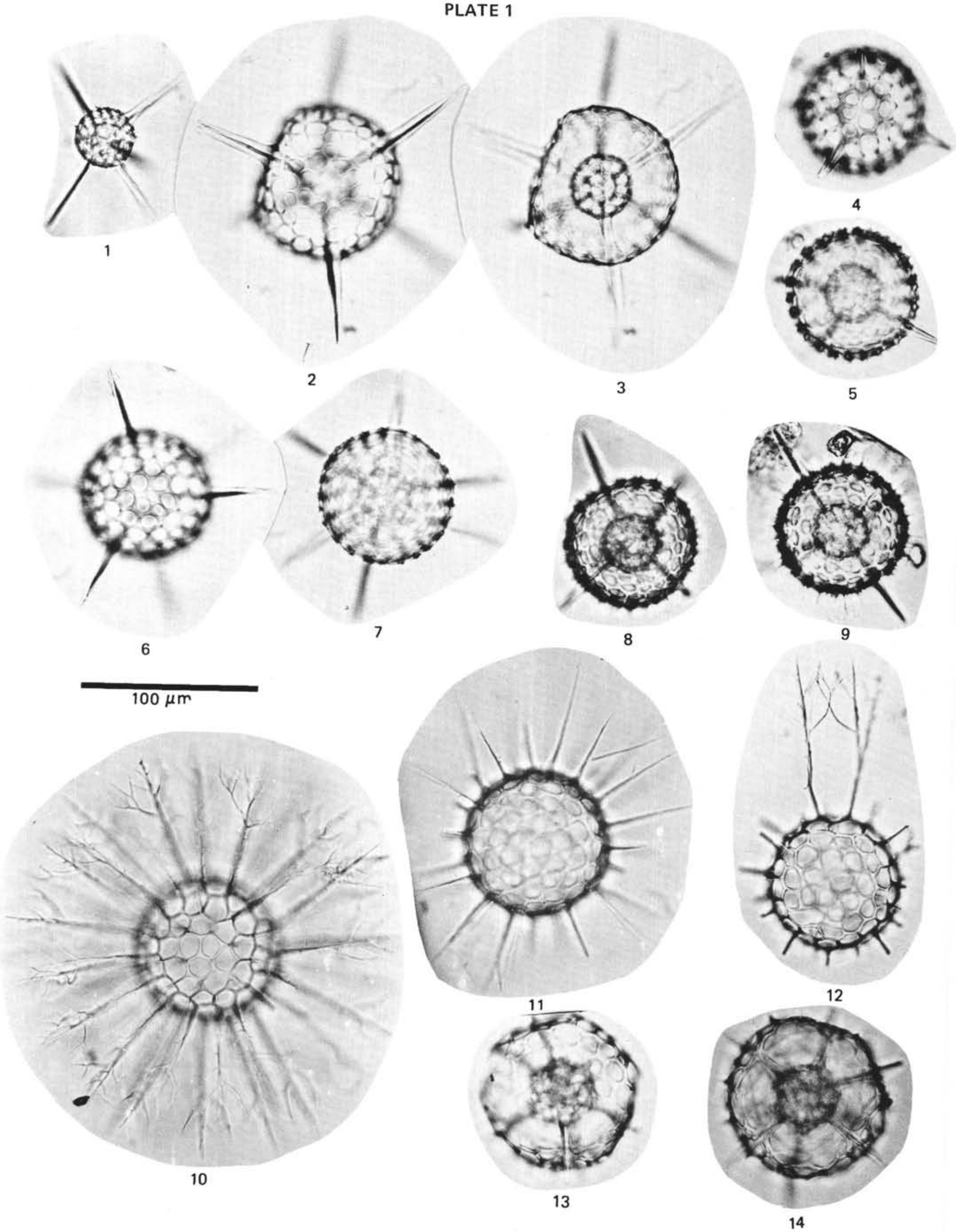

PLATE 2

Scale bar is 100 μm

Figures 1-6	*Echinomma leptodermum* Jørgensen, 1900. 1, 2. Same specimen Kvaenangen 24/1-1899. 3, 4. Same specimen Kvaenangen 24/1-1899. 5. Helligvaer 12/1-1899. 6. Michal Sars st. no. 2, 2/2-1901.
Figures 7-15	*Cromyechinus borealis* (Cleve, 1899). 7, 8. Vestfjorden 1/2-1899. 9. Helligvaer 12/1-1899. 10. Senja 21/1-1899. 11, 12. Vestfjorden 1/2-1899. 13, 14. Vesterålen 19/1-1899. 15. Vesterålen 22/3-1899.

PLATE 3

Scale bar is 100 μm

Figures 1-4	*Drymyomma elegans* Jørgensen, 1900. 1, 2. Senja 21/1-1899. 3, 4. Vesterålen 19/1-1899.
Figures 5-9	*Arachnosphaera dichotoma* Jørgensen, 1900. 5. Herdlafjorden 20/1-1899. 6-9. Herdlafjorden 28/2-1899.
Figures 10-16	*Rhizoplegma boreale* (Cleve, 1899). 10-14. Vesterålen 19/1-1899. 15, 16. Raftsund 3/2-1899.

(see page 1134)

PLATE 4

Scale bar is 100 μm

Figures 1-3	*Rhizoplegma boreale* (Cleve, 1899). 1. Helligvaer 12/1-1899. 2, 3. Vesterålen 19/1-1899.
Figure 4	*Stylodictya validispina* Jørgensen, 1900. Vesterålen 22/3-1899.
Figure 5	*Stylodictya tenuispina* Jørgensen, 1900. Vesterålen 22/3-1899.
Figures 6-10	*Phorticium clevei* (Jørgensen, 1900). 6, 7. Vestfjorden 1/2-1899. 8, 9. Herdlafjorden 20/1-1899. 10. Byfjorden 21/2-1899.

(see page 1135)

PLATE 2

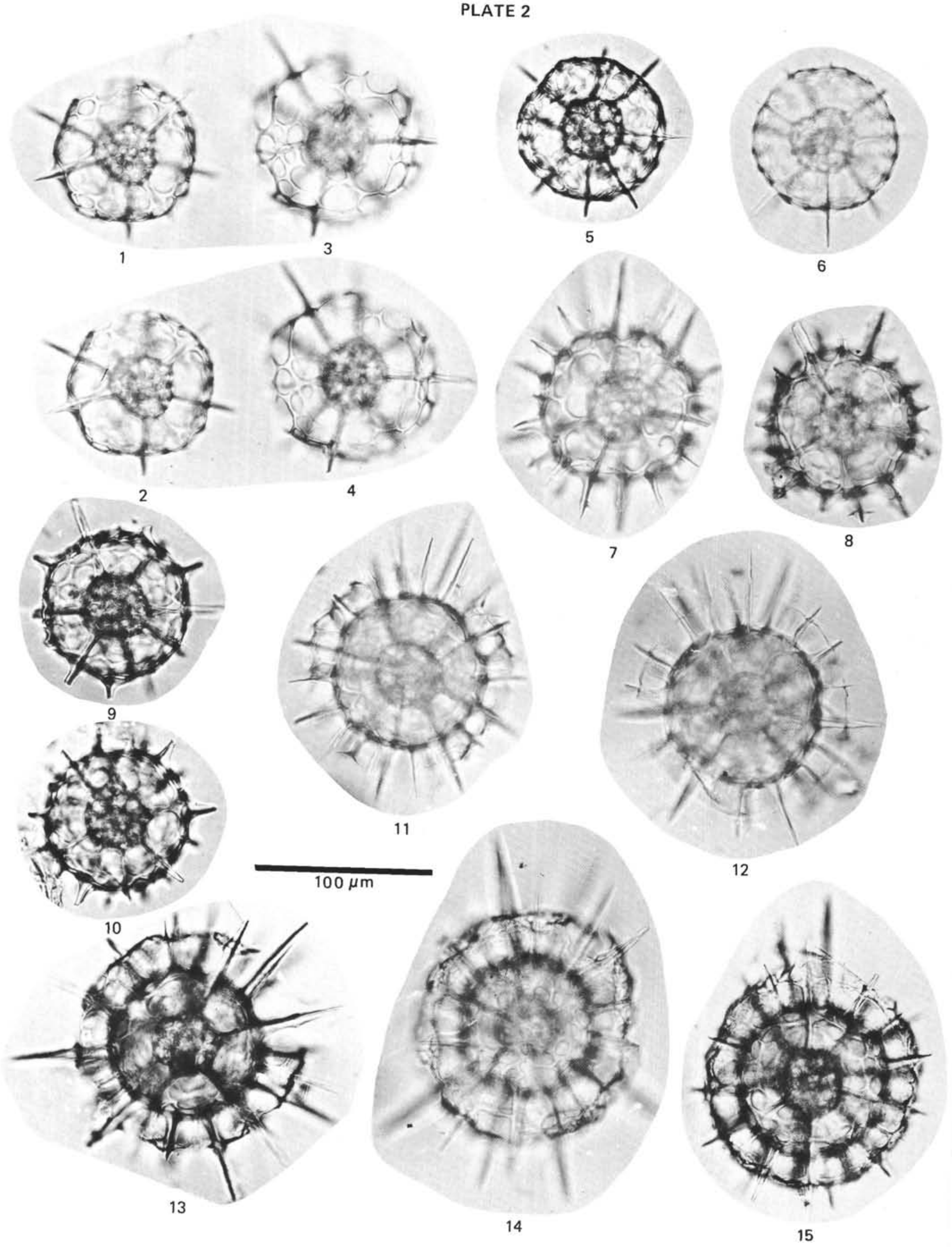

PLATE 3

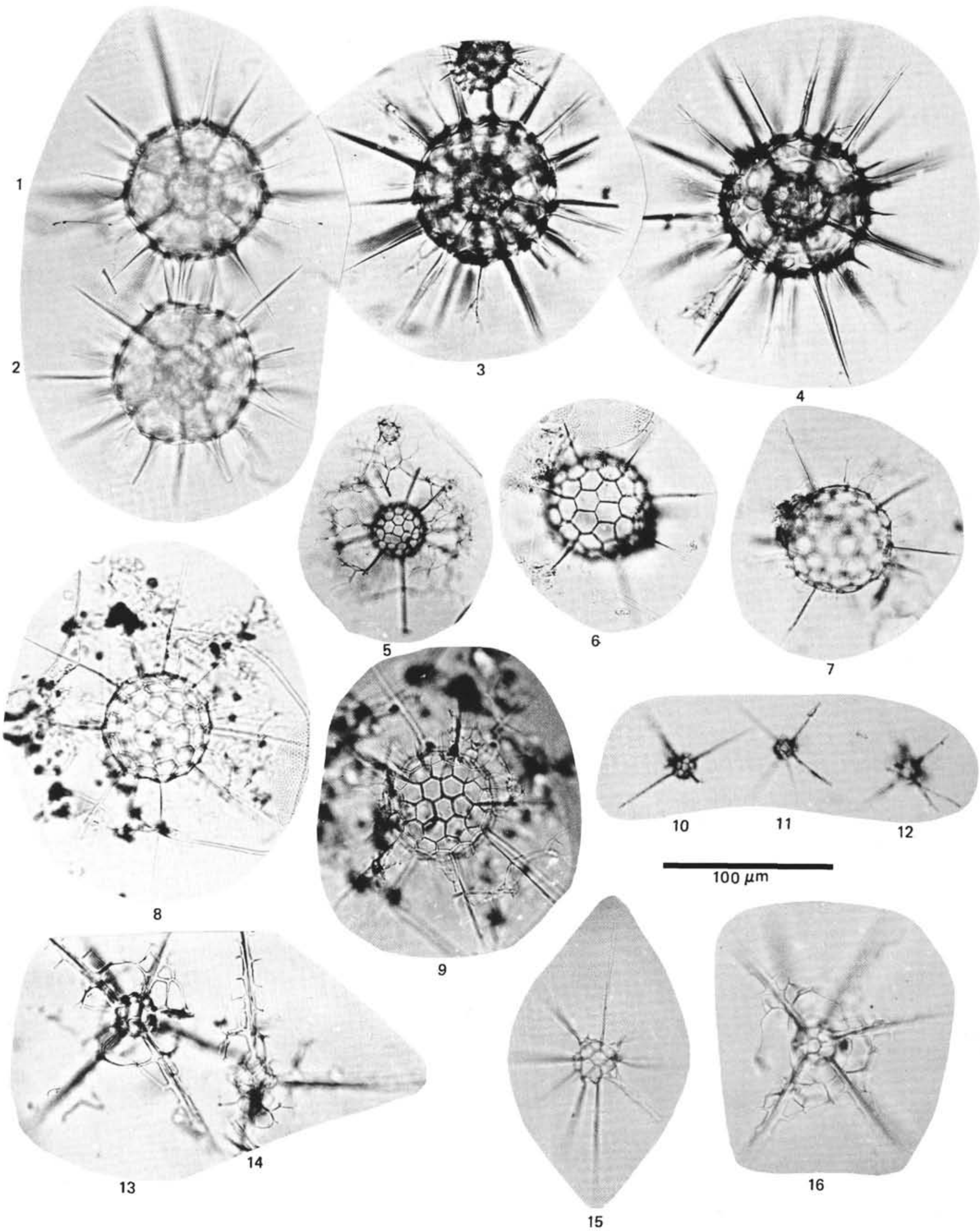

PLATE 4

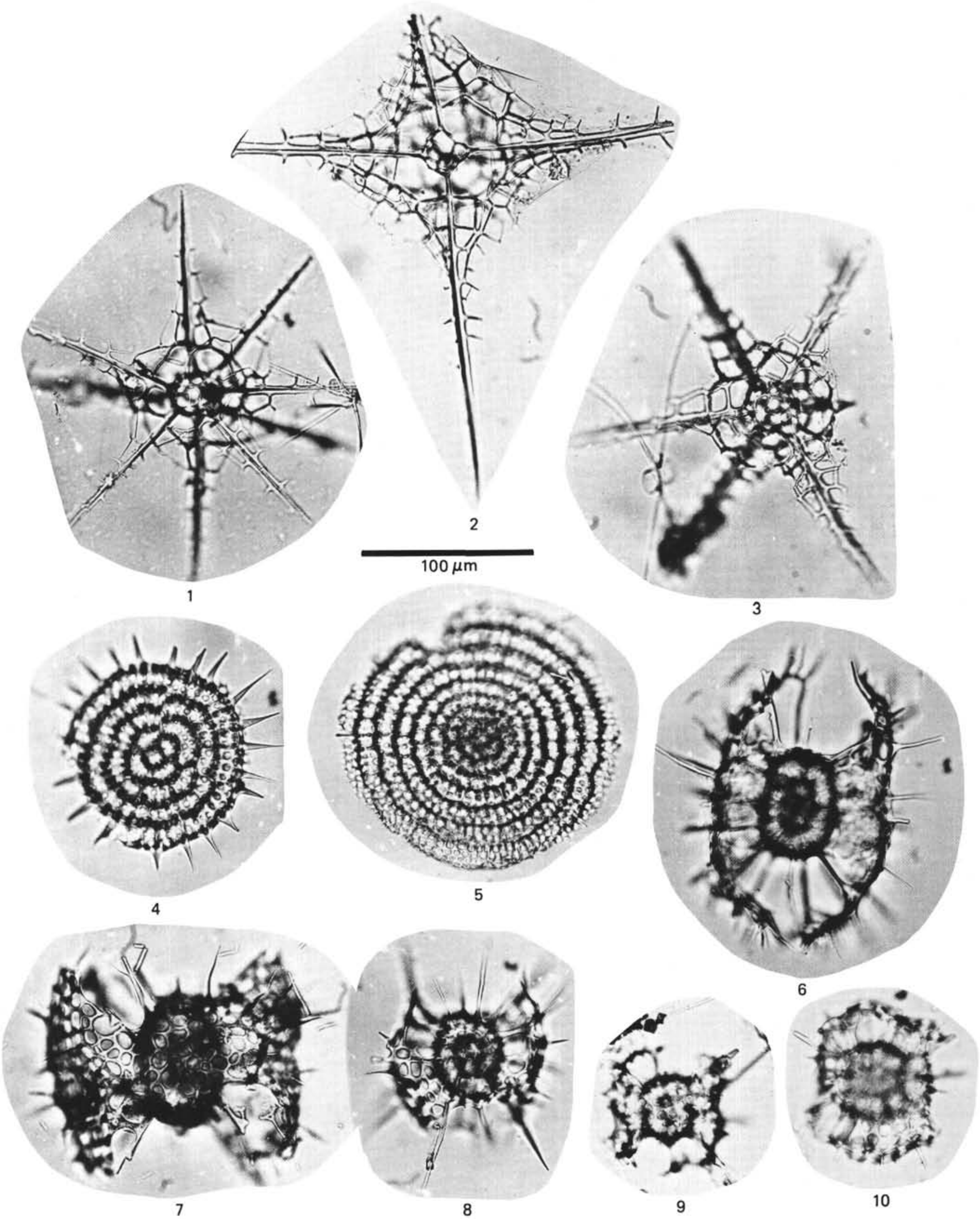

PLATE 5

Scale bar is 100 μm

Figure 1	*Lithelius spiralis* Haeckel, 1860. Vesterålen 19/1-1899.
Figures 2-8	*Larcospira minor* (Jørgensen, 1900). 2-4. Herdlafjorden 28/2-1899. 5-7. Vesterålen 19/1-1899. 8. Vestfjorden 1/2-1899.
Figures 9-12	*Streblacantha circumtexta* (Jørgensen, 1900). 9, 10, 12. Vestfjorden 1/2-1899. 11. Tysfjorden 28/2-1899.

PLATE 6

Scale bar is 100 μm

Figures 1-6	*Campylacantha cladophora* Jørgensen, 1905. All from Kvaenangen 24/1-1899.
Figure 7	*Plagiacantha arachnoides* (Claparede, 1855). Herdlafjorden 28/2-1899.
Figures 8-10	*Plectacantha oikiskos* Jørgensen, 1905. 8. Senja 21/1-1899. 9. Helligvaer 12/1-1899. 10. Herdlafjorden 28/2-1899.
Figure 11	*Plectacantha trichoides* Jørgensen, 1905. Herdlafjorden 28/2-1899.
Figures 12-18	*Phormacantha hystrix* (Jørgensen, 1900). 12-17. Same specimen; all from Vestfjorden 1/2-1899. 18. Vesterålen 19/1-1899.

(see page 1138)

PLATE 5

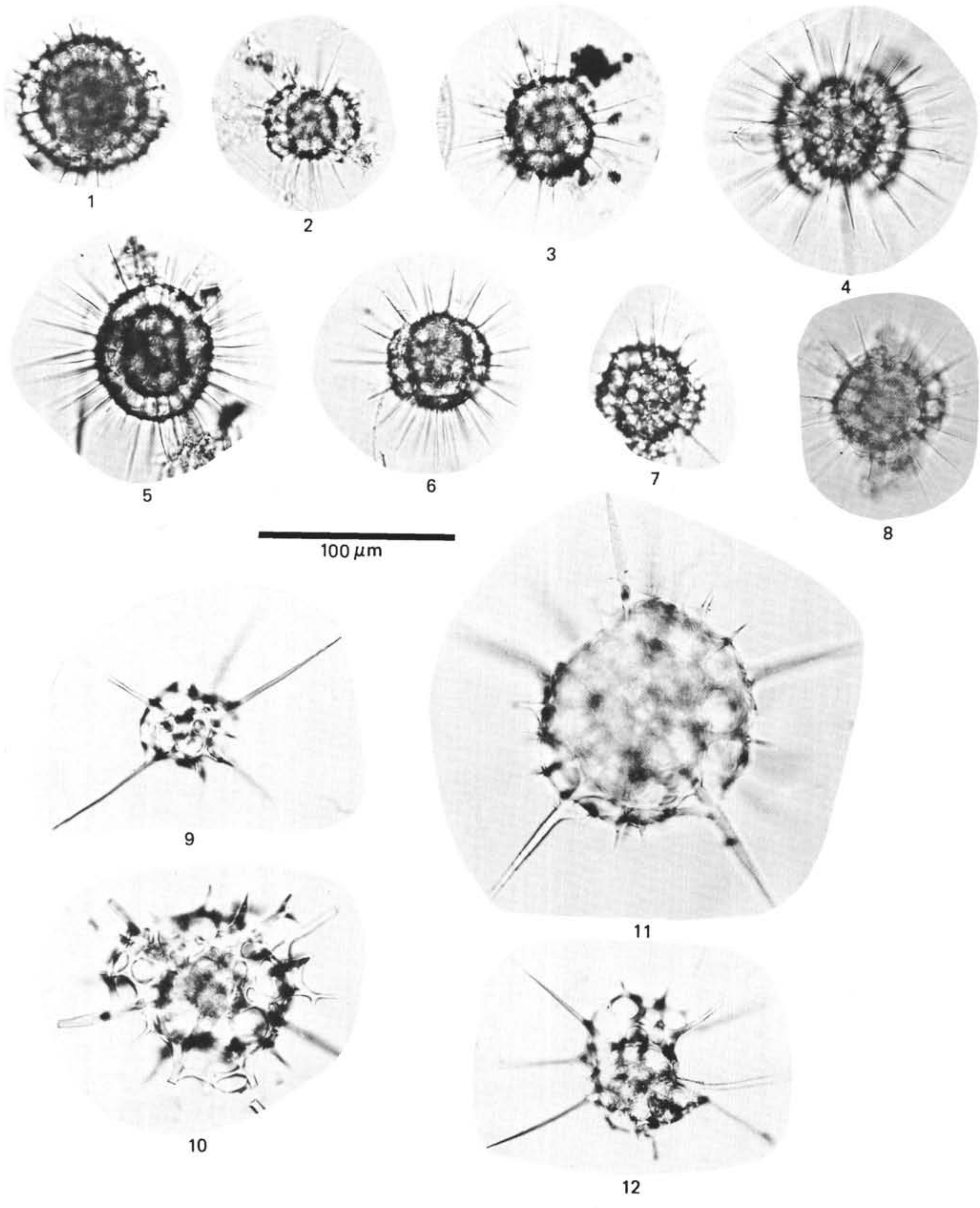

PLATE 6

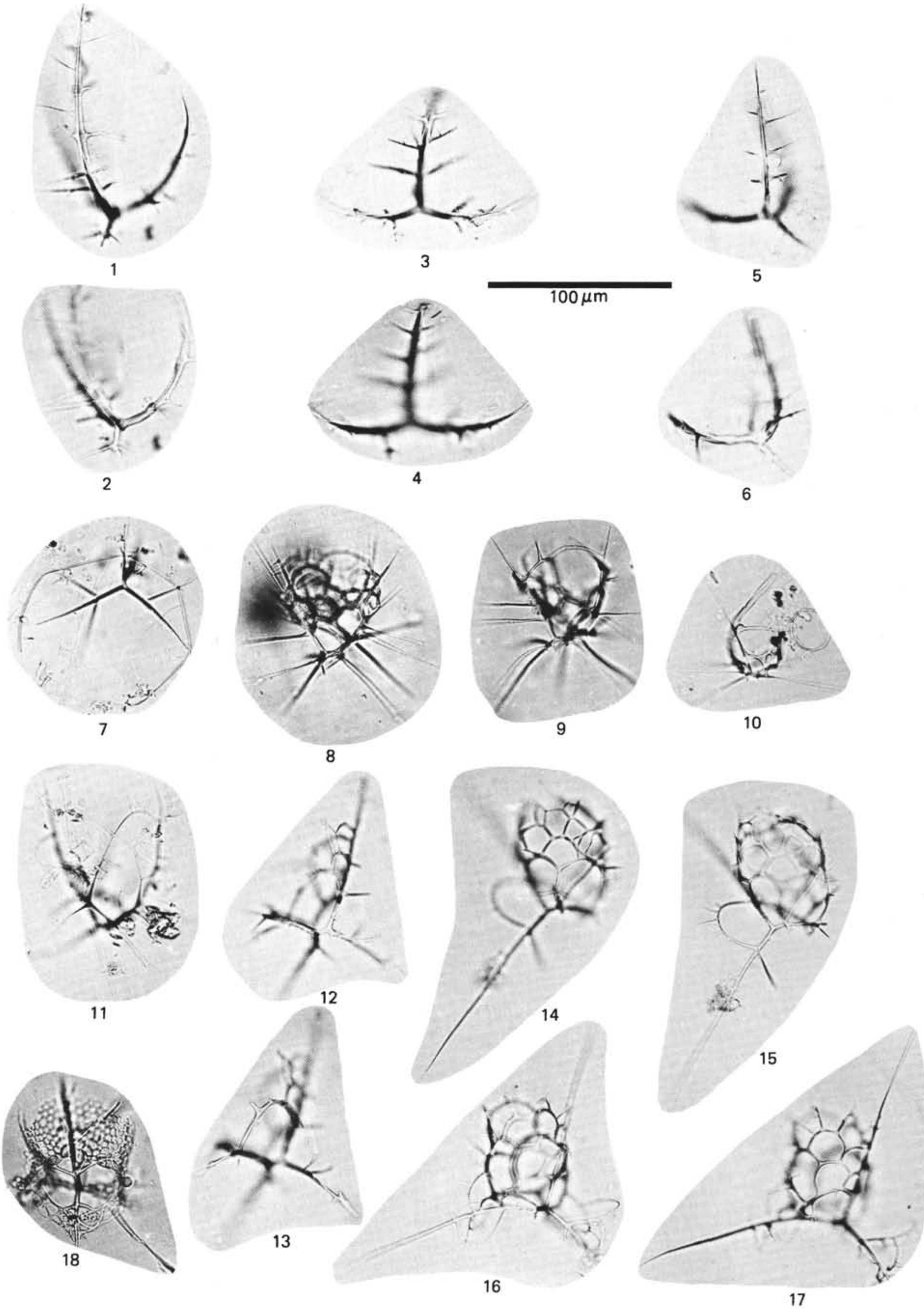

PLATE 7

Scale bar is 100 μm

Figures 1-4 *Euscenium* (?) *corynephorum* Jørgensen, 1900.
1, 2. Hjeltefjorden 21/1-1899.
3, 4. Same specimen, Raftsund 3/2-1899.

Figures 5-8 *Cladoscenium tricolpium* (Haeckel, 1882).
5. Herdlafjorden 20/1-1899.
6. Byfjorden 21/1-1899.
7. Helligvaer 12/1-1899.
8. Vesterålen 19/1-1899.

Figures 9-15 *Peridium longispinum* Jørgensen, 1900.
9, 10. Senja 21/1-1899.
11, 12. Herdlafjorden 28/2-1899.
13. Malangen 29/1-1899.
14. Helligvaer 12/1-1899.
15. Vesterålen 19/1-1899.

(see page 1140)

PLATE 8

Scale bar is 100 μm

Figures 1-13 *Lithomelissa setosa* Jørgensen, 1900.
1-3. Herdlafjorden 20/1-1899.
4. Herdlafjorden 28/2-1899, apical view.
5. Byfjorden 21/2-1899.
6-8. Malangen 29/1-1899.
9. Helligvaer 12/1-1899.
10-13. Kvaenangen 24/1-1899.

Figures 14-18 *Lithomelissa hystrix* Jørgensen, 1900.
14, 15. Same specimen; all from Vesterålen 19/1-1899.

Figures 19-24 *Ceratocyrtis histricosus* (Jørgensen, 1905).
19, 20. Same specimen.
22. Skråven 4/2-1899.
21, 23, 24. Vestfjorden 1/2-1899.

(see page 1141)

PLATE 7

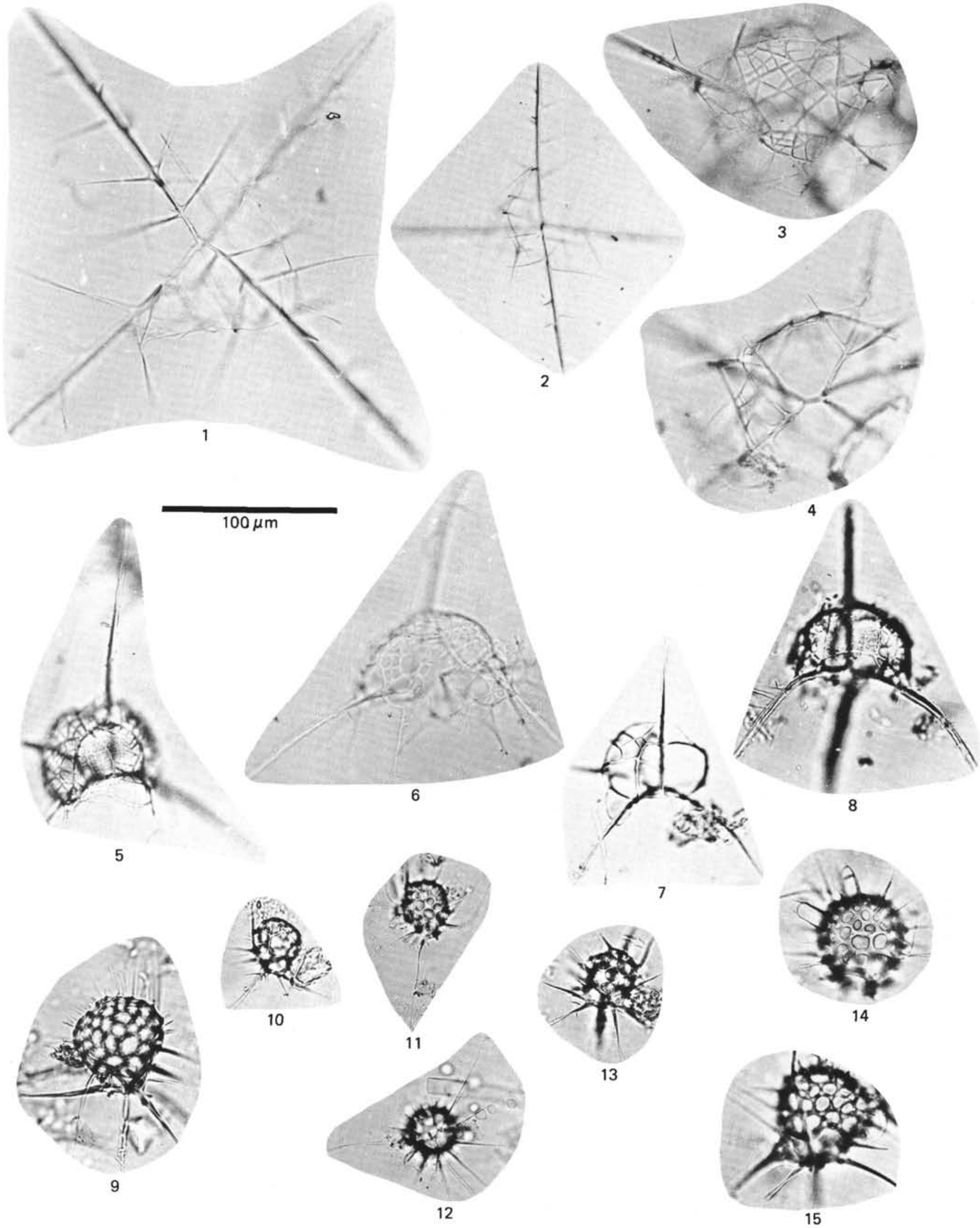

PLATE 8

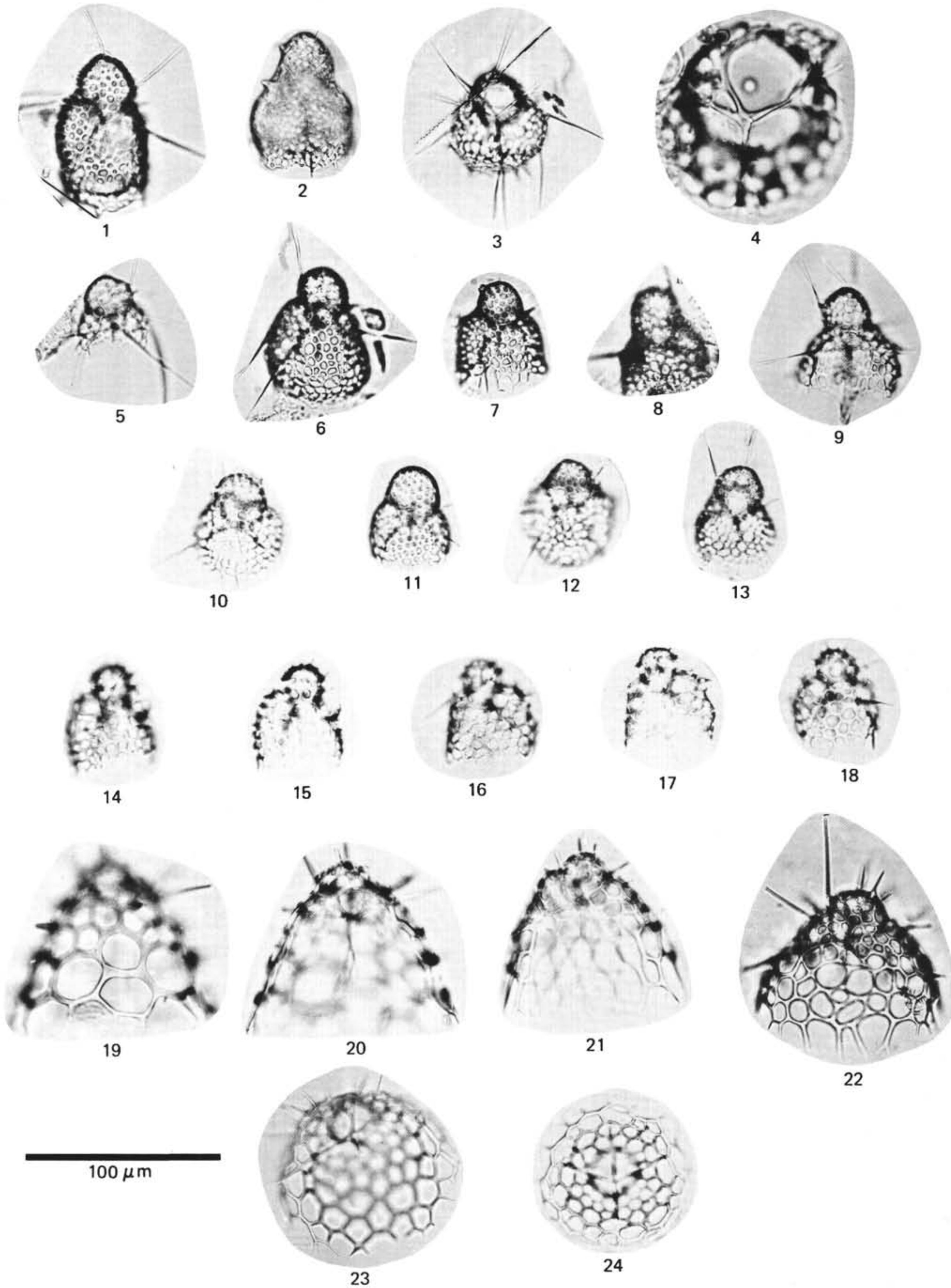

PLATE 9

Scale bar is 100 μm

Figures 1-5	*Pseudodictyophimus gracilipes* (Bailey, 1856). 1-4. Vesterålen 19/1-1899. 5. Malangen 29/1-1899.
Figure 6	*Litharachnium tenthorium* Haeckel, 1862. Skråven 4/4-1899.
Figures 7-10	*Gonosphaera primordialis* Jørgensen, 1905. Herdlafjorden 28/2-1899.
Figures 11-15	Corocalyptra craspedota (Jørgensen, 1900). 11-14. Vestfjorden 1/2-1899. 15. Vesterålen 19/1-1899.

PLATE 10

Scale bar is 100 μm

Figure 1	*Dictyoceras acanthicum* Jørgensen, 1900. Kvaenangen 24/1-1899.
Figures 2-6	*Androcyclas gamphonycha* (Jørgensen, 1900). 2. Vestfjorden 13/1-1899. 3. Skråven 4/2-1899. 4, 5. Herdlafjorden 21/6-1899. 6. Vestfjorden 1/2-1899.
Figures 7-12	*Stichocorys seriata* (Jörgensen, 1905). 7, 8. Vesterålen 19/1-1899. 9, 10. Kvaenangen 24/1-1899. 11, 12. Kvaenangen 6/2-1899.
Figures 13, 14	*Ceratospyris hyperborea* Jørgensen, 1905. Vestfjorden 1/2-1899.

(see page 1144)

PLATE 9

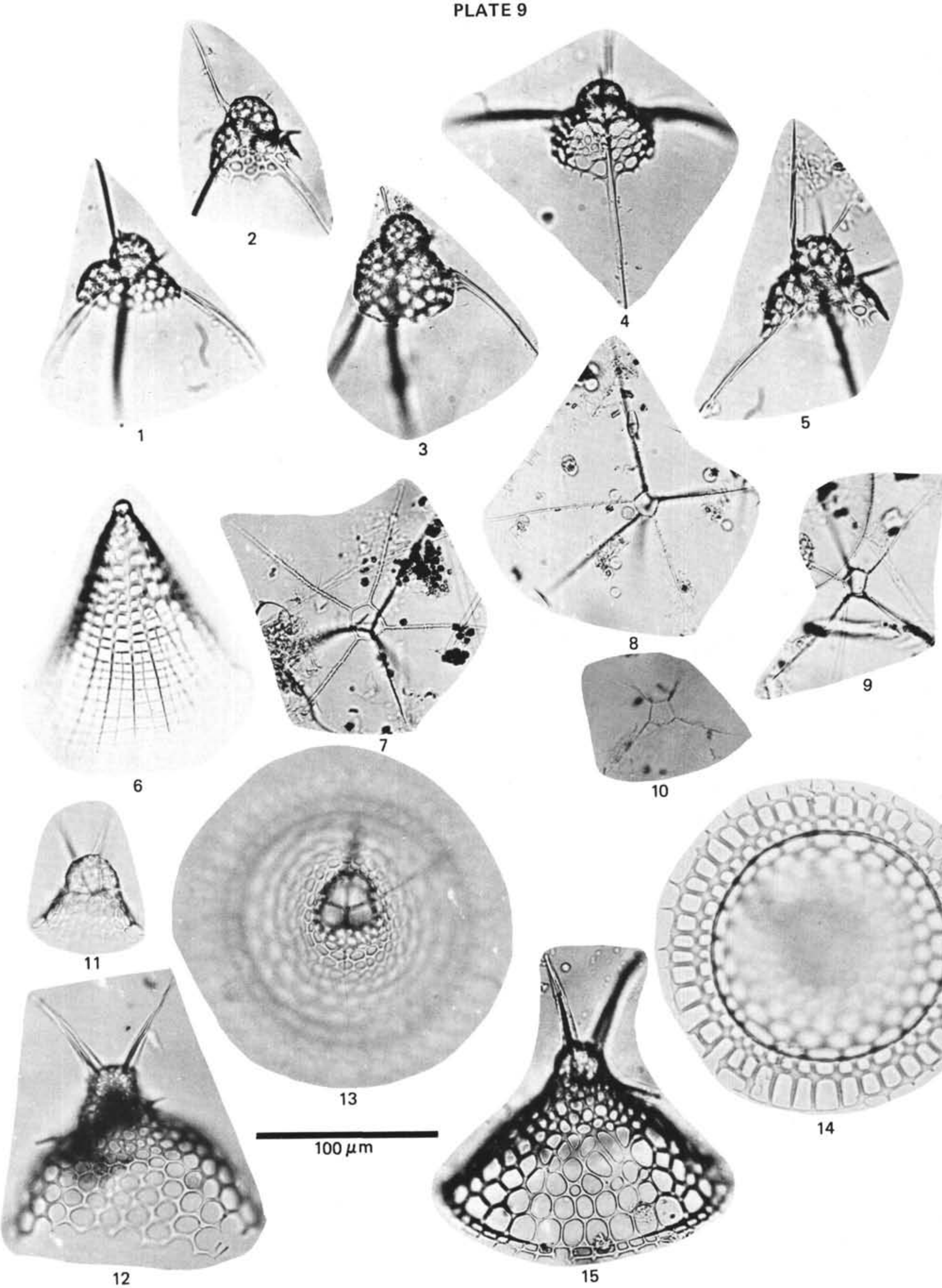

PLATE 10

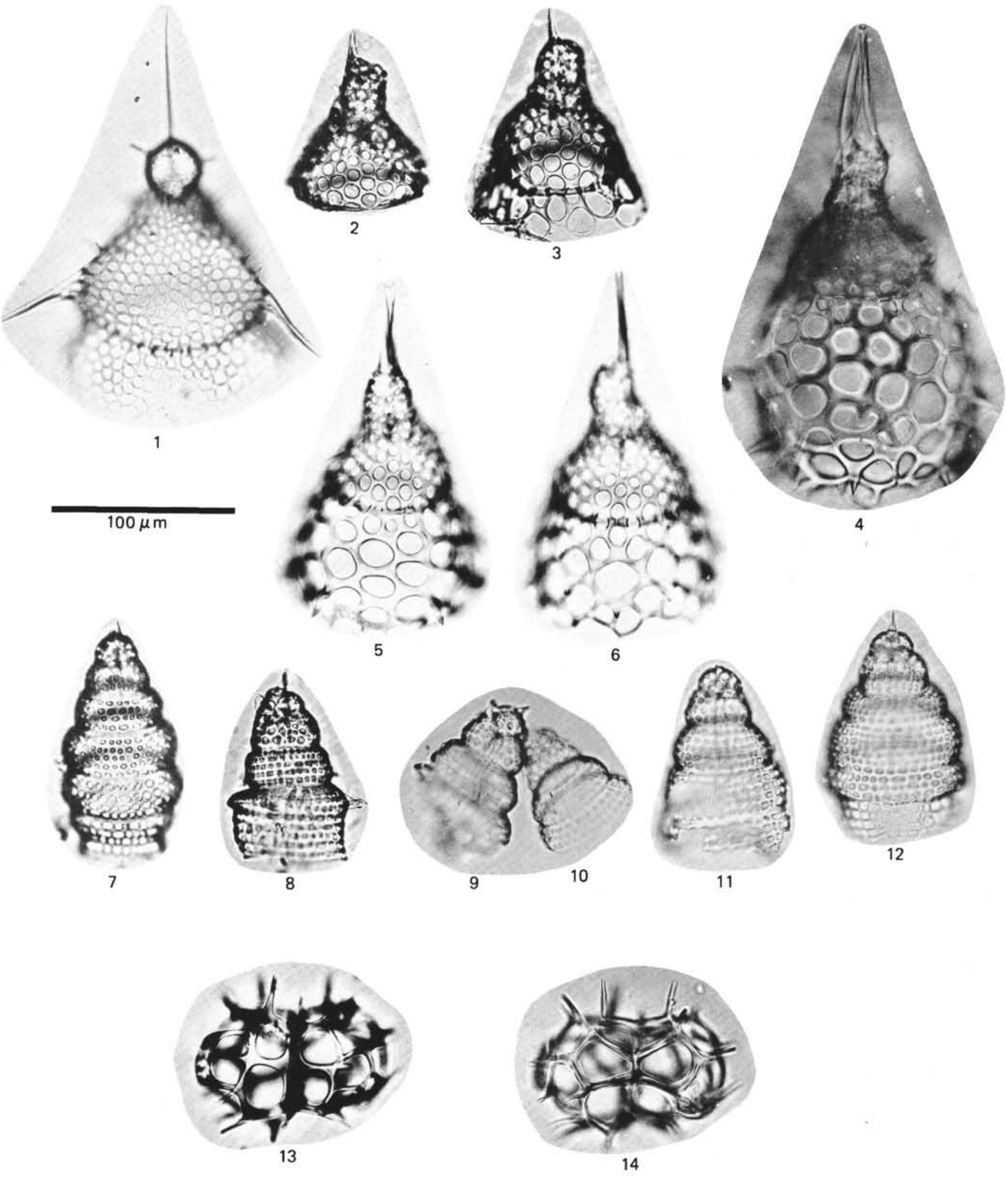

PLATE 11

Scale bar is 100 μm

Figures 1-3	*Ceratocyrtis galeus* (Cleve, 1899). 349-1-1, 10-12 cm.
Figures 4, 5	*Ceratocyrtis histricsus* (Jørgensen, 1905). 349-1-1, 10-12 cm.
Figures 6, 7	*Pseudodictyophimus gracilipes* (Bailey, 1856). 349-1-1, 10-12 cm.
Figure 8	*Spongotrochus glacialis* Popofsky, 1908. 349-1-1, 10-12 cm.
Figures 9, 10	*Cycladophora davisiana* Ehrenberg, 1862.
Figure 11	*Dictyoceras acanthicum* Jørgensen, 1900. 349-1-1, 10-12 cm.
Figures 12, 13	*Artostrobus joergenseni* Petrushevskaya, 1971. 349-1-1, 10-12 cm.
Figure 14	*Artostrobus annulatus* (Bailey, 1856). 349-1-1, 10-12 cm.
Figure 15	*Cornutella profunda* Ehrenberg, 1854. 349-1-1, 10-12 cm.
Figure 16	*Lithomitra lineata* Ehrenberg, 1838. 349-1-1, 10-12 cm.
Figures 17, 18	*Lithomitra platycephala* (?) (Ehrenberg, 1872). 349-1-1, 10-12 cm.
Figures 19-23	*Lithomelissa setosa* Jørgensen, 1900. 349-1-1, 10-12 cm.
Figures 24-27	*Artobotrys borealis* (Cleve, 1899). 349-1-1, 10-12 cm.
Figures 28-32	*Amphimelissa setosa* (Cleve, 1899). 349-1-1, 10-12 cm.

(see page 1146)

PLATE 11

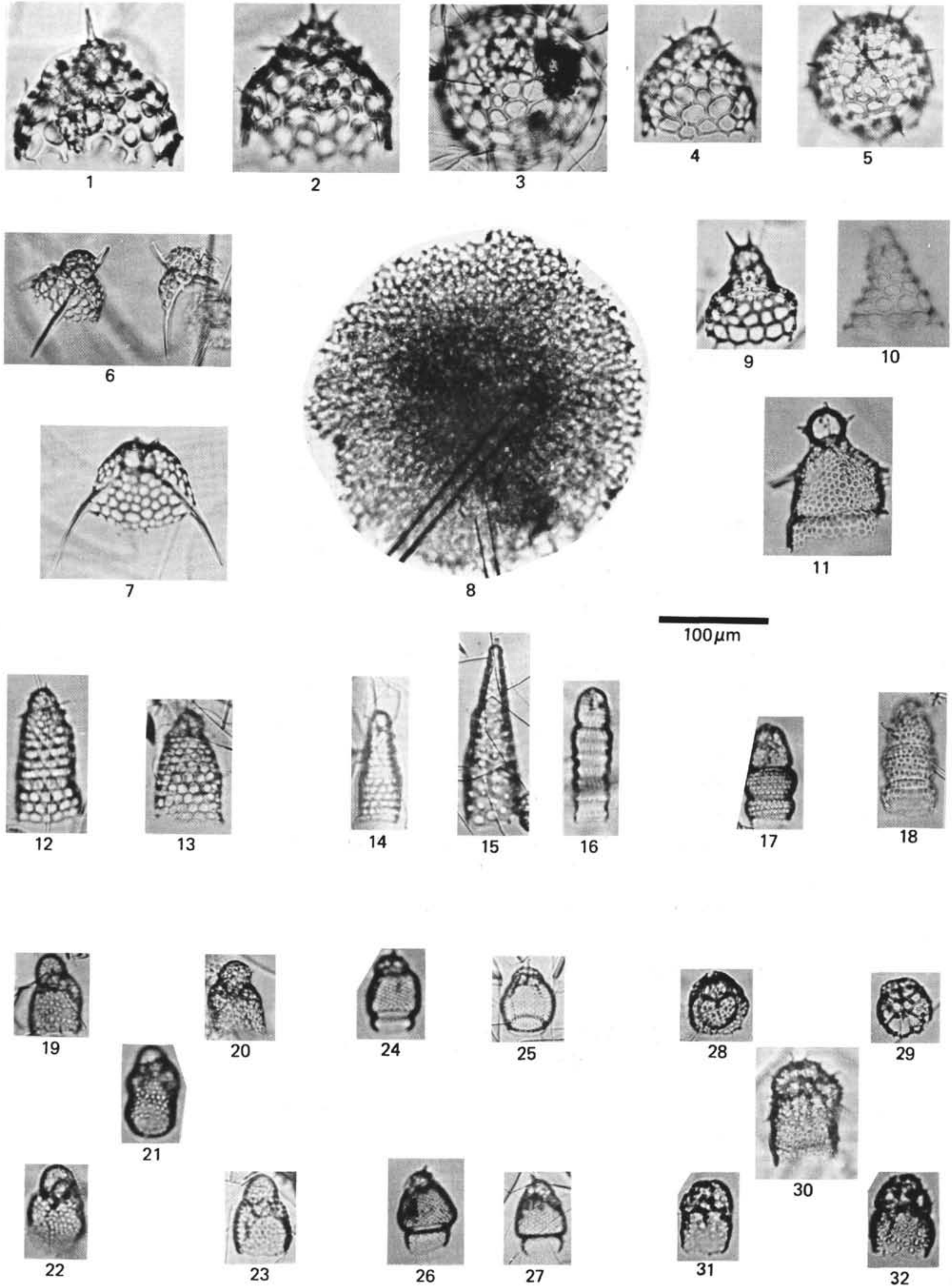
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PLATE 12

Scale bar is 100 μm except Figure 13 is 30 μm

Figures 1-3	*Protocystis tridens* (Haeckel, 1887). 1. North Atlantic, no date, Cleve collection. 2, 3. Herdlafjorden, 20/1 and 14/3 1899, respectively. Jørgensen collection.
Figure 4	*Protocystis xiphodon* (Haeckel, 1887). Vesterålen 19/1 1899, Jørgensen collection.
Figures 5-7	*Protocystis harstoni* (Murray, 1885). 5. Herdlafjorden, 14/3 1899, Jørgensen collection. 6, 7. North Atlantic, no date, Cleve collection.
Figures 8-11	*Challengeron diodon* Haeckel, 1887. 8, 9. Herdlafjorden, 28/2 1899, Jørgensen collection. 10, 11. North Atlantic, no date, Cleve collection.
Figures 12, 13	*Porospathis holostoma* (Cleve, 1899). North Atlantic, no date, Cleve collection.
Figure 14	*Cadium melo* (Cleve, 1899). North Atlantic, no date, Cleve collection.
Figure 15	*Cadium bullatum* (?) Stadum and Ling, 1969. North Atlantic, no date, Cleve collection.

(see page 1148)

PLATE 13

Scale bar is 50 μm

Figures 1-8	*Antarctissa* (?) sp. 348-4-2, 106-108 cm.
Figures 9-14	*Antarctissa whitei* n. sp. 348-6-3, 50-52 cm.
Figures 15-21	*Challengeron* (?) spp. 348-6, CC.

(see page 1149)

PLATE 12

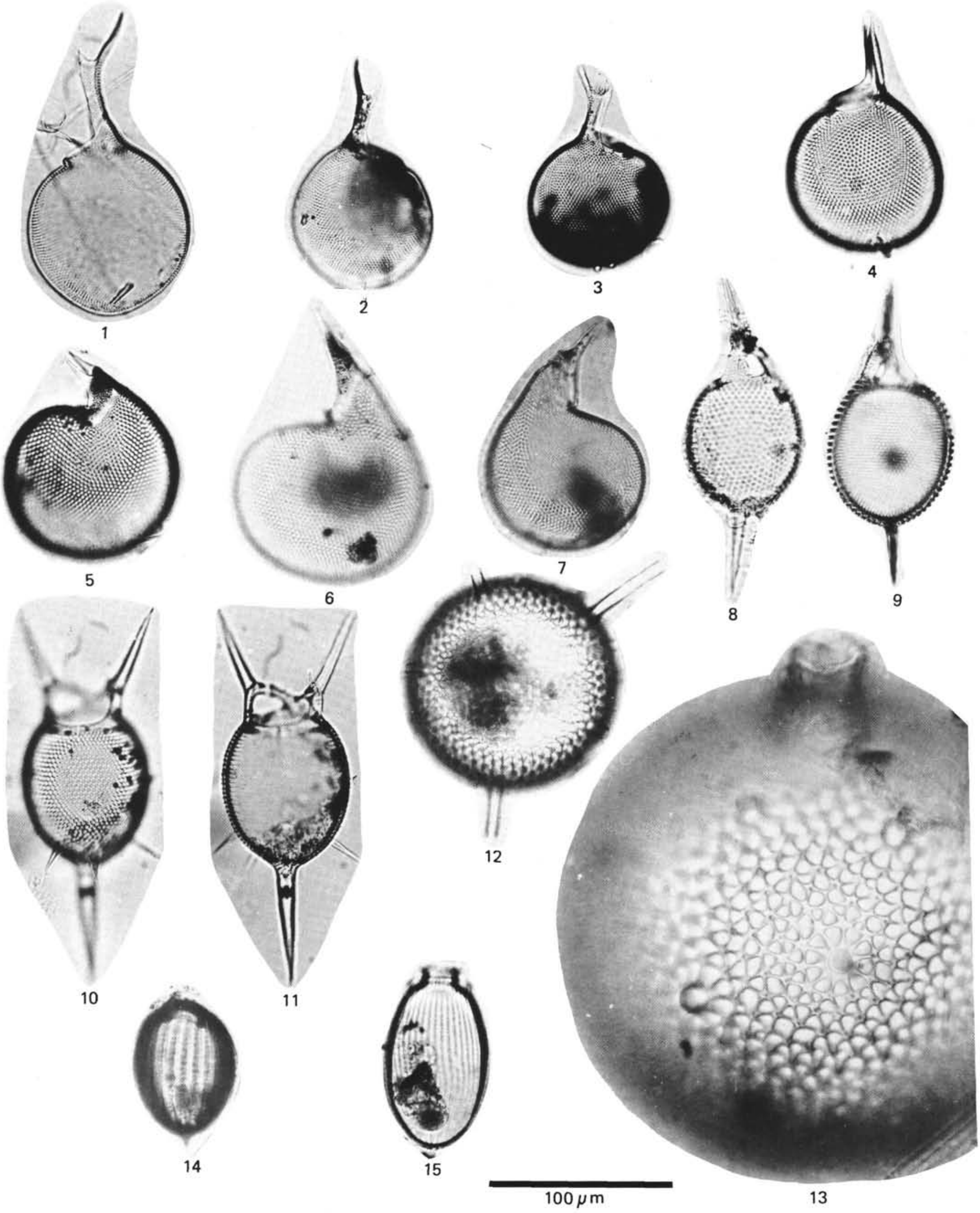

PLATE 13

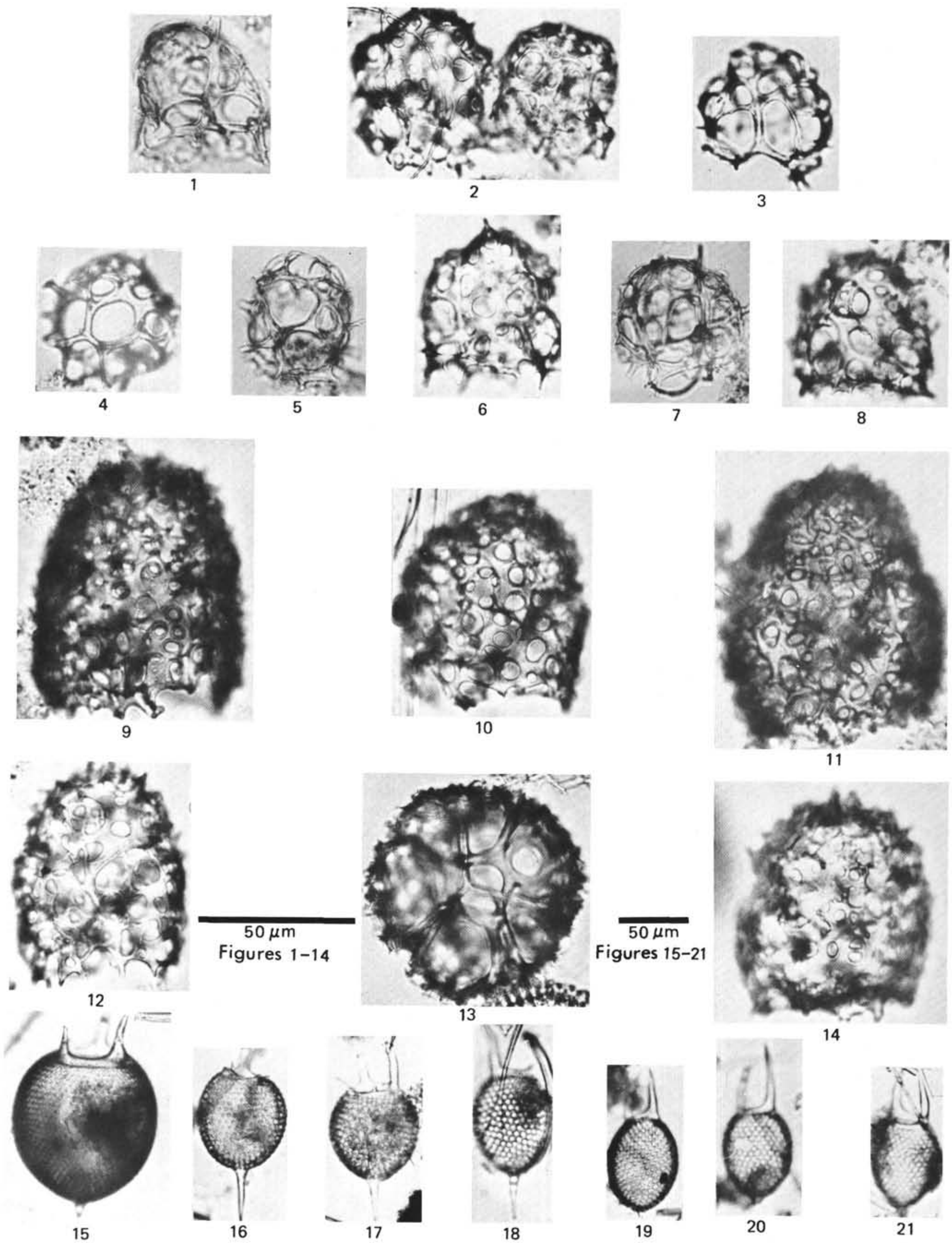

PLATE 14

Scale bar is 100 μm

Figures 1-6	*Hexalonche* sp. A. 1-3. 338-8-2, 53-55 cm. 4, 5. 338-8-3, 45-47 cm. 6. 338-11-3, 135-137 cm.
Figures 7-9	*Hexalonche* sp. B. 7. 338-11-3, 135-137 cm. 8. 338-11-1, 145-147 cm. 9. 338-11, CC.
Figures 10-12	*Heteracantha dentata* Mast, 1910. 10. 338-10-1, 115-117 cm. 11, 12. 338-12-2, 145-147 cm.
Figures 13, 14	*Heliodiscus* sp. 338-11-3, 135-137 cm.
Figures 15, 16	*Stylosphaera* sp. 338-11-3, 135-137 cm.
Figure 17	*Pylosphaera* (?) sp. 338-13-3, 145-147 cm.
Figure 18	*Spongotrochus glacialis* Popofsky, 1908. 338-10-1, 115-117 cm.

PLATE 14

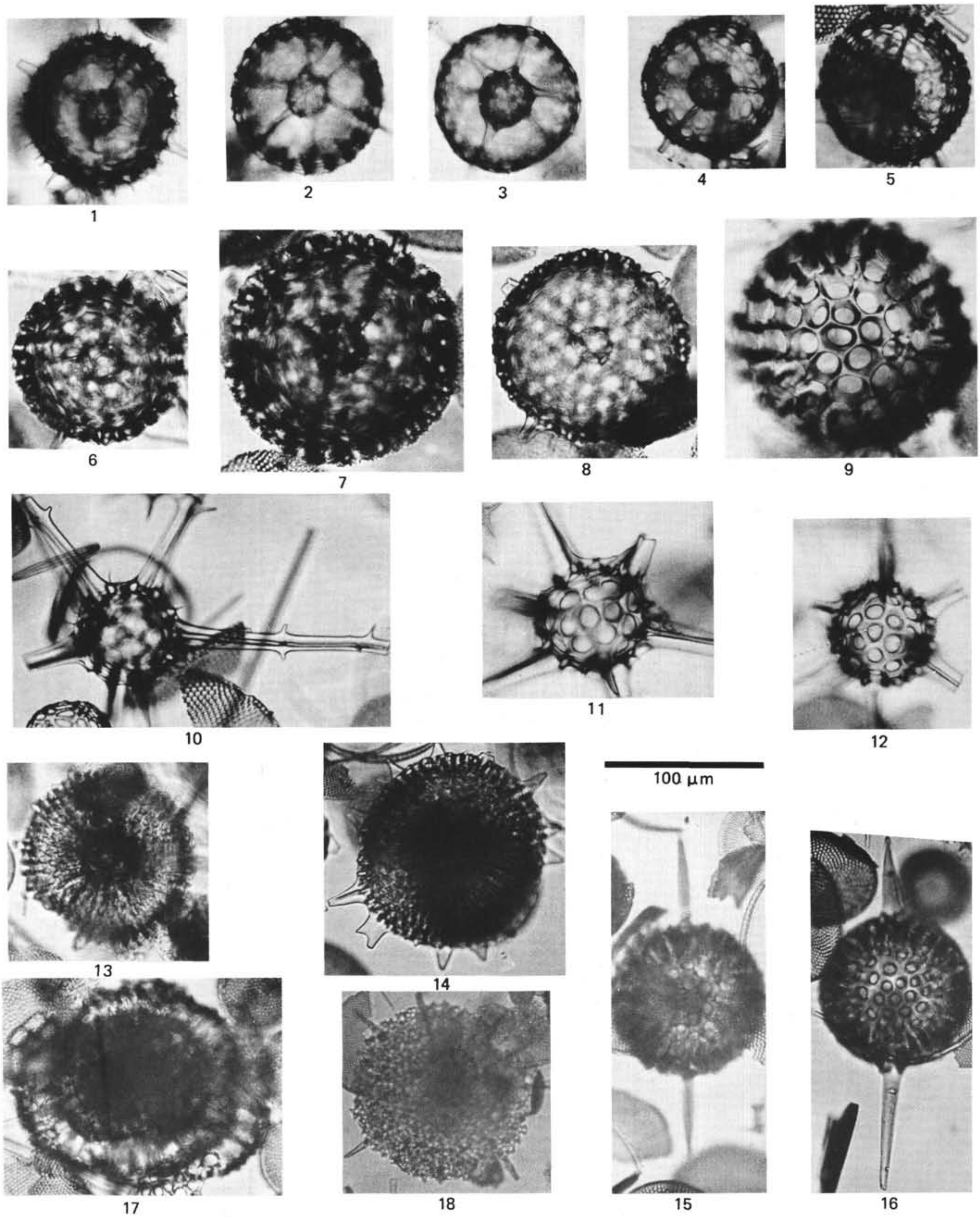

PLATE 15

Scale bar is 100 μm

Figures 1-3	*Ceratocyrtis* sp. 1. 341-28-3, 79-81 cm. 2, 3. 341-29-2, 100-102 cm.
Figure 4	*Antarctissa whitei* n. sp. 341-25, CC.
Figure 5	*Lychnocanium grande* Clark and Campbell, 1942. 341-25, CC.
Figures 6-8	*Ceratocyrtis* sp. aff. *C. histricosus* (Jørgensen, 1905). 338-8-2, 53-55 cm.
Figures 9-11	*Lithomelissa* sp. 338-8-2, 53-55 cm.
Figures 12-17	*Lithomelissa stigi* n. sp. 338-8-2, 120-122 cm; 338-8-3, 45-47 cm.
Figures 18-22	*Tricerospyris* sp. 18. 338-8-3, 45-47 cm. 19. 338-8, CC. 20, 21. 338-9-1, 85-87 cm. 22. 338-10-1, 115-117 cm.
Figure 23	*Cornutella* sp. 338-8-3, 45-47 cm.
Figure 24	*Corocalyptra* sp. aff. *C. craspedota* (Jørgensen, 1900). 338-9-1, 85-87 cm.
Figure 25	Nassellaria. Gen. et sp. indet. 338-9-1, 85-87 cm.
Figures 26-28	*Lithomitra* sp. 26, 27. 338-9-1, 85-87 cm. 28. 338-10, CC.

PLATE 15

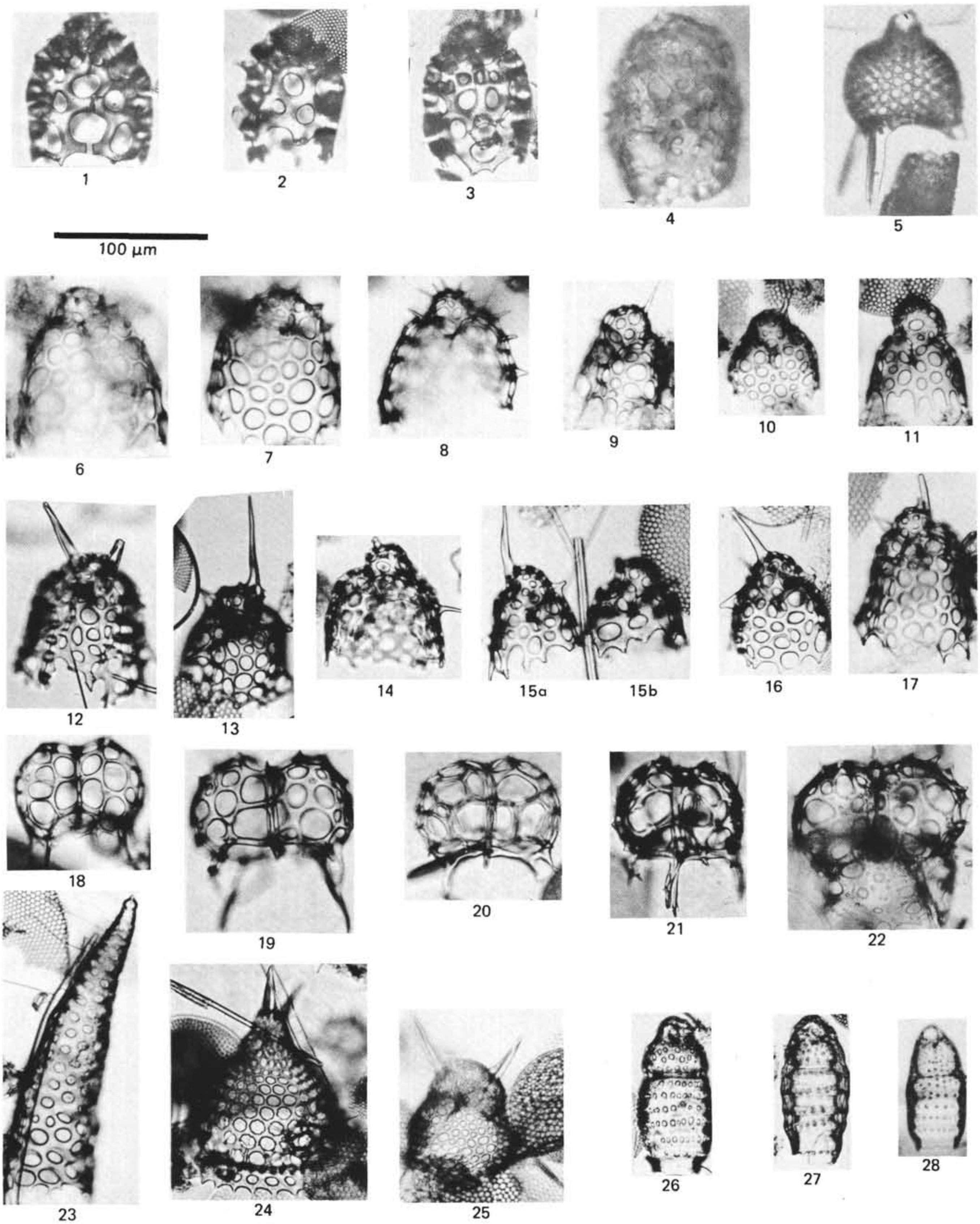
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PLATE 16

Scale bar is 100 μm

Figures 1-5	*Pseudodictyophimus* sp. aff. *P. gracilipes* (Bailey, 1856). 1. 338-9-1, 85-87 cm. 2. 338-9, CC. 3, 4. 338-10-1, 115-117 cm. 5. 338-11, CC.
Figures 6-8	*Botryostrobus* sp. 6. 338-9, CC. 7, 8. 338-10, CC.
Figures 9, 10	*Botryostrobus* sp. 9. 338-13-3, 145-147 cm. 10. 338-10, CC.
Figures 11-13	*Lipmanella xiphephorum* sensu Petrushevskaya and Kozlova, 1972. 11, 12. 338-11-3, 135-137 cm. 13. 338-12-2, 145-147 cm.
Figures 14-16	*Lithomelissa* (?) sp. 14, 15. 338-10-2, 146-148 cm. 16. 338-11-1, 145-147 cm.
Figures 17-21	*Stichocorys biconica* Vinassa de Regny, 1900. 338-11-3, 135-137 cm.
Figures 22, 23	*Tricolocapsa papillosa* (Ehrenberg, 1872). 22. 338-11-1, 145-147 cm. 23. 338-11-3, 135-137 cm.

PLATE 16

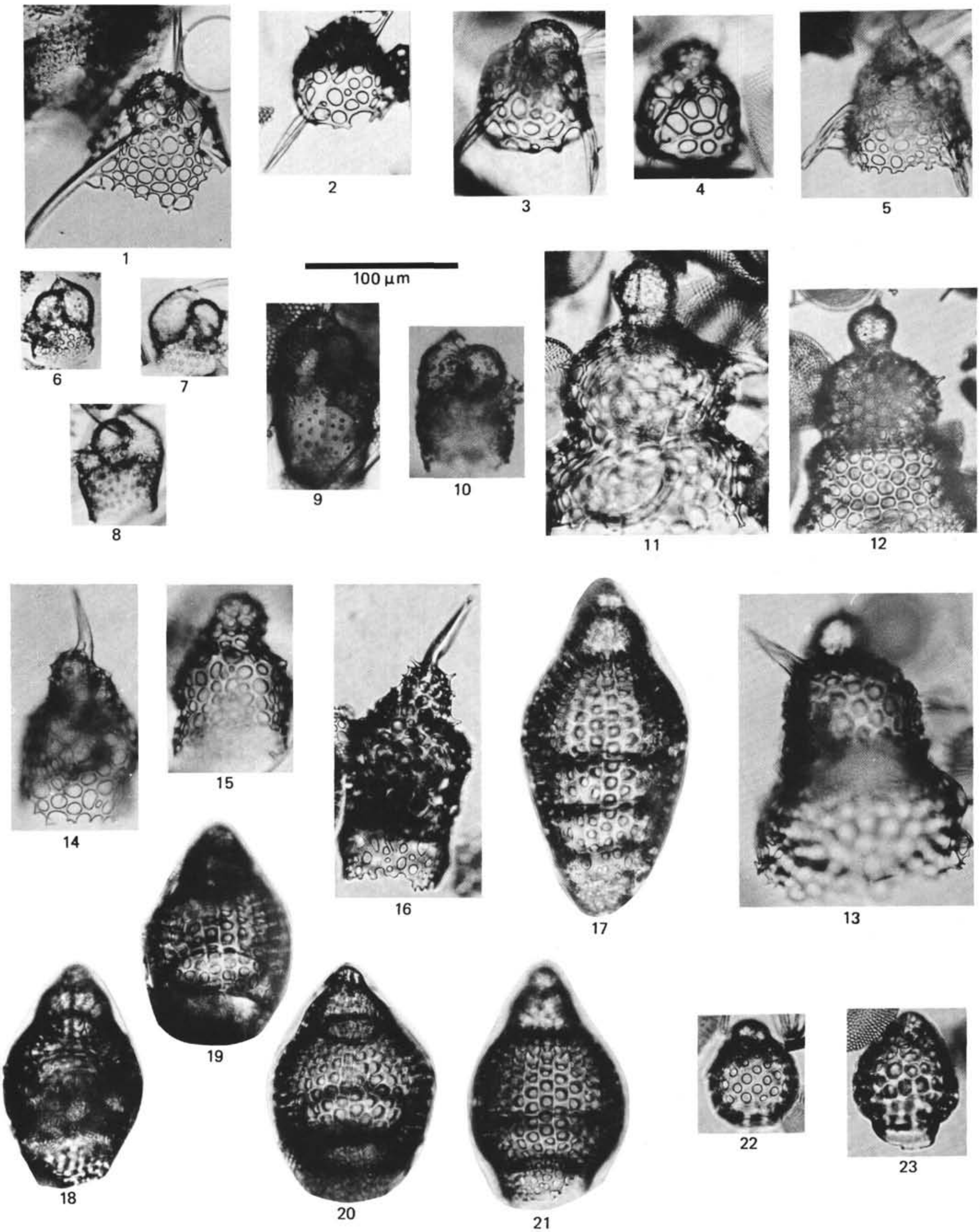

PLATE 17

Scale bar is 100 μm

Figures 1-5	*Ceratocyrtis mashae* n. sp. 1, 2. 338-11-3, 135-137 cm. 3. 338-12-3, 145-147 cm. 4, 5. 338-16, CC.
Figures 6-10	*Ceratocyrtis robustus* n. sp. 6, 7. 338-15-4, 130-132 cm. 8. 338-17, CC. 9,10. 338-19-3, 80-82 cm.
Figures 11-13	*Cyrtocapsella eldholmi* n. sp. 338-12-2, 145-147 cm.
Figures 14-16	*Cyrtocapsella* sp. 14. 338-10-2, 60-62 cm. 15, 16. 338-11-3, 135-137 cm.
Figures 17, 18	*Cyrtocapsella japonica* (Nakaseko, 1962). 338-15-4, 130-132 cm.
Figures 19, 20	*Cyrtocapsella tetrapera* Haeckel, 1887. 338-15-4, 130-132 cm.

PLATE 18

Scale bar is 100 μm

Figure 1	*Peripyramis* sp. 338-12, CC.
Figures 2-6	*Stichocorys* sp. 2. 338-12-2, 145-147 cm. 3. 338-13-5, 125-127 cm. 4, 5. 338-15-2, 145-147 cm. 6. 338-15-4, 120-122 cm.
Figures 7-11	Trissospyris sp. A. 7. 338-13-3, 145-147 cm. 8, 9. 338-13, CC. 10. 338-15-2, 145-147 cm. 11. 338-21-1, 100-102 cm.
Figures 12-17	Trissospyris sp. B. 12-14. 338-13, CC. 15, 16. 338-14-2, 140-142 cm. 17. 338-14, CC.
Figures 18-21	*Ceratocyrtis* sp. 338-15-2, 145-147 cm.
Figures 22-27	*Gondwanaria japonica* (Nakaseko, 1963). 22, 23. 338-13, CC. 24-27. 338-15-2, 145-147 cm.

(see page 1158)

PLATE 17

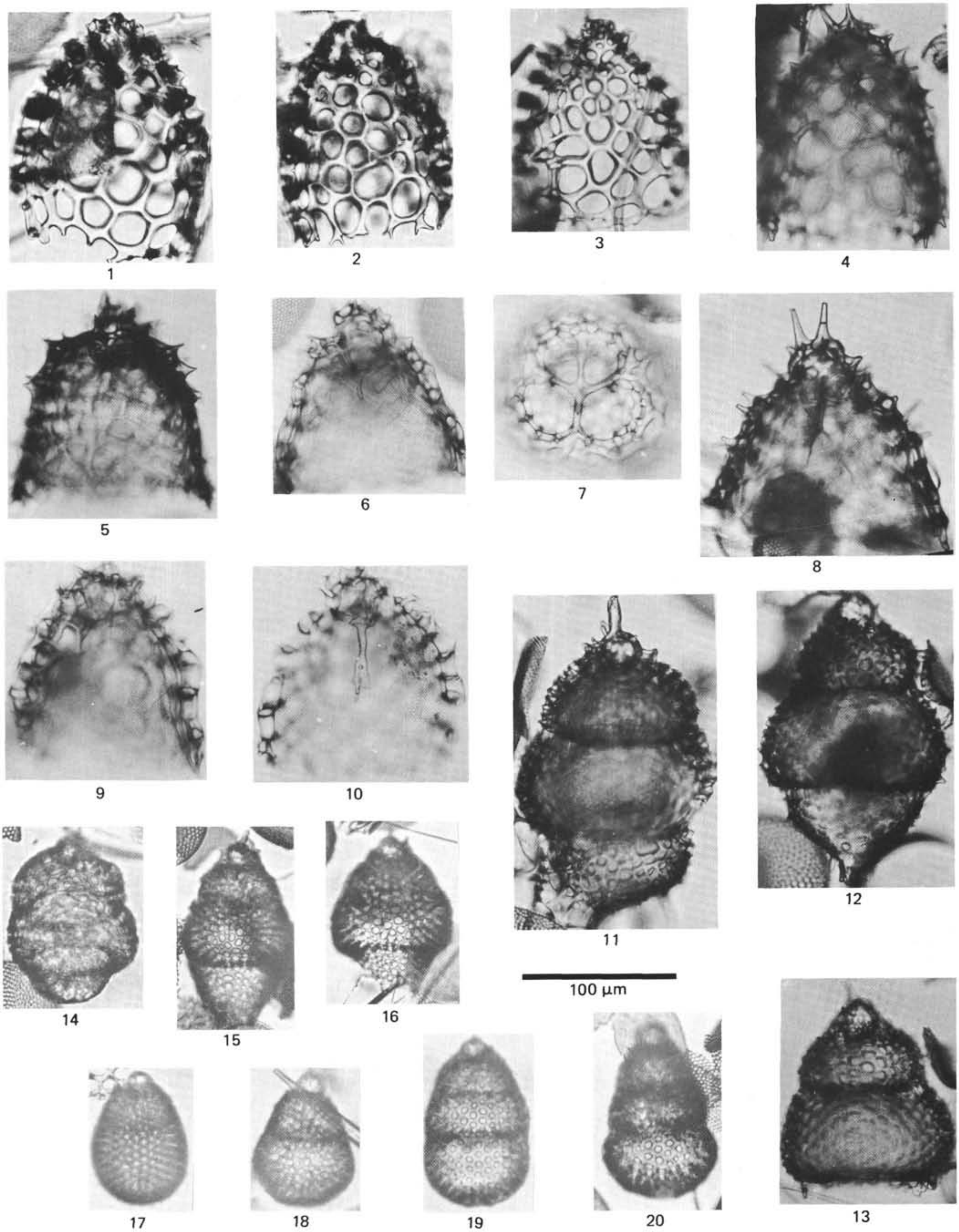

PLATE 18

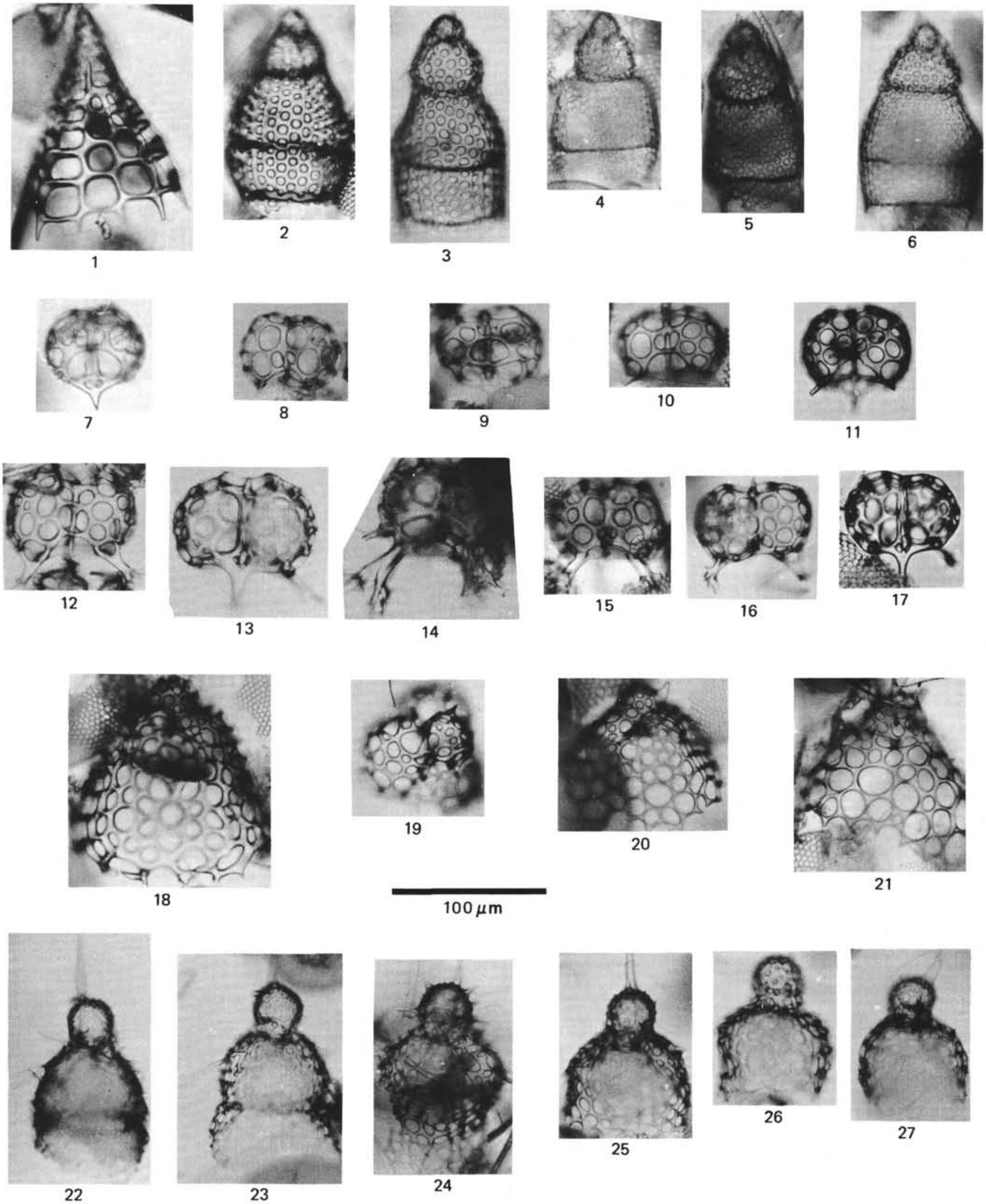
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PLATE 19

Scale bar Figures 6-9 is 0 μm, Figures 1-4, 10-12, 100 μm

Figures 1, 2	*Actinomma* sp. 338-15-4, 130-132 cm.
Figures 3, 4	*Hexalonche* sp. 338-17, CC.
Figure 5	*Hexaconthium* sp. 338-26, CC.
Figures 6-9	*Velicucullus oddgurneri* n. sp. 6, 7. 338-12, CC. 8. 338-11-3, 135-137 cm. 9. 338-12-2, 145-147 cm.
Figures 10-12	*Antarctissa* (?) sp. 338-29-3, 123-125 cm

(see page 1160)

PLATE 20

Scale bar is 175 μm

Figure 1	*Spongodiscus* sp. 338-8-2, 120-122 cm.
Figures 2, 3	*Spongotrochus glacialis* Popofsky, 1908 2. 338-8-2, 53-55 cm. 3. 338-8-3, 45-47 cm.
Figures 4-6	*Phorticium* sp. 4. 338-19, CC 5, 6. 338-21, CC
Figure 7	*Actinomma* sp. 338-10, CC.
Figures 8, 9	*Actinomma holtedahli* n. sp. 8. 338-15-2, 145-147 cm. 9. 338-15-4, 130-132 cm.
Figures 10, 11	*Phacodiscus testatus* Kozlova, 1966. 338-28, CC
Figures 12, 13	*Heliodiscus* sp. aff. *H. hexasteriscus* (?) Clark and Campbell, 1942.

(see page 1161)

PLATE 19

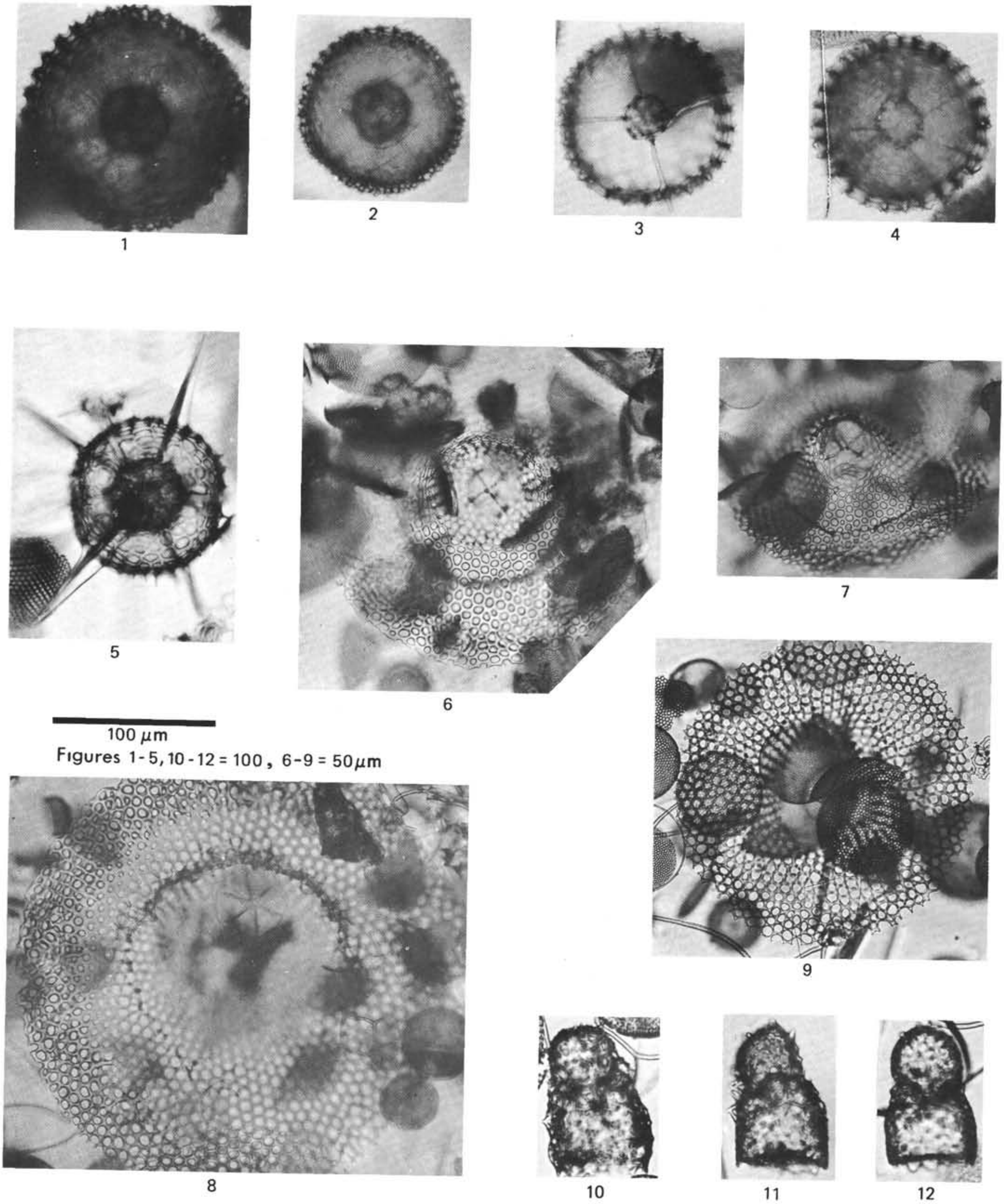

PLATE 20

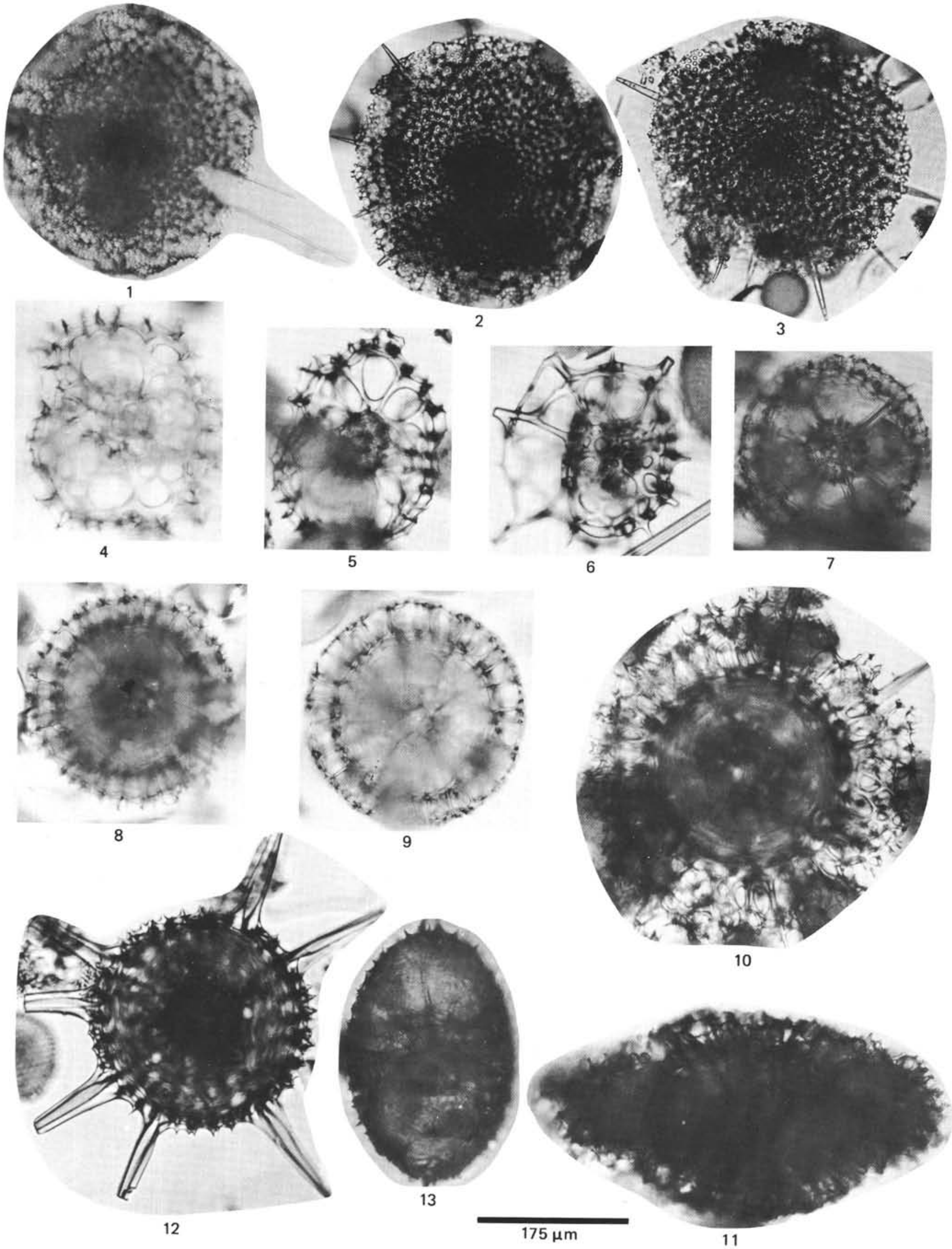

PLATE 21

Scale bar is 100 μm

Figures 1-3	*Calocyclas talwanii* Bjørklund and Kellogg, 1972. 1. 338-29-1, 148-150 cm. 2. 340-8, CC. 3. 340-10, CC.
Figures 4-7	*Calocyclas extensa* (Clark and Campbell, 1942). 4. 340-8, CC. 5-7. 343-5, CC
Figures 8-10	*Calocyclas* sp. 343-5, CC.
Figure 11	*Lophocorys norvegiensis* Bjørklund and Kellogg, 1972. 338-26, CC.
Figures 12-15	*Lophocorys* sp. 12. 338-26, CC. 13-15. 340-8, CC.
Figures 16, 17	*Lophocorys biaurita* (Ehrenberg, 1875). 339-8-2, 80-82 cm.

PLATE 21

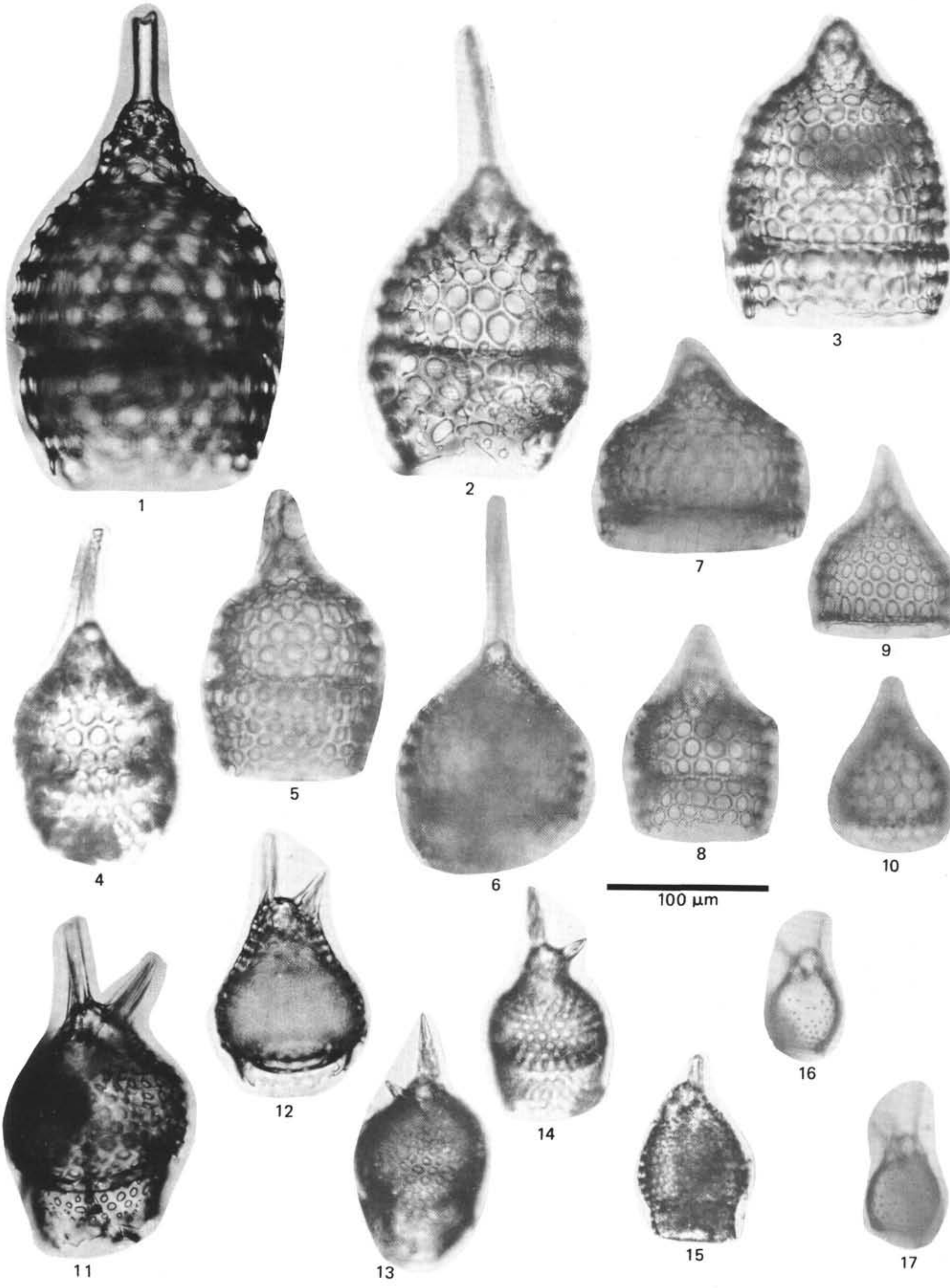

PLATE 22

Scale bar is 100 μm

Figures 1, 2	*Calocyclas* sp. 338-26-3, 67-69 cm.
Figures 3, 4	*Calocyclas* sp. 339-9, CC.
Figure 5	*Calocyclas* sp. 339-11, CC.
Figures 6-9	*Spongomelissa* sp. sensu Chen, 1975. 6. 338-21-1, 100-102 cm. 7, 8. 338-21, CC. 9. 338-26-3, 67-69 cm.
Figure 10	*Tripilidium* (?) *clavipes advena* Clark and Campbell, 1942. 339-12-2, 110-112 cm.
Figures 11, 12	*Nassellaria* indet. 338-19, CC.
Figures 13, 14	*Peripyramis magnifica* Clark and Campbell, 1942. 339-12-2, 110-112 cm.
Figures 15-17	*Theocalyptra tetracantha* Bjørklund and Kellogg, 1972. 15, 16. 338-27, CC. 17. 339-12-2, 110-112 cm.

PLATE 22

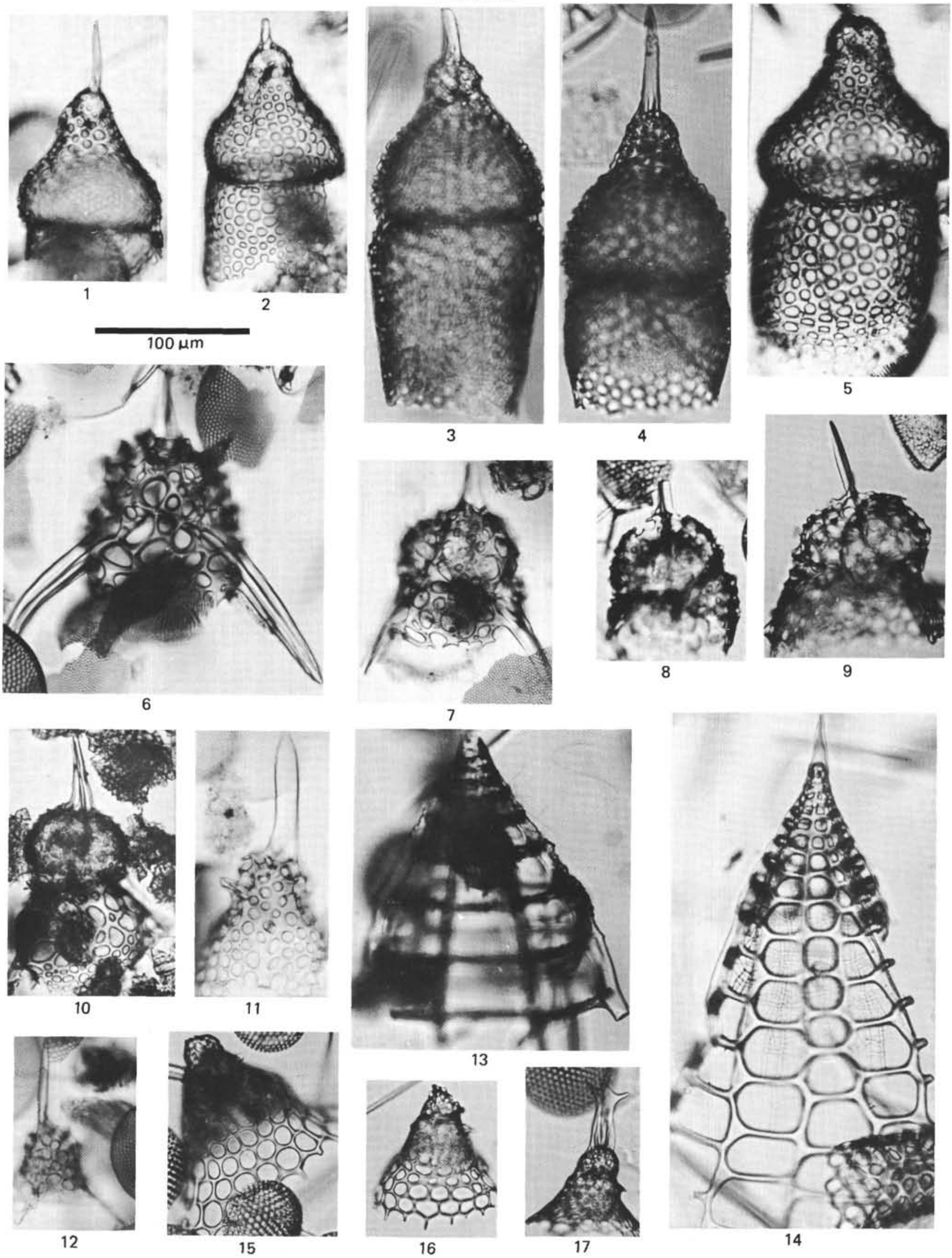

PLATE 23

Scale bar is 100 μm

Figures 1-3	*Lithomitra* sp. 338-26-3, 67-69 cm.
Figures 4-6	*Lithomitra* sp. 339-8-2, 110-112 cm.
Figures 7-14	*Botryostrobus joides* Petrushevskaya, 1975. 7, 8. 339-8-3, 80-82 cm. 9-13. 339-9, CC. 14. 338-26-3, 67-69 cm.
Figures 15-21	*Artostrobus quadriporus* n. sp. 339-11, CC.
Figure 22	*Ceratospyris* sp. 339-8-3, 80-82 cm.
Figures 23, 24	*Cornutella* sp. aff. *C. californica* Clark and Campbell, 1942. 339-11, CC.
Figures 25-27	Gen. et sp. indet. 339-11, CC.

PLATE 24

Scale bar Figures 1-5 is 100 μm; Figure 6, 50 μm; Figures 7-9, 150μm

Figures 1, 2	Gen. and sp. indet. 339-9, CC.
Figures 3-5	*Pterocyrtidium* sp. aff. *P. reschetnjakae* sensu Petrushevskaya, 1971. 339-11, CC.
Figures 6-9	*Arachnocalpis tumulosa* Kozlova, 1966. 343-5, CC.
Figures 10, 11	*Lychnocanium* (?) sp. 339-11, CC.

(see page 1168)

PLATE 23

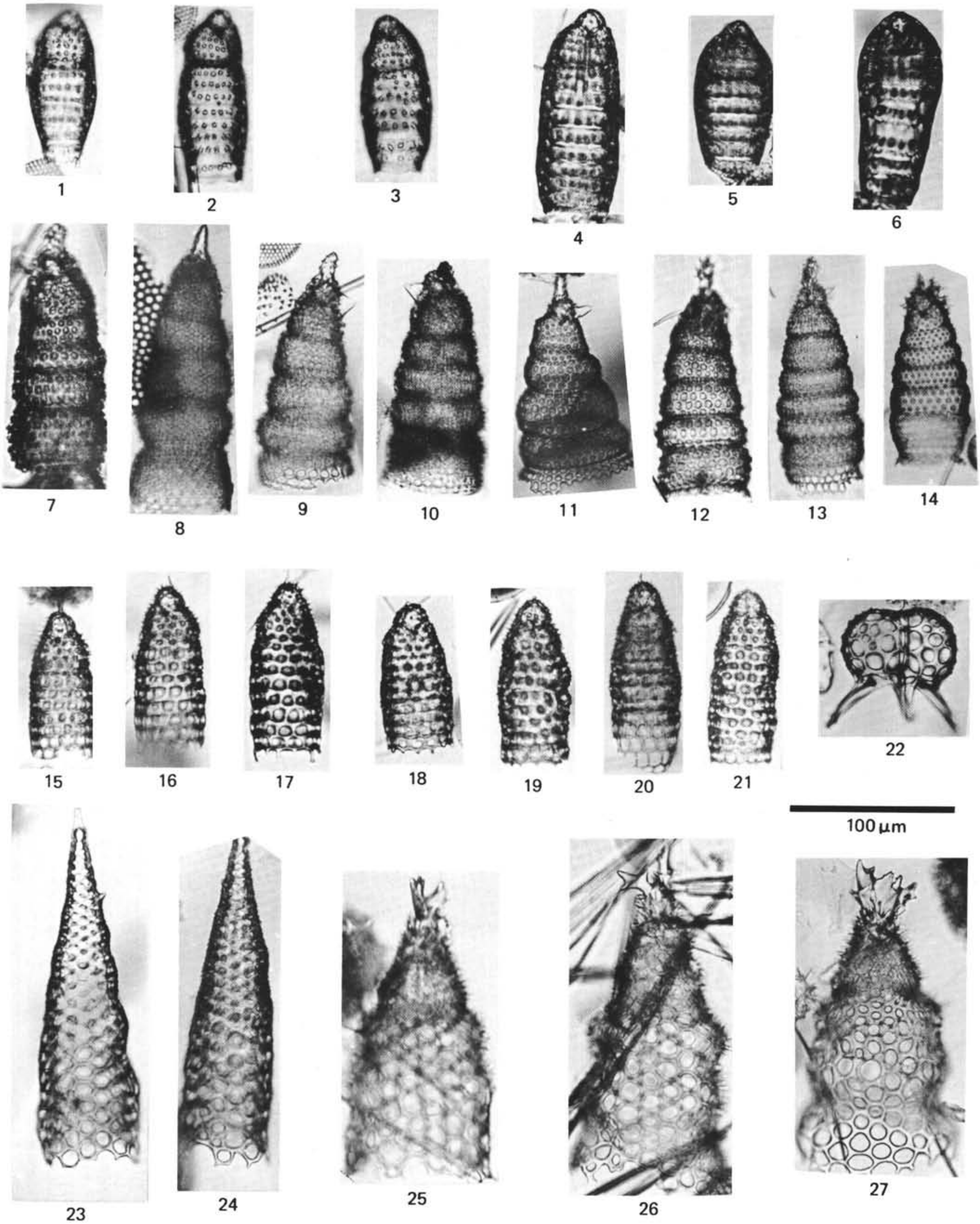
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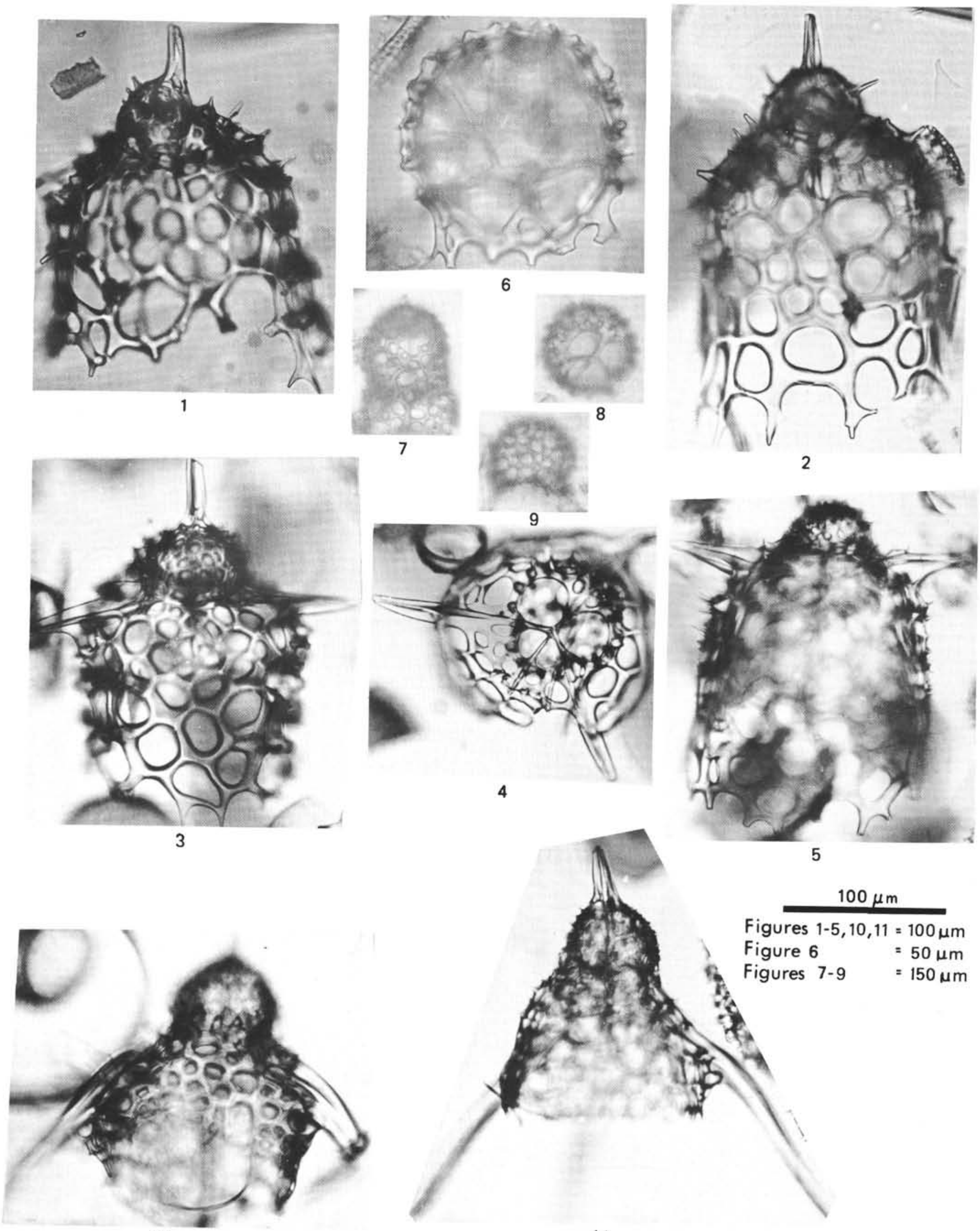
PLATE 24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100 μm
Figures 1-5,10,11 = 100 μm
Figure 6 = 50 μm
Figures 7-9 = 150 μm