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Eocene-Oligocene planktic diatom stratigraphy in the low latitudes and the high southern latitudes

ABSTRACT

The first and last stratigraphic occurrences of selected planktic diatom species for the low and high latitudes in the Eocene and Oligocene are given. Stratigraphic datums for these species are used to define two separate diatom zonations: one (with 12 zones) for low latitudes (Early Eocene to Late Oligocene), and the other (with four zones) for the Oligocene of the high southern latitudes. Cosmopolitan species are well represented in both latitudinal regions during the latest Eocene and in the Late Oligocene. But correlation between the two latitudinal regions is more difficult during the Early Oligocene owing to a dominance of paleogeographically restricted species. Eleven new species, three new varieties, and two new combinations are defined in the appendix, which also includes a species list.

INTRODUCTION

Fossil diatoms have been studied since the 19th century, but early interest in this group was largely taxonomic. Only during the last 30 years has the stratigraphic value of diatoms been recognized for sediments deposited in areas of coastal and oceanic upwelling. Recently, as a consequence of hydrocarbon exploration in the polar regions, interest in high-latitude diatom stratigraphy has grown considerably; calcareous planktic microfossils are of low diversity in these regions and often are absent or poorly preserved in the sediments.

Pioneer work in diatom stratigraphy was undertaken by Soviet scientists, who described species occurrences and their approximate ranges in the Paleogene. These investigations started in the 1930s with Uspjenskaja (1935, 1936, 1940, 1948, 1950) and were followed by papers by Krotov and Shibkova (1961), Gleser (1961, 1967, 1978, 1979), Sheshukova-Poretzkaya (1962), Gleser et al. (1965), Gleser and Sheshukova-Poretzkaya (1967, 1968, 1969), Jousé (1973, 1978), Gleser and Jousé (1974), Palatnaja (1976), and Olshtynskaya (1976, 1977). For the California and northwestern European Paleogene diatomaceous deposits, comparable work was done by Hanna (1927, 1931, 1932), Hustedt (1935), Kanaya (1957) and Benda (1965, 1972).

A detailed diatom stratigraphy has been developed for the Neogene, using deep-sea cores (Burckle 1972, 1978; Koizumi 1973; Schrader and Fenner 1976; Dzinoridze et al. 1978; Barron 1980, in press; Weaver and Gombos 1981). For a long time, however, our knowledge about stratigraphic ranges of Paleogene diatom species has been exclusively based on outcrops found on land, mostly within the U.S.S.R.

The Soviet studies resulted in the definition of diatom assemblage zones for the Eocene and Oligocene of the U.S.S.R., the Norwegian Sea and the low latitudes. But a major problem was the determination of their age because the diatomites of the U.S.S.R. rarely contain sufficient calcareous fossils to adequately estimate their age. Thus they were sometimes dated only by the mollusks found in the underlying or overlying beds. In a few cases, this led to an incorrect age assignment with far-reaching consequences. For example, the *Pyxilla oligocaenica* Zone of Jousé, which is now known to be within the early Middle Eocene, was considered to be either of Oligocene age (e.g. Jousé in Proshkina-Lavrenko 1949; Strelnikova 1960; Gleser 1961; Krotov and Shibkova 1961; Paramonova 1964; Olshtynskaya 1977) or of Late Eocene age (Gleser et al. 1965; Gleser and Sheshukova-Poretzkaya 1967; Gleser 1969, 1978, 1979). As a consequence, the underlying diatom zones, now known to be of Early Eocene age, were assigned to the Late and Middle Eocene. This age assignment was basically accepted, even by Jousé (1979), although in her paper

Jousé reinterpreted the age of the *P. oligocaenica* Zone as Middle Eocene. Such uncertainties in age determinations led to much confusion about the stratigraphic ranges of Eocene and Oligocene diatom species.

These stratigraphic problems were overcome when continuously cored diatomaceous sediments, well dated by other planktic microfossil groups, became available through the Deep Sea Drilling Project (DSDP) in the 1970s, and thus allowed, for the first time, the stratigraphic ranges of diatom species to be accurately determined.

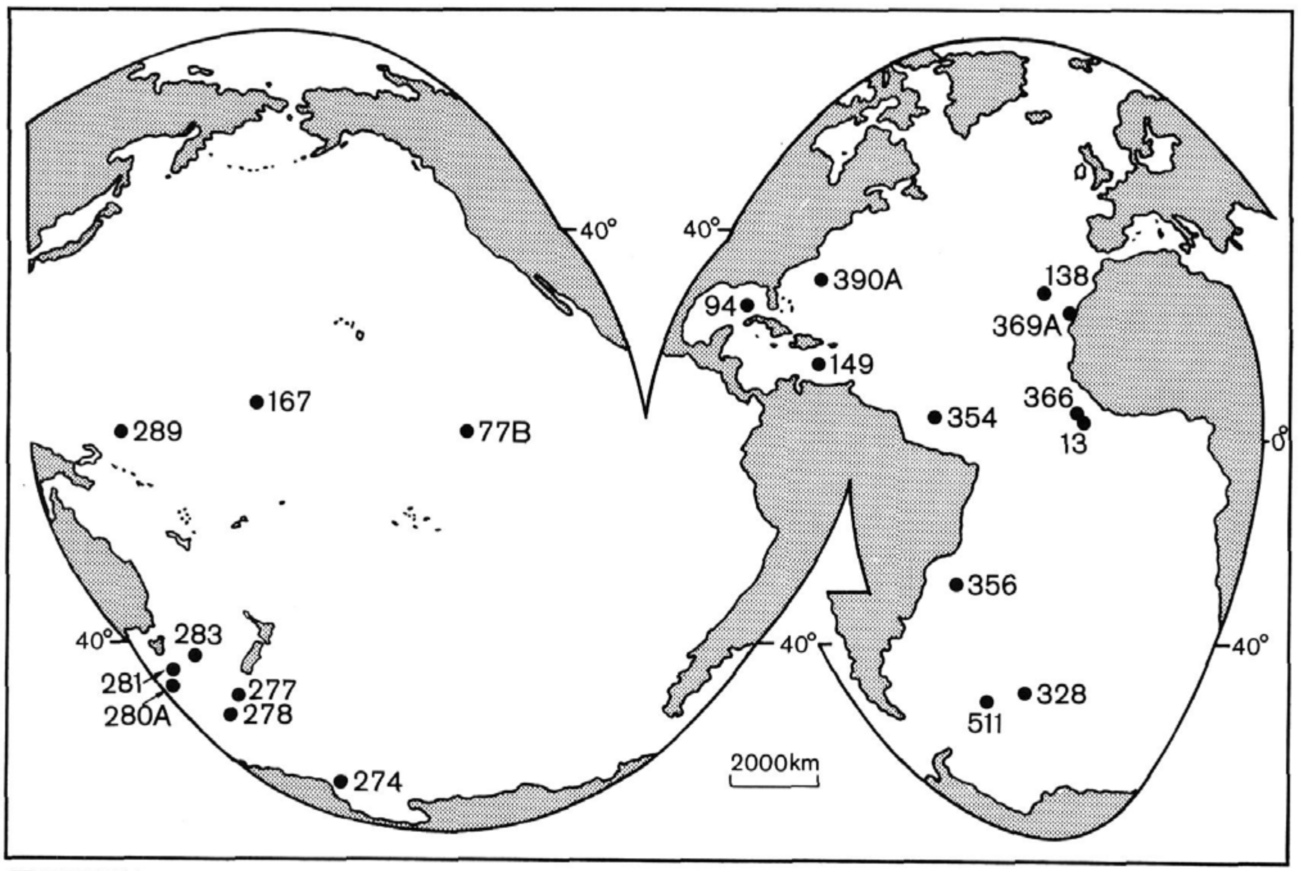
The relatively wide geographical occurrence of diatomaceous sediments of Eocene and Oligocene age in DSDP cores permitted several authors to propose local diatom zonations within this time interval, e.g. Jousé (1973, 1979), McCollum (1975), Gombos (1976), Schrader (1976), Schrader and Fenner (1976), Dzinoridze et al. (1978) and Gombos and Ciesielski (1983).

The present paper deals with only the zonal schemes applicable to the low- and high-latitude diatom provinces during the Eocene and Oligocene. They are the result of assemblage analysis of closely spaced samples through the diatomaceous Eocene-Oligocene sections of DSDP sites within these belts (Fenner 1978, 1982, in press a, unpublished data). Of the many sites studied (see text-fig. 1), well-dated sections with well-preserved diatom assemblages were chosen to construct composite sequences in order to demonstrate the stratigraphic ranges of the selected marker species (text-figs. 2, 3, 5).

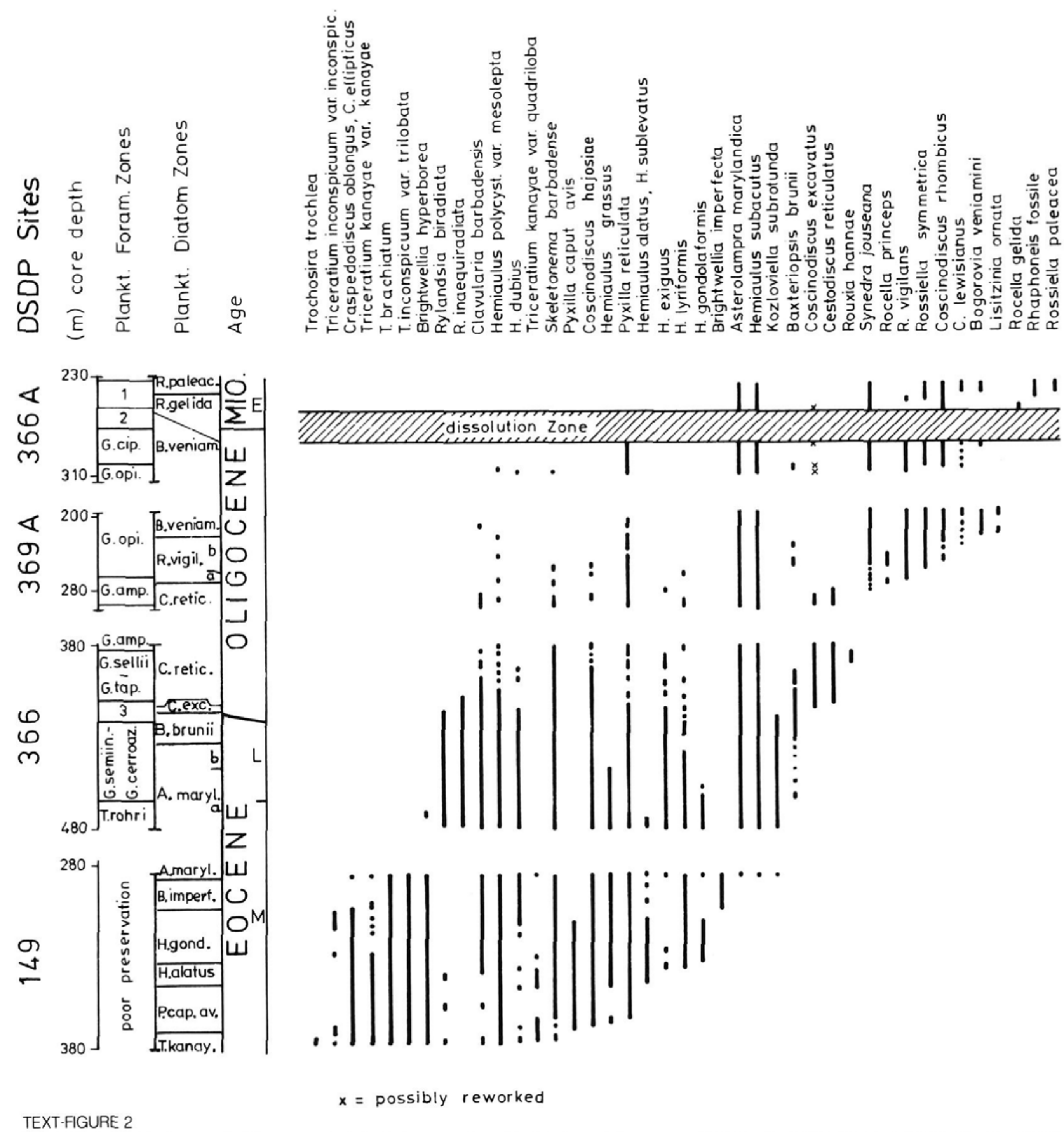
The Paleogene of the Norwegian Sea will not be dealt with here. Schrader and Fenner (1976) and Dzinoridze et al. (1978) have proposed diatom zonations for it, which are discussed and correlated to the herein defined low-latitude diatom zonation by Fenner (in press b).

All the stratigraphic marker species used in the zonations proposed here are relatively dissolution-resistant, easily identifiable in the light microscope and, if rare, are at least consistent and continuous in their occurrence. The diatom datums and proposed zones are correlated with the zonations of other planktic microfossil groups. The correlations with diatom zones proposed by other workers, as well as the interlatitudinal correlation of diatom zones, are given in text-figure 6 and discussed briefly at the end of this paper.

Unfortunately, neither a detailed oxygen isotope record



TEXT-FIGURE 1
Location of DSDP sites, for establishing diatom zonations. Map: Coode's homolosine equal-area projection, true distances on mid-meridians and parallels 0° to 40°.



TEXT-FIGURE 2

Low-latitude *Middle Eocene to Oligocene* planktic diatom zonation. Planktic foraminifera zones after Krasheninnikov and Pflaumann (1978). Eocene-Oligocene boundary is placed using last occurrence of *Discoaster barbadiensis* and *D. saipanensis* for its definition (Lancelot et al. 1978; Bukry 1978a). The results from the diatomaceous sediment sequences illustrated here are based on detailed diatom assemblage analysis of one to three samples per DSDP section (that is a total of 275 samples for the sequences illustrated in this figure). Zones: 1 = *Globigerinoides primordius-Globorotalia kugleri*; 2 = *G. kugleri* s. str.; 3 = *G. "centralis"-Globigerina turritilina.*

nor paleomagnetic data presently exist for the Eocene-Oligocene diatomaceous sequences. These would provide a test of whether the datums are isochronous and would allow recognition of further datums.

In the appendix, all species used in the proposed zone definitions are listed together, with reference to a good illustration and description. The new species and varieties are also defined and illustrated.

Low-latitude zonation (text-figs. 2, 3, 4, 6)

Jousé (1973, 1979) presented the first low-latitude diatom zonation for the Eocene and Oligocene, compiling information from deep-sea sediments found on land and from those recovered from deep-sea cores. The zones she proposed are assemblage zones. Gombos (1982) proposed a late Early Eocene to early Middle Eocene diatom zonation based on results from DSDP Site 390A, using the last occurrence of *Craspedodiscus undulatus* Gombos and the first occurrence of *Brightwellia hyperborea* Grunow as datums for their definition.

The zonation proposed here and the stratigraphic ranges of diatom species are demonstrated in a composite profile of the continuously cored and hiatus-free diatomaceous sections of Caribbean and eastern equatorial Atlantic DSDP Sites 149, 366, 366A, and 369A for the Oligocene to Middle Eocene, and DSDP Sites 94 and 390A from the Gulf of Mexico and the northwest Atlantic for the Middle and Early Eocene. The sections for text-figure 2 are chosen so that there is neither overlap nor a large gap in time between them. In addition to the sections illustrated, results from the Pacific and Atlantic DSDP Sites 77B, 138, 167, 289, and 356 (Fenner 1978, 1982, in press a) are used as a control in selecting the marker species, in testing the consistency of their stratigraphic range throughout the low latitudes, and in assuring their wide and common occurrence there. For the definitions of the zones, mostly stratigraphic first-occurrence datums were used, because most last occurrences do not provide good datums owing to gradual decrease in abundance and rare, scattered occurrence before the final extinction. This is especially true in the Oligocene. Furthermore, by using first occurrence datums, problems possibly due to reworking are avoided.

Text-figure 4 gives the correlation of the low-latitude diatom zones with the calcareous nannofossil zones and the radiolarian zones. Text-figure 6 shows the correlation of the zones of Jousé (1973, 1979) to those proposed here. This correlation was done using the presently accepted age for the DSDP reference sections used by Jousé based on other microfossil groups (as listed in the Initial Reports of the Deep Sea Drilling Project), as well as by applying the herein-proposed diatom zonation to the species occurrences (listings of species by Jousé and my own results) at these sites.

***Craspedodiscus oblongus* Zone**

Category: Partial Range Zone.

Age: Early Eocene to earliest Middle Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Triceratium kanayae*, n. sp.; base: first occurrence of *Craspedodiscus oblongus* (Greville) Grunow.

Discussion: The marker species *C. oblongus* has a cosmopolitan distribution. It differs from *C. ellipticus* (Greville) Gombos, which is similar in outline and in the size of its areolae, but has an elliptical depressed central part, whereas that in *C. oblongus* is round. The first occurrence of *Hemiaulus polycystinorum* Ehrenberg var. *mesolepta* Grunow occurs within this zone.

Reference section: DSDP 390A-6-6, 30–31 cm to 390A-6-2, 101–102 cm.

***Triceratium kanayae* Zone**

Category: Partial Range Zone.

Age: Middle Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Pyxilla caput avis* Brun; base: first occurrence of *Triceratium kanayae.*

Discussion: In this zone are the first occurrences of many diatom species, such as *Hemiaulus kljushnikovii* Gleser, *H. dubius* Grunow, *Brightwellia hyperborea, Rylandsia biradiata* Greville, *Clavularia barbadensis* Greville, and *Skeletonema barbadense* Greville. The first occurrence of *Triceratium kanayae* coincides approximately with the first occurrence of *T. inconspicuum* Greville var. *trilobata* Fenner. While *T. inconspicuum* var. *trilobata* is cosmopolitan, *T. kanayae* seems to be characteristic of low latitudes.

Reference section: Base: DSDP 390A-5-3, 100–101 cm; Top: DSDP 149-41-6, 70–71 cm.

***Pyxilla caput avis* Zone**

Category: Partial Range Zone.

Age: Middle Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Hemiaulus alatus* Greville; base: first occurrence of *Pyxilla caput avis.*

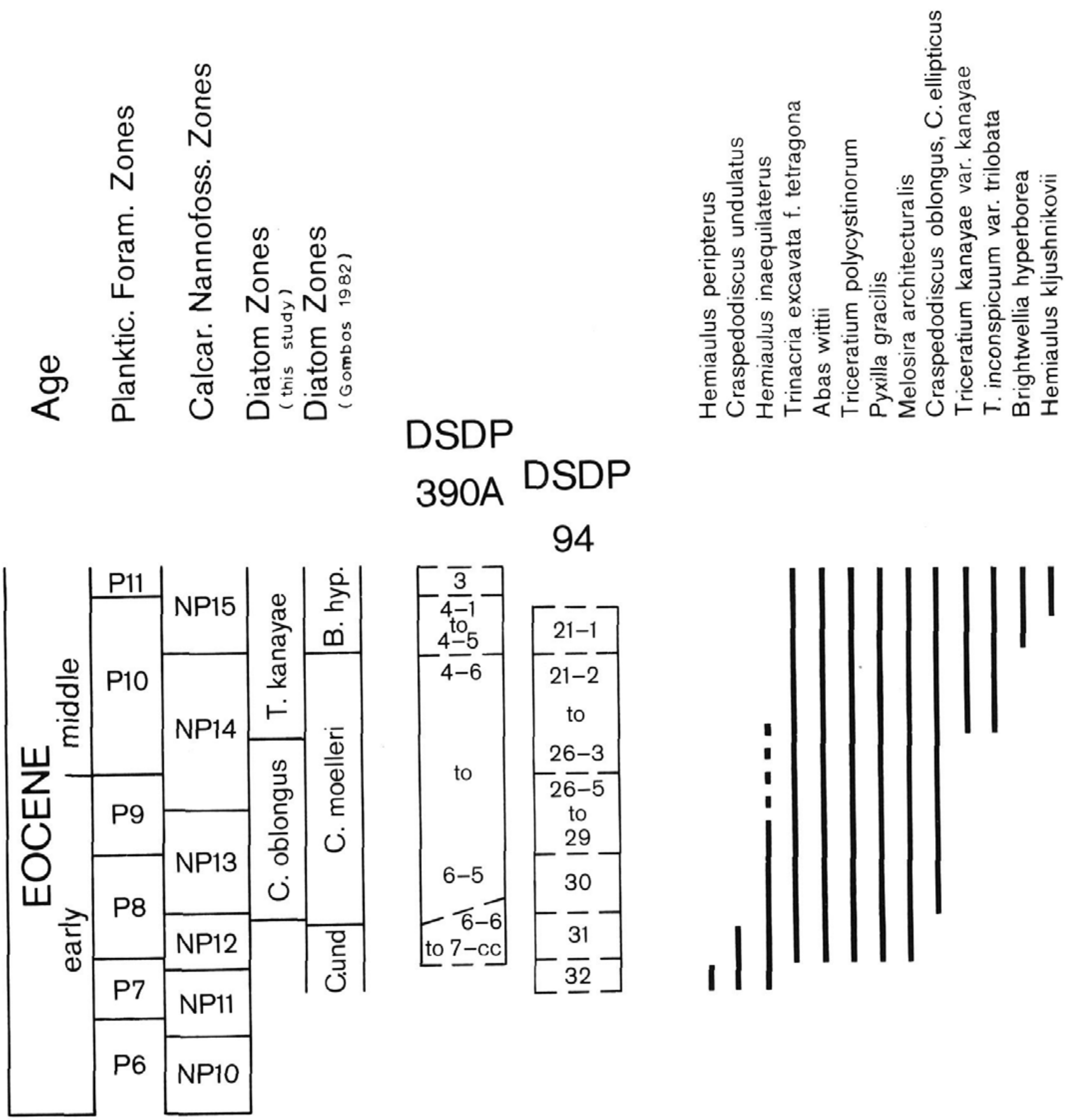
Remarks: The first occurrences of *Coscinodiscus hajosiae,* n. sp. and *Hemiaulus grassus,* n. sp. occur in this zone.

Reference section: DSDP 149-41-5, 100–101 cm to 149-39-1, 120–121 cm.

***Hemiaulus alatus* Zone**

Category: Partial Range Zone.

Age: Middle Eocene.

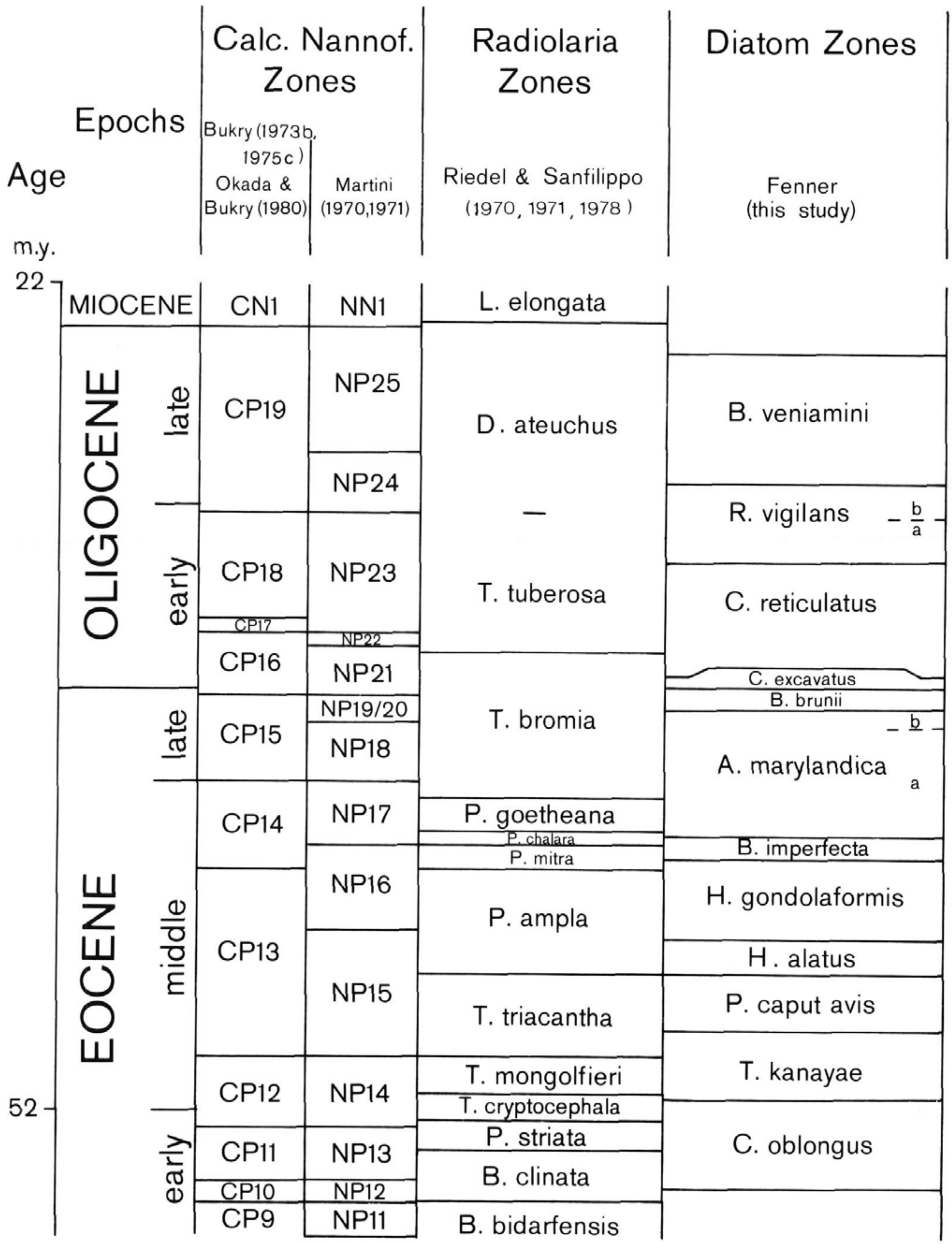


TEXT-FIGURE 3
Early to Middle Eocene diatom zonation. Age assignment of the calcareous microfossil zones after Berggren et al. (in press). Calcareous microfossil stratigraphy after Hay (1973), Bukry (1973a, 1978b), Schmidt (1978), and Gradstein et al. (1978). Results of the diatomaceous DSDP sediment sequences illustrated here are based on detailed diatom assemblage analysis of at least one sample per DSDP core. (A total of 32 samples has been analyzed.)

Author: New zone proposed herein.

Definition: Top: first occurrence of *Hemiaulus gondolaformis*, n. sp.; base: first occurrence of *Hemiaulus alatus*.

Discussion: The paleogeographic distribution of Middle Eocene diatom species is not well known due to the poor recovery of Middle Eocene diatomaceous sediments in the high latitudes. Present data suggest that both marker



TEXT-FIGURE 4
Correlation of the proposed low-latitude diatom zones with the calcareous nannofossil and radiolarian zones. Age assignment of the latter is after Berggren et al. (in press).

species used for the identification of this zone are low-latitude species. The first common occurrence of *Hemiaulus alatus* coincides with the first common and continuous occurrence of *Hemiaulus grassus*. This zone also contains the first occurrences of *Hemiaulus lyriformis* Greville and *H. exiguus* Greville.

Reference section: DSDP 149-38-3, 140–141 cm to 149-38-1, 150–151 cm.

Hemiaulus gondolaformis Zone

Category: Partial Range Zone.

Age: Middle Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Brightwellia imperfecta* Jousé; base: first occurrence of *Hemiaulus gondolaformis*.

Discussion: Hemiaulus gondolaformis has, up to now, been found only in low-latitude sediments. It is easy to identify in valve view as well as in girdle-band view, or even in fragments (see appendix).

The last occurrence of *Pyxilla caput avis* occurs within this zone.

Reference section: DSDP 149-37-4, 140–141 cm to 149-35-1, 75–76 cm.

Brightwellia imperfecta Zone

Category: Partial Range Zone.

Age: Middle Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Asterolampra marylandica* Ehrenberg; base: first occurrence of *Brightwellia imperfecta*.

Discussion: B. imperfecta is a characteristic marker species. Although it is generally found only broken, it can be identified easily from fragments. This species is found in high and low latitudes.

Reference section: DSDP 149-34-3, 140–141 cm to 149-33-2, 140–141 cm.

Asterolampra marylandica Zone

Category: Partial Range Zone.

Age: Middle Eocene to earliest Late Eocene.

Author: New zone proposed herein.

Definition: Top: first continuous occurrence of normal-sized and areolated *Baxteriopsis brunii* (van Heurck) Karsten; base: first occurrence of *Asterolampra marylandica*.

Subzones: The last occurrence of the low-latitude species *Hemiaulus grassus* is used to separate Subzone a from Subzone b.

Discussion: For remarks on *B. brunii* see *B. brunii* Zone. The first occurrence of the cosmopolitan *Asterolampra marylandica* approximately coincides with the first occurrence of *Hemiaulus subacutus* Grunow and the last occurrence of *Triceratium kanayae, T. inconspicuum* var. *trilobata*, and *Brightwellia imperfecta*. Within Subzone a, the last occurrences of *Hemiaulus alatus, Brightwellia hyperborea, Craspedodiscus oblongus-C. ellipticus*, and *Triceratium inconspicuum* var. *inconspicuum* Greville are also found.

Reference section: Top: DSDP 149-33-2, 75–76 cm, base: DSDP 366-12-1, 73–74 cm.

Baxteriopsis brunii Zone

Category: Partial Range Zone.

Age: Late Eocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Coscinodiscus excavatus* Greville; base: first continuous occurrence of normal-sized *Baxteriopsis brunii*.

Discussion: Extremely rare, small, single specimens of *Baxteriopsis brunii* already occur below the base of this zone. These specimens also have a finer areolation: seven or eight areolae in 10 μm, compared with their normal-sized, more common, successors, which have five to seven areolae in 10 μm.

Reference section: DSDP 366-11-CC to 366-10-2, 130–131 cm.

Coscinodiscus excavatus Zone

Category: Partial Range Zone.

Age: Earliest Oligocene.

Author: Jousé (1973), modified herein.

Definition: Top: first occurrence of *Cestodiscus reticulatus*, n. sp.; base: first occurrence of *Coscinodiscus excavatus*.

Discussion: Jousé (1973) proposed a *C. excavatus* var. *quadriocellata*-"*C. pulchellus*" (= *Cestodiscus convexus* Castracane) Assemblage Zone, which covers the entire Early Oligocene (*C. convexus* first appears in the Late Eocene, and becomes common in the earliest Oligocene above the first occurrence of *Coscinodiscus excavatus*).

The zone proposed here covers only the earliest Oligocene. I have found that, in the low-latitude sites of the Atlantic and Pacific oceans, *C. excavatus* consistently occurs before *Cestodiscus reticulatus*, which allows the identification of the short time interval between these two first occurrence datums. In relation to other microfossil datums near the Eocene-Oligocene boundary at DSDP Sites 366 and 167 *Coscinodiscus excavatus* first occurs above the last occurrences of *Discoaster barbadiensis* Tan Sin Hok, *D. saipanensis* Bramlette and Riedel and *Globigerapsis index* (Finlay). It occurs at Site 366 below the last occurrence of *Globorotalia "centralis"* Cushman and Bermudez and approximately coincides with the LAD of *Hantkenina* spp.

Checking the larger sized diatom fraction for the first occurrence of *C. excavatus* is of help in the fast and easy identification of this zone. Both marker species of this zone are low-latitude species.

At the top of this zone most of the typical Late Eocene species show a strong decrease in abundance.

Reference sample: DSDP 366-10-2, 85 cm.

Cestodiscus reticulatus Zone

Category: Range Zone.

Age: Early Oligocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Rocella vigilans*, n. sp. base: first occurrence of *Cestodiscus reticulatus.*

Remarks: The total stratigraphic range of *Rouxia hannae* Jousé occurs within this zone. Its highest stratigraphic occurrence is found in Planktic Foraminifera Zone P20 and the calcareous nannofossil *Sphenolithus predistentus* Zone. This species is found in the same stratigraphic position in Southern Ocean sediments.

Many Late Eocene diatom species such as *Skeletonema barbadense, Hemiaulus polycystinorum* var. *mesolepta, H. exiguus, Coscinodiscus hajosiae,* and *Baxteriopsis brunii* strongly decrease in abundance from the base of the zone toward its top. The first occurrence of *Synedra jouseana* Sheshukova-Poretskaya falls into the upper part of this zone. But this is not a good stratigraphic datum because of the rare and scattered occurrence of this species within the lower part of its range.

A strong increase in abundance of *Cestodiscus* spp. occurs just above the base of the *C. reticulatus* Zone. At DSDP Site 366, this increase in abundance immediately succeeds the isotopic shift.

This zone is limited to the low and middle latitudes owing to the paleogeographic restriction of the marker species, *C. reticulatus.* Also, the strong increase in abundance of *Cestodiscus* spp., which seems to succeed the oxygen isotopic shift in the low latitudes, is not found in the high southern latitudes. For species description see appendix.

Reference section: Base: DSDP 366-10-1, 130–131 cm; top: DSDP 369A-25-2, 128–129 cm.

Rocella vigilans Zone

Category: Partial Range Zone.

Age: Late Oligocene.

Author: Jousé (1973), modified herein.

Definition: Top: first occurrence of *Bogorovia veniamini* Jousé; base: first occurrence of *Rocella vigilans,* n. sp.

Subzones: Two subzones are defined. The first occurrence of *Rossiella symmetrica,* n. sp. is used to define the base of Subzone b.

Discussion: All three marker species are found in the low and high latitudes. Within Subzone b are the first occurrences of *Coscinodiscus rhombicus* Castracane and *C. lewisianus* Greville. In the lower part of its range *C. rhombicus* is relatively rare, so that its first occurrence can be missed easily. *Coscinodiscus lewisianus* is generally extremely rare, so that it is only of limited stratigraphic value.

The *Rocella vigilans-Craspedodiscus coscinodiscus* Zone of Jousé (1973) for the low latitudes encompasses the whole of the Late Oligocene above the first occurrences of *Craspedodiscus coscinodiscus* Ehrenberg and *Rocella princeps* (Jousé), n. comb. and reaches into the earliest Miocene.

Reference section: DSDP 369A-25-1, 129–130 cm to 369A-19-CC.

Bogorovia veniamini Zone

Category: Partial Range Zone.

Age: Late Oligocene.

Author: Jousé (1973), modified herein.

Definition: Top: first occurrence of *Rocella gelida* (Mann) Bukry; base: first occurrence of *Bogorovia veniamini.*

Discussion: For the low latitudes, Jousé (1973) defined a *Bogorovia veniamini* Zone, the base of which she placed at the first occurrence of *Rossiella paleacea* (Grunow) Desikachary & Maheshwari and the top at the last occurrence of *B. veniamini,* which confines this zone to the Early Miocene. Also the high southern latitude *B. veniamini* Zone of Schrader (1976), which he defined at DSDP Site 278, and the base of which he put at the last occurrence of *Pyxilla* spp. is restricted to the Early Miocene. Gombos (1976) defined the base of his high southern latitude "*B. veniamini*" Zone by the last occurrence of *Pyxilla prolongata* Brun (= "prolongata-type" of *P. reticulata* Grove & Sturt). In that study he considered the base of his zone correlative with the base of the *B. veniamini*

Zone of Schrader (1976). It now is known that the last occurrence of the "prolongata-type" of *P. reticulata* occurs in the Late Oligocene. This harmonizes with the fact that the "*B. veniamini*" Zone of Gombos (1976), as defined at DSDP Site 328B, overlaps the *Naviculopsis biapiculata* Zone of Bukry (1974) (Busen and Wise 1976), while the *B. veniamini* Zone of Schrader (1976) has its base above the *N. biapiculata* Zone of Bukry (1974) (Bukry 1975b) in the Early Miocene.

In a later publication, Weaver and Gombos (1981) redefined the "*B. veniamini*" Zone for the high southern latitudes as the total range of "*B. veniamini*" (= *Rossiella symmetrica*).

In the zonation proposed here for the low latitudes the *B. veniamini* Zone is restricted totally to the Late Oligocene, using the first occurrence of that species to define the base of this zone.

Reference section: Base: DSDP 369A-19-6, 128–129 cm; top: 366A-28-6, 130–131 cm.

Rocella gelida Zone

Category: Partial Range Zone.

Age: Latest Oligocene to earliest Miocene.

Author: Bukry and Foster (1974), modified by Barron (1983).

Definition: Top: first occurrence of *Rossiella paleacea*; base: first occurrence of *Rocella gelida*.

Discussion: In the lower part of this zone, the first appearance of *Rocella gelida* var. *schraderi* (Bukry) Barron occurs. For further details see Barron (in press).

SOUTHERN OCEAN ZONATION (text-fig. 5)

The first descriptions of Eocene-Oligocene diatom assemblages in the Southern Ocean and the definition of local diatom zones were given by McCollum (1975), Schrader (1976), Hajós (1976), Gombos (1976), and Weaver and Gombos (1981). Gombos and Ciesielski (1983) have defined zones from the Late Eocene through the Oligocene, based on results from DSDP Sites 511 and 513A.

While studying the diatomaceous sections of DSDP Sites 274, 278, 280A, 328, 328B, 329, and 511 in the Southern Ocean I have found longer stratigraphic ranges for some of the marker species (*Pyxilla reticulata, Asteromphalus oligocenicus* Schrader and Fenner, *Rhizosolenia gravida* Gombos and Ciesielski, and *Melosira architecturalis* Brun) than did Gombos and Ciesielski (1983).

Two of their other marker species, *Triceratium groningensis* Reinhold and *Kozloviella minor* Jousé, were not encountered. The discrepancies in the observed stratigraphic ranges are probably due to differences in methods. Gombos and Ciesielski (1983), using mostly magnifications of $\times 400$ and $\times 600$ and by examining only seven traverses of the unsieved HCl- and H_2O_2-insoluble residue, preferred to look at the larger sized and the more common smaller sized diatoms. In this way, they might well have missed *Melosira architecturalis* Brun and *Pyxilla reticulata* in the Late Oligocene where these species are represented by relatively small and rare specimens.

Because of the above-indicated differences, a new zonation is proposed here (text-fig. 5). For the definition of the zones, mainly first occurrence datums are used in order to avoid problems caused by reworking, which is an inherent character in Late Paleogene sediments of the Circum-Antarctic, relating to the existence and strength of the Circum-Antarctic Current.

To demonstrate the ranges of the marker species, the results from DSDP Sites 274, 278, and 511 of the sites studied (listed above) are used to compose a sequence of diatomaceous sections from the latest Eocene to the earliest Miocene. A small unsampled interval seems to be present between the Oligocene diatomaceous sections of DSDP Sites 278 and 274. A hiatus between the *Rocella vigilans* and the *R. gelida* Zones (latest Oligocene) of DSDP Site 278 seems probable, based on the crowding of first occurrences of several marker species that coincide with a lithologic change to nannochalk with higher calcium carbonate content above. Further information on this interval in the latest Oligocene can be obtained from DSDP Site 513A (Gombos and Ciesielski 1983), which, despite its relatively northern position, contains the characteristic high southern latitude species *Hemiaulus taurus* Gombos and Ciesielski.

Rylandsia inaequiradiata Zone

Category: Range Zone.

Age: Late Eocene to earliest Oligocene.

Author: Gombos and Ciesielski (1983).

Definition: Top: last occurrence of *Rylandsia inaequiradiata* Barker and Meakin; base: first occurrence of *R. inaequiradiata*.

Discussion: The last occurrence of *R. inaequiradiata* occurs in high and low latitudes above the LAD of *Discoaster saipanensis*.

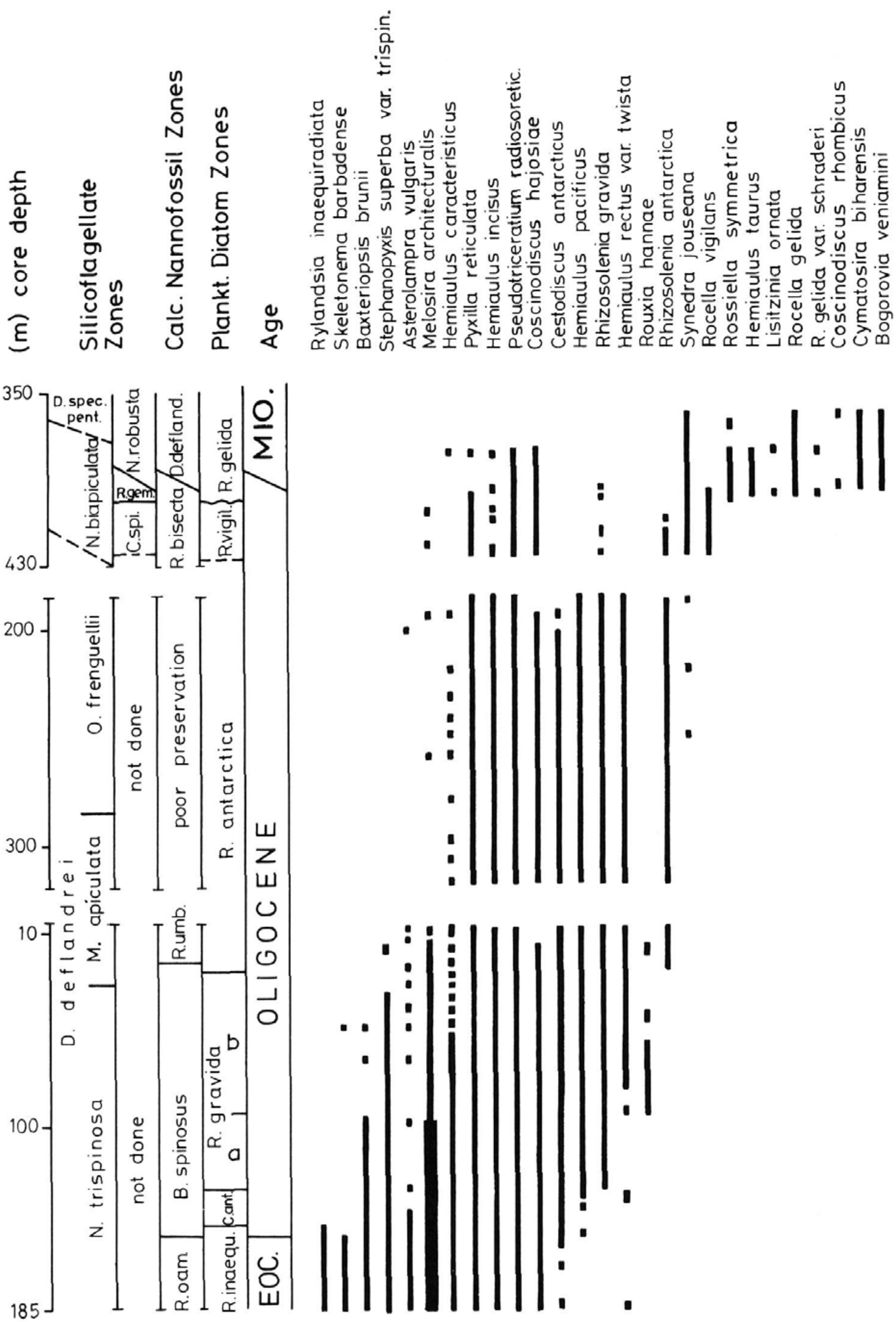
Cestodiscus antarcticus Zone

Category: Partial Range Zone.

Age: Early Oligocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Rhizosolenia gravida*; base: last occurrence of *Rylandsia inaequiradiata*.


DSDP Sites
511
274
278
(m) core depth
Silicoflagellate Zones
Calc. Nannofossil Zones
Plankt. Diatom Zones
Age
N. trispinosa
D. deflandrei
M. apiculata
O. frenguellii
D. spec. pent.
N. biapiculata
N. robusta
not done
C. spi.
R. gem.
R. oam.
B. spinosus
R. umb.
poor preservation
R. bisecta
D. defland.
R. inaequ.
C. ant.
R. gravida
a
b
R. antarctica
R. vigil.
R. gelida
EOC.
OLIGOCENE
MIO.
Rylandsia inaequiradiata
Skeletonema barbadense
Baxteriopsis brunii
Stephanopyxis superba var. trispin.
Asterolampra vulgaris
Melosira architecturalis
Hemiaulus caracteristicus
Pyxilla reticulata
Hemiaulus incisus
Pseudotriceratium radiosoretic.
Coscinodiscus hajosiae
Cestodiscus antarcticus
Hemiaulus pacificus
Rhizosolenia gravida
Hemiaulus rectus var. twista
Rouxia hannae
Rhizosolenia antarctica
Synedra jouseana
Rocella vigilans
Rossiella symmetrica
Hemiaulus taurus
Lisitzinia ornata
Rocella gelida
R. gelida var. schraderi
Coscinodiscus rhombicus
Cymatosira biharensis
Bogorovia veniamini

Discussion: No useful first-appearance datum could be found around the Eocene-Oligocene boundary at DSDP Site 511. The first appearance of the Circum-Antarctic species *Hemiaulus pacificus* (Hajós) Gombos and Ciesielski is too sporadic to provide a reliable datum. The same is the case for the likewise Circum-Antarctic species *Cestodiscus antarcticus*, n. sp. It has its first, rare occurrences in the Late Eocene.

Reference section: DSDP 511-16-2, 13–14 cm to 511-16-1, 22–24 cm.

Rhizosolenia gravida Zone

Category: Partial Range Zone.

Age: Early Oligocene.

Author: Gombos and Ciesielski (1983), modified herein.

Definition: Top: first occurrence of *Rhizosolenia antarctica*, n. sp.; base: first occurrence of *Rhizosolenia gravida*.

Subzones: The first occurrence of *Rouxia hannae* defines the base of Subzone b. Subzone a differs from Subzone b by the absence of this species and *Hemiaulus rectus twista* Fenner, n. var. (except for extremely sporadic single occurrences), and by the consistent occurrence of *Baxteriopsis brunii*, and the common to rare presence of *Melosira architecturalis*, which becomes rare to very rare above.

Discussion: Rhizosolenia gravida is characteristic of the Circum-Antarctic region. Its first appearance coincides with the first consistent occurrence of *Hemiaulus pacificus*. Subzone b contains the last occurrence of *Stephanopyxis superba* var. *trispinosa* Gombos, which seems to be a good stratigraphic datum in the Circum-Antarctic. The first occurrence of *Rouxia hannae* occurs in the same stratigraphic position as in the low latitudes.

Reference section: DSDP 511-15-1, 98–100 cm to 511-5-2, 96–97 cm.

Rhizosolenia antarctica Zone

Category: Partial Range Zone.

Age: Oligocene.

Author: New zone proposed herein.

Definition: Top: first occurrence of *Rocella vigilans*; base: first occurrence of *Rhizosolenia antarctica*, n. sp.

Discussion: The robust calyptra of *R. antarctica*, which is characterized by the broad spine with a rounded end, is a typical element of the Circum-Antarctic diatom assemblage during the late Oligocene.

The first occurrence of *Synedra jouseana* is in this zone. It is not considered a good stratigraphic datum, however, as it is rare in the lower part of its range.

Reference section: Base: DSDP 511-4-3, 34–35 cm; top: 274-20-3, 88–89 cm.

Rocella vigilans Zone

Category: Partial Range Zone.

Age: Late Oligocene.

Author: Gombos and Ciesielski (1983), modified herein.

Definition: Top: first occurrence of *Rocella gelida*; base: first occurrence of *Rocella vigilans*.

Discussion: The *R. vigilans* Zone as defined here includes both the *R. vigilans* Zone of Gombos and Ciesielski (1983) and their overlying *Triceratium groningensis* Zone. This latter zone was not retained because *T. groningensis* was not encountered at DSDP Site 278 and is known from other sites to be present in the Eocene (Fenner 1978, 1982).

The early forms of *R. vigilans* are slightly concave, whereas the later forms are completely flat. Both are included here under *R. vigilans*. Further stratigraphic refinement might be achieved if both forms were listed separately as proposed in Gombos (in press).

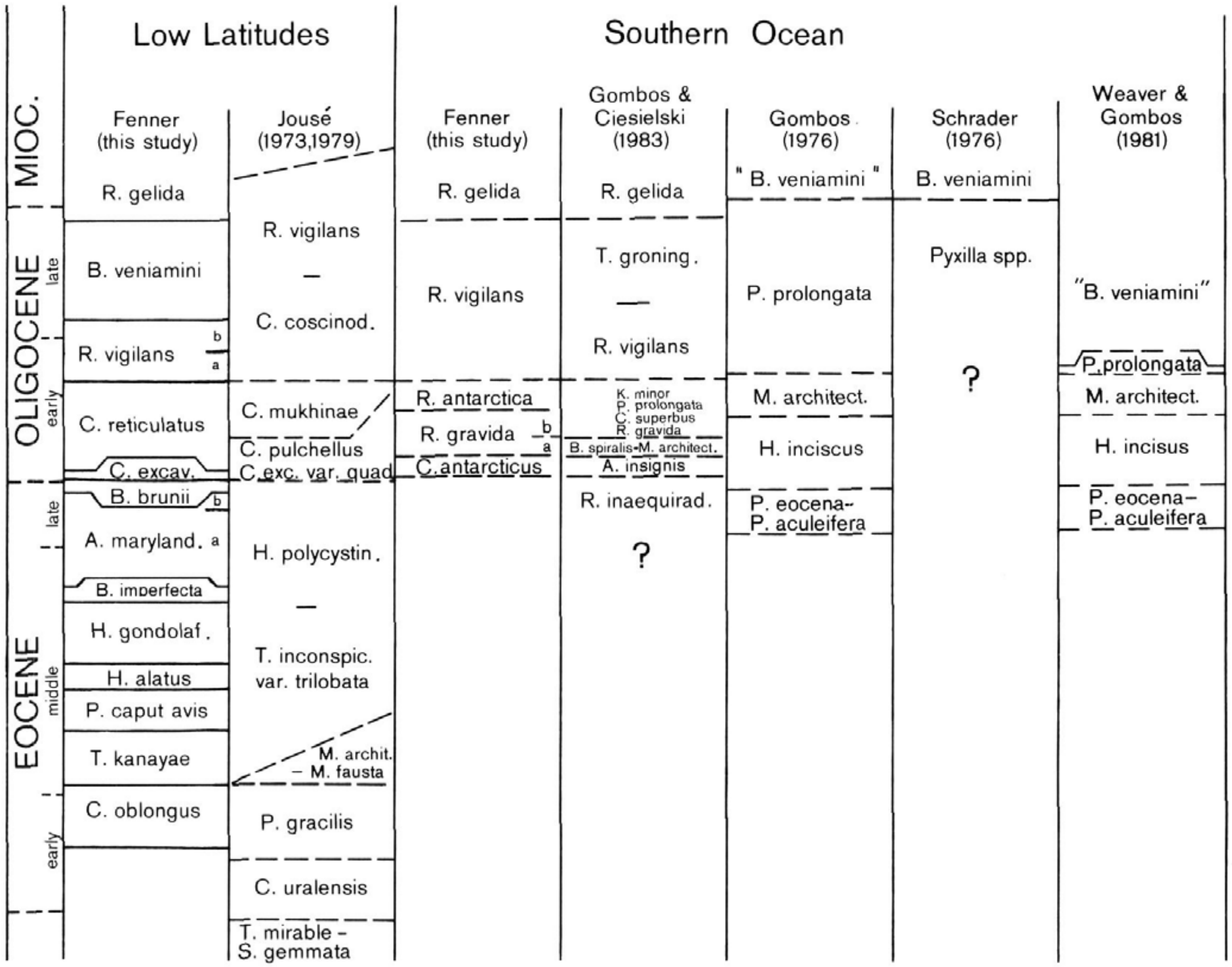
Within the *R. vigilans* Zone *Lisitzinia ornata* Jousé, *Coscinodiscus rhombicus*, *Cymatosira biharensis* Pantocsek, *Bogorovia veniamini*, and *Hemiaulus taurus* have their first occurrences.

Pyxilla reticulata becomes rare in the Late Oligocene with the larger forms with a long apical prolongation ("prolongata-type") disappearing and only the smaller forms with a shorter apical prolongation ("johnsoniana-type") surviving into the earliest Miocene. This is found in the low and the high southern latitudes. Jousé (1979) and Gombos and Ciesielski (1983) reported that *Pyxilla prolongata*

←

TEXT-FIGURE 5

Late Eocene-Oligocene high southern latitude planktic diatom zonation. Silicoflagellate zones, left column: Bukry (1975a, 1975b), Ciesielski (1975); right column: Perch-Nielsen (1975). Calcareous nannofossil zones (Bukry 1975a, 1975b; Burns 1975; Edwards and Perch-Nielsen 1975; Wise 1983). Oligocene-Miocene boundary is placed at the LAD of *Reticulofenestra bisecta* (Edwards and Perch-Nielsen 1975); the Eocene-Oligocene boundary at the LAD of *D. saipanensis* (Wise 1983). The results of the diatomaceous DSDP sediment sequences illustrated here are based on detailed diatom assemblage analysis of 75 samples spaced in roughly equal intervals through the sequences.



TEXT-FIGURE 6
Correlation of the main diatom zonations for the Eocene and Oligocene in the low and high southern latitudes.

(= "prolongata-type") does not range beyond the Early/Late Oligocene boundary.

Reference section: DSDP 278-34-3, 93–94 cm to DSDP 278-31-3, 92–93 cm.

Rocella gelida Zone

Category: Concurrent Range Zone.

Age: Latest Oligocene to earliest Miocene.

Author: Gombos and Ciesielski (1983).

Definition: Top: last occurrence of *Rossiella symmetrica*; base: first occurrence of *Rocella gelida.*

Remarks: The first occurrence of *Rocella gelida* var. *schraderi* is in the lower part of this zone.

CONCLUSIONS

In text-figure 6 the correlation between the high southern and the low latitude diatom zonations is given. It is based on the first and last occurrences of the cosmopolitan species *Rylandsia inaequiradiata, Baxteriopsis brunii, Asterolampra vulgaris* Greville, *Melosira architecturalis, Pyxilla reticulata, Rouxia hannae, Rocella vigilans, R. gelida, R. gelida* var. *schraderi, Rossiella symmetrica, Lisitzinia ornata, Coscinodiscus rhombicus,* and *Bogorovia veniamini.*

This list of species shows that cosmopolitan species are well represented in both latitudinal regions during the latest Eocene and in the Late Oligocene. In the Early Oligocene most of the dominant and newly occurring species are restricted in their paleogeographic occurrence, and the cosmopolitan species of the Late Eocene gradually disappear. This leads to an increased differentiation between the low and high southern latitude diatom assemblages, which makes interlatitudinal correlation difficult. The strong change in assemblage composition near the Eocene-Oligocene boundary toward a *Cestodiscus* spp. dominated assemblage in the Early Oligocene (50–80% of the diatom assemblage; in the Late Eocene, ca. 20%), which is characteristic of the low latitudes in the Atlantic and Pacific oceans, is not evident in the Circum-Antarctic region.

APPENDIX

Description of new species

Cestodiscus antarcticus Fenner, **n. sp.**
Plate 1, figure 1

Description: The valve face is slightly convex and covered with large areolae (3–4 in 10 μm), which are arranged in rows radiating from the center and decreasing slightly in size toward the margin. The areolation on the margin is much finer, with seven areolae in 10 μm. Around the upper part of the margin is a circle of 11 to 13 spines. The margin is offset from the valve face by a narrow hyaline ring, which often can not be recognized in smaller, more convex specimens.

Differential diagnosis: This species differs from *Cestodiscus convexus* by its flat to only slightly convex valve face, and from *C. trochus* Castracane by its larger areolae, which are not arranged in fascicles.

Paleogeographic occurrence: This species is characteristic of the Circum-Antarctic region.

Holotype: Plate 1, figure 1, from DSDP 274-33-3, 90–91 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D.

Cestodiscus reticulatus Fenner, **n. sp.**
Plate 1, figure 10

Coscinodiscus superbus Hardmann sensu FENNER 1978, pl. 14, figs. 2–3, not figs. 1, 4.

Description: The valve is circular in outline and varies in diameter between 30 and 60 μm. It is convex with a slightly concave central part which occupies approximately half of the valve diameter. The mantle is wide and slopes down steeply. The central part has single, widely spaced, large areolae which are connected by a reticulate net of hyaline ribs. The areolae become more closely spaced and smaller toward the margin. In the upper portion of the sloping peripheral part and often difficult to recognize, is a ring of small hyaline spaces, each with a spine in its center. Each such space (between 6 and 10 depending on size of valve), is regularly positioned relative to one another. The margin is densely areolated, with eight areolae in 10 μm, arranged in radial rows. The number of marginal striae in 10 μm is 14 to 16.

Differential diagnosis: This species differs from *Cestodiscus robustus* Jousé (both occur in the Early Oligocene and have a similar shape) in having hyaline ribs in the central part and lacking small pores. This character also differentiates this species from all other *Cestodiscus* species.

Paleogeographic occurrence: Cestodiscus reticulatus is a low-latitude species.

Holotype: Plate 1, figure 10, from DSDP 354-12-1, 49–50 cm. The holotype is in the collection of DSDP slides of Dr. Schrader, Oregon University, Corvallis, Oregon, U.S.A.

A paratype is deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D., slide number Zu 2/62.

Coscinodiscus hajosiae Fenner, **n. sp.**
Plate 2, figure 1

Podosira aff. *maxima* DZINORIDZE et al. 1978, pl. 4, figs. 6–7.
Hyalodiscus ambiguus Grun. sensu PARAMONOVA 1964, pl. 2, fig. 2.
Coscinodiscus spiralis HAJÓS 1976, p. 826, pl. 7, figs. 1–3.
non *Coscinodiscus spiralis* KARSTEN 1905, p. 81, pl. 5, figs. 5a–b.

Description: The valves are convex. The areolae are arranged in distinct spiral rows, and leave free a central area, in which a cluster of pores can be recognized in the light microscope. There are 12–13 areolae in 10 μm and 16 marginal striae in 10 μm. An electron microscopical study of the central cluster of fine pores is necessary to decide whether the placement of this species in the genus *Coscinodiscus* is correct.

Differential diagnosis: Coscinodiscus tenerrimus Jousé (1973) differs from *C. hajosiae* in being flat and having coarser areolae (10–12 in 10 μm); also it has fine spines between the areolae and in the central area.

Paleogeographic occurrence: This species is present in high- and low-latitude sediments.

Holotype: Plate 2, figure 1 from DSDP 369A-24-2, 130–131 cm; deposited in the Hustedt Collection, Institut f. Meeresforschung, Bremerhaven, B.R.D.

Hemiaulus gondolaformis Fenner, **n. sp.**
Plate 2, figures 7–9

Description: The valve outline is linear oblong to narrowly lanceolate. The valve face is thickly silicified and rises gently toward the horns. It is narrowly segmented by numerous pseudosepta, which are not all strictly aligned transapically. In the center of the central segment is a labiate process. There are 2–3 areolae in 10 μm on the valve face, which decrease in size on the horns. The horns are relatively short and taper toward the top, where a strong spine splays off inward. A hyaline ridge surrounds the valve face and connects the horns. The valve margin is sharply offset from the valve face in its type of areolation and the thickness of the siliceous wall. It is very delicate and thin, and densely areolated with small areolae, about five in 10 μm. These are arranged in vertical rows, becoming radially arranged below the horns. The delicate margin is often broken off, leaving only the thickly silicified valve face. The latter is characteristic and allows definitive species identification.

Differential diagnosis: This species differs from all other species of the genus *Hemiaulus* by its narrow width and the numerous pseudosepta crossing it. Besides, in no other *Hemiaulus* species is a margin possessing a type of areolation and wall thickness distinctly different from that of the valve face known.

Paleogeographic occurrence: Hemiaulis gondolaformis is a species characteristic of the low latitudes.

Holotype: Plate 2, figure 9, from Barbados, slide number B.M. 3049 of the Greville Collection of the British Museum (Nat. Hist.), London, England.

Paratype: Plate 1, figure 6, from DSDP 366-15-CC, Sierra Leone Rise, deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D., slide number Zu 2/77.

Hemiaulus grassus Fenner, **n. sp.**
Plate 1, figure 7

? *Hemiaulus polymorphus* Grun. sensu A. Schmidt (1887) in A. SCHMIDT ET AL. 1874–, pl. 143, fig. 30.

Description: The valve outline is broadly elliptical. The horns taper toward their top where a stout spine is splayed off inward at an angle of approximately 30°. The valve face is segmented by transapical pseudosepta into arched segments of about equal height. Each pseudoseptum is split at its free end into two short branches. The valve face is surrounded by a hyaline ridge that runs from horn to horn. The areolation on the mantle in the central part of the valve is coarse, with three areolae in 10 μm; the areolae gradually decrease in size toward the apices. At the upper part of the horns the number of areolae in 10 μm is about seven.

Differential diagnosis: Hemiaulis polycystinorum (Ehr.) Grunow differs from *H. grassus* by having straight horns with a straight spine on top, and the size of the areolae in *H. polycystinorum* diminishes less markedly from the central part of the valve toward the horns. *Hemiaulus grassus* is easily differentiated from *H. proteus* Heiberg, which, in valve view, has a wasp-waistlike, narrow middle segment.

Paleogeographic occurrence: This species is found in the low and middle latitudes.

Holotype: Plate 1, figure 7, from DSDP 366-14-3, 50–51 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D., slide number Zu 2/58.

Hemiaulus peripterus Fenner, **n. sp.**
Plate 1, figures 8–9

?*Periptera capra* sensu WEISSE 1854, pl. 3, fig. A.

Description: The valve outline is narrowly lanceolate with long, narrow horns and a long acute downward extension of the mantle at each pole. The valves are, as far as can be seen in the light microscope, structureless. Only in the center of the valve face can a round, slightly elevated structure be seen.

Differential diagnosis: The central structure and the complete lack of areolae differentiate this species from *H. caracteristicus* Hajós.

Paleogeographic occurrence: This species is found in high and low latitudes.

Holotype: Plate 1, figure 8, from DSDP 384-7-4, 100 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D.

Hemiaulus rectus twista Fenner, **n. var.**
Plate 2, figure 6

Description: The valve outline is elliptical. The lobes on the valve face are separated from each other by transapical sulci, the central lobe being slightly higher than the neighboring ones. The horns are straight and wide, tapering only slightly distally, and are surmounted by a robust, straight spine. The aerolae are arranged in radial rows radiating from the center of the valve face, and in vertical rows on the horns and the margin. There are four or five areolae on 10 μm. Their size decreases toward the top of the horns. Characteristic of this variety is the marked twisting of the horns into opposite directions away from the apical axis. The twisting affects not only the horns but also the whole valve, including its base.

Differential diagnosis: Hemiaulus rectus var. *twista* is similar in shape to *Hemiaulus muticus* Strelnikova, but differs from it in its larger areolae, smooth, non-lobate base and the twisted valves.

Paleogeographic occurrence: This variety is characteristic of the Circum-Antarctic region.

Holotype: Plate 2, figure 6, from DSDP 280A-5-CC; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D.

Kozloviella subrotunda Fenner, **n. sp.**
Plate 2, figure 2

Description: The valve outline is subcircular and the valve face slightly convex. The observed valve diameter varies from 50 to 160 μm. The areolae are arranged in radial rows, leaving free a central hyaline area. In the center, the number of areolae is five or six in 10 μm; toward the margin the areolae decrease in size to eight or nine areolae in 10 μm. The areolae are closed on the outside by a cribrum of cross- or tripod-like robust bars often preserved in whole or in part, which thicken where they join the margin of the areola. The hyaline lines running between the longest radial rows terminate at the margin as small processes, one per line.

Differential diagnosis: This species differs from other *Kozloviella* species by the shape of its valve. In *K. pacifica* Jousé, the valve shape is almost semicircular, with the hyaline area displaced toward the convex margin; in *K. meniscosa* Fenner the valve is sickle-shaped with the hyaline area displaced toward the concave margin.

Paleogeographic occurrence: This species commonly occurs in low-latitude sediments.

Holotype: Plate 2, figure 2, from DSDP 366-12-1, 130–131 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D., slide number Zu 2/57.

Rhizosolenia antarctica Fenner, **n. sp.**
Plate 2, figure 5

Description: The calyptra narrows at about one-third of its height to one-half to one-third of its basal width. In the basal part, above the broad hyaline basal ring the areolation is dense and fine, with 15 or 16 areolae in 10 μm. Higher up, the areolae increase in size and become sparser. Characteristic of this species is the broad, robust spine with a broadly rounded tip.

Differential diagnosis: Rhizosolenia hebetata var. *subacuta* Grunow and *R. hebetata* f. *hiemalis* Gran, which also have a broad spine with a rounded tip, differ from *R. antarctica* by the conical shape of their spine and the elliptical widening of the central canal at the base of it.

Paleogeographic occurrence: This species is characteristic of the Circum-Antarctic region.

Holotype: Plate 2, figure 5, from DSDP 274-34-3, 50–51 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D.

Rocella vigilans Fenner **n. sp.**
Plate 1, figure 11

Coscinodiscus vigilans sensu KOLBE 1954, p. 36, pl. 1, figs. 13–14, not *Coscinodiscus vigilans* A. Schmidt 1888, in A. SCHMIDT ET AL. 1874–, pl. 114, fig. 11.

Description: The valve outline is circular. The densely areolated valve face is flat, with the shallow margin practically perpendicular. The size of the areolae is more or less constant over the whole valve face, decreasing only slightly at the margin. From specimen to specimen, however, they vary in that there may be from three to six areolae in 10 μm. Characteristic is the presence of a subcentric "double-pore." Early forms of this species have a slightly convex valve.

Differential diagnosis: Other species, which also possess the subcentral "double-pore" and the type of areolation of *R. vigilans,* are *R. princeps* Jousé and *R. praenitida* Fenner. *Rocella princeps,* which Jousé (1973) reported from the Late Oligocene and Middle Miocene, is similar to *R. vigilans,* differing from it only in the transverse or wedge-shaped undulation of its valve face. I have found variants of *R. vigilans* with a concentrically undulated valve face in Planktic Foraminiferal Zones P 20 and P 21 at DSDP Site 369A. Further studies are necessary to determine the stratigraphical value of these undulated varieties. *Rocella vigilans* ranges from the Late Oligocene into the Miocene, and is not synonymous with *Coscinodiscus vigilans* Schmidt or *C. subconcavus* Schmidt as was proposed by Kolbe (1954). The two latter species, which were described from the Paleocene of Archangelsk-Kurojedowo, lack the subcentral "double-pore."

Paleogeographic occurrence: R. vigilans is characteristic of the Late Oligocene in the high and low latitudes. In high latitudes it tends to gigantism as does *R. gelida* (Mann) Bukry.

Holotype: Plate 1, figure 11, from DSDP 366A-33-1, 130–131 cm; deposited in the Hustedt Collection, Inst. f. Meereskunde, Bremerhaven, B.R.D.

Rossiella symmetrica Fenner, **n. sp.**
Plate 1, figures 2–4

Bogorovia veniamini Jousé sensu GOMBOS 1976, p. 593, pl. 1, figs. 6–7; pl. 12, figs. 1, 2, 4.
Rossiella sp. GOMBOS and CIESIELSKI 1983.

Description: The valve outline is linear-oblong to elliptical. Some narrowly elliptical forms have rostrate apices. The valve length varies from 14–95 μm, the width from 5–15 μm. The valve face is covered with irregularly arranged polygonal to round areolae. There are six or seven areolae in 10 μm in the older specimens, but the size of the areolae increases through the Late Oligocene toward the Miocene until there are only five or six in 10 μm. Between the marginal areolae, short marginal processes are present. These can be recognized only in girdle-band view or when the valve is viewed at an oblique angle. In valve view, these processes resemble marginal thickenings. The apices are slightly raised and carry a special organelle. In a few cases a single subcentral process was observed.

Differential diagnosis: This species differs from Miocene *R. paleacea* in its narrow width, the symmetrical shape of its valve outline, and the smaller size and arrangement of its areolae. *Rossiella* ("*Bogorovia*") *paleacea* var. *elongata,* which was described by Barron (1981) from the lower part of the upper Miocene, differs from *R. symmetrica* in its narrowly lanceolate, slightly asymmetric, shape. *Bogorovia veniamini* differs from all *Rossiella* species by having hyaline transapical ribs that are relatively broad at the margin but thin out toward the apical axis where they either fuse in an irregular pattern or peter out.

Paleogeographic occurrence: This species is common in high and low latitudes.

Holotype: Plate 1, figure 2, from DSDP 369A-18-3, 132–133 cm; deposited in the Hustedt Collection, Inst. f. Meeresforschung, Bremerhaven, B.R.D.

Triceratium kanayae kanayae Fenner, **n. sp., n. var.**
Plate 1, figures 5–6

Triceratium sp. a KANAYA 1957, pp. 102–103, pl. 7, figs. 5–7.
Triceratium schulzii Jousé sensu FENNER 1978, p. 535, pl. 30, figs. 1, 3–11, 15–20.

Description: The valves of this relatively small species vary in side-length from 25 to 40 μm. The corners are broadly rounded and offset from the central part of the valve face by a sulcus. The valve face is flat and the corners are not raised. The areolation is coarse. A basal septum is present under the corners.

Characteristic of this species are one to three short vertical ribs projecting inward from the margin at each apex.

Differential diagnosis: This species differs from *Triceratium inconspicuum* var. *trilobata* by the vertical internal ribs at the apices.

Paleogeographic occurrence: This species is characteristic of the middle Eocene of the low and middle latitudes.

Holotype: Plate 1, figure 5, from DSDP 356-6-3, 30–31 cm; deposited in the Hustedt Collection, Institut f. Meeresforschung, Bremerhaven, B.R.D.

Triceratium kanayae quadriloba Fenner, **n. sp., n. var.**
Plate 2, figures 3–4

Description: This variety differs from the species by being fourangled.

Remarks: This variety occurs in the sediments during intervals in which *T. kanayae* var. *kanayae* is common to abundant. Its occurrence may be environmentally controlled.

Holotype: Plate 2, figure 4, from DSDP 356-9-2, 30–31 cm, deposited in the Hustedt Collection, Institut f. Meeresforschung, Bremerhaven, B.R.D.

LIST OF SPECIES

For each species one reference to a good illustration and description is given.

Abas witti (Grunow) Ross and Sims 1980
Synonym: Syringidium poyseri Boyer 1922, p. 9, pl. 2, fig. 4.—
Ross and Sims 1980, pp. 120–122, pl. 2, figs. 10–15.

Asterolampra insignis Schmidt 1889
Schmidt et al. 1874–, pl. 137, figs. 1–3.

Asterolampra marylandica Ehrenberg 1844
Hustedt 1930, pp. 485–487, fig. 271.

Asterolampra vulgaris Greville 1862
Greville 1862b, p. 47, pl. 7, figs. 17–25.

Asteromphalus symmetricus Schrader and Fenner 1976
Schrader and Fenner 1976, p. 966, pl. 21, figs. 7, 10–12.

Baxteriopsis brunii (van Heurck) Karsten 1928
van Heurck 1896, p. 460, fig. 190.

Bogorovia veniamini Jousé 1973
Jousé 1973, p. 351, pl. 4, figs. 1–3.

Brightwellia hyperborea Grunow 1883
van Heurck 1883, pl. 128, fig. 8.

Brightwellia imperfecta Jousé 1974
Gleser and Jousé 1974, p. 56, pl. 2, figs. 5–7.

Brightwellia spiralis Gleser 1964
Sheshukova-Poretzkaya and Gleser 1964, p. 82, pl. 2, fig. 3.

Clavularia barbadensis Greville 1865b
Synonyms: Clavularia catenata Brun 1896, p. 236, pl. 20, figs. 12–13; *Cymatosira* sp. 1 Fenner 1978, p. 518, pl. 32, figs. 2–5.
Fenner in press b, pl. 3, fig. 1.

Coscinodiscus excavatus Greville 1861, p. 829, pl. 8, fig. 26.

Coscinodiscus excavatus var. *sellatus* (Jousé) Fenner, n. comb.
Basionym: Coscinodiscus sellatus Jousé 1973, pp. 348–349, pl. 2, figs. 2–4.

Coscinodiscus lewisianus Greville 1866
Greville 1866, p. 78, pl. 8, figs. 8–10.

Coscinodiscus rhombicus Castracane 1886
Synonyms: Coscinodiscus lanceolatus Castracane 1886, p. 164, pl. 17, fig. 19; *Coscinodiscus? naviculoides* Truan y Luard and Witt 1888, p. 14, pl. 2, fig. 10; *Coscinodiscus punctatus* Ehr. var. *rhombica* Rattray 1889, p. 547.
Castracane 1886, p. 164, pl. 22, fig. 11.

Coscinodiscus uralensis Jousé 1951
Gleser et al. 1974, pl. 20, fig. 6.

Craspedodiscus ellipticus (Greville) Gombos 1982
Gombos 1982, p. 231, pl. 3, figs. 13–14.

Craspedodiscus oblongus (Greville) Schmidt 1866
Schmidt et al. 1874–, pl. 66, figs. 7–9.

Craspedodiscus moelleri Schmidt 1893
Schmidt et al. 1874–, pl. 184, fig. 3.

Craspedodiscus undulatus Gombos 1982
Gombos 1982, pp. 232–233, pl. 2, fig. 12; pl. 3, figs. 15, 18–19.

Cymatosira biharensis Pantocsek 1889
Pantocsek 1889, p. 68, pl. 3, figs. 41–42.

Goniothecium decoratum Brun 1891
Brun 1891, p. 28, pl. 12, fig. 6.

Hemiaulus alatus Greville 1865
Greville 1865b, p. 31, pl. 3, fig. 14.

Hemiaulus caracteristicus Hajós 1976
Hajós 1976, pp. 828–829, pl. 15, fig. 10.

Hemiaulus dubius Grunow 1884
Synonym: Hemiaulus biharensis Pantocsek 1892, pl. 38, figs. 528–529.
Grunow 1884, p. 9 (61), pl. 5 (E), fig. 54.

Hemiaulus exiguus Greville 1865
Greville 1865b, p. 29, pl. 4, fig. 20.

Hemiaulus inaequilaterus Gombos 1976
Gombos 1976, p. 594, pl. 20, figs. 5-7.

Hemiaulus incisus Hajós 1976
Hajós 1976, p. 829, pl. 23, figs. 4-9.

Hemiaulus kljushikovii Gleser 1964
Sheshukova-Poretzkaya and Gleser 1964, p. 87, pl. 3, fig. 8.

Hemiaulus lyriformis Greville 1865
Greville 1865b, p. 30, pl. 3, fig. 11.

Hemiaulus muticus Strelnikova 1979
Dzinoridze et al. 1979, p. 55, figs. 116–118.

Hemiaulus pacificus (Hajós) Gombos and Ciesielski 1983
Fenner in press b, pl. 12, fig. 2.

Hemiaulus polycystinorum Ehr. var. *mesolepta* Grunow 1884
Grunow 1884, p. 65, pl. 2 (b), fig. 43.

Hemiaulus subacutus Grunow 1884
Grunow 1884, p. 61, pl. 5 (E), fig. 55.

Hemiaulus taurus Gombos and Ciesielski 1983
Gombos and Ciesielski 1983, pl. 19, figs. 1-8.

Kozloviella minor Jousé 1973
Jousé 1973, p. 352, pl. 4, fig. 18.

Lisitzinia ornata Jousé 1978
Jousé 1978, pp. 47–48, pl. 10, figs. 1-6.

Melosira architecturalis Brun 1892 in Schmidt et al. 1874–
Synonym: Cyclotella hannae Kanaya 1957, pp. 82–84, pl. 3, figs. 10–14.
Schmidt et al. 1874–, pl. 177, figs. 45–50.

Pseudodimerogramma filiformis Schrader and Fenner 1976
Schrader and Fenner 1976, p. 993, pl. 3, figs. 21–22.

Pseudotriceratium radiosoreticulatum Grunow 1883
van Heurck 1883, pl. 112, fig. 5.

Pyxilla caput avis Brun 1896
Brun 1896, pp. 242–243, pl. 19, fig. 11.

Pyxilla gracilis Tempère and Forti 1909
Forti 1909, p. 24, pl. 2, fig. 5.

Pyxilla oligocaenica Jousé 1955
Jousé 1955, pp. 98–99, pl. 6, figs. 5–6; pl. 7, figs. 3–4.

Pyxilla reticulata Grove and Sturt 1887
Synonyms: Pyxilla gracilis var. *saratoviana* Tempère and Forti, in Forti 1909, pl. 2, figs. 7–8; *Pyxilla johnsoniana* sensu Forti 1909, pl. 2, fig. 2, not *Pyxilla johnsoniana* Greville 1865a, p. 2, pl. 1, fig. 6; *Pyxilla johnsoniana* Grev. var. *corniculum* Brun 1893–1896, p. 243, pl. 19, figs. 12–13; *Pyxilla prolongata* Brun 1893, p. 176, pl. 24, fig. 7; *Pyrgupyxis prolongata* (Brun) Hendey (1969), p. 5.
Fenner in press b, pl. 9, figs. 6–10.

Raphidodiscus marylandicus Christian 1887
Christian 1887, pp. 66–68.

Rhaphoneis fossile (Grunow) Andrews 1978
Andrews 1978, p. 386, pl. 3, figs. 12–23; pl. 6, fig. 6.

Rhizosolenia gravida Gombos and Ciesielski 1983
Gombos and Ciesielski 1983, pl. 11, figs. 1–7.

Rhizosolenia norwegica Schrader 1976
Schrader and Fenner 1976, pp. 996–997, pl. 9, figs. 4, 10.

Rocella gelida (Mann) Bukry 1978
Bukry 1978b, pl. 5, figs. 1-13.

Rocella gelida var. *schraderi* (Bukry) Barron 1983
Bukry 1978b, p. 788, pl. 6, figs. 1–10; pl. 7, fig. 1.

Rocella princeps (Jousé) Fenner, n. comb.
Basionym: Coscinodiscus princeps Jousé 1973, p. 350, pl. 3, figs. 8–12.
Description: Jousé 1973, p. 350, pl. 3, figs. 8–12.
Remarks: For discussion see under *R. vigilans.*

Rossiella paleacea (Grunow) Desikachary and Maheshwari 1958
Desikachary and Maheshwari 1958, p. 28, fig. 1.

Rouxia hannae Jousé 1973
Jousé 1973, pp. 349–350, pl. 2, fig. 13.

Rylandsia biradiata Greville 1861
Greville 1861b, p. 68, pl. 8, fig. 1.

Rylandsia inaequiradiata Barker and Meakin 1945
Barker and Meakin 1945, p. 21, pl. 4, fig. 9.

Sceptroneis gemmata Grunow 1866
Grunow 1866, p. 146.

Sceptroneis pesplanus Fenner and Schrader 1976
Schrader and Fenner 1976, p. 998, pl. 22, figs. 30–31; pl. 25, figs. 10–11.

Sceptroneis pupa Schrader and Fenner 1976
Schrader and Fenner 1976, p. 999, pl. 22, figs. 17–21; pl. 24, figs. 11–13.

Skeletonema barbadense Greville 1865
Synonym: Melosira sp. 1 Fenner 1978, p. 524, pl. 7, figs. 7–9.
Greville 1865c, p. 43, pl. 5, fig. 1.

Stephanopyxis superba (Greville) Grunow var. *trispinosa* Gombos 1976
Gombos 1976, p. 597, pl. 30, figs. 3–6.

Synedra jouseana Sheshukova-Poretzkaya 1962
Sheshukova-Poretzkaya 1962, p. 208, fig. 4.

Thalassiosira fraga Schrader 1976
Schrader and Fenner 1976, p. 1001, pl. 16, figs. 9–12.

Thalassiosira irregulata Schrader 1976
Schrader and Fenner (1976), pp. 1001–1002, pl. 20, figs. 10–12.

Triceratium brachiatum Brightwell 1856
Brightwell 1856, p. 274, pl. 17, fig. 3.

Triceratium inconspicuum Grev. var. *trilobata* Fenner 1978
Synonym: Triceratium barbadense Grev. sensu Kanaya 1957, pp. 100–101, pl. 7, figs. 1–4; not *Triceratium barbadense* Greville, 1861a, p. 44, pl. 4, fig. 12.
Fenner 1978, p. 534–535, pl. 30, figs. 23–26.

Triceratium polycystinorum Pantocsek 1889
Synonym: Triceratium subvenosum Hustedt 1936, p. 46, pl. 8, fig. 13.
Pantocsek 1889, pl. 6, fig. 105.

Triceratium mirabile Jousé 1949
Proshkina-Lavrenko 1949, p. 166, pl. 62, fig. 5.

Trinacria excavata Heiberg f. *tetragona* Schmidt 1890
Schmidt et al. 1874–, pl. 152, figs. 26–28.

Trochosira trochlea Hanna 1927
Hanna 1927, p. 123, pl. 21, figs. 8–9.

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PLATE 1

All figures × 1500

1 *Cestodiscus antarcticus* Fenner, n. sp.
Holotype, DSDP 274-33-3, 90–91 cm.

2–4 *Rossiella symmetrica* Fenner, n. sp.
2, holotype, DSDP 369A-18-3, 132–133 cm; 3–4, DSDP 366A-26-3, 98–99 cm.

5–6 *Triceratium kanayae kanayae* Fenner, n. sp., n. var.
5, holotype, DSDP 356-6-3, 30–31 cm; 6, DSDP 356-7-5, 30–31 cm.

7 *Hemiaulus grassus* Fenner, n. sp.
Holotype, DSDP 366-14-5, 130–131 cm.

8–9 *Hemiaulus peripterus* Fenner, n. sp.
8, holotype, DSDP 384-7-4, 100–101 cm; 9, DSDP 208-29-5, 100–101 cm.

10 *Cestodiscus reticulatus* Fenner, n. sp.
Holotype, DSDP 354-12-1, 49–50 cm. Both photos are of the same valve focused at different depth.

11 *Rocella vigilans* Fenner, n. sp.
Holotype, DSDP 366A-33-1, 130–131 cm.

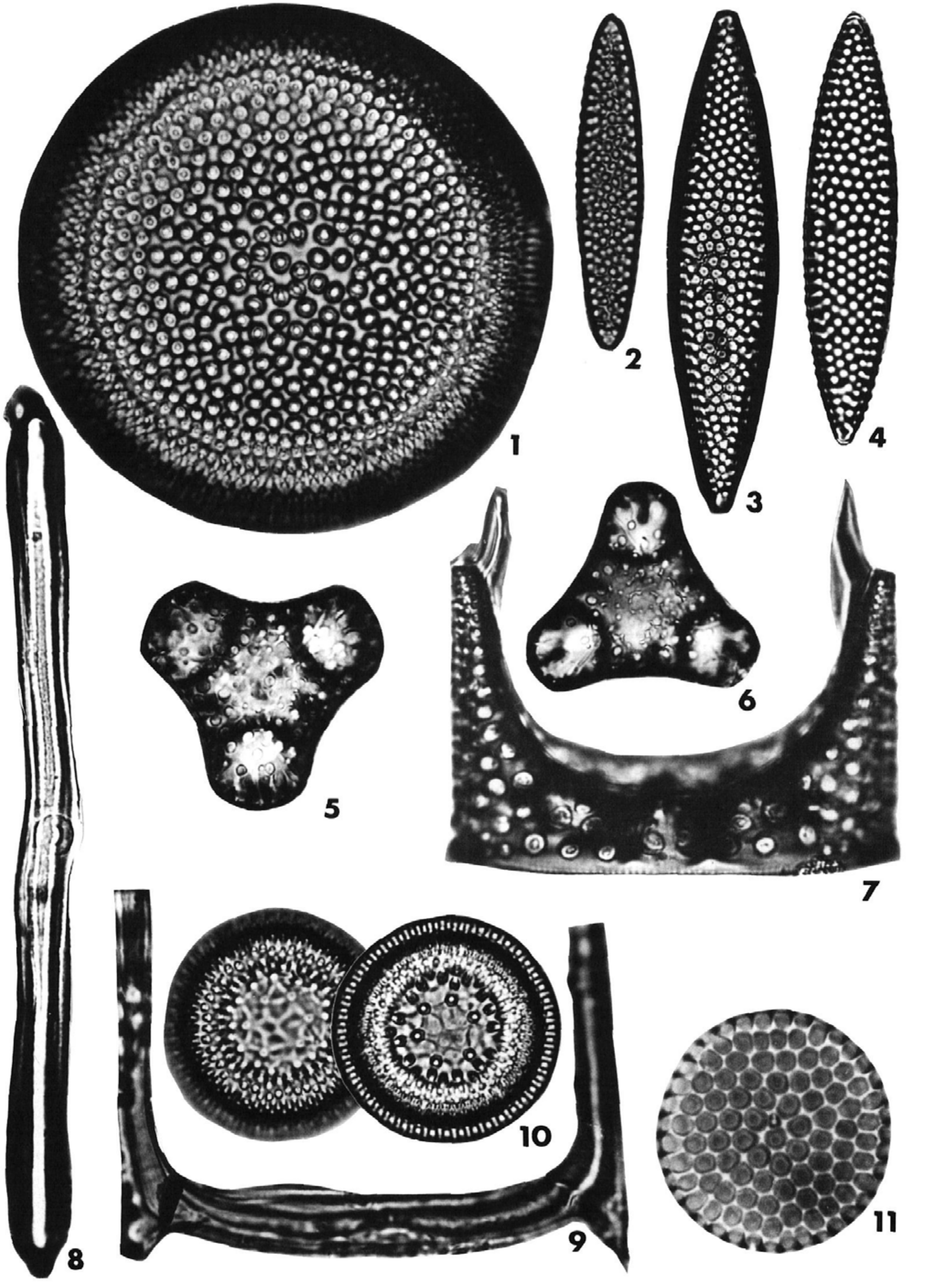
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PLATE 2

Figures 1–2, 7: × 1000; 3–6, 8: × 1500

1 *Coscinodiscus hajosiae* Fenner, n. sp.
Holotype, DSDP 369A-24-2, 130–131 cm.

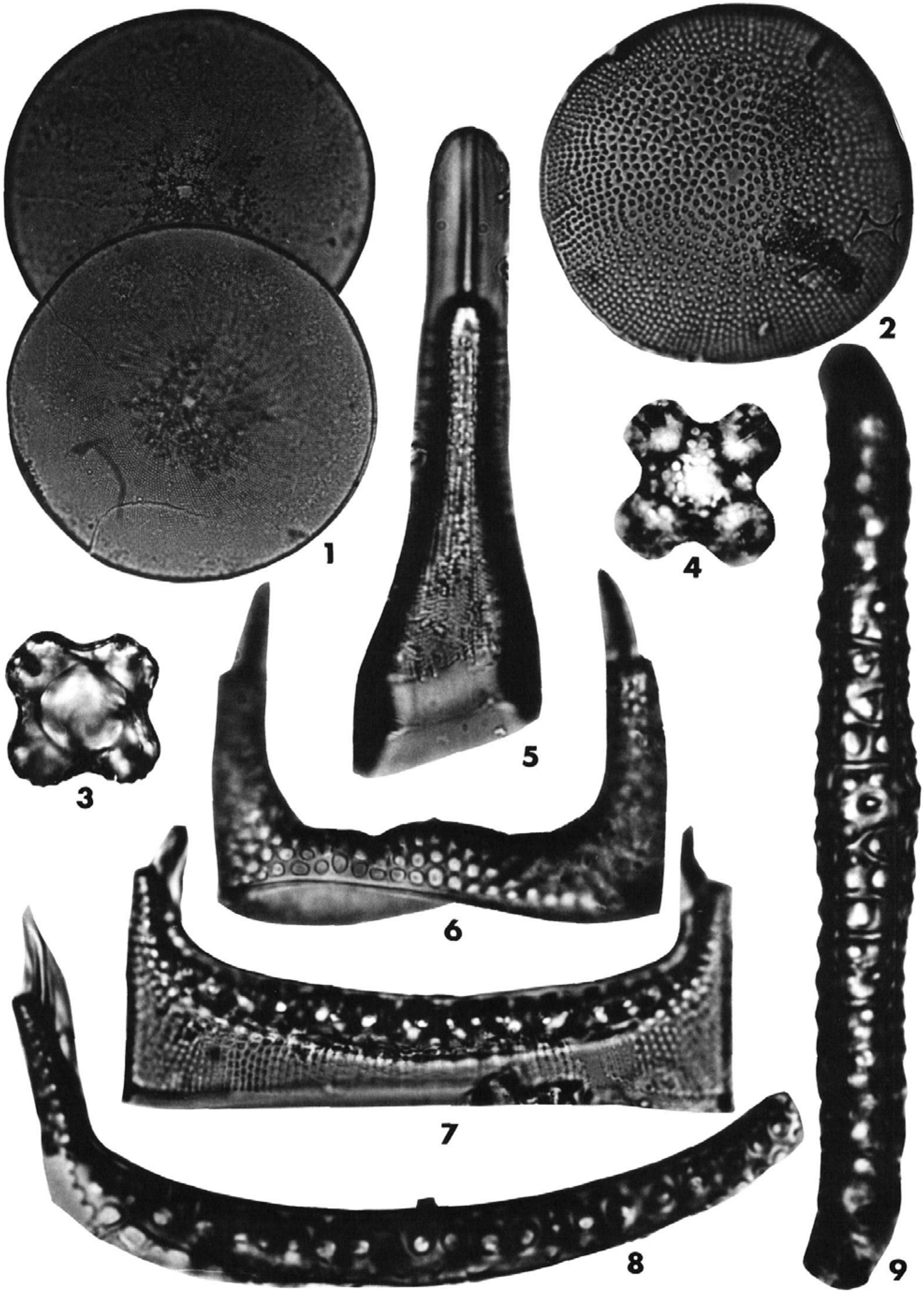
2 *Kozloviella subrotunda* Fenner, n. sp.
Holotype, DSDP 366-12-1, 130–131 cm.

3–4 *Triceratium kanayae quadriloba* Fenner, n. sp., n. var.
4, holotype; 3–4, DSDP 356-9-2, 30–31 cm.

5 *Rhizosolenia antarctica* Fenner, n. sp.
Holotype, DSDP 274-34-3, 50–51 cm.

6 *Hemiaulus rectus twista* Fenner, n. sp., n. var.
Holotype, DSDP 280A-5-CC.

7–9 *Hemiaulus gondolaformis* Fenner, n. sp.
7, holotype, Barbados, British Museum (Natural History) slide number B.M. 3049, Greville collection; 8–9, DSDP 366-15-CC.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