

7. NEOGENE DIATOMS FROM DEEP SEA DRILLING PROJECT LEG 62¹

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INTRODUCTION

All sites cored on Leg 62 lie between 20°N and 40°N in the central western Pacific, a region of very low diatom productivity. Thus, it is not surprising that diatoms are absent or of minor importance at these sites. Only in the Neogene of Site 464 do they attain any real significance.

This location of the Leg 62 sites in middle latitudes has both advantages and disadvantages for biostratigraphy and paleoceanographic interpretation. On the one hand, because both warm-water (tropical) and cool-water (subarctic) species are present, it is possible to use the zonations of both Burckle (1972, 1978; Burckle and Opdyke 1977) and Koizumi (1975a, 1977), which allows greater resolution than the use of either one alone. However, the middle latitudes are marginal to the regions in which the two zonations were established, so that certain marker species do not occur at all, whereas others have a somewhat different range (usually shorter) than in the source regions. First and last appearances may thus be due to environmental rather than evolutionary events.

Figure 1 compares the two biostratigraphic zonations used, and includes the age ranges currently accepted for some of the important species encountered in Leg 62 sediments.

OCCURRENCE OF DIATOMS AT EACH SITE

Diatoms are consistently present only in the Neogene of Sites 464 and 466. For these two sites, Tables 1 and 2 show the preservation and abundance of diatoms in each sample studied.

Site 463

No diatoms were recovered at Site 463, in the Mid-Pacific Mountains (21°21'N, 174°40'E).

Site 464

Diatoms are present in Lithologic Units IA and IB (clayey radiolarian ooze and siliceous clay), which occur in Cores 1 through 5 (Table 1). Abundance and preservation are best from Core 2 through Core 4, Section 3 (3.5–27 m). Below this, clay content increases, and the number of diatoms decreases; diatoms are essentially absent below Core 5, Section 3 (36.5 m).

Core 1 (0–3.5 m) consists of two manganese-enriched blebs of sediment, in which the diatoms are fairly

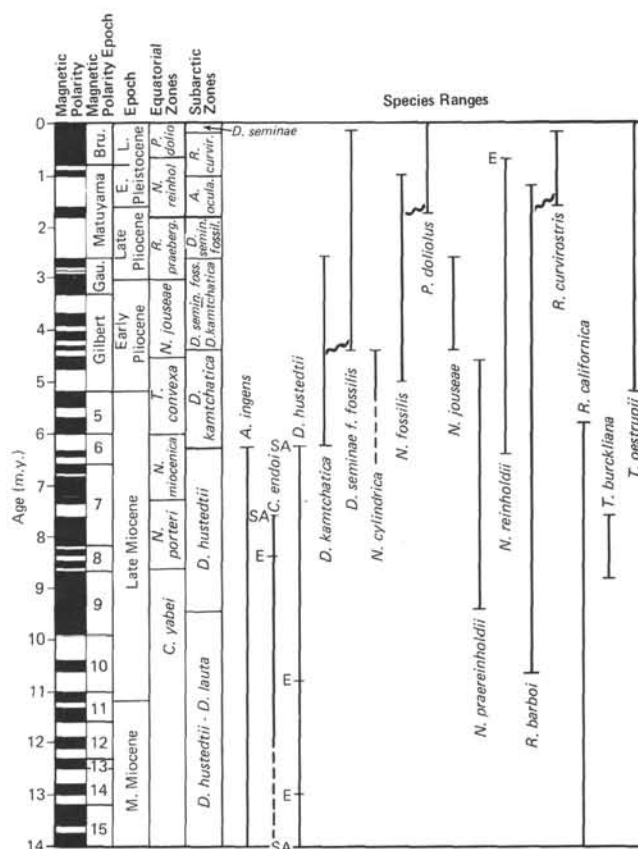


Figure 1. Age ranges of marker species encountered on Leg 62. Ages are those reported by Burckle (1972, 1978; Burckle and Opdyke, 1977) and Koizumi (1975a, 1977). Wavy lines indicate an evolutionary transition. Broken lines indicate that the age of an event has not been established precisely. Diachronous events are labeled as E (equatorial) or SA (subarctic).

well preserved, but very fragmented. The presence of *Nitzschia fossilis*, *N. reinholdii*, *Pseudoeunotia doliolus*, and *Rhizosolenia curvirostris* limits this core to the *Nitzschia reinholdii* Zone, probably equivalent to the *Actinocyclus oculatus* Zone, in the early Pleistocene.

The interval from Core 2 through Core 3, Section 2 (3.5–16 m) contains *Nitzschia fossilis*, *N. reinholdii*, and scattered *Denticula kamtchatica* and *N. jouseae*; it represents the early Pliocene. These species characterize the lower *Rhizosolenia praebergonii* and the *Nitzschia jouseae* Zones, equivalent to the *Denticula seminae fossilis*–*D. kamtchatica* and upper *D. kamtchatica* Zones. Below this interval there is a sequence (Core 3, Section 3 through Core 4, Section 2; 16–24 m) for which

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| Sample | Sub-bottom Depth (m) | General Abundance | Preservation | <i>Actinocyclus curvatus</i> <i>A. divus</i> <i>A. ehrenbergii</i> <i>A. ellipticus</i> <i>A. ingens</i> | <i>Asterolampra</i> spp. <i>Asteromphalus</i> spp. <i>Bacteriastrum</i> spp. <i>Coscinodiscus endoi</i> <i>C. lineatus</i> | <i>C. marginatus</i> <i>C. marginatus fossilis</i> <i>C. nodulifer</i> <i>C. radiatus</i> <i>C. stellaris</i> | <i>Denticula hustedtii</i> <i>D. kamtschatica</i> <i>D. seminae fossilis</i> <i>Hemidiscus cuneiformis</i> <i>Nitzschia cylindrica</i> | <i>N. fossilis</i> <i>N. jouseae</i> <i>N. marina</i> <i>N. praereinholdii</i> <i>N. reinholdii</i> | <i>Pseudoeunotia dololus</i> <i>Rhizolenia curvirostris</i> <i>R. hebetata hiemalis</i> <i>R. styliformis</i> <i>Rouxia californica</i> | <i>Stephanopoxis</i> spp. <i>Thalassionema nitzschoides</i> <i>Thalassiosira burckiana</i> <i>T. oestrupii</i> <i>T. trifurcata</i> <i>Thalassiothrix longissima</i> <i>Triceratium</i> spp. | Equatorial Zone (Burckle, 1972) | Subarctic Zone (Koizumi, 1975a) | Age |
|---------------|----------------------|-------------------|--------------|--|--|---|--|---|---|--|--|---------------------------------|-------------------|
| 464-1-1, 0 cm | 0 | F | F | | | F | | F F P | P R | P F | <i>Nitzschia reinholdii</i> | ? | early Pleistocene |
| 2-1, 115 | 4 | P | G | R R R F | F R | F R F | F R R | P R F | R | C F F | | | |
| 2-2, 115 | 6 | P | G | R R | R | F R F | R R | F R | R | C C | | | |
| 2-3, 115 | 7 | C | G | R R F | R R | F R | F | F F | | C C | | | |
| 2-4, 90 | 9 | A | G | R R | R | F | F | F F | | C C | | | |
| 2-5, 115 | 10 | A | G | R R | R | F | F | F F | | C C | | | |
| 2-6, 115 | 12 | A | G | | R | R | R | F F | | R C | | | |
| 2-7, 32 | 13 | A | G | R | R | P P | R R | P F | | F F | | | |
| 2, CC | 13 | A | G | | R | P P | R F | F F | | P P | | | |
| 3-1, 115 | 14 | A | E | | R | P | F | P | | F F | | | |
| 3-2, 115 | 15 | A | E | R R | | P | P | F R | R R | P R | | | |
| 3-3, 115 | 17 | A | E | | R F | R P | F | R | R | V A | | | |
| 3-4, 115 | 18 | A | E | | R | P | F | | | F F | | | |
| 3-5, 115 | 20 | C | G | | | P | P | R | | F F | | | |
| 3-6, 73 | 21 | P | F | | R | P | P | F | | F C | | | |
| 3, CC | 22 | F | F | | | P | P | | | F C | | | |
| 4-1, 95 | 23 | P | F | | | R F | C | P | | P F | R R | | |
| 4-2, 95 | 25 | P | F | | F | C | F | C | | F R R | | | |
| 4-3, 95 | 26 | P | F | R R | R | F F | P | P R | | F | | | |
| 4-4, 130 | 28 | F | P | | R | F F | P | P | | C C | | | |
| 4-5, 32 | 29 | R | P | R | | F F | F | F | | P P | | | |
| 4, CC | 32 | R | P | | | F F | F | F | | P P | | | |
| 5-1, 55 | 32 | R | P | | | F | F | F | | P | | | |
| 5-2, 55 | 34 | R | P | R F | R R F R | F R | F F | | R R | C P | | | |
| 5-3, 55 | 35 | R | P | R | R F | R | F | F | | R C | | | |
| | | | | | | | | | | | <i>Nitzschia porteri</i> or <i>Coscinodiscus yabei</i> | <i>Denticula hustedtii</i> | late Miocene |

Note: Abundance terms are B = barren, 0%; VR = very rare, 0-2%; R = rare, 2-5%; F = few, 5-15%; P = present, 15-40%; C = common, 40-60%; A = abundant, 60-85%; VA = very abundant, 85-100%. Preservation terms are P = poor, highly fragmented, resistant species only; F = fair, fragments common, mostly resistant species; G = good, whole valves, some thin-walled forms present; E = excellent, thin-walled species well preserved. (Values for species refer to abundance relative to other diatoms, while values for general abundance refer to diatoms relative to other sediment components.)

Table 2. Occurrence of diatoms at Site 466.

| Sample | Sub-bottom Depth (m) | General Abundance | Preservation | <i>Actinocyclus ehrenbergii</i> <i>A. ellipticus</i> <i>Coscinodiscus crenulatus</i> <i>C. lineatus</i> <i>Denticula seminae fossilis</i> <i>Hemidiscus cuneiformis</i> <i>Nitzschia fossilis</i> <i>N. jouseae</i> <i>N. marina</i> <i>N. reinholdii</i> <i>N. seriata</i> <i>Pseudoenotia doliolus</i> <i>Rhizosolenia bergonii</i> <i>R. barboi</i> <i>R. styliformis</i> <i>Thalassionema nitzschioides</i> <i>Thalassiosira eccentrica</i> <i>T. oestrupii</i> <i>Thalassiothrix longissima</i> | Equatorial Zone (Burckle, 1972) | Subarctic Zone (Koizumi, 1975a) | Age |
|--|--|--|--|--|--|------------------------------------|-------------------|
| 466-1-1, 0 cm 1-1, 83 1-2, 83 1-3, 83 1-4, 83 1-6, 30 1,CC 2-1, 130 | 0 1 2 4 5 8 8 9 | VR F R R R R VR VR | F F G F F P P F | R R R R + | <i>Pseudoenotia doliolus</i> | ? | late Pleistocene |
| 2-2, 130 2-3, 130 2-4, 130 | 11 12 14 | VR VR R | P F F | + | <i>Nitzschia reinholdii</i> | ? | early Pleistocene |
| 2-5, 130 2-6, 130 | 15 17 | B B | B | | ? | ? | ? |
| 2,CC 3-1, 112 3-2, 112 3-3, 112 3-4, 112 3-5, 112 3,CC 4-1, 106 4-2, 106 4,CC | 17 19 20 22 23 25 27 28 29 36 | VR VR R R R B B VR VR B | P P F F P B B P P B | R R R F F + | ? | ? | Pliocene |
| 5-1, 63 5-2, 63 | 37 39 | VR VR | P P | + | <i>Nitzschia jouseae</i> or lower <i>Rhizosolenia praebergonii</i> | ? | early Pliocene |

Note: + = taxon present in sample with very rare diatoms; no attempt to assess relative abundance. Other symbols as in Table 1.

the age is uncertain. *N. fossilis*, *N. reinholdii*, and occasional *D. kamtchatica* are the only stratigraphic markers present. If the absence of *N. jouseae* is evolutionary (i.e., if this interval represents a period prior to the appearance of *N. jouseae*), the principle of superposition would indicate that this section represents the *Thalassiosira convexa* or upper *Nitzschia miocenica* Zone (equivalent to the *Denticula kamtchatica* Zone) of the very early Pliocene or latest Miocene. This interpretation is used in Figure 2, but it must be stressed that unequivocal Miocene marker species are absent. Diatoms become more abundant and better preserved upward through Core 3, and then become slightly less abundant above Core 2, Section 4 (9.5 m), although their general abundance and preservation remain good throughout. In general, the samples are dominated by a constant assemblage of warm-water species; however, there are two interesting variations in this pattern. One is the occurrence of an almost pure *Thalassionema nitzschioides* ooze in Sample 464-3-3, 115 cm (17 m). The other is a slight increase above this level of cooler-water species, such as *Coscinodiscus marginatus* and *Actinocyclus divisus*. In particular, Samples 464-2-6, 115 cm through 464-2,CC (12–13 m) contain rare *Stephanopyxis* spe-

cies, *Coscinodiscus stellaris*, and *Thalassiosira trifulta*, which in modern oceans characterize cold, highly productive regions (see Paleoenvironmental Remarks).

Between Samples 464-4-3, 95 cm and 464-5-2, 55 cm (26.5–34 m), diatoms are rather rare, and few biostratigraphically important species are present. Stratigraphic position indicates that these samples are also late Miocene or early Pliocene.

In Core 5, diatoms are rare and usually fragmented, but Sections 2 and 3 (33.5–35 m) contain *Denticula hustedtii*, *Actinocyclus ingens*, *Nitzschia cylindrica*, *Rouxia californica*, *Thalassiosira burckliana*, *Coscinodiscus endoi*, and possible *Nitzschia praereinholdii*. Thus, the samples represent the lower *Nitzschia porteri* or upper *Coscinodiscus yabei* Zones of the late Miocene, equivalent to the middle to lower *Denticula hustedtii* Zone.

Site 465

At Site 465, diatoms were recovered only from the top part of Core 465-1, Section 1 (50 cm). They are very rare and poorly preserved. The only species present are *Nitzschia marina*, *Thalassionema nitzschioides*, *Pseudoenotia doliolus*, *Coscinodiscus radiatus*, *Actinocyclus*

ehrenbergii, and *Thalassiosira oestrupii*, warm-water species of the Quaternary (*Pseudoeunotia doliolus* Zone).

Site 466

Diatoms are rare throughout the first five cores from Site 466 and are absent below Sample 466-5-2, 63 cm (39 m; Table 2). Several samples within this interval are also barren. The assemblage consists of warm-water elements, with only scattered individuals of cool-water affinity.

The interval from Core 1 through Core 2, Section 1 (0–9.5 m) contains *Pseudoeunotia doliolus* and rare *Denticula seminae fossilis*; it is therefore late Pleistocene (*Pseudoeunotia doliolus* Zone).

Samples 466-2-2, 130 cm through 466-2-4, 130 cm (11–14 m) contain rare *Pseudoeunotia doliolus* and *Nitzschia reinholdii*, which restrict these samples to the early Pleistocene *Nitzschia reinholdii* Zone.

Between Samples 466-2-5, 130 cm and 466-4, CC (15–36 m), diatoms are either absent or rare, and poorly preserved. The presence of *Nitzschia fossilis* and *N. reinholdii*, together with the absence of *Pseudoeunotia doliolus*, suggests that this interval is probably Pliocene, but no zonal assignment can be made.

The upper part of Core 5 (Sections 1 and 2, 36.5–39.5 m) contains *Nitzschia jouseae*, indicating that at least this portion of Core 5 is early Pliocene, probably within the *Nitzschia jouseae* Zone (or lower *Rhizosolenia praebergonii* Zone). Diatoms are undiagnostic or absent below this level.

STRATIGRAPHIC REMARKS

The series of diatom zones represented at the Leg 62 sites is so incomplete that long-range biostratigraphic correlations cannot be made. However, it may be worthwhile to compare the three DSDP sites on Hess Rise which have yielded diatom floras: 310, 464, and 466. The section at Site 310 (Koizumi, 1975b; Burckle, personal communication) is by far the longest and most complete (Fig. 2), all diatom zones through the *Nitzschia porteri* Zone being represented. Site 464 definitely has two hiatuses, and may have more, while Site 466 has an undated interval which could include a short hiatus. Thickness of section, and consequently sedimentation rate, varies at different sites, but shows no consistent pattern—certainly the shallowest site is only somewhat more complete than the deepest site. Nor do the thicknesses of the zones change in a consistent way along this transect: the *Pseudoeunotia doliolus* Zone disappears northward, while the *Nitzschia reinholdii* Zone alternately expands and contracts.

The pattern of sedimentation on Hess Rise may be due either to changes in biologic productivity or to changes in erosion patterns, or both. The consistent presence of the *Nitzschia reinholdii* and *Nitzschia jouseae*/lower *Rhizosolenia praebergonii* intervals may be a result of very high productivity during the early Pliocene and early Pleistocene, with much lower production at other times. Alternatively, productivity may have been relatively constant through time, but erosion by intermediate waters may have occurred, interrupted

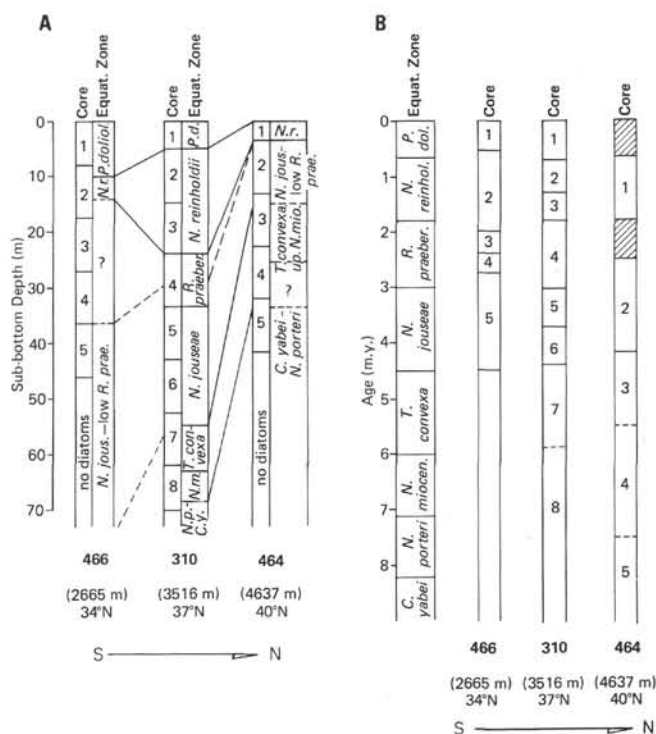


Figure 2. Diatom zones at sites on Hess Rise. Zonation is that of Burckle (1978). Sites represent a north-south transect, water depth increasing northward. A. Zone thicknesses. B. Core ages. Diagonal lines indicate hiatuses at Site 464; question marks represent undated and probably condensed intervals.

during the times corresponding to these two zones, when deposition would have been continuous. This latter explanation, which allows for local variations in current action on the topographically complex Hess Rise, would account for the completeness of the record at Site 310 and the condensed sections and hiatuses at the other sites.

PALEOENVIRONMENTAL REMARKS

Given the relative paucity of diatoms at Leg 62 sites, it may be somewhat presumptuous to draw any paleoenvironmental conclusions at all. However, two points do seem worthy of note.

First, it may be significant that on the southern part of Hess Rise (Site 466, 34°11'N) the diatom flora is almost completely composed of warm-water species, whereas on the northern part of Hess Rise (Site 464, 39°51'N) slightly greater numbers of cool-water species occur. The present subarctic front lies at about 42°N (Dodimead et al., 1963) and forms a sharp boundary between assemblages dominated by cool- or warm-water species (Sancetta, 1979). The slight difference between Sites 464 and 466 in the early Pliocene may therefore indicate a front not too far north—certainly no farther north than at present.

The second and more intriguing point is the upward change in floral composition at Site 464, previously mentioned. Within the early Pliocene(?) (Table 1), there

is a fairly consistent assemblage of warm-water species, followed by a period of almost pure *Thalassionema nitzschioides* accumulation. Above this level (Sample 464-3-3, 115 cm; 17 m) the number of cool-water elements increases, although their overall abundance remains low, and some levels contain such taxa as *Stephanopyxis* species, *Coscinodiscus stellaris*, and *Thalassiosira trifulta*. These groups today are characteristic of cold, highly productive waters. *T. nitzschioides*, too, seems to be more abundant in regions of high productivity (Burckle, pers. comm.). It is possible, therefore, that this sequence represents a moderate but distinct cooling of middle-latitude waters, coincident with more vigorous circulation and heightened productivity.

While some workers have found evidence of cooling in the early Pliocene, others have not. Keller (1978) reports two increases in *Neogloboquadrina pachyderma* (sinistral) at Site 310, one at 4.7 m.y. and one at 3.0 m.y. Koizumi (1975b) also indicates an increase in cold-water diatoms at Site 310, within the *Nitzschia jouseae* Zone. Keigwin (1978) reports an increase in *N. pachyderma* (sinistral) in the Panama Basin at about 3.1 m.y. Kennett and Vella (1974) also report several events indicative of early Pliocene cooling in the southwest Pacific (ice rafting; increases in sinistral *N. pachyderma*), although the time control of some events is questionable. On the other hand, oxygen isotopes do not show a distinct event within this time. Shackleton and Opdyke (1977), using oxygen isotopes in the central equatorial Pacific, find fairly stable conditions before 3.2 m.y., and an alternating glacial-interglacial regime beginning then. Keigwin (pers. comm.) finds no significant excursions at Site 310, although his sampling interval is rather wide. The age, and even the existence, of this cooling event shown by the diatoms must remain equivocal.

FLORAL REFERENCES

Because most of the species identified in Tables 1 and 2 are commonly recognized and have been well-reported elsewhere, there is no point in giving detailed descriptions or references. Consequently, I have given only the reference for the original description and, if necessary, a second, more-complete description.

- Actinocyclus curvatus* Janisch (1886) [in Schmidt]
Description. Hustedt (1930).
Remarks. *Coscinodiscus curvatus* Grunow (1886) [in Schmidt] has been included, since the distinguishing marginal nodule often is not visible.
- Actinocyclus divisus* (Grunow) Hustedt (1958)
Description. Hustedt (1930), as *Coscinodiscus divisus*.
- Actinocyclus ehrenbergii* Ralfs (1861) [in Pritchard]
Description. Hustedt (1930).
- Actinocyclus ellipticus* Grunow (1880) [in Cleve and Grunow]
Description. Rattray (1890).
Remarks. All varieties are included.
- Actinocyclus ingens* Rattray (1890)
- Asterolampra* species
Remarks. Several forms of the genus occur in rare cases. *A. marylandica* and *A. grevillii* were the most common species.
- Asteromphalus* species
Remarks. Several forms of the genus occur in a few samples. *A. robustus* and *A. imbricatus* were the most common species.
- Bacteriastrum* species
Remarks. Representatives of this genus are so rarely preserved in the sediment that accurate species distinctions are not possible.
- Coscinodiscus crenulatus* Grunow (1884)
Description. Hustedt (1930).

- Coscinodiscus endoi* Kanaya (1959)
- Coscinodiscus lineatus* Ehrenberg (1838)
Description. Hustedt (1930).
Remarks. All forms have been included; most have a narrow band of very small areolae inside the margin.
- Coscinodiscus marginatus* Ehrenberg (1841)
Description. Hustedt (1930).
- Coscinodiscus marginatus* forma *fossilis* Jousé (1961)
- Coscinodiscus nodulifer* Schmidt (1886)
Description. Hustedt (1930).
- Coscinodiscus radiatus* Ehrenberg (1841)
Description. Hustedt (1930).
- Cocinodiscus stellaris* Roper (1858)
Description. Hustedt (1930).
- Denticula hustedtii* Simonsen and Kanaya (1961)
- Denticula kamtschatica* Zabelina (1934)
- Denticula seminae* forma *fossilis* Schrader (1973a)
- Hemidiscus cuneiformis* Wallich (1860)
Description. Hustedt (1930).
- Nitzschia cylindrica* Burckle (1972)
- Nitzschia fossilis* (Frenguelli) Kanaya (1970) [in Kanaya and Koizumi]
- Nitzschia jouseae* Burckle (1972)
- Nitzschia marina* Grunow (1880) [in Cleve and Grunow]
- Nitzschia praereinholdii* Schrader (1973b)
- Nitzschia reinholdii* Kanaya and Koizumi (1970)
- Nitzschia seriata* Cleve (1883)
Description. Hasle (1972).
- Pseudoeunotia dolioles* (Wallich) Grunow (1880) [in Cleve and Grunow]
Description. Hustedt (1959).
- Rhizosolenia barboi* Brun (1894)
- Rhizosolenia bergonii* Peragallo (1892)
Description. Hustedt (1930).
- Rhizosolenia curvirostris* Jousé (1968)
Description. Donahue (1970).
- Rhizosolenia hebetata* forma *heimalis* Gran (1904)
Description. Hustedt (1930).
- Rhizosolenia styliformis* Brightwell (1858)
Description. Hustedt (1930).
- Rouxia californica* Peragallo (1910) [in Tempere and Peragallo]
- Stephanopyxis* species
Remarks. These rare specimens were not identified to the species level.
- Thalassionema nitzschioides* Grunow (1880) [in Cleve and Grunow]
Description. Hustedt (1959).
- Thalassiosira burckliana* Schrader (1974)
- Thalassiosira eccentrica* (Ehrenberg) Cleve (1904)
Description. Hustedt (1930), as *Coscinodiscus eccentricus*.
Remarks. Most of the observed individuals have a distinct central strutted tubulus.
- Thalassiosira oestrupii* (Ostenfeld) Proschkina-Lavrenko (1956)
- Thalassiosira trifulta* Fryxell (1979)
- Thalassiothrix longissima* Cleve and Grunow (1880)
Description. Hustedt (1959).
- Triceratium cinnamomeum* Greville (1863)

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