# 5. LATE PLIOCENE-QUATERNARY QUANTITATIVE DIATOM STRATIGRAPHY IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN<sup>1</sup>

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#### ABSTRACT

The practically continuous, paleomagnetically dated late Gauss-Brunhes sediment profiles of ODP Sites 699 and 701, south of the present Polar Front Zone (PFZ), and Site 704, north of the present PFZ, are used for a high-resolution study of abundance fluctuations of eight stratigraphic marker species in space and time. Ecological restrictions and preferences of the diatom species *Hemidiscus karstenii*, *Actinocyclus ingens f. planus*, *Thalassiosira elliptipora*, *Thalassiosira kolbei*, *Thalassiosira vulnifica*, *Simonseniella barboi*, *Cosmiodiscus insignis*, and *Nitzschia weaveri* are deduced.

The ages of their first abundant appearance datums (FAAD), last-appearance datums (LAD), and last abundant appearance datums (LAAD) at the three sites are determined. The interpolated datum ages agree relatively well with those determined by other authors, if one interprets most of their LADs as LAADs. FAADs and LAADs produce more accurate datums than LADs. For the late Matuyama (younger than approximately 2.0 Ma), when PFZ fluctuations effected all three site sites, the datum ages determined agree within the methodically caused limits of accuracy for each datum. For the early Matuyama (older than approximately 2.0 Ma) the results can be interpreted as either that the ages of the FAAD of *T. kolbei* and LAAD of *T. vulnifica* datums determined at Sites 699 and 701 are more reliable or that these datums are diachronous between these two sites and Site 704. Such a diachroneity could be caused by different paleoceanographic conditions (stable subantarctic conditions over Site 704 and stable antarctic conditions over Sites 699 and 701).

A few taxonomic changes were necessary. One new genus is defined (Simonseniella gen. nov.) and five new combinations are proposed: Simonseniella barboi (Brun) comb. nov., Simonseniella praebarboi (Schrader) comb. nov., Simonseniella curvirostris (Jousé) comb. nov., Thalassiosira elliptipora (Donahue) comb. nov., and Thalassiosira vulnifica (Gombos) comb. nov.

## INTRODUCTION

The late Pliocene-Quaternary in the antarctic-subantarctic realm of the Southern Ocean is characterized by a highly endemic diatom flora. The first to establish a zonation for the late Neogene in this region with planktonic diatoms were Jousé et al. (1963). Following the example of Opdyke et al. (1966), Hays (1967), and Hays and Opdyke (1967), who calibrated radiolarian datums against the paleomagnetic record, Donahue (1970), Abbott (1972, 1974), and McCollum (1975) calibrated the first- and last-appearance datums (FAD and LAD) of diatom species in piston cores from the antarctic sectors of the Indian and Pacific oceans to magnetostratigraphy. The ages established in these studies have been subsequently revised (Burckle et al., 1978; Ciesielski, 1983).

I have had considerable difficulty applying these ages because several of the species (e.g., *Thalassiosira vulnifica* and *Cosmiodiscus insignis*) were found to occur consistently at much younger ages at Ocean Drilling Program (ODP) Leg 114 sites. Others, such as *Simonseniella barboi*, occur so sporadically at some sites that it was difficult to decide where to place the LAD. For this reason the LAD of *S. barboi* was not listed in the compilation of datums presented in Ciesielski, Kristoffersen, et al. (1988). As I am reluctant to declare these much younger stratigraphic occurrences of *T. vulnifica* and *C. insignis* as reworking, I used the long, paleomagnetically dated Pliocene-Quaternary sequences recovered by Leg 114 at Sites 699, 701, and 704 (Table 1) to (1) define quantitatively the position of the LADs, last abundant appearance datums (LAADs), and first abundant appearance datums (FAADs) of these and six additional stratigraphic marker species, (2) determine their ages, and (3) select which of these datums are the most reliable. During part of the late Pliocene–Quaternary the studied sites were below different water masses within the Southern Ocean (Westall and Fenner, this volume); therefore, this material offered the opportunity to test how the occurrence and abundance–as well as the age of the FAADs, LADs, and LAADs–of these species may be controlled by ecological parameters related to the different surface water masses.

#### MATERIAL

Hole 699A from the northern slope of the Southeast Georgia Rise, Hole 701C from the deep-sea passage east of the Islas Orcadas Rise, and Hole 704B from the Meteor Rise in the southeast Atlantic were selected for the quantitative diatom study (Table 1 and Fig. 1). Sites 699 and 701 today lie south of the Polar Front Zone (PFZ; Fig. 1) and have been south of or beneath this zone throughout most of the time interval studied here (Westall and Fenner, 1990, this volume). During the Gauss and the early Matuyama magnetic Chrons Site 704 was located predominantly beneath subantarctic surface waters, which resulted in the accumulation of calcareous ooze at this site. During the late Olduvai magnetic Event the PFZ moved northward across Site 704, and it has since moved back and forth frequently. Consequently, the surface waters overlying Site 704 have alternated among antarctic, PFZ, and subantarctic water masses. ("Subantarctic" is used for the region and surface waters between the PFZ and the Subtropical Convergence. "Antarctic" denotes the region and surface waters south of the PFZ.) The shifts in water masses resulted in the alternating deposition of siliceous and calcareous oozes at the site. The siliceous oozes reflect periods when Site 704

<sup>&</sup>lt;sup>1</sup> Ciesielski, P. F., Kristoffersen, Y., et al., 1991. Proc. ODP, Sci. Results, 114: College Station, TX (Ocean Drilling Program).

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Table 1. Location and thickness of sediment deposited during the Brunhes and Matuyama magnetic Chrons at the studied Leg 114 holes.

	Loc	ation	Water	Brunhes + Matuyam			
Hole	Longitude	Latitude	(m)	(m)			
699A	51°32.537'S	30°40.619'W	3705.5	29.6			
701C	51°59.085'S	23°12.700'W	4636.7	65.5-70			
704A	46°52.757'S	07°25.250'E					
704B	46°52.785'S	07°25.231'E	2532.3	168			

was beneath antarctic surface waters; the calcareous oozes, those beneath subantarctic and northern PFZ surface waters.

All three sites provide long sediment sequences of late Neogene age with a good paleomagnetic reversal record (Hailwood and Clement, this volume; Clement and Hailwood, this volume). The interval from the top of the Gauss magnetic Chron to the present was chosen for study, because this period has a characteristic paleomagnetic reversal pattern that is well dated. The top of the Gauss was picked within the framework provided by micropaleontological data.

Throughout this study the terms Brunhes (0-0.73 Ma), Matuyama (0.73-2.47 Ma), and Gauss (2.47-3.4 Ma), as well as the shorter paleomagnetic events Jaramillo (0.91-0.98 Ma), Olduvai (1.66-1.88 Ma), and Réunion (2.0-2.04 Ma), are used as chronostratigraphic units.

In addition, the chosen interval was thought to be free of hiatuses, and the relatively high sedimentation rates at all three sites are ideal for a high-resolution study. Site 704 especially provides a sediment sequence of unequaled length (132.5 m) and completeness through the Matuyama magnetic Chron, with accumulation rates of 70 to 110 m/m.y. In parts of the section sedimentation rates up to 400 m/m.y. may be reached (Fig. 8). The high accumulation rates, which are two to more than 10 times higher than those determined for Sites 699 and 701 (Figs. 6-8), are caused by high rates of supply at Site 704 of both calcareous shells of planktonic organisms and biosiliceous components (mainly diatoms). At Sites 699 and 701 below the carbonate compensation depth, calcareous microfossils were rarely observed within the interval investigated. The few short hiatuses recognized in this study at the top of the Matuyama (Site 699) and the top of the Gauss magnetic Chron (Site 704) do not reduce the value of these profiles.

Diatom abundance throughout the studied intervals is very high, generally more than  $10^7$  and commonly reaching  $10^8$ , but never falling to less than  $10^6$  diatom valves per gram sediment (Figs. 3–5 and Appendix). Reworking is not a problem at the sites studied. Even in the samples that contain reworked diatoms (compare Figs. 3 and 5) reworked specimens are very few.

#### METHODS

Samples were systematically taken every 40 cm in Hole 704B and every 15 cm in Hole 701C. Many additional samples were taken where lithologic changes were observed. In Hole 699A sample spacing is more irregular, but it is generally every 25 to 60 cm. The samples were prepared for diatom analysis by boiling the sample in an equal aliquot of 30% H<sub>2</sub>O<sub>2</sub> and 10% HCl. The samples were so rich in diatoms that additional washings using sodium hexametaphosphate were unnecessary to separate out the clay. Slides with a homogeneous distribution of particles guaranteeing statistical reproducibility of the results were made following the method of Battarbee (1973).

Hyrax (refractive index n.d. = 1.71; solvent, toluene) was used as a mounting medium.

Counts were made at  $1000 \times$  magnification using a Leitz Orthoplan microscope with oil-immersion objective PL Apo Oel 100/1.32. A minimum of 300 diatom valves per sample was counted. Of the many fragmented valves present only those that represent more than one-half of the valve were counted as one valve. In the case of very long pennate diatoms (e.g., *Thalassiothrix longissima*), which practically always occur as fragments, each pole was counted as half a valve.

# RESULTS AND DISCUSSION

# Species Abundances and Paleogeographic Distribution

Graphic plots of the abundance fluctuations of eight diatom species, *Hemidiscus karstenii*, *Actinocyclus ingens* f. *planus*, *Thalassiosira elliptipora*, *Thalassiosira vulnifica*, *Thalassiosira kolbei*, *Simonseniella barboi*, *Cosmiodiscus insignis*, and *Nitzschia weaveri* (compare the "Taxonomy" section and Plates 1–3), which are generally used as stratigraphic markers in Southern Ocean sediments, are presented for ODP Holes 699A, 701C, and 704B (Figs. 3–5 and Appendix). Their abundance changes downhole and regionally are discussed as follows.

## Hemidiscus karstenii

Hemidiscus karstenii is generally considered a characteristic subantarctic species. Indeed, this species has been reported from nowhere else in Quaternary sediments. During the Miocene, however, it may have had a wider geographic distribution, as suggested by illustrations of this species (as Actinocyclus ellipticus) from the late Miocene in the North Pacific (Akiba, 1985) and from the early Miocene of the equatorial Pacific (A. ellipticus; Barron, 1985a). This suggests that H. karstenii retreated to the higher latitudes only during the end of its stratigraphic range.

The late Quaternary abundance fluctuations of this species in sediments deposited under subantarctic surface waters have been studied in great detail by Burckle et al. (1978) and Burckle (1982). At the sites investigated here, this species shows its highest abundance (reaching maximum values of more than 15%) with three distinct abundance peaks in Hole 704B.

For the whole interval in which the H. karstenii peaks occur in this hole, oxygen isotopes indicate relatively warm surface-water temperatures (Hodell and Ciesielski, this volume) and calcareous-siliceous oozes document sedimentation below subantarctic to northern PFZ surface waters (Fig. 2). The preference of H. karstenii for relatively warm temperatures was previously stated by Burckle et al. (1978) and Burckle (1982), who found its maxima occurring within interglacials (isotope stages 7 to 11). In accordance with its preference for subantarctic surface waters, the relative abundance of this species is much less at the more southern Sites 699 and 701. Here, south of the PFZ, the characteristic abundance fluctuations described by Burckle et al. (1978) cannot be reproduced. Thus, the stratigraphic value of the Ouaternary acmes of this species seems to be restricted to the subantarctic and PFZ regions. But the reduced abundance at Sites 699 and 701 and the absence of the characteristic abundance fluctuations in the Brunhes described by Burckle (1982) could also be due to a hiatus, with sediments from most of the time interval from isotope stages 7 to 11 missing. However, this alternative interpretation seems improbable.

Additional intervals in which *H. karstenii* is found—although in low abundance—occur within the Olduvai and within



Figure 1. Location of the Leg 114 sites studied in the South Atlantic. Submarine topography after Couper (1983). Present position of the PFZ after Lutjeharms (1985) and Petersen and Whitworth (in press).



Figure 2. Percent abundance of *Hemidiscus karstenii* in Hole 704B plotted against the calcium carbonate content of the sediment (Westall and Fenner, this volume) and the oxygen isotope ratio determined from shells of *Neogloboquadrina pachyderma* (Hodell and Ciesielski, this volume).

the period from the Réunion magnetic Event to the top of the Gauss.

## Actinocyclus ingens f. planus

Actinocyclus ingens Rattray (1890) was a cosmopolitan species during the Miocene. In low latitudes it disappeared during the middle Miocene (e.g., Barron 1981, 1985b), while in the Northwest and Northeast Pacific region, as well as in California, the typical A. ingens persists longer. There, its LAAD falls in the late Miocene (e.g., Schrader, 1973; Koizumi and Kanaya, 1976; Koizumi, 1980; Akiba et al., 1982; Koizumi and Tanimura, 1985; Akiba, 1985). Higher up in the section in Pliocene to Brunhes sediments of the same regions only a form of A. *ingens* with flat valves is present. This form was named A. *ingens* f. *planus* by Whiting and Schrader (1985). The occurrence of this form cannot be considered as reworked. The same form of A. *ingens* probably occurs in upper Pliocene–Quaternary sediments in the circum-antarctic region ("Taxonomy" section). The LAD of A. *ingens* of 0.62 Ma determined by Ciesielski (1983) concerned this late Neogene form.

A. ingens f. planus is present at all three Leg 114 sites studied. In Hole 704B, it shows a downcore abundance pattern with three acme intervals within which its abundance exceeds 40% of the diatom assemblage (reaching values up to 80%). At the two sites farther south A. ingens f. planus is also common but never as dominant. Whereas three acmes can also be identified at Site 701, only one in the approximate stratigraphic position of acme A.i.2 can be recognized at Site 699. Other acmes cannot be identified at Site 699 because of coring gaps and because the time interval for which acme A.i.1 could be expected is represented by a hiatus. The onset and duration of these acmes is not synchronous at the three sites (see the "Quantitative Diatom Stratigraphy" section). For example, the end of the oldest of these acmes (A.i.3) at Site 704 is environmentally controlled. It is related to a drastic decrease in the calcium carbonate content of the sediment, meaning that there was a withdrawal of subantarctic surface waters to north of this site. Not all abundance fluctuations of this species can be related so clearly to paleoceanographic changes. More data have to be obtained in order to understand what controls the formation of such A. ingens f. planusdominated diatom assemblages.

## Thalassiosira elliptipora

*Thalassiosira elliptipora* is present at Site 704 only rarely or with just single, sporadic occurrences, whereas at Sites 699 and 701 it reaches relative abundances of more than 20%. This species is endemic to the Southern Ocean. The results of this study indicate that it was most common in northern antarctic surface waters and occurred less abundantly in subantarctic and northern Polar Front waters.

The very characteristic large valves of T. elliptipora, with elongated areolae, occur during the peak abundance of this species from below the Jaramillo magnetic Event into the basal part of the Brunhes. Above and below this interval, a variety of this species generally occurs in which only the areolae just above the margin are elongated. This variety was not included in the T. elliptipora counts presented here.

## Thalassiosira vulnifica

Thalassiosira vulnifica has never been reported from outside the Southern Ocean and therefore is considered endemic to that region. It shows high abundances in all three sites within the upper Gauss to lowermost Matuyama and then continues with low abundance into the Brunhes. Another slight increase in abundance of this species is noted from below to within the Jaramillo magnetic Event. This species shows no obvious preference for either antarctic or subantarctic surface waters. The longest stratigraphic occurrence of this species is found below the PFZ.

#### Simonseniella barboi

Simonseniella barboi is listed in most studies of North Pacific sediments (e.g., Koizumi, 1975; Harper, 1980; Barron, 1981) as ranging to the end of the Actinocyclus oculatus Zone (within the Jaramillo). Others, such as Koizumi and Tanimura (1985), report it as ranging into the Simonseniella curvirostris Zone (basal Bruhnes).

S. barboi seems to have a shorter stratigraphic range in Southern Ocean sediments, where it is not found in sediments younger than 1.5 m.y. Within the high southern latitudes, S. barboi is most abundant (reaching 50% of the diatom assemblage) at the northernmost Site 704, which was under predominantly subantarctic surface waters during the late Pliocene. High abundances of this species were also recorded in semiquantitative studies from other subantarctic sites, such as Deep Sea Drilling Project (DSDP) Sites 514 and 594 (Ciesielski, 1983, 1986). At Sites 699 and 701 under the PFZ to northern antarctic surface waters, however, this species occurs only sporadically throughout its supposed stratigraphic range. At all three of these sites the acme of S. barboi co-occurs with the first acme of Actinocyclus ingens f. planus, which prefers subantarctic surface waters. Within the Southern Ocean S. barboi accordingly seems to have had its main occurrence in subantarctic surface waters.

### Thalassiosira kolbei and Nitzschia weaveri

The endemic Southern Ocean species *Thalassiosira kolbei* and *Nitzschia weaveri* also preferred subantarctic surface waters. Both reach abundances close to 20% at Site 704 under subantarctic conditions. Under PFZ and northern antarctic surface waters, at Sites 699 and 701, these species are present within their stratigraphic range but in much reduced abundance.

#### Cosmiodiscus insignis

Cosmiodiscus insignis is known from upper Miocenelower Pliocene sediments in the North Pacific and Japan (e.g., Koizumi, 1975; Harper, 1980; Barron, 1985b). In the Southern Ocean this species occurs in the Gauss, strongly decreases in abundance in the uppermost Gauss (McCollum, 1975; Ciesielski, 1983; this study), and completely disappears in the early Matuyama (this study). During its acme C. insignis flourished in subantarctic as well as in antarctic surface waters.

These results show that the eight stratigraphic marker species investigated are not equally common in antarctic and subantarctic surface waters. Thalassiosira elliptipora shows a preference for Polar Front and antarctic surface waters, while Thalassiosira kolbei, Simonseniella barboi, Nitzschia weaveri, and Hemidiscus karstenii are especially abundant or predominantly present in sediments deposited under subantarctic surface waters. Actinocyclus ingens f. planus prefers subantarctic surface waters, but nevertheless is common also below antarctic surface waters. In addition, Thalassiosira vulnifica and Cosmiodiscus insignis are equally common in sediments deposited below northern antarctic and subantarctic surface waters. In spite of the differing ecological preferences and regional distribution patterns of these species, their downhole abundance fluctuations with the succession of acmes are the same at all three sites, independent of their location during the time of sediment deposition north, within, or south of the Polar Front.

## **Quantitative Diatom Stratigraphy**

The consistency of the sequence of acmes of the eight species at Sites 699, 701, and 704 allows use of the pattern for a rough correlation of the holes.

Immediately following the decline of Nitzschia weaveri the acme of Thalassiosira vulnifica starts in the late Gauss. Still within the Gauss magnetic Chron it overlaps with the acme of Cosmiodiscus insignis and in the lowermost Matuyama with that of Thalassiosira kolbei. At all three sites this later acme occurs between the top of the Gauss and the base of the Olduvai magnetic Event. It overlaps in its upper part with an acme of Actinocyclus ingens f. planus (A.i.3) and a more or less pronounced acme of Simonseniella barboi. The acmes of these latter two species, which both prefer warmer waters, have a similar stratigraphic extent. Both end within the Olduvai, with the retreat of subtropical surface waters toward the north. The acmes of both species are only poorly recognizable at Site 699 farther south. Between the top of the Olduvai and the base of the Jaramillo is another acme of A. ingens f. planus (A.i.2). This acme is recognizable at all three sites, but seems to been of different duration (Table 2). The acme of Thalassiosira elliptipora, with its characteristic double peak, starts below the Jaramillo but above acme A.i.2. The T. elliptipora acme continues to just within the Brunhes Chron. Within the lower Brunhes Chron above the T. elliptipora acme and well below the acme of Hemidiscus karstenii is another acme of A. ingens f. planus (A.i.1).





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Figure 4. Abundance fluctuations of the diatom species *Hemidiscus karstenii*, *Actinocyclus ingens* f. *planus*, *Thalassiosira elliptipora*, *Thalassiosira vulnifica*, *Simonseniella barboi*, *Thalassiosira kolbei*, and *Nitzschia weaveri* during the past 3.0 m.y. in Hole 701C. Paleomagnetic data from Clement and Hailwood (this volume).



Figure 5. Abundance fluctuations of the diatom species Hemidiscus karstenii, Actinocyclus ingens f. planus, Thalassiosira elliptipora, Thalassiosira vulnifica, Simonseniella barboi, Thalassiosira kolbei, and Nitzschia weaveri during the past 2.5 m.y. at Site 704. Paleomagnetic data from Hailwood and Clement (this volume).

Table 2. Ages for LADs, LAADs, and FAADs of the diatom species studied at Sites	699, 701,	and 704.
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		Hole		Ciesielski	McCollum	
Datum	699A	701C	704A/B	(1983)	(1975)	
LAAD T. elliptipora		0.70-0.72	0.72-0.75			
FAAD T. elliptipora	0.98-1.02	0.97-1.04	0.96-1.04			
Acme A. ingens f. planus (A.i.2) top	1.03-1.09	1.12 - 1.22	1.19			
(A.i.2) base	1.22-1.29	1.15-1.32	1.32-1.33			
Acme A. ingens f. planus (A.i.3) top	1.94-1.98?	1.75-1.89	1.77-1.86			
(A.i.3) base	1.96-2.00?	1.99-2.09	1.96-2.04			
LAD S. barboi	1.54-1.59	1.5-1.6	1.74-1.77	1.58		
LAAD S. barboi	1.7-1.80?	1.72-1.83?	1.77-1.84			
LAD T. kolbei		1.56-1.66	1.75-1.84	1.89	1.85	
LAD T. kolbei step 2	1.88-1.92	1.78-1.90	1.80-1.91	1	1	
step 1	1.99-2.03	1.92-1.99	1.97-2.09	<u>ا</u> ب	نے	
FAAD S. barboi	2.49-2.55?	2.02-2.10?	1.95-2.02			
FAAD T. kolbei	2.32 - 2.48	2.17 - 2.38	2.14-2.21			
LAAD T. vulnifica step 3	Coring gap	2.06-2.21	1.97-2.07			
step 2	2.36-2.43	2.29 - 2.44	2.16-2.24	2.22		
step 1	2.44-2.50	2.40-2.59	2.24-2.30 (as LAD)	8		
LAD C. insignis	2.0-2.03	1.94-1.98	2.16-2.22	2.49	2.5	
LAAD C. insignis	2.55-2.65	2.42 - 2.85		-	-	
FAAD T. vulnifica	2.69-2.74	2.41-2.84				
LAD N. weaveri	2.62 - 2.68	2.42 - 2.6	2.39-2.41	2.64		
LAAD N. weaveri	2.69-2.74	2.44-2.85				

Note: Ages are derived by plotting the results in Figures 3-5 on the age-depth plots (Figs. 6-8). ? = uncertain age determination because of scarcity of that species.

The ages of the LADs, LAADs, and FAADs presented here for these species were interpolated between datums provided by paleomagnetic polarity reversal boundaries as identified at the respective sites by Hailwood and Clement (this volume) and Clement and Hailwood (this volume). Between these datums constant sedimentation rates are assumed. The LAADs of *C. insignis* and *N. weaveri* helped to ensure correct identification of the Matuyama/Gauss boundary. The ages are given as age spans reflecting the accuracy possible with the available sample spacing for diatom analysis and paleomagnetic analysis. More variable sedimentation rates than these shown by the age-depth curves in Figures 6 through 8 are, of course, possible, but these were not considered in making the age determinations.

The resulting ages for the most prominent changes in diatom species abundances are given in Table 2. For the Brunhes no independent age determinations of diatom datums were made; those established by Ciesielski (1983) and Burckle (1982) were used for the age-depth plots (Figs. 6–8). For the FAAD of *H. karstenii* an age of 0.41 Ma is reinterpolated from the data of Burckle (1982) using the ages for oxygen isotope stages published by Imbrie et al. (1984).

In the late Matuyama (younger than approximately 2.0 Ma) drastic changes in diatom species abundances occurred at all three sites synchronously (Table 2)-within the accuracy possible with the existing sample spacing. This is valid for FAADs and LAADs equally. For the FAAD and LAAD of the endemic Southern Ocean species T. elliptipora the accuracy is ±40,000 yr. S. barboi also seems to disappear synchronously, but this species prefers subantarctic surface waters and is so rare at the two southern sites that it is difficult to pick its LAAD. Because of these ecological influences, the uncertainty concerning its age is larger than it appears in Table 2. The LAAD of T. kolbei occurs in two steps, each within an accuracy of  $\pm 70,000-90,000$  yr. At sites with low sedimentation rates the wider time span comprising both steps must be used for this datum. The acmes of A. ingens f. planus are all generally diachronous and thus do not provide useful stratigraphic datums. The greatly shortened interval of the *T. elliptipora* acme and the absence of the *A. ingens* f. *planus* acme A.i.1 at Site 699 can best be explained by a hiatus, with sediments from the uppermost Jaramillo to lowermost Brunhes missing. The ages for the LADs of *S. barboi* and *T. kolbei* vary greatly and do not provide good datums.

Within the early Matuyama (older than approximately 2.0 Ma) datums of three species are determined. The LAAD of *T. vulnifica* occurs at all sites in three steps. But the age of these steps at Sites 699 and 701 differs from that determined for Site 704. Such a discrepancy in the interpolated ages of the datum also exists for the FAAD of *T. kolbei*. All of the datums at the two southern sites seem to be on average 100,000 to 200,000 yr older than at Site 704, which was then below subantarctic surface waters. Whether the FAAD of *S. barboi* is also diachronous or occurred at the same time over the studied area cannot be decided because this species occurs only rarely and sporadically at the southern Sites 699 and 701. In addition, at Site 699 the critical time interval was not cored.

Within the uppermost Gauss, diatom ages could only be determined at Sites 699 and 701. The three late Gauss diatom FAADs and LAADs studied at Site 704 all occur at the same depth, which indicates the presence of a short hiatus. Therefore, these datums could not be used to test whether discrepancies exist in the ages of the diatom datums of the late Gauss at Site 704 and at Sites 699 and 701. For the LAAD of *C. insignis* the data at Site 699 suggest an age between 2.55 and 2.65 Ma, which falls within the uppermost Gauss magnetic Epoch. The results at Site 701 also agree with this age assignment, although the age cannot be interpolated with much accuracy because the sample spacing for both paleomagnetic and diatom analyses is relatively wide. The FAAD of *T. vulnifica* and the LAAD of *N. weaveri* (2.62–2.74 Ma) are coupled at the three studied sites.

#### DISCUSSION

If the LADs from previous investigations (Table 2) are interpreted as LAADs (except for the LAD of *Simonseniella* 



Figure 6. Age-depth curve for Hole 699A based on magnetostratigraphy after Hailwood and Clement (this volume) with plots of the resulting sedimentation rates and depth intervals of diatom datums. Diagonal boundaries in the "Magnetic polarity" column give the sample interval within which the magnetic reversal boundary lies. The wide depth interval for each of the paleomagnetic polarity reversals also results in an interval for the sedimentation rates between the reversals. The dashed line in the early Matuyama results from the application of datum ages determined for Site 704. Circled + = magnetic reversal boundaries; wavy line = inferred hiatus. Datums: 1 = LAAD Hemidiscus karstenii; 2 = FAAD H. karstenii; 3 = LAD Stylatractus universus; 4 = LAAD Actinocyclus ingens f. planus; 5 = LAD Pterocanium triloban; 6 = LAAD Thalassiosira elliptipora; 7 = FAAD T. elliptipora; 8 = top of A. ingens f. planus acme A.i.2; 9 = base of A. ingens f. planus acme A.i.2; 10 = LAAD Simonseniella barboi; 11 = top of A. ingens f. planus acme A.i.3; 12(1) = LAAD Thalassiosira kolbei, step 1; 12(2) = LAAD T. kolbei, step 2; 13 = FAAD S. barboi; 14 = base of A. ingens f. planus acme A.i.3; 15(1) = LAAD Thalassiosira vulnifica, step 1; 15(2) = LAAD T. vulnifica, step 2; 15(3) = LAAD T. vulnifica, step 3; 16 = FAAD T. kolbei; 17 = LAAD Cosmiodiscus insignis; 18 = FAAD T. vulnifica; 19 = LAAD Nitzschia weaveri. The two radiolarian datums LAD S. universus (0.425 Ma) and LAD P. triloban (0.7 Ma) are plotted according to J. D. Hays and H. Y. Ling (pers. comm., 1989).

*barboi*; Ciesielski, 1983), then these ages are close to those resulting from this study. The LAD of *Thalassiosira vulnifica* is not listed in Table 2, but at all three sites this species continues with low abundance into the Brunhes. As these occurrences are not bound to samples in which reworking occurs (marked by arrows at the right margin in Figs. 3 and 5) this species is considered to have existed throughout the Matuyama and the lower Brunhes just beyond the LAAD of *Thalassiosira elliptipora*.

The age discrepancies for the LAAD of *T. vulnifica* and FAAD of *Thalassiosira kolbei* within the early Matuyama can be explained either as reflecting diachronous datums or by

assuming that the ages interpolated at Site 704 or at Sites 699 and 701 are not correct.

There are considerable ecological differences between Site 704 and the other two sites studied during the period when the LAAD of *T. vulnifica* and FAAD of *T. kolbei* occurred, which would make diachronous datums plausible. Combined information from accumulation rates, calcium carbonate content of the sediment, abundance changes of diatoms, *Actiniscus* spp., resting spores of choanoflagellates, and the abundance of ice-rafted debris indicates that during the late Matuyama all three Leg 114 sites were affected by strong north-south fluctuations in the location of the PFZ (Westall and Fenner,



Figure 7. Age-depth curve for Hole 701C based on magnetostratigraphy after Clement and Hailwood (this volume) with plots of the resulting sedimentation rates and depth intervals of diatom datums. Diagonal boundaries in the "Magnetic polarity" column give the sample interval within which the magnetic reversal boundary lies. The wide depth interval for each of the paleomagnetic polarity reversals also results in an interval for the sedimentation rates between the reversals. The dashed line in the early Matuyama results from the application of datum ages determined for Site 704. Circled + = magnetic reversal boundaries; wavy line = inferred hiatus. Datum codes same as for Figure 6.

this volume). But before 2.0 Ma the situation was different. For that period high calcium carbonate values at Site 704 (Froelich et al., this volume) indicate that this site was located predominantly below subantarctic surface waters. Relatively stable conditions seem to have prevailed over Sites 699 and 701 also, but there were antarctic surface waters at these latter sites. Thus, the diachroneity of the LAAD of T. vulnifica could be caused by differences in the survival of this species south of and north of the PFZ. In this case the acme of T. kolbei—although this species seems to have preferred subantarctic surface waters.

The second possibility (i.e., that the age at Site 704 has to be younger than at the other two sites) was tested by plotting the older datum ages determined for Sites 699 and 701 with the age-depth curve of Site 704 (Fig. 8). The result is that the older age range determined for these datums at Sites 699 and 701 can be accommodated within the framework set by the magnetic reversal boundaries at Site 704 by just changing the sedimentation rates. Extremely high sedimentation rates would be required for a part of the profile for which the CaCO<sub>3</sub> values indicate deposition below northern PFZ or subantarctic surface waters. Thus, it is possible that the ages derived by interpolation at Site 704 are not realistic.

As a third possibility, the validity at Sites 699 and 701 of the younger ages of the LAAD of *T. vulnifica* and the FAAD of *T.* 

*kolbei* derived at Site 704 was also tested (Figs. 6 and 7). The age-depth plots show that these younger ages cannot be accommodated by merely changing the sedimentation rates within the framework of paleomagnetic datums. Only the presence of a hiatus in the earliest Matuyama at these sites would accommodate the younger ages.

The physical properties of bulk density and porosity do not provide support for such a hiatus (D. Nobes, pers. comm., 1989). For the Site 701 diatom data, the occurrence of the LAADs of *Cosmiodiscus insignis*, *Nitzschia weaveri*, and *Nitzschia interfrigidaria* and the FAAD of *T. vulnifica* all within the narrow core interval between 67.9 and 72.8 m below seafloor (mbsf) suggests lower sedimentation rates or a hiatus in the upper Gauss.

Two possibilities remain that might resolve the discrepancies in the interpolated ages of the FAAD of *T. kolbei* and LAAD of *T. vulnifica*: either a diachroneity of the datums or the possibility that the ages determined at Sites 699 and 701 are valid for the northern antarctic as well as for the subantarctic region. However, neither of these possibilities can be fully proven or disproven. To resolve this question further equally detailed studies are necessary.

#### SUMMARY

1. The ages determined for the diatom datums show that LAADs and FAADs are better suited as stratigraphic tools



Figure 8. Age-depth curve for Holes 704A and 704B based on magnetostratigraphy after Hailwood and Clement (this volume) with plots of the resulting sedimentation rates and depth intervals of diatom datums. The sample spacing for the determination of magnetic polarity is very dense at this site. The dashed line in the early Matuyama results from the application of datum ages determined for Sites 699 and 701. Circled + = magnetic reversal boundary; wavy line = inferred hiatus. Datum codes same as for Figure 6.

than LADs and FADs. Because of the sporadic occurrence of a species toward the end of its stratigraphic range the LAD results are too variable. If interpreted as LAADs, the LAD ages determined by earlier investigators largely agree with the age intervals obtained in this study.

Two possibilities remain concerning the ages of the early Matuyama diatom datums. Either the ages determined at Site 699 are more reliable and the ages determined at Site 704 are incorrect, or diachroneities in the datum ages exist between the antarctic and the subantarctic region.

2. Ecological influences on the stratigraphic utility of the studied species are obvious in the case of the species that prefer subantarctic surface waters, such as *Hemidiscus* 

*karstenii* and *Simonseniella barboi*, which do not provide accurate datums south of the PFZ. The acmes of *Actinocyclus ingens* f. *planus* also seem to be significantly ecologically controlled.

3. For the other species ecological preferences are determined based on the paleogeographical abundance patterns of these species. *Thalassiosira elliptipora* prefers northern antarctic and PFZ surface waters. *Nitzschia weaveri*, like *Thalassiosira kolbei*, preferred subantarctic surface waters. *Cosmiodiscus insignis* and *Thalassiosira vulnifica* are common in both regions. After its decrease in abundance in the early Matuyama T. vulnifica persisted, although with low abundances, into the Brunhes magnetic Chron. 4. Based on the detailed quantitative diatom stratigraphy the Réunion magnetic Event in ODP Holes 701C and 704A was identified. Further, this stratigraphy suggests that the magnetic reversal in Hole 699A between 10.44 and 10.74 mbsf represents the base of the Jaramillo magnetic Event.

In Hole 699A a short hiatus is present, with sediments of the lowermost Brunhes and uppermost Matuyama missing. A short hiatus is present in Hole 704A in the uppermost Gauss magnetic Chron. A similar hiatus may be present in Hole 701C.

## TAXONOMY

In the following, references to the original and some later supplemental descriptions and illustrations of the species treated in this study are given. Additional remarks are provided where necessary. The species are listed in alphabetical order.

Actinocyclus ingens f. planus Whiting and Schrader (1985) (Pl. 2, Figs. 1, 2)

**Description.** Whiting and Schrader (1985), p. 74, pl. 3, fig. 12. **Remarks.** This form of *Actinocyclus ingens* occurs commonly in upper Pliocene–Pleistocene sediments of the Southern Ocean. Its valves are flat, and the pseudocellus was never clearly identified.

Cosmiodiscus insignis Jousé (1961)

Description. Jousé (1961), p. 67, pl. 2, fig. 8; McCollum (1975), p. 527, pl. 8, fig. 5.

Hemidiscus karstenii Jousé in Jousé et al. (1963) (Pl. 1, Fig. 2)

**Description.** Jousé et al. (1963), p. 78, pl. 2, figs. 7–9; Jousé (1965), p. 6, pl. 1, figs. 6, 7.

Nitzschia weaveri Ciesielski (1983) (Pl. 3, Fig. 4)

Description. Ciesielski (1983), p. 655, pl. 1, figs. 1-10.

Genus Simonseniella gen. nov.

**Description.** Species of this genus are characterized by strongly elongated valves, which terminate in a structureless flat area surrounded by a ring of spines, below which a field of fine pores is present on each side of the valve. At the top of this pore field on one side of the valve, a round to oval opening is present, which might represent the external opening of a labiate process.

Besides the type species, *Simonseniella praebarboi* (Schrader) comb. nov. and *Simonseniella curvirostris* (Jousé) comb. nov. also belong to this genus.

Simonseniella praebarboi (Schrader) comb. now.

Basionym. Rhizosolenia praebarboi Schrader (1973), p. 709, pl. 24, figs. 1–3.

#### Simonseniella curvirostris (Jousé) comb. nov.

Basionym. Rhizosolenia curvirostris (Jousé) (1968), p. 19, pl. 3, fig. 2 Description. Illustrations of these species made with the scanning electron microscope (SEM) are in Sancetta (1984) and Akiba and Yanagisawa (1985). The *Rhizosolenia alata* species group is closely related to this genus. The valves of these species also terminate in a structureless area surrounded by a ring of spines (Hasle, 1975), but the slitlike opening present on one side below this ring of spines is not connected with the presence of a pore field.

Type species. Simonseniella barboi (Brun) comb. nov.

This genus is dedicated to Dr. R. Simonsen, whose friendly and helpful support is gratefully remembered.

Simonseniella barboi (Brun) comb. nov. (Pl. 3, Figs. 1, 3)

Basionym. Pyxilla (Rhizosolenia?) barboi Brun (1894), p. 87, pl. 5, figs. 16, 17, and 23.

Synonyms. Rhizosolenia barboi (Brun) Tempère and Peragallo (1908) p. 26, no. 47; Rhizosolenia curvirostris var. inermis Jousé (1971), p. 15, pl. 2, figs. 1, 2.

**Description.** The very long and slender, tubelike valves of this species are more or less curved in their upper part. The valve outline is oval in cross section. The top of the valve is formed by a structureless oval area, which is surrounded by a ring of spines. The spines at each end of the oval area are stronger and longer than the other spines. On each flank of the valve just below the ring of spines is a field of fine pores. The round opening present in the upper part of one of these pore fields may represent the external opening of a labiate process. Along the edge of the valve, starting below the enlarged spines, a few rows of fine pores run along the length of the valve.

Toward the end of its stratigraphic range in the antarctic realm the valves of this species become narrower. Within its peak occurrence hyaline flanges are present in the upper part of the valves along the edges below the longer spines.

> Thalassiosira elliptipora (Donahue) comb. nov. (Pl. 1, Fig. 3; Pl. 3, Fig. 2)

Basionym. Coscinodiscus elliptipora Donahue (1970), p. 201, pl. 4, figs. e, i-m.

Description. Ciesielski (1986), p. 875, pl. 1, fig. 6.

Remarks. Because of the presence of strutted tubuli scattered over the valve face this species was transferred to the genus *Thalassiosira*.

Thalassiosira kolbei (Jousé) Gersonde (in press; J. Barron, pers.

comm., 1989) (Pl. 1, Figs. 1, 4; Pl. 2, Figs. 3, 4)

Basionym. Coscinodiscus kolbei Jousé (1965), p. 4, pl. 1, fig. 3.

Synonym. Coscinodiscus (cf.) kolbei Jousé sensu Donahue (1970), p. 202, pl. 5.

**Description.** The valves are circular in outline. The valve face is flat to moderately convex and perforated by large areolae (approximately 3-5 in 10  $\mu$ m). In the more or less flat valves these are arranged in linear rows. In the convex valves the rows of areolae form a fasciculate, "eccentrica-type" pattern. Between the areolae "pores" are visible with the light microscope. SEM observations show that they are strutted tubuli. Around the margin a ring of strutted tubuli is present. There are two marginal labiate processes. In the convex valves a ring of occluded processes is usually observed (e.g., Pl. 1, Fig. 1). Because of the types and arrangement of processes present and because the areolae have an internal cribrum, this species is included in the genus *Thalassiosira*.

Thalassiosira vulnifica (Gombos) comb. nov. (Pl. 2, Fig. 2)

Basionym. Coscinodiscus vulnificus Gombos (1976), p. 593, pl. 4, figs. 1-3; pl. 42, fig. 112.

Remarks. Because of the presence of strutted tubuli scattered over the valve face this species was transferred to the genus *Thalassiosira*.

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APPENDIX Diatom Ahu	ndance and Abundance of the Stuc	lied Species with the Diatom	Assemblages from Ha	ales 600A 701	C 704A	and 704B.
ALL LINDIA. DIGIOIN ADU	nuance and Abanaance of the Stud	neu species with the Diatom	Assemblinges from He		0, 10 111,	

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
114-699A-										
1H-1, 2	0.02	7.80	0.00							
1H-1, 25–27	0.25	8.36	0.15							
1H-1, 124–126	1.24	8.27	0.30							
1H-2, 28-30	1.78	7.97	0.00							
1H-2, 60-61	2.10	8.15								
1H-2, 75–77	2.25	8.07								
1H-2, 106–107	2.56	8.20								
1H-3, 36-37	3.36	7.50								
1H-3, 72-74	3.72	7.93		0.00	0.00					
1H-3, 73	3.73	7.50		4.20	0.25					
1H-3, 124–126	4.24	7.96	0.00	0.00	0.00					
1H-4, 9–10	4.50	7.97	0.30							
1H-4, 24-26	4.74	7.99	2.00							
1H-4, 75–76	5.25	8.20	0.20	0.00						
1H-4, 126–128	5.76	8.23	0.00	0.40						
1H-5, 55-56	6.55	8.20	0.00	0.00						
1H-5, 66	6.66	7.90	0100	0.00						
1H-5, 75-77	6.75	7.82		0.05						
1H-5, 104–106	7.04	8.00		0.00						
1H-5, 135-137	7.31	8.21		0.30						
1H-6, 6-7	7.55	7.79		0.00						
1H-6, 35-37	7.85	8.29		1.70	0.00					
1H-6, 75-76	8.35	8.00		0.30	0.30					
2H-1, 74-75	9.34	8.20		0.00	0.00	0.00				
2H-2, 15,5	10.25	7.60		2.40	4.20	0.60				
2H-2, 15-16	10.25	7.67		4.10	8.50	1.50				
2H-2, 35-37	10.45	7.67		5.80	21.60	1.70				
2H-2, 85-8/ 2H-2, 142	10.95	7.38		2.90	0.00	0.70				
2H-2, 142.5	11.33	7.20		7.70	0.70	1.30				
2H-2, 144	11.54	7.50		0.00	0.00	0.00				
2H-2, 145	11.55	7.30		13.60	0.20	0.60				
2H-2, 145-146 2H-2, 147	11.56	7.50		9.30	0.80	0.60				
2H-3, 34-36	11.94	7.48		30.10	1.40	4.90				
2H-3, 94-95	12.54	7.70		26.90	0.00	1.30				
2H-3, 127	12.87	7.60		39.80		1.00				
2H-3, 130-130 2H-4, 5-6	13.16	7.28		1.10		0.40				
2H-4, 42-44	13.52	8.00	0.00	74.30		2.50				
2H-4, 85	13.95	7.80	0.20	61.70	0.00	0.40				0.00
2H-4, 105-106	14.15	7.70	0.00	40.00	0.30	0.30				0.30
2H-4, 127 2H-4, 136–138	14.37	7.12		16.90	0.30	0.70				0.00
2H-5, 15-17	14.75	7.53		20.30	0.60	0.00				0.00
2H-CC	18.10	7.45		1.20	0.00	1.20	0.00			8.00
3H-1, 16–17	18.26	7.57	0.00	40.40	0.40	1.80	0.00			0.00
3H-1, 59-61	18.69	7.40	0.30	18.40	0.30	0.60	0.00			0.25
3H-1, 106-107	19.16	7.60	0.00	22.50	0.00	0.40	10100			0.00
3H-1, 144-146	19.54	7.03		4.80	1.00	0.50				
3H-2, 11–12 3H-2, 45, 47	19.71	7.72	0.00	12.40	0.00	0.00	0.00			
3H-2, 45-47 3H-2, 85-87	20.05	7.6/	0.00	16.00	0.40	3.50	0.50			
3H-2, 130-131	20.90	7.30	0.00	24.40	0.30	0.60	0.00			
3H-3, 18-19	21.28	7.40	0.00	18.40	0.00	0.30		0.00		
3H-3, 28	21.38	7.82	0.30	0.00	0.00	0.00	0.00	0.00		
3H-3, 33-37 3H-3, 104-106	21.55	7.51	0.00	6.00	0.50	1.30	0.00	1.90		
3H-3, 124-125	22.35	7.69		44.70	0.00	1.80	0.230.000	0.30		
3H-4, 15-17	22.75	7.51		0.00	0.20	3.00	0.00	0.60		
3H-4, 29-30	22.90	7.44		0.40	0.90	1.40	0.40	1.30		0.00
3H-4, 54 3H-4, 62-64	23.14	7.90		0.00	0.40	1.20	0.00	4.60		0.30
3H-4, 126-127	23.86	7.50		3.40	0.00	0.60	0.00	1.20		0.30
3H-CC			0.00	0.00		0.70	0.00	2.00		0.00
4H-1, 62	28.22	6.90	0.30	2.40		2.20	0.60	1.30		0.30

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
4H-1, 108-109	28.68	7.40	0.60	0.60		8.20	0.40	0.90		0.30
4H-1, 138-139	28.98	7.41	0.00	2.50		5.00	0.10	0.60		0.00
4H-2, 6–7	29.16	6.80	0.30	0.30		5.80	0.00	0.30		0.30
4H-2, 80 4H-2, 80	29.71	6.47	0.60	0.00		14.60	0.30	0.60		0.30
4H-2, 109-111	30.19	7.16	0.00			9.10	0.00	0.30		0.30
4H-2, 122-123	30.32	7.57	0002727			8.70		0.00		0.30
4H-2, 143	30.53	6.80	0.00			9.10		0.90		0.00
4H-3, 25-24 4H-3, 59	31.19	7.06	0.00			18.90		1.20		6.70
4H-3, 60-62	31.20	7.39				9.30		0.60	0.00	7.60
4H-3, 109-110	31.70	7.02		0.00		9.30		1.70	0.35	16.60
4H-3, 114-116 4H-4 9-10	31.74	6.85 7.40		0.00		8.80		5.30	4.50	18.50
4H-4, 49-51	32.59	6.78		0.00		1.00		0.00	8.20	23.70
4H-4, 51	32.61	6.99				0.70		0.70	5.43	13.80
4H-4, 81-82	32.91	6.43	0.00			1.60		0.60	6.84	24.10
4H-4, 88-90 4H-5, 12-13	33.72	6.93	0.30			2.80		0.70	4.44	13.80
4H-5, 59-61	34.19	7.50	0.00			1.40		0.00	2.40	11.00
4H-5, 109-111	34.69	7.45		1727-12164		0.40		0.40	2.09	1.25
4H-5, 127–128	34.87	7.53		0.00		0.90		0.90	1.90	2.84
4H-6, 18–19	35.28	7.50		0.40		1.60		1.20	3.30	2.10
5H-1, 46-47	37.56	7.50		0.00		0.30		0.60	1.20	2.70
5H-1, 84	37.94	7.28		0.90		1.20		0.30	1.20	0.00
5H-1, 140-141 5H-1, 147-148	38.51	7.55		0.40		1.10		0.40	5.30	0.00
5H-2, 75-76	39.35	7.38	0.00	0.30		0.30		0.30	0.60	0.00
5H-2, 102-104	39.62	7.67	0.30	0.00		0.60		0.30	0.00	
5H-2, 130-131	39.90	7.97	0.00	0.00		0.00		0.40	0.20	
5H-3, 26-27 5H-3, 74-76	40.36	8.00	0.00	0.60				0.30	0.00	
5H-3, 77	40.87	8.15	0.00	1.00				0.30		
5H-3, 130-131	41.40	7.85		0.20				0.70		
5H-4, 26-27	41.86	7.92		2.80			0.20	0.00		
5H-4, 130-131 5H-5, 50-51	42.90	7.90		0.40			0.20	0.00		
5H-5, 104-105	44.15	7.81		0.00			0.00	0.30		
6H-1, 34-35	46.94	7.50		0.70			0.30	0.30		
114-701C-										
1H-1, 2-3	0.02	8.05								
1H-1, 15-16	0.15	7.89								
1H-1, 43-46 1H-1, 60-62	0.45	8.00								
1H-1, 75-76	0.75	8.06								
1H-1, 90-91	0.90	7.90								
1H-1, 105–106 1H-1, 120–121	1.05	8.14		0.00						
1H-1, 120-121 1H-1, 135-136	1.35	7.93		0.30						
1H-2, 2-3	1.52	8.04		0.00						
1H-2, 15-16	1.65	7.93								
1H-2, 45-46	1.80	7.97								
1H-2, 60-61	2.10	8.07		0.00						
1H-2, 75-76	2.25	8.14		0.20						
1H-2, 90-91 1H-2, 105, 106	2.40	8.24		0.00						
1H-2, 100–100 1H-2, 120–121	2.70	8.20								
1H-2, 135-137	2.85	8.14								
1H-3, 2-3	3.02	8.14								
1H-3, 30-31	3.15	8.08								
1H-3, 45-46	3.45	7.85								
1H-3, 60-61	3.60	7.81								
1H-3, 75-76	3.75	7.86								
1H-3, 105-106	4.05	8.08								
1H-3, 120-121	4.20	8.09								
1H-3, 135-136	4.35	8.13								
1H-4, 2-3 1H-4, 15-16	4.52	8.13	0.00							
1H-4, 30-31	4.80	8.25	0.05							
1H-4, 45-46	4.95	7.94	0.00							

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# J. M. FENNER

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
1H-4, 60-61	5.10	8.03								
1H-4, 75–76	5.25	8.25								
1H-4, 90-91 1H-4, 105-106	5.40	8.20	0.00							
IH-4, 116	5.66		0.40							
1H-4, 120-121	5.70	8.14	0.00							
1H-4, 135-137 1H-5, 2-3	5.85	8.22								
1H-5, 15-16	6.15	8.16								
1H-5, 30-31	6.30	8.35								
1H-5, 45-46 1H-5, 60-61	6.45	8.18								
1H-5, 75-76	6.75	8.28								
1H-5, 90-91	6.90	8.26								
1H-5, 105-106 1H-5, 120-121	7.05	8.21								
1H-5, 135–136	7.35	8.38								
1H-6, 2–3	7.52	8.45								
1H-6, 15–16	7.65	8.43								
1H-6, 45-46	7.95	8.47								
1H-6, 60-61	8.10	8.18		0.00						
1H-6, 75-76	8.25	7.50		0.30						
1H-6, 105–106	8.55	8.20		0.00						
1H-6, 120-121	8.70	8.35								
1H-6, 135–136	8.85	8.42		0.00		0.00			0.00	
1H-7, 15–16	9.15	8.53		0.15		0.60			0.60	
1H-7, 30-31	9.30	8.35		0.00		0.00			0.00	0.00
1H-7, 45-46 1H-CC	9.45	8.11								0.00
2H-3, 110-112	10.40	8.14								0.00
2H-3, 135-137	10.65	8.13	0.00							
2H-4, 10-12 2H-4, 35-37	11.15	8.55	0.00	0.00						
2H-5, 15-17	12.45	8.71	0.00	0.07						
2H-5, 40-42	12.70	7.92		0.00						
2H-5, 89-91	12.95	8.39		0.12						
2H-5, 114-116	13.44	8.27		0.00						
2H-5, 140-142 2H-6, 15-17	13.70	8.45		0.00						
2H-6, 40-42	14.20	8.30		0.00	0.00					
2H-6, 69-71	14.49	8.03		1.05	0.35					
2H-6, 95-97 2H-CC	14.75	8.50		1.30	0.00					
3H-1, 0-2	15.82	8.41		1.10	0.00					
3H-1, 25-27	16.05	8.62		0.63	0.30					
3H-1, 50-52 3H-1, 75-77	16.30	8.52		1.85	0.00					
3H-1, 100-102	16.80	7.56		0.37	0.30					
3H-1, 125-127	17.05	7.55		2.60	1.30					
3H-2, 0-2 3H-2, 25-27	17.55	7.73		14.60	0.40					
3H-2, 50-52	17.80	8.27		3.40	0.30					12012-111
3H-2, 75-77	18.05	8.23		9.00	0.00			0.00		0.00
3H-2, 100-102	18.20	8.42		2.84	0.10			0.10		0.50
3H-2, 125-127	18.55	8.19		4.90	0.00			0.00		0.00
3H-2, 147–149 3H-3 0–2	18.77	8.56		2.90						
3H-3, 25–27	19.05	8.52		3.90	0.00					
3H-3, 50-52	19.30	8.76		2.50	0.70			0.00		
3H-3, 75-77 3H-3, 100-102	19.55	8.64		5.00	0.30			0.00		
3H-3, 125–127	20.05	7.74		5.50	0.30			0.00		
3H-4, 0-2	20.30	8.34		5.27	0.00			0.02		
3H-4, 25-27 3H-4, 50-52	20.55	7.95		10.20	0.00			0.00		
3H-4, 75-77	21.05	7.68		7.55	0.40					
3H-4, 99.5	21.29	7.83		0.00	1.40					
3H-4, 125-127	21.55	8.08		4.15	1.03					
3H-4, 147-149	21.77	8.34		8.20	1.50					

# LATE PLIOCENE-QUATERNARY DIATOM STRATIGRAPHY

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
3H-5 0-2	21.80	8 49		8 30	0.80			0.00		
3H-5, 25-27	22.05	8.58		10.20	0.90			0.10		
3H-5, 50-52	22.30	8.47		10.20	2.00			0.00		
3H-5, 75-77	22.55	7.56		9.40	9.90					
3H-5, 98-100 3H-5, 125-127	22.78	7.74		6.50	9.40	0.00				
3H-5, 147-149	23.27	7.80		18.50	10.80	0.40				
3H-6, 0-2	23.30	7.78		16.10	5.90	0.00				
3H-6, 25-27	23.55	7.84		11.60	15.10	1.30				
3H-6, 68	23.80	6.20		0.00	19.00	0.00				
3H-6, 75-77	24.05	8.14		9.20	11.20	0.80				
3H-6, 100-102	24.30	7.83		14.10	14.40	1.80				
3H-6, 125-127 3H-6, 147-149	24.55	8.08		16.90	7.50	2.00				
3H-7, 0–2	24.80	8.29		7.10	4.80	0.70				
3H-7, 25-27	25.05	7.92		12.90	10.70	0.74				
3H-CC 4H-1 10-12	25.30	8.28		7.70	32.30	1.30				
4H-1, 35-37	25.65	7.34		2.55	0.00	0.00				
4H-1, 60-62	25.90	7.78		8.00	0.25					
4H-1, 85-87	26.15	8.16		3.05	0.55					
4H-1, 110–112 4H-1, 135–137	26.40	8.61		3.30	0.00					
4H-2, 85-87	27.65	8.36		6.70	2.30					
4H-2, 135-137	28.15	7.12		13.65	4.40	0.00				
4H-3, 10-12	28.40	7.72		5.62	8.25	0.40				
4H-3, 55-37 4H-3, 60-62	28.65	7.90		8.84	33.20	0.30				
4H-3, 85-87	29.15	7.42		5.10	20.40	0.00				
4H-3, 110-112	29.40	7.70		10.10	8.10	2.70				
4H-3, 135–137	29.65	7.10		2.45	7.35	1.40				
4H-4, 10-12 4H-4, 35-37	29.90	7.40		7.82	3.15	5.55				
4H-4, 60-62	30.40	7.40		1.28	5.77	1.90				
4H-4, 86-87	30.66	7.91		4.30	7.20	0.00				
4H-5, 10-12	31.40	7.55		14.85	2.70	5.40				
4H-5, 60-62	31.90	7.92		6.20	0.45	11.00				
4H-5, 85-87	32.15	7.93		5.77	4.50	0.00				
4H-6, 10-12	32.90	7.85		25.00	0.00	4.50				
4H-6, 23.5 4H-6, 35-37	33.10	7.68		20.00	0.25	2.10				
4H-CC	35.70	7.46		8.60	3.40	0.75				
5H-4, 60-62	39.90	7.37		12.45	0.00	1.70				
5H-4, 85-87	40.15	7.64		18.10		0.82	0.00			
5H-4, 139–141	40.40	7.05		9.15		0.30	0.30			
5H-5, 9-11	40.89	7.66		19.80		1.44	0.00			
5H-5, 35-37	41.15	7.69		26.10		0.30		0.00		
5H-5, 60-62 5H-5, 85-87	41.40	7.68		20.50		2.75		0.00		
5H-5, 110-112	41.90	7.67		26.60		0.76		0.00		
5H-5, 135-137	42.15	7.75		30.35		2.55				
5H-6, 9–11	42.39	7.82		30.45		0.85				
5H-6, 60-62	42.03	7.43		21.20		2.10				
5H-6, 85-87	43.15	7.61		14.60		0.85				
5H-6, 110-112	43.40	7.66		21.90		3.77				
5H-6, 135-137 5H-CC	43.65	7.73	0.00	25.95	0.00	0.60	0.00	0.00		
6H-1, 85-87	45.15	7.79	0.00	22.85	0.00	2.22	0.60	0.30		
6H-1, 110-112	45.40	7.87		22.40		3.10	0.00	0.00		
6H-1, 135-137	45.65	7.72	0.00	27.70		1.56	0.40			
6H-2, 35-37	45.90	7.75	0.00	32.15		1.50	0.75	0.00		
6H-2, 60-62	46.40	7.47	0.00	48.60		0.00	0.30	0.30		
6H-2, 85-87	46.65	7.55	0.00	45.60		0.57	0.00	0.30		
6H-2, 110-112 6H-2, 135, 137	46.90	7.88	0.15	25.95		1.02	0.00	0.15		
6H-3, 10–12	47.40	7.65	0.00	26.05		1.70	0.24	0.20		
6H-3, 60-62	47.90	7.78		37.38		0.70	0.23	0.23		
6H-3, 85-87	48.15	7.66		46.42		0.85	0.00	0.30		
6H-3, 135–137	48.40	7.00		26.50		3.77	0.25	0.00		

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
6H-4, 60-62	49.40	7.98		29.45		0.85	0.14	0.43		
6H-4, 85-87	49.65	7.70		31.15		1.45	0.00	0.72	0.00	0.00
6H-4, 110-112 6H-4, 135-137	49.90	7.71		37.01		0.97	0.78	0.90	0.00	0.22
6H-5, 10-12	50.40	7.83		27.35		0.91	0.46	1.05	0.00	0.00
6H-5, 35-37	50.65	7.91		29.97		1.66	0.90	3.30		
6H-5, 60-62	50.90	7.78		42.61		1.56	1.56	2.10		0.00
6H-5, 85-87	51.15	7.69		21.10		3.10	0.35	0.87		0.15
6H-5, 110-112	51.40	7.67		12.00		2.75	1.57	1.57		0.00
6H-5, 135–137	51.65	8.05		15.95		1.15	0.58	2.88		0.20
6H-6, 10-12 6H 6 35 37	52.15	7.83		21.84		2.93	1.73	2.13		0.00
6H-6 85-87	52.15	7.51		39.00		1 23	0.25	5.70		
6H-CC	53.80	7.51		16.88		1.00	1.00	0.00		
7H-2, 8-9	55.38	7.86		3.80		2.20	0.30	2.70		
7H-4, 8-9	58.38	7.96		6.80		3.55	0.00	0.90		0.00
7H-4, 100-102	59.30	7.92	671676.V	1.43		0.70	0.24	2.15		0.20
7H-CC	63.30	7.56	0.00	14.85		0.00	0.00	0.50		0.50
8H-2, 10-11	64.90	7.74	0.85	0.00		7.05		0.43		0.00
8H-4 10-11	67.90	8 15	0.00			11.00		0.00	0.00	0.95
8H-CC	72.80	7.16				2.65		0.65	7.30	7.60
9H-1, 120-121	74.00	7.48				1.82		0.45	0.45	3.80
9H-2, 80-81	75.10	7.98				1.44		0.85	3.16	3.73
9H-4, 80-81	78.10	7.85	0.00			0.90		0.00	4.90	0.00
9H-4, 100–102	78.30	7.17	0.35			0.70		0.00	3.13	1.40
9H-CC	82.30	7.56	0.00			1.05		0.50	1.05	2.00
114B-704B-										
1H-1, 10–12	0.10	6.70	0.00							
1H-1, 50-52	0.50	7.80	0.00							
1H-1, 90-92 1H-1, 130-132	1.30	7.40	0.10							
1H-2, 10-12	1.60	8.10	0.00							
1H-2, 50-52	2.00	7.30	0.00							
1H-2, 90-92	2.40	7.80	0.30							
1H-2, 100-102	2.50	7.80	0.40							
1H-2, 130–132	2.80	8.10	0.00							
1H-3, 50-52	3.50	8.00	3.20	0.00				0.00		
1H-3, 90-92 1H-3, 130-132	4 30	7.90	1.00	0.00				0.10		
1H-4, 10–12	4.60	7.70	1.90	0.00				0.00		
1H-4, 50-52	5.00	7.50	15.90	0.10						
1H-4, 90-92	5.40	7.50	0.00	0.30						
1H-4, 100–102	5.60	8.45	0.00	0.00						
IH-4, 130–132	5.80	7.80	0.70							
1H-5, 10-12 1H-5, 50-52	6.50	6.30	6 70							
1H-CC	6.70	6.80	1.50							
2H-1, 10-12	6.80	6.30	3.25	0.00						
2H-1, 50-52	7.20	7.90	0.00	0.20						
2H-1, 90-92	7.60	6.60	0.90	0.00	0.00					
2H-1, 130-132 2H 2, 10, 12	8.00	7.20	0.00	0.10	0.00					
2H-2, 10-12 2H-2, 50-52	8.70	8.25	0.00	0.20	0.05					
2H-2, 90-92	9.10	8.10	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0.00	0.00					
2H-2, 130-132	9.50	8.20								
2H-3, 10-12	9.80	8.30		0.00						
2H-3, 50-52	10.20	8.00		0.20						
2H-3, 90-92	10.60	8.10		0.60						
2H-3, 130-132 2H-4, 90-92	12 10	7.75		0.50						
2H-4, 130-132	12.50	7.70		1.00						
2H-5, 10-12	12.80	8.30		0.05						
2H-5, 50-52	13.20	7.60		1.20	0.00		0.00	0.00		
2H-5, 90-92	13.60	8.30		12.50	0.05	0.00	0.05	0.05		
2H-5, 130-132	14.00	8.25		8.00	0.00	0.00	0.00	0.00		
2H-0, 10-12 2H-CC	14.30	6.60		16 30	0.03	0.20		0.60		
3H-1, 10-12	16.30	7.70		54.40	0.00	1.10		0.00		
3H-1, 50-52	16.70	7.30		58.00		0.80		0.20		
3H-1, 90-92	17.10	7.00		70.30		1.10	0.00	0.00		
3H-1, 130-132	17.50	7.20		73.80		0.50	0.05	0.05		
3H-2, 50-52	18.20	7.30		10.20		0.00	0.00	0.00		
311-2, 90-92	18.60	1.50		5.29		0.00				

# LATE PLIOCENE-QUATERNARY DIATOM STRATIGRAPHY

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%
3H-2, 130-132	19.00	7.40		7.80		0.00				
3H-3, 10-12	19.30	7.50		6.83		0.20				
3H-3, 50-52	19.70	7.55		8.60		1.10				
3H-3, 90-92 3H-3, 130-132	20.10	7.40		36.08		0.00				
3H-4, 10-12	20.30	7.40		32.30		0.30				
3H-4, 50-52	21.20	7.30		50.53		0.70				
3H-4, 90-92	21.60	7.30		66.25		0.05				
3H-4, 130-132	22.00	7.30		64.80		0.00				
3H-5, 10-12	22.30	7.80		41.81		0.70				
3H-5, 90-92	22.70	7.00		50.55		0.50				
3H-5, 130-132	23.50	7.20		38.60		0.00				
3H-6, 10-12	23.80	7.45		10.33	0.00	0.00				
3H-6, 50-52	24.20	7.55		35.20	0.50	0.20				
3H-6, 90-92	24.60	7.70		9.32	0.00	0.00				
3H-0, 130-132 3H-7 10-12	25.00	7.50		18.10		0.00				
3H-7, 50-52	25.70	7.80		11.57		0.60				
3H-CC	25.75	7.70		23.30		0.00				
4H-1, 100-102	26.70	7.50		20.82	5350	12 - 925				
4H-1, 103–104	26.74	7.70		15.02	0.00	0.00				
4H-1, 140–142	27.10	7.60		59.70	0.05	0.30				
4H-2, 50-52	27.30	7.90		17.83	0.00	2.30				
4H-2, 60-62	27.80	7.60		3.44		0.20				
4H-2, 75-77	27.95	7.60		14.96		0.75				
4H-2, 100–102	28.20	7.70		16.50		0.30		0.00		
4H-2, 103-104	28.25	7.70		49.23		0.30		0.00		
4H-3, 50-52	29.20	7.70		45.86	0.00	0.20		0.00		
4H-3, 90-92	29.60	7.65		7.73	0.20	0.20		0100		
4H-3, 103-104	29.70	7.70		21.69	0.00	0.20				
4H-3, 130–132	30.00	7.70		6.24	0.10	0.00	0.00	0.00		0.00
4H-4, 10-12 4H-4 50 52	30.30	7.70	0.00	2.74	0.00	0.20	0.00	0.00		0.00
4H-4, 90-92	31.10	7.40	0.20	2.00	0.30	0.80	3.10	2.00		1.10
4H-4, 103-104	31.20	7.60	0.00	17.51	0.20	0.00	18.94	1.43		0.00
4H-4, 110-112	31.30	7.80	0.00	2.22	0.00	0.00	74.70	0.20		
4H-4, 130–132	31.50	7.30	0.30	7.60	0.20	0.30	1.30	0.30		
4H-5, 10-12 4H-5, 50-52	31.80	7.30	0.00	3.64	0.00	0.00	0.00	0.00		
4H-5, 90-92	32.60	7.75		4.75	0.00					
4H-5, 103-104	32.70	7.80		3.19	0.30					0.00
4H-5, 130-132	33.00	8.10		1.50	0.10			0.00		0.10
4H-6, 10-12	33.30	8.10		3.68	0.30			0.25		0.00
4H-6, 50-52 4H-6, 90-92	33.70	7.90		6.14	0.25	0.00		0.00		
4H-6, 103-104	34.20	8.20		4.09	0.30	0.30	0.00	0.00		
4H-CC	35.20	7.50		6.10	0.70	0.40	0.40	0.20		
5H-1, 30-32	35.50	7.50		2.92	7.80	0.90	0.00	0.00		
5H-1, 70-72	35.90	7.50		6.67	0.00	0.00		0.25		
5H-1, 90-92 5H-1, 110-112	36.10	7.90		12.25	0.05	0.10		0.10		
5H-1, 140-142	36.60	7.60		5.40	0.40	0.00		0.00		
5H-2, 30-32	37.00	7.50		12.37	0.60	0.50		0.00		
5H-2, 70-72	37.40	7.10		9.03	0.90	0.00		0.05		
5H-2, 110–112	37.80	7.50		11.14	0.50	0.70		0.10		
5H-2, 145-147	38.15	8.00		11.60	0.20	0.80		0.00		
5H-3, 70-72	38.90	7.50		8 58	0.20	0.90		0.00		
5H-3, 110-112	39.30	7.60		16.90	2.00	0.70				
5H-3, 145-147	39.65	7.70		19.20	0.00	0.80				
5H-4, 30-32	40.00	7.80		9.50	0.60	1.30				
5H-4, 70-72 5H-4, 110, 112	40.40	7.20		12.10	2.80	1.30				
5H-4, 145-147	40.80	7.90		10.70	1.40	0.50				
5H-5, 30-32	41.50	7.40		13.70	2.70	0.30				
5H-5, 70-72	41.90	7.60		21.90	0.00	1.00				
5H-5, 110-112	42.30	7.20		12.70	0.20	0.70				
5H-5, 130-132	42.50	7.90		19.50	0.00	0.90				
5H-6 30-32	42.65	7.60		17.60	0.80	0.50				
5H-6, 70-72	43.40	6.80		6.30	0.80	0.00				
5H-6, 110-112	43.80	7.70		8.00	0.50	0.00				

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
5H-6, 145-147	44.15	7.80		5.70	0.00	1.50				
5H-7, 30-32	44.50	7.90		3.14	0.00	0.00				
5H-CC	44.70	7.20		6.21	0.30	0.30				
6H-2, 60-62	46.80	7.90		26.48	0.00	0.50				
6H-2, 90-92	47.10	7.80		15.00	1.17	0.30				
6H-2, 110-112 6H-2, 130-132	47.50	7.90		25.60	0.00	0.50				
6H-3, 10-12	47.80	7.90		19.67		0.90				
6H-3, 50-52	48.20	7.80		23.93		0.20				
6H-3, 90-92	48.60	8.00		11.31		0.50				
6H-3, 130–132	49.00	7.60		17.70		1.20				
6H-4, 10-12 6H-4, 50-52	49.30	7.60		13.10		0.70				
6H-4, 90-92	50.10	7.60		11.30		0.40				
6H-4, 130-132	50.50	7.60		14.00		0.00				
6H-5, 10-12	50.80	7.60		28.90		0.60				
6H-5, 50-52	51.20	7.90		7.35		0.90				
6H-5, 90-92	51.60	8.00		14.50		0.80				
6H-5, 100-102 6H-6, 10-12	52.30	7.90		20.38		0.30				
6H-6, 50-52	52.70	7.80		26.84		0.00				
6H-6, 90-92	53.10	7.90		15.07		0.50				
6H-6, 130-132	53.50	7.60		13.60		0.00				
6H-7, 10-12	53.80	7.60		13.84		1.20				
6H-7, 50-52	54.20	7.30		16.36		0.00				
6H-CC	54.60	7.60		19.70		0.90				
7H-1, 80-82	55.00	7.70		11.11		0.60	0.00			
7H-1, 135-137	55.55	7.50		18.96		0.90	0.40			
7H-2, 70-72	56.40	7.70		27.30		0.80	0.00			
7H-2, 110–112	56.80	8.00		23.19		0.70				
7H-2, 140-142 7H-3, 10-12	57.10	7.70		14 70		1.30		0.00		
7H-3, 50-52	57.70	7.90		33.50		0.20		0.40		
7H-3, 90-92	58.10	8.00		36.60		1.40		0.20		
7H-3, 130-132	58.50	7.90		54.20		0.70		0.00		
7H-4, 10–12	58.80	8.00		45.30		0.60				
7H-4, 50-52 7H 4 90 92	59.20	7.90		51.00		0.80				
7H-4, 130-132	60.00	7.90		61.60		1.50				
7H-5, 10-12	60.30	7.50		50.80		0.80				
7H-5, 50-52	60.70	7.60		37.80		1.10				
7H-5, 90-92	61.10	7.70		39.00		0.80		0.00		
/H-5, 130-132	61.50	7.70		21.80		0.20		0.50		
7H-6, 50-52	62.20	7.40		8.30		1.50		0.00		
7H-6, 90-92	62.60	7.50		12.70		0.30				
7H-6, 130-132	63.00	7.80		40.50		1.40		0.00		
7H-7, 10-12	63.30	7.90		35.60		0.40		0.20		
7H-7, 50–52	63.70	7.90		38.20		0.00		0.10		
7H-CC 8H-1 10-12	63.75	7.60		65.70		0.50		0.00		
8H-1, 50-52	64.20	7.50		8.70		0.00				
8H-2, 50-52	65.70	8.00		68.70		0.40				
8H-2, 130-132	66.50	7.75		72.00		0.90				
8H-3, 10-12	66.80	8.00		61.95		0.00				
8H-3, 50-52	67.20	7.95		37.15		0.00				
8H-3, 90-92	67.60	8.00		62.60		0.30	0.00			
8H-3, 130-132	68.00	7.90		15.66		0.40	0.20			
8H-4, 10-12	68.30	7.90		8.88		0.80	0.00			
8H-4, 50-52	68.70	7.80		22.15		0.00	0.30			
8H-CC	73.20	7.80		35.70		0.20	0.20			
9H-1, 10-12 9H-1, 50, 52	73.30	7.90		20.05		0.70	0.35			
9H-1, 90-92	74.10	7.70		26.94		0.70	1.00	0.00		
9H-1, 130-132	74.50	7.80		21.39		1.70	0.30	0.30		
9H-2, 10-12	74.80	7.80		22.80		0.70	0.20	0.00		
9H-2, 50-52	75.20	7.75		25.70		0.20	0.40			
9H-2, 90-92	75.60	7.83		17.70		0.00	0.00			
9H-2, 130-132 0H-3 10 12	76.00	7.89		14.30		0.50				
9H-3, 10-12 9H-3, 50-52	76.30	7.80		14.06		0.30				
9H-3, 90-92	77.10	7.67		14.68		0.30				
9H-3, 130-132	77.50	7.83		11.16		0.20				

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
9H-4, 10-12	77.80	7.56		8.67		0.00				
9H-4, 50-52	78.20	7.99		4.79		0.00				
9H-4, 90-92	78.60	7.54		13.38		0.20				
9H-4, 130-132 9H-5, 10-12	79.00	7.80		25.37		0.00				
9H-5, 50-52	79.70	7.87		18.20		0.40		0.00		
9H-5, 90-92	80.10	7.90		11.20		0.30		0.30		
9H-5, 130-132	80.50	7.48		14.95		0.00		0.00		
9H-6, 10-12	80.80	7.87		15.38		0.30				
9H-6, 50-52 9H-6, 90, 92	81.20	7.67		16.25		0.00				
9H-6, 130-132	82.00	7.61		11.80		0.00				
9H-7, 10-12	82.30	7.64		15.00		0.15		0.00		
9H-7, 50-52	82.70	7.78		26.95		0.15		0.25		
9H-CC	82.75	7.57		16.84		0.00		0.00		
10H-1, 10-12	82.80	7.91		25.35						
10H-1, 90-92	83.60	7.19		19.00		0.00				
10H-1, 130-132	84.00	7.99		15.63		0.60				
10H-2, 10-12	84.30	7.96		20.35		0.00				
10H-2, 50-52	84.70	8.06		14.44		0.00		0.00		
10H-2, 90-92	85.10	7.94		16.85		0.20		0.20		
10H-2, 130–132	85.50	7.81		18.04		0.20		0.20		
10H-3, 10-12	85.80	7.98		19.25		0.20		0.00		
10H-3, 50-52 10H-3, 90-92	86.60	7.80		13.35		0.60				
10H-3, 130-132	87.00	8.15		8.27		0.00		0.00		
10H-4, 10-12	87.30	7.60		9.68		0.00		0.20		
10H-4, 50-52	87.70	8.10		22.59				0.00		
10H-4, 90-92	88.10	7.98		13.93						
10H-4, 130–132	88.50	7.89		7.76		0.00				
10H-5, 10-12 10H 5, 50, 52	88.80	7.93		17.99		0.20				
10H-5, 50-52 10H-5, 90-92	89.60	7.65	0.00	8 45		0.30				
10H-5, 130-132	90.00	7.51	0.20	10.11		0.00				
10H-6, 10-12	90.30	7.58	0.40	10.20		0.00				
10H-6, 50-52	90.70	7.53	0.00	7.88		0.25				
10H-6, 90-92	91.10	7.72		14.21		0.00				
10H-6, 130-132	91.50	7.95		22.86		0.00				
10H-CC	92.20	8.07		20.15		0.20				
11H-1, 10-12	92.30	7.98		23.81		0.00				
11H-1, 90-92	93.10	7.93		31.14						
11H-2, 10-12	93.80	7.90		35.35		0.00				
11H-2, 90-92	94.60	8.08		25.27		0.20				
11H-3, 10-12	95.30	7.96		22.69		0.30				
11H-4 10-12	96.80	7 84		20.36		0.20				
11H-4, 50-52	97.20	7.97	0.00	20.90		0.00		0.00		
11H-4, 90-92	97.60	8.09	1.35	10.13		0.20		0.30		
11H-4, 130-132	98.00	8.06	1.16	7.13		0.00		0.00		
11H-6, 50-52	100.20	7.90	1.23	13.05		0.20				
11H-6, 90–92	100.60	8.18	0.10	18.86		0.00				
114B-704A-										
9H-4, 85-86	79.05	7.66		12.59		0.12				
9H-5, 85-86	80.50	8.09		13.42		0.00				
9H-6, 85-86	82.05	8.15		15.70						
9H-CC	83.20	8.17		13.36						
10H-2 130-131	86.00	8.03		13 14						
10H-3, 130-131	87.50	7.73		36.28		0.00				
10H-4, 130-131	89.00	8.09		31.07		0.32				
10H-5, 130-131	90.00	8.05		37.35		0.00				
10H-7, 87-88	91.58	7.93	0.00	45.03						
10H-CC	92.70	7.93	0.00	26.33						
11H-2 55_56	94.75	8.00	0.03	21.33						
11H-3, 55-56	96.25	7,92	0.00	37.65		0.00	0.00			
11H-4, 55-56	97.75	7.96	1175-717K	28.20		0.10	0.10			
11H-5, 55-56	99.25	8.09		36.08		1.03	1.37			
11H-6, 55-56	100.75	8.00		31.15		0.10	4.61	0.00	0.00	
11H-7, 55-56	102.10	6.71		27.80		0.34	7.46	1.02	0.30	
12H-1 82 84	102.20	7.66		30.74		0.00	25.00	0.00	0.00	
1211-1, 03-84	105.05	7.44		20.03		0.00	14.10	1.80		

Core, section, interval (cm)	Depth (mbsf)	log diatom valves/g sediment	Hemidiscus karstenii (%)	Actinocyclus ingens f. planus (%)	Thalassiosira elliptipora (%)	Thalassiosira vulnifica (%)	Simon- seniella barboi (%)	Thalassiosira kolbei (%)	Nitzschia weaveri (%)	Cosmio- discus insignis (%)
12H-2, 30-31	104.00	7.95		79.21		0.20	0.20	0.00		
12H-2, 83-84	104.53	7.85		51.19		0.80	0.00	0.00		
12H-3, 83-84	106.03	7.51		15.34		0.00	35.10	1.60		
12H-4, 83-84	107.53	7.40		21.02		0.30	13.60	0.80		
12H-5, 30-31	108.50	7.81		10.20		0.00	35.71	4.85		
12H-5, 83-84	109.03	7.67		7.85		0.00	47.40	6.80		
12H-6, 83-84	110.53	7.54		13.06		0.50	8.90	5.00		
12H-CC	111.70	7.63		10.33		0.00	7.80	1.90		
13H-1, 130-131	113.00	8.06		78.62		0.20	0.00	0.00		
13H-2, 130-131	114.50	7.77		77.39		0.90	0.40	0.00		
13H-3, 130-131	116.00	8.07		7.29		0.00	50.10	1.10		
13H-4, 130-131	117.50	7.63		5.90			49.60	1.20		
13H-5, 30-31	118.00	7.49		26.60		0.00	29.12	1.98		
13H-5, 130-131	119.00	7.67		13.46		0.50	8.60	1.20		
13H-6, 130-131	120.50	7.33		14.18		0.30	25.10	8.00		
13H-7, 30-31	121.00	8.16		13.33		0.13	26.98	4.13		
13H-CC	121.20	7.69		8.67		0.00	37.10	4.10		
14H-1, 125-126	122.45	7.85		6.00			25.00	2.30		
14H-2, 125-126	123.95	6.67		5.40			35.60	0.90		
14H-3, 125–126	125.45	7.78		6.60		0.00	19.20	0.00		
14H-3, 133–133.5	125.53	7.31		39.70		0.29	8.35	0.29		
14H-3, 134	125.54	7.25	0.00	14.20		0.34	1.35	0.34		12122
14H-3, 134.5-135	125.55	7.47	0.28	8.30		0.28	4.42	0.28		0.00
14H-4, 125–126	126.95	8.06	0.00	3.78		0.00	4.20	1.30		0.40
14H-5, 125–126	128.45	7.54	0.00	0.50		1.00	1.00	6.80		0.00
14H-CC	130.70	7.70	1.00	0.40		1.20	0.20	8.50		
15H-1, 115–116	131.85	7.73	0.00	0.00		4.50	0.00	5.20		
15H-2, 115–116	133.35	7.70	0.54			0.54		14.95		
15H-3, 115–116	134.85	7.58	0.40			1.20	0.00	21.20		
15H-4, 115–116	136.35	7.81	0.00	0.00		1.17	2.92	7.89		
15H-5, 115-116	137.85	7.94	0.00	0.28		1.10	0.00	6.90		
15H-6, 115-116	139.35	7.89	0.67	0.00		1.68		10.40		
ISH-CC	140.20	7.57	0.68	0.34		1.02		8.8/		
16H-1, 134-135	141.55	7.97	0.00	0.26		0.79		0.79		
16H-2, 134-135	143.05	7.94	0.00	0.00		0.40		17.70		0.00
1011-3, 134-135	144.55	6.98	1.28	0.00		0.60	0.00	0.00		0.00
1011-4, 134-135	140.00	7.33	0.50	0.26		4.60	0.00	1.30		0.80
16H-5, 134-135	147.55	7.18	0.00	2.00		0.90	1.10	4.90		2.90
1011-00	149.70	7.70	0.00	0.50		5.00	0.00	0.50		0.50
17H-1, 104-105	152.25	6.02	0.50	0.00		0.00	0.00	1.00		0.00
1711-2, 104-105	152.25	7.44	3.10	1.20		1.90	3 10	7.40		0.00
17H-4 104 105	155.75	7.44	0.00	1.20		0.40	2.80	5.60		0.40
17H-5, 104-105	155.25	7.66	0.00	4.00		0.40	4.10	4.10		0.70
17H_6 104 105	158 25	7.00	1.43	0.00		10.70	4.10	0.00		0.00
17H-CC	150.25	6.88	0.00	1.55		6 70	0.00	2.10		1.00
188-1 105-106	160.25	7 28	0.00	0.00		1.20	0.40	0.80		3 30
18X-2 105-106	161.75	7 38		0.00		1.40	0.00	0.50	0.00	0.50
18X-3, 105-106	163 25	7.15		0.67		4 70	0.00	3 30	0.67	5 30
18X-4 105-106	164 75	7 40		0.00		3.90	0.00	8 80	0.00	0.00
18X-5, 105-106	166.25	7.74		0.00		6.90	0.00	8.00	0.00	0.00
18X-6, 105-106	167 75	7.91				0.00		0.00		0.00
18X-CC	168 70	6.96				6 60		0.00	0.00	0.40
19X-1, 103-104	169 74	7 59				0.00		4.40	20.35	27 90
19X-2, 103-104	171.24	7.67	0.00			0.00		8.60	12.14	5.70
19X-3, 103-104	172.74	7.62	1.85					2.50	17.28	10.50
.77 5, 105-104	1/2./4	7.02	1.05					2.50	11.20	10.00



Plate 1. Magnification 1500×. 1. Thalassiosira kolbei convex valve type; Sample 114-704B-12H-5, 10–12 cm. 2. Hemidiscus karstenii; Sample 114-704B-1H-3, 130–131 cm. 3. Thalassiosira elliptipora; Sample 114-701C-3H-5, 25–27 cm. 4. Thalassiosira kolbei, flat valve type, high and low focus; Sample 114-704B-12H-2, 130–131 cm.



Plate 2. 1, 2. Actinocyclus ingens f. planus; Sample 114-699A-2H-4, 42-44 cm. 1. Inside view of valve, GPI photo archive no. 3585/30; 2. outside view of valve, GPI photo archive no. 3595/31. 3, 4. Thalassiosira kolbei; Sample 114-704B-12H-7, 10-12 cm. 3. Inside view of valve (marginal part), GPI photo archive no. 3637/21; 4. outside view of valve, GPI photo archive no. 3637/16.



Plate 3. 1. Simonseniella barboi, GPI photo archive no. 3637/19; Sample 114-704B-12X-1, 10-12 cm. 2. Thalassiosira elliptipora, inside view of valve (central part), GPI photo archive no. 3819/15a; Sample 114-701C-4H-4, 10-12 cm. 3. Simonseniella barboi, GPI photo archive no. 3779/9; Sample 114-704B-12X-7, 10-12 cm. 4. Nitzschia weaveri, GPI photo archive no. 3603/13; Sample 114-699A-4H-4, 88-90 cm. 5. Thalassiosira vulnifica, GPI photo archive no. 3819/22a; Sample 114-701C-4H-4, 10-12 cm.