UPPER MIOCENE TO PLIOCENE DIATOM TAXONOMY AND BIOSTRATIGRAPHIC SYNTHESIS OF ODP HOLE 695A, JANE BASIN, WEDDELL SEA, ANTARCTICA

by

Aradhna Srivastav

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Upper Miocene to Pliocene Diatom Taxonomy and Biostratigraphic Synthesis of ODP Hole 695A, Jane Basin, Weddell Sea, Antarctica

BY

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UPPER MIOCENE TO PLIOCENE DIATOM TAXONOMY

AND BIOSTRATIGRAPHIC SYNTHESIS OF ODP HOLE 695A,

JANE BASIN, WEDDELL SEA, ANTARCTICA

Aradhna Srivastav, Ph.D.

University of Nebraska, 2003

Advisor: David M. Harwood

A new age model for the upper Miocene to Pliocene sedimentary section from Ocean Drilling Program (ODP) Hole 695A enables extrapolation of absolute ages of diatom datums and provides better understanding of paleoenvironmental conditions in the Weddell Sea. Four hiatuses in the sedimentary record, spanning <5.8 to >5.1 Ma, <4.9 to >4.8 Ma, <4.2 to 1 >3.8 Ma, and 3.0 Ma to Recent, are present. Sediment accumulation rates of 400 m/m.y. between 6.4 to 4.9 Ma, and 166 between 4.8 to 3.0 Ma suggest the presence of a poly-thermal ice sheet in Antarctica during the early Pliocene. Peaks in abundance of *Thalassionema nitzschioides* and *T. nitzschioides* var. *parva* reflect fluctuations in the strength of latitudinal thermal gradients between the Antarctic and Subantarctic sectors of the Weddell Sea, and are correlated to intervals of climatic warming noted in the Kerguelen Plateau region of the Southern Ocean. The first occurrence of Southern Ocean endemic diatom taxon *Fragilariopsis kerguelensis* and late Pliocene hiatuses reflect increased thermal isolation of the Southern Ocean, cold-polar ice sheets on Antarctica, and increased bottom water erosional activity after ~3.25 Ma. This sedimentary section, assigned to the *Fragilariopsis reinholdii* through *Thalassiosira orbiculata-Thalassiosira vulnifica* diatom biostratigraphic zones, contain amongst other diatom taxa, *Cyclomedius maccollumii* n. gen., n. comb., *Fragilariopsis acutalis* n. sp., *Fragilariopsis extensa* n. sp., *Fragilariopsis serpentina* n. sp., *Fragilariopsis pingua*

n. sp., *Synedropsis rostrata* n. sp., *Synedropsis bicapitata* n. sp., *Synedropsis capula* n. sp., *Denticulopsis rhombiformis* n. sp., and *Rouxia quartera* n. sp. Renaming of diatom taxa *Thalassiosira insigna* sensu Harwood and Maruyama as *Thalassiosira orbiculata* n. sp. and *Actinocyclus fasciculatus* Harwood and Maruyama as *Actinocyclus bohatyi* n. sp., elevation of *Thalassiosira oliverana* var. *sparsa* to species level as *Thalassiosira sparsa* n. stat., and amendment of the morphological description of *Thalassiosira striata* clarifies their respective systematic positions. Additionally, *Thalassiosira sparsa*, *Thalassiosira fasciculata*, and *Thalassiosira tumida* groups, defined herein, provide insight into the evolutionary history of the genus *Thalassiosira.*

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1.0 INTRODUCTION AND OBJECTIVES

Recovery of sedimentary records enabling an understanding of the Cenozoic history of the Weddell Sea was one of the goals of the Ocean Drilling Program (ODP) Leg 113. The Weddell Sea basin formed as a result of the break-up of Gondwana during the Jurassic and was subsequently shaped by the motions of the Antarctic and South American plates (Livermore and Woolett, 1993). The spreading between the two plates led to the opening of the Drake Passage and the establishment of the Antarctic Circumpolar Current during the middle Cenozoic. This augmented the thermal isolation of the Antarctic region, which may have aided the development of the Antarctic cryosphere (Kennett, 1977).

Past variations in the size and character of the Antarctic ice sheets have influenced global paleoclimate and global ocean circulation through bottom water formation. Events that shaped the history of the Southern Ocean and the Antarctic continent help us understand climatic evolution and make predictions regarding future global climate changes. The stability of the Antarctic ice sheets and their effect on the oceans and climate of the Antarctic region have been the focus of Antarctic research in the last two decades (Harwood, 1986a; Hambrey and Barrett, 1993; Clapperton and Sugden, 1990; Webb and Harwood, 1991; Wise et al., 1991; Kennett and Warnke, 1992; Miller and Mabin, 1998). The development of a chronostratigraphic framework to correlate events around Antarctica and in different regions around the globe, relies on the calibration of magnetic reversal events recorded in sediments to radiometric dates and biostratigraphic datums. Biostratigraphic records are complicated by preservational biases, hiatuses, reworking, and environmentally induced migration of taxa. These are problems that can be mitigated in part by compiling and comparing information from stratigraphic sections from different sectors of the Southern Ocean.

Sedimentary records from holes drilled during past ODP legs in the Southern Ocean have provided key diatom biostratigraphic information. However, disconformities within the upper Miocene and lower Pliocene intervals (Gersonde and Burckle, 1990; Baldauf and Barron, 1991; Harwood and Maruyama, 1992; Censarek and Gersonde, 2002) (Fig. 1.a; Table 1.a) have hindered the development of a reliable diatom biostratigraphy for the uppermost Miocene. The Quaternary to upper Miocene sequence recovered from ODP Hole 695A, which was drilled during ODP Leg 113 in February 1987, holds the potential to provide information for part of these unrecovered time periods and helps one to understand the latest Miocene to Pliocene history of the Weddell Sea sector of the Southern Ocean. This study examined the sedimentary sequence from ODP Hole 695A with the following eight objectives:

1. Document the diatom assemblage with descriptions and illustrations of new taxa identified in ODP Hole 695A.
2. Further develop the initial uppermost Miocene to Pliocene diatom biostratigraphy for ODP Hole 695A by Gersonde and Burckle (1990) and test the utility of existing diatom zonal schemes.
3. Apply the diatom biostratigraphic ages derived from ODP Hole 695A to the available paleomagnetic data for ODP Hole 695A in order to refine correlation to the Geomagnetic Polarity Timescale (GPTS) of Berggren et al. (1995).
4. Identify the location of disconformities and duration of hiatuses in ODP Hole 695A.
5. Extrapolate ages of new and previously published diatom datums at ODP Hole 695A in order to refine the stratigraphic ranges of the Southern Ocean diatoms and enhance their quality for future studies.
6. Reconstruct paleoenvironmental conditions based on the diatom assemblages.
7. Improve the knowledge of selected diatom species by revising the taxonomic position of taxa and attempt to better understand morphological distinctions between related taxa.

8. Use morphological variations in diatom taxa to understand evolutionary development and help understand paleoecology of Recent and fossil taxa to improve future paleoenvironmental reconstructions.

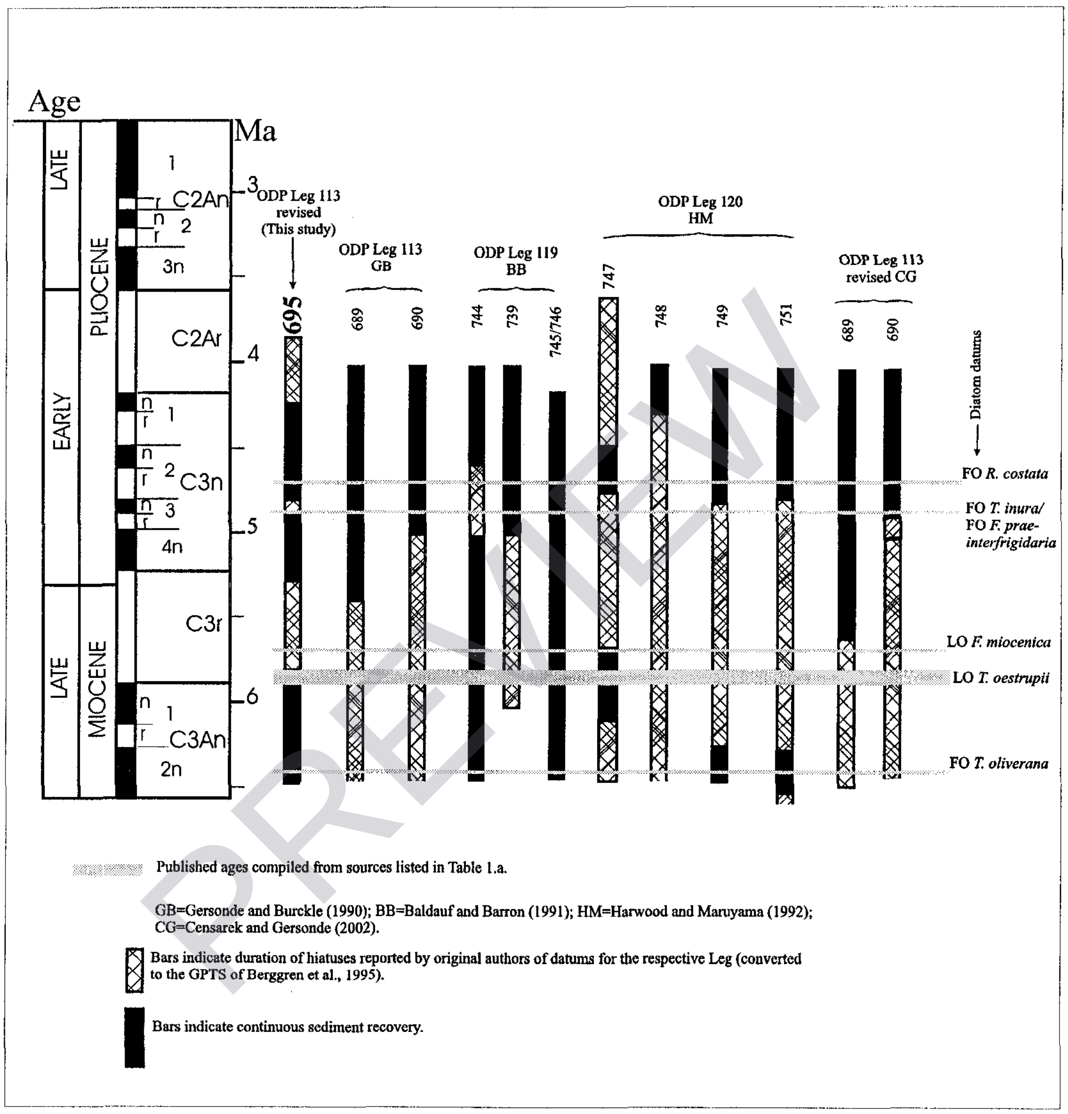

Figure 1.a. Position of late Miocene to early Pliocene hiatuses, compiled from previous ODP legs, with respect to diatom datums used in this publication.

Numerical ages of Miocene/Pliocene disconformities taken from recent ODP legs			
Leg	**Site**	**Age (Ma)**	**Sources**
ODP Leg 113	689	5.4-6. 9	GB
	690	5.0-8.7	
ODP Leg 119	744	4.6-5.0	BB
	739	5.0-6.0	
ODP Leg 120	747	3.60-4.5 4.7-5.7 6.5-8.6	HM
	748	4.3-8.9	
	749	4.8-6.3	
ODP Leg 113 (revised)	680	5.4-6.4	
	690	>4.8-<4.9 >4.98-7.6	CG
ODP Leg 177	1088	Indication of a disconformity in *F. reinholdii* Zone between 5.54 and 7.39	According to Cande and Kent (1995) GPTS
	1092	>3.8-<4.45 and >4.9-<5.3	

Table 1.a. Numerical ages of latest Miocene to earliest Pliocene hiatuses, used in the construction of Figure 1.a, and discussions in the text. All ages adjusted to the Berggren et al. (1995) GPTS, unless noted otherwise.

GB-Gersonde and Burckle (1990);
BB-Baldauf and Barron (1991);
HM-Harwood and Maruyama (1992);
CG-Censarek and Gersonde (2002).

2.0 DESCRIPTION OF ODP HOLE 695A

ODP Leg 113 drilled nine sites in the northeast Weddell Sea to examine the Neogene history of the Weddell Sea. Three of the nine sites (Sites 695, 696, and 697) are located on the northern margin of the Weddell Sea (Fig. 2.a). ODP Site 695 is the intermediate of three sites that make a depth transect (Fig. 2.b) located on the northwest flank of the Jane Basin (62° 23.5' S, 43° 27.1' W), on the southeast margin of the South Orkeney Microcontinent (SOM).

One hole was drilled at Site 695 using the advanced piston core (APC) and extended core barrel (XCB) coring tools and techniques. A 341.0 m thick Quaternary to upper Miocene sequence was recovered, for which a good paleomagnetic record was also established (Hamilton and O'Brien, written comm., 1997; O'Brien, 1990). Core recovery from ODP Hole 695A ranged from good to moderate. The sediment sequence recovered is of mixed terrigenous, volcanic, and biogenic (largely diatomaceous) origin (Fig. 2.c). Prior to ODP Leg 113, no high-resolution stratigraphic sequences had been obtained using the Hydraulic Piston Corer (HPC), Advanced Piston Corer (APC) or Extended Core Barrel (XCB) (Barker, Kennett et al., 1988) from the southern high latitudes. The use of these coring tools helped recover long cores from ODP Hole 695A and allowed high-resolution sampling for the present study aiding the development of a magnetostratigraphic framework, from which an integrated bio-magnetostratigraphy could be developed.

2.1 LITHOSTRATIGRAPHY

Sediments recovered from ODP Hole 695A were divided into the following three lithostratigraphic

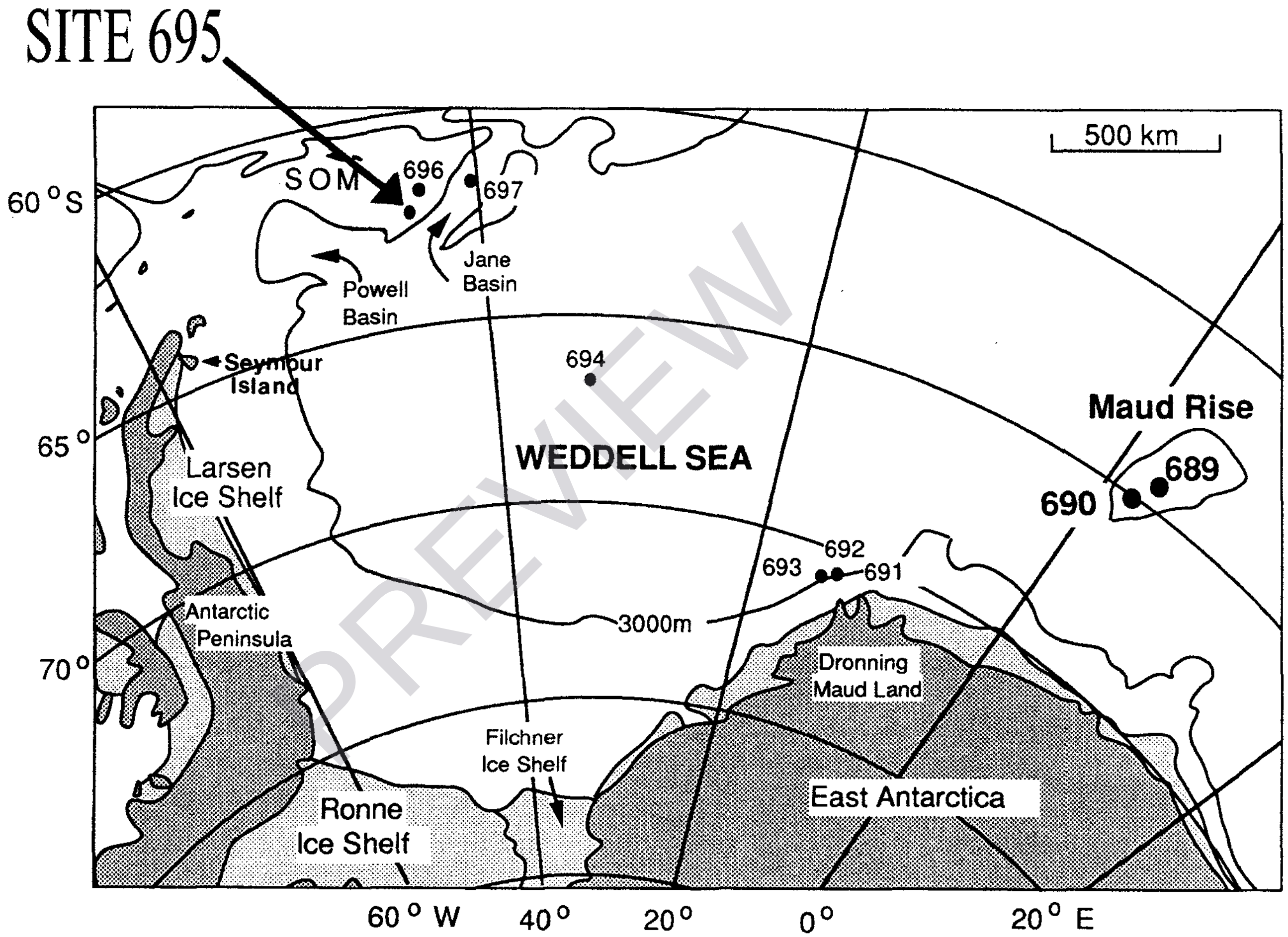

Figure 2.a. Location of the sites drilled during ODP Leg 113, including Site 695 in the Weddell Sea (after Barker et al., 1988). SOM: South Orkeney Microcontinent.

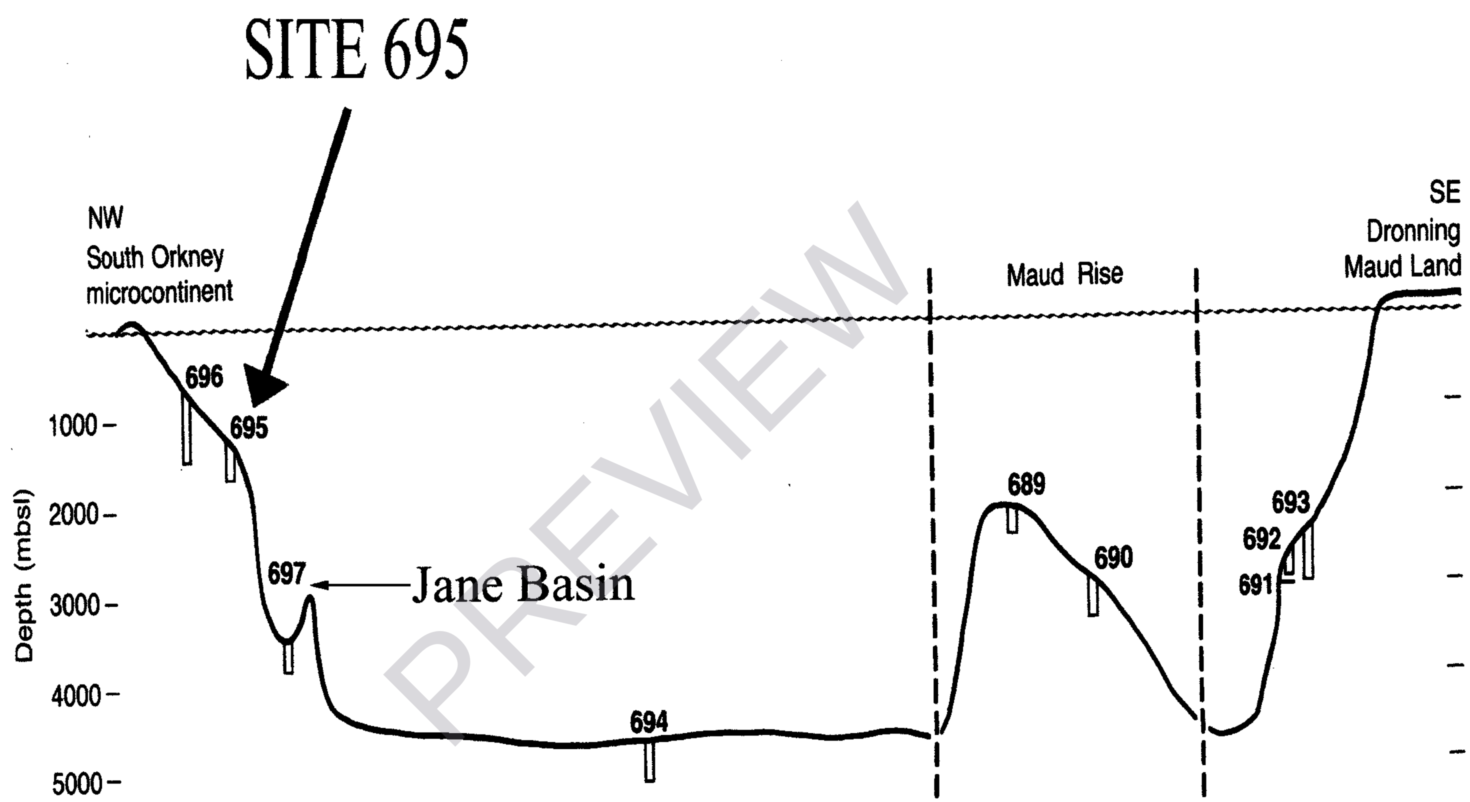

Figure 2.b. Schematic northwest-southeast transect across the Weddell Sea showing the relative position and depth distribution of ODP Leg 113 sites (after Barker, Kennett et al., 1988).

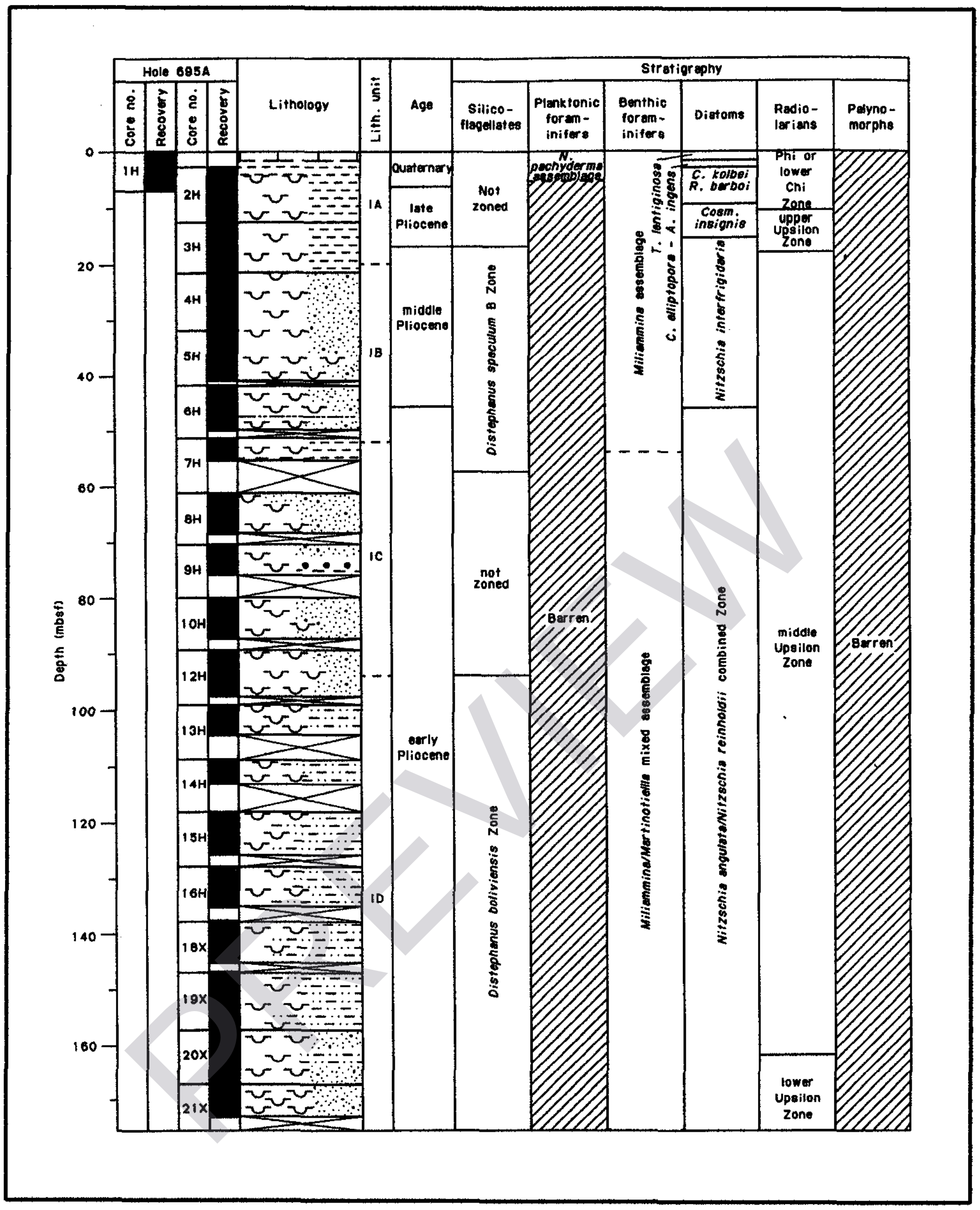

Figure 2.c. Lithostratigraphy, biostatigraphy, initial age interpretation, and core recovery of ODP Hole 695A based on shipboard data from Barker, Kennett et al., (1988). Black bars indicate core recovery; lithologic symbol on the far left indicates diatomaceous ooze, reflecting the abundance of diatoms (Figure continued on the next page).

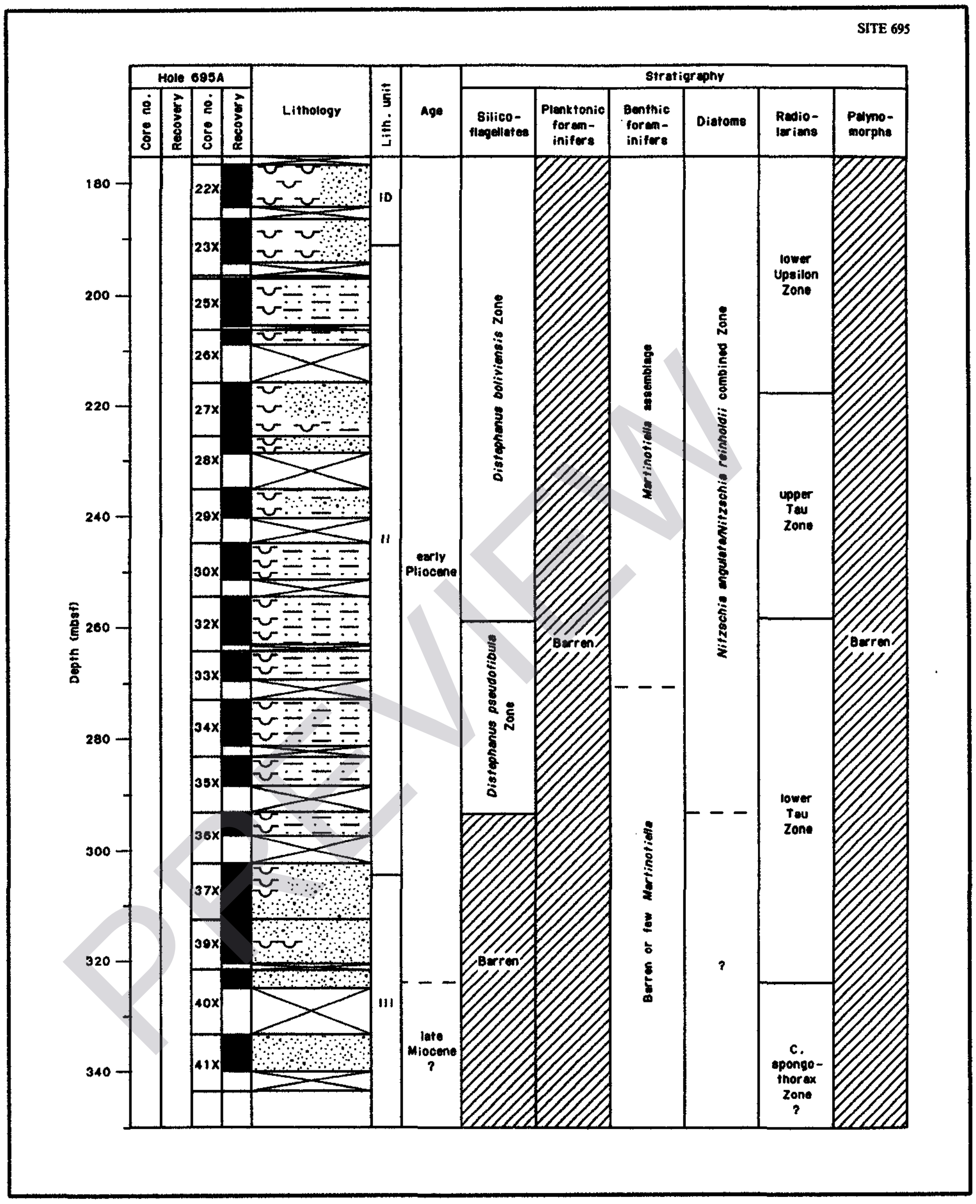

Figure 2.c. Continued from the previous page.

units (Fig. 2.c) (Barker, Kennett et al., 1988):

Lithologic Unit I (Depth 0–190 mbsf): Sample ODP 113-695A, 1H-01, 30–32 cm down to Sample ODP 113-695A, 23X-03, 80 cm is assigned to Lithologic Unit I. The total thickness of this unit is 190.0 m and it is diatom-rich. It is further subdivided into four subunits:

Subunit 1A (Depth: 0–19.0 mbsf, Age: Quaternary to mid Pliocene): This subunit consists of diatom bearing silty and clayey mud. Minor amounts of altered ash and ice-rafted detritus are present.

Subunit IB (Depth: 19.9–52.3 mbsf; Age: mid to early Pliocene): This subunit consists of muddy diatom ooze and diatom-bearing, silty mud, and contains minor amounts of altered ash and ice-rafted detritus.

Subunit IC (Depth: 52.3–93.7 mbsf; Age: early Pliocene): This subunit consists of predominantly silty and muddy diatom ooze containing minor amounts of altered ash and ice-rafted detritus.

Subunit ID (Depth 93.7–190.0 mbsf; Age: early Pliocene): This subunit consists of diatom ooze and diatomaceous silty mud. The amount of ice-rafted detritus in Unit Subunit ID is lower than in subunits 1A, IB, and IC.

Lithologic Unit II (Depth 190–306.9 mbsf): Sample ODP 113-695A, 23X-03, 80 cm through Section ODP 113-695A, 37X-03 is assigned to Lithologic Unit II. The total thickness of this unit is 116.9 m. It is early Pliocene in age. The predominant lithologies of Unit II are dark greenish gray to dark gray diatom-bearing silty and clayey mud. A marked decrease in the abundance of diatoms from Lithologic Unit I to Lithologic Unit II is noted at the top of Unit II.

Lithologic Unit III (Depth 306–341.1 mbsf): Section ODP 113-695A, 37X-04 through Section ODP 113-695A, 41X-05 is assigned to Lithologic Unit III. This unit is early Pliocene to late Miocene in age. The sediments consist predominantly of dark bluish gray, and dark gray, silty mud. Diatom abundance is low. Variable amounts of volcanic material are present throughout the Unit in form of grayish green to greenish gray layers of ash with gradational color contacts at their tops and bases.

2.2 BIOSTRATIGRAPHY

Planktonic and benthic foraminifera, silicoflagellates, radiolarians, and diatoms are reported from ODP Hole 695A. Calcareous nannoplankton are absent from all sections. Planktonic foraminifera are absent from all pre-Quaternary sections. Benthic foraminifera were reported from all core catcher samples during the shipboard studies, but were scarce. Silicoflagellates are present (McCartney and Wise, 1990), but in low diversity throughout Lithologic Units I and II, and are absent from Lithologic Unit III.

Diatoms and radiolarians were studied using core catcher samples during the shipboard and shore-based studies and its findings (Barker, Kennett at al., 1988; Gersonde and Burckle, 1990; Lazarus, 1990) are further discussed in Chapter 5. Figure 2.c presents the initial shipboard biostratigraphic assignments.

2.3 MAGNETOSTRATIGRAPHY

A paleomagnetic polarity zonation was assigned to ODP Hole 695A using remnant magnetization measurements of 493 specimens from the hole (O'Brien, 1990). All specimens were subjected to shore-based alternating field demagnetization using a cryogenic magnetometer.

Table 2.a presents the polarity reversal boundaries within ODP Hole 695A sediments (O'Brien, 1990).