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REVISED DIATOM STRATIGRAPHY OF THE EXPERIMENTAL MOHOLE DRILLING, GUADALUPE SITE

By

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ABSTRACT: Thirty-four diatom-bearing samples were obtained from cores recovered at the Experimental Mohole Drilling (EMD), Guadalupe Site. A planktonic-diatom stratigraphy is defined through correlation of ranges of key species of the EMD with a continuously cored section off California (DSDP, leg 18, Site 173). The Pliocene-Miocene boundary (defined as the base of the Gilbert Reversed Paleomagnetic Epoch) occurs between samples EMD-8-10-44/45 cm. and EMD-8-10-100/101 cm. The Middle Miocene to Late Miocene boundary (defined as occurring within Geomagnetic Epoch 11) occurs between samples EMD-8-15-100/101 cm. and EMD-8-15-200/201 cm. The youngest investigated sediment (EMD-8-9-5/6 cm.) correlates with North Pacific Diatom Zone 10 of Middle Pliocene age (upper part of the Gilbert Magnetic Epoch); the oldest investigated sediment (EMD-7-2-0/17 cm.) correlates with North Pacific Diatom Zone 24, with NN 6 Standard Nannoplankton Zone, and with the *Dictyocha octacantha* Silicoflagellate Zone. The sedimentation rate for the interval from 80 to 95 meters below the sea floor is about 7 meters/million years; it increases abruptly over the interval from 95 to 115 meters below the sea floor to approximately 30 m./m.y. and decreases again to approximately 7 m./m.y. for the interval from 115 to 135 meters below the sea floor. One new genus and ten new species of diatoms are described, and five new combinations of names are proposed.

List of new taxonomic entries and new combinations:

a. New genus.

Cussia

b. New species.

Biddulphia moholensis	CAS 54409
Coscinodiscus moholensis	CAS 54410
Cussia lancettula	CAS 54411
Cussia moholensis	CAS 54413
Nitzschia burcklia	CAS 54415
Nitzschia kanayensis	CAS 54417
Nitzschia moholensis	CAS 54419
Nitzschia riedelia	CAS 54420
Nitzschia seiboldia	CAS 54422
Rouxia moholensis	CAS 54424

c. New combinations.

Cussia mediopunctata
Cussia mediopunctata var. *matraensis*
Cussia paleacea
Cussia praepaleacea
Cussia tatsunokuchiensis

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INTRODUCTION

This study is a revision of the planktonic diatoms contained in 34 samples from cores recovered during the Experimental Mohole Drilling near Guadalupe Island off Baja California (Riedel *et al.*, 1961). Age correlative samples from cores (Lamont-Doherty Geological Observatory) and from a drill hole of the Deep Sea Drilling Project, leg 18, Site 173 near Cape Mendocino, California were also used in this study (chart 1, table 1).

Previous zonations of the Experimental Mohole Drilling cores have been made on Foraminifera (Parker, 1964; Bandy and Ingle, 1970), on calcareous nannoplankton (Martini and Bramlette, 1963; Martini, 1971), on silicoflagellates (Martini, 1972), and on diatoms (Kanaya, 1971).

After publication of the Neogene diatom zonation of the East-Equatorial Pacific (Burckle, 1972) and the completion of a Neogene diatom zonation of the

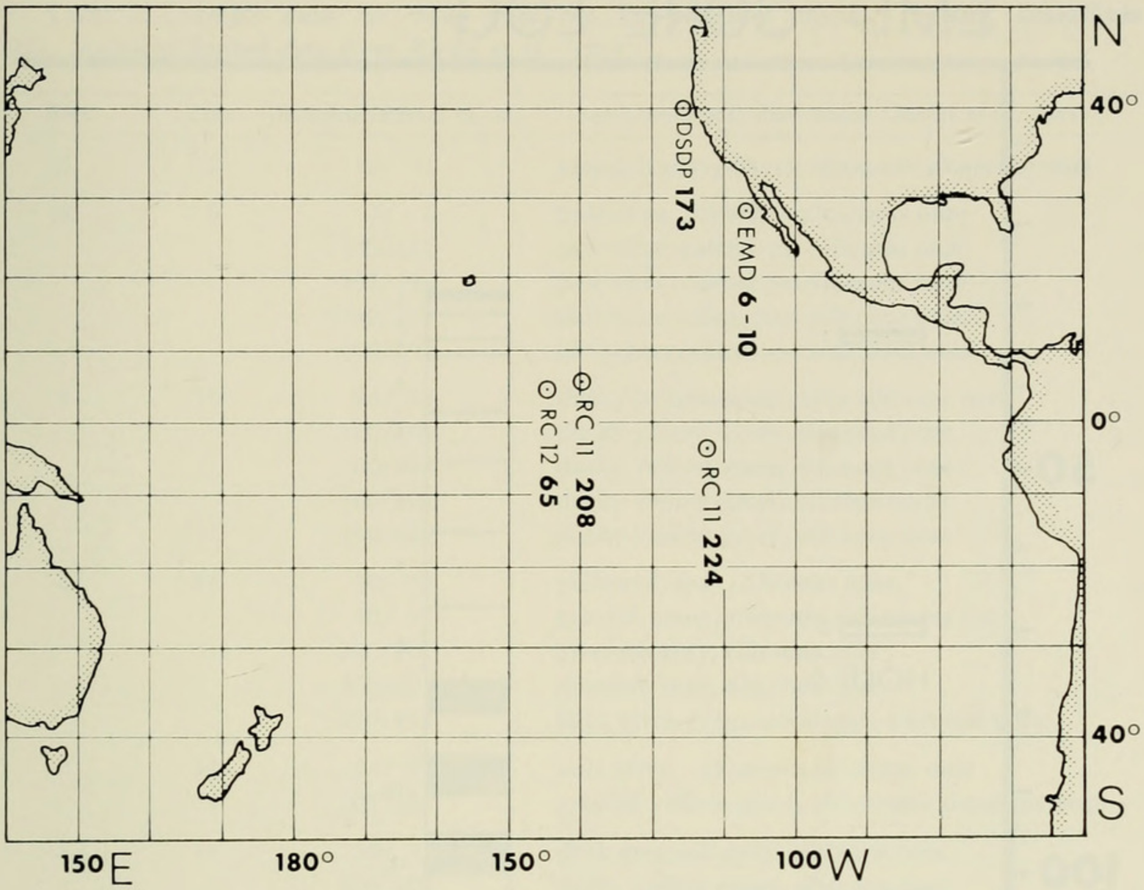


CHART 1. Index map showing localities of investigated cores. DSDP 173: Deep Sea Drilling Project, leg 18, Site 173; EMD: Experimental Mohole Drilling, Guadalupe Site; RC-65, 208, 224: Robert Conrad cores (Lamont Doherty Geological Observatory).

TABLE 1. *List of cores used in this study, with references to published descriptions. IRDSDP—Initial reports of the Deep Sea Drilling Project; LDGO—Lamont Doherty Geological Observatory; SIO—Scripps Institution of Oceanography.*

Core No.	Inst.	Latitude	Longitude	Water Depth (m.)	Author
RC-12-65	LDGO	04° 39′ N	144° 58′ W	4868	Burckle 1972
RC-11-208	LDGO	05° 21′ N	139° 58′ W	4920	Burckle 1972
RC-11-224	LDGO	03° 32′ S	122° 05.5′ W	4319	Burckle 1972
EMD-6,8,7,10	SIO	28° 59′ N	117° 30′ W	3566	Riedel *et al.* 1961
					Parker 1964
					Martini 1971
					Kanaya 1971
DSDP-173	SIO-DSDP	39° 57.7′ N	125° 27.12′ W	2927	IRDSDP 1973

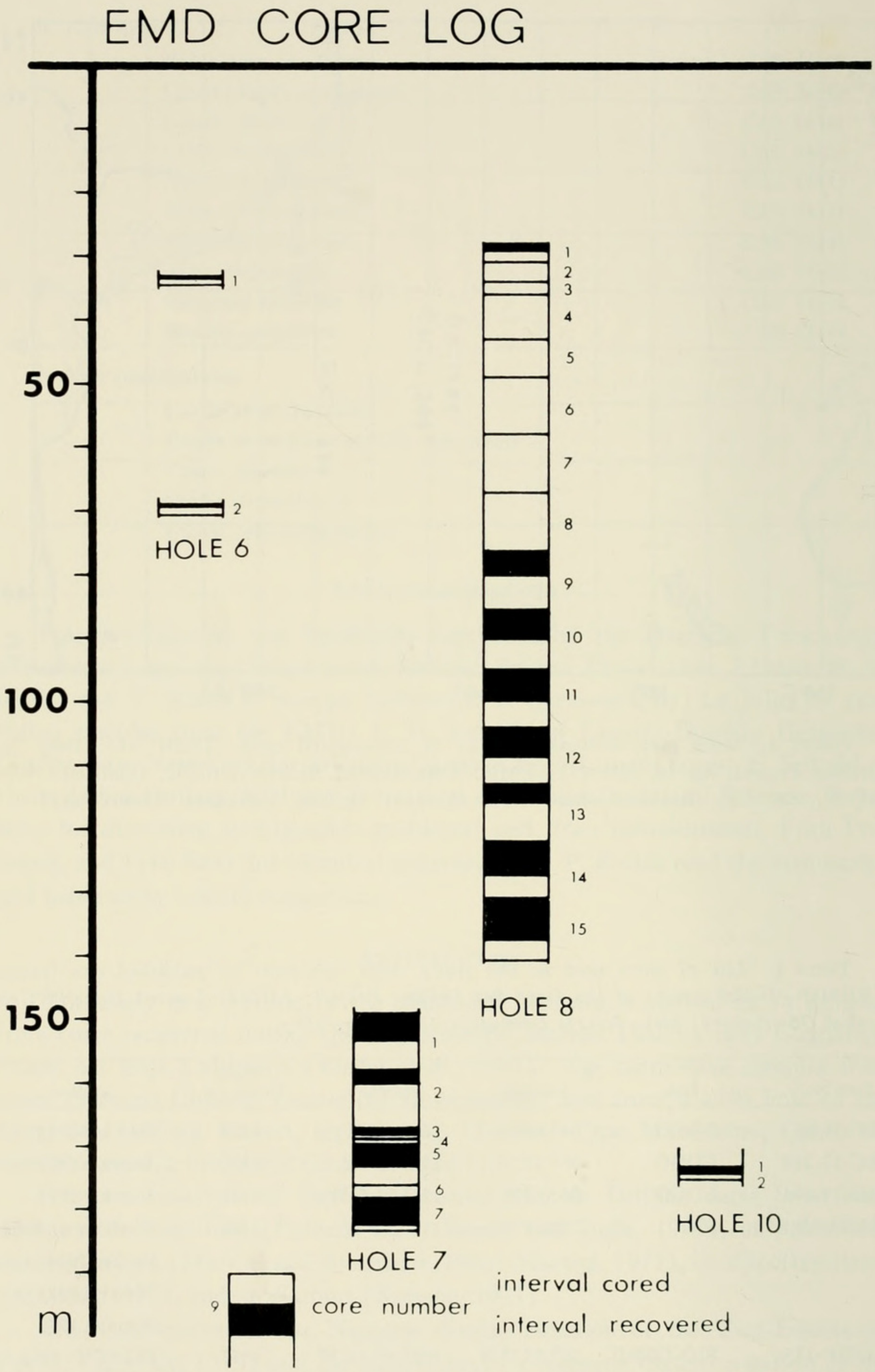


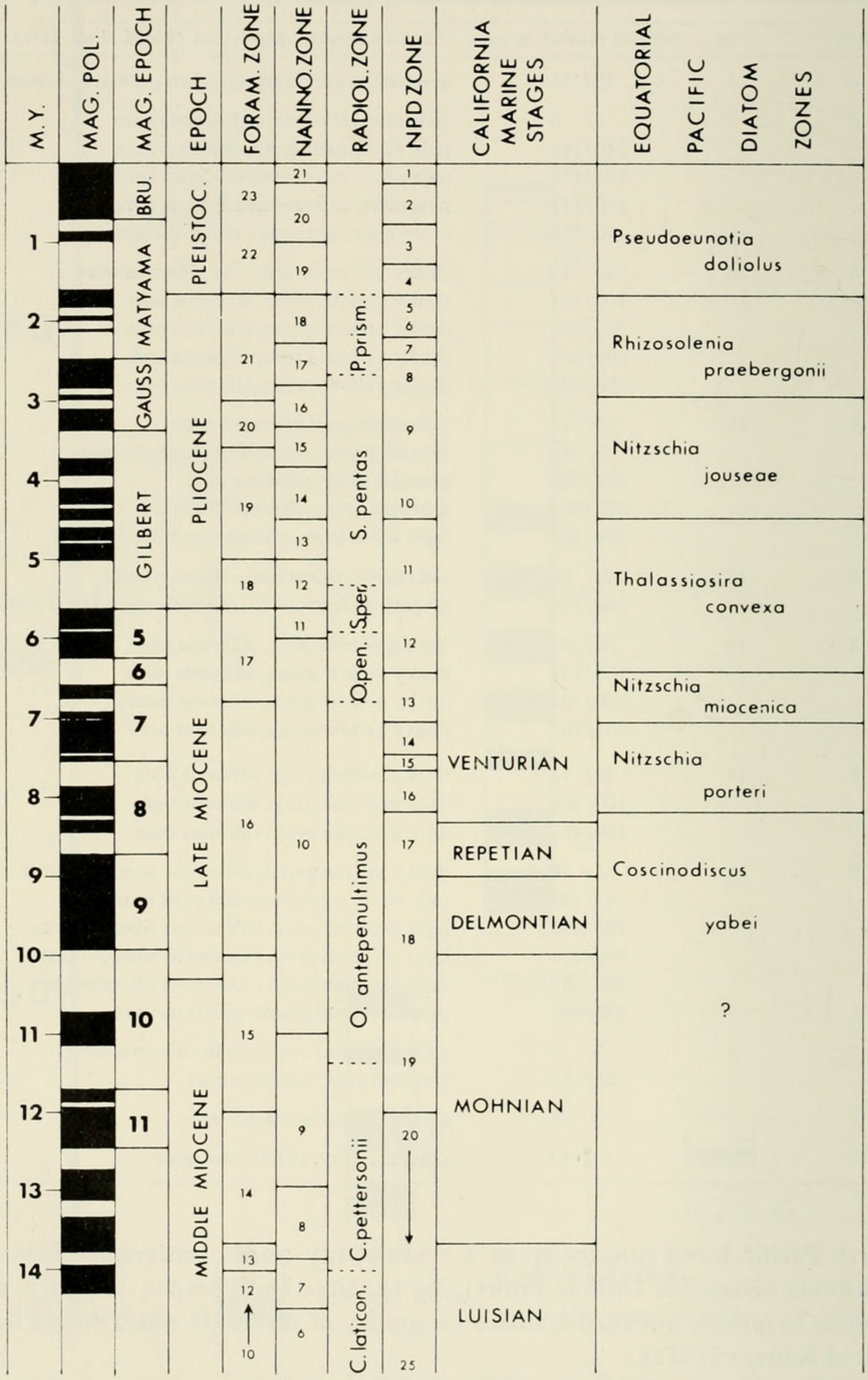
Chart 2. Core log, Experimental Mohole Drilling, Guadalupe Site. Black intervals: interval recovered.

Table 2. *Sample data for cores from the Experimental Mohole Drilling, Guadalupe Site. Sedimentological data from Riedel* et al. *(1961).*

Hole	Core	Sampled interval in cm.	Sedimentological observations (Riedel *et al.*, 1961)
6	2	30/ 31	greenish gray, clayey siliceous-calcareous ooze
8	9	5/ 6	pale olive, siliceous-calcareous ooze
		140/141	pale olive, calcareous-siliceous ooze
		193/194	pale olive, calcareous-siliceous ooze
		240/241	pale olive, calcareous-siliceous ooze
		290/291	olive-gray, siliceous-calcareous ooze
8	10	44/ 45	dusky yellow-green, silty siliceous ooze
		100/101	dusky yellow-green, siliceous ooze
		200/201	dusky yellow-green, siliceous ooze
		300/301	dusky yellow-green, siliceous ooze
		400/401	dusky yellow-green, siliceous ooze
8	11	30/ 31	yellowish gray, siliceous ooze
		90/ 91	grayish green, siliceous-calcareous ooze
		200/201	greenish gray, siliceous ooze
		300/301	greenish gray, siliceous ooze
		390/391	light olive-gray, calcareous-siliceous ooze
8	12	94/ 95	pale olive, calcareous-siliceous ooze
		203/204	grayish yellow-green, siliceous-calcareous ooze
8	13	30/ 31	dark greenish-gray, siliceous ooze
		100/101	dusky yellow green, siliceous ooze
		200/201	dusky yellow green, siliceous ooze
		262/265	dusky yellow green, siliceous ooze
8	14	10/ 11	dark greenish gray, siliceous ooze
		100/101	dark greenish gray, siliceous ooze
		400/401	dark greenish gray, siliceous ooze
8	15	35/ 36	dusky yellow green, siliceous-calcareous ooze
		93/ 95	pale olive, calcareous-siliceous ooze
		100/101	light greenish gray, calcareous siliceous ooze
		200/201	light greenish gray, calcareous siliceous ooze
		300/301	light greenish gray, calcareous siliceous ooze
		504/505	pale olive, calcareous-siliceous ooze
7	1	5/ 6	yellowish gray, calcareous-siliceous ooze
		41/ 42	greenish gray, siliceous ooze
7	2	0/ 17	greenish gray, siliceous ooze
10	1	30/ 43	greenish gray, calcareous ooze

North Pacific based principally on a continuously cored stratigraphic hole off California (Deep Sea Drilling Project, leg 18, Site 173, Schrader, 1973a) it was possible to prepare a revised diatom stratigraphy of the EMD which differs from that of Kanaya (1971).

NEOGENE CORRELATION



Methods

Samples from Lamont-Doherty Geological Observatory were taken by L. H. Burckle; samples of the EMD were taken by T. Walsh, and samples from DSDP Site 173 were made by the author.

Treatment of the diatom material and slide preparation followed the standardized methods of Schrader (MS.). Slides were mounted with Aroclor 4465 and key species were marked with a diamond microscopical specimen marker. All important species were photographed through a Leitz Orthoplan, Apo Oil 92 ×, 1.4 n.A. and 10 × Periplan ocular. Holotypes, paratypes, and some other duplicates are deposited at the Department of Geology, California Academy of Sciences. Other illustrated specimens are in the author's collection. Additional samples have been deposited at the Bundesanstalt für Bodenforschung, Hannover (L. Benda), and at the Friedrich Hustedt Arbeitsplatz für Diatomeenkunde, Bremerhaven (R. Simonsen).

Epochs and Age Boundaries

The Upper-Middle Miocene boundary is placed within Geomagnetic Epoch 11 following Burckle (1972). This boundary is shifted by Berggren (1972) to the upper part of Geomagnetic Epoch 10 (see chart 3).

The Miocene-Pliocene boundary is placed at the top of Geomagnetic Epoch 5 (bottom of the Reversed Gilbert Magnetic Epoch) (Burckle, 1972).

Other boundaries are defined by the range of species in the Equatorial Pacific (Burckle, 1972) and the North Pacific (Schrader, 1973a).

Most of the Equatorial and North Pacific Zones are defined by evolutionary events and morphotypic ranges of species (for definition of terms see Riedel and Sanfilippo, 1971).

Stratigraphic Distribution of Diatoms

The distribution of important planktonic diatom taxa is indicated in table 3. A great effort has been made to recognize and define reworked taxa. Ranges are plotted by symbols representing abundance and type of occurrence (allochthonous or autochthonous). Abundance and preservation was generally good

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Chart 3. Correlation of the North Pacific Diatom Zonation (Schrader, 1973a) with Californian Marine Stages (Berggren, 1972; Bandy and Ingle, 1970), the Equatorial Pacific Diatom Zonation (Burckle, 1972), the Radiolarian Zonation (Riedel and Sanfilippo, 1971; Moore, 1971; after Berggren, 1972), the Standard Calcareous Nannoplankton Zonation (Martini, 1971; Bramlette and Wilcoxon, 1967; Baumann and Roth, 1969; Martini and Worsley, 1970), the Planktonic Foraminiferal Zones (Blow, 1969; after Berggren, 1972), the Paleomagnetic Stratigraphy (Burckle, 1972; Abdel-Monem *et al.*, 1971), and the Radiometric Time Scale (Cox, 1969; Abdel-Monem *et al.*, 1971).

Table 3. *List of planktonic diatom species recovered from core samples of the Experimental Mohole Drilling, Guadalupe Site. Diatom species are tabulated using the following abbreviations: — not present; R—rare (only a few specimens per slide); F—frequent (more than 10 specimens per slide); C—common (more than 50 specimens per slide); A—abundant (mass occurrence of species); X—reworked older species.*

Total abundance of diatoms in each sample is tabulated as: A—abundant; C—common; R—rare.

Preservation of diatoms is tabulated as: G—good; M—moderate (etched and many broken frustules).

Experimental Mohole Drilling Guadalupe Site — DIATOMS (- = not present; R = rare; F = frequent; C = Common; A = abundant; X = reworked)	Actinocyclus okhotensis	" ehrenbergii	" ellipticus	" " var. moronensis	" cubitus	Asterolampra marylandica	Bruniopsis mirabilis	Cladogramma dubium	Coscinodiscus endoi	" lewisianus	" marginatus	" nodulifer	Cussia paleacea	" praepaleacea	Coscinodiscus temperei	" vetustissimus	" " var. javanicus	" symbolophorus	" antiquum	" yabei	Denticula dimorpha	" hustedtii	" hyalina var. hustedtii	" lauta	" nicobarica	" punctata var. hustedtii	Correlation with North Pacific Diatom Zonation, SCHRADER, JRDDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/ 31	R	R	R	-	-	-	-	R	R	-	R	R	-	-	-	R	-	-	-	-	-	F	-	X	X	-	10	
EM - 10 - 1 - 30/ 43	-	-	-	-	-	-	-	-	-	-	F	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	?	
EM - 8 - 9 - 5/ 6	R	R	R	-	-	R	R	R	-	-	F	-	-	-	R	R	-	R	-	-	-	-	A	-	-	-	10	
EM - 8 - 9 - 140/141	-	-	R	-	-	-	R	-	R	-	F	R	-	-	R	F	-	-	-	-	-	-	F	-	-	X		Nitzschia jouseae Partial Range Zone
EM - 8 - 9 - 193/194	-	R	-	-	-	R	R	R	R	-	R	R	-	-	R	R	-	R	-	-	-	-	A	-	-	-		
EM - 8 - 9 - 240/241	-	R	R	-	-	R	R	R	R	X	R	R	-	X	R	R	-	R	-	-	-	R	R	X	-	-		
EM - 8 - 9 - 290/291	-	R	R	-	-	-	R	R	R	-	R	-	X	X	R	R	-	R	-	X	-	R	R	X	-	X	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/ 45	-	-	R	-	-	-	R	R	R	-	R	R	X	X	R	R	-	R	-	X	X	A	F	X	-	-		
EM - 8 - 10 - 100/101	-	R	R	-	-	R	R	-	-	-	F	-	X	-	R	R	-	-	-	X	-	C	F	X	-	-	12	
EM - 8 - 10 - 200/201	-	R	R	-	-	-	R	R	R	-	C	-	X	-	R	R	-	-	-	-	-	C	F	-	-	-		
EM - 8 - 10 - 300/301	-	R	R	-	-	-	R	-	-	-	R	R	X	-	R	R	-	R	-	-	X	-	-	-	-	-		Nitzschia miocenica Partial Range Zone
EM - 8 - 10 - 400/401	-	R	R	-	-	-	R	R	R	-	C	-	X	-	R	R	-	R	-	-	-	-	-	-	-	-	13	
EM - 8 - 11 - 30/ 31	-	R	R	-	-	R	R	R	R	-	C	-	-	-	R	R	-	R	-	-	-	C	R	R	-	-		
EM - 8 - 11 - 90/ 91	-	R	R	-	-	-	R	-	-	-	C	-	-	-	-	R	-	R	-	-	-	F	R	R	-	-		
EM - 8 - 11 - 200/201	-	R	R	-	-	-	R	-	-	-	C	R	-	-	-	R	-	R	-	X	-	F	-	R	-	-		
EM - 8 - 11 - 300/301	-	R	R	-	-	R	R	R	R	-	R	R	-	-	-	R	-	R	-	-	R	F	-	R	X	-	14	
EM - 8 - 11 - 390/391	-	R	R	-	-	R	R	-	-	-	C	R	-	-	R	R	-	R	-	X	R	C	-	R	-	-		
EM - 8 - 12 - 94/ 95	-	R	R	-	-	R	R	-	-	-	C	-	-	-	-	R	-	R	-	-	-	C	-	R	-	-		
EM - 8 - 12 - 203/204	-	R	R	-	-	R	R	-	-	-	F	-	X	R	R	R	-	R	-	-	R	C	-	R	-	-	15	Nitzschia porteri Partial Range Zone
EM - 8 - 13 - 30/ 31	-	R	R	-	-	R	R	-	-	-	C	-	-	R	-	R	-	R	-	-	-	C	-	C	-	-		
EM - 8 - 13 - 100/101	-	R	R	-	-	-	R	-	-	-	R	-	-	-	-	R	-	R	-	-	R	C	-	R	-	R	16	
EM - 8 - 13 -262/265	-	R	-	-	-	-	R	-	-	-	F	-	-	-	-	R	-	R	-	R	-	C	-	R	-	F	17	
EM - 8 - 14 - 10/ 11	-	-	-	-	-	-	R	R	R	X	R	-	R	R	-	R	-	R	-	R	-	C	-	R	-	R		Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 100/101	-	-	-	-	-	-	R	-	-	X	R	-	R	R	-	R	-	-	-	R	R	C	-	C	-	R	18	
EM - 8 - 14 - 400/401	-	-	-	-	-	-	R	-	-	-	R	-	R	R	-	R	-	-	-	R	R	A	-	F	-	R		
EM - 8 - 15 - 35/ 36	-	R	R	-	-	-	F	-	-	-	F	-	R	R	-	R	-	-	-	R	-	C	-	R	-	F	19	
EM - 8 - 15 - 93/ 95	-	R	R	-	-	-	R	-	-	X	F	-	R	R	-	R	-	-	-	R	-	F	-	R	-	R		
EM - 8 - 15 - 100/101	-	R	R	-	R	R	R	R	R	-	F	-	R	R	-	R	-	-	-	R	-	C	-	R	R	F		
EM - 8 - 15 - 200/201	-	R	R	-	R	-	R	-	-	-	F	-	R	R	-	F	R	R	R	R	-	C	-	R	R	R	20	
EM - 8 - 15 - 300/301	-	F	R	R	R	R	R	-	-	-	F	R	R	R	-	R	R	-	R	R	-	C	-	R	R	R		
EM - 8 - 15 - 504/505	-	R	R	R	-	R	R	-	-	R	F	R	R	R	-	R	R	-	-	R	-	C	-	R	R	R	21	
EM - 7 - 1 - 5/ 6	-	-	-	R	-	-	R	R	R	F	F	-	R	R	-	R	-	R	-	R	-	C	-	-	F	-	22	
EM - 7 - 1 - 41/ 42	-	-	R	-	-	R	R	-	-	F	F	-	-	-	-	R	-	-	-	-	-	C	-	R	F	-	23	

TABLE 3. *Continued.*

Experimental Mohole Drilling Guadalupe Site

DIATOMS

- \- = not present
- R = rare
- F = frequent
- C = Common
- A = abundant
- X = reworked

Experimental Mohole Drilling Guadalupe Site	Ethmodiscus rex	Hemiaulus c.f. polymorphus	Hemidiscus cuneiformis	" simplicissimus	Lithodesmium californicum	" minusculum	Mediaria splendida	Macrora stella (non diatomaceae)	Nitzschia cylindrica	" jouseae	" praereinholdii	" seiboldia	" riedelia	" burcklia	" californica	Rhaphoneis angularis	" angustata	" sacchalinensis	" margaritalimbata	Rhizosolenia barboi	" hebetata var.	" miocenica	" praealata	" praebarboi	" styliformis	Correlation with North Pacific Diatom Zonation, SCHRADER, JRDDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/ 31	R	R	-	R	R	-	-	-	-	-	R	-	-	-	-	R	-	-	-	R	R	X	R	-	R	10	
EM - 10 - 1 - 30/ 43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	?	
EM - 8 - 9 - 5/ 6	R	R	R	-	-	R	-	-	-	R	R	-	-	-	-	-	-	-	-	F	-	-	R	-	R	10	
EM - 8 - 9 - 140/141	-	-	R	R	R	R	-	-	-	-	R	-	-	-	R	-	-	R	-	R	-	-	R	-	R		Nitzschia jouseae Partial Range Zone
EM - 8 - 9 - 193/194	-	R	R	R	-	R	-	-	R	R	R	-	X	R	-	-	-	-	-	R	-	-	-	-	R		
EM - 8 - 9 - 240/241	R	R	R	R	R	R	-	-	-	R	R	-	X	R	R	-	-	-	-	R	R	X	R	-	R		
EM - 8 - 9 - 290/291	R	R	R	R	R	R	-	-	R	-	R	-	-	-	R	-	-	-	-	-	-	X	-	X	R	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/ 45	R	R	R	R	R	-	-	-	R	-	R	-	X	-	-	-	R	-	-	F	-	X	R	-	R		
EM - 8 - 10 - 100/101	R	R	R	R	R	-	-	-	R	-	R	-	-	R	R	-	R	-	-	C	R	X	R	X	R	12	
EM - 8 - 10 - 200/201	-	R	R	R	R	R	-	-	R	-	R	-	-	-	R	-	R	-	-	R	-	-	-	-	R		
EM - 8 - 10 - 300/301	R	R	R	R	R	R	-	-	-	-	R	-	-	-	R	-	-	-	-	R	-	-	-	X	R		Nitzschia miocenica Partial Range Zone
EM - 8 - 10 - 400/401	R	R	R	R	R	R	-	-	-	-	-	-	-	-	-	-	R	-	-	C	R	-	-	-	R	13	
EM - 8 - 11 - 30/ 31	R	R	R	R	R	-	-	-	-	-	R	-	-	R	R	-	-	-	-	R	R	R	-	-	R		
EM - 8 - 11 - 90/ 91	R	R	R	R	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	F	R	R	-	-	R		
EM - 8 - 11 - 200/201	-	R	-	R	R	R	-	-	-	-	-	-	-	-	-	-	R	-	-	C	-	R	-	-	R		
EM - 8 - 11 - 300/301	R	R	-	R	R	R	-	-	-	-	R	-	X	-	-	R	-	-	-	R	R	-	R	-	R	14	
EM - 8 - 11 - 390/391	R	R	-	R	R	-	-	-	-	-	R	-	-	-	-	R	R	-	-	R	-	-	R	-	R		
EM - 8 - 12 - 94/ 95	R	R	-	R	R	-	-	-	-	-	R	-	-	R	-	-	R	-	R	R	-	-	-	-	R		Nitzschia porteri Partial Range Zone
EM - 8 - 12 - 203/204	R	R	-	R	R	-	-	-	-	-	R	R	-	R	-	-	R	-	R	F	R	R	-	R	R	15	
EM - 8 - 13 - 30/ 31	R	R	-	-	R	-	R	-	-	-	R	R	-	-	-	-	-	-	-	R	-	-	-	R	R		
EM - 8 - 13 - 100/101	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	-	16	
EM - 8 - 13 -262/265	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	R	R	-	R	R	17	
EM - 8 - 14 - 10/ 11	R	-	-	-	-	-	R	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	-		Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 100/101	R	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	-	R	R	18	
EM - 8 - 14 - 400/401	R	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	R	-	-	R	R		
EM - 8 - 15 - 35/ 36	R	R	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	F	R	19	
EM - 8 - 15 - 93/ 95	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	R	R		
EM - 8 - 15 - 100/101	-	R	-	-	-	-	R	-	-	-	-	R	R	-	-	-	R	-	-	-	-	R	-	R	R		
EM - 8 - 15 - 200/201	-	R	-	-	-	-	R	R	-	-	-	R	R	-	-	-	R	-	-	-	R	-	-	R	R	20	
EM - 8 - 15 - 300/301	-	R	-	-	-	-	R	R	-	-	-	R	R	-	-	-	R	-	-	-	R	R	-	R	R		
EM - 8 - 15 - 504/505	-	R	-	-	-	-	R	-	-	-	-	R	R	-	-	-	R	-	R	-	R	R	-	F	-	21	
EM - 7 - 1 - 5/ 6	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	-	R	22	
EM - 7 - 1 - 41/ 42	-	-	-	-	-	-	R	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	R	-	23	
EM - 7 - 2 - 0/ 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	24	

TABLE 3. *Continued.*

Experimental Mohole Drilling Guadalupe Site

DIATOMS: - = not present; R = rare; F = frequent; C = Common; A = abundant; X = reworked

Sample	Rouxia californica	" c.f. diploneides	Stephanopyxis turris	Synedra jouseana	Thalassionema nitzschioides	" claviformis	Thalassiosira convexa	" decipiens	" excentrica	" antiqua	" spec. A (BURCKLE)	" nativa	" praeconvexa	" oestrupii	" usatchevii	Thalassiothrix longissima	Triceratium condecorum	" cinnamomeum	Craspedodiscus coscinodiscus	Actinocyclus ingens	Abundance	Preservation	Sponge Spicules	Silt	Correlation with North Pacific Diatom Zonation, SCHRADER, JRDDP leg. 18	Correlation with the Equatorial Pacific Diatom Zonation BURCKLE (1972)
EM - 6 - 2 - 30/31	R	-	R	X	A	-	R	R	R	R	-	R	-	R	-	C	-	-	-	R	A	G	-	R	10	
EM - 10 - 1 - 30/43	-	-	R	-	C	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	R	G	-	-	?	
EM - 8 - 9 - 5/6	-	-	R	X	A	-	-	R	-	R	-	-	-	R	-	A	-	-	-	R	A	G	-	-	10	
EM - 8 - 9 - 140/141	R	-	R	X	A	-	-	R	R	-	-	R	-	-	-	A	-	R	-	C	A	G	-	-		Nitzschia jouseae Partial Range Zone
EM - 8 - 9 - 193/194	R	X	R	-	A	-	R	-	-	-	-	C	-	-	-	C	-	R	-	R	A	G	C	F		
EM - 8 - 9 - 240/241	R	X	R	X	A	-	R	R	R	-	-	R	-	-	R	C	-	-	-	R	A	G	R	F		
EM - 8 - 9 - 290/291	R	X	R	X	C	-	R	-	R	-	-	F	-	-	R	C	-	R	-	R	A	G	F	F	11	Thalassiosira convexa Partial Range Zone
EM - 8 - 10 - 44/45	C	-	R	-	C	-	R	R	-	-	-	R	-	-	R	A	R	R	-	R	A	G	-	-		
EM - 8 - 10 - 100/101	C	-	R	-	C	-	-	-	-	-	-	R	-	-	-	C	R	R	-	R	A	G	-	-	12	
EM - 8 - 10 - 200/201	R	-	R	-	C	-	-	-	R	-	-	-	-	-	-	C	-	-	-	R	C	G	C	F		
EM - 8 - 10 - 300/301	F	-	R	-	C	-	-	-	-	-	-	-	-	-	-	F	-	-	-	R	A	G	-	-		
EM - 8 - 10 - 400/401	-	-	R	-	C	-	-	-	-	-	-	-	-	-	-	C	-	-	-	R	A	G	-	-	13	Nitzschia miocenica Partial Range Zone
EM - 8 - 11 - 30/31	-	-	R	-	C	-	-	R	R	-	-	-	-	-	-	A	-	-	-	F	A	G	C	F		
EM - 8 - 11 - 90/91	-	-	R	-	C	-	-	R	R	-	-	R	-	-	-	A	R	R	-	F	A	G	R	C		
EM - 8 - 11 - 200/201	-	-	R	R	C	R	-	-	-	-	-	R	-	-	-	A	-	R	-	R	A	G	R	R		
EM - 8 - 11 - 300/301	-	R	R	R	C	R	-	-	R	-	-	R	-	-	-	C	-	R	-	R	A	G	-	-	14	
EM - 8 - 11 - 390/391	R	R	R	R	C	R	-	-	R	-	-	R	-	-	-	F	-	R	-	R	A	G	F	C		
EM - 8 - 12 - 94/95	-	-	R	R	C	-	-	-	-	-	-	R	-	-	?	A	-	R	-	F	A	G	-	-	15	
EM - 8 - 12 - 203/204	-	-	R	R	C	R	-	-	R	-	-	-	-	-	-	C	-	R	-	R	A	G	R	R		Nitzschia porteri Partial Range Zone
EM - 8 - 13 - 30/31	-	-	R	R	R	R	-	-	-	-	R	-	-	-	-	A	-	-	-	R	A	M	C	C		
EM - 8 - 13 - 100/101	-	-	R	-	C	-	-	-	-	-	-	-	-	-	-	A	-	-	-	R	A	M	C	C	16	
EM - 8 - 13 -262/265	-	-	R	-	C	R	-	-	-	-	R	-	-	-	-	C	-	-	-	F	A	G	C	C	17	
EM - 8 - 14 - 10/11	-	-	R	R	C	R	-	-	-	-	-	-	-	-	-	A	-	-	-	R	A	G	-	-		
EM - 8 - 14 - 100/101	-	-	R	R	C	R	-	-	-	-	-	-	-	-	-	A	-	-	-	R	A	G	-	-	18	Coscinodiscus yabei Partial Range Zone
EM - 8 - 14 - 400/401	-	-	R	-	R	F	-	-	-	-	-	-	-	-	-	A	-	-	R	F	A	G	-	-		
EM - 8 - 15 - 35/36	-	-	R	-	C	R	-	-	-	-	-	-	-	-	-	A	-	R	F	F	A	G	-	-	19	
EM - 8 - 15 - 93/95	-	R	R	R	C	-	-	-	-	-	-	-	-	-	-	C	-	-	F	R	A	G	-	-		
EM - 8 - 15 - 100/101	-	R	R	R	C	-	-	-	-	-	-	-	-	-	-	F	-	R	R	R	A	G	-	-		
EM - 8 - 15 - 200/201	-	-	R	R	A	-	-	-	-	-	-	-	-	-	-	C	-	-	R	F	A	G	-	-	20	
EM - 8 - 15 - 300/301	-	-	R	F	R	-	-	-	-	-	-	-	-	-	-	A	-	R	R	F	A	G	-	-		
EM - 8 - 15 - 504/505	-	-	R	R	C	-	-	-	-	-	-	-	-	-	-	A	-	-	R	F	A	G	-	-	21	
EM - 7 - 1 - 5/6	-	-	R	-	C	-	-	-	-	-	-	-	-	-	-	A	-	-	R	C	A	G	-	-	22	
EM - 7 - 1 - 41/42	-	-	R	F	C	-	-	-	-	-	-	-	-	-	-	A	-	-	R	C	A	G	-	-	23	
EM - 7 - 2 - 0/17	-	-	R	R	C	-	-	-	-	-	-	-	-	-	-	A	-	-	R	C	C	M	R	F	24	

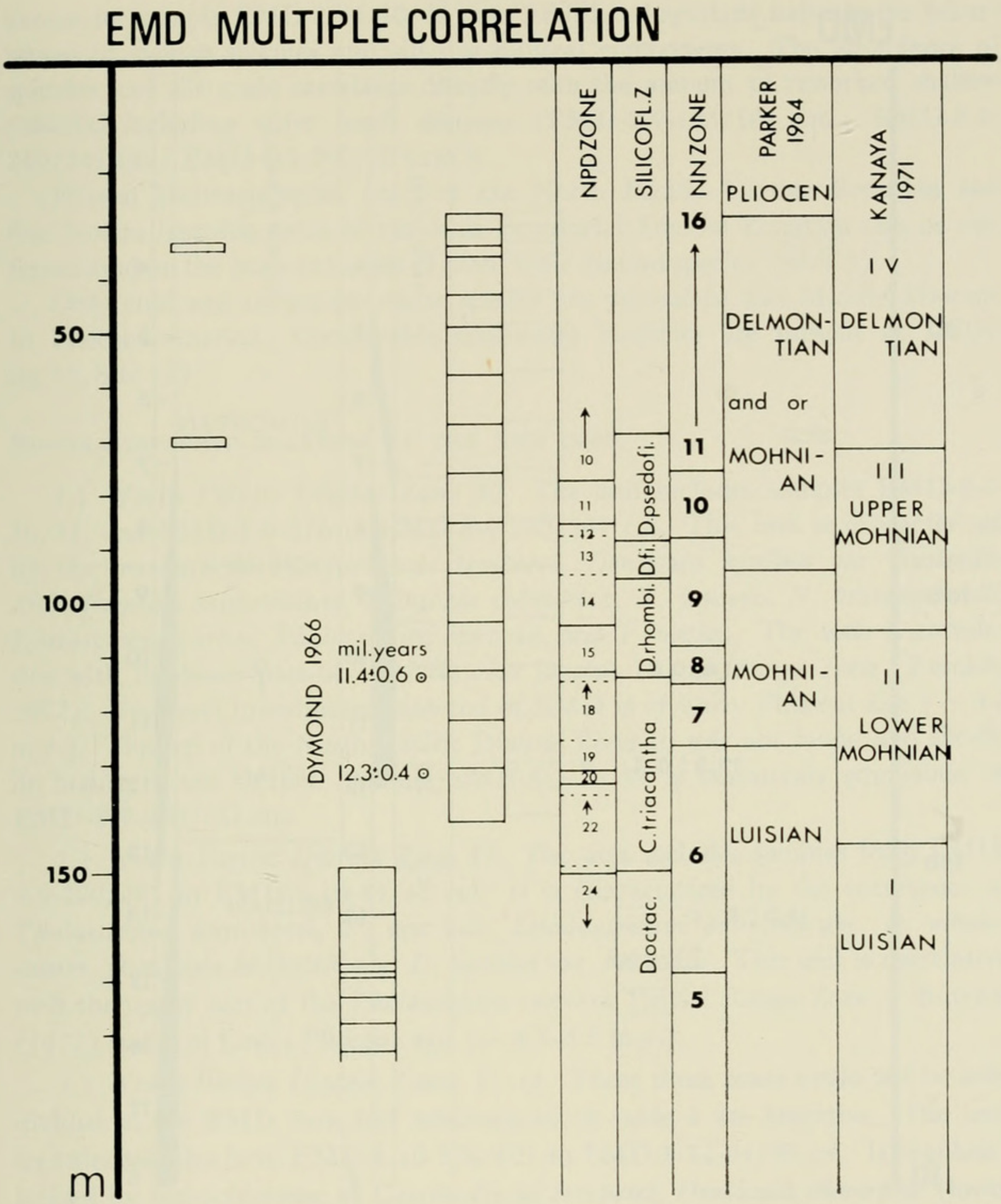


Chart 4. Multiple microplankton correlation of the Experimental Mohole Drilling, Guadalupe Site, with North Pacific Diatom Zonation (Schrader, 1973a), Silicoflagellate Zonation (Martini, 1972), Standard Calcareous Nannoplankton Zonation (Martini, 1971), and Californian Marine Stages (Parker, 1964; Kanaya, 1971). Potassium-Argon dates from Dymond (1966).

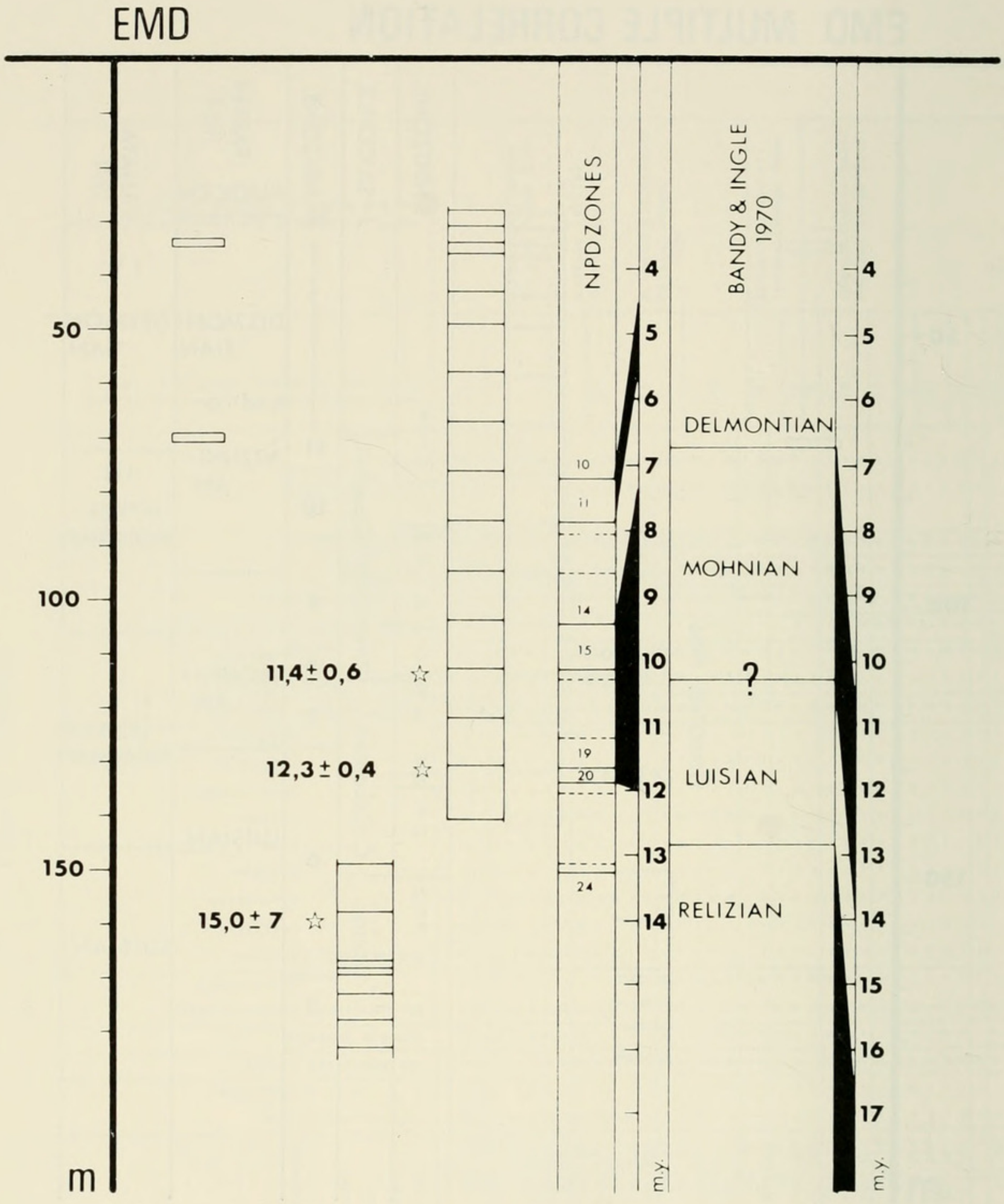


Chart 5. Correlation of the diatom zonation of the Experimental Mohole Drilling, Guadalupe Site, with the North Pacific Diatom Zonation (Schrader, 1973a) and with Californian Marine Foraminiferal Stages (Bandy and Ingle, 1970). Absolute time scale for the North Pacific Diatom Zonation from Schrader (1973a) and chart 4; dates for the Californian Marine Stages from Bandy and Ingle (1970). Potassium-Argon dates from Dymond (1966) and Krueger (1964).

except for sample EMD-10-1-30/43 cm. Additional symbols indicate the occurrences of sponge spicules and silt-size mineral components. The abundance of spicules and silt grain correlates directly with the amount of reworked shallow material including older fossil diatoms (EMD-8-9-193/194 cm.; EMD-8-9-240/241 cm.; EMD-8-9-290/291 cm.).

Fifteen biostratigraphic units of the North Pacific Diatom Zonation and five biostratigraphic units of the East-Equatorial Diatom Zonation can be differentiated on the basis of ranges of planktonic diatom species (table 3).

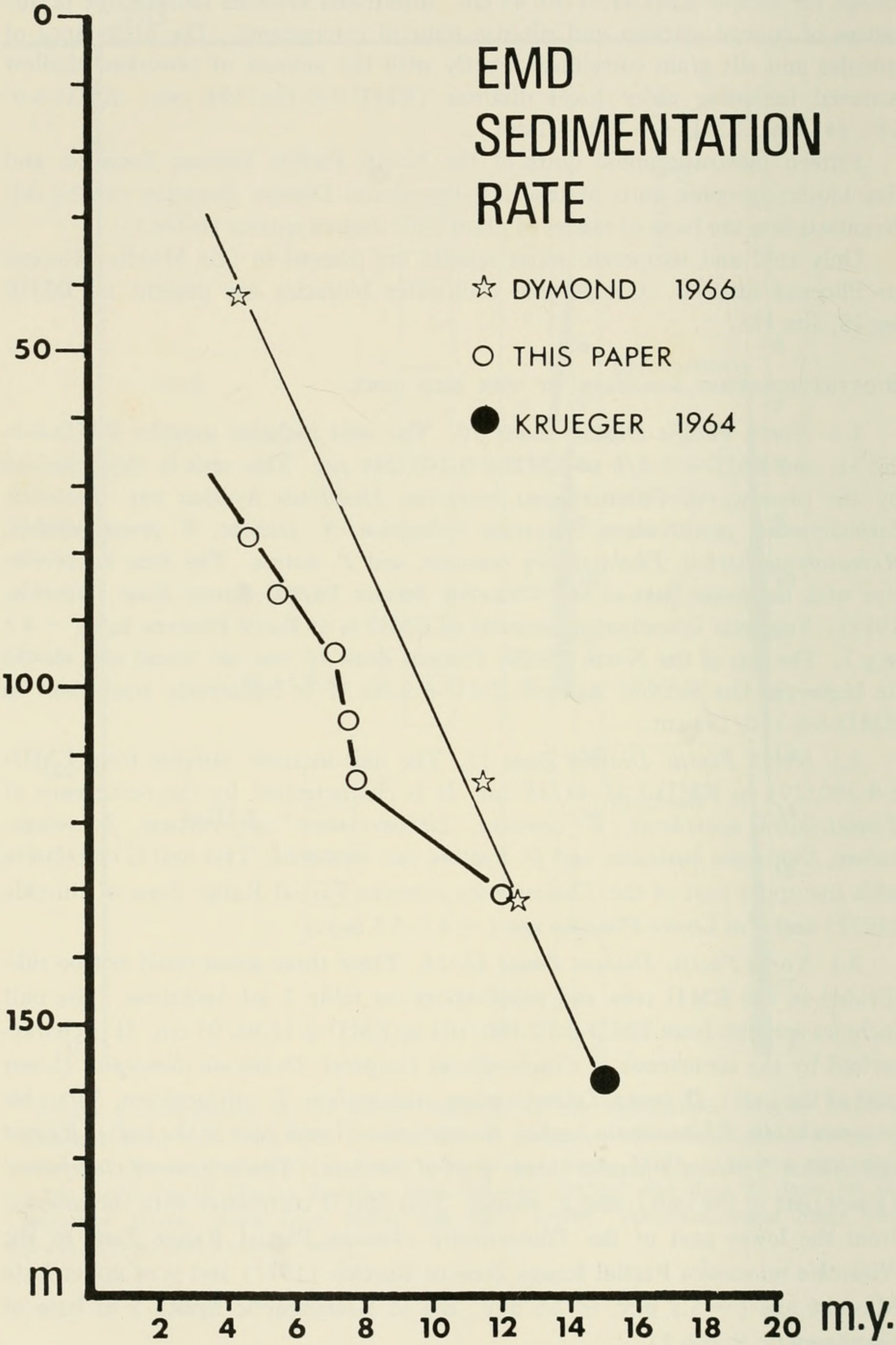
Only cold and temperate water species are present in this Middle Miocene to Pliocene interval. Comparable cool-water biofacies are present at DSDP leg 18, Site 173.

Biostratigraphic zonation of the EMD core.

1.) *North Pacific Diatom Zone 10.* The unit includes samples EMD-6-2-30/31, and EMD-8-9-5/6 to EMD-8-9-240/241 cm. This unit is characterized by the presence of *Coscinodiscus temperei, Denticula hyalina* var. *hustedtii, Lithodesmium minusculum, Nitzschia cylindrica, N. jouseae, N. praereinholdii, Rhizosolenia barboi, Thalassiosira convexa,* and *T. nativa.* The zone is correlative with the lower part of the *Nitzschia jouseae* Partial Range Zone (Burckle, 1972). Youngest investigated material of EMD is of Early Pliocene age (~ 4.2 m.y.). The top of the North Pacific Diatom Zone 10 was not found and should lie higher in the section. Sample EMD-6-2-30/31 is tentatively equivalent to EMD-8-9-140/141 cm.

2.) *North Pacific Diatom Zone 11.* The unit includes samples from EMD-8-9-290/291 to EMD-8-10-44/45 cm. It is characterized by the occurrence of *Thalassiosira usatchevii, T. convexa, Lithodesmium californicum, L. minusculum, Denticula hustedtii,* and *D. hyalina* var. *hustedtii.* This unit is correlative with the upper part of the *Thalassiosira convexa* Partial Range Zone of Burckle (1972) and is of Lower Pliocene age (~ 4.5–5.5 m.y.).

3.) *North Pacific Diatom Zones 12–14.* These three zones could not be subdivided in the EMD core and subdivisions on table 3 are tentative. The unit includes samples from EMD-8-10-100/101 to EMD-8-12-94/95 cm. It is characterized by the occurrence of *Coscinodiscus temperei, Denticula dimorpha* (lower part of the unit), *D. lauta, Lithodesmium minusculum, L. californicum, Nitzschia praereinholdii, Rhizosolenia barboi, R. miocenica* (lower part of the unit), *Rouxia californica, Synedra jouseana* (lower part of the unit), *Thalassionema claviformis* (lower part of the unit), and *T. nativa.* This unit is correlative with the interval from the lower part of the *Thalassiosira convexa* Partial Range Zone to the *Nitzschia miocenica* Partial Range Zone of Burckle (1972) and is of upper Late Miocene age (~ 5.5 m.y. to 7.6 m.y., top of Geomagnetic Epoch 5 to base of Geomagnetic Epoch 7).


EMD
SEDIMENTATION
RATE
☆ DYMOND 1966
○ THIS PAPER
● KRUEGER 1964
0
50
100
150
m
2
4
6
8
10
12
14
16
18
20
m.y.

4.) *North Pacific Diatom Zone 15.* The unit includes samples from EMD-8-12-203/204 to EMD-8-13-30/31 cm. It is characterized by the occurrence of *Cussia praepaleacea, Denticula dimorpha, D. hustedtii, D. lauta, Nitzschia praereinholdii, N. burcklia, Rhizosolenia barboi, R. miocenica, R. praebarboi, Synedra jouseana, Thalassionema claviformis,* and *T.* species A. (Burckle, 1972). This unit is correlative with the upper part of the *Nitzschia porteri* Partial Range Zone of Burckle (1972) and is of upper Late Miocene age (upper part of Geomagnetic Epoch 8; ~ 7.8 m.y.).

5.) *North Pacific Diatom Zone 16.* This unit was only present in sample EMD-8-13-100/101 cm. It differs from North Pacific Diatom Zone 15 in the lack of *Nitzschia praereinholdii* and of *Cussia paleacea,* and in the consistent presence of *Rhizosolenia praebarboi.* This zone is correlative with the lower part of the *Nitzschia porteri* Partial Range Zone of Burckle (1972) and is of middle Late Miocene age (~ 8.2 m.y.–middle part of Geomagnetic Epoch 8).

6.) *North Pacific Diatom Zones 17–19.* These zones could not be divided and subdivisions on table 3 are tentative. The unit includes samples EMD-8-13-262/265 to EMD-8-15-100/101 cm. It is characterized by the occurrence of *Bruniopsis mirabilis, Cussia paleacea, C. praepaleacea, Coscinodiscus yabei, Denticula dimorpha* (upper part of the unit), *D. hustedtii, D. lauta, D. punctata* var. *hustedtii, Mediaria splendida, Nitzschia burcklia* (upper part of the unit), *N. riedelia* (lower part of the unit), *Rhizosolenia miocenica, R. praebarboi, Synedra jouseana,* and *Craspedodiscus coscinodiscus* (lower part of the unit). This unit is correlative with the *Coscinodiscus yabei* Partial Range Zone of Burckle (1972), the base of which has not been defined. It ranges from the middle part of Geomagnetic Epoch 8 to the middle part of Geomagnetic Epoch 11 (~ 8.3 m.y. to 12 m.y.). The base of this unit represents the Late-Middle Miocene boundary as defined by Burckle (1972), but note should be made of the different boundary chosen by Berggren (1972) (chart 3).

7.) *North Pacific Diatom Zone 20.* The unit includes samples from EMD-8-15-200/201 to EMD-8-15-300/301 cm. It is characterized by the occurrence of *Actinocyclus cubitus, Cussia paleacea, C. praepaleacea, Coscinodiscus vetustissimus* var. *javanicus, C. antiquum, C. yabei, Denticula hustedtii, D. lauta, D. nicobarica, D. punctata* var. *hustedtii, Mediaria splendida, Macrora stella, Nitzschia* species 2 (Schrader), *N. riedelia, Rhizosolenia praebarboi, Synedra jouseana,* and *Craspedodiscus coscinodiscus.* This unit has not been correlated to paleomagnetic stratigraphy, but it does correlate with NN 6 of the Standard Calcareous Nannoplankton Zonation (Martini, 1971), and with the *Corbisema triacantha* Zone of the Silicoflagellate Zonation (Martini, 1972). This Zone is of

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Chart 6. Sedimentation rate of the core samples from the Experimental Mohole Drilling, Guadalupe Site, as determined by Potassium-Argon dates (Dymond, 1966) and by diatom zonation. Note change of sedimentation rate at 95 meters below the sea floor.

upper Middle Miocene age. Dymond (1966) determined the absolute age of sample EMD-8-15-86 cm. as 12.3 ± 0.4 m.y. according to the Potassium-Argon dating method. This age correlates well with the top of Zone 20 of the North Pacific Diatom Zonation which has an approximate age of 12 m.y.

8.) *North Pacific Diatom Zones 21–23.* These zones could not be divided precisely and the subdivisions on table 3 are tentative. The unit includes samples from EMD-8-15-504/505 cm. to EMD-7-2-41/42 cm. It is characterized by the occurrence of *Actinocyclus ellipticus* var. *moronensis*, *Coscinodiscus lewisianus*, *Cussia paleacea*, *C. praepaleacea*, *Coscinodiscus yabei*, *Denticula hustedtii*, *D. lauta*, *D. nicobarica*, *Mediaria splendida*, *Nitzschia riedelia*, *N.* species 2 (Schrader), and *Rhizosolenia praebarboi.* The unit has not been correlated to paleomagnetic stratigraphy, but it is correlative with NN 6 of the Standard Nannoplankton Zonation (Martini, 1971), and is of Middle Miocene age.

9.) *North Pacific Diatom Zone 24.* This unit was found at EMD-7-2-0/17 cm. and is distinguished from the upper unit by the absence of *Bruniopsis mirabilis*, *Denticula hustedtii*, *Mediaria splendida*, *Nitzschia riedelia*, and other species. The unit has not been correlated to paleomagnetic stratigraphy, but it is correlative with NN 6 of the Standard Nannoplankton Zonation (Martini, 1971) and with the *Dictyocha octacantha* Silicoflagellate Zone of Martini (1972). It is of Middle Miocene age.

SPECIES FOUND IN EXPERIMENTAL MOHOLE DRILLING SAMPLES

Genera are arranged alphabetically in the list, and species are arranged alphabetically within each genus.

Species and varieties have been identified following descriptions of Hustedt (1930, 1959), Sheshukova-Poretzkaya (1967), Schrader (1973a), and Hanna (1926, 1930, 1932).

Descriptions and discussions are given for species not adequately treated in the literature.

Species which could not be positively assigned to a known species are numbered (if only one or two individuals were found) or described as new and illustrated.

Holotypes and paratypes will be deposited in the California Academy of Sciences diatom collection.

Genus **Actinocyclus** Ehrenberg

Actinocyclus cubitus Hanna and Grant.

DESCRIPTION. Hanna and Grant, 1926, p. 118, pl. 11, fig. 3.

Actinocyclus ehrenbergi Ralfs.

DESCRIPTION. Hustedt, 1930, pp. 525–532, numerous figures.
REMARKS. No subdivisions of this species have been made.

Table 4. *List of samples and corresponding Department of Geology catalog numbers, California Academy of Sciences, San Francisco. A split of the cleaned fraction of each sample is stored at the California Academy of Sciences.*

Sample Number	CAS Number
EMD-6-2-30/31	54427
EMD-10-1-30/43	54428
EMD-8-9-5/6	54429
EMD-8-9-140/141	54430
EMD-8-9-193/194	54431
EMD-8-9-240/241	54432
EMD-8-9-290/291	54433
EMD-8-10-44/45	54434
EMD-8-10-100/101	54435
EMD-8-10-200/201	54436
EMD-8-10-300/301	54437
EMD-8-10-400/401	54438
EMD-8-11-30/31	54439
EMD-8-11-90/91	54440
EMD-8-11-200/201	54441
EMD-8-11-300/301	54442
EMD-8-11-390/391	54443
EMD-8-12-94/95	54444
EMD-8-12-203/204	54445
EMD-8-13-30/31	54446
EMD-8-13-100/101	54447
EMD-8-13-262/265	54448
EMD-8-14-10/11	54449
EMD-8-14-100/101	54450
EMD-8-14-400/401	54451
EMD-8-15-35/36	54452
EMD-8-15-93/95	54453
EMD-8-15-100/101	54454
EMD-8-15-200/201	54455
EMD-8-15-300/301	54456
EMD-8-15-504/505	54457
EMD-7-1-5/6	54458
EMD-7-1-41/42	54459
EMD-7-2-0/17	54460

Actinocyclus ellipticus Grunow.

Description. Hustedt, 1930, p. 533, fig. 303.

Actinocyclus ellipticus var. **moronensis** (Deby) Kolbe.

Description. Kolbe, 1954, p. 21, pl. 3, figs. 29–30.

Actinocyclus ingens Rattray.

Description. Kanaya, 1971, p. 554, numerous figures.

Actinocyclus okhotensis Jouse.

Description. Koizumi, 1968, p. 208, pl. 32, figs. 7–10; Donahue, 1970, p. 135, pl. 2, figs. 2–5.

Genus **Asterolampra** Ehrenberg

Asterolampra grevillei (Wallich) Greville.

Description. Hustedt, 1930, pp. 489–491, fig. 274.

Asterolampra marylandica Ehrenberg.

Description. Hustedt, 1930, pp. 485–487, fig. 271.

Genus **Biddulphia** Gray

Biddulphia moholensis Schrader, new species.

Description. Valve lanceolate-rhombic with produced bluntly rounded apices, 60 μ long, 16 μ in the middle part, 4 μ wide at the apices. Valve with radially arranged rows of punctae, 15 in 10 μ; punctae in quincunx. Middle part slightly lifted from the valve surface with three spines and without any central area. Valves with stronger solitary spines on both sides of the median apical line near the valve mantle and with two to three solitary spines at both apices near the valve mantle.

Discussion. No similar species was found mentioned in the literature. This species was placed within the genus *Biddulphia* because of the shape of the valve and the arrangement of the spines.

Holotype. Figure 4: 3–4, from EMD-8-9-290/291 cm. California Academy of Sciences, Department of Geology no. 54409 (diatom collection).

Derivation of name. This species is named 'moholensis' in memory of the Experimental Mohole Drilling.

Occurrence. Found only in the Neogene section off Baja California, in a sample in North Pacific Diatom Zone 11.

Genus **Bruniopsis** (Tempere) Karsten

Bruniopsis mirabilis (Brun) Karsten.

Description. Kolbe, 1954, p. 24, pl. 4, fig. 44; Kanaya, 1971, p. 555.

Genus **Cladogramma** Ehrenberg

Cladogramma dubium Lohmann.

Description. Lohmann, 1948, p. 168, pl. 9, fig. 5; Sheshukova-Poretzkaya, 1967, p. 192, pl. 24, fig. 6, pl. 29, fig. 4.

Genus **Coscinodiscus** Ehrenberg

Coscinodiscus antiquus (Grunow) Rattray.

DESCRIPTION. Grunow, 1884, p. 84, pl. 4 (D), fig. 24.

Coscinodiscus moholensis Schrader, new species.

DESCRIPTION. Valve circular, 38 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae on the concave plication are round, on the convex plication they are polygonal, radially arranged in a complete meshwork over the valve surface. Areolae 6–7 in 10 μ, of about the same size all over the valve. Areolae forming fascicles. Margin clearly defined with a secondary plication forming triangulate uplifted areas 5 μ wide. On top of each of these areas is one elongated areola. Margin well defined and separated from the valve structure by a small hyaline area. Margin 1–2 μ wide, chambered, radially striated.

DISCUSSION. This species differs from all other species of the *Coscinodiscus plicatus* group in the formation of the triangulate uplifted marginal areas. No reference to such a form was found in the literature.

DERIVATION OF NAME. Dedicated to the memory of the Experimental Mohole Drilling.

HOLOTYPE. Figure 3: 3–5 from EMD-8-13-100/101 cm. California Academy of Sciences, Department of Geology no. 54410 (diatom collection).

OCCURRENCE. Found in the Neogene Section off Baja California, from a sample in North Pacific Diatom Zone 16.

Coscinodiscus endoi Kanaya.

(Figure 3: 11–12.)

DESCRIPTION. Kanaya, 1959, pp. 76–77, pl. 3, figs. 8–11; Koizumi, 1968, p. 211, pl. 32, figs. 21–22.

Coscinodiscus lewisianus Greville.

DESCRIPTION. Kanaya, 1971, p. 555, pl. 40.5, figs. 4–6.

Coscinodiscus marginatus Ehrenberg.

DESCRIPTION. Hustedt, 1930, pp. 416–418, fig. 223.

DISCUSSION. No attempt has been made here to subdivide *C. marginatus* and *C. marginatus* var. *fossilis* Jouse.

Coscinodiscus nodulifer A. Schmidt.

DESCRIPTION. Hustedt, 1930, pp. 426–427, fig. 229.

Coscinodiscus plicatus Grunow.

DESCRIPTION. Grunow, 1884, p. 86, pl. 3, figs. 10, 27; Kolbe, 1954, pp. 34–35 (no illustration); Schrader, 1973a, p. 703, pl. 6, fig. 23.

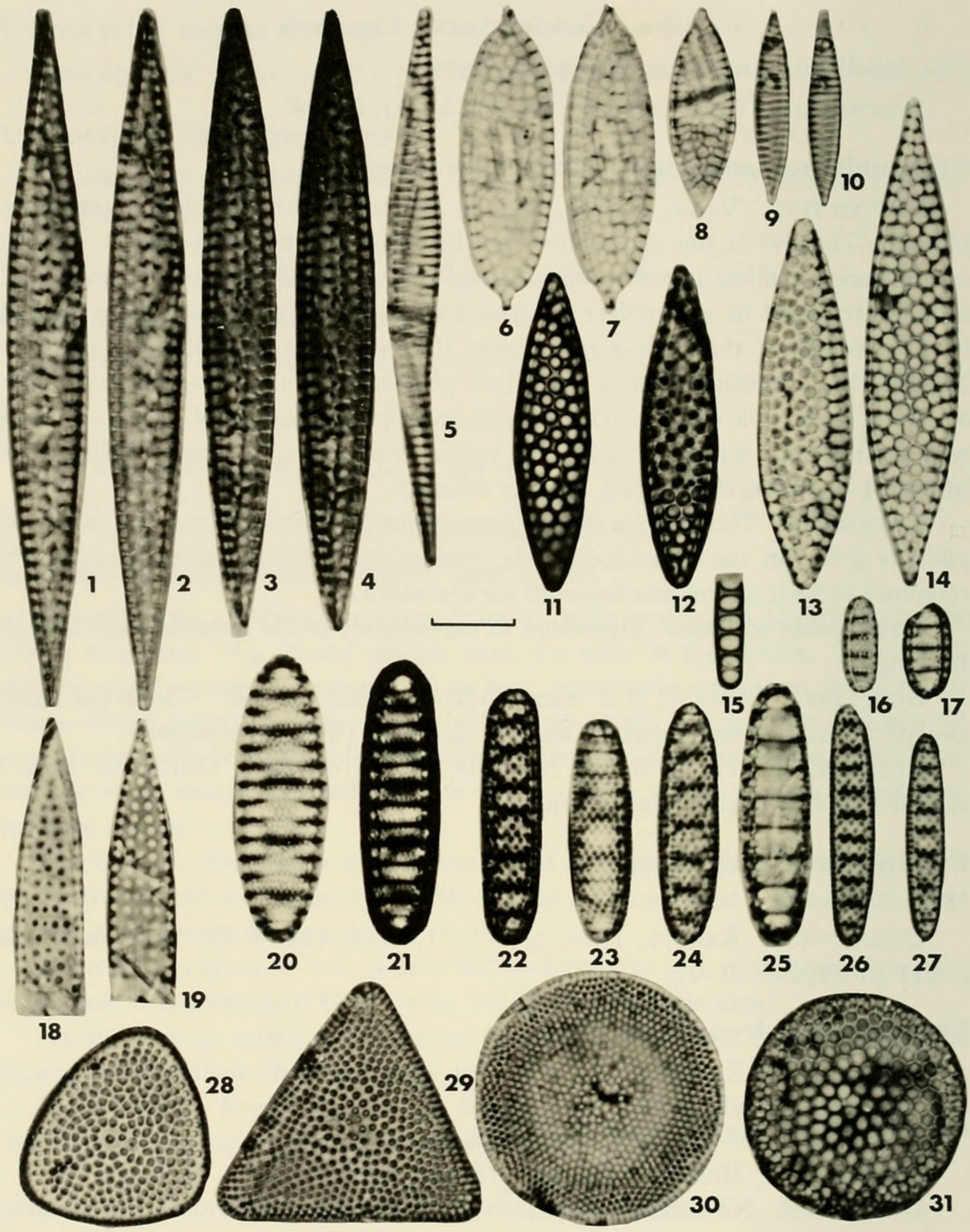

Figure 1. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-10-100/101 cm. *Cussia moholensis* Schrader, new species; 2. EMD-8-10-100/101 cm. *C. moholensis*, California Academy of Sciences, Department of Geology no. 54414; 3. EMD-8-9-290/291 cm., *C. moholensis* (type); 4. EMD-8-9-290/291 cm., *C. moholensis*, California Academy of Sciences, Department of Geology no. 54413; 5. EMD-8-15-100/101 cm., *C. lancettula* Schrader, new species, California Academy of Sciences, Department of Geology no. 54112; 6. EMD-8-11-300/301 cm., *C. tatsunokuchiensis* (Koizumi), new combination; 7. EMD-8-11-300/301 cm., *C. tatsunokuchiensis*; 8. EMD-7-1-5/6 cm., *C. praepaleacea* (Schrader), new combination; 9. EMD-8-15-100/101 cm., *C. lancettula* (type); 10. EMD-8-

Coscinodiscus symbolophorus Grunow.
(Figure 1: 30.)

DESCRIPTION. Hustedt, 1930, pp. 396–398, fig. 208 (as *Coscinodiscus stellaris* var. *symbolophora* (Grunow) Jörgensen); Schrader, 1973a, p. 703, pl. 22, figs. 8–9.

Coscinodiscus temperei Brun.
(Figure 2: 29–33.)

DESCRIPTION. Kanaya, 1959, p. 84, pl. 4, fig. 8.

DISCUSSION. See Schrader, 1973a, p. 704.

Coscinodiscus vetustissimus Pantocsek.

DESCRIPTION. Hustedt, 1930, p. 412, fig. 220.

Coscinodiscus vetustissimus var. **javanicus** Reinhold.

DESCRIPTION. Reinhold, 1937, p. 102, pl. 8, figs. 7–8; Kanaya, 1971, p. 555, pl. 40.2, fig. 1.

Coscinodiscus yabei Kanaya.
(Figure 3: 6–8.)

DESCRIPTION. Kanaya, 1959, pp. 86–87, pl. 5, figs. 5–9; Schrader, 1973a, p. 704, pl. 6, figs. 1–6.

Coscinodiscus species 1 Schrader.

DESCRIPTION. Valve circular, 24 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round, arranged in radial rows forming a complete network over the entire valve. Areolae 8 in 10 μ and of the same size all over the valve surface. Secondary spiral structure of areolae well developed, interrupted by the axis of the plica-

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15-100/101 cm., *C. lancettula*, California Academy of Sciences, Department of Geology no. 54411; 11. EMD-8-15-93/94 cm., *C. paleacea* (Grunow), new combination; 12. EMD-8-15-93/94 cm., *C. paleacea*; 13. EMD-8-15-504/505 cm., *C. paleacea*; 14. EMD-8-15-504/505 cm., *C. paleacea*; 15. EMD-8-9-240/241 cm., *Denticula dimorpha* Schrader; 16. EMD-8-15-504/505 cm., *D. lauta* Bailey; 17. EMD-8-9-516 cm., *D. lauta*; 18. EMD-8-10-100/101 cm., *Cussia* species 1 Schrader; 19. EMD-8-10-100/101 cm., *Cussia* species 1 Schrader; 20. EMD-8-9-140/141 cm., *Denticula hustedtii* Simonsen and Kanaya; 21. EMD-8-9-140/141 cm., *D. hustedtii*; 22. EMD-8-15-93/94 cm., *D. punctata* var. *hustedtii* Schrader; 23. EMD-8-15-504/505 cm., *D. punctata* var. *hustedtii*; 24. EMD-8-9-140/141 cm., *D. punctata* var. *hustedtii*; 25. EMD-7-2-0/17 cm., *D. hyalina* Schrader; 26. EMD-7-2-0/17 cm., *D. nicobarica* Grunow; 27. EMD-7-1-5/6 cm., *D. nicobarica*; 28. EMD-8-15-300/301 cm., *Triceratium antiquum* Pantocsek; 29. EMD-8-15-35/36 cm., *T. cinnamomeum* Greville; 30. EMD-8-15-200/201 cm., *Coscinodiscus symbolophorus* Grunow; 31. EMD-8-11-30/31 cm., *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko.

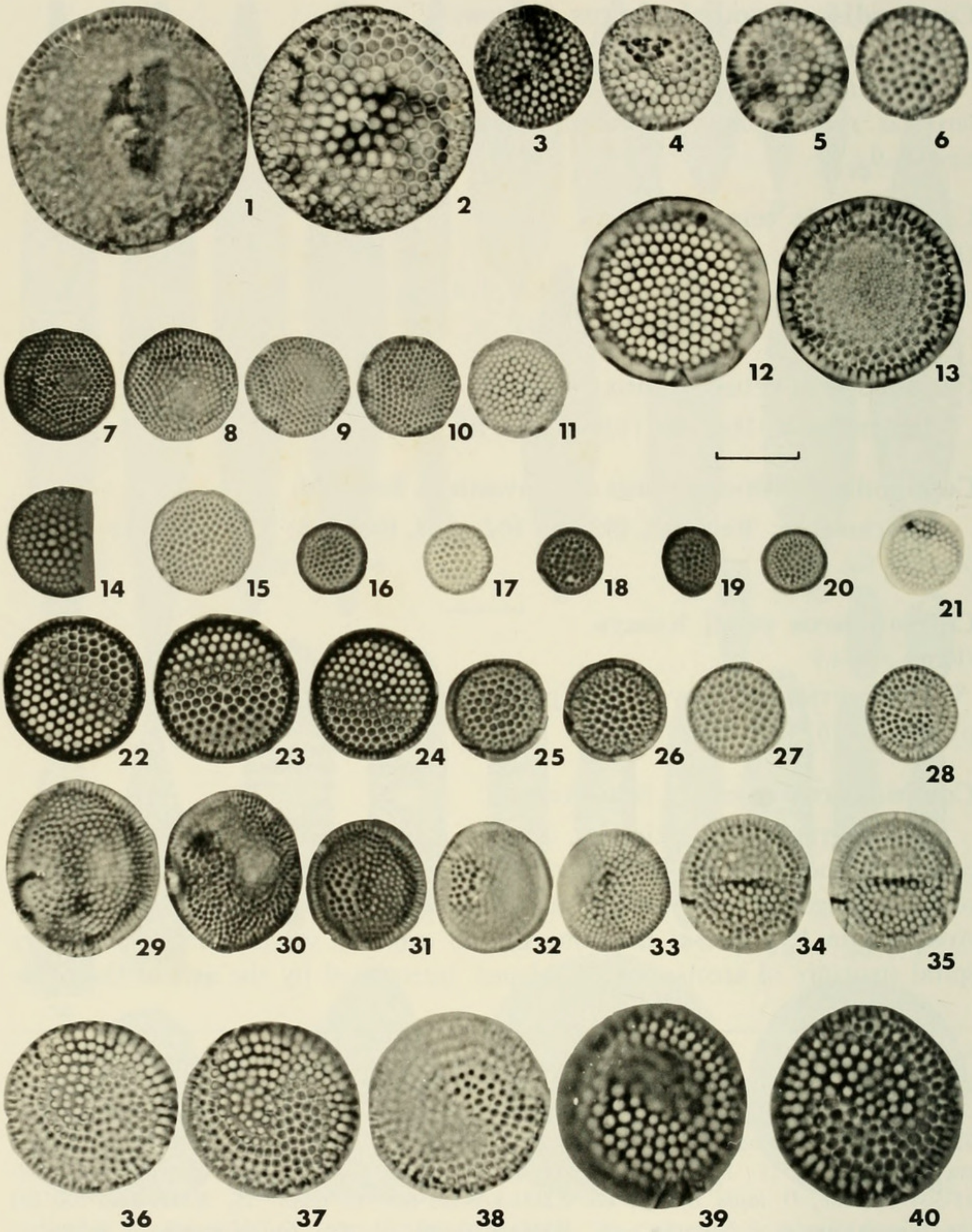

Figure 2. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-11-30/31 cm., *Thalassiosira oestruppi* (Ostenfeld) Proshkina-Lavrenko; 2. EMD-8-11-30/31 cm., *T. oestruppi*; 3. RC-12-65-1915/1917.5 cm., *T.* species A. Burckle; 4. EMD-8-13-30/31 cm., *T.* species A. Burckle; 5. EMD-8-9-140/141 cm., *T. convexa* Mukhina; 6. EMD-8-9-240/241 cm., *T. convexa* Mukhina; 7. RC-12-65-1105/1107.5 cm., *T. praeconvexa* Burckle; 8. RC-12-65-1105/1107.5 cm., *T. praeconvexa*; 9. EMD-8-10-44/45 cm., *T. praeconvexa*; 10. EMD-8-10-44/45 cm., *T. praeconvexa*; 11. EMD-8-9-240/241 cm., *T. nativa* Sheshukova-Poretzkaya; 12. EMD-8-9-140/141 cm., *T. nativa*; 13. EMD-8-9-

tion. Margin clearly defined, not separated from the meshwork, 2–2.5 μ wide, radially striated.

DISCUSSION. This species differs from *C. yabei* Kanaya in the round areolae, and in the striated valve margin. It is close to *Coscinodiscus flexuosus* Brun but differs in the nonseparated valve margin, and the nonchambered margin (see Schrader, 1973a, p. 702). Only one specimen was observed.

FIGURED SPECIMEN. Figure 4: 13–14 from EMD-8-9-290/291 cm., a sample from North Pacific Diatom Zone 11.

Coscinodiscus species 2 Schrader.

DESCRIPTION. Valve circular, 15–16 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round on the concave plication, polygonal on the convex plication, arranged in radial rows, forming a complete network over the entire valve. Areolae decreasing in size slightly towards the margin, approximately 11 in 10 μ. Secondary spiral structure of the areolae well developed. Margin clearly defined, not separated from the meshwork, 2 μ wide, radially striated, 16 in 10 μ, margin not chambered.

DISCUSSION. This species is close to the above mentioned species but differs in the finer structure and the more finely striated margin. No similar species have been found in the literature. Only one specimen was observed.

FIGURED SPECIMEN. Figure 2: 34–35 from EMD-8-9-193/194 cm., a sample belonging to North Pacific Diatom Zone 10.

Coscinodiscus species 3 Schrader.

DESCRIPTION. Valve circular, 21–22 μ in diameter, surface with a tangential plication, concave on one side, convex on the other. Central area absent. Areolae round on the concave plication, polygonal on the convex plication; areolae decreasing in size slightly towards the margin, 10 in 10 μ, arranged in radial rows, forming a complete network over the entire valve. Secondary radial rows present

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140/141 cm., *T. nativa*; 14. EMD-8-9-193/194 cm., *T. nativa*; 15. EMD-8-9-240/241 cm., *T. nativa*; 16. EMD-8-9-5/6 cm., *T. nativa*; 17. EMD-8-11-300/301 cm., *T. nativa*; 18. EMD-8-9-193/194 cm., *T. nativa*; 19. EMD-8-9-193/194 cm., *T. nativa*; 20. EMD-8-9-193/194 cm., *T. nativa*; 21. EMD-8-11-390/391 cm., *T. nativa*; 22. EMD-8-9-390/391 cm., *T.* species 2 Schrader; 23. EMD-8-9-390/391 cm., *T.* species 2; 24. EMD-8-9-390/391 cm., *T.* species 2; 25. EMD-8-9-5/6 cm., *T. nativa* Sheshukova-Poretzkaya; 26. EMD-8-9-5/6 cm., *T. nativa*; 27. EMD-8-9-193/194 cm., *T.* species 2 Schrader; 28. EMD-8-15-504/505 cm., *T.* species 2; 29. EMD-8-9-5/6 cm., *Coscinodiscus temperei* Brun; 30. EMD-8-9-5/6 cm., *C. temperei*; 31. EMD-8-9-5/6 cm., *C. temperei*; 32. EMD-8-10-44/45 cm., *C. temperei*; 33. EMD-8-10-44/45 cm., *C. temperei*; 34. EMD-8-9-193/194 cm., *C.* species 2 Schrader; 35. EMD-8-9-193/194 cm., *C.* species 2; 36. EMD-7-2-0/17 cm., *C.* species 3 Schrader; 37. EMD-7-2-0/17 cm., *C.* species 3; 38. EMD-7-2-0/17 cm., *C.* species 3; 39. EMD-8-9-290/291 cm., *C. yabei* Kanaya; 40. EMD-8-9-290/291 cm., *C. yabei.*

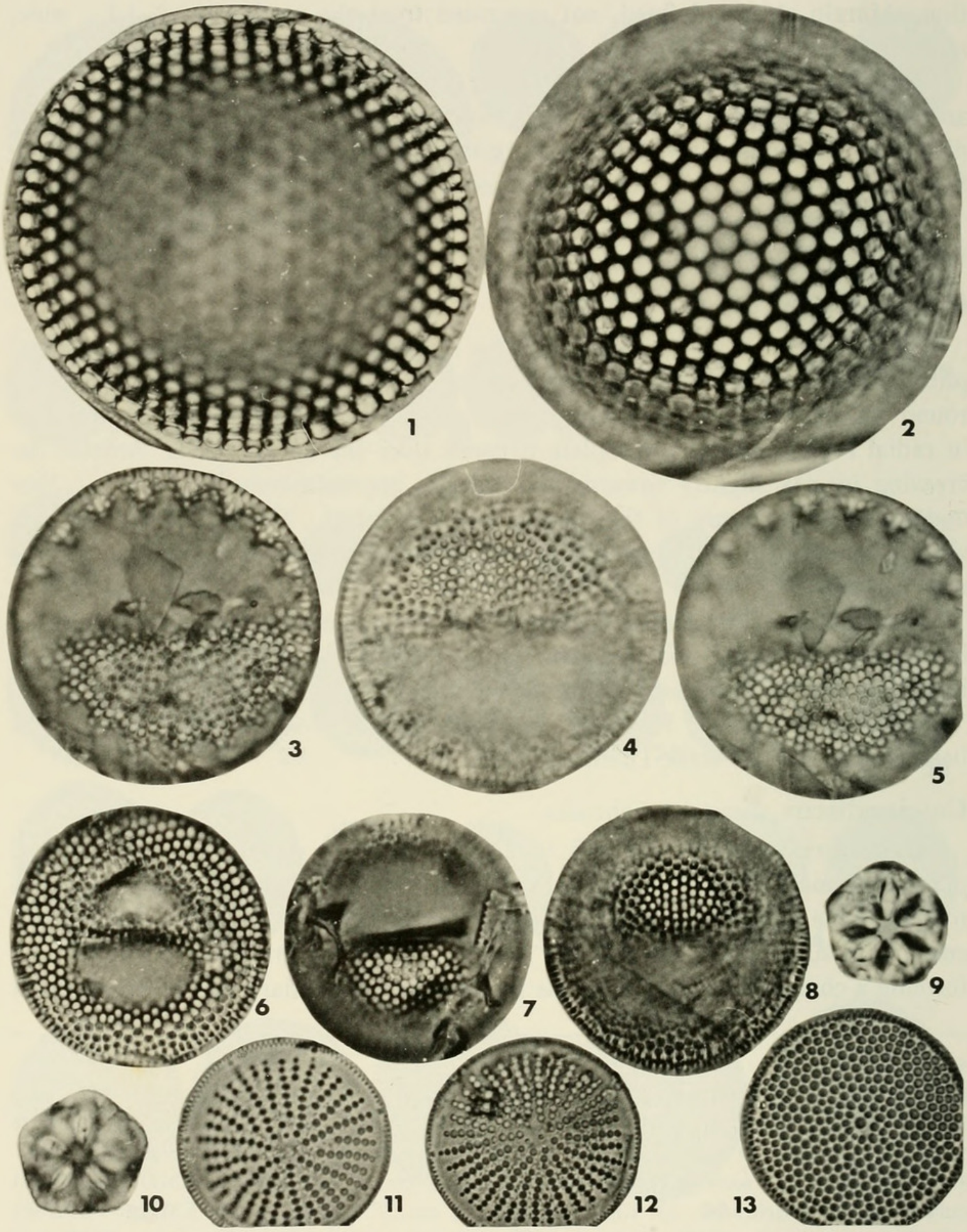

Figure 3. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-12-94/95 cm., *Thalassiosira usatchevii* Jouse; 2. EMD-8-12-94/95 cm., *T. usatchevii;* 3. EMD-8-13-100/101 cm., *Coscinodiscus moholensis* Schrader, new species; 4. EMD-8-13-100/101 cm., *C. moholensis*; 5. EMD-8-13-100/101 cm., *C. moholensis*; California Academy of Sciences, Department of Geology no. 54410; 6. RC-12-65-2142.5/2145 cm., *Coscinodiscus yabei* Kanaya; 7. RC-12-65-2142.5/2145 cm., *C. yabei*; 8. RC-12-65-2142.5/2145 cm., *C. yabei*; 9. EMD-7-1-5/6 cm., *Liostephania* species 1 Schrader; 10. EMD-7-1-5/6 cm., *L.* species 1; 11. EMD-8-9-140/141 cm., *Coscinodiscus endoi* Kanaya; 12. EMD-8-9-140/141 cm., *C. endoi*; 13. EMD-8-15-504/505 cm., *C. vetustissimus* Pantocsek.

with an interstitial mesh. Secondary spiral structure of the areolae well developed. Margin clearly defined, not separated from the meshwork, radially striated 12 in 10 μ. Margin chambered with two areolae between each chamber.

Discussion. This species is close to *Coscinodiscus flexuosus* Brun but differs in the absence of a hyaline area between the valve structure and the marginal structure. Final taxonomic decision can only be made if more individuals are found. Only one specimen was observed.

Figured specimen. Figure 2: 36–38 from EMD-7-2-0/17 cm., a sample from North Pacific Diatom Zone 24.

Genus **Craspedodiscus** Ehrenberg

Craspedodiscus coscinodiscus Ehrenberg.

Description. Kolbe, 1954, p. 36, pl. 1, fig. 4; Kanaya, 1971, p. 555, pl. 40.4, figs. 1–3.

Genus **Cussia** Schrader, new genus

Coscinodiscus e.p. Rattray, 1890, p. 597, fig. 149.
Stoschia (?) e.p. Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.
Coscinodiscus e.p. Schrader, 1973a. (*C. paleaceus*, *C. praepaleaceus*).
Rhaphoneis e.p. Hajos, 1968, p. 143, pl. XLI, figs. 16–27.
Rhaphoneis e.p. Koizumi, 1972, p. 349, pl. 42, figs. 3–4.

Description. Cells solitary, free. Valves elliptical-lanceolate with a symmetrical and/or asymmetrical transapical axis, flat. Valve surface usually either with round areolae or with transapical costae forming a pennate-like surface ornamentation with a zigzag apical costa forming a pseudoraphe-like morphological band; in between the costae are hyaline intercostal membranes. Valve center not furnished with a central area. Spines or apiculi absent. Valve margin usually narrow with a coarse striation.

Type species. *Stoschia* (?) *paleacea* Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.

Distribution. Widely distributed in Neogene marine sediments (Mediterranean Sea and Pacific, Atlantic, and Indian oceans).

Discussion. *Stoschia* Janisch was not validly published by Janisch, but the description was distributed to diatomists privately by the author (Janisch, C.: The diatoms of the "Gazelle" Expedition, 17 plates with manuscript index, no date). Rattray, 1890, p. 548, combined *Stoschia* with *Coscinodiscus* and combined the species *Stoschia admirabilis* Janisch (circa 1888) with *Coscinodiscus reniformis* Castracane (1886, p. 160, pl. 12, fig. 12). Grunow (1883 *in* Van Heurck) established the species *Stoschia paleacea*; this species was newly combined by Rattray (1890, p. 597, fig. 149) and named *Coscinodiscus paleaceus* (Grunow) Rattray. As soon as the evolution of the genus under discussion was clarified, the taxonomic position of some other species could be detected which have been described under *Rhaphoneis* by Hajos (1968) and Koizumi (1972).

Derivation of name. Dedicated to the scientific vessel *Cuss I*, which drilled the Experimental Mohole Drilling.

Cussia lancettula Schrader, new species.

Description. Valves elliptical-lanceolate with acute rounded ends. 24–70 μ long, 4–7 μ wide. Transapical axis symmetrical. Valve surface flat with transapical costae, 10–12 in 10 μ, slightly curved near the apices. Transapical costae not divided in the middle part, divided and in decussate arrangement towards the apices, connected in the middle by an apical zigzag line which simulates a pseudoraphe. Intercostal membranes homogenous even in oblique light. Margin not separated from the valve structure.

Discussion. This species differs from *Cussia praepaleacea* in that the margin is not separated, and the transapical structure is simple.

Derivation of name. From the Latin word 'lancea' meaning 'lance.'

Holotype. Figure 1: 9–10 from EMD-8-15-100/101 cm., a sample from North Pacific Diatom Zone 19. California Academy of Sciences, Department of Geology no. 54411 (diatom collection).

Paratype. Figure 1: 5. California Academy of Sciences, Department of Geology no. 54412 (diatom collection).

Cussia mediopunctata (Hajos), new combination.

Raphoneis mediopunctata Hajos, 1968, p. 143, pl. XLI, figs. 16–27.

Discussion. The illustrations of Hajos verify this new combination. The girdle view is most characteristic, as are the other mentioned morphological features. Unfortunately the micrographs do not show clearly if as stated "in der Längsmittellinie der Schalen zieht sich eine Punktreihe." This species is close to *Cussia moholensis* but differs in the presence of round areolae.

Cussia mediopunctata var. **matraensis** (Hajos), new combination.

Raphoneis mediopunctata var. *matraensis* Hajos, 1968, p. 144, pl. XLII, figs. 1–5.

Cussia moholensis Schrader, new species.

Description. Valves elliptical-lanceolate with acute apices, 76–85 μ long, 9–10 μ wide. Transapical axis symmetrical. Valve surface flat with marginal transapical costae 7 in 10 μ and extending 2–3 μ into the valve surface. In between the marginal transapical costae are round areolae. Valve surface with scattered, sometimes transapically orientated costae, which form a pseudoraphe-like medium apical zigzag line. Intercostal membranes homogenous even in oblique light.

Discussion. This species differs from *Cussia lancettula* in having scattered medium costae and wider valves.

Derivation of name. Dedicated to the memory of the Experimental Mohole Drilling.

HOLOTYPE. Figure 1: 3–4 from EMD-8-9-290/291 cm., a sample from North Pacific Diatom Zone 11. California Academy of Sciences, Department of Geology no. 54413 (diatom collection).

PARATYPE. Figure 1: 1–2. California Academy of Sciences, Department of Geology no. 54414 (diatom collection).

Cussia paleacea (Grunow), new combination.

(Figure 1: 11–14.)

Stoschia paleacea GRUNOW *in* Van Heurck, 1883, pl. 128, fig. 6.
Coscinodiscus paleaceus (Grunow) RATTRAY, 1890, p. 597, fig. 149.
Coscinodiscus paleaceus (Grunow) RATTRAY, *in* Schrader, 1973a, p. 703, pl. 3, figs. 10–12.

DESCRIPTION. Kolbe, 1954, p. 34, pl. 3, fig. 32.

Cussia praepaleacea (Schrader), new combination.

(Figure 1: 8.)

Coscinodiscus praepaleaceus SCHRADER, 1973a, p. 703, pl. 3, figs. 1–9.

DESCRIPTION. Schrader, 1973a, p. 703, pl. 3, figs. 1–9.

Cussia tatsunokuchiensis (Koizumi), new combination.

(Figure 1: 6–7.)

Raphoneis tatsunokuchiensis KOIZUMI, 1972, p. 349, pl. 42, figs. 3–4.

DESCRIPTION. Koizumi, 1972, p. 349, pl. 42, figs. 3–4.

Cussia species 1 Schrader.

DISCUSSION. Only two fragments were found with coarsely punctated transapical lines, 7 in 10 μ, the punctae forming straight-apical lines. Middle structure separated from the marginal line of punctae by a hyaline area parallel to the margin. No mention of similar species has been found in the literature.

FIGURED SPECIMEN. Figure 1: 18–19.

Genus **Denticula** Kützing

Denticula dimorpha Schrader.

(Figure 1: 15.)

DESCRIPTION. Schrader, 1973a, p. 704, pl. 1, fig. 42.

Denticula hustedtii Simonsen and Kanaya.

(Figure 1: 20–21.)

DESCRIPTION. Simonsen and Kanaya, 1961, p. 501, pl. 1, figs. 19–25, pl. 2, figs. 36–47.

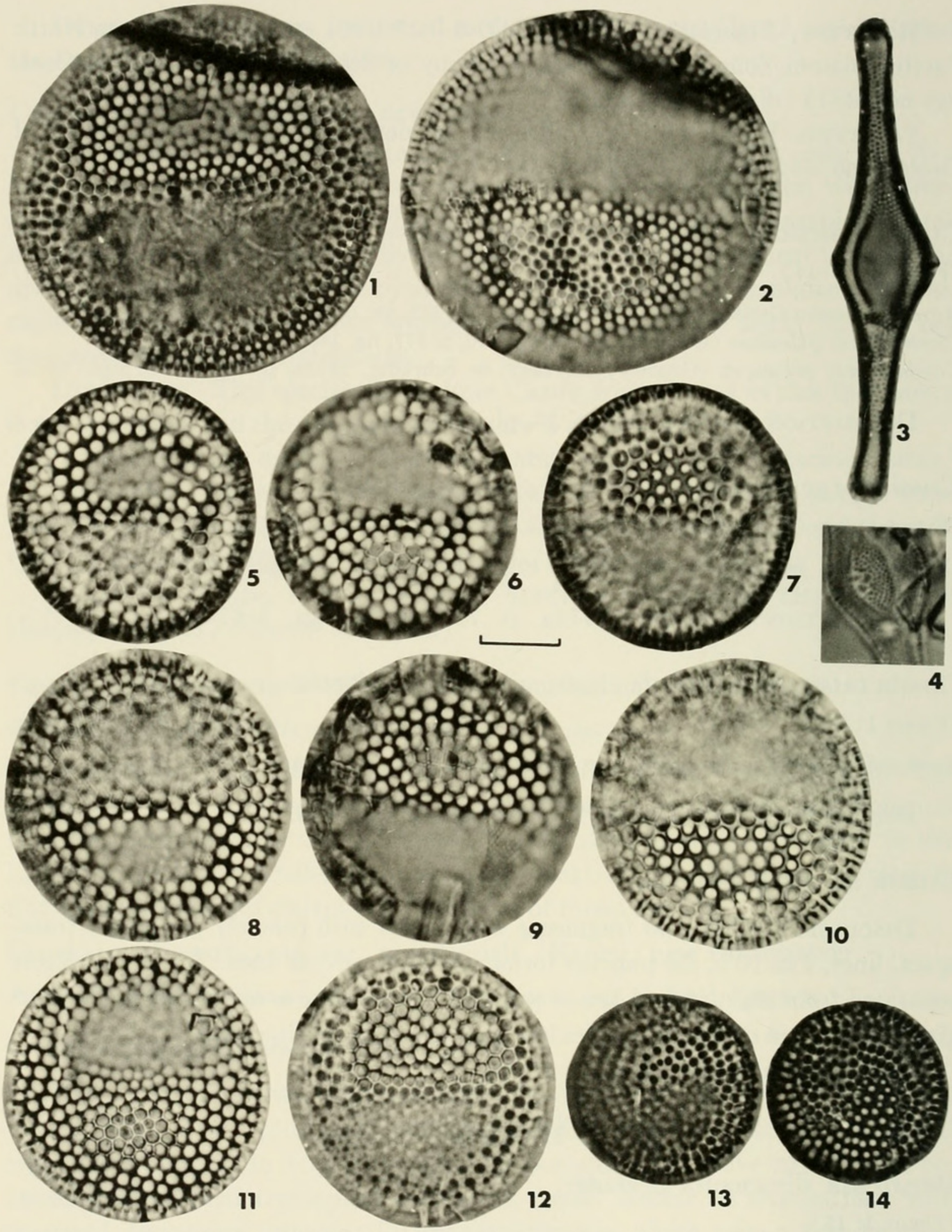

Figure 4. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-9-290/291 cm., *Coscinodiscus plicatus* Grun; 2. EMD-8-9-290/291 cm., *C. plicatus*; 3. EMD-8-9-290/291 cm., *Biddulphia moholensis* Schrader, new species; 4. EMD-8-9-290/291 cm., *B. moholensis,* California Academy of Sciences, Department of Geology no. 54409; 5. EMD-8-10-100/101 cm., *Coscinodiscus yabei* Kanaya; 6. EMD-8-10-100/101 cm., *C. yabei*; 7. EMD-8-10-100/101 cm., *C. yabei*; 8. EMD-8-10-100/101 cm., *C. yabei*; 9. EMD-8-10-100/101 cm., *C. yabei*; 10. EMD-8-10-100/101 cm., *C. yabei*; 11. EMD-8-10-300/301 cm., *C. plicatus* Grunow; 12. EMD-8-10-300/301 cm., *C. plicatus*; 13. EMD-8-9-290/291 cm., *C.* species 1 Schrader; 14. EMD-8-9-290/291 cm., *C.* species 1.

Denticula hyalina Schrader.
(Figure 1: 25.)

Description. Schrader, 1973a, pp. 704–705, pl. 1, figs. 12–20, 22.

Denticula hyalina var. **hustedtii** Schrader.

Description. Schrader, 1973b, p. 418, pl. 1, fig. 9.

Denticula lauta Bailey.
(Figure 1: 16–17.)

Description. Simonsen and Kanaya, 1961, pp. 500–501, pl. 1, figs. 1–8.

Denticula nicobarica Grunow.
(Figure 1: 26–27.)

Description. Simonsen and Kanaya, 1961, p. 503, pl. 1, figs. 11–13.

Denticula punctata Schrader.

Description. Schrader, 1973a, p. 705, pl. 1, figs. 27–28, 25–26.

Denticula punctata var. **hustedtii** Schrader.
(Figure 1: 22–24.)

Description. Schrader, 1973a, p. 705, pl. 1, figs. 23–24.

Genus **Ethmodiscus** Castracane

Ethmodiscus rex (Rattray) Hendey.

Description. Hendey, 1953, pp. 51–57, pl. 1, figs. 1–6, pl. 2, figs. 1–3.

Genus **Hemiaulus** Ehrenberg

Hemiaulus cf. **H. polymorphus** Grunow.

Description. Hustedt, 1930, pp. 880–881, figs. 525–526.

Discussion. The specimens which are tentatively identified here as *Hemiaulus polymorphus* differ from the original description in the lack of pseudoseptae.

Genus **Hemidiscus** Wallich

Hemidiscus cuneiformis Wallich.

Description. Hustedt, 1930, pp. 904–907, fig. 542.

Hemidiscus simplicissimus Hanna and Grant.

Description. Hanna and Grant, 1926, p. 147, pl. 16, fig. 13; Schrader, 1973a, p. 706, pl. 24, figs. 12–13.

Genus **Liostephania** Ehrenberg

Liostephania species 1 Schrader.

DISCUSSION. Flat silicified disks belonging to this genus were found occasionally with a moderately well preserved diatom association. Hanna and Brigger (1970) pointed out that these disks are silicified remains of inner chambers of either *Asterolampra* or *Asteromphalus*.

FIGURED SPECIMEN. Figure 3: 9–10.

Genus **Lithodesmium** Ehrenberg

Lithodesmium californicum Grunow.

DESCRIPTION. Schrader, 1973a, p. 706, pl. 12, figs. 11, 20.

Lithodesmium minusculum Grunow.

DESCRIPTION. Schrader, 1973a, p. 706, pl. 12, fig. 7.

Genus **Macrora** Hanna (not a diatom genus, taxonomic position uncertain)

Macrora stella (Azpeitia) Hanna.

DESCRIPTION. Hanna, 1932, p. 196, pl. 12, fig. 7.

Genus **Mediaria** Sheshukova-Poretzkaya

Mediaria splendida Sheshukova-Poretzkaya.

DESCRIPTION. Sheshukova-Poretzkaya, 1967, p. 306, pl. 47, fig. 14, pl. 48, fig. 8.

Genus **Melosira** Agardh

Melosira sulcata (Ehrenberg) Kützing.

DESCRIPTION. Hustedt, 1930, pp. 276–278, figs. 118–120.

Genus **Nitzschia** Hassal

Nitzschia californica Schrader.

DESCRIPTION. Schrader, 1973a, p. 707, pl. 26, fig. 6; pl. 5, fig. 15.

Nitzschia cylindrica Burckle.
(Figure 5: 23–30.)

DESCRIPTION. Burckle, 1972, pp. 239–240, pl. 2, figs. 1–6.

Nitzschia burcklia Schrader, new species.

DESCRIPTION. Valve elliptical with slightly convex margins and broadly rounded apices. 30–33 μ long, 5 μ wide. Transapical costae 11–12 in 10 μ. In between the middle two costae one 'secondary' costa is inserted which is small and derives at the central nodule. Intercostal membranes hyaline, even in oblique light. Transapical costae and intercostal membranes straight in transapical direction, reaching the well developed apical field. Apical field with 2–3 apical costae. Keel well developed, keel punctae 11 in 10 μ. Central nodule present, raphe marginal.

DISCUSSION. This species differs from the allied species *N. riedelia, N. rolandii, N. kanayensis* in the presence of the 'secondary transapical costae' in the middle of the valves.

DERIVATION OF NAME. Dedicated to Dr. Lloyd Burckle of Lamont-Doherty Geological Observatory, New York.

HOLOTYPE. Figure 6: 29 from EMD-8-9-240/241 cm., a sample from North Pacific Diatom Zone 10. California Academy of Sciences, Department of Geology no. 54415 (diatom collection).

PARATYPE. Figure 6: 30. California Academy of Sciences, Department of Geology no. 54416 (diatom collection).

Nitzschia cf. **N. heteropolica** Schrader.

(Figure 5: 42.)

DESCRIPTION. Schrader, 1973a, p. 707, pl. 26, figs. 1–2.

DISCUSSION. Only one fragment was found in the EMD samples and thus a positive identification could not be made.

Nitzschia invisa Schrader.

(Figure 6: 31.)

DESCRIPTION. Schrader, 1973a, p. 707, pl. 26, fig. 5.

Nitzschia jouseae Burckle.

DESCRIPTION. Burckle, 1972, p. 240, pl. 2, figs. 17–21.

Nitzschia kanayensis Schrader, new species.

DESCRIPTION. Valves elliptical with slightly convex margins, 18–25 μ long, 4–4.5 μ wide, apices broadly rounded. Transapical costae 13–16 in 10 μ, straight transapical in the middle part of the valve, slightly convex towards the apices. Apical field well developed with 2–3 apical costae. Intercostal membranes hyaline even in oblique light. Raphe marginal, keel indistinct; keel punctae hardly visible, about 17 in 10 μ (compare fig. 6: 28).

DISCUSSION. This species is close to *Nitzschia rolandii* and *N. riedelia* but differs in the finer structure and the apical fields.

DERIVATION OF NAME. Dedicated to Dr. Taro Kanaya.

HOLOTYPE. Figure 6: 23 from EMD-8-15-200/201 cm., a sample from North

Pacific Diatom Zone 20. California Academy of Sciences, Department of Geology no. 54417 (diatom collection).

Paratypes. Figure 6: 25, 28. California Academy of Sciences, Department of Geology nos. 54418, 54426 (diatom collection).

Occurrence. Found only in the Neogene section off Baja California and at DSDP Site 173.

Nitzschia miocenica Burckle.

(Figure 5: 17–22.)

Description. Burckle, 1972, pp. 240–241, pl. 2, figs. 10–15.

Nitzschia moholensis Schrader, new species.

Description. Valves elliptical with convex margins and slightly capitate apices. Apices heteromorph. 26 μ long, 5 μ wide in the middle. Transapical costae 10 in 10 μ, straight in transapical direction in the middle of the valves, slightly curved towards the apices. Intercostal membranes with two rows of punctae (20 in 10 μ), punctae in decussate arrangement 10 in 10 μ. Raphe marginal, central nodule absent, keel indistinct; keel punctae about 10 in 10 μ.

Discussion. No similar species has been found mentioned in the literature.

Derivation of name. Dedicated to the memory of the Experimental Mohole Drilling.

Holotype. Figure 6: 10–11 from EMD-8-11-300/301 cm., a sample from North Pacific Diatom Zone 14. California Academy of Sciences, Department of Geology no. 54419 (diatom collection).

Occurrence. Found only in the Neogene section of Baja California.

Nitzschia porteri Burckle non Frenguelli.

(Figure 5: 31–32.)

Description. Burckle, 1972, no description, pl. 2, fig. 16.

Discussion. Frenguelli, 1949, p. 116, pl. 1, fig. 33–34 described a species with "elongato-ovalibus" valves and "striis transversis delicatis, 12–13 in 10 μ." Burckle's figured specimen has elliptical valves with parallel margins and distinct transapical intercostal membranes with one row of punctae and transapical costae which form a slight angle with the transapical direction. I have not yet changed the name because of lack of the original Frenguelli material from Tiltil y Mejillones.

Nitzschia praereinholdii Schrader.

(Figure 6: 1–9, 13–15.)

Description. Schrader, 1973a, p. 708, pl. 5, figs. 24–25, 20, 23, 26.

Nitzschia cf. **N. praereinholdii** Schrader.

(Figure 6: 16–19.)

DESCRIPTION. Schrader, 1973a, p. 708, pl. 5, figs. 20, 23–26.

DISCUSSION. Specimens (from EMD-8-9-240/241 cm.) have been placed doubtfully in *N. praereinholdii* because they possess bent raphe bars near the apices similar to *Nitzschia marina* Grunow.

Nitzschia riedelia Schrader, new species.

DESCRIPTION. Valves elliptical with slightly convex margins and broadly rounded apices, 22–30 μ long, 5–6 μ wide in the middle of the valves. Transapical costae straight in transapical direction in the middle part of the valve, curved near the apices, 11–13 in 10 μ in the middle becoming closer near the apices, approximately 15 in 10 μ. Intercostal membranes hyaline even in oblique light. Apical field not developed. Raphe marginal, central nodule absent, keel distinct, about 15 keel-punctae in 10 μ.

DISCUSSION. This species is close to *N. burcklia* but differs in the absence of apical fields and a central nodule. It is close to *N. rolandii* but differs in having finer transapical costae, no central nodule, and hyaline intercostal membranes noticeable even in oblique light.

DERIVATION OF NAME. Dedicated to W. R. Riedel of Scripps Institution of Oceanography, La Jolla.

HOLOTYPE. Figure 6: 21 from EMD-8-15-504/505 cm., a sample from North Pacific Diatom Zone 21. California Academy of Sciences, Department of Geology no. 54420 (diatom collection).

PARATYPE. Figure 6: 20. California Academy of Sciences, Department of Geology no. 54421 (diatom collection).

OCCURRENCE. Found in North Pacific sediments of Middle Miocene age.

Nitzschia rolandii Schrader.

DESCRIPTION. Schrader, 1973a, p. 708, pl. 5, fig. 31, pl. 26, figs. 3–5.

Nitzschia seiboldia Schrader, new species.

DESCRIPTION. Valves elliptical with slightly convex margins, and broadly rounded apices. 28–45 μ long, 5–6 μ wide in the middle of the valves. Transapical costae straight in transapical direction in the middle of the valve and becoming curved towards the apices, 12 in 10 μ. Intercostal membranes punctated, with two rows of fine punctae neighboured to the transapical costae. Punctae in decussate arrangement, approximately 20–25 in 10 μ. Raphe marginal, keel distinct with about 11 keel punctae in 10 μ, central nodule absent. Apices dimorph, one apex with downwards curved transapical costae, the other with curved transapical costae, apical field absent.

DISCUSSION. This species is close to *Nitzschia* species 2 Schrader (Schrader, 1973a, p. 708, pl. 5, figs. 16–18); no other similar species has been found in the literature. Specimens from the EMD generally are broken, and some are twisted

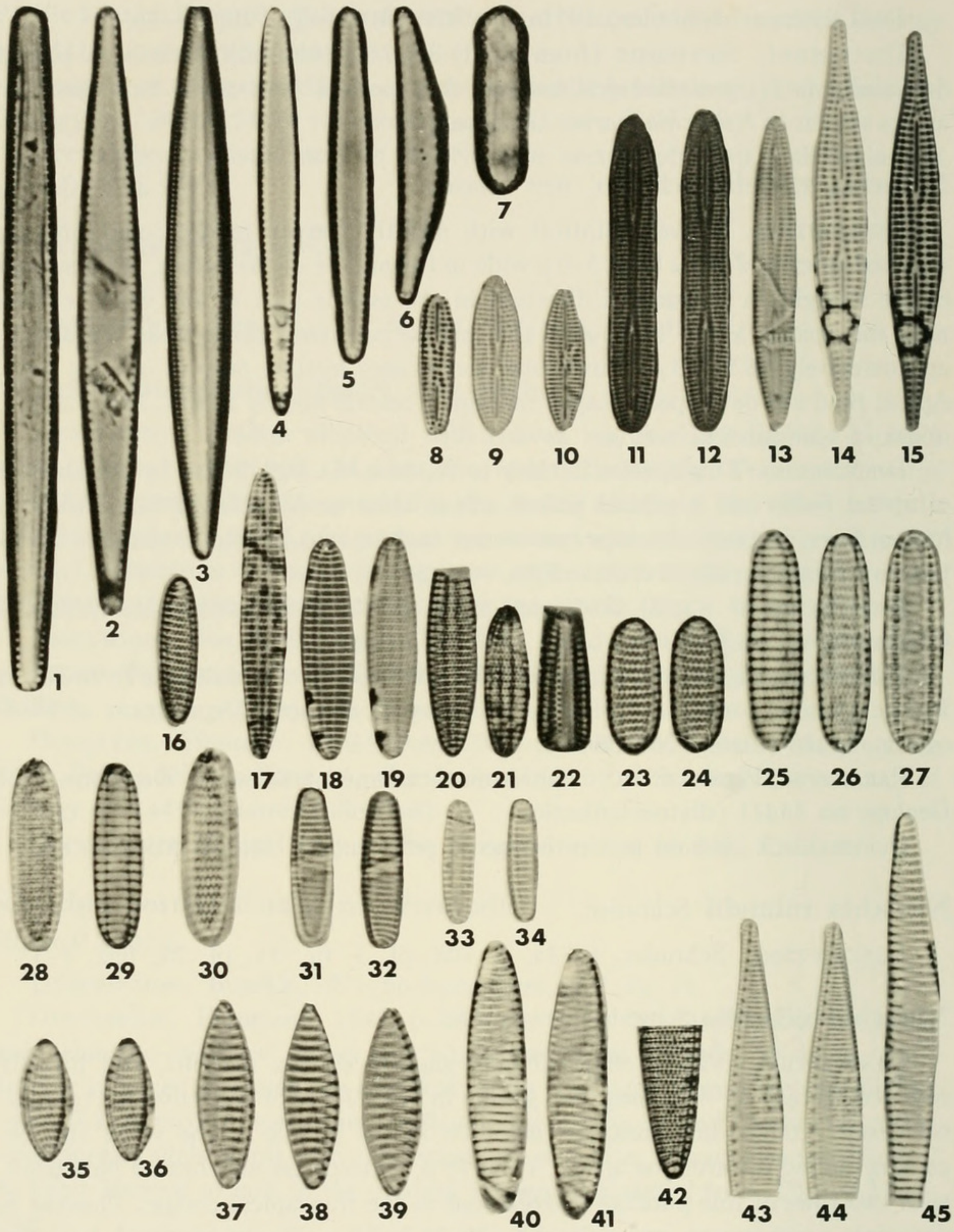

Figure 5. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-9-193/194 cm., *Thalassionema nitzschioides* Grunow; 2. EMD-8-9-240/241 cm., *T. nitzschioides*; 3. EMD-8-15-300/301 cm., *Synedra jouseana* Sheshukova-Poretzkaya; 4. EMD-8-15-504/505 cm., *Thalassionema nitzschioides* Grunow; 5. EMD-8-15-504/505 cm., *T. nitzschioides*; 6. EMD-8-15-504/505 cm., *T. nitzschioides*, aberrant specimens; 7. EMD-8-9-240/241 cm., *T. hirosakiensis* (Kanaya) Schrader; 8. EMD-8-15-200/201 cm., *Rouxia naviculoides* Schrader; 9. EMD-8-9-240/241 cm., *R. moholensis* Schrader, new species; 10. EMD-8-11-30/31 cm., *R.* cf. *R. naviculoides* Schrader; 11. EMD-8-9-240/241 cm.,

in apical direction (the author found numerous individuals in samples from San Felipe CAS no. 39904 (Hanna in Hertlein, 1968)).

Derivation of name. Dedicated to Prof. E. Seibold, who encouraged the author during many years with advice and help.

Holotype. Figure 5: 40–41 from EMD-8-15-300/301 cm., a sample from North Pacific Diatom Zone 21. California Academy of Sciences, Department of Geology no. 54422 (diatom collection).

Paratype. Figure 5: 45. California Academy of Sciences, Department of Geology no. 54423 (diatom collection).

Nitzschia species.

The following *Nitzschia* species are treated informally and assigned numbers, because they were found only once, or found only as fragments. The corrected taxonomic assignments will require additional or better preserved specimens.

Nitzschia species 3 Schrader.

Discussion. Valve linear-elliptical, 15 μ long, 4 μ wide. 13 transapical costae in 10 μ. This species is close to *Nitzschia porteri* Burckle non Frenguelli, but differs in the smaller size, in the heteropol apical fields, and in the finer structure of the intercostal membranes.

Figured specimen. Figure 5: 33–34.

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R. moholensis Schrader, new species (type); 12. EMD-8-9-240/241 cm., *R. moholensis*, California Academy of Sciences, Department of Geology no. 54424; 13. EMD-8-9-240/241 cm., *R.* species 1 Schrader; 14. EMD-8-9-193/194 cm., *R. californica* M. Peragallo; 15. EMD-8-9-193/194 cm., *R. californica*; 16. RC-12-65-1915/1917.5 cm., *Nitzschia porteri* Burckle non Frenguelli; 17. RC-12-65-1105/1107.5 cm., *N. miocenica* Burckle; 18. RC-12-65-1105/1107.5 cm., *N. miocenica*; 19. RC-12-65-1105/1107.5 cm., *N. miocenica*; 20. RC-12-65-1105/1107.5 cm., *N. miocenica*; 21. RC-12-65-1105/1107.5 cm., *N. miocenica*; 22. RC-12-65-1105/1107.5 cm., *N. miocenica* (girdle view); 23. EMD-8-9-193/194 cm., *N. cylindrica* Burckle; 24. EMD-8-9-193/194 cm., *N. cylindrica*; 25. EMD-8-10-100/101 cm., *N. cylindrica*; 26. EMD-8-10-100/101 cm., *N. cylindrica*; 27. EMD-8-10-100/101 cm., *Nitzschia cylindrica* Burckle; 28. EMD-8-10-100/101 cm., *N. cylindrica*; 29. EMD-8-10-100/101 cm., *N. cylindrica*; 30. EMD-8-10-100/101 cm., *N. cylindrica*; 31. EMD-8-10-44/45 cm., *N. porteri* Burckle non Frenguelli; 32. EMD-8-10-44/45 cm., *N. porteri*; 33. EMD-8-10-44/45 cm., *N.* species 3 Schrader; 34. EMD-8-10-44/45 cm., *N.* species 3; 35. EMD-8-15-100/101 cm., *N.* species 7 Schrader; 36. EMD-8-15-100/101 cm., *N.* species 7; 37. EMD-8-15-200/201 cm., *N.* species 8 Schrader; 38. EMD-8-15-200/201 cm., *N.* species 8; 39. EMD-8-15-200/201 cm., *N.* species 8; 40. EMD-8-15-300/301 cm., *N. seiboldia* Schrader, new species (type); 41. EMD-8-15-300/301 cm., *N. seiboldia* (type), California Academy of Sciences, Department of Geology no. 54422; 42. EMD-8-15-200/201 cm., *Nitzschia* cf. *N. heteropolica* Schrader; 43. EMD-8-15-504/505 cm., *N.* species 4 Schrader; 44. EMD-8-15-504/505 cm., *N.* species 4; 45. EMD-8-15-300/301 cm., *N. seiboldia* Schrader new species, California Academy of Sciences, Department of Geology no. 54423.

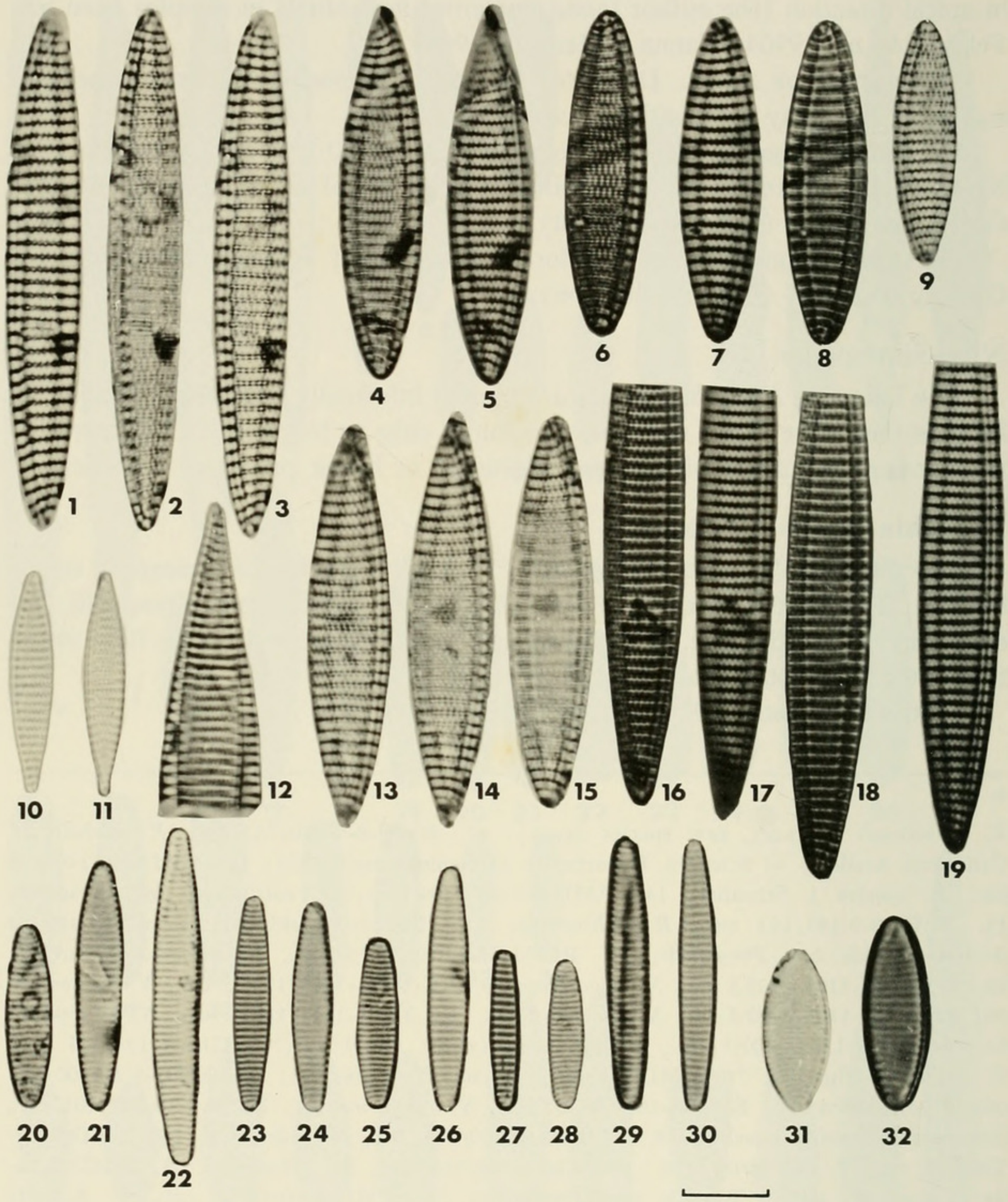

FIGURE 6. Magnification 1000 ×, Leitz-Orthoplan, Apo Oil 92/1.40 n.A. 1. EMD-8-11-300/301 cm., *Nitzschia praereinholdii* Schrader; 2. EMD-8-11-300/301 cm., *N. praereinholdii*; 3. EMD-8-11-300/301 cm., *N. praereinholdii*; 4. EMD-8-11-30/31 cm., *N. praereinholdii*; 5. EMD-8-11-30/31 cm., *N. praereinholdii*; 6. EMD-8-9-193/194 cm., *N. praereinholdii*; 7. EMD-8-9-193/194 cm., *N. praereinholdii*; 8. EMD-8-9-193/194 cm., *N. praereinholdii*; 9. EMD-6-2-30/31 cm., *N. praereinholdii*; 10. EMD-8-11-300/301 cm., *N. moholensis* Schrader, new species (type); 11. EMD-8-11-300/301 cm., *N. moholensis* (type), California Academy of Sciences, Department of Geology no. 54419; 12. EMD-8-11-390/391 cm., *N.* species 5 Schrader; 13. EMD-6-2-30/31 cm., *N. praereinholdii* Schrader; 14. EMD-6-2-30/31 cm., *N. praereinholdii*; 15. EMD-6-2-30/31 cm., *N. praereinholdii*;

Nitzschia species 4 Schrader.

DISCUSSION. Only fragments have been found. They display a central nodulus, a marginal well defined keel with 9 keel punctae in 10 μ and 17 transapical costae in 10 μ. Intercostal membranes with one row of punctae. No similar species has been observed in the literature.

FIGURED SPECIMEN. Figure 5: 43–44.

Nitzschia species 5 Schrader.

DISCUSSION. Only one fragment has been found. It has 9 transapical costae in 10 μ, intercostal membranes with double rows of small punctae in decussate arrangement, rows near the transapical costae. This species is close to *Nitzschia reinholdii* Kanaya but differs from the latter in the lanceolate valve, the arrangement of keel punctae, here 9 in 10 μ, and the finer punctated intercostal membranes.

FIGURED SPECIMEN. Figure 6: 12.

Nitzschia species 6 Schrader.

DISCUSSION. Valve elliptical with convex margins, 22 μ long, 8 μ wide, with 12 transapical costae in 10 μ, slightly convex near the apices. Intercostal membranes hyaline even in oblique light, with about 14 keel punctae in 10 μ. This species is close to *Nitzschia invisa* Schrader but differs from it in the coarser arrangement of transapical costae. It is also similar to *Nitzschia porteri* Frenguelli, but owing to the fact that I have not seen a *N. porteri* from Tiltil the correct taxonomic position could not be ascertained. *Nitzschia porteri* possesses 12–13 keel punctae in 10 μ and 12–13 transapical striae in 10 μ.

FIGURED SPECIMEN. Figure 6: 32.

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16. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 17. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 18. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 19. EMD-8-9-240/241 cm., *Nitzschia* cf. *N. praereinholdii*; 20. EMD-7-1-41/42 cm., *N. riedelia* Schrader, new species, California Academy of Sciences, Department of Geology no. 54421; 21. EMD-8-15-504/505 cm., *N. riedelia* (type), California Academy of Sciences, Department of Geology no. 54420; 22. EMD-8-15-504/505 cm., *N. rolandii* Schrader; 23. EMD-8-15-200/201 cm., *N. kanayensis* Schrader, new species (type), California Academy of Sciences, Department of Geology no. 54417; 24. EMD-8-15-93/94 cm., *N. rolandii* Schrader; 25. EMD-8-11-300/301 cm., *N. kanayensis* Schrader, new species, California Academy of Sciences, Department of Geology no. 54418; 26. EMD-8-11-300/301 cm., *N. rolandii* Schrader; 27. EMD-8-10-44/45 cm., *N. rolandii*; 28. EMD-8-9-240/241 cm., *N. kanayensis* Schrader, new species, California Academy of Sciences, Department of Geology no. 54426; 29. EMD-8-9-240/241 cm., *N. burcklia* Schrader, new species (type), California Academy of Sciences, Department of Geology no. 54415; 30. EMD-8-9-240/241 cm., *N. burcklia*, California Academy of Sciences, Department of Geology no. 54416; 31. EMD-8-11-300/301 cm., *N. invisa* Schrader; 32. EMD-8-11-300/301 cm., *N.* species 6 Schrader.

Nitzschia species 7 Schrader.

Discussion. Only one fragment of this small *Nitzschia* species has been observed. It is 15 μ long, 6 μ wide, with 11–12 transapical costae in 10 μ, curved near the apices; intercostal membranes have two rows of punctae with punctae in decussate arrangement. No similar species has been observed in the literature.

Figured specimen. Figure 5: 35–36.

Nitzschia 8 Schrader.

Discussion. Only one specimen has been observed. It is 23 μ long, 7 μ wide, with 9 transapical costae in 10 μ; intercostal membranes finely punctated. Apices heteropol. Transapical costae curved near the apices. Keel distinct, with 9 keel punctae in 10 μ. No similar species has been observed in the literature.

Figured specimen. Figure 5: 37–39.

Genus **Rhaphoneis** Ehrenberg

Rhaphoneis angularis Lohmann.

Description. Lohmann, 1938, pp. 92–93, pl. 22, figs. 6–8.

Rhaphoneis angustata Pantocsek.

Description. Sheshukova-Poretzkaya, 1967, pp. 241–242, pl. 41, fig. 8, pl. 43, fig. 2.

Rhaphoneis margaritalimbata Mertz.

Description. Mertz, 1966, p. 27, pl. 6, figs. 1–3.

Rhaphoneis sacchalinensis Sheshukova-Poretzkaya.

Description. Sheshukova-Poretzkaya, 1967, p. 242, pl. 42, fig. 2.

Genus **Rhizosolenia** Ehrenberg

Rhizosolenia barboi Brun.

Description. Donahue, 1970, p. 136; Schrader, 1973a, p. 709, pl. 24, figs. 4–7.

Rhizosolenia hebetata forma **hiemalis** Gran.

Description. Hustedt, 1930, pp. 590–592, fig. 337.

Rhizosolenia miocenica Schrader.

Description. Schrader, 1973a, p. 709, pl. 10, figs. 2–6, 9–11.

Rhizosolenia praealata Schrader.

Description. Schrader, 1973a, p. 709, pl. 10, fig. 13.

Rhizosolenia praebarboi Schrader.

Description. Schrader, 1973a, pp. 709–710, pl. 24, figs. 1–3.

Rhizosolenia styliformis Brightwell.

Description. Hustedt, 1930, pp. 584–588, figs. 333–335.

Genus **Rouxia** Brun and Héribaud

Rouxia californica M. Peragallo.

Description. Hanna, 1930, pp. 186–188, pl. 14, figs. 6–7.

Rouxia moholensis Schrader, new species.

Description. Valves linear-oblong with parallel margins slightly constricted in the middle. Apices broadly rounded, 35–42 μ long, 6 μ wide in the middle. The two rudimentary raphe bars widely separated and situated near the apices. Transapical striae 18 in 10 μ, transapical in the middle of the valve, becoming radial towards the apices. Transapical striae formed by elliptical pores. No apical lines are present. Axial area narrow, central area thin-elongated. Valves isopol.

Discussion. This species differs from *Rouxia diploneides* in its finer structure and lack of apical lines.

Derivation of name. Dedicated in memory of the Experimental Mohole Drilling.

Holotype. Figure 5: 11–12 from EMD-8-9-240/241 cm., a sample from North Pacific Diatom Zone 10. California Academy of Sciences, Department of Geology no. 54424 (diatom collection).

Occurrence. Found in the Neogene Section off Baja California.

Rouxia naviculoides Schrader.

(Figure 5: 8.)

Description. Schrader, 1973a, p. 710, pl. 3, figs. 27–32.

Rouxia cf. **R. naviculoides** Schrader.

(Figure 5: 10.)

Discussion. Specimens found are tentatively placed in *R. naviculoides*, but they differ from others of that species in the butterflylike arrangement of the central area.

Rouxia species 1 Schrader.

Discussion. Only one specimen of this species was found. It is close to *R. moholensis* but differs in the coarser structure, and in the presence of one apical line near the middle axis.

Figured specimen. Figure 5: 13.

Genus **Stephanopyxis** Ehrenberg

Stephanopyxis turris (Greville and Arnotte) Ralfs.

Description. Hustedt, 1930, pp. 304–307, figs. 140–144.

Genus **Synedra** Ehrenberg

Synedra jouseana Sheshukova-Poretzkaya.

Description. Sheshukova-Poretzkaya, 1967, p. 245; Schrader, 1973a, p. 710, pl. 23, figs. 21–23, 25, 38.

Genus **Thalassionema** Grunow

Thalassionema hirosakiensis (Kanaya) Schrader.

(Figure 5: 7.)

Description. Kanaya, 1959, pp. 104–106, pl. 9, figs. 11–15; Schrader, 1973a, p. 711, pl. 23, figs. 31–33.

Thalassionema claviformis Schrader.

Description. Schrader, 1973a, p. 711, pl. 23, figs. 11, 15.

Thalassionema nitzschioides Grunow.

(Figure 5: 1–2, 4–6.)

Description. Hustedt, 1959, pp. 244–246, fig. 725; Hasle, 1967, p. 111, figs. 5, 27–34, 39–44.

Genus **Thalassiosira** Cleve

Thalassiosira convexa Mukhina.

(Figure 2: 5–6.)

Description. Donahue, 1970, pp. 136–137, pl. 3, figs. a–f.

Thalassiosira decipiens (Grunow) Joergensen.

Description. Hustedt, 1930, pp. 322–323, fig. 158.

Thalassiosira excentrica (Ehrenberg) Cleve.

Description. Sheshukova-Poretzkaya, 1967, pp. 141–142, pl. 14, fig. 4.

Thalassiosira antiqua (Grunow) Cleve.

Description. Sheshukova-Poretzkaya, 1967, pp. 143–144, pl. 14, fig. 3.

Thalassiosira species A Burckle.

(Figure 2: 3–4.)

Description. Burckle, 1972, p. 241, pl. 1, fig. 1.

Thalassiosira nativa Sheshukova-Poretzkaya.
(Figure 2: 11–21, 25–26.)

DESCRIPTION. Sheshukova-Poretzkaya, 1967, p. 145, pl. 14, fig. 7.

Thalassiosira praeconvexa Burckle.
(Figure 2: 7–10.)

DESCRIPTION. Burckle, 1972, pp. 241–242, pl. 2, figs. 7–9.

Thalassiosira oestrupii (Ostenfeld) Proshkina-Lavrenko.
(Figure 1: 31; Figure 2: 1–2.)

DESCRIPTION. Hustedt, 1930, p. 318, fig. 155 as *Coscinosira oestruppii.*

Thalassiosira usatchevii Jouse.
(Figure 3: 1–2.)

DESCRIPTION. Sheshukova-Poretzkaya, 1967, p. 150, pl. 15, fig. 3.

Thalassiosira species 2 Schrader.

DISCUSSION. This species is close to *Thalassiosira nativa* but differs in lacking numerous scattered strutted tubuli in the center. No other similar species were found mentioned in the literature.

FIGURED SPECIMEN. Figure 2: 22–24, 27–28.

Genus **Thalassiothrix** Cleve and Grunow

Thalassiothrix longissima Cleve and Grunow.

DESCRIPTION. Hasle, 1967, p. 114, fig. 20.

Genus **Triceratium** Ehrenberg

Triceratium antiquum Pantocsek.
(Figure 1: 28.)

DESCRIPTION. Pantocsek, 1886, p. 51, pl. 13, fig. 115; Azpeitia, 1911, p. 221, pl. 12, fig. 2.

Triceratium cinnamomeum Greville.
(Figure 1: 29.)

DESCRIPTION. Greville, 1863, p. 232, pl. 9, fig. 12.

Triceratium condecorum Brightwell.

DESCRIPTION. Hanna, 1932, p. 221, pl. 17, figs. 1, 3.

SUMMARY AND CONCLUSIONS

(1) The North Pacific Diatom Zonation as established from cores obtained during the DSDP leg 18, north of 35° North longitude, provided a basis

for establishing a diatom stratigraphy of core samples from the Experimental Mohole Drilling site off Guadalupe Island, Mexico.

(2) Paleoclimatic oscillations found at the EMD site are comparable to those found at DSDP leg 18, Site 173; no warm period was detected comparable to those found in Lamont Doherty Cores south of 10° longitude.

(3) North Pacific Diatom Zones 20 to 24 are correlative with the lower part of the *Corbisema triacantha* Silicoflagellate Zone and the upper part of the *Dictyocha octacantha* Silicoflagellate Zone of Martini (1972), and with NN 6 Standard Nannoplankton Zone of Martini (1971).

(4) The base of the Late Miocene as defined by Burckle (1972), as occurring within Geomagnetic Epoch 11 of the tropics, and as defined by Bolli (1957) as the *Globorotalia mayeri* Zone below the *Globorotalia menardii* Zone, is correlative with North Pacific Diatom Zone 19, and in the Experimental Mohole Drilling it is between samples EMD-8-15-100/101 cm. and EMD-8-15-200/201 cm. This boundary is correlative (chart 4) with the *Corbisema triacantha* Silicoflagellate Zone (Martini, 1972), with the NN 6 Zone of the Standard Nannoplankton Zone of Martini (1971), with the Luisian stage of California (Parker, 1964; Kanaya, 1971; Bandy and Ingle, 1970). Berggren (1972) placed the Middle to Late Miocene boundary within the upper part of the N 15 Standard Foraminiferal Zone and indicated a radiometric age of 13.5 m.y. for the Luisian-Mohnian boundary, which correlates with the Late to Middle Miocene boundary of Bandy and Ingle (1970). The different correlations are compared in charts 3 and 4.

Dymond (1966) determined a Potassium-Argon date of 12.3 ± 0.4 m.y. for a glass sample from EMD-8-15-89 cm. This date agrees with the correlation of the base of North Pacific Diatom Zone 19 with the paleomagnetic scale, and the correlation of the paleomagnetic scale with the radiometric time scale (Berggren, 1972).

(5) The Pliocene-Late Miocene boundary as defined by Burckle (1972) is at the end of Geomagnetic Epoch 5 at about 5.5 million years B.P. In the Experimental Mohole Drilling this boundary is between samples EMD-8-10-44/45 cm. and EMD-8-10-100/101 cm., and it correlates with the *Dictyocha pseudofibula* Silicoflagellate Zone of Martini (1972), with the NN 10 Standard Nannoplankton Zone of Martini (1971), and with the upper Mohnian Stage of Bandy and Ingle (1970).

(6) The sedimentation rate for the Experimental Mohole Drilling Core in the interval from 80–95 meters below the sea floor, is about 7 meters/million years; for the interval from 95 to 115 meters it is approximately 30 m./m.y., and for the interval from 115 to 135 meters below the sea floor approximately it is again 7 m./m.y. The abrupt increase of sedimentation rate

corresponds with the increase of silt sized minerals and sponge spicules. The sedimentation rate determined by correlation of North Pacific Diatom Zones to paleomagnetic stratigraphy and hence to the radiometric time scale, differs from that obtained by using Dymond's (1966) Potassium-Argon dates (charts 4, 5).

(7) Published correlations of planktonic marine diatoms (Kanaya, 1971), of planktonic foraminiferans (Parker, 1964; Bandy and Ingle, 1970) with the Californian Marine Stages contain discrepancies which could not be resolved in this paper because of a lack of stratotype diatom-bearing material from California [the North Pacific Diatom Zones have not yet been correlated to the Californian Marine Stages].

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