AN ABSTRACT OF THE THESIS OF

David W. Murray for the degree of Master of Science

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Title: Paleo-Oceanography of the Gulf of California Based on Silicoflagellates from Marine Varved Sediments

Abstract Approved: Signature redacted for privacy.

Hans J. Schrader

Plankton and surface sediment samples from the Gulf of California were analyzed to determine the present geographic distribution of silicoflagellate species in this area. Variations in the composition of the silicoflagellate assemblage are related to water mass distributions. Seven species and three forms were identified in these samples. Octactis pulchra is associated with high levels of primary productivity in the surface waters and is found in greatest abundance in the central Gulf of California. Dictyocha messanensis dominates the silicoflagellate assemblage in stations outside the Gulf of California and increases in relative abundance with decreasing amounts of O. pulchra. D. calida and D. spec. 1 forms are associated with equatorial waters and have the highest relative abundance near the mouth of the Gulf. D. epiodon and Distephanus speculum are associated with cold California Current Water and Dictyocha epiodon is present in minor abundance in Gulf samples. D. spec. 2 has a patchy distribution with low relative abundance in these samples.

Downcore sediment samples were analyzed from six locations in the southern Gulf of California. The results suggest that major variations

in the relative composition of the silicoflagellate assemblage have not occurred over the past 1000 years.

Sediment material obtained from the basin slopes in the central Gulf of California exhibit alternating light and dark laminations. A laminae couplet equals one year of deposition. The composition of the silicoflagellate assemblage was determined in one hundred twenty individual laminae samples from the top section of a box core from the central Gulf. There is no indication of a characteristic assemblage composition associated with either light or dark laminations in these samples. A high relative abundance of O. pulchra is present in the well laminated sections of the core. D. spec. 1, D. epiodon, D. calida, and D. spec. 2 are periodically in great abundance spanning more than one laminae sample.

Variations in the relative abundance of silicoflagellate species in the central Gulf of California during the last 38,000 years were determined from DSDP Leg 64 Site 480 samples. The results indicate that O. pulchra was in lower relative abundance and Distephanus speculum, Dictyocha epiodon, and D. spec. 1 forms were in greater abundance during the glacial period compared to the present. This suggests that there was a decrease in primary production, an increase in Pacific water influence, and a decrease in surface water temperatures in the central Gulf of California during the last major glacial interval compared to the present conditions.

PALEO-OCEANOGRAPHY OF THE GULF OF CALIFORNIA BASED ON SILICOFLAGELLATES FROM MARINE VARVED SEDIMENTS

by

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FOR MY PARENTS,

GRANDPARENTS,

AND ALL THE NAIVE ORRS IN THE WORLD.

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C^{14} analyses were provided by Minze Stuiver, University of Washington, and Steve Robinson, USGS, Menlo Park, California. Hans Schrader provided most of the data from consecutive samples in three Kasten cores. Steve Crawford processed the DSDP Site 480 samples and analyzed the coarse fraction in Cores 3 and 4. Bill Gilbert did most of the drafting, Anne Matherne helped with some drafting and compiled the appendix tables, and Dave Reinert photographed and printed the figures. Becky Simpkins devoted a large amount of time doing an excellent job in typing the thesis. Carolyn Lupoli was very helpful in providing Xerox copies of figures and the thesis ASAP. I appreciate the information and assistance that you all provided. THANKS!!

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Finally, I would like to quote some unknown author who said;

> "...when you are up to your ass in alligators,
> it is difficult to remind yourself that your initial
> objective was to drain the swamp."

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PALEO-OCEANOGRAPHY OF THE GULF OF CALIFORNIA
BASED ON SILICOFLAGELLATES FROM MARINE VARVED SEDIMENTS

1. INTRODUCTION

Silicoflagellates, which constitute a minor component of the phytoplankton, are autotrophic marine algae with siliceous skeletons. Very little is known about their ecology although work by Gemeinhardt (1934) and Yanagisawa (1943) show a temperature dependence in the distribution of silicoflagellate species. By mapping the distribution of silicoflagellates in surface sediments from the North Pacific, Poelchau (1976) shows a direct association between water mass and species distribution. Lipps (1970) suggests that distributions are also linked to salinity and nutrient availability, although only limited work has been done to support this conclusion. Recently, workers have used the temperature dependence of silicoflagellates in estimating paleotemperatures for Eocene to Recent siliceous sediments (Mandra, 1969; Jendrzojewski and Zarillo, 1971, 1972; Bukry, 1973; Bukry and Foster, 1973; Ciesielski and Weaver, 1973; Mandra et al., 1973; Poelchau, 1974; Schrader and Richert, 1974).

Silicoflagellates are most commonly found in marine environments with high diatom concentrations. Fluctuations in the abundance of diatoms are accompanied by similar changes in the abundance of silicoflagellates (Martini, 1971). Laminated diatom rich sediments obtained from the Gulf of California during DSDP Leg 64 and the Oregon State University BAV79 and BAM80 cruises permit the study of fine scale variations in the sediment assemblage since the Late Pleistocene. The different silicoflagellate species and forms, although a minor component of the opal microfloral assemblage, were few in number and easily recognized in these diatom rich sediments. This study uses the association of silicoflagellates to particular water masses (Poelchau, 1976) to document the variations of water masses in the Gulf of California and the productivity of the surface waters over Recent global climatic changes. The objectives are to:

1) document the association between the distribution of the silicoflagellate assemblage in the plankton and surface sediments in the southern Gulf of California and the relationship to water masses;

2) document recent changes (past 50 years) in the composition of the silicoflagellate assemblage on a seasonal basis by looking at the fine scale variations (events from one to five years in length) in the Gulf at the present;

3) characterize recent downcore trends (past 2000 years) in the composition of the silicoflagellate assemblage in the southern Gulf;

4) compare the composition of the silicoflagellate assemblage in the Gulf of California during both a glacial and an interglacial period to document changes in ocean circulation, sea surface temperature, and productivity levels in this area.

2. THE SETTING

2.1 Physiography

The Gulf of California is a long narrow marginal sea between the west coast of Mexico and the Baja Peninsula. It is closed on three sides and open to the Pacific Ocean at its southern end. The northern Gulf is mostly at shelf depth (van Andel, 1964) and is separated from the southern region by a chain of islands at approximately 29°N (Figure 2.1). The southern region consists of a series of basins formed by spreading centers located in NE-SW trending enechelon troughs connected by a series of NW-SE trending transform faults (Moore, 1973). These basins are deeper toward the mouth of the Gulf.

2.2 Meteorological and Oceanographic Aspects

The regional winds generally blow from the northwest during winter and early spring and from the southeast during the summer months. The surface circulation in the southern Gulf is linked to this regional wind pattern with flow that is predominantly southeasterly in the winter and northwesterly in the summer (Figure 2.2). Measurements of the surface currents across the mouth of the Gulf (Roden, 1964) indicate variable currents with southeasterly flow ranging between 10 and 15 cm/sec commonly from February to May and northwesterly flow with speeds up to 10 cm/sec from June to September. The currents are weak and flow towards a westerly or southwesterly direction during the remaining months of the year (Roden, 1964).

Upwelling of nutrient rich waters is also associated with this wind pattern. Upwelling has been observed on the eastern side of the Gulf during the winter and spring when the winds are from the northwest and on

Figure 2.1 Bathymetry of the Gulf of California after Bischoff and Niemitz (1980) showing locations of Kasten cores BAV79 A-5, BAV79 B-29, BAM80 E-17, BAM80 F-30, BAM80 G-34, BAM80 I-42; box core BAV79 A-2; Hydraulic Piston Core (HPC) DSDP Leg 64, Site 480.

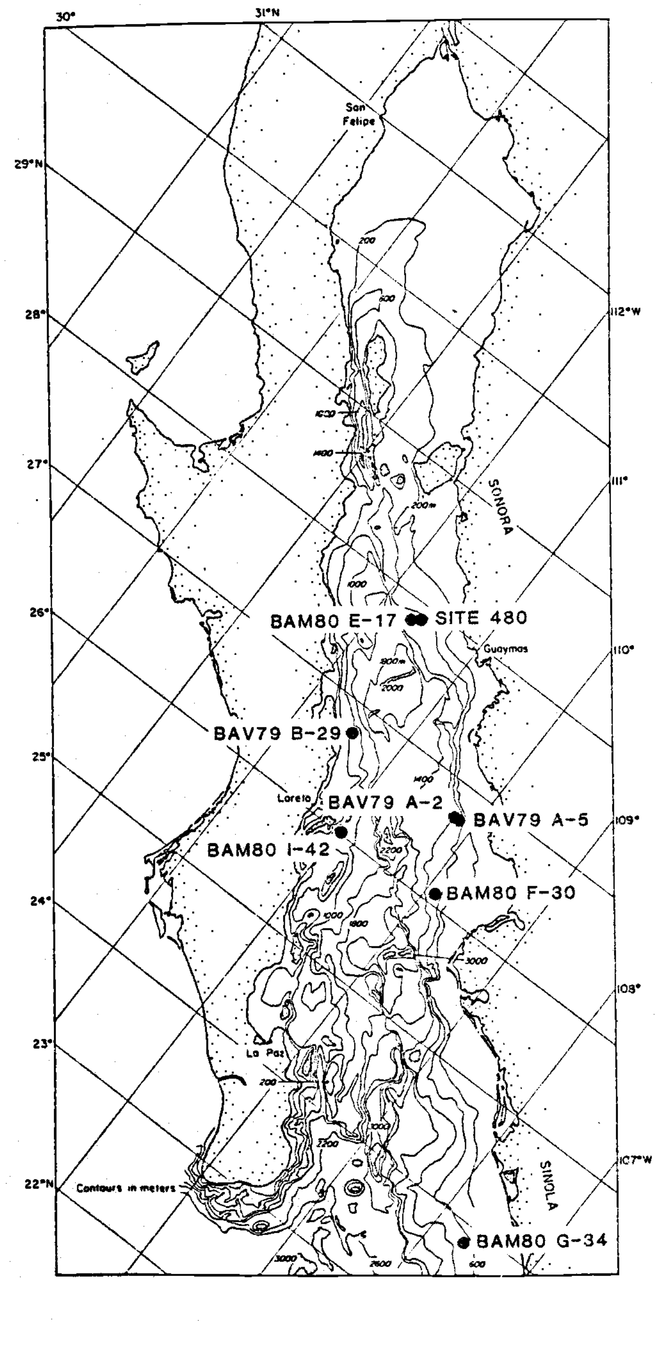

30°
31°N
San Felipe
29°N
28°
112°W
27°
111°
SONORA
26°
BAM80 E-17
SITE 480
Guaymas
110°
BAV79 B-29
25°
Loreto
BAV79 A-2
BAV79 A-5
109°
BAM80 I-42
BAM80 F-30
24°
108°
23°
La Paz
107°W
22°N
Contours in meters
SINOLA
BAM80 G-34

Figure 2.1

Figure 2.2 Ocean surface circulation in the Gulf of California (Wille, 1966) and adjacent areas (Wyrtki, 1965; Namias, 1971). Large arrows show prevailing wind direction for (A) August to October and (B) February to April. The shaded areas are locals of upwelling (Roden and Groves, 1959). This figure is from Matherne (1982).

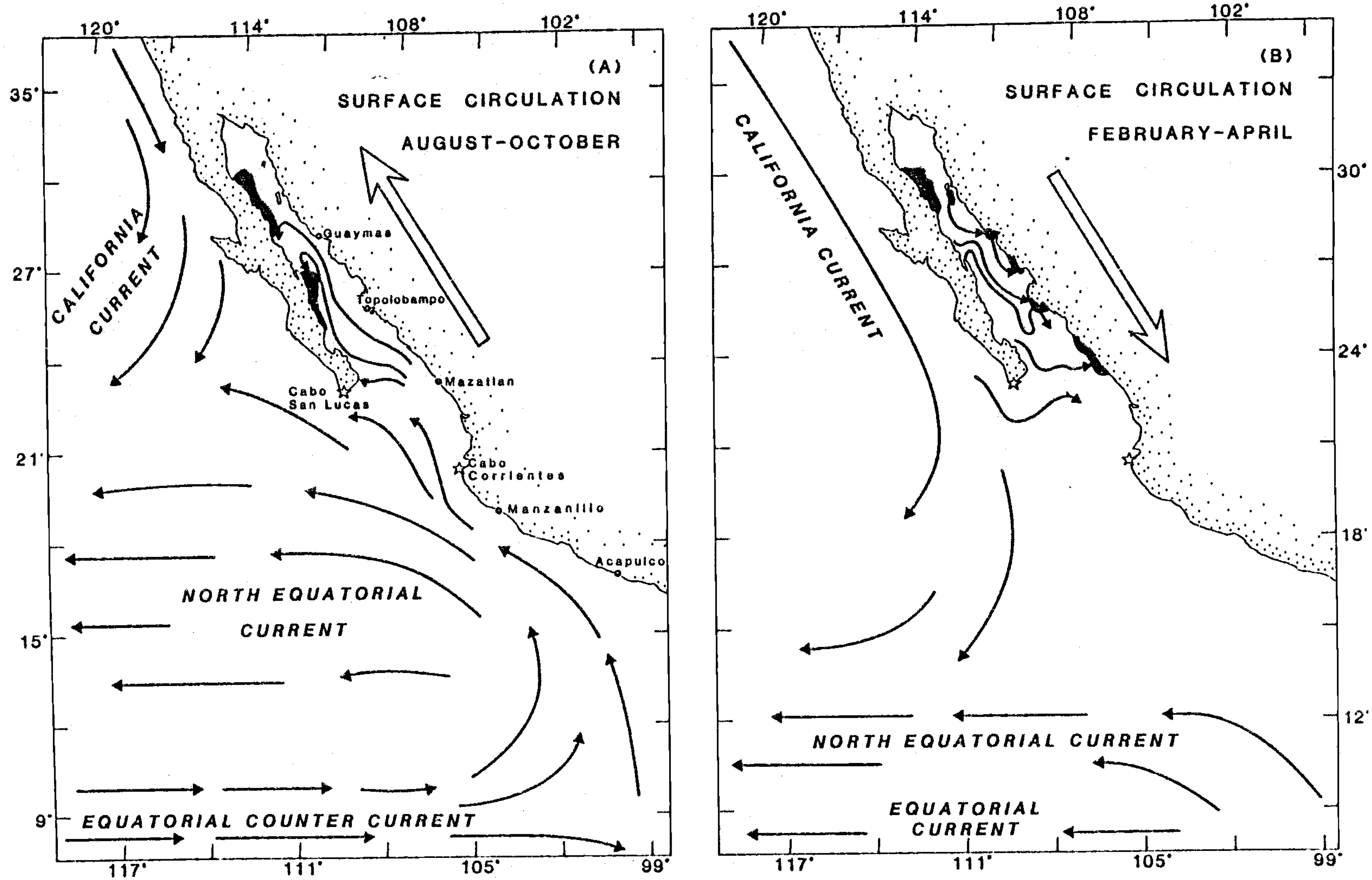

(A)
SURFACE CIRCULATION
AUGUST-OCTOBER
CALIFORNIA CURRENT
Guaymas
Topolobampo
Mazatlan
Cabo San Lucas
Cabo Corrientes
Manzanillo
Acapulco
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTER CURRENT
(B)
SURFACE CIRCULATION
FEBRUARY-APRIL
CALIFORNIA CURRENT
NORTH EQUATORIAL CURRENT
EQUATORIAL CURRENT
120°
114°
108°
102°
35°
30°
27°
24°
21°
18°
15°
12°
9°
117°
111°
105°
99°

Figure 2.2

and on the western side during the summer months when the winds are from the southeast (Roden and Groves, 1959).

The average annual rainfall is greater for the east side (30 cm) than on the west side (12 cm) of the Gulf and increases towards the south (Roden, 1958). Rainfall mostly occurs during the summer months in the southern Gulf, and because of the general absence of permanent streams, the main terrigenous imput is from runoff during the summer. Average annual evaporation is approximately 17 times the annual runoff into the Gulf by all streams including the Colorado River prior to damming (Byrne and Emery, 1960). Average monthly sea surface temperatures range from 15-21°C in February to 28-30°C in August (Robinson, 1973). Temperatures generally decrease up the Gulf.

The thermohaline structure of the southern Gulf is similar to that of the equatorial Pacific with modifications due to extensive evaporation at the surface and by mixing with California Current Water (Roden, 1964). Three surface water types have been observed in the upper 200 meters of the southern Gulf. Cold California Current Water with low salinity ($T < 22°C$, $S < 34.6°/_{oo}$) is observed turning east around the tip of Baja and penetrating into the Gulf (Figure 2.2). The extent of this penetration depends upon the season and year of observation (Stevenson, 1970). Warm Eastern Tropical Pacific Water with intermediate salinities ($T > 25°C$, $34.6 < S < 34.9°/_{oo}$) flows in from the southeast (Figure 2.2). Wyrtki (1967) identifies the boundary of tropical surface waters as the 25°C isotherm. During the summer months, its northern position reaches above the southern tip of Baja California apparently limiting the influence of the California Current (Robinson, 1973). The third type is warm, highly saline Gulf Water ($22 < T < 25°C$, $S > 34.9°/_{oo}$) formed within the Gulf by evaporation of Equatorial Water (Roden and Groves, 1959). A subsurface water mass which is formed by a mixture of California Current and Subtropical Subsurface Water ($13 < T < 20°C$, $34.6 < S < 34.9°/_{oo}$) lies between 50 and 200 meters (Warsh et al., 1973). This water layer originates from the south Pacific Ocean and has been observed to reach as far north as 29°N within the Gulf (Mundhenke, 1969).

Low oxygen concentrations at intermediate depths are characteristic of Gulf waters (Roden, 1964). In general, oxygen concentrations are higher than 1 ml/l in the upper 100 m and decrease to less than 0.5 ml/l below 150 m. At intermediate depths (500-1100 m) the concentration of oxygen is occasionally undetectable by the Winkler method. The oxygen minimum at the entrance of the Gulf is more pronounced than in the interior and it covers a larger depth interval (Roden, 1964). Oxygen concentrations increase from the minimum to about 2.4 ml/l at 3500 m at the mouth of the Gulf.

The influence of the Gulf of California upon the adjacent Pacific Ocean is small. Flux into and out of the Gulf estimated by Roden (1964) using a salt budget calculation indicates a flow in of 1.19 Sv and a flow out of 1.17 Sv, with the difference accounted for by evaporation. General observations indicate that the Pacific supplies nutrient rich waters at depth to the Gulf of California and receives nutrient poor waters at the surface.

2.3 Primary Production

Plankton blooms have been observed in many locations in the Gulf of California throughout the year mainly near steep slopes and in the lee of capes and islands (Byrne, 1957; van Andel, 1964). These blooms are caused by the upwelling of nutrient rich waters in association with the seasonal wind patterns. Revelle (1950) indicates that upwelling is less intense on the west side of the Gulf than on the east side which is at a maximum in the winter and early spring.

Zeitzschel (1969) summarized primary productivity data from six cruises to the Gulf of California and reported an average integrated rate of .382 $gC/m^2/d$ (range:.002-.952) for the whole Gulf. Both Zeitzschel's data and work by Round (1967) indicate that the central Gulf has the highest phytoplankton levels.

Similar levels of primary productivity have been reported from the upwelling areas off the west coast of Baja California (Owen, 1974), North Africa (Huntsman and Barber, 1977), and Peru (Guillen, et al., 1972). These levels are 2 to 3 times those reported from the open Pacific or Atlantic at similar latitudes (Zeitzschel, 1969).

2.4 Laminated Sediments

Sediments exhibiting millimeter to sub-millimeter thick alternating dark and light laminations have been obtained from the slopes of the basins in the Gulf of California (van Andel, 1964; Calvert, 1966; Schrader, Kelts, et al., 1980; Schrader, 1979). These sediments are deposited within the region where the intense oxygen minimum zone intersects the sediment-water interface. Because of the low oxygen values, infauna are not present (Calvert, 1966) and the sediments accumulate relatively undisturbed.

These sediments are generally diatom rich with the dark laminae containing more clay material than the light laminae (Calvert, 1966; Donegan and Schrader, in press). Numerous authors have proposed models for laminae formation (Calvert, 1966; Schrader, Murray, et al., 1980; Donegan and Schrader, in press) which indicate that a laminae couplet (light and dark) represents deposition during one year. Baumgartner et al. (1981) found close agreement between sedimentation rates based on ^{210}Pb dating and rates determined from counting of couplets (varves). Based on previous studies, the laminated sediments from the central Gulf are being deposited at a rate of 1-3 m/1000 years.

Sediment texture estimated in material obtained from the central Gulf (Donegan and Schrader, 1981) indicates diatoms generally comprise 60-90% of the sediment and terrigenous material generally comprises 5-25%. Minor amounts of other microfossils and amorphous organic carbon are present. Studies of the diatoms in the sediments (Calvert, 1966; Round, 1967, 1968; Matherne, 1982) indicate a relatively well preserved assemblage with core top abundances on the order of 10^6-10^8 diatoms per gm dry sediment. Similar abundances have been found beneath the upwelling areas of the west coast of South America and South Africa (Schuette and Schrader, 1979, 1981).

3. MATERIALS AND METHODS

3.1 Plankton Material

3.1.1 Recovery of Plankton Material

Underway near-surface plankton samples were obtained during the BAM80 (September 30, 1980-December 2, 1980) cruise. Non-quantitative samples were collected by pumping seawater, at a rate of 18 l/minute, from an intake in the ship's hull three meters below the surface, through a phytoplankton net with 33 μm mesh size. The duration of the sampling period varied depending upon how quickly the net became clogged with material. Generally the sampling period was 30 minutes for stations outside the Gulf of California and 10 to 15 minutes for stations within the Gulf where plankton in the surface was more abundant. At the end of each sampling period, the material collected was placed in plastic or glass bottles and approximately 1 ml of concentrated formaldehyde was added. Local environmental conditions obtained during sampling are given in Table 3.1.

3.1.2 Processing of Plankton Material

The material from each station was placed in 25 x 200 mm test tubes which hold approximately 75 ml of liquid. The test tubes were filled to the top with distilled water. After 24 hours, two thirds of the supernatant liquid was gently removed using a vacuum pump. The test tubes were again filled with distilled water and after 24 hours, two thirds of the supernatant liquid was removed. This procedure was

Table 3.1 Phytoplankton station locations and local conditions at each station. Data from BAM80 cruise report (in preparation by Schrader). Greenwich Mean Time (GMT) equals local time +8 hours for stations P1 to P92 and +7 hours for P96 to P200.

Sample	Position Start	Position End	Date/Time (local) Start/End	Sampling Duration (min)	Surface (°C) Temperature Begin/End	Wind(°)Speed Direction/ (Kts)	Sea State
P1	31°03.8'N 116°33.6'W	30°57.5'N 116°31.2'W	10/31, 0000-0030	30	19.5	ENE/7	2
P2	30°25.8'N 116°18.0'W	30°19.5'N 116°15.1'W	10/31, 0030-0030	30	19.0-18.0	NW-NNW/2-4	1
P3	29°49.3'N 116°04.2'W	29°42.8'N 116°01.5'W	10/31, 0600-0630	30	18.0-17.5	ENE-NE/4-7	1
P4	29°12.5'N 115°34.5'W	29°06.5'N 115°33.0'W	10/31, 0900-0930	30	19.5-20.0	WNW/1	0
P5	28°35.8'N 115°34.5'W	28°29.5'N 115°33.0'W	10/31, 1200-1230	30	20.8-21.5	WSW-S/2-8	1
P6	28°01.1'N 115°22.7'W	27°56.7'N 115°17.7'W	10/31, 1500-1530	30	20.5-23.5	N-NNE/6-9	2
P7	27°31.5'N 114°54.0'W	27°27.4'N 114°51.0'W	10/31, 1800-1830	30	21.6-21.0	ESE-SE/4	2
P8	27°00.0'N 114°26.5'W	26°54.6'N 114°22.0'W	10/31, 2100-2130	30	21.0-21.5	WNW/2	1
P9	26°28.0'N 113°58.5'N	26°21.5'N 113°55.0'W	11/1, 0000-0030	30	22.0-22.2	NE/3	2
P10	25°58.2'N 113°32.1'W	25°53.3'N 113°27.5'W	11/1, 0300-0330	30	23.5-23.0	N/4	1
P11	25°28.7'N 113°03.0'W	25°23.5'N 112°57.5'W	11/1, 0600-0630	30	23.3-23.5	NE/6	1
P12	25°00.0'N 112°36.7'W	24°54.7'N 112°33.0'W	11/1, 0900-0930	30	24.0-24.5	E-ENE/3-4	2-3
P13	24°32.1'N 112°09.5'W	24°27.0'N 112°04.0'W	11/1, 1200-1230	30	24.6-25.4	SW/1-6	0-1
P14	24°08.0'N 111°32.6'W	24°01.0'N 111°33.5'W	11/1, 1500-1530	30	25.5-25.8	W-WSW/5-10	2-3
P15	23°42.2'N 111°02.2'W	23°37.5'N 110°57.0'W	11/1, 1800-1830	30	27.0-27.0	NE-NNE/7-12	2
P16	23°15.5'N 110°30.0'W	23°11.5'N 110°25.0'W	11/1, 2100-2130	30	26.5	SSE-WSW/7-12	2
P17	22°51.0'N 109°58.4'W	22°50.0'N 109°51.0'W	11/2, 000-0030	30	28.7-28.5	NNE-NE/13.16	2-3
P18	23°08.7'N 109°24.5'W	23°14.3'N 109°23.0'W	11/2, 0300-0330	30	28.3-28.4	NNE-W/18	4
P19	23°47.0'N 109°26.0'W	23°54.0'N 109°27.0'W	11/2, 0600-0630	30	28.0-28.1	NNW/18	3
P20	24°23.0'N 109°37.5'W	24°27.5'N 109°40.5'W	11/2, 0900-0930	30	28.0-28.2	NNW/12	3
P21	24°54.5'N 109°48.0'W	25°01.5'N 109°49.0'W	11/2, 1200-1230	30	27.8-27.5	NNW/4-12	3
P22	25°33.0'N 109°58.0'W	25°38.8'N 110°00.5'W	11/2, 1500-1530	30	27.8-28.3	NW/18	4
P23	26°07.0'N 110°10.7'W	26°14.0'N 110°14.0'W	11/2, 1800-1830	30	27.0	WNW/3-8	2-4
P24	26°43.5'N 110°26.0'W	26°48.5'N 110°27.0'W	11/2, 2100-2130	30	26.3	WNW/14	3
P25	27°18.5'N 110°40.5'W	27°24.6'N 110°43.5'W	11/3, 0000-0030	30	26.0	WNW/19	4
P26	27°53.0'N 110°52.0'W	27°53.5'N 110°52.8'W	11/3, 0300-0330	30	24.2-24.0	-	-
P27	27°36.5'N 111°04.0'W	27°31.5'N 111°09.3'W	11/3, 0600-0630	30	24.5-24.8	NWN/-	2
P28	27°18.2'N 111°24.5'W	27°21.0'N 111°25.0'W	11/3, 0918-0948	30	26.6-26.4	WNW/2-5	1-4
P29	27°33.0'N 111°22.3'W	27°35.3'N 111°22.3'W	11/3, 1200-1215	15	24.5-25.0	WNW/5	4
P30	27°39.0'N 111°22.5'W	27°39.7'N 111°22.3'W	11/3, 1523-1538	15	24.9	NW/15	3
P31	27°54.5'N 111°24.6'W	27°58.6'N 111°25.0'W	11/3, 1800-1830	30	25.3-25.0	NW/18	4
P37	28°01.8'N 111°27.6'W		11/4, 1118-1129	11	24.7-25.2	NWN	4

Table 3.1 (continued)

Sample	Position Start	Position End	Date/Time (local) Start/End	Sampling Duration (min)	Surface (°C) Temperature Begin/End	Wind(°)Speed Direction/ (Kts)	Sea State
P40	27°39.9'N 111°21.0'W		11/4, 1754-1811	17	24.3-25.0	WNW	4
P47	28°00.5'N 111°27.5'W		11/6, 2030-2043	13	27.0	calm	-
P52	27°54.2'N 111°30.0'W		11/7, 0100	15	26.0	WNW	2
P57	27°56.7'N 111°27.5'W		11/7, 0400	15	24.5	NW	3
P60	27°27.8'N 111°12.0'W		11/7, 2200	15	26.0	ESE-NW	4
P61	27°21.8'N 111°05.0'W		11/7, 2230	15	26.5	ESE-NW	4
P63	27°11.0'N 110°55.7'W		11/7, 2330	15	26.0	NW	4
P66	26°55.0'N 110°44.2'W		11/8, 0100	15	25.5	SSW	3
P69	26°40.2'N 110°32.6'W		11/8, 0230	15	26.0	S-NNE	3-4
P73	26°20.4'N 110°13.0'W		11/8, 0430	15	25.9	NNE	4
P76	25°45.5'N 109°38.3'W		11/8, 1800	15	27.5	S	2
P78	25°23.5'N 109°24.0'W		11/8, 2000	15	27.5	ESE	2
P82	24°49.0'N 108°38.5'W		11/9, 0000	15	27.0	N	3
P85	24°24.4'N 108°05.0'W		11/9, 0300	15	28.0	-	-
P89	23°51.0'N 107°20.0'W		11/9, 0700	15	28.0	E	2
P92	23°25.2'N 106°40.0'W		11/9, 1000	15	28.7	ESE	3
P96	24°00.5'N 108°02.2'W		11/13, 1750-1810	12	28.0	WNW	3
P98	24°14.9'N 108°19.9'W		11/13, 1952-2004	12	28.0	NNW	3
P101	24°13.2'N 108°51.0'W		11/13, 2255-2305	10	28.0	NW	4

Sample	Position Start	Position End	Date/Time (local) Start/End	Sampling Duration (min)	Surface (°C) Temperature Begin/End	Wind(°)Speed Direction/ (Kts)	Sea State
P102	24°40.4'N 109°01.3'W		11/14, 2350-0000	10	28.0	WNW	4
P105	24°57.6'N 109°35.0'W		11/14, 0255-0305	10	26.9	NW	4
P106	25°04.2'N 109°47.0'W		11/14, 0355-0405	10	26.8	NW	4
P108	25°04.6'N 110°06.2'W		11/14, 0500-0510	10	26.8	NW	4
P109	25°19.4'N 110°15.6'W		11/14, 0655-0705	10	27.0	WNW	4
P110	25°25.3'N 110°25.3'W		11/14, 0755-0805	10	27.0	NNW	3
P111	25°28.4'N 110°34.5'W		11/14, 0855-0905	10	29.2	NNW	5
P112	-		11/14, 2040-2050	10	-	NNW	3
P113	26°03.0'N 110°42.0'W		11/14, 2149-2210	21	-	N	0
P114	26°04.2'N 110°49.3'W		11/14, 2254-2313	19	-	NNE	2
P122	26°37.0'N 111°29.8'W		11/16, 0925-0935	10	24.75	NW/19	5
P127	26°35.5'N 111°29.8'W		11/16, 1155-1205	10	25.0	NW/19	5
P134	24°52.7'N 108°57.3'W		11/18, 0750-0800	10	-	-	-
P136	24°37.8'N 108°23.5'W		11/18, 1010-1024	14	-	-	-
P137	24°29.7'N 108°26.2'W		11/18, 1113-1138	25	-	-	-
P138	24°16.0'N 108°02.0'W		11/18, 1314-1324	10	-	-	-
P143	23°20.3'N 106°59.0'W		11/20, 2200	10	26.5	-	-
P154	23°29.0'N 106°55.0'W		11/22, 0645	10	25.5	-	-
P157	23°14.2'N 107°05.3'W		11/22, 1300	10	26.5	-	-

Table 3.1 (continued)

Sample	Position Start	Position End	Date/Time (local) Start/End	Sampling Duration (min)	Surface (°C) Temperature Begin/End	Wind(°)Speed Direction/ (Kts)	Sea State
P159	23°03.5'N 107°19.8'W		11/28, 1155	10	26.0	-	-
P160	23°01.0'N 107°48.5'W		11/28, 1400	15	26.5	-	-
P161	23°02.6'N 108°01.0'W		11/28, 1657	30	26.0	-	-
P162	23°00.2'N 108°14.0'W		11/28, 1755	30	26.0	-	-
P163	22°56.3'N 108°38.8'W		11/28, 2000	30	25.5	-	-
P164	22°55.2'N 109°05.7'W		11/28, 2200	30	25.0	-	-
P165	22°51.0'N 109°34.3'W		11/29, 0000	30	25.5	-	-
P166	22°49.5'N 110°01.0'W		11/29, 0215	30	27.0	-	-
P167	23°09.0'N 110°22.5'W		11/29, 0400	30	26.5	-	-
P168	23°26.8'N 110°43.6'W		11/29, 0610	20	23.9	-	-
P170	23°38.8'N 110°55.5'W		11/29, 0755	20	23.9	-	-
P171	23°57.2'N 111°26.5'W		11/29, 0945	30	24.5	-	-
P172	24°15.2'N 111°49.2'W		11/29, 1145	20	24.25	-	-
P173	24°33.2'N 112°12.5'N		11/29, 1347	20	24.5	-	-
P174	24°54.0'N 112°33.5'W		11/29, 1545	30	24.5	-	-
P176	25°24.0'N 113°09.8'W		11/29, 1945	30	23.5	-	-
P177	25°49.5'N 113°25.0'W		11/29, 2125	30	23.5	-	-
P179	26°24.4'N 113°49.5'W		11/30, 0215	30	21.5	-	-
P180	26°48.0'N 114°17.5'W		11/30, 0405	30	21.0	-	-
P182	27°29.2'N 114°58.0'W		11/30, 0800	30	20.0	-	-
P184	27°55.4'N 115°05.2'W		11/30, 1155	30	19.3	-	-
P186	28°51.5'N 115°26.0'W		11/30, 1555	30	18.5	-	-
P187	29°08.2'N 115°32.3'W		11/30, 1755	30	18.25	-	-
P190	29°45.9'N 115°56.3'W		11/30, 2345	30	18.0	-	-
P192	30°09.0'N 116°10.0'W		12/1, 0345	30	18.7	-	-
P193	30°21.8'N 116°18.0'W		12/1, 1600	30	18.0	-	-
P198	31°10.0'N 116°33.8'W		12/1, 1800	30	18.75	-	-
P199	31°24.7'N 116°45.6'W		12/1, 1945	30	17.5	-	-
P200	31°36.2'N 116°51.8'W		12/1, 2200	30	17.5	-	-

repeated eight more times to desalt the sample. Examination of the supernatant liquid showed that very little of the plankton material was lost using this method. The material was resuspended by vigorously shaking the test tube and 300-400 μl was immediately withdrawn using a disposable glass pipette and placed evenly on a water-covered 18 mm square coverslip. This procedure was performed twice for each sample. The coverslips were allowed to dry slowly and then mounted on standard microscopic slides using Hyrax (R.I. = 1.71) as a mounting medium.

The remainder of each sample was then chemically treated to obtain a concentrated siliceous fraction using methods outlined by Simonsen (1974) and Fryxell (1975). Approximately 10-15 ml of a saturated solution of $KMnO_4$ was added to each sample and then let stand for 24 hours. 10-15 ml of reagent grade HCl (37%) was added to the mixture. After 24 hours, the test tubes were placed in a water bath and boiled slowly until the solution changed from purple to light yellow in color. All samples were cleaned to remove the acid with the same method used to remove the salt. Microscopic slides were made from the siliceous fraction following the same procedure used to make slides of the desalted material. A few drops of concentrated formaldehyde was added to the remainder of the siliceous fraction and the material was placed in capped glass vials.

3.2 Box Core Material

3.2.1 Recovery and Curation

Core BAV79 A-2 (Table 3.2, Figures 2.1, 3.1.1, and 3.1.2) was obtained using a lightweight Reineck Box Corer during the BAV79 (Sept.

Table 3.2 Locations, water depth, and length of cores used in this study. All cores are stored at the Core Repository, School of Oceanography, Oregon State University.

	Total Core Length (cm)	Latitude (°N)	Longitude (°W)	Water Depth (m)
BAV79 A-2 (Box core)	35	26°43.4'	110°08.6'	710
BAV79 A-5 (Kasten core)	185	26°43.4'	110°07.0'	705
BAV79 B-29 (Kasten core)	197	26°42.0'	111°25.0'	635
BAM80 E-17 (Kasten core)	449.5	27°55.2'	111°36.6'	620
BAM80 F-30 (Kasten core)	276.5	26°08.1'	109°53.4'	620
BAM80 G-34 (Kasten core) (1)	408	23°50.7'	107°41.8'	620
BAM80 I-42 (Kasten core)	237	26°00.5'	110°59.0'	705
DSDP Leg 64 Site 480 (HPC) (2)	15,200	27°54.0'	111°39.3'	655

(1) only the laminated section (0-255 cm) was analyzed
(2) Schrader, H., Kelts, K., et al., (1980).

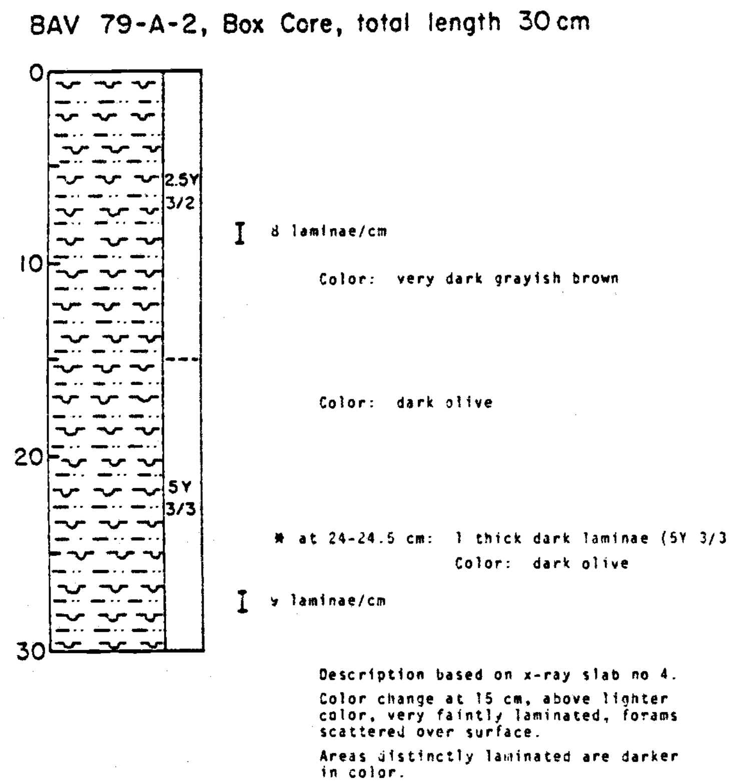


Figure 3.1.1 Lithologic summary of box core BAV79 A-2. The depth scale in the left column is in centimeters. The lithology is from DSDP notation for muddy diatom ooze. The colors were determined using a Munsell color chart.

Figure 3.1.2 Positive print of an X-ray picture of box core BAV79 A-2-2. Darker lines indicate higher density material than lighter lines.

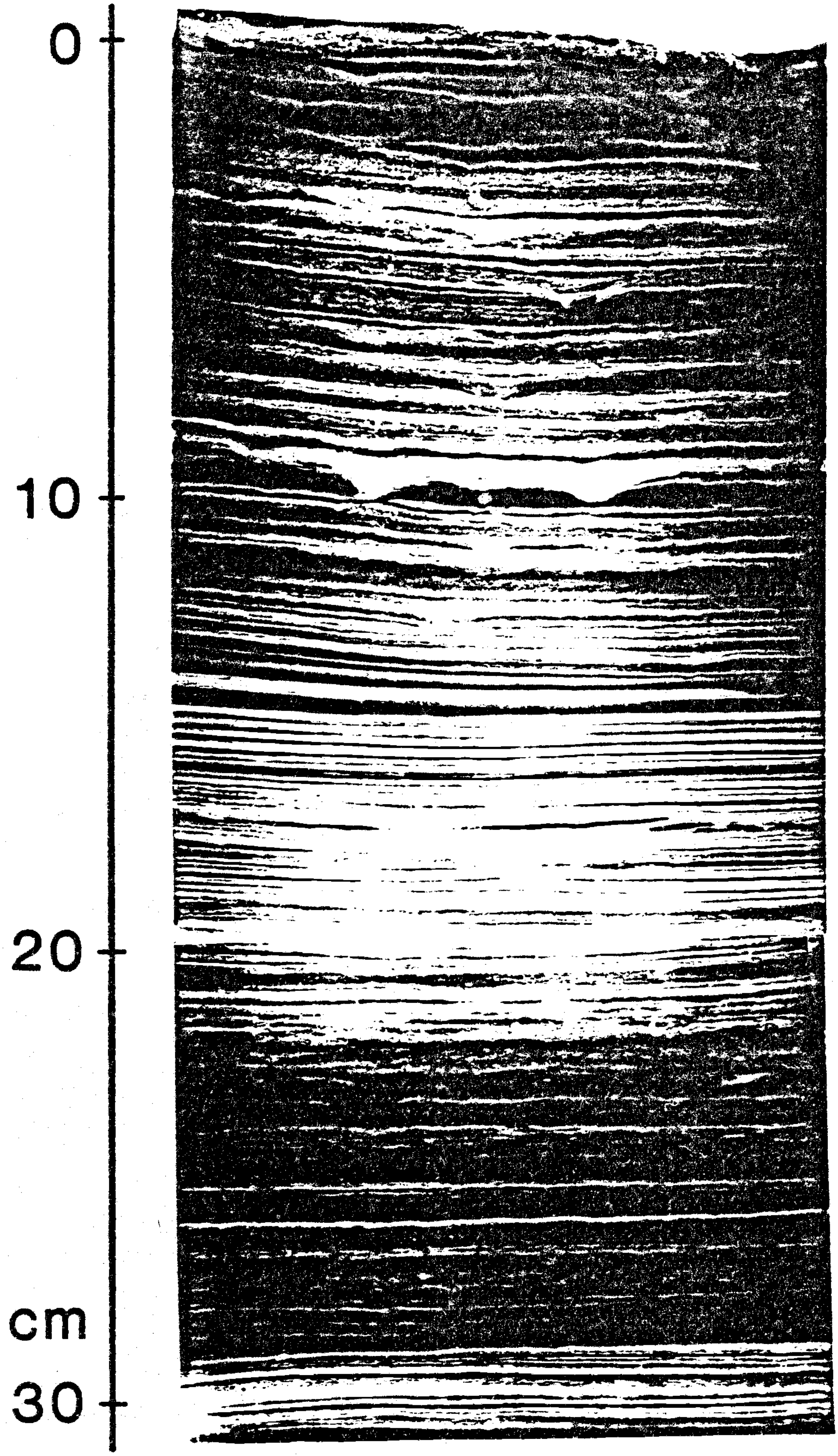


Figure 3.1.2

7, 1979-Sept. 30, 1979) cruise. After placing a sheet of plastic on top of the sediment surface, the core was sealed using two component polyurethane foam and the entire box was transported in a refrigerated van to Oregon State University for curation.

When the box was opened, it was noticed that the sediment height was 11 cm shorter than when sealed on board ship. This compaction is attributed to dewatering of the sediment. A Teflon coated metal sheet was used to subsample the core into 1 or 4 cm thick slabs. This method tended to compact the sediment by an additional 5 cm but laminations seen in the core (Figure 3.1.2) were not distorted and the material was useful for the focus of this study.

3.2.2 Individual Laminae Samples

The top 21.1 cm of a 1 x 15 x 30 cm slab (labeled BAV79 A-2-2) taken 3.5-4.5 cm from one side of the core was sampled on an individual laminae basis. The slab was left uncovered in a refrigerator to partially dry it until the distinction between light and dark laminae was more evident. A dissecting probe was used to pick a small amount of material from each laminae and the material was placed in separate 10 x 75 mm test tubes. Depths of distinct horizons were noted during the sampling process and photographs of the sampled core were taken to help document exact sample locations. Five drops of technical grade H_2O_2 (35%) and five drops of distilled water were added to each sample. The test tubes were placed in large glass beakers and the solutions were slowly boiled to dissolve some of the organic matter and to disperse the material. After cooling, the material of the first sample was resuspended by vigorous shaking and 300-400 μl (generally the whole sample) was withdrawn using a disposable glass pipette and divided evenly between two water-covered 18 mm square coverslips. This procedure was performed for each sample. The coverslips were allowed to dry slowly and mounted on standard microscopic slides using Hyrax as a mounting medium.

3.2.3 Composite Samples

Successive 2.5 cm long samples were taken from the upper 22.5 cm of BAV79 A-2-2. The sediment was placed in 400 ml beakers and 25 ml of a mixture of H_2O_2 (35%) and distilled water was added. The solution was boiled for 15 minutes which helped to dissolve some of the organic matter and disperse the sediment material. After a brisk stirring to homogenize the sample, 300-400 μl was immediately withdrawn using a disposable glass pipette and divided evenly between two water-covered coverslips. This procedure was performed for each sample and microscopic slides were made using the same procedure as for the individual laminae material.

3.3 Kasten Core Material

3.3.1 Recovery and Curation

Six Kasten cores (Figure 2.1, Table 3.2) containing laminated sediments obtained during the BAV79 and BAM80 cruises were analyzed in this study. A 7 cm (BAV79) or 4 cm (BAM80) thick layer of sediment from each Kasten core was placed in plastic trays on board ship. Samples for this study were obtained from the material in these trays. A 1 cm thick layer for X-ray analysis along with bulk density samples were also obtained from Kasten cores during the BAM80 cruise. All material in the trays was sealed with plastic wrap and transported in a refrigerated van to Oregon State University for storage.

3.3.2 Composite Samples

Before subsampling for this study the exposed face of all cores was scraped clean. Successive 5 cm composite samples were taken along the length of each cores by scraping a microscopic slide across the exposed face. The samples were placed in plastic capped vials, freeze-dried, and then homogenized. Approximately 0.4 gm of dried material from each sample was placed in 400 ml beakers. 25 ml of H_2O_2 (35%) was added and the samples were boiled until most of the organic material was dissolved and the strong boiling reaction subsided. Excessive foaming was stopped by adding a few drops of methanol. Samples were placed in 60 ml (5.5 cm high) plastic bottles and allowed to stand for 90 minutes. Two thirds of the supernatant liquid was decanted using a vacuum pump. These bottles were then filled with distilled water and thoroughly stirred. After 90 minutes, two thirds of the supernatant liquid was again removed. The process was continued until the supernatant liquid was fairly clear after 90 minutes. It was observed that no whole silicoflagellates and generally only clay sized particles were removed using this procedure. After the last decantation, the bottles were fillted with distilled water so that they contained 50 ml of solution. After a vigorous shaking a 25 μl aliquot was immediately withdrawn from the sample bottle using an Eppendorf automatic pipette. The material was spread evenly over a water-covered coverslip. This procedure was performed twice for each sample and after the coverslips were dried slowly, each was mounted on standard microscopic slides using Hyrax as a mounting medium.

3.3.3 Texture

Texture of the sediment from each of the six Kasten cores was estimated microscopically at 1000 times magnification (objective: Pl Apo/Oil 100x/1.32; ocular: Periplan GW 10xM) using 2.5 cm long scrapings from various levels in each Kasten core. Each sample, which contained a number of light and dark laminae, was placed in a 400 ml beaker containing 15 ml of distilled water. The solution was stirred to homogenize the sample and a 100 μl split was immediately withdrawn using an automatic Eppendorf pipette. The splits were spread evenly over water-covered coverslips, dried slowly, and mounted on standard microscopic slides using Hyrax as a mounting medium. Estimates of the relative clay (<4μm), silt (4 to 63 μm), and sand (63 μm to 2 mm) sized proportions were made. Within each size class, the terrigenous and biogenous amounts were estimated. This method was used by Donegan and Schrader (in press) for similar sediment material and closely follows DSDP shipboard standards for smear slide analysis (Kulm et al., 1973).

3.3.4 Sedimentation Rates

Sedimentation rates were determined for the Kasten cores by a continuous counting of the laminae along the length of each core. The cores were divided into 2.5 cm intervals (5 cm intervals in BAV79 B-29 [Matherne, 1982]) and counts of laminae were made in each interval. Where laminae were faint or indistinct, laminae counts were estimated based on the thickness of laminae form surrounding intervals. When an interval containing a thick terrigenous layer or the intersection of two plastic trays was encountered, the length was adjusted to subtract out these features.

Rates were calculated by assuming two laminae represent a varve which is equal to one year or deposition. Thus, the #varves/cm = #years/cm and the inverse will give sedimentation rates in cm/yr.

3.4 Hydraulic Piston Core [DSDP Leg 64, Site 480]

Scrapings from the working half were taken at 10 cm intervals along the entire length of the 152 meter core (Crawford and Schrader, in press). The sediment material was weighed before and after drying. The samples were boiled in 25 ml of H_2O_2 (35%) and 25 ml of saturated sodium pyrophosphate solution in order to remove the organic matter and disperse the clay sized material. The samples were then wet sieved through a 150 μm mesh metal sieve to separate the coarse and fine fractions. The fine fraction was processed for siliceous microfossil analysis using the same methods outlined for the Kasten core material except that 100 μl splits were used for each sample and Aroclor 4465 (R.I.=1.67) was used as a mounting medium. The coarse fraction was dried and placed in foraminiferal counting trays.

3.5 Microscopical Analysis

3.5.1 Silicoflagellate Assemblage

A Leitz Orthoplan microscope with 400 times magnification (objective: dry 40x/0.65; ocular: Periplan GW 10xM) was used to determine the composition of the silicoflagellate assemblage in each of the microscopic slides analyzed. Approximately 150-200 silicoflagellates were counted from each sample, although in many of the phytoplankton and individual laminae slides, limited abundances prohibited reaching this figure. When possible, extra mounts were made with a higher concentration of material (generally 200 μl) in an attempt to reach a representative count for each sample. Traverses scanned most of the coverslip and only individuals, where greater than one half of the skeleton was present, were counted. Replicate counts on a given slide and on additional slides from the same sample generally yield differences of less than 10% in the relative abundance of a given species but may reach 25% at times. Replicate counts of less than 150 individuals tend to increase this difference.

Taxonomy for this study follows Poelchau (1976) along with an in-house nomenclature for those species present in the Gulf of California sediments that were not found in North Pacific surface sediments. The silicoflagellates species found in the Gulf are pictured in Plates I-VI and a brief description of each is given in Appendix 1.

3.5.2 Semi-quantitative Abundances

Estimates of silicoflagellates per gram of dry sediment were obtained from processed Kasten core and hydraulic piston core samples. Three random traverses (representing approximately 1/10 of the slide) were made over a slide at 400 times magnification (objective: dry 40x/ 0.65; ocular: Periplan GW 10xM) and the number of silicoflagellates was tallied. The following equation was used to obtain semi-quantitative abundances.

$$A = \frac{B \text{ silicos}}{C \text{ mm}^2} \times \frac{18^2 \text{ mm}}{\text{Slide}} \times \frac{\text{Slide}}{D \times 10^{-3} \text{ml}} \times \frac{E \text{ ml}}{F \text{ g dry sediment}}$$

where A = abundance of silicoflagellates/gram dry sediment

B = number of silicoflagellates in transects.

C = area covered by transects (transects x .585 mm x 18 mm)

D = sample split in μl

E = sample dilution

F = dry weight

This is a modification of the equation used by Schrader and Gersonde (1978) to estimate the total number of diatoms per gram of dry sediment.

4. RESULTS AND DISCUSSION

4.1 Silicoflagellates in Phytoplankton and Surface Sediments

4.1.1 Studies from Nearby Areas

Because silicoflagellates are a minor component in the phytoplankton, details of species distributions have rarely been documented in plankton studies. A major problem in using previous reports where distributions of silicoflagellates have been documented is that names of particular species differ from study to study. It is sometimes difficult to convert from one taxonomic scheme to another when species identified in the samples are not pictured in the manuscript.

Poelchau (1976) determined the silicoflagellate assemblage in sediment surface samples from the North Pacific. He identified six species and two forms in the samples and five of these species, *Dictyocha messanensis* Haeckel, *D. calida* Poelchau, *D. epiodon* Ehrenberg, *Distephanus speculum* (Ehrenberg) Haeckel, and *Octactis pulchra* Schiller are present in Gulf of California sediments. Poelchau divided *Dictyocha messanensis* Haeckel into *D. messanensis* fa. *messanensis* Haeckel and *D. messanensis* fa. *spinosa* Lemmermann. This study did not make this distinction.

DeVries and Schrader (1981) report *Dictyocha* spp. and *Distephanus speculum* present in sediments from the upper-slope mud lens off Peru. Further analysis of these sediments indicates that *Dictyocha* spp. corresponds to *D. messanensis*, *D. calida*, and *D. spec.1* using the nomenclature in this study, and *Octactis pulchra* was incorrectly identified as *Distephanus speculum*. *Dictyocha messanensis*, *D. calida*, *D. spec.1* and *O. pulchra* also comprise the silicoflagellate assemblage in a surface sample of core Y69 106P (2°59.0'N, 86°33.0'W; 2870 m water depth) from the Panama Basin.

O'Kane (1970) reported two species and seven varieties in plankton samples obtained during March 1968 to November 1969 from Monterey Bay, California. These correspond to D. messanensis, D. epiodon, Distephanus speculum, and Octactis pulchra in this study. Distephanus speculum was the most abundant of these during the sample period in Monterey Bay and is also the most abundant silicoflagellate in surface sediments from the Santa Barbara Basin (Schrader, pers. comm.).

Based on these studies, one can establish a biogeographic distribution, in the North Pacific and the Tropics, of the species which are present in the Gulf of California. Distephanus speculum, a cold water species, is abundant in the Bering Sea and subarctic Pacific and extends to the south along the continental margins. Dictyocha epiodon mainly occurs in the Alaskan Gyre and in the western North Pacific. Its distribution also extends south along western North America in association with the California Current. Dictyocha messanensis is a cosmopolitan species and dominates the assemblage away from the continental margins south of 45°N. Dictyocha calida is found in relatively low abundance and is associated with the Equatorial Countercurrent. Octactis pulchra is found in the eastern tropical Pacific in association with locals of high primary production in upwelling areas. Dictyocha spec. 1 is present in the eastern tropical Pacific continental margin area.

4.1.2 Phytoplankton

The composition of the silicoflagellate assemblage was determined in ninety-nine plankton samples from the BAM80 cruise (Figure 4.1) and were chosen to obtain a representative spacial and temporal distribution from the data set. Seven species and three forms were identified in the samples. Silicoflagellates generally make up less than two percent of the siliceous assemblage which is dominated by diatoms. In a few samples where "blooms" of Dictyocha messanensis or Octactis pulchra have been observed, silicoflagellates comprise up to five percent of the siliceous assemblage.

Local sea surface temperature and wind conditions were obtained at each station (Table 3.1). During the month of November, winds were generally from the northwest in the Gulf of California with higher speeds observed at the end of the month. These results are consistant with the average wind pattern for this period (Roden, 1964). Sea-surface temperature values show an equatorward shift during the study period. This temperature distribution closely follows the mean sea-surface temperature pattern established by Robinson (1973) for the same time period.

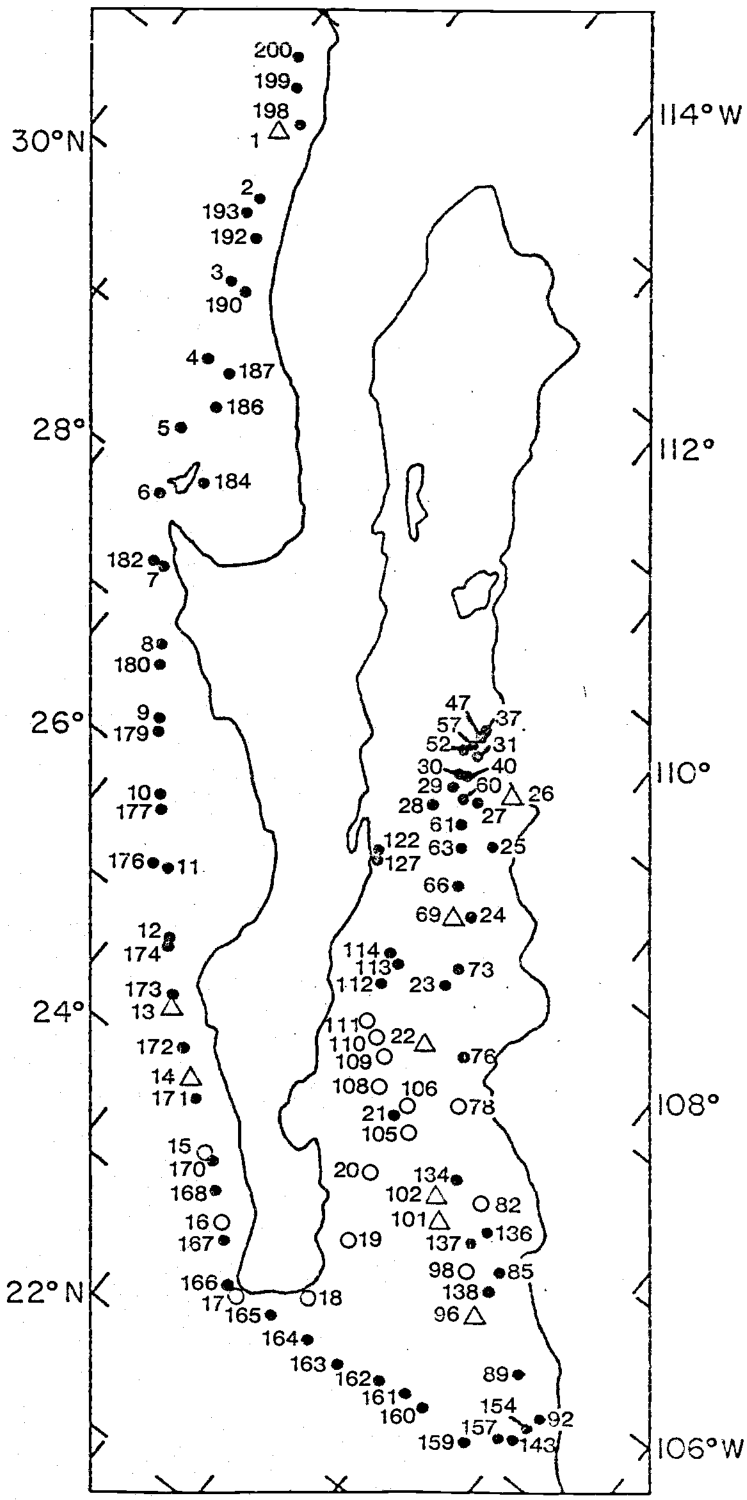
Figures 4.2.1 and 4.2.2 show the relative percent distribution of each of the species present. The samples, which were taken over the period from 10/31/80 to 12/2/80, are considered to be time equivalent in order to observe the general areal distribution of the species during the sampling period. In most of the samples from the area near the mouth of the Gulf silicoflagellates, and siliceous material in general, were not abundant and usually less than fifty individuals were counted (Figure 4.2.1).

Figure 4.1 Location of all phytoplankton stations, from the BAM80 cruise, used in this study. Co-ordinates for each station are given in Table 3.1.

O = <10 silicoflagellates counted from the sample

Δ = 10-50 silicoflagellates counted from the sample

● = >50 silicoflagellates counted from the sample


30°N
28°
26°
24°
22°N
114°W
112°
110°
108°
106°W
200
199
198
1
2
193
192
3
190
4
187
186
5
184
6
182
7
8
180
9
179
10
177
176
11
12
174
173
13
172
14
171
15
170
168
16
167
166
17
165
18
164
163
162
161
160
159
157
154
143
92
89
47
57
37
52
31
30
40
29
60
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28
27
61
122
63
25
127
66
69
24
114
113
112
23
73
111
110
22
109
76
108
106
21
78
105
20
134
102
82
101
136
19
137
98
85
138
96

Figure 4.1

Figure 4.2.1, 4.2.2 The distribution of the relative percent of silicoflagellate species in BAM80 phytoplankton samples. See Figure 4.1 for key to station location symbols.

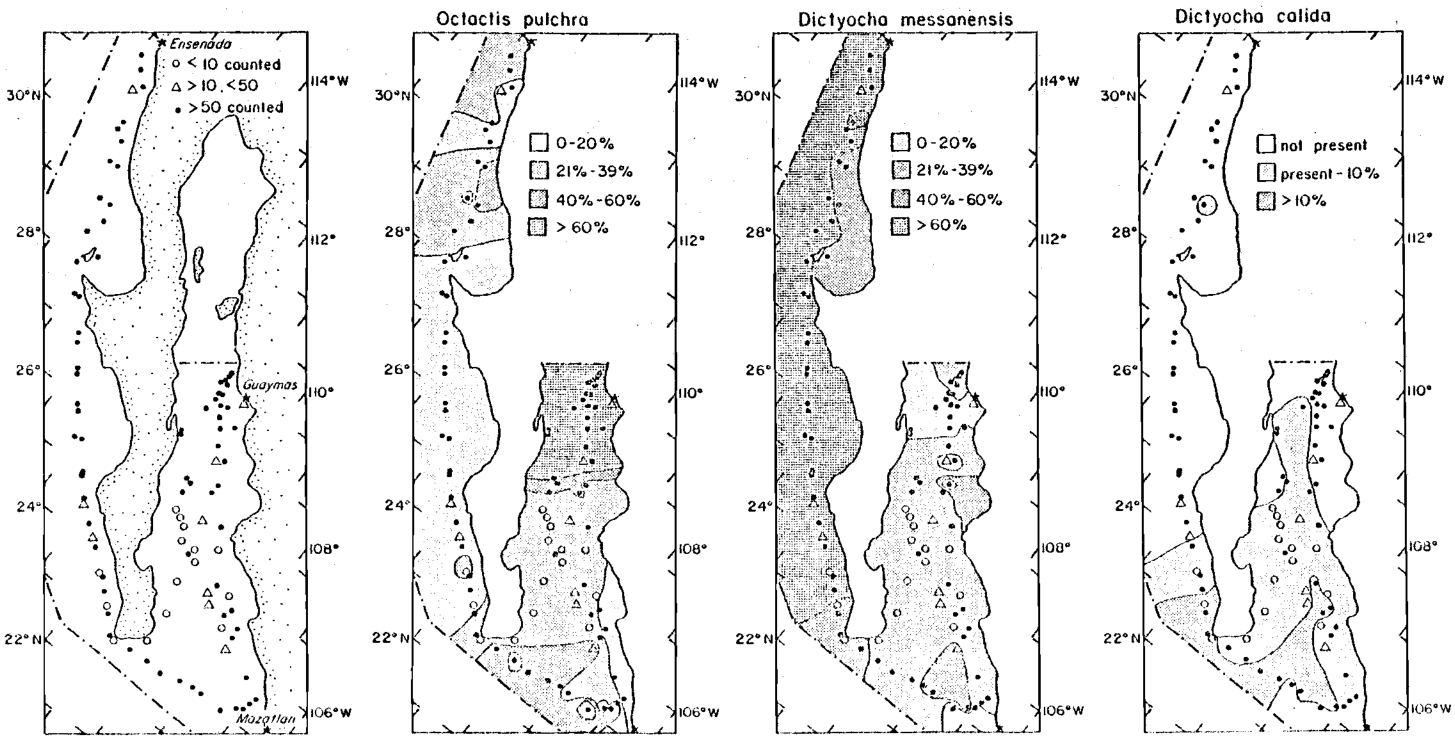

Ensenada
o < 10 counted
△ > 10 ,<50
• > 50 counted
Guaymas
Mazatlan
30°N
28°
26°
24°
22°N
114°W
112°
110°
108°
106°W
Octactis pulchra
0-20%
21%-39%
40%-60%
> 60%
Dictyocha messanensis
0-20%
21%-39%
40%-60%
> 60%
Dictyocha calida
not present
present - 10%
> 10%

Figure 4.2.1

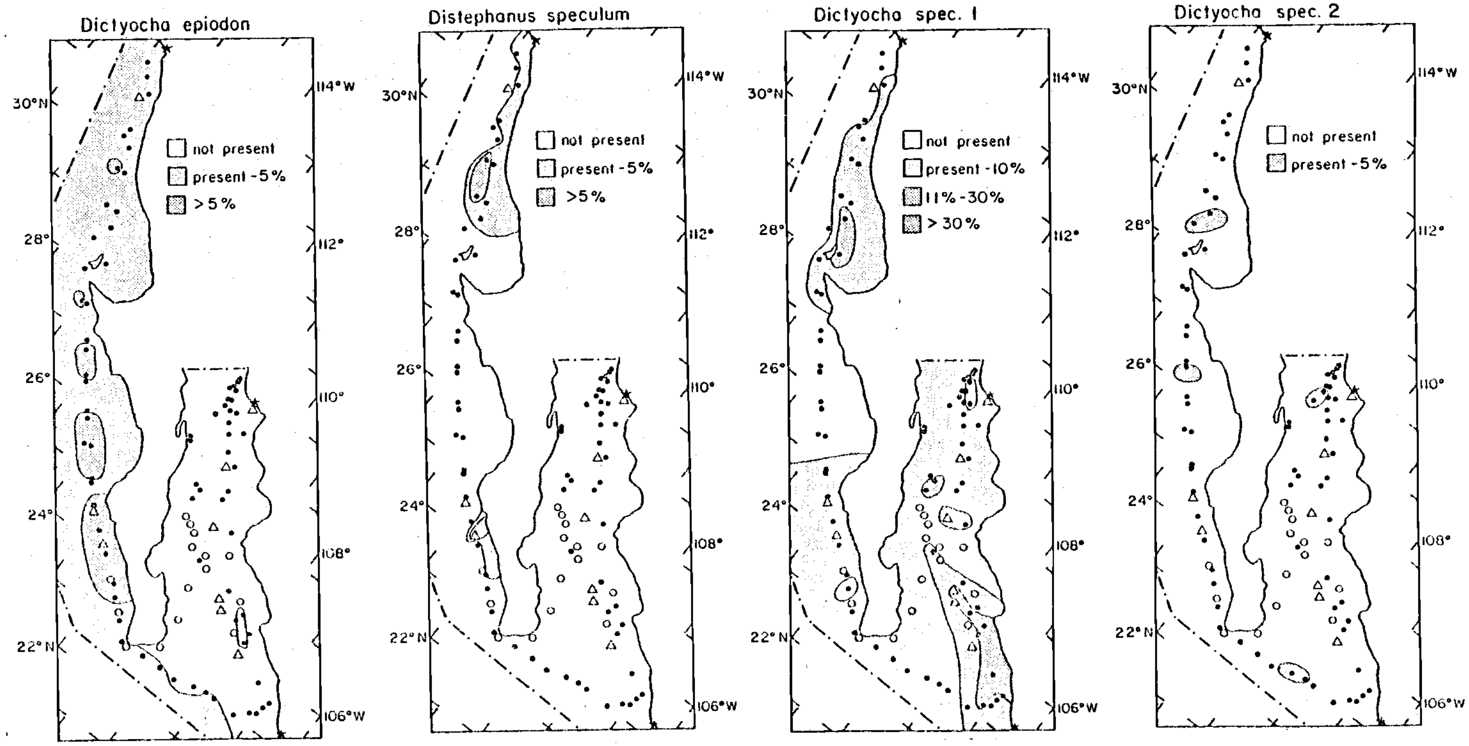

Dictyocha epiodon
not present
present -5%
>5%
Distephanus speculum
not present
present -5%
>5%
Dictyocha spec. 1
not present
present -10%
11%-30%
> 30%
Dictyocha spec. 2
not present
present -5%
30°N
28°
26°
24°
22°N
114°W
112°
110°
108°
106°W

Figure 4.2.2

Because counting less than 150 individuals does not always yield a representative assemblage for a particular location, nearby samples where more representative counts were obtained, were used in positioning of contours of species distribution.

In the phytoplankton samples, Octactis pulchra is in greatest abundance in the central Gulf above 26°N (Figure 4.2.1). It is also present in high abundance at the mouth of the Gulf and between 29°N and 30°N in the Pacific coastal stations. It can be seen that the highest abundance of Octactis pulchra in these samples is in the surface waters of the Guaymas and Carmen Basins, which coincides with the area showing highest levels of primary productivity in earlier studies (Round, 1968; Zeitzschel, 1969). Samples in these regions are also indicative of high levels of primary production based on the diatoms present (abundant Chaetoceros spp. vegetative cells, Bacteriastrum spp., Thalassionema-Thalassiothrix spp., a.o.). These results imply that high nutrient levels are associated with increased abundance of O. pulchra. Previous studies have documented that upwelling of nutrient rich waters occurs on the east side of the Gulf of California in association with strong northwest winds. The distribution of O. pulchra implies that there are high nutrient levels on both sides of the central Gulf possibly indicating that mixing, more than upwelling, is responsible for bringing nutrients to the surface to support high levels of primary production. Results from Donegan and Schrader (in press) are supportive of this statement.

Dictyocha messanensis dominates the silicoflagellate assemblage in the Pacific stations west of Baja (Figure 4.2.1). Some "blooms" of this species were observed at stations along the northern part of the Baja Peninsula. This species also dominates in samples where silicoflagellates are rare in abundance, such as stations at the mouth of the Gulf. It was generally observed that a smaller form of D. messanensis (Plate II:6,7) persisted in samples from the Pacific Ocean, whereas a larger form of D. messanensis (Plate II:3,5) was more prevalent in Gulf stations. Within the Gulf this species increases in relative abundance when either O. pulchra or D. spec. 1 decreases in abundance. This may indicate that O. pulchra and D. spec. 1 are more susceptible to blooms than is D. messanensis. Poelchau (1974) presents support for this observation.

The warm water species, Dictyocha calida, which is associated with the Equatorial Countercurrent, is present in relatively high abundance at the mouth of the Gulf and is present in low numbers in waters extending up to 27.5°N within the Gulf (Figure 4.2.1). This species is also present on the Pacific side of Baja as far north as 24°N which corresponds to the 24°C isotherm (Table 3.1).

The distribution of Dictyocha epiodon (Figure 4.2.2), which is associated with California Current Water, moves further to the south along the Baja peninsula during the sampling period in association with the 25-26°C isotherms (Table 3.1). Its distribution extends across the mouth of the Gulf by the end of November. Wyrtki (1967) uses the 25°C isotherm to mark the boundary of tropical surface waters. Thus, variations in the southward extent of D. epiodon in the surface waters of the eastern Pacific could be an indication of the movement of the front between the California Current and Subtropical Surface Water. The presence of both D. epiodon and D. calida near the mouth of the Gulf indicates a mixing of Equatorial waters and California Current Water in this region.

Distephanus speculum, a cold water species, is found in minor abundance at the Pacific stations along the north coast of Baja California above 28.5°N and also near the coast between 23.5-24.5°N (Figure 4.2.2). This lower region had measured temperatures between 25-26°C which is generally considered as an upper limit for Distephanus speculum.

Dictyocha spec. 1 has three forms distinguished in these samples and is present in most localities studied within the Gulf, reaching its highest abundance of greater than 50% near the mouth of the Gulf on the mainland side (Figure 4.2.2). Here the assemblage mainly consists of D. spec. 1 fa. A. Further to the north, along the mainland side, a mixed assemblage of D. spec. 1 fa. A and fa. B is present. A similar mixed assemblage is also found on the Baja side of the area near the mouth of the Gulf of California. D. spec. 1 fa. B dominates the assemblage in the central Gulf on the Baja side and in samples above 28°N from Pacific stations. D. spec. 1 fa. C is present in Pacific samples above 29°N in minor amounts. Although in relatively low abundance compared to other silicoflagellate species present, form "A" is the dominant form of D. spec. 1 in Pacific stations along the lower part of the Baja peninsula. Generally, D. spec. 1 increases in abundance to the south. As was mentioned earlier, it is found in nearshore stations on the Peru slope at approximately 16°S and in the Panama Basin. Poelchau (1976) did not report its presence in any of his North Pacific surface sediment samples which have a poor representation along the eastern tropical and subtropical continental margin. This information may suggest that this species has a tropical to subtropical margin distribution and its presence in the Gulf of California is indicative of Equatorial waters moving up the coast of Central America and Mexico in association with southwesterly winds and El Niño type events.

Dictyocha spec. 2 shows no apparent preferred distribution in these samples (Figure 4.2.2). This species was never found more than two percent of the silicoflagellate assemblage when present.

4.1.3 Surface Sediments

The composition of the silicoflagellate assemblage in the 0-5 cm composite sample from each of the six Kasten cores (Figure 2.1, Table 3.2) used in this study. Each sample represents an average of approximately 15 years of deposition, based on laminae counts over these intervals. Variations in the composition of the silicoflagellate assemblage in the Gulf of California can be seen in Figure 4.3.

The relative percent of O. pulchra decreases down the Gulf from greater than 40% to less than 5%. All other forms increase in relative abundance down the Gulf with greatest abundances of D. spec. 1, D. spec. 2, and D. epiodon in BAM80 G-34.

Absolute abundances of silicoflagellates per gram of dry sediment and textural composition were also determined in the surface sediments from the six Kasten cores (Tables 4.1 and 4.2). Abundances range from 15×10^6 silicoflagellates per gram of dry sediment in the surface of BAM80 E-17 to 0.2×10^6 silicoflagellates per gram of dry sediment in BAM80 G-34. Abundances in BAM80 E-17 are higher than those reported from the North Pacific by Poelchau (1976), except for the area beneath the Western Convergence off of Japan. Diatom abundances are at least one order of

Figure 4.3 The relative composition of the silicoflagellate assemblage in surface samples from the Gulf of California. Histograms represent relative percent of each species in the 0-5 cm sample from each Kasten core. Lines point to respective core locations.

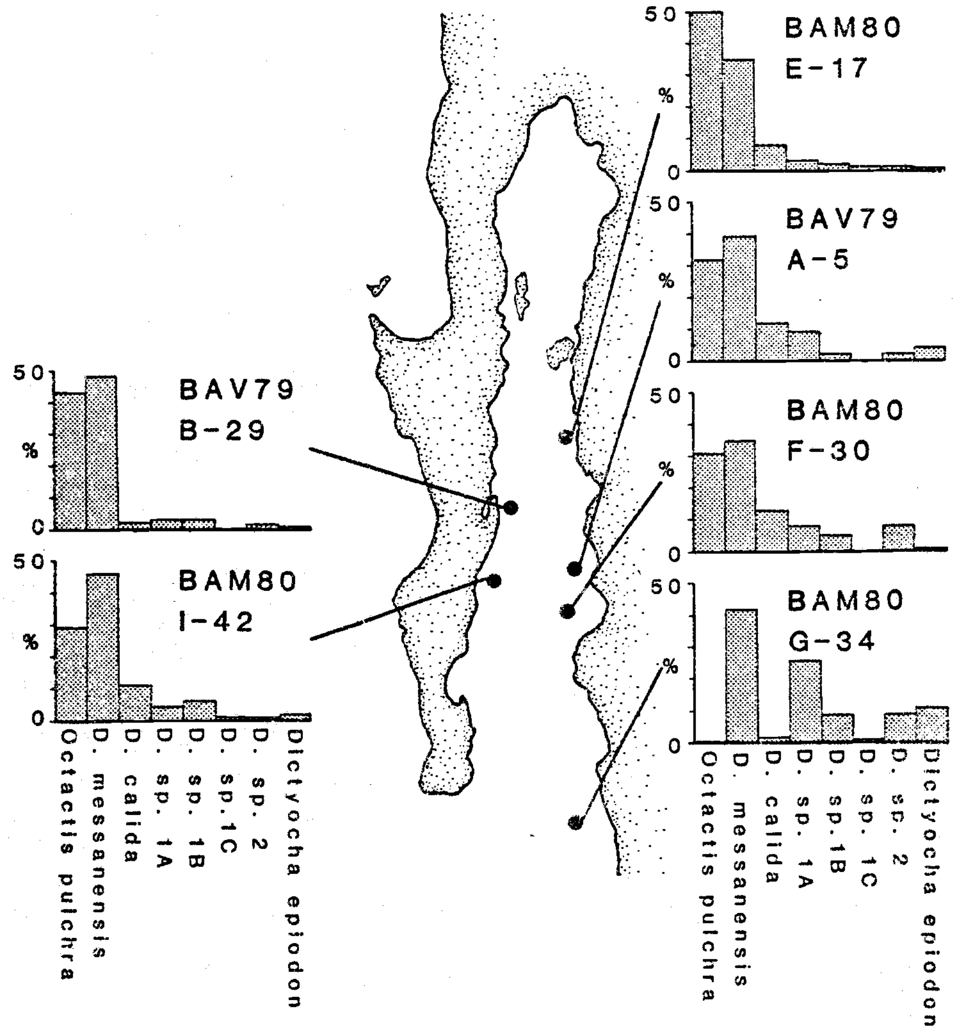

BAM80
E-17
BAV79
A-5
BAM80
F-30
BAM80
G-34
BAV79
B-29
BAM80
I-42
50
%
0
Octactis pulchra
D. messanensis
D. calida
D. sp. 1A
D. sp. 1B
D. sp. 1C
D. sp. 2
Dictyocha epiodon

Figure 4.3

Table 4.1 Semi-quantitative abundance of silicoflagellates in sediments from the Gulf of California

	Silicoflagellate Abundance (10^6 silicoflagellates/gm dry sediment)
BAV79 A-5	0.2 - 1.5
BAV79 B-29	1.5 - 3.0
BAM80 E-17	1.5 - 15.0
BAM80 F-30	0.5 - 2.0
BAM80 G-34(1)	0.2 - 1.5
BAM80 I-42	2.0 - 4.0
DSDP Site 480(2)	
Laminated Section	3.0 - 8.0
Homogeneous Section	0.2 - 0.5

(1) only the laminated section of G-34 (0-255 cm) was examined

(2) only samples above Core 7 (30 m) were examined

Table 4.2 Visual estimation of the textural composition in surface samples from all Kasten cores used in this study. The % Biogenous/% Terrigenous is the proportion of biogenous vs. terrigenous material in the total sample.

		Clay	Silt	Sand[1]	% Biogenous/% Terrigenous[2]
BAV79 A-5	0 - 2.5 cm	50 - 70%	30 - 40%	0 - 10%	50 - 60 / 40 - 50
BAV79 B-29	0 - 2.5 cm	30 - 40%	50 - 70%	0 - 10%	60 - 80 / 20 - 40
BAM80 E-17	0 - 2.5 cm	20 - 60%	40 - 80%	0 - 10%	60 - 90 / 10 - 40
BAM80 F-30	0 - 2.5 cm	60 - 80%	20 - 40%	0 - 10%	30 - 50 / 50 - 70
BAM80 G-34	0 - 2.5 cm	60 - 70%	20 - 40%	0 - 10%	20 - 30 / 70 - 80
BAM80 I-42	0 - 2.5 cm	30 - 40%	60 - 70%	0 - 10%	60 - 90 / 10 - 40

(1) The sand-sized fraction is composed of large centric diatoms

(2) Diatoms generally comprise 90% of the biogenous fraction in all areas.
Silicoflagellates are <2% of the biogenous fraction in all areas.
Radiolaria increase in abundance towards the mouth of the Gulf.
Coccoliths are present in A-5, B-29, and I-42.
Biogenic carbonate is not present in the surface samples from E-17 or F-30.

magnitude greater than silicoflagellates in BAV79 B-29 and BAM80 E-17 (Matherne, 1982). Further analysis indicates a similar relationship in the other four cores. Generally, terrigenous clay content increases down the Gulf on the mainland side. This is consistent with increasing rainfall towards the mouth of the Gulf (Section 2.1). The high content of silt sized material is generally a reflection of a well preserved diatom and silicoflagellate assemblage. The decrease in absolute abundance of diatoms and silicoflagellates and an increase in clay content towards the mouth of the Gulf is associated with poorer preservation. This may explain why O. pulchra and D. calida, which are more delicate forms, are in such low abundance in BAM80 G-34.

The relative distribution of O. pulchra, D. messanensis, and D. spec. 1 in the surface sediment samples is generally consistent with the assemblage obtained from phytoplankton samples. Variations noted in the presence of D. epiodon and D. calida are probably a reflection of the extent to which their associated water masses influence the Gulf of California over a sampled time interval.

4.1.4 Summary

A summary of these results indicates that O. pulchra is indicative of high levels of productivity in tropical and subtropical regions. D. messanensis dominates the assemblage with decreasing amounts of O. pulchra in the Gulf of California and has much higher abundances outside the Gulf. D. calida is associated with the Equatorial Countercurrent and is found both north and south of the equator.

D. epiodon is a transitional zone species associated with the California Current, and Distephanus speculum is a cold water species also associated with the California Current. Dictyocha spec. 1 is associated with Equatorial Water along the continental margin. Because of the poor documentation of the distribution of D. spec. 2, its biogeographic distribution can not be determined at this time.

4.2 Fine Scale (0-5 year) Downcore Changes

4.2.1 Individual Laminae Samples

The top 21.1 cm of box core BAV79 A-2 (Figures 3.1.1 and 3.1.2) was sampled laminae by laminae to ascertain the fine scale variability in the composition of the silicoflagellate assemblage from a greater than fifty year time interval. The downcore plots of relative abundance of each species in the top 120 laminae (Figure 4.4) indicate a large variability in composition over time. Results from this core do not support a model in which a characteristic silicoflagellate assemblage is associated with either light or dark laminae as proposed by Donegan and Schrader (in press) for two nearby areas in the Gulf of California.

From Figure 3.1.2, it can be seen that the top 10 cm of the core exhibits a large amount of disturbed areas with individual laminations becoming more distinct below this level. Because the laminae are not as clear in the upper 10 cm, the ability to sample individual laminae in this interval is questionable. Some samples may be a mixture of a few seasons of deposition. A composite sample was taken over the interval from 10.1 - 10.6 cm because the section was disturbed and laminae were indistinct. A gap in the sampling record occurs

Figure 4.4 Relative percent of silicoflagellates in the top 120 laminae from box core BAV79 A-2. A tentative time scale is given in the left hand column. Column A is depth in centimeters. Column B is the laminae number with the surface of the core = no. 1. A gap in sampling record occurs between laminae no. 10 and no. 11. Heavy lines indicate the relative abundance of silicoflagellates in composite samples from each interval. X-ray slab no. 2 was used for this study.

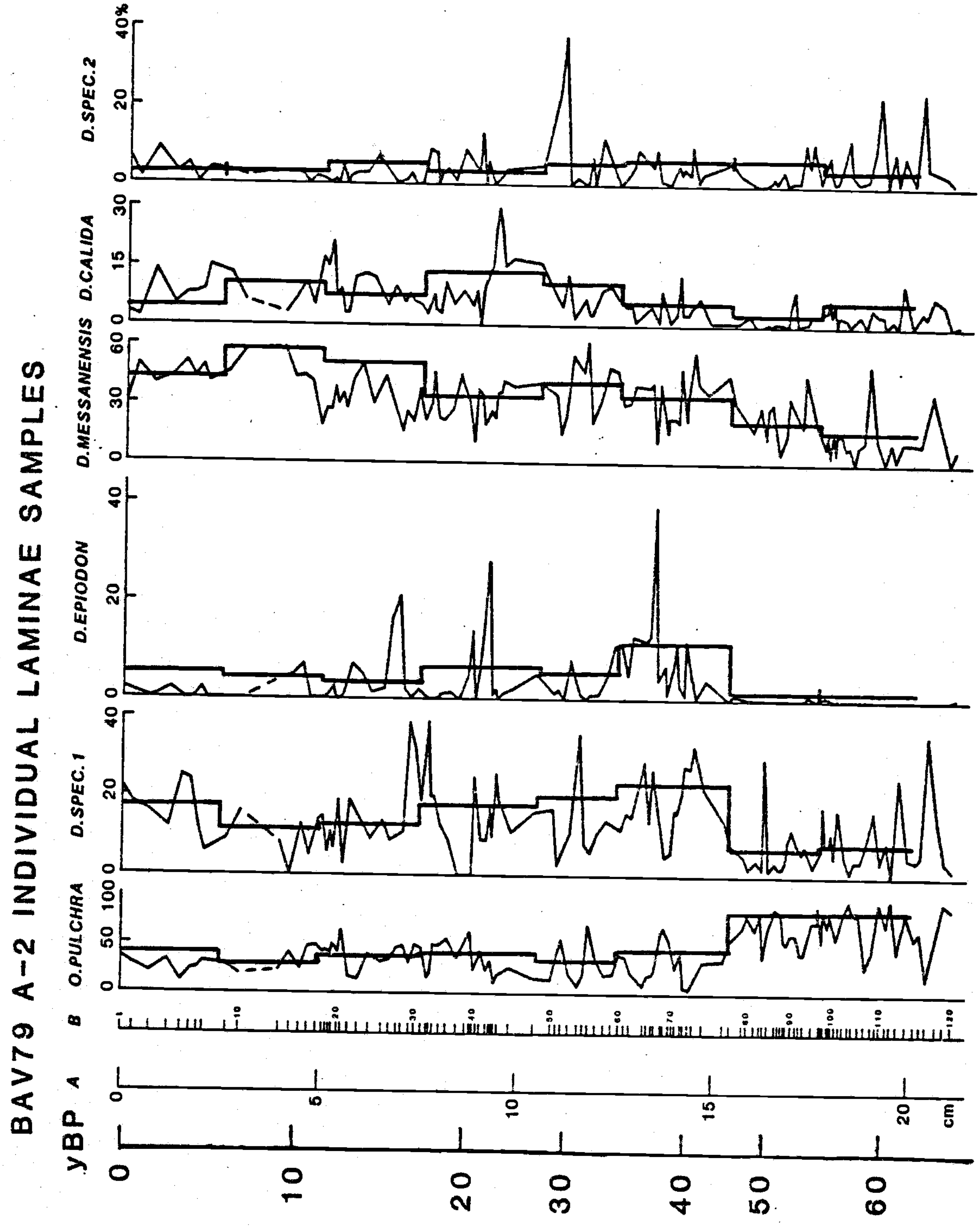

BAV79 A-2 INDIVIDUAL LAMINAE SAMPLES
D.SPEC.2
D.CALIDA
D.MESSANENSIS
D.EPIODON
D.SPEC.1
O.PULCHRA
B
A
yBP
cm
40%

Figure 4.4

from 3.0 - 4.0 cm (between laminae #10 and #11). Before being sampled laminae by laminae, the subsection of BAV79 A-2 was allowed to partially dry (Sec. 3.2.2). During this process, portions of the core shrank and breaks in the section occurred. This did not disturb the sampling record but it does mean that the reported distances between laminae (Figure 4.4, Column B) are not true representations of original laminae thicknesses.

Silicoflagellate abundances are generally low in individual samples in this core. The upper disturbed section has a greater terrigenous clay content and poorer preservation of the silicoflagellate assemblage than the section below. Because of this, it was difficult to obtain a representative count in most of the samples. A better record could be obtained from cores in an area where laminations are thicker and more distinct (to ease in the sampling process and reduce the number of missing laminae), and, where silicoflagellates are present in greater abundance (to obtain a representative count from each laminae).

General trends show Octactis pulchra in lower relative abundance in the upper, more disturbed, section of the core with higher abundances in the well laminated section. This may be a reflection of the productivity in the overlying waters with higher abundances of O. pulchra corresponding to higher levels of primary productivity. The decomposition of the high flux of organic matter from the surface waters associated with high levels of primary production would lead to a strengthening of the oxygen minimum zone. This would exclude benthic life and preserve the laminations.

Dictyocha messanensis shows an opposite relationship to Octactis pulchra. D. messanensis has been described as a cosmopolitan species in the North Pacific below 45°N and tends to dominate the assemblage in Gulf samples with a decrease in O. pulchra. Its relative increase may either be a reflection of increased influence of oceanic waters in the region or a decrease in the productivity levels in the overlying waters.

D. spec. 1, D. epiodon, D. calida, and D. spec. 2 are all generally present in low abundances with intervals of extreme high abundances. These may be interpreted as oceanographic related event indicators and are used to establish time equivalent depositional horizons in the Gulf (Schrader, in prep.). Using previously established associations of D. epiodon and D. calida to the California Current and Equatorial Countercurrent, respectively, one can interpret these peak abundances as representative of a high influence of these particular water masses in the Gulf of California over time. Generally more than one laminae comprise a peak event which indicates that the associated water mass influences an area for more than one season.

Based on the number of laminae sampled and taking into account breaks in the sampling record due to indistinct laminations, a tentative time scale can be assigned to the section (Figure 4.4). The break in the sampling record from 3.0 - 4.0 cm is assumed to represent 3 years of deposition and the composite sample between 10.0 - 10.6 cm represents 2 years of deposition so a total of 5 years was added to the time scale.

An initial attempt to relate variations in the composition of the silicoflagellate assemblage to time equivalent changes in the flow of the California Current (Chelton, 1981) yields a poor correlation. Present work by Schrader (pers. comm.) and Baumgartner et al. (1981) indicates that a single core from a given area may contain small gaps in the laminae record. Thus, it may be necessary to obtain a suite of cores from an area and establish time equivalent horizons between cores where gaps in the record (if any) can be resolved. The composition in the silicoflagellate assemblage in this complete laminae record could then be compared to oceanographic and atmospheric variations over the same time interval.

4.2.2 Composite vs. Individual Laminae Samples

Successive 2.5 cm composite samples were taken from core BAV79 A-2 to determine how well the silicoflagellate assemblage in a composite of a number of laminae represents the assemblage in individual laminae within the interval. Because these sediments are laminated and unmixed, a 2.5 cm composite scraping across each interval was used to obtain a time averaged signal from the whole interval. The mean for each species from the individual laminae in a given depth interval was compared with the values (± 10% counting error) from the composite sample over that same interval. The results (Table 4.3) indicate a significant difference between 14 out of 56 of the means tested. This was determined using a Student T test statistic and a 95% confidence limit. The results indicate that in these 14 cases, the composite sample is not a representative mixing of the laminae over these intervals.

Table 4.3 A comparison between the relative percent of silicoflagellate species in composite samples (C) of BAV79 A-2 and mean values of the relative percent of each species in individual laminae from each interval (L). Values with an * indicate those cases where the value (±10% counting error) obtained from the composite sample is significantly different from the mean value of the laminae counts. This was determined using a Student T test statistic and a 95% confidence limit.

	0.0-2.5 cm		2.5-5.0 cm		5.0-7.5 cm		7.5-10.5 cm		10.5-12.5 cm		12.5-15.3 cm		15.3-17.6 cm		17.6-20.0 cm		20.0-22.5 cm	
	C	L	C	L	C	L	C	L	C	L	C	L	C	L	C	L	C	L
Octactis pulchra	36	27*	23	34*	31	38*	34	35	27	30	35	32	75	65*	76	72	59	-
Dictyocha messanensis	40	44	54	44	47	32*	30	31	37	39	30	33	17	24*	12	11	26	-
Dictyocha calida	3	8*	9	9	6	9*	12	11	9	7	5	6	1	2	4	3	3	-
Dictyocha spec 1A	11	11	4	6	8	12	9	7	10	6*	7	7	4	5	5	7	7	-
Dictyocha spec 1B,1C	5	6	6	3*	3	3	7	7	9	7	13	11	1	1	1	1	2	-
Dictyocha spec 2	2	4	2	2	4	2	2	4*	4	9	5	4	5	3*	2	5*	3	-
Dictyocha epiodon	4	1*	3	2	2	4	5	4	4	3	10	8	0	0	0	0	<1	-
Total counted/ Laminae per interval	169/8		160/7		211/15		212/20		206/10		237/18		223/17		207/20		215/-	

The problems may lie in the counting and sampling of the individual laminae. As mentioned earlier, in most samples less than 150 silicoflagellates were counted. This would tend to increase the counting error. The laminae were very thin in many instances and sampling using a probe may not have obtained a representative sample from each laminae. There are also sections where gaps exist in the sampling record which could have an effect on the mean value from the interval. Generally, a good record was obtained from the lower, well laminated section of the core. The 10% estimate of the variability in the counts from the composite samples may be a low value in many instances. A more accurate estimate of the error could reduce the number of cases where the assemblage in the composite sample differs from the mean values of the individual laminae samples. In concluding that the composite sample is representative of the mean of the individual laminae samples within an interval, it must be assumed that each laminae contributes the same relative amount to the composite sample. This does not take into account variations in laminae thickness or silicoflagellate abundance downcore. Any of these errors in counting or sampling could account of the differences between the composite samples and the individual laminae samples.

Even with these errors, the downcore assemblage in the 2.5 cm composite samples show the same trends present in the individual laminae samples (Figure 4.4). There is no significant difference in the mean of each species from individual laminae and composite samples when the entire sampled interval is considered. The relative range in abundance of each species is greatly decreased and the amplitudes of species events are reduced when composite samples are used. By using sampling intervals of greater than 2.5 cm, the amplitudes of species events would be further reduced and only major events or trends of each species would be seen.

4.2.3 Summary

These results indicate that there is a high variability in the composition of the silicoflagellate assemblage from laminae to laminae. There is no indication of a characteristic assemblage associated with either light or dark laminations in this area. A high relative abundance of *Octactis pulchra* is found in the well laminated sections of the core and *D. spec. 1*, *D. epiodon*, *D. calida*, and *D. spec. 2* periodically exhibit high abundances generally spanning more than one season of deposition. These "events" can be used to correlate between cores and to oceanographic and atmospheric data.

The composition of the silicoflagellate assemblage in composite 2.5 cm samples generally represent the mean of the individual laminae samples from the corresponding section in the core. Major events and trends of the silicoflagellate assemblage can be seen from composite samples although the amplitudes of species events are reduced.

4.3 Recent (0-2000 year) Downcore Variations

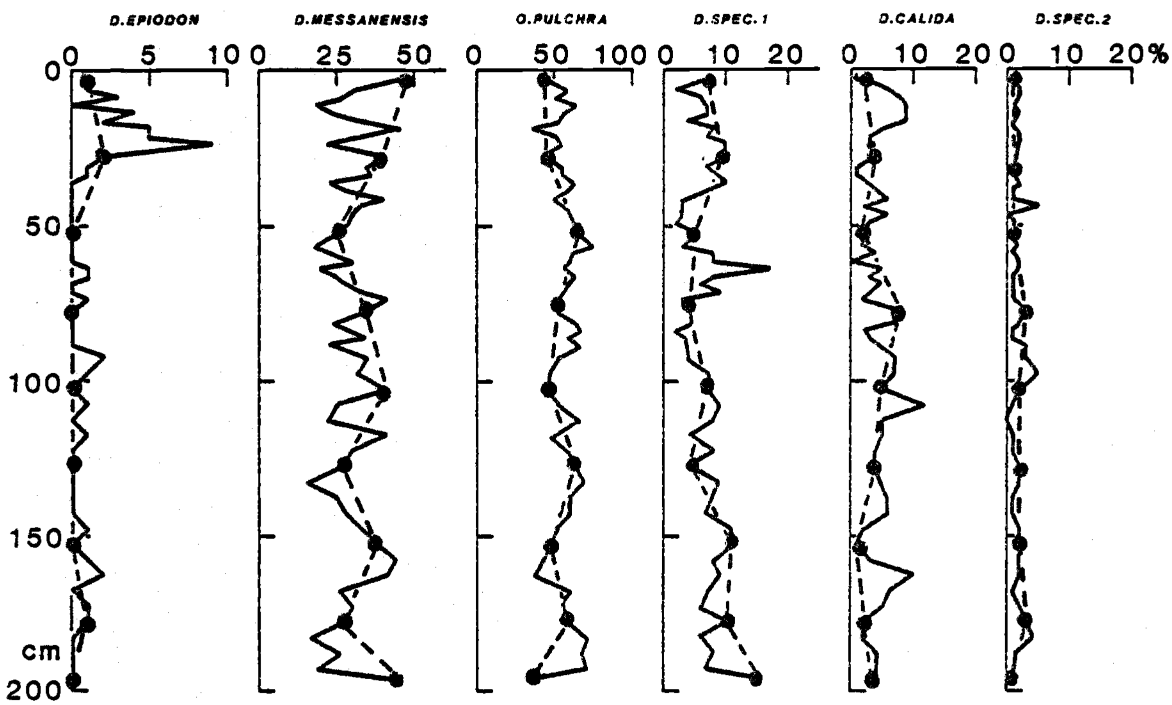
The results in Section 4.2.2 indicate that the silicoflagellate assemblage obtained from a 2.5 cm composite sample generally represents the mean of the assemblage from individual laminae within the same section. A 2.5 cm interval also tends to retain some of the fine scale (0-5 year) events observed in the individual laminae samples (Figure 4.4). Larger sampling intervals reduce the representation of the high amplitude events in each species and thus more general trends in the silicoflagellate assemblage are observed. Composite 5 cm samples from Kasten cores were used to examine general trends in the assemblage downcore, but also retaining some of the signal from individual species events. Based on laminae counts, a 5 cm composite sample represents 13-40 years of deposition with average values from 19-27 years.

4.3.1 Consecutive Samples vs. Samples at 25 cm Intervals

Using three Kasten cores, a comparison was made between the silicoflagellate assemblage in consecutive 5 cm and 2.5 cm composite samples, and, samples taken every 25 cm (Figures 4.5 and 4.6). Hans Schrader provided the silicoflagellate data from the consecutive samples. This comparison was made to determine if major downcore assemblage variations in the detailed record are preserved when the cores are sampled in less detail. These variations are on the order of hundreds of years. An F test statistic was used to determine if the variance of each species in the detailed record is significantly different from the record when samples are taken every 25 cm. In all cases, at a 95%

Figure 4.5 and 4.6 Downcore plots of the relative percent of each silicoflagellate species in 5 cm and 2.5 cm composite samples. The midpoint of each interval was used to note its depth location on the graphs. Solid lines connect values from consecutive samples (data from Hans Schrader). Dashed lines connect values from samples every 25 cm (large points).

BAV 79 B-29 2.5 and 5cm composite samples



BAV 79 A-5 5cm composite samples

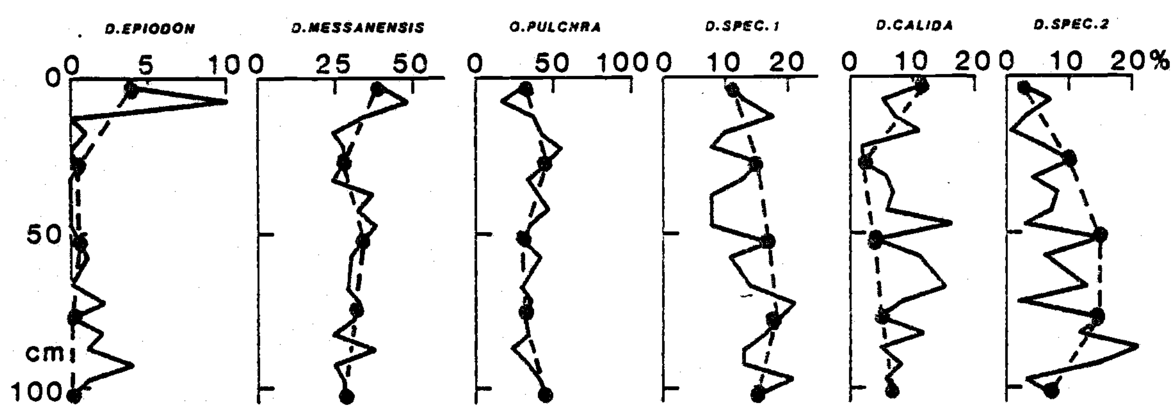


Figure 4.5

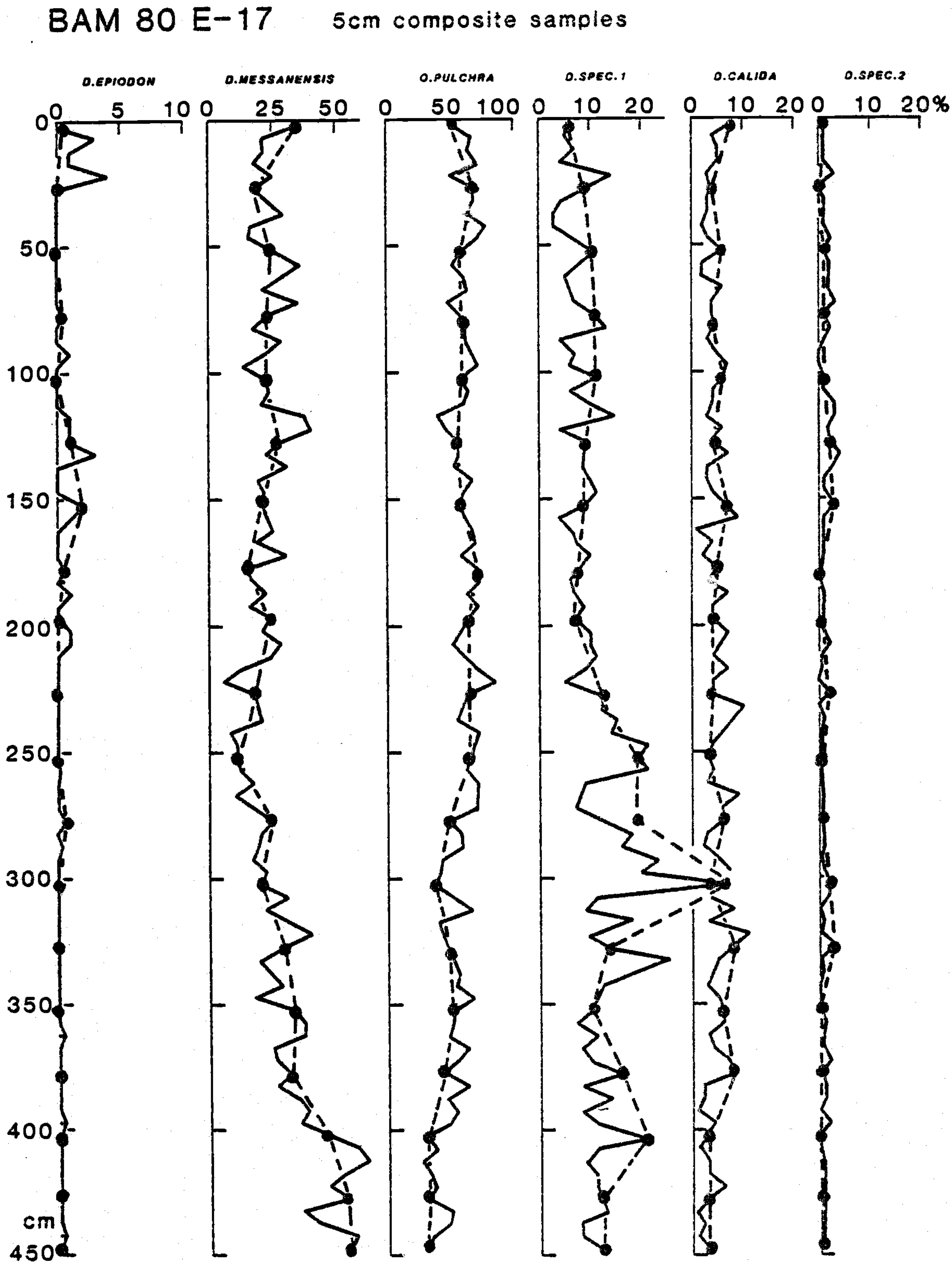

BAM 80 E-17
5cm composite samples
D.EPIODON
D.MESSANENSIS
O.PULCHRA
D.SPEC.1
D.CALIDA
D.SPEC.2
0 5 10
0 25 50
0 50 100
0 10 20
0 10 20
0 10 20%
0
50
100
150
200
250
300
350
400
cm
450

Figure 4.6

confidence level, there is no significant difference in the variability of each species using consecutive versus 25 cm sample spacing. This indicates that major downcore trends in the record can be obtained with a fewer number of samples. It should be noted, however, that the results in Section 4.2.2 suggest that a finer sample spacing must be used to determine the details of particular silicoflagellate events within the record of each species (i.e. the D. epiodon event in the top 25 cm of the three Kasten cores in Figures 4.5 and 4.6).

4.3.2 Sedimentation Rates

The Kasten cores were dated by varve chronology (Figure 4.7) and by C^{14} analysis (Table 4.4). DeMaster (1979) and Matherne (1982) discuss the problems in using C^{14} dating versus varve chronology in the sediments from the Gulf of California. In most cases, C^{14} dates were obtained for only two to three samples per core. It is felt that because of the high sedimentation rates in the Gulf and the dating problems associated with the input of older carbon into the system (DeMaster, 1979), the varve chronology gives a better estimate of the sedimentation rate, provided no major hiatuses occur in the core. Results in Figure 4.7 and Table 4.4 indicate that the rates determined by C^{14} analysis are approximately one half the rates determined using varve chronology. The relative ranking of each core from high to low sedimentation rates is the same using either method. The core with the highest rate is BAV79 B-29 with BAM80 E-17 showing a similar sedimentation rate. Cores BAV79 A-5, BAM80 F-30, and BAM80 I-42 have

Figure 4.7 Downcore plot of cummulative age, based on a continuous counting of laminae, versus depth in centimeters. This assumes that two laminae equal one year and that the top of the core equals 0 yBP. The sedimentation rate for each core is determined by dividing the total cummulative age for each core by its length. The data for BAV79 B-29 are from Matherne (1982).

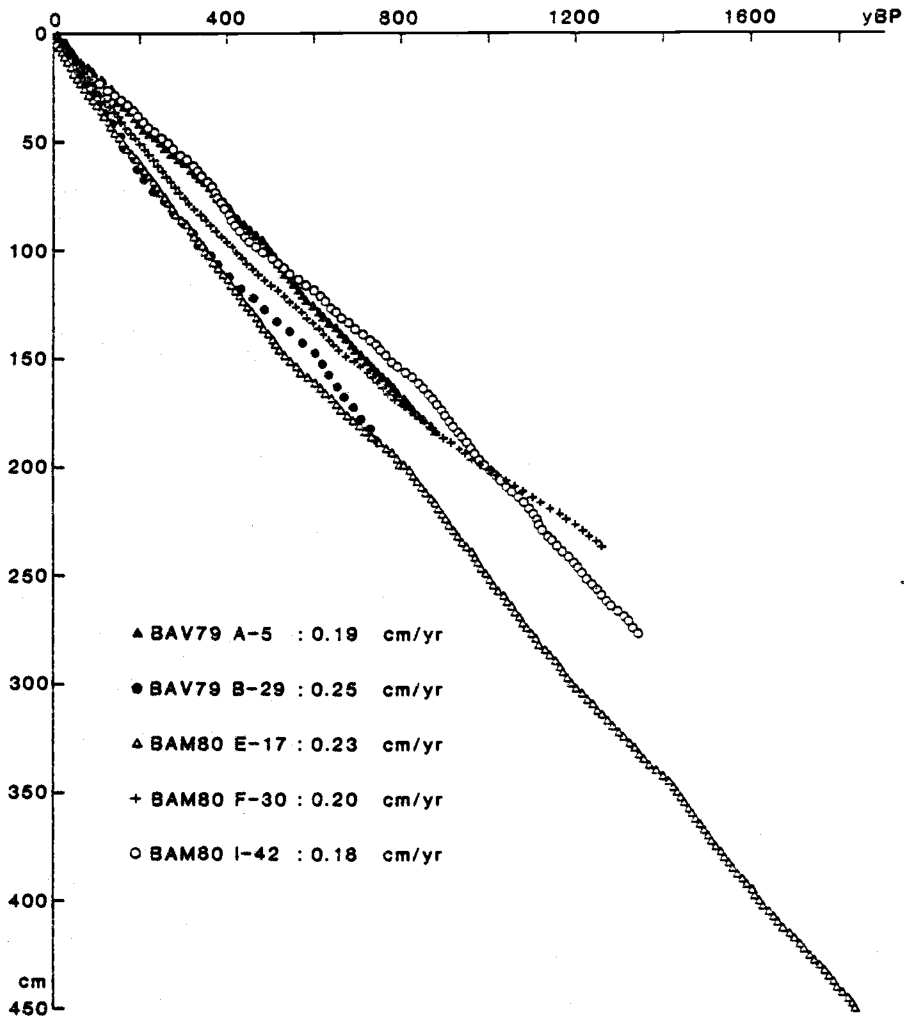

0
400
800
1200
1600
yBP
0
50
100
150
200
250
300
350
400
cm
450
▲ BAV79 A-5 : 0.19 cm/yr
● BAV79 B-29 : 0.25 cm/yr
△ BAM80 E-17 : 0.23 cm/yr
+ BAM80 F-30 : 0.20 cm/yr
○ BAM80 I-42 : 0.18 cm/yr

Figure 4.7

Table 4.4 Sedimentation rate based on C^{14} analysis. Dating of samples from BAV79 A-5 and B-29 by M. Stuiver, University of Washington, and BAM80 E-17, F-30, G-34, and I-42 by S. Robinson, USGS, Menlo Park, California.

Kasten Core	Sample Depth (cm)	C^{14} Age (yBP)	Average Sed. Rate for entire core (cm/y)
BAV79 A-5	15 - 25	1030 ± 15	.08
	55 - 65	1350 ± 20	
	115 - 130	2350 ± 20	
	175 - 185	2930 ± 20	
BAV79 B-29	20 - 30	960 ± 70	.20
	185 - 197	1800 ± 80	
BAM80 E-17	15 - 28	770 ± 60	.13
	147 - 159	∿ 1700	
	298 - 308	3000 ± 50	
BAM80 F-30	10 - 20	1070 ± 35	.10
	85 - 95	∿ 1700	
	180 - 190	2710 ± 40	
BAM80 G-34	15 - 35	1410 ± 30	.03
	130 - 135	4680 ± 35	
BAM80 I-42	75 - 85	1725 ± 40	.08
	155 - 165	2780 ± 35	

comparable rates which are about three-fourths the sedimentation rates from BAV79 B-29 and BAM80 E-17. Many disturbed areas were found in the BAM80 G-34 sediment record and a sedimentation rate based on laminae counts was not determined. General observations of laminae thickness and C^{14} dating indicate that BAM80 G-34 has a very low sedimentation rate compared to the other five cores.

Variations in the sedimentation rate downcore can be determined using laminae counts. Initially laminae were counted in 2.5 cm consecutive intervals downcore and the sedimentation rate for each interval was determined. A comparison between downcore rates in 2.5 cm versus 5 cm intervals was made (Figure 4.8, E-17 Plot A and E-17 Plot B). The results indicate that major trends in the variation of sedimentation rates downcore are observed when either 5 cm or 2.5 cm intervals are used for counting laminae. The remainder of the plots of the variation in sedimentation rate downcore use 5 cm intervals. These results show that the highest rates are found at the top of the core indicating that laminae are thicker in these intervals. This is due to the high water content in these core surface samples and that as the sediments dewater, they become more compact. Laminae are generally thicker and more distinct in BAV79 B-29 and BAM80 E-17 than in BAV79 A-5, BAM80 F-30, or BAM80 I-42.

4.3.3 Major Downcore Trends (0-2000 yBP)

Taking into account the relative differences in sedimentation rate between cores, a comparison of the composition of the silicoflagellate assemblage between areas can be made. The major trends in

Figure 4.8 Variations in sedimentation rate downcore. E-17 plot A uses rates determined in 2.5 cm intervals by counting the number of laminae within each interval. E-17 plot B, B-29, I-42, A-5, and F-30 use rates determined from 5 cm intervals. The data points downcore have been smoothed using a three point running average. The dashed lines in the plots are the mean sedimentation rates determined from varve chronology (Figure 4.7).

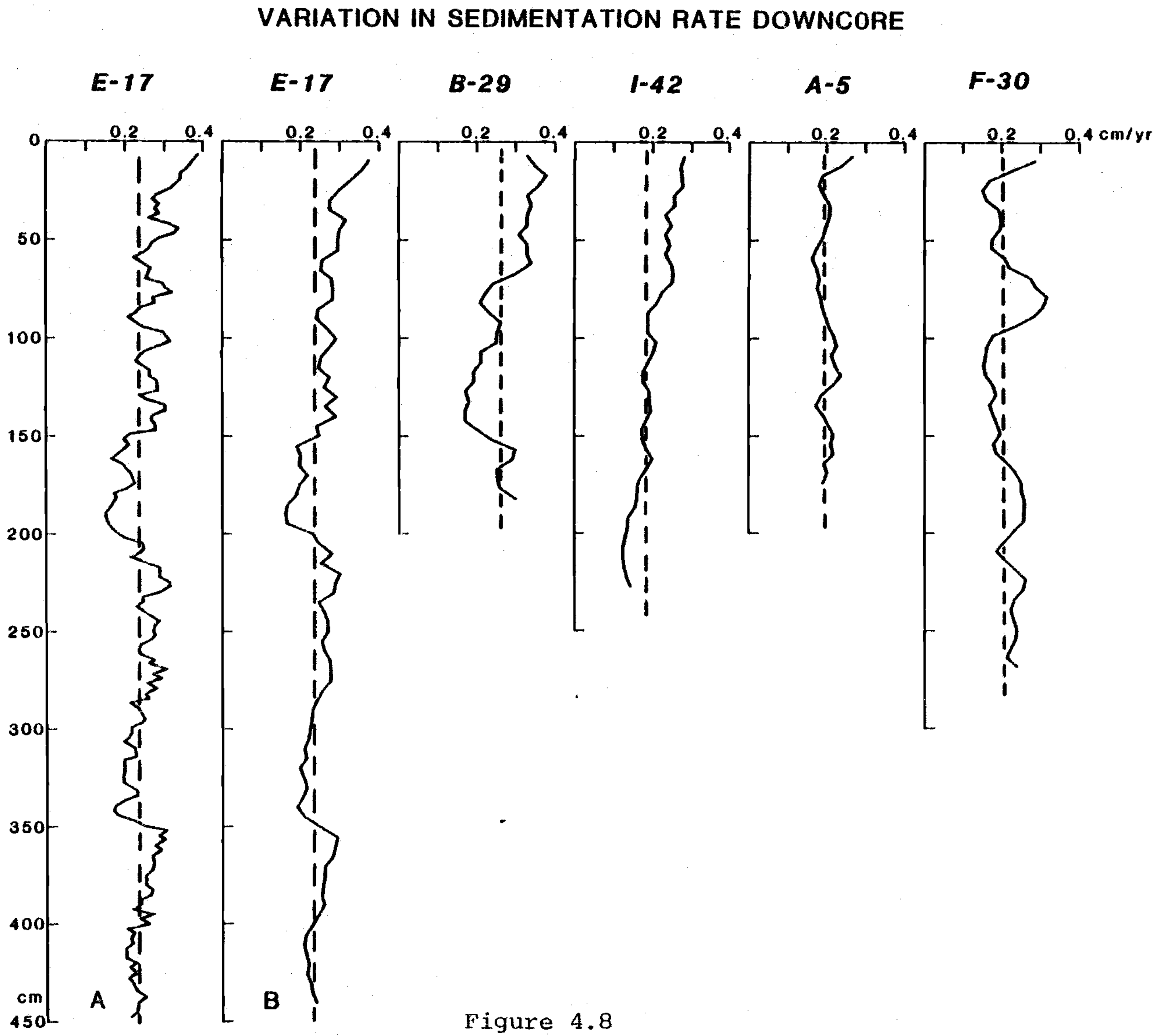
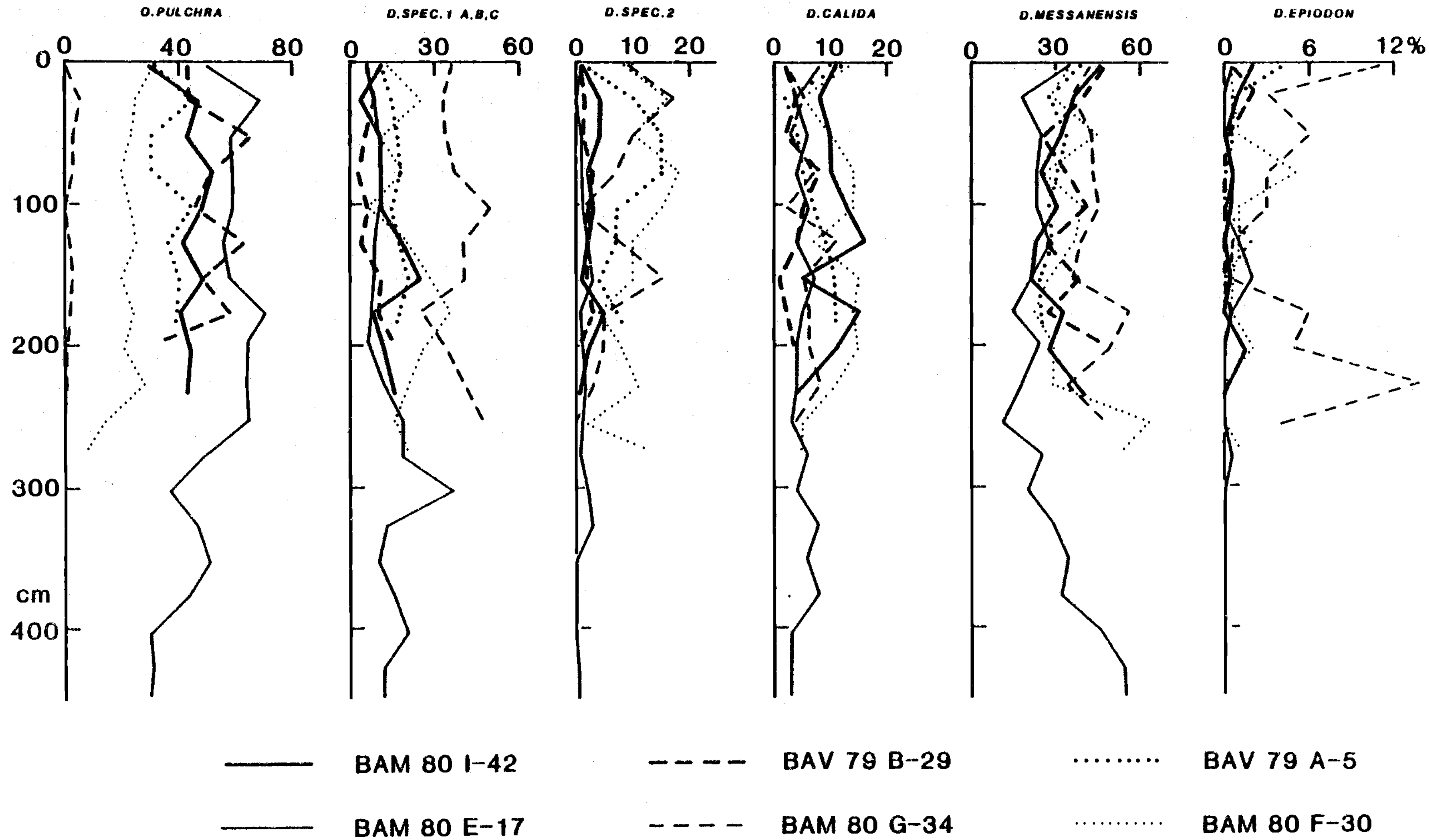

VARIATION IN SEDIMENTATION RATE DOWNCORE
E-17
E-17
B-29
I-42
A-5
F-30
0.2
0.4
0.4 cm/yr
0
50
100
150
200
250
300
350
400
cm
450
A
B

Figure 4.8

the assemblage from the six Kasten core locations in the southern Gulf of California are presented in Figure 4.9. The overall mean assemblage composition in each core for approximately the last 1000 years is presented in Table 4.5. The relative abundances of each species over the last 1000 years are similar to the relationships established between areas for surface samples (Figure 4.3). The 1000 yBP level corresponds to approximately 250 cm depth downcore in BAM80 E-17, 200 cm downcore in BAM80 F-30, 200 cm downcore in BAM80 I-42, and slightly below the base of BAV79 A-5 and BAV79 B-29. Because of the disturbed record in BAM80 G-34, its downcore record cannot be correlated to the other cores. From the 1000 yBP level to the base of E-17 (2000 y BP), there is a general decrease in the relative abundance of O. pulchra and an increase in D. messanensis and D. spec. 1. There is also a notable absence of D. epiodon in the lower section of BAM80 E-17. These results suggest that there are lower productivity levels, a greater influence of warmer Equatorial Water, and a decrease in California Current Water influence during the 1000-2000 yBP time interval compared to the present conditions. Pisias (1979) indicates that sea surface temperatures in the Santa Barbara Basin were higher during this time period than they are at the present. Data from Chelton (1981) shows that higher sea surface temperatures off southern California are synchronous with a decrease in the southward transport in the California Current. A similar situation have occurred in this region during the 1000-2000 yBP time interval.

Figure 4.9 Plots downcore of the relative abundance of each silicoflagellate species in 5 cm composite samples taken every 25 cm. Core locations are given in Table 3.2.



O.PULCHRA
D.SPEC.1 A,B,C
D.SPEC.2
D.CALIDA
D.MESSANENSIS
D.EPIODON
0 40 80
0 30 60
0 10 20
0 10 20
0 30 60
0 6 12%
0
100
200
300
cm
400
BAM 80 I-42
BAM 80 E-17
BAV 79 B-29
BAM 80 G-34
BAV 79 A-5
BAM 80 F-30

Figure 4.9

Table 4.5 Mean values of each species over the length of each core using 5 cm composite samples taken every 25 cm.

	BAM80[(1)] E-17	BAM80[(2)] E-17	BAV79 B-29	BAM80 I-42	BAV79 A-5	BAM80 F-30	BAM80 G-34
Octactis pulchra	60.7	51.9	50.6	43.5	37.4	21.8	2.1
Dictyocha messanensis	21.6	28.0	36.2	31.5	29.6	36.3	42.7
Dictyocha calida	5.3	5.2	3.6	9.8	7.6	10.7	5.3
Dictyocha spec. 1A	5.5	5.4	4.0	3.3	9.9	11.7	28.6
Dictyocha spec. 1B, 1C	4.8	8.0	3.8	9.3	6.5	8.1	9.3
Dictyocha spec. 2	1.3	1.2	1.8	2.5	8.5	10.3	7.2
Dictyocha epiodon	0.6	0.4	0.4	0.7	1.0	1.3	5.2

(1) Mean values in the top 2.5 m only

(2) Mean values over the total 4.5 m length

4.3.4 Summary

The same general trends in the composition of the silicoflagellate assemblage can be obtained using a 5 cm composite sample every 25 cm versus consecutive sampling. Varve chronology yields sedimentation rates that are twice the C^{14} determined rates. BAV79 B-29 and BAM80 E-17 have the highest average sedimentation rates (0.24 - 0.26 cm/yr), and, BAV79 A-5, BAM80 F-30, and BAM I-42 have average rates which are three-fourths of these values (0.18 - 0.20 cm/yr). Major downcore trends indicate that the relative composition of the siliccflagellate assemblage has remained constant over the last 1000 years. During the 1000 - 2000 yBP interval, there are lower productivity levels, a greater influence of Equatorial waters and a decrease of California Current Water in Gulf of California compared to present conditions.

4.4 DSDP Leg 64 Site 480

4.4.1 Stratigraphic Correlation between DSDP Site 480 and BAM80 E-17

Water content values of 85% in the first section of DSDP Site 480 suggest that the top of the core is near the sediment-water interface (Schrader, Kelts, et al., 1980). A 4.5 m long Kasten core (BAM80 E-17) was obtained within 5 km of Site 480 (Figure 2.1 and Table 3.2). By stratigraphically correlating the two cores, it can be determined how much sediment material is missing from the top of DSDP Site 480.

The composition of the silicoflagellate assemblage was determined in consecutive 10 cm composite samples in DSDP Site 480 (Figure 4.10) and consecutive 5 cm composite samples in BAM80 E-17 (Figure 4.6). Laminae thickness from the bottom two meters in BAM80 E-17 and the top two meters of DSDP Site 480 indicate that BAM80 E-17 has approximately twice the sedimentation rate of Site 480. Data on varve counts in the upper section of DSDP Site 480 is from A. Soutar (pers. comm., 1980). This would mean that a 10 cm composite sample in DSDP Site 480 represents an average of four 5 cm composite samples from BAM80 E-17. The amplitude of species events downcore in BAM80 E-17 would therefore be smoothed out in the DSDP Site 480 record and the comparison can be made only between species showing major trends. The best correlation of the relative downcore silicoflagellate abundance indicates that the top of DSDP Site 480 corresponds to the 180 cm level in BAM80 E-17. This is based on the trends in _O. pulchra_ and _D. messanensis_ in each core. Results from laminae thicknesses indicate that this represents approximately 750 years of missing record.

Figure 4.10 Downcore plot of the relative percent abundance of each silicoflagellate species in consecutive 10 cm composite samples. Values are plotted at midpoints of the composite sample intervals.

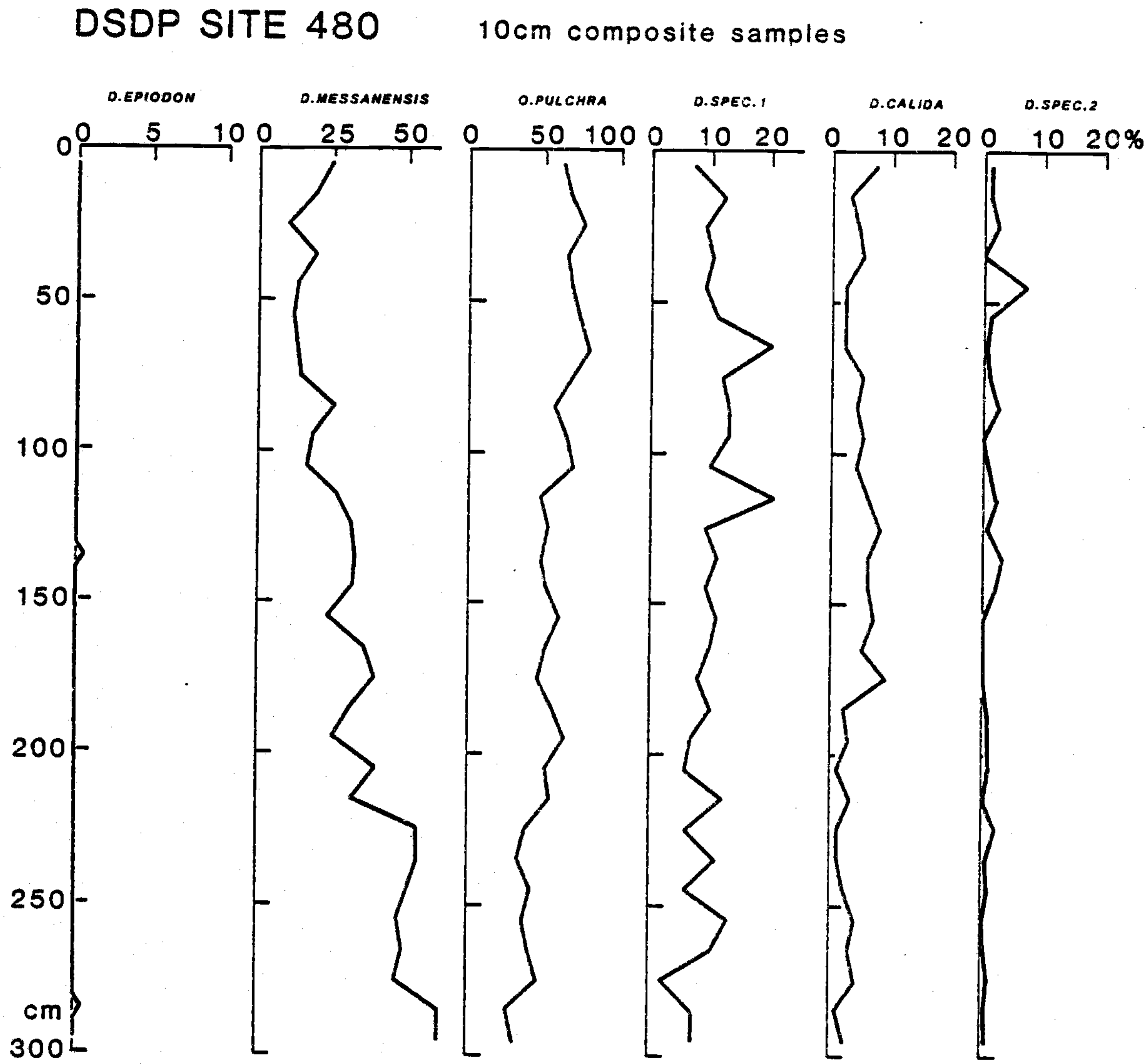

DSDP SITE 480
10cm composite samples
D.EPIODON
D.MESSANENSIS
O.PULCHRA
D.SPEC.1
D.CALIDA
D.SPEC.2
0 5 10
0 25 50
0 50 100
0 10 20
0 10 20
0 10 20%
0
50
100
150
200
250
cm
300

Figure 4.10

An average estimated sedimentation rate, based on laminae widths in the first two sections of Core 1 of DSDP Site 480 is 0.12 cm/yr. The record in Figure 4.10 represents the time interval from 3250 to 750 yBP. During this time period a notable absence of D. epiodon and a general increase in the abundance of O. pulchra can be observed. These results suggest decreased levels in primary production in the central Gulf of California and a decrease in California Current influence compared to the recent situation. O. pulchra reaches its current levels at approximately 1300 yBP. D. messanensis shows an opposite relative distribution to that of O. pulchra. D. spec. 1 has its highest relative abundance between 2000 and 1200 yBP. This corresponds to a period where Pisias (1979) shows higher sea-surface temperatures off southern Calfornia indicating a decrease in the southward transport of the California Current. These same results were found in BAM 80 E-17.

4.4.2 General Trends (0-30 meters)

An analysis of the composition of the silicoflagellate assemblage downcore in DSDP Site 480 by Matherne, et al. (1980) indicates major assemblage changes at various levels downcore. The upper 30 meters of the core was examined more closely to determine the changes in the assemblage over this interval. The general trends in the relative abundance of silicoflagellate species in the upper 30 meters were determined using 10 cm composite samples taken approximately every 70 cm (Figure 4.11).

Figure 4.11 Downcore plots of relative percent abundance of each of the silicoflagellate species. D. spec. 1 is a combination of D. spec. 1B and D. perlaevis forms. The dotted line in the D. spec. 1. plot is the relative abundance of D. spec. 1A. Column A shows the intervals that are examined in greater detail in Figure 4.12. Column B is the depth downhole in meters. Column C is the recovery record. Shaded areas are recovered intervals while intervals not recovered are left blank. The numbers indicate core number. Column D indicates major laminated (thin lines) and non-laminated (blank areas) intervals. The temperature values (°C) are from an equation for annual mean sea-surface temperatures in the east Pacific (Poelchau, 1974). See text for explanation. The δO^{18} results are from Shackleton and Hall (in press). The assemblage at top of Core 5 is anamalous to the assemblage in samples above and below and a dashed line is used to indicate this anomaly. The information on the recovery record was provided by the shipboard scientific party DSDP Leg 64.

DSDP LEG 64, SITE 480 10cm composite samples

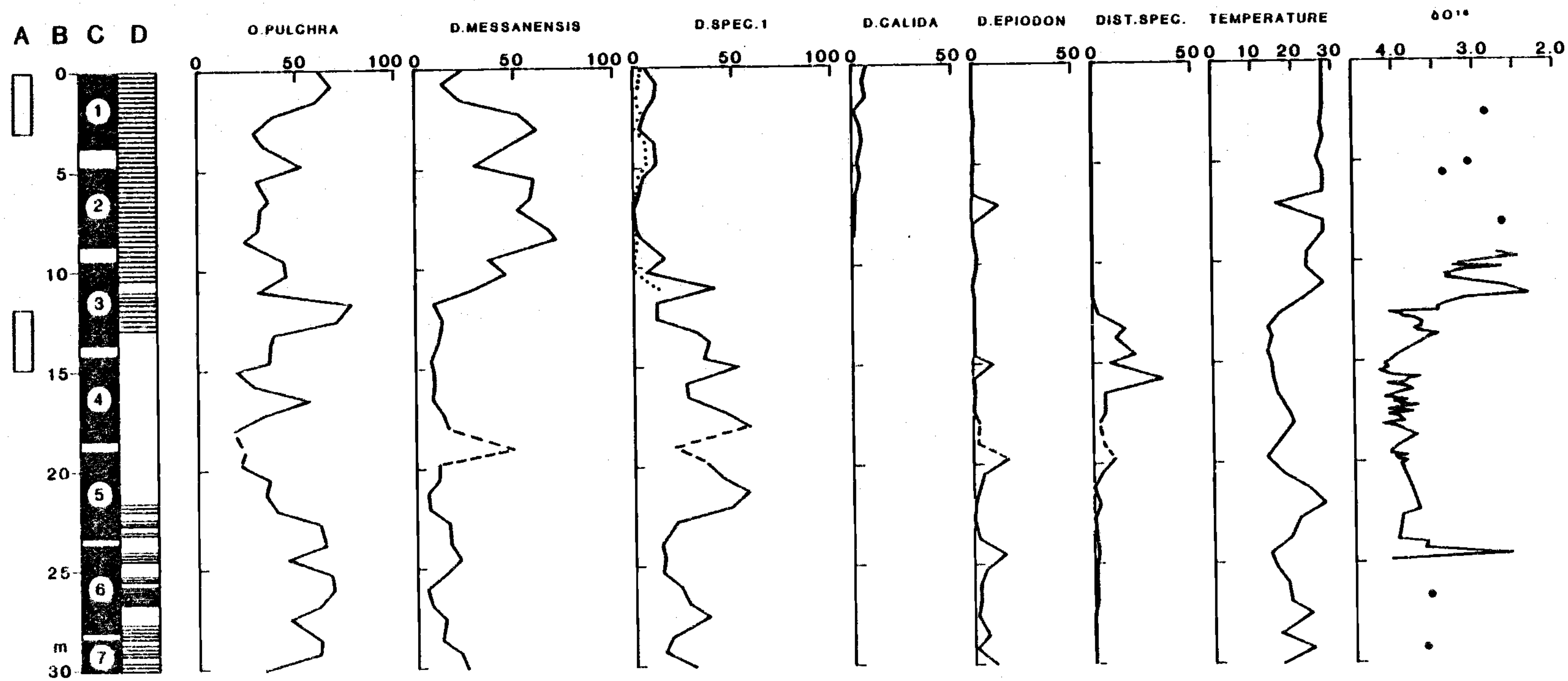


Figure 4.11

Based on laminae thicknesses, the average sedimentation rate for the upper 10 meters is 1 m/1000 years. This would indicate that the 10,000 yBP level is in the lower section of Core 2 at approximately 8 meters downcore. Results from pollen data (Heusser and Burckle, 1981) support this conclusion. Results from δO^{18} analysis in this core (Shackleton and Hall, in press) suggest that the oxygen isotopic Stage 2/1 boundary is in the upper part of Core 3 at approximately 12 meters. Their results also indicate that the oxygen isotopic Stage 2/3 boundary is at the base of Core 5 at approximately 23 meters. This yields an average sedimentation rate of 0.6 m/1000 years using a 2/3 boundary age of 29,000 yBP and a 1/2 boundary age of 11,000 yBP (Hays, et al., 1976; Woillard and Mook, 1982). Within this interval, the core exhibits either mottled features or it is homogeneous. The biogenic component is much reduced and silicoflagellate abundances are one order of magnitude lower than those reported in the upper section (Table 4.1). If the terrigenous supply remains essentially constant, sedimentation rates would be lower in this section because of a reduced biogenic input. The fact that these sediments are homogeneous or mottled indicate that a benthic community which could bioturbate the sediments must have been present in this area. This would mean that oxygen levels were higher at the sediment-water interface compared to the present situation. A decrease in the flux of organic matter as a result of decreased primary productivity in the surface waters could cause such a situation. The section from 23 to 30 meters has both laminated and homogeneous intervals. This suggests that the average sedimentation rate for the interval may be between the rate for a completely homogeneous section and a totally laminated section. If an intermediate sedimentation rate of 0.8 m/1000 years is used for this interval, the 30 meter level corresponds to 38,000 yBP. This time scale based on sedimentation rates over each interval, is only tentative and relies on the fact that no major hiatuses are present in the section.

The general trends of the silicoflagellate assemblage in the upper 30 meters are presented in Figure 4.11. O. pulchra shows a general decrease below the middle of Core 1. There is a marked increase in the middle of Core 3 corresponding to an interval where the siliceous microfossil assemblage shows excellent preservation. This is based on the presence of weakly silicified diatom species such as Chaetoceros spp. vegetative cells and an increase in absolute abundance of siliceous microfossils. O. pulchra has generally lower values throughout the homogeneous section with high levels in Core 6. This corresponds to high productivity levels in the surface waters during oxygen isotopic Stage 3. Lower levels are associated with Stage 2, with a lag time before higher levels are reached again in the upper section of the core. These decreases in productivity may be the result of a lowering of the wind intensity and nutrient levels over time. Dictyocha messanensis shows an opposite distribution downcore compared to O. pulchra and D. spec. 1. Increases in D. messanensis may be just a reflection of a decrease in the absolute abundance of these other two species. Analysis of the variations downcore of the absolute abundance of each species could help resolve this problem. The D. spec. 1 plot is a combination of the downcore distribution of D. spec. 1B, and D. perlaevis forms (Plates IV, V, and VI). Below the 10 m level, the D. perlaevis

(D. spec. 1C form) and the D. perlaevis (large D. calida form) dominate the assemblage. Above this level, D. spec. 1B dominates. The dotted line in Figure 4.11 indicates the relative abundance of D. spec. 1A. This species is absent below the 12 meter level except in core material that has fallen down from higher up in the hole. The distribution of D. spec. 1 downcore may represent the influence of eastern Pacific margin tropical to subtropical waters in the Gulf if D. perlaevis has a similar ecology to that of D. spec. 1. The downcore distribution of D. calida shows that this species is present in low relative abundance above 10 meters but is absent below this level. Poelchau (1974) notes the presence of D. calida at the 100,000 yBP level in core SCAN 29Pb (33°16'N, 153°44'E, 5857 m water depth) taken in an area west of the Shatsky Rise. This may indicate that the absence of D. calida below 10 meters in DSDP Site 480 is a reflection of the decrease influence of the Equatorial Countercurrent in the Gulf over the 38,000 to 10,000 yBP time interval. D. spec. 2 is never present in high abundance in these samples and is not found below the 10 meter depth in this section. The downcore distribution of Dictyocha epiodon indicates that the influence of the California Current has decreased since the last glacial maximum and had a greater influence before this time. Distephanus speculum has its greatest relative abundance within the last glacial period (29,000-18,000 yBP) which indicates that cold waters were present in the Gulf of California during this time interval. The apparent discrepancy between the abundance of Dictyocha epiodon and Distephanus speculum indicating the presence of California Current Water in the Gulf during the last glacial period can not be resolved at this time.

Analysis of samples from the top of Cores 4 and 5 yields a silicoflagellate assemblage that is drastically different from samples above and below. This includes the presence of D. calida, D. spec. 1A and 1B and high values of D. messanensis. By looking at the data of the detailed core lithology from A. Soutar (pers. comm., 1980) it is noticed that a disturbance due to coring is found on the top of Core 4. This same situation may exist at the top of Core 5 and could possibly account for the anomalous assemblage at the top of Core 2. These results suggest that anomalous species assemblages at the top of the cores may be indicative of material falling down the hole from higher levels in the sediment section.

Poelchau (1974) developed sea-surface temperature equations for the North Pacific based on the relative abundance of silicoflagellate species in North Pacific surface sediments. He used this equation to estimate paleotemperatures and found a close agreement between the relative temperature trends established by Moore (1973) based on the radiolarian assemblage variations in the same core. This study uses the following equation to estimate annual mean surface temperatures in the East Pacific from Poelchau (1974) to determine temperature trends in the Gulf of California from DSDP Site 480 samples (Figure 4.11).

$$\ell n\, T_{am} = .74511 - 18.0871(X) - 11.3426(E) - 16.9935(S) + 7.8948(X^2) + 5.89(E^2) + 12.4377(S^2) + 22.943(X \cdot E) + 27.873(X \cdot S) + 17.0418(E \cdot S) + 6.0562(X^3)$$

where E = D. epiodon

X = D. messanensis, D. calida, and D. perlaevis forms.

S = Distephanus speculum

T_{am} = annual mean sea-surface temperature

The relative percent values of these three variables (E, X, and S) are normalized to a sum of one before they are used in the equation.

This equation emphasizes the fact that Dictyocha epiodon and Distephanus speculum represent colder temperatures in the samples. It does not place a high weight on the fact that Dictyocha calida and possibly D. perlaevis indicate warmer temperatures. This equation does not use the relative abundance of O. pulchra which is present in high abundance in the Gulf of California. Excluding O. pulchra will cause minor species to have higher relative abundance and induces errors in the temperature estimate. Only the general trend in mean annual sea-surface temperatures based on the composition of the silicoflagellate assemblage should be used and not the magnitude of the temperature values. Results in Figure 4.11 show low temperature values during oxygen isotopic Stages 2 and 3 and higher values since this time. The general trends agree with results from Moore, et al. (1980) which indicate an increased flow of California Current and cooler temperatures near the mouth of the Gulf.

4.4.3 Interglacial vs. Glacial Assemblage

The present day (interglacial) composition of the silicoflagellate assemblage can be compared to the assemblage from a section that was determined to be a glacial stage by δO^{18} stratigraphy (Shackleton and Hall, in press). Consecutive 10 cm composite samples from approximately three meters in each section were examined and the results are presented in Figure 4.12.

Figure 4.12 Consecutive 10 cm composite samples from three levels in DSDP Leg 64 Site 480. Data points are plotted using the midpoint of each sample interval. Column A indicates depth downhole in centimeters. Column B is the DSDP notation for corresponding core and section numbers. Column C indicates major structural features in the sections. = laminated intervals; = layered intervals; = mottled intervals; = disturbed due to coring; = gap in the coring record. See text for the explanation of Productivity Index, Cal. Current Index, and Equatorial Index. The temperature values are determined using the equation from Poelchau (1974). δO^{18} values are from Shackleton and Hall (in press). The dashed lines at the top of Core 4 connect samples which exhibit an assemblage that is anomalous to surrounding samples. The last glacial maximum at 18,000 yBP is indicated at 1250 cm downhole.

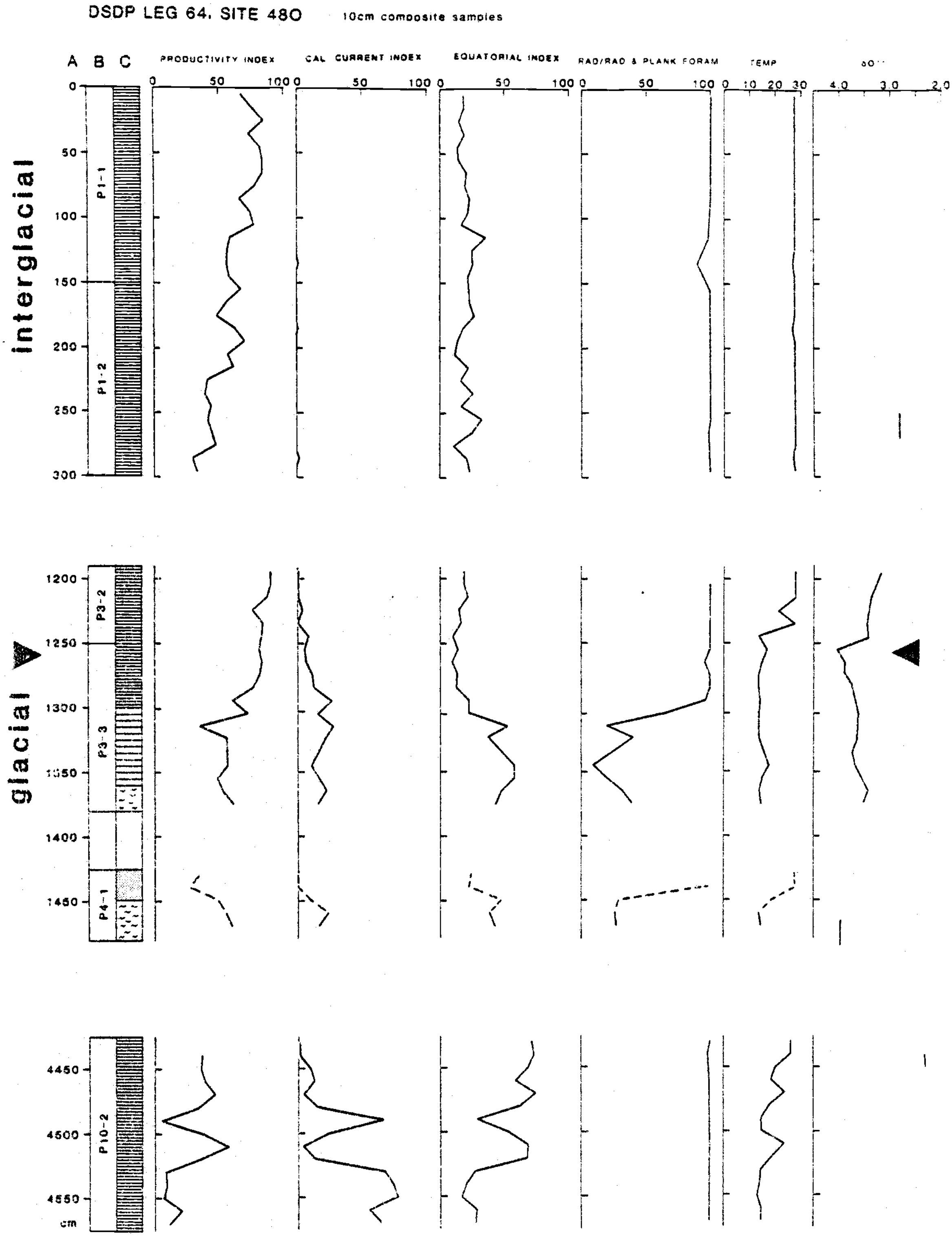

DSDP LEG 64, SITE 480
10cm composite samples
A B C
PRODUCTIVITY INDEX
CAL CURRENT INDEX
EQUATORIAL INDEX
RAD/RAD & PLANK FORAM
TEMP
interglacial
glacial
P1-1
P1-2
P3-2
P3-3
P4-1
P10-2
cm

Figure 4.12

Based on ecologies, species groupings were used to reduce the number of variables.

$$\text{Productivity Index} = \frac{OP}{OP + DM + DC + DP + DE + DS} \times 100$$

$$\text{Cal. Current Index} = \frac{DE + DS}{\text{All Species}} \times 100$$

$$\text{Equatorial Index} = \frac{DC + DS1 + DP}{\text{All Species}} \times 100$$

Where: OP = relative percent of *Octactis pulchra*

DM = relative percent of *Dictyocha messanensis*

DC = relative percent of *D. calida*

DP = relative percent of *D. perlaevis*

DS1 = relative percent of *D. spec. 1*

DE = relative percent of *D. epiodon*

DS = relative percent of *Distephanus speculum*

All Species = total of all species present (100%)

Large values of the Productivity Index in Gulf samples represent high productivity levels in the Gulf of California. In most instances it looks similar to the downcore plot of *O. pulchra*. Samples with higher values of the Cal. Current Index than the present, represent times of increased influence of cold California Current Water in the Gulf. A large influence of equatorial waters in the Gulf of California is represented by high values of the Equatorial Index.

The downcore trends in the 0 to 300 cm section of the silicoflagellate species are discussed in Section 4.4.1. To reiterate, this section represents the time interval from 3250 to 750 yBP. There is a notable absence in the California Current influence in the Gulf. There is also a higher amount of equatorial waters in the Gulf in the lower part of the section than at the present. There are lower productivity values, as indicated by silicoflagellates in the lower section than at the present. These results can be compared to results obtained by applying the following ratio to the data from the coarse fraction samples.

$$X = \frac{\text{Radiolaria}}{\text{Radiolaria + Planktonic Foraminifera}} \times 100$$

High values of x correspond to high relative levels of productivity (Diester-Haass, 1977)

These results are presented in Figure 4.12. The comparisons indicate that silicoflagellates may give a more sensitive indication of the variations in productivity levels in the surface waters of the Gulf of California. Temperature values are high throughout this upper section reflecting the absence of the species associated with the cool California Current waters.

Results from δO^{18} analysis by Shackleton and Hall (in press) indicate that there is a transition from the present interglacial to the last glacial stage in the middle of Core 3. This section was examined in detail to determine changes in the silicoflagellate assemblage at this transition. The assemblage during the glacial period indicate low productivity levels in the surface waters. The results from the coarse fraction analysis support this conclusion. There is a high influence of the California Current and equatorial waters during this time interval. This may indicate that there was a large exchange of waters between the Pacific Ocean and the Gulf of California during the glacial period. At approximately 13 m downcore there is a marked change in assemblage composition with the present relative composition of the silicoflagellate assemblage attained by 1225 cm downcore. There is an apparent lag of 800 years between the change in assemblage composition and the δO^{18} changes. This value is obtained using sedimentation rates for this section determined in Section 4.4.2. This may represent the time it takes for the bottom waters at DSDP Site 480 to show the effects of global changes.

Two samples from Section 2 of Core 10 in DSDP Site 480 yield δO^{18} values associated with an interglacial period (Shackleton and Hall, in press). The composition of the silicoflagellate assemblage indicates high relative abundance of species associated with Pacific waters. The assemblage also indicates that colder waters are present in the Gulf during this interval. The productivity ratio from coarse fraction analysis suggests that high productivity levels are present in the surface waters at this time. A possible solution is that the δO^{18} value is measured at a transitional boundary and that, during this interval, there are major fluctuations in the intensity of the influence of the California Current and the Equatorial Countercurrent in the Gulf of California which disguise the productivity signal seen from the silicoflagellates. By using a sedimentation rate of 0.8 m/1000 years for the section between 30 meters and 45 meters, the 45 meter level is approximately 56,000 yBP. Data from Hays et al. (1976) indicates that the oxygen isotopic Stage 3/4 boundary is at 61,000 yBP. This might suggest that the section is close to the 3/4 boundary and that the sediment record within this interval was deposited near the end of oxygen isotopic Stage 4 when worldwide temperatures were colder than the present. This section is therefore not a good representation of an interglacial period.

4.4.4 Summary

These results indicate that there are approximately 750 years of the sediment record missing from the top of DSDP Site 480. The average estimated sedimentation for the upper 10 meters is 1 m/1000 years. The oxygen isotopic Stage 2/1 boundary is at the 12 meter level and the Stage 3/2 boundary is at the 23 meter level. The average sedimentation rate for Stage 2 is 0.6 m/1000 yrs. The average estimated sedimentation rate in the section from 23 meters to 45 meters is 0.8 m/1000 yrs. This places the 30 meter level at approximately 38,000 yBP. General downcore trends show high productivity values associated with the present interglacial period and lower levels associated with the last glacial period. There is an increase in the influence of Pacific waters during the glacial period compared to the present with colder waters present in the Gulf of California during the last glacial maximum. Species found in the upper section of DSDP Site 480 such as D. spec. 1A and 1B and D. calida can be used to determine if anomalous assemblage compositions at the tops of the Cores are the result of material falling down the hole from above.

CONCLUSIONS

1) Areal distributions of silicoflagellate species in plankton and surface sediment samples from the Gulf of California are indicative of variations in water mass characteristics. Octactis pulchra is associated with areas of high levels of surface primary productivity. Dictyocha messanensis increases in abundance with decreasing amounts of O. pulchra. D. calida and D. spec. 1 forms, which are associated with tropical waters, have their highest relative abundance near the mouth of the Gulf and decrease to the north. The distributions of Distephanus speculum and Dictyocha epiodon correspond to the California Current and decrease in abundance to the south along the Baja Peninsula. D. epiodon is present in minor abundance in Gulf of California surface sediments.

2) There is a high variability in the composition of the silicoflagellate assemblage from laminae to laminae. There is also no indication that a characteristic assemblage composition is associated with either light or dark laminae. Octactis pulchra is present in greater relative abundance in the well laminated sections of the core analyzed in this study. D. spec. 1, D. epiodon, D. calida, and D. spec. 2 periodically exhibit high abundance values which usually span more than one season of deposition. The composition of the silicoflagellate assemblage in 2.5 cm composite samples generally represent the mean composition of individual laminae samples from the corresponding section in the core. Although the amplitudes of species events are reduced, major events and downcore trends in each of the silicoflagellate species can be obtained from composite samples.

3) Major downcore trends of each species indicate that the relative composition of the assemblage has remained the same over the last 1000 years. During the 2000-1000 yBP interval, there were lower productivity levels, a greater influence of Equatorial waters, and a decrease of California Current Water in the Gulf of California compared to present conditions.

4) A comparison of the assemblage composition between the present interglacial and the last glacial period indicates that there was an increased influence in Pacific waters, a decrease in surface primary productivity, and colder surface water temperatures in the central Gulf of California during the last major glacial period.

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APPENDICIES

Plate I

	Octactis pulchra Schiller
Figure 1,5	BAV79 A-2-2, Lam. No. 96; seven and nine spine variants
2,4a.b	BAV79 A-2-2, Lam. No. 103; apical ring preserved
3	BAV79 A-2-2, Lam. No. 8; common form
6	BAM80 P160, phytoplankton; seven spine variant
7	DSDP Leg 64, Site 480; P1-2, 40-50 cm; seven spine variant
8	BAV79 A-2-2, Lam. No. 14; thick basal ring
	Distephanus speculum (Ehrenberg) Haeckel
9a,b	DSDP Leg 64, Site 480; P8-2, 100-110 cm; small apical ring
10a,b,	DSDP Leg 64, Site 480; P20-2, 120-130 cm; large apical ring
11	DSDP Leg 64, Site 480; P3-3, 30-40 cm; aberrant form

The scale given is for all figures.

PLATE I

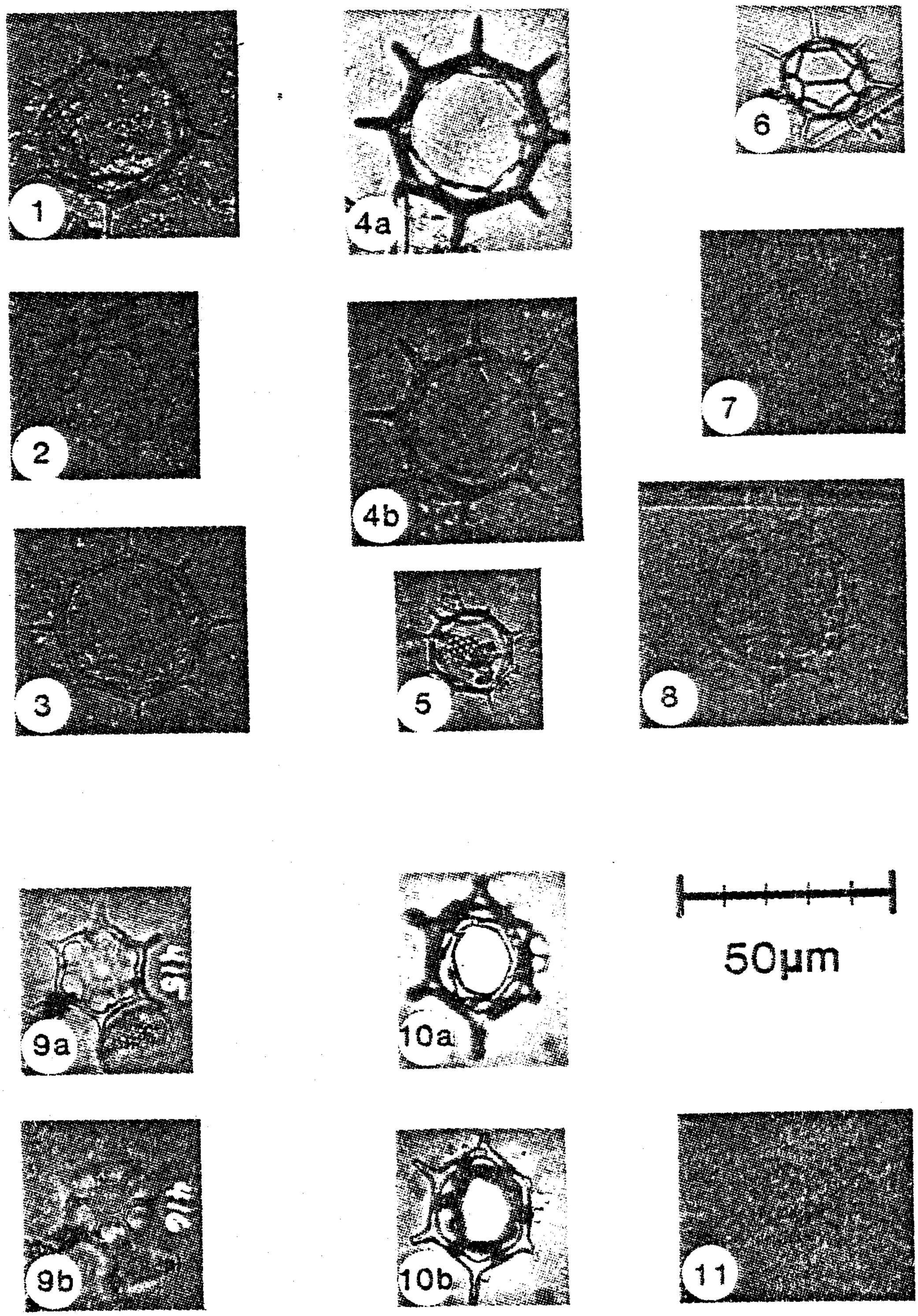


Plate II

		Dictyocha messanensis Haeckel
Figure	1a,b;13	BAM80 E-17, 50-55 cm
	2	DSDP Leg 64, Site 480; P1-1, 30-40 cm
	3	BAV79 A-2-2, Lam. No. 16
	4;10	DSDP Leg 64, Site 480; P1-2, 40-50 cm
	5a,b	BAM80 E-17, 75-80 cm; common large form
	6;7	DSDP Leg 64, Site 480p P1-1, 80-90 cm; common small form
	8	BAM80 P186, phytoplankton; aberrant form
	9	BAV79 A-2-2, Lam. No. 22; five-sided variant
	11	BAV79 A-2-2, Lam. No. 16; aberrant form
	12	BAV79 A-2-2, Lam. No. 82

The scale for all figures is given on Plate I.

PLATE II

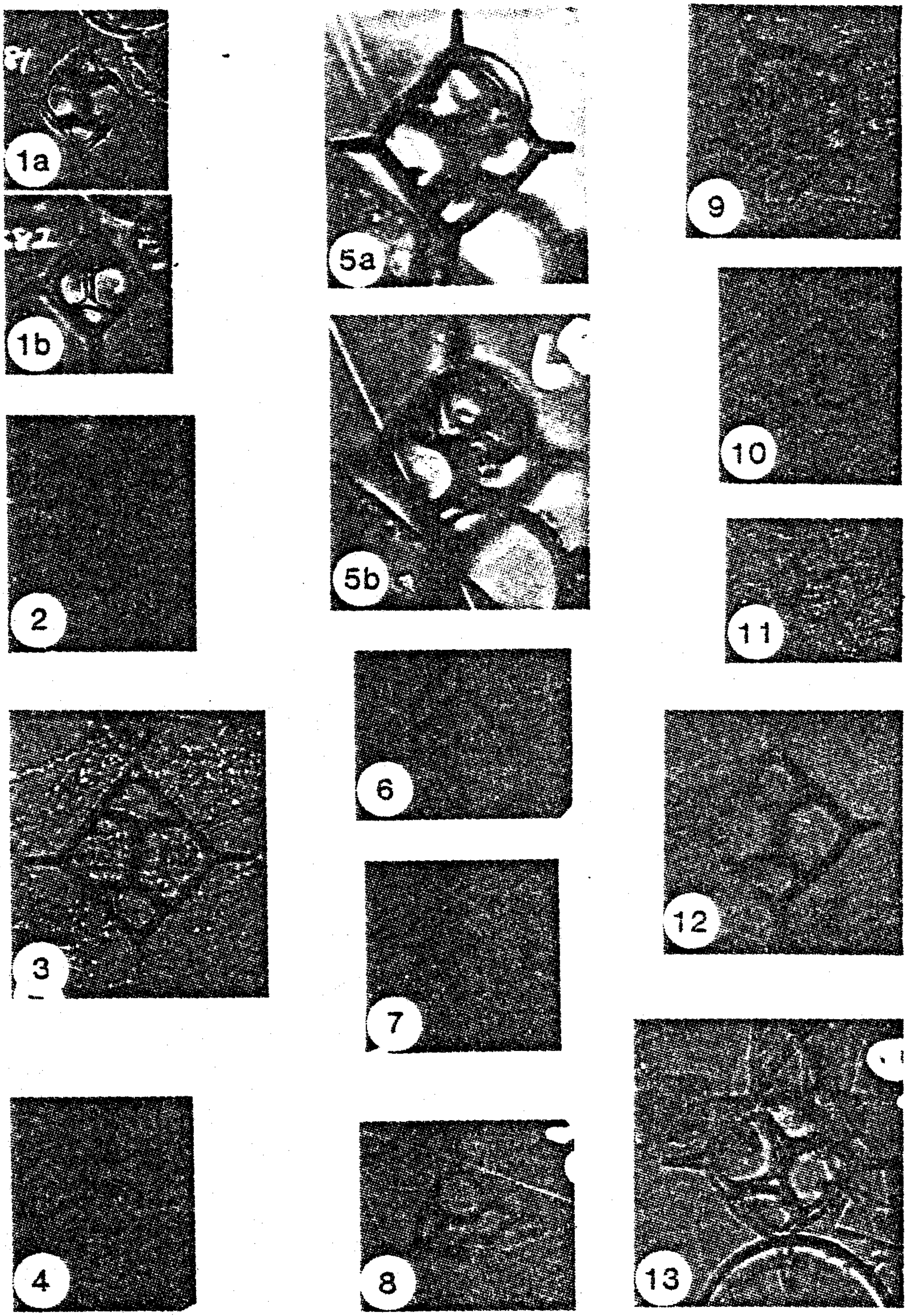


Plate III

	Dictyocha spec. 2
Figure 1	BAV79 A-2-2, Lam. No. 8; most common form
2	BAV79 A-2-2, Lam. No. 103
3	BAV79 A-2-2, Lam. No. 69
4	BAV79 A-2-2, Lam. No. 93
	D. spec. 2 - D. messanensis forms
5	BAV79 A-2-2, Lam. No. 69
6	BAV79 A-2-2, Lam. No. 93
7	BAV79 A-2-2, Lam. No. 51
	Dictyocha perlaevis Frenguelli
8	DSDP Leg 64, Site 480; P10-2, 0-10 cm; small form
	Dictyocha calida Poelchau
9	BAV79 A-2-2, Lam. No. 99; most common form
10	BAM80 P161, phytoplankton
11	BAM80 E-17, 100-105 cm, five-sided variant
12	BAV79 A-2-2, Lam. No. 22
13;17	BAV79 A-2-2, Lam. No. 98
14	BAM80 P160, phytoplankton
15	BAV79 A-2-2, Lam. No. 97; five-sided variant
16	DSDP Leg 64, Site 480; P1-1, 0-10 cm
18	BAV79 A-2-2, Lam. No. 8; three-sided variant

The scale for all figures is given on Plate I.

PLATE III

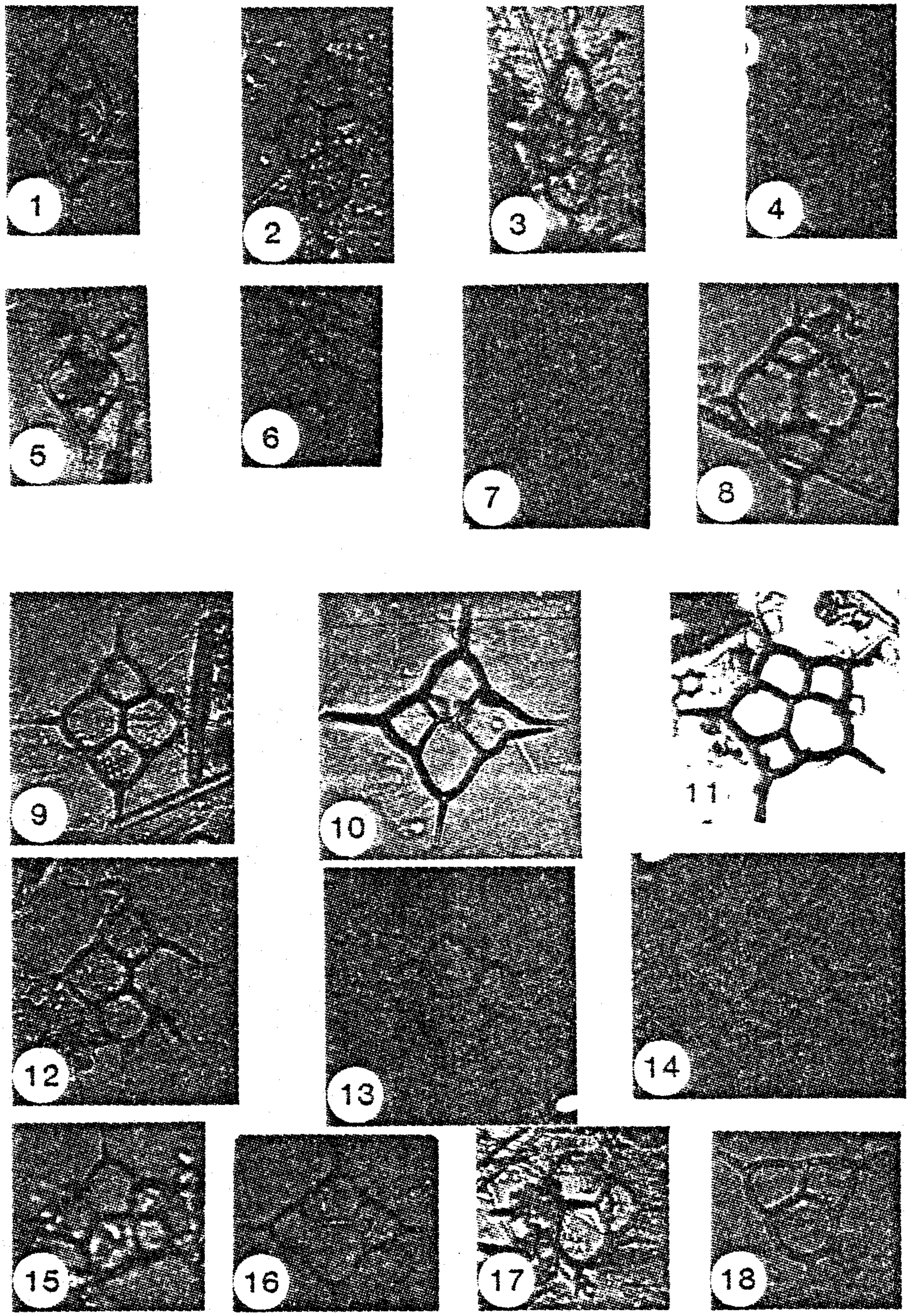


Plate IV

		Dictyocha perlaevis Frenguelli (D. spec.1C)
Figure	1	BAV79 A-2-2, Lam. No. 91; common form
	2	BAM80 E-17, 25-30 cm
	3	DSDP Leg 64, Site 480; P5-3, 0-10 cm
	4	BAV79 A-2-2, Lam. No. 98
	5	DSDP Leg 64, Site 480; P5-3, 70-80 cm
	6	BAV79 A-2-2, Lam. No. 73
		Dictyocha epiodon Ehrenburg
	7	BAV79 A-2-2, Lam. No. 14; most common form
	8	DSDP Leg 64, Site 480; P2-2, 70-80 cm
	9	BAV79 A-2-2, Lam. No. 24; aberrant form
	10	BAV79 A-2-2, Lam. No. 26; aberrant form
	11	BAV79 A-2-2, Lam. No 65; aberrant form
	12	BAV79 A-2-2, Lam. No. 63; aberrant form

The scale for all figures is given on Plate I.

PLATE IV

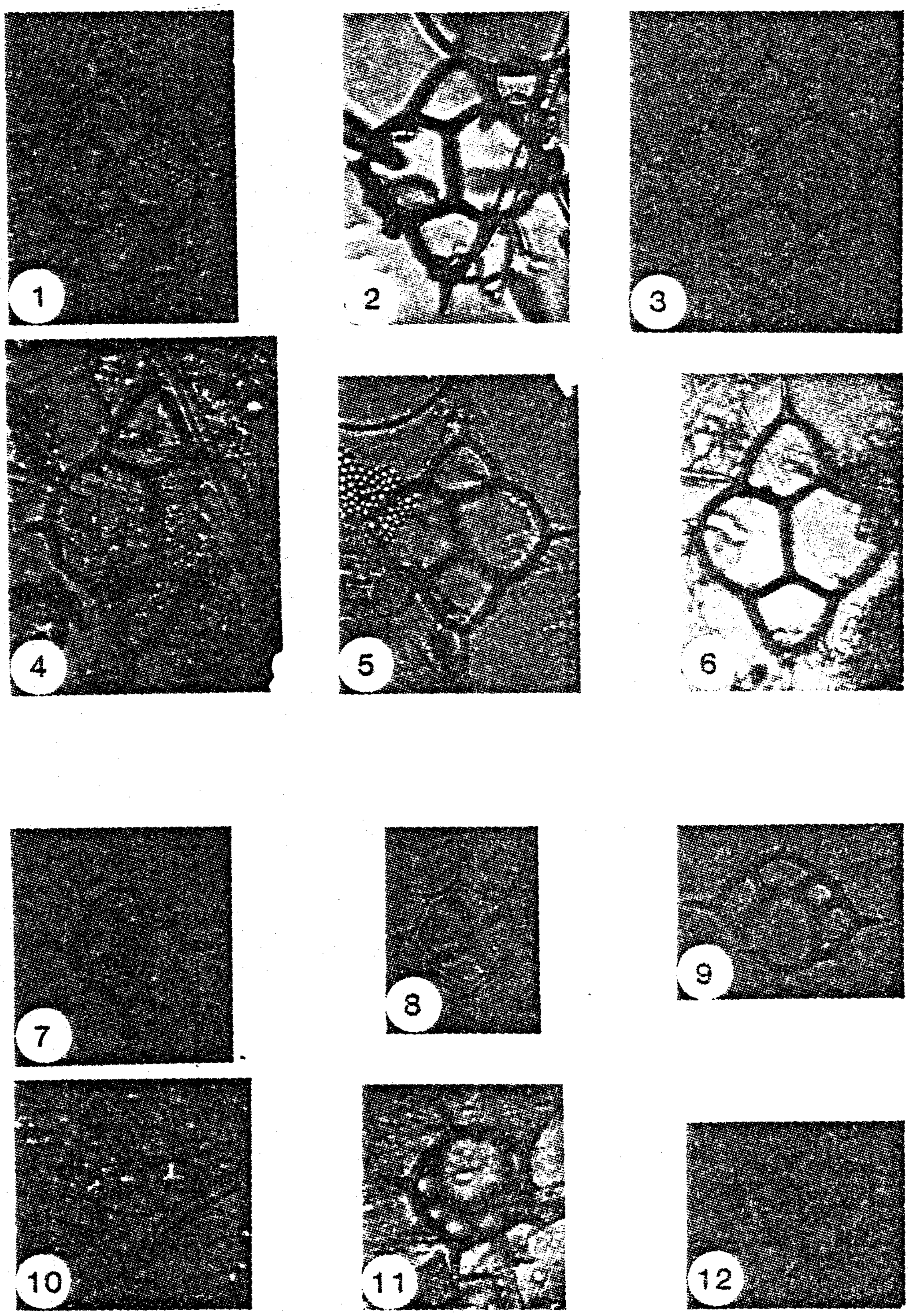


Plate V

		Dictyocha spec. 1B
Figure	1	BAM80 E-17, 125-130 cm; most common form
	2	BAV79 A-2-2, Lam. No. 73; aberrant form
	3	BAM80 P136; phytoplankton
	4	BAM80 E-17, 25-30 cm; aberrant form
	5	DSDP Leg 64, Site 480; P1-1, 70-80 cm
	6	BAV79 A-2-2, Lam. No. 99; aberrant form
		Dictyocha spec. 1A
	7	BAM80 E-17, 125-130 cm; most common form
	8	BAV79 A-2-2, Lam. No. 103
	9	BAM80 P136, phytoplankton
	10	BAV79 A-2-2, Lam. No. 5; aberrant form
	11	BAV79 A-2-2, Lam. No. 99
	12	BAV79 A-2-2, Lam. No. 59; aberrant form

The scale for all figures is given on Plate I.

PLATE V

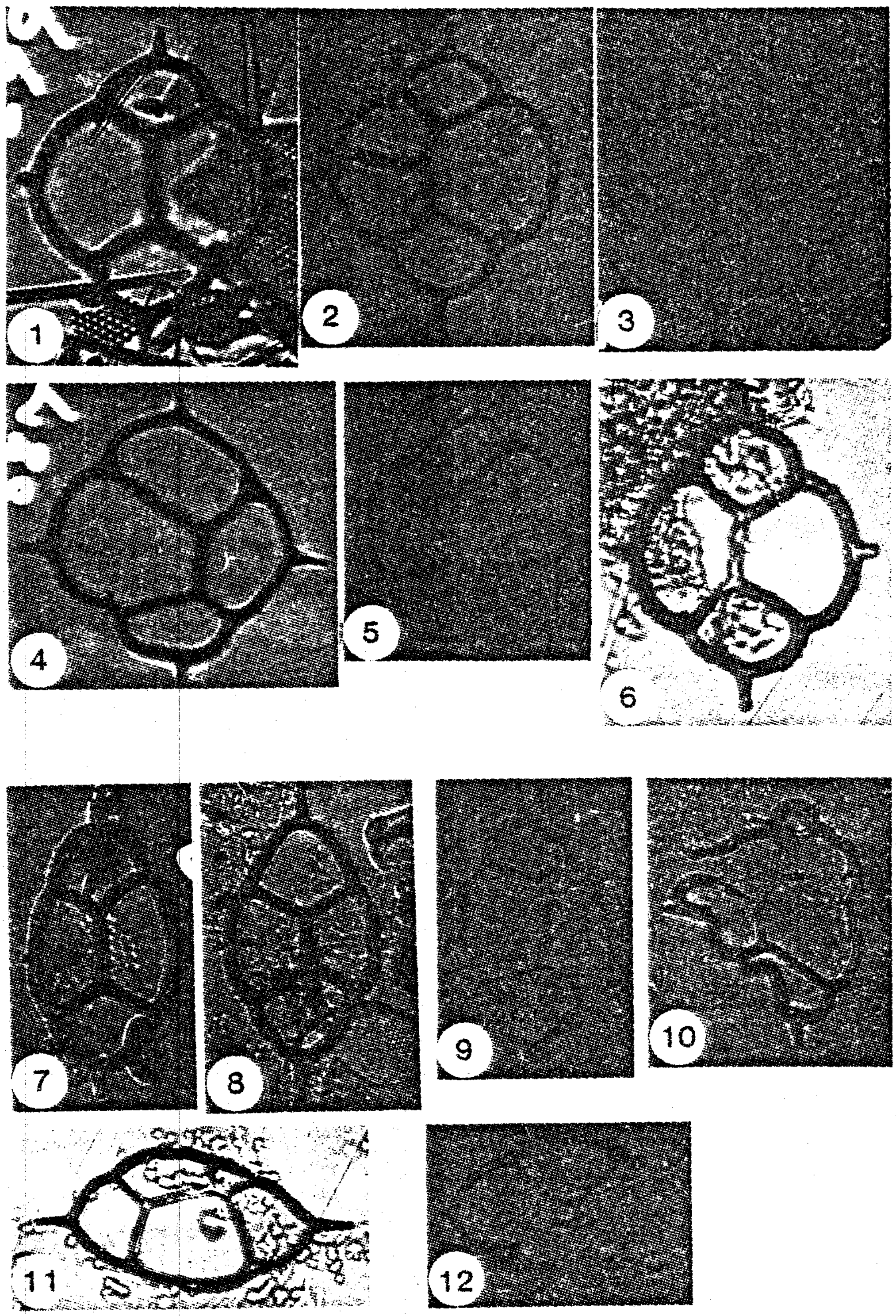


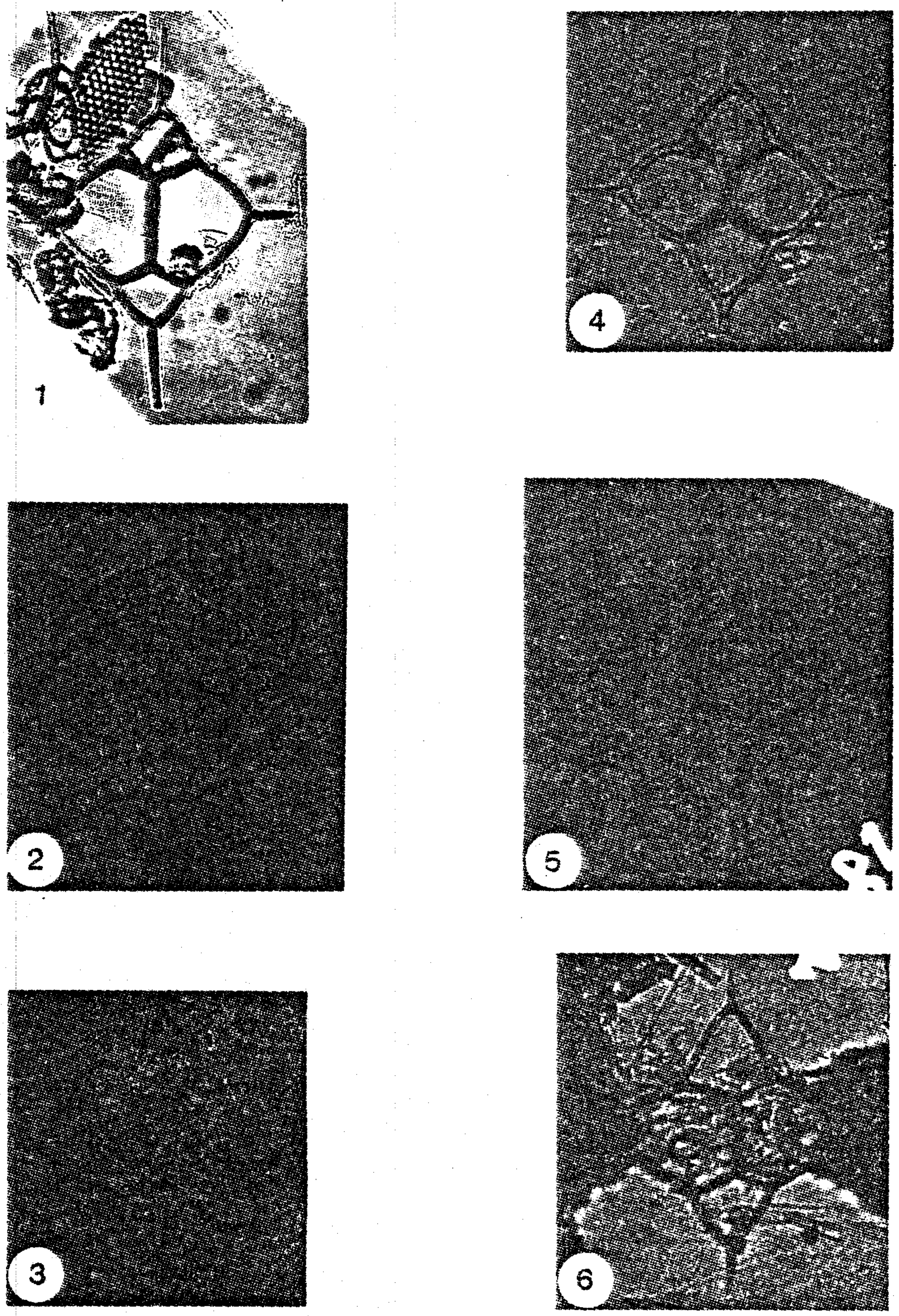
Plate VI

Dictyocha perlaevis Frenguelli (large *D. calida* form)

Figure	1	DSDP Leg 64, Site 480; P6-2, 90-100 cm
	2	DSDP Leg 64, Site 480; P1-1, 30-40 cm
	3	DSDP Leg 64, Site 480; P1-2, 30-40 cm; aberrant form
	4	DSDP Leg 64, Site 480; P3-3, 91-100 cm
	5	DSDP Leg 64, Site 480; P3-2, 130-140 cm
	6	BAV79 A-2-2, Lam. No. 100

The scale for all figures is given on Plate I.

PLATE VI



APPENDIX 1

Species Notes

A systematic discussion for the following species can be found in Poelchau (1976).

Dictyocha calida Poelchau

Plate 3, Figures 9-18

Dictyocha messanensis Haeckel

Plate 2, Figures 1-13

Remarks: The two forms of this species discussed in Poelchau (1976) are combined in this study.

Dictyocha epiodon Ehrenberg

Plate 4, Figures 7-12

Distephanus speculum (Ehrenberg) Haeckel

Plate 1, Figures 9-11

Octactis pulchra Schiller

Plate 1, Figures 1-8

The following species are found in samples from this study and were not found in North Pacific surface sediment samples.

Dictyocha spec. 1 fa. *A*

Plate 5, Figures 7-12

Remarks: This form is similar to the form identified by Bukry (1980) as *Dictyocha perlaevis perlaevis* (elongate) which has a much shorter minor axis than is typical of *Dictyocha perlaevis perlaevis*. The length of the major axis of the basal ring in Gulf of California samples is 45-55 μm. The spines on the basal ring in the Gulf forms are shorter than in the forms described by Bukry (1980).

Dictyocha spec. 1 fa. B

Plate 5, Figures 1-6

Remarks: This form is similar to the form described by Bukry (1976) as Dictyocha perlaevis delicata. The forms in the Gulf of California do not always have an apical bar and struts that are distinctly thinner than the basal ring. The length of the major and minor axes of this form are approximately equal which distinguishes it from Dictyocha spec. 1 fa. A.

Dictyocha perlaevis Frenguelli

Plate 5, Figures 1-6, and Plate 6, Figures 1-6

Remarks: Two forms of this species are differentiated in Gulf of California samples. Dictyocha spec. 1 fa. C is similar to Dictyocha perlaevis perlaevis discussed by Bukry (1979) except that only forms with more of a pinched outline of the basal ring than either D. spec. 1. fa. A or D. spec. 1 fa. B are included. The D. perlaevis (large D. calida form) is described by Bukry (1979) as Dictyocha calida ampliata. It is distinguished from D. spec. 1 fa. C because of the more distinctly pinched outline and longer spines on the basal ring.

Dictyocha spec. 2

Plate 3, Figures 1-4

Remarks: This species is similar to Dictyocha calida. It differs from D. calida because the length of the minor axis is approximately one third the major axis in D. spec. 2. The spine lengths on the basal ring of D. spec. 2 are generally smaller than those in D. calida. Forms of this species shown in Plate 3, Figures 5-7 have a more rhombic basal ring and resemble D. messanensis more than D. calida.

REFERENCES FOR APPENDIX 1

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Appendix 2. Relative percent of each silicoflagellate species in plankton, individual laminae, and Kasten core samples used in this study. Percent values are rounded to the nearest whole number. A "P" listed for a species percent value indicates that the respective species is present in the sample but no percent value is calculated. The total number of silicoflagellates counted per sample is listed under Total Counted. A "R" in this column indicates that silicoflagellates are rarely found in the sample. Some of the data from consecutive samples in Kasten cores was provided by Hans Schrader.

BAM 80 PHYTOPLANKTON SAMPLES

SAMPLE	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted
P- 1	4	91	0	0	0	4	0	45
P- 2	30	60	0	0	0	1	9	278
P- 3	32	51	0	3	0	5	9	170
P- 4	4	90	0	1	0	4	1	152
P- 5	30	68	0	0	1	1	0	154
P- 6	21	75	0	4	0	0	0	106
P- 7	5	91	0	1	0	3	0	245
P- 8	0	96	0	0	0	4	0	202
P- 9	3	88	0	0	0	9	0	194
P- 10	0	98	0	0	0	2	0	60
P- 11	0	93	0	0	0	7	0	213
P- 12	1	93	0	0	0	6	0	210
P- 13	0	94	0	0	0	6	0	17
P- 14	0	85	0	0	0	8	8	13
P- 15	22	78	0	0	0	0	0	9
P- 16	P	P	0	0	0	0	0	R
P- 17	0	P	0	0	0	0	0	R
P- 18	0	P	0	0	0	0	0	R
P- 19	0	P	0	0	0	0	0	R
P- 20	0	P	0	0	0	0	0	R
P- 21	26	50	2	20	0	0	0	201
P- 22	12	60	0	28	0	0	0	25
P- 23	44	39	11	7	0	0	0	179
P- 24	85	12	0	3	0	0	0	273
P- 25	61	35	0	4	0	0	0	54
P- 26	67	19	0	7	0	0	0	27
P- 27	84	16	0	0	0	0	0	237
P- 28	76	17	1	4	2	0	0	329
P- 29	92	7	0	1	1	0	0	304
P- 30	79	20	0	1	0	0	0	209
P- 31	85	15	0	0	0	0	0	262
P- 37	74	25	0	1	0	0	0	101
P- 40	78	21	0	1	0	0	0	277
P- 47	73	25	0	2	0	0	0	216
P- 52	75	25	0	P	0	0	0	232

BAM 80 PHYTOPLANKTON SAMPLES

SAMPLE	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted
P- 57	77	23	0	0	0	0	0	155
P- 60	80	18	0	3	0	0	0	128
P- 61	82	17	0	1	0	0	0	228
P- 63	89	9	0	2	0	0	0	158
P- 66	76	22	0	2	0	0	0	207
P- 69	79	18	0	3	0	0	0	32
P- 73	29	68	0	4	0	0	0	62
P- 76	27	41	3	28	0	0	0	102
P- 78	P	P	0	P	0	0	0	5
P- 82	0	0	0	0	0	0	0	B
P- 85	8	34	1	57	0	0	0	77
P- 89	5	39	1	54	0	0	0	239
P- 92	5	36	1	58	0	0	0	162
P- 96	42	42	0	17	0	0	0	24
P- 98	P	P	0	0	0	0	0	R
P-101	9	30	0	61	0	0	0	23
P-102	15	26	0	59	0	0	0	27
P-105	0	P	0	P	0	0	0	R
P-106	0	0	0	0	0	0	0	B
P-108	0	0	0	0	0	0	0	B
P-109	P	P	0	P	0	0	0	R
P-110	0	P	0	P	0	0	0	R
P-111	P	P	0	P	0	0	0	R
P-112	55	30	0	14	0	0	0	173
P-113	40	37	2	20	0	0	0	169
P-114	72	24	0	4	0	0	0	156
P-122	80	14	1	6	0	0	0	187
P-127	81	13	1	5	0	0	0	216
P-134	39	34	12	15	0	0	0	193
P-136	23	32	31	23	0	1	0	225
P-137	15	34	13	38	0	0	0	129
P-138	25	30	6	39	0	1	0	182
P-143	59	19	1	21	0	0	0	217
P-154	49	27	2	22	0	0	0	180
P-157	10	44	10	36	0	0	0	178

BAM 80 PHYTOPLANKTON SAMPLES

SAMPLE	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted
P-159	77	13	4	5	0	0	0	244
P-160	30	46	16	5	2	2	0	57
P-161	42	50	6	2	1	0	0	132
P-162	60	21	15	4	0	0	0	53
P-163	52	33	11	4	0	0	0	227
P-164	64	27	5	3	0	1	0	185
P-165	43	46	9	2	0	0	0	166
P-166	26	59	10	3	0	1	0	106
P-167	28	48	21	1	0	2	0	120
P-164	3	86	3	0	0	8	0	214
P-170	8	75	3	7	0	7	1	136
P-171	2	89	1	1	0	8	0	192
P-172	0	88	0	1	0	11	0	213
P-173	3	90	0	1	0	6	0	185
P 174	11	85	0	1	0	3	0	198
P-176	1	93	0	0	0	6	0	216
P-177	2	86	0	0	0	12	0	221
P-179	11	85	0	0	1	3	0	237
P-180	9	83	0	0	0	8	0	279
P-182	2	81	0	1	0	13	0	184
P-184	19	49	0	29	0	3	0	192
P-186	22	70	0	7	1	P	1	214
P-187	44	40	1	12	0	2	2	249
P-190	55	40	0	4	0	1	1	214
P-192	6	91	0	2	0	1	0	247
P-193	10	86	0	2	0	2	0	197
P-198	16	82	0	1	0	P	1	226
P-199	33	63	0	0	0	4	0	213
P-200	28	70	0	0	0	2	1	212

BAV79 A-2-2

INDIVIDUAL LAMINAE SAMPLES

LAM. NO.	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
1	36	31	3	13	9	6	2	207
2	29	50	2	11	7	2	1	123
3	21	40	14	14	2	9	0	57
4	33	44	5	10	2	3	2	88
5	11	51	8	11	14	5	0	37
6	24	43	8	19	5	0	0	37
7	27	49	9	7	5	3	2	152
8	32	43	15	4	2	4	0	162
9	29	46	13	6	3	3	0	104
10	19	57	6	8	8	2	0	63
11	24	58	3	5	3	3	4	103
12	41	43	7	0	0	3	5	58
13	25	44	11	8	5	0	7	101
14	48	41	5	3	2	2	0	61
15	49	19	17	12	2	1	0	84
16	42	28	15	11	4	0	0	107
17	44	27	21	4	2	1	1	224
18	41	38	7	7	4	0	3	115
19	50	30	9	7	0	5	0	44
20	42	35	3	16	3	0	0	31
21	64	28	3	2	1	2	1	192
22	17	42	12	14	5	3	7	161
23	15	50	13	5	10	3	5	40
24	40	30	12	7	2	7	1	179
25	33	44	5	13	1	3	2	110
26	35	30	10	7	2	0	16	126
27	47	16	6	5	5	1	21	124
28	49	26	8	11	0	3	2	97
29	35	21	6	37	2	0	0	52
30	22	38	5	29	3	0	2	58
31	46	22	3	14	5	9	1	74
32	16	30	7	23	16	8	0	74
33	31	46	4	12	8	0	0	52
34	50	23	3	7	13	3	0	30
35	49	22	11	9	4	4	1	134

BAV79 A-2-2

INDIVIDUAL LAMINAE SAMPLES

LAM. NO.	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
36	56	28	5	3	5	1	2	94
37	36	45	9	0	0	9	0	11
38	54	30	5	0	0	5	5	37
39	63	11	9	0	0	3	14	35
40	25	38	0	0	25	13	0	8
41	29	35	10	8	10	0	6	48
42	43	20	11	6	3	6	11	35
43	23	26	15	4	5	0	28	101
44	33	23	25	8	9	1	1	109
45	19	36	30	9	1	2	2	96
46	11	36	24	13	13	4	0	55
47	20	42	15	10	9	4	1	113
48	28	39	17	6	5	4	2	256
49	17	41	16	9	7	5	5	160
50	15	35	7	15	2	24	1	86
51	37	15	5	2	1	38	2	112
52	56	25	13	0	6	0	0	32
53	20	55	2	5	6	2	10	84
54	9	46	7	10	26	0	1	69
55	20	62	3	6	2	7	0	162
56	70	21	3	3	3	1	1	239
57	35	32	9	7	4	12	1	94
58	19	49	10	4	10	5	5	84
59	21	47	7	6	7	0	11	137
60	41	30	5	6	6	2	11	191
61	38	31	5	8	8	5	5	239
62	23	40	1	8	7	9	13	159
63	10	39	5	7	22	5	12	267
64	19	41	4	4	10	9	13	182
65	21	11	1	1	26	1	39	268
66	25	41	9	8	12	1	4	203
67	65	16	3	1	8	1	7	227
68	68	23	1	2	3	2	1	238
69	56	23	3	1	5	5	6	204
70	35	21	13	5	12	3	11	237

BAV79 A-2-2

INDIVIDUAL LAMINAE SAMPLES

LAM. NO.	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
71	26	48	3	8	8	4	3	108
72	52	22	3	3	18	3	1	117
73	7	36	4	12	16	10	12	69
74	6	56	6	10	17	1	4	71
75	15	41	7	16	17	3	0	73
76	33	36	1	12	10	4	4	137
77	35	45	1	12	2	6	0	101
78	55	31	1	5	3	3	1	202
79	68	22	3	2	3	1	1	242
80	81	17	1	1	1	0	0	247
81	67	29	0	4	0	0	0	69
82	83	13	1	1	1	1	0	183
83	38	28	0	24	6	2	0	50
84	66	31	1	1	1	1	0	213
85	88	5	1	3	1	4	0	199
86	86	12	0	2	0	0	0	236
87	82	15	0	2	0	1	0	213
88	55	34	5	3	1	1	0	64
89	52	30	9	6	3	1	0	198
90	62	26	0	11	1	1	0	132
91	61	19	1	8	0	11	0	134
92	43	45	1	4	2	5	0	115
93	41	36	3	6	2	11	1	237
94	74	19	3	2	1	1	0	279
95	74	8	4	5	2	8	1	253
96	55	16	7	10	8	3	1	226
97	84	4	3	3	5	1	0	183
98	69	17	6	5	3	1	0	125
99	81	5	0	8	3	3	0	37
100	73	16	3	3	2	4	0	120
101	57	15	2	16	1	9	0	82
102	66	8	2	12	1	12	0	104
103	83	9	0	4	1	3	0	209
104	96	0	2	1	0	1	0	178
105	83	9	3	3	1	1	0	135

BAV79 A-2-2

INDIVIDUAL LAMINAE SAMPLES

LAM. NO.	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
106	82	12	0	4	0	2	0	51
107	27	60	5	9	0	9	0	22
108	44	13	3	16	1	23	0	126
109	74	6	3	7	2	7	0	98
110	95	1	0	3	1	0	0	209
111	70	11	2	8	1	9	0	105
112	97	2	0	0	0	1	0	124
113	44	11	11	25	0	8	0	36
114	83	11	1	4	1	1	0	216
115	57	10	4	4	0	24	0	49
116	66	19	3	5	1	5	0	219
117	16	36	8	20	16	4	0	25
118	64	14	6	11	3	3	0	179
119	94	1	0	3	1	1	0	156
120	88	7	1	1	1	1	0	212

BAV79 A-5 depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
0.0- 5.0	32	39	12	9	2	2	4	231
5.0- 10.0	17	48	5	6	7	7	10	162
10.0- 15.0	38	34	7	8	10	3	0	162
15.0- 20.0	42	25	11	9	1	11	1	205
20.0- 25.0	56	28	2	7	1	6	0	195
25.0- 30.0	45	27	2	11	4	10	1	273
30.0- 35.0	34	24	6	11	2	4	0	167
35.0- 40.0	40	37	7	6	2	8	0	230
40.0- 45.0	47	32	6	7	1	7	0	165
45.0- 50.0	35	38	16	6	2	3	0	88
50.0- 55.0	30	34	4	13	4	15	1	178
55.0- 60.0	42	30	11	4	7	6	1	106
65.0- 70.0	29	29	15	10	4	13	0	165
70.0- 75.0	36	33	8	16	5	2	2	132
75.0- 80.0	31	31	5	11	7	15	0	172
80.0- 85.0	33	24	12	8	9	12	2	153
85.0- 90.0	23	37	5	8	5	21	1	213
90.0- 95.0	34	25	8	7	6	15	4	170
95.0-100.0	41	28	6	11	10	3	1	235
100.0-105.0	45	28	7	10	5	7	0	213
125.0-130.0	36	29	9	12	5	7	2	206
150.0-155.0	41	24	11	3	18	4	0	273
180.0-185.0	39	25	11	10	7	8	0	169

DAV 79 B-29

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
0.0- 5.0	43	48	2	3	3	1	1	230
5.0- 7.5	58	31	6	1	1	2	1	163
7.0- 10.0	55	26	8	3	3	2	3	208
10.0- 12.5	64	19	9	3	4	1	0	223
12.5- 15.0	55	24	9	3	4	2	4	186
15.0- 17.5	52	32	9	1	3	1	2	233
17.5- 20.0	36	45	5	2	6	1	5	209
20.0- 22.5	51	32	3	4	3	2	5	244
22.5- 25.0	55	22	3	2	8	2	9	254
25.0- 30.0	44	40	4	5	4	1	2	199
30.0- 32.5	56	35	1	3	4	1	1	246
32.5- 35.0	55	36	1	3	5	1	1	247
35.0- 37.5	62	23	3	2	8	2	0	270
37.5- 40.0	59	29	4	3	4	1	0	214
40.0- 42.5	49	40	6	1	2	1	0	215
42.5- 45.0	56	33	2	1	2	5	0	215
45.0- 47.5	60	30	6	2	1	0	0	168
47.5- 50.0	62	29	3	1	1	1	0	209
55.0- 55.0	66	25	2	2	3	1	0	282
55.0- 57.5	75	18	2	2	1	2	0	154
57.5- 60.0	61	24	4	6	2	1	0	161
60.0- 62.5	60	30	0	4	4	2	0	171
62.5- 65.0	56	20	5	9	8	2	1	222
65.0- 67.5	63	25	3	4	4	1	1	246
67.5- 70.0	60	27	5	3	3	1	0	166
70.0- 72.5	55	33	3	7	2	1	0	199
72.5- 75.0	53	41	2	1	2	1	1	188
75.0- 80.0	52	34	8	2	1	3	0	241
80.0- 82.5	64	24	7	1	3	2	0	232
82.5- 85.0	67	29	2	2	1	0	1	222
85.0- 87.5	59	34	3	1	2	1	0	212
87.5- 90.0	66	23	5	1	2	3	0	221
90.0- 95.0	52	35	7	1	3	3	2	198
95.0-100.0	47	32	7	5	2	5	1	203
100.0-105.0	46	41	5	4	2	2	0	221

BAV 79 B-29

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
105.0-110.0	52	25	12	4	5	1	1	204
110.0-115.0	65	22	5	3	5	0	0	209
115.0-120.0	48	41	5	2	2	1	1	209
120.0-125.0	58	30	4	3	5	1	0	222
125.0-130.0	63	27	4	0	4	2	0	240
130.0-135.0	68	16	5	4	5	2	0	231
135.0-140.0	59	25	6	2	6	1	0	201
140.0-145.0	59	28	6	1	6	1	0	235
145.0-150.0	51	33	2	3	8	2	1	224
150.0-155.0	48	38	1	5	6	2	0	226
155.0-160.0	43	44	3	3	5	2	1	195
160.0-165.0	37	41	10	3	6	2	2	227
165.0-170.0	60	26	6	2	5	1	0	214
170.0-175.0	55	30	5	3	3	2	1	183
175.0-180.0	58	27	2	4	6	3	1	245
180.0-185.0	71	17	2	1	5	4	0	178
185.0-190.0	67	26	4	1	7	1	0	206
190.0-195.0	70	19	4	3	4	1	0	181
195.0-200.0	35	45	4	11	5	1	0	170

DAM 80 E-17

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
0.0- 5.0	50	35	8	3	3	1	1	228
5.0- 10.0	67	21	4	2	3	1	3	199
10.0- 15.0	64	22	5	2	5	1	1	207
15.0- 20.0	72	18	5	2	2	1	1	258
20.0- 25.0	51	25	3	6	8	3	4	249
25.0- 30.0	69	18	4	5	4	0	0	364
30.0- 35.0	69	23	3	2	2	1	0	260
35.0- 40.0	64	29	3	2	1	1	0	213
40.0- 45.0	78	17	2	3	0	1	0	196
45.0- 50.0	72	16	3	6	1	2	0	212
50.0- 55.0	58	25	6	9	1	1	0	266
55.0- 60.0	52	36	2	6	2	2	0	259
60.0- 65.0	61	29	2	3	2	2	0	233
65.0- 70.0	64	21	6	3	3	2	0	248
70.0- 75.0	48	35	4	5	2	3	3	274
75.0- 80.0	59	23	4	8	3	1	1	245
80.0- 85.0	63	18	4	7	6	2	0	234
85.0- 90.0	63	29	3	3	1	1	1	234
90.0- 95.0	67	22	5	4	3	0	0	244
95.0-100.0	72	14	7	3	3	0	0	260
100.0-105.0	59	23	6	9	2	1	0	283
105.0-110.0	65	24	4	3	3	1	0	268
110.0-115.0	62	21	4	4	6	3	0	257
115.0-120.0	40	38	3	8	7	3	1	320
120.0-125.0	47	40	6	3	1	2	1	234
125.0-130.0	56	28	4	5	4	2	1	248
130.0-135.0	56	22	7	6	3	4	3	289
135.0-140.0	54	30	3	4	5	3	0	238
140.0-145.0	67	19	3	3	7	1	0	288
145.0-150.0	60	22	4	4	7	1	0	268
150.0-155.0	58	21	7	5	4	3	2	273
155.0-160.0	62	23	9	2	2	1	1	253
160.0-165.0	67	25	1	4	2	1	0	224
165.0-170.0	70	19	4	3	4	1	0	244
170.0-175.0	58	30	2	8	2	1	0	304

BAM 80 E-17

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp.2	Dictyocha epiodon	Total counted
175.0-180.0	71	15	5	4	4	1	1	283
180.0-185.0	73	17	3	2	4	0	0	229
185.0-190.0	63	22	7	4	3	1	1	246
190.0-195.0	72	16	4	3	5	1	0	247
195.0-200.0	64	24	4	1	6	1	0	288
200.0-205.0	59	21	7	4	6	1	1	248
205.0-210.0	52	28	6	4	6	2	1	185
210.0-215.0	60	24	4	3	8	1	0	241
215.0-220.0	71	12	7	5	4	1	0	237
220.0-225.0	85	6	4	1	4	0	0	227
225.0-230.0	64	18	4	4	8	2	0	341
230.0-235.0	59	19	10	7	5	0	0	230
235.0-240.0	55	21	8	4	11	1	0	216
240.0-245.0	72	8	6	2	12	1	1	223
245.0-250.0	68	11	4	7	14	1	0	214
250.0-255.0	65	11	3	5	14	1	0	278
255.0-260.0	63	12	4	4	17	1	1	232
260.0-265.0	71	17	3	4	5	1	0	224
265.0-270.0	71	10	9	3	5	1	0	206
270.0-275.0	69	17	6	3	4	1	0	223
275.0-280.0	49	25	6	4	15	1	1	215
280.0-285.0	58	20	2	4	14	1	0	257
285.0-290.0	59	19	5	3	13	1	1	216
290.0-295.0	53	17	7	6	17	1	0	227
295.0-300.0	52	22	4	4	16	1	0	225
300.0-305.0	37	20	4	13	24	2	0	195
305.0-310.0	50	30	8	2	9	2	0	222
310.0-315.0	66	22	3	4	5	0	0	212
315.0-320.0	40	31	11	6	12	1	0	169
320.0-325.0	43	39	8	4	6	1	0	237
325.0-330.0	47	29	8	6	7	3	0	214
330.0-335.0	52	19	4	3	22	0	0	221
335.0-340.0	56	23	3	6	12	1	0	215
340.0-345.0	54	28	5	5	7	0	0	219
345.0-350.0	66	17	6	2	9	0	0	212

BAM 80 E-17

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
350.0-355.0	51	33	6	2	8	0	0	192
355.0-360.0	51	37	6	2	5	1	0	214
360.0-365.0	47	37	3	4	7	1	1	229
365.0-370.0	63	25	4	1	7	1	0	225
370.0-375.0	55	26	7	5	5	2	0	254
375.0-380.0	44	32	8	6	10	0	0	180
380.0-385.0	63	26	2	3	5	1	9	218
385.0-390.0	46	35	2	1	13	1	0	218
390.0-395.0	53	38	1	1	7	0	0	226
395.0-400.0	48	36	4	3	8	2	1	248
400.0-405.0	30	46	3	1	20	0	0	195
405.0-410.0	38	58	1	3	8	0	0	212
410.0-415.0	26	62	3	1	8	1	0	223
415.0-420.0	33	52	3	5	6	1	0	229
420.0-425.0	36	47	6	5	6	1	0	214
425.0-430.0	31	54	3	6	6	1	0	171
430.0-435.0	50	36	1	4	9	1	0	224
435.0-440.0	48	42	2	2	6	1	0	213
440.0-445.0	34	57	1	3	5	1	1	235
445.0-450.0	30	55	3	3	9	1	0	194

BAM 80 F-30

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
0.0- 5.0	31	35	13	8	5	8	1	156
25.0- 30.0	25	27	5	17	8	16	1	207
50.0- 55.0	23	45	10	8	3	10	1	262
75.0- 80.0	20	26	14	12	5	18	5	215
100.0-105.0	23	40	14	4	2	15	1	169
125.0-130.0	25	37	7	14	6	10	1	256
150.0-155.0	20	27	15	12	15	10	1	248
175.0-180.0	24	23	14	11	24	4	1	236
200.0-205.0	21	29	15	19	7	8	2	183
225.0-230.0	28	29	11	11	10	11	0	238
250.0-255.0	14	63	5	8	8	2	0	288
270.0-276.0	8	54	5	16	4	12	1	187

BAM 80 G-34

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
1.0- 5.0	1	42	2	26	10	9	11	233
25.0- 30.0	6	36	5	23	10	17	3	247
50.0- 55.0	3	43	3	20	14	10	6	173
75.0- 80.0	3	43	7	24	13	7	3	221
100.0-105.0	1	45	2	44	5	1	3	183
125.0-130.0	2	39	11	40	1	7	1	210
150.0-155.0	3	36	5	39	2	15	1	184
175.0-180.0	2	56	6	21	4	5	6	215
200.0-205.0	1	49	6	31	3	5	5	166
225.0-230.0	1	34	8	17	24	3	14	151
250.0-255.0	0	47	3	30	16	0	4	74

BAM 80 I-42

depth(cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha spp. 1B and 1C	Dictyocha sp. 2	Dictyocha epiodon	Total counted
0.0- 5.0	29	46	11	4	7	1	2	167
25.0- 30.0	47	37	8	2	2	4	1	195
50.0- 55.0	43	32	10	4	7	4	0	203
75.0- 80.0	52	24	10	5	6	2	1	215
100.0-105.0	48	30	8	2	9	3	1	188
125.0-130.0	41	23	16	4	15	2	0	229
150.0-155.0	48	21	5	2	23	1	1	210
175.0-180.0	40	33	15	5	3	5	0	151
200.0-205.0	44	28	11	3	11	2	1	194
230.0-237.0	43	40	4	2	10	1	0	253

Appendix 3. Relative percent of each silicoflagellate species in DSDP Leg 64 Site 480 samples. Percent values are rounded to the nearest whole percent. The total number of silicoflagellates counted per sample is listed under Total Counted. Core depth values are listed using DSDP sample notation. Hole depth values are depths calculated downhole. Radiolaria and planktonic Foraminifera values are from coarse fraction samples. Temperature values are obtained using the Poelchau (1974) equation given in the text. Samples with an "*" indicate those used for the study of the top 30 meters.

DSDP Leg 64
Site 480

core depth (cm)	hole depth (cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha sp. 1B, 1C, and D. perlaevis forms	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted	Radiolaria	Planktonic Foraminifera	Temperature
*P 1-1, 0- 10;	0- 10	62	24	7	4	3	1	0	0	268	100	0	27.5
P 1-1, 10- 20;	10- 20	66	19	3	4	8	1	0	0	226	100	0	27.5
P 1-1, 20- 30;	20- 30	75	10	4	4	5	2	0	0	197	-	-	27.5
P 1-1, 30- 40;	30- 40	65	19	5	3	7	0	0	0	208	-	-	27.5
P 1-1, 40- 50;	40- 50	68	13	2	2	7	7	0	0	241	-	-	27.5
P 1-1, 50- 60;	50- 60	73	12	2	4	7	1	0	0	204	100	0	27.5
P 1-1, 60- 70;	60- 70	69	11	2	4	13	1	0	0	238	-	-	27.5
*P 1-1, 70- 80;	70 80	68	14	5	3	9	1	0	0	214	-	-	27.5
P 1-1, 80- 90;	80- 90	56	25	4	5	8	2	0	0	217	-	-	27.5
P 1-1, 90-100;	90- 100	64	18	5	5	8	0	0	0	223	95	0	27.5
P 1-1,100-110;	100- 110	68	16	4	3	7	1	0	0	202	-	-	27.5
P 1-1,110-120;	110- 120	47	26	6	4	16	2	0	0	215	116	1	27.5
P 1-1,120-130;	120- 130	52	31	8	4	5	1	0	0	215	-	-	27.5
P 1-1,130-140;	130- 140	48	32	6	5	6	3	1	0	210	114	13	26.2
*P 1-1,140-150;	140- 150	51	31	6	4	5	2	0	0	205	-	-	27.5
P 1-2, 0- 10;	150- 160	60	23	7	2	9	0	0	0	152	100	0	27.5
P 1-2, 10- 20;	160- 170	51	35	5	4	6	0	0	0	199	-	-	27.5
P 1-2, 20- 30;	170- 180	46	39	9	3	5	0	0	0	233	-	-	27.5
P 1-2, 30- 40;	180- 190	55	31	2	5	5	1	0	1	222	100	0	26.5
P 1-2, 40- 50;	190- 200	64	35	3	3	4	1	0	0	223	-	-	27.5
P 1-2, 50- 60;	200- 210	52	39	1	1	5	1	0	0	207	-	-	27.5
P 1-2, 60- 70;	210- 220	54	31	3	3	9	0	0	0	228	-	-	27.5
*P 1-2, 70- 80;	220- 230	38	53	1	4	2	2	0	0	208	100	0	27.5
P 1-2, 80- 90;	230- 240	34	53	1	2	9	1	0	0	222	161	0	27.5
P 1-2, 90-100;	240- 250	41	50	2	2	4	1	0	0	208	100	0	27.5
P 1-2,100-110;	250- 260	36	47	4	6	7	0	0	0	198	100	0	27.5
P 1-2,110-120;	260- 270	40	48	3	2	8	1	0	0	205	150	0	27.5
P 1-2,120-130;	270- 280	45	46	4	0	2	1	0	0	201	-	-	27.5
P 1-2,130-140;	280- 290	26	60	1	2	5	1	1	0	209	-	-	26.8
P 1-2,140-150;	290- 300	30	60	2	1	6	1	0	0	212	100	0	27.5
*P 1-3, 0- 10;	300- 310	29	62	4	1	2	1	1	0	217	-	-	26.8
*P 1-3, 70- 80;	370- 380	34	49	5	6	5	1	0	0	164	-	-	27.5
*P 2-1, 0- 10;	475- 485	53	30	3	7	5	1	1	0	210	-	-	26.1
*P 2-1, 70- 80;	545- 555	30	60	4	3	2	1	0	0	199	-	-	27.5
*P 2-2, 20- 30;	645- 655	36	58	2	1	1	1	0	0	213	-	-	27.5

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SITE 480

core depth (cm)	hole depth (cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha sp. 1B, 1C, and D. perlaevis forms	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted	Radiolaria	Planktonic Foraminifera	Temperature
*P 2-2, 70- 80;	696- 705	32	52	2	0	0	0	14	0	223	-	-	15.9
*P 2-3, 20- 30;	795- 805	31	67	1	1	0	0	0	0	217	-	-	27.5
*P 2-3, 70- 80;	845- 855	24	71	1	2	1	0	0	0	201	-	-	27.5
*P 3-1, 0- 10;	950- 960	44	37	0	1	15	0	2	0	177	-	-	23.5
*P 3-1, 70- 80;	1020-1030	45	46	0	1	6	0	2	0	211	-	-	23.3
*P 3-2, 0- 10;	1100-1110	31	38	0	13	28	0	0	0	129	-	-	27.5
*P 3-2, 70- 80;	1170-1180	78	9	0	1	11	0	1	0	203	-	-	23.2
P 3-2, 90-100;	1190-1200	75	9	0	0	16	0	0	0	240	167	0	27.5
P 3-2,100-110;	1200-1210	75	9	0	0	16	0	0	0	239	204	0	27.5
P 3-2,110-120;	1210-1220	70	11	0	0	19	0	0	0	223	225	0	27.5
P 3-2,120-130;	1220-1230	67	20	0	0	11	0	0	2	211	158	0	21.4
P 3-2,130-140;	1230-1240	71	15	0	0	14	0	0	0	201	97	0	27.5
P 3-2,140-150;	1240-1250	75	10	0	0	18	0	2	5	242	259	0	13.7
*P 3-3, 0- 10;	1250-1260	70	14	0	0	11	0	1	3	224	191	0	16.5
P 3-3, 10- 20;	1260-1270	75	12	0	0	8	0	1	4	240	176	0	14.8
P 3-3, 20- 30;	1270-1280	70	8	0	0	12	0	2	8	241	109	0	13.4
P 3-3, 30- 40;	1280-1290	67	11	0	0	11	0	1	10	228	169	0	13.5
P 3-3, 40- 50;	1290-1300	46	9	0	0	20	0	1	22	226	188	5	14.1
P 3-3, 50- 60;	1300-1310	56	9	0	0	20	0	1	13	204	163	83	13.5
P 3-3, 60- 70;	1310-1320	19	14	0	0	45	0	1	22	148	84	348	13.7
*P 3-3, 70- 77;	1320-1327	38	13	0	0	32	0	1	17	151	118	176	13.7
P 3-3, 91-100;	1341-1350	29	14	0	0	49	0	1	8	226	48	516	17.8
P 3-3,100-110;	1350-1360	24	12	0	0	50	0	1	13	172	87	341	15.0
P 3-3,110-120;	1360-1370	30	9	0	0	43	0	1	18	208	56	120	13.8
*P 3-3,120-130;	1370-1380	37	12	0	0	38	0	1	12	233	53	84	14.7
P 4-1, 0- 10;	1425-1435	32	59	4	0	6	0	0	0	227	-	-	-
P 4-1, 10- 20;	1435-1445	25	66	1	3	3	1	0	0	213	248	7	-
P 4-1, 20- 30;	1445-1455	33	26	1	3	31	0	1	6	116	110	269	-
*P 4-1, 30- 40;	1455-1465	36	8	0	0	35	0	1	21	226	88	247	13.5
P 4-1, 40- 50;	1465-1475	37	12	0	0	37	0	1	13	211	106	294	14.5
*P 4-1, 70- 80;	1495-1505	20	9	0	0	53	0	10	9	162	-	-	14.6
*P 4-2, 0- 10;	1575-1585	29	10	0	0	26	0	0	35	178	-	-	15.1
*P 4-2, 70- 80;	1645-1655	57	9	0	0	27	0	1	6	163	-	-	16.0
*P 4-3, 0- 10;	1725-1735	33	14	0	0	47	0	0	6	170	-	-	19.2
*P 4-3, 70- 80;	1795-1805	18	17	0	0	58	0	3	3	60	-	-	20.0

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SITE 480

core depth (cm)	hole depth (cm)	Octactis pulchra	Dictyocha messanensis	Dictyocha calida	Dictyocha sp. 1A	Dictyocha sp. 1B, 1C, and D perlaevis forms	Dictyocha sp. 2	Dictyocha epiodon	Distephanus speculum	Total counted	Radiolaria	Planktonic Foraminifera	Temperature
*P 5-1, 0- 10;	1900-1910	24	50	1	4	16	0	2	5	221	-	-	-
*P 5-1, 70- 80;	1970-1980	22	12	0	0	37	0	18	11	170	-	-	13.5
*P 5-2, 0- 10;	2050-2060	36	12	0	0	45	0	5	4	172	-	-	17.7
*P 5-2, 70- 80;	2120-2130	34	6	0	0	58	0	3	0	80	-	-	23.7
*P 5-3, 0- 10;	2200-2210	40	7	0	0	49	0	1	3	198	-	-	27.5
*P 5-3, 70- 80;	2270-2280	62	17	0	0	21	0	0	0	166	-	-	21.4
*P 6-1, 0- 10;	2375-2385	65	18	0	0	13	0	3	1	141	-	-	19.2
*P 6-1, 70- 80;	2445-2455	45	23	0	0	15	0	16	2	195	-	-	14.3
*P 6-2, 0- 10;	2525-2535	67	15	0	0	14	0	6	1	234	-	-	15.6
*P 6-2, 70- 80;	2595-2605	69	5	0	0	23	0	3	1	188	-	-	18.3
*P 6-3, 10- 20;	2685-2695	61	8	0	0	27	0	3	1	210	-	-	19.3
*P 6-3, 70- 80;	2745-2755	46	15	0	0	38	0	2	0	220	-	-	24.1
*P 7-1, 0- 10;	2850-2860	62	13	0	0	18	0	7	0	110	-	-	16.2
*P 7-1, 70- 80;	2920-2930	62	23	0	0	15	0	1	0	200	-	-	24.7
*P 7-2, 0- 10;	3000-3010	33	26	0	0	30	0	11	0	200	-	-	16.9
P10-2, 0- 10;	4425-4435	19	32	0	0	48	0	1	0	220	105	0	26.2
P10-2, 10- 20;	4435-4445	18	31	0	0	50	0	1	0	211	170	2	26.2
P10-2, 20- 30;	4445-4455	17	24	0	0	52	0	7	0	208	-	-	20.4
P10-2, 30- 40;	4455-4465	22	27	0	0	42	0	9	0	209	151	0	18.8
P10-2, 40- 50;	4465-4475	19	19	0	0	59	0	3	0	243	115	0	23.8
P10-2, 50- 60;	4475-4485	18	26	0	0	45	0	11	0	219	197	0	18.0
P10-2, 60- 70;	4485-4495	4	11	0	0	26	0	58	0	252	123	0	14.7
P10-2, 70- 80;	4495-5505	20	14	0	0	46	0	20	0	221	250	0	15.1
P10-2, 80- 90;	4505-4515	24	16	0	0	57	0	3	0	197	181	0	23.6
P10-2, 90-100;	4515-4525	16	21	0	0	53	0	10	0	210	156	0	18.6
P10-2,100-110;	4525-4535	6	7	0	0	25	0	62	0	234	110	0	14.6
P10-2,110-120;	4535-4545	7	11	0	0	18	0	65	0	212	217	0	14.4
P10-2,120-130;	4545-4555	6	5	0	0	16	0	73	0	212	103	0	13.4
P10-2,130-140;	4555-4565	15	12	0	0	25	0	48	0	224	194	0	14.7
P10-2,140-150;	4565-4575	8	10	0	0	24	0	58	0	207	178	0	14.7