

AN ABSTRACT OF THE THESIS OF

Anne Marie Matherne for the degree of Master of Science in Oceanography presented on December 18, 1981.

Title: Paleooceanography of the Gulf of California: A 350-Year Diatom Record

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Abstract approved: _____

Hans Schrader

Downcore diatom assemblage variations as preserved in varved sediments from the central Gulf of California are used to detect changes in the overlying water masses over the last 300-350 years. Four laminated Kasten cores from the slopes of the Guaymas Basin were examined, B-29 and B-28 from the Baja side and E-9 and E-10 from the mainland side of the Gulf. Average sedimentation rates during the last 800-900 years, based on varve chronology, are: B-29, .26 cm/yr; B-28, .24 cm/yr; E-9, .24 cm/yr; and E-10, .23 cm/yr. Varve counts were combined with silicoflagellate biostratigraphic horizons to establish a time scale for the upper 90 cm of sediment in the four cores. Variation in sediment diatom assemblages were analysed over the same interval.

Factor analysis resolved two factors accounting for 84% of the variance in the diatom assemblage. Factor 1, accounting for 56% of the data variance, is interpreted to reflect changes in productivity levels in the Gulf. High levels of this factor correspond to intervals of increased productivity, low levels are indicative of periods of increased oceanic influence. Factor 2 (28% of the data vari-

ance) is interpreted as reflecting the persistent high primary productivity conditions characteristic of the central Gulf. Six ecological groups were defined for the minor species based on available literature data. Two of these groups were used to further characterize trends delineated by factor analysis.

Conditions in the Gulf of California over about the last 350 years can be divided into three stages based on major trends in productivity levels. Stage III(ca. 1600-1750) was a period of predominantly high productivity levels, alternating with intervals of increased oceanic influence. These fluctuating conditions may be the result of widely fluctuating climatic extremes associated with the Little Ice Age. Stage II(ca. 1750-1870) corresponds roughly to the maximum extent of the Little Ice Age in western North America. Oceanic influence in the Gulf was enhanced and productivity levels declined. Intensification of Pacific equatorial circulation associated with the Little Ice Age may have stabilized during the maximum, resulting in a stronger and more northward reaching Equatorial Current, with a greater influence in the Gulf than at present. Gulf productivity levels rose with the climatic amelioration following the end of the Little Ice Age(Stage I-ca. 1870-present), and colder waters were present in the central Gulf. This may be tied to an increase in California Current influence with the deintensification of equatorial circulation. It may also reflect increased upwelling

due to a more stable zonal wind system, as opposed to the wide fluctuations in climatic conditions characteristic of the Little Ice Age during Stage III.

Paleoceanography of the Gulf of California:
A 350 - Year Diatom Record

by

Anne Marie Matherne

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and Dave Murray - on the occasion of my finishing, in anticipation of your finishing and for what we will have shared doing it.

To all of you, I give my thanks.

And Jim, I think it's the middle of May.

Look! He said, and hunkered in solemn attire
to lift his son, like any God or farmer,
and pointed. Over the capitol dome, to the west,
a wing of one-and-many geese went sliding.

honking south like old Model T's redeemed,
gone glorious. Oh, not for the lesson in it,
not for the high-falutin falling mind
organizing itself to swim or fly

with ease searching out the dire vacuity:
not for that: for "thisness": twenty-four geese
enroute from swamp to swamp, encountering a dome
at twilight, passing and touching an unseen mark;

they freeze, fall out of time and into thought;
an ideograph in the blood of man and son.
No image. The pure idea of holiness.
His mother said when they told their vision, "Ah!"

John Gardner

The Sunlight Dialogues

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PALEOCEANOGRAPHY OF THE GULF OF CALIFORNIA

A 350 - YEAR DIATOM RECORD

INTRODUCTION

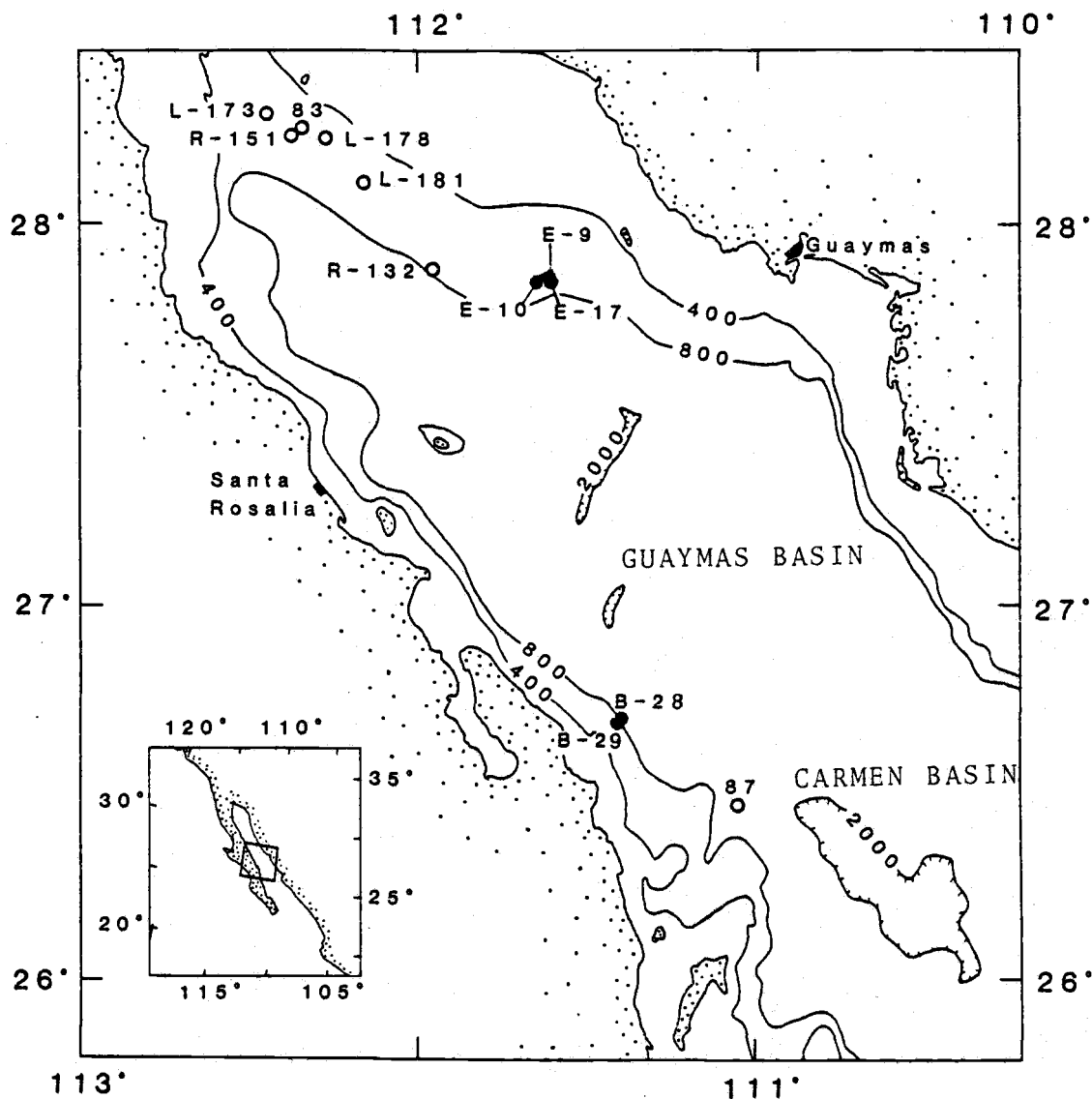
This study will document the composition and variability of the diatom assemblage preserved in varved sediments from the central Gulf of California over the last 300-350 years. Key diatom species or species groups within the total assemblage will be identified for interpreting paleoecologic and paleoclimatic changes. A record of changing water mass conditions in the central Gulf over approximately the last 350 years will be established based on the diatom flora, and the interaction between these conditions and general climatic trends affecting the central Gulf will be modeled.

A number of phytoplankton surveys have been made in the Gulf of California, and the distribution of phytoplankton in Gulf waters has been described (Allen, 1934, 1937, 1938; Cupp and Allen, 1938; Gilbert and Allen, 1943; Tafall, 1943; Round, 1967). However, no long-term systematic phytoplankton studies have been undertaken to date. The distribution of microfossils in Gulf sediments, based on coarse fraction analysis, has been documented by Bandy (1961). Radiolaria distribution in near-surface sediments has been recorded by Benson (1966) and Molina-Cruz (in press). Surface and down-core silicoflagellate assemblages will be described by Murray and Schrader (in prep.).

Schrader (in prep.) has established stratigraphic horizons in a suite of cores throughout the Gulf based on peaks in abundance of certain silicoflagellate species. Schrader, Murray et al. (1980) and Donegan and Schrader (in press) have proposed mechanisms for laminae formation within the Gulf, based on the diatom flora within a series of laminae in sediments from the Baja and mainland sides of the Guaymas Basin slope.

Round (1968) described the distribution of diatom assemblages in a suite of Gulf cores, for both surface and downcore sediments. His samples included what were termed a slightly laminated (R-132) and a well laminated (R-151) core from the Guaymas Basin slopes (Figure 1). Round's results differ substantially from the present work, mainly with respect to diatom abundances downcore. It was not possible, based on his papers, to determine the reason for this discrepancy. Round (1967,1968) is therefore acknowledged as previous work in this area, but results of the two studies will not be compared in this paper.

Figure 1. Central Gulf of California, showing the location on the Guaymas Basin slopes of Kastan cores B-29, B-28, E-9, and E-10, used in this study. Other cores discussed in the text are BAM-80 E-17(OSU); L-173, L-178, and L-181(Calvert, 1966b); 87 and 89(DeMaster, 1979); R-132 and R-151(Round, 1969).



BACKGROUND

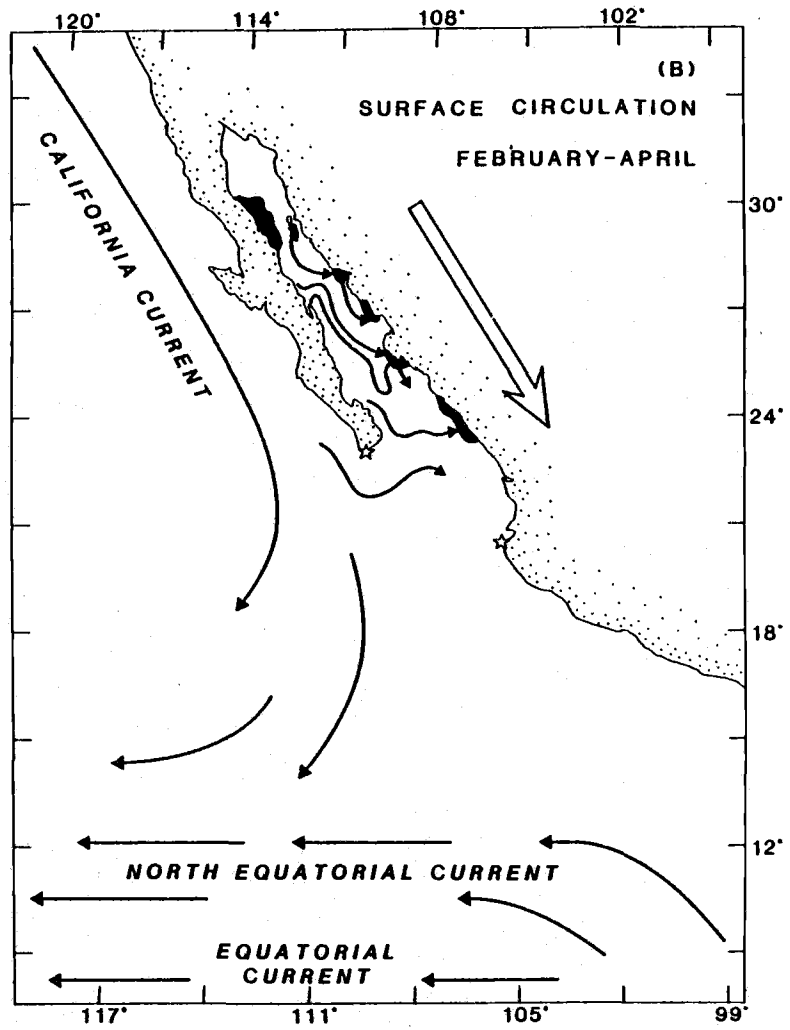
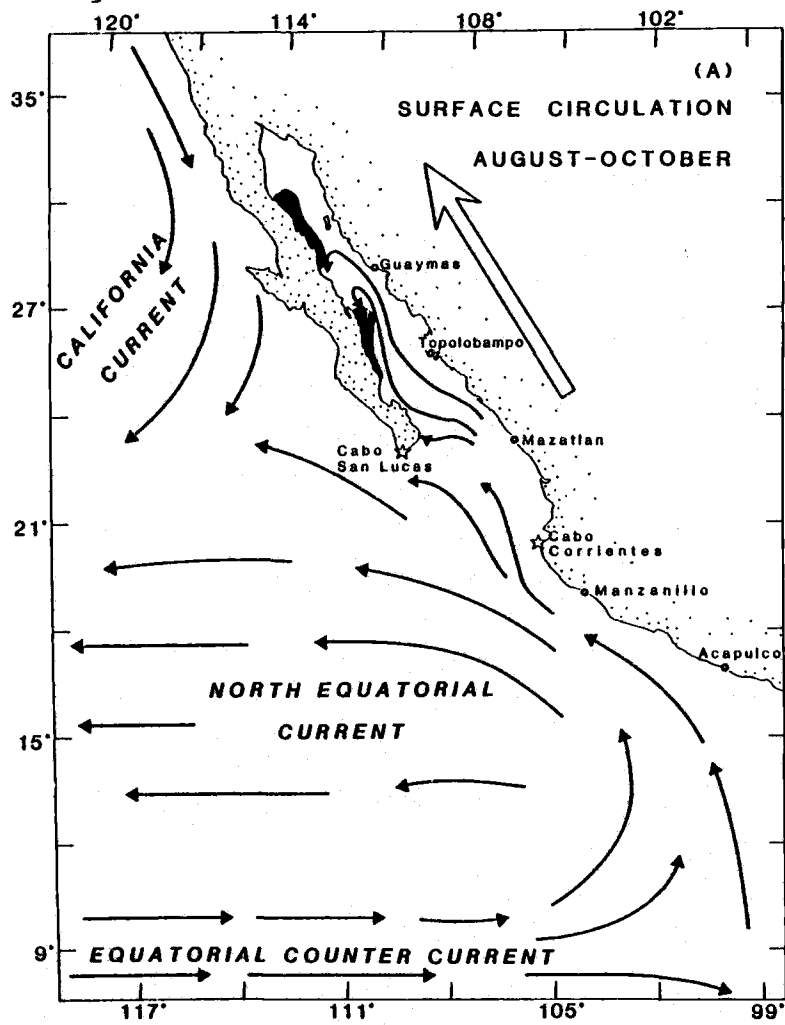
The Gulf of California is a large evaporative basin. It is approximately 1000 km long and 150 km wide and in open communication with the Pacific Ocean at its southern end (Roden, 1964). It is divided into a series of basins and trenches separated from each other by transverse ridges which deepens towards the mouth of the Gulf (Shepard, 1950).

The Guaymas Basin slopes, in the central Gulf of California, are areas of high primary productivity (Zeitzschel, 1969) and well-laminated diatom-rich sediments (Calvert, 1966a; Schrader, Kelts et al., 1980). The laminated sediments, found between 400-800 m depth where the oxygen minimum zone intersects the sediment water interface (Calvert, 1964, and data from BAV79 and BAM80 cruises) show no bioturbation and undisturbed sediment accumulation.

Surface circulation in the Gulf is strongly linked to regional winds which blow from the northwest during winter and early spring, then change to southeasterly in direction during the summer months (Roden, 1964) (Figure 2). Roden and Groves (1959) have documented significant upwelling along both coasts of the Gulf associated with these wind systems. Upwelling was found to occur along the mainland coast from about November to April associated with northwesterly winds, and along the Baja coast primarily from August to October during times of southeasterly

Figure 2. Surface circulation in the Gulf of California and adjacent areas of the Pacific. Gulf circulation data from CALCOFI 5-23 June, 1957 (A) and 6-26 February, 1957 (B) (Wille, 1966). Arrow shows prevailing wind direction. Areas of upwelling are shaded. Pacific circulation after Namias (1971) and Wyrтки (1965).

Figure 2:



winds.

The details of Gulf circulation have not been well established. Roden (1958) concluded on the basis of drift data that winter surface circulation is characterized by southward currents north of Cape Corrientes, and that summer surface circulation is characterized by northward currents along the Mexican coast and into the Gulf, with southward flow outward near Baja California. Granados and Schwartzlose (in press) and Rosas-Cota (1976) support a general pattern of southward flow throughout the entire Gulf in the winter and northward flow in the summer, with more complex reversing conditions in spring and fall.

Three distinct water masses may be distinguished above 200 m depth in the Gulf (Griffiths, 1968; Stevenson, 1970; Warsh and Warsh, 1971; Roden, 1972; Warsh et al., 1973; Alvarez-Sanchez, 1974). California Current Water ($<22^{\circ}\text{C}$, $<34.6\%$) flows southward along the west coast of Baja California (Figure 2b) and has been observed turning east around the tip of Baja California and penetrating into the Gulf. The extent of this incursion varies on a seasonal and annual basis (Stevenson, 1970; Alvarez-Sanchez, 1974). Equatorial Water (often $>25^{\circ}\text{C}$, $34.6\text{--}34.8\%$) has been observed reaching above the tip of Baja California during the summer (Figure 2a), apparently limiting the southern influence of the California Current (Wyrski, 1967; Stevenson, 1970). Gulf water ($22^{\circ}\text{--}25^{\circ}\text{C}$, $>34.9\%$) is formed within the Gulf by evaporation of

Equatorial Pacific Water, probably north of 25°N latitude (Stevenson, 1970). An additional subsurface water mass (13-20°C, 34.6-34.9‰) is composed of a mixture of California Current and Pacific subtropical subsurface water (Warsh et al., 1973).

Precipitation is minimal over the eastern margin of the Baja peninsula, and no major rivers discharge into the Gulf. Rainfall occurs primarily on the mainland side, in the form of a summer "monsoon" during July and August. River discharge on the mainland side increases towards the south (Hastings and Turner, 1965). These precipitation patterns result in variable runoff into the central Gulf and a seasonal input of terrigenous material to Gulf waters. Prior to its damming in 1935, the Colorado River was the primary source of sediment discharge into the Gulf (Byrne, 1957). However, its impact as a source of nutrient supply at this time was not documented, nor was it ascertained whether the influence of its sediment supply extended as far south as the central Gulf.

Besides being affected by local climatic conditions, communication of the Gulf with the Pacific leaves it open to factors influencing circulation in the eastern Equatorial Pacific such as the Southern Oscillation and occurrence of El Niño events. Meteorological and oceanographic conditions associated with these phenomena have been described by Quinn (1971), Miller and Laurs (1975), Wyrski (1975, 1977), and Quinn et al. (1978) among others. Al-

though the main emphasis of much of this work concerns the effect of El Niño events on South American waters and Peruvian fisheries, Wyrski (1973, 1975) reported an increase in sea surface temperatures off Central America and abnormally high sea level at Manzanillo associated with the 1972/1973 El Niño event. Sea surface temperature anomalies (Miller and Laurs, 1975) show the extension of warm waters north to the mouth of the Gulf at this time. These facts imply that intrusion of Equatorial Water into the Gulf was associated with this El Niño event. Roden (1964) reported positive sea level anomalies along the coast of Mexico and into the Gulf as far north as Guaymas during 1957-1958. This also coincides with a strong El Niño event (Quinn et al, 1978), suggesting that the anomalies were again indicative of Equatorial Water intrusion into the Gulf, with effects as far north as the Guaymas Basin. These two strong El Niño events show that the Southern Oscillation does under certain conditions influence circulation and water mass characteristics in the Gulf of California.

METHODS

This work is based on an analysis of the diatom fraction of samples from four Kasten cores obtained during the BAV79 cruise of the H-1 Mariano Matamoros within the Gulf of California in September 1979. Cores B-29 and B-28 were taken from the Baja side, and E-9 and E-10 from the mainland side of the Gulf, from laminated sediments of the Guaymas Basin slopes (Figure 1 and Table 1). Because of the apparently seasonal nature of laminae deposition (Calvert, 1966b; Bruland, 1974; DeMaster, 1979) and high sedimentation rates (averaging .24cm/yr-see Results and Discussion), time correlations between cores can be made with much finer resolution than is possible in downcore studies elsewhere.

The cores in Area B are located 1.3 km apart; those in Area E are separated by 2.7 km. Cores were sampled from the same area to examine local variability in contemporaneous diatom floras, and to provide an "average" record for each side of the Gulf, correcting for "patchiness" of diatom distributions due to localized blooms in surface waters. Cores from opposite sides of the Gulf but at similar distances from its mouth were chosen to show the effects of water mass changes or mixing effects across the central Gulf. The cores were subsampled to a depth of 92.5 cm. Based on varve chronostratigraphy, this provides a record of approximately the last 300-350 years, including changes associated with the "Little Ice Age" (17th

Table 1. Locations and depth within the Gulf of California of the four Kasten cores used in this study. The cores were recovered during the September, 1979, cruise of the Mexican Research vessel H-1 Mariano Matamoros and are stored at the core repository of the OSU School of Oceanography.

<u>Core</u>	<u>Location</u>	<u>Depth (m)</u>
BAV79-B28	26°42.5'N, 111°24.5'W	712
BAV79-B29	26°42.0'N, 111°25.0'W	635
BAV79-E9	27°53.2'N, 111°37.2'W	660
BAV79-E10	27°52.2'N, 111°39.7'W	644

-19th centuries, Bjerknes, 1965).

The Kasten cores were subsampled on board ship shortly after core recovery using 27.5 x 15 x 7 cm plastic boxes. The core barrels were opened, and the two exposed sides scraped clean to remove the material around the outer edges contaminated by the coring process. The plastic boxes were pressed into the sediment continuously from top to bottom. Nylon filament was run along the edge beneath each box to cut through the sediment and separate the boxed material from the remainder of the core. The boxes containing the core material were removed and covered with plastic lids, and were sealed with electrical tape to prevent drying of the sediment. Using this subsampling method, a continuous record of each core was obtained, disturbed only at the junction between adjacent boxes.

Detailed descriptions were made of all cores before further subsampling took place. The cores were described in terms of color, using a Munsell color chart (Figure 3, column 3), structure (finely laminated, faintly laminated, and homogenous), and disturbances of the sediment structures (Figure 3, column 4). Textural and compositional characteristics of B-29 and E-9 are documented by Donegan and Schrader (in press) for those intervals indicated in Figure 3 column 8. Downcore variations in laminae thickness and in sedimentation rates were determined by a continuous count of the number of laminae per 5 cm increment

Figure 3a-d. Core lithologies and sample locations for Kasten cores B-29, B-28, E-9, and E-10. 1 = depth(cm). 2 = subsample boxes. 3 = color; white = lighter and shaded = darker intervals. 4 = lithology;  = homogenous,  = faintly laminated,  = finely laminated,  = disturbed,  = laminated, broken lines = wedging of laminae, dark bands = thick light laminae. 5-8 = sample locations; 5 = diatom assemblage composition, 6 = silicoflagellate assemblage composition (Schrader, in prep.), 7 = absolute abundance of diatoms, 8 = textural and compositional analysis (Donegan and Schrader, in press).

Figure 3a.

BAV79 B-29 KASTEN CORE

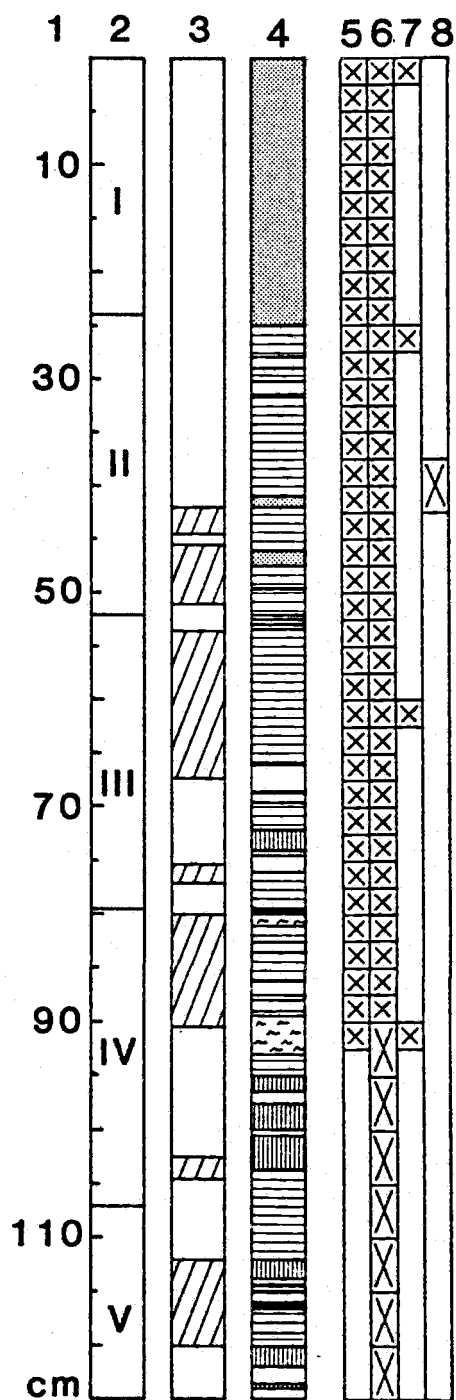


Figure 3b.

BAV79 B-28 KASTEN CORE

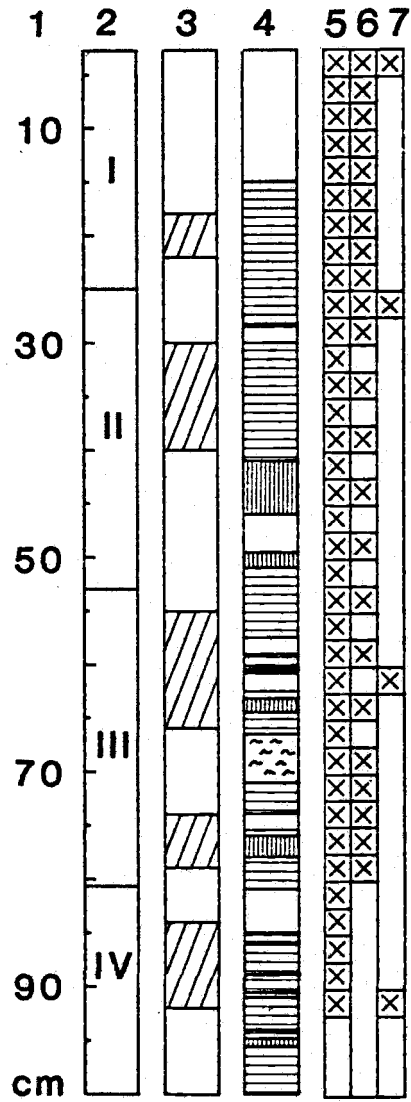


Figure 3c.

BAV79 E-9 KASTEN CORE

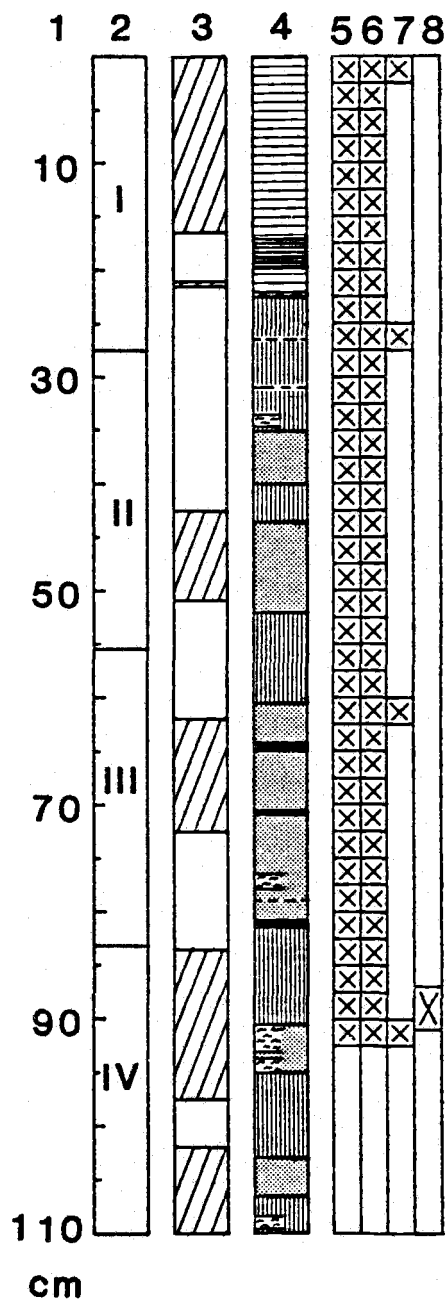
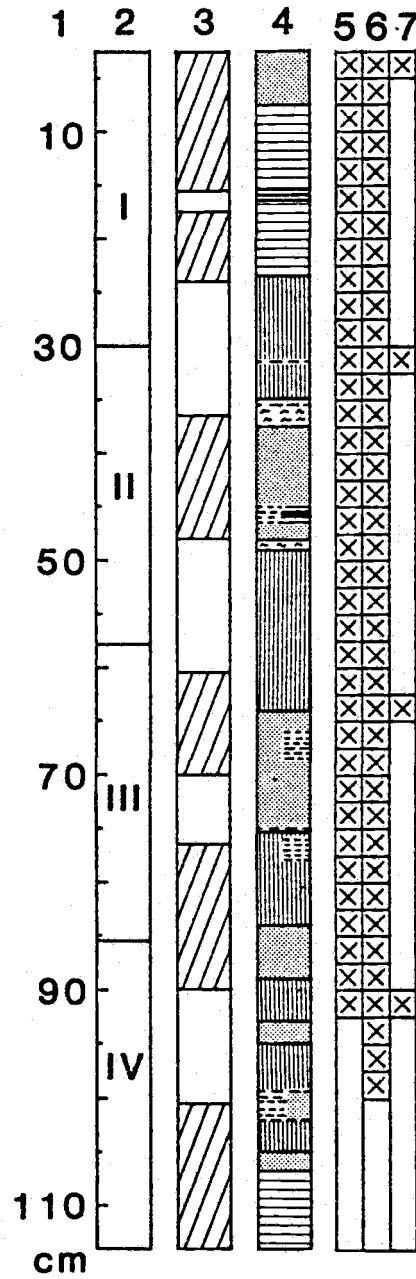


Figure 3d.

BAV79 E-10 KASTEN CORE



as detailed below.

The boxed cores were subsampled for floral analysis from the top of the recovered surface to 92.5 cm depth, using continuous 2.5 cm composite samples (Figure 2, column 5). Because of surface disturbance in boxing cores B-28 and E-10, sampling began at 2.5 cm below the recovered core surface. Core B-28 was slightly overpenetrated, and some surface material was lost from the top of all four Kasten cores in siphoning off the overstanding water after recovery.

The boxed core samples were first scraped clean to remove any contaminated material. Samples were taken by scraping about 1 cm³ wet sample from across the width of the core using the end of a standard size (2.5 x 7.6 cm) glass microscopical slide. Each sample was transferred to a plastic vial for drying. Where the sample interval spanned two adjacent boxes, the approximately 0.5 cm of sediment lost in boxing the cores is not included in the sample. All sample scrapings were taken straight across the core width, which in most cases parallels the bedding. In core E-9, beginning at 65 cm, the laminae dip at an angle of 16° at their maximum slope. This constitutes an offset, between one side of the core and the other, of about 2.5 cm or one sample interval. Each sample in E-9, between interval 65-92.5 cm, therefore contains material from its stated depth and from the sample interval directly above it. The effect on floral abundance curves is

the same as calculating a two-point running average on an unbiased data set. Curves for E-9 below 65 cm will be somewhat smoothed as compared to the portion of the curves above this point (see Figure 9c).

The samples were dried overnight in an oven at 60°C. A representative sample split was obtained by pulverizing the dried sample with a spatula to homogenize it. About 0.5 g dry sample was then weighed on a Sartorius 1106 top load balance and transferred to a 400 ml beaker. Fifteen ml H_2O_2 and 15 ml of a solution of about 300 ml distilled water to about 15 g Calgon (a dispersant) were added to the beakers. The solution was boiled until foaming stopped to disperse and remove all acid soluble and organic material, then transferred to a 50 ml plastic bottle. The clay component of the samples was removed by repeated settling and decantation, in which the vials were filled to 50 ml with distilled water (a 5.5 cm high column of water), allowed to stand for 90 minutes, and then siphoned to remove about 25 ml of overstanding water. Slides were prepared using 25 μ l or 50 μ l sample splits with Aroclor 4465 mounting medium (index of refraction = 1.67) after the methods of Schrader (1974) and Schrader and Gersonde (1978).

Analysis of samples was carried out on a Leitz-Orthoplan Orthomat microscope using plan-apochromatic oil immersion objectives. Counts were made using 1000X magnification (Objective: Pl Apo/Oil 100X/1.32; Ocular:

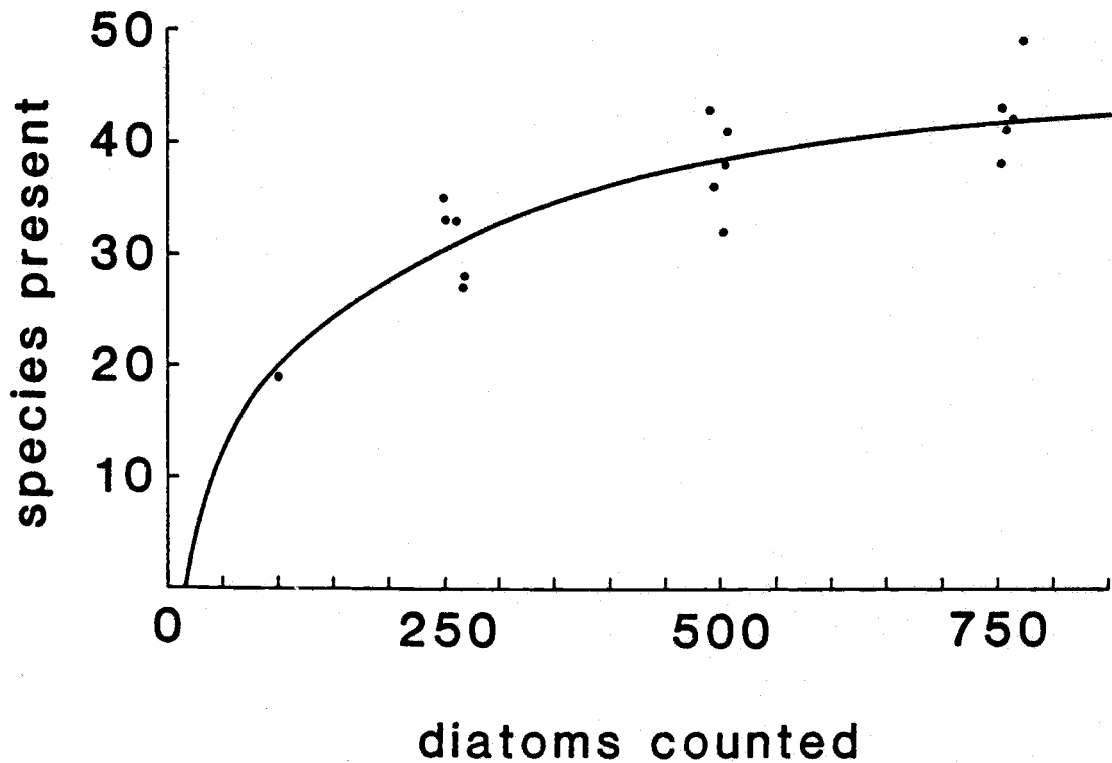
Periplan GW 10X M) with counting procedures after Schrader and Gersonde (1978). Random counts were made by beginning at the center of the slide and counting in successive traverses until approximately 500 valves were counted.

In determining the number of valves to be counted per sample, a sufficient number of diatoms must be counted to detect species present in minor amounts which may be important signals of environmental change, but also to allow completion of a count in a reasonable amount of time per sample. Counts of approximately 100, 250, 500, and 750 diatoms and Chaetoceros spores were made on a set of five slides. It was found that when 500 and 750 valves were counted, fewer than 10-12% new specimens of each species were encountered (Figure 4). On this basis, it was decided that 500 valves per slide, including Chaetoceros spores, would give a representative sample of the assemblage present.

Absolute abundance of the total diatom fraction was estimated at four depths downcore for each of the four cores (Figure 2, column 7). All diatoms present in one complete traverse across the middle of the slide (1000X power) were counted. Absolute abundance was calculated as:

$$\frac{\text{diatoms counted}}{\% \text{ area of slide counted} \times \text{g spl per slide}} = \text{abundance} \frac{\text{diatoms}}{\text{g dry sediment}}$$

Figure 4. Decrease in new species encountered with increasing number of diatoms counted. x = total number of diatom valves counted. y = number of different species identified. $y = -31.2 + 11.2 \ln x$. $r^2 = 0.78$.



Sedimentation rates were determined for all four cores based on a continuous count of the number of laminae present within the entire core length (about 2 m of sediment). Laminae counts were made by marking 5 cm intervals on a cleaned core surface and counting the number of laminae within successive increments downcore. Where sediments were disturbed or faintly laminated to homogenous, counts were extrapolated based on the width of the surrounding laminae. The entire core was counted in order to compare sedimentation rates obtained by this method to those based on ^{14}C dating for the same depth interval. Laminae counts were converted to sedimentation rates by assuming that two laminae (1 varve) represents one year of deposition (Calvert, 1964; Baumgartner et al., 1981), such that # varves/cm = # years/cm. Baumgartner et al. (1981) found that varve counts agree well with sedimentation rates based on ^{210}Pb dating in several cores from the central Gulf.

Time correlative levels between cores were determined using biostratigraphic horizons of the silicoflagellate species Dictyocha epidon, D. messanensis, D. species A+B+2, and Octactis pulchra. These horizons were established as part of a Gulf-wide biostratigraphic study by Schrader (in prep.).

Diatom taxonomy was based on an opal phytoplankton atlas compiled by Schrader and Schuette for the Gulf sediments. Ninety-six diatom species and species groups were

identified in this study. Before subjecting the data to statistical analysis, the fifty species out of ninety-six recorded having the highest percent total abundance in all 146 samples were selected. This was done to reduce errors associated with estimating the abundance of species present in trace amounts. Species eliminated by this method had a percent total abundance of less than 1% of all diatoms counted within the 146 sample data set, and generally occurred in fewer than 20%, and usually less than 10% of the samples counted. The fifty species used for analysis, with the percent abundance and percent of occurrence of each, are listed in Table 2.

A variety of statistical techniques were used to analyze the data, including cluster analysis, polar ordination, factor analysis, and grouping of species according to ecological criteria based on available literature. Since no single standard technique exists for analyzing diatom data, several methods were tested to see how the data set would respond to each type of manipulation. Results of the factor analysis and of the ecological groupings were used in the data interpretation.

Principal components and factors for the factor analysis were determined using methods described in Cooley and Lohnes (1971), and the varimax rotation was as described in Kaiser (1958). All factor analysis programs were written by P. Loubere, O.S.U. School of Oceanography, using the IMSL (1979) subroutine library. For the factor anal-

Table 2. The fifty most abundant diatom species and species groups of the ninety-six identified within the total data set, with percent total abundance for all counts together and percent occurrence over the 146 sample suite. This list was further reduced to thirty-seven species by grouping within the fifty species before factor analysis, as described in the text. Species involved in this reduction are designed by *.

Species	% total abundance	% occurrence
<u>Chaetoceros</u> spores	21	99
<u>Pseudoeunotia doliolus</u> (Wallich) Grunow	17	100
"needles"	15	100
* <u>Thalassiothrix pseudonitzschoides</u>	13	100
* <u>Cyclotella striata</u> (Kützing) Grunow	4	99
* <u>Thalassionema intergrade</u> v. <u>parva</u> (<u>T. pseudonitzschoides</u>)	3	100
* <u>Actinopterychus senarius</u> (Ehrenberg) Ehrenberg	3	99
<u>Thalassiosira oestrupii</u> (Ostenfeld) Proshkina-Lavrenko	3	99
<u>Coscinodiscus nodulifer</u> A. Schmidt	2	97
<u>Roperia tessellata</u> (Roper) Grunow	2	97
* <u>Actinopterychus splendens</u> (Shadbolt) Ralfs	1	97
* <u>Cyclotella stylorum</u> Brightwell	1	98
<u>Coscinodiscus radiatus</u> Ehrenberg	1	97
<u>Thalassiosira lineata</u> Jousé	1	93
* <u>Actinocyclus curvatulus</u> Janisch	1	96
* <u>Thalassiosira eccentrica</u> (Ehrenberg) Cleve	1	91

Table 2 (continued)

Species	% total abundance	% occurrence
<u>Thalassionema nitzschioides</u> v. <u>parva</u> Heiden	1	86
<u>Bacteriastrum</u> several species	1	91
<u>Rhizosolenia alata</u> Brightwell	1	92
* <u>Thalassiosira symmetrica</u> Fryxell et Hasle	1	84
* <u>Thalassiosira leptopus</u> (Grunow) Fryxell et Hasle	1	87
* <u>Planktoniella sol</u> (Wallich) Schütt	1	71
<u>Rhizosolenia styliiformis</u> Brightwell	1	75
<u>Rhizosolenia calcar-avis</u> M. Schultze	<1	84
<u>Rhizosolenia bergonii</u> H. Peragallo	<1	88
* <u>Thalassiosira punctifera</u> (Grunow) Fryxell	<1	71
<u>Thalassiothrix longissima</u> Cleve et Grunow	<1	57
<u>Skeletonema costatum</u> (Greville) Cleve	<1	43
<u>Thalassiosira simonsenii</u> Hasle et Fryxell	<1	60
<u>Thalassiothrix mediterranea</u> Pavillard	<1	58
<u>Nitzschia bicapitata</u> Cleve	<1	56
<u>Thalassiosira spinosa</u> Simonsen	<1	45
<u>Asteromphalus flabellatus</u> (Brebisson) Greville	<1	52
* <u>Thalassiosira pacifica</u> Hasle	<1	41

Table 2 (continued)

Species	% total abundance	% occurrence
<u>Coscinodiscus perforatus</u> Ehrenberg	<1	43
* <u>Coscinodiscus curvatulus</u> Grunow	<1	41
<u>Hemidiscus cuneiformis</u> Wallich	<1	45
<u>Actinocyclus octonarius</u> Ehrenberg	<1	38
* <u>Thalassionema nitzschioides</u> Grunow	<1	29
<u>Asteromphalus arachne</u> (Brebisson) Ralfs	<1	36
<u>Stephanopyxis turris</u> (Grev. et Arn.) Ralfs	<1	24
<u>Lithodesmium</u> spp.	<1	33
<u>Asteromphalus heptactis</u> (Brebisson) Ralfs	<1	24
<u>Paralia sulcata</u> (Ehrenberg) Cleve	<1	34
* <u>Thalassiosira leptopus</u> v. 1	<1	25
<u>Synedra indica</u> Taylor	< 1	23
* <u>Thalassiosira</u> sp. 6	<1	16
<u>Coscinodiscus stellaris</u> Roper	<1	19
<u>Coscinodiscus asteromphalus</u> Ehrenberg	<1	27
<u>Diploneis smithii</u> (Brebisson) Cleve	<1	17

ysis, some species within the fifty most abundant ones were combined into a single group. The groupings, and the reasons for them follow:

Actinocyclus curvatulus and Coscinodiscus curvatulus - a

number of individuals were encountered in which the pseudonodulus of A. curvatulus was present but difficult to distinguish, and it was felt that all occurrences of A. curvatulus were not detected in counting. These two species were therefore combined into a single category for factor analysis.

Small Thalassiosira - the groups Thalassiosira sp. 4 and Thalassiosira sp. 6 (Plate II) came to be used during counting as general categories for small centrals which were obviously not Thalassiosira oestrupii, and were subsequently combined into one category. Cluster analysis and ordination techniques on the diatom abundance data indicate that this group is behaving in some distinctive fashion within the cores. It is felt that its occurrence may be related to that of the other small Thalassiosira species, T. oestrupii v. parva and small frustules of T. oestrupii. Combining these four groups into a single category in subsequent studies might establish a defineable trend within the data set for this group.

Thalassiosira eccentrica group - this group includes the species Thalassiosira eccentrica, T. symmetrica, T. punctifera, T. sp. (pacificae? Hasle), and Plank-

toniella sol. Again, this represents a case where, although distinctions were made during the course of counting, it is not felt that consistently correct identifications were made. These species were grouped together.

Thalassiosira lineata, Thalassiosira leptopus, and Thalassiosira simonsenii - these were maintained as separate categories since it was felt that they were consistently distinguished in counting. However, Thalassiosira sp. 5 (Plate I) was included in the T. simonsenii category, since it was sometimes difficult to distinguish these two species.

Cyclotella striata/stylorum and Actinopterychus senarius/splendens - these groups were distinguishable during counting, but are felt to represent similar ecological responses, and were therefore grouped for factor analysis.

"needles" - a study subsequent to this work by Schuette and Schrader (in press) has resulted in a redefinition of the Thalassionema intergrade and Thalassionema intergrade parva categories as the single newly described species Thalassiothrix pseudonitzschoides. T. nitzschoides and T. pseudonitzschoides appear to have a similar ecological distribution, so these categories, plus the category of unidentified Thalassionema and Thalassiothrix end fragments, were combined. Thalassionema nitzschoides

var. parva, Thalassiothrix longissima, and Thalassiothrix mediterranea were retained as separate categories.

The literature references used in determining the ecological groupings are given in Table 3, and the resultant ecological groups are listed in Table 4. Appendix II summarizes the ecological data from all sources for each diatom species.

The distributions of the three most abundant diatom species or groups, Chaetoceros spores, Pseudoeunotia doliolus, and the "needles" group, are represented by Factors 1 and 2 of the factor analysis (see Results and Discussion). The ecological groups were derived in an attempt to further characterize changes in Gulf conditions delineated by the three major species or groups as defined by these two factors. The ecological groups combine the abundances of some of the minor species in order to emphasize the effect of those species defined as indicative of similar environmental conditions. The abundance of each ecological group is the summation of the relative percent abundances of its component species with respect to the total diatom count for each sample, and its occurrence is expressed as the percent abundance of that group within each sample downcore.

Table 3. Literature sources for ecological groupings of diatom species.

Belyaeva (1970, 1971, 1972)

Cupp (1943)

Desrosieres (1969)

DeVries and Schrader (1981)

Fryxell and Hasle (1972, 1980)

Gersonde (1980)

Guillard and Kilham (1977)

Hasle (1959)

Hasle and Fryxell (1977)

Jousé et al. (1971)

Kanaya and Koizumi (1966)

Kolbe (1954)

Kozlova and Muhina (1967)

Muhina (1971)

Pavillard (1935)

Rampi (1952)

Russian studies (Semina, 1958; Jousé, 1962, 1963; Jousé et al., 1962) as summarized in Kanaya and Koizumi (1966)

Sancetta (1979)

Schuette and Schrader (1979, 1981)

Smayda (1963, 1966)

Venrick (1971)

Table 4. Diatom groupings based on a summary of available ecological information. Analysis was performed omitting the highly abundant Chaetoceros spores, "needles" group, and Pseudoeunotia doliolus (indicated by *) from their groups before calculating abundances.

COLD

Actinocyclus curvatulus
Coscinodiscus curvatulus
C. marginatus
C. tabularis
Thalassiothrix longissima

WARM

Asteromphalus flabellatus
Biddulphia dubia
B. longicruris
Coscinodiscus nodulifer
Nitzschia interruptestriata
N. marina
Planktoniella sol
Rhizosolenia bergonii
Roperia tessellata
Thalassionema nitzschioides
 var. parva
Thalassiosira lineata

"UPWELLING"

Skeletonema costatum
 *Chaetoceros spores

OCEANIC

Actinocyclus curvatulus
Asteromphalus arachne
A. heptactis
Coscinodiscus nodulifer
C. marginatus
C. tabularis
Hemidiscus cuneiformis
Nitzschia marina
Rhizosolenia bergonii
R. calcar-avis
R. styliiformis
Thalassionema nitzschioides
 var. parva
Thalassiosira oestrupii
 *Pseudoeunotia doliolus

MEROPLANKTIC/NERITIC

Actinocyclus octonarius
Actinoptychus splendens
A. senarius
Biddulphia dubia
B. longicruris
B. rhombus

Table 4 (continued)

MEROPLANKTIC/NERITICCoscinodiscus curvatulusC. graniiC. perforatusCyclotella striataC. stylorumHemiaulus longicornisLithodesmium undulatumParalia sulcataThalassiosira eccentrica group* Thalassionema nitzschioidesTEMPERATEBiddulphia rhombusCoscinodiscus stellarisC. symbolophorusThalassiothrix mediterraneaBENTHICSBiddulphia regiaDiploneis smithiiTrachyneis aspera

RESULTS AND DISCUSSION

Diatom Preservation and Abundances

Diatom assemblages in the upper 92.5 cm of all four cores are well preserved. Delicate and weakly silicified species are present in the sediments, such as Nitzschia sicula, Synedra indica, Chaetoceros vegetative cells, and Rhizosolenia spp. valves. These forms are similar in morphological characteristics or degree of silicification to Skeletonema costatum, Hemiaulus hauckii, Hemiaulis sinensis, a.o. species also found in the Gulf which have been previously defined as indicative of well-preserved assemblages (Schrader, 1971; Schrader and Matherne, 1981; Schuette and Schrader, 1981). Semi-quantitative estimates of total diatom abundance (valves plus spores) at four levels in each core show little fluctuation in diatom abundances downcore. Valves range from 10^7 - 10^8 diatoms/g dry sediment (Table 5) with Area E averaging slightly higher values than Area B.

Sedimentation Rates

Varve counts per 5 cm intervals for the four Kasten cores and associated sedimentation rates are given in Table 6. Table 7 gives ^{14}C age determinations and calculated sedimentation rates for cores B-29 and E-9. Based on varve chronology, B-29 has an average sedimentation rate of .26 cm/yr and ranges .17-.36 cm/yr. B-28 averages .24 cm/yr and ranges .15-.33 cm/yr. In Area E, E-9 aver-

Table 5. Total diatom abundance, including Chaetoceros spores, at four depths within Kasten cores E-9, E-10, B-29, and B-28. Semi-quantitative estimates of abundance are based on a count of total diatoms (valves plus spores) within one complete traverse across the middle of the slide at 1000X power. The abundance was calculated as: (#diatoms/traverse)/((g spl/slide) X (.024 percent of slide covered per traverse)).

Cores	Depth (cm)	Diatoms/Traverse	g spl/traverse (dry weight)	abundance (diatoms/g dry sediment)
E-9	0- 2.5	512	1.1×10^{-5}	4.6×10^7
	25.0-27.5	500	1.4×10^{-5}	3.6×10^7
	60.0-62.5	562	7.2×10^{-6}	7.8×10^7
	90.0-92.5	555	6.1×10^{-6}	9.1×10^7
E-10	2.5- 5.0	350	8.2×10^{-7}	4.3×10^8
	30.0-32.5	364	5.3×10^{-7}	6.9×10^8
	62.5-65.0	250	5.3×10^{-7}	1.3×10^8
	90.0-92.5	195	4.3×10^{-7}	4.5×10^8
B-29	0.0- 2.5	227	1.1×10^{-5}	2.1×10^7
	30.0-32.5	307	1.9×10^{-5}	1.6×10^8
	60.0-62.5	362	5.3×10^{-7}	6.8×10^7
	90.0-92.5	562	1.3×10^{-5}	4.3×10^7
B-28	2.5- 5.0	150	1.0×10^{-5}	1.5×10^7
	30.0-32.5	217	1.0×10^{-5}	2.2×10^7
	60.0-62.5	415	1.0×10^{-5}	4.2×10^7
	90.0-92.5	336	1.0×10^{-5}	3.4×10^7

Table 6. Sedimentation rates for cores B-29, B-28, E-9, and E-10. Rates, in terms of cm/yr, are calculated based on number of varves per 5 cm interval over the entire core length. Sedimentation rates were smoothed using a 3-point running average to eliminate small scale variability.

Depth (cm)	B-29		B-28		E-9		E-10	
	# varves	sed.rate (cm/yr)	# varves	sed.rate (cm/yr)	#varves	sed.rate (cm/yr)	# varves	sed.rate (cm/yr)
0- 5	14						16	
5- 10	18	.33	18		16		19	.27
10- 15	13.5	.35	15.5	.29	15	.33	19	.28
15- 20	11	.38	17.5	.29	14.5	.34	15	.31
20- 25	15	.36	18	.27	14	.36	15	.30
25- 30	15.5	.33	19.5	.27	13.5	.32	20	.27
30- 35	15	.31	18	.29	20	.28	20	.24
35- 40	18.5	.29	14	.29	20	.26	23.5	.25
40- 45	18.5	.30	19.5	.32	17	.29	16	.27
45- 50	13.5	.32	13.5	.30	15.5	.28	16.5	.29
50- 55	15	.33	17	.31	20.5	.27	19.5	.25
55- 60	16.5	.33	18	.29	20.5	.27	25	.23
60- 65	14.5	.34	16	.29	15.5	.31	22	.22
65- 70	13.5	.30	18	.32	12.5	.38	21.5	.25
70- 75	22	.24	13	.33	11.5	.35	17.5	.24
75- 80	27	.22	15	.25	19	.31	24	.23
80- 85	19.5	.21	33	.18	18	.24	25	.21
85- 90	24	.23	37.5	.15	26.5	.23	23	.22
90- 95	20.5	.26	32.5	.14	20.5	.20	21.5	.21
95-100	12.5	.25	34	.15	27	.21	27	.20
100-105	27	.25	31.5	.16	24	.18	25.5	.18
105-110	21	.21	26.5	.19	32	.20	29	.19
110-115	24	.21	21.5	.22	18	.28	25	.20
115-120	25.5	.19	20.5	.25	34.5	.18	21.5	.23

Table 6. (continued)

Depth (cm)	B-29		B-28		E-9		E-10	
	# varves	sed.rate (cm/yr)	# varves	sed.rate (cm/yr)	#varves	sed.rate (cm/yr)	#varves	sed.rate (cm/yr)
120-125	30	.19	17	.29	31	.17	17.5	.25
125-130	25.5	.19	15	.26	20.5	.24	20	.23
130-135	25	.18	26.5	.24	10.5	.28	27.5	.21
135-140	33	.17	20.5	.21	23.5	.26	24.5	.20
140-145	28.5	.17	25	.23	23	.21	23	.19
145-150	29	.20	19	.23	25	.21	31	.19
150-155	16	.24	22.5	.21	23	.21	26.5	.18
155-160	16.5	.30	30.5	.20	25	.22	24.5	.20
160-165	17.5	.29	22.5	.20	21	.23	24	.20
165-170	17.5	.27	23.5	.22	20	.24	27	.21
170-175	21.5	.25	23.5	.21	22	.23	21.5	.19
175-180	20.5	.26	25	.19	22	.20	31	.21
180-185	16.5	.30	30.5		32	.19	20.5	.20
185-190	12.5				23.5	.19	24.5	.21
190-195					25.5		26.5	
Average rate (cm/yr)	.26		.24		.24		.23	
Range (cm/yr)	.17- .36		.15 - .33		.17 - .38		.18 - .33	

Table 7. ^{14}C age determinations and calculated sedimentation rates for cores B-29 and E-9. Age determinations by M. Stuiver.

Core	Depths (cm)	age (years)	^{14}C sedimentation rate (cm/yr)
B-29	20-30	960 ± 70	.20
	185-197	1800 ± 80	
E-9	15-25	950 ± 80	.14
	30-45	1000 ± 80	
	110-125	1680 ± 90	
	180-190	2100 ± 80	

ages .24 cm/yr, with a .17-.38 cm/yr range, and E-10 averages .23 cm/yr, with a .18-.33 cm/yr range. The ^{14}C based sedimentation rate is comparable to that derived from varve chronology in B-29 (.20 cm/yr), but yielded a much lower rate for core E-9 (.14 cm/yr).

Table 8 compares sedimentation rates based on ^{14}C , ^{210}Pb , and varve thickness by several investigators in the Gulf of California. Location of these cores is shown in Figure 1. Much variation exists in determination by different methods, although agreement between two methods for the same core exists in some cases.

Errors in the varve chronology arise from the over or underestimation of varves represented by faintly laminated or homogenous intervals, the interpretation of subseasonal laminae as varves in finely laminated intervals or loss of portions of the sediment column due to episodes of erosion. Recounts of laminae for purposes of testing the repeatability of this method over various intervals showed differences of 0-20% in number of laminae counted, depending on the clarity of laminae definition in that area. However, independent counts of E-10 by two investigators differed by less than 2% when averaged over the entire 195 cm of core length.

Differences between ^{14}C derived sedimentation rates and those based on varve thickness are due to several factors. In ^{14}C dating, the experimental error for individual sample ages is on the order of ± 80 years and each sam-

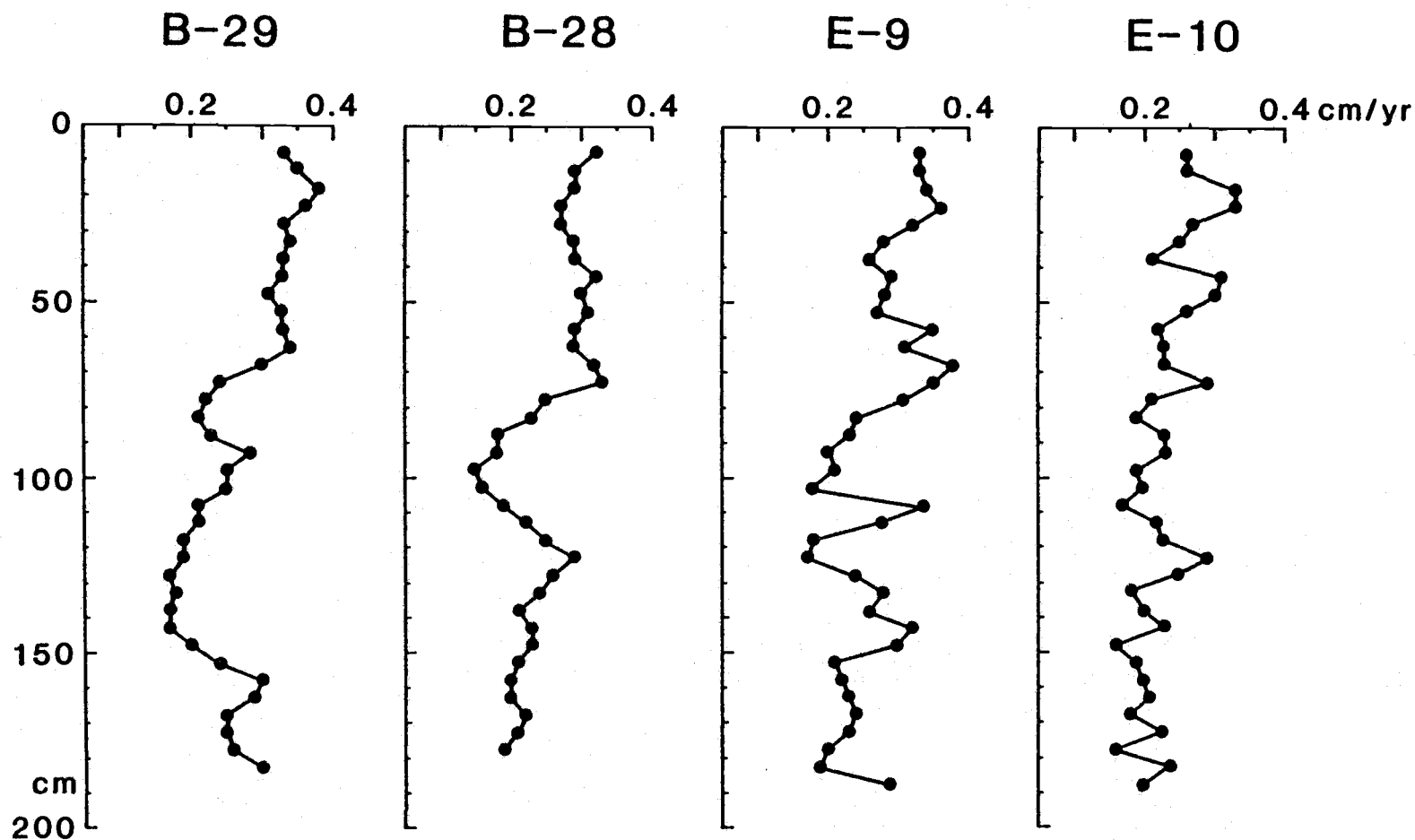
Table 8. Comparison of sedimentation rates determined by ^{14}C , ^{210}Pb , and varve thickness methods on laminated cores from the Gulf of California. Location of cores in the Gulf is shown in Figure 1. ^{14}C dating for B-29 and E-9 by M. Stuiver, University of Washington, and for E-17 by S. Robinson, USGS, Menlo Park, California.

Core	Location	latitude	longitude	depth (m)	sedimentation rate (cm/yr)			source
					^{14}C	^{210}Pb	varve thickness	
B-29	Guaymas Basin	26°42'N	111°25.0'W	635	.20		.26	BAV-79
E-9	Guaymas Basin	27°53.2'N	111°37.2'W	660	.14		.24	BAV-79
E-17	Guaymas Basin	27°55.2'N	111°36.6'W	670	.13		.24	BAM-80 (Murray, 1982)
87	Carmen Basin	26°28.3'N	110° 0.0'W	527	.07	.20	.20	DeMaster (1979)
83	San Pedro Martir Basin	28°14.7'N	112°21.0'W	975	1.0	1.1	1.1	DeMaster (1979)
L-173	San Pedro Martir Basin	28°16.0'N	112°26.7'W	906	.54		.56	Calvert (1966b)
L-178	Guaymas Basin	28°12.0'N	112°19.0'W	849	.42		.34	Calvert (1966b)
L-181	Guaymas Basin	28°6.0'N	112° 8.0'W	787	.47		.25	Calvert (1966b)

ple is a 10-15 cm composite, giving a range of possible ages over a depth interval. Water loss and sediment compaction cause an apparent decrease in the average sedimentation rate with depth downcore. For example, over the upper 95 cm of sediment, the interval used for diatom assemblage analysis, average sedimentation rates based on varve thickness are .30 cm/yr for B-29, .27 cm/yr for B-28, .30 cm/yr for E-9, and .25 cm/yr for E-10, somewhat higher values than are obtained by averaging values over the entire core length. In addition, ^{14}C derived sedimentation rates are based on the assumption of constant sedimentation rates over the time interval in question. Based on varve chronologies (Figure 5), these rates have varied by up to a factor of two within the last 700-800 years and have fluctuated within this range over time. In the San Pedro Martir Basin, ^{14}C and varve thickness methods gave comparable sedimentation rates for cores 83 (DeMaster, 1979) and L-173 (Calvert, 1966b) (Figure 1). The San Pedro Martir Basin is an area of continual turbulence due to tidal mixing. As a result, sedimentation rates may be more constant here than elsewhere in the Gulf where seasonal wind patterns exert a stronger control on mixing, eliminating some of the variability between sedimentation rates calculated using ^{14}C and varve thickness methods.

Sedimentation rates based on ^{210}Pb dates agree with rates based on varve thickness in cores from the Carmen and San Pedro Martir Basins (DeMaster, 1979) and the

Figure 5. Variation in sedimentation rates with depth for cores B-29, B-28, E-9, and E-10. Rates (cm/yr) were calculated based on number of varves per 5 cm interval. Curves were smoothed using a 3-point running average to reduce small scale variability.



Guaymas Basin (Baumgartner et al., 1981). Because of its shorter half life, ^{210}Pb is a more accurate method of isotopic dating than ^{14}C (Faure, 1977). Varve thickness for these box cores was measured over approximately the upper 100 cm of sediment, where less compaction would be present than in the longer sediment intervals measured using ^{14}C . For these reasons, ^{210}Pb and varve chronology methods give equivalent sedimentation rates for these cores.

Dating of Sediments

Precise dating of a given downcore depth using ^{14}C is problematic in the Gulf of California for several reasons. In addition to the experimental error inherent in this method and the composite sample necessary for each age determination, error is attributed to the presence of upwelling in the waters of the Gulf. Surface sediment ^{14}C anomalies under upwelling areas have been reported for a number of locations (Berger et al., 1966; Taylor and Berger, 1967). Oceanic deep waters, which have been isolated from the atmosphere for up to 1000 years, have low $^{14}\text{C}/^{12}\text{C}$ ratios relative to atmospheric levels. When these waters are upwelled to the surface, they begin to equilibrate with atmospheric CO_2 . The $^{14}\text{C}/^{12}\text{C}$ ratio of the resulting surface water varies between the initial low value of the upwelled deep water and the relatively high atmospheric levels depending upon the intensity of upwelling

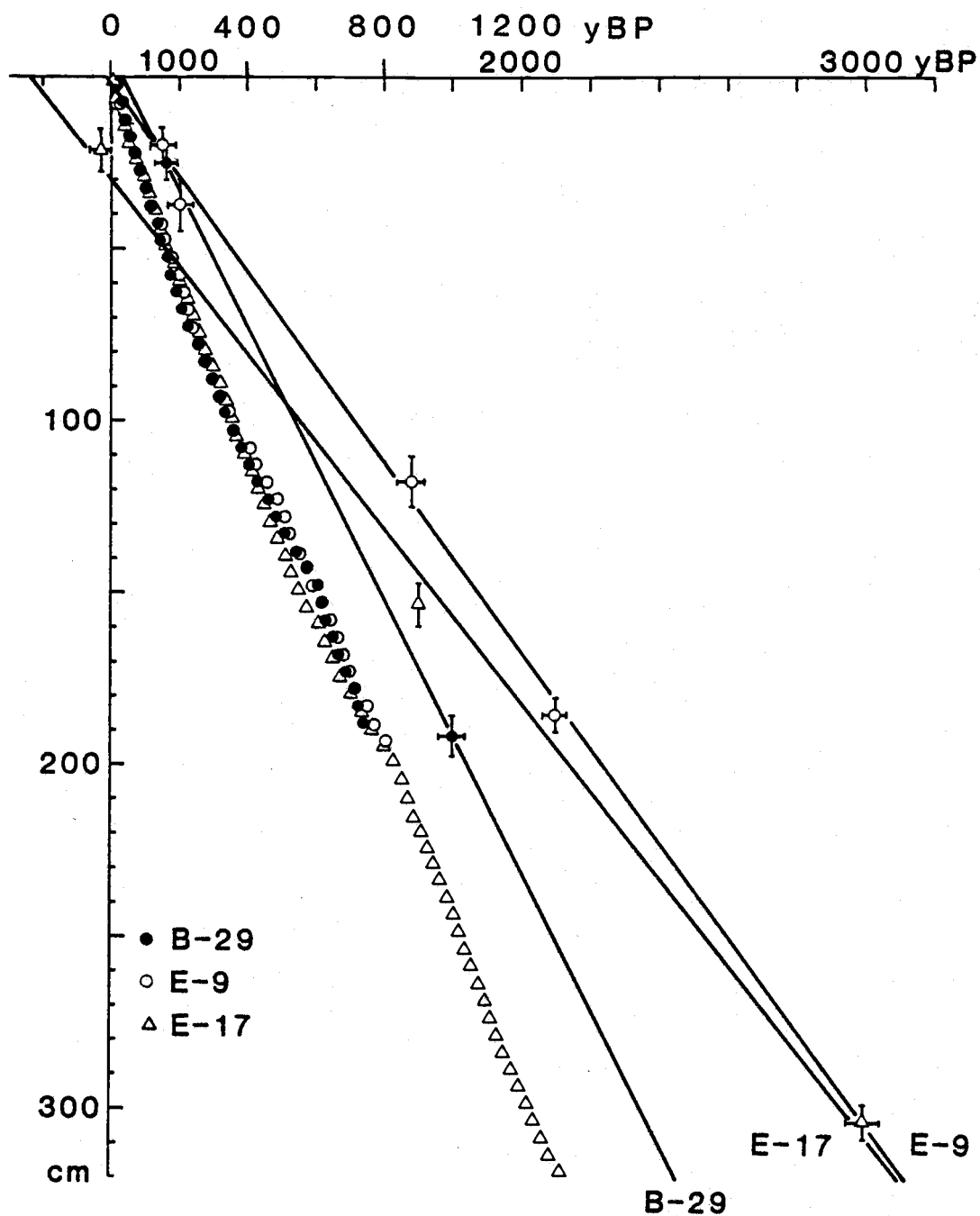
and the rate of equilibration with atmospheric CO_2 . This surface water $^{14}\text{C}/^{12}\text{C}$ is incorporated by the plankton, and their organic or calcareous remains imprint this ratio on the sediments below. Surface age anomalies in Gulf sediments are, therefore, a direct function of upwelling intensity and air-sea equilibration times relative to the rate of incorporation by the associated plankton

(DeMaster, 1979). However, to establish absolute age with depth based on ^{14}C derived sedimentation rates, it must be assumed that the surface ^{14}C anomaly remained constant, and that the apparent surface age did not fluctuate over time. DeMaster (1979) suggests that this may not be a valid assumption for the Carmen Basin, and postulates that variations in surface age anomalies may account for the difference between ^{14}C derived sedimentation rates and those based on ^{210}Pb and varve thickness in core 87 from that area. In the Guaymas Basin, downcore variation in levels of primary productivity, as reflected by fluctuations in abundance of the upwelling indicative Chaetoceros group (Figure 9 - Productivity Factor), indicate that upwelling intensity in this area has not remained constant over time. Surface age anomalies must also have varied, causing ^{14}C derived sedimentation rates and those based on varve thickness to differ.

The relationships of absolute age to depth based on cumulative varve counts and on ^{14}C ages are compared in Figure 6. Varve chronologies assume that sediment surface

Figure 6. Absolute age with depth based on cumulative varve counts and on ^{14}C dating. Varve chronologies, represented by triangles and circles, assume that the core surface represents zero years BP. The chronology for E-17 is from data by Murray(1982). Solid lines represent ^{14}C age versus depth. Error bars are given for each data point. The youngest age for each line is the sediment surface anomaly for that core. Data for cores B-29 and E-9 is by M. Stuiver and for core E-17 is by S. Robinson. Upper scale (yBP) refers to varve chronologies; lower scale refers to ^{14}C derived chronologies.

Figure 6.

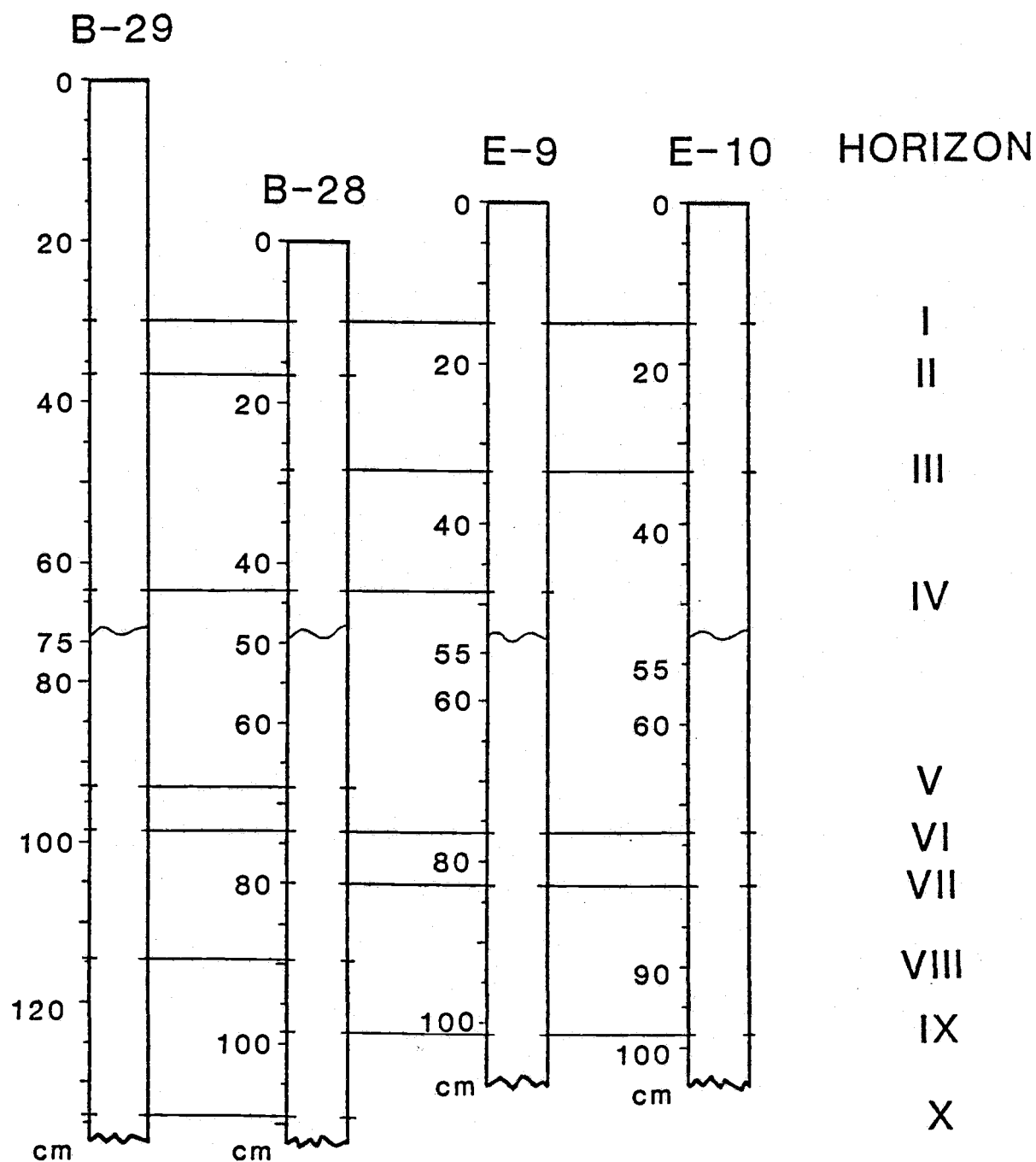


age equals zero. The earliest age for each ^{14}C chronology is the sediment surface age for that core. Berger et al. (1966) reported anomalies of 615 and 620 years, uncorrected for ^{13}C , for two Gulf locations based on analysis of a clam and a snail shell. DeMaster (1979) sampled both the surface of a laminated box core from the Carmen Basin and phytoplankton from the overlying water column, and reported a ^{14}C surface anomaly of 800 years for both samples. The extrapolated surface anomaly for B-29 is 830 years and for E-9 is 780 years. Although ^{14}C rates and ages are a reasonable estimate for areas with much lower sedimentation rates than the Gulf of California and for cores covering thousands of years, the error inherent in this method becomes significant over the geologically short time spans considered here. The varve chronologies are felt to give a better estimate of age with depth for laminated sediments from the Gulf of California than can be obtained using ^{14}C .

Intercore Correlations

Correlations among the four Kasten cores are shown in Figure 7. Core depths are adjusted so that horizontal lines represent time equivalent horizons between cores. All data were generated and made available by Schrader. The silicoflagellates Dictyocha epiodon, D. messanensis, and the group D. species A+B+2 (Plate I, Figures 1-3) were used for this purpose. A Gulf-wide biostratigraphic

Figure 7. Intercore correlations among Kasten cores B-29, B-28, E-9, and E-10 based on biostratigraphic horizons of the silicoflagellates Dictyocha epidon, Dictyocha messanensis, and the group Dictyocha species A + B + 2. (based on data from a paper by Schrader, in preparation).

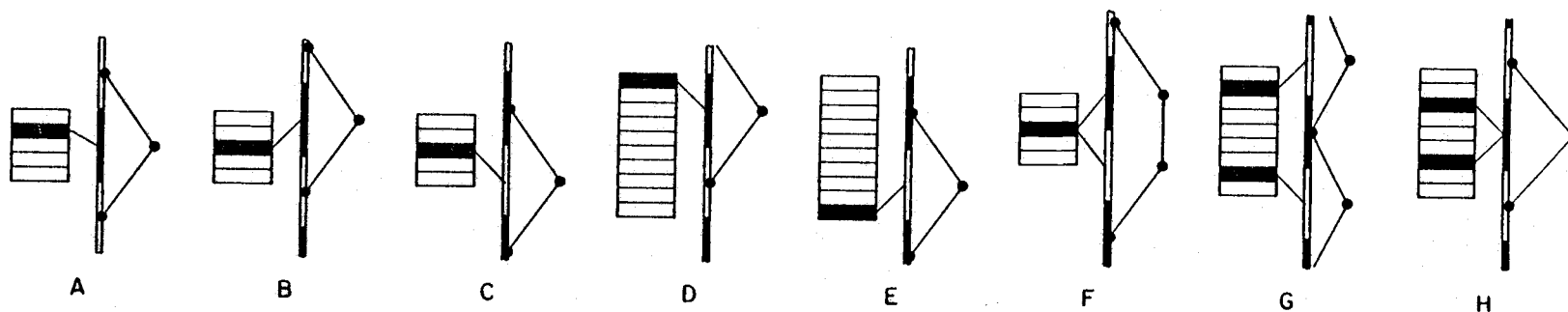


study by Schrader (in preparation) has shown these horizons to be time correlative throughout the Gulf.

Based on an expansion of the D. epiodon horizon in the top of B-29, it appears that the upper portion of this core was "smeared out" during the subsampling process, so that the upper soupy sediments extend beyond their original length. The surface of core B-28 was lost due to overpenetration during coring. The tops of these cores do not, therefore, represent time equivalent horizons, and correlations are drawn as in Figure 7. The downcore lithologies of the two cores support such an adjustment. In E-9 and E-10, equivalent horizons occur at equal depths downcore.

In establishing biostratigraphic horizons and in discussing variation in abundance of diatom groups based on an analysis of composite samples, it should be noted that variability exists in the apparent downcore position of peaks of abundance. This is due both to inaccuracy in the sampling methods and to the fact that events occurring at any level within the 2.5 cm composite sample are represented by a single point at the midpoint of the sample interval (Figure 8A). An event occurring within a single season (one lamina) could have occurred at any point within an approximately 5-19 year time interval, based on sedimentation rates of 2-7.5 varves per cm (see Sedimentation Rates). By extension, a difference of one sample interval in depth of occurrence of an event could be due

Figure 8. Schematic diagram illustrating variability in peaks of abundance depending upon positioning of the sample interval. Five laminae represent a 2.5 cm interval. Dark and light bars denote positioning of sample intervals with respect to laminae group. Resulting curve is drawn by plotting points at center of each 2.5 cm interval.



merely to sampling error (Figure 8B-C) or could represent a difference in lamina position of up to 5 cm, a 10-38 year time difference (Figure 8D-E). If the lamina or laminae responsible for a peak occurred at the boundary between two sample intervals, the peak could occur in either or both of the associated samples (compare Figure 8B-C and Figure 8F). If present in both samples, the resulting peak would be broader, as if occurring over a longer time interval instead of as an instantaneous event. The ability to resolve individual events is also dependent on sample spacing. Two separate lamina spaced slightly closer together would be combined into a single peak of occurrence, instead of appearing as two peaks if the lamina were more than 2.5 cm apart (Figure 8G-H).

The preceding discussion illustrates the limits on the accuracy with which an event within a single core can be dated using the sampling strategy of this study combined with varve chronology. It also illustrates the offset possible between the level of occurrence of peaks in two cores which correspond to laminae determined by biostratigraphic methods to be at time correlative depths. For example, compare Figure 8 and Figure 9, E-9 and E-10, at the following levels: Figure 8B and 8C, and E-9 (55-57.5 cm) and E-10 (57.5-60 cm) - warm group; Figure 8B and 8F, and E-9 (55-60 cm) and E-10 (55-57.5 cm) - productivity factor; Figure 8F-G and E-9 (17.5-20 cm) and E-10 (15-17.5 cm and 20-22.5 cm) - cold group. In general,

correlations based on this sampling method have a time accuracy of $\pm 5-19$ years (one sample interval), depending on laminae thickness over the interval in question.

Analyses of Diatom Assemblage Data

Counts of diatom species for the 146 sample data set, in terms of absolute numbers counted, are included as Appendix I.

Of the techniques used to analyze the data, factor analysis and ecological groupings derived from literature sources provided the best means for data interpretation. In order to examine changes in a set of variables over time, it is most useful to have a statistical technique which gives some measure of the degree to which a variable changes or is represented with depth downcore. While polar ordination and cluster analysis define endmember sets for the data base, with factor analysis one can define the degree to which a given factor is represented in the assemblage over time. The ecological groupings are similarly plotted as fluctuations in abundance with depth downcore. The usefulness of the later method is constrained in that the establishment of the limiting ranges of species is influenced by sampling bias, i.e. areas where collections have been made, as well as by the species' actual distributions. Undoubtedly, the ranges of some species will be expanded as more work is done. However, these groups are based on a large enough series of studies so that the

groupings are felt to be representative of the ranges indicated.

The thirty-seven most abundant species or species groups, as defined previously, were analyzed using R-mode factor analysis, which defines interrelations in a matrix of correlations between variables. Use of the variance-covariance matrix, which emphasizes the effect of the more abundant species, resolved two factors accounting for 84% of the variance in the data set. While indicating several well-defined trends, each factor was highly correlated with only one or two species. This indicates that diatom species within the samples are not grouping together into well-defined associations, but are varying in a primarily independent fashion.

The factor structure matrix for Factors 1 and 2 is shown in Table 9. Factor 1, which accounts for 56% of the data variance, is highly positively correlated to Chaetoceros spores (.9858) and negatively correlated to Pseudoenotia doliolus (-.7387), indicating that the two species are varying in an inverse fashion. Curves of Factor 1 factor loadings with depth are virtually identical to plots of relative percent abundance of Chaetoceros spores with depth. P. doliolus relative percent abundances vary inversely to those of Chaetoceros spores in almost all cases.

Chaetoceros is reported as a neritic species associated with high productivity, primarily upwelling areas (Smayda, 1963, 1966; Desrosieres, 1969; Sancetta, 1979;

Table 9. Factor structure matrix for the first four factors. The analysis was run using the variance-covariance matrix. Factors 1-2 account for 84% of the data variance.

Species	Factor	
	1	2
<u>Actinocyclus curvatulus/</u> <u>Coscinodiscus curvatulus</u> group	-.1411	-.0632
<u>Chaetoceros</u> spores	.9858	-.0975
<u>Thalassiosira eccentrica</u> group	-.2918	-.1737
<u>T. oestrupii</u>	-.0369	.1389
<u>T. lineata</u>	.0152	-.0250
<u>T. leptopus</u>	-.0158	-.3284
<u>Coscinodiscus nodulifer</u>	.4564	.3121
<u>C. marginatus</u>	.0019	.0817
<u>C. radiatus</u>	-.1133	-.2078
<u>Roperia tessellata</u>	-.1462	-.0846
<u>Bacteriastrum</u> spp.	.0131	.2078
<u>Skeletonema costatum</u>	.3967	-.0430
<u>Nitzschia bicapitata</u>	.2100	.1128
<u>Actinoptychus senarius/splendens</u>	-.0790	-.1890
<u>Rhizosolenia alata</u>	.2115	.1152
<u>R. bergonii</u>	.0768	.0910
<u>R. stylorum</u>	-.0080	.0905
<u>R. calcar-avis</u>	.2680	.0043
<u>Cyclotella striata/stylorum</u>	-.4270	-.0070
<u>Thalassiothrix longissima</u>	.1182	.2379
<u>T. mediterranea</u>	.1742	.2470
<u>Pseudoeunotia doliolus</u>	-.7387	-.6037
"needles" group	-.3082	.9284
<u>Thalassionema nitzschioides</u> var. <u>parva</u>	.0621	.1231
<u>Actinocyclus octonarius</u>	-.0754	-.0146
<u>Asteromphalus arachne</u>	.0529	-.2059
<u>A. flabellatus</u>	.0919	-.0128
<u>A. heptactis</u>	-.1497	-.1769

Table 9. (continued)

Species	Factor	
	1	2
<u>Coscinodiscus</u> <u>asteromphalus</u>	.1052	-.0159
<u>C.</u> <u>perforatus</u>	.0169	-.0651
<u>Hemidiscus</u> <u>cuneiformis</u>	-.0560	-.1154
<u>Lithodesmium</u> spp.	-.1215	-.0212
<u>Paralia</u> <u>sulcata</u>	-.0247	-.1056
<u>Stephanopyxis</u> <u>turris</u>	.0877	-.1980
<u>Thalassiosira</u> <u>simonsenii</u>	-.0277	.0148
<u>T.</u> <u>spinosa</u>	-.0170	-.0389
<u>T.</u> "small" group	-.0828	-.1989

Schuette and Schrader, 1979, 1981). Sancetta (1979) found Chaetoceros spores to be indicative of cold, high primary productivity waters. Schuette and Schrader (1981) reported highest concentrations of Chaetoceros spores associated with nutrient depleted conditions on the outer edges of an area characterized by cold, newly upwelled water. Pseudo-eunotia doliolus, on the other hand, is an oceanic species with occurrences reported in equatorial to subarctic waters (Kolbe, 1954; Hasle, 1959; Venrick, 1971; Jousé et al., 1971; Sancetta, 1979; among others). Positive loadings of Factor 1 are interpreted as indicating pulses of productivity, perhaps associated with especially high levels of surface nutrients due to more favorable upwelling or mixing conditions, or to a higher input of nutrients to these waters. Negative loadings of Factor 1 represent more oceanic influenced conditions, and may be associated with the intrusion of Equatorial Pacific or California Current waters into the central Gulf of California.

Factor 2, which accounts for 28% of the data variance, closely corresponds to the distribution of the single species group Thalassionema/Thalassiothrix "needles", which has a correlation to Factor 2 of .9284. Thalassionema nitzschioides, one of the components of this group, is cosmopolitan in distribution but present in highest abundances in neritic environments (Kolbe, 1954; Smayda, 1963, 1966; Venrick, 1971). Schuette and Schrader (1981) report T. nitzschioides as characterizing sediments beneath

areas of recurrent upwelling. Pseudoeunotia doliolus is negatively correlated to this factor, though to a lesser degree than to the Productivity Factor (-.6037). Assuming that the components of the "needles" group reflect similar ecological conditions to those reported for Thalassionema nitzschioides, Factor 2 is interpreted as reflecting the persistent high primary productivity conditions characteristic of the Gulf.

In determining intervals of positive and negative influence of Factors 1 and 2 for each core, 25% of the variance in the distribution of the factor about the mean is considered to be due to counting error. Replicate counts of a group of slides showed this range of error in counts of the three abundant species or species groups represented by the factors. Schrader and Gersonde (1978) suggest a similar range of counting error for the samples in their study.

For the ecological groupings, the range of percent abundance for a given group is similar among all four cores. Abundances for the groups are low, but all except the benthic group occurs in abundances as high as 4% of the total diatom assemblage in at least one of the cores. The benthic group represents less than 1% of the assemblage in all samples and is omitted from further discussion.

Because individual ecological groups represent a small percentage of the total diatom assemblage, the

counting error is greater than for the three major groups. Therefore, peaks of abundance were considered significant only if they exceeded $\pm$ one standard deviation about the population mean for that group. Using this criteria, generally one or two peaks of abundance were resolved for each group in at least one core, variation being within the counting error at other depths. The oceanic and neritic groups showed a greater degree of fluctuation than the other groups. Intervals of somewhat higher or lower influence occurred, but no well-defined peaks or declines in abundance were resolved.

Variations with depth of the Factors and the ecological groups are presented in Figure 9. The Factors are presented in terms of relative factor loadings. The ecological groupings are expressed as relative percent abundance of occurrence. Depth in centimeters is plotted from the middle of each 2.5 cm composite sample. For purposes of discussion, peaks in abundance are expressed as occurring from the top of the upper sample to the base of the lower sample in which the peak occurs. A peak occurring in one sample is expressed as present within a 2.5 cm interval e.g. at 30-32.5 cm depth.

In B-29, positive influence of the Productivity Factor occurs at 10-22.5 cm and 80-87.5 cm; negative influence occurs at 5-7.5 cm and in general over the interval 40-75 cm. Positive influence of the "Needles" Factor occurs at 52.5-57.5 cm. This factor shows negative values at 0-15

Figure 9a-d. Variation with depth of factor loadings and ecological group abundances for Kasten cores B-29, B-28, E-9, and E-10. The Productivity Factor and "Needles" Factor are presented in terms of relative factor loadings. The ecological groups warm, cold, temperate (temp), "upwelling" (upw), oceanic (ocn), and neritic (nrtc) are expressed as percent abundance of the total diatom assemblage (valves plus spores). Vertical lines delineate 25% of the data variance about the mean for the factors and $\pm$ one standard deviation about the mean for the ecological groups, reflecting variability in the data distribution attributed to counting error.

Figure 9a.

BAV79 B-29

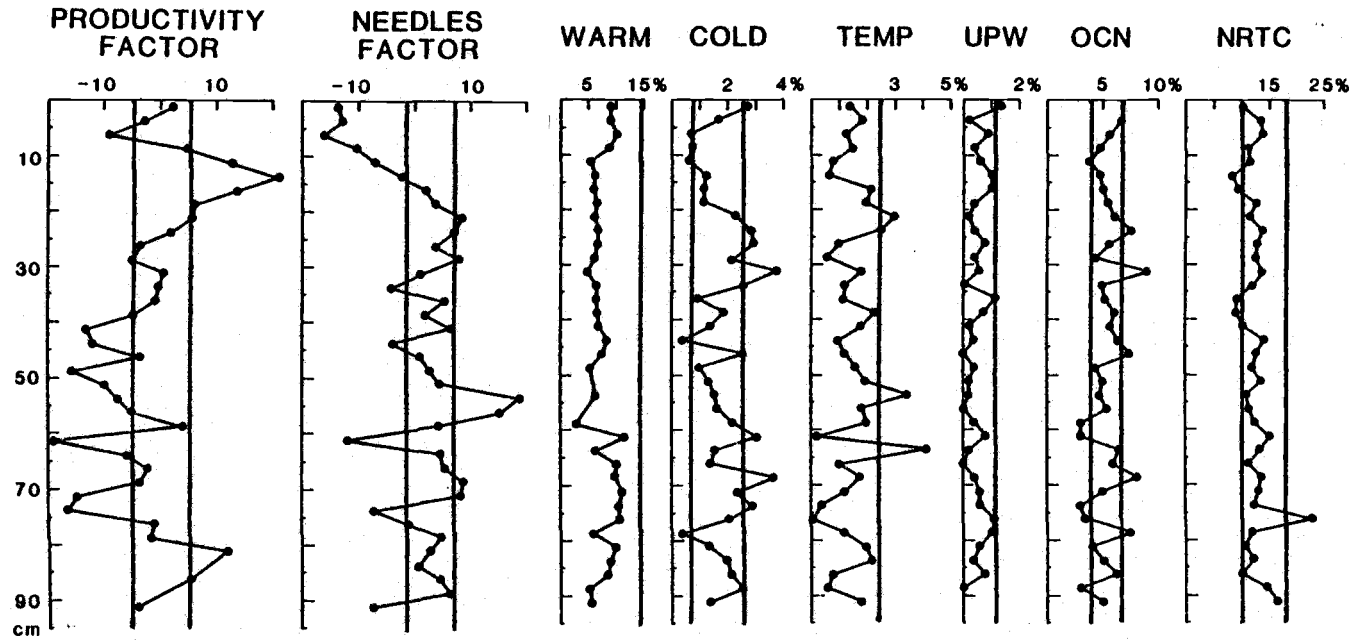


Figure 9b,

BAV79 B-28

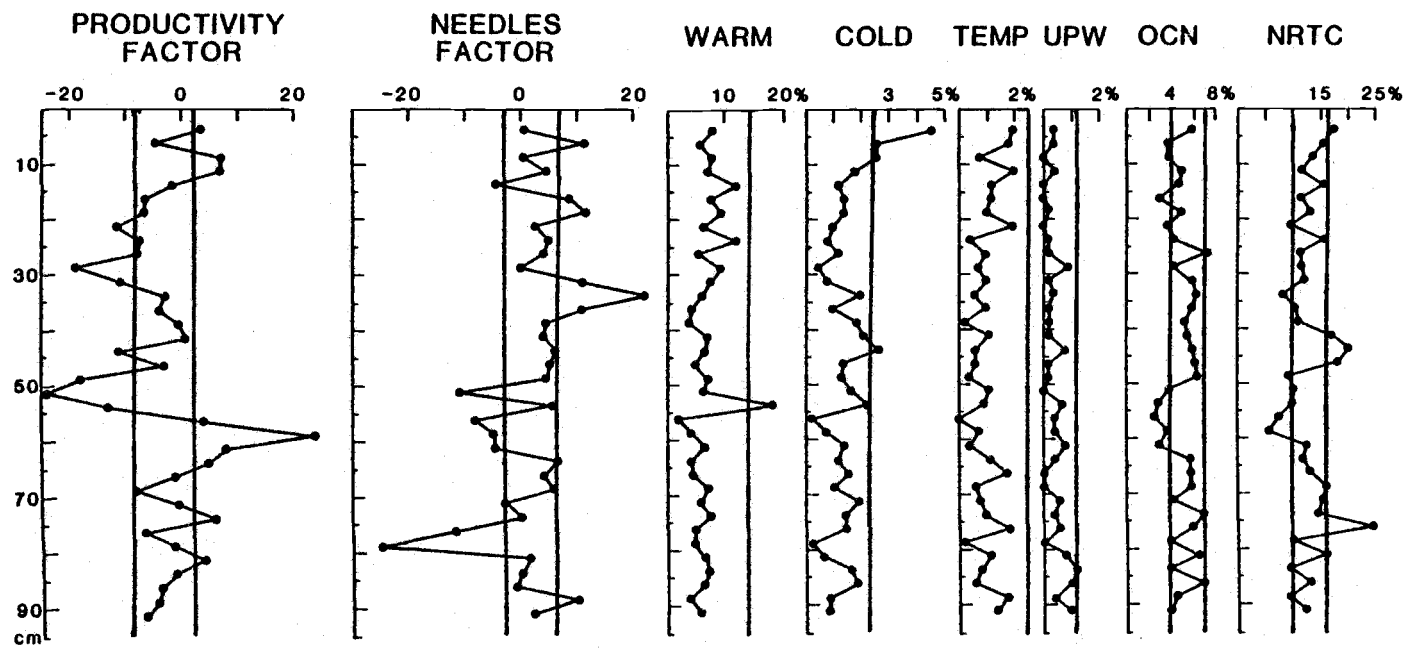


Figure 9c.

BAV79 E-9

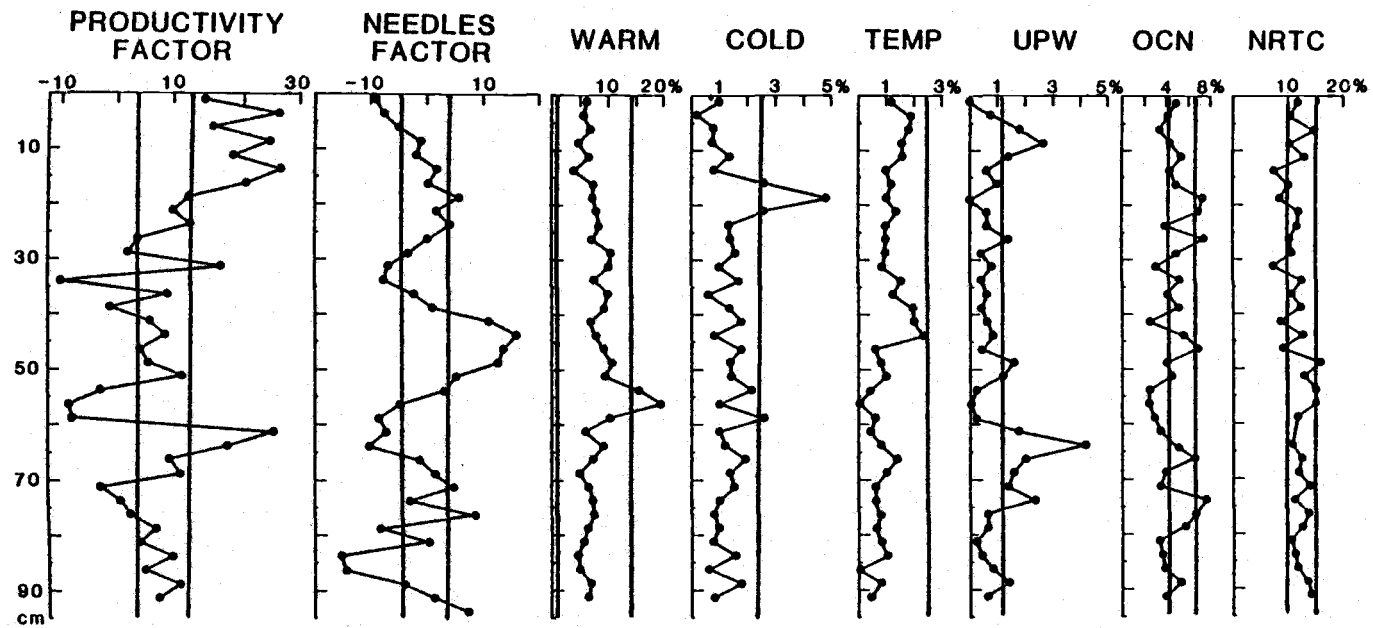
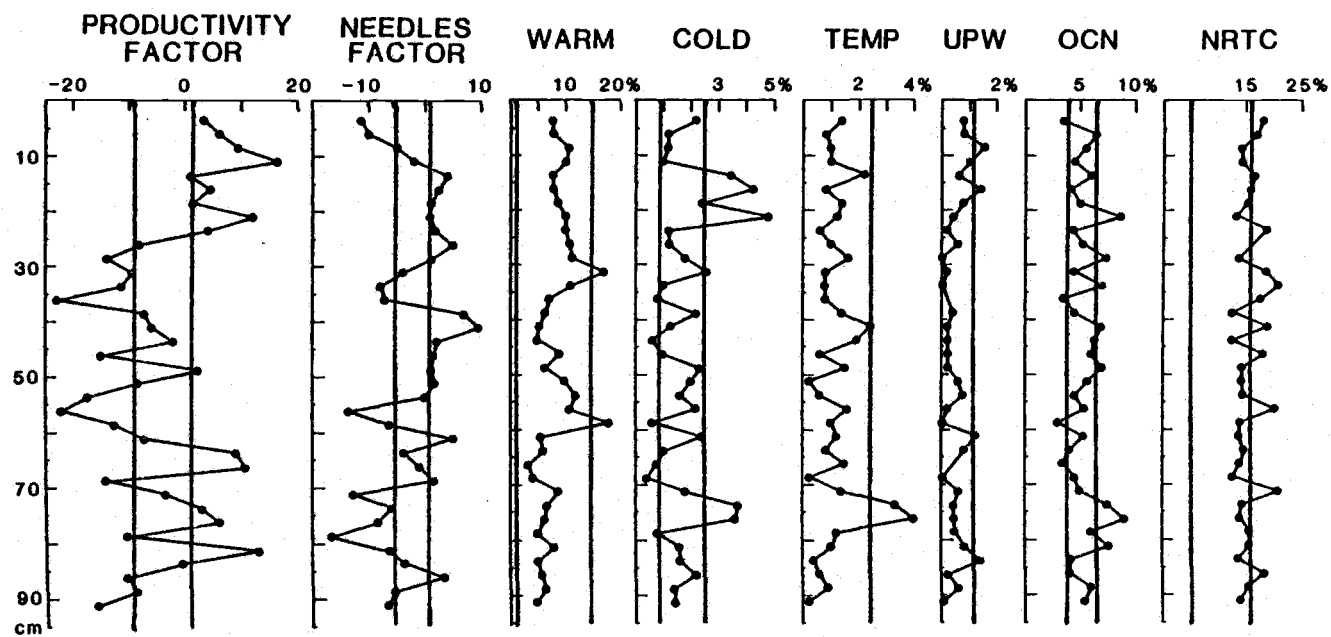


Figure 9d.

BAV79 E-10



cm, 60-62.5 cm, 72.5-75 cm, and 90-92.5 cm, with minor negative peaks at 32.5-35 cm and 42.5-45 cm. No significant peaks occur in the warm or "upwelling" groups. The cold group is relatively high over the interval 22.5-32.5 cm and at 60-62.5 cm, 67.5-70 cm, and 72.5-75 cm. The temperate group peaks at 20-25 cm, 52.5-55 cm, and 62.5-65 cm. The oceanic group was slightly lower in abundance at 57.5-62.5 cm and 72.5-77.5 cm and slightly higher in abundance at 30-32.5 cm and 67.5-70 cm. The neritic group was slightly lower at 12.5-17.5 cm and 35-40 cm, and had one peak at 75-77.5 cm.

In B-28, high positive levels of the Productivity Factor occur generally over the intervals 2.5-12.5 cm and 55-82.5 cm and high negative levels occur generally at 20-32.5 cm and 42.5-55 cm. Positive levels of the "Needles" Factor occur at 5-7.5 cm, 17.5-20 cm, and a higher peak at 30-37.5 cm; negative levels are at 50-52.5 cm, 55-57.5 cm, and an extreme negative peak at 75-80 cm. There is one warm peak at 52.5-55 cm and no peaks in the "upwelling" or temperate groups. The cold group is higher at 2.5-5 cm. The oceanic group is somewhat lower at 52.5-62.5 cm. The neritic group peaks at 42.5-47.5 cm and 75-77.5 cm and is low at 55-60 cm.

E-9 shows high positive influence of the Productivity Factor at 0-17.5 cm and 60-65 cm. Influence of this factor is generally negative over the interval 27.5-60 cm except for a positive peak at 30-32.5 cm. The "Needles"

Factor has a minor positive peak at 17.5-20 cm, and positive intervals at 40-52.5 cm, 75-77.5 cm, and 90-92.5 cm. There is a peak of the warm group at 52.5-57.5 cm and of the "upwelling" group at 5-12.5 cm and generally from 60-75 cm. The cold group peaks at 17.5-20 cm. No peak of the temperate group occurs. There are no distinctive fluctuations in the oceanic group except for a somewhat lower interval at 52.5-62.5 cm. The neritic group also shows no distinctive fluctuations, although values are generally somewhat lower at 12.5-47.5 cm.

The Productivity Factor in E-10 is generally positive at 2.5-25 cm and negative at 27.5-60 cm. Values fluctuate below this point, being positive at 62.5-67.5 cm, 72.5-77.5 cm, and 80-82.5 cm and negative at 67.5-70 cm, 77.5-80 cm, and 85-92.5 cm. The "Needles" Factor shows a positive influence at 12.5-30 cm, 37.5-52.5 cm, 60-62.5 cm, and 85-87.5 cm. Negative influence of this factor occurs at 2.5-7.5 cm, 32.5-37.5 cm, 55-57.5 cm. and generally at 70-80 cm. Peaks of the warm group occur at 30-32.5 cm and 57.5-60 cm. The "upwelling" group shows a slight increase at 7.5-10 cm and 15-17.5 cm. Cold group peaks occur at 12.5-22.5 cm and 72.5-77.5 cm. The temperate group has a single peak at 72.5-77.5 cm. The oceanic group is slightly higher at 20-22.5 cm and 72.5-82.5 cm. The neritic group averages a somewhat higher abundance than in the other cores, particularly at 22.5-57.5 cm and 70-72.5 cm.

Area E shows a higher level of primary productivity than Area B, based on absolute abundances of Chaetoceros spores, the major component of the Productivity Factor. This factor shows greater fluctuation in Area E than in Area B, while the "Needles" Factor is more variable in Area B, with a strong positive and a strong negative peak in that area. In Area E, the "Needles" Factor is generally characterized by alternating intervals of high and low influence. The distribution of peaks of the ecological groups differs between the two areas. Area E shows a greater influence of the warm and upwelling groups and Area B shows more influence of the temperate group.

Gulf Oceanographic Conditions for the Last 350 Years

In examining variations in the diatom sediment assemblage for the central Gulf, it is assumed that closely spaced cores from the same side of the Gulf were influenced by the same oceanographic conditions. Differences in the diatom record of the two cores not attributable to counting error is due to the "patchy" response of the diatom population to environmental conditions. A response present in either core would, by this assumption, represent an event which occurred in that area. A composite record for each side of the Gulf can therefore be established by combining the records of the two cores from each area. Using the biostratigraphic markers to establish time-equivalent horizons and the varve counts for each core to determine number

of years between horizons, an approximate time scale can be established for the composite record.

Figure 10 shows the composite record for Area B and Area E with respect to the factors and the cold and warm groups, which were felt to give well-defined responses for both areas. The upper datum for the time scale is tentatively established based on silicoflagellate biostratigraphy (Schrader, in preparation).

Conditions in the Gulf over about the last 350 years can be divided into three stages based on the distribution of the Productivity Factor. Stage III (ca. 1600-1750) was a period of moderate to high productivity levels in the Gulf, fluctuating in Area E between intervals of high productivity and high oceanic influence. Stage II (ca. 1750-1870) was a period of increased oceanic influence. During Stage I (ca. 1870-present), oceanic influence decreased and productivity levels were high.

At the present time, periodic short-term increases in oceanic influence in the Gulf can be associated with the occurrence of El Niño-type events. Although no single set of atmospheric and oceanic conditions accounts for all strong El Niño events (Quinn et al., 1978), several studies (Miller and Laurs, 1975; Wyrski, 1977; Bretschneider, 1980) have detected an increase in sea level or sea surface temperatures around the mouth of the Gulf and as far north as San Francisco associated with the events of 1957/58 and 1971/72. A study by Roden (1964) reported positive sea

Figure 10. Composite record for Areas B and E summarizing variation with respect to time in the distribution of the Productivity Factor, "Needles" Factor, warm group and cold group. For the factors, areas shaded in black indicate intervals of high positive(+) and high negative (-) influence. Dark intervals for the warm and cold groups reflect periods of increased abundance of these groups.

Figure 10.



level anomalies in the Gulf as far north as the Guaymas Basin during 1957/58. Both 1957/58 and 1971/72 marked strong two-phased El Niño events, in which the initial rise in sea level along the coast of South America was followed by intensification of the North Equatorial Countercurrent and a rise in sea level off Central America (Wyrтки, 1977). Under these circumstances it appears that oceanic influence in the Gulf is increased due to the northward incursion of Equatorial Pacific waters, resulting in conditions analogous to Figure 2A although stronger in the extent and duration of intrusion. The expected effect would be an increase in warm oceanic surface waters in the Gulf.

The anti-El Niño, a period of buildup of high sea level in the western Pacific prior to an El Niño event, is characterized by a strong South Equatorial Current and a weak North Equatorial Current and countercurrent (Wyrтки, 1977). This may result in conditions analogous to Figure 2B. Equatorial waters no longer exclude California Current waters from the Gulf. Under strong anti-El Niño-type conditions, this water mass can intrude further into the Gulf than at other times, leading to an increased influence of cold oceanic surface waters.

The coincidence of cold indicators with increased oceanic influence in Area B at about 1750-1760, 1768-1775, and 1790-1800 may reflect such events. The period 1750-1760, in which a strong increase in oceanic influence coincides with peaks of both the cold and warm groups, may

represent the effect of anti-El Niño followed by El Niño type conditions associated with the strong El Niño event (Quinn et al., 1978) of 1763. The occurrence of warm indicators with a productivity high at 1845-1855 may be due to sampling bias. A period of high oceanic influence at 1835-1845 correlates to a strong two-phase El Niño event at 1844/45. The warm peak may indicate an increase in abundance of species introduced by this El Niño event, whose peak of occurrence was picked up in the subsequent sample interval during which an increase in productivity also occurred. Changes in the southern extent of the California Current can occur over periods longer than a single El Niño event (decadal variations - Huang, 1974). Cold indicators in the Gulf indicative of California Current intrusion may reflect such longer term changes as well as being tied to specific anti-El Niño events.

The time period covered by this study includes the Little Ice Age (seventeenth to nineteenth centuries, Bjerknes, 1965). This was a climatic anomaly accompanied by increased glaciation in western Europe, Iceland, and western North America. Average conditions were more severe than at the present. The period was also characterized by widely fluctuating climatic extremes and an equatorward shift of Northern Hemisphere atmospheric circulation (Gribbin and Lamb, 1978). A shift of atmospheric circulation and steepening of the latitudinal temperature gradient resulted in an intensification of Pacific equatorial cir-

ulation during the Pleistocene glaciations (Arrhenius, 1952; CLIMAP, 1976). The Little Ice Age may have also intensified Pacific equatorial circulation, although to a much lesser degree than the Pleistocene glacial periods. The result would be to somewhat stabilize the Southern Oscillation (Quinn, personal communication, 1981), leading to conditions similar to 1915-1918, under which an extensive equatorial dry zone developed westward from South America (Quinn, 1971). It is postulated that, under intensified equatorial circulation associated with the Little Ice Age, conditions such as those described for El Niño type events in the Gulf were enhanced, Equatorial Water more regularly penetrated into the central Gulf, leading to periods of increased oceanic influence.

Gulf Stage III reflects the oscillating conditions characteristic of the Little Ice Age. Productivity levels were moderate to high during this time, intervals of moderate influence in Area B generally accompanied by increased oceanic influence in Area E. The "Needles" Factor was generally low throughout this period, but also shows a greater degree of fluctuation than during later times. Alternating intensification and relaxation of atmospheric circulation would lead to a similar intensification

and relaxation of upwelling in the Gulf. Pulses of productivity such as occurred near the end of Stage III may be tied to an increase in upwelling intensity due to an intensified zonal wind system. Intervals of increased oceanic influence may reflect periods of intensified equatorial circulation.

The peak of the Little Ice Age in western North America was marked by two glacial maxima in British Columbia, at 1725-1760 and at 1860 (Bjerknes, 1965). Glacial extent decreased only slightly during the intervening period. This period of maximum intensity roughly coincides with an interval of increased oceanic influence in the Gulf. Intensification of Pacific equatorial circulation may have stabilized during the Little Ice Age maximum. This would result in a stronger and more northward reaching Equatorial Current, with a greater influence in the Gulf than at the present time.

This period of increased oceanic activity in the Gulf ended shortly after the second glacial maximum in 1860. Climatic amelioration after 1860 was accompanied by increased productivity in the Gulf and by colder waters during the beginning of Stage I. Relaxation of equatorial circulation after the Little Ice Age may have resulted in increased California Current influence in the Gulf. High productivity levels along with colder waters may also reflect stronger upwelling due to a more stable zonal wind system, as opposed to the wide fluctuation in conditions

characteristic of the Little Ice Age during Stage III.

SUMMARY AND CONCLUSIONS

1) R-mode factor analysis of the diatom taphocoenoses in four Kasten cores from the central Gulf of California, two from the mainland side and two from the Baja side, shows that 56% of the data variance can be accounted for by a single factor. This factor is dominated by two of the most abundant species, Chaetoceros spores and Pseudoeunotia doliolus, which are inversely related. Positive factor loadings represent periods of high productivity; negative factor loadings indicate increased oceanic influence in the Gulf. Factor 2 (28% of the data variance) is dominated by the "needles" group, and is interpreted as indicative of the persistent high primary productivity conditions characteristic of the central Gulf. Changes in these factors downcore are felt to reflect general trends in climatic and oceanographic conditions in the central Gulf over the approximately 350 year period covered by the study.

Individual ecological groups as calculated in this study represent small percentages of the total diatom sediment assemblage. However, this method can be used in the interpretation of Gulf oceanographic conditions to further characterize trends delineated by the results of the factor analysis. The effect of these groups could be better defined by use of a counting scheme which takes a larger sample of the minor species, more accurately defining the distribution of these groups.

2) Conditions in the Gulf over about the last 350 years can be divided into three stages based on major trends in the Productivity Factor.

Stage III (ca. 1600-1750) was a period of moderate to high productivity levels alternating with intervals of increased oceanic influence. These fluctuating conditions may be the result of widely fluctuating climatic extremes associated with the Little Ice Age. Pulses in productivity such as occurred near the end of Stage III may be tied to increased upwelling intensity due to an intensified zonal wind system. Periods of increased oceanic influence may reflect periods of intensified equatorial circulation and subsequent intrusion of Equatorial Water into the Gulf.

Stage II (ca. 1750-1870) roughly corresponds to the maximum extent of the Little Ice Age in western North America. The influence of oceanic waters in the Gulf was enhanced during this period as compared to present conditions. Intensification of Pacific equatorial circulation may have stabilized during the Little Ice Age maximum resulting in a stronger and more northward reaching Equatorial Current, with a greater influence in the Gulf than at present time.

Climatic amelioration after the Little Ice Age peak was accompanied by increased productivity in the Gulf of California (Stage I - ca. 1870-present), and by colder waters in the central Gulf. This may be tied to an increase in California Current influence with the

de-intensification of equatorial circulation. It may also reflect stronger upwelling due to a more stable zonal wind system, as opposed to the wide fluctuations in climatic conditions characteristic of the Little Ice Age during Stage III.

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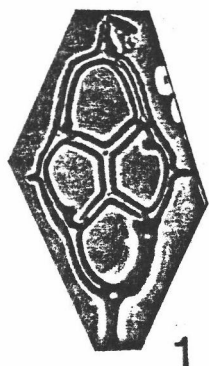
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PLATES

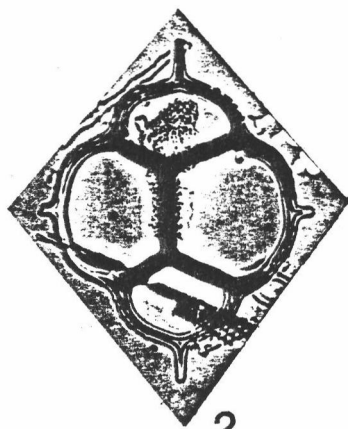
PLATE I

Scale B corresponds to Figure 2. All other figures correspond to Scale A. Photos and taxonomic nomenclature are taken from a siliceous microfossil atlas for the Gulf of California compiled by Schrader and Schuette(unpub.).

1. Dictyocha sp. 2
2. Dictyocha sp. 1A
3. Dictyocha sp. 1B
- 4.-5. Thalassiosira leptopus var. 1
- 6.-7. Thalassiosira sp. 5



1



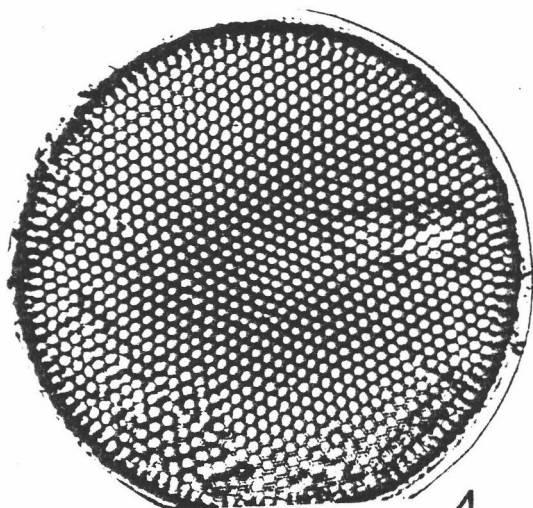
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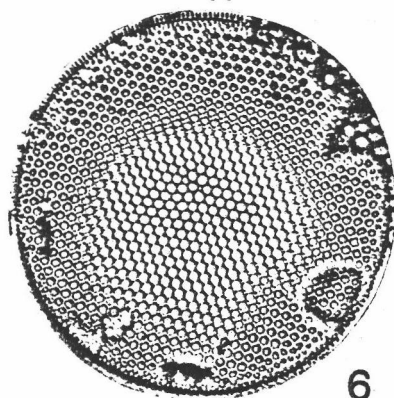
3

10 μ m
B

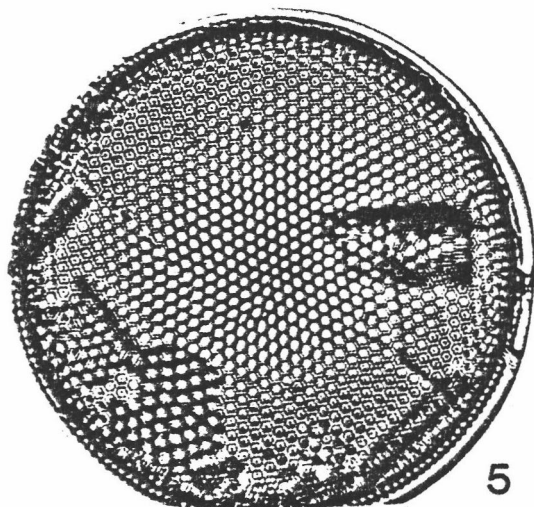
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A



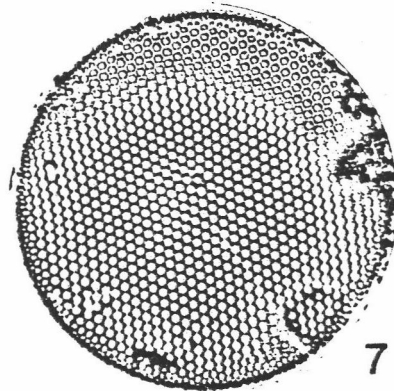
4



6



5



7

PLATE II

Scale B corresponds to Figure 5. All other figures correspond to Scale A. Photos and taxonomic nomenclature are taken from a siliceous microfossil atlas for the Gulf of California compiled by Schrader and Schuette (unpub.).

1.-4. Thalassiothrix pseudonitzschoides

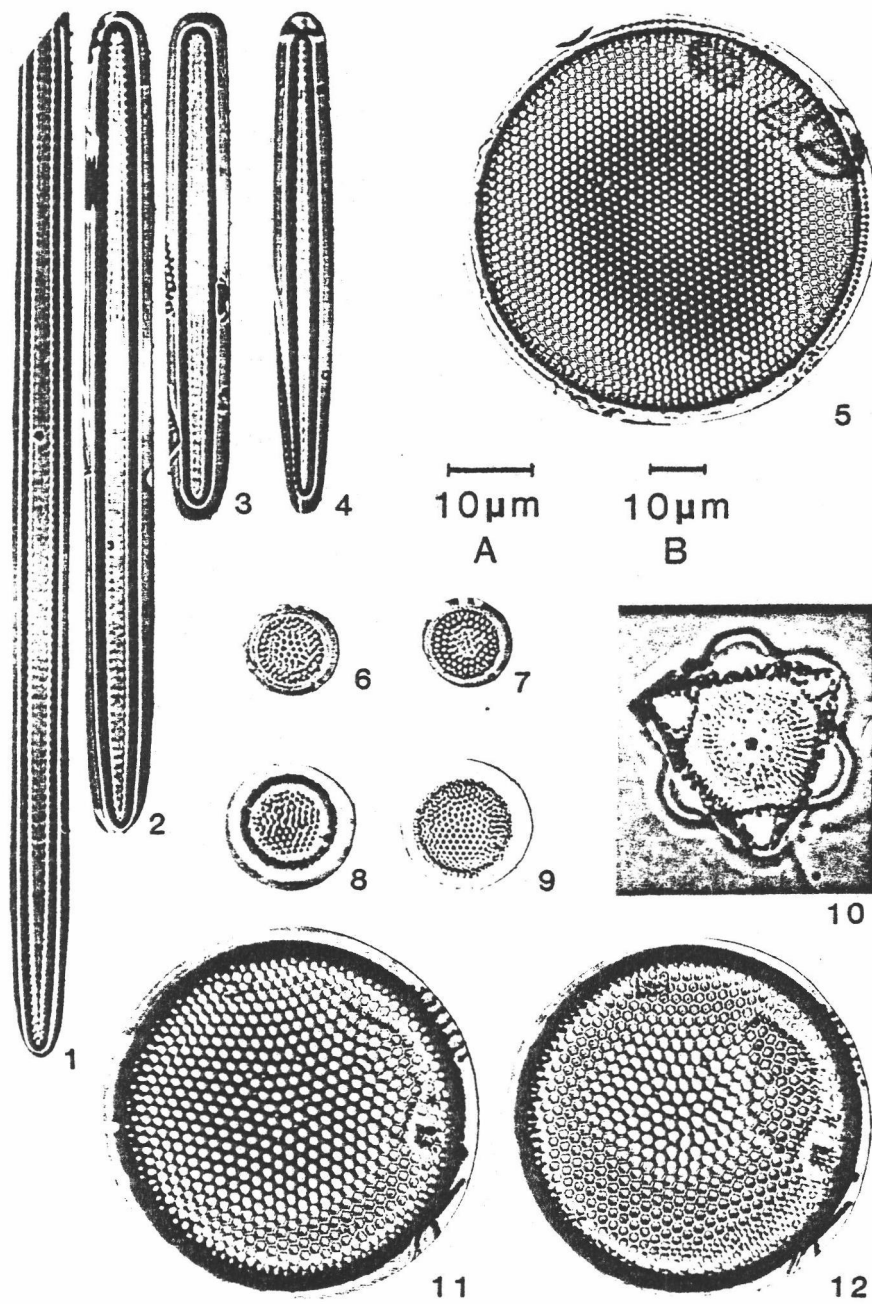
5. Thalassiosira leptopus var. 1

6.-7. Thalassiosira sp. 6

8.-9. Thalassiosira sp. 4

10. Lithodesmium sp. 1

11.-12 Thalassiosira (pacifica? Hasle)



APPENDICES

Appendix I: Data Table

The diatom assemblage for each sample analyzed in cores B-29, B-28, E-9, and E-10 is presented as number of diatoms counted for each species in that sample.

	<i>Coscinodiscus curvatus</i>	<i>Actinocyclus curvatus</i>	<i>Chaetoceros</i> spores	<i>Thalassiosira eccentrica</i>	<i>Thalassiosira symmetrica</i>	<i>Thalassiosira oestrupii</i>	<i>Planktoniella sol</i>	<i>Thalassiosira lineata</i>	<i>Thalassiosira leptopus</i>	<i>Thalassiosira leptopus</i> var. 1	<i>Coscinodiscus nodulifer</i>	<i>Coscinodiscus marginatus</i>	<i>Coscinodiscus radiatus</i>	<i>Roperia tessellata</i>	<i>Bacteriastrium</i>	<i>Skeletonema costatum</i>	<i>Nitzschia bicapitata</i>	<i>Thalassiosira punctifera</i>	<i>Actinopterychus senarius</i>	<i>Actinopterychus splendens</i>	<i>Rhizosolenia alata</i>	<i>Rhizosolenia bergonii</i>	<i>Rhizosolenia styliformis</i>	<i>Rhizosolenia calcar-avis</i>	<i>Cyclotella striata</i>
BAV79 B-29																									
0.0-2.5	0	0	135	4	2	12	0	15	5	0	6	0	4	6	4	0	0	0	0	0	0	0	0	6	10
2.5-5.0	0	0	116	9	6	25	1	11	4	0	10	0	3	5	0	0	0	1	19	4	4	1	0	0	12
5.0-7.5	0	0	92	5	5	21	0	7	0	0	15	0	7	20	0	0	0	21	7	4	4	4	10	9	
7.5-10.0	0	2	149	9	3	19	0	8	3	0	8	0	1	7	2	2	0	12	14	1	5	0	0	13	
10.0-12.5	0	1	182	5	7	15	0	4	1	0	0	0	2	14	1	2	0	1	11	10	2	0	0	7	
12.5-15.0	0	4	193	6	1	16	0	4	3	0	4	0	3	10	0	4	0	1	10	4	4	0	0	11	
15.0-17.5	1	3	168	4	5	16	0	4	6	0	5	1	4	17	2	4	2	1	14	8	4	1	3	4	
17.5-20.0	0	6	132	4	4	18	0	13	6	0	7	0	9	12	6	0	5	1	22	8	4	0	1	13	
20.0-22.5	0	9	126	5	7	22	1	10	4	0	8	0	1	6	9	0	5	0	13	8	4	0	0	13	
22.5-25.0	1	10	98	9	2	30	2	5	6	0	5	1	6	21	9	1	2	0	15	10	3	2	0	12	
25.0-27.5	1	9	89	5	5	24	1	7	2	0	8	0	6	19	2	0	0	0	25	3	0	4	1	17	
27.5-30.0	1	8	82	4	3	13	0	9	4	0	14	0	5	6	1	0	2	0	19	6	3	1	1	14	
30.0-32.5	0	18	108	4	0	38	0	14	0	0	8	0	4	0	6	0	0	0	20	10	4	0	2	14	
32.5-35.0	3	9	111	9	8	16	0	5	2	0	11	0	3	15	3	0	1	1	11	8	1	2	0	14	
35.0-37.5	0	3	102	5	5	22	0	12	1	0	17	0	9	5	4	1	0	0	11	0	1	0	0	11	
37.5-40.0	2	2	93	2	2	19	0	3	4	0	9	1	3	18	7	2	1	3	16	1	2	2	1	8	
40.0-42.5	0	3	45	3	6	19	1	2	0	0	19	1	5	11	5	1	0	2	18	3	7	0	0	10	
42.5-45.0	0	2	61	4	4	22	0	7	3	0	10	0	5	34	5	0	2	1	14	10	3	1	2	23	
45.0-47.5	4	4	82	4	5	26	0	12	5	0	23	0	0	6	4	0	1	2	13	6	1	2	0	25	
47.5-50.0	2	1	51	2	6	15	1	2	3	0	11	0	1	5	8	0	1	2	6	5	2	4	2	23	
50.0-52.5	3	2	63	1	13	13	0	5	6	0	16	0	2	7	10	0	1	0	14	8	1	0	0	16	
52.5-55.0	3	2	62	0	5	13	0	9	2	0	12	0	1	2	12	0	1	1	3	3	2	1	0	24	
55.0-57.5	0	3	79	1	5	21	0	8	0	0	6	0	3	1	1	0	2	0	9	5	1	3	2	25	
57.5-60.0	1	6	124	0	2	7	0	11	2	0	4	0	7	6	8	0	2	0	8	4	4	2	2	30	
60.0-62.5	2	16	16	3	2	8	2	2	5	1	54	0	4	7	1	0	0	6	18	4	2	0	0	31	
62.5-65.0	2	5	80	0	4	19	0	10	3	0	7	0	4	11	14	0	3	0	13	6	5	2	1	23	
65.0-67.5	1	5	90	0	3	22	0	14	2	0	17	0	4	14	3	0	0	2	15	3	0	1	3	22	
67.5-70.0	2	11	73	1	3	23	0	12	3	0	16	0	4	10	4	0	3	2	24	10	5	5	1	19	
70.0-72.5	2	7	30	2	2	12	4	7	3	0	24	0	8	14	3	0	3	4	12	5	1	2	2	24	
72.5-75.0	0	14	30	2	4	10	2	4	9	1	39	0	1	8	1	0	0	7	14	5	0	0	0	19	
75.0-77.5	4	5	106	1	3	2	20	12	4	2	14	0	7	7	5	3	3	3	11	7	2	1	5	4	53
77.5-80.0	0	1	96	4	2	20	3	8	3	3	9	0	1	5	2	3	1	2	7	12	5	1	3	1	18
80.0-82.5	2	0	145	0	2	13	4	3	1	0	25	0	5	10	8	1	3	2	15	4	4	3	0	13	
82.5-85.0	1	0	166	1	9	22	8	12	5	2	13	0	1	5	9	2	3	4	16	5	3	4	2	2	13
85.0-87.5	0	2	128	1	2	19	5	10	4	0	7	0	6	6	2	1	3	2	11	2	5	2	4	1	13
87.5-90.0	0	3	116	0	3	13	10	3	1	1	6	0	5	6	2	0	1	1	15	4	1	0	0	1	23
90.5-92.5	0	2	98	0	7	14	1	4	4	2	17	1	6	3	8	0	3	1	9	10	2	1	1	2	35

BAV79 B-29	<i>Coscinodiscus centralis</i>	<i>Coscinodiscus granii</i>	<i>Coscinodiscus obscurus</i>	<i>Coscinodiscus perforatus</i>	<i>Coscinodiscus stellaris</i>	<i>Coscinodiscus symbolophorus</i>	<i>Coscinodiscus tabularis</i>	<i>Coscinodiscus thorii</i>	<i>Diploneis smithi</i>	<i>Glyphodesmids sp. 1</i>	<i>Grammatophora spp</i>	<i>Hemidiscus cuneiformis</i>	<i>Hemiaulus sinensis</i>	<i>Hemiaulus longicornis</i>	<i>Lithodesmium sp. 1</i>	<i>Lithodesmium undulatum</i>	<i>Navicula sp. 1</i>	<i>Navicula sp. 3</i>	<i>Navicula sp. 6</i>	<i>Navicula nummularia</i>	<i>Nitzschia interruptestriata</i>	<i>Nitzschia marina</i>	<i>Nitzschia sicula</i>
0.0-2.5	0	1	0	6	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	1	0	0	
2.5-5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	
5.0-7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	
7.5-10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10.0-12.5	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	
12.5-15.0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	
15.0-17.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
17.5-20.0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	
20.0-22.5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
22.5-25.0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	2	0	
25.0-27.5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
27.5-30.0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	
30.0-32.5	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	
32.5-35.0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	
35.0-37.5	0	0	0	5	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
37.5-40.0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	
40.0-42.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	
42.5-45.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
45.0-47.5	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	
47.5-50.0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
50.0-52.5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	
52.5-55.0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	
55.0-57.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	
57.5-60.0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
60.0-62.5	0	0	0	4	0	0	0	0	3	0	0	0	0	0	2	0	0	1	0	0	0	1	
62.5-65.0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	
65.0-67.5	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	
67.5-70.0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	0	0	0	
70.0-72.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
72.5-75.0	0	0	0	2	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	
75.0-77.5	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	
77.5-80.0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	
80.0-82.5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	
82.5-85.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
85.0-87.5	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	
87.5-90.0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
90.0-92.5	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	

BAU79 B-28	Odontella aurita	Paralia sulcata	Pleurosigma sp. 1	Stephanopyxis turris	Surirella fastuosa	Synedra sp. 1	Synedra indica	Thalassiosira anguste-lineata	Thalassiosira gravida	Thalassiosira pacifica	Thalassiosira plicata	Thalassiosira simonsenii	Thalassiosira spinosa	Thalassiosira tenera	Thalassiosira sp. 2	Thalassiosira sp. 4	Thalassiosira sp. 5	Thalassiosira sp. 6	Thalassiothrix vanhoefenii	Trachyneis aspera	Triceratium spp	Biddulphia dubia
0.0-2.5	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0
5.0-7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5-10.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0-12.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5-15.0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15.0-17.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.5-20.0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0-22.5	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
22.5-25.0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
25.0-27.5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
27.5-30.0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
30.0-32.5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32.5-35.0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
35.0-37.5	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0
37.5-40.0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
40.0-42.5	1	1	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
42.5-45.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45.0-47.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
47.5-50.0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
50.0-52.5	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
52.5-55.0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
55.0-57.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
57.5-60.0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0
60.0-62.5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
62.5-65.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65.0-67.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67.5-70.0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
70.0-72.5	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
72.5-75.0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0
75.0-77.5	0	0	0	3	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
77.5-80.0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
80.0-82.5	1	1	0	1	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0
82.5-85.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
85.0-87.5	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
87.5-90.0	0	0	0	0	0	1	1	0	1	1	1	4	0	0	0	1	1	0	4	0	0	0
90.0-92.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

BAU79 E-10	Cyclotella stylonum	Thalassiothrix longissima	Thalassiothrix mediterranea	Pseudoecunotia dolioilus	Thalassionema nitzschioides	Thalassionema nitzschioides var. parva	Thalassionema nitzschioides var. parva 1	Thalassiothrix pseudonitzschioides	Thalassionema/Thalassiothrix fragments	Actinocyclus octonarius	Actinocyclus subtilis	Amphora spp.	Asteromphalus arachne	Asteromphalus flabellatus	Asteromphalus heptactis	Asteromphalus petersonii	Biddulphia longicruris	Biddulphia regia	Biddulphia rhombus	Cocconeis spp	Cyclotella caspia	Chaetoceros spp vegetative cells	Coscinodiscus africanus	Coscinodiscus argus	Coscinodiscus asteromphalus
2.5-5.0	10	0	0	82	0	0	0	49	33	2	0	0	0	0	1	0	0	0	0	0	0	0	1	2	
5.0-7.5	10	1	0	76	0	2	14	41	42	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	
7.5-10.0	4	0	0	67	1	0	0	49	50	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	
10.0-12.5	0	0	0	45	0	0	0	64	51	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
12.5-15.0	8	0	0	62	0	1	16	70	72	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	
15.0-17.5	7	0	0	57	1	0	8	75	61	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	
17.5-20.0	3	0	0	68	0	1	7	53	83	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
20.0-22.5	3	0	0	47	0	2	14	49	56	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	
22.5-25.0	9	0	0	64	0	0	8	75	59	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
25.0-27.5	10	0	0	87	1	0	23	86	66	1	0	0	1	2	1	0	0	0	0	0	1	0	0	0	
27.5-30.0	6	0	0	124	0	2	24	81	59	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	
30.0-32.5	9	0	0	106	0	2	17	54	46	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	
32.5-35.0	6	0	0	112	0	1	21	60	43	0	0	0	1	2	0	0	0	0	0	1	0	0	0	0	
35.0-37.5	15	0	1	156	0	0	23	79	60	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	
37.5-40.0	7	0	1	88	0	5	12	121	68	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
40.0-42.5	12	0	2	55	0	0	18	80	89	1	0	0	1	2	1	0	0	0	1	0	1	2	0	0	
42.5-45.0	18	0	3	72	0	2	30	73	71	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	
45.0-47.5	19	0	1	97	0	0	18	84	66	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0	
47.5-50.0	6	0	0	70	0	0	16	80	54	0	0	0	0	0	2	0	0	1	0	0	0	0	1	0	
50.0-52.5	8	0	0	91	0	1	13	76	73	1	0	0	0	1	1	1	0	0	0	0	1	6	0	2	
52.5-55.0	6	0	0	137	0	3	13	77	78	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
55.0-57.5	16	0	0	169	0	7	9	63	42	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	
57.5-60.0	4	0	0	170	0	4	8	76	47	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	
60.0-62.5	2	0	0	91	0	0	11	88	83	1	0	0	0	2	2	0	0	0	0	0	5	0	0	1	
62.5-65.0	6	0	0	70	0	1	9	57	64	3	0	0	0	1	2	0	0	0	0	0	0	0	0	0	
65.0-67.5	6	0	2	67	0	0	7	78	72	1	0	0	0	0	1	0	0	0	0	1	12	0	0	0	
67.5-70.0	2	0	0	131	0	3	6	110	86	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	
70.0-72.5	10	0	0	116	0	1	4	44	45	0	0	0	1	0	0	0	0	0	0	1	4	0	0	0	
72.5-75.0	6	0	0	84	0	5	8	61	50	0	0	0	1	1	1	0	0	0	0	0	2	0	1	1	
75.0-77.5	5	0	0	78	1	2	16	45	41	0	0	0	0	3	1	0	0	0	0	0	5	0	0	1	
77.5-80.0	1	0	0	154	0	4	9	63	39	0	0	0	0	0	1	0	1	0	0	0	2	0	2	1	
80.0-82.5	7	0	0	53	0	3	14	30	55	1	0	0	2	1	0	0	0	0	0	1	9	0	0	2	
82.5-85.0	4	0	0	101	0	0	14	75	62	1	0	0	0	1	2	0	0	0	0	0	2	0	1	1	
85.0-87.5	11	0	0	80	0	1	14	95	72	0	0	0	0	2	1	0	0	0	0	0	0	0	0	1	
87.5-90.0	14	0	0	111	0	0	17	60	60	0	0	0	1	2	3	0	0	0	0	0	6	0	0	0	
90.0-92.5	7	0	0	142	0	2	7	87	68	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	

BAU79 E-10	Coscinodiscus centralis	Coscinodiscus granii	Coscinodiscus obscurus	Coscinodiscus perforatus	Coscinodiscus stellaris	Coscinodiscus symbolophorus	Coscinodiscus tabularis	Coscinodiscus thorii	Diploneis smithii	Glyphodesmis sp. 1	Grammatophora spp	Hemidiscus cuneiformis	Hemiaulus sinensis	Hemiaulus longicornis	Lithodesmium sp. 1	Lithodesmium undulatum	Navicula sp. 1	Navicula sp. 3	Navicula sp. 6	Navicula nummularia	Nitzschia interruptestriata	Nitzschia marina	Nitzschia sicula
2.5-5.0	0	0	0	0	1	0	0	0	1	0	0	4	0	0	0	0	0	0	0	0	1	0	1
5.0-7.5	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7.5-10.0	0	1	1	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10.0-12.5	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
12.5-15.0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
15.0-17.5	0	1	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
17.5-20.0	0	1	2	4	3	0	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0
20.0-22.5	0	4	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
22.5-25.0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0
25.0-27.5	0	2	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
27.5-30.0	0	1	0	0	0	1	2	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0
30.0-32.5	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
32.5-35.0	0	0	1	0	0	0	1	0	1	0	0	4	0	0	0	2	0	0	0	0	0	0	1
35.0-37.5	0	0	1	1	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
37.5-40.0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0
40.0-42.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	0	0	0	0	1	1	
42.5-45.0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
45.0-47.5	0	0	0	1	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
47.5-50.0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0
50.0-52.5	0	1	1	0	0	0	0	1	1	0	0	3	1	0	0	1	0	0	0	0	0	1	0
52.0-55.0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
55.0-57.5	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
57.5-60.0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
60.0-62.5	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0
62.5-65.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
65.0-67.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
67.5-70.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70.0-72.5	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
72.5-75.0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	1	1	0	0	0	0	0	0	0
75.0-77.5	0	2	0	0	6	0	6	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	0
77.5-80.0	0	0	1	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
80.0-82.5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0
82.5-85.0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0
85.0-87.5	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	1	1
87.5-90.0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	2	1	1
90.0-92.5	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

BAV79 E-10	Odontella aurita	Paralia sulcata	Pleurosigma sp. 1	Stephanopyxis turris	Surirella fastuosa	Synedra sp. 1	Synedra indica	Thalassiosira anguste-lineata	Thalassiosira gravida	Thalassiosira pacifica	Thalassiosira plicata	Thalassiosira simonsenii	Thalassiosira spinosa	Thalassiosira tenera	Thalassiosira sp. 2	Thalassiosira sp. 4	Thalassiosira sp. 5	Thalassiosira sp. 6	Thalassiothrix vanhoefenii	Trachyneis aspera	Triceratium spp	Biddulphia dubia
2.5-5.0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
5.0-7.5	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
7.5-10.0	0	1	0	0	0	0	1	0	0	1	0	1	4	0	0	0	0	0	0	0	0	0
10.0-12.5	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
12.5-15.0	0	0	0	1	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0
15.0-17.5	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
17.5-20.0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0-22.5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
22.5-25.0	0	0	0	1	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0
25.0-27.5	0	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0
27.5-30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
30.0-32.5	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
32.5-35.0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
35.0-37.5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37.5-40.0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
40.0-42.5	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
42.5-45.0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
45.0-47.5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47.5-50.0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
50.0-52.5	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
52.5-55.0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
55.0-57.5	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
57.5-60.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
60.0-62.5	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
62.5-65.0	1	1	0	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	0	0	0	0
65.0-67.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67.5-70.0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
70.0-72.5	0	1	0	1	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	1	0
72.5-75.0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
75.0-77.5	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0
77.5-80.0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
80.0-82.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
82.5-85.0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0
85.0-87.5	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
87.5-90.0	0	1	0	0	0	0	0	0	0	1	0	4	1	0	0	0	0	1	0	0	0	0
90.0-92.5	0	0	0	0	0	0	0	0	1	0	0	3	2	0	0	0	1	0	0	0	0	0

Appendix II: Ecological Data

The following table represents a list of those diatom species identified in the sediments of the Gulf of California for the purposes of this study for which ecological data could be derived from the literature. The ecological data is based primarily on studies from the Pacific Ocean. Numbers in parentheses refer to the list of source references following the table. The designations are those terms used by the original authors. Because of the variety of classification schemes used, an attempt to present a standard nomenclature would give a false sense of consistency to the various studies. It should be noted that in some cases (e.g. Kozlova and Muhina (1967), and Jousé et al. (1971)) the same terms are used in classifying assemblages where the corresponding geographic boundaries are similar, but not precisely the same. Also, due to the numerous revisions in diatom taxonomy, particularly since the advent of SEM techniques, some caution should be used in applying taxonomy as used in older works to present day studies.

Guillard and Kilham (1977) summarize the ecological results of a number of Pacific phytoplankton studies cited here. The ecological information of Gersonde (1980) represents a summary of the available literature on those species, and includes many studies in non-Pacific waters.

Actinocyclus curvatulus - oceanic; N. boreal (1); transitional (S. of Subarctic Front) (4); cold water (3)

A. octonarius - meroplanktic, cosmopolitan in mid and low

latitudes and in turbulent near-shore waters (11,22); polyhalobous; mesoeuryhaline (22)

- A. subtilis - Equatorial Pacific (2,7) - mainly upwelling enriched (7); warm (3); Gulf of Panama - especially during strong upwelling (9); transitional - south of Subarctic Front (10); N. Pacific and S. Equatorial Current (14); temperate; not common off southern California (23)

Actinopterychus senarius - meroplanktic, cosmopolitan in mid and low latitudes in near-shore turbulent waters (11); neritic (12, 22, 23); polyhalobous, meioeuryhaline, cosmopolitan (22); not common off southern California (23)

Actinopterychus splendens - neritic (12); benthic, polyhalobous, cosmopolitan (22)

Asteromphalus arachne - Equatorial Pacific - eutrophic (8); central Pacific (10)

- A. flabellatus - Equatorial Pacific - eutrophic (8); Gulf of Panama - low during all conditions (9)

A. heptactis - Equatorial Pacific (8, 17) - eutrophic (8); subarctic (10); oceanic; temperate; occasionally found in large numbers off California but usually not numerous (23)

A. petersonii - Equatorial Pacific - eutrophic (8)

Biddulphia dubia - neritic; warm waters; subtropical to tropical; reported only occasionally off southern California (23)

B. longicruris - coastal (10); neritic; temperate to subtropical - more abundant in warmer waters (23)

B. regia - benthic; polyhalobous; (?)cosmopolitan (22)

B. rhombus - neritic; north temperate; rare off California (23)

Chaetoceros spp. - Equatorial Pacific - eutrophic indicator (8); Gulf of Panama (9); continental margin (11); neritic (12)

Chaetoceros spores - cold, high productivity water (4); seaward edge of nutrient - replete upwelled waters (11); nutrient-replete successional stage in euphotic zone (5)

Coscinodiscus africanus - Equatorial Pacific (2, 15,16); warm water (3)

- C. argus - planktic (?meroplanktic; neritic); polyhalobous; euryhaline; cosmopolitan (22)
- C. asteromphalus - inner shelf (12); south Boreal (16); planktic; polyhalobous; meioeuryhaline; cosmopolitan (22)
- C. centralis - planktic; polyhalobous; cosmopolitan (22); temperate or north temperate (23)
- C. curvatus - subArctic Front (4); north Boreal (15); (?)meroplanktic (22); neritic (22,23); polyhalobous (22); cosmopolitan (24)-but more abundant in colder water (22); low abundance in Pacific to California (23)
- C. granii - planktic; (?)meroplanktic, neritic (22, 23), polyhalobous; meio-to mesoeuryhaline, cosmopolitan (22); Gulf of Panama - upwelling (9); not uncommon off California (23); north temperate or boreal (23)
- C. marginatus - planktic; polyhalobous (22); oceanic; north Boreal (1, 15); cold (3, 22); SubArctic (4, 10, 22); Gulf of Panama - low during all seasons (9); not common off California (23)
- C. nodulifer - planktic; polyhalobous (22); Equatorial Pacific (2, 16, 17) - mainly upwelling enriched (7); tropical (1, 15, 22); warm (3, 22); central Pacific (10); subtropical (10); oceanic (11, 12)
- C. obscurus - planktic, polyhalobous; cosmopolitan (22)
- C. perforatus - planktic; polyhalobous (22); south Boreal (1); warm (3, 22); inner shelf, meroplanktic (12); mainly coastal (7); Gulf of Panama - upwelling (9)
- C. radiatus - planktic (?meroplanktic, neritic); polyhalobous; euryhaline; cosmopolitan (22,23); equatorial (2, 17); subtropical (1, 15); south Boreal (1, 5, 16); tropical oceanic (11)
- C. stellaris - planktic, polyhalobous, cosmopolitan; mainly temperate (22, 23); Sea of Okhotsk - extremely cold winters, incomplete summer mixing (4); transitional (south of Subarctic Front) (10); rare off California (23)
- C. symbolophorus - planktic; polyhalobous; mainly temperate (22)
- C. tabularis - oceanic; south Boreal (1); subarctic (10)

Cyclotella caspia - Gulf of Panama - strong to mild upwelling (9)

Cyclotella striata - planktic (2), mesohalobous (22); sublittoral; north Boreal (1); meroplanktic, cosmopolitan in mid to low latitudes and in turbulent near-shore waters (11)

Cyclotella stylum - planktic; (?)mesohalobous (22); meroplanktic; cosmopolitan in mid to low latitudes and in turbulent near-shore waters (11)

Diploneis smithii - benthic; polyhalobous, pleioeuryhaline, cosmopolitan (22)

Hemidiscus cuneiformis - planktic; polyhalobous (22); warm water (3, 22); oceanic (1, 12, 15, 23); Equatorial Pacific (2, 16, 17) - eutrophic indicator (8); tropical (1, 15); central Pacific (10); transitional - south of Subarctic Front (10); subtropical; reported rarely off southern California (23)

Hemiaulus longicornis - planktic; polyhalobous (22); neritic; south temperate or subtropical; fairly common but never abundant off southern California and southward (23)

Hemiaulus sinensis - planktic; polyhalobous (22)

Lithodesmium undulatum - (?)meroplanktic; polyhalobous; oligo - to meioeuryhaline, cosmopolitan (22); neritic; south temperate; not uncommon off southern California (23)

Navicula nummularia - benthic (2, 22); polyhalobous (22)

Nitzschia bicapitata - planktic; polyhalobous; cosmopolitan; (?)warm water (22); Equatorial Pacific - mainly upwelling enriched (7); subtropical (15, 16); central Pacific (10); N. Pacific and south Equatorial Current (14); subarctic (10)

N. interruptestriata - planktic; polyhalobous; warm water (tropical (22)/subtropical (5, 22))

N. marina - planktonic; polyhalobous (22); warm water (3, 22); Equatorial Pacific (2, 16) - mainly upwelling enriched (7); tropical (1, 15); oceanic (11)

N. sicula - Equatorial Pacific - mainly upwelling enriched (7); subtropical (15, 16); central Pacific (10); north Pacific and south Equatorial Current (14)

Paralia sulcata - coastal (11); neritic (1, 22); north Boreal (1); meroplanktic; polyhalobous; mesoeuryhaline; cosmopolitan (22)

- Planktoniella sol - Equatorial Pacific (7, 16, 17, 18) - eutrophic indicator (7, 8); south Equatorial Current (14); tropical (1, 15, 23); warm (3); Gulf of Panama - mild upwelling (9); subtropical; not uncommon off southern California (23)
- Pseudoeunotia doliolus - Equatorial Pacific (2, 17) - eutrophic indicator (7, 8); warm water (3, 23); tropical, oceanic (1, 11); south Equatorial Current (14); subtropical (1, 15, 16); subtropical/ California Current; Subarctic Front (4); subarctic; transitional (10)
- Rhizosolenia alata - planktic; polyhalobous; meio-to mesoeuryhaline, cosmopolitan (22); Equatorial Pacific - mainly oligotrophic (7); south Equatorial Current and north Pacific (14); subarctic (10); Gulf of Panama - especially during strong upwelling (9); oceanic; often coastal; temperate; common off California and north to Alaska (23)
- R. bergonii - planktic; polyhalobous (22); Equatorial Pacific (2, 7, 16, 17) - eutrophic indicator (8); warm water (3, 22, 23), tropical oceanic (1, 11, 15, 22); south Equatorial Current (14); central Pacific (10); subtropical (22); Gulf of Panama - mild upwelling (9)
- R. calcar-avis - planktic; polyhalobous; euryhaline; warm water; tropical/temperate (22); Equatorial Pacific - mainly oligotrophic (7); central Pacific (10); Gulf of Panama - mild upwelling (9)
- R. styliformis - planktic; polyhalobous; meioeuryhaline (22); cosmopolitan (7, 10, 22); Equatorial Pacific - mainly oligotrophic (7); south Equatorial Current (14); central Pacific (10); south Boreal (16); Gulf of Panama - mild upwelling (9); oceanic; north temperate; common off California - sometimes fairly numerous (23)
- Roperia tessalata - Equatorial Pacific (2, 7); warm water (3); tropical oceanic (1, 11, 12); subtropical (15, 16); central Pacific (10); transitional (south of Subarctic Front) (10); south Boreal (1)
- Skeletonema costatum - Gulf of Panama (9); coastal (10); Peru upper slope - upwelling (11, 19); neritic; cosmopolitan (23)
- Stephanopyxis turris - meroplanktic; (neritic); polyhalobous, oligoeuryhaline; cosmopolitan - mainly subtropical to temperate (22); Gulf of Panama - mild to

strong upwelling (9)

Surirella fastuosa - occasional in plankton off southern and Lower California (23)

Synedra indica - planktic, polyhalobous (22)

Thalassionema nitzschioides - planktic (?meroplanktic), polyhalobous, ?pleio to meioeuryhaline (22), cosmopolitan (10) - but more often in cold water (22); neritic (1, 10, 23); continental margin (11); Equatorial Pacific - mainly upwelling enriched (7); Gulf of Panama - mild to strong upwelling (9); subtropical (15, 16); Boreal (1); subtropical/California Current (4); North Pacific and south Equatorial Current (14); Subarctic Front (4, 10); off California and from Alaska to the Gulf of California (23)

T. nitzschioides var. parva - planktic, polyhalobous, ?euryhaline, warm water (22); tropical oceanic (11); Equatorial Pacific - mainly upwelling enriched (7)

T. eccentrica - planktic; polyhalobous; ?euryhaline (22); continental margin (11); neritic (12); Equatorial (17); south Equatorial Current (14); central Pacific; transitional; subarctic (10); north Boreal (1, 15); cold (3); cosmopolitan (2) - mainly coastal (20); common by never abundant off California (23)

T. gravida - neritic (1, 15, 23); arcto-boreal (1, 15); cold water (3); northern; never common off California (23); spores = cold, high productivity water (4)

T. leptopus - planktic; polyhalobous; ?euryhaline; warm water (22); cosmopolitan (2); warm to temperate (0°-40°C at least, in culture) (21); chiefly oceanic but frequently neritic; reported occasionally off California (23)

T. lineata - planktic; polyhalobous (22); Equatorial (2) - mainly upwelling enriched (7); warm water (3, 22); tropical to subtropical (1, 15, 16, 21, 22); Gulf of Panama - especially mild to strong upwelling (9)

T. oestrupii - planktic; polyhalobous; tropical (11, 15); subtropical (1, 16); subtropical/California Current (4); Subarctic Front (4); cosmopolitan (13, 22); oceanic (11, 13); occasionally coastal (13)

T. symmetrica - cosmopolitan (6.5°-28.5°C at least, in culture) (20)

T. tenera - cosmopolitan, preferably coastal (21)

Thalassiothrix longissima - north Boreal (5); subarctic (10); planktic; polyhalobous (22); arctic-boreal to north temperate; present in low abundance - Gulf of California to Alaska (23)

T. mediterranea - Gulf of Panama - mild to no upwelling (9); temperate to south temperate; present - sometimes in moderately large numbers, off southern California and in Gulf of California (23)

Trachyneis aspera - benthic; polyhalobous; meioeuryhaline; cosmopolitan (22)

Triceratum - mostly benthic genus (1)

- (1) Russian studies (Semina, 1958; Jousé, 1962, 1963; Jousé et al., 1962) as summarized in Kanaya and Koizumi (1966)
- (2) Kolbe (1954)
- (3) Kanaya and Koizumi (1966)
- (4) Sancetta (1979)
- (5) Guillard and Kilham (1977)
- (6) Kozlova and Muhina (1967)
- (7) Belyaeva (1970, 1971, 1972)
- (8) Desrosieres (1969)
- (9) Smayda (1963, 1966)
- (10) Venrick (1971)
- (11) Schuette and Schrader (1979)
- (12) Schuette and Schrader (1981)
- (13) Fryxell and Hasle (1980)
- (14) Hasle (1959)
- (15) Jousé et al. (1971)
- (16) Muhina (1971)
- (17) Pavillard (1935)
- (18) Rampi (1952)
- (19) DeVries and Schrader (1981)
- (20) Fryxell and Hasle (1972)
- (21) Hasle and Fryxell (1977)
- (22) Gersonde (1980)
- (23) Cupp (1943)