64. MICROFOSSIL DISTRIBUTION IN COARSE-FRACTION (>150 μm) ANALYSIS OF DEEP SEA DRILLING PROJECT SITE 480, CENTRAL GULF OF CALIFORNIA: PRELIMINARY RESULTS[1]

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ABSTRACT

We examined the relative abundance of various components in the coarse fraction (>150 μm) from a selected portion of the DSDP Site 480 piston core. The components consist mainly of diatoms, radiolarians, benthic and planktonic foraminifers with minor amounts of sponge spicules, terrigenous material, volcanic glass(?), dehydrated gypsum crystals, and spines of unknown biological origin. The examination shows that the siliceous organisms abound in the laminated sediments and that the calcareous organisms are more abundant in the nonlaminated sediments. Seasonal upwelling is responsible for the deposition of laminated sediments. The upwelling creates a strong oxygen-minimum zone, restricting the occurrence of burrowing benthic organisms and benthic foraminifers.

INTRODUCTION

Hydraulic piston coring recovered a nearly continuous, 152-meter sediment section from the Guaymas Basin in the central Gulf of California (Fig. 1). Site 480 is in a highly productive area (Zeitzschel, 1969), where a strong oxygen-minimum layer in the water column impinges on the slopes of the seafloor (Calvert, 1966). The lack of oxygen eliminates the burrowing benthic endofauna and thus preserves the laminae formed by seasonal upwelling during the dry season and preserves terrigenous material during the wet season (Byrne and Emery, 1960). Down-core, the laminated sections are separated by nonlaminated zones, probably caused by increased oxygen in the water. The oxygen increase allows the establishment of a benthic community of organisms whose burrowing destroys the laminations (Schrader et al., 1980).

This chapter examines the relative abundance of various components in the sediment coarse fraction greater than 150 μm. Trends in the abundance of coarse-fraction components can then be used to examine ecological changes. We are concerned with an 8.6-meter section of Hole 480 from a depth of 7.8 meters to 16.4 meters. The section represents approximately 12,000 years—assuming that one pair of laminae indicates one year and that each pair of laminae averages about 0.7 mm in thickness (Schrader et al., 1980).

The sampling interval of 10 cm allows us to examine large-scale ecological changes occurring over hundreds of years. Changes occurring on this scale are primarily due to world-wide climatic fluctuations rather than local or regional short-term changes. We chose this section for preliminary study because it has sections of laminated and nonlaminated sediments.

METHODS

Surface scrapings from Hole 480 were taken at 10-cm intervals over the length of the core. Each 10-cm interval was represented by a composite sample weighed before and after drying. We then prepared the samples for diatom analysis by boiling them in H_2O_2 and sodium pyrophosphate to remove the organic matter and disperse the clay-size material. We sieved the samples through a 150 μm mesh to obtain the coarse fraction. The remainder of the material was processed for diatom analysis (Schrader and Gersonde, 1978), and the coarse fraction was dried and placed in microscopical counting slides. Counts of radiolarians, benthic foraminifers, and planktonic foraminifers were made and multiplied by a factor (1 g/sample wt.) standardizing the data to one-gram dry sample.

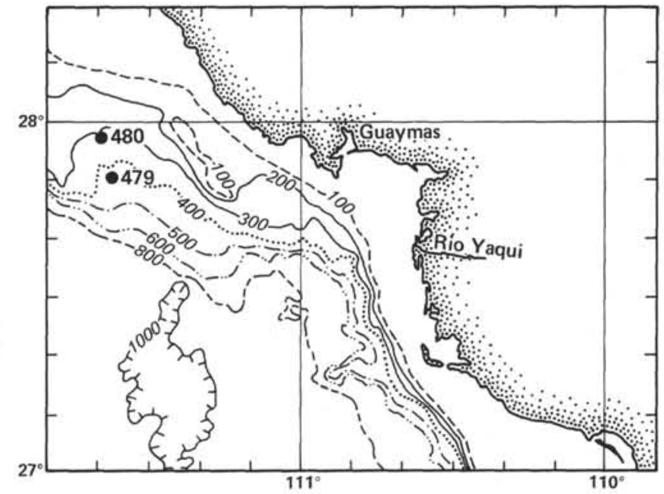

Figure 1. DSDP Site 480. Depth contours are in fathoms (1 fathom = 1.83 m).

MICROFOSSIL DISTRIBUTION

The vertical distribution of microfossils in the interval from 780 cm to 1640 cm is shown in Figure 2. This figure should be used only for recognizing general trends in the distribution of the microfossils. The scale is logarithmic and too small for accurately plotting and reading the actual fossil counts. The original data (Table 1) should be consulted for more specific information.

The first column shows the distribution of laminated and nonlaminated sections as well as a gap in the stratigraphic column. We do not know whether this gap represents a missing section or if it was caused by a separa-

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[1] Curray, J. R., Moore. D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

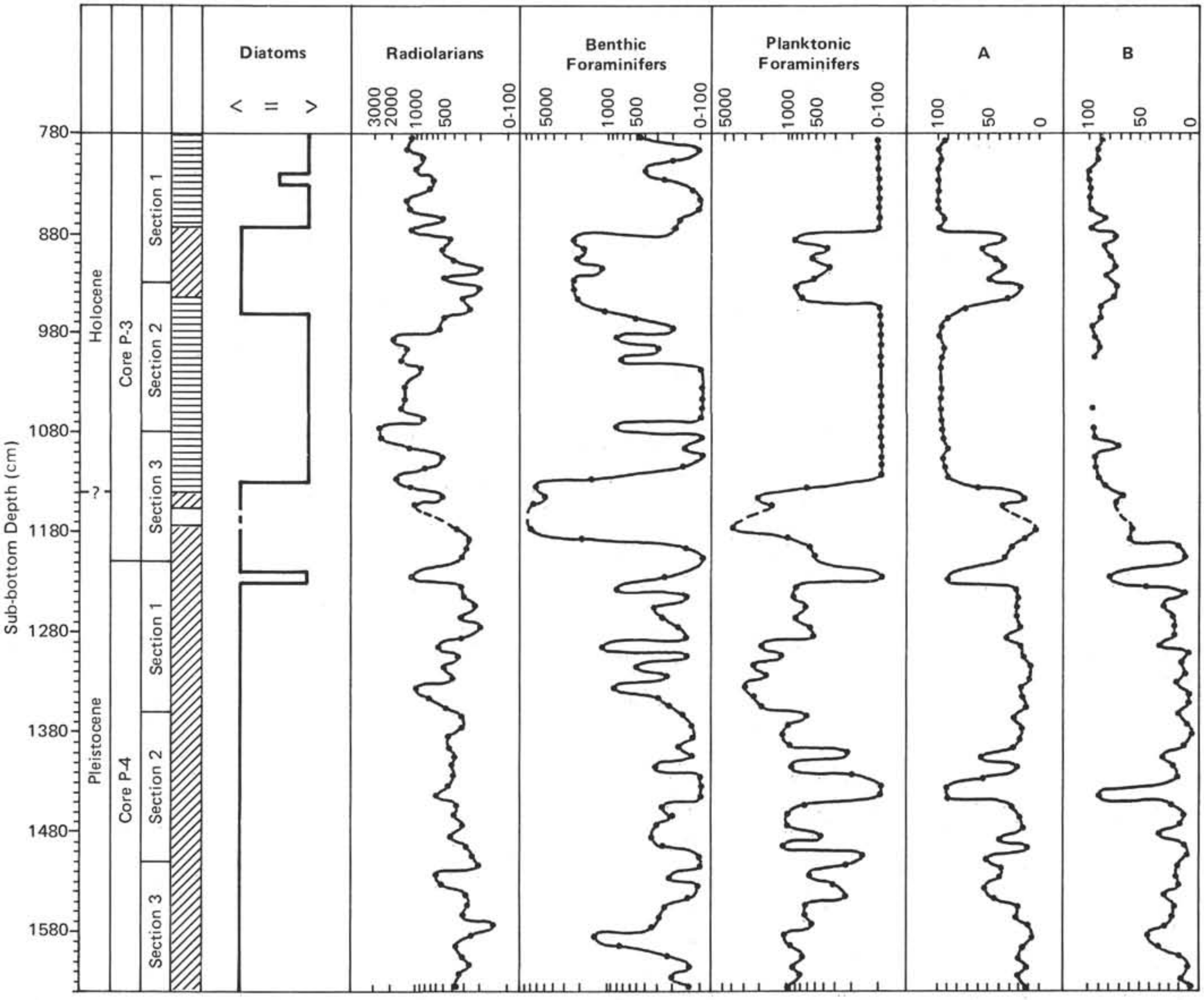

Figure 2. Numbers of microfossils in one-gram dry sample plotted against depth. (Diatom abundance was recorded as less than, equal to, or greater than other microfossils in the sample. Radiolarians, benthic foraminifers, and planktonic foraminifers are recorded on a logarithmic scale. Column A is radiolarians/radiolarians + planktonic foraminifers. Column B is benthic foraminifers/planktonic + benthic foraminifers. Horizontal lines on the stratigraphic column represent laminated sections, and diagonal lines represent nonlaminated sections. The blank area is a stratigraphic gap.)

tion of the core material during the coring process. The lack of data in the interval from 1020 to 1030 cm was caused by an anomalously low sample weight, which in turn provided a very high standardizing factor. This yielded obviously erroneous counts, so we excluded this sample. No data are available for the 1210 to 1220-cm sample.

The relative abundance of diatoms is shown in the second column of Figure 2. The diatoms were not counted individually, but we made visual estimations of their abundance compared to the other fossils. Figure 2 shows that diatoms are generally in greater abundance than all other microfossils in laminated sections and in lesser abundance in nonlaminated sections. Most of the diatoms consist of species of *Coscinodiscus* (not *Coscinodiscus nodulifer*) in laminated and nonlaminated sediments. Occasional blooms of *Thalassiothrix longissima* occur in the laminated sections, for example, in the 1000- to 1010-cm interval.

Radiolarians are common in every sample and show a distribution pattern similar to that of the diatoms. Radiolarians, in general, are much more abundant in laminated sections. Their average abundance in the nonlaminated zones is 400 to 500 per gram of dry sample. In the laminated sections, they average 1000 to 2000 per gram. It was not obvious that any change in predominant species occurred or that there was any change in the nassellarian/spumellarian ratio when we compared the laminated and nonlaminated sections—this based on a cursory visual examination. A closer inspection might reveal differences.

Benthic foraminifers show a distribution pattern opposite to that of diatoms and radiolarians. In laminated sections, they average under 200 per gram of dry sam-

Table 1. Counts and ratios of microfossils for each 10-cm depth increment from Cores 3 and 4, DSDP Hole 480.

Sample (interval in cm)	Radiolarians	Benthic Foraminifers	Planktonic Foraminifers	Radiolarians: Radiolarians + Benthic Foraminifers	Benthic Foraminifers: Planktonic + Benthic Foraminifers
3-1, 0-10	1213	432	61	95	88
10-20	1379	30	3	100	91
20-30	859	197	19	98	91
30-40	1122	413	0	100	100
40-50	659	266	0	100	100
50-60	736	122	0	100	100
60-70	1343	24	0	100	100
70-80	1328	43	0	100	100
80-90	501	179	30	94	86
90-100	1231	185	3	100	98
100-110	454	2582	874	34	75
110-120	540	1976	387	58	84
120-130	422	2257	552	43	80
130-140	200	1256	373	35	77
140-150	544	2544	512	52	83
3-2, 0-10	202	2530	854	19	75
10-20	336	2325	735	31	76
20-30	271	1191	102	73	92
30-40	543	543	45	92	92
40-50	605	197	5	99	98
50-60	2017	847	8	100	99
60-70	1386	299	25	98	92
70-80	1559	772	14	99	98
80-90	941	0	0	100	
90-100					
100-110	1448	0	0	100	
110-120	1418	0	0	100	
120-130	1580	80	0	100	100
130-140	883	0	0	100	
140-150	2875	888	0	100	100
3-3, 0-10	2731	14	0	100	100
10-20	1250	163	57	96	74
20-30	545	80	0	100	100
30-40	896	175	0	100	100
40-50	1880	1670	50	97	97
50-60	1255	6868	639	66	91
60-70	529	5601	2192	19	72
70-77	1180	7150	1760	40	80
77-91					
91-100	398	7603	4283	9	64
100-110	287	2218	1125	20	66
110-120	297	154	636	32	19
120-130	355	74	563	39	12
4-1, 0-10					
10-20	1278	266	32	98	89
20-30	363	921	888	29	51
30-40	352	152	988	26	13
40-50	244	334	676	27	33
50-60	375	290	909	29	24
60-70	218	187	629	26	23
70-80	354	157	562	39	22
80-90	658	1353	2155	23	39
90-100	383	162	1389	22	10
100-110	533	550	2799	16	16
110-120	435	255	1935	18	12
120-130	1162	944	3351	26	22
130-140	833	320	2763	23	10
140-150	542	252	2192	20	10
4-2, 0-10	340	176	693	33	20
10-20	331	134	1114	23	11
20-30	477	127	1235	28	9
30-40	475	182	1003	32	15
40-50	392	136	224	64	38
50-60	408	316	970	30	25
60-70	403	59	218	65	21
70-80	456	0	0	100	
80-90	647	32	0	100	100
90-100	374	265	653	36	29
100-110	400	200	1032	28	16
110-120	313	310	1069	23	22
120-130	424	329	429	50	43
130-140	296	256	1212	20	17
140-150	262	31	162	62	16
4-3, 0-10	220	90	245	47	27
10-20	625	224	631	50	26
20-30	564	102	333	63	23
30-40	292	138	245	54	36
40-50	286	247	645	31	28
50-60	311	288	686	31	30
60-70	160	344	588	21	37
70-80	258	1505	1212	18	55
80-90	389	760	972	29	44
90-100	320	235	711	31	25
100-110	288	136	899	24	13
110-120	350	221	782	31	22
120-130	370	156	1026	27	13

ple; in the upper, nonlaminated section (875–960 cm) and in the upper portion of the lower nonlaminated section (1140–1190 cm), the benthic foraminifers average several thousand per gram of dry sample. Below 1190 cm, their numbers fluctuate considerably and average several hundred per gram of dry sample, even though the section is completely nonlaminated. The benthic foraminifers have periodic fluctuations of numbers in laminated and nonlaminated sections. The pulses of increase in the laminated sections (810–820, 980–990, 1000–1010, and 1070–1080) contain a low diversity fauna consisting of *Virgulina* and *Bolivina* species. These pulses correspond to increases in radiolarian numbers, but the planktonic foraminiferal abundance does not change. The pulses of increase in the nonlaminated sections correspond to increased numbers of radiolarians and planktonic foraminifers. The benthic foraminiferal diversity in these zones is much greater than in the laminated sections. The proportion of the fauna made up of *Virgulina* is reduced. *Bolivina* is the most abundant representative, but species of *Uvigerina, Planulina, Bulimina*, and others occur.

Planktonic foraminifers have a distributional pattern similar to the benthic foraminifers. They have large numbers averaging over 1000 per gram of dry sample in the nonlaminated sections and near zero in the laminated sections. The laminated zones contain a cold-water fauna dominated by *Globigerina pachyderma* mixed with a smaller number of warm water species including *Globorotalia menardii*. This mixture is caused by the seasonal upwelling bringing cold waters to the surface during part of the year. The nonlaminated sections are represented by what Bandy (1961) terms a eurythermal fauna predominated by *Globigerina bulloides*.

The ratio of radiolarians to radiolarians + planktonic foraminifers is shown in Figure 2. Except for the 1220–1230- and the 1430–1450-cm intervals, the highest ratios occur in the laminated zones. Diester–Haass (1977) suggests that this ratio can be correlated to productivity in surface waters: The higher ratios reflect high productivity. Our study agrees: We found the highest ratios in sediments reflecting seasonal upwelling.

The last column of Figure 2 shows the ratio of benthic foraminifers to total foraminifers. In the upper half of the stratigraphic section, benthic foraminifers are more abundant than planktonic foraminifers; in the lower half, the planktonic foraminifers are more numerous.

Minor components of the coarse fraction consist of small numbers of sponge spicules, terrigenous material (quartz and mica), volcanic glass(?), dehydrated gypsum, and spines of unknown biological origin. These spines are about 1 mm in length and taper from a blunt to a pointed end. The width of the blunt end averages about 0.1 mm. They are flat and have no internal canal or structure. The spines are clear, and a test with HCl confirmed their calcium carbonate composition. Their occurrence is restricted to the interval from 890 to 910 cm, where they compose about 20% of the sample. The volcanic glass(?) consists of a sphere and a tear-drop-shaped fragment of translucent, amber-colored material in the 1030 to 1040-cm sample. The dehydrated gypsum (bassanite) is variously abundant from 1171 cm to the base of the section. It does not occur in the upper, nonlaminated zone, or in any of the laminated sections. This mineral occurs in single and twinned crystals whose composition we determined by X-ray analysis. These crystals formed within the sediment column as indicated by the incorporation of diatom frustules and other fossils into the crystal form.

CONCLUSIONS

The trends in the relative abundance of the microfossils (Fig. 2) lie in the ecological differences that accumulate and preserve laminated sediments. The laminated sediments accumulate under conditions such as those prevailing in the Gulf. The seasonal wind patterns cause upwelling that, in turn, provides nutrients for large diatom blooms (van Andel, 1964). These high productivity conditions (Zeitzschel, 1978) provide nutrients for other planktonic organisms, such as radiolarians and planktonic foraminifers, to flourish. Under these conditions, the diatoms and radiolarians accumulate in large numbers. Decaying organic matter descends, increasing the carbon dioxide in the water column and creating a strong oxygen-minimum zone. The increased CO_2 creates water that aggressively dissolves the calcium carbonate (Berger, 1976). Thus, the effects of dissolution fluctuate with the overlying productivity. As productivity increases, the lysocline becomes shallower and planktonic foraminifers dissolve more readily. The same occurs in the benthic boundary layer and in the interstitial waters. But as dissolution occurs, the water becomes increasingly saturated with calcium carbonate, thus decreasing the dissolution effects. Because the oxygen-minimum zone impinges on the sea floor, the number of benthic foraminifers in the laminated sections is small. A few species apparently adapted and survived in low oxygen environments, but their numbers and diversity are low. They are also masked by the large accumulation of siliceous organisms. The benthic foraminifers are probably not dissolved because they are rapidly buried and because the interstitial waters are less aggressive than the water column in dissolving calcium carbonate—particularly in the low-oxygen conditions where the interstitial waters are not exchanged with the bottom waters by burrowing organisms (Berger and Soutar, 1970).

The nonlaminated sediments accumulate under considerably different conditions. Diatom production is lower, and with this low primary productivity comes lower production of other planktonic organisms. There are fewer radiolarians in these sections. Benthic and planktonic foraminifers are very abundant because of the increased oxygen content of the water and decreased dissolution effects. Their increase is also facilitated by the lack of masking or of dilution by siliceous organisms.

The peaks in abundance of radiolarians, benthic foraminifers, and planktonic foraminifers in general seem to correspond to one another (particularly in the lower half of the section), suggesting that the environmental conditions causing the fluctuations affect the bottom waters as well as the surface waters. The most probable cause of the fluctuations is changing climatic conditions that alter the upwelling pattern (= lower primary productivity and lower nutrient levels), temperature, and sea level. All probably contribute to the fluctuating abundance of the organisms. The peaks of abundance are probably a response to periodic increases in primary productivity. If these conditions persist long enough, the anoxic environment is established; as a result, foraminiferal preservation declines and laminated sediments accumulate.

The transition from laminated to nonlaminated and from nonlaminated to laminated sediments indicates some difference in timing between the changes in numbers of organisms and the sedimentological changes. In moving up the section, the first transition is from nonlaminated to laminated. At about 1200 cm the benthic foraminiferal population increases dramatically. Planktonic foraminifers and radiolarians also increase near this point. These increases might be a response to renewed upwelling conditions that allowed the foraminifers to flourish until the oxygen-minimum zone was reestablished and dissolution effects increased.

In changing from a laminated to a nonlaminated sequence (about 945 cm), the organisms respond well before the laminae cease to accumulate. The sedimentological changes lag behind the biological changes, probably because it takes a significant period of time before a benthic community is sufficiently established to destroy the seasonal laminations. Based on the contacts of the upper, nonlaminated section, it appears that it takes approximately twice as long to establish the benthic foraminiferal community as it does to remove it. Each 10-cm interval represents about 150 years in the laminated sections and somewhat less in the nonlaminated. It took approximately 400 to 500 years for the benthic foraminifers to reach their peak and only 100 to 200 years for their numbers to decline the same amount. Another explanation is that some sediments were originally deposited as laminae but were later bioturbated. This occurs near the transition from a laminated to a nonlaminated sequence. X-radiographs of the sediment show that thin sections of nonlaminated sediments are occasionally found within the laminated zones.

A significant change in the benthic/planktonic foraminiferal ratio occurs near the middle of the section. In the lower half, the planktonic foraminifers are more abundant, and in the upper half, the benthonic foraminifers are more numerous. This change corresponds to the previously mentioned changes occurring at about 1200 cm. The change in the ratio is caused by the availability of increased nutrient for the benthic community. Prior to the establishment of upwelling conditions, the primary productivity was low, and less organic matter and nutrients were available to the bottom-dwelling fauna. After primary productivity is increased, nutrient availability is no longer limiting, and perhaps the controlling factor becomes a greater fecundity in the benthic foraminifers.

The major nonlaminated zones represent glacial periods that caused major fluctuations in climate and sea level. Although a detailed, chronological framework has not been established for the core, it appears that the nonlaminated section of the lower half of Figure 2 represents conditions during the last glaciation. Thus, the Pleistocene/Holocene boundary occurs somewhere near the midsection. The idea that nonlaminated sections might represent cooler climatic periods or glacial intervals is reinforced by the presence of colder-water diatom floras in these sediments rather than in the laminated sections.

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