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# The evolution of Miocene surface and near-surface marine temperatures: Oxygen isotopic evidence

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## ABSTRACT

**Oxygen isotopic analyses of planktonic foraminifera have provided a picture of many aspects of the evolution of the temperature structure of surface and near-surface oceans during the Miocene. In time slice studies oceanographic conditions have been interpreted from synoptic maps of isotopic data at between 22 and 27 locations in the Atlantic, Pacific and Indian Oceans. Three time slice intervals were examined: 22 Ma (foraminiferal zone N4B) and 16 Ma (N8) in early Miocene time; and 8 Ma (N17) in late Miocene time. In time series studies, the evolution of oceanographic conditions at single localities during an extended period of time were inferred from $\delta^{18}O$ values of planktonic foraminifera.**

**Surface waters warmed throughout the early Miocene at almost all localities examined. At 22 Ma, the Pacific Ocean was characterized by relatively uniform temperatures in the equatorial region but a marked east-west asymmetry in the tropical South Pacific, with higher temperatures in the west. Between 22 Ma and 16 Ma, tropical Pacific surface waters warmed, but warmed more in the east than the west. At 16 Ma, the asymmetric distribution of temperatures in the South Pacific Ocean remained, and the latitudinal temperature gradient, inferred from the isotopic data, was gentler than that of either the late Miocene or Modern ocean.**

**Between the late early Miocene and late Miocene, surface waters at most low-latitude Pacific sites warmed while those at high latitudes cooled or remained unchanged. However, surface waters at high northern latitudes in the Atlantic Ocean as well as in the eastern equatorial Atlantic cooled, while water temperatures remained**

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**relatively unchanged at most South Atlantic sites. Surface waters warmed in the southernmost Atlantic, off the tip of South Africa. By 8 Ma, the east-to-west asymmetry of the temperature distribution in the tropical South Pacific Ocean had lessened. Surface water temperatures had become quite similar to those of the Modern ocean except that those in the equatorial Pacific Ocean were lower than today's. This is reflected in the latitudinal gradient of surface temperatures at 8 Ma which is less steep than that of modern temperatures.**

**The pattern of surface temperatures and their evolution through the Miocene is consistent with the biogeographic distributions of planktonic foraminifera described by Kennett et al. (this volume). The isotopic data provide a more detailed picture of the evolution of Miocene surface temperatures than had been hitherto available, and serve as a framework against which hypotheses can be tested regarding the cause of the middle Miocene cooling of deep waters and the formation of the East Antarctic ice sheet.**

## INTRODUCTION

Abundant sedimentologic, paleontologic and geochemical evidence indicate that the climate of the world underwent major changes during the Miocene epoch. Among the most striking manifestations of these changes were the cooling of deep-ocean waters and the rapid growth of the East Antarctic ice sheet during the middle Miocene. Oxygen isotopic ratios of planktonic and benthic foraminifera from the Pacific Ocean have suggested that these events were accompanied by a significant decrease in meridional heat transport and an associated increase in the latitudinal temperature gradient. Low-latitude regions in the Pacific warmed while high-latitude regions cooled as Antarctic ice volume increased (Savin et al., 1975).

In the Cenozoic Paleoceanography Project (CENOP), the details of the evolution of Miocene oceanographic conditions and climate have been investigated using a variety of approaches. In time slice studies, an attempt has been made to construct global synoptic maps of either proxy data or inferred oceanographic conditions at selected times during the Miocene. Such studies require good stratigraphic control in order to assure that the time slice maps are indeed synoptic. In time series studies, downcore variations of stable isotopic ratios, lithology, and microfloral and microfaunal assemblages have been examined in detail at individual drilling sites. The goal of such studies is to determine how oceanographic conditions varied through time at a single locality. In this paper we present the results of three time slice studies (at 22, 16, and 8 Ma) based upon oxygen and carbon isotopic analyses of a large number of planktonic foraminifera of Miocene age from Deep Sea Drilling Project (DSDP) sites in the Atlantic, Pacific and Indian Oceans. We have related these to the results of new and previously published oxygen isotopic time series studies of Miocene planktonic foraminifera from the Atlantic and Pacific Oceans. The planktonic foraminiferal isotopic data of the time slice and time series studies are the basis of our interpretation of the evolution of the temperature structure of surface and near-surface oceans over much of the world through Miocene time. The isotopic data can also be used to evaluate and constrain interpretations based upon microfaunal and microfloral biogeographic data.

## ISOTOPIC ANALYSES AND NOTATION

Isotopic analyses that have not been previously published were carried out at one of three laboratories: Case Western Reserve University, Scripps Institution of Oceanography, or University of Rhode Island. Results are reported in the usual delta ($\delta$) notation as deviations in per mil (parts per thousand) of the $^{18}O/^{16}O$ or $^{13}C/^{12}C$ ratio of the sample from that of the PDB standard. In each laboratory, analyses were related to PDB through repeated analyses of NBS-20 (Solenhofen Limestone), for which Craig's (1957), values, $\delta^{18}O = -4.14$ and $\delta^{13}C = -1.06$ were assumed. Analytical precision (1 standard deviation) of both oxygen and carbon isotopic ratios in each laboratory, as judged by replicate analyses of the same sample, is usually better than 0.1 per mil.

## TIME SLICE STUDIES

Three Miocene time intervals were chosen for synoptic studies of global oceanographic conditions from isotopic measurements presented in this paper as well as from sedimentologic and paleontologic data discussed in the companion papers in this volume. The time slice intervals (Figure 1) were chosen to represent three oceanographic regimes which were inferred from an earlier study of benthic foraminiferal isotopic time series data (Savin et al., 1981):

1) an early early Miocene interval characterized by bottom waters warmer than those of today although cooler than those of the later early Miocene, and a relatively small volume of Antarctic ice (planktonic foraminiferal Zone N4B, ~22 Ma);

2) a late early Miocene interval characterized by warm bottom waters and minimal Antarctic ice (Zone N8, ~16 Ma);

3) a late Miocene interval characterized by cold bottom waters and a large Antarctic ice sheet (Zone N17, ~8 Ma).

An attempt was made to choose time slice intervals for which the benthic oxygen isotopic record suggested relatively little variability on a time scale of about one million years. This was done to minimize the effect of small errors in stratigraphic correlation on the accuracy of the synoptic maps to be constructed. A further consideration in the choice of the time slice intervals was that the

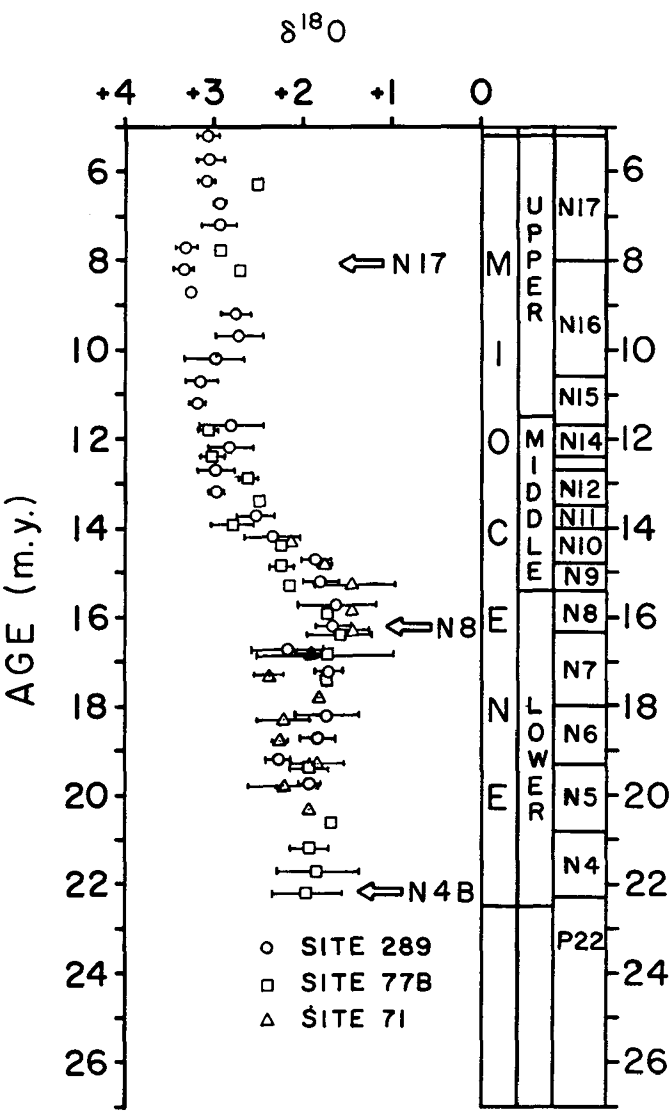



Figure 1. $\delta^{18}O$ values of benthic foraminifera from equatorial Pacific DSDP Sites 71, 77B and 289, adjusted for estimated effect of isotopic disequilibrium and averaged over 500,000-year intervals. From Savin et al. (1981). Times chosen for the CENOP time slice intervals in foraminiferal zones N4B, N8, and N17 are indicated.

intervals be represented in the sediments of a large and geographically well-distributed number of DSDP sites. The DSDP sites chosen for planktonic isotopic time slice study are listed in Table 1 and shown on the map in Figure 2. Each time slice study was based upon isotopic analysis of between 2 and 19 sediment samples per site. The sampled interval was chosen to represent approximately 100,000 years of sedimentation where possible, but in some instances may have been as long as several hundred thousand years (Barron et al., this volume).

For each time slice interval at each site, planktonic and benthic foraminifera were separated for isotopic analysis. Typically, between two and four species of planktonic foraminifera were separated, but occasionally as few as one or as many as eight

TABLE 1. CENOP TIME SLICE SITES FOR PLANKTONIC FORAMINIFERAL ISOTOPIC STUDY

| | Time Slice N17 | Time Slice N8 | Time Slice N4B | Latitude | Longitude | Water depth |
|---|---|---|---|---|---|---|
| **Atlantic Ocean** | | | | | | |
| SITE 14 | | | X | 28 19.89'S | 20 56.46'W | 4346 m |
| SITE 15 | | X | | 30 53.38'S | 17 58.99'W | 3938 m |
| SITE 16 | X | | | 30 20.15'S | 15 42.79'W | 3526 m |
| SITE 18 | | | X | 27 58.72'S | 08 00.70'W | 4018 m |
| SITE 357 | | | X | 30 00.25'S | 35 33.59'W | 2086 m |
| SITE 360 | X | X | X | 35 50.75'S | 18 05.79'E | 2949 m |
| SITE 362 | X | X | X | 19 45.45'S | 10 31.96'E | 1325 m |
| SITE 366A | | X | X | 05 40.7'N | 19 51.1'W | 2853 m |
| SITE 369A | | X | | 26 35.5'N | 14 59'W | 1752 m |
| SITE 391A | | X | | 28 13.61'N | 175 37.00'W | 4974 m |
| SITE 398D | | X | | 40 57.6'N | 10 43.1'W | 3910 m |
| SITE 407 | | | X | 63 56.32'N | 30 34.56'W | 2472 m |
| SITE 408 | | X | | 63 56.32'N | 10 43.1'W | 3910 m |
| SITE 516 | X | X | | 30 16.59'S | 35 17.11'W | 1313 m |
| SITE 526A | X | X | X | 30 7.4'S | 3 8.3'E | 1054 m |
| **Pacific Ocean** | | | | | | |
| RC12-418 | X | | | 38 6'N | 170 1.2'E | |
| SITE 55 | | X | X | 9 18.11'N | 142 32.1'E | 2850 m |
| SITE 62.1 | X | | | 1 52.2'N | 141 56.3'E | 2591 m |
| SITE 71 | | X | X | 4 28.28'N | 140 18.91'W | 4419 m |
| SITE 77B | X | X | X | 0 28.90'N | 133 13.70'W | 4291 m |
| SITE 158 | X | | | 6 37.36'N | 85 14.16'W | 1953 m |
| SITE 173 | X | | | 39 57.71'N | 125 27.12'W | 2927 m |
| SITE 206C | X | X | X | 32 00.75'S | 165 27.15'E | 3196 m |
| SITE 207A | X | | | 36 57.75'S | 165 26.06'E | 1389 m |
| SITE 208 | X | X | X | 26 06.61'S | 161 13.27'E | 1545 m |
| SITE 279 | | X | X | 51 20.14'S | 162 38.10'E | 3341 m |
| SITE 281 | X | X | | 47 59.84'S | 147 45.85'E | 1591 m |
| SITE 289 | X | X | X | 00 29.92'S | 158 30.69'E | 2206 m |
| SITE 292 | X | X | X | 15 39.11'N | 124 39.05'E | 2943 m |
| SITE 296 | X | X | X | 29 20.41'N | 133 31.52'E | 2920 m |
| SITE 310 | X | | | 36 52.11'N | 176 54.09'E | 3516 m |
| SITE 317B | X | X | X | 12 00.09'S | 162 15.78'W | 2598 m |
| SITE 319 | X | X | | 13 01.04'S | 101 31.46'W | 4296 m |
| SITE 448 | | X | X | 16 20.46'N | 134 52.45'E | 3483 m |
| SITE 470 | X | | | 28 54.56'N | 117 31.11'W | 3549 m |
| SITE 495 | | X | X | 12 29.78'N | 91 02.26'W | 4140 m |
| **Indian Ocean** | | | | | | |
| SITE 214 | X | X | X | 11 20.21'S | 88 43.08'E | 1671 m |
| SITE 237 | X | X | | 7 49.99'S | 58 07.48'E | 1623 m |
| SITE 238 | X | X | | 11 09.21'S | 70 31.56'E | 2832 m |

species were analyzed. In most cases, isotopic analyses were made using between 0.3 and 0.8 mg of $CaCO_3$. Mean values of the isotopic compositions of each planktonic species at each site for each time slice are tabulated in Appendix I and the complete planktonic data set, except for South Atlantic sites, is presented in Appendix II (on microfiche). Data for the South Atlantic sites are included in Hodell and Kennett (this volume).

Figure 3 is a graph of $\delta^{18}O$ and $\delta^{13}C$ values of four planktonic species from the N17 time slice at Site 296 plotted against subbottom depth. The quality of the data in this figure is typical of the majority of time slice data sets. We consider it to be a data set of good quality, in that its applicability to this study is straightforward. The variability in the $\delta^{18}O$ values of any of the planktonic species, which reflects a combination of analytical errors and real oceanographic variability, is small. (In this case, the standard deviation of the $\delta^{18}O$ value of each species is less than 0.2 per mil.) Furthermore, the relative ranking of $^{18}O$-enrichments of the planktonic species is consistent throughout the sequence. In most data sets, as in this one, changes in the $^{18}O$-rankings of the species are rare, and involve reversals of relatively small magnitude when present.

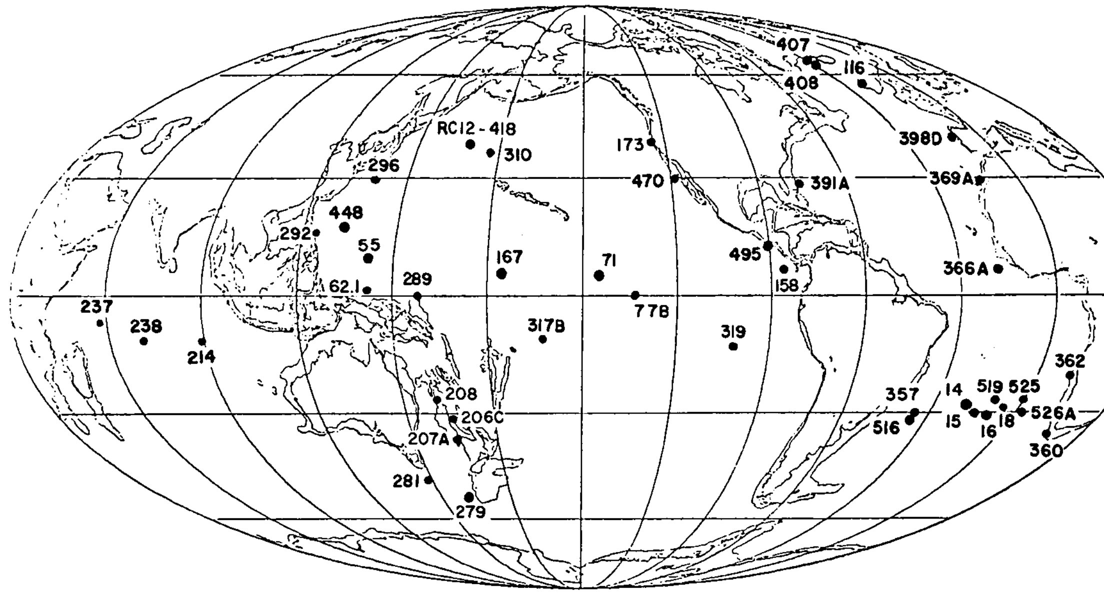



Figure 2. Map of sites from which samples were taken for use in the stable isotopic time slice study.

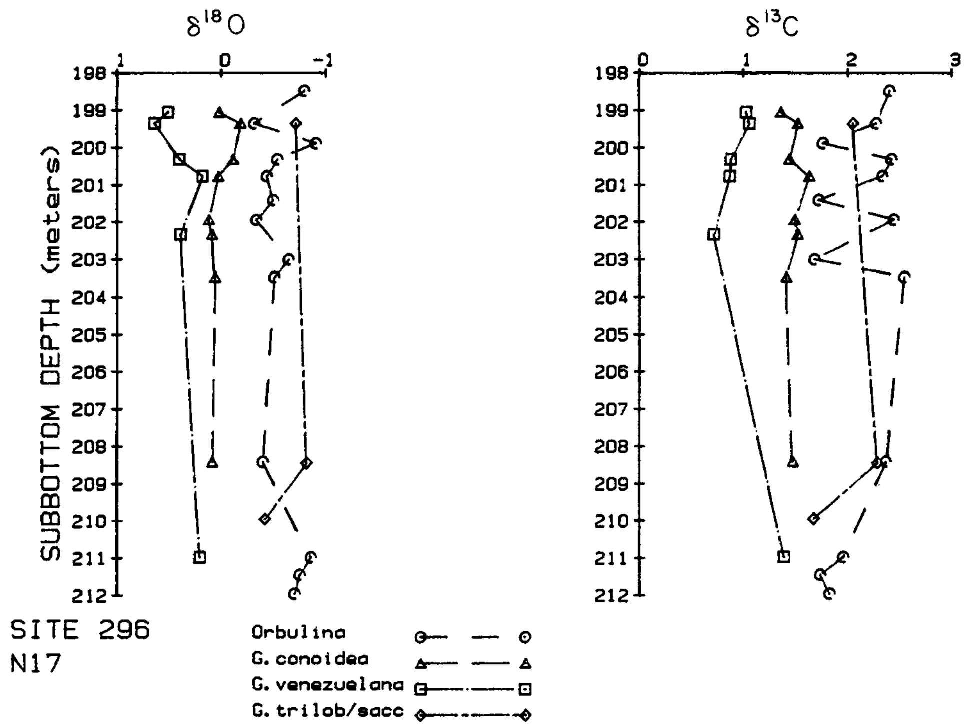



Figure 3. $\delta^{18}O$ and $\delta^{13}C$ values of four planktonic foraminiferal species from the N17 time slice interval of DSDP Site 296. The data are typical of the quality of most time slice data sets.

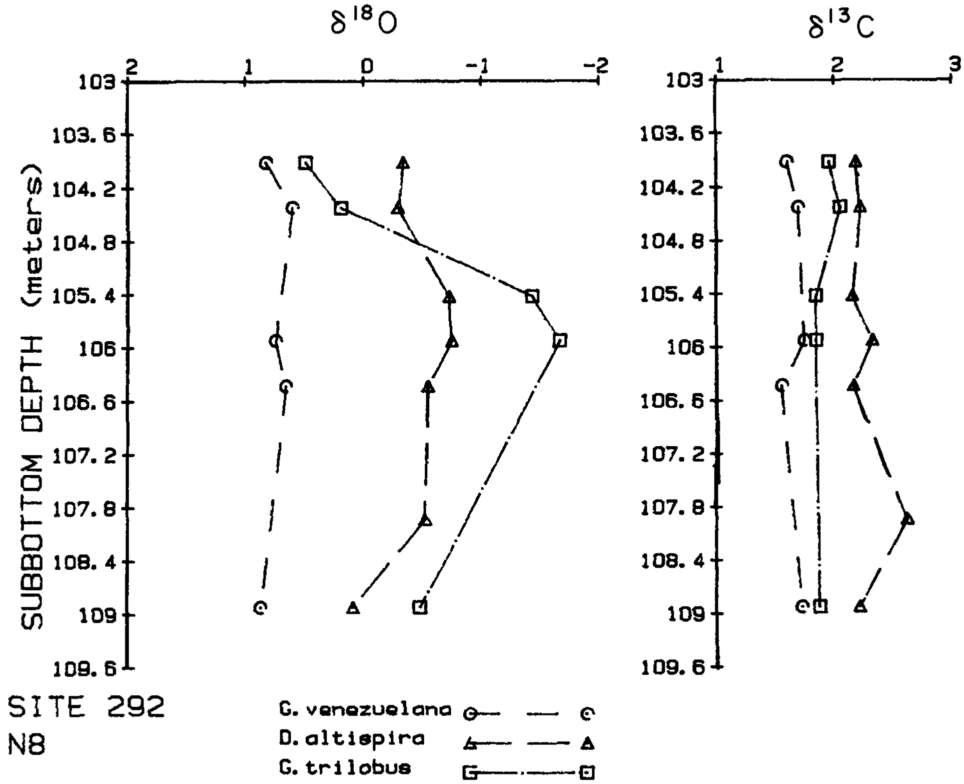



Figure 4. $\delta^{18}O$ and $\delta^{13}C$ values of three planktonic foraminiferal species from the N8 time slice interval of DSDP Site 292. The data are an example of one of the few data sets of quality less than optimum for purposes of this study.

Figure 4 illustrates one of the small number of time slice data sets of less than optimum quality, in this case the N8 data set for DSDP Site 292. We consider it to be of lesser quality because the standard deviations of some $\delta^{18}O$ values are large, the order of $^{18}O$-enrichment of planktonic species changes within the sequence, and the magnitudes of reversals in the relative $^{18}O$-enrichments are large. That is, the combination of analytical error plus real oceanographic variability decreases the accuracy with which oceanographic conditions at the site can be characterized by the mean $\delta^{18}O$ value of a planktonic foraminiferal species. If oceanographic conditions were, indeed, relatively stable at a locality during the time interval represented by a time slice sample set, and if the isotopic data were representative of conditions during that interval, the order of $^{18}O$-enrichment of species, reflecting depth stratification and seasonal succession, should remain constant.

Each planktonic $\delta^{18}O$ value used in a time slice reconstruction is the average of all of the analyses of a species from the appropriate interval at a single site. One measure of the suitability of the mean value as an indicator of conditions is the standard deviation about the mean. Sixty-two percent of the 193 standard deviations are 0.2 per mil or less, 85 percent are 0.3 per mil or less, and 95 percent are 0.4 per mil or less. As sample sizes increase, standard deviations converge on a value of about 0.2 per mil. The observed distribution of standard deviations closely resembles the theoretical distribution of a series of measurements of identical samples with a normally distributed analytical error of 0.2 per mil and a distribution of sample sizes identical to that of the time slice data set.

### *A Modern Isotopic Time Slice*

In this section we demonstrate, through the comparison of modern oceanographic conditions with the $\delta^{18}O$ values of shallow-dwelling Holocene planktonic foraminifera, that: a) when data from large numbers (hundreds) of sites are available, synoptic maps and latitudinal $\delta^{18}O$ gradient plots of the foraminiferal data reflect the major features of surface and near-surface oceanography; and b) a modern time slice which yields a useful, though not detailed, picture of modern marine surface temperature distribution can be generated from a relatively small number of sites. We conclude that analysis of Miocene foraminifera from a similar number of sites permits the reconstruction of Miocene oceanographic conditions with comparable detail.

***Synoptic Maps.*** While isotopic analyses of Recent planktonic foraminifera are unavailable from the vicinity of each of the sites used in the Miocene time slice reconstructions, there are a large number of published isotopic analyses of shallow-dwelling planktonic foraminifera in core-top samples from South Pacific,

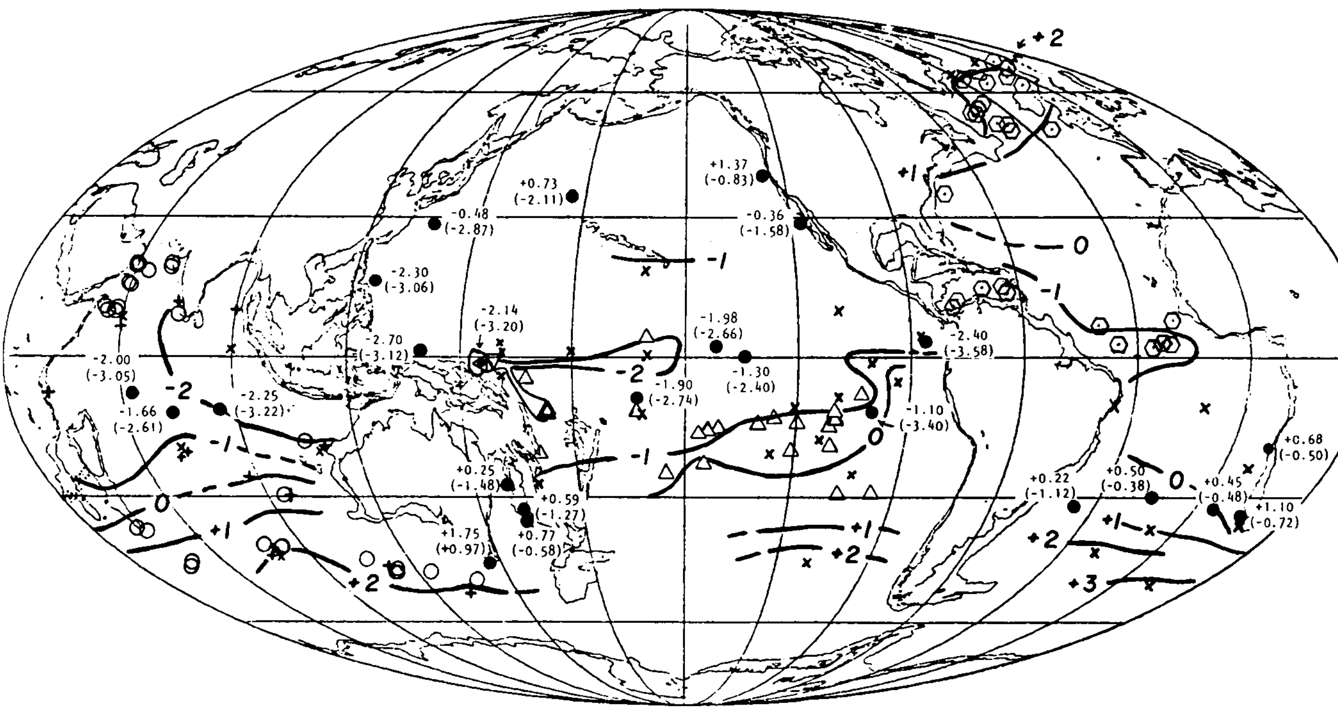



Figure 5. Contours drawn about published $\delta^{18}O$ values of core-top, and presumed Holocene, shallow-dwelling planktonic foraminifera. Data sources are: (Δ) Savin and Douglas, 1973; (X) Shackleton, 1977; (+) Williams, 1977; (O) Curry and Matthews, 1981; (·) Vincent and Shackleton, 1981; (⟨●⟩) Durazzi, 1981. Data are listed in Appendix III. Dark circles are locations of sites used in the N17 time slice reconstruction. Numbers associated with those points are calculated modern equilibrium $\delta^{18}O$ values for winter and, in parentheses, for summer as explained in text. Equilibrium $\delta^{18}O$ values were not used in drawing contours.

Indian and Atlantic Ocean sediments (Savin and Douglas, 1973; Shackleton, 1977; Williams, 1977; Curry and Matthews, 1981; Vincent and Shackleton, 1980; Durazzi, 1981; and others). Data compiled from a number of sources are contoured on the map in Figure 5 and listed in Appendix III (on microfiche). In general, where sample distribution is relatively dense, the $^{18}O/^{16}O$ ratios of shallow-dwelling Holocene planktonic foraminifera provide a reasonable picture of surface temperature distribution and circulation. For example, the expected latitudinal temperature gradients, the steepening of temperature gradients at the subtropical convergence in the South Pacific and South Atlantic, the tongue of cool water extending westward across the equatorial Pacific, and the westward increase in temperature in the equatorial Pacific are all evident from the core-top isotopic data.

Comparison of the Holocene foraminiferal data set with modern oceanographic conditions at each of the Holocene sites is now in progress. Some idea of the accuracy with which Recent oceanographic conditions are reflected in the isotopic ratios of shallow-dwelling foraminifera from core-top samples can be obtained from the comparison between modern conditions at each of the late Miocene (N17) time slice localities and the conditions inferred from the isotopic ratios of the Holocene foraminifera. Using data from the National Oceanographic Data Center (NODC), we have examined winter (minimum) and summer (maximum) surface temperatures as well as $\delta^{18}O$ values of calcite in isotopic equilibrium with surface waters (referred to below as equilibrium $\delta^{18}O$ values). Calculations of the latter were made using relationships between salinity and surface water $\delta^{18}O$ values derived from the data of Craig and Gordon (1965) and listed in Table 2, and the relationship

$$t\,(^\circ C) = 16.4 - 4.2^* (\delta_c - \delta_w) + 0.13 * (\delta_c - \delta_w)^2$$

TABLE 2. RELATIONSHIPS BETWEEN SALINITY AND $\delta^{18}O$ OF SURFACE WATERS USED IN CALCULATIONS OF EQUILIBRIUM $\delta^{18}O$ VALUES

| Ocean | Relationship# |
|---|---|
| Equatorial Pacific | $\delta^{18}O$ = 0.222 x salinity - 7.50 |
| Pacific E-W transect 13° S | $\delta^{18}O$ = 0.553 x salinity - 19.35 |
| South Pacific | $\delta^{18}O$ = 0.687 x salinity - 23.74 |
| N.E. Pacific | $\delta^{18}O$ = 0.544 x salinity - 18.63 |
| Indian* | $\delta^{18}O$ = 0.481 x salinity - 16.53 |
| South Atlantic | $\delta^{18}O$ = 0.106 x salinity - 3.00 |

# $\delta^{18}O$ values of surface water relative to S.M.O.W.
*Relationship given by Williams (1977).

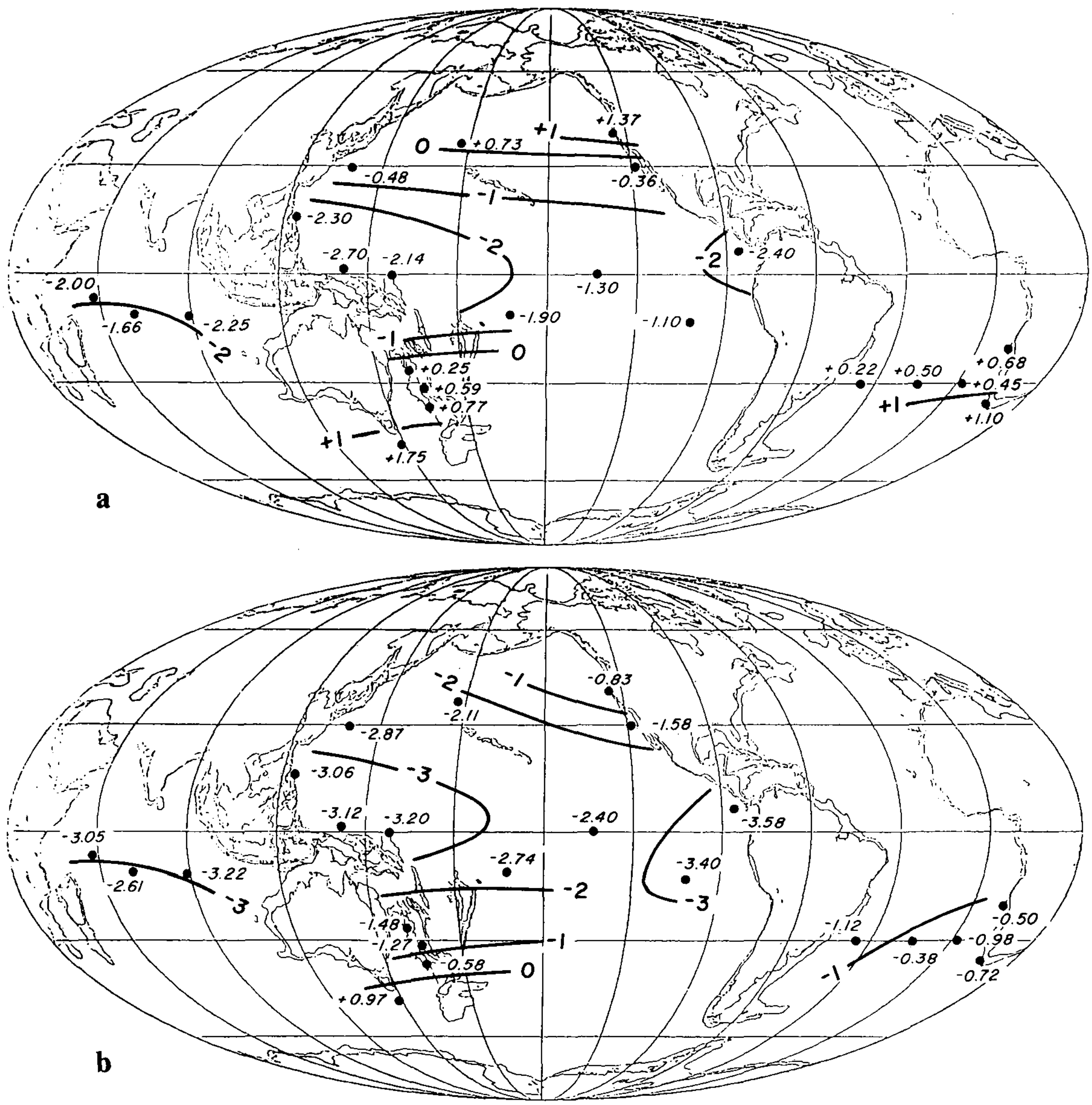



Figure 6. Equilibrium $\delta^{18}O$ values calculated for surface water at each of the sites used in the late Miocene (N17) time slice reconstruction: 6a. shows highest (coldest annual) value at each site; 6b. shows lowest (warmest annual) value.

where $\delta_c$ is the isotopic composition of $CO_2$ liberated from calcite at 25° C and $\delta_w$ is the isotopic composition of $CO_2$ in equilibrium with water at the same temperature (Epstein, unpublished manuscript).

Equilibrium $\delta^{18}O$ values for winter and summer (i.e., most positive and most negative values) at the 23 sites used in the late Miocene time slice study are plotted on maps in Figures 6a and 6b, and are superimposed on the contours drawn through the Holocene data set in Figure 5. In most cases where comparisons can be drawn, Holocene $\delta^{18}O$ values interpolated from the contours fall between the winter and summer equilibrium values as expected, indicating that the Holocene data provide useful information about the Modern oceans.

The modern oceanographic data and equilibrium $\delta^{18}O$ values also provide information about the detail with which global oceanographic conditions can be inferred from 22 to 27 data points, the number of localities examined in the Miocene time slice studies. A map of modern winter (i.e., coldest annual) surface temperature at the 23 sites used in construction of the late Miocene time slice is shown in Figure 7. Relatively gross features of the modern surface conditions can be discerned from the limited amount of data on this map or from the equilibrium $\delta^{18}O$ values plotted in Figures 6a and b. Westward-increasing surface temperatures in the western equatorial Pacific transect are evident, as is the high temperature at Site 158 in the eastern equatorial Pacific. However, the single data point in that region

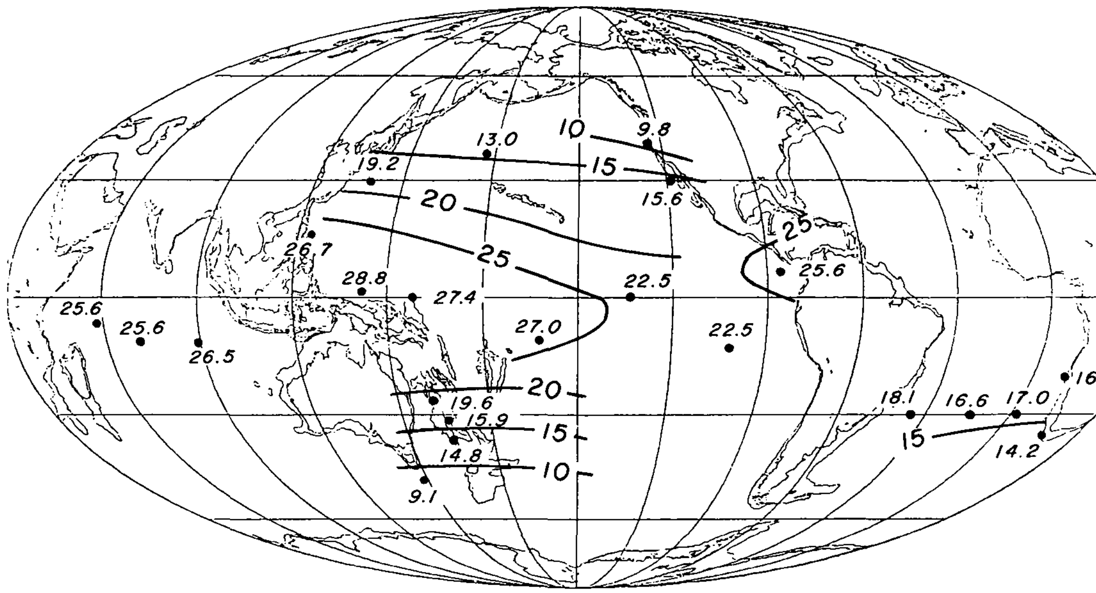



Figure 7. Modern winter (coldest annual) surface temperature at each of the 23 sites used in construction of the late Miocene (N17) time slice.

gives no indication of the complex and convoluted shape of surface isotherms evident in the more densely sampled Holocene planktonic data set of Figure 5. From the small number of data points, it can be discerned, as expected, that Pacific winter temperatures poleward of 30° latitude are markedly lower than those at lower latitudes. Winter temperatures in the tropical Indian Ocean are similar to those in the Pacific, while those of higher southern latitudes (30 to 45°) in the Pacific are similar to those at comparable latitudes in the Atlantic. Most of the above generalizations about winter surface temperatures also hold true for summer surface temperatures (not shown).

Conclusions drawn about modern oceanographic conditions from 23 surface temperature measurements (Figure 7) are similar to those that can be drawn from the equilibrium $\delta^{18}O$ data (Figures 6a and b). Because of the large contour intervals used (1 per mil or 5°C), the effects of local variations in $\delta^{18}O$ of sea water have been largely obscured. While relatively crude, significant details of modern oceanography can be discerned. The resolution of Miocene oceanography from a similar number of data points should be comparable.

***Latitudinal Gradient Diagrams.*** In Figure 8, all of the Holocene $\delta^{18}O$ values of shallow-dwelling planktonic foraminifera are plotted as a function of latitude. In Figures 9a and b, the modern winter and summer equilibrium $\delta^{18}O$ values of all of the sites used in the N17 time slice reconstruction are plotted in similar fashion. Superimposed upon the modern equilibrium values are envelopes about the Holocene data. The overlap between the Holocene data and the winter equilibrium $\delta^{18}O$ data is almost complete, while many of the summer equilibrium $\delta^{18}O$ values, especially for latitudes north of 10° S, are more negative (i.e., warmer) than the measured Holocene values. The relationship between the modern equilibrium data for the N17 sites and the Holocene data reflects the fact that shallow-dwelling planktonic foraminifera live below the sea surface where temperatures are lower than surface temperatures, and, especially in the case of subtropical and higher latitudes, growth of foraminiferal species may also be seasonally biased. Many of the summer equilibrium $\delta^{18}O$ values at the N17 sites are markedly lower than Holocene values at similar latitudes. Although a disproportionately large number of the N17 sites are located near coastal currents, there is no good correlation between salinity or proximity to coastal regions and the distance a summer equilibrium $\delta^{18}O$ value plots above the envelope about the Holocene data. Thus it is unlikely that the depleted values in the late Miocene are due to dilution of surface sea water at the N17 sites with low-$^{18}O$ fresh water.

These comparisons of modern equilibrium $\delta^{18}O$ values with Holocene isotopic data demonstrate the usefulness of even relatively few oxygen isotopic data points in defining major regional temperature differences and latitudinal temperature gradients. However, detailed reconstructions of surface oceanography require large amounts of isotopic data. Furthermore, because of factors such as seasonal growth patterns and depth stratification of foraminiferal species, the details of the relationship between the isotopic data and the temperature of the sea surface remain unclear.

### ***Presentation of Data for Miocene Time Slices***

In the discussion of the Miocene synoptic reconstructions that follows, the isotopic data of the late Miocene (N17) time slice are compared with the contours defined by the Holocene data set, which is taken to represent the response of shallow-dwelling foraminifera to modern oceanographic conditions. Differences between the Holocene and the late Miocene reconstruc-

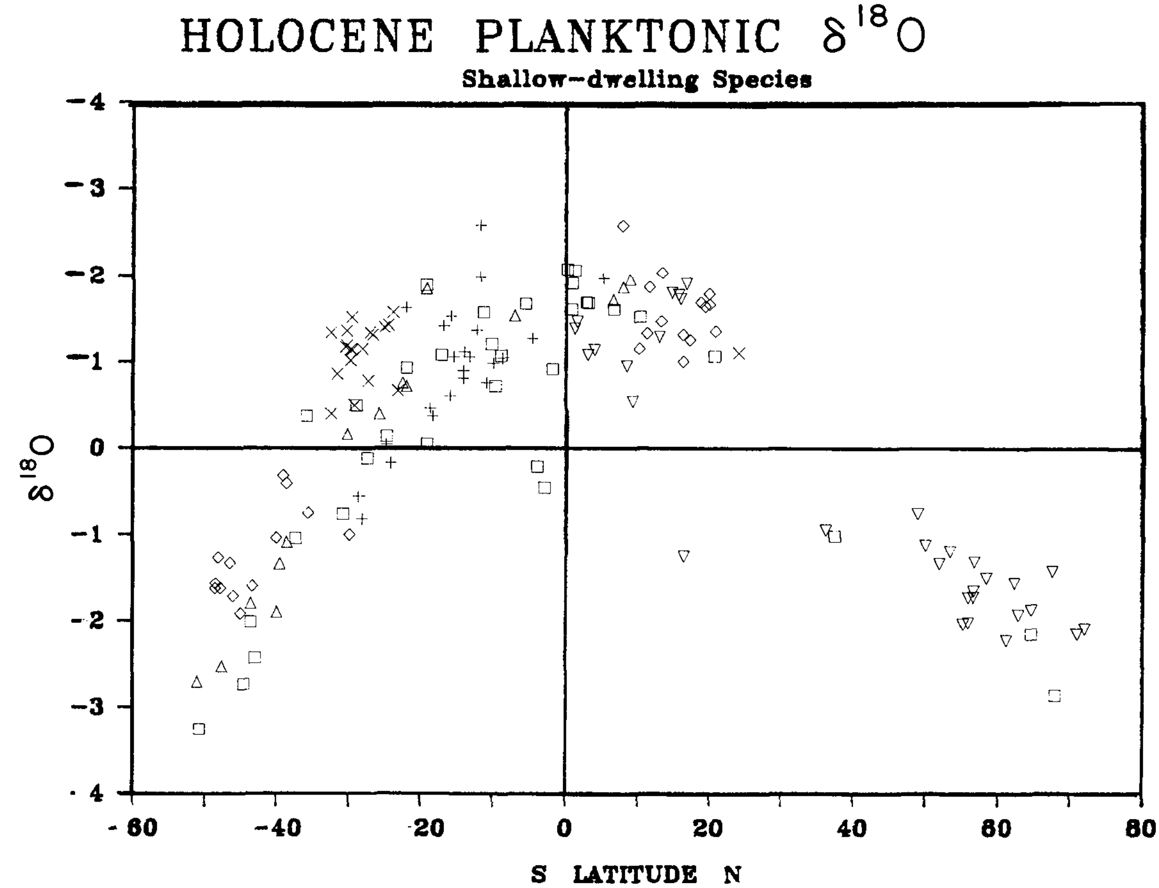



Figure 8. Latitudinal gradient of measured $\delta^{18}O$ values of Holocene shallow-dwelling planktonic foraminifera (See Figure 5). Data sources are: (□) Shackleton, 1977; (+) Savin and Douglas, 1973; (◊) Curry and Matthews, 1981; (Δ) Williams, 1977; (X) Vincent and Shackleton, 1980; (∇) Durazzi, 1981.

tions are then interpreted in terms of changes in oceanographic conditions between 8 Ma and the present. Similarly, the N8 synoptic reconstruction is compared with the N17 reconstruction and the N4B reconstruction is compared with the N8.

### *The N17 (8 Ma) Time Slice*

***Synoptic Map of Planktonic $\delta^{18}O$ Values.*** For most time slice localities, between two and five species of planktonic foraminifera were isotopically analyzed. This was done because living planktonic foraminifera are depth-stratified within the water column, and additional data obtained by analysis of multiple species should provide information about the thermal structure of the water column, especially in tropical regions where seasonal temperature variations are small. First we have considered the $\delta^{18}O$ values of those species with the lowest $^{18}O/^{16}O$ ratios in the samples from which they were taken, i.e., those inferred to be shallowest-dwelling, providing the most accurate information about conditions in surface or near-surface waters. The $\delta^{18}O$ values of deeper-dwelling planktonic species, the interpretation of their depth stratification and the implications for the three-dimensional temperature structure of the water columns will be discussed later. At all but one of the sites from the tropical Pacific and Indian Oceans, either *Globigerinoides sacculifer* or *Dentoglobigerina altispira* was the species with the lowest (i.e., warmest) $\delta^{18}O$ value. At Site 77B, analyses of *Gs. sacculifer* are not available, and *Globigerinoides quadrilobatus* exhibits the lowest $\delta^{18}O$ value of the species analyzed. At higher latitude Pacific sites, the species with the lowest $\delta^{18}O$ value was either *Globigerina nepenthes*, or *Orbulina universa.* In the South Atlantic, *Globigerinoides* exhibits the lowest $\delta^{18}O$ values.

***Late Miocene Surface Waters.*** Figure 10 is a map showing the lowest $\delta^{18}O$ values. The resemblance is clear between the $\delta^{18}O$ values of the late Miocene (N17) shallow-dwelling foraminifera and those of the Holocene (Figure 5), in most parts of the world where comparable data are available. Contours drawn through the Holocene Indian Ocean and South Atlantic data (Figure 7) are compatible with the late Miocene time slice data in almost every case. Woodruff et al. (1981), concluded that the average $\delta^{18}O$ value of sea water at 8 Ma did not differ from the

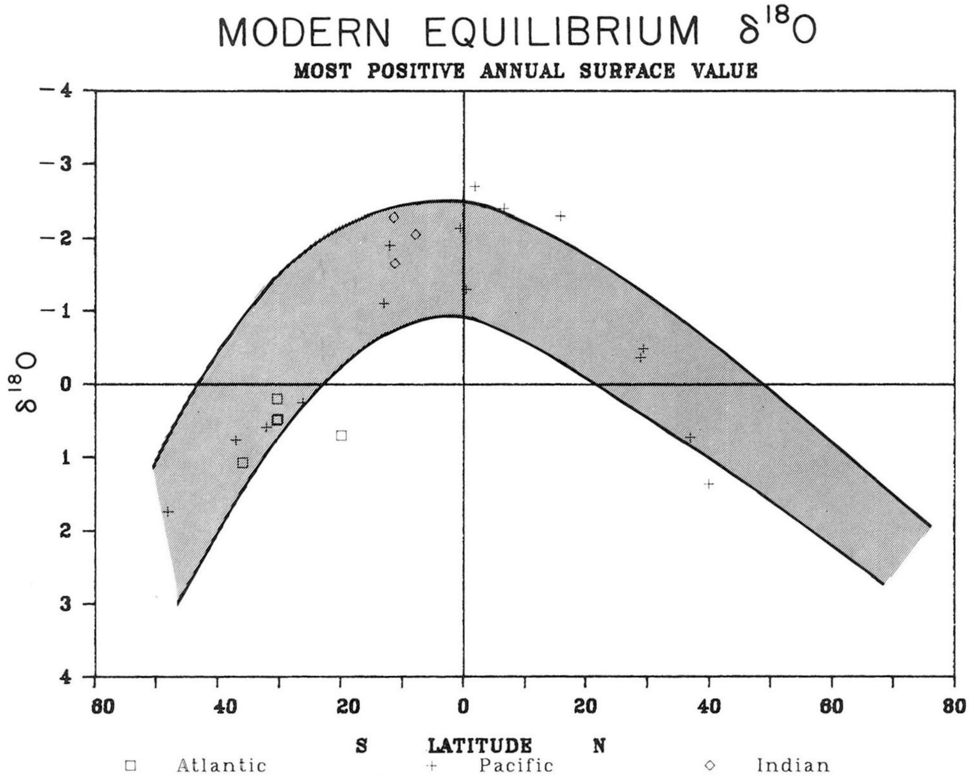



Figure 9a. Latitudinal gradient of highest (coldest annual) calculated modern equilibrium $\delta^{18}O$ values at all of the sites used in the N17 time slice reconstruction. The shaded region is an envelope about the measured Holocene data plotted in Figure 8.

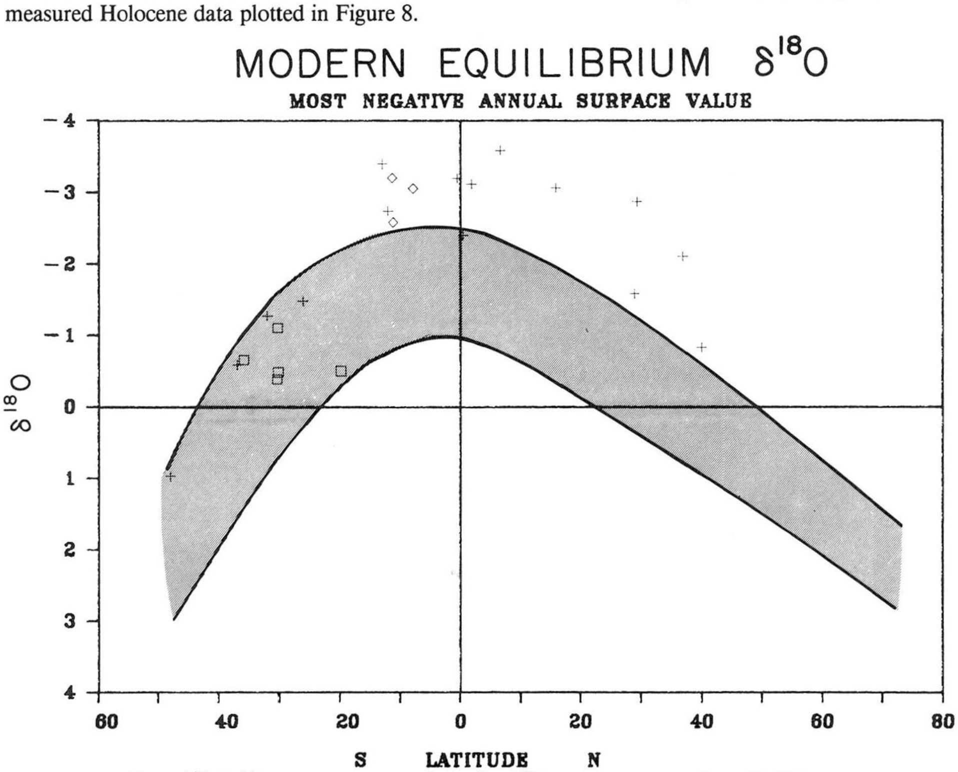



Figure 9b. Latitudinal gradient of lowest (warmest annual) calculated modern equilibrium $\delta^{18}O$ values at all of the sites used in the N17 time slice reconstruction. The shaded region is an envelope about the measured Holocene data plotted in Figure 8.

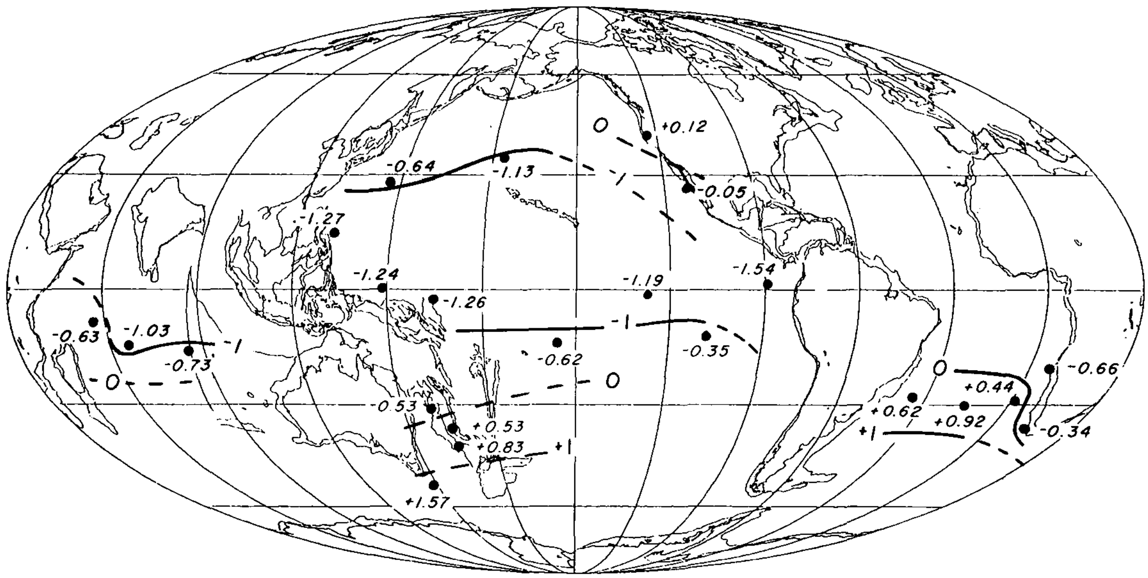



Figure 10. Map of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the most negative (warmest) $\delta^{18}O$ at each of the backtracked N17 time slice sites.

modern value by more than 0.3 per mil. Barring major differences between the regional variations in $\delta^{18}O$ values of modern surface waters and those at 8 Ma, the comparable $\delta^{18}O$ values of the late Miocene (N17) and Holocene foraminifera imply comparable water temperatures. There are no northwest Pacific or southwest Pacific Holocene data sets with which to compare the N17 samples, but the steep latitudinal gradient of late Miocene $\delta^{18}O$ values (2.1 per mil) in the southwest Pacific defined by Sites 208, 206, 207, and 281 is consistent with the modern steep latitudinal temperature gradient associated with the modern subtropical convergence in that region. Only in the western equatorial Pacific is there evidence of a significant difference between late Miocene and Holocene surface temperatures. At Site 289, the N17 $\delta^{18}O$ value of *Gs. sacculifer* is –1.26 per mil while nearby Holocene values are between –1.7 and –2.1 per mil. While there are no comparisons with Holocene data at Sites 62.1 and 292, to the west of Site 289, the $\delta^{18}O$ values of shallow-dwelling N17 planktonic foraminifera are approximately 1 per mil more positive (i.e., cooler) than winter equilibrium $\delta^{18}O$ values at those sites (Figure 6a), suggesting the possibility of significant warming of the western equatorial Pacific between 8Ma and the present.

The $\delta^{18}O$ values of shallow-dwelling late Miocene (N17) foraminifera are plotted as a function of backtracked latitude (Sclater et al., this volume) in Figure 11a. Superimposed on that data is the envelope about the Holocene data from Figure 8, offset by 0.3 per mil, the value assumed for the change in the $^{18}O/^{16}O$ ratio of sea water between 8 Ma and the present. Figure 11b is a similar plot, in which modern winter and summer equilibrium $\delta^{18}O$ values, offset by 0.3 per mil, are superimposed on the N17 data for 8 Ma. We conclude that the late Miocene (N17) latitudinal temperature gradient, as inferred from the oxygen isotopic ratios of shallow-dwelling planktonic foraminifera was somewhat shallower than that of the Holocene or of today, primarily because of higher Modern equatorial temperatures.

Given the uncertainties inherent in the interpretation of foraminiferal isotopic data (including some uncertainty in the average $\delta^{18}O$ value of sea water at 8 Ma), details of differences between surface conditions at 8 Ma and those of today cannot be resolved by the relatively small N17 data set.

***Depth Stratification of Late Miocene Planktonic Foraminifera.*** The relative rankings of $^{18}O$-enrichments of species of planktonic foraminiferal species from a single sample have frequently been interpreted as reflecting the relative rankings of depth habitats of those species during test growth. Interspecific differences in $^{18}O$-enrichments may also be affected by such factors as growth at different seasons, disequilibrium precipitation of calcite (Fairbanks et al., 1980), or encrustation with $CaCO_3$ associated with gametogenesis in water deeper and colder than that in which most chamber growth occurs (Duplessy et al., 1981). In addition, especially in subtropical and higher latitudes, interspecific differences may reflect the seasonal succession of foraminiferal species.

Average $\delta^{18}O$ values of each species of planktonic foraminifera at each late Miocene (N17) time slice site are shown in the histograms of Figure 12. The $\delta^{18}O$ values are a general indication of the temperature of the water inhabited by each species. (The values are, of course, also affected by regional variations in the $^{18}O/^{16}O$ ratio of sea water.) For tropical sites (30°N to 30°S) for which the data on the histogram are unshaded, the relative rankings of species primarily reflect depth stratification. However, when higher latitude samples are considered, indiscriminate comparisons of $\delta^{18}O$ values can be somewhat misleading, since

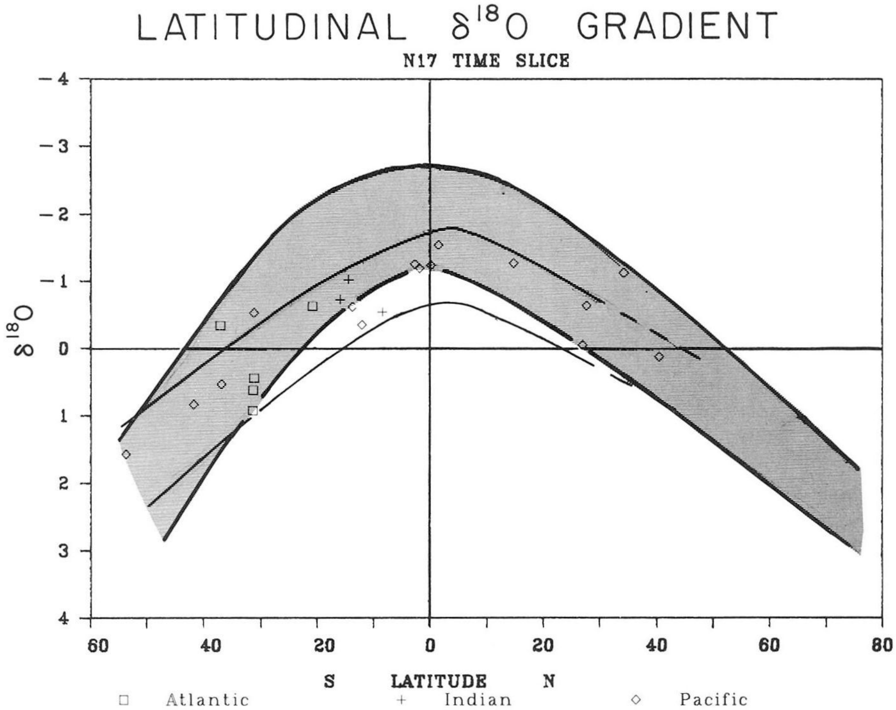



Figure 11a. Latitudinal gradient of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the lowest (warmest) $\delta^{18}O$ value at each of the N17 time slice sites. Shaded region is an envelope about the measured Holocene planktonic foraminiferal $\delta^{18}O$ values of Figure 8, displaced by 0.3 per mil to adjust for the estimated effect of changing ice volume on the mean $\delta^{18}O$ isotopic ratio of the oceans between 8 Ma and the present.

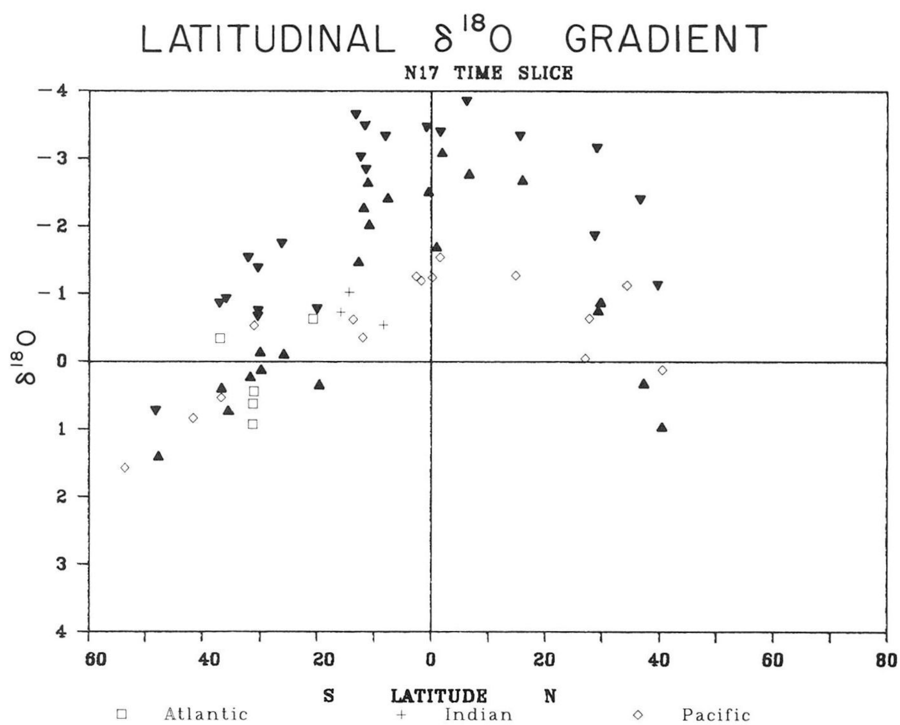



Figure 11b. Latitudinal gradient of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the lowest (warmest) $\delta^{18}O$ value at each of the N17 time slice sites (squares, crosses and diamonds). Filled triangles are calculated equilibrium $\delta^{18}O$ values for modern surface waters at each of the same sites (upward pointing = winter; downward pointing = summer) displaced by 0.3 per mil.

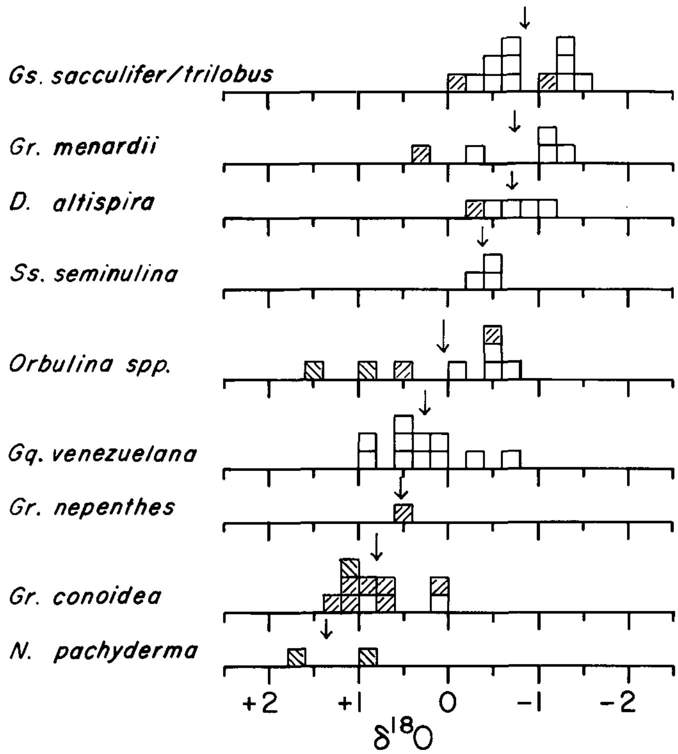



Figure 12. Histogram of average $\delta^{18}O$ values of individual species of planktonic foraminifera from each site in the N17 time slice study. Unshaded squares are data for samples with backtracked latitudes between 30°N and 30°S. (▨) indicates latitudes between 30 and 40° and (▧) indicates latitudes higher than 40°. Arrows indicate mean values of the averages for each species.

calcification may be seasonally biased and species that are deeper dwellers in the tropics may live closer to the surface in the cooler regions.

When the isotopic rankings of species are compared among sites, most species show consistent ranking from one site to another. In the tropics, *Gs. sacculifer/trilobus, D. altispira* and *Globorotalia menardii* consistently have similar low (i.e., warm) $\delta^{18}O$ values, indicative of growth near the surface. Among those, *Gs. sacculifer* usually exhibits the lowest $\delta^{18}O$ value. In tropical regions, *Globoquadrina venezuelana* invariably has the highest $\delta^{18}O$ value, indicating growth deep within the near-surface water column. At higher latitudes in the Pacific and in the South Atlantic, *Globorotalia conoidea* and *Neogloboquadrina pachyderma* consistently have the highest $\delta^{18}O$ values. Of all the species in the N17 samples analyzed, only *Orbulina universa* exhibits a wide range of $\delta^{18}O$ values, ranging from a low value, similar to that of *Gs. sacculifer* at tropical western Pacific Site 292 to high values, only slightly lower than those of *Gr. conoidea* and *N. pachyderma* at high latitude Sites 207 and 281.

***Three Dimensional Temperature Structure of the Late Miocene Oceans.*** When isotopic data are available for several planktonic species in a sample, including both shallow-dwelling and deep-dwelling species, the range of measured $\delta^{18}O$ values of those species should be a minimum for the annual range of equilibrium $\delta^{18}O$ values in the photic zone at the time the sediment was deposited.

Isotopic rankings of planktonic foraminiferal species of the N17 time slice along west-to-east transects in the tropical Pacific and Indian Oceans are shown in Figure 13. The total range of $\delta^{18}O$ values within a sample varies from as low as 0.65 and 0.89

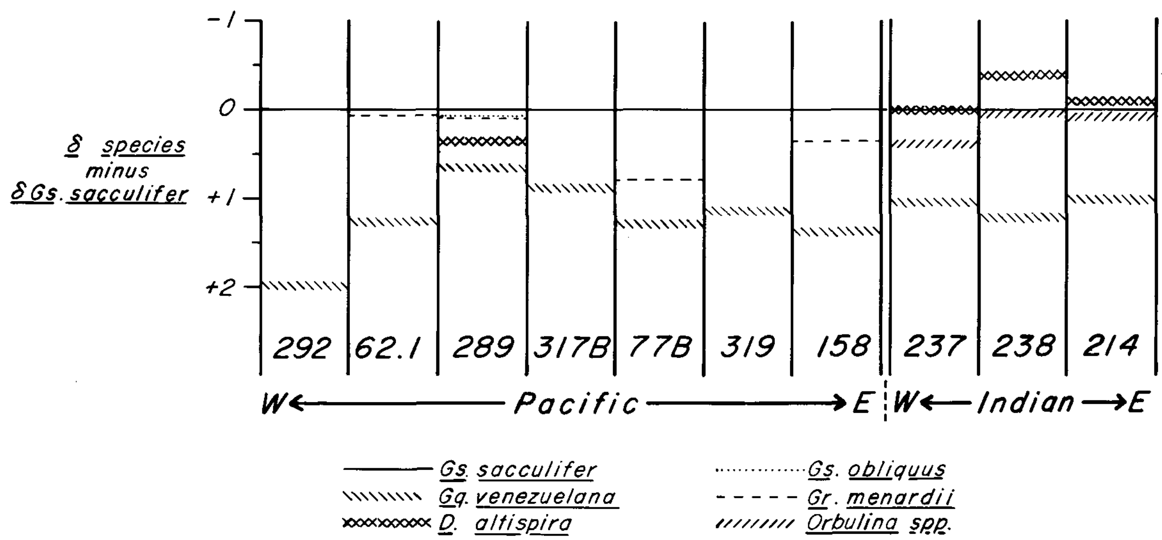



Figure 13. Ranges of $\delta^{18}O$ values of individual planktonic foraminiferal species at N17 time slice sites along west-to-east transects in the tropical Pacific and Indian Oceans. Values plotted are the differences between the $\delta^{18}O$ value of each species and that of *Gs. sacculifer* at the same site. (At Site 77B *Gs. sacculifer* was not analyzed and *Gs. quadrilobatus* was used instead.) Most values were obtained by averaging the differences in $\delta^{18}O$ values of foraminiferal species level-by-level (Appendix II) within a time slice sequence and may differ slightly from differences between mean values. Equilibrium $\delta^{18}O$ values were calculated as described in the text.

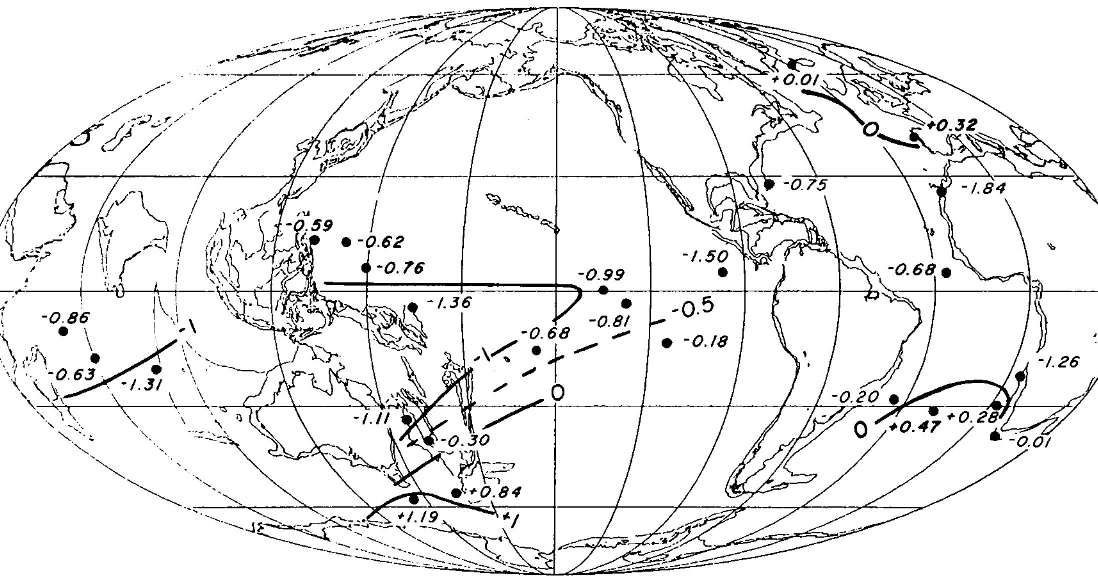



Figure 14. Map of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the most negative (warmest) $\delta^{18}O$ at each of the backtracked N8 time slice sites.

per mil at Sites 289 and 317B to 2.0 per mil at Site 292. At the remaining sites, the $\delta^{18}O$ ranges from 1.13 to 1.50 per mil. Attempts to compare the temperature structure of the tropical N17 ocean with that of today by correlating the measured N17 isotopic ranges with equilibrium $\delta^{18}O$ values in the photic zone (i.e., the upper 90 or 120 m) were inconclusive. However, it is noteworthy that the largest range of N17 $\delta^{18}O$ values was found at Site 292 where the smallest range of equilibrium $\delta^{18}O$ values (1.1 per mil between 0 and 90 m and 1.65 per mil between 0 and 120 m) are found. This suggests that at this site the thermal structure of the late Miocene water column may have been different from the Modern. (The likelihood of warming of the surface waters at this site since 8 Ma has already been noted.) We speculate that the position of the Kuroshio Current shifted relative to Site 292, which is now to the east of the western boundary current, and that during late Miocene time this site lay to the west of the boundary current, where the thermal gradient in the upper portion of the water column would have been steeper.

### *The N8 (16Ma) Time Slice*

***Synoptic Map of Planktonic $\delta^{18}O$ Values.*** The geographic coverage of time slice locations for the late early Miocene (N8) synoptic reconstruction is more complete in the Atlantic and less complete in the Pacific than is the coverage for the late Miocene (N17) reconstruction. Figure 14 is a map showing the lowest $\delta^{18}O$ value at each of the localities examined in the study of the N8 time slice. Most features of the distribution of $\delta^{18}O$ values on this map are similar to those of the corresponding map for the late Miocene (N17) time slice reconstruction (Figure 10). However, there are two notable differences in the Pacific data. First, $\delta^{18}O$ values of the westernmost tropical Pacific sites (55, 292, and 448) indicate lower temperatures than in the central and eastern equatorial Pacific during N8. In contrast, the $\delta^{18}O$ values of the N17 planktonic foraminifera from the westernmost tropical Pacific sites are among the warmest in the entire late Miocene synoptic reconstruction. Second, $\delta^{18}O$ values (and probably surface temperatures) of N8 planktonic foraminifera from Site 208, between Australia and New Zealand, are similar to tropical values. In contrast, during N17 the surface temperature at Site 208 was intermediate between those of the tropics and higher latitudes. In addition, the data suggest the existence of an east-west temperature gradient in the South Pacific during the N8 interval which was considerably weaker during N17.

The differences between $\delta^{18}O$ values of shallow-dwelling planktonic foraminifera in the N17 reconstructions and those from the same (or in two cases, nearby) sites in the N8 synoptic reconstructions are compared on the map in Figure 15. The differences have been adjusted by 0.5 per mil to compensate for the change in the $^{18}O/^{16}O$ ratio of sea water inferred to have been caused by the growth of the Antarctic ice sheet during early middle Miocene time (Woodruff et al., 1981). On this map, sites inferred to have warmed between N8 and N17 are indicated by negative values, and sites inferred to have cooled by positive values. Changes smaller than 0.35 per mil can probably be considered insignificant.

Assuming that the ice volume adjustment of 0.5 per mil is correct, and that there have not been any major changes in the regional variation of the $^{18}O/^{16}O$ ratio of surface waters, tropical Pacific surface waters typically warmed by 2 to 5°C between 16 Ma and 8 Ma. An error in the estimate of the ice volume adjustment of 0.2 per mil (40 percent of the value of the adjustment) would cause estimated temperature changes to be in error by only about 1°C. Surface temperatures remained unchanged during the

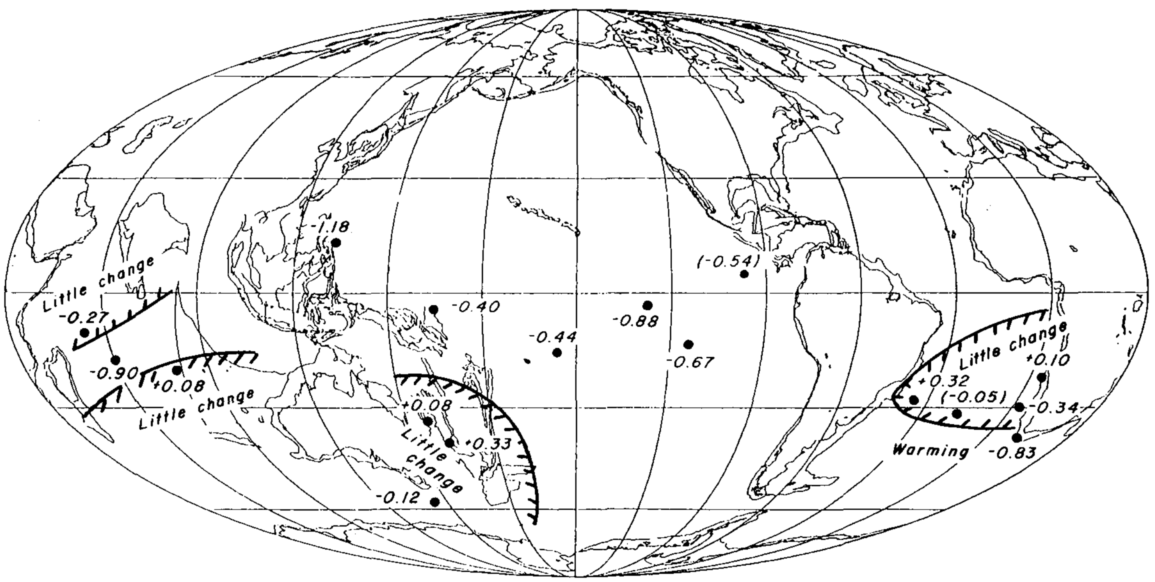



Figure 15. Map of the difference between $\delta^{18}O$ values of shallow-dwelling planktonic foraminiferal species in the N17 time slice and shallow-dwelling species in the N8 time slice. Numbers in parentheses are comparisons made between $\delta^{18}O$ values of different but nearby N17 and N8 sites. Others are comparisons made at a single site. Values have been adjusted by 0.5 per mil, the estimated change in the $\delta^{18}O$ value of sea water between 16 Ma and 8 Ma. Negative numbers imply warming surface waters and positive numbers imply cooling. Only differences greater than 0.35 per mil are considered significant.

N8 to N17 interval at the four southwestern Pacific localities. The most southerly of the South Atlantic sites (Site 360) appears to have warmed, while temperatures at the other South Atlantic sites remained essentially unchanged. There are no comparisons on Figure 15 for sites north of 30°N latitude because the N17 synoptic reconstruction included no Atlantic sites, and the N8 reconstruction included no Pacific sites in that region. Latitudinal gradients in $\delta^{18}O$ values of shallow-dwelling N8 planktonic foraminifera are shown in Figure 16, upon which is superimposed an envelope drawn about the N17 data adjusted by 0.5 per mil. The gradients drawn from the limited number of sites suggest that the late early Miocene latitudinal $\delta^{18}O$ gradient, and the temperature gradient inferred from it, were more gentle than those of the late Miocene interval. This reflects a warming of the tropics while high latitude temperatures changed little. It should be noted that while estimates of the magnitude of temperature changes are dependent upon the value assumed for the ice volume adjustment, the shapes of the latitudinal temperature gradients are not.

***Depth Stratification of Late Early Miocene Planktonic Foraminifera.*** Average $\delta^{18}O$ values of each species of planktonic foraminifera analyzed at each of the N8 time slice localities are shown in the histograms in Figure 17. Values for samples with backtracked latitudes between 30°N and 30°S are shown as unshaded squares. The tropical species, *Gs. sacculifer/trilobus, D. altispira, Globigerinoides subquadratus, Globorotalia siakensis* and *Globorotalia peripheroronda,* have similar ranges of $\delta^{18}O$ values. This is true both when all sites are considered together and when species from individual sites are compared (Figure 18). We conclude from the $^{18}O/^{16}O$ ratios that all of these species calcify in the upper portion of the water column and have $\delta^{18}O$ values indicative of surface or near-surface conditions.

As in the late Miocene samples, *Gq. venezuelana* is consistently the most $^{18}O$-enriched of the tropical late early Miocene planktonic foraminiferal species, and indicative of a deep-water habitat. In samples from which it was analyzed, primarily at higher latitudes, *Globoquadrina dehiscens* consistently yielded high (i.e., cold) $\delta^{18}O$ values.

***Synoptic Map of Planktonic $\delta^{18}O$ Values.*** There are reasons (discussed below) to believe that the isotopic ratios of some of the N4B samples may have been affected by diagenetic alteration of the carbonate, and therefore the N4B reconstruction is subject to greater uncertainty than either of the other two Miocene time slice reconstructions. $\delta^{18}O$ values of the N4B planktonic foraminiferal species with the lowest $^{18}O/^{16}O$ ratios at each time slice location are shown in Figure 19. The pattern of $\delta^{18}O$ values for the Pacific Ocean is generally similar to that of N8, except that in the N8 time slice equatorial $\delta^{18}O$ values were somewhat more positive (cooler) in the west than in the east, whereas in the N4B time slice they are slightly more positive in the east. In the South Atlantic, while $\delta^{18}O$ values of all of the N8 samples are similar, there are significant north-south and east-west gradients in the $\delta^{18}O$ values of the N4B samples. The South Atlantic samples are discussed in more detail by Hodell and Kennett (this volume).

Differences at individual sites between the $\delta^{18}O$ values of late early Miocene (N8) and early early Miocene (N4B) shallow-

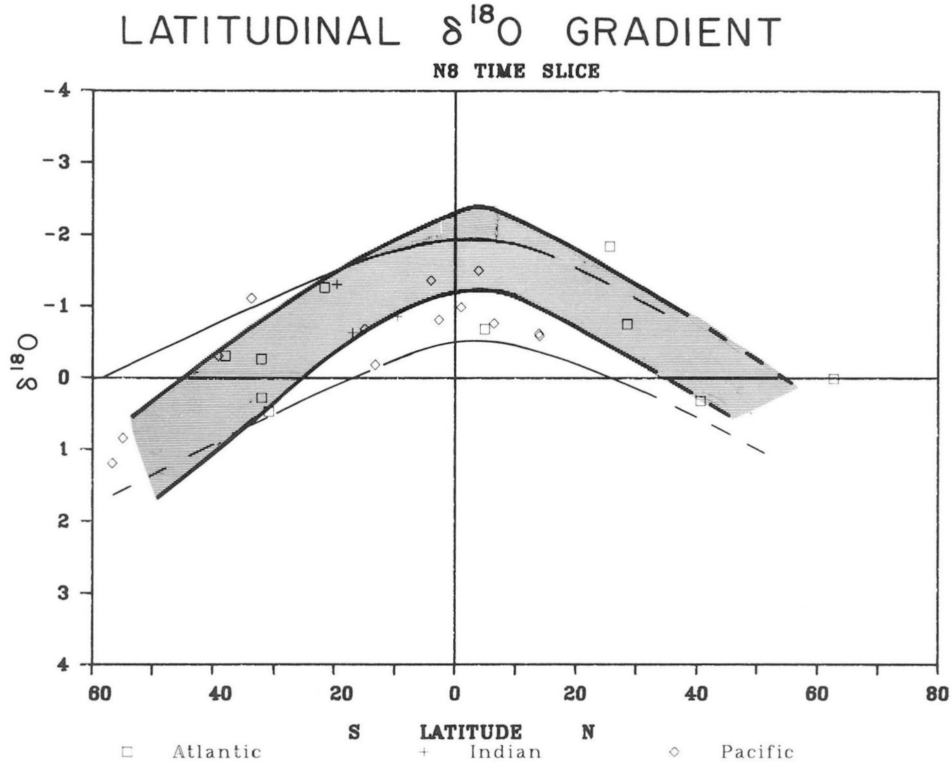



Figure 16. Latitudinal gradient of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the most negative (warmest) $\delta^{18}O$ value at each of the N8 time slice sites. Shading indicates an envelope through the $\delta^{18}O$ values of the shallow-dwelling planktonic foraminifera of the N17 time slice (Figure 12) adjusted by 0.5 per mil to compensate for the estimated change in the average $\delta^{18}O$ value of sea water between 16 and 8 Ma.

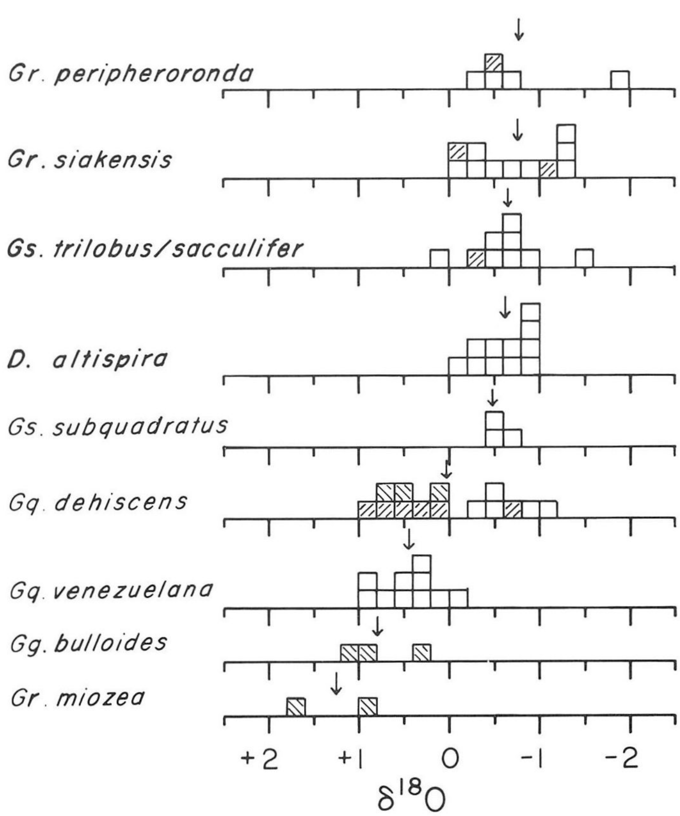



Figure 17. Histogram of average $\delta^{18}O$ values of individual species of planktonic foraminifera from each site in the N8 time slice study. Unshaded squares are data for samples with backtracked latitudes between 30°N and 30°S. (▨) indicates latitudes between 30 and 40° and (▧) indicates latitudes higher than 40°. Arrows indicate mean values of the averages for each species.

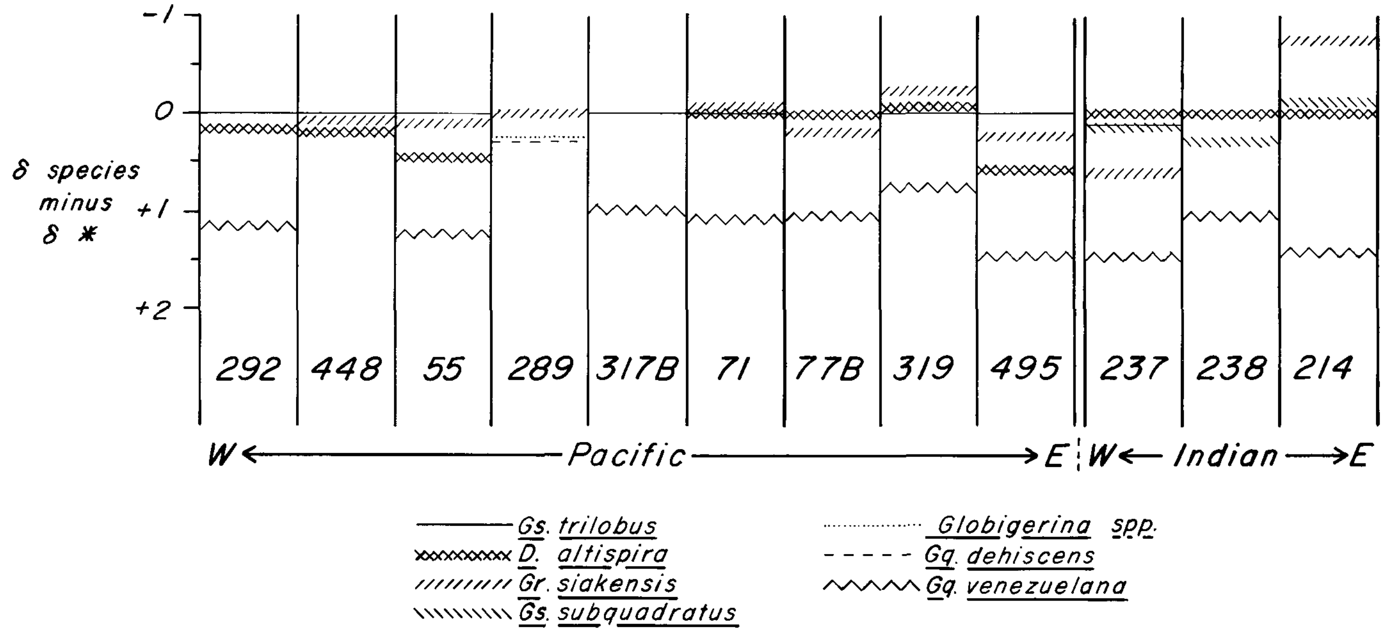



Figure 18. Ranges of $\delta^{18}O$ values of planktonic foraminiferal species at individual N8 time slice sites along west-to-east transects in the tropical Pacific and Indian Oceans. The vertical axis is the difference between the $\delta^{18}O$ value of the species in each sample with a low (warm) $^{18}O/^{16}O$ ratio, typically *Gs. trilobus, Gr. siakensis* or *D. altispira*, and the $\delta^{18}O$ value of each other species in the sample. Values plotted were obtained as described in caption of Figure 14.

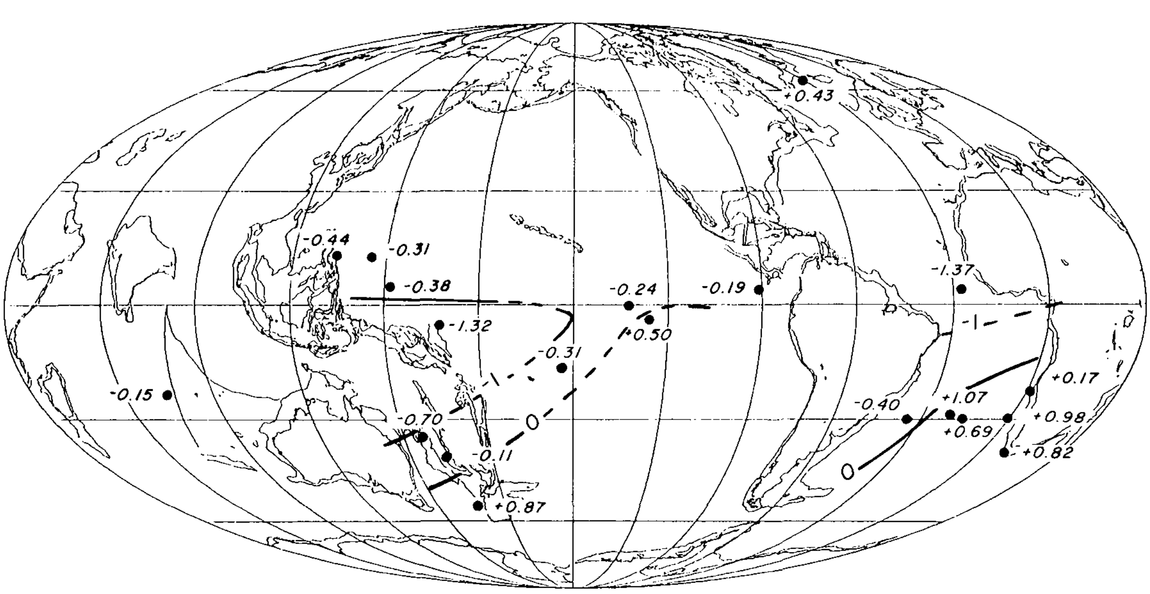



Figure 19. Map of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the most negative (warmest) $\delta^{18}O$ at each of the backtracked N4B time slice sites.

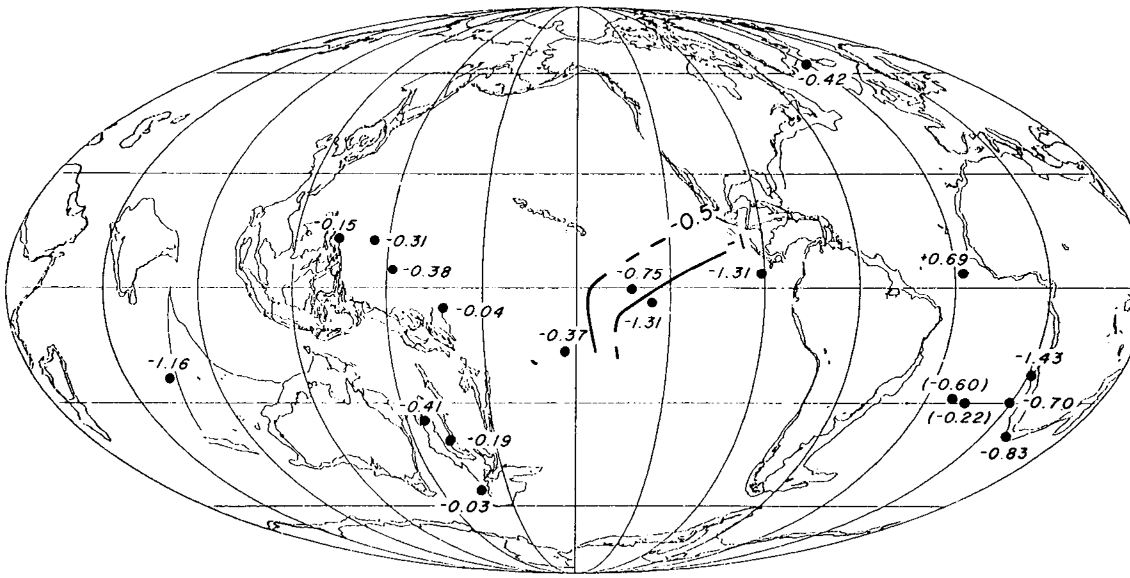



Figure 20. Map of the difference between $\delta^{18}O$ values of shallow-dwelling planktonic foraminiferal species in the N8 time slice and shallow-dwelling species in the N4B time slice. Negative numbers imply warming surface waters and positive numbers imply cooling. Only differences greater than 0.35 per mil are considered significant.

dwelling foraminifera are shown in Figure 20. On this map a negative value at a site corresponds to warming between N4B and N8 and a positive value corresponds to cooling. No adjustment was made for change in the $^{18}O/^{16}O$ ratio of sea water between N4B and N8, reflecting the conclusion of Woodruff et al. (1981) that changes in the volume of continental ice during this time period were not sufficient to cause significant changes in the isotopic composition of the oceans. However, it is conceivable that during N4B remnants of a temporary Oligocene Antarctic ice sheet were sufficiently large to affect the average $\delta^{18}O$ value of sea water, and if deglaciation did occur between 22 Ma and 16 Ma, surface waters would have warmed less or cooled more between N4B and N8 than inferred from the $\delta^{18}O$ values plotted in Figure 20.

The comparison of the two early Miocene time slices in Figure 20 shows that little temperature change (i.e., a change in $\delta^{18}O$ of less than 0.35 per mil) occurred at the sites along the western margin of the Pacific Ocean. In contrast, eastern and central Pacific surface or near-surface waters warmed significantly, as much as 4 to 6°C during that time. Waters at the one Indian Ocean time slice site and at all but two of the Atlantic sites also warmed significantly, in most cases between about 3 and 5°C from 22 Ma to 16 Ma. The N4B data do not clearly define a latitudinal $\delta^{18}O$ or temperature gradient (Figure 21).

***Depth Stratification of Early Early Miocene Planktonic Foraminifera.*** A histogram of $\delta^{18}O$ values of N4B planktonic foraminifera is shown in Figure 22. Data for tropical sites are shown as unshaded squares. Species common to the N17 and N8 intervals apparently occupied similar depth habitats in N4B based upon the $\delta^{18}O$ depth rankings. When all sites are considered as a group, as on the histograms, tropical species *Globorotalia kugleri, Gr. siakensis, Globigerina angustiumbilicata, and Gs. trilobus* have $\delta^{18}O$ values indicating calcification in surface or near-surface waters. When comparisons are made among different species from individual samples (Figure 23) *Gr. kugleri* invariably has a $\delta^{18}O$ value lower (i.e., warmer) than that of *Gr. siakensis* by 0.2 or 0.3 per mil and lower than that of *Gs. trilobus* by 0.3 to 0.7 per mil. Thus, while analyses of planktonic foraminifera from the N8 and N17 time slices indicated that *Gs. sacculifer/trilobus* consistently had a $\delta^{18}O$ value as low as, or lower than, any other species in a sample, this is not the case for the N4B samples.

Either *Gr. kugleri* (and perhaps also *Gr. siakensis*) secreted calcium carbonate out of isotopic equilibrium with sea water at 22 Ma or *Gs. trilobus* secreted its test at shallow depths at 22 Ma compared with 16 Ma. (The isotopic systematics of *Gr. siakensis* have been discussed in more detail by Barrera et al., this volume.) At tropical Pacific Sites 292 and 55, *Gs. trilobus* and *Gq. venezuelana* have similar $\delta^{18}O$ values, suggesting that early early Miocene *Gs. trilobus* was a deeper-dwelling species than late early Miocene or younger *Gs. trilobus*. However, there is less consistency in the N4B data than in the N8 and N17 data, making such inferences less certain. For example, at Site 71, *Gq. venezuelana, Gr. siakensis* and *Gg. angustiumbilicata* all have similar $\delta^{18}O$ values, suggesting that *Gq. venezuelana* calcified near the surface. Yet, at Site 317B, the $\delta^{18}O$ value of *Gq. venezuelana* strongly suggests a deeper-dwelling species. In the Site 77B time series data, the difference between the N4B $\delta^{18}O$ values of *Gg. venezuelana* and *Cibicidoides* spp. is extremely small, perhaps indicating diagenetic alteration of the older Miocene samples at that site. Although all samples have been examined superficially

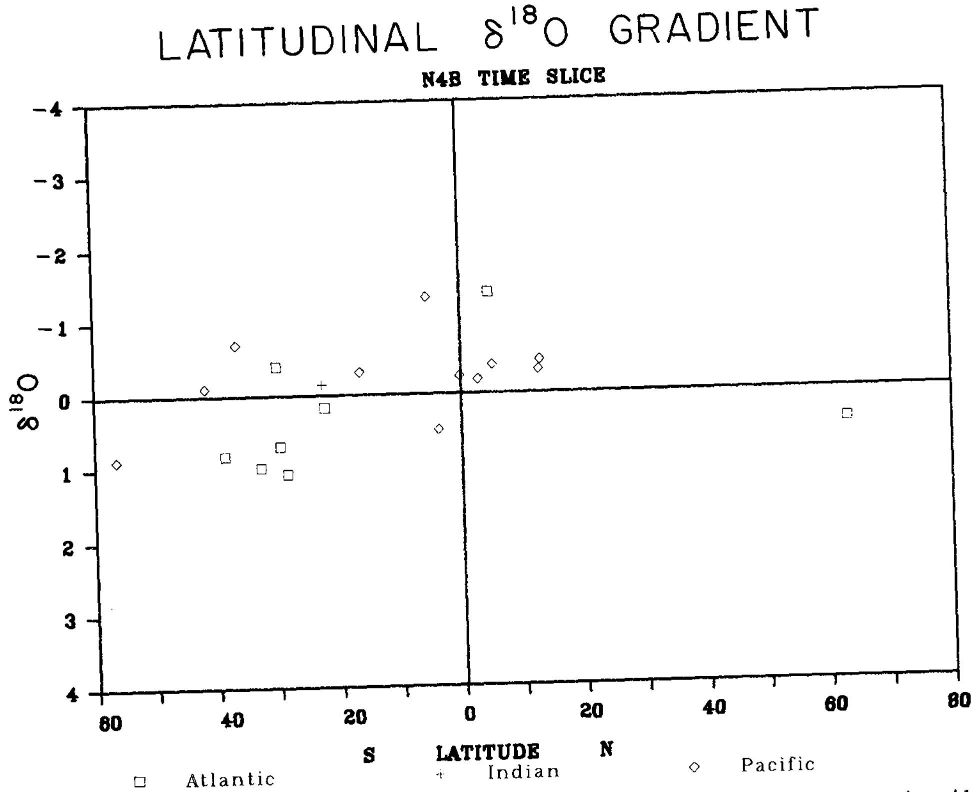



Figure 21. Latitudinal gradient of the average $\delta^{18}O$ values of the planktonic foraminiferal species with the most negative (warmest) $\delta^{18}O$ value at each of the N4B time slice sites.

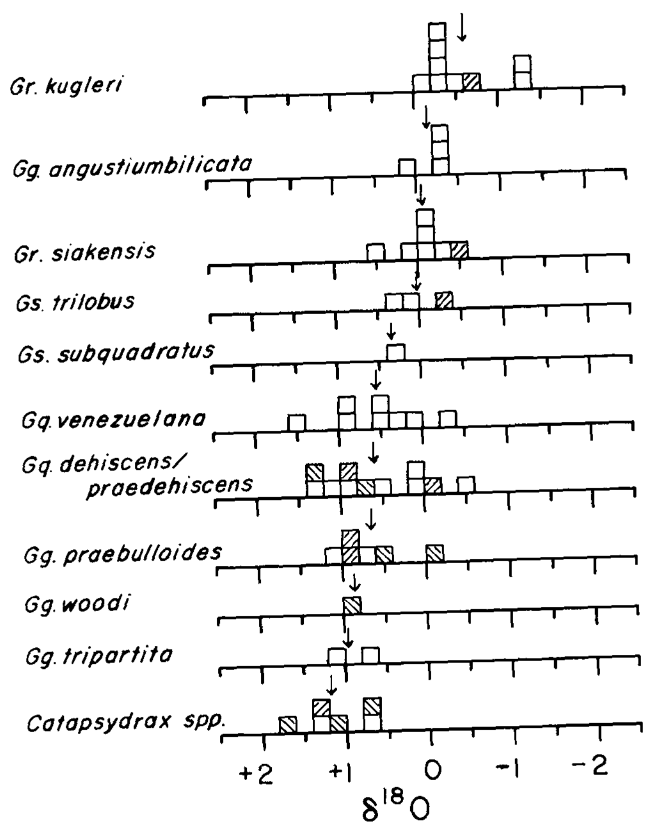



Figure 22. Histogram of average $\delta^{18}O$ values of individual species of planktonic foraminifera from each site in the N4B time slice study. Unshaded squares are data for samples with backtracked latitudes between 30°N and 30°S. (▨) indicates latitudes between 30 and 40° and (▧) indicates latitudes higher than 40°. Arrows indicate mean value of the averages for each species.

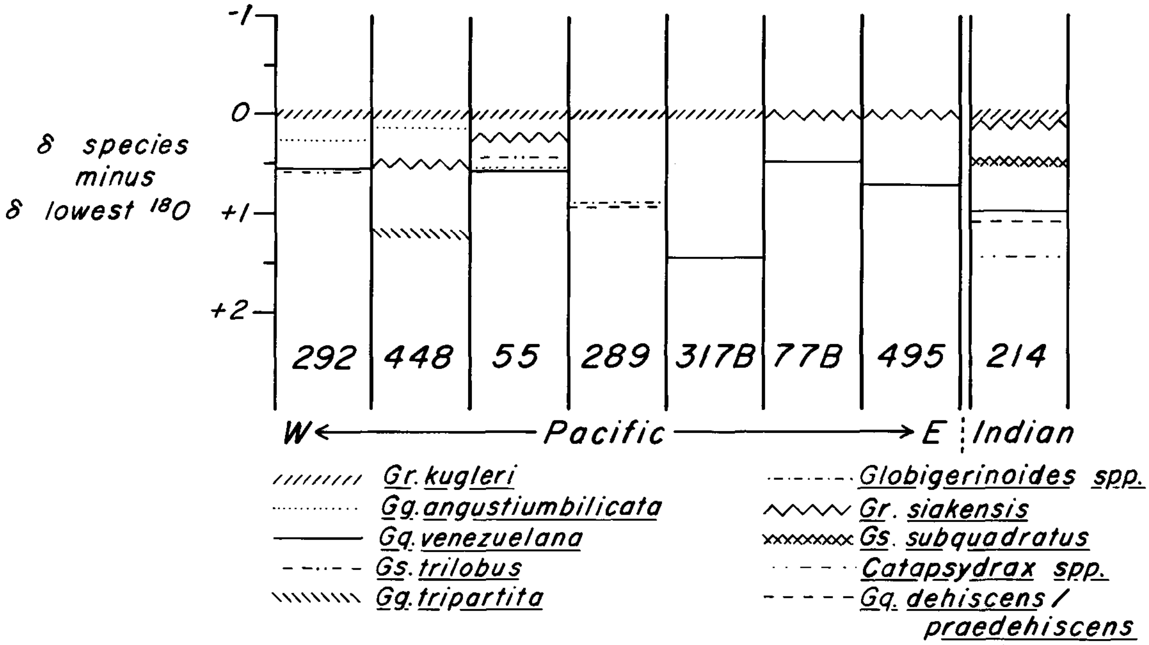



Figure 23. Ranges of $\delta^{18}O$ values of planktonic foraminiferal species at individual N4B time slice sites along a west-to-east transect in the tropical Pacific and at one site in the Indian Ocean. The vertical axis is the difference between the $\delta^{18}O$ value of the species in each sample with the lowest (warmest) $^{18}O/^{16}O$ ratio and the $\delta^{18}O$ value of each other species in the sample. Values plotted were obtained as described in caption of Figure 14.

to check for the effects of diagenesis, the extent to which diagenesis may have modified original isotopic compositions has not been examined in detail, and diagenetic alteration is more likely to have affected samples from the older, deeper portions of the sedimentary sections.

At higher latitudes, $\delta^{18}O$ values indicate that *Gg. praebulloides* was most commonly the shallowest-dwelling N4B planktonic species while either *Gq. dehiscens* or *Catapsydrax* spp. was the deepest.

## TIME SERIES STUDIES

Relevant published Miocene planktonic foraminiferal isotopic time series studies from a variety of locations are listed in Table 3. Additional new time series data for planktonic foraminifera from Sites 77B and 289 are included in this paper and tabulated in Appendix IV (on microfiche).

Planktonic foraminiferal oxygen isotopic data for 19 sites are plotted in Figure 24. Where available, benthic data are also plotted for reference. Stratigraphic age assignments used in plotting the data are based on the core descriptions in the Initial Reports of DSDP, or in the case of sites which were also used in the CENOP time slice reconstructions, on the biostratigraphy of Barron et al. (this volume). While many of the time series curves span only a small portion of the Miocene epoch, the data add considerably to our understanding of the evolution of the Miocene oceans.

TABLE 3. MIOCENE PLANKTONIC FORAMINIFERAL ISOTOPIC TIME SERIES DATA AND SOURCES

| Site | Sources |
|---|---|
| 55 | Douglas and Savin (1971) |
| 77B | This paper |
| 116 | Rabussier-Lointier (1980); Blanc and Duplessy (1982) |
| 158 | Keigwin (1979) |
| 167 | Douglas and Savin (1973); Rabussier-Lointier (1980) |
| 173 | Barrera et al. |
| 208 | Loutit et al. (1983) |
| 237 | Rabussier-Lointier (1980) |
| 238 | Vincent et al. (1980) |
| 281 | Loutit (1981) |
| 289 | Shackleton (1982); This paper |
| 310 | Keigwin (1979) |
| 357 | Boersma and Shackleton (1977) |
| 354 | Boilzi (1983) |
| 366 | Rabussier-Lointier (1980) |
| 470 | Barrera et al. (this volume) |
| 495 | Barrera et al. (this volume) |
| 519 | McKenzie et al. (1984) |
| 525 | Shackleton et al. (1984) |

Where the appropriate portion of the middle Miocene section was analyzed, the benthic foraminiferal time series curves show a clearly defined enrichment in $\delta^{18}O$ values between approximately 17 and 15 Ma, which Savin et al. (1975), Shackleton and Kennett (1975), Woodruff et al. (1981) and Savin et al. (1981) have interpreted as reflecting a combination of the cooling of bottom waters and the growth of the Antarctic ice sheet, and the concomitant increase in the $^{18}O/^{16}O$ ratio of sea water.

The late early Miocene interval, just prior to the early middle Miocene cooling of bottom waters, is represented in Figure 24 by data from a number of sites in tropical and high latitudes of the South Pacific. The planktonic foraminiferal $\delta^{18}O$ values indicate that, barring a significant decrease in mean oceanic $\delta^{18}O$ due to

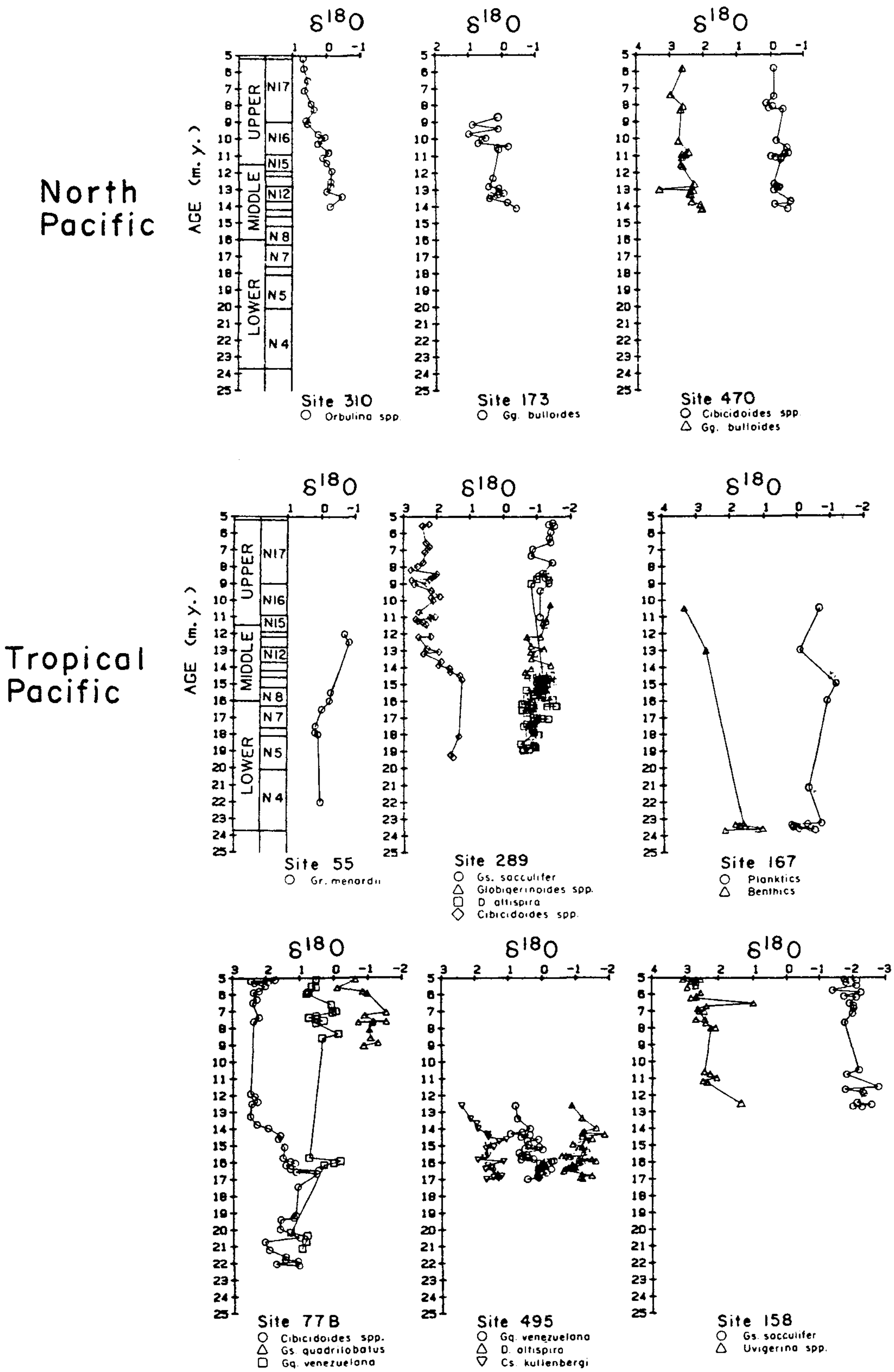
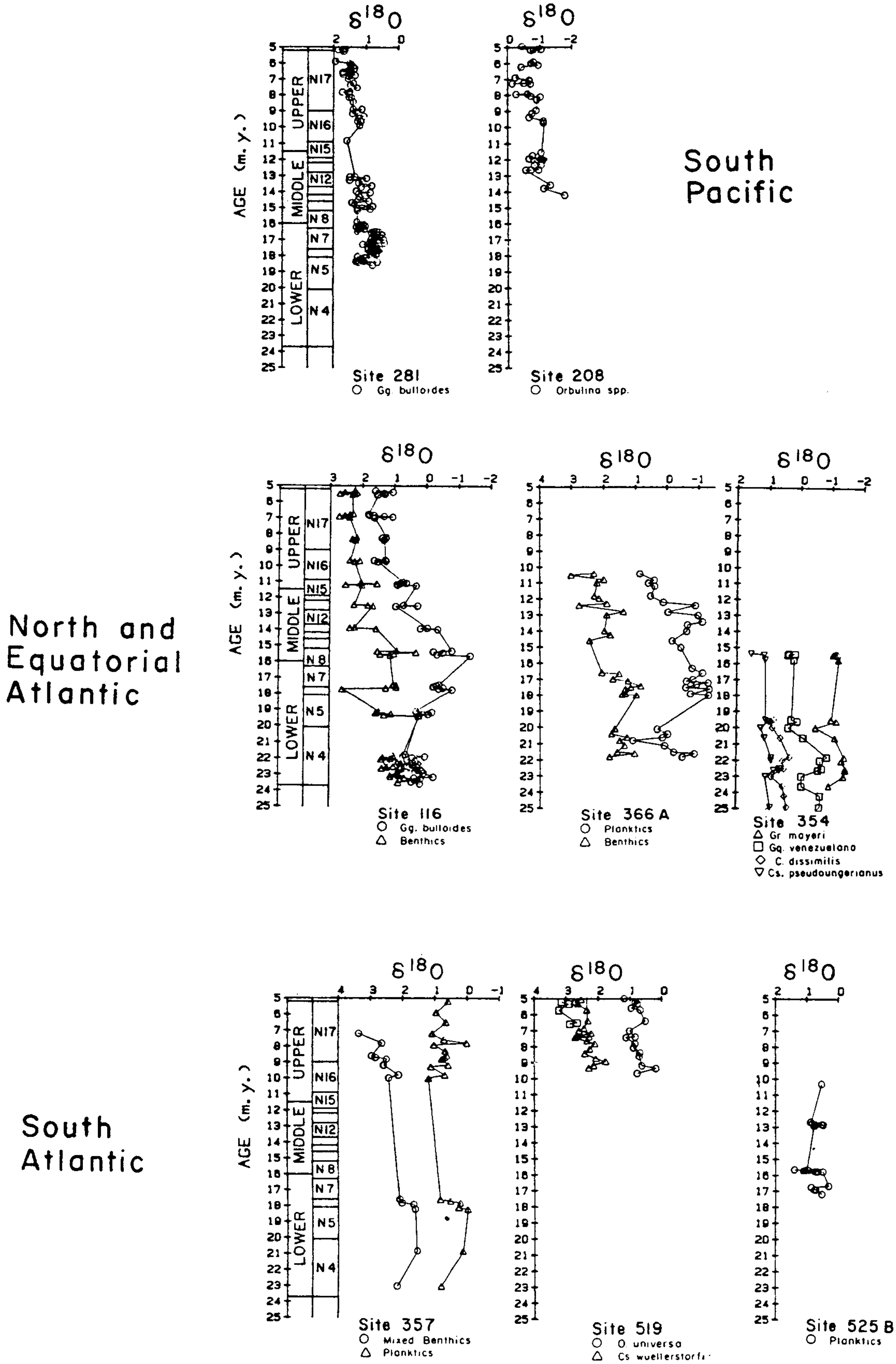
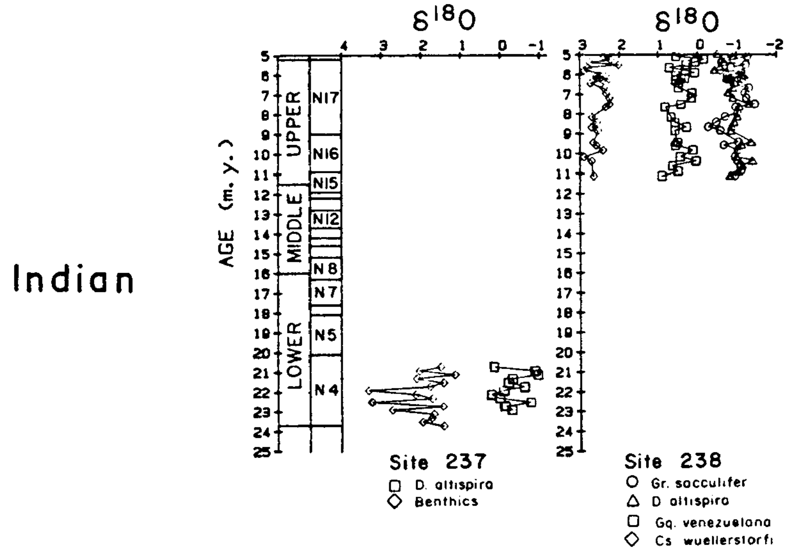



Figure 24 (this and following pages). $\delta^{18}O$ values of planktonic and benthic foraminifera from several Atlantic, Pacific and Indian Ocean sites plotted as a function of sample age. Data sources are listed in Table 3. Age assignments are discussed in the text.


South Pacific
North and Equatorial Atlantic
South Atlantic
δ18O
AGE (m. y.)
UPPER
MIDDLE
LOWER
N17
N16
N15
N12
N8
N7
N5
N4
Site 281
○ Gg. bulloides
Site 208
○ Orbulina spp.
Site 116
○ Gg. bulloides
△ Benthics
Site 366 A
○ Planktics
△ Benthics
Site 354
△ Gr. mayeri
□ Gq. venezuelana
◇ C. dissimilis
▽ Cs. pseudoungerianus
Site 357
○ Mixed Benthics
△ Planktics
Site 519
○ O. universa
△ Cs. wuellerstorfi
□ O. umbonatus
Site 525 B
○ Planktics




deglaciation, surface waters warmed over a wide range of latitudes in the Pacific (0.4 per mil between 18 and 15.5 Ma at Site 55; 0.4 per mil between 18.5 and 16.5 Ma at Site 281; 0.3 per mil between 16.5 and 14.5 Ma and 0.4 per mil between 19 and 14.5 Ma at Site 289; and 0.35 per mil between 16.8 and 14.5 Ma at Site 495).

When considered over a longer time interval, regional differences in the evolution of Pacific middle Miocene surface temperatures become apparent. The middle Miocene appears to have been a time of warming of surface waters at western tropical Pacific Sites 55, 167, and 289, and a time of cooling at high latitude Pacific Site 281. (Note that either a decrease or no change in the $\delta^{18}O$ values of a shallow-dwelling species during middle Miocene time would correspond to surface water warming because of the ice volume related change in $\delta^{18}O$ of sea water during that interval.) The latter half of the middle Miocene was a time of warming at Site 470 in the eastern Pacific (29°N) and a time of cooling at Site 310 (36°N) in the central Pacific. During the late Miocene, there was either warming or little temperature change at low latitude Pacific Sites 158, 289, and 470 and Indian Ocean Site 238, and cooling at higher latitude Sites 208, 281 and 310. Regional differences also exist in the evolution of Atlantic Ocean surface temperatures during the Miocene. Both at Site 116 in the North Atlantic and Site 366 in the eastern equatorial Atlantic, late early Miocene surface waters were warmer than those of the early early Miocene, and waters subsequently underwent considerable cooling throughout the middle Miocene. At Site 116 the cooling continued through most of the Miocene. The record is less well-defined in the South Atlantic, but the available data for Site 525B at approximately 30°S suggest little temperature change or a slight warming between 17 and 10 Ma.

## DISCUSSION AND CONCLUSIONS

The time series and time slice studies described above provide a general picture of the evolution of the surface and near-surface temperature structure of the Miocene oceans. Pacific early Miocene temperature distribution patterns differed from those of today chiefly in the existence of a shallower early Miocene latitudinal temperature gradient and a marked east-to-west temperature gradient in the southwestern and south-central tropical Pacific. At most localities temperatures showed little change or increased throughout the early Miocene, with greater warming occurring in the eastern equatorial region than elsewhere in the Pacific, resulting in a lessening of the above-mentioned east-to-west gradient. Information from a single locality suggests that the tropical Indian Ocean warmed as well.

Just prior to the early middle Miocene cooling of deep waters, surface temperatures increased at all sites for which data are available. Subsequently, regional differences in the evolution of surface temperatures became pronounced. In the Pacific Ocean, surface waters at most low-latitude sites warmed while those at higher north and south latitude sites cooled or underwent little change. By 8 Ma the east-to-west temperature gradient in the southwest and south-central Pacific had largely disappeared. Pacific surface temperatures were similar to those of today except that tropical waters were cooler at 8 Ma.

At one site in the North Atlantic (Site 116) surface waters cooled significantly throughout the middle and late Miocene, as they did in the late middle and early late Miocene in the equatorial Atlantic (Site 366). At most South Atlantic sites there was little temperature change, although surface waters apparently warmed off the southern tip of South Africa.

Kennett et al. (this volume) have examined the biogeographic distribution of planktonic foraminifera in Pacific Ocean sediments during the Miocene. Their conclusions about the development of oceanographic conditions between the late early Miocene and late Miocene intervals are largely consistent with those drawn in this paper from the isotopic data. Specifically, it was concluded from the isotopic data that there was an east-to-west temperature gradient in the surface waters of the tropical Pacific during the early Miocene, and that this gradient had become markedly lessened by the late Miocene. Kennett et al. noted an east-to-west provinciality in the South Pacific early Miocene (N8 and N4B) fauna which had essentially disappeared by the late Miocene (N17).

On the basis of a limited number of isotopic analyses of planktonic and benthic foraminifera from the tropical Pacific, Savin et al. (1975) pointed out that the middle Miocene cooling of deep waters was accompanied by a warming of tropical surface waters. They concluded that this reflected a decrease in meridional heat transport. The results of the present study do not lead to a unique explanation of the causes of the marked cooling of early middle Miocene deep waters or the establishment of large Antarctic ice sheets at that time. However, the isotopic data in this paper do provide a framework against which theories of the causes of these events can be tested.

## ACKNOWLEDGMENTS

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APPENDIX I. SUMMARIES OF ISOTOPIC DATA FOR EACH SPECIES OF PLANKTONIC FORAMINIFERA FROM EACH SITE FOR EACH TIME SLICE

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| **SUMMARY N17 TIME SLICE** | | | | | | | | |
| RC12-418 | Gr. conoidea | 0.66 | 0.22 | 6 | 1.67 | 0.16 | 6 | CWRU |
| 452-55cm | | | | | | | | |
| DSDP 16 | Gr. conoidea | 1.37 | 0.09 | 5 | 1.90 | 0.09 | 5 | URI |
| 9-1 | Globigerinoides spp. | 0.92 | 0.10 | 5 | 2.02 | 0.10 | 5 | URI |
| to | | | | | | | | |
| 10-5 | | | | | | | | |
| DSDP 62.1 | Gs. sacculifer & | -1.24 | 0.21 | 4 | 1.92 | 0.22 | 4 | CWRU |
| 23-5 | trilobus | | | | | | | |
| to | Gr. menardii | -1.19 | 0.04 | 3 | 1.44 | 0.08 | 3 | CWRU |
| 24-2 | Gq. venezuelana | 0.01 | 0.33 | 6 | 1.48 | 0.21 | 6 | CWRU |
| DSDP 77B | Gq. venezuelana | 0.10 | 0.24 | 2 | 0.74 | 0.05 | 2 | CWRU |
| 15-4 | Gs. quadrilobatus | -1.19 | 0.11 | 2 | 2.18 | 0.20 | 2 | CWRU |
| to | Gr. menardii | -0.39 | 0.09 | 2 | 0.97 | 0.03 | 3 | CWRU |
| 16-4 | | | | | | | | |
| DSDP 158 | Gq. venezuelana | -0.23 | 0.18 | 7 | 1.16 | 0.18 | 7 | URI |
| 19-6 | Gr. menardii | -1.25 | 0.33 | 8 | 1.31 | 0.09 | 8 | URI |
| to | Gs. sacculifer & | -1.54 | 0.33 | 9 | 1.80 | 0.22 | 9 | URI |
| 21-1 | trilobus | | | | | | | |
| DSDP 173 | Gg. bulloides | 0.12 | | 1 | 0.84 | | 1 | CWRU |
| 17CC | | | | | | | | |
| DSDP 206 | Gg. nepenthes | 0.53 | 0.15 | 6 | 1.42 | 0.22 | 6 | URI |
| 21-6 | Gr. conoidea | 0.76 | 0.11 | 8 | 1.72 | 0.29 | 8 | URI |
| to | | | | | | | | |
| 24-3 | | | | | | | | |
| DSDP 207A | Orbulina spp. | 0.83 | 0.13 | 6 | 2.33 | 0.22 | 6 | URI |
| 6-2 | Gr. conoidea | 1.17 | 0.22 | 7 | 1.61 | 0.24 | 7 | URI |
| to | N. pachyderma | 0.97 | 0.05 | 2 | 1.38 | 0.00 | 2 | URI |
| 7-3 | | | | | | | | |
| DSDP 208 | Orbulina spp. | -0.53 | 0.12 | 2 | 2.00 | 0.36 | 2 | URI |
| | Gr. conoidea | 0.06 | 0.22 | 2 | 1.19 | 0.22 | 2 | URI |
| | D. altispira | -0.36 | 0.52 | 3 | 2.24 | 0.38 | 3 | URI |
| | Gs. sacculifer | -0.20 | 0.47 | 3 | 2.58 | 0.30 | 3 | URI |
| DSDP 214 | Gs. sacculifer | -0.57 | 0.17 | 17 | 2.36 | 0.21 | 17 | SCRIPPS |
| 14-1 | D. altispira | -0.68 | 0.10 | 12 | 2.54 | 0.23 | 12 | SCRIPPS |
| to | O. universa | -0.49 | 0.23 | 10 | 2.09 | 0.22 | 10 | SCRIPPS |
| 15-2 | Gq. venezuelana | 0.44 | 0.13 | 17 | 1.51 | 0.08 | 17 | SCRIPPS |
| | Ss. seminulina | -0.45 | 0.05 | 6 | 2.23 | 0.13 | 6 | SCRIPPS |
| | Gs. conglobatus & | -0.73 | 0.11 | 5 | 2.45 | 0.04 | 5 | SCRIPPS |
| | obliquus | | | | | | | |
| DSDP 237 | Gs. sacculifer | -0.56 | 0.22 | 6 | 1.84 | 0.39 | 6 | SCRIPPS |
| 12-6 | D. altispira | -0.55 | 0.22 | 6 | 2.07 | 0.09 | 6 | SCRIPPS |
| to | O. universa | -0.18 | 0.22 | 6 | 1.84 | 0.15 | 6 | SCRIPPS |
| 13-1 | Gr. limbata | -0.41 | 0.21 | 8 | 1.16 | 0.21 | 8 | SCRIPPS |
| | Gq. venezuelana | 0.50 | 0.13 | 5 | 0.95 | 0.17 | 5 | SCRIPPS |
| | Ss. seminulina | -0.25 | 0.27 | 6 | 1.77 | 0.28 | 6 | SCRIPPS |
| | Gs. conglobatus & | -0.63 | 0.10 | 6 | 2.09 | 0.24 | 6 | SCRIPPS |
| | obliquus | | | | | | | |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| DSDP 238 | Gs. sacculifer | -0.75 | 0.32 | 8 | 2.44 | 0.17 | 8 | SCRIPPS |
| 24-6 | D. altispira | -1.03 | 0.18 | 6 | 2.48 | 0.40 | 6 | SCRIPPS |
| to | O. universa | -0.70 | 0.56 | 6 | 2.25 | 0.37 | 5 | SCRIPPS |
| 27-5 | Gr. limbata | -0.35 | 0.27 | 6 | 1.35 | 0.18 | 6 | SCRIPPS |
| | Gq. venezuelana | 0.47 | 0.15 | 8 | 1.26 | 0.16 | 8 | SCRIPPS |
| | Ss. seminulina | -0.48 | 0.33 | 6 | 1.85 | 0.27 | 6 | SCRIPPS |
| | Gq. dehiscens | 0.35 | | 1 | 2.18 | | 1 | SCRIPPS |
| DSDP 281 | Orbulina spp. | 1.57 | 0.11 | 3 | 2.22 | 0.18 | 3 | URI |
| 6-4 to 7-4 | N. pachyderma | 1.76 | 0.12 | 7 | 1.61 | 0.15 | 7 | URI |
| DSDP 289 | Gq. venezuelana | -0.61 | 0.08 | 5 | 1.38 | 0.05 | 5 | CWRU |
| 27-6 | D. altispira | -0.91 | 0.08 | 2 | 1.89 | 0.02 | 2 | CWRU |
| to | Gs. obliquus | -1.20 | 0.05 | 2 | 2.24 | 0.07 | 2 | CWRU |
| 29-2 | Gr. menardii | -1.14 | 0.14 | 5 | 1.37 | 0.23 | 5 | CWRU |
| | Gs. sacculifer | -1.26 | 0.10 | 6 | 2.68 | 0.13 | 6 | CWRU |
| | Globigerinoides spp. | -1.23 | | 1 | 2.84 | | 1 | CWRU |
| DSDP 292 | Gq. venezuelana | 0.83 | 0.18 | 4 | 1.32 | 0.18 | 4 | CWRU |
| 9-1 to 9-5 | Gs. sacculifer & trilobus | -1.27 | 0.23 | 6 | 1.55 | 0.11 | 6 | CWRU |
| DSDP 296 | Orbulina spp. | -0.58 | 0.16 | 13 | 2.11 | 0.32 | 13 | CWRU |
| 22-2 to | Gs. trilobus & sacculifer | -0.64 | 0.17 | 3 | 2.00 | 0.25 | 3 | CWRU |
| 23-4 | Gr. conoidea | 0.01 | 0.10 | 8 | 1.48 | 0.08 | 8 | CWRU |
| | Gq. venezuelana | 0.39 | 0.16 | 6 | 0.99 | 0.21 | 6 | CWRU |
| DSDP 310 | Orbulina spp. | 0.58 | 0.16 | 4 | 1.51 | 0.10 | 4 | CWRU |
| 8-4 | Gr. menardii | 0.27 | | 1 | 1.36 | | 1 | CWRU |
| to 8-6 | Gr. menardii & merotumida | 0.18 | | 1 | 1.03 | | 1 | CWRU |
| | Gs. sacculifer & trilobus | -1.13 | | 1 | 1.75 | | 1 | CWRU |
| DSDP 317B | Gq. venezuelana | 0.26 | 0.09 | 8 | 1.58 | 0.25 | 8 | URI |
| 9-4 to 10-4 | Gs. sacculifer & trilobus | -0.62 | 0.28 | 8 | 2.61 | 0.28 | 8 | URI |
| DSDP 319 | Gq. venezuelana | 0.82 | 0.11 | 4 | 1.5 | 0.07 | 4 | URI |
| 3-1 to 3CC | Gs. sacculifer | -0.35 | 0.12 | 3 | 2.07 | 0.51 | 3 | URI |
| DSDP 360 | Gr. conoidea | 1.09 | 0.37 | 9 | 0.98 | 0.36 | 9 | URI |
| | Globigerinoides spp. | -0.34 | 0.24 | 8 | 1.36 | 0.30 | 8 | URI |
| DSDP 362 | Gr. conoidea | 0.80 | 0.12 | 6 | 0.88 | 0.45 | 6 | URI |
| | Globigerinoides spp. | -0.66 | 0.41 | 5 | 1.63 | 0.15 | 5 | URI |
| DSDP 470 9-1 to 9CC | Gg. bulloides | -0.08 | 0.19 | 4 | 0.81 | 0.16 | 4 | CWRU |
| DSDP 516A | Gr. conoidea | 1.05 | 0.10 | 5 | 1.55 | 0.17 | 5 | URI |
| 13-1 to 14-3 | Globigerinoides spp. | 0.62 | 0.24 | 5 | 1.77 | 0.20 | 5 | URI |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| DSDP 526A | Gr. conoidea | 0.99 | 0.08 | 7 | 1.33 | 0.13 | 7 | URI |
| 9-1 to | Globigerinoides spp. | 0.44 | 0.13 | 6 | 1.95 | 0.25 | 6 | URI |
| 11-3 | | | | | | | | |
| **SUMMARY N8 TIME SLICE** | | | | | | | | |
| DSDP 15 | Gq. dehiscens | 0.93 | 0.02 | 2 | 2.15 | 0.13 | 2 | URI |
| | Globigerinoides spp. | 0.47 | 0.19 | 3 | 2.37 | 0.37 | 3 | URI |
| DSDP 55 | Gq. venezuelana | 0.36 | 0.31 | 5 | 1.68 | 0.17 | 5 | CWRU |
| 8-5 | D. altispira | -0.35 | 0.25 | 8 | 2.25 | 0.20 | 8 | CWRU |
| to | Gs. trilobus | -0.76 | 0.31 | 7 | 2.10 | 0.20 | 7 | CWRU |
| 11-1 | Gr. peripheroronda & siakensis | -0.64 | 0.27 | 5 | 1.68 | 0.19 | 5 | CWRU |
| DSDP 71 | Gq. venezuelana | 0.22 | 0.16 | 10 | 2.22 | 0.33 | 10 | CWRU |
| 19-2 | D. altispira | -0.91 | 0.16 | 8 | 3.09 | 0.58 | 8 | CWRU |
| to | Gr. siakensis | -0.99 | 0.21 | 10 | 2.18 | 0.15 | 9 | CWRU |
| 22-6 | Gs. trilobus | -0.94 | 0.22 | 6 | 2.76 | 0.07 | 6 | CWRU |
| DSDP 77B | Gq. venezuelana | 0.24 | 0.35 | 4 | 1.97 | 0.09 | 4 | CWRU |
| 26-2 | D. altispira | -0.81 | 0.16 | 4 | 2.78 | 0.13 | 4 | CWRU |
| to | Gr. siakensis | -0.62 | 0.02 | 2 | 1.89 | 0.04 | 2 | CWRU |
| 27-2 | | | | | | | | |
| DSDP 206 | Gq. dehiscens | 0.33 | 0.12 | 7 | 1.70 | 0.19 | 7 | URI |
| 31-1 | Gs. sacculifer | -0.30 | 0.25 | 3 | 2.40 | 0.04 | 3 | URI |
| to | Gr. siakensis | -0.14 | 0.15 | 7 | 1.65 | 0.10 | 7 | URI |
| 32-3 | Globigerinoides spp. | -0.25 | 0.17 | 3 | 2.12 | 0.32 | 7 | URI |
| DSDP 208 | Gr. siakensis | -1.11 | 0.01 | 2 | 1.77 | 0.23 | 2 | URI |
| 21-4 | Gr. peripheroronda | -0.58 | 0.10 | 2 | 1.67 | 0.13 | 2 | URI |
| to | Gq. dehiscens | -0.69 | 0.66 | 3 | 1.62 | 0.39 | 4 | URI |
| 21-6 | | | | | | | | |
| DSDP 214 | D. altispira | -0.57 | 0.21 | 3 | 2.41 | 0.12 | 3 | SCRIPPS |
| 20-4 | Gq. venezuelana | 0.85 | 0.01 | 2 | 1.56 | 0.10 | 2 | SCRIPPS |
| to | Gs. subquadratus | -0.69 | 0.15 | 2 | 2.20 | 0.02 | 2 | SCRIPPS |
| 22-6 | Gr. siakensis | -1.31 | | 1 | 0.51 | | 1 | SCRIPPS |
| DSDP 237 | D. altispira | -0.86 | 0.22 | 11 | 2.31 | 0.47 | 11 | SCRIPPS |
| 18-1 | Gq. venezuelana | 0.59 | 0.28 | 11 | 1.35 | 0.35 | 11 | SCRIPPS |
| to | Gs. subquadratus | -0.56 | 0.18 | 4 | 1.97 | 0.32 | 4 | SCRIPPS |
| 19-3 | Gs. trilobus & sacculifer | -0.54 | 0.26 | 3 | 2.02 | 0.15 | 3 | SCRIPPS |
| | Gr. limbata | -0.61 | | 1 | 0.91 | | 1 | SCRIPPS |
| | Gr. siakensis | -0.26 | | 1 | 0.69 | | 1 | SCRIPPS |
| DSDP 238 | D. altispira | -0.63 | 0.16 | 3 | 2.61 | 0.45 | 3 | SCRIPPS |
| 38-5 | Gq. venezuelana | 0.40 | 0.01 | 3 | 1.73 | 0.06 | 3 | SCRIPPS |
| to | Gs. subquadratus | -0.51 | | 1 | 2.52 | | 1 | SCRIPPS |
| 41-2 | Gq. dehiscens | -0.59 | | 1 | 2.03 | | 1 | SCRIPPS |
| | Gr. peripheroronda | -0.27 | | 1 | 1.56 | | 1 | SCRIPPS |
| DSDP 279A | Gq. dehiscens | 0.84 | 0.26 | 6 | 2.32 | 0.13 | 4 | URI |
| | Gr. miozea | 0.88 | 0.15 | 6 | 2.52 | 0.14 | 6 | URI |
| | Gg. bulloides | 0.93 | 0.07 | 5 | 2.49 | 0.33 | 5 | URI |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| DSDP 281 | Gr. miozea | 1.61 | 0.08 | 4 | 2.01 | 0.16 | 4 | URI |
| 10-3 | Gg. bulloides & praebulloides | 1.19 | 0.14 | 3 | 2.05 | 0.07 | 3 | URI |
| DSDP 289 | Gr. siakensis | -1.36 | 0.18 | 6 | 1.57 | 0.20 | 5 | URI |
| 51-6 | Gq. dehiscens | -1.06 | 0.28 | 5 | 1.98 | 0.38 | 5 | URI |
| to | Globigerina spp. | -1.11 | 0.21 | 6 | 2.06 | 0.17 | 6 | URI |
| 55-2 | Globigerinoides spp. | -1.08 | 0.10 | 3 | 2.26 | 0.23 | 3 | CWRU |
| | Gs. ruber | -1.11 | | 1 | 2.45 | | 1 | CWRU |
| DSDP 292 | Gq. venezuelana | 0.73 | 0.10 | 5 | 1.67 | 0.07 | 5 | CWRU |
| 12-2 | D. altispira | -0.39 | 0.28 | 5 | 2.27 | 0.08 | 5 | CWRU |
| to | Gs. trilobus | -0.59 | 0.85 | 5 | 1.92 | 0.08 | 5 | CWRU |
| 12-5 | | | | | | | | |
| DSDP 317B | Gq. venezuelana | 0.13 | 0.24 | 5 | 2.14 | 0.19 | 5 | URI |
| 17-1 | Gs. trilobus | -0.68 | 0.22 | 4 | 2.17 | 0.29 | 5 | URI |
| to | | | | | | | | |
| 18-3 | | | | | | | | |
| DSDP 319 | Gq. venezuelana | 0.90 | 0.28 | 5 | 2.24 | 0.10 | 5 | CWRU |
| 11-3 | D. altispira | -0.17 | 0.32 | 4 | 3.02 | 0.20 | 4 | CWRU |
| to | Gs. trilobus | 0.04 | 0.13 | 8 | 2.51 | 0.20 | 8 | CWRU |
| 12-3 | Gr. siakensis | -0.18 | 0.22 | 10 | 1.90 | 0.08 | 10 | CWRU |
| DSDP 360 | Gq. dehiscens | 0.58 | 0.33 | 9 | 2.32 | 0.16 | 9 | URI |
| 22-2 | Globigerinoides spp. | -0.01 | 0.14 | 7 | 2.44 | 0.32 | 7 | URI |
| to | | | | | | | | |
| 22-6 | | | | | | | | |
| DSDP 362 | Gq. dehiscens | -0.51 | 0.10 | 5 | 2.15 | 0.13 | 5 | URI |
| 36CC | Globigerinoides spp. | -1.26 | 0.17 | 5 | 2.69 | 0.17 | 5 | URI |
| to | | | | | | | | |
| 37-2 | | | | | | | | |
| DSDP 366A | Globigerinoides spp. | -0.56 | 0.16 | 3 | 2.03 | 0.14 | 3 | URI |
| | Gr. peripheroronda | -0.62 | 0.12 | 4 | 1.58 | 0.26 | 4 | URI |
| | D. altispira | -0.68 | 0.17 | 3 | 2.45 | 0.10 | 3 | URI |
| DSDP 369A | Globigerinoides spp. | -1.84 | 0.25 | 4 | 1.98 | 0.31 | 4 | URI |
| | Gq. dehiscens | -0.92 | 0.41 | 2 | 0.92 | 0.04 | 2 | URI |
| | Gr. peripheroronda | -1.83 | 0.13 | 2 | 0.66 | 0.21 | 2 | URI |
| DSDP 391 | Globigerinoides spp. | -0.75 | 0.00 | 2 | 1.79 | 0.01 | 2 | URI |
| 10-4 | Gq. dehiscens | -0.21 | 0.15 | 2 | 1.22 | 0.34 | 2 | URI |
| to | Gr. peripheroronda | -0.58 | 0.01 | 2 | 1.07 | 0.05 | 2 | URI |
| 11-6 | | | | | | | | |
| DSDP 398 | Globigerinoides spp. | 0.32 | 0.39 | 6 | 2.07 | 0.29 | 6 | URI |
| | Gq. dehiscens | 0.57 | 0.26 | 9 | 1.53 | 0.22 | 9 | URI |
| DSDP 408 | Globigerinoides spp. | 0.01 | | 1 | 1.14 | | 1 | URI |
| | Gq. dehiscens | 0.08 | 0.36 | 4 | 1.23 | 0.06 | 4 | URI |
| | Gg. praebulloides | 0.26 | 0.12 | 6 | 1.22 | 0.24 | 6 | URI |
| DSDP 448 | D. altispira | -0.49 | 0.12 | 4 | 2.87 | 0.05 | 4 | CWRU |
| 2CC | Gs. trilobus | -0.62 | 0.26 | 5 | 2.21 | 0.13 | 5 | CWRU |
| to | Gr. siakensis | -0.35 | | 1 | 2.34 | | 1 | CWRU |
| 3-2 | | | | | | | | |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| DSDP 495 | Gq. venezuelana | -0.05 | 0.13 | 18 | 2.06 | 0.21 | 18 | CWRU |
| 26-1 | D. altispira | -0.98 | 0.22 | 17 | 2.89 | 0.34 | 16 | CWRU |
| to | Gr. siakensis | -1.29 | 0.25 | 17 | 1.93 | 0.23 | 17 | CWRU |
| 27-5 | Gs. sacculifer | -1.50 | 0.36 | 12 | 3.02 | 0.23 | 12 | CWRU |
| DSDP 516 | Gq. dehiscens | 0.06 | 0.11 | 5 | 1.55 | 0.13 | 5 | URI |
| 21-1 | Globigerinoides spp. | -0.20 | 0.06 | 4 | 1.80 | 0.20 | 4 | URI |
| to | | | | | | | | |
| 22-2 | | | | | | | | |
| DSDP 526A | Gq. dehiscens | 0.74 | 0.19 | 7 | 1.38 | 0.11 | 7 | URI |
| 21-1 | Globigerinoides spp. | 0.28 | 0.18 | 4 | 1.99 | 0.08 | 4 | URI |
| to | | | | | | | | |
| 21-4 | | | | | | | | |
| **SUMMARY N4 TIME SLICE** | | | | | | | | |
| DSDP 14 | Gq. dehiscens | 1.38 | 0.10 | 4 | 1.79 | 0.09 | 4 | URI |
| 2-1 | Gg. praebulloides | 1.07 | 0.06 | 4 | 1.66 | 0.02 | 4 | URI |
| to | | | | | | | | |
| 2-4 | | | | | | | | |
| DSDP 18 | Gq. dehiscens | 1.08 | 0.18 | 6 | 1.80 | 0.22 | 6 | URI |
| 4-2 | Gg. praebulloides | 0.69 | 0.21 | 4 | 1.69 | 0.24 | 4 | URI |
| to | | | | | | | | |
| 5-5 | | | | | | | | |
| SITE 55 | Gq. venezuelana | 0.20 | 0.25 | 4 | 1.98 | 0.04 | 4 | CWRU |
| 12-2 | Gs. trilobus | 0.06 | 0.30 | 4 | 1.97 | 0.20 | 4 | CWRU |
| to | Gr. kugleri | -0.38 | | 1 | 1.76 | | 1 | CWRU |
| 13-2 | Gr. siakensis | -0.15 | | 1 | 1.77 | | 1 | CWRU |
| | Gr. angustium-bilicata | 0.17 | 0.05 | 4 | 1.79 | 0.17 | 4 | CWRU |
| SITE 71 | Gq. venezuelana | -0.21 | 0.46 | 5 | 1.74 | 0.15 | 5 | CWRU |
| 32-2 | Gr. siakensis | -0.21 | 0.17 | 5 | 1.63 | 0.13 | 5 | CWRU |
| to | Gr. angustium-bilicata | -0.24 | 0.14 | 2 | 1.82 | 0.10 | 2 | CWRU |
| 33-6 | | | | | | | | |
| SITE 77B | Gq. venezuelana | 0.99 | 0.19 | 4 | 1.29 | 0.03 | 4 | CWRU |
| 30-5 | Gr. siakensis | 0.50 | 0.05 | 3 | 1.32 | 0.06 | 3 | CWRU |
| to | | | | | | | | |
| 31-6 | | | | | | | | |
| DSDP 206 | Catapsydrax spp. | 0.67 | 0.17 | 5 | 1.27 | 0.21 | 5 | URI |
| | Gr. praebulloides | -0.11 | 0.18 | 4 | 0.79 | 0.02 | 3 | URI |
| SITE 208 | Gq. dehiscens | -0.14 | 0.21 | 8 | 1.22 | 0.26 | 8 | URI |
| 23-3 | Globigerinoides | -0.70 | 0.20 | 5 | 1.71 | 0.36 | 5 | URI |
| to | Gr. kugleri | -0.69 | 0.19 | 2 | 2.03 | 0.11 | 2 | URI |
| 24-4 | Gr. siakensis | -0.50 | 0.14 | 3 | 1.11 | 0.04 | 3 | URI |
| | Gs. trilobus | -0.29 | | 1 | 1.23 | | 1 | URI |
| DSDP 214 | Gr. siakensis | -0.03 | 0.08 | 2 | 0.65 | 0.35 | 2 | SCRIPPS |
| 23-1 | Gq. venezuelana | 0.83 | 0.10 | 2 | 1.06 | 0.44 | 2 | SCRIPPS |
| to | Gq. subquadratus | 0.34 | | 1 | 1.52 | | 1 | SCRIPPS |
| 23-6 | Gr. kugleri | -0.15 | | 1 | 1.34 | | 1 | SCRIPPS |
| | Gq. dehiscens | 0.95 | | 1 | 1.21 | | 1 | SCRIPPS |
| | Catapsydrax spp. | 1.30 | 0.22 | 2 | 1.05 | 0.05 | 2 | SCRIPPS |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| SITE 279A | Gq. dehiscens | 1.28 | 0.11 | 4 | 1.35 | 0.14 | 4 | URI |
| 10-2 | Gg. woodi | 0.87 | 0.13 | 4 | 1.74 | 0.24 | 4 | URI |
| to | Catapsydrax spp. | 1.79 | 0.05 | 4 | 1.11 | 0.05 | 4 | URI |
| 11-6 | | | | | | | | |
| SITE 289 | Gq. dehiscens & praedehiscens | -0.52 | 0.19 | 4 | 1.41 | 0.14 | 4 | URI |
| 66-2 | | | | | | | | |
| to | Gr. kugleri | -1.32 | 0.13 | 2 | 1.67 | 0.11 | 2 | URI |
| 69-3 | Globigerinoides spp. | -0.42 | 0.03 | 3 | 1.94 | 0.13 | 3 | URI |
| SITE 292 | Gq. venezuelana | 0.16 | 0.17 | 4 | 1.70 | 0.11 | 4 | CWRU |
| 14-2 | Gs. trilobus | 0.28 | 0.05 | 5 | 1.72 | 0.05 | 5 | CWRU |
| to | Gr. kugleri | -0.44 | 0.12 | 6 | 1.75 | 0.16 | 6 | CWRU |
| 15-4 | Gg. angustium-bilicata | -0.27 | 0.21 | 6 | 1.59 | 0.16 | 6 | CWRU |
| SITE 296 | Gq. venezuelana | 0.52 | 0.00 | 2 | 1.38 | 0.04 | 2 | CWRU |
| 34-3 | | | | | | | | |
| to | | | | | | | | |
| 34CC | | | | | | | | |
| SITE 317B | Gq. venezuelana | 1.48 | 0.41 | 3 | 2.21 | 0.19 | 4 | URI |
| 25-1 | Gr. kugleri | -0.31 | 0.16 | 4 | 1.93 | 0.15 | 4 | URI |
| to | Gg. tripartita | 1.15 | | 1 | 2.00 | | 1 | URI |
| 25-6 | | | | | | | | |
| DSDP 357 | Gq. dehiscens | 0.54 | 0.20 | 11 | 1.28 | 0.34 | 11 | URI |
| 12-1 | Gr. kugleri | -0.40 | 0.30 | 7 | 1.80 | 0.25 | 7 | URI |
| to | | | | | | | | |
| 13.6 | | | | | | | | |
| DSDP 360 | Gq. dehiscens | 0.96 | 0.18 | 4 | 1.79 | 0.09 | 4 | URI |
| 26-1 | Gg. praebulloides | 0.82 | 0.14 | 3 | 1.98 | 0.18 | 3 | URI |
| to | | | | | | | | |
| 26-2 | | | | | | | | |
| DSDP 362 | Gq. dehiscens | 0.17 | 0.13 | 10 | 1.18 | 0.14 | 10 | URI |
| 39-3 | Catapsydrax spp. | 0.75 | 0.14 | 8 | 1.13 | 0.14 | 8 | URI |
| to | | | | | | | | |
| 40-6 | | | | | | | | |
| DSDP 366A | Globigerinoides spp. | -0.98 | 0.16 | 5 | 1.84 | 0.16 | 5 | URI |
| | Gr. kugleri | -1.37 | 0.37 | 4 | 1.65 | 0.16 | 4 | URI |
| to | Gq. praedehiscens | 0.17 | 0.13 | 3 | 0.91 | 0.09 | 3 | URI |
| DSDP 407 | Catapsydrax spp. | 1.16 | 0.15 | 8 | 0.67 | 0.12 | 8 | URI |
| | Gg. praebulloides | 0.43 | 0.19 | 8 | 0.38 | 0.13 | 8 | URI |
| to | Gq. dehiscens | 0.74 | 0.10 | 8 | 0.53 | 0.11 | 8 | URI |
| SITE 448 | Gr. siakensis | 0.16 | 0.15 | 3 | 1.65 | 0.19 | 3 | CWRU |
| 6-1 | Gg. tripartita | 0.78 | 0.07 | 3 | 1.71 | 0.08 | 3 | CWRU |
| to | Gr. kugleri | -0.31 | 0.10 | 5 | 1.64 | 0.05 | 5 | CWRU |
| 8-1 | Gg. angustium-bilicata | -0.23 | 0.14 | 5 | 1.58 | 0.05 | 5 | CWRU |
| DSDP 495 | Gq. venezuelana | 0.40 | 0.33 | 6 | 1.14 | 0.16 | 6 | CWRU |
| 38-1 | Gr. siakensis | -0.19 | 0.36 | 6 | 1.01 | 0.14 | 6 | CWRU |
| to | | | | | | | | |
| 39-4 | | | | | | | | |

APPENDIX I (continued)

| Site | Taxonomy | $\delta^{18}O$ | Std. Dev. | No. of Samp. | $\delta^{13}C$ | Std. Dev. | No. of Samp. | Lab. |
|---|---|---|---|---|---|---|---|---|
| DSDP 526A | Catapsydrax spp. | 1.38 | 0.23 | 8 | 1.72 | 0.18 | 8 | URI |
| 27-1 to 29-3 | Gg. praebulloides | 0.98 | 0.08 | 5 | 1.50 | 0.21 | 5 | URI |

APPENDIX II. ISOTOPIC DATA FOR ALL PLANKTONIC FORAMINIFERAL ANALYSES FOR EACH OF THE THREE TIME SLICES

(See microfiche in pocket inside back cover.)

APPENDIX III. COMPILATION FROM PUBLISHED SOURCES OF OXYGEN ISOTOPIC COMPOSITIONS OF SHALLOW-DWELLING PLANKTONIC FORAMINIFERA OF HOLOCENE AGE

(See microfiche in pocket inside back cover.)

APPENDIX IV. ISOTOPIC TIME SERIES DATA FOR SITES 77B AND 289

SITE 289 TIME SERIES DATA (All data from CWRU except where indicated from URI)

| Core/ Section | Depth (cm) | Subbottom Depth (m) | Cibicidoides species | | Globocassiduline species | | Globigerinoides acculifer | | Globigerina species (URI) | | Globigerinoides species | | Dentoglobigerina altiapira | | Globoquadrina Venezuelana | | Globorotalia menardii | | Globigerinoides obliquus | | Globigerinoides ruber | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ |
| 17-5 | 72-80 | 158.76 | | | | | -1.47 | 2.54 | | | | | | | | | | | | | | |
| 18-2 | 86-94 | 163.90 | | | 3.97 | -0.37 | -1.34 | 2.53 | | | | | | | | | | | | | | |
| 18-5 | 76-84 | 168.30 | | | | | -1.51 | 2.39 | | | | | | | | | | | | | | |
| 20-5 | 63-71 | 187.17 | | | | | -1.40 | 2.43 | | | | | | | | | | | | | | |
| 22-4 | 69-77 | 204.73 | | | | | -1.36 | 1.94 | | | | | | | | | | | | | | |
| 23-1 | 86-94 | 211.44 | | | | | -1.40 | 2.16 | | | | | | | | | | | | | | |
| 24-2 | 81-89 | 220.85 | | | | | -0.87 | 2.62 | | | | | | | | | | | | | | |
| 25-2 | 49-57 | 230.07 | | | | | -0.82 | 2.43 | | | | | | | | | | | | | | |
| 26-2 | 22-30 | 239.26 | | | | | -1.45 | 2.79 | | | | | | | | | | | | | | |
| 27-5 | 83-91 | 253.87 | | | | | -1.16 | 2.79 | | | | | | | | | | | | | | |
| 27-6 | 32-34 | 254.83 | 1.99 | 0.76 | | | -1.25 | 2.78 | | | | | | | -0.47 | 1.44 | -1.27 | 1.00 | -1.15 | 2.17 | | |
| 28-1 | 82-86 | 257.34 | 2.02 | 0.59 | | | -1.05 | 2.43 | | | | | | | -0.66 | 1.33 | -1.31 | 1.22 | | | | |
| 28-2 | 52-60 | 258.56 | | | | | -1.33 | 2.68 | | | | | | | | | | | | | | |
| 28-3 | 82-86 | 260.34 | 2.13 | 0.79 | | | -1.24 | 2.82 | | | | | | | -0.61 | 1.43 | -0.93 | 1.63 | -1.25 | 2.30 | | |
| 28-4 | 102-104 | 262.03 | 2.21 | 0.81 | | | | | -1.23 | 2.84 | | | -0.99 | 1.91 | -0.71 | 1.41 | -1.11 | 1.46 | | | | |
| 28-5 | 82-90 | 263.36 | | | | | -1.35 | 2.71 | | | | | | | | | | | | | | |
| 29-2 | 4-8 | 267.56 | 2.30 | 0.81 | | | -1.35 | 2.65 | | | | | -0.82 | 1.87 | -0.60 | 1.31 | -1.06 | 1.56 | | | | |
| 30-2 | 73-80 | 277.77 | | | | | -1.09 | 2.71 | | | | | | | | | | | | | | |
| 31-5 | 83.91 | 291.91 | | | | | | | | | -1.39 | 2.72 | | | | | | | | | | |
| 32-4 | 83-91 | 299.87 | | | | | -1.07 | 2.13 | | | | | | | | | | | | | | |
| 33-5 | 52-60 | 310.56 | | | | | | | | | -1.26 | 2.21 | | | | | | | | | | |
| 34-5 | 82-90 | 320.36 | | | | | | | | | -1.25 | 1.85 | | | | | | | | | | |
| 35-2 | 76-81 | 325.29 | | | | | | | | | -1.16 | 1.33 | | | | | | | | | | |
| 36-4 | 125-132 | 338.29 | | | | | | | | | -1.19 | 1.96 | | | | | | | | | | |
| 37-5 | 75-83 | 348.79 | | | | | | | | | -1.09 | 2.08 | | | | | | | | | | |
| 39-5 | 62-70 | 367.66 | | | | | | | | | -0.68 | 2.57 | | | | | | | | | | |
| 40-3 | 82-90 | 374.36 | | | | | | | | | -0.80 | 2.31 | | | | | | | | | | |
| 41-2 | 82-90 | 382.36 | | | | | | | | | -1.19 | 1.66 | | | | | | | | | | |
| 42-2 | 86-94 | 391.90 | | | | | | | | | -0.78 | 2.10 | | | | | | | | | | |
| 42-5 | 87-93 | 396.90 | | | | | | | | | -0.92 | 2.29 | | | | | | | | | | |
| 44-2 | 75-83 | 410.79 | | | | | | | | | -0.81 | 2.11 | | | | | | | | | | |
| 46-2 | 75-83 | 429.79 | | | | | | | | | -1.39 | 2.05 | | | | | | | | | -1.03 | 2.46 |
| 47-1 | 97-99 | 437.98 | | | | | | | | | | | | | | | | | | | | |
| 47-2 | 52-60 | 439.06 | | | | | | | | | -0.80 | 2.70 | | | | | | | | | -0.47 | 3.05 |
| 48-1 | 97-99 | 447.48 | | | | | | | | | | | | | | | | | | | | |
| 48-2 | 82-90 | 448.86 | | | | | | | | | -0.63 | 2.18 | | | | | | | | | | |
| 49-2 | 82-90 | 458.36 | | | | | | | | | -0.69 | 2.28 | | | | | | | | | | |
| 49-5 | 89-97 | 462.93 | | | | | | | | | | | | | | | | | | | -0.74 | 2.47 |
| 50-2 | 82-90 | 467.86 | | | | | | | | | -1.40 | 1.93 | | | | | | | | | | |
| 51-2 | 90-98 | 477.44 | | | | | | | -1.15 | 1.96 | | | | | | | | | | | | |
| 51-6 | 96-99 | 483.48 | | | | | | | | | | | | | | | | | | | -1.11 | 2.45 |
| 52-2 | 82-90 | 486.86 | | | | | | | -1.15 | 2.53 | | | | | | | | | | | | |
| 54-2 | 90-98 | 505.94 | | | | | | | -0.94 | 2.28 | | | | | | | | | | | | |
| 56-2 | 82-90 | 524.86 | | | | | | | -1.26 | 1.51 | | | | | | | | | | | | |
| 57-2 | 112-119 | 534.65 | | | | | | | | | -0.94 | 1.74 | | | | | | | | | | |
| 59-2 | 92-100 | 553.46 | | | | | | | | | -0.82 | 1.48 | | | | | | | | | | |
| 61-6 | 77-82 | 582.08 | -0.08 | 0.40 | | | | | | | | | | | | | | | | | | |
| 66-2 | 82-90 | 619.86 | 0.67 | 0.51 | | | | | | | | | | | | | | | | | | |
| 67-6 | 78-83 | 635.29 | 0.53 | 0.35 | | | | | | | | | | | | | | | | | | |

APPENDIX IV (continued)

SITE 77B TIME SERIES DATA (All data from CWRU)

| Core/ Section | Depth (cm) | Subbottom Depth (m) | Cibicidoides species | | Mixed Benthics | | Uvigerina species | | Globorotalia plesiotumida | | Globigerinoides quadrolobatus | | Globigerina venezuelana | | Globorotalia menardii | | Dentoglogigerina altispira | | Globorotalia siakensis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ | $\delta^{18}O$ | $\delta^{13}C$ |
| 5-4 | 50-52 | 50.91 | | | | | | | -1.63 | 1.34 | | | | | | | | | | |
| 9-2 | 46-54 | 84.20 | | | | | | | | | -0.64 | 1.55 | 0.52 | 0.63 | | | | | | |
| 9-3 | 51-53 | 85.72 | 2.45 | -0.20 | | | | | | | | | | | | | | | | |
| 9-4 | 55-59 | 87.27 | 1.94 | -0.19 | | | | | | | | | | | | | | | | |
| 9-5 | 52-56 | 88.74 | 2.33 | -0.15 | | | | | | | | | | | | | | | | |
| 10-1 | 75-79 | 92.27 | 2.01 | 0.01 | | | | | | | | | 0.65 | 0.76 | | | | | | |
| 10-2 | 100-107 | 94.04 | | | | | 3.08 | -1.13 | | | -1.11 | 1.57 | 0.52 | 0.34 | | | | | | |
| 10-3 | 106-110 | 95.58 | 2.20 | -0.11 | | | | | | | | | | | | | | | | |
| 10-4 | 100-107 | 97.40 | | | | | | | | | -0.86 | 1.21 | | | | | | | | |
| 10-5 | 104-108 | 98.56 | 2.37 | -0.04 | | | | | | | | | 0.74 | 0.94 | | | | | | |
| 10-6 | 100-108 | 100.04 | | | | | | | | | -0.98 | 1.46 | | | | | | | | |
| 11-1 | 78-83 | 101.40 | | | | | | | | | | | 0.79 | 0.76 | | | | | | |
| 12-1 | 115-122 | 110.79 | | | | | | | | | | | 0.08 | 0.42 | | | | | | |
| 12-2 | 108-112 | 112.79 | 2.27 | 0.07 | | | | | | | | | | | | | | | | |
| 12-4 | 107-111 | 115.19 | 2.39 | 0.32 | | | | | | | | | | | | | | | | |
| 13-3 | 92-98 | 122.75 | | | 2.86 | -0.46 | | | | | | | -0.06 | 0.63 | | | | | | |
| 13-4 | 52-60 | 123.96 | | | | | | | | | -1.55 | 1.64 | 0.04 | 0.92 | | | | | | |
| 13-6 | 50-58 | 126.84 | | | | | | | | | -0.91 | 1.96 | 0.52 | 0.82 | | | | | | |
| 13-6 | 79-81 | 127.10 | 1.83 | 0.19 | | | | | | | | | | | | | | | | |
| 14-1 | 27-29 | 128.28 | 2.20 | 0.61 | | | | | | | | | | | | | | | | |
| 14-1 | 50-52 | 128.51 | | | | | | | | | | | 0.73 | 1.48 | | | | | | |
| 14-1 | 100-102 | 129.01 | | | | | | | | | | | 0.49 | 1.42 | | | | | | |
| 14-1 | 148-150 | 129.49 | | | | | | | | | | | 0.54 | 1.08 | | | | | | |
| 14-2 | 46-48 | 129.97 | | | | | | | | | | | 0.54 | 1.25 | | | | | | |
| 14-3 | 28-30 | 131.29 | | | | | | | | | | | 0.29 | 1.44 | | | | | | |
| 14-3 | 77-79 | 131.78 | | | | | | | | | -1.16 | 1.33 | -0.35 | 0.93 | | | | | | |
| 14-3 | 127-129 | 132.28 | | | | | | | | | -1.55 | 2.14 | | | | | | | | |
| 14-4 | 25-27 | 132.76 | | | | | | | | | -0.74 | 2.50 | | | | | | | | |
| 14-4 | 95-102 | 133.49 | | | | | | | | | -1.13 | 2.57 | 0.53 | 1.28 | | | | | | |
| 15-2 | 100-107 | 139.64 | | | | | | | | | -1.04 | 1.84 | | | | | | | | |
| 15-5 | 10-14 | 143.22 | | | | | | | | | | | -0.14 | 0.79 | | | | | | |
| 15-6 | 40-44 | 145.02 | | | | | | | | | | | | | -0.29 | 0.94 | | | | |
| 16-1 | 102-110 | 147.26 | | | | | | | | | -1.07 | 2.38 | 0.34 | 0.69 | | | | | | |
| 16-2 | 94-98 | 148.66 | | | | | | | | | | | | | -0.48 | 1.00 | | | | |
| 16-4 | 49-56 | 151.23 | | | | | | | | | -1.30 | 1.98 | | | | | | | | |
| 16-6 | 51-58 | 154.25 | | | | | | | | | -0.89 | 2.57 | 0.18 | 1.20 | | | | | | |
| 21-6 | 70-74 | 197.22 | | | | | | | | | | | | | | | -0.21 | 0.86 | | |
| 26-2 | 95-99 | 237.07 | 1.53 | 1.40 | | | | | | | | | 0.76 | 1.82 | | | -1.07 | 2.84 | | |
| 26-4 | 92-96 | 240.04 | 1.31 | 1.12 | | | | | | | | | -0.16 | 1.98 | | | -0.81 | 2.56 | -0.63 | 1.85 |
| 26-5 | 92-96 | 241.54 | 1.17 | 1.12 | | | | | | | | | 0.04 | 2.04 | | | 0.74 | 2.83 | | |
| 26-6 | 92-96 | 243.04 | 1.44 | 1.44 | | | | | | | | | 0.32 | 2.03 | | | -0.63 | 2.87 | -0.60 | 1.92 |
| 27-2 | 92-96 | 246.24 | 1.31 | 0.97 | | | | | | | | | | | | | | | | |
| 30-5 | 103-107 | 278.25 | | | | | | | | | | | 1.30 | 1.26 | | | | | 0.44 | 1.25 |
| 30-6 | 103-107 | 279.95 | | | | | | | | | | | 0.82 | 1.27 | | | | | | |
| 31-2 | 103-107 | 282.85 | 2.06 | 0.95 | | | | | | | | | 0.86 | 1.34 | | | | | 0.50 | 1.40 |
| 31-5 | 103-107 | 287.35 | | | | | | | | | | | 0.97 | 1.30 | | | | | -0.36 | 1.23 |
| 31-6 | 104-108 | 288.86 | 1.94 | 0.75 | | | | | | | | | | | | | | | 0.56 | 1.32 |

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**The Miocene Ocean:**
**Paleoceanography and Biogeography**

**The evolution of Miocene surface and near-surface marine temperatures: Oxygen isotopic evidence**

by
Samuel M. Savin et al.

**Appendixes II and III**

# APPENDIX II

## ISOTOPIC DATA FOR ALL PLANKTONIC FORAMINIFERAL ANALYSES FOR EACH OF THE THREE TIME SLICES

SITE RC 12-418 N17 TIME SLICE

| Depth (cm) | Globorotalia conoidea d O18 | d C13 |
|---|---|---|
| 452-455 | | |
| 472-475 | 0.41 | 1.64 |
| 493-496 | 0.95 | 1.61 |
| 514-517 | 0.33 | 1.84 |
| 531-534 | 0.68 | 1.84 |
| 552-555 | 0.76 | 1.68 |
| 569-572 | 0.85 | 1.38 |
| | | |
| average | 0.66 | 1.67 |
| std.dev. | 0.22 | 0.16 |
| # samp. | 6 | 6 |

SITE 62.1 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Globigerinoides sacculifer & trilobus d O18 | d C13 | Globorotalia menardii d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 23-5 | 47-51 | 222.49 | 0.37 | 1.30 | -0.91 | 1.83 | -1.22 | 1.38 |
| 23-5 | 143-147 | 223.45 | 0.46 | 1.21 | -1.46 | 1.59 | | |
| 23-6 | 143-147 | 224.95 | 0.11 | 1.31 | | | -1.22 | 1.55 |
| 24-1 | 97-101 | 225.99 | -0.41 | 1.72 | -1.35 | 2.07 | | |
| 24-1 & 24-2 | 97-101 & 52-56 | 226.52 | | | | | -1.14 | 1.39 |
| 24-2 | 52-56 | 227.04 | -0.28 | 1.60 | -1.23 | 2.17 | | |
| 24-2 | 143-147 | 227.95 | -0.22 | 1.73 | | | | |
| | average | | 0.01 | 1.48 | -1.24 | 1.92 | -1.19 | 1.44 |
| | std.dev. | | 0.33 | 0.21 | 0.21 | 0.22 | 0.04 | 0.08 |
| | # samp. | | 6 | 6 | 4 | 4 | 3 | 3 |

SITE 77B N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Globigerinoides quadrilobatus d O18 | d C13 | Globorotalia menardii d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 15-5 | 10-14 | 143.32 | -0.14 | 0.79 | | | | |
| 15-6 | 40-44 | 145.02 | | | | | -0.29 | 0.94 |
| 16-1 | 102-110 | 147.26 | 0.34 | 0.69 | -1.07 | 2.38 | | |
| 16-2 | 94-98 | 148.66 | | | | | -0.48 | 1.00 |
| 16-4 | 49-56 | 151.23 | | | -1.30 | 1.98 | | |
| | **average** | | 0.10 | 0.74 | -1.19 | 2.18 | -0.39 | 0.97 |
| | **std.dev.** | | 0.24 | 0.05 | 0.11 | 0.20 | 0.09 | 0.03 |
| | **# samp.** | | 2 | 2 | 2 | 2 | 2 | 2 |

SITE 158 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana | | Globorotalia menardii | | Globigerinoides trilobus & sacculifer | |
|---|---|---|---|---|---|---|---|---|
| | | | del O18 | del C13 | del O18 | del C13 | del O18 | del C13 |
| 19-6 | 40-44 | 169.92 | -0.12 | 1.20 | -1.83 | 1.32 | -1.90 | 1.79 |
| 20-1 | 60-64 | 171.62 | -0.28 | 1.20 | -1.37 | 1.40 | -1.91 | 2.15 |
| 20-2 | 116-120 | 173.68 | -0.08 | 1.43 | -1.10 | 1.48 | -1.46 | 1.48 |
| 20-3 | 63-67 | 174.65 | 0.07 | 1.17 | -1.40 | 1.29 | -1.09 | 1.91 |
| 20-4 | 15-19 | 175.67 | | | -1.22 | 1.21 | -1.89 | 2.11 |
| 20-4 | 102-106 | 176.54 | | | -1.40 | 1.21 | -1.36 | 1.58 |
| 20-5 | 127-131 | 178.29 | -0.46 | 1.24 | -1.12 | 1.26 | -1.78 | 1.78 |
| 20-6 | 65-69 | 179.17 | -0.29 | 0.77 | | | -1.01 | 1.54 |
| 21-1 | 348-42 | 180.38 | -0.45 | 1.13 | -0.59 | 1.27 | -1.44 | 1.84 |
| | average | | -0.23 | 1.16 | -1.25 | 1.31 | -1.54 | 1.80 |
| | std.dev. | | 0.18 | 0.18 | 0.33 | 0.09 | 0.33 | 0.22 |
| | # samp. | | 7 | 7 | 8 | 8 | 9 | 9 |

SITE 206 N17 TIME SLICE

| Core/ sect. | Depth (cm.) | Subbottom depth(m) | Globigerina nepenthes d O18 | d C13 | Globorotalia conoidea d O18 | d C13 |
|---|---|---|---|---|---|---|
| 21-6 | 140-148 | 191.94 | 0.56 | 1.34 | 0.83 | 1.76 |
| 22-1 | 124-131 | 193.28 | 0.58 | 1.19 | 0.75 | 1.47 |
| 22-3 | 35-45 | 195.40 | 0.29 | 1.49 | 0.76 | 1.57 |
| 22-5 | 106-113 | 199.10 | | | 0.66 | 1.54 |
| 22CC | | 201.00 | 0.61 | 1.35 | 0.56 | 2.44 |
| 23-2 | 50-58 | 203.04 | 0.41 | 1.28 | 0.70 | 1.59 |
| 24-1 | 106-114 | 211.10 | | | 0.89 | 1.64 |
| 24-3 | 64-71 | 213.68 | 0.75 | 1.88 | 0.89 | 1.78 |
| | **average** | | 0.53 | 1.42 | 0.76 | 1.72 |
| | **std.dev.** | | 0.15 | 0.22 | 0.11 | 0.29 |
| | **# samp.** | | 6 | 6 | 8 | 8 |

SITE 207A N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Orbulina species d O18 | d C13 | Globorotalia conoidea d O18 | d C13 | Neogloboquadrina pachyderma d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 6-2 | 142-150 | 94.96 | | | 0.98 | 1.54 | 0.91 | 1.38 |
| 6-3 | 142-150 | 96.46 | 0.62 | 2.69 | 1.58 | 2.18 | | |
| 6-4 | 142-150 | 97.96 | 0.72 | 2.47 | 0.96 | 1.53 | | |
| 6-5 | 142-150 | 99.46 | | | | | 1.02 | 1.37 |
| 6-6 | 142-150 | 100.96 | 0.97 | 2.37 | 0.94 | 1.41 | | |
| 7-1 | 142-150 | 102.96 | 0.86 | 2.13 | 1.17 | 1.58 | | |
| 7-2 | 142-150 | 103.96 | 0.80 | 2.03 | 1.40 | 1.59 | | |
| 7-3 | 142-150 | 105.46 | 0.98 | 2.26 | 1.17 | 1.47 | | |
| | average | | 0.83 | 2.33 | 1.17 | 1.61 | 0.97 | 1.38 |
| | std.dev. | | 0.13 | 0.22 | 0.22 | 0.24 | 0.05 | .00 |
| | # samp. | | 6 | 6 | 7 | 7 | 2 | 2 |

SITE 208 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Orbulina species d O18 | Orbulina species d C13 | Globorotalia conoidea d O18 | Globorotalia conoidea d C13 | Dentoglobigerina altispira d O18 | Dentoglobigerina altispira d C13 | Globigerinoides sacculifer d O18 | Globigerinoides sacculifer d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 16-1 | 60-64 | 194.62 | -0.40 | 2.36 | | | -0.79 | 1.95 | 0.35 | 2.89 |
| 16-2 | 56-64 | 196.10 | | | -0.16 | 0.97 | -0.66 | 1.99 | -0.15 | 2.67 |
| 16-4 | 145-149 | 199.97 | -0.65 | 1.64 | 0.28 | 1.41 | 0.38 | 2.77 | -0.79 | 2.17 |
| | average | | -0.53 | 2.00 | 0.06 | 1.19 | -0.36 | 2.24 | -0.20 | 2.58 |
| | std.dev. | | 0.12 | 0.36 | 0.22 | 0.22 | 0.52 | 0.38 | 0.47 | 0.30 |
| | # samp. | | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |

SITE 214 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth (m) | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Globigerinoides sacculifer del O18 | Globigerinoides sacculifer del C13 | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 | Orbulina universa del O18 | Orbulina universa del C13 | Sphaeroidinellopsis seminulina del O18 | Sphaeroidinellopsis seminulina del C13 | Globigerinoides conglobatus & obliquus del O18 | Globigerinoides conglobatus & obliquus del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14-1 | 40-44 | 123.92 | 0.61 | 1.49 | -0.66 | 2.46 | -0.61 | 2.61 | -0.48 | 2.03 | -0.42 | 2.27 | -0.88 | 2.39 |
| 14-1 | 80-82 | 124.31 | 0.52 | 1.58 | -0.48 | 2.51 | | | | | | | | |
| 14-1 | 120-124 | 124.72 | 0.64 | 1.52 | -0.87 | 2.33 | -0.48 | 1.96 | -0.96 | 2.26 | | | | |
| 14-2 | 43-47 | 125.45 | 0.56 | 1.38 | -0.69 | 2.49 | -0.72 | 2.64 | -0.32 | 2.00 | -0.51 | 2.44 | -0.76 | 2.44 |
| 14-2 | 120-124 | 126.22 | 0.18 | 1.62 | -0.67 | 2.44 | -0.70 | 2.39 | -0.82 | 2.33 | | | | |
| 14-3 | 56-60 | 127.08 | 0.26 | 1.42 | -0.77 | 2.70 | -0.83 | 2.80 | | | -0.43 | 2.23 | -0.73 | 2.51 |
| 14-3 | 104-106 | 127.55 | 0.24 | 1.44 | -0.76 | 2.11 | | | | | | | | |
| 14-3 | 130-134 | 127.72 | | | | | | | | | | | | |
| 14-4 | 10-14 | 128.12 | 0.56 | 1.48 | -0.61 | 2.17 | -0.79 | 2.62 | | | -0.52 | 2.27 | -0.54 | 2.44 |
| 14-4 | 80-82 | 128.81 | 0.46 | 1.40 | -0.55 | 2.06 | | | | | | | | |
| 14-4 | 120-124 | 129.22 | 0.50 | 1.44 | -0.71 | 2.67 | -0.63 | 2.30 | -0.54 | 2.21 | | | | |
| 14-5 | 44-48 | 129.96 | 0.33 | 1.58 | -0.40 | 2.17 | -0.61 | 2.75 | -0.41 | 1.79 | | | | |
| 14-5 | 83-85 | 130.34 | 0.39 | 1.69 | -0.52 | 2.58 | | | | | | | | |
| 14-5 | 123-127 | 130.75 | 0.41 | 1.54 | -0.16 | 2.24 | -0.56 | 2.71 | -0.42 | 2.45 | | | | |
| 14-6 | 18-22 | 131.20 | 0.35 | 1.56 | -0.59 | 2.47 | -0.79 | 2.71 | -0.29 | 1.87 | -0.39 | 2.11 | -0.76 | 2.46 |
| 14-6 | 80-82 | 131.81 | 0.46 | 1.52 | -0.47 | 2.33 | | | | | | | | |
| 14-6 | 119-123 | 132.21 | 0.59 | 1.45 | -0.34 | 1.99 | -0.71 | 2.36 | -0.12 | 1.79 | | | | |
| 15-2 | 10-14 | 134.62 | 0.45 | 1.54 | -0.49 | 2.48 | -0.71 | 2.66 | -0.53 | 2.13 | -0.41 | 2.05 | | |
| | | average | 0.44 | 1.51 | -0.57 | 2.36 | -0.68 | 2.54 | -0.49 | 2.09 | -0.45 | 2.23 | -0.73 | 2.45 |
| | | std.dev. | 0.13 | 0.08 | 0.17 | 0.21 | 0.10 | 0.23 | 0.23 | 0.22 | 0.05 | 0.13 | 0.11 | 0.04 |
| | | # samp. | 17 | 17 | 17 | 17 | 12 | 12 | 10 | 10 | 6 | 6 | 5 | 5 |

Site 237 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth (m) | Globigerinoides sacculifer del O18 | Globigerinoides sacculifer del C13 | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 | Orbulina universa del O18 | Orbulina universa del C13 | Globorotalia limbata del O18 | Globorotalia limbata del C13 | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Sphaeroidinellopsis seminulina del O18 | Sphaeroidinellopsis seminulina del C13 | Globigerinoides obliquus del O18 | Globigerinoides obliquus del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-6 | 80-84 | 109.82 | -0.72 | 1.94 | -0.56 | 2.00 | -0.44 | 2.15 | -0.45 | 1.34 | 0.27 | 0.77 | -0.61 | 1.98 | -0.64 | 2.08 |
| 12-6 | 120-124 | 110.22 | -0.57 | 2.48 | -0.38 | 2.25 | -0.43 | 1.86 | -0.69 | 1.33 | 0.56 | 1.27 | -0.35 | 2.18 | -0.63 | 2.54 |
| 13-1 | 10-14 | 111.12 | -0.63 | 1.19 | -0.24 | 1.96 | 0.14 | 1.72 | -0.15 | 0.82 | | | 0.11 | 1.76 | -0.44 | 1.83 |
| 13-1 | 41-45 | 111.43 | -0.40 | 1.89 | -0.77 | 2.09 | -0.03 | 1.75 | -0.43 | 0.98 | 0.60 | 0.93 | -0.25 | 1.58 | -0.61 | 1.87 |
| 13-1 | 80-84 | 111.82 | -0.85 | 1.61 | -0.87 | 2.11 | -0.04 | 1.81 | -0.62 | 1.19 | 0.63 | 0.91 | -0.50 | 1.81 | -0.79 | 2.22 |
| 13-1 | 112-122 | 112.22 | -0.16 | 1.95 | -0.49 | 2.02 | -0.25 | 1.75 | -0.14 | 1.31 | 0.46 | 0.88 | 0.09 | 1.31 | -0.64 | 1.98 |
| | | average | -0.56 | 1.84 | -0.55 | 2.07 | -0.18 | 1.84 | -0.41 | 1.16 | 0.50 | 0.95 | -0.25 | 1.77 | -0.63 | 2.09 |
| | | std.dev. | 0.22 | 0.39 | 0.22 | 0.09 | 0.22 | 0.15 | 0.21 | 0.20 | 0.13 | 0.17 | 0.27 | 0.28 | 0.10 | 0.24 |
| | | # samp. | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

SITE 238 — N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom Depth (m.) | Globigerinoides sacculifer del O18 | Globigerinoides sacculifer del C13 | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 | Orbulina universa del O18 | Orbulina universa del C13 | Globorotalia limbata del O18 | Globorotalia limbata del C13 | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Sphaeroidinellopsis seminulina del O18 | Sphaeroidinellopsis seminulina del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24-6 | 51-59 | 221.05 | -0.70 | 2.42 | -1.01 | 1.78 | -0.15 | 1.93 | 0.04 | 1.27 | 0.67 | 1.08 | -0.16 | 1.47 | | |
| 25-3 | 70-78 | 228.24 | -0.47 | 2.53 | -0.93 | 2.46 | -0.37 | 1.72 | -0.16 | 1.38 | 0.57 | 1.10 | -0.49 | 1.80 | 0.35 | 2.18 |
| 25-6 | 76-84 | 232.80 | -0.27 | 2.08 | -0.87 | 2.50 | 0.02 | | -0.43 | 1.54 | 0.28 | 1.09 | -0.02 | 1.69 | | |
| 26-2 | 90-98 | 236.44 | -0.58 | 2.11 | -0.85 | 2.46 | | | | | 0.57 | 1.25 | | | | |
| 27-2 | 33-39 | 245.36 | -0.86 | 2.48 | | | -1.02 | 2.56 | -0.19 | 1.43 | 0.34 | 1.43 | -0.45 | 1.79 | | |
| 27-2 | 105-111 | 246.08 | | | | | | | | 0.98 | | | | | | |
| 27-3 | 21-27 | 246.74 | | | | | | | | | | | | | | |
| 27-3 | 102-110 | 247.56 | -1.04 | 2.62 | -1.37 | 2.54 | | | -0.67 | | 0.50 | 1.23 | -0.82 | 2.01 | | |
| 27-4 | 20-26 | 248.23 | | | | | | | | | | | | | | |
| 27-4 | 93-99 | 248.96 | -1.37 | 2.67 | | | -1.52 | 2.68 | | | 0.24 | 1.51 | | | | |
| 27-5 | 86-94 | 250.40 | -0.67 | 2.44 | -1.12 | 3.16 | -1.13 | 2.35 | -0.69 | 1.48 | 0.56 | 1.38 | -0.96 | 2.33 | | |
| | | average | -0.75 | 2.44 | -1.03 | 2.48 | -0.70 | 2.25 | -0.35 | 1.35 | 0.47 | 1.26 | -0.48 | 1.85 | 0.35 | 2.18 |
| | | std.dev. | 0.32 | 0.17 | 0.18 | 0.40 | 0.56 | 0.37 | 0.27 | 0.18 | 0.15 | 0.16 | 0.33 | 0.27 | | |
| | | # samp. | 8 | 8 | 6 | 6 | 6 | 5 | 6 | 6 | 8 | 8 | 6 | 6 | 1 | 1 |

SITE 281 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Orbulina species d O18 | Orbulina species d C13 | Neogloboquadrina pachyderma d O18 | Neogloboquadrina pachyderma d C13 |
|---|---|---|---|---|---|---|
| 6-4 | 45-47 | 50.46 | | | 2.00 | 1.66 |
| 6-4 | 90-92 | 50.91 | | | 1.65 | 1.64 |
| 6-5 | 10-12 | 51.61 | | | 1.73 | 1.78 |
| 6-5 | 105-107 | 52.56 | | | 1.63 | 1.71 |
| 6-6 | 10-12 | 53.11 | | | 1.68 | 1.56 |
| 6-6 | 90-92 | 53.91 | | | 1.78 | 1.67 |
| 7-2 | 128-130 | 57.79 | 1.72 | 2.00 | | |
| 7-3 | 90-92 | 58.91 | 1.47 | 2.45 | 1.84 | 1.28 |
| 7-4 | 10-12 | 59.61 | 1.53 | 2.20 | | |
| | **average** | | 1.57 | 2.22 | 1.76 | 1.61 |
| | **std.dev.** | | 0.11 | 0.18 | 0.12 | 0.15 |
| | **# samp.** | | 3 | 3 | 7 | 7 |

SITE289 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Dentoglobigerina altispira d O18 | d C13 | Globigerinoides obliquus d O18 | d C13 | Globorotalia menardii d O18 | d C13 | Globigerinoides sacculifer d O18 | d C13 | Globigerinoide species d O18 | d C1: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27-6 | 32-34 | 254.83 | -0.47 | 1.44 | | | -1.15 | 2.17 | -1.27 | 1.00 | -1.25 | 2.78 | | |
| 28-1 | 82-86 | 257.34 | -0.66 | 1.33 | | | | | -1.31 | 1.22 | -1.05 | 2.43 | | |
| 28-2 | 52-60 | 258.56 | | | | | | | | | -1.33 | 2.68 | | |
| 28-3 | 82-86 | 260.34 | -0.61 | 1.43 | | | -1.25 | 2.30 | -0.93 | 1.63 | -1.24 | 2.82 | | |
| 28-4 | 102-104 | 262.03 | -0.71 | 1.41 | -0.99 | 1.91 | | | -1.11 | 1.46 | | | -1.23 | 2.84 |
| 28-5 | 82-90 | 263.36 | | | | | | | | | -1.35 | 2.71 | | |
| 29-2 | 4-8 | 267.56 | -0.60 | 1.31 | -0.82 | 1.87 | | | -1.06 | 1.56 | -1.35 | 2.65 | | |
| | average | | -0.61 | 1.38 | -0.91 | 1.89 | -1.20 | 2.24 | -1.14 | 1.37 | -1.26 | 2.68 | -1.23 | 2.84 |
| | std.dev. | | 0.08 | 0.05 | 0.08 | 0.02 | 0.05 | 0.07 | 0.14 | 0.23 | 0.10 | 0.13 | | |
| | # samp. | | 5 | 5 | 2 | 2 | 2 | 2 | 5 | 5 | 6 | 6 | 1 | 1 |

SITE 292 N17 TIME SLICE

| Core/ sect | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globigerinoides sacculifer & trilobus d O18 | Globigerinoides sacculifer & trilobus d C13 |
|---|---|---|---|---|---|---|
| 9-1 | 146-150 | 74.48 | | | -1.50 | 1.66 |
| 9-2 | 93-97 | 75.45 | 0.61 | 1.21 | -1.37 | 1.39 |
| 9-2 | 146-150 | 75.98 | 0.95 | 1.09 | -0.95 | 1.47 |
| 9-3 | 50-54 | 76.52 | 1.05 | 1.55 | -1.37 | 1.62 |
| 9-3 | 93-97 | 76.95 | | | -1.47 | 1.46 |
| 9-3 | 146-150 | 77.48 | 0.69 | 1.42 | -0.94 | 1.67 |
| | average | | 0.83 | 1.32 | -1.27 | 1.55 |
| | std.dev. | | 0.18 | 0.18 | 0.23 | 0.11 |
| | # samp. | | 4 | 4 | 6 | 6 |

SITE 296 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Orbulina species d O18 | d C13 | Globorotalia conoidea d O18 | d C13 | Globoquadrina venezuelana d O18 | d C13 | Globigerinoides trilobus & sacculifer d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 22-2 | 44-52 | 198.48 | -0.79 | 2.40 | | | | | | |
| 22-2 | 103-107 | 199.05 | | | 0.02 | 1.36 | 0.51 | 1.03 | | |
| 22-2 | 133-137 | 199.35 | -0.31 | 2.27 | -0.18 | 1.52 | 0.64 | 1.06 | -0.71 | 2.05 |
| 22-3 | 39-37 | 199.88 | -0.90 | 1.76 | | | | | | |
| 22-3 | 79-83 | 200.31 | -0.53 | 2.42 | -0.11 | 1.44 | 0.40 | 0.88 | | |
| 22-3 | 124-128 | 200.76 | -0.43 | 2.33 | 0.03 | 1.63 | 0.18 | 0.87 | | |
| 22-4 | 36-44 | 201.40 | -0.49 | 1.72 | | | | | | |
| 22-4 | 92-96 | 201.94 | -0.33 | 2.44 | 0.12 | 1.49 | | | | |
| 22-4 | 131-135 | 202.33 | | | 0.09 | 1.52 | 0.39 | 0.72 | | |
| 22-5 | 46-54 | 203.00 | -0.64 | 1.68 | | | | | | |
| 22-5 | 94-98 | 203.46 | -0.50 | 2.54 | 0.06 | 1.41 | | | | |
| 23-2 | 42-44 | 207.93 | | | | | | | | |
| 23-2 | 90-92 | 208.41 | -0.39 | 2.36 | 0.09 | 1.47 | | | | |
| 23-2 | 92-96 | 208.44 | | | | | | | -0.81 | 2.28 |
| 23-3 | 92-96 | 209.94 | | | | | | | -0.41 | 1.67 |
| 23-4 | 46-48 | 210.97 | -0.85 | 1.95 | | | 0.21 | 1.39 | | |
| 23-4 | 92-96 | 211.44 | -0.74 | 1.73 | | | | | | |
| 23-4 | 143-147 | 211.95 | -0.69 | 1.82 | | | | | | |
| | average | | -0.58 | 2.11 | 0.01 | 1.48 | 0.39 | 0.99 | -0.64 | 2.00 |
| | std.dev. | | 0.19 | 0.32 | 0.10 | 0.08 | 0.16 | 0.21 | 0.17 | 0.25 |
| | # samp. | | 13 | 13 | 8 | 8 | 6 | 6 | 3 | 3 |

SITE 310 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth (m) | Orbulina species d O18 | d C13 | Globorotalia menardii d O18 | d C13 | Globorotalia menardii/plesiotumida/merotumida d O18 | d C13 | Globigerinoides sacculifer & trilobus d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 8-4 | 133-137 | 67.85 | 0.82 | 1.38 | | | | | | |
| 8-5 | 56-60 | 68.58 | 0.61 | 1.45 | 0.27 | 1.36 | 0.18 | 1.03 | | |
| 8-5 | 109-113 | 69.11 | 0.42 | 1.57 | | | | | | |
| 8-6 | 42-46 | 69.94 | 0.47 | 1.62 | | | | | -1.13 | 1.75 |
| | average | | 0.58 | 1.51 | 0.27 | 1.36 | 0.18 | 1.03 | -1.13 | 1.75 |
| | std.dev. | | 0.16 | 0.10 | | | | | | |
| | # samp. | | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 1 |

SITE 317B N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globigerinoides sacculifer & trilobus d O18 | Globigerinoides sacculifer & trilobus d C13 |
|---|---|---|---|---|---|---|
| 9-5 | 100-104 | 80.02 | 0.20 | 1.87 | -0.47 | 2.72 |
| 9-5 | 143-147 | 80.45 | 0.05 | 1.73 | 0.01 | 3.23 |
| 9-6 | 60-64 | 81.12 | 0.38 | 1.87 | -0.99 | 2.66 |
| 9-6 | 120-124 | 81.72 | 0.32 | 1.69 | -0.80 | 2.50 |
| 10-1 | 53-57 | 83.05 | 0.32 | 1.63 | -0.63 | 2.39 |
| 10-1 | 113-117 | 83.65 | 0.25 | 1.27 | -0.64 | 2.38 |
| 10-2 | 11-15 | 84.13 | 0.27 | 1.36 | -0.69 | 2.66 |
| 10-2 | 66-70 | 84.68 | 0.27 | 1.19 | -0.76 | 2.30 |
| | average | | 0.26 | 1.58 | -0.62 | 2.61 |
| | std.dev. | | 0.09 | 0.25 | 0.28 | 0.28 |
| | # samp. | | 8 | 8 | 8 | 8 |

SITE 319 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globigerinoides sacculifer d O18 | Globigerinoides sacculifer d C13 |
|---|---|---|---|---|---|---|
| 3-2 | 118-120 | 21.69 | 0.79 | 1.59 | -0.50 | 2.64 |
| 3-3 | 8-10 | 23.09 | 0.65 | 1.53 | -0.34 | 2.17 |
| 3-3 | 118-120 | 23.19 | 0.93 | 1.49 | | |
| 3CC | | 28.50 | 0.90 | 1.40 | -0.21 | 1.40 |
| | average | | 0.82 | 1.50 | -0.35 | 2.07 |
| | std.dev. | | 0.11 | 0.07 | 0.12 | 0.51 |
| | # samp. | | 4 | 4 | 3 | 3 |

SITE 470 N17 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth (m) | Globigerina bulloides d O18 | d C13 |
|---|---|---|---|---|
| 9-1 | 54-59 | | 0.16 | 0.87 |
| 9-2 | 54-59 | | -0.04 | 0.86 |
| 9-3 | 54-59 | | -0.07 | 0.96 |
| 9 | CC | | -0.36 | 0.53 |
| | average | | -0.08 | 0.81 |
| | std.dev. | | 0.19 | 0.16 |
| | # samp. | | 4 | 4 |

SITE 55 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Dentoglobigerin altispira d O18 | Dentoglobigerin altispira d C13 | Globigerinoides trilobus d O18 | Globigerinoides trilobus d C13 | Globorotalia peripheroronda & siakensis d O18 | Globorotalia peripheroronda & siakensis d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 8-5 | 60-64 | 70.62 | 0.44 | 1.91 | -0.48 | 2.53 | -0.93 | 1.88 | -0.55 | 1.76 |
| 8-6 | 30-34 | 71.82 | 0.56 | 1.84 | -0.49 | 2.55 | -1.07 | 1.94 | -0.83 | 1.72 |
| 8-6 | 80-84 | 72.32 | 0.08 | 1.46 | -0.65 | 2.15 | | | | |
| 10-2 | 91-95 | 84.73 | | | -0.50 | 2.16 | -0.72 | 2.18 | | |
| 10-4 | 98-102 | 87.80 | -0.06 | 1.58 | -0.53 | 2.35 | -0.82 | 1.98 | | |
| 10-6 | 130-134 | 91.12 | | | -0.11 | 2.13 | -1.12 | 2.19 | -1.01 | 1.95 |
| 11-1 | 83-87 | 92.25 | | | 0.04 | 2.16 | -0.27 | 2.51 | -0.59 | 1.54 |
| 11-1 | 148-150 | 92.89 | 0.77 | 1.62 | -0.05 | 1.95 | -0.36 | 2.05 | -0.20 | 1.41 |
| | average | | 0.36 | 1.68 | -0.35 | 2.25 | -0.76 | 2.10 | -0.64 | 1.68 |
| | std.dev. | | 0.31 | 0.17 | 0.25 | 0.20 | 0.31 | 0.20 | 0.27 | 0.19 |
| | # samp. | | 5 | 5 | 8 | 8 | 7 | 7 | 5 | 5 |

SITE 71 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Dentoglobigerina altispira d O18 | d C13 | Globorotalia siakensis d O18 | d C13 | Globigerinoides trilobus d O18 | d C1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 19-2 | 140-144 | 163.92 | 0.07 | 1.92 | -0.94 | 2.67 | -1.36 | 2.06 | -0.60 | 2.71 |
| 19-5 | 100-104 | 168.02 | 0.16 | 1.96 | -0.59 | 2.93 | -0.97 | 2.07 | -0.95 | 2.83 |
| 20-2 | 136-140 | 172.88 | 0.27 | 3.04 | -1.11 | 2.92 | -0.75 | 2.23 | -0.88 | 2.81 |
| 20-4 | 96-100 | 175.48 | -0.02 | 1.99 | -0.91 | 4.57 | -0.83 | 2.09 | -1.00 | 2.77 |
| 20-6 | 90-94 | 178.42 | 0.28 | 1.91 | -1.04 | 2.59 | -1.30 | 1.99 | -1.35 | 2.63 |
| 21-2 | 106-110 | 181.58 | 0.43 | 2.06 | -0.91 | 3.04 | -0.82 | 2.17 | | |
| 21-6 | 100-104 | 187.52 | 0.10 | 2.19 | -1.01 | 2.92 | -0.79 | 2.50 | -0.84 | 2.79 |
| 22-2 | 136-140 | 191.88 | 0.14 | 2.44 | -0.73 | 3.07 | -0.98 | 2.18 | | |
| 22-4 | 100-104 | 194.52 | 0.56 | 2.39 | | | -1.17 | | | |
| 22-6 | 100-104 | 197.52 | 0.22 | 2.27 | | | -0.94 | 2.31 | | |
| | average | | 0.22 | 2.22 | -0.91 | 3.09 | -0.99 | 2.18 | -0.94 | 2.76 |
| | std.dev. | | 0.16 | 0.33 | 0.16 | 0.58 | 0.21 | 0.15 | 0.22 | 0.07 |
| | # samp. | | 10 | 10 | 8 | 8 | 10 | 9 | 6 | 6 |

SITE 77B N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Dentoglobigerina altispira d O18 | d C13 | Globorotalia siakensis d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 26-2 | 95-99 | 237.07 | 0.76 | 1.82 | -1.07 | 2.84 | | |
| 26-4 | 92-96 | 240.04 | -0.16 | 1.98 | -0.81 | 2.56 | -0.63 | 1.85 |
| 26-5 | 92-96 | 241.54 | 0.04 | 2.04 | -0.74 | 2.83 | | |
| 26-6 | 92-96 | 243.04 | 0.32 | 2.03 | -0.63 | 2.87 | -0.60 | 1.92 |
| | **average** | | 0.24 | 1.97 | -0.81 | 2.78 | -0.62 | 1.89 |
| | **std.dev.** | | 0.35 | 0.09 | 0.16 | 0.13 | 0.02 | 0.04 |
| | **# samp.** | | 4 | 4 | 4 | 4 | 2 | 2 |

SITE 206 N8 TIME SLICE

| Core/ sect. | Depth (cm.) | Subbottom depth(m) | Globoquadrina dehiscens d O18 | Globoquadrina dehiscens d C13 | Globigerinoides sacculifer d O18 | Globigerinoides sacculifer d C13 | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 | Globigerinoides species d O18 | Globigerinoides species d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 31-1 | 108-116 | 278.12 | 0.48 | 1.75 | | | -0.09 | 1.58 | -0.14 | 1.73 |
| 31-3 | 107-115 | 281.11 | 0.35 | 1.41 | -0.46 | 2.36 | 0.00 | 1.63 | | |
| 31-5 | 106-114 | 284.10 | 0.35 | 1.50 | | | -0.11 | 1.78 | -0.50 | 2.10 |
| 31-6 | 106-114 | 285.60 | 0.47 | 1.83 | | | -0.17 | 1.46 | | |
| 32-1 | 106-114 | 287.10 | 0.16 | 1.85 | | | -0.27 | 1.65 | -0.12 | 2.52 |
| 32-2 | 92-100 | 288.46 | 0.33 | 1.97 | -0.49 | 2.46 | 0.08 | 1.78 | | |
| 32-3 | 107-115 | 290.11 | 0.16 | 1.59 | 0.05 | 2.37 | -0.39 | 1.69 | | |
| | average | | 0.33 | 1.70 | -0.30 | 2.40 | -0.14 | 1.65 | -0.25 | 2.12 |
| | std.dev. | | 0.12 | 0.19 | 0.25 | 0.04 | 0.15 | 0.10 | 0.17 | 0.32 |
| | # samp. | | 7 | 7 | 3 | 3 | 7 | 7 | 3 | 3 |

SITE 208 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globorotalia siakensis d O18 | d C13 | Globorotalia peripheroronda d O18 | d C13 | Globoquadrina dehiscens d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 21-4 | 52-60 | 320.06 | -1.12 | 2.00 | | | -0.19 | 2.12 |
| 21-5 | 50-58 | 321.54 | | | | | -0.27 | 1.73 |
| 21-5 | 142-150 | 322.46 | -1.09 | 1.54 | -0.48 | 1.54 | -1.62 | 1.02 |
| 21-6 | 96-104 | 323.50 | | | -0.68 | 1.80 | | 1.59 |
| | average | | -1.11 | 1.77 | -0.58 | 1.67 | -0.69 | 1.62 |
| | std.dev. | | 0.01 | 0.23 | 0.10 | 1.10 | 0.66 | 0.39 |
| | # samp. | | 2 | 2 | 2 | 2 | 3 | 4 |

SITE 214 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m.) | Dentoglobigerina altispira del O18 | del C13 | Globoquadrina venezuelana del O18 | del C13 | Globigerinoides subquadratus del O18 | del C13 | Globorotalia siakensis del O18 | del C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 20-4 | 100-102 | 186.51 | | | 0.84 | 1.66 | | | | |
| 21-2 | 101-103 | 193.02 | | | | | | | | |
| 21-3 | 39-41 | 193.90 | -0.74 | 2.28 | | | -0.84 | 2.17 | -1.31 | 0.51 |
| 21-3 | 110-112 | 194.61 | | | | | | | | |
| 21-4 | 40-42 | 195.41 | | | | | | | | |
| 21-5 | 46-48 | 196.97 | -0.69 | 2.58 | | | -0.54 | 2.22 | | |
| 21-5 | 103-105 | 197.54 | -0.28 | 2.38 | | | | | | |
| 22-1 | 47-49 | 200.48 | | | | | | | | |
| 22-6 | 47-49 | 207.98 | | | 0.85 | 1.46 | | | | |
| | | average | -0.57 | 2.41 | 0.85 | 1.56 | -0.69 | 2.20 | -1.31 | 0.51 |
| | | std.dev. | 0.21 | 0.12 | 0.01 | 0.10 | 0.15 | 0.02 | | |
| | | # samp. | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 |

Site 237 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Globigerinoides subquadratus del O18 | Globigerinoides subquadratus del C13 | Globigerinoides trilobus & sacculifer del O18 | Globigerinoides trilobus & sacculifer del C13 | Globorotalia limbata del O18 | Globorotalia limbata del C13 | Globorotalia siakensis del O18 | Globorotalia siakensis del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-1 | 117-123 | 159.70 | -0.85 | 3.27 | 0.75 | 1.84 | -0.61 | 2.51 | | | | | | |
| 18-2 | 32-36 | 160.34 | -0.93 | 2.96 | 0.74 | 1.87 | | | | | | | | |
| 18-2 | 131-138 | 161.34 | -1.06 | 2.57 | 0.47 | 1.40 | | | | | | | | |
| 18-3 | 88-96 | 162.42 | -0.98 | 2.09 | 0.20 | 1.13 | | | | | | | | |
| 18-3 | 138-140 | 162.89 | -0.30 | 2.48 | 0.76 | 1.89 | -0.83 | 1.69 | -0.87 | 1.87 | | | -0.26 | 0.69 |
| 18-4 | 62-65 | 163.65 | -0.98 | 2.01 | 0.18 | 1.44 | | | | | | | | |
| 18-5 | 121-129 | 165.75 | -1.04 | 1.98 | 1.21 | 1.26 | | | | | | | | |
| 18-6 | 71-79 | 166.75 | -0.66 | 1.51 | 0.40 | 0.97 | | | | | | | | |
| 19-1 | 121-129 | 169.25 | -1.06 | 2.15 | 0.67 | 0.98 | | | | | | | | |
| 19-2 | 51-57 | 170.05 | -0.93 | 2.10 | 0.60 | 0.95 | -0.38 | 1.83 | -0.24 | 2.22 | -0.61 | 0.91 | | |
| 19-3 | 65-69 | 171.67 | -0.72 | 2.31 | 0.49 | 1.13 | -0.41 | 1.84 | -0.51 | 1.97 | | | | |
| | | average | -0.86 | 2.31 | 0.59 | 1.35 | -0.56 | 1.97 | -0.54 | 2.02 | -0.61 | 0.91 | -0.26 | 0.69 |
| | | std.dev. | 0.22 | 0.47 | 0.28 | 0.35 | 0.18 | 0.32 | 0.26 | 0.15 | | | | |
| | | # samp. | 11 | 11 | 11 | 11 | 4 | 4 | 3 | 3 | 1 | 1 | 1 | 1 |

SITE 238 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m.) | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Globigerinoides subquadratus del O18 | Globigerinoides subquadratus del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 | Globorotalia peripheroronda del O18 | Globorotalia peripheroronda del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38-5 | 80-84 | 354.82 | -0.80 | 2.93 | 0.39 | 1.72 | -0.51 | 2.52 | -0.59 | 2.03 | -0.27 | 1.56 |
| 38-6 | 67-71 | 356.19 | -0.66 | 2.92 | 0.42 | 1.81 | | | | | | |
| 40-1 | 88-92 | 367.90 | | | | | | | | | | |
| 41-2 | 83-87 | 378.85 | -0.42 | 1.97 | 0.40 | 1.66 | | | | | | |
| | | average | -0.63 | 2.61 | 0.40 | 1.73 | -0.51 | 2.52 | -0.59 | 2.03 | -0.27 | 1.56 |
| | | std.dev. | 0.16 | 0.45 | 0.01 | 0.06 | | | | | | |
| | | # samp. | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |

SITE 279A N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina dehiscens d O18 | d C13 | Globorotalia miozea d C13 | d C13 | Globigerina bulloides d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 3-1 | 114-118 | 109.66 | 0.96 | 2.20 | 0.83 | 2.43 | 1.00 | 2.73 |
| 3-3 | 104-108 | 112.56 | 0.87 | 2.37 | 0.73 | 2.66 | 0.83 | 2.67 |
| 3-4 | 98-102 | 114.00 | 0.80 | | 0.84 | 2.75 | 0.90 | 2.75 |
| 3-6 | 100-104 | 117.02 | 0.32 | | 0.70 | 2.34 | | |
| 4-1 | 104-108 | 119.06 | 0.94 | 2.51 | 1.07 | 2.55 | 0.91 | 2.44 |
| 4-2 | 104-108 | 120.56 | 1.17 | 2.18 | 1.08 | 2.41 | 1.03 | 1.88 |
| | average | | 0.84 | 2.32 | 0.88 | 2.52 | 0.93 | 2.49 |
| | std.dev. | | 0.26 | 0.13 | 0.15 | 0.14 | 0.07 | 0.33 |
| | # samp. | | 6 | 4 | 6 | 6 | 5 | 5 |

SITE 281 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globorotalia miozea d O18 | d C13 | Globigerina bulloides & praebulloides d O18 | d C13 |
|---|---|---|---|---|---|---|
| 10-3 | 53-55 | 87.04 | 1.57 | 1.84 | 1.21 | 2.15 |
| 10-4 | 12-14 | 88.13 | 1.56 | 1.91 | 1.02 | 2.04 |
| 10-4 | 93-95 | 88.94 | 1.74 | 2.03 | 1.35 | 1.97 |
| 10-6 | 90-92 | 91.91 | 1.56 | 2.27 | | |
| | average | | 1.61 | 2.01 | 1.19 | 2.05 |
| | std.dev. | | 0.08 | 0.16 | 0.14 | 0.07 |
| | # samp. | | 4 | 4 | 3 | 3 |

SITE 289 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 | Globoquadrina dehiscens d O18 | Globoquadrina dehiscens d C13 | Globigerina species d O18 | Globigerina species d C13 | Globigerinoides species d O18 | Globigerinoides species d C13 | Globigerinoides ruber d O18 | Globigerinoides ruber d C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51-2 | 90-98 | 477.44 | | | | | | | -1.15 | 1.96 | | |
| 51-6 | 96-99 | 483.48 | | | | | | | | | -1.11 | 2.45 |
| 52-2 | 82-90 | 486.86 | -1.52 | 1.72 | -1.26 | 2.21 | -1.45 | 2.17 | -1.15 | 2.53 | | |
| 52-5 | 76-81 | 491.29 | -1.41 | | -1.43 | 2.50 | -1.11 | 2.32 | | | | |
| 53-4 | 82-90 | 499.36 | -1.43 | 1.89 | -0.70 | 2.07 | -0.98 | 2.17 | | | | |
| 54-2 | 90-98 | 505.94 | -1.54 | 1.43 | -1.11 | 1.73 | -1.24 | 1.86 | -0.94 | 2.28 | | |
| 54-4 | 90-94 | 508.92 | -1.26 | 1.36 | -0.79 | 1.40 | -1.14 | 1.89 | | | | |
| 55-2 | 90-94 | 515.42 | -1.01 | 1.43 | | | -0.76 | 1.93 | | | | |
| | average | | -1.36 | 1.57 | -1.06 | 1.98 | -1.11 | 2.06 | 0.68 | 1.54 | -1.11 | 2.45 |
| | std.dev. | | 0.18 | 0.20 | 0.28 | 0.38 | 0.21 | 0.17 | 0.10 | 0.23 | | |
| | # samp. | | 6 | 5 | 5 | 5 | 6 | 6 | 3 | 3 | 1 | 1 |

SITE 292 N8 TIME SLICE

| Core/ sect | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Dentoglobigerina altispira d O18 | d C13 | Globigerinoides trilobus d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 12-2 | 90-94 | 103.92 | 0.82 | 1.60 | -0.33 | 2.19 | 0.48 | 1.96 |
| 12-2 | 140-144 | 104.42 | 0.59 | 1.70 | -0.44 | 2.21 | 0.18 | 2.06 |
| 12-3 | 90-94 | 105.42 | | | | | -1.44 | 1.85 |
| 12-3 | 140-144 | 105.92 | 0.74 | 1.75 | -0.75 | 2.33 | -1.67 | 1.85 |
| 12-4 | 41-45 | 106.43 | 0.65 | 1.56 | -0.54 | 2.40 | | |
| 12-5 | 140-144 | 108.92 | 0.87 | 1.73 | 0.09 | 2.22 | -0.48 | 1.88 |
| | average | | 0.73 | 1.67 | -0.39 | 2.27 | -0.59 | 1.92 |
| | std.dev. | | 0.10 | 0.07 | 0.28 | 0.08 | 0.85 | 0.08 |
| | # samp. | | 5 | 5 | 5 | 5 | 5 | 5 |

SITE317B N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth | Globoquadrina venezuelana d O18 | d C13 | Globigerinoides trilobus d O18 | d C13 |
|---|---|---|---|---|---|---|
| 17-1 | 92-96 | 149.94 | 0.06 | 1.98 | -1.03 | 1.84 |
| 17CC | | 158.50 | 0.00 | 2.36 | -1.29 | 2.47 |
| 18-1 | 48-52 | 159.00 | | | -0.84 | 2.50 |
| 18-1 | 142-146 | 159.94 | -0.63 | 2.39 | | |
| 18-2 | 142-146 | 161.44 | -0.11 | 1.97 | | 1.85 |
| 18-3 | 142-146 | 162.94 | -0.12 | 2.01 | -0.70 | 2.21 |
| | average | | -0.16 | 2.14 | -0.97 | 2.17 |
| | std.dev. | | 0.24 | 0.19 | 0.22 | 0.29 |
| | # samp. | | 5 | 5 | 4 | 5 |

SITE 317B N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globigerinoides trilobus d O18 | Globigerinoides trilobus d C13 |
|---|---|---|---|---|---|---|
| 17-1 | 92-96 | 149.94 | 0.35 | 1.98 | -1.03 | 1.84 |
| 17CC | | 158.50 | 0.29 | 2.36 | -1.29 | 2.47 |
| 18-1 | 48-52 | 159.00 | | | -0.84 | 2.50 |
| 18-1 | 142-146 | 159.94 | -0.34 | 2.39 | | |
| 18-2 | 142-146 | 161.44 | 0.18 | 1.97 | | 1.85 |
| 18-3 | 142-146 | 162.94 | 0.17 | 2.01 | -0.70 | 2.21 |
| | average | | 0.13 | 2.14 | -0.97 | 2.17 |
| | std.dev. | | 0.24 | 0.19 | 0.22 | 0.29 |
| | # samp. | | 5 | 5 | 4 | 5 |

SITE 366A N8 TIME SLICE

| Core | Section | Subbottom Depth(m.) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globorotalia peripheroronda del O18 | Globorotalia peripheroronda del C13 | Dentoglobigerina altispira del O18 | Dentoglobigerina altispira del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 156.12 | -0.77 | 1.94 | -0.69 | 1.23 | -0.91 | 2.48 |
| | | 159.47 | | | -0.49 | 1.89 | | |
| | | 161.56 | -0.37 | 2.23 | -0.52 | 1.76 | -0.52 | 2.56 |
| | | 162.47 | -0.53 | 1.91 | -0.77 | 1.42 | -0.60 | 2.32 |
| | | Average | -0.56 | 2.03 | -0.62 | 1.58 | -0.68 | 2.45 |
| | | Std. Dev. | 0.16 | 0.14 | 0.12 | 0.26 | 0.17 | 0.10 |
| | | # samp. | 3 | 3 | 4 | 4 | 3 | 3 |

SITE 369A N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 | Globorotalia peripheroronda del O18 | Globorotalia peripheroronda del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 134.42 | -2.19 | 1.54 | -0.51 | 0.88 | | |
| | | 136.32 | -1.48 | 2.02 | | | -1.96 | 0.44 |
| | | 139.25 | -1.85 | 2.42 | -1.32 | 0.97 | | |
| | | 139.96 | -1.85 | 1.94 | | | -1.69 | 0.87 |
| | | Mean | -1.84 | 1.98 | -0.92 | 0.93 | -1.83 | 0.66 |
| | | Std. Dev. | 0.25 | 0.31 | 0.40 | 0.06 | 0.13 | 0.21 |
| | | Number | 4 | 4 | 2 | 2 | 2 | 2 |

SITE 391A N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 | Globorotalia peripheroronda del O18 | Globorotalia peripheroronda del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 376.04 | -0.75 | 1.78 | -0.05 | 1.56 | -0.59 | 1.02 |
| | | 382.05 | -0.74 | 1.80 | -0.36 | 0.88 | -0.56 | 1.12 |
| | | Average | -0.75 | 1.79 | -0.21 | 1.22 | -0.58 | 1.07 |
| | | Std. Dev. | .00 | 0.01 | 0.15 | 0.34 | 0.02 | 0.05 |
| | | # samp. | 2 | 2 | 2 | 2 | 2 | 2 |

SITE 398D N8 TIME SLICE

| Core/ sect. | Depth (cm.) | Subbottom depth(m) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 |
|---|---|---|---|---|---|---|
| | | 433.23 | -0.17 | 2.38 | 0.50 | 1.67 |
| | | 434.77 | 0.05 | 1.81 | 0.22 | 1.32 |
| | | 436.30 | | | 0.57 | 1.42 |
| | | 437.77 | | | 0.22 | 1.52 |
| | | 439.26 | | | 1.01 | 1.87 |
| | | 440.74 | -0.04 | 2.30 | 0.37 | 1.76 |
| | | 452.25 | 0.67 | 1.78 | 0.83 | 1.68 |
| | | 453.77 | 0.59 | 1.77 | 0.57 | 1.14 |
| | | 455.22 | 0.83 | 2.39 | 0.84 | 1.42 |
| | | Average | 0.32 | 2.07 | 0.57 | 1.53 |
| | | Std. dev. | 0.39 | 0.29 | 0.26 | 0.22 |
| | | # samp. | 6 | 6 | 9 | 9 |

SITE 408 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 | Globigerina praebulloides del O18 | Globigerina praebulloides del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 293.12 | | | 0.33 | 1.23 | 0.06 | 1.49 |
| | | 295.25 | | | 0.16 | 1.20 | 0.17 | 1.32 |
| | | 296.73 | | | 0.49 | 1.15 | 0.25 | 1.35 |
| | | 298.25 | 0.01 | 1.14 | | | 0.31 | 1.22 |
| | | 301.26 | | | | | 0.36 | 1.21 |
| | | 309.24 | | | -0.47 | 1.32 | 0.44 | 0.72 |
| | | average | 0.01 | 1.14 | 0.13 | 1.23 | 0.27 | 1.22 |
| | | std. dev. | | | 0.36 | 0.06 | 0.12 | 0.24 |
| | | # samp. | 1 | 1 | 4 | 4 | 6 | 6 |

SITE 448 N8 TIME SLICE

| Core/ sect | Depth (cm) | Subbottom depth(m) | Dentoglobigerina altispira d O18 | d C13 | Globigerinoides trilobus d O18 | d C13 | Globorotalia siakensis d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 2CC | | 14.50 | -0.39 | 2.93 | -0.82 | 2.38 | | |
| 3-1 | 48-52 | 15.00 | | | -0.38 | 2.27 | | |
| 3-1 | 109-113 | 15.61 | -0.36 | 2.86 | -0.26 | 2.01 | -0.35 | 2.34 |
| 3-2 | 40-44 | 16.42 | -0.67 | 2.91 | -0.67 | 2.25 | | |
| 3-2 | 94-98 | 16.96 | -0.52 | 2.79 | -0.95 | 2.14 | | |
| | average | | -0.49 | 2.87 | -0.62 | 2.21 | -0.35 | 2.34 |
| | std.dev. | | 0.12 | 0.05 | 0.26 | 0.13 | | |
| | # samp. | | 4 | 4 | 5 | 5 | 1 | 1 |

SITE 495 N8 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth (m) | Globoquadrina venezuelana d O18 | d C13 | Dentoglobigerina altispira d O18 | d C13 | Globorotalia siakensis d O18 | d C13 | Globigerinoides sacculifer d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 26-1 | 75-79 | 238.27 | -0.33 | 1.95 | -1.08 | 2.63 | -1.54 | 1.79 | -2.06 | 2.69 |
| 26-1 | 98-102 | 238.50 | -0.26 | 1.94 | -1.58 | 2.78 | -1.45 | 1.75 | | |
| 26-1 | 140-144 | 238.92 | -0.09 | 2.03 | -1.18 | 2.59 | -1.76 | 1.37 | | |
| 26-2 | 98-102 | 240.00 | 0.09 | 2.14 | -1.08 | 3.09 | -1.18 | 2.02 | -1.17 | 3.03 |
| 26-2 | 140-144 | 240.42 | -0.01 | 2.09 | -1.14 | 2.99 | -1.52 | 1.74 | -1.75 | 2.95 |
| 26-3 | 75-79 | 241.27 | -0.15 | 2.15 | -0.87 | 2.87 | -1.89 | 1.97 | -1.70 | 2.77 |
| 26-3 | 92-96 | 241.44 | -0.02 | 2.19 | -0.90 | 3.14 | -1.02 | 2.08 | -1.25 | 2.99 |
| 26-3 | 140-144 | 241.92 | -0.05 | 2.28 | -0.91 | 3.21 | -1.17 | 2.13 | -1.16 | 3.19 |
| 26-4 | 98-102 | 243.00 | 0.02 | 2.21 | -0.94 | 3.11 | -1.15 | 2.09 | -1.33 | 3.46 |
| 26-4 | 140-144 | 243.42 | 0.04 | 2.25 | -0.99 | 2.71 | -1.06 | 2.15 | -1.73 | 2.71 |
| 26-5 | 75-79 | 244.27 | 0.07 | 2.16 | -0.76 | 2.79 | -1.19 | 2.23 | -1.58 | 3.32 |
| 26-5 | 98-102 | 244.50 | 0.13 | 2.19 | -0.85 | 2.99 | -1.27 | 2.14 | -1.94 | 2.85 |
| 26-5 | 136-140 | 244.88 | 0.04 | 1.97 | -0.91 | 3.66 | -1.12 | 1.98 | -0.73 | 3.07 |
| 26-6 | 52-56 | 245.54 | -0.25 | 2.30 | -0.68 | 2.97 | -1.12 | 2.15 | -1.58 | 3.16 |
| 26-6 | 103-107 | 246.05 | -0.09 | 2.17 | -0.99 | | -1.22 | 2.00 | | |
| 27-1 | 75-79 | 247.77 | 0.13 | 1.70 | -0.62 | 2.06 | -1.16 | 1.69 | | |
| 27-3 | 75-79 | 250.77 | -0.12 | 1.90 | | | | | | |
| 27-5 | 75-79 | 253.77 | 0.00 | 1.48 | -1.17 | 2.71 | -1.06 | 1.57 | | |
| | average | | -0.05 | 2.06 | -0.98 | 2.89 | -1.29 | 1.93 | -1.50 | 3.02 |
| | std.dev. | | 0.13 | 0.21 | 0.22 | 0.34 | 0.25 | 0.23 | 0.36 | 0.23 |
| | # samp. | | 18 | 18 | 17 | 16 | 17 | 17 | 12 | 12 |

SITE 55 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globigerinoides trilobus d O18 | Globigerinoides trilobus d C13 | Globorotalia kugleri d O18 | Globorotalia kugleri d C13 | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 | Globigerina angustiumbilicata d O18 | Globigerina angustiumbilicata d C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12-2 | 52-58 | 105.35 | 0.41 | 2.00 | 0.55 | 2.18 | | | | | | |
| 12-3 | 55-61 | 106.88 | 0.24 | 1.93 | -0.13 | 1.90 | | | | | | |
| 12-4 | 52-58 | 108.35 | -0.22 | 2.03 | 0.04 | 1.67 | | | | | 0.24 | 1.54 |
| 12-5 | 58-64 | 109.91 | | | -0.21 | 2.12 | | | | | 0.17 | 1.77 |
| 12-6 | 60-65 | 111.43 | | | | | | | | | 0.09 | 1.83 |
| 13-1 | 45-50 | 112.98 | 0.38 | 1.96 | | | -0.38 | 1.76 | -0.15 | 1.77 | 0.17 | 2.03 |
| | average | | 0.20 | 1.98 | 0.06 | 1.97 | -0.38 | 1.76 | -0.15 | 1.77 | 0.17 | 1.79 |
| | std.dev | | 0.25 | 0.04 | 0.30 | 0.20 | | | | | 0.05 | 0.17 |
| | # samp. | | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | 4 |

SITE 71 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Globorotalia siakensis d O18 | d C13 | Globigerina angustiumbilicata d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 32-2 | 125-129 | 282.77 | -0.20 | 1.72 | -0.40 | 1.80 | | |
| 32-4 | 125-129 | 285.77 | 0.47 | 1.48 | 0.06 | 1.40 | | |
| 32-6 | 125-129 | 288.77 | 0.09 | 1.85 | -0.11 | 1.66 | | |
| 33-5 | 75-80 | 296.78 | -0.54 | 1.73 | -0.19 | 1.61 | -0.10 | 1.92 |
| 33-6 | 15-19 | 297.67 | -0.85 | 1.90 | -0.39 | 1.67 | -0.38 | 1.71 |
| | average | | -0.21 | 1.74 | -0.21 | 1.63 | -0.24 | 1.82 |
| | std.dev. | | 0.46 | 0.15 | 0.17 | 0.13 | 0.14 | 0.10 |
| | # samp. | | 5 | 5 | 5 | 5 | 2 | 2 |

SITE 77B N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 |
|---|---|---|---|---|---|---|
| 30-5 | 103-107 | 278.25 | 1.30 | 1.26 | 0.44 | 1.25 |
| 30-6 | 103-107 | | 0.82 | 1.27 | | |
| 31-2 | 103-107 | 282.85 | 0.86 | 1.34 | 0.50 | 1.40 |
| 31-5 | 103-107 | 287.35 | 0.97 | 1.30 | | |
| 31-6 | 104-108 | 288.86 | | | 0.56 | 1.32 |
| | average | | 0.99 | 1.29 | 0.50 | 1.32 |
| | std.dev. | | 0.19 | 0.03 | 0.05 | 0.06 |
| | # samp. | | 4 | 4 | 3 | 3 |

SITE 206 N4 TIME SLICE

| Core/ sect. | Depth (cm.) | Subbottom depth(m) | Catapsydrax species d O18 | d C13 | Globigerina praebulloides d O18 | d C13 |
|---|---|---|---|---|---|---|
| | | 415.29 | 0.50 | 1.50 | -0.20 | |
| | | 419.00 | 0.45 | 1.35 | -0.30 | 0.77 |
| | | 424.54 | 0.76 | 1.46 | -0.12 | 0.82 |
| | | 432.96 | 0.92 | 1.12 | 0.19 | 0.77 |
| | | 433.54 | 0.73 | 0.94 | | |
| | **average** | | 0.67 | 1.27 | -0.11 | 0.79 |
| | **std.dev.** | | 0.17 | 0.21 | 0.18 | 0.02 |
| | **# samp.** | | 5 | 5 | 4 | 3 |

SITE 208 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina dehiscens d O18 | Globoquadrina dehiscens d C13 | Globigerinoides species d O18 | Globigerinoides species d C13 | Globorotalia kugleri d O18 | Globorotalia kugleri d C13 | Globigerinoides trilobus d O18 | Globigerinoides trilobus d C13 | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23-3 | 96-104 | 375.00 | 0.15 | 0.99 | -0.99 | 1.76 | | | | | | |
| 23-4 | 56-64 | 376.10 | 0.06 | 1.26 | -0.63 | 1.58 | | | | | -0.35 | 1.09 |
| 23-5 | 142-150 | 378.46 | -0.46 | 0.82 | -0.80 | 1.48 | | | | | -0.68 | 1.07 |
| 23-6 | 96-104 | 379.50 | -0.38 | 1.01 | -0.70 | 1.36 | | | | | -0.47 | 1.16 |
| 23CC | | 380.00 | 0.09 | 1.12 | | | | | -0.29 | 1.23 | | |
| 24-2 | 58-66 | 401.12 | -0.23 | 1.50 | -0.39 | 2.37 | -0.50 | 1.92 | | | | |
| 24-3 | 142-150 | 403.46 | -0.13 | 1.58 | | | -0.87 | 2.13 | | | | |
| 24-4 | 100-102 | 404.51 | -0.20 | 1.46 | | | | | | | | |
| | average | | -0.14 | 1.22 | -0.70 | 1.71 | -0.69 | 2.03 | -0.29 | 1.23 | -0.50 | 1.11 |
| | std.dev. | | 0.21 | 0.26 | 0.20 | 0.36 | 0.19 | 0.11 | | | 0.14 | 0.04 |
| | # samp. | | 8 | 8 | 5 | 5 | 2 | 2 | 1 | 1 | 3 | 3 |

SITE 214 — N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globorotalia siakensis del O18 | Globorotalia siakensis del C13 | Globoquadrina venezuelana del O18 | Globoquadrina venezuelana del C13 | Globigerinoides subquadratus del O18 | Globigerinoides subquadratus del C13 | Globorotalia kugleri del O18 | Globorotalia kugleri del C13 | Globoquadrina dehiscens del O18 | Globoquadrina dehiscens del C13 | Catapsydrax species del O18 | Catapsydrax species del C13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23-1 | 69-71 | 210.20 | | | | | | | | | | | | |
| 23-2 | 47-49 | 211.48 | 0.05 | 0.99 | 0.73 | 0.62 | 0.34 | 1.52 | | | | | 1.07 | 0.99 |
| 23-2 | 110-112 | 212.11 | -0.11 | 0.30 | | | | | -0.15 | 1.34 | 0.95 | 1.21 | 1.52 | 1.10 |
| 23-3 | 120-122 | 213.71 | | | | | | | | | | | | |
| 23-4 | 110-112 | 215.11 | | | | | | | | | | | | |
| 23-6 | 94-96 | 217.95 | | | 0.93 | 1.50 | | | | | | | | |
| | | average | -0.03 | 0.65 | 0.83 | 1.06 | 0.34 | 1.52 | -0.15 | 1.34 | 0.95 | 1.21 | 1.30 | 1.05 |
| | | std.dev. | 0.08 | 0.35 | 0.10 | 0.44 | | | | | | | 0.22 | 0.05 |
| | | # samp. | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |

SITE 279A N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina dehiscens d O18 | Globoquadrina dehiscens d C13 | Globigerina woodi d O18 | Globigerina woodi d C13 | Catapsydrax species d O18 | Catapsydrax species d C13 |
|---|---|---|---|---|---|---|---|---|
| 11-3 | 72-77 | 188.25 | 1.39 | 1.48 | 1.07 | 1.45 | 1.72 | 1.15 |
| 11-4 | 104-108 | 190.06 | 1.36 | 1.13 | 0.77 | 1.88 | 1.78 | 1.03 |
| 11-5 | 57-62 | 191.10 | 1.12 | 1.32 | 0.73 | 1.56 | 1.87 | 1.09 |
| 11-6 | 145-150 | 193.48 | 1.25 | 1.46 | 0.89 | 2.05 | 1.80 | 1.17 |
| | average | | 1.28 | 1.35 | 0.87 | 1.74 | 1.79 | 1.11 |
| | std.dev. | | 0.11 | 0.14 | 0.13 | 0.24 | 0.05 | 0.05 |
| | # samp. | | 4 | 4 | 4 | 4 | 4 | 4 |

SITE 289 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina dehiscens & praedehiscens d O18 | d C13 | Globorotalia kugleri d O18 | d C13 | Globigerinoides species d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 66-2 | 38-42 | 619.40 | -0.49 | 1.28 | | | | |
| 66-2 | 82-90 | 619.86 | -0.24 | 1.45 | -1.18 | 1.55 | -0.44 | 1.80 |
| 68-4 | 38-42 | 641.40 | | | -1.45 | 1.78 | -0.38 | 2.11 |
| 68-6 | 38-42 | 644.40 | -0.58 | 1.29 | | | -0.43 | 1.91 |
| 69-2 | 65 | 648.15 | -0.78 | 1.63 | | | | |
| | average | | -0.52 | 1.41 | 0.09 | 1.67 | -0.42 | 1.94 |
| | std.dev. | | 0.19 | 0.14 | 0.14 | 0.11 | 0.03 | 0.13 |
| | # samp. | | 4 | 4 | 2 | 2 | 3 | 3 |

SITE 292 N4 TIME SLICE

| Core/ sect | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Globigerinoides trilobus d O18 | d C13 | Globorotalia kugleri d O18 | d C13 | Globigerina angustiumbilicata d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 14-2 | 40-44 | 122.42 | | | 0.21 | 1.64 | | | | |
| 14-3 | 140-144 | 124.84 | -0.12 | 1.58 | 0.32 | 1.75 | -0.29 | 1.49 | | |
| 14-4 | 40-44 | 125.42 | 0.33 | 1.71 | 0.24 | 1.78 | -0.31 | 1.75 | 0.16 | 1.58 |
| 14-5 | 140-144 | 127.92 | | | 0.32 | 1.75 | | | | |
| 14-6 | 50-54 | 128.52 | 0.17 | 1.63 | 0.32 | 1.67 | | | -0.37 | 1.53 |
| 15-1 | 141-145 | 131.43 | | | | | -0.54 | 1.63 | -0.23 | 1.59 |
| 15-2 | 50-54 | 132.02 | 0.26 | 1.88 | | | -0.60 | 1.55 | -0.40 | 1.34 |
| 15-3 | 140-144 | 134.42 | | | | | -0.51 | 1.87 | -0.50 | 1.60 |
| 15-4 | 40-44 | 134.92 | | | | | -0.40 | 1.94 | -0.27 | 1.87 |
| | average | | 0.16 | 1.70 | 0.28 | 1.72 | -0.44 | 1.71 | -0.27 | 1.59 |
| | std.dev. | | 0.17 | 0.11 | 0.05 | 0.05 | 0.12 | 0.16 | 0.21 | 0.16 |
| | # samp. | | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 6 |

SITE 296 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 |
|---|---|---|---|---|
| 34-3 | 142-150 | 314.96 | 0.52 | 1.34 |
| 34CC | | 320.00 | 0.52 | 1.41 |
| | average | | 0.52 | 1.38 |
| | std.dev. | | 0.00 | 0.04 |
| | # samp. | | 2 | 2 |

SITE 317B N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Globoquadrina venezuelana d O18 | d C13 | Globorotalia kugleri d O18 | d C13 | Globigerina tripartita d O18 | d C13 |
|---|---|---|---|---|---|---|---|---|
| 25-1 | 142-146 | 226.44 | | 2.53 | -0.44 | 1.81 | | |
| 25-2 | 142-146 | 227.94 | 1.40 | 2.05 | -0.45 | 2.01 | | |
| 25-3 | 142-146 | 229.44 | 2.02 | 2.12 | | | | |
| 25-4 | 142-146 | 230.94 | 1.03 | 2.14 | -0.05 | 2.13 | | |
| 25-6 | 79-83 | 233.31 | | | -0.29 | 1.76 | 1.15 | 2.00 |
| | average | | 1.48 | 2.21 | -0.31 | 1.93 | 1.15 | 2.00 |
| | std.dev. | | 0.41 | 0.19 | 0.16 | 0.15 | | |
| | # samp. | | 3 | 4 | 4 | 4 | 1 | 1 |

SITE 366A N4 TIME SLICE

| Core | Section | Subbottom depth(m) | Globigerinoides species del O18 | Globigerinoides species del C13 | Globorotalia kugleri del O18 | Globorotalia kugleri del C13 | Globoquadrina praedehiscens del O18 | Globoquadrina praedehiscens del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 234.56 | -1.19 | 1.73 | -1.40 | 1.83 | 0.07 | 0.82 |
| | | 236.28 | -0.95 | 1.65 | -1.91 | 1.44 | 0.09 | 0.87 |
| | | 238.34 | | | 1.12 | 1.56 | 0.35 | 1.03 |
| | | 239.82 | -0.73 | 2.09 | | | | |
| | | 241.32 | -1.09 | 1.75 | -1.29 | 1.77 | | |
| | | 244.92 | -0.95 | 1.97 | | | | |
| | | Mean | -0.98 | 1.84 | -0.87 | 1.65 | 0.17 | 0.91 |
| | | std. dev. | 0.16 | 0.16 | 1.17 | 0.16 | 0.13 | 0.09 |
| | | # samp. | 5 | 5 | 4 | 4 | 3 | 3 |

SITE 407 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth(m) | Catapsydrax species del O18 | del C13 | Globigerina praebulloides del O18 | del C13 | Globoquadrina dehiscens del O18 | del C13 |
|---|---|---|---|---|---|---|---|---|
| | | 269.13 | 1.32 | 0.80 | 0.66 | 0.56 | 0.74 | 0.44 |
| | | 269.43 | 1.18 | 0.73 | 0.36 | 0.35 | 0.76 | 0.52 |
| | | 270.22 | 1.34 | 0.71 | 0.30 | 0.54 | 0.69 | 0.39 |
| | | 270.62 | 1.03 | 0.46 | 0.67 | 0.44 | 0.72 | 0.41 |
| | | 272.49 | 0.89 | 0.73 | 0.26 | 0.42 | 0.65 | 0.63 |
| | | 272.99 | 1.18 | 0.66 | 0.60 | 0.28 | 0.59 | 0.57 |
| | | 273.99 | 1.14 | 0.80 | 0.23 | 0.24 | 0.88 | 0.64 |
| | | 274.72 | 1.22 | 0.52 | 0.32 | 0.22 | 0.89 | 0.66 |
| | | Average | 1.16 | 0.68 | 0.43 | 0.38 | 0.74 | 0.53 |
| | | Std. Dev. | 0.14 | 0.12 | 0.17 | 0.12 | 0.10 | 0.10 |
| | | # samp. | 8 | 8 | 8 | 8 | 8 | 8 |

SITE 448 N4 TIME SLICE

| Core/ sect | Depth (cm) | Subbottom depth(m) | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 | Globigerina tripartita d O18 | Globigerina tripartita d C13 | Globorotalia kugleri d O18 | Globorotalia kugleri d C13 | Globigerina angustiumbilicata d O18 | Globigerina angustiumbilicata d C13 |
|---|---|---|---|---|---|---|---|---|---|---|
| 6-1 | 78-82 | 43.80 | | | 0.77 | 1.68 | | | | |
| 6-2 | 140-144 | 45.92 | 0.03 | 1.49 | | | -0.23 | 1.43 | -0.16 | 1.58 |
| 6-3 | 76-80 | 46.78 | 0.36 | 1.91 | 0.86 | 1.82 | -0.42 | 1.46 | -0.18 | 1.59 |
| 6-4 | 142-146 | 48.94 | 0.08 | 1.55 | 0.70 | 1.64 | -0.43 | 1.40 | -0.51 | 1.51 |
| 7-1 | 74-78 | 53.26 | | | | | -0.19 | 2.03 | -0.18 | 1.56 |
| 8-1 | 77-81 | 62.79 | | | | | -0.27 | 1.90 | -0.11 | 1.67 |
| | average | | 0.16 | 1.65 | 0.78 | 1.71 | -0.31 | 1.64 | -0.23 | 1.58 |
| | std.dev. | | 0.15 | 0.19 | 0.07 | 0.08 | 0.10 | 0.27 | 0.14 | 0.05 |
| | # samp. | | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 5 |

SITE495 N4 TIME SLICE

| Core/ sect. | Depth (cm) | Subbottom depth | Globoquadrina venezuelana d O18 | Globoquadrina venezuelana d C13 | Globorotalia siakensis d O18 | Globorotalia siakensis d C13 |
|---|---|---|---|---|---|---|
| 38-1 | 80-84 | 352.32 | 0.38 | 0.92 | -0.33 | 0.99 |
| 38-2 | 62-66 | 353.64 | 0.22 | 1.00 | -0.20 | 0.90 |
| 38-3 | 78-82 | 355.30 | 1.02 | 1.11 | 0.28 | 1.11 |
| 38-4 | 75-79 | 356.77 | 0.28 | 1.38 | 0.01 | 1.26 |
| 39-1 | 140-144 | 362.42 | -0.04 | 1.30 | | |
| 39-2 | 130-134 | 363.82 | | | 0.01 | 0.92 |
| 39-3 | 140-144 | 365.42 | 0.56 | 1.11 | -0.88 | 0.88 |
| 39-4 | 110-114 | 366.62 | | | | |
| | average | | 0.40 | 1.14 | -0.19 | 1.01 |
| | std.dev. | | 0.33 | 0.16 | 0.36 | 0.14 |
| | # samp. | | 6 | 6 | 6 | 6 |

# APPENDIX III

## COMPILATION FROM PUBLISHED SOURCES OF OXYGEN ISOTOPIC COMPOSITIONS OF SHALLOW-DWELLING PLANKTONIC FORAMINIFERA OF HOLOCENE AGE

**APPENDIX III** The Evolution of Miocene Surface and Near-

Samuel Savin et al. Surface Marine Temperatures: Oxygen Isotopic

Holocene Core Top Delta 018 Values Evidence.

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| SHACKLETON (1977) | | | | | | |
| V28-14 | 64.78 N | 29.57 W | G. pachyderma | 0 | 2.18 | 2.15 |
| | | | | 10 | 2.16 | |
| | | | | 20 | 2.11 | |
| V28-56 | 68.03 N | 6.12 W | G. pachyderma | 0 | 2.86 | 2.86 |
| | | | | 10 | 2.86 | |
| | | | | 20 | 2.85 | |
| RC8-18 | -24.07 S | 15.12 W | G.sacculifer | 0 | | Probably |
| | | | | 10 | 0.32 | not |
| | | | | 20 | 0.66 | Holocene |
| RC11-86 | -35.78 S | 18.45 E | G.sacculifer | 0 | -0.37 | -0.38 |
| | | | | 5 | -0.46 | |
| | | | | 10 | -0.16 | |
| | | | | 16 | -0.55 | |
| | | | | 20 | -0.37 | |
| RC12-294 | -37.26 S | 10.10 W | G.bulloides | 0 | 0.96 | 1.03 |
| | | | | 9 | 1.18 | |
| | | | | 20 | 0.96 | |
| V19-240 | -30.58 S | 13.28 E | G. inflata | TW5 | 0.75 | 0.75 |
| | | | | 0 | 0.72 | |
| | | | | 10 | 0.78 | |
| V19-248 | -24.57 S | 4.83 E | G.ruber | 2 | -0.13 | -0.15 |
| | | | | 10 | -0.17 | |
| V19-282 | -2.75 S | 4.58 E | G.dutertrei | 11 | 0.31 | 0.45 |
| | | | | 31 | 0.59 | |
| V22-38 | -9.55 S | 34.25 W | G.sacculifer | 0 | -0.50 | -0.73 |
| | | | | 6 | -0.75 | |
| | | | | 11 | -0.95 | |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| V22-174 | -10.07 S | 12.82 W | G.ruber | 0 | -1.23 | -1.22 |
| | | | | 10 | -1.21 | |
| | | | G.sacculifer | 0 | -0.92 | -0.83 |
| | | | | 10 | -0.74 | |
| RC11-120 | -43.52 S | 79.87 E | G.bulloides | 5 | 2.03 | 2.01 |
| | | | | 10 | 1.91 | |
| | | | | 15 | 1.90 | |
| | | | | 20 | 2.15 | |
| | | | | 25 | 2.04 | |
| RC13-275 | -50.72 S | 13.43 E | G.pachyderma | 0 | 3.29 | 3.25 |
| | | | | 9 | 3.27 | |
| | | | | 19 | 3.19 | |
| RC15-94 | -42.90 S | 20.86 W | G.bulloides | 0 | 2.33 | 2.42 |
| | | | | 19 | 2.51 | |
| V19-188 | 6.87 N | 60.67 E | G.sacculifer | 10 | -1.62 | -1.62 |
| | | | | 20 | -1.62 | |
| V20-170 | -21.80 S | 69.23 E | G.sacculifer | 5 | -0.94 | -0.94 |
| RC11-147 | -19.10 S | 112.75 E | G.sacculifer | 5 | -1.88 | -1.90 |
| | | | | 15 | -1.92 | |
| RC14-37 | 1.47 N | 90.17 E | G.sacculifer | TW0 | -2.09 | -2.07 |
| | | | | TW10 | -2.22 | |
| | | | | TW20 | -1.90 | |
| BNFC43-PC3 | 10.49 N | 109.03 W | G.sacculifer | 3 | -1.80 | -1.53 |
| | | | | 6 | -1.44 | |
| | | | | 9 | -1.36 | |
| E20-18 | -44.55 S | 111.33 W | G.bulloides | 0 | 2.73 | 2.73 |
| E21-11 | -39.97 S | 112.15 W | G.bulloides | 0 | 2.93 | Probably not Holocene |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| RC8-94 | -27.28 S | 102.08 W | G.sacculifer | 0 | 0.05 | 0.11 |
| | | | | 4 | 0.10 | |
| | | | | 8 | 0.18 | |
| RC9-124 | -28.75 S | 172.59 E | G.sacculifer | 5 | -0.51 | -0.51 |
| | | | | 10 | -0.51 | |
| RC10-114 | -11.18 S | 162.92 W | G.sacculifer | 0 | -1.65 | -1.59 |
| | | | | 2 | -1.45 | |
| | | | | 6 | -1.66 | |
| RC11-230 | -8.80 S | 110.80 W | G.sacculifer | 0 | -1.08 | -1.08 |
| RC13-81 | -19.02 S | 124.23 W | G.sacculifer | TW7 | -0.08 | -0.06 |
| | | | | TW10 | -0.04 | |
| RC13-113 | -1.65 S | 103.63 W | G.sacculifer | 0 | -0.89 | -0.93 |
| | | | | 20 | -0.96 | |
| V19-41 | -14.10 S | 96.20 W | G.sacculifer | 0 | -0.67 | Probably |
| | | | | 10 | -0.52 | not |
| | | | | 20 | -0.34 | Holocene |
| | | | | 30 | -0.18 | |
| | | | | 40 | -0.44 | |
| V19-55 | -17.00 S | 114.18 W | G.sacculifer | 0 | -1.09 | -1.09 |
| V21-33 | -3.80 S | 92.08 W | G.sacculifer | 0 | 0.18 | 0.21 |
| | | | | 1 | 0.23 | |
| V21-59 | 20.92 N | 158.10 W | G.sacculifer | 0 | -0.96 | -1.08 |
| | | | | 2 | -1.19 | |
| | | | | 4 | -1.01 | |
| | | | | 6 | -1.22 | |
| | | | | 8 | -1.00 | |
| V21-146 | 37.68 N | 163.03 E | G.inflata | 2 | 1.01 | 1.01 |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| V24-109 | 0.43 N | 158.80 E | G.sacculifer | 0 | -2.08 | -2.08 |
| V24-166 | -16.52 S | 150.78 E | G.sacculifer | 5 | -0.88 | Probably |
| | | | | 9 | -1.53 | not |
| | | | | 19 | -0.60 | Holocene |
| V28-203 | 0.95 N | 179.42 W | G.sacculifer | 1 | -1.66 | -1.62 |
| | | | | 5 | -1.69 | |
| | | | | 10 | -1.63 | |
| | | | | 15 | -1.50 | |
| V28-235 | -5.45 S | 160.48 E | G.sacculifer | 5 | -1.80 | -1.68 |
| | | | | 10 | -1.69 | |
| | | | | 15 | -1.55 | |
| V28-238 | 1.02 N | 160.48 E | G.sacculifer | 2 | -1.90 | -1.92 |
| | | | | 5 | -1.90 | |
| | | | | 10 | -1.97 | |
| V28-239 | 3.25 N | 159.18 E | G.sacculifer | 5 | -1.72 | -1.69 |
| | | | | 10 | -1.72 | |
| | | | | 15 | -1.64 | |
| Y69-106 | 2.98 N | 86.55 E | G. sacculifer | 0 | -1.95 | -1.70 |
| | | | | 6 | -1.61 | |
| | | | | 10 | -1.53 | |

SAVIN AND DOUGLAS (1973)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| AMPH 22G | -8.57 S | 107.20 W | G.trilob+sacc | 4 | -1.05 | |
| AMPH 30PG | -18.52 S | 111.15 W | G.sacc+trilob | 2 | -0.47 | |
| AMPH 37 | -18.27 S | 121.08 W | G.sacc+congl | 4 | -0.38 | |
| AMPH 79 | -12.13 S | 163.33 W | G.congl+sacc | 2 | -1.38 | |
| DWBG 23A | -16.70 S | 145.80 W | G.ruber+congl | 2 | -1.43 | |
| DWBG 32 | -24.08 S | 146.18 W | G.congl+trilo | 6 | 0.16 | |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| DWBG 118C | -28.03 S | 96.33 W | G.congl | 1 | 0.81 | |
| DWBG 137 | -9.88 S | 110.68 W | G.sacc+trilob | 4 | -1.00 | |
| DWHG 74 | -28.48 S | 106.50 W | G.congl | 3 | 0.55 | |
| DWHG 84 | -15.73 S | 112.22 W | G.sacc+trilob | 2 | -0.62 | |
| DWHG 85 | -13.15 S | 110.63 W | G.sacc+trilob | 2 | -1.07 | |
| LSDH 78G | -4.52 S | 168.03 E | G.sacculifer | 2 | -1.28 | |
| MSN 126 | -24.68 S | 154.75 W | G.conglobatus | 2 | -0.05 | |
| PROA 47G | -21.95 S | 167.95 E | G.ruber | 2 | -1.64 | |
| PROA 66 | -10.75 S | 175.42 E | G.congl+ruber | 2 | -0.77 | |
| PROA 69D | -11.60 S | 175.15 E | G.sacc+tri | D | -2.00 | |
| PROA 71D | -11.57 S | 175.18 E | G.sacc+tri | D | -2.60 | |
| RIS 74G | -14.00 S | 119.60 W | G.sacc+tri | 4 | -0.82 | |
| RIS 76G | -13.90 S | 125.35 W | G.sacculifer | 2 | -1.13 | |
| RIS 78V | -14.03 S | 130.30 W | G.sacc+tri | 5 | -0.91 | |
| RIS 84G | -15.25 S | 142.45 W | G.sacc+tri | 2 | -1.07 | |
| RIS 91G | -15.67 S | 147.45 W | G.sacc+congl | 3 | -1.54 | |
| TET 38 | 5.35 N | 160.50 W | G.ruber+sacc | 4 | -1.98 | |
| CURRY AND MATTHEWS (1981) | | | | | | |
| A15-585HC | 20.15 N | 69.43 E | G.bulloides | | -1.67 | |
| A15-586PG | 20.13 N | 67.93 E | G.bulloides | | -1.80 | |
| A15-591HC | 21.00 N | 59.55 E | G.bulloides | | -1.36 | |
| A15-596 | 18.93 N | 61.38 E | G.bulloides | | -1.70 | |
| A15-597AHC | 17.43 N | 57.18 E | G.bulloides | | -1.26 | |
| A15-612HC | 13.58 N | 104.50 E | G.bulloides | | -2.04 | |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del O18 | Average Del O18 |
|---|---|---|---|---|---|---|
| E45-27 | -43.31 S | 105.55 E | G.bulloides | | 1.59 | |
| E45-70-1 | -48.50 S | 114.48 E | G.bulloides | | 1.56 | |
| E45-73A | -48.55 S | 114.44 E | G.bulloides | | 1.62 | |
| E45-77-1 | -46.45 S | 114.42 E | G.bulloides | | 1.32 | |
| E48-11 | -29.66 S | 93.53 E | G.bulloides | | 0.99 | |
| E48-22A | -39.90 S | 85.71 E | G.bulloides | | 1.03 | |
| E48-27A | -38.54 S | 79.90 E | G.bulloides | | 0.4 | |
| RC9-139 | -47.77 S | 123.10 E | G.bulloides | | 1.62 | |
| RC9-161 | 19.57 N | 59.60 E | G.bulloides | | -1.65 | |
| RC14-7 | -35.52 S | 44.75 E | G.bulloides | | 0.74 | |
| RC14-9 | -39.02 S | 47.88 E | G.bulloides | | 0.31 | |
| V14-103 | 11.44 N | 56.23 E | G.bulloides | | -1.34 | |
| V14-104 | 13.43 N | 53.45 E | G.bulloides | | -1.48 | |
| V16-64 | -46.02 S | 44.33 E | G.bulloides | | 1.71 | |
| V16-65 | -45.00 S | 45.77 E | G.bulloides | | 1.91 | |
| V16-113 | -48.08 S | 137.65 E | G.bulloides | | 1.26 | |
| V19-178 | 8.12 S | 73.25 E | G.bulloides | | -2.59 | |
| V34-83 | 10.40 N | 57.96 E | G.bulloides | | -1.16 | |
| V34-85 | 11.80 N | 57.61 E | G.bulloides | | -1.88 | |
| V34-87 | 16.48 N | 59.76 E | G.bulloides | | -1.32 | |
| V34-88 | 16.52 N | 59.53 E | G.bulloides | | -1.01 | |
| Williams (1977) | | | | | | |
| RC12-339 | 9.13 N | 90.03 E | G.sacculifer | | -1.97 | |
| V19-178 | 8.12 N | 73.25 E | G.sacculifer | | -1.88 | |
| V19-185 | 6.70 N | 59.33 E | G.sacculifer | | -1.73 | |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del O18 | Average Del O18 |
|---|---|---|---|---|---|---|
| V19-202 | -6.98 S | 41.18 E | G.sacculifer | | -1.54 | |
| RC11-147 | -19.07 S | 112.75 E | G.sacculifer | | -1.86 | |
| V20-170 | -21.80 S | 69.23 E | G.sacculifer | | -0.73 | |
| V20-175 | -22.30 S | 68.00 E | G.sacculifer | | -0.77 | |
| V18-207 | -25.63 S | 87.12 E | G.sacculifer | | -0.41 | |
| RC11-126 | -30.07 S | 94.42 E | G.sacculifer | | -0.17 | |
| E48-27A | -38.53 S | 79.90 E | G.bulloides | | 1.08 | |
| E48-23A | -39.52 S | 83.72 E | G.bulloides | | 1.33 | |
| E48-22A | -39.90 S | 85.42 E | G.bulloides | | 1.89 | |
| RC11-120 | -43.52 S | 79.87 E | G.bulloides | | 1.79 | |
| E45-73A | -47.55 S | 114.43 E | G.bulloides | | 2.52 | |
| RC8-63 | -51.08 S | 129.97 E | G.bulloides | | 2.70 | |
| Vincent, Killingley and Berger (1982) | | | | | | |
| ERDC 123Bx | -0.02 S | 160.42 E | G.sacculifer | 0-1 | -1.57 | |
| | | | | 2-3 | -1.75 | |
| | | | | 5-6 | -1.83 | |
| | | | | 8-9 | -2.18 | |
| | | | | 11-12 | -1.97 | |
| | | | | 13-14 | -2.04 | |
| | | | | 15-16 | -1.70 | |
| | | | | 17-18 | -1.71 | |
| | | | | 19-20 | -1.72 | |
| | | | | 21-22 | -1.61 | |
| | | | | 22-23 | -1.70 | |
| | | | | 23-24 | -1.67 | |
| | | | | 24-25 | -1.56 | |
| | | | | 26-27 | -1.62 | -1.76 |
| Berger, Killingley and Vincent (1978) | | | | | | |
| ERDC-92 | -2.23 S | 157.00 E | G.sacculifer | | | -2.06 |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| Vincent and Shackleton (1980) | | | | | | |
| 358 B x | -29.33 S | 31.98 E | G.sacculifer | | -1.05 | |
| | | | | | -1.03 | -1.04 |
| 361 C x | -26.55 S | 36.00 E | G.sacculifer | | -1.32 | -1.32 |
| 361 F x | -25.83 S | 37.35 E | G.sacculifer | | -1.53 | |
| | | | | | -1.61 | -1.57 |
| 361 J x | -25.65 S | 37.75 E | G.sacculifer | | -1.37 | |
| | | | | | -1.19 | |
| | | | | | -1.12 | -1.23 |
| 362 C o | -24.90 S | 39.43 E | G.sacculifer | | -1.41 | -1.41 |
| 362 E o | 24.27 S | 41.42 E | G.sacculifer | | -1.11 | -1.11 |
| 363 C x | -23.75 S | 43.17 E | G.sacculifer | | -1.58 | -1.58 |
| 363 F x | -23.67 S | 43.35 E | G.sacculifer | | -1.68 | |
| | | | | | -1.69 | -1.69 |
| 366 B o | -23.15 S | 43.13 E | G.sacculifer | | -1.96 | |
| | | | | | -1.92 | -1.94 |
| 367 H x | -22.67 S | 39.35 E | G.sacculifer | | -1.42 | |
| | | | | | -1.19 | -1.31 |
| 368 B x | -23.02 S | 38.62 E | G.sacculifer | | -0.68 | -0.68 |
| 369 B o | -23.80 S | 37.77 E | G.sacculifer | | -1.52 | |
| | | | | | -1.46 | -1.49 |
| 369 H x | -24.20 S | 36.02 E | G.sacculifer | | -0.91 | |
| | | | | | -1.01 | -0.96 |
| 370 C x | -24.42 S | 35.62 E | G.sacculifer | | -1.44 | -1.44 |
| 372 K x | -25.12 S | 34.57 E | G.sacculifer | | -1.22 | |
| | | | | | -1.39 | -1.31 |
| 374 A o | -26.92 S | 33.83 E | G.sacculifer | | -1.35 | -1.35 |
| 374 C o | -27.15 S | 34.15 E | G.sacculifer | | -0.79 | -0.79 |
| 375 B o | -28.00 S | 35.27 E | G.sacculifer | | -1.16 | -1.16 |
| 375 F o | -29.05 S | 36.72 E | G.sacculifer | | -0.51 | -0.51 |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| Vincent and Shackleton (1980) | | | (continued) | | | |
| 379 B o | -32.38 S | 42.93 E | G.sacculifer | | -0.41 | -0.41 |
| 379 B x | -32.38 S | 42.93 E | G.sacculifer | | -1.35 | -1.35 |
| 385 B x | -34.25 S | 35.98 E | G.sacculifer | | -0.70 | |
| | | | | | -0.74 | -0.72 |
| 387 E o | -31.38 S | 33.80 E | G.sacculifer | | -0.87 | -0.87 |
| 388 D x | -30.32 S | 30.30 E | G.sacculifer | | -1.18 | -1.18 |
| 389 B x | -30.17 S | 32.07 E | G.sacculifer | | -1.37 | -1.37 |
| 389 D o | -30.17 S | 31.62 E | G.sacculifer | | -1.20 | -1.20 |
| 389 F o | -29.95 S | 31.52 E | G.sacculifer | | -1.10 | |
| | | | | | -1.21 | -1.16 |
| 390 F x | -29.63 S | 31.60 E | G.sacculifer | | -1.03 | -1.03 |
| 390 J x | -29.58 S | 31.63 E | G.sacculifer | | -1.03 | -1.03 |
| 390 M x | -29.57 S | 31.65 E | G.sacculifer | | -1.16 | -1.16 |
| 391 A o | -29.48 S | 31.75 E | G.sacculifer | | -1.53 | -1.53 |
| 391 D o | -29.43 S | 31.77 E | G.sacculifer | | -1.15 | -1.15 |
| Durazzi (1981) | | | | | | |
| RC13-190 | 1.78 N | | G.sacculifer | | -1.48 | -1.48 |
| V25-60 | 3.28 N | | G.sacculifer | | -1.09 | -1.09 |
| V27-180 | 1.33 N | | G.sacculifer | | -1.40 | -1.40 |
| V27-179 | 4.20 N | | G.sacculifer | | -1.15 | -1.15 |
| V22-26 | 8.72 N | | G.sacculifer | | -0.96 | -0.96 |
| V26-46 | 9.57 N | | G.sacculifer | | -0.55 | -0.55 |
| RC13-158 | 13.18 N | | G.sacculifer | | -1.30 | -1.30 |
| RC13-154 | 14.88 N | | G.sacculifer | | -1.81 | -1.81 |
| V26-115 | 15.85 N | | G.sacculifer | | -1.79 | -1.79 |

Appendix III (continued)

| Site | Latitude | Longitude | Species | Depth (cm) | Del 018 | Average Del 018 |
|---|---|---|---|---|---|---|
| Vincent and Shackleton (1980) | | | (continued) | | | |
| V26-124 | 16.13 N | | G.sacculifer | | -1.74 | -1.74 |
| V26-117 | 16.90 N | | G.sacculifer | | -1.92 | -1.92 |
| RC10-49 | 16.57 N | | G. bulloides | | 1.24 | 1.24 |
| V24-1 | 36.50 N | | G. bulloides | | 0.94 | 0.94 |
| V29-183 | 49.13 N | | G. bulloides | | 0.75 | 0.75 |
| V27-17 | 50.10 N | | G. bulloides | | 1.12 | 1.12 |
| V27-19 | 52.10 N | | G. bulloides | | 1.33 | 1.33 |
| V30-116 | 53.63 N | | G. bulloides | | 1.19 | 1.19 |
| V27-111 | 56.07 N | | G. bulloides | | 1.73 | 1.73 |
| V23-23 | 56.08 N | | G. bulloides | | 2.02 | 2.02 |
| V30-118 | 55.42 N | | G. bulloides | | 2.03 | 2.03 |
| V30-124(?) | 56.73 N | | G. bulloides | | 1.72 | 1.72 |
| V30-122(?) | 56.80 N | | G. bulloides | | 1.65 | 1.65 |
| V27-110 | 56.90 N | | G. bulloides | | 1.31 | 1.31 |
| V30-126 | 58.57 N | | G. bulloides | | 1.5 | 1.5 |
| V27-38 | 61.37 N | | G. bulloides | | 2.22 | 2.22 |
| V27-36 | 62.45 N | | G. bulloides | | 1.56 | 1.56 |
| V27-34 | 63.02 N | | G. bulloides | | 1.93 | 1.93 |
| V28-34 | 64.83 N | | G. bulloides | | 1.87 | 1.87 |
| V28-41 | 67.68 N | | G. bulloides | | 1.42 | 1.42 |
| V28-30 | 71.17 N | | G. bulloides | | 2.15 | 2.15 |
| V28-29 | 72.18 N | | G. bulloides | | 2.09 | 2.09 |