

15. OXYGEN AND CARBON ISOTOPE DATA FROM LEG 74 FORAMINIFERS¹

N. J. Shackleton and M. A. Hall, The Godwin Laboratory, Free School Lane, Cambridge CB2 3RS, England
and
A. Boersma, Lamont-Doherty Geological Observatory, Palisades, New York²

ABSTRACT

Oxygen and carbon isotope measurements have been made in picked planktonic and benthonic foraminifers from the five sites drilled on Leg 74, covering the whole Cenozoic. For the Neogene, the coverage gives good information on the development of the vertical temperature structure of Atlantic deep water. For the Paleogene, vertical gradients were weak and it is possible to combine data from different sites to obtain a very detailed record of both the temperature and carbon isotope history of Atlantic deep waters.

INTRODUCTION

One of the purposes of the Leg 74 drilling was to provide a suite of sites in which deep-water ^{18}O paleotemperature measurements could be made over a range of paleodepths. Ultimately this will enable a better description of variations in the vertical temperature structure of the ocean through time. It is not possible to complete such an analysis in the time available for the preparation of the *Initial Reports*, but a start has been made in obtaining the data. This chapter summarizes results that have been obtained to date and will give a good indication of the potential of different parts of the section for isotopic work.

METHODS AND RESULTS

Oxygen and carbon isotope measurements were made using a VG Isogas 903 triple collector mass spectrometer to analyze carbon dioxide released from picked foraminifers. The standard method of reaction on line at 50°C using 100% orthophosphoric acid was employed; the reaction line in use is shown in Figure 1.

To obtain seafloor records, benthic foraminifers were selected for analysis. Where possible, monospecific or monogenetic assemblages were picked. Where this proved impractical, species which have similar deviations from isotopic equilibrium were grouped together. In a number of levels it was possible to analyze more than one picking and so provide further data on species-dependent departures from isotopic equilibrium. Appendix A shows the adjustment factors which have been applied to the species analyzed in this chapter in order to obtain as good an approximation as possible to seafloor equilibrium values for ^{13}C and ^{18}O values. These adjustments must be made to take account of genetically controlled departures from isotopic equilibrium (Duplessy et al., 1970; Shackleton, 1974; Vincent et al., 1979; Graham et al., 1981). Appendix B gives the raw values and Appendix C the values adjusted on the basis of Appendix A, averaged where more than one measurement was obtained, and with the age estimate used for plotting (based on the timescales developed in Shackleton et al., this volume). Appendix A includes a number of mixtures; we recognize that there is additional uncertainty involved in these cases since the relative contributions are not known, but we consider that measurements based on specified mixtures are at least better than analyses of unspecified mixed species. A small number of measurements in Appendix B that were neither used in Appendix C nor plotted in the

figures are marked with asterisks. These values include bad analyses, out-of-place samples, and some values for which correction factors are unknown or unreliable. For example, *Oridorsalis* appears to be close to isotopic equilibrium for ^{18}O , but to be erratic in its ^{13}C composition. It is possible that this reflects the presence of more than one species, or a significant effect of size on isotopic composition. It is interesting to note that Savin et al. (1981) found a perplexing variation in the difference in ^{13}C content between *Oridorsalis* and other species.

Figure 2 shows the oxygen and carbon isotope records for benthic and planktonic foraminifers from Sites 525–529. Oxygen isotope values are adjusted for departures from isotopic equilibrium (Shackleton, 1974), and carbon isotope values are adjusted so as to provide an estimate of the ^{13}C content of ocean deep water; members of the *Cibicides* genus are thought to provide a good estimate of this quantity in the modern ocean (Graham et al., 1981; Duplessy et al., pers. comm. 1982; Vincent et al., 1981) so that adjustments are made to *Cibicides* for ^{13}C and to *Uvigerina* for ^{18}O . Because Site 526 is significantly shallower and at present the seafloor is bathed by a different water mass, values from this site cannot be plotted with those from the deeper sites.

For planktonic species, we still do not know the order of depth stratification sufficiently well to confidently pick the best surface indicator in every sample. Additionally, it is sometimes useful to obtain a record from deep-dwelling species as well as from surface species (Boersma and Shackleton, 1978; Biolzi, pers. comm., 1982). Thus Table 4 contains data from several different species in some samples.

In the discussion below, oxygen isotope values are discussed in terms of temperature ($^{\circ}\text{C}$) using the relationship between oxygen isotopic fractionation and temperature established by O'Neil et al. (1969) and discussed by Shackleton (1974). It is assumed that in the absence of an Antarctic ice sheet, the ocean had an oxygen isotopic composition of -1.2% on the PDB scale (Shackleton and Kennett, 1975).

DISCUSSION

Maestrichtian

Analyses of a number of samples in the uppermost part of the Maestrichtian show that there is a significant deep-water temperature variability, with deep-water temperatures varying between about 10° and 6.5°C (Fig. 2). No values as cold as this were encountered again through the Paleocene or lower Eocene. No significant deep-water temperature difference was observed in the immediate vicinity of the Cretaceous/Tertiary boundary, at which time the deep-water temperature was about 10°C.

Abathomphalus mayeroensis and *Planoglobulina glabrata* were analyzed in several Maestrichtian samples. Both ^{13}C and ^{18}O data indicate that of these two, the lat-

¹ Moore, T. C., Jr., Rabinowitz, P. D., et al., *Init. Repts. DSDP*, 74: Washington (U.S. Govt. Printing Office).

² Present address: P.O. Box 404, RR 1, Stony Point, New York.

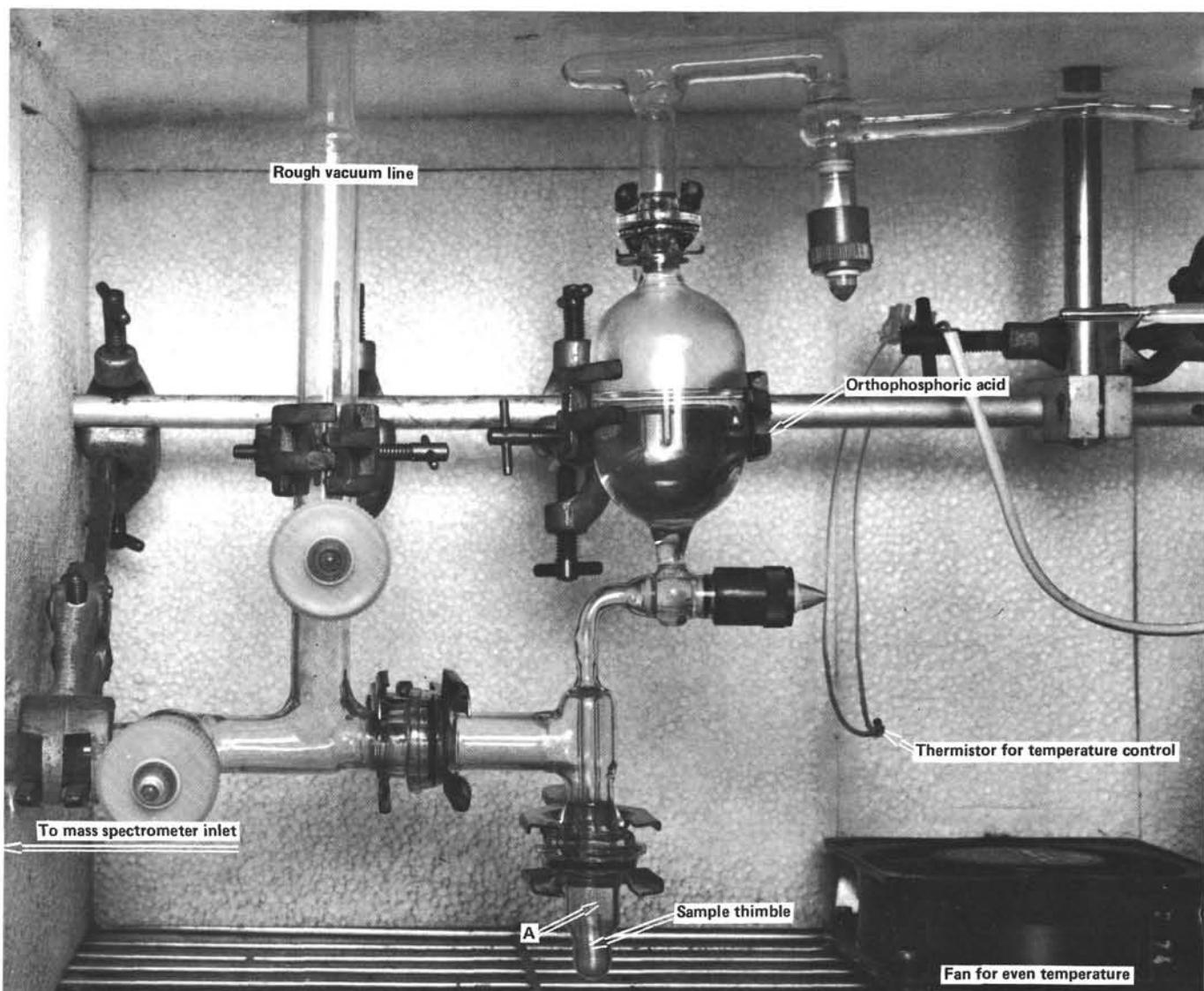


Figure 1. Reaction system used to generate CO₂ from foraminifers for isotopic analysis. The whole region illustrated is kept at 50°C. Orthophosphoric acid is dropped onto the foraminifers, which have previously been cleaned and vacuum-roasted in the thimble visible within container A. The acid is replenished monthly and is kept pumped so that it does not take up moisture.

ter calcified closer to the sea surface; on the basis of its isotopic composition surface temperatures between 13° and 16°C may be calculated. Mixed, very small (63–75 µm) species from a sample in Hole 527 at 280.10 m (10 cm below top of Maestrichtian) yield ¹⁸O and ¹³C values closer to those given by *A. mayeroensis*, implying that they are not good indicators of surface conditions.

Paleocene-Eocene

No remarkable changes in deep-water temperature occurred during the Paleocene, although there was apparently less variability and a somewhat higher mean temperature than during the late Maestrichtian. In the early Eocene a significant rise in deep-water temperature is observed, culminating in temperatures of about 12°C. After a few million years a considerable decline in temperature occurred relatively rapidly at about 50 Ma. The dating of this event is well controlled to within the interval of Magnetic Anomaly 21 on the basis of the measure-

ments in Core 527-17. Only a small amount of late Eocene data was obtained; however, the values are consistent with those observed elsewhere, implying a deep-water temperature of about 7°C. The temperature decline within Magnetic Anomaly 21 was not unidirectional but was accompanied by considerable variability that would warrant detailed investigation in a site with a higher accumulation rate over this interval.

Surface temperature appears to have been low in the first 2 m.y. of the Paleocene, but this is probably an artifact of our inability to analyze species which truly reflect surface conditions. Mixed, very small (63–75 µm) planktonic foraminifers dominated by *Woodringina* and carefully cleaned of obvious Cretaceous specimens were analyzed from 279.91 m in Hole 527 and yielded an ¹⁸O value similar to that of the sample analyzed at the top of the Maestrichtian. Because, as already mentioned, this Maestrichtian measurement was not regarded as a good estimate of surface temperature, we have no reason to

suppose that the Danian measurement enables us to estimate lowermost Danian surface temperature. On the other hand, these very small foraminifers do register essentially the same change in ^{13}C values that is registered by bulk sediment (Shackleton and Hall, this volume). Thus it seems likely that these specimens were calcifying relatively close to the sea surface (certainly well above the oxygen minimum). If the oxygen isotopic composition of these very small specimens is not significantly affected by post-depositional processes (which cannot be definitely established), then we may reasonably argue that the similarity in ^{18}O values between the very small specimens analyzed on either side of the Cretaceous/Tertiary boundary constitutes evidence that there was not a significant change in surface temperature at that boundary. However, this is a difficult point to establish conclusively.

Later in the Paleocene and in the early Eocene, surface temperatures were apparently higher than during the Maestrichtian or, indeed, than during any other part of the Cenozoic. Surface temperatures dropped during the middle Eocene just as deep-water temperatures did. It is interesting to note that this more or less parallel trend in surface and deep-water temperatures during the Eocene shows that there was no thermal isolation between mid-latitude and high-latitude water masses.

Preliminary examination of the benthic data suggests that the vertical temperature and ^{13}C gradients between Sites 525 and 527 were too small during the Paleocene to be measured without considerably more data. The two sites then occupied approximately the same positions in the water column as Sites 526 and 525 occupy today; thus there would have been measurable isotopic differences between them, given oceanographic gradients similar to those now prevailing.

Oligocene

At Site 529 detailed measurements were made at the Eocene/Oligocene boundary, where a very sharp transition was observed. The data should be regarded with caution, however, since the nannofossil *I. recurvus* is not present in the uppermost Eocene sediments, implying that the latest Eocene may be missing at this site (Manivit, this volume). It is interesting to note that the oxygen isotope values obtained in benthic foraminifers just above the boundary (or hiatus) are the most positive observed in the Oligocene. The values, about $+2.5\text{\textperthousand}$ (adjusted to isotopic equilibrium), are in fact similar to the *lightest* values observed in the late Miocene. This value may be regarded as favoring the presence of an ice sheet in Antarctica for a brief interval in the early Oligocene; in the absence of any significant quantity of ice, a value of $+2.5\text{\textperthousand}$ would indicate a temperature of 2°C at a paleodepth of around 3000 m. This would certainly imply at least freezing winters at sea level around Antarctica, which itself would be consistent with substantial glaciation. It seems perhaps more likely that deep water was not so cold as 2° , and that there was a significant amount of ice on Antarctica for this short interval early in the Oligocene. (An isolated measurement from 225.67 m at Site 528 gave an even more positive ^{18}O

value, but this may have been the result of mixing with one or more Neogene specimens, since the sample proved to contain some drillpipe rust indicative of downhole contamination).

Although we conclude that there may have been some accumulation of ice on Antarctica during the early Oligocene, as claimed by Matthews and Poore (1980), we have reached this conclusion by accumulating more benthic foraminiferal data and extending the argument used by Shackleton and Kennett (1975). We do not agree with the approach taken by Matthews and Poore (1980), who have argued that global ice volume in the Cenozoic may be estimated by assuming that the surface temperature in the tropics is more or less invariant. Indeed, were one to apply this argument to the data set discussed by Shackleton and Boersma (1981), one would conclude that during the early Eocene ocean surface temperature ranged between 28°C at the equator and 18°C at high latitudes, while somewhere on the continents sufficient ice was stored to render the oceans even more isotopically positive than today. For the early Oligocene, Poore and Matthews (in press) have obtained a data set considerably more detailed than ours; it documents isotopically positive values similar to those that we have obtained, but their interpretation is again based on the model of Matthews and Poore (1980), with which we disagree.

The total range in ^{18}O values in benthic samples from the Oligocene at Sites 528 and 529 is of the order $0.7\text{\textperthousand}$ (from 1.8 to $2.5\text{\textperthousand}$), but this is among a relatively small number of analyses and must underestimate the total range of variation.

Site 526, where the paleodepth was significantly shallower during the Oligocene than the present 1000 m, shows a rather different benthic temperature record. The values are isotopically lighter by the equivalent of $2\text{--}3^\circ$, and show a greater variability of about 1\textperthousand , or more than 3° . Unfortunately, the isotopic results from Site 526 sediments are somewhat unsatisfactory. Differences between species are not as one expects on the basis of present-day calibrations or of between-species comparisons at other sites. Matthews et al. (1980) have suggested that, in very shallow sites, aragonite that was preserved during initial sedimentation may very readily go into solution in the pore waters and reprecipitate on the foraminifers. If this is indeed the case, the values obtained may actually be closer to deep-water isotopic equilibrium than the original calcite was; this would explain the fact that between-species differences are very small in these sediments.

Early-Middle Miocene

Unfortunately the middle Miocene was not well recovered at any Leg 74 site. However, the fragmentary recovery is sufficient to reveal the deep-water temperature maximum of the middle Miocene and the associated positive extreme in ^{13}C values first observed by Shackleton and Kennett (1975) and to give hints of the important high-frequency variation in both isotope ratios that was revealed for the first time by the detailed work of Woodruff et al. (1981) from DSDP Site 289. Comparison of the planktonic and benthic records (Fig. 2A)

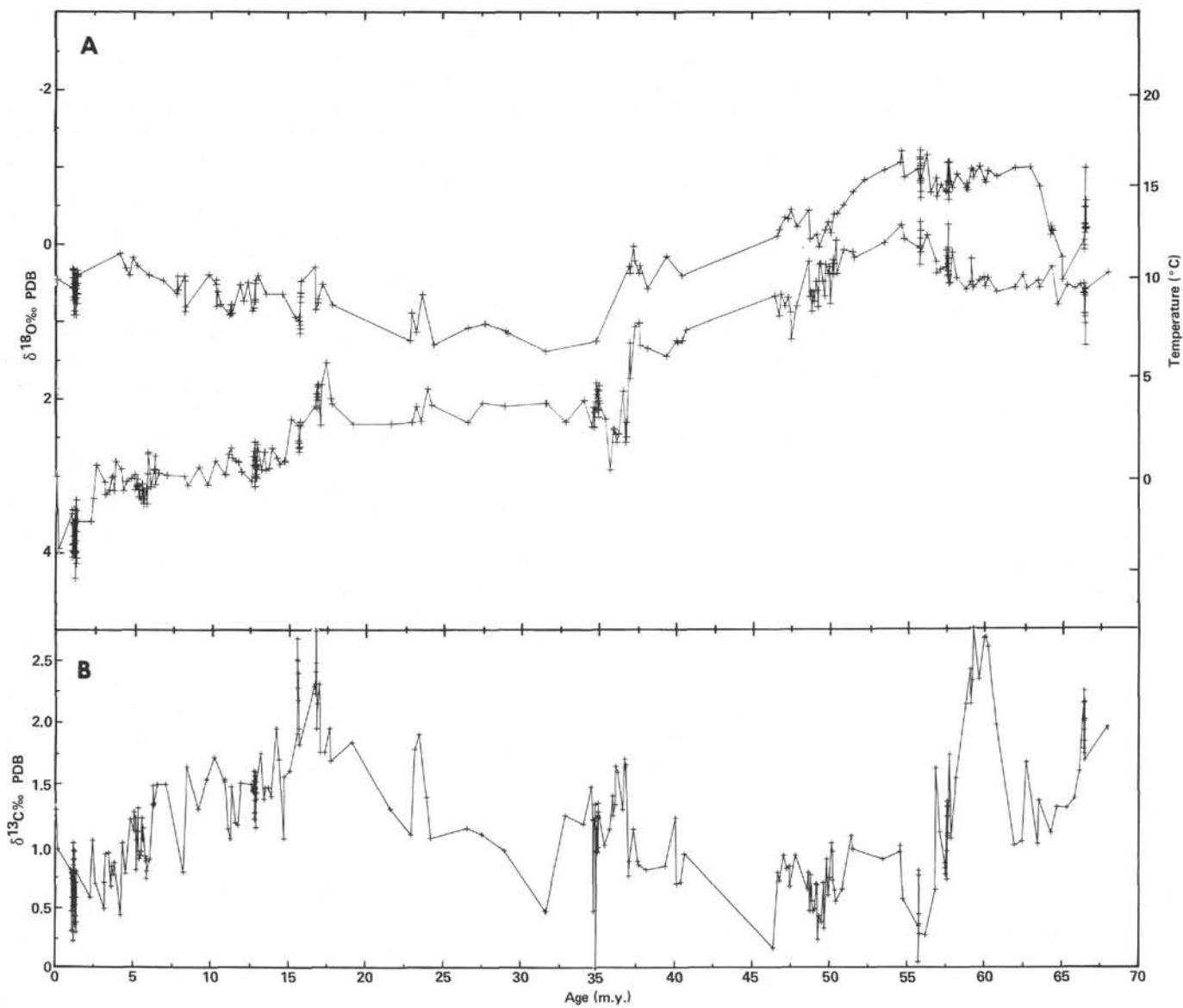


Figure 2. A. Oxygen isotope record in benthic and planktonic foraminifers from Sites 525–529, Maestrichtian to Recent. For planktonic species, data are selected to represent as well as possible those species that apparently calcify near the ocean surface. The temperature scale is calculated for a time without an Antarctic ice sheet. B. Carbon isotope record in benthic foraminifers from Sites 525–529, Maestrichtian to Recent. All data in Figure 2A–B are plotted on a common timescale (from Appendix C). C. Carbon isotope record in planktonic foraminifers from Sites 525–529, Maestrichtian to Recent. All data are plotted on a common timescale (from Appendix D). In samples from which more than one species was analyzed, the isotopically heaviest value is plotted, and analyses of species which are known to deposit their carbonate at depth are not plotted.

shows that the temperature gradient between surface and deep water was approximately the same from the late Eocene to the middle Miocene.

Late Miocene and Pliocene: Changing Vertical Gradients

The drilling of Site 526 provided the unusual opportunity of examining the vertical temperature and ^{13}C gradients within the ocean interior and the evolution of these gradients through the late Miocene. Table 1 shows mean ^{18}O and ^{13}C values over 1 m.y. increments (from Appendix C) in Sites 526 and 525.

It is striking that the vertical temperature gradient between the two sites was approximately 1° throughout this interval, with only rather subtle variations, whereas

the carbon isotopic gradient actually reversed in the lower Pliocene. Today, Site 526 is bathed by Antarctic Intermediate Water (AIW) with a lower ^{13}C content than the North Atlantic Deep Water (NADW) that is found at the depth of the seafloor at Site 525 (~ 2500 m); the ^{13}C difference is about 0.2‰ (Kroopnick, 1981, from Station 103). In parts of the lower Pliocene, benthic foraminifers from Site 526 were isotopically more positive than at Site 525. Table 2 shows values from the deep Pacific; during the early Pliocene there was clearly an isotopic gradient between the South Atlantic and the deep Pacific just as strong as there is today, and it seems likely that NADW extended up to the depth of Site 526, perhaps with a reduction in the formation of AIW. These data show that the conclusion reached by Keigwin

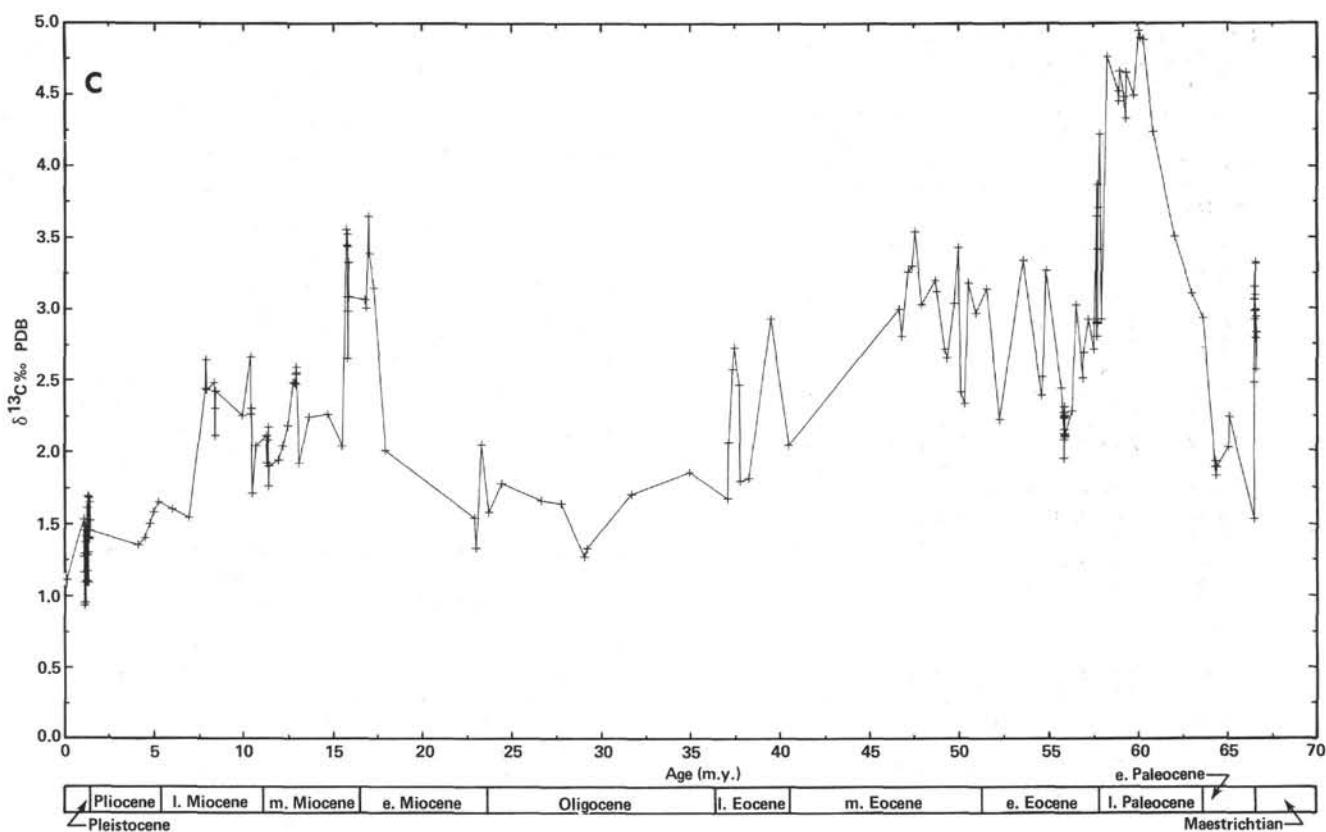


Figure 2. (Continued).

(1982), that the production of NADW was significantly less before the Panama Isthmus closed about 3 Ma, is not correct. Our data show an early Pliocene ^{13}C difference between South Atlantic NADW and deep Pacific water of more than 1\textperthousand well prior to that event. It may be that the early Pliocene Caribbean is not an appropriate position from which to monitor the ^{13}C content of NADW.

The so-called "carbon shift" at about 6.4 Ma (Haq et al., 1980), when ocean-dissolved CO_2 became isotopically lighter for ^{13}C , is reasonably clearly expressed and indeed has been used as a guide to correlating Holes 525B and 526. Occurring just above the appearance of *Amaurolithus primus* at Hole 525B, it provides a useful datum, because this first appearance was not readily determined under the conditions of more extensive overgrowth observed in the late Miocene nannofossils of Site 526. However, it is certainly not such a striking effect as is observed in the Pacific, and indeed there is a clear overlap between pre-"carbon shift" values and those observed in the lower Pliocene (Fig. 2B).

The deep-water ^{18}O record of the late Miocene is thought to reflect the history of Antarctic glaciation, and the isotopic difference between the mean value for 16–17 Ma and today's equilibrium value is about $1.2\text{\textperthousand}$. This means that if ocean isotopic composition changed by about $0.9\text{\textperthousand}$ (Shackleton and Kennett, 1975), there was a deep-water temperature drop of only a little over a degree. By contrast, surface temperatures changed considerably; the temperature difference between the surface

and the deep water bathing the shallowest site (526) has increased by about 6°C since the middle Miocene. This dramatic increase in temperature gradients during the last 15 Ma is a fascinating aspect of global paleoclimatology. It must be emphasized again that its interpretation is not affected by current uncertainty (Matthews and Poore, 1980) regarding the history of global oceanic isotopic composition, which affects the absolute temperatures estimated, but not temperature gradients.

Pleistocene

A lower Pleistocene section was analyzed from Hole 528A, where Cores 4–6 were sampled at close intervals. Benthic foraminifers were analyzed in part of the section, chiefly as a check on the reliability of the data obtained. Evidently early Pleistocene climatic variability is easily detectable. With only a single penetration of the site it would not be possible to obtain a long record suitable for spectral analysis. However, the material is suitable for paleoclimatic work; both faunal change and dissolution variability could be examined in relation to the ^{18}O record in this material.

CONCLUSIONS

The ^{18}O analyses in benthic foraminifers record the largely well-established temperature and ice-volume history of the Cenozoic. The temperature maximum in the early Eocene, the cooling early in the middle Eocene, and the very rapid cooling at the Eocene/Oligocene boundary are all well displayed. The accumulation of

Table 1. Oxygen and carbon isotope data averaged in million-year increments for Sites 525 and 526, Pliocene to middle Miocene.

Increment	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	No. of analyses
Site 525			
3-4	3.17 ± 0.10	0.79 ± 0.17	6
4-5	3.06 ± 0.12	0.87 ± 0.33	4
5-6	3.14 ± 0.19	1.02 ± 0.17	19
6-7	2.97 ± 0.15	1.32 ± 0.22	6
7-8	3.00	1.50	1
8-9	3.13	1.64	1
9-10	3.01 ± 0.16	1.42 ± 0.17	2
10-11	2.93 ± 0.11	1.59 ± 0.11	3
11-12	2.79 ± 0.10	1.29 ± 0.19	6
12-13	2.85 ± 0.15	1.44 ± 0.12	20
13-14	2.82 ± 0.14	1.49 ± 0.15	5
14-15	2.81 ± 0.03	1.57 ± 0.37	4
15-16	2.49 ± 0.16	2.18 ± 0.35	10
16-17	1.96 ± 0.12	2.32 ± 0.23	8
17-24	2.09 ± 0.25	1.65 ± 0.37	12
Site 526			
3-4	2.78 ± 0.12	1.11 ± 0.27	11
4-5	2.96 ± 0.10	0.94 ± 0.18	26
5-6	2.91 ± 0.12	0.91 ± 0.16	25
6-7	2.76 ± 0.10	1.07 ± 0.23	24
7-8	2.79 ± 0.09	1.47 ± 0.22	11
8-9	2.89 ± 0.07	1.51 ± 0.09	6
9-10	2.87 ± 0.16	1.44 ± 0.14	10
10-11	2.92 ± 0.11	1.42 ± 0.10	11
11-12	2.67 ± 0.14	1.22 ± 0.17	8
12-13	2.63 ± 0.17	1.36 ± 0.15	14
13-14	2.51 ± 0.14	1.54 ± 0.14	19
14-15	2.33 ± 0.09	1.64 ± 0.36	2
16-17	No data		
16-17	2.05 ± 0.23	2.24 ± 0.36	4
17-24	1.73 ± 0.20	1.59 ± 0.22	7

Table 2. Oxygen and carbon isotope data averaged in million-year increments for deep equatorial Pacific cores V28-179, V28-185, and RC12-66.

Increment	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	No. of analyses
3-4	3.31 ± 0.23	-0.22 ± 0.23	49
4-5	3.06 ± 0.17	-0.30 ± 0.25	39
5-6	3.22 ± 0.13	-0.22 ± 0.20	26
6-7	3.09 ± 0.17	-0.10 ± 0.29	23

Note: Sources are: Shackleton and Odyke, 1977; Keigwin and Shackleton, 1980; Shackleton, 1982; and Shackleton, unpublished data). Note that the data in the increment 6-7 m.y. are virtually all from between 6 and 6.5 Ma, after the late Miocene ^{13}C change.

Antarctic ice in the middle Miocene is clearly recorded although sediment recovery was poor in this part of the section and details of the transition are not well resolved. A good late Miocene record at Site 525 will clarify events during that time. A fairly good early Oligocene record is also available from Site 529. Although frequent slumps would preclude use of this section for detailed time-series analysis, it provides important evidence supporting the existence of limited Antarctic glaciation during the

earliest Oligocene. The details of the Paleogene section permit the climatic events to be better dated than before. High deep-water temperatures were attained close to the Paleocene/Eocene boundary at about 56 Ma, and a temperature decline occurred over a period of about a million years early in the middle Eocene (~ 50–49 Ma).

ACKNOWLEDGMENTS

We are deeply grateful to Captain Clark and the team aboard the *Glomar Challenger* for Leg 74 for successfully drilling our objectives and enabling these studies to be carried out. Laboratory work was supported by NERC Grant GR3/3606 to N.J.S. We thank C. Solanki and M. Tabeki for laboratory assistance and John Line for computing advice. We are very grateful to R. K. Matthews, E. Vincent, and T. C. Moore for their helpful reviews of the manuscript, and especially to the former for making available the manuscript of his joint contribution with R. Z. Poore to Volume 73 of the *Initial Reports* (Poore and Matthews, in press).

REFERENCES

- Belanger, P. E., Curry, W. B., and Matthews, R. K., 1981. Core-top evaluation of benthic foraminiferal isotopic ratios for paleo-oceanographic interpretations. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 33:205–220.
- Boersma, A., and Shackleton, N. J., 1978. Oxygen and carbon isotope record through the Oligocene, DSDP Site 366, Equatorial Atlantic. In Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP*, 41: Washington (U.S. Govt. Printing Office), 957–962.
- Duplessy, J.-C., Lalou, C., and Vinot, A. C., 1970. Differential isotopic fractionation in benthic foraminifera and palaeotemperatures reassessed. *Science*, 168:250–251.
- Graham, D. W., Corliss, B. H., Bender, M. L., and Keigwin, L. D., Jr., 1981. Carbon and oxygen isotopic disequilibrium of recent deep-sea benthic Foraminifera. *Mar. Micropaleontol.*, 6:483–497.
- Haq, B. U., et al., 1980. Late Miocene carbon isotopic shift and synchrony of some phytoplanktonic biostratigraphic events. *Geology*, 8:427–431.
- Keigwin, L. D., Jr., 1979. Late Cenozoic stable isotope stratigraphy and paleoceanography of DSDP sites from the east equatorial and central north Pacific Ocean. *Earth Planet. Sci. Lett.*, 45:361–382.
- Keigwin, L. D., Jr., 1982. Isotopic paleoceanography of the Caribbean and East Pacific: Role of Panama Uplift. *Science*, 217:350–353.
- Keigwin, L. D., Jr., and Shackleton, N. J., 1980. Uppermost Miocene carbon isotope stratigraphy of a piston core in the equatorial Pacific. *Nature*, 284:613–614.
- Kroopnick, P., 1980. The distribution of ^{13}C in the Atlantic Ocean. *Earth Planet. Sci. Lett.*, 49:469–484.
- Matthews, R. K., Curry, W. B., Lohman, K. E., Sommer, M. A., and Poore, R. Z., 1980. Late Miocene paleo-oceanography of the Atlantic: Oxygen isotope data on planktonic and benthic Foraminifera. *Nature*, 283:555–557.
- Matthews, R. K., and Poore, R. Z., 1980. Tertiary $\delta^{18}\text{O}$ record and glacio-eustatic sealevel fluctuations. *Geology*, 8:501–504.
- O'Neil, J. R., Clayton, R. N., and Mayeda, T. K., 1969. Oxygen isotope fractionation in divalent metal carbonates. *J. Chem. Phys.*, 51:5547–5558.
- Poore, R. Z., and Matthews, R. K., in press. Late Eocene–Oligocene oxygen and carbon isotope record from South Atlantic Ocean, Deep Sea Drilling Project Site 522. In Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office).
- Savin, S. M., Douglas, R. G., Keller, G., Killingley, J. S., Shaughnessy, L., Sommer, M. A., Vincent, E., and Woodruff, F., 1981. Miocene benthic foraminiferal isotope records: A synthesis. *Mar. Micropaleontol.*, 6:423–450.
- Shackleton, N. J., 1974. Attainment of isotopic equilibrium between ocean water and the benthonic Foraminifera genus *Uvigerina*: Isotopic changes in the ocean during the last glacial. *C.N.R.S. Colloquium*, 219:203–209.
- _____, 1982. The deep sea sediment record of climatic variability. *Prog. Oceanogr.*, 11:199–218.
- Shackleton, N. J., and Boersma, A., 1981. The climate of the Eocene ocean. *J. Geol. Soc. London*, 138:153–157.

- Shackleton, N. J., Imbrie, J., and Hall, M. A., in press. Oxygen and carbon isotope record of East Pacific core V19-30: implications for the formation of deep water in the late Pleistocene North Atlantic. *Earth Planet. Sci. Lett.*
- Shackleton, N. J., and Kennett, J. P., 1975. Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: Oxygen and carbon isotope analyses in DSDP Sites 277, 279, and 281. In Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 743-755.
- Shackleton, N. J., and Opdyke, N. D., 1977. Oxygen isotope and paleomagnetic evidence for early Northern Hemisphere glaciation. *Nature*, 270:216-219.
- Vincent, E., Killingley, J. S., and Berger, W. H., 1981. Stable isotopes in benthic Foraminifera from Ontong-Java Plateau, box cores ERDC 112 and 123. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 33:221-230.
- Woodruff, F., Savin, S. M., and Douglas, R. G., 1981. Miocene stable isotope record: A detailed Pacific ocean study and its paleoclimatic implications. *Science*, 212:665-668.

APPENDIX A Isotopic Analyses of Benthic and Planktonic Foraminifers

Adjustment factors applied to the isotopic analyses of benthic foraminiferal species in order to obtain the best estimates of oxygen isotopic equilibrium and carbon isotopic composition of ocean deep-water dissolved CO₂.

Genus or Species	Computer Abbreviation	Adjustment	
		¹⁸ O	¹³ C
<i>Uvigerina</i>	UVIG	0.0	0.9
<i>Hoeglundina</i>	HELEGANS	-0.40	-1.3
<i>Cibicidoides</i>	CIB	0.5	0.0
<i>C. kullenbergi</i>	CIBKULL	0.5	0.0
<i>C. wuellerstorffi</i>	PWUELL	0.64	0.0
<i>C. havanensis</i>	CIBHAV	0.5	0.0
<i>Melonis</i>	MELONIS	0.3	0.8
<i>M. pompilioides</i>	MELPOMP	0.3	0.6
<i>M. barleearnum</i>	MELBARL	0.4	1.0
<i>Bulimina</i>	BULIMINA	0.0	0.0
<i>B. jarvisi</i>	BJARV	0.0	0.0
<i>Globocassidulina</i>	GLOBOCAS	-0.1	0.5
<i>Nuttalides</i>	NUTT	0.35	0.0
<i>Gavelinella</i>	GAVELIN	0.3	0.0
<i>Gyroidina</i>	GYROID	0.0	0.0
<i>Oridorsalis</i>	ORID	0.0	1.0
<i>Stilostomella</i>	STABYSS	-0.15	1.0
<i>Sphaeroidina</i>	SBULL	-0.1	-0.1
<i>Favocassidulina</i>	FAVOCASS	-0.1	0.5
<i>Planulina renzi</i>	PRENZI	0.6	0.0
<i>Pullenia bulloides</i>	PULBUL	0.0	0.3
<i>Rectuvigerina</i>	RECTUVIG	0.0	0.9
<i>Anomalinoides</i>	ANOMALIN	0.3	0.3
<i>Gavelinella</i>	GAVELIN	0.3	0.0
<i>Nodosaria</i>	NOD	0.0	0.0
<i>Osangularia</i>	OSANG	0.0	0.0
NUTT + CIB	NUTTCIB	0.4	0.0
UVIG + GLOBOCAS	UVIGGLOB	-0.05	0.7
PWUELL + CIBKULL	WUELKULL	0.5	0.0
GLOBOCAS + BJARV	GLOBOJAR	0.0	0.25
ORID etc.	ORIDMIX	0.0	0.5
ORID + BUL	ORIDBUL	0.0	0.5
NUTT + ALAB	NUTTALAB	0.4	0.0
CIB + GAV	CIBGAV	0.5	0.0
BUL + CIB	BULCIB	0.15	0.0
UVIG + STABYSS	UVIGSTIL	0.0	1.0
GLOBOCAS + ORID	GLOBORID	0.0	0.75
UVIG + GLOBOCAS	UVIGGLOB	0.0	0.7
ORID + GYROID	ORIDGYR	0.0	0.5
STABYSS + BJARV	STILJARV	0.0	0.5
GLOBOCAS + STABYSS	GLOBSTIL	0.0	0.7
UVIG + BUL	UVIGBUL	0.0	0.45
NUTT + CIB	NUTTCIB	0.4	0.0
NUTT + GAV	NUTTGAV	0.35	0.0

Note: These figures are derived from our assessment of all the data available to us. Although a slightly different set of adjustments might be derived on the basis of data from Leg 74 alone, we consider that this would impede comparison with other sites.

APPENDIX B
Isotopic Analyses of Benthic Foraminifers from Sites 525-529

Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)
Hole 525B				Hole 525B (cont.)				Hole 525A (cont.)			
0.80	UVIG	3.95	0.08	139.18	PWUELL	2.52	1.50	287.10	NUTT	0.34	0.78
11.66	FAVOCASS	3.69	-0.03	139.18	UVIGGLOB	2.97	0.95*	287.10	ORID	0.65	0.31*
11.66	PWUELL	2.96	0.70	139.41	GLOBOCAS	2.86	1.00	289.01	BULIMINA	0.93	0.79
13.05	GLOBOCAS	3.40	0.50	139.41	PWUELL	2.09	1.39	289.01	NUTT	0.33	0.68
13.05	PWUELL	2.66	1.10	139.46	GLOBOCAS	2.78	0.94	290.51	NUTTCIB	0.28	0.70
19.01	PWUELL	2.45	0.50	139.61	GLOBOCAS	3.09	1.19	290.51	ORIDMIX	0.64	0.40*
19.34	PWUELL	2.61	0.71	139.61	PWUELL	1.87	1.30	292.01	BULIMINA	0.81	0.92
22.10	GLOBOCAS	3.41	0.51	139.81	PWUELL	2.13	1.46	292.01	NUTT	0.42	0.74
22.20	CIBKULL	2.64	0.87	139.81	MIXED	2.96	0.86*	292.01	ORID	0.69	0.31
22.20	NUTT	3.21	0.27	140.01	PWUELL	2.22	1.53	293.50	ORID	0.38	-0.05
22.20	GLOBOCAS	3.32	0.57	140.21	GLOBOCAS	2.58	1.12	295.01	CIB	0.01	0.76
22.20	PWUELL	2.76	0.86	140.21	PWUELL	2.00	1.59	295.01	NUTT	-0.13	0.33
22.40	CIBKULL	2.89	0.74	140.41	PWUELL	2.43	1.63	298.00	NUTT	-0.29	0.65
22.40	GLOBOCAS	3.73	0.49	140.41	SBULL	2.77	0.90	302.29	NUTTCIB	-0.37	1.08
22.40	PWUELL	2.90	0.74	140.71	PWUELL	2.50	1.37	302.39	ORIDBUL	0.15	0.83*
23.61	GLOBOCAS	3.28	0.36	140.91	UVIGGLOB	2.86	0.97	322.79	NUTTALAB	-0.43	0.89
27.78	GLOBOCAS	3.29	0.45	141.11	PWUELL	2.16	1.48	337.85	CIBGAV	-0.59	1.16
33.35	GLOBOCAS	3.11	0.34	141.31	PWUELL	2.37	1.44	337.85	NUTT	-0.78	0.83
35.10	GLOBOCAS	3.30	0.27	141.51	PWUELL	2.26	1.46	358.19	BULCIB	-0.21	0.35
42.26	PWUELL	2.28	0.45	141.71	CIB	2.30	1.57	358.29	CIB	-0.42	0.69
44.88	GLOBOCAS	3.30	0.53	142.21	PWUELL	2.24	1.47	358.29	GAVELIN	-0.31	0.82
48.05	GLOBOCAS	3.18	0.28	142.41	PWUELL	2.19	1.46	358.39	MIXED	-0.59	0.80
54.08	GLOBOCAS	3.14	0.72	142.41	SBULL	2.96	0.93	358.49	MIXED	-0.25	0.45
55.58	GLOBOCAS	3.14	0.96	142.61	PWUELL	2.19	1.40	358.59	CIB	-0.38	0.66
58.81	GLOBOCAS	3.09	0.63	142.61	STABYSS	2.68	0.80	358.59	ORID	-0.49	-0.14
59.11	GLOBOCAS	3.29	0.78	142.81	PWUELL	2.39	1.38	358.69	CIBGAV	-0.80	0.06
60.31	GLOBOCAS	3.37	0.83	143.01	PWUELL	2.34	1.43	358.99	NUTT	-0.10	0.47
61.71	CIB	2.57	1.14	143.41	CIB	2.09	1.52	359.09	BULIMINA	0.07	0.32
61.71	GLOBOCAS	3.32	0.81	149.57	PWUELL	2.28	1.75	359.09	NUTT	-0.34	0.37
62.01	GLOBOCAS	3.44	0.79	153.47	PWUELL	2.05	1.38	359.19	BULIMINA	0.19	0.31
62.91	GLOBOCAS	3.17	0.26	155.65	GLOBOCAS	3.01	1.21	359.19	NUTT	-0.10	0.53
62.91	STABYSS	3.17	0.08	155.65	PWUELL	2.18	1.30	359.29	NUTT	-0.36	0.21
62.91	UVIG	3.09	0.41	155.65	PWUELL	2.43	1.40	359.39	NUTT	-0.20	0.44
63.21	GLOBOCAS	3.23	0.31	157.91	PWUELL	2.26	1.47	359.49	NUTT	-0.21	0.37
66.81	GLOBOCAS	3.58	0.81	159.41	PWUELL	2.00	1.40	359.59	NUTT	-0.26	0.29
66.81	ORID	3.07	-0.30*	162.31	GLOBOCAS	2.87	1.45	371.57	NUTT	-0.48	0.28
66.81	UVIG	3.31	0.42	163.81	GLOBOCAS	2.95	1.20	379.21	NUTT	0.01	1.63
66.91	GLOBOCAS	3.24	0.62	166.45	GLOBOCAS	2.90	0.56	382.21	NUTT	-0.04	1.11
67.41	GLOBOCAS	3.29	0.46	166.61	GLOBOCAS	2.94	1.11	385.81	NUTT	-0.07	0.86
67.91	CIB	2.70	0.86	166.61	PRENZI	2.20	1.50	387.31	NUTT	-0.32	0.96
67.91	GLOBOCAS	3.45	0.43	169.90	GLOBOCAS	2.37	1.11	390.09	NUTT	-0.26	1.06
70.61	CIBKULL	2.88	0.70	174.61	GLOBOCAS	2.64	2.01	393.36	NUTT	0.07	1.55
70.61	GLOBOCAS	3.38	0.76	174.71	GLOBOCAS	2.67	2.18	403.35	CIB	-0.03	2.43
70.61	PRENZI	2.67	0.82	174.91	GLOBOCAS	2.68	1.86	403.40	NUTT	-0.18	2.15
70.68	PWUELL	2.70	0.83	174.91	PWUELL	2.06	2.20	404.59	CIB	0.06	2.49
72.11	GLOBOCAS	3.04	0.56	175.02	GLOBOCAS	2.67	2.00	404.59	NUTT	0.13	2.18
72.11	PRENZI	2.67	0.85	175.31	CIBKULL	2.12	1.83	404.65	NUTTCIB	0.15	2.76
72.18	PWUELL	2.51	0.95	175.31	GLOBOCAS	2.85	2.03	408.91	NUTT	0.10	2.35
73.61	PWUELL	2.67	1.23	175.51	GLOBOCAS	2.71	1.89	411.91	NUTT	0.06	2.68
75.14	GLOBOCAS	3.30	0.56	175.51	GLOBOCAS	2.72	1.90	412.81	CIB	0.12	2.80
75.81	GLOBOCAS	3.64	0.78	176.01	GLOBOCAS	2.40	1.45	412.81	NUTT	0.09	2.57
75.81	PRENZI	2.60	1.02	176.41	CIBHAV	1.84	1.69	415.35	NUTT	0.07	2.61
79.06	GLOBOCAS	3.29	0.64	176.41	GLOBOCAS	2.45	1.45	422.01	NUTT	0.25	1.98
79.06	PWUELL	2.51	0.73	188.71	BULIMINA	1.39*	1.25*	433.72	NUTT	0.19	1.01
79.71	CIBKULL	2.79	0.76	189.51	GLOBOCAS	2.20	1.79	436.05	NUTT	0.03	1.04
79.71	GLOBOCAS	3.24	0.56	190.31	ORIDGYR	1.94	1.81	442.50	NUTT	-0.01	1.28
79.71	PRENZI	2.49	0.95	190.61	CIB	1.48	2.23	442.50	ORID	0.59	1.01*
81.01	PRENZI	2.77	0.88	191.01	GLOBOCAS	1.86	1.94	442.70	NUTT	-0.11	1.34
82.06	GLOBOCAS	3.08	0.40	191.01	STILJARV	1.94	1.88	442.90	NUTT	0.11	1.31
82.31	GLOBOCAS	2.88	0.30	191.21	ORIDGYR	2.13	1.98	442.90	ORID	0.42	1.07*
82.31	PRENZI	2.05	0.68	191.41	ORID	2.02	1.74	444.00	GAVELIN	-0.18	1.20
82.49	GLOBOCAS	2.84	0.00	191.61	CIBKULL	1.32	1.95	444.00	NUTT	0.05	1.41
82.49	PWUELL	2.20	0.79	192.20	GLOBOCAS	1.92	1.51	444.20	NUTT	0.20	1.18
82.49	UVIG	2.52	0.22	192.20	GLOBOCAS	1.93	1.78	470.91	GAVELIN	-0.06	1.62
82.93	GLOBOCAS	3.11	0.47	194.21	CIBKULL	1.32	1.76	470.91	NUTT	0.12	1.69
82.93	PWUELL	2.49	0.98	195.91	GLOBOCAS	1.64	1.26	470.91	ORID	0.34	1.61
88.01	PRENZI	2.55	0.90	201.05	GLOBOCAS	2.10	1.45				
94.31	GLOBOCAS	3.01	0.90								
95.04	PRENZI	2.35	1.27								
95.04	GLOBOCAS	2.97	1.00								
95.69	PRENZI	2.37	1.48	174.60	GLOBOCAS	2.45	1.41	6.71	GLOBOCAS	3.92	0.42
95.69	GLOBOCAS	2.85	0.83	193.60	GLOBOCAS	2.44	1.81	6.71	PWUELL	3.42	1.19
96.21	GLOBOCAS	3.22	0.85	203.10	GLOBOCAS	2.17	1.19	15.51	PWUELL	3.68	0.57
97.71	GLOBOCAS	3.07	1.00	212.60	GLOBOCAS	2.43	1.34	16.31	PWUELL	2.66	0.87
99.37	CIBKULL	2.64	1.40	222.10	CIB	1.98	1.14	17.11	PWUELL	2.56	1.05
99.37	GLOBOCAS	3.13	1.10	231.91	GLOBOCAS	2.26	0.95	17.31	PWUELL	2.64	0.99
103.54	GLOBOCAS	3.22	1.12	241.40	PRENZI	2.30	0.84	17.51	PWUELL	2.61	1.08
103.54	PRENZI	2.53	1.65	241.40	STABYSS	1.61	1.75	17.71	PWUELL	2.75	0.67
109.11	PWUELL	2.25	1.30	241.40	STABYSS	2.13	0.80	18.31	PWUELL	2.42	0.52
113.47	GLOBOCAS	3.36	1.04	250.86	GLOBOCAS	2.31	1.46	22.11	GLOBOCAS	3.16	0.09
113.47	PWUELL	2.34	1.54	250.86	GYROID	2.33	1.18	25.51	PWUELL	2.30	1.04
117.25	GLOBOCAS	2.84	1.30	250.86	PRENZI	1.93	1.81	26.71	CIB	2.72	0.07
117.25	PWUELL	2.23	1.64	250.86	STABYSS	2.23	0.93	26.71	PWUELL	2.16	0.87
123.91	CIB	2.49	1.52	260.37	CIB	1.16	1.19				
124.11	GLOBOCAS	3.01	1.09	260.37	GLOBOCAS	2.17	1.09	28.91	PWUELL	2.00	0.85
124.11	PRENZI	2.44	1.49	263.91	BJARV	1.99	0.80	28.91	UVIG	2.73	0.51
126.59	PWUELL	2.08	1.14	263.91	GLOBOCAS	2.07	1.03	29.01	UVIG	2.62	0.37
128.51	CIB	2.14	1.06	263.91	GLOBOCAS	2.37	0.31	29.20	UVIG	2.57	0.36
129.56	CIB	2.27	1.48	279.63	NUTTCIB	0.52	0.78	29.60	UVIG	2.82	0.74
132.71	CIBKULL	2.38	1.19	281.10	CIB	0.39	1.11	29.79	UVIG	2.73	0.41
132.71	UVIGSTIL	2.74	0.55*	281.10	NUTT	0.33	0.73	29.79	UVIG	2.76	0.44
134.64	CIB	2.32	1.17	282.60	NUTTCIB	0.47	0.83	30.10	GLOBOCAS	2.65	0.45
137.20	GLOBORID	3.00	0.98*	284.10	NUTTCIB	0.41	0.92	30.10	PWUELL	2.35	0.84
137.20	PRENZI	2.30	1.51	284.10	ORID	0.77	0.39*	30.10	UVIG	2.85	0.52

Hole 526A

Hole 526B

Appendix B. (Continued).

Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)
Hole 526A (cont.)				Hole 526A (cont.)				Hole 526A (cont.)			
30.20	PWUELL	2.39	0.92	57.54	PWUELL	2.34	1.27	99.51	GLOBOCAS	2.44	1.16
30.20	UVIG	2.77	0.73	57.71	PWUELL	2.06	1.24	99.81	GLOBOCAS	2.68	1.16
30.52	PWUELL	2.38	0.80	57.91	PWUELL	2.03	1.18	103.00	GLOBOCAS	2.39	1.19
30.52	UVIG	2.77	0.46	58.11	PWUELL	2.05	1.25	103.21	GLOBOCAS	2.68	1.18
30.72	UVIG	2.83	0.68	58.31	PWUELL	2.06	1.27	103.21	GYROID	3.10	0.39*
31.11	PWUELL	2.33	0.93	58.51	ORID	2.67	0.65*	103.61	GLOBOCAS	2.47	1.07
31.11	UVIG	2.75	0.39	58.51	PWUELL	2.09	1.28	103.61	UVIG	2.79	0.54
31.30	PWUELL	2.19	0.83	58.64	PWUELL	2.01	1.24	104.51	PWUELL	2.03	1.74
31.41	PWUELL	2.35	0.88	58.71	PWUELL	1.81	1.01	104.51	PWUELL	2.17	1.76
31.41	UVIG	2.73	0.41	58.71	STABYSS	2.84	0.37	104.71	GLOBOCAS	2.68	1.17
31.60	PWUELL	2.43	0.90	58.71	UVIG	2.96	0.28	105.11	GLOBOCAS	2.79	1.18
31.71	PWUELL	2.47	0.79	58.86	PWUELL	2.11	1.16	105.11	CIB	2.29	1.77
32.01	PWUELL	2.25	0.72	60.16	PWUELL	1.98	1.47	105.31	GLOBOCAS	2.71	0.63
32.20	PWUELL	2.33	1.00	60.40	GLOBOCAS	2.80	0.83	105.51	PWUELL	2.05	1.59
33.05	PWUELL	2.39	0.96	60.40	PWUELL	1.99	1.28	106.01	GLOBOCAS	2.82	1.19
34.55	PWUELL	2.36	1.06	60.60	GLOBOCAS	2.86	1.25	106.01	GYROID	2.50	0.97
36.05	PWUELL	2.37	0.98	60.89	GLOBOCAS	3.12	1.17	106.01	PWUELL	2.01	1.53
36.59	PWUELL	2.24	0.87	60.89	PWUELL	2.24	1.72	106.21	CIB	1.96	1.40
38.02	PWUELL	2.32	0.87	61.09	GLOBOCAS	2.90	1.17	106.41	GLOBOCAS	2.54	1.01
39.52	GLOBOCAS	3.03	0.26	61.09	PWUELL	2.10	1.55	106.41	GLOBOCAS	2.57	1.03
39.52	PWUELL	2.31	1.00	61.29	GLOBOCAS	2.87	1.03	106.85	CIBKULL	1.94	1.45
41.02	PWUELL	2.45	0.71	61.29	PWUELL	2.15	1.62	107.09	GLOBOCAS	2.26	0.70
41.28	GLOBOCAS	2.68	0.17	61.49	GLOBOCAS	2.87	1.09	107.09	PWUELL	1.78	1.67
41.28	PWUELL	2.19	0.83	61.49	PWUELL	2.32	1.57	110.81	CIBKULL	1.89	1.50
41.42	PWUELL	2.17	1.08	61.66	PWUELL	2.25	1.60	110.81	GYROID	2.45	1.32
44.42	PWUELL	2.22	1.09	63.41	GLOBOCAS	2.89	0.77	110.81	PWUELL	1.73	1.62
45.80	GLOBOCAS	3.21	0.42	63.51	GLOBOCAS	2.79	0.52	111.80	PWUELL	1.62	1.79
45.80	PWUELL	2.28	1.00	63.81	GLOBOCAS	2.93	0.77	116.27	PWUELL	1.69	2.34
46.41	PWUELL	2.32	0.90	65.41	PWUELL	2.32	1.42	116.27	GLOBOCAS	2.14	1.74
46.51	PWUELL	2.43	0.89	65.41	GLOBOCAS	2.91	1.03	116.41	GYROID	2.15	1.89
46.61	PWUELL	2.47	0.80	66.16	CIBKULL	2.31	1.41	116.41	GLOBOCAS	2.16	1.85
46.71	PWUELL	2.42	1.05	66.16	GLOBOCAS	3.03	1.08	116.41	GLOBOCAS	2.22	2.10
46.91	PWUELL	2.30	1.10	66.16	GLOBOCAS	3.07	1.09	116.51	CIBKULL	1.23	1.72
47.07	PWUELL	2.34	1.08	66.16	ORID	2.90	0.73	116.57	GLOBOCAS	2.14	2.02
47.14	PWUELL	2.45	1.07	66.31	GLOBOCAS	2.97	0.92	119.51	ANOMAL	1.44	1.44
47.31	PWUELL	2.56	1.25	66.31	GLOBOCAS	3.17	1.16	120.76	CIB	1.32	1.75
47.52	PWUELL	2.30	1.06	66.51	CIB	2.29	1.40	124.92	GLOBOCAS	1.89	1.35
47.71	PWUELL	2.41	0.91	66.51	GLOBOCAS	2.86	0.78	129.80	BJARV	1.45*	0.90*
47.91	PWUELL	2.40	1.05	66.51	GLOBOCAS	3.05	1.07	129.80	HELEGANS	3.30*	2.96*
48.11	PWUELL	2.36	1.04	66.71	GLOBOCAS	3.07	0.92	133.74	CIB	1.57	1.65
48.31	PWUELL	2.43	0.96	70.47	GLOBOCAS	2.89	1.15	157.53	CIB	1.16	1.54
48.41	GLOBOCAS	2.82	0.23	72.51	GLOBOCAS	2.62	1.10	157.53	GLOBSTIL	1.21	0.86
48.41	PWUELL	2.36	1.22	74.38	PWUELL	2.51	1.34	159.45	CIB	1.13	1.43
48.64	PWUELL	2.38	1.02	74.38	GLOBOCAS	2.98	0.75	159.45	CIBKULL	1.17	1.35
48.81	PWUELL	2.22	0.88	74.51	GLOBOCAS	3.18	1.00	159.45	GLOBOCAS	1.39	1.11
49.01	GLOBOCAS	2.86	0.29	74.71	GLOBOCAS	2.97	1.03	159.45	GYROID	1.62	1.11
49.22	GLOBOCAS	3.00	0.45	75.11	GLOBOCAS	3.16	0.81	160.85	CIB	1.45	1.26
49.22	PWUELL	2.41	1.10	75.29	GLOBOCAS	2.87	0.95	160.85	GLOBSTIL	1.45	0.38
49.41	PWUELL	2.30	1.03	75.48	GLOBOCAS	2.91	1.00	164.87	SBULL	1.64	1.04
49.61	GLOBOCAS	2.98	0.30	75.51	GLOBOCAS	2.95	0.85	164.87	STABYSS	1.54	0.29
49.99	PWUELL	2.25	0.84	75.68	GLOBOCAS	2.94	0.74	164.87	UVIGBUL	1.54	0.58
49.99	GLOBOCAS	2.93	0.47	75.90	GLOBOCAS	2.97	1.14	168.15	CIB	1.37	1.23
50.20	GLOBOCAS	2.91	0.59	78.01	GLOBOCAS	2.99	0.96	168.15	CIB	1.52	1.12
51.21	GLOBOCAS	2.93	0.25	78.21	CIBKULL	2.45	1.19	169.50	CIB	1.65	1.35
51.21	PWUELL	2.26	0.82	78.21	GLOBOCAS	2.98	0.93	170.47	CIB	1.41	1.24
51.61	GLOBOCAS	2.75	0.19	78.21	PULBUL	2.83	0.66	170.47	UVIG	1.78	0.76
51.61	PWUELL	2.19	0.78	78.41	PWUELL	2.28	1.46	172.18	CIB	1.48	0.80
51.81	GLOBOCAS	2.82	0.22	78.41	GLOBOCAS	2.33	0.68*	174.54	CIB	1.73	1.32
51.81	PWUELL	2.24	0.63	78.61	GLOBOCAS	2.94	0.87	175.70	CIB	1.55	1.25
52.01	BULIMINA	2.72	0.07*	78.81	GLOBOCAS	3.13	0.88	175.90	CIB	1.33	0.88
52.01	GLOBOCAS	2.77	0.11	79.01	GLOBOCAS	2.99	1.01	176.10	UVIG	1.34	0.69
52.01	PWUELL	2.29	0.51	79.21	GLOBOCAS	3.05	0.71	176.40	CIB	1.29	1.53
52.21	PWUELL	2.24	0.73	79.41	GLOBOCAS	2.83	1.08	176.79	CIB	1.39	1.34
52.41	PWUELL	2.40	0.82	79.61	GLOBOCAS	3.12	0.88	176.79	UVIGCIB	1.45	0.58
52.61	PWUELL	2.14	0.86	79.81	GLOBOCAS	3.18	0.89	177.34	CIB	1.49	1.04
52.71	PWUELL	2.21	0.81	80.01	GLOBOCAS	2.99	0.97	177.34	UVIG	1.40	0.77
52.81	PWUELL	2.20	1.01	80.01	GLOBOCAS	3.29	0.89	177.71	CIB	1.48	1.23
52.81	UVIGGLOB	2.81	0.24	80.50	GLOBOCAS	2.87	0.81	179.82	CIB	1.56	1.40
53.11	PWUELL	2.39	1.06	83.81	GLOBOCAS	2.87	0.83	181.32	STABYSS	1.80	0.78
53.31	CIBKULL	2.21	0.43	84.01	GLOBOCAS	2.62	0.44	181.60	CIB	1.57	1.39
53.31	GLOBOCAS	2.97	0.55	84.21	GLOBOCAS	2.97	0.62	185.11	UVIG	1.51	0.78
53.31	PWUELL	2.29	0.81	84.41	GLOBOCAS	2.62	0.75	186.60	STABYSS	1.31	0.58
53.51	GLOBOCAS	3.05	0.27	85.57	GLOBOCAS	2.81	0.82	187.46	CIB	1.36	1.26
53.51	PWUELL	2.05	0.70	87.07	GLOBOCAS	2.75	0.72	188.61	UVIG	1.39	0.58
53.51	STABYSS	2.72	-0.29	87.07	GLOBOCAS	2.81	0.67	190.11	BULIMINA	1.40	0.43*
53.71	PWUELL	2.39	1.17	88.31	GLOBOCAS	2.59	0.59	190.11	CIB	1.32	1.03
53.91	CIBKULL	2.05	0.46	88.57	GLOBOCAS	2.88	0.98	190.11	UVIG	1.57	0.58
53.91	PWUELL	2.16	0.82	90.01	GLOBOCAS	2.72	0.74	193.64	CIB	1.16	1.24
54.11	CIBKULL	2.04	0.62	90.21	GLOBOCAS	2.90	0.82	196.00	UVIG	1.51	0.78
54.11	GLOBOCAS	2.97	0.11	91.40	GLOBOCAS	2.61	0.77	201.90	UVIG	1.31	0.73
54.21	GLOBOCAS	2.73	0.20	91.61	GLOBOCAS	2.81	1.00	203.40	UVIG	1.30	1.01
54.31	GLOBOCAS	2.91	0.62	93.21	GLOBOCAS	2.94	1.21	205.95	BULIMINA	1.36	0.47*
54.31	PWUELL	2.10	1.10	95.31	BULIMINA	2.60	1.02*	205.95	CIB	1.05	1.41
54.50	GLOBOCAS	2.85	0.27	95.31	GLOBOCAS	2.90	0.88	205.95	UVIG	1.43	0.80
55.64	PWUELL	2.10	1.20	95.61	GLOBOCAS	2.60	0.87	208.32	BULIMINA	1.58	0.72
56.04	GLOBOCAS	2.86	0.40	95.81	GLOBOCAS	3.09	0.62	217.53	BULIMINA	0.55	0.78
56.04	PWUELL	2.24	1.13	96.01	GLOBOCAS	2.73	0.89	217.53	GYROID	0.90	1.16
56.21	PWUELL	2.25	1.27	96.21	GLOBOCAS	2.67	0.90	217.53	NUTT	0.41	0.77
56.61	GYROID	2.54	0.41*	96.41	GLOBOCAS	2.72	1.03	240.94	PWUELL	2.18	0.87
56.61	PWUELL	2.11	1.29	96.61	GLOBOCAS	2.76	0.78	240.94	PWUELL	2.37	0.79
56.81	GYROID	2.91	0.11*	96.81	GLOBOCAS	2.51	0.80	241.10	PWUELL	1.08	0.96
56.81	PWUELL	2.13	1.07	97.11	GLOBOCAS	2.42	0.69	241.71	NUTT	0.67	0.66
57.01	PWUELL	2.26	1.25	98.51	GLOBOCAS	2.57	0.98	241.71	NUTT	0.44	1.02
57.27	GYROID	2.69	0.44*	98.80	GLOBOCAS	2.59	0.83	243.61	NUTT	0.17	0.86
57.27	RECTUVIG	2.64									

Appendix B. (Continued).

Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)
Hole 527 (cont.)				Hole 528A (cont.)				Hole 529 (cont.)			
143.29	NUTT	0.02	0.66	8.95	UVIG	3.52	-0.05	131.49	GLOBOCAS	2.20	0.64
143.11	NUTTCIB	0.33	0.60	9.05	CIBKULL	3.48	0.48	131.49	GYROID	2.50	0.65*
142.88	NUTT	0.19	0.48	9.15	GLOBOCAS	4.27	-0.52	135.71	GLOBORID	2.05	0.34
142.71	MIXED	0.37	0.45	9.15	UVIG	3.94	-0.26	141.46	BULIMINA	1.99	0.66
142.71	NUTT	0.29	0.78	9.35	ORID	4.04	-0.54	141.46	GLOBOCAS	2.29	0.76
142.31	NUTT	0.17	0.57	9.35	UVIG	3.92	-0.18	151.55	BULIMINA	2.05	0.47
142.48	NUTTCIB	0.38	0.84	9.45	GLOBOCAS	3.99	0.03	156.21	CIB	1.79	1.24
143.61	NUTTCIB	0.21	0.47	9.45	UVIG	3.90	0.13	160.75	GLOBOCAS	1.93	0.90
143.75	NUTTCIB	0.46	0.76	9.55	PWUELL	3.05	0.66	160.75	GYROID	2.19	0.94
143.98	NUTTCIB	0.19	0.55	9.55	UVIG	3.52	0.02	163.91	BJARV	2.35	1.47
144.21	NUTTCIB	0.33	0.47	9.75	GLOBOCAS	3.65	0.13	168.89	CIB	1.75	1.33
144.52	NUTTCIB	0.07	0.49	9.75	UVIG	4.03	-0.50	168.89	GLOBOCAS	2.05	0.58
144.79	CIB	0.09	0.69	9.95	GLOBOCAS	3.62	0.04	168.89	GLOBOCAS	2.10	0.88
145.11	NUTT	-0.10	0.24	9.95	UVIG	3.76	0.04	170.73	CIB	1.94	0.74
145.31	NUTT	-0.11	0.43	10.05	CIBKULL	3.53	0.70	170.73	GYROID	2.60	0.66
145.76	NUTTCIB	0.07	0.38	10.05	UVIG	3.96	-0.05	170.73	STABYSS	2.20	0.41*
146.28	NUTTCIB	-0.15	0.33	10.15	GLOBOCAS	4.00	-0.51	172.23	CIB	1.66	1.20
146.77	NUTTCIB	-0.03	0.89	10.15	PWUELL	3.23	0.20	175.23	CIB	1.62	1.20
147.02	NUTTCIB	-0.12	0.60	10.15	UVIG	3.88	-0.37	175.41	GLOBOCAS	2.13	0.83
147.68	NUTTCIB	-0.21	1.02	10.25	GLOBOCAS	4.00	-0.08	176.73	CIBGLOB	1.54	1.15
147.93	NUTT	-0.11	0.72	10.25	UVIG	4.05	-0.02	178.23	CIB	1.44	0.01
148.24	NUTT	-0.41	0.64	10.35	CIBKULL	3.24	0.96	179.62	ORID	1.87	0.13
152.28	NUTT	-0.19	0.97	10.35	UVIG	3.49	0.20	181.50	CIB	1.49	0.95
164.69	NUTT	-0.43	0.57	10.45	CIBKULL	2.94	0.85	181.50	ORID	1.97	0.10*
199.91	NUTT	-0.21	0.77	10.55	CIBKULL	3.71	0.86	182.15	CIB	1.77	0.86
199.51	NUTT	-0.29	0.82	10.55	PWUELL	3.30	0.86	182.15	BULSTIL	1.96	0.51
202.11	CIB	0.22	1.25	10.55	UVIG	3.89	0.05	183.41	BJARV	2.22	1.08
218.34	ORID	0.53	1.70	10.62	GLOBOCAS	3.90	0.07	183.41	GLOBOCAS	2.34	0.88
218.34	CIB	0.33	2.42	10.62	ORID	4.09	-0.59	183.41	ORID	2.04	0.60*
218.34	NUTT	0.12	2.02	10.62	PWUELL	3.54	0.25	183.63	CIB	1.54	1.12
218.34	GAVELIN	0.17	2.01	10.75	CIBKULL	3.35	0.97	183.63	ORID	1.74	0.35*
256.30	ORID	0.55	0.68	10.87	CIBKULL	2.99	0.93	184.87	UVIGORID	1.75	0.60
258.10	NUTTGAV	0.20	1.02	10.87	UVIG	3.65	-0.04	184.87	GYROID	2.07	0.98
261.10	NUTT	0.19	1.37	10.95	UVIG	4.33	0.06	184.87	GLOBORID	1.80	0.65
260.62	GAVELIN	0.15	1.02	11.03	GLOBOCAS	4.19	-0.35	184.87	STABYSS	1.82	0.55
267.31	NUTT	0.65	1.41	11.03	UVIG	3.89	-0.32	185.13	CIB	1.84	0.98
267.51	ORID	0.26	0.65	11.15	UVIG	4.14	-0.37	185.13	NOD	1.94	0.65*
267.72	GAVELIN	-0.16	1.13	11.25	GLOBOCAS	3.83	-0.06	185.57	CIB	1.55	1.27
267.72	NUTT	0.50	1.29	11.35	CIBKULL	2.68	0.62	189.01	MIXED	2.05	0.70
267.79	NUTTGAV	-0.14	1.11	11.35	UVIG	3.46	-0.35	192.98	BJARV	2.37	1.40
267.79	ORID	0.32	0.65*	11.55	CIB	3.57	0.31	193.21	BULIMINA	2.44	1.00
267.92	GAVELIN	0.58	1.12	11.64	GLOBOCAS	4.48	-0.39	193.21	GLOBORID	2.34	0.73
267.92	NUTT	-0.02	1.32	11.64	ORID	4.10	-0.78	194.18	BJARV	2.45	1.33
267.92	ORID	0.42	0.57*	11.64	PWUELL	3.06	0.59	194.55	BJARV	2.55	1.64
268.11	GAVELIN	-0.02	1.19	11.64	UVIG	4.36	-0.28	195.57	BJARV	2.44	1.59
270.11	ORID	0.59	1.01*	11.75	UVIG	3.46	-0.19	197.90	GYROID	1.95	1.01
270.11	NUTT	0.42	1.28	11.85	UVIG	3.60	-0.10	197.90	UVIG	1.82	0.66
270.11	NUTT	0.58	1.36	24.25	GLOBOCAS	2.93	0.01	199.00	BJARV	2.38	1.58
271.71	NUTTGAV	0.33	1.30	24.25	GLOBOCAS	3.01	0.39	199.00	CIB	2.22	1.81
271.71	ORID	0.61	1.09*	44.35	CIB	2.61	0.49	199.20	BJARV	2.28	1.43
271.92	NUTT	0.18	1.30	45.15	CIB	2.50	0.61	199.20	ORID	2.30	0.83
271.92	ORID	0.56	0.94*	45.15	UVIGGLOB	3.05	0.29	199.50	BJARV	2.48	1.65
273.25	ORID	0.32	1.06*	200.04	NUTT	0.60	0.76	200.04	BJARV	1.32	0.77
273.25	NUTT	0.35	1.31	200.04	NUTT	0.60	0.76	200.04	STABYSS	1.06	0.80
276.21	NUTTCIB	0.15	1.39	225.67	NUTTCIB	2.51	1.13	200.13	BJARV	1.47	0.95
278.33	NUTTCIB	0.10	1.61	227.54	NUTTCIB	0.87	0.75	200.13	NUTT	0.91	0.88
279.71	NUTTGAV	0.26	2.16	237.98	CIB	1.08	1.19	200.20	BULIMINA	1.73	0.87
279.91	NUTTGAV	0.14	2.03	237.98	NUTT	0.92	0.69	200.78	BJARV	1.18	1.12
280.10	NUTTGAV	0.27	2.01	246.40	NUTTCIB	0.72	0.90	200.78	NUTT	0.58	1.14
280.28	NUTT	0.53	2.01	249.40	NUTT	0.31	0.17	201.39	BJARV	1.19	0.97
280.49	NUTTGAV	0.27	1.79	250.60	NUTTCIB	0.29	0.71	201.39	NUTT	0.47	0.77
280.68	NUTT	0.66	2.26	250.60	ORIDBUL	0.58	0.23*	201.53	NOD	1.30	0.84
280.85	NUTTGAV	0.57	1.94	252.00	NUTT	0.33	0.81	202.58	BJARV	1.44	0.83
281.19	NUTTGAV	0.30	1.75	256.61	NUTTCIB	-0.19	0.65	202.58	NUTT	0.89	0.76
281.40	NUTT	0.94	2.17	257.47	NUTTCIB	0.07	1.01	205.20	BJARV	1.44	0.83
281.40	NUTT	0.94	2.17	263.01	NUTTCIB	-0.52	1.03	206.60	BULIMINA	1.24	1.22
281.59	NUTT	-0.27	1.70*	312.07	NUTT	-0.14	0.65	207.35	BJARV	1.37	0.79
281.59	NUTT	0.53	1.85	313.53	NUTT	0.05	1.32	207.35	NUTT	0.77	0.57
281.59	NUTT	-0.27	1.70	313.56	NUTT	-0.02	1.36	207.35	NUTT	0.88	0.74
281.59	NUTT	0.53	1.85	313.82	NUTT	-0.11	1.24	207.88	ANOMAL	0.34	0.67
282.00	NUTTGAV	0.20	2.03	314.21	CIB	-0.12	1.08	207.88	CIB	0.47	0.73
282.20	NUTT	0.22	1.70	314.21	NUTT	-0.18	1.32	207.88	BULIMINA	1.26	0.82
				315.99	NUTT	0.13	1.74	207.88	ORID	1.10	0.32
								207.88	OSANGUL	1.06	0.83
8.87	UVIG	3.50	-0.09					222.50	BJARV	1.34	0.74
8.95	CIBKULL	2.85	0.77	0.11	HELEGANS	3.61	2.89	222.50	NUTT	0.75	0.60
8.95	ORID	3.49	-0.41	0.11	PWUELL	2.19	1.01	268.84	MIXED	-0.27	0.73

Note: Asterisks denote values that have not been used in Appendix C or in the figures. In the majority of cases these are ^{13}C values for species whose departure from isotopic equilibrium is poorly defined or very variable; in a small number of cases it is suspected either that the sample was displaced or that the analysis was suspect. For explanations of computer abbreviations, see Appendix A.

APPENDIX C
Isotopic Analyses of Benthic Foraminifers from Sites 525-529, Adjusted on the Basis of Appendix A

Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (%)	$\delta^{13}\text{C}$ (%)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (%)	$\delta^{13}\text{C}$ (%)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (%)	$\delta^{13}\text{C}$ (%)
Hole 525B														
0.80	0.163	UVIG	3.95	0.98	174.91	15.650	MEAN	2.64	2.28	17.31	2.042	PWUELL	3.28	0.99
11.66	2.216	MEAN	3.60	0.59	175.02	15.658	GLOBOCAS	2.57	2.50	17.51	2.067	PWUELL	3.25	1.08
13.05	2.402	MEAN	3.30	1.05	175.31	15.680	MEAN	2.69	2.18	17.71	2.093	PWUELL	3.39	0.67
19.01	3.126	PWUELL	3.09	0.50	175.51	15.695	MEAN	2.62	2.40	18.31	2.170	PWUELL	3.06	0.52
19.34	3.138	PWUELL	3.25	0.71	176.01	15.732	GLOBOCAS	2.30	1.95	22.11	2.655	GLOBOCAS	3.06	0.59
22.10	3.234	MEAN	3.25	0.94	176.41	15.761	MEAN	2.35	1.82	25.51	3.090	PWUELL	2.94	1.04
22.20	3.237	MEAN	3.32	0.93	189.51	16.731	GLOBOCAS	2.10	2.29	26.71	3.243	PWUELL	2.80	0.87
22.40	3.244	MEAN	3.32	0.82	190.31	16.790	ORIDGYR	1.94	2.31					
23.61	3.287	GLOBOCAS	3.18	0.86	190.61	16.812	CIB	1.98	2.23					
27.78	3.432	GLOBOCAS	3.19	0.95	190.65	16.815	CIB	1.98	2.23					
33.35	3.644	GLOBOCAS	3.01	0.84	191.01	16.842	MEAN	1.85	2.41	28.91	3.525	MEAN	2.69	1.13
35.10	3.748	GLOBOCAS	3.20	0.77	191.05	16.845	MEAN	1.85	2.41	29.01	3.537	UVIG	2.62	1.27
42.26	4.171	PWUELL	2.92	0.45	191.21	16.856	GYRORID	2.13	2.48	29.20	3.562	UVIG	2.57	1.26
44.88	4.326	GLOBOCAS	3.20	1.03	191.25	16.859	GYRORID	2.13	2.48	29.60	3.633	UVIG	2.82	1.64
48.05	4.513	GLOBOCAS	3.08	0.78	191.41	16.871	ORID	2.02	2.74	29.79	3.697	UVIG	2.73	1.31
54.08	4.841	GLOBOCAS	3.04	1.22	191.45	16.874	ORID	2.02	2.74	29.90	3.733	UVIG	2.76	1.34
55.58	4.923	GLOBOCAS	3.04	1.46	191.61	16.886	CIBKULL	1.82	1.95	30.10	3.800	MEAN	2.80	1.07
58.81	5.063	GLOBOCAS	2.99	1.13	191.65	16.889	CIBKULL	1.82	1.95	30.20	3.833	MEAN	2.90	1.28
59.11	5.074	GLOBOCAS	3.19	1.28	192.20	16.930	MEAN	1.83	2.15	30.52	3.940	MEAN	2.90	1.08
60.31	5.116	GLOBOCAS	3.27	1.33	193.60	17.070	GLOBOCAS	2.34	2.31	30.72	4.007	UVIG	2.83	1.58
61.71	5.164	MEAN	3.15	1.23	194.01	17.134	CIBKULL	1.82	1.76	31.11	4.110	MEAN	2.86	1.11
62.01	5.175	GLOBOCAS	3.34	1.29	194.21	17.165	CIBKULL	1.82	1.76	31.30	4.127	PWUELL	2.83	0.83
62.91	5.206	MEAN	3.05	1.05	195.91	17.430	GLOBOCAS	1.54	1.76	31.41	4.137	MEAN	2.86	1.10
63.21	5.217	GLOBOCAS	3.13	0.81	201.05	17.748	GLOBOCAS	2.00	1.95	31.60	4.154	PWUELL	3.07	0.90
66.81	5.342	MEAN	3.28	1.31						31.71	4.164	PWUELL	3.11	0.79
66.91	5.346	GLOBOCAS	3.14	1.12						32.01	4.191	PWUELL	2.89	0.72
67.41	5.363	GLOBOCAS	3.19	0.96						32.20	4.208	PWUELL	2.97	1.00
67.91	5.381	MEAN	3.28	0.90	203.10	17.823	GLOBOCAS	2.07	1.69	33.05	4.284	PWUELL	3.03	0.96
70.61	5.475	MEAN	3.31	0.93	212.60	19.187	GLOBOCAS	2.33	1.84	34.55	4.419	PWUELL	3.00	1.06
70.68	5.478	PWUELL	3.34	0.83	222.10	21.613	MEAN	2.32	1.30	36.05	4.526	PWUELL	3.01	0.98
72.11	5.528	MEAN	3.11	0.96	231.91	22.955	GLOBOJAR	2.30	1.09	36.59	4.549	PWUELL	2.88	0.87
72.18	5.530	PWUELL	3.15	0.95	241.40	23.241	MEAN	2.10	1.78	38.02	4.609	PWUELL	2.96	0.87
73.61	5.580	PWUELL	3.31	1.23	250.86	23.526	MEAN	2.29	1.90	39.52	4.673	MEAN	2.94	0.88
75.14	5.633	GLOBOCAS	3.20	1.06	260.37	23.971	MEAN	1.87	1.39	41.02	4.737	PWUELL	3.09	0.71
75.81	5.657	MEAN	3.37	1.15	263.91	24.229	MEAN	2.08	1.06	41.28	4.748	MEAN	2.71	0.75
79.06	5.770	MEAN	3.17	0.94	279.63	46.733	NUTTCIB	0.92	0.78	41.42	4.754	PWUELL	2.81	1.08
79.71	5.793	MEAN	3.17	0.92	281.10	47.101	MEAN	0.79	0.92	44.42	4.882	PWUELL	2.86	1.09
81.01	5.838	PRENZI	3.37	0.88	282.60	47.477	NUTTCIB	0.87	0.83	45.80	4.940	MEAN	3.02	0.96
82.06	5.875	GLOBOCAS	2.98	0.90	284.10	47.860	MEAN	0.79	0.92	46.41	4.966	PWUELL	2.96	0.90
82.31	5.884	MEAN	2.72	0.74	287.10	47.710	MEAN	0.67	0.78	46.51	4.971	PWUELL	3.07	0.89
82.49	5.890	MEAN	2.70	0.80	289.01	49.252	MEAN	0.80	0.68	46.61	4.975	PWUELL	3.11	0.80
82.93	5.905	MEAN	3.07	0.98	290.51	49.677	MEAN	0.66	0.70	46.71	4.979	PWUELL	3.06	1.05
88.01	6.083	PRENZI	3.15	0.90	292.01	50.050	MEAN	0.76	0.74	46.91	4.988	PWUELL	2.94	1.10
94.31	6.303	MEAN	2.93	1.34	293.50	50.255	ORID	0.38	0.95	47.07	4.994	PWUELL	2.98	1.08
95.04	6.328	MEAN	2.92	1.49	295.01	50.462	MEAN	0.37	0.55	47.14	4.997	PWUELL	3.09	1.07
95.69	6.351	GLOBOCAS	2.75	1.33	298.00	50.874	NUTT	0.06	0.65	47.31	5.019	PWUELL	3.20	1.25
96.21	6.369	GLOBOCAS	3.12	1.35	302.29	51.464	MEAN	0.09	1.08	47.52	5.054	PWUELL	2.94	1.06
97.71	6.600	GLOBOCAS	2.97	1.50	302.39	51.477	ORIDBUL	0.15	1.33	47.71	5.086	PWUELL	3.05	0.91
99.37	7.145	MEAN	3.00	1.50	322.79	53.502	ALABNUTT	-0.08	0.89	47.91	5.120	PWUELL	3.04	1.05
103.54	8.505	MEAN	3.13	1.64	337.85	54.604	MEAN	-0.26	0.95	48.11	5.154	PWUELL	3.00	1.04
109.11	9.228	PWUELL	2.89	1.30	338.01	54.617	MEAN	-0.26	1.00	48.31	5.188	PWUELL	3.07	0.96
113.47	9.794	MEAN	3.12	1.54	358.19	55.808	CIBBUL	0.04	0.35	48.41	5.205	MEAN	2.86	0.98
117.25	10.285	MEAN	2.81	1.72	358.29	55.811	MEAN	0.04	0.76	48.64	5.244	PWUELL	3.02	1.02
123.91	10.932	CIB	2.99	1.52	358.39	55.814	BENTHICS	-0.09	0.80	48.81	5.273	PWUELL	2.86	0.88
124.11	10.948	MEAN	2.98	1.54	358.49	55.818	BENTHICS	0.25	0.45	49.01	5.306	GLOBOCAS	2.76	0.79
126.59	11.142	PWUELL	2.72	1.14	358.59	55.821	MEAN	0.19	0.76	49.22	5.342	MEAN	2.98	1.03
128.51	11.293	CIB	2.64	1.06	358.69	55.824	CIBGAV	-0.30	0.06	49.41	5.374	PWUELL	2.94	1.03
129.56	11.375	CIB	2.77	1.48	358.99	55.834	NUTT	0.25	0.47	49.61	5.408	GLOBOCAS	2.88	0.80
132.71	11.623	MEAN	2.81	1.19	359.09	55.838	MEAN	0.04	0.35	49.99	5.472	MEAN	2.86	0.91
134.64	11.774	CIB	2.82	1.17	359.19	55.841	MEAN	0.22	0.42	50.20	5.508	GLOBOCAS	2.81	1.09
137.20	11.975	MEAN	2.95	1.51	359.29	55.844	NUTT	-0.01	0.21	51.21	5.679	MEAN	2.87	0.79
139.18	12.645	MEAN	3.07	1.50	359.39	55.848	NUTT	0.15	0.44	51.61	5.747	MEAN	2.74	0.74
139.41	12.734	MEAN	2.75	1.45	359.49	55.851	NUTT	0.14	0.37	51.81	5.781	MEAN	2.80	0.68
139.46	12.753	GLOBOCAS	2.68	1.44	359.59	55.854	NUTT	0.09	0.29	52.01	5.814	MEAN	2.77	0.56
139.61	12.801	MEAN	2.75	1.50	371.57	56.255	NUTT	-0.13	0.28	52.21	5.848	PWUELL	2.88	0.73
139.81	12.811	MEAN	2.87	1.46	379.21	56.888	NUTT	0.36	1.63	52.41	5.882	PWUELL	3.04	0.82
140.01	12.820	PWUELL	2.86	1.53	382.21	57.167	NUTT	0.31	1.11	52.61	5.916	PWUELL	2.78	0.86
140.21	12.830	MEAN	2.56	1.61	385.81	57.503	NUTT	0.28	0.86	52.71	5.933	PWUELL	2.85	0.81
140.41	12.839	MEAN	2.87	1.22	387.31	57.643	NUTT	0.03	0.96	52.81	5.950	MEAN	2.80	0.98
140.71	12.853	PWUELL	3.14	1.37	390.09	57.902	NUTT	0.09	1.06	53.11	6.001	PWUELL	3.03	1.06
140.91	12.863	UVIGGLOB	2.86	1.27	393.36	58.206	NUTT	0.42	1.55	53.31	6.035	MEAN	2.84	0.76
141.11	12.872	PWUELL	2.80	1.48	403.35	59.144	CIB	0.47	2.43	53.51	6.068	MEAN	2.74	0.73
141.31	12.881	PWUELL	3.01	1.44	403.40	59.149	NUTT	0.17	2.15	53.71	6.102	PWUELL	3.03	1.17
141.51	12.891	PWUELL	2.90	1.46	404.59	59.265	MEAN	0.52	2.34	53.91	6.136	MEAN	2.68	0.64
141.71	12.900	CIB	2.80	1.57	404.65	59.271								

Appendix C. (Continued).

Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)
Hole 526A (cont.)					Hole 526A (cont.)					Hole 528A				
60.16	7.194	PWUELL	2.62	1.47	168.15	27.188	MEAN	1.95	1.18	8.87	1.002	UVIG	3.50	0.81
60.40	7.235	MEAN	2.77	1.31	169.50	27.788	CIB	2.15	1.35	8.95	1.011	MEAN	3.45	0.74
60.60	7.269	GLOBOCAS	2.76	1.75	170.47	28.143	MEAN	1.85	1.45	9.05	1.022	CIBKULL	3.98	0.48
60.89	7.318	MEAN	2.95	1.70	172.18	28.413	CIB	1.98	0.80	9.15	1.033	MEAN	4.06	0.32
61.09	7.352	MEAN	2.77	1.61	174.54	28.787	CIB	2.23	1.32	9.35	1.056	MEAN	3.98	0.59
61.29	7.386	MEAN	2.78	1.58	175.70	28.971	CIB	2.05	1.25	9.45	1.067	MEAN	3.90	0.78
61.49	7.420	MEAN	2.87	1.58	175.90	29.002	CIB	1.83	0.88	9.55	1.078	MEAN	3.61	0.79
61.66	7.448	PWUELL	2.89	1.60	176.10	29.034	UVIG	1.34	1.59	9.75	1.101	MEAN	3.79	0.52
63.41	7.745	GLOBOCAS	2.79	1.27	176.40	29.081	CIB	1.79	1.53	9.95	1.124	MEAN	3.64	0.74
63.51	7.762	GLOBOCAS	2.69	1.02	176.79	29.143	MEAN	1.80	1.19	10.05	1.135	MEAN	4.00	0.78
63.81	7.813	GLOBOCAS	2.83	1.27	177.34	29.230	MEAN	1.70	1.36	10.15	1.146	MEAN	3.88	0.24
65.41	8.083	MEAN	2.89	1.47	177.71	29.289	CIB	1.98	1.23	10.25	1.158	MEAN	3.98	0.65
66.16	8.210	MEAN	2.90	1.58	179.82	29.623	CIB	2.06	1.40	10.35	1.169	MEAN	3.62	1.03
66.31	8.236	MEAN	2.97	1.54	181.32	29.860	STABYSS	1.65	1.78	10.45	1.180	CIBKULL	3.44	0.85
66.51	8.270	MEAN	2.83	1.42	181.60	29.904	CIB	2.07	1.39	10.55	1.191	MEAN	4.01	0.89
66.71	8.304	GLOBOCAS	2.97	1.42	183.95	30.276	STIL	1.40	1.69	10.62	1.199	MEAN	3.98	0.53
70.47	8.947	GLOBOCAS	2.79	1.65	185.11	30.480	UVIG	1.51	1.68	10.75	1.214	CIBKULL	3.85	0.97
72.51	9.298	GLOBOCAS	2.52	1.60	186.60	30.745	STABYSS	1.16	1.58	10.87	1.228	MEAN	3.57	0.90
74.38	9.620	MEAN	3.02	1.30	187.46	30.899	CIB	1.86	1.26	10.95	1.237	UVIG	4.33	0.96
74.51	9.642	GLOBOCAS	3.08	1.50	188.61	31.103	UVIG	1.39	1.48	11.03	1.246	MEAN	3.99	0.37
74.71	9.676	GLOBOCAS	2.87	1.53	190.11	31.371	MEAN	1.60	1.26	11.15	1.259	UVIG	4.14	0.53
75.11	9.745	GLOBOCAS	3.06	1.31	193.64	32.000	CIB	1.66	1.24	11.25	1.270	GLOBOCAS	3.73	0.44
75.29	9.776	GLOBOCAS	2.77	1.45	196.00	32.420	UVIG	1.51	1.68	11.35	1.282	MEAN	3.32	0.59
75.48	9.809	GLOBOCAS	2.81	1.50	201.90	33.471	UVIG	1.31	1.63	11.55	1.304	CIB	4.07	0.31
75.51	9.814	GLOBOCAS	2.85	1.35	203.40	33.738	UVIG	1.30	1.91	11.64	1.314	MEAN	4.14	0.39
75.68	9.843	GLOBOCAS	2.84	1.24	205.95	34.193	MEAN	1.45	1.56	11.75	1.327	UVIG	3.46	0.71
75.90	9.881	GLOBOCAS	2.87	1.64	208.32	34.615	BULIMINA	1.58	0.72	11.85	1.338	UVIG	3.60	0.80
78.01	10.244	GLOBOCAS	2.89	1.46	217.53	36.255	MEAN	0.73	0.97	24.25	2.570	MEAN	2.87	0.70
78.21	10.278	MEAN	2.89	1.53						44.35	3.547	CIB	3.11	0.49
78.41	10.313	MEAN	2.92	1.46						45.15	3.569	MEAN	3.03	0.68
Hole 527					Hole 528					Hole 529				
78.81	10.382	GLOBOCAS	3.03	1.38	40.94	3.808	PWUELL	2.82	0.87	225.67	35.820	NUTTCIB	2.91	1.13
79.01	10.416	GLOBOCAS	2.89	1.51	101.10	8.265	PWUELL	3.01	0.79	227.54	37.063	NUTTCIB	1.27	0.75
79.21	10.450	GLOBOCAS	2.95	1.21	134.70	41.847	NUTT	1.43	0.96	237.98	40.156	MEAN	1.43	0.94
79.41	10.485	GLOBOCAS	2.73	1.58	137.50	45.012	NUTT	1.02	0.66	246.40	44.920	NUTTCIB	1.12	0.90
79.61	10.519	GLOBOCAS	3.02	1.38	138.61	47.140	NUTT	0.79	1.02	249.40	46.439	NUTT	0.66	0.17
79.81	10.554	GLOBOCAS	3.08	1.39	138.81	47.523	NUTTCIB	0.57	0.86	250.60	46.837	MEAN	0.64	0.71
80.01	10.588	MEAN	3.04	1.43	139.01	47.617	NUTT	0.83	0.56	252.00	47.302	NUTT	0.68	0.81
80.50	10.661	GLOBOCAS	2.77	1.31	139.41	47.658	NUTT	0.76	0.77	256.61	48.632	NUTTCIB	0.21	0.65
83.81	11.141	GLOBOCAS	2.77	1.33	142.31	48.346	NUTT	0.52	0.57	257.40	49.217	NUTTCIB	0.47	1.01
84.01	11.170	GLOBOCAS	2.52	0.94	142.48	48.406	NUTTCIB	0.78	0.84	263.01	52.630	NUTTCIB	-0.12	1.03
84.21	11.199	GLOBOCAS	2.87	1.12	142.71	48.488	MEAN	0.51	0.62	312.07	56.869	NUTT	0.21	0.65
84.41	11.228	GLOBOCAS	2.52	1.25	142.88	48.548	NUTT	0.54	0.48	313.53	57.622	NUTT	0.40	1.32
85.57	11.396	GLOBOCAS	2.71	1.32	143.11	48.629	NUTTCIB	0.73	0.60	313.56	57.623	NUTT	0.33	1.36
87.07	11.614	MEAN	2.68	1.20	143.29	48.693	NUTT	0.37	0.66	313.82	57.640	NUTT	0.24	1.24
88.31	11.794	GLOBOCAS	2.49	1.09	143.61	48.805	NUTTCIB	0.61	0.47	314.21	57.666	MEAN	0.28	1.20
88.57	11.832	GLOBOCAS	2.78	1.48	143.75	48.853	NUTTCIB	0.86	0.76	315.99	57.782	NUTT	0.48	1.74
90.01	12.050	GLOBOCAS	2.62	1.24	143.98	48.932	NUTTCIB	0.59	0.55					
90.21	12.086	GLOBOCAS	2.80	1.32	144.21	49.010	NUTTCIB	0.73	0.47					
91.40	12.298	GLOBOCAS	2.51	1.27	144.52	49.117	NUTTCIB	0.47	0.49					
91.61	12.336	GLOBOCAS	2.71	1.50	144.79	49.209	CIB	0.59	0.69					
93.21	12.621	GLOBOCAS	2.84	1.71	145.11	49.319	NUTT	0.25	0.24	0.11	0.029	MEAN	3.02	1.30
95.31	12.870	MEAN	2.70	1.38	145.31	49.387	NUTT	0.24	0.43	131.49	26.571	MEAN	2.30	1.14
95.61	12.889	GLOBOCAS	2.50	1.37	145.76	49.542	NUTTCIB	0.47	0.38	135.71	27.540	SUBGORID	2.05	1.09
95.81	12.902	GLOBOCAS	2.99	1.12	146.28	49.720	NUTTCIB	0.25	0.33	141.46	28.982	MEAN	2.09	0.96
96.01	12.915	GLOBOCAS	2.63	1.39	146.77	49.888	NUTTCIB	0.37	0.89	151.33	31.611	BULIMINA	2.05	0.47
96.21	12.928	GLOBOCAS	2.57	1.40	147.02	49.973	NUTTCIB	0.28	0.60	151.55	31.670	BULIMINA	2.05	0.47
96.41	12.940	GLOBOCAS	2.62	1.53	147.68	50.199	NUTTCIB	0.19	1.02	156.21	32.911	CIB	2.29	1.24
96.61	12.953	GLOBOCAS	2.66	1.28	147.93	50.285	NUTT	0.24	0.72	160.75	34.120	MEAN	2.01	1.17
96.81	12.966	GLOBOCAS	2.41	1.30	148.24	50.384	NUTT	-0.06	0.64	163.91	34.629	BJARV	2.35	1.47
97.11	12.985	GLOBOCAS	2.32	1.19	152.28	51.567	NUTT	0.16	0.97	168.89	34.735	MEAN	2.10	1.21
98.51	13.074	GLOBOCAS	2.47	1.48	164.69	54.786	NUTT	-0.08	0.57	170.73	34.774	MEAN	2.36	0.47
98.80	13.093	GLOBOCAS	2.49	1.33	199.51	57.517	NUTT	0.06	0.82	172.23	34.806	CIB	2.16	1.20
98.91	13.100	GLOBOCAS	2.42	1.55	199.91	57.545	NUTT	0.14	0.77	175.23	34.870	CIB	2.12	1.20
99.11	13.113	GLOBOCAS	2.57	1.50	202.11	57.699	MEAN	0.49	1.10	175.41	34.873	GLOBOCAS	2.03	1.33
99.31	13.125	GLOBOCAS	2.36	1.35	218.34	58.833	MEAN	0.57	2.15	176.73	34.901	CIBGLOB	1.79	1.15
99.81	13.157	GLOBOCAS	2.58	1.66	256.30	62.762	ORID	0.55	1.68	178.23	34.933	CIB	1.94	0.01
99.51	13.138	GLOBOCAS	2.34	1.65	258.10	62.959	NUTTGAV	0.55	1.02	179.62	34.963	ORID	1.87	1.13
103.00	13.361	GLOBOCAS	2.29	1.69	260.62	63.502	GAVELIN	0.45	1.02	181.50	35.003	MEAN	1.98	0.95
103.21	13.374	GLOBOCAS	2.58	1.68	261.10	63.577	NUTT	0.54	1.37	182.15	35.017	MEAN	2.12	0.94
103.61	13.400	MEAN	2.58	1.50	267.31	64.279	NUTT	1.00	1.41	183.41	35.043	MEAN	2.23	1.23
104.51	13.457	MEAN	2.74	1.75	267.51	64.307	ORID	0.26	1.65	183.63	35.048	MEAN	1.89	1.24
104.71	13.470	GLOBOCAS	2.58	1.67	267.72	64.343	MEAN	0.50	1.21	184.87	35.074	MEAN	1.82	1.34
105.11	13.495	MEAN	2.74	1.73	267.79	64.356	MEAN	0.27	1.11	185.13	35.080	MEAN	2.14	0

APPENDIX D
Isotopic Analyses of Planktonic Foraminifers from Sites 525–529

Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)									
Hole 525B																							
99.37	7.145	<i>Globigerina bulloides</i>	3.10	0.94	387.31	57.643	<i>Subbotina patagonica</i>	-0.40	1.76	214.71	35.753	<i>Globigerinatheka index</i>	0.24	2.80									
117.25	10.285	<i>Globigerinoides sacculifer</i>	0.53	2.66	390.09	57.902	<i>Morozovella marginodentata</i>	-0.41	1.78	214.71	35.753	<i>Catapsydrax</i> sp.	0.19	2.72									
117.25	10.285	<i>Globorotalia conoidea</i>	0.47	2.66	404.65	59.271	<i>Subbotina patagonica</i>	-0.73	2.93	122.81	22.817	<i>Globogaudrina dehiscens</i>	1.25	1.54									
139.18	12.645	<i>Globogaudrina dehiscens</i>	1.07	1.90	393.36	58.206	<i>Morozovella velascoensis</i>	-0.42	3.49	119.51	17.827	<i>Globigerina apertura</i>	0.79	2.01									
139.18	12.645	<i>Globigerina nepenthes</i>	0.87	2.48	393.36	58.206	<i>Subbotina patagonica</i>	-0.91	4.76														
139.41	12.734	<i>G. nepenthes</i>	0.83	2.48	403.35	59.144	<i>Morozovella velascoensis</i>	-0.27	2.41														
139.41	12.734	<i>Globogaudrina dehiscens</i>	0.85	1.81	403.35	59.144	<i>Subbotina patagonica</i>	-0.56	3.24														
139.61	12.801	<i>G. dehiscens</i>	0.94	1.84	404.59	59.265	<i>S. patagonica</i>	-0.64	3.08														
139.61	12.801	<i>Globigerina nepenthes</i>	0.51	2.47	404.59	59.265	<i>Morozovella velascoensis</i>	-0.95	4.33														
139.81	12.811	<i>G. nepenthes</i>	0.72	2.54	404.65	59.271	<i>M. pseudomediterranei</i>	-0.40	3.23														
139.81	12.811	<i>Globogaudrina dehiscens</i>	0.74	1.83	404.65	59.271	<i>M. velascoensis</i>	-0.87	4.65														
140.01	12.820	<i>Globigerina nepenthes</i>	0.75	2.59	408.91	59.687	<i>M. velascoensis</i>	-1.01	4.49														
140.01	12.820	<i>Globogaudrina dehiscens</i>	0.91	1.84	408.91	59.687	<i>Subbotina patagonica</i>	-0.66	3.12														
140.21	12.830	<i>Globigerina nepenthes</i>	0.47	2.55	411.91	59.981	<i>S. patagonica</i>	-0.49	3.63														
140.21	12.830	<i>Globogaudrina dehiscens</i>	0.50	1.90	411.91	59.981	<i>Morozovella velascoensis</i>	-0.83	4.94														
141.71	12.900	<i>G. dehiscens</i>	0.71	2.19	412.81	60.069	<i>Subbotina patagonica</i>	-0.42	3.50														
141.71	12.900	<i>G. dehiscens</i>	0.78	1.65	412.81	60.069	<i>Morozovella velascoensis</i>	-0.80	4.89														
174.61	15.628	<i>Globigerinoides sacculifer</i>	1.00	3.55	415.35	60.237	<i>Subbotina patagonica</i>	-0.44	3.51														
174.71	15.635	<i>Globogaudrina dehiscens</i>	1.38	3.02	415.35	60.237	<i>Morozovella velascoensis</i>	-0.95	4.88														
174.91	15.650	<i>Globigerinoides sacculifer</i>	0.94	3.44	422.01	60.800	<i>M. marginodentata</i>	-0.88	4.24														
175.31	15.680	<i>G. sacculifer</i>	1.05	3.52	422.01	60.800	<i>Subbotina patagonica</i>	-0.56	3.18														
175.51	15.695	<i>Globogaudrina dehiscens</i>	1.16	2.65	422.01	60.800	<i>Acarinina nitida</i>	-0.63	3.90														
175.51	15.695	<i>Globigerinoides sacculifer</i>	1.10	3.43	433.72	61.984	<i>Morozovella spp.</i>	-0.99	3.51														
175.81	15.717	<i>G. sacculifer</i>	0.75	2.98	Hole 525A (cont.)																		
176.01	15.732	<i>G. sacculifer</i>	0.68	3.08	Hole 526A (cont.)																		
176.21	15.746	<i>G. sacculifer</i>	0.63	3.32	Hole 526A																		
176.41	15.761	<i>G. sacculifer</i>	0.48	3.08	30.80	4.033	<i>Globigerinoides ruber</i>	0.13	1.35	258.10	62.959	<i>Planorotalites ehrenbergi</i>	-0.15	1.74									
176.41	15.761	<i>G. sacculifer</i>	0.77	2.48	34.55	4.419	<i>G. ruber</i>	0.32	1.40	258.10	62.959	<i>Planorotalites compressa</i>	-0.14	1.81									
176.41	15.761	<i>Globogaudrina altissima</i>	0.30	3.06	39.52	4.673	<i>Globigerina nepenthes</i>	0.41	1.50	261.10	63.577	<i>M. uncinata</i>	-0.75	2.94									
188.71	16.671	<i>Globigerinoides sacculifer</i>	0.85	3.00	44.42	4.882	<i>G. nepenthes</i>	0.18	1.58	267.31	64.279	<i>Planorotalites compressa</i>	-0.13	1.90									
189.51	16.731	<i>Globigerinoides spp.</i>	0.76	3.64	48.11	5.154	<i>G. nepenthes</i>	0.29	1.65	267.51	64.307	<i>P. compressa</i>	-0.24	1.94									
191.41	16.871	<i>G. spp.</i>	0.71	3.38	52.61	5.916	<i>G. nepenthes</i>	0.41	1.60	267.72	64.343	<i>P. compressa</i>	-0.20	1.84									
191.61	16.886	<i>G. spp.</i>	0.52	3.14	58.11	6.847	<i>Globigerinoides mitra</i>	0.48	1.54	267.92	64.378	<i>P. compressa</i>	-0.18	1.90									
194.21	17.165	<i>G. spp.</i>	0.63	3.32	63.41	7.745	<i>Globigerinoides sacculifer</i>	0.65	2.44	271.92	65.068	<i>P. compressa</i>	0.45	2.25									
Hole 525A																							
279.10	46.600	<i>Morozovella spp.</i>	-0.11	3.00	63.61	7.779	<i>Globigerinoides sacculifer</i>	0.85	2.18	279.91	66.447	Mixed planktonics, 63–75 μm	-0.06	1.54									
279.63	46.733	<i>M. aragonensis</i>	-0.19	2.81	63.81	7.813	<i>G. sacculifer</i>	0.60	2.43	280.10	66.464	<i>Planoglobulina spp.</i>	-0.22	2.99									
281.10	47.101	<i>M. aragonensis</i>	-0.35	3.26	63.81	7.813	<i>G. seigle</i>	0.86	1.24	280.10	66.464	<i>Abathomphalus mayeroensis</i>	-0.41	2.36									
282.60	47.477	<i>M. aragonensis</i>	-0.45	3.54	63.81	7.813	<i>Globigerina nepenthes</i>	1.12	2.16	280.49	66.481	<i>Abathomphalus mayeroensis</i>	-0.53	2.07									
284.10	47.860	<i>M. aragonensis</i>	-0.23	3.03	64.01	7.846	<i>G. nepenthes</i>	1.16	2.20	280.49	66.481	<i>Planoglobulina spp.</i>	-0.49	3.16									
287.10	48.710	<i>M. aragonensis</i>	-0.07	3.12	64.21	7.880	<i>G. nepenthes</i>	1.06	2.23	280.68	66.489	<i>Abathomphalus mayeroensis</i>	-0.26	2.12									
288.60	49.135	<i>M. subbotinæ</i>	0.31	1.75	66.31	8.236	<i>Globigerinoides sacculifer</i>	0.42	2.48	280.68	66.489	<i>Planoglobulina spp.</i>	-0.27	2.93									
288.60	49.135	<i>M. lenticularis</i>	-0.13	2.72	66.51	8.270	<i>G. sacculifer</i>	0.71	2.68	280.85	66.496	<i>Abathomphalus mayeroensis</i>	-0.14	2.14									
289.10	49.277	<i>M. aragonensis</i>	0.03	2.66	66.51	8.270	<i>G. ruber</i>	0.88	2.30	280.85	66.496	<i>Planoglobulina spp.</i>	-0.15	3.33									
290.51	49.677	<i>M. aragonensis</i>	-0.19	3.04	66.51	8.270	<i>G. sacculifer</i>	0.48	2.11	281.19	66.510	<i>Abathomphalus mayeroensis</i>	-0.09	2.11									
292.01	50.050	<i>M. spp.</i>	-0.15	2.42	66.51	8.270	<i>Globigerina nepenthes</i>	0.73	2.02	281.19	66.510	<i>Planoglobulina spp.</i>	-0.21	3.32									
293.51	50.256	<i>M. spp.</i>	-0.39	2.34	66.71	8.304	<i>Globigerinoides sacculifer</i>	0.82	2.42	281.40	66.519	<i>Abathomphalus mayeroensis</i>	-0.48	2.99									
295.01	50.462	<i>M. spp.</i>	-0.40	3.18	75.51	9.814	<i>G. sacculifer</i>	0.40	2.25	281.40	66.519	<i>P. spp.</i>	-0.99	3.10									
299.01	50.875	<i>M. aragonensis</i>	-0.51	2.97	75.51	9.814	<i>Globigerina nepenthes</i>	0.55	1.91	281.40	66.519	<i>Abathomphalus mayeroensis</i>	-0.17	2.08									
302.39	51.477	<i>M. spp.</i>	-0.68	3.14	78.41	10.313	<i>G. obesa</i>	1.23	1.65	281.59	66.527	<i>Planoglobulina spp.</i>	-0.26	2.80									
322.79	53.502	<i>M. spp.</i>	-0.96	3.34	78.41	10.313	<i>G. nepenthes</i>	0.81	2.30	282.00	66.545	<i>P. spp.</i>	-0.20	3.00									
337.85	54.604	<i>M. aragonensis</i>	-1.21	2.53	78.81	10.382	<i>G. nepenthes</i>	0.62	1.71	282.20	66.553	<i>Abathomphalus mayeroensis</i>	-0.46	1.70									
358.19	55.808	<i>M. acuta</i>	-0.79	2.09	80.01	10.588	<i>G. obesa</i>	1.55	1.63	282.40	66.562	<i>Planoglobulina spp.</i>	-0.57	2.95									
358.19	55.808	<i>Subbotina trilocularis</i>	-0.65	1.24	80.01	10.588	<i>G. nepenthes</i>	0.79	2.04	282.70	66.574	<i>P. spp.</i>	-0.57	2.58									
358.29	55.811	<i>Morozovella acuta</i>	-1.02	2.28	83.81	11.141	<i>G. nepenthes</i>	0.92	2.11	282.70	66.574	<i>Abathomphalus mayeroensis</i>	-0.58	2.06									
358.39	55.814	<i>Globigerina acuta</i>	-0.82	1.10	83.81	11.141	<i>Globigerina conoidea</i>	1.27	1.78	283.14	66.593	<i>Planoglobulina spp.</i>	-0.22	2.84									
358.39	55.814	<i>M. acuta</i>	-1.13	2.16	84.21	11.199	<i>Globigerina nepenthes</i>	0.86	1.92	Hole 528A													
358.49	55.818	<i>Globigerina acuta</i>	-0.63	2.13	97.11	12.985	<i>G. dehiscens</i>	0.41	1.92	8.87	1.002	<i>Globigerinoides ruber</i>	0.58	1.53									
358.49	55.818	<i>Chiloguembelina wilcoxensis</i>	-0.54	1.00	105.51	13.521	<i>Globogaudrina dehiscens</i>	1.05	1.76	8.95	1.011	<i>G. ruber</i>	0.33	1.16									
358.49	55.818	<i>Morozovella subbotinæ</i>	-1.13	2.28	105.51	13.521	<i>Globigerina nepenthes</i>	0.65	2.24	9.05	1.022	<i>Globorotalia inflata</i>	1.74	1.06									
358.49	55.818	<i>Chiloguembelina wilcoxensis</i>	-0.47	1.03	110.81	14.579	<i>Globigerinoides sacculifer</i>	0.79	2.49	9.05	1.022	<i>Globigerinoides ruber</i>	0.45	1.27									
358.49	55.834	<i>Morozovella subbotinæ</i>	-1.05	2.32	110.81	14.579	<i>G. subquadratus</i>	0.65	2.26	9.05	1.022	<i>G. ruber</i>	0.35	0.95									
358.49	55.834	<i>M. acuta</i>	-0.45	2.07	110.81	14.579	<i>Globigerina nepenthes</i>	0.94	2.29	10.05	1.135	<i>G. ruber</i>	0.49	1.10									
359.09	55.838	<i>Chiloguembelina wilcoxensis</i>	-0.36	0.91	157.53	23.546	<i>G. dehiscens</i>	0.88	1.52	10.15	1.146	<i>G. ruber</i>	0.88	1.41									
359.09	55.838	<i>Morozovella subbotinæ</i>	-0.85	2.11	160.11	23.609	<i>Catapsydrax sp.</i>	1.09	1.48	10.25	1.158	<i>G. ruber</i>	0.53	1.45									
359.49	55.851	<i>Chiloguembelina wilcoxensis</i>	-0.27	0.75	160.11	23.609	<i>G. alispis</i>	0.96	2.03	10.35	1.169	<i>G. ruber</i>	0.39	1.61									
359.49	55.851	<i>M. subbotinæ</i>	-0.82	2.12	160.11																		

Appendix D. (Continued).

Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)	Sub-bottom Depth (m)	Age (m.y.)	Species	$\delta^{18}\text{O}$ (‰)	$\delta^{13}\text{C}$ (‰)
Hole 528														
228.29	37.285	<i>Globigerinatheka</i> spp.	0.02	2.58	141.46	28.982	<i>Catapsydrax</i> sp.	1.69	1.64	201.53	37.712	<i>G. cerroazulensis</i>	0.27	1.80
252.00	47.302	<i>Morozovella aragonensis</i>	-0.33	3.30	151.33	31.611	<i>C. sp.</i>	1.64	1.51	201.53	37.712	<i>Catapsydrax</i> sp.	0.41	1.78
256.61	48.632	<i>M. spp.</i>	-0.44	3.20	151.33	31.611	<i>Turborotalia</i> spp.	1.38	1.71	202.58	38.202	<i>Globigerina cerroazulensis</i>	0.57	1.82
312.07	56.869	<i>M. subbotinae</i>	-0.86	2.52	156.21	32.911	<i>Catapsydrax</i> sp.	1.33	1.86	202.58	38.202	<i>Catapsydrax</i> sp.	0.77	1.68
312.07	56.869	<i>Subbotina patagonica</i>	-0.45	1.56	156.21	32.911	<i>Globorotalia siakensis</i>	1.34	1.86	205.20	39.424	<i>Globigerinatheka index</i>	0.59	2.26
312.99	57.464	<i>S. patagonica</i>	-0.13	1.66	168.89	34.735	<i>Globigerina pseudoampliapertura</i>	1.35	1.96	205.20	39.424	<i>Globigerina cerroazulensis</i>	0.60	1.91
312.99	57.464	<i>Morozovella rex</i>	-0.68	2.72	168.89	34.735	<i>Catapsydrax</i> sp.	1.13	1.91	205.20	39.424	<i>Catapsydrax echinatus</i>	0.15	2.93
313.56	57.623	<i>M. velascoensis</i>	-1.06	3.65	175.41	34.873	<i>Globigerina pseudoampliapertura</i>	1.25	1.86	205.20	39.424	<i>C. sp.</i>	0.60	1.89
313.56	57.623	<i>Subbotina patagonica</i>	-0.26	2.21	175.41	34.873	<i>Turborotalia</i> spp.	1.41	1.80	205.20	39.424	<i>Turborotalia increbescens</i>	0.54	2.14
313.82	57.640	<i>Morozovella acuta</i>	-0.82	3.87	175.41	34.873	<i>Globigerina euggeria</i>	1.34	2.12	205.20	39.424	<i>Globigerina winkleri</i>	0.64	2.04
313.82	57.640	<i>Subbotina patagonica</i>	-0.32	2.22	175.41	34.873	<i>Catapsydrax</i> sp.	1.26	1.80	207.35	40.424	<i>Globigerinatheka index</i>	0.60	2.06
314.21	57.666	<i>Morozovella subbotinae</i>	-0.77	3.42	176.73	34.901	<i>C. sp.</i>	1.00	1.60	207.35	40.428	<i>Globigerina cerroazulensis</i>	0.54	1.85
314.21	57.666	<i>Subbotina patagonica</i>	-0.24	2.17	183.41	35.043	<i>Globigerina cerroazulensis</i>	1.41	1.90	207.35	40.428	<i>G. copulenta</i>	0.65	1.86
315.99	57.782	<i>S. patagonica</i>	-0.38	2.92	183.41	35.043	<i>Catapsydrax</i> sp.	1.19	1.63	207.35	40.428	<i>Catapsydrax</i> sp.	0.71	1.57
315.99	57.782	<i>Morozovella rex</i>	-0.80	4.22	183.63	35.048	<i>C. unicavus</i>	1.30	1.76	207.35	40.428	<i>Globigerinatheka subconglobata</i>	0.40	2.05
					193.21	36.037	<i>C. sp.</i>	1.15	1.92	207.35	40.428	<i>Globigerina winkleri</i>	0.57	2.01
					198.95	36.790	<i>C. sp.</i>	1.33	2.08	220.59	46.605	<i>Acarinina</i> sp.	0.62	2.86
					199.20	36.823	<i>Globigerina pseudoeoecaena</i>	1.17	2.25	220.59	46.605	<i>Globigerina cerroazulensis</i>	0.57	1.96
37.77	12.079	<i>Globigerinoides ruber</i>	0.47	1.11	199.20	36.823	<i>Catapsydrax</i> sp.	1.21	2.10	222.50	47.497	<i>Catapsydrax unicavus</i>	0.94	1.60
121.81	24.348	<i>G. tripartita</i>	0.74	2.04	200.04	37.017	<i>Globigerina cerroazulensis</i>	0.28	1.68	222.50	47.497	<i>Globigerina cerroazulensis</i>	0.46	1.82
121.81	24.348	<i>Globoquadrina praedehiscens</i>	1.30	1.78	200.13	37.059	<i>G. cerroazulensis</i>	0.46	1.87	222.50	47.497	<i>Globigerinatheka mexicana</i>	0.40	2.37
121.81	24.348	<i>Catapsydrax</i> sp.	1.43	1.83	200.13	37.059	<i>Turborotalia increbescens</i>	0.37	2.07	222.50	47.497	<i>Globigerina winkleri</i>	0.65	2.11
121.81	24.348	<i>Globoquadrina</i> spp.	1.40	1.41	200.13	37.059	<i>Globigerinatheka index</i>	0.52	2.75	222.50	47.497	<i>Globigerinatheka subconglobata</i>	0.46	2.29
121.81	24.348	<i>Globigerina ouachitensis</i>	1.39	1.54	200.13	37.059	<i>Globigerina winkleri</i>	0.66	2.09	222.50	47.497	<i>Catapsydrax</i> sp.	0.90	1.50
121.81	24.348	<i>G. sellii</i>	1.47	1.83	200.13	37.059	<i>Catapsydrax</i> sp.	0.52	1.84	238.11	52.201	<i>Globorotalia bullbrookii</i>	-0.63	1.34
121.81	24.348	<i>Globoquadrina transdehiscens</i>	1.49	1.83	200.78	37.362	<i>Hantkenina</i> spp.	0.30	2.22	238.11	52.201	<i>G. pseudotiplensis</i>	-0.57	1.62
131.49	26.571	<i>Globigerina angulisuturalis</i>	1.08	1.66	200.78	37.362	<i>Globigerinatheka index</i>	0.21	2.73	238.11	52.201	<i>Morozovella aragonensis</i>	-0.83	2.23
131.49	26.571	<i>Catapsydrax</i> sp.	1.48	1.46	200.78	37.362	<i>Catapsydrax</i> sp.	0.59	1.95	238.11	52.201	<i>Chiloguembelina wilcoxensis</i>	-0.63	0.70
136.31	27.678	<i>Globigerina tripartita</i>	1.44	1.77	200.78	37.362	<i>Globigerina cerroazulensis</i>	0.37	2.17	238.11	52.201	<i>Morozovella soldadoensis</i>	-0.83	1.62
136.31	27.678	<i>G. globularis</i>	1.23	1.46	201.39	37.647	<i>Catapsydrax</i> sp.	0.62	1.90	238.11	52.201	<i>M. subbotinae</i>	-0.24	1.04
136.31	27.678	<i>G. angulisuturalis</i>	1.03	1.64	201.39	37.647	<i>Globigerinatheka index</i>	0.37	2.47	245.68	54.545	<i>M. spp.</i>	-1.06	2.40
136.31	27.678	<i>Catapsydrax unicavus</i>	1.16	1.38	201.39	37.647	<i>Catapsydrax unicavus</i>	0.72	1.70	268.84	57.639	<i>M. spp.</i>	-0.80	2.81
136.31	27.678	<i>Globigerina gortanii</i>	1.21	1.47	201.53	37.712	<i>Globigerina gortanii</i>	0.97	2.07					

Note: Ages are estimated as described in Shackleton et al. (this volume).