21. STABLE ISOTOPE AND CALCIUM CARBONATE RECORDS FROM HYDRAULIC PISTON CORED HOLE 574A: HIGH-RESOLUTION RECORDS FROM THE MIDDLE MIOCENE[1]

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ABSTRACT

Detailed stable isotopic and calcium carbonate records (with a sampling resolution of 3000 yr.) from the middle Miocene section of hydraulic piston corer (HPC) Hole 574A provide a sequence that records the major shift in the oxygen isotopic composition of the world's oceans that occurred at about 14 Ma. The data suggest that this transition was rapid and spans about 30,000 yr. of sediment deposition. In intervals before and after the shift, the mean $\delta^{18}O$ values are characterized by a constant mean with a high degree of variability. The degree of variability in both the $\delta^{18}O$ and $\delta^{13}C$ records is comparable to that observed for the Pliocene and earliest Pleistocene and does not show a significant change before or after the major shift in the $\delta^{18}O$ record. Whereas the oxygen isotopic record is characterized by relatively stable mean values before and after the middle Miocene event, the $\delta^{13}C$ record shows a number of significant offsets in the mean value separated by intervals of high-frequency variations.

Time and frequency domain analysis of all records from Hole 574A indicate that the frequency components shown to be related to orbital changes in the Pleistocene record are also present in the middle Miocene. The high variability observed in the Site 574 isotopic records places important constraints on models describing the role of formation of the Antarctic ice sheet during the middle Miocene climatic transitions. Thus, HPC Hole 574A provides a valuable sequence for detailed study of climatic variability during an important time in the Earth's history, although we cannot provide a definitive explanation of the major oxygen isotopic event of the middle Miocene.

INTRODUCTION

Site 574 was drilled at a location that was within the equatorial divergence zone in the early and middle Miocene. As would be expected in this oceanographic setting, sedimentation rates during the middle Miocene at Site 574 were relatively high (30 to 35 m/m.y.). In Hole 574A the hydraulic piston corer (HPC) was used to recover sediments to 186 m sub-bottom depth to provide a high-quality sediment section spanning the last 16.5 m.y. To make a detailed examination of the oceanographic and climatic variability during the Miocene, selected intervals were sampled at 10-cm spacing. In selecting the intervals for detailed analysis, the following criteria were considered: (1) high sedimentation rates so that records with resolution better than 5000 yr. could be obtained; (2) shipboard evaluation of carbonate fossil preservation indicating that adequate numbers of foraminiferal tests would be available for stable isotopic analyses; (3) intervals that spanned major paleoclimatic or paleoceanographic events of particular importance; and (4) at least 15 m of good continuous recovery to provide a sequence long enough for statistical analysis.

In Hole 574A three intervals in the middle Miocene section were sampled at 10-cm intervals providing a resolution of 3000 to 5000 yr.: 100–115 m, 140–160 m, and 168–186 m sub-bottom. The latter two intervals span the foraminiferal biostratigraphic Zones N9 and N10. A major shift in the mean oxygen isotopic composition of the ocean, which has been associated with the onset of major glaciation in Antarctica, occurred during this interval (Woodruff et al., 1981; Shackleton and Kennett, 1975). Detailed analysis of the sections from Hole 574A provides high-resolution records of the variability in the stable isotopic composition and deposition of calcium carbonate in the deep central equatorial Pacific.

METHODS

The analytical methods used in stable isotope studies of foraminifers from deep-sea sediments are essentially standardized. Samples were disaggregated by shaking them on a commercial orbital shaker in distilled water and were then washed through a 150-μm sieve. Although both the coarse fraction and the dried fine residue were weighed, we do not present the data here because the coarse fraction in these sediments is not invariably dominated by foraminifers. Thus, the percentage of coarse material may not be a useful indication of the extent of dissolution. Benthic foraminifers for isotopic analysis were picked from the coarse fraction. In order to minimize the effect of sample selection on the variance of the isotope record, we aimed to pick similar species of similar size over long intervals of the core. The majority of the analyses are of *Planulina (= Cibicidoides) wuellerstorfi*, and many of the remainder are *Cibicidoides kullenbergi* and similar forms. The number of individuals analyzed was controlled almost entirely by the number present in the samples available; the average number is about six. Occasionally other species were analyzed, chiefly to increase the number of comparisons available. In particular *Oridorsalis* sp. was picked in a long run of samples, and *Globocassidulina subglobosa, Gyroidina* sp., and *Cibicidoides havanensis* were also picked occasionally.

The picked specimens were crushed and cleaned ultrasonically to remove adhering fine-grained material before being roasted *in vacuo* at about 410°C for 30 min. to remove possible organic contaminants. Carbon dioxide was released by the action of 100% orthophosphoric acid in the extraction line shown by Shackleton et al. (1984) and analyzed in a VG Micromass 903 mass spectrometer. Analytical precision is about ±0.07‰. The analyses shown in Table 1 have been normalized for genetically controlled departure from isotopic equilibrium using the adjustment factors given in the footnote to Table 1.

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[1] Mayer, L., Theyer, F., et al., *Init. Repts. DSDP*, 85: Washington (U.S. Govt. Printing Office).

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Table 1. Stable isotopic data from HPC Hole 574A.

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574-A-12-3, 80	102.50	*Oridorsalis* sp.	2.88	0.91
574A-12-3, 100	102.70	*Oridorsalis* sp.	2.66	1.28
574A-12-3, 100	102.70	*C. kullenbergi*	2.96	1.02
574A-12-3, 120	102.90	*G. subglobosa*	2.82	0.97
574A-12-3, 140	103.10	*G. subglobosa*	2.70	0.66
574A-12-3, 140	103.10	*C. kullenbergi*	2.87	0.81
574A-12-4, 0	103.20	*Oridorsalis* sp.	2.92	0.67
574A-12-4, 0	103.20	*C. kullenbergi*	3.00	1.14
574A-12-4, 20	103.40	*Oridorsalis* sp.	2.91	0.68
574A-12-4, 20	103.40	*C. kullenbergi*	2.91	1.03
574A-12-4, 40	103.60	*C. kullenbergi*	2.67	1.02
574A-12-4, 60	103.80	*Oridorsalis* sp.	2.70	1.03
574A-12-4, 60	103.80	*C. kullenbergi*	2.75	1.05
574A-12-4, 80	104.00	*Oridorsalis* sp.	2.93	0.95
574A-12-4, 80	104.00	*C. kullenbergi*	3.02	0.94
574A-12-4, 100	104.20	*Oridorsalis* sp.	3.21	0.74
574A-12-4, 100	104.20	*C. kullenbergi*	3.06	0.86
574A-12-4, 120	104.40	*Oridorsalis* sp.	3.05	0.70
574A-12-4, 120	104.40	*C. kullenbergi*	3.20	0.65
574A-12-4, 140	104.60	*Oridorsalis* sp.	2.96	0.75
574A-12-4, 140	104.60	*C. kullenbergi*	2.73	0.97
574A-12-5, 0	104.70	*C. kullenbergi*	3.02	0.67
574A-12-5, 0	104.70	*Oridorsalis* sp.	2.91	0.65
574A-12-5, 20	104.90	*C. kullenbergi*	2.73	1.06
574A-12-5, 40	105.10	*C. kullenbergi*	2.86	0.98
574A-12-5, 60	105.30	*C. kullenbergi*	2.70	0.78
574A-12-5, 80	105.50	*C. kullenbergi*	2.97	0.70
574A-12-5, 100	105.70	*Oridorsalis* sp.	3.03	0.74
574A-12-5, 120	105.90	*C. kullenbergi*	2.97	0.75
574A-12-5, 120	105.90	*Oridorsalis* sp.	2.85	0.85
574A-12-5, 140	106.10	*Oridorsalis* sp.	2.79	0.69
574A-12-6, 0	106.20	*Oridorsalis* sp.	2.69	0.84
574A-12-6, 0	106.20	*C. kullenbergi*	2.73	0.99
574A-12-6, 20	106.40	*Oridorsalis* sp.	2.89	0.58
574A-12-6, 20	106.40	*C. kullenbergi*	2.84	1.07
574A-12-6, 40	106.60	*Oridorsalis* sp.	2.69	0.64
574A-12-6, 40	106.60	*Oridorsalis* sp.	2.94	0.67
574A-12-6, 40	106.60	*Oridorsalis* sp.	2.47	0.72
574A-12-6, 60	106.80	*Oridorsalis* sp.	2.81	0.89
574A-12-6, 60	106.80	*Gyroidina* sp.	2.71	0.04
574A-12-6, 60	106.80	*C. kullenbergi*	2.80	0.97
574A-12-6, 80	107.00	*P. wuellerstorfi**	2.91	0.79
574A-12-6, 80	107.00	*Oridorsalis* sp.	2.83	0.51
574A-12-6, 100	107.20	*P. wuellerstorfi*	3.13	0.88
574A-12-6, 100	107.20	*C. kullenbergi*	2.84	0.87
574A-12-6, 120	107.40	*Oridorsalis* sp.	2.90	1.31
574A-12-6, 120	107.40	*P. wuellerstorfi**	2.54	0.87
574A-12-6, 140	107.60	*Oridorsalis* sp.	2.82	0.54
574A-12-6, 140	107.60	*P. wuellerstorfi**	3.12	0.81
574A-12-7, 0	107.70	*C. kullenbergi*	2.70	0.65
574A-12-7, 0	107.70	*P. wuellerstorfi**	2.75	0.80
574A-12-7, 20	107.90	*C. kullenbergi*	2.86	0.80
574A-12-7, 20	107.90	*P. wuellerstorfi*	2.77	0.93
574A-13-1, 100	109.20	*C. kullenbergi*	2.66	0.79
574A-13-1, 120	109.40	*C. kullenbergi*	2.50	0.48
574A-13-1, 140	109.60	*C. kullenbergi*	2.38	0.34
574A-13-2, 0	109.70	*P. wuellerstorfi*	2.93	0.64
574A-13-2, 20	109.90	*C. kullenbergi*	2.74	0.41
574A-13-2, 20	109.90	*P. wuellerstorfi*	2.94	0.73
574A-13-2, 40	110.10	*C. kullenbergi*	2.08	0.51
574A-13-2, 60	110.30	*Oridorsalis* sp.	2.36	0.74
574A-13-2, 60	110.30	*P. wuellerstorfi*	2.62	0.57
574A-13-2, 80	110.50	*C. kullenbergi*	2.85	0.50
574A-13-2, 100	110.70	*G. subglobosa*	2.90	0.48
574A-13-2, 100	110.70	*C. kullenbergi*	2.79	0.67
574A-13-2, 120	110.90	*C. kullenbergi*	2.78	0.75
574A-13-2, 140	111.10	*C. kullenbergi*	2.66	0.56
574A-13-2, 140	111.10	*Oridorsalis* sp.	2.71	0.53
574A-13-3, 0	111.20	*Oridorsalis* sp.	2.96	0.63
574A-13-3, 0	111.20	*C. kullenbergi*	2.97	0.61
574A-13-3, 20	111.40	*Oridorsalis* sp.	2.77	1.20
574A-13-3, 40	111.60	*Oridorsalis* sp.	2.79	0.64
574A-13-3, 40	111.60	*C. kullenbergi*	2.62	0.67
574A-13-3, 60	111.80	*C. kullenbergi*	2.57	0.61
574A-13-3, 80	112.00	*C. kullenbergi*	2.98	0.78
574A-13-3, 80	112.00	*Oridorsalis* sp.	2.81	0.72

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-13-3, 100	112.20	*C. kullenbergi*	2.83	0.89
574A-13-3, 100	112.20	*C. kullenbergi*	2.75	0.80
574A-13-3, 120	112.40	*C. kullenbergi*	2.38	0.69
574A-13-3, 140	112.60	*C. kullenbergi*	2.70	0.49
574A-13-3, 140	112.60	*C. kullenbergi*	2.70	0.72
574A-13-4, 0	112.70	*Oridorsalis* sp.	2.93	0.36
574A-13-4, 0	112.70	*C. kullenbergi*	3.00	0.80
574A-13-4, 20	112.90	*C. kullenbergi*	2.53	0.80
574A-14-1, 0	113.10	*Oridorsalis* sp.	2.78	0.57
574A-14-1, 0	113.10	*C. kullenbergi*	2.88	0.90
574A-14-1, 20	113.30	*C. kullenbergi*	2.81	0.87
574A-14-1, 40	113.50	*C. kullenbergi*	2.78	0.78
574A-14-1, 60	113.70	*C. kullenbergi*	2.75	0.92
574A-14-1, 80	113.90	*C. kullenbergi*	2.66	0.84
574A-14-1, 100	114.10	*C. kullenbergi*	2.72	0.82
574A-14-1, 120	114.30	*C. kullenbergi*	2.70	0.87
574A-14-1, 140	114.50	*C. kullenbergi*	2.80	0.80
574A-14-2, 0	114.60	*C. kullenbergi*	2.69	0.87
574A-14-2, 17	114.77	*C. kullenbergi*	2.73	0.89
574A-14-2, 40	115.00	*C. kullenbergi*	2.72	0.93
574A-14-2, 60	115.20	*C. havanensis*	2.83	0.56
574A-14-2, 60	115.20	*C. kullenbergi*	2.87	0.95
574A-14-2, 80	115.40	*C. kullenbergi*	2.73	0.88
574A-19-1, 1	141.41	*C. kullenbergi*	2.60	1.27
574A-19-1, 11	141.51	*C. kullenbergi*	2.52	1.15
574A-19-1, 21	141.61	*C. kullenbergi*	2.36	1.04
574A-19-1, 31	141.71	*C. kullenbergi*	2.37	0.84
574A-19-1, 41	141.81	*C. kullenbergi*	2.64	0.82
574A-19-1, 51	141.91	*C. kullenbergi*	2.83	1.04
574A-19-4, 11	146.01	*C. kullenbergi*	2.54	1.13
574A-19-1, 61	142.01	*C. kullenbergi*	2.63	1.17
574A-19-4, 21	146.11	*C. kullenbergi*	2.21	1.26
574A-19-1, 71	142.11	*C. kullenbergi*	2.79	1.20
574A-19-1, 81	142.21	*C. kullenbergi*	2.85	1.36
574A-19-1, 91	142.31	*C. kullenbergi*	2.79	1.23
574A-19-1, 101	142.41	*C. kullenbergi*	2.75	1.23
574A-19-1, 108	142.48	*C. kullenbergi*	2.75	1.28
574A-19-1, 112	142.52	*Oridorsalis* sp.	2.51	1.37
574A-19-1, 121	142.61	*C. kullenbergi*	2.45	1.04
574A-19-1, 131	142.71	*C. kullenbergi*	2.50	1.18
574A-19-1, 141	142.81	*C. kullenbergi*	2.59	1.06
574A-19-2, 1	142.91	*C. kullenbergi*	2.38	0.98
574A-19-2, 11	143.01	*C. kullenbergi*	2.41	1.05
574A-19-2, 21	143.11	*C. kullenbergi*	2.39	0.84
574A-19-2, 31	143.21	*C. kullenbergi*	2.63	1.20
574A-19-2, 41	143.31	*C. kullenbergi*	2.61	1.12
574A-19-2, 51	143.41	*C. kullenbergi*	2.68	1.20
574A-19-2, 61	143.51	*C. kullenbergi*	2.65	1.17
574A-19-2, 71	143.61	*C. kullenbergi*	2.64	1.14
574A-19-2, 81	143.71	*C. kullenbergi*	2.65	1.14
574A-19-2, 91	143.81	*C. kullenbergi*	2.67	0.81
574A-19-2, 101	143.91	*C. kullenbergi*	2.54	1.08
574A-19-2, 111	144.01	*C. kullenbergi*	2.63	0.89
574A-19-2, 121	144.11	*C. kullenbergi*	2.62	1.15
574A-19-2, 131	144.21	*C. kullenbergi*	2.41	1.12
574A-19-2, 141	144.31	*C. kullenbergi*	2.44	1.24
574A-19-3, 1	144.41	*C. havanensis*	2.37	1.21
574A-19-3, 1	144.41	*P. wuellerstorfi*	2.42	1.27
574A-19-3, 11	144.51	*C. kullenbergi*	2.32	1.16
574A-19-3, 31	144.71	*C. kullenbergi*	2.58	1.27
574A-19-3, 41	144.81	*C. kullenbergi*	2.37	1.17
574A-19-3, 61	145.01	*C. kullenbergi*	2.41	1.22
574A-19-3, 61	145.01	*P. wuellerstorfi*	2.46	1.33
574A-19-3, 71	145.11	*C. kullenbergi*	2.25	1.08
574A-19-3, 81	145.21	*C. kullenbergi*	2.47	1.17
574A-19-3, 91	145.31	*C. kullenbergi*	2.47	1.24
574A-19-3, 101	145.41	*C. kullenbergi*	2.60	1.29
574A-19-3, 111	145.51	*C. kullenbergi*	2.56	0.97
574A-19-3, 111	145.51	*C. kullenbergi*	2.50	1.26
574A-19-3, 121	145.61	*C. kullenbergi*	2.60	1.18
574A-19-3, 131	145.71	*C. kullenbergi*	2.58	1.15
574A-19-3, 141	145.81	*P. wuellerstorfi*	2.63	1.11
574A-19-4, 1	145.91	*C. kullenbergi*	2.62	1.14
574A-19-4, 31	146.21	*P. wuellerstorfi*	2.41	1.13
574A-19-4, 41	146.31	*P. wuellerstorfi*	2.20	0.93
574A-19-4, 51	146.41	*C. kullenbergi*	2.25	0.77

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-19-4, 61	146.51	*P. wuellerstorfi*	2.40	1.09
574A-19-4, 61	146.51	*C. kullenbergi*	2.12	0.60
574A-19-4, 71	146.61	*P. wuellerstorfi*	2.54	1.18
574A-19-4, 71	146.61	*C. kullenbergi*	1.97	0.84
574A-19-4, 81	146.71	*P. wuellerstorfi*	2.66	1.31
574A-19-4, 91	146.81	*P. wuellerstorfi*	2.48	1.27
574A-19-4, 101	146.91	*P. wuellerstorfi*	2.43	1.13
574A-19-4, 111	147.01	*P. wuellerstorfi*	2.96	1.38
574A-19-4, 121	147.11	*C. kullenbergi*	2.55	1.35
574A-19-4, 131	147.21	*C. kullenbergi*	2.59	1.28
574A-19-4, 141	147.31	*P. wuellerstorfi*	2.52	1.16
574A-19-5, 1	147.41	*P. wuellerstorfi*	2.77	1.29
574A-19-5, 11	147.51	*P. wuellerstorfi*	2.84	1.32
574A-19-5, 21	147.61	*P. wuellerstorfi*	2.70	1.18
574A-19-5, 31	147.71	*P. wuellerstorfi*	2.56	1.31
574A-19-5, 41	147.81	*P. wuellerstorfi*	2.54	1.32
574A-19-5, 51	147.91	*P. wuellerstorfi*	2.64	1.38
574A-19-5, 61	148.01	*P. wuellerstorfi*	2.46	1.14
574A-19-5, 71	148.11	*P. wuellerstorfi*	2.39	1.18
574A-19-5, 81	148.21	*P. wuellerstorfi*	2.40	1.10
574A-19-5, 91	148.31	*P. wuellerstorfi*	2.24	1.02
574A-19-5, 101	148.41	*P. wuellerstorfi*	2.23	0.95
574A-19-5, 111	148.51	*C. kullenbergi*	2.29	0.89
574A-19-5, 121	148.61	*C. kullenbergi*	2.42	0.96
574A-19-5, 131	148.71	*C. kullenbergi*	2.09	1.19
574A-19-5, 141	148.81	*C. kullenbergi*	2.12	0.98
574A-19-6, 1	148.91	*C. kullenbergi*	2.54	1.11
574A-19-6, 1	148.91	*C. havanensis*	2.43	0.64
574A-19-6, 11	149.01	*C. kullenbergi*	2.55	1.32
574A-19-6, 21	149.11	*C. kullenbergi*	2.44	1.47
574A-19-6, 31	149.21	*C. kullenbergi*	2.49	1.43
574A-19-6, 41	149.31	*C. kullenbergi*	2.54	1.34
574A-19-6, 51	149.41	*C. kullenbergi*	2.48	1.30
574A-19-6, 61	149.51	*C. kullenbergi*	2.40	1.29
574A-19-6, 71	149.61	*C. kullenbergi*	2.23	1.36
574A-19-6, 81	149.71	*C. kullenbergi*	2.54	1.31
574A-19-6, 91	149.81	*C. kullenbergi*	2.32	1.17
574A-19-6, 101	149.91	*C. kullenbergi*	2.40	1.46
574A-19-6, 111	150.01	*C. kullenbergi*	2.11	1.34
574A-19-6, 121	150.11	*C. kullenbergi*	2.31	1.38
574A-19-6, 131	150.21	*C. kullenbergi*	2.55	1.58
574A-19-6, 141	150.31	*C. kullenbergi*	2.67	1.68
574A-19-7, 1	150.41	*C. kullenbergi*	2.45	1.70
574A-19-7, 11	150.51	*C. kullenbergi*	2.72	1.74
574A-19-7, 21	150.61	*C. kullenbergi*	2.72	1.81
574A-19-7, 21	150.61	*Oridorsalis* sp.	2.35	1.73
574A-19-7, 31	150.71	*C. kullenbergi*	2.46	1.59
574A-19-7, 41	150.81	*C. kullenbergi*	2.64	1.81
574A-20-1, 61	151.51	*C. kullenbergi*	2.46	1.75
574A-20-1, 71	151.61	*C. kullenbergi*	2.75	1.96
574A-20-1, 71	151.61	*Oridorsalis* sp.	2.46	1.95
574A-20-1, 81	151.71	*C. kullenbergi*	2.59	1.95
574A-20-1, 81	151.71	*Oridorsalis* sp.	2.59	2.04
574A-20-1, 91	151.81	*C. kullenbergi*	2.55	1.84
574A-20-1, 91	151.81	*Oridorsalis* sp.	2.74	1.88
574A-20-1, 101	151.91	*C. kullenbergi*	2.73	2.01
574A-20-1, 101	151.91	*Oridorsalis* sp.	2.66	1.78
574A-20-1, 111	152.01	*Oridorsalis* sp.	2.74	1.71
574A-20-1, 111	152.01	*C. kullenbergi*	2.77	2.03
574A-20-1, 121	152.11	*C. kullenbergi*	2.61	1.83
574A-20-1, 121	152.11	*Oridorsalis* sp.	2.61	1.67
574A-20-1, 131	152.21	*C. kullenbergi*	2.80	2.01
574A-20-1, 131	152.21	*Oridorsalis* sp.	2.31	1.48
574A-20-1, 141	152.31	*C. kullenbergi*	2.72	1.69
574A-20-1, 141	152.31	*Oridorsalis* sp.	2.53	1.64
574A-20-2, 1	152.41	*C. kullenbergi*	2.80	1.93
574A-20-2, 1	152.41	*Oridorsalis* sp.	2.66	2.06
574A-20-2, 11	152.51	*C. kullenbergi*	2.74	1.85
574A-20-2, 21	152.61	*C. kullenbergi*	2.75	1.98
574A-20-2, 21	152.61	*Oridorsalis* sp.	2.67	1.93
574A-20-2, 31	152.71	*C. kullenbergi*	2.63	1.79
574A-20-2, 41	152.81	*C. kullenbergi*	2.64	1.74
574A-20-2, 41	152.81	*Oridorsalis* sp.	2.53	1.56
574A-20-2, 51	152.91	*C. kullenbergi*	2.53	1.64
574A-20-2, 51	152.91	*Oridorsalis* sp.	2.59	1.56
574A-20-2, 61	153.01	*C. kullenbergi*	2.58	1.70

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-20-2, 61	153.01	*Oridorsalis* sp.	2.60	1.75
574A-20-2, 71	153.11	*C. kullenbergi*	2.76	1.82
574A-20-2, 81	153.21	*C. kullenbergi*	2.64	1.74
574A-20-2, 81	153.21	*Oridorsalis* sp.	2.65	1.73
574A-20-2, 91	153.31	*C. kullenbergi*	2.52	1.72
574A-20-2, 101	153.41	*C. kullenbergi*	2.59	1.79
574A-20-2, 101	153.41	*Oridorsalis* sp.	2.74	1.88
574A-20-2, 111	153.51	*C. kullenbergi*	2.57	1.80
574A-20-2, 111	153.51	*Oridorsalis* sp.	2.57	1.80
574A-20-2, 121	153.61	*P. wuellerstorfi*	2.60	1.21
574A-20-2, 121	153.61	*C. kullenbergi*	2.72	1.17
574A-20-2, 131	153.71	*C. kullenbergi*	2.69	1.04
574A-20-2, 141	153.81	*C. kullenbergi*	2.56	1.76
574A-20-2, 141	153.81	*Oridorsalis* sp.	2.56	1.68
574A-20-3, 1	153.91	*C. kullenbergi*	2.81	1.83
574A-20-3, 11	154.01	*Oridorsalis* sp.	2.80	1.73
574A-20-3, 11	154.01	*C. kullenbergi*	2.68	1.70
574A-20-3, 21	154.11	*Oridorsalis* sp.	2.62	1.99
574A-20-3, 31	154.21	*C. kullenbergi*	2.82	1.77
574A-20-3, 31	154.21	*Oridorsalis* sp.	2.69	1.75
574A-20-3, 41	154.31	*C. kullenbergi*	2.64	1.88
574A-20-3, 41	154.31	*Oridorsalis* sp.	2.64	1.75
574A-20-3, 61	154.51	*C. kullenbergi*	2.61	1.80
574A-20-3, 71	154.61	*Oridorsalis* sp.	2.63	1.62
574A-20-3, 81	154.71	*C. kullenbergi*	2.45	1.56
574A-20-3, 91	154.81	*Oridorsalis* sp.	2.37	1.98
574A-20-3, 91	154.81	*C. kullenbergi*	2.64	1.87
574A-20-3, 101	154.91	*Oridorsalis* sp.	2.57	1.61
574A-20-3, 101	154.91	*C. kullenbergi*	2.78	1.72
574A-20-3, 111	155.01	*C. kullenbergi*	2.69	1.65
574A-20-3, 121	155.11	*C. kullenbergi*	2.55	1.62
574A-20-3, 131	155.21	*C. kullenbergi*	2.63	1.70
574A-20-3, 141	155.31	*C. kullenbergi*	2.72	1.70
574A-20-3, 141	155.31	*Oridorsalis* sp.	2.45	1.75
574A-20-4, 1	155.41	*C. kullenbergi*	2.57	1.64
574A-20-4, 11	155.51	*C. kullenbergi*	2.53	1.54
574A-20-4, 21	155.61	*C. kullenbergi*	2.41	1.64
574A-20-4, 31	155.71	*C. kullenbergi*	2.06	1.40
574A-20-4, 41	155.81	*C. kullenbergi*	2.21	1.22
574A-20-4, 41	155.81	*Oridorsalis* sp.	2.14	1.11
574A-20-4, 51	155.91	*C. havanensis*	2.34	1.04
574A-20-4, 61	156.01	*C. kullenbergi*	2.06	1.56
574A-20-4, 71	156.11	*C. havanensis*	1.95	0.92
574A-20-4, 71	156.11	*Oridorsalis* sp.	2.02	1.20
574A-20-4, 81	156.21	*C. havanensis*	1.85	1.39
574A-20-4, 91	156.31	*P. wuellerstorfi*	1.88	1.30
574A-20-4, 91	156.31	*Oridorsalis* sp.	1.50	1.26
574A-20-4, 101	156.41	*P. wuellerstorfi*	2.39	1.41
574A-20-4, 101	156.41	*C. kullenbergi*	2.22	0.89
574A-20-4, 111	156.51	*C. kullenbergi*	2.02	1.35
574A-20-4, 121	156.61	*C. kullenbergi*	1.93	1.43
574A-20-4, 121	156.61	*Oridorsalis* sp.	1.65	1.19
574A-20-4, 141	156.81	*P. wuellerstorfi*	2.19	1.16
574A-20-5, 1	156.91	*P. wuellerstorfi*	2.28	1.17
574A-20-5, 11	157.01	*C. kullenbergi*	2.26	1.17
574A-20-5, 21	157.11	*C. kullenbergi*	2.10	1.56
574A-20-5, 31	157.21	*Oridorsalis* sp.	2.13	1.08
574A-20-5, 41	157.31	*C. havanensis*	2.06	1.31
574A-20-5, 51	157.41	*P. wuellerstorfi*	2.08	1.33
574A-20-5, 61	157.51	*C. kullenbergi*	2.20	1.10
574A-20-5, 71	157.61	*C. kullenbergi*	1.99	1.33
574A-20-5, 71	157.61	*Oridorsalis* sp.	2.07	1.25
574A-20-5, 81	157.71	*C. havanensis*	2.04	1.24
574A-20-5, 91	157.81	*P. wuellerstorfi*	2.03	1.38
574A-20-5, 41	157.31	*C. kullenbergi*	1.87	1.45
574A-20-5, 91	157.81	*P. wuellerstorfi*	2.03	1.38
574A-20-5, 101	157.91	*P. wuellerstorfi*	1.90	1.28
574A-20-5, 101	157.91	*Oridorsalis* sp.	1.69	1.41
574A-20-5, 111	158.01	*P. wuellerstorfi*	2.24	1.29
574A-20-5, 111	158.01	*Oridorsalis* sp.	1.93	1.34
574A-20-5, 121	158.11	*P. wuellerstorfi*	2.43	1.33
574A-20-5, 131	158.21	*P. wuellerstorfi*	2.53	1.41
574A-20-5, 141	158.31	*Oridorsalis* sp.	2.26	1.26
574A-20-5, 141	158.31	*P. wuellerstorfi*	2.52	1.44
574A-20-6, 1	158.41	*P. wuellerstorfi*	2.65	1.51
574A-20-6, 11	158.51	*C. kullenbergi*	2.38	1.25

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-20-6, 11	158.51	*Oridorsalis* sp.	2.41	1.41
574A-20-6, 21	158.61	*Oridorsalis* sp.	2.13	1.67
574A-20-6, 21	158.61	*C. kullenbergi*	2.18	1.60
574A-20-6, 31	158.71	*C. kullenbergi*	2.13	1.59
574A-20-6, 41	158.81	*C. kullenbergi*	1.82	1.29
574A-20-6, 51	158.91	*Oridorsalis* sp.	2.00	1.37
574A-20-6, 61	159.01	*Oridorsalis* sp.	2.07	1.32
574A-20-6, 61	159.01	*C. kullenbergi*	2.05	1.30
574A-20-6, 71	159.11	*C. kullenbergi*	2.33	1.39
574A-20-6, 81	159.21	*C. kullenbergi*	2.11	1.22
574A-20-6, 91	159.31	*C. kullenbergi*	2.28	1.47
574A-20-6, 101	159.41	*C. kullenbergi*	2.10	1.51
574A-20-6, 111	159.51	*C. kullenbergi*	2.10	1.58
574A-20-6, 121	159.61	*C. kullenbergi*	2.10	1.62
574A-20-6, 131	159.71	*Oridorsalis* sp.	1.92	1.56
574A-20-6, 141	159.81	*C. kullenbergi*	1.85	1.41
574A-22-1, 1	168.41	*C. kullenbergi*	1.79	1.30
574A-22-1, 1	168.41	*P. wuellerstorfi*	2.13	1.63
574A-22-1, 11	168.51	*P. wuellerstorfi*	2.21	1.66
574A-22-1, 21	168.61	*C. kullenbergi*	1.85	1.58
574A-22-1, 31	168.71	*P. wuellerstorfi*	2.07	1.83
574A-22-1, 41	168.81	*P. wuellerstorfi*	1.72	1.74
574A-22-1, 61	169.01	*P. wuellerstorfi*	1.65	1.78
574A-22-1, 71	169.11	*P. wuellerstorfi*	1.88	1.80
574A-22-1, 81	169.21	*P. wuellerstorfi*	1.85	1.73
574A-22-1, 91	169.31	*P. wuellerstorfi*	1.94	1.70
574A-22-1, 101	169.41	*P. wuellerstorfi*	1.95	1.57
574A-22-1, 111	169.51	*P. wuellerstorfi*	2.08	1.56
574A-22-1, 21	168.61	*P. wuellerstorfi*	2.14	1.80
574A-22-1, 121	169.61	*P. wuellerstorfi*	1.88	1.50
574A-22-1, 131	169.71	*P. wuellerstorfi*	2.14	1.64
574A-22-1, 141	169.81	*P. wuellerstorfi*	2.16	1.71
574A-22-2, 1	169.91	*P. wuellerstorfi*	2.16	1.62
574A-22-2, 11	170.01	*P. wuellerstorfi*	2.04	1.96
574A-22-2, 21	170.11	*P. wuellerstorfi*	1.91	1.88
574A-22-2, 31	170.21	*P. wuellerstorfi*	1.84	1.93
574A-22-2, 41	170.31	*C. kullenbergi*	1.55	1.76
574A-22-2, 41	170.31	*P. wuellerstorfi*	1.76	1.75
574A-22-2, 51	170.41	*C. kullenbergi*	1.65	1.65
574A-22-2, 61	170.51	*P. wuellerstorfi*	1.67	1.66
574A-22-2, 71	170.61	*C. kullenbergi*	2.20	1.56
574A-22-2, 71	170.61	*P. wuellerstorfi*	1.82	1.73
574A-22-2, 81	170.71	*P. wuellerstorfi*	1.89	1.61
574A-22-2, 91	170.81	*P. wuellerstorfi*	2.30	1.69
574A-22-2, 101	170.91	*P. wuellerstorfi*	2.10	1.71
574A-22-2, 111	171.01	*P. wuellerstorfi*	2.12	1.63
574A-22-2, 121	171.11	*P. wuellerstorfi*	2.38	1.68
574A-22-2, 131	171.21	*P. wuellerstorfi*	2.16	1.67
574A-22-2, 146	171.36	*P. wuellerstorfi*	2.14	1.73
574A-22-3, 1	171.41	*P. wuellerstorfi*	2.14	1.90
574A-22-3, 11	171.51	*P. wuellerstorfi*	1.99	1.71
574A-22-3, 21	171.61	*Gyroidina* sp.	1.78	0.73
574A-22-3, 21	171.61	*C. kullenbergi*	2.07	1.80
574A-22-3, 21	171.61	*P. wuellerstorfi*	1.97	1.88
574A-22-3, 31	171.71	*C. kullenbergi*	2.13	1.62
574A-22-3, 31	171.71	*P. wuellerstorfi*	2.17	1.84
574A-22-3, 41	171.81	*C. kullenbergi*	2.03	1.89
574A-22-3, 51	171.91	*P. wuellerstorfi*	2.15	1.74
574A-22-3, 61	172.01	*P. wuellerstorfi*	1.99	1.74
574A-22-3, 71	172.11	*P. wuellerstorfi*	2.10	1.92
574A-22-3, 81	172.21	*P. wuellerstorfi*	1.94	1.53
574A-22-3, 91	172.31	*P. wuellerstorfi*	1.94	1.51
574A-22-3, 101	172.41	*P. wuellerstorfi*	1.88	1.49
574A-22-3, 111	172.51	*C. kullenbergi*	1.96	0.99
574A-22-3, 121	172.61	*P. wuellerstorfi*	2.17	1.47
574A-22-3, 131	172.71	*C. kullenbergi*	1.94	1.48
574A-22-3, 141	172.81	*P. wuellerstorfi*	1.75	1.40
574A-22-4, 1	172.91	*P. wuellerstorfi*	1.84	1.16
574A-22-4, 11	173.01	*P. wuellerstorfi*	1.76	1.65
574A-22-4, 21	173.11	*P. wuellerstorfi*	1.57	1.36
574A-22-4, 31	173.21	*P. wuellerstorfi*	1.82	1.60
574A-22-4, 41	173.31	*P. wuellerstorfi*	1.77	1.33
574A-22-4, 51	173.41	*P. wuellerstorfi*	1.94	1.62
574A-22-4, 61	173.51	*P. wuellerstorfi*	1.85	1.59
574A-22-4, 71	173.61	*P. wuellerstorfi*	1.78	1.27
574A-22-4, 81	173.71	*P. wuellerstorfi*	2.17	1.56

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-22-4, 91	173.81	*P. wuellerstorfi*	2.43	1.49
574A-22-4, 101	173.91	*P. wuellerstorfi*	2.42	1.54
574A-22-4, 111	174.01	*P. wuellerstorfi*	2.31	1.52
574A-22-4, 121	174.11	*P. wuellerstorfi*	2.08	1.36
574A-22-4, 131	174.21	*P. wuellerstorfi*	1.85	1.23
574A-22-4, 146	174.36	*C. kullenbergi*	1.83	1.18
574A-22-5, 61	175.01	*P. wuellerstorfi*	2.16	1.53
574A-22-5, 71	175.11	*P. wuellerstorfi*	1.79	1.35
574A-22-5, 81	175.21	*P. wuellerstorfi*	1.88	1.40
574A-22-5, 91	175.31	*P. wuellerstorfi*	1.81	1.55
574A-22-5, 101	175.41	*C. kullenbergi*	1.76	1.34
574A-22-5, 111	175.51	*P. wuellerstorfi**	1.53	1.19
574A-22-5, 121	175.61	*P. wuellerstorfi*	1.92	1.47
574A-22-5, 131	175.71	*P. wuellerstorfi**	1.78	1.41
574A-22-5, 141	175.81	*P. wuellerstorfi**	1.80	1.17
574A-22-6, 1	175.91	*P. wuellerstorfi**	1.70	1.28
574A-22-6, 11	176.01	*P. wuellerstorfi*	1.97	1.40
574A-22-6, 21	176.11	*P. wuellerstorfi*	1.85	1.37
574A-22-6, 21	176.11	*C. kullenbergi*	1.65	1.07
574A-22-6, 31	176.21	*P. wuellerstorfi*	2.16	1.45
574A-22-6, 41	175.31	*P. wuellerstorfi*	2.15	1.54
574A-22-6, 61	176.51	*P. wuellerstorfi*	2.10	1.63
574A-22-6, 71	176.61	*P. wuellerstorfi*	1.90	1.50
574A-22-6, 81	176.71	*P. wuellerstorfi**	1.74	1.27
574A-22-6, 91	176.81	*P. wuellerstorfi**	1.70	1.36
574A-22-6, 101	176.91	*P. wuellerstorfi**	1.82	1.31
574A-22-6, 111	177.01	*P. wuellerstorfi*	1.92	1.47
574A-22-6, 111	177.01	*C. kullenbergi*	1.55	1.13
574A-22-6, 121	177.11	*P. wuellerstorfi*	1.93	1.36
574A-22-6, 131	177.21	*P. wuellerstorfi*	1.70	1.26
574A-22-6, 141	177.31	*P. wuellerstorfi*	1.83	1.33
574A-22-7, 1	177.41	*C. kullenbergi*	1.86	1.21
574A-22-7, 11	177.51	*P. wuellerstorfi*	2.10	1.44
574A-22-7, 21	177.61	*P. wuellerstorfi*	2.00	1.40
574A-22-7, 31	177.71	*P. wuellerstorfi*	2.06	1.38
574A-22-7, 41	177.81	*P. wuellerstorfi*	2.02	1.32
574A-23-1, 6	177.96	*C. kullenbergi*	1.94	1.31
574A-23-1, 6	177.96	*P. wuellerstorfi*	1.84	1.28
574A-23-1, 21	178.11	*P. wuellerstorfi*	1.76	1.54
574A-23-1, 31	178.21	*P. wuellerstorfi*	1.62	1.50
574A-23-1, 41	178.31	*P. wuellerstorfi**	1.63	1.42
574A-23-1, 41	178.31	*C. kullenbergi*	1.62	0.94
574A-23-1, 51	178.41	*P. wuellerstorfi*	1.70	1.52
574A-23-1, 71	178.61	*P. wuellerstorfi*	1.59	1.32
574A-23-1, 1	177.91	*P. wuellerstorfi*	2.11	1.49
574A-23-1, 11	178.01	*P. wuellerstorfi*	1.97	1.29
574A-23-1, 21	178.11	*P. wuellerstorfi*	1.91	1.24
574A-23-1, 31	178.21	*P. wuellerstorfi*	1.73	1.24
574A-23-1, 41	178.31	*P. wuellerstorfi*	2.05	1.44
574A-23-1, 51	178.41	*P. wuellerstorfi*	1.89	1.43
574A-23-1, 61	178.51	*P. wuellerstorfi*	1.77	1.41
574A-23-1, 81	178.71	*P. wuellerstorfi*	1.80	1.29
574A-23-1, 91	178.81	*P. wuellerstorfi*	1.68	1.29
574A-23-1, 101	178.91	*P. wuellerstorfi*	1.92	1.30
574A-23-1, 111	179.01	*P. wuellerstorfi*	1.85	1.30
574A-23-1, 121	179.11	*P. wuellerstorfi*	1.89	1.40
574A-23-1, 132	179.22	*P. wuellerstorfi*	1.76	1.35
574A-23-1, 147	179.37	*P. wuellerstorfi*	1.55	1.32
574A-23-2, 21	179.61	*P. wuellerstorfi*	1.39	1.24
574A-23-2, 11	179.51	*C. kullenbergi*	1.59	1.25
574A-23-2, 21	179.61	*C. kullenbergi*	1.59	1.34
574A-23-2, 31	179.71	*C. kullenbergi*	1.36	1.04
574A-23-2, 41	179.81	*C. kullenbergi*	1.84	1.12
574A-23-2, 51	179.91	*C. kullenbergi*	1.45	1.12
574A-23-2, 51	179.91	*P. wuellerstorfi*	1.72	1.31
574A-23-2, 61	180.01	*C. kullenbergi*	1.73	1.37
574A-23-2, 61	180.01	*P. wuellerstorfi*	1.70	1.00
574A-23-2, 71	180.11	*P. wuellerstorfi*	2.08	1.37
574A-23-2, 81	180.21	*P. wuellerstorfi*	1.99	1.39
574A-23-2, 91	180.31	*P. wuellerstorfi*	1.99	1.42
574A-23-2, 101	180.41	*C. kullenbergi*	1.84	1.19
574A-23-2, 111	180.51	*C. kullenbergi*	1.69	1.32
574A-23-2, 111	180.51	*C. kullenbergi*	1.89	1.37
574A-23-2, 121	180.61	*P. wuellerstorfi*	1.69	1.31
574A-23-2, 132	180.72	*C. kullenbergi*	1.58	1.42
574A-23-2, 147	180.87	*P. wuellerstorfi*	2.15	1.38

Table 1. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Species	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
574A-23-3, 1	180.91	*P. wuellerstorfi*	1.85	1.46
574A-23-3, 11	181.01	*P. wuellerstorfi*	2.02	1.55
574A-23-3, 21	181.11	*P. wuellerstorfi*	2.11	1.63
574A-23-3, 31	181.21	*P. wuellerstorfi*	1.89	1.55
574A-23-3, 41	181.31	*P. wuellerstorfi*	2.14	1.66
574A-23-3, 51	181.41	*P. wuellerstorfi*	2.02	1.19
574A-23-3, 61	181.51	*P. wuellerstorfi*	2.10	1.53
574A-23-3, 71	181.61	*P. wuellerstorfi*	2.22	1.50
574A-23-3, 81	181.71	*P. wuellerstorfi*	2.01	1.52
574A-23-3, 91	181.81	*P. wuellerstorfi*	1.66	1.37
574A-23-3, 101	181.91	*P. wuellerstorfi*	1.69	1.46
574A-23-3, 112	182.02	*P. wuellerstorfi*	1.90	1.61
574A-23-3, 132	182.22	*P. wuellerstorfi*	1.55	1.31
574A-23-3, 147	182.37	*P. wuellerstorfi*	1.65	1.20
574A-23-4, 1	182.41	*P. wuellerstorfi*	2.24	1.34
574A-23-4, 11	182.51	*P. wuellerstorfi*	2.23	1.47
574A-23-4, 21	182.61	*P. wuellerstorfi*	2.17	1.60
574A-23-4, 31	182.71	*P. wuellerstorfi*	2.18	1.55
574A-23-4, 41	182.81	*P. wuellerstorfi*	2.11	1.57
574A-23-4, 51	182.91	*P. wuellerstorfi*	2.10	1.76
574A-23-4, 61	183.01	*P. wuellerstorfi*	2.13	1.78
574A-23-4, 71	183.11	*P. wuellerstorfi*	2.04	1.75
574A-23-4, 81	183.21	*P. wuellerstorfi*	1.98	1.63
574A-23-4, 91	183.31	*P. wuellerstorfi*	2.01	1.59
574A-23-4, 101	183.41	*P. wuellerstorfi*	2.32	1.66
574A-23-4, 111	183.51	*P. wuellerstorfi*	2.24	1.57
574A-23-4, 121	183.61	*P. wuellerstorfi*	2.31	1.70
574A-23-4, 132	183.72	*P. wuellerstorfi*	2.31	1.75
574A-23-4, 147	183.87	*C. kullenbergi*	1.76	1.70
574A-23-5, 1	183.91	*P. wuellerstorfi*	1.86	1.79
574A-23-5, 11	184.01	*C. kullenbergi*	1.53	1.47
574A-23-5, 21	184.11	*P. wuellerstorfi*	1.70	1.73
574A-23-5, 31	184.21	*P. wuellerstorfi*	1.63	1.50
574A-23-5, 41	184.31	*P. wuellerstorfi*	2.04	1.76
574A-23-5, 51	184.41	*P. wuellerstorfi*	2.05	1.85
574A-23-5, 61	184.51	*P. wuellerstorfi*	1.68	1.61
574A-23-5, 71	184.61	*P. wuellerstorfi*	1.81	1.36
574A-23-5, 81	184.71	*P. wuellerstorfi*	2.31	1.88
574A-23-5, 91	184.81	*P. wuellerstorfi*	2.44	1.79
574A-23-5, 101	184.91	*P. wuellerstorfi*	2.41	1.64
574A-23-5, 111	185.01	*P. wuellerstorfi*	2.07	1.48
574A-23-5, 121	185.11	*P. wuellerstorfi*	2.27	1.69
574A-23-5, 132	185.22	*C. kullenbergi*	2.11	1.63
574A-23-5, 132	185.22	*Oridorsalis* sp.	2.06	1.79
574A-23-5, 147	185.37	*C. kullenbergi*	1.95	1.72
574A-23-5, 147	185.37	*P. wuellerstorfi*	2.22	1.85
574A-23-5, 147	185.37	*Oridorsalis* sp.	2.02	1.95
574A-23-6, 1	185.41	*P. wuellerstorfi*	2.01	1.72
574A-23-6, 11	185.51	*C. kullenbergi*	1.89	1.62
574A-23-6, 11	185.51	*Oridorsalis* sp.	1.73	1.53
574A-23-6, 21	185.61	*P. wuellerstorfi*	2.19	1.81
574A-23-6, 31	185.71	*P. wuellerstorfi*	2.18	1.81
574A-23-6, 41	185.81	*P. wuellerstorfi*	2.14	1.62
574A-23-6, 51	185.91	*P. wuellerstorfi*	2.15	1.72
574A-23-6, 61	186.01	*P. wuellerstorfi*	2.23	1.69

Note: Asterisks identify samples run with some specimens of *Cibicidoides* spp. All $\delta^{18}O$ analyses have been normalized to values of *Uvigerina* sp., and $\delta^{13}C$ analyses have been normalized to values of *Cibicidoides* spp., by the corrections given below:

$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)	Species
0.64	0.00	*P. wuellerstorfi*
0.00	1.00	*Oridorsalis* sp.
−0.10	0.50	*G. subglobosa*
0.50	0.00	*C. kullenbergi*
0.50	0.00	*C. havanensis*
0.50	0.00	*P. wuellerstorfi* with *Cibicidoides* spp.
0.00	0.00	*Gyroidina* sp.

RESULTS

All isotopic analyses are given in Table 1 and the calcium carbonate data in Table 2. The data are plotted versus sub-bottom depth in Figure 1. The general statistics for the sampled intervals of Hole 574A are listed in Tables 3 and 4. Data from other isotopic sequences are shown in Table 3 for comparison.

Oxygen Isotopes

The oxygen isotopic record (Fig. 1) appears to be characterized by two intervals of relatively constant means separated by a rapid transition at 155 m sub-bottom. The shift in the mean oxygen isotopic ratio in Hole 574A at 155 m occurs within 11 samples and spans a 1.1-m interval. Within each of these intervals of constant means, the high-frequency variability is quite similar and is well above the analytical noise level. In the intervals above 155 m and below 155 m the variation around the means is similar, but the difference between the means is about 0.6‰. As shown in Table 3 the variance of these records is comparable to Pliocene benthic isotopic records from the North Atlantic (Site 552), and the range of the Hole 574A data is more than half that observed for the upper Pleistocene.

Carbon Isotopes

The carbon isotopic record shows a degree of variability similar to that observed for the oxygen data, but it displays considerable low-frequency variations rather than a steplike change in the time-averaged mean value (Fig. 1). In the interval between 168 and 186 m sub-bottom there appears to be a long-term trend with values of about 1.7‰ at 186 m decreasing to values of about 1.4‰ at 172 m. At about 172 m sub-bottom $\delta^{13}C$ values increase sharply (within 50 cm of section) to values near 1.9‰. The oxygen isotopic values do not show a similar shift in this interval, although the high-frequency correlation between $\delta^{13}C$ and $\delta^{18}O$ is greater in this interval than in the other intervals examined (Table 3).

At 155 m sub-bottom the carbon isotopic values show a further increase of about 0.4‰, which is coincident with the shift in the time-averaged $\delta^{18}O$ values. This interval of maximal $\delta^{13}C$ values spans about 6 m of section, and at about 151 m sub-bottom $\delta^{13}C$ values become lower, decreasing to a mean of about 1.1‰. This transition in $\delta^{13}C$ values (about 0.6‰) spans an interval of about 2 m.

Above the transition in the $\delta^{13}C$ values at 148 m sub-bottom, the carbon isotopic values show variations on the order 0.20 to 0.80‰, which are comparable to variations observed in the deeper part of the section. The variability in the interval between 100 and 115 m is significantly less than in the deeper intervals, having a mean value of about 0.8‰.

Calcium Carbonate

Whereas the isotopic data from Hole 574A show significant shifts in the mean value over the interval examined, the calcium carbonate records show an essentially constant mean of about 85% (Fig. 1), and no interval

Table 2. Detailed calcium carbonate analyses for Holes 574 and 574A.

Sub-bottom depth (m)	Sample (level in cm)	$CaCO_3$ (%)
61.00	574-8-1, 0	72.82
61.20	574-8-1, 20	76.83
61.40	574-8-1, 40	85.56
61.60	574-8-1, 60	85.95
62.00	574-8-1, 100	84.17
62.40	574-8-1, 140	79.35
62.50	574-8-2, 0	73.90
62.70	574-8-2, 20	83.47
62.90	574-8-2, 40	83.19
63.10	574-8-2, 60	80.18
63.30	574-8-2, 80	84.68
63.50	574-8-2, 100	84.24
63.70	574-8-2, 120	86.41
63.90	574-8-2, 140	88.53
64.00	574-8-3, 0	86.58
64.20	574-8-3, 20	84.63
64.40	574-8-3, 40	85.01
64.60	574-8-3, 60	80.03
64.80	574-8-3, 80	80.42
65.00	574-8-3, 100	80.29
65.20	574-8-3, 120	78.07
65.40	574-8-3, 140	73.78
65.50	574-8-4, 0	68.36
65.70	574-8-4, 20	77.88
65.90	574-8-4, 40	82.90
66.10	574-8-4, 60	82.31
66.30	574-8-4, 80	86.99
66.50	574-8-4, 100	88.58
66.70	574-8-4, 120	85.33
66.90	574-8-4, 140	84.43
67.00	574-8-5, 0	80.87
67.20	574-8-5, 20	73.18
67.40	574-8-5, 40	85.13
67.60	574-8-5, 60	76.37
67.80	574-8-5, 80	66.05
68.00	574-8-5, 100	62.82
68.20	574-8-5, 120	44.95
68.40	574-8-5, 140	34.74
68.50	574-8-6, 0	25.43
68.70	574-8-6, 20	51.24
68.90	574-8-6, 40	56.19
69.10	574-8-6, 60	49.33
69.30	574-8-6, 80	56.24
69.50	574-8-6, 100	57.31
69.70	574-8-6, 120	61.91
69.90	574-8-6, 140	45.45
70.00	574-8-7, 0	51.54
70.20	574-8-7, 20	64.58
70.40	574-8-7, 40	68.85
70.50	574-9-1, 0	64.91
70.70	574-9-1, 20	56.85
70.90	574-9-1, 40	56.21
71.10	574-9-1, 60	21.55
71.30	574-9-1, 80	12.43
71.50	574-9-1, 100	40.12
71.70	574-9-1, 120	46.83
71.90	574-9-1, 140	43.73
72.00	574-9-2, 0	42.81
72.20	574-9-2, 20	34.46
72.40	574-9-2, 40	38.95
72.60	574-9-2, 60	53.67
72.80	574-9-2, 80	60.13
73.00	574-9-2, 100	51.61
73.20	574-9-2, 120	53.86
73.40	574-9-2, 140	54.79
73.50	574-9-3, 0	48.14
73.70	574-9-3, 20	58.82
73.90	574-9-3, 40	74.69
74.10	574-9-3, 60	76.87
74.30	574-9-3, 80	74.17
74.70	574-9-3, 120	65.61
74.90	574-9-3, 140	55.70
75.00	574-9-4, 0	49.03
75.20	574-9-4, 20	15.07
75.40	574-9-4, 40	25.34
75.60	574-9-4, 60	27.65
75.80	574-9-4, 80	15.30
76.00	574-9-4, 100	34.80
76.20	574-9-4, 120	35.78
76.40	574-9-4, 140	27.34
76.50	574-9-5, 0	41.32
76.70	574-9-5, 20	12.44
76.90	574-9-5, 40	16.37
77.30	574-9-5, 80	1.69
77.50	574-9-5, 100	6.24
77.70	574-9-5, 120	53.35
77.90	574-9-5, 140	46.34
78.00	574-9-6, 0	15.59
78.20	574-9-6, 20	38.66
78.40	574-9-6, 40	73.76
78.60	574-9-6, 60	43.91
78.80	574-9-6, 80	44.42
79.00	574-9-6, 100	35.87
79.20	574-9-6, 120	33.71
79.40	574-9-6, 140	67.53
79.50	574-9-7, 0	62.14
79.70	574-9-7, 20	26.99
79.90	574-9-7, 40	41.49
80.00	574-10-1, 0	71.11
80.20	574-10-1, 20	73.37
80.40	574-10-1, 40	83.41
80.60	574-10-1, 60	73.48
80.80	574-10-1, 80	73.28
81.00	574-10-1, 100	71.02
81.20	574-10-1, 120	78.39
81.40	574-10-2, 140	68.77
81.50	574-10-2, 0	59.18
81.70	574-10-2, 20	66.19
81.90	574-10-2, 40	72.07
82.10	574-10-2, 60	72.83
82.30	574-10-2, 80	74.14
82.50	574-10-2, 100	73.77
82.70	574-10-2, 120	30.76
82.90	574-10-2, 140	45.91
83.00	574-10-3, 0	45.53
83.20	574-10-3, 20	63.75
83.40	574-10-3, 40	59.55
83.60	574-10-3, 60	64.63
83.80	574-10-3, 80	25.88
84.00	574-10-3, 100	27.97
84.20	574-10-3, 120	40.69
84.40	574-10-3, 140	43.59
84.50	574-10-4, 0	26.15
84.70	574-10-4, 20	39.28
84.90	574-10-4, 40	65.97
85.10	574-10-4, 60	75.87
85.30	574-10-4, 80	79.15
85.50	574-10-4, 100	75.12
85.70	574-10-4, 120	60.22
85.90	574-10-4, 140	83.99
86.00	574-10-5, 0	81.44
86.20	574-10-5, 20	86.87
86.40	574-10-5, 40	76.43
86.60	574-10-5, 60	71.07
86.80	574-10-5, 80	73.30
87.00	574-10-5, 100	67.07
87.20	574-10-5, 120	64.68
87.40	574-10-5, 140	61.08
87.50	574-10-6, 0	59.28
87.70	574-10-6, 20	76.47
87.90	574-10-6, 40	82.47
88.10	574-10-6, 60	78.17
88.30	574-10-6, 80	71.58
88.50	574-10-6, 100	69.74
88.70	574-10-6, 120	66.59
88.90	574-10-6, 140	58.62
89.00	574-10-7, 0	53.61
89.19	574-10-7, 19	25.34
89.90	574-11-1, 40	39.62
90.10	574-11-1, 60	81.08
90.30	574-11-1, 80	76.85
90.50	574-11-1, 100	81.56

Table 2. (Continued).

Sub-bottom depth (m)	Sample (level in cm)	$CaCO_3$ (%)
90.70	574-11-1, 120	80.43
90.90	574-11-1, 140	79.51
91.00	574-11-2, 0	82.73
91.20	574-11-2, 20	82.52
91.40	574-11-2, 40	73.98
91.60	574-11-2, 60	81.79
91.80	574-11-2, 80	79.72
92.00	574-11-2, 100	78.49
92.20	574-11-2, 120	67.96
92.40	574-11-2, 140	75.13
92.50	574-11-3, 0	70.72
92.70	574-11-3, 20	76.10
92.90	574-11-3, 40	69.94
93.10	574-11-3, 60	69.54
93.30	574-11-3, 80	81.81
93.50	574-11-3, 100	82.92
93.70	574-11-3, 120	88.00
93.90	574-11-3, 140	88.25
94.00	574-11-4, 0	89.41
94.20	574-11-4, 20	84.10
94.40	574-11-4, 40	89.34
94.60	574-11-4, 60	91.42
94.80	574-11-4, 80	93.35
95.00	574-11-4, 100	92.07
95.20	574-11-4, 120	92.39
95.40	574-11-4, 140	93.03
95.50	574-11-5, 0	93.74
95.70	574-11-5, 20	89.85
95.90	574-11-5, 40	89.21
96.10	574-11-5, 60	93.12
96.30	574-11-5, 80	89.77
96.50	574-11-5, 100	84.57
96.70	574-11-5, 120	85.51
96.90	574-11-5, 140	84.79
97.00	574-11-6, 0	93.36
97.20	574-11-6, 20	93.17
97.40	574-11-6, 40	90.08
97.60	574-11-6, 60	90.64
97.80	574-11-6, 80	90.98
98.00	574-11-6, 100	87.09
98.20	574-11-6, 120	86.24
98.40	574-11-6, 140	84.79
98.60	574-12-1, 0	83.84
98.80	574-12-1, 20	86.80
99.00	574-12-1, 40	88.31
99.20	574-12-1, 60	87.10
99.40	574-12-1, 80	84.63
99.60	574-12-1, 100	82.55
99.80	574-12-1, 120	90.07
100.00	574-12-1, 140	88.11
100.10	574-12-2, 0	91.28
100.30	574-12-2, 20	88.08
100.50	574-12-2, 40	90.84
100.70	574-12-2, 60	95.11
100.90	574-12-2, 80	91.14
101.10	574-12-2, 100	87.91
101.30	574-12-2, 120	86.26
101.50	574-12-2, 140	82.42
101.60	574-12-3, 0	88.52
101.80	574-12-3, 20	86.82
102.00	574-12-3, 40	85.61
102.20	574-12-3, 60	87.05
102.40	574-12-3, 80	85.31
102.60	574-12-3, 100	84.02
102.80	574-12-3, 120	84.02
103.00	574-12-3, 140	84.84
103.10	574-12-4, 0	86.89
103.30	574-12-4, 20	77.28
103.50	574-12-4, 40	87.28
103.70	574-12-4, 60	87.62
103.90	574-12-4, 80	89.92
104.10	574-12-4, 100	89.42
104.30	574-12-4, 120	88.96
104.50	574-12-4, 140	83.81
104.60	574-12-5, 0	82.88
104.80	574-12-5, 20	88.82
105.00	574-12-5, 40	92.03
105.20	574-12-5, 60	90.54
105.40	574-12-5, 80	86.91
105.60	574-12-5, 100	85.43
105.80	574-12-5, 120	84.56
106.00	574-12-5, 140	88.71
106.10	574-12-6, 0	85.99
106.30	574-12-6, 20	88.78
106.50	574-12-6, 40	87.31
106.70	574-12-6, 60	89.06
106.90	574-12-6, 80	90.23
107.10	574-12-6, 100	89.46
107.30	574-12-6, 120	89.14
107.50	574-12-6, 140	90.94
107.60	574-12-7, 0	88.08
107.80	574-12-7, 20	91.37
108.00	574-12-7, 40	99.99
108.70	574A-13-1, 50	89.25
108.90	574A-13-1, 70	87.27
109.30	574A-13-1, 110	89.21
109.50	574A-13-1, 130	88.55
109.70	574A-13-2, 0	87.43
109.90	574A-13-2, 20	85.03
110.00	574A-13-2, 30	84.98
110.20	574A-13-2, 50	88.50
110.40	574A-13-2, 70	86.99
110.60	574A-13-2, 90	80.34
110.80	574A-13-2, 110	82.68
111.00	574A-13-2, 130	78.92
111.20	574A-13-3, 0	82.41
111.40	574A-13-3, 20	87.66
111.50	574A-13-3, 30	83.03
111.70	574A-13-3, 50	79.50
111.90	574A-13-3, 70	85.96
112.10	574A-13-3, 90	84.30
112.30	574A-13-3, 110	82.11
112.50	574A-13-3, 130	82.07
112.70	574A-13-4, 0	82.60
112.90	574A-13-4, 20	77.80
113.00	574A-13-4, 30	81.30
113.20	574A-14-1, 10	86.09
113.40	574A-14-1, 30	87.35
113.60	574A-14-1, 50	88.96
113.80	574A-14-1, 70	89.00
114.00	574A-14-1, 90	89.79
114.20	574A-14-1, 110	58.59
114.40	574A-14-1, 130	87.68
114.60	574A-14-2, 0	87.84
114.80	574A-14-2, 20	88.02
114.90	574A-14-2, 30	86.55
115.10	574A-14-2, 50	89.95
115.30	574A-14-2, 70	88.61
115.50	574A-14-2, 90	85.04
115.70	574A-14-2, 110	80.42
115.90	574A-14-2, 130	78.20
116.10	574A-14-3, 0	66.11
116.30	574A-14-3, 20	75.28
116.40	574A-14-3, 30	78.16
116.80	574A-14-3, 70	82.67
117.00	574A-14-3, 90	82.40
117.20	574A-14-3, 110	80.74
117.60	574A-14-4, 0	71.19
117.80	574A-14-4, 20	85.68
117.90	574A-14-4, 30	89.52
118.10	574A-15-1, 0	89.43
118.10	574A-15-1, 0	91.73
118.30	574A-15-1, 20	94.20
118.50	574A-15-1, 40	93.06
118.50	574A-15-1, 40	92.99
118.70	574A-15-1, 60	93.40
118.90	574A-15-1, 80	92.67
119.10	574A-15-1, 100	92.69
119.30	574A-15-1, 120	89.82
119.60	574A-15-2, 0	92.89
119.80	574A-15-2, 20	91.74
120.00	574A-15-2, 40	88.90

Table 2. (Continued).

Sub-bottom depth (m)	Sample (level in cm)	$CaCO_3$ (%)
120.20	574A-15-2, 60	94.82
120.40	574A-15-2, 80	91.19
120.60	574A-15-2, 100	90.23
120.80	574A-15-2, 120	88.61
121.00	574A-15-2, 140	93.02
121.10	574A-15-3, 0	93.13
121.30	574A-15-3, 20	98.42
121.50	574A-15-3, 40	91.76
121.70	574A-15-3, 60	93.16
121.90	574A-15-3, 80	93.66
122.10	574A-15-3, 100	99.51
122.30	574A-15-3, 120	95.64
122.50	574A-15-3, 140	96.98
122.60	574A-15-4, 0	88.14
123.40	574A-16-1, 60	94.21
123.60	574A-16-1, 80	90.53
123.80	574A-16-1, 100	92.37
124.00	574A-16-1, 120	92.11
124.20	574A-16-1, 140	87.80
124.30	574A-16-2, 0	93.58
124.50	574A-16-2, 20	93.97
124.70	574A-16-2, 40	95.17
124.90	574A-16-2, 60	95.27
125.10	574A-16-2, 80	93.19
125.30	574A-16-2, 100	96.46
125.50	574A-16-2, 120	92.99
125.70	574A-16-2, 140	96.29
125.80	574A-16-3, 0	97.95
126.00	574A-16-3, 20	95.52
126.20	574A-16-3, 40	90.89
126.40	574A-16-3, 60	95.39
126.60	574A-16-3, 80	95.61
126.80	574A-16-3, 100	91.76
127.00	574A-16-3, 120	94.48
127.80	574A-17-1, 0	78.18
128.00	574A-17-1, 20	85.67
128.20	574A-17-1, 40	87.03
128.40	574A-17-1, 60	86.30
128.60	574A-17-1, 80	79.77
128.80	574A-17-1, 100	81.60
129.00	574A-17-1, 120	79.72
129.20	574A-17-1, 140	83.86
129.30	574A-17-2, 0	82.98
129.50	574A-17-2, 20	84.99
129.70	574A-17-2, 40	86.71
129.90	574A-17-2, 60	84.96
130.10	574A-17-2, 80	83.67
130.30	574A-17-2, 100	85.22
130.50	574A-17-2, 120	86.79
130.70	574A-17-2, 140	87.37
130.80	574A-17-3, 0	88.66
131.00	574A-17-3, 20	87.78
131.20	574A-17-3, 40	85.94
131.40	574A-17-3, 60	88.71
131.60	574A-17-3, 80	89.08
131.80	574A-17-3, 100	86.66
131.90	574A-18-1, 0	79.68
132.10	574A-18-1, 20	81.26
132.30	574A-18-1, 40	80.91
132.50	574A-18-1, 60	78.80
132.70	574A-18-1, 80	78.66
133.10	574A-18-1, 120	74.99
133.30	574A-18-1, 140	72.27
133.40	574A-18-2, 0	71.91
133.60	574A-18-2, 20	75.86
133.80	574A-18-2, 40	72.03
134.00	574A-18-2, 60	65.42
134.20	574A-18-2, 80	74.92
134.40	574A-18-2, 100	75.94
134.60	574A-18-2, 120	81.96
134.80	574A-18-2, 140	83.31
134.90	574A-18-3, 0	81.21
135.30	574A-18-3, 40	77.19
135.50	574A-18-3, 60	82.96
135.70	574A-18-3, 80	78.88
135.90	574A-18-3, 100	77.01
136.10	574A-18-3, 120	79.63
136.30	574A-18-3, 140	78.01
136.40	574A-18-4, 0	98.63
136.60	574A-18-4, 20	88.76
136.80	574A-18-4, 40	84.99
137.00	574A-18-4, 60	97.89
137.20	574A-18-4, 80	89.61
137.40	574A-18-4, 100	88.93
137.60	574A-18-4, 120	85.87
137.80	574A-18-4, 140	80.98
137.90	574A-18-5, 0	84.14
138.10	574A-18-5, 20	81.90
138.30	574A-18-5, 40	85.49
138.50	574A-18-5, 60	82.58
138.70	574A-18-5, 80	81.78
138.90	574A-18-5, 100	97.65
139.10	574A-18-5, 120	84.25
139.30	574A-18-5, 140	85.20
139.40	574A-18-6, 0	86.16
139.60	574A-18-6, 20	87.52
139.80	574A-18-6, 40	88.62
140.00	574A-18-6, 60	89.38
140.20	574A-18-6, 80	88.20
140.40	574A-18-6, 100	83.98
140.60	574A-18-6, 120	81.63
140.90	574A-18-7, 0	77.72
141.10	574A-18-7, 20	81.34
141.30	574A-18-7, 40	83.57
141.40	574A-19-1, 0	85.75
141.50	574A-19-1, 10	85.39
141.60	574A-19-1, 20	86.84
141.70	574A-19-1, 30	81.74
141.80	574A-19-1, 40	83.59
141.90	574A-19-1, 50	85.91
142.00	574A-19-1, 60	88.11
142.10	574A-19-1, 70	85.39
142.20	574A-19-1, 80	87.34
142.30	574A-19-1, 90	94.64
142.40	574A-19-1, 100	87.99
142.50	574A-19-1, 110	86.25
142.60	574A-19-1, 120	85.53
142.70	574A-19-1, 130	85.44
142.80	574A-19-1, 140	85.25
142.90	574A-19-2, 0	82.75
143.00	574A-19-2, 10	87.40
143.10	574A-19-2, 20	86.26
143.10	574A-19-2, 20	88.09
143.20	574A-19-2, 30	87.99
143.30	574A-19-2, 40	88.31
143.40	574A-19-2, 50	90.31
143.50	574A-19-2, 60	86.57
143.60	574A-19-2, 70	91.95
143.70	574A-19-2, 80	89.91
143.80	574A-19-2, 90	85.85
143.90	574A-19-2, 100	89.11
144.00	574A-19-2, 110	93.71
144.10	574A-19-2, 120	86.89
144.20	574A-19-2, 130	83.96
144.30	574A-19-2, 140	88.35
144.40	574A-19-3, 0	91.78
144.50	574A-19-3, 10	88.61
144.70	574A-19-3, 30	88.37
144.80	574A-19-3, 40	87.85
144.90	574A-19-3, 50	89.47
145.00	574A-19-3, 60	86.80
145.10	574A-19-3, 70	85.11
145.20	574A-19-3, 80	88.26
145.30	574A-19-3, 90	86.54
145.40	574A-19-3, 100	88.26
145.50	574A-19-3, 110	89.83
145.60	574A-19-3, 120	89.53
145.70	574A-19-3, 130	86.12
145.80	574A-19-3, 140	87.13
145.90	574A-19-4, 0	85.48
146.00	574A-19-4, 10	80.53
146.10	574A-19-4, 20	85.19

Table 2. (Continued).

Sub-bottom depth (m)	Sample (level in cm)	$CaCO_3$ (%)
146.20	574A-19-4, 30	90.90
146.30	574A-19-4, 40	85.02
146.40	574A-19-4, 50	86.27
146.50	574A-19-4, 60	78.61
146.60	574A-19-4, 70	79.75
146.70	574A-19-4, 80	76.21
146.80	574A-19-4, 90	74.91
146.90	574A-19-4, 100	67.53
147.00	574A-19-4, 110	74.44
147.10	574A-19-4, 120	77.07
147.20	574A-19-4, 130	84.05
147.30	574A-19-4, 140	83.62
147.40	574A-19-5, 0	84.85
147.50	574A-19-5, 10	80.95
147.60	574A-19-5, 20	80.66
147.70	574A-19-5, 30	80.95
147.80	574A-19-5, 40	78.17
147.90	574A-19-5, 50	68.07
148.00	574A-19-5, 60	84.07
148.10	574A-19-5, 70	76.50
148.20	574A-19-5, 80	79.89
148.30	574A-19-5, 90	79.91
148.40	574A-19-5, 100	84.79
148.50	574A-19-5, 110	75.48
148.60	574A-19-5, 120	74.71
148.70	574A-19-5, 130	67.62
148.80	574A-19-5, 140	78.34
148.90	574A-19-6, 0	80.70
149.00	574A-19-6, 10	87.24
149.10	574A-19-6, 20	90.33
149.20	574A-19-6, 30	89.81
149.30	574A-19-6, 40	88.26
149.40	574A-19-6, 50	88.28
149.50	574A-19-6, 60	88.15
149.60	574A-19-6, 70	87.13
149.70	574A-19-6, 80	93.55
149.80	574A-19-6, 90	88.62
149.90	574A-19-6, 100	89.14
150.00	574A-19-6, 110	93.23
150.10	574A-19-6, 120	88.24
150.20	574A-19-6, 130	92.01
150.30	574A-19-6, 140	89.06
150.40	574A-19-7, 0	90.74
150.50	574A-19-7, 10	91.13
150.60	574A-19-7, 20	91.84
150.70	574A-19-7, 30	93.51
150.80	574A-19-7, 40	90.42
151.50	574A-20-1, 60	82.34
151.70	574A-20-1, 80	80.86
151.90	574A-20-1, 100	86.18
152.10	574A-20-1, 120	86.29
152.30	574A-20-1, 140	90.17
152.40	574A-20-2, 0	90.08
152.60	574A-20-2, 20	87.91
152.80	574A-20-2, 40	87.97
153.00	574A-20-2, 60	83.91
153.20	574A-20-2, 80	87.67
153.40	574A-20-2, 100	85.82
153.60	574A-20-2, 120	82.15
153.80	574A-20-2, 140	84.57
153.90	574A-20-3, 0	87.72
154.10	574A-20-3, 20	86.53
154.30	574A-20-3, 40	86.92
154.50	574A-20-3, 60	88.11
154.70	574A-20-3, 80	88.87
154.90	574A-20-3, 100	87.66
155.10	574A-20-3, 120	86.66
155.30	574A-20-3, 140	88.22
155.40	574A-20-4, 0	87.65
155.60	574A-20-4, 20	82.72
155.80	574A-20-4, 40	82.20
156.00	574A-20-4, 60	63.10
156.20	574A-20-4, 80	73.98
156.40	574A-20-4, 100	76.33
156.60	574A-20-4, 120	81.01
156.80	574A-20-4, 140	86.32
156.90	574A-20-5, 0	79.23
157.10	574A-20-5, 20	82.93
157.30	574A-20-5, 40	77.46
157.70	574A-20-5, 80	76.74
157.90	574A-20-5, 100	87.16
158.10	574A-20-5, 120	90.13
158.30	574A-20-5, 140	89.99
158.40	574A-20-6, 0	90.73
158.60	574A-20-6, 20	89.85
158.80	574A-20-6, 40	87.38
159.00	574A-20-6, 60	91.54
159.20	574A-20-6, 80	95.93
159.40	574A-20-6, 100	93.49
159.60	574A-20-6, 120	99.99
159.80	574A-20-6, 140	93.51
159.90	574A-21-1, 0	93.22
160.10	574A-21-1, 20	92.58
160.30	574A-21-1, 40	91.66
168.40	574A-22-1, 0	85.99
168.60	574A-22-1, 20	88.44
168.80	574A-22-1, 40	89.81
169.00	574A-22-1, 60	88.25
169.20	574A-22-1, 80	92.67
169.40	574A-22-1, 100	93.30
169.60	574A-22-1, 120	89.72
169.80	574A-22-1, 140	90.05
169.90	574A-22-2, 0	88.79
170.10	574A-22-2, 20	93.34
170.30	574A-22-2, 40	86.95
170.50	574A-22-2, 60	89.77
170.70	574A-22-2, 80	68.87
170.90	574A-22-2, 100	93.97
171.10	574A-22-2, 120	99.99
171.30	574A-22-2, 140	94.43
171.40	574A-22-3, 0	99.99
171.60	574A-22-3, 20	91.65
171.80	574A-22-3, 40	91.47
172.00	574A-22-3, 60	91.69
172.20	574A-22-3, 80	91.87
172.40	574A-22-3, 100	90.21
172.60	574A-22-3, 120	95.44
172.80	574A-22-3, 140	92.43
172.90	574A-22-4, 0	86.92
173.10	574A-22-4, 20	82.78
173.30	574A-22-4, 40	79.18
173.50	574A-22-4, 60	86.36
173.70	574A-22-4, 80	85.48
173.90	574A-22-4, 100	85.22
174.10	574A-22-4, 120	86.55
174.30	574A-22-4, 140	84.54
174.40	574A-22-5, 0	85.03
174.60	574A-22-5, 20	79.62
174.80	574A-22-5, 40	84.70
175.00	574A-22-5, 60	94.41
175.20	574A-22-5, 80	98.03
175.40	574A-22-5, 100	93.14
175.60	574A-22-5, 120	87.09
175.80	574A-22-5, 140	88.30
175.90	574A-22-6, 0	91.72
176.10	574A-22-6, 20	89.94
176.30	574A-22-6, 40	90.24
176.50	574A-22-6, 60	91.66
176.70	574A-22-6, 80	91.77
176.90	574A-22-6, 100	89.31
177.10	574A-22-6, 120	86.18
177.30	574A-22-6, 140	83.68
177.40	574A-22-7, 0	83.85
177.60	574A-22-7, 20	81.80
177.80	574A-22-7, 40	87.46
177.90	574A-23-1, 0	87.42
178.00	574A-23-1, 10	90.45
178.10	574A-23-1, 20	92.89
178.20	574A-23-1, 30	92.22
178.30	574A-23-1, 40	88.23
178.40	574A-23-1, 50	87.79
178.50	574A-23-1, 60	87.69

Table 2. (Continued).

Sub-bottom depth (m)	Sample (level in cm)	$CaCO_3$ (%)
178.60	574A-23-1, 70	87.75
178.70	574A-23-1, 80	83.32
178.80	574A-23-1, 90	75.64
178.90	574A-23-1, 100	79.94
179.00	574A-23-1, 110	81.88
179.10	574A-23-1, 120	73.10
179.19	574A-23-1, 129	73.60
179.30	574A-23-1, 140	59.95
179.30	574A-23-1, 140	59.95
179.40	574A-23-2, 0	57.71
179.50	574A-23-2, 10	60.84
179.60	574A-23-2, 20	87.96
179.70	574A-23-2, 30	82.11
179.80	574A-23-2, 40	84.76
179.90	574A-23-2, 50	77.28
180.00	574A-23-2, 60	82.29
180.10	574A-23-2, 70	88.53
180.20	574A-23-2, 80	88.43
180.30	574A-23-2, 90	88.23
180.40	574A-23-2, 100	86.49
180.50	574A-23-2, 110	85.18
180.60	574A-23-2, 120	90.01
180.69	574A-23-2, 129	84.91
180.80	574A-23-2, 140	90.27
180.90	574A-23-3, 0	80.41
181.00	574A-23-3, 10	84.71
181.10	574A-23-3, 20	86.46
181.20	574A-23-3, 30	85.04
181.30	574A-23-3, 40	86.37
181.40	574A-23-3, 50	87.69
181.50	574A-23-3, 60	85.31
181.60	574A-23-3, 70	87.86
181.70	574A-23-3, 80	88.16
181.80	574A-23-3, 90	68.48
181.90	574A-23-3, 100	70.49
182.00	574A-23-3, 110	63.55
182.10	574A-23-3, 120	68.27
182.19	574A-23-3, 129	87.59
182.30	574A-23-3, 140	78.27
182.40	574A-23-4, 0	84.84
182.50	574A-23-4, 10	87.04
182.60	574A-23-4, 20	82.91
182.70	574A-23-4, 30	87.09
182.80	574A-23-4, 40	84.46
182.90	574A-23-4, 50	85.18
183.00	574A-23-4, 60	87.89
183.10	574A-23-4, 70	85.91
183.20	574A-23-4, 80	86.20
183.30	574A-23-4, 90	90.75
183.40	574A-23-4, 100	89.02
183.50	574A-23-4, 110	89.00
183.60	574A-23-4, 120	87.16
183.69	574A-23-4, 129	85.93
183.80	574A-23-4, 140	83.43
183.90	574A-23-5, 0	81.77
184.00	574A-23-5, 10	74.99
184.10	574A-23-5, 20	77.69
184.20	574A-23-5, 30	83.91
184.30	574A-23-5, 40	68.19
184.40	574A-23-5, 50	75.12
184.50	574A-23-5, 60	78.64
184.60	574A-23-5, 70	77.63
184.70	574A-23-5, 80	84.49
184.80	574A-23-5, 90	84.93
184.90	574A-23-5, 100	84.52
185.00	574A-23-5, 110	84.23
185.10	574A-23-5, 120	83.99
185.19	574A-23-5, 129	79.76
185.30	574A-23-5, 140	76.19
185.40	574A-23-6, 0	81.68
185.50	574A-23-6, 10	82.21
185.60	574A-23-6, 20	82.61
185.70	574A-23-6, 30	77.14
185.80	574A-23-6, 40	74.40
185.90	574A-23-6, 50	82.22

Table 3. General statistics for Hole 574A isotopic data.

Hole or Core	Interval	Mean	Variance	Standard deviation	Range	Correlation $\delta^{18}O$ vs. $\delta^{13}C$
574A	100–115 m	2.78 (0.78)	0.031 (0.03)	0.18 (0.17)	1.1 (0.86)	0.1
574A	140–160 m	2.44 (1.36)	0.064 (0.08)[a]	0.25 (0.28)	1.3 (1.22)	0.2
574A	168–188 m	1.94 (1.51)	0.049 (0.04)[a]	0.22 (0.20)	1.1 (0.97)	0.4
552[b]	1–2 Ma	— —	0.148 (0.12)	0.38 (0.35)	1.7 (1.60)	0.6
552[b]	2.5–3.5 Ma	— —	0.063 (0.07)[a]	0.25 (0.25)	1.5 (2.0)	−0.0
289[c]	Core 55	— —	0.062[a]	0.24	0.9	
V22-174[d]	0–1 Ma	— —	0.150	0.40	1.8	

Note: Values given are for $\delta^{18}O$ and, in parentheses, for $\delta^{13}C$.
[a] Pair-wise F-test shows that these values are not significantly different.
[b] Data from Shackleton et al. (1982).
[c] Data from Shackleton (1980).
[d] Data from Imbrie et al. (1984).

Table 4. General statistics for high-resolution calcium carbonate data from Hole 574A.

Interval (m)	Number of samples	Mean	Variance	Standard deviation	Range	Correlation $CaCO_3$ vs. $\delta^{18}O$	Correlation $CaCO_3$ vs. $\delta^{13}C$
126–137	54	83.0	49.0	6.5	33	a	a
140–160	142	85.7	34.0	5.8	37	0.32	0.26
168–186	133	84.6	60.0	7.7	42	0.27	0.15

[a] Overlap with isotope record insufficient for meaningful calculations.

shows a significant change in the mean (Table 4). Between 128 and 137 m there is an interval of reduced calcium carbonate, with values being particularly low (below 80%) between 132 and 134 m. Isotopic data have not yet been obtained for this interval.

The calcium carbonate records also display little high-frequency variability and can be described as having relatively small-amplitude fluctuations with a number of short "events" of reduced $CaCO_3$. This is especially evident below 135 m sub-bottom.

The relationship between the isotopic records and the calcium carbonate data is weak. The correlation coefficients between these data sets are relatively low (Table 4), with a positive correlation between $\delta^{18}O$ and calcium carbonate. In general, carbonate events (times of reduced carbonate) tend to occur during intervals of increased $\delta^{18}O$ values; however, not all $\delta^{18}O$ maxima correspond to marked carbonate minima. Offsets in the isotopic records do tend to coincide with "events" in the calcium carbonate data; the offset in $\delta^{18}O$ values at 155 m is accompanied by a marked decrease in $CaCO_3$. The change in $\delta^{13}C$ at 150 m is marked by a series of carbonate events (Fig. 1), although the offset in $\delta^{13}C$ at 172 m is not clearly reflected in the $CaCO_3$ data.

DISCUSSION OF RESULTS

Correlation with Middle Miocene Data from Site 289

The isotopic records from benthic foraminifers from DSDP Site 289 (Woodruff et al., 1981; Shackleton, 1982) are the most detailed data available for comparison with the Hole 574A data. Although the sedimentation rate at Site 289 is one to two times that in Hole 574A, the sampling interval used in our study is closer than that in the best studied cores from Site 289. Thus, in general, our resolution is better than that available for Site 289. In making a comparison of the Site 289 data (Fig. 2) (Wood-

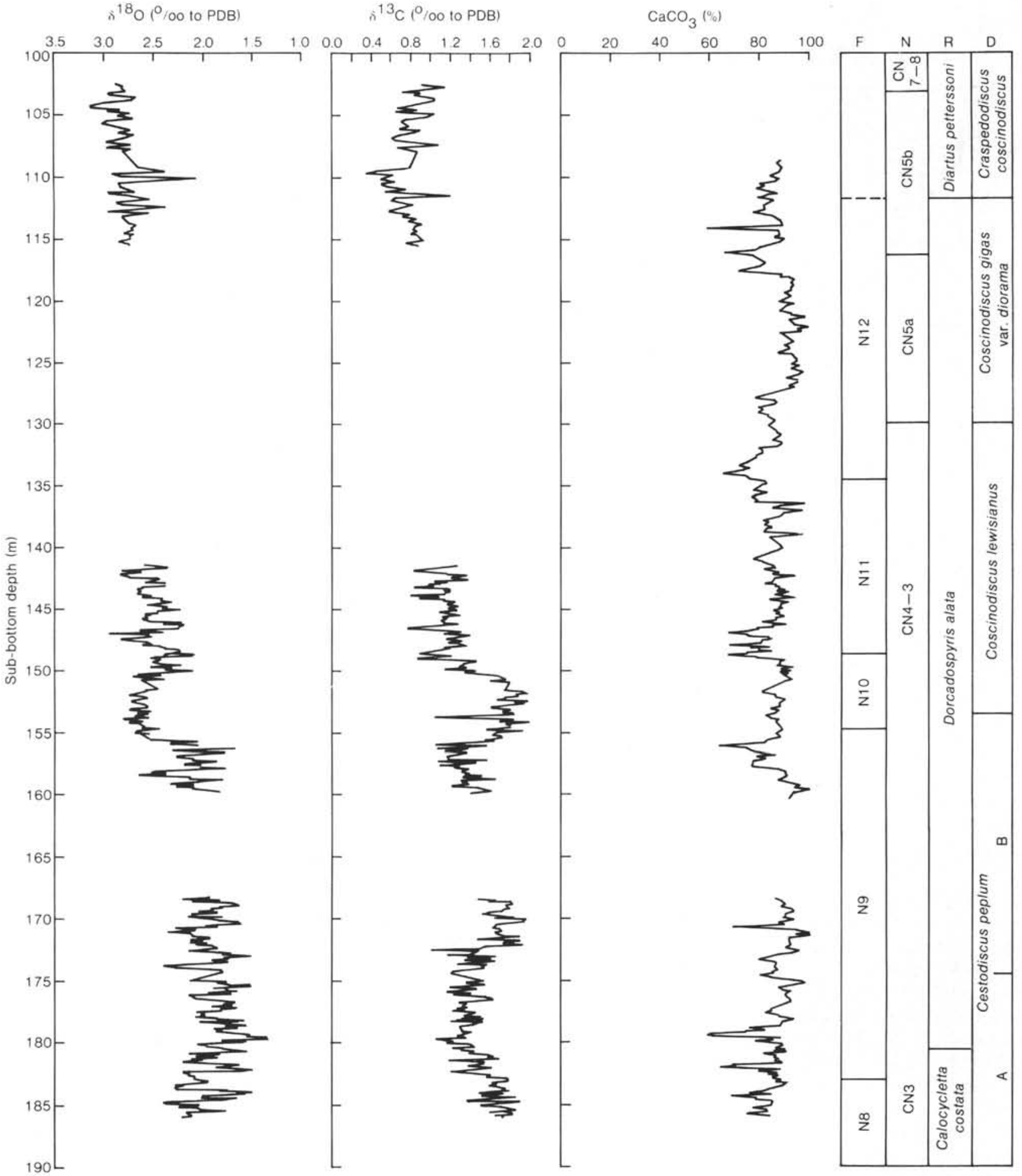

Figure 1. Detailed isotopic and carbonate records from middle Miocene section of HPC Hole 574A. Data are plotted versus sub-bottom depth and with microfossil stratigraphic zones as defined in the site chapter (this volume).

ruff et al., 1981) and the Hole 574A data, one must be aware that the apparent differences may reflect errors in biostratigraphic uncertainties, different water depths, different sampling resolutions, and possible drilling disturbance at Site 289.

The Site 289 data suggest that the transition in isotopic composition is associated with increased variability (an observation that may, however, result from a strong sampling bias). Close examination of the Site 289 data shows an interval of variable isotopic values within foraminiferal Zones N8 through N10 preceding a sharp break at the N10/N11 zonal boundary, which is followed by another interval of variable $\delta^{18}O$ and $\delta^{13}C$ values. In Hole 574A the transitions in $\delta^{18}O$ and $\delta^{13}C$ values ap-

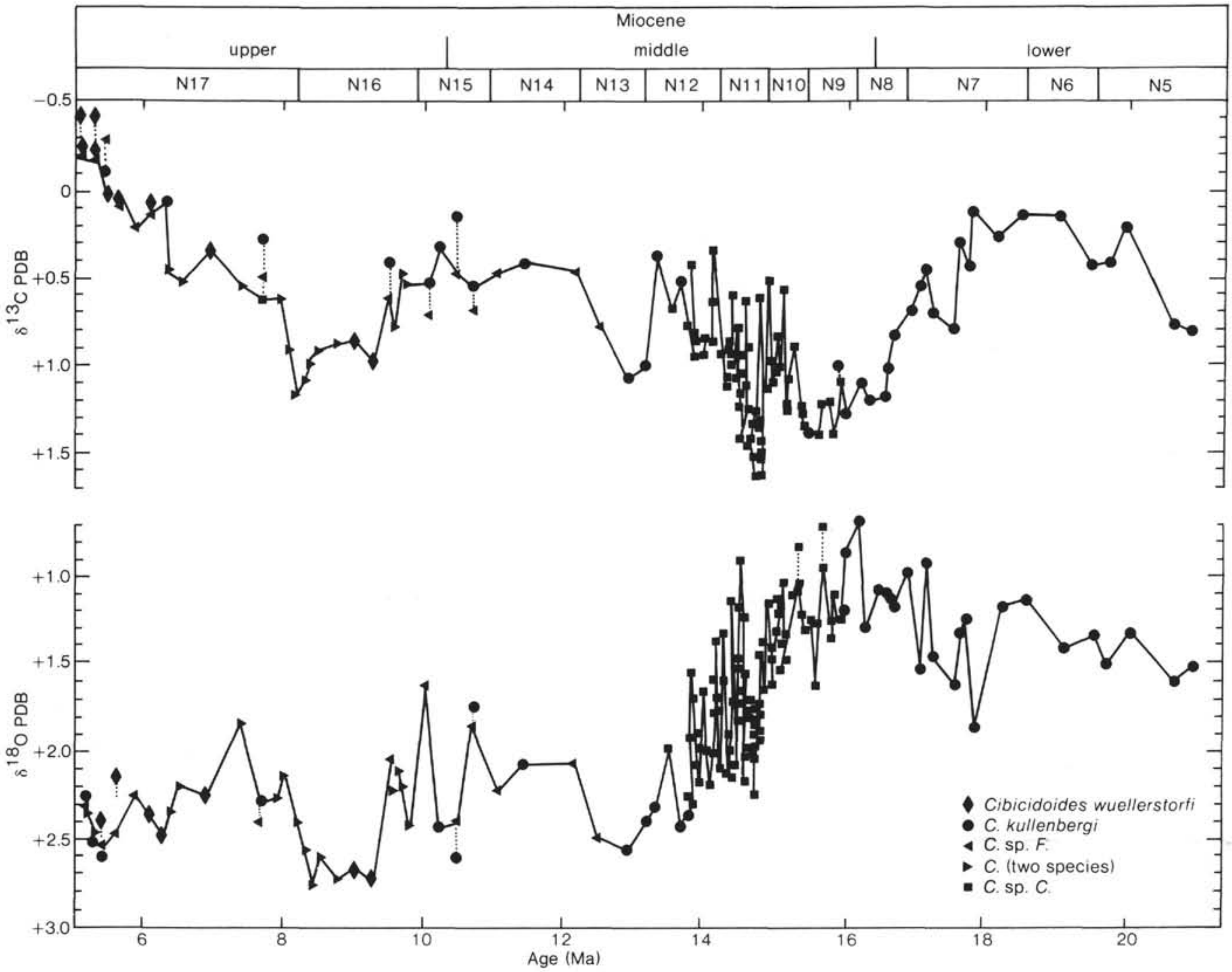

Figure 2. Detailed stable isotopic analysis from DSDP Site 289. Figure from Woodruff et al. (1981); copyright 1981 by the AAAS.

pear to occur at the N9/N10 zonal boundary with no significant offset at the N10/N11 boundary. The offset in the δ^{18}O values in Hole 574A is about 0.7 to 0.8‰, a value consistent with the Site 289 data at the N10/N11 zonal boundary. In the Site 289 data there appears to be an increase in the δ^{18}O values during the interval following Zone N11. Much of this interval has not been analyzed in Hole 574A, but the interval at 100 m sub-bottom, which spans the later part of Zone N12 and the beginning of N13, does not show a marked decrease in the mean δ^{18}O value (Table 3). Thus, from the Site 289 data, Woodruff et al. (1981) suggest that the transition in benthic isotopes spanned an interval of between 16.5 and 13 Ma, with the greatest change between approximately 14.8 and 14.0 Ma. The transition in Hole 574A seems to occur more rapidly, over 1.1 m of section, and from the long-term sedimentation rate estimates for Site 574, this represents about 30,000 to 100,000 yr.

At the transition in the δ^{18}O record of Hole 574A, the carbon isotopic values show an increase of 0.4‰, which in general is opposite to the carbon isotopic trend defined for the Site 289 data. However, in the Site 289 data, there is a similar increase in δ^{13}C at the N10/N11 zonal boundary, which is then followed by a decrease in carbon isotopic values. The carbon and oxygen isotopic data from Zone N11 at Site 289 are similar in both direction and magnitude to the Hole 574A data from foraminiferal Zone N10.

We suggest that the lack of correlation implied by the foraminiferal zonation is not real. The diatom stratigraphy from both sites shows that this transition occurs near the same diatom zonal boundary (Barron et al., this volume). A lag of approximately several hundred thousand years between the response of the deep Pacific (Site 574) and the intermediate waters (Site 289) is oceanographically unreasonable given the mixing times of the ocean. Thus, it seems possible that the disagreement in the foraminiferal stratigraphies reflects the increased dissolution of calcareous fossils at Site 574. In many intervals, dissolution prevents the precise location of both foraminifers and calcareous nannofossil zonal boundaries (Barron et al., this volume).

A possible explanation for the differences in the rapidity of the middle Miocene oxygen isotopic event recorded at Sites 289 and 574 is that the section in Hole 574A is not complete. Comparison of the length of foraminiferal zones in Hole 574A and at Site 289 shows that at Hole 574A the length of Zone N10 is smaller than expected as compared to N11. Zone N9 is relatively long in Hole 574A, supporting the suggested drop in sedimentation rate in Zone N10 (above 155 m sub-bottom) at Site 574. However, in view of the reservations expressed above on the problems in foraminiferal zonation, such comparisons may not be meaningful.

Comparison of Sites 574 and 289 carbonate records (Site 574 chapter, this volume) suggests that the carbonate record at Site 574 is as complete as at Site 289. Given the continuity suggested by the carbonate records from Sites 574 and 289 and the similarity in the isotopic response of both the $\delta^{18}O$ and $\delta^{13}C$ records at both sites, we suggest that the Hole 574A data may give a reasonable representation of the important transition in the oceanic oxygen isotopic composition during the middle Miocene.

Stable Isotope Records and Implication for Middle Miocene Paleoceanography

The high-resolution oxygen isotopic data from Hole 574A span the interval of the middle Miocene during which a major paleoceanographic and climatic event apparently occurred. The shift in the benthic and planktonic isotopic records from high-latitude sites during the middle Miocene has been inferred to represent the onset of major glaciation in Antarctica (Shackleton and Kennett, 1975). It has been assumed that before this event little ice was present and that changes in $\delta^{18}O$ values of foraminifers reflected changes in oceanic temperatures. This assumption has recently been questioned by Matthews and Poore (1980; see Miller and Thomas, this volume), who suggest that the isotopic shift represents a major cooling of oceanic deep-water masses.

The data from Hole 574A provide some limitations on both of these models. There are a number of mechanisms that can change the benthic isotopic composition in the ocean as measured at any one location. The most important are (1) changes in the volume of water stored as ice sheets; (2) changes in the temperature of the waters overlying the seafloor at the site[3]; and (3) changes in the origin of the overlying waters that may affect the isotopic composition of the water without affecting temperature. Mechanisms (2) and (3) are related but the processes required to change the average temperature of the Pacific Basin as a whole and those required to change the site of deep- and bottom-water mass formation are not necessarily the same.

If we assume that there was no major ice before the middle Miocene event, then the high degree of variability measured in the interval from 168 to 186 m of Hole 574A represents changes either in the benthic temperatures or the benthic water mass at Site 574, or both. The range in $\delta^{18}O$ of 1.1‰ at this time would represent changes in temperatures of over 4°C. Using the estimated sedimentation rates for this site, the dominant frequency of variation is on the order of 40,000 yr. (see below). Because Site 574 is at 4400 m in the central Pacific, we would conclude that on time scales of tens of thousands of years the bottom-water temperatures in the deep Pacific have changed about 2 to 4°C. If the deep-water structure of the Pacific were similar today, a very large volume of water would be responding to changing oceanographic conditions over relatively short periods of time. Thus, if there were no major fluctuations in ice volume during the earliest middle Miocene, the benthic isotopic data from Hole 574A would require considerable variability in the deep-water structure of the Pacific Ocean. Multiple sources of deep water, with contributions varying on time scales similar to the variations seen in Pleistocene records, are suggested. The high correlation between the $\delta^{18}O$ and $\delta^{13}C$ records within the oldest interval studied (Table 3) supports the hypothesis that these records reflect the changing character of the deep-water masses of the Pacific.

A second alternative, however, is that a significant and varying amount of ice was present prior to the middle Miocene isotopic shift. If so, then a major change in the deep-water structure of the Pacific during the middle Miocene is not a necessary requirement, and the high degree of variability observed in the benthic isotopic values of both Sites 289 (Shackleton, 1982) and 574 can be explained by changes in ice volume. The Hole 574A data would then suggest that the volume of ice varied on time scales of a few tens of thousands of years.

The rapidity of the transition is not inconsistent with the hypothesis of significant ice growth. Pleistocene records show that ice sheets, equivalent to a 1.8‰ isotopic shift, waxed and waned on a time scale of 100,000 yr., not unlike the rate estimated from Hole 574A. As pointed out by Matthews and Poore (1980), however, the middle Miocene isotopic enrichment is not seen in tropical planktonic records. By assuming that tropical temperatures have remained constant with time, they conclude that the middle Miocene isotopic shift is a change in deep-ocean temperatures and not an ice-volume signal. However, if it is assumed that the $\delta^{18}O$ values for *Globoquadrina altispira* analyzed in Core 55 of Site 289 correspond to a surface-water temperature of 28°C as implied by the Matthews and Poore (1980) model, this would require ice volumes during the early Miocene greater than that observed during the Pleistocene (Shackleton, 1982).

The uniform magnitude in the isotopic shift observed at Sites 289 and 574 would require a similar temperature change throughout much of the water column of the Pacific. But if the assumption of Matthews and Poore is correct, this temperature change would not be reflected at low latitudes.

The high-resolution data from Site 574 do not allow us to conclusively state which hypothesis concerning the cause of the middle Miocene isotopic shift is correct, but the degree and nature of the variability of the data do place constraints on the oceanographic conditions in the Pacific during the middle Miocene.

Statistical Analysis of Middle Miocene Time Series

One of the original objectives of sampling the HPC section of Site 574 was to obtain long, continuous, paleoceanographic records of high time resolution for de-

[3] Note that we do not use the term *bottom water* to avoid confusion with oceanic bottom-water masses, such as the present-day Antarctic Bottom Water. Sites such as 289 at 2200 m have never experienced true bottom water.

tailed time series work. Time series analysis of high-resolution records available from Pleistocene sediments have been instrumental in developing models describing the causes of climatic change during the past 1 m.y. (Imbrie et al., 1984). These studies have shown that a significant fraction of the variability in the climate and oceans of the Pleistocene reflects a response to the changing configuration of the Earth's orbit (Hays et al., 1976; Kominz et al., 1979; Imbrie et al., 1984). During the late Pleistocene, the nature of the response of the climatic system to orbital forcing was partially related to the response of large Northern Hemisphere ice sheets. During this interval, the long-period component of the Earth's orbit, which is the eccentricity having a dominant 100,000-yr. period of variation, is most strongly reflected in the climate records. During the early Pleistocene when the Northern Hemisphere ice sheets were smaller, the tilt component (a period of 41,000 yr.) of the Earth's orbit geometry dominated the variance spectra of the isotopic records (Pisias and Moore, 1981; Shackleton et al., 1982). Thus, changes in variance spectra of paleoceanographic records have proved useful in developing an understanding of the causes of climate change.

Since variations in the Earth's orbit are not unique to the Pleistocene, we can use HPC material from pre-Pleistocene sections to determine whether variations in oceanographic parameters occur at frequencies similar to those in the Pleistocene, and if time-scale resolution improves, whether such variations are related to responses of the Earth's climate system to orbital changes.

Of the data presently available from Site 574, the interval from 168 to 186 m provides an interval suitable for an initial analysis. In this interval there are no major changes in the means of the oxygen isotopic and carbonate values, and the $\delta^{13}C$ data below the offset at 172 m are a long enough series to provide statistically useful results. The data were converted from a depth sequence to a time series using the sedimentation rate of 32 m/m.y. (site chapter, this volume). This is consistent with additional detailed diatom stratigraphic data from this site (Barron, this volume). The data are plotted versus absolute age in Figure 3. The variance spectra for these data are shown in Figure 4. The method used for calculating the spectra is given in Pisias et al. (1973).

The most striking feature of these spectra is the dominance of a frequency component corresponding to a period of 40,000 yr. in the $\delta^{18}O$ record (Fig. 4A). The similarity of this frequency to that of the orbital tilt component is suggestive of a significant response to orbitally induced changes in solar insolation in the middle Miocene. The presence of this spectral peak, however, is not conclusive proof that orbital variations did cause climate change in this time interval.

The $\delta^{13}C$ spectrum shows a dominance of very long period components in the data. This component is also observed in Plio-Pleistocene $\delta^{13}C$ records and probably relates to the long residence time of carbon in the ocean (100,000 yr.; Broecker, 1974). In addition to the very low frequency component, the carbon isotope spectrum contains spectral components at 46,000 and 26,000 yr. and a high frequency component at 14,000 yr. The latter is also present in the oxygen isotopic data, and cross spectra calculations show that they are related with a coherence of over 0.95. This suggests that during the interval represented by these data, very high frequency variations affecting both the carbon and oxygen isotopic composition of the deep Pacific were present in the middle Miocene. The 26,000-yr. component is near the frequency of variation in orbital precession (23,000 yr. at present-day) and is suggestive of a possible cause. More importantly, the data suggest a response in the carbon isotopic system that is independent of the oxygen isotopes, which do not display this frequency component (Figs. 2 and 3).

The spectrum of the calcium carbonate data displays a pattern very similar to that of Pleistocene records, with a dominant 100,000-yr. component and indications of frequency components at 40,000 and 25,000 yr. The general form of this spectrum is similar to that of upper Pleistocene oxygen isotope records. Again, these results strongly suggest significant variability in the middle Miocene oceans and the possibility that orbitally induced variations in solar insolation (the Milankovitch hypothesis of climate change) was operating at times remote from the late Pleistocene.

CONCLUSIONS

The detailed isotopic and carbonate data from Site 574 clearly show that a high degree of oceanic variability occurred in the early part of the middle Miocene. Initial time series analysis shows that the amplitude and frequency characteristics of the paleoclimate records from Site 574 are comparable to records from the Pliocene and lower Pleistocene. This suggests that the processes controlling climate change during late Cenozoic are likely to have been important prior to 16 Ma.

The detailed analysis of the major shift in the oxygen isotopic composition of the ocean during the middle Miocene shows that this oceanic "event" occurred over a time interval of approximately 30,000 yr. The degree of oceanic variability implied by these data is the same before and after the event. The high degree of variability prior to the middle Miocene must be accounted for in models describing the presence or absence of major continental ice sheets during this interval. Significant variations in ice volume prior to 16 Ma could explain the high degree of variability observed. If ice sheets were not of importance prior to 16 Ma, then the data would suggest a significantly different deep-water structure in the Pacific during the early Miocene.

Finally, the high degree of variability observed in these high-resolution records show the importance of detailed sampling of high-quality sediment sections to aid in defining the true nature of oceanic and climatic variability.

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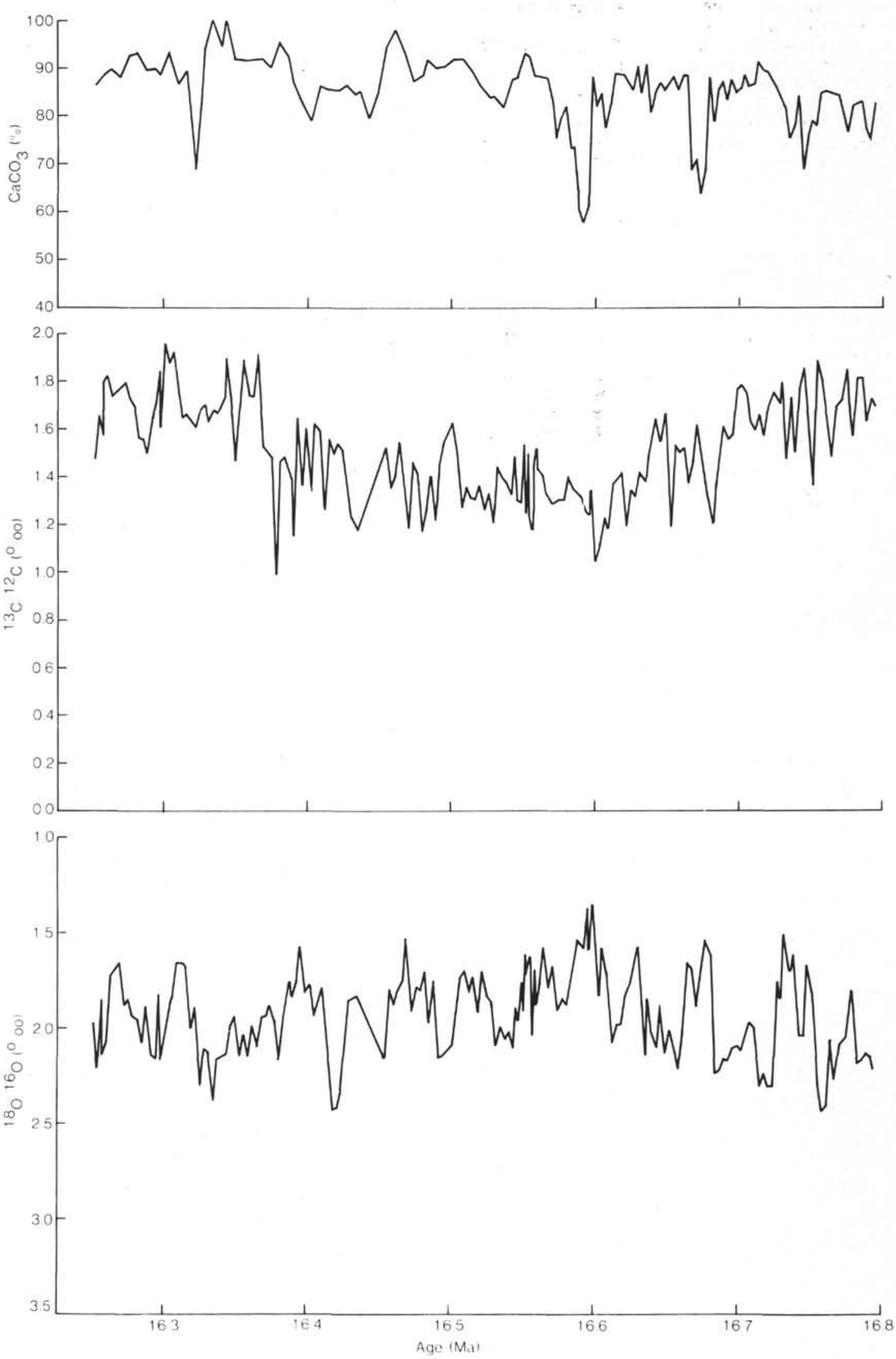

Figure 3. Detailed isotopic and carbonate data for sub-bottom depths from 168 to 188 m (16.2 to 16.8 Ma) in Hole 574A. Ages were derived from sedimentation rate estimates made in the site chapter (this volume).

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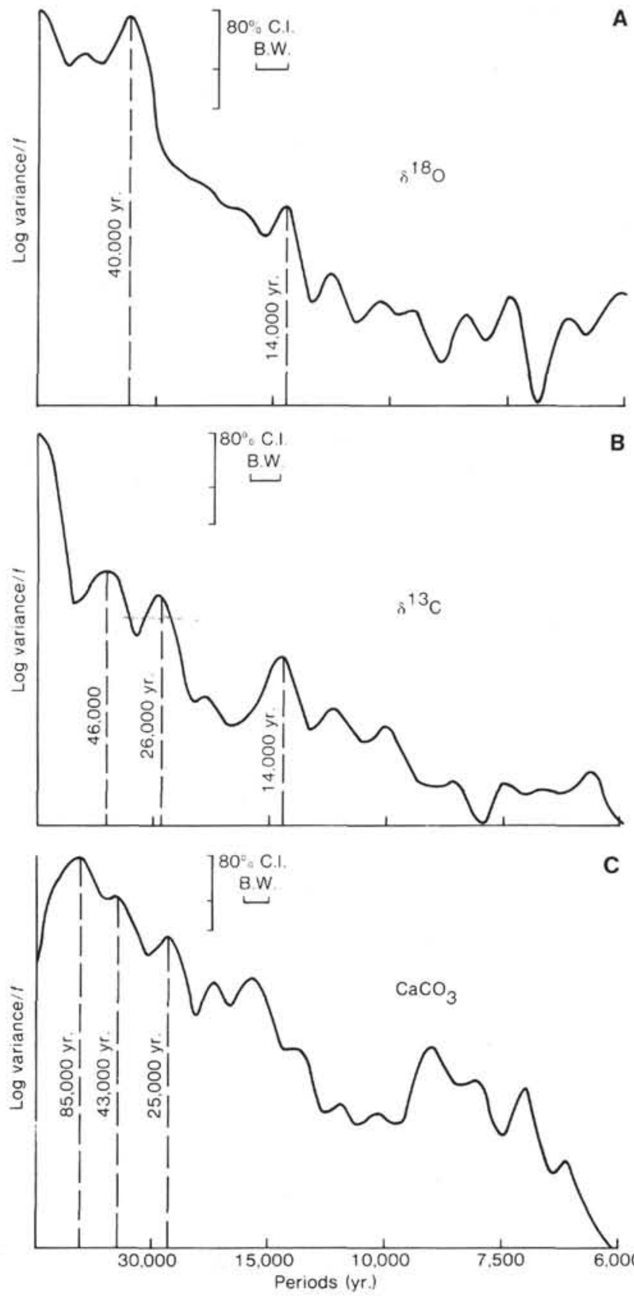

Figure 4. Variance spectra for $\delta^{18}O$, $\delta^{13}C$, and $CaCO_3$ data for 16.2 to 16.8 Ma plotted in Figure 3. Spectra were calculated from 41 lags of the auto-covariance function (Jenkins and Watts, 1968). Time series contained 145 data points sampled at 3,000-yr. intervals. All spectra are plotted on a linear frequency scale versus log variance. Shown are the 80% confidence interval (C.I.) of spectral estimates and the bandwidth (B.W.) used to calculate smoothed spectra. A. Variance spectra for $\delta^{18}O$ record showing the 40,000-yr. spectral peak. B. Variance spectra for $\delta^{13}C$ showing important 46,000, 26,000, and 14,000-yr. peaks and long period components. C. Variance spectra for $CaCO_3$.