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17. Data Report: Oligocene Paleoceanography of the Equatorial Pacific Ocean: Planktonic and Benthic Foraminifer Stable Isotope Results from Site 1218[1]

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ABSTRACT

To document the evolution of the early cryosphere, stable isotope analyses were conducted on the planktonic and benthic foraminifers from Ocean Drilling Program Site 1218. We generated two parallel 54-m-long records at 10-cm resolution and thus produced a standard Pacific stable isotope reference curve for the 26.4- to 30.0-Ma interval within the Oligocene. These data are necessary to document the timing and magnitude of glacial events through the Oligocene. Pronounced variations are recorded in both planktonic and benthic foraminifer $\delta^{13}C$ between +0.32‰ and +1.67‰ and –0.18‰ and +1.09‰, respectively. There is an overall increase in $\delta^{18}O$ though the record, toward heavier values in the late Oligocene.

INTRODUCTION

The Oligocene is the most enigmatic epoch of the Cenozoic and marks the establishment of the "icehouse" world, which continues to the present day. During this period, Antarctica was partially glaciated and permanent ice sheets were absent from the Northern Hemisphere. Previous work has suggested that the volume of the Antarctic ice sheet oscillated through the Oligocene (e.g., Miller et al., 1991); however, until now, cores covering this interval have lacked the necessary resolu-

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tion to document the timing and magnitude of glacial events in the Southern Hemisphere. We investigate the Oligocene climate, using 54-m-long high-resolution benthic and planktonic foraminifer stable isotope records from Ocean Drilling Program (ODP) Site 1218.

Site 1218 (8°53.38′N, 135°22.00′W) is located in the eastern equatorial Pacific Ocean, in a water depth of 4826 m (Shipboard Scientific Party, 2002). At this site, an entire Oligocene sequence was recovered that indicated high sedimentation rates, clear magneto- and biostratigraphy, orbital cyclicity, and abundant foraminifers through most of the Oligocene. This presents the opportunity to examine Oligocene climate and paleoceanography at a much greater resolution than previous studies and provides significant insights into ice volume and sea level changes and their relationship to orbital variations in solar insolation. The high sedimentation rates (average = 15 m/m.y.) and the 10-cm sampling resolution applied here result in an average frequency of 1 sample per 6 k.y. The stable isotopic data from planktonic and benthic foraminifers thus provide a standard isotopic reference curve for the tropical Pacific against which future studies can be compared.

MATERIALS AND METHODS

Stable isotopic data were generated from planktonic and benthic foraminifers from Site 1218. A continuous sequence of sediments was obtained by using multiple holes at Site 1218. We sampled a composite splice from Holes 1218A, 1218B, and 1218C (122–172 meters below seafloor [mbsf]; 137–192 revised meters composite depth [rmcd]), at 5-cm resolution, corresponding to an age range of 26.4–30.0 Ma. The sample set was divided between alternative samples; planktonic and benthic foraminifer samples were washed and prepared at The University of Edinburgh (United Kingdom) and Stockholm University (Sweden), respectively. Each resulting data set is therefore at 10-cm (~6 k.y.) resolution for planktonic and benthic foraminifers.

Samples were washed through a 63-µm mesh and dry-sieved. Multiple specimens (mean $N = 9$) of the planktonic foraminifer *Globoquadrina venezuelana* were picked from the >250-µm size fraction and analyzed isotopically on the Prism III mass spectrometer at The University of Edinburgh. Prior to isotope analysis, specimens were sonicated in methanol to remove attached particles.

For benthic foraminifer analyses, single specimens of *Cibicidoides grimsdalei* and *Cibicidoides havanensis* were picked (mean size = 350–400 µm). To remove organic contaminants, specimens were soaked in hydrogen peroxide (~3%). Specimens were crushed, sonicated in methanol, and oven dried at 50°C. Benthic foraminifers were analyzed isotopically at Stockholm University on a Finnigan MAT-252 mass spectrometer.

To examine the variability of the <63-µm size fraction, we also generated a bulk carbonate stable isotope record. Samples typically weighed 115–130 mg (average = 86 wt% $CaCO_3$). Samples were examined at 10-cm resolution from 147 to 154 rmcd, corresponding to an age of 27.1–27.6 Ma.

All stable isotope data are referenced to the Vienna Peedee belemnite (VPDB) standard and are reported in the delta (δ) notation as permil (‰). Analytical precision estimated by replicate analyses of MAB2B and COR1D standards at The University of Edinburgh and NBS-19, IAEA-CO-1, and CARB-1 standards at Stockholm University yielded standard deviations better than 0.08‰ for $\delta^{18}O$ and 0.05‰ for $\delta^{13}C$. In total, 490 and 688 analyses were performed on planktonic and benthic foraminifers, respectively, including repeat measurements, with 82 analyses of fine-fraction carbonate.

RESULTS

Foraminifer Oxygen Isotope Record

To adjust for vital effects, benthic foraminifer oxygen isotope values were adjusted by +0.64‰ (Shackleton and Opdyke, 1973). The original and corrected benthic isotope results are shown in Table T1. Carbon isotope values were not corrected.

Oxygen isotope values in benthic foraminifers fluctuate between +1.5‰ and +3.1‰ (Fig. F1). There is a small increase (0.4‰) in oxygen isotope values in benthic foraminifers from the early to late part of the record. High-amplitude variations of ~1‰ on the scale of 1.5 to 2.0 m are recorded in the benthic foraminifer oxygen isotope record with longer-term oscillations of heavy $\delta^{18}O$ occurring every ~15 m.

Planktonic foraminifer oxygen isotope values vary between –0.88‰ and +0.91‰ (Fig. F1). Fluctuations every 2 m of ~0.8‰ are evident between 165 and 180 rmcd. Through the record, there is a 1‰ increase in values from a mean of –0.35‰ at 185 rmcd to +0.30‰ at 137 rmcd. From 165 to 158 rmcd, planktonic foraminifer oxygen isotope values increase from –0.59‰ to +0.80‰. Oxygen isotope values then decrease to –0.48‰. There is a prominent short-term increase in $\delta^{18}O$ at 151 rmcd, where oxygen isotope values shift by 1‰ over 1.5 m. Coeval increases (0.7‰ to 1.0‰) in both planktonic and benthic foraminifer $\delta^{18}O$ are recorded at 141.9, 158.8, and 177.3 rmcd.

Foraminifer Carbon Isotope Records

Benthic foraminifer $\delta^{13}C$ values fluctuate between –0.18‰ and +1.09‰ (Fig. F2). In both the planktonic and benthic foraminifer records, intervals of light $\delta^{13}C$ occur every ~6.2 ± 0.8 m. Higher-frequency variability is also evident on 2-m intervals. High-amplitude oscillations (1‰) are recorded in planktonic foraminifer $\delta^{13}C$ between +0.24‰ and +1.57‰ through the Oligocene (Fig F2). Maxima in planktonic (>1.4‰) and benthic $\delta^{13}C$ occur at 141.9, 158.8, and 177.3 rmcd and coincide with increases in $\delta^{18}O$.

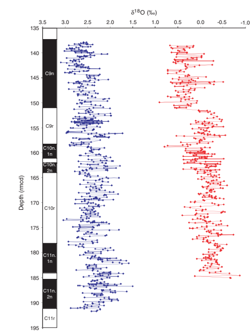
Stable isotope data for planktonic and benthic foraminifer are tabulated in Tables T2 and T1, respectively. Sediment depths are given in three formats: meters below seafloor, meters composite depth, and revised meters composite depth. Ages are detailed for both the Cande and Kent (1995) timescale and the revised astronomical timescale (Pälike et al., unpubl. data). The data are discussed further in Wade and Pälike (2004).

Fine-Fraction Bulk Sediment Isotope Results

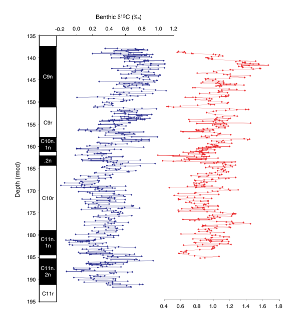
Stable isotope results from fine-fraction bulk analyses reveal large cyclic variations between –0.56‰ and +0.39‰ and +1.94‰ and +1.33‰ for $\delta^{18}O$ and $\delta^{13}C$, respectively (Fig. F3; Table T3). Clear cycles are evident of 1.1 ± 0.4 m in both the oxygen and carbon isotopic records. The

T1. Planktonic foraminifer (*G. venezuelana*) stable isotope data, p. 9.

F1. Planktonic and adjusted benthic foraminifer oxygen isotope data, p. 6.

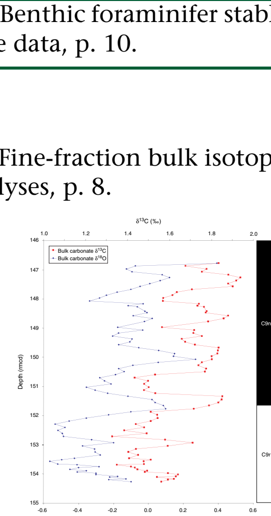


F2. Planktonic and benthic foraminifer carbon isotope data, p. 7.



T2. Benthic foraminifer stable isotope data, p. 10.

F3. Fine-fraction bulk isotopic analyses, p. 8.



T3. Fine-fraction bulk isotope data, p. 11.

bulk isotope data are generally heavier in $\delta^{13}C$ and lighter in $\delta^{18}O$ compared to those of the planktonic foraminifers.

SUMMARY

The detailed stable isotope stratigraphy covering 3.6 m.y. in the Oligocene is the highest-resolution record of this interval yet produced and provides a standard Pacific reference curve for this interval. Pronounced oxygen isotope increases, coupled with maxima in $\delta^{13}C$ in both planktonic and benthic foraminifers, occur at 141.9, 158.8, and 177.3 rmcd. The astronomical timescale, coupled with the benthic and planktonic foraminifer stable isotope records at Site 1218, will allow the timing and magnitude of Southern Hemisphere variations in ice volume to be documented. Both short- and long-term cyclic variations evident in planktonic and benthic foraminifer and fine-fraction stable isotope records are thought to be related to Milankovitch climate oscillations. These data are used to examine orbital variations in solar insolation through the Oligocene and their effect on Antarctic ice volume, tropical productivity, and deep waters (Wade and Pälike, 2004).

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Wade, B.S., and Pälike, H., 2004. Oligocene climate dynamics. *Paleoceanography,* 19(PA4019):10.1029/2004PA001042.

Figure F1. Planktonic and adjusted benthic foraminifer oxygen isotope data from Site 1218. Magnetochronology is shown on the left. Blue = benthic foraminifer oxygen isotopes, red = planktonic foraminifer oxygen isotopes.

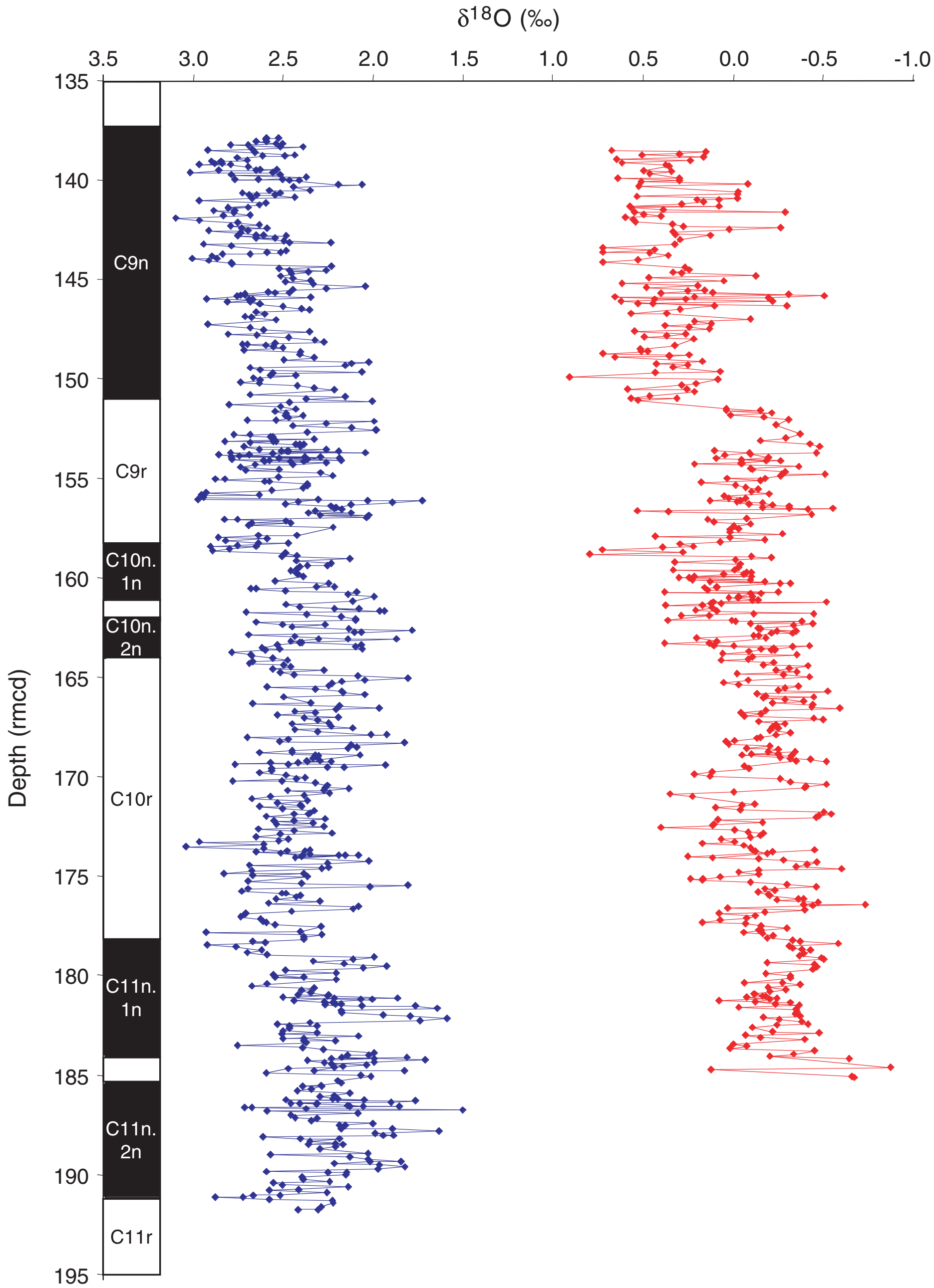

Figure F2. Planktonic and benthic foraminifer carbon isotope data from Site 1218. Magnetochronology is shown on the left.

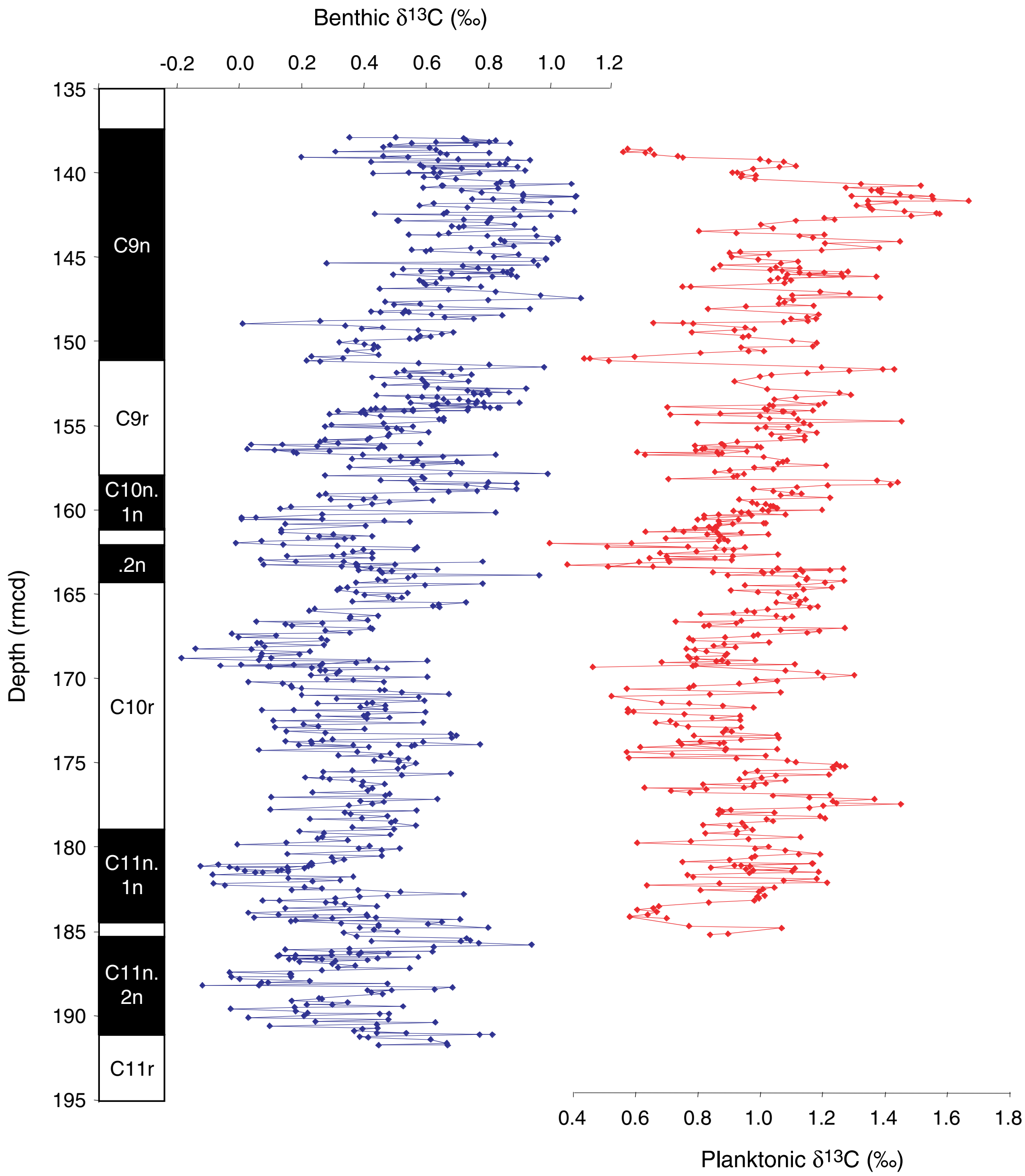

Figure F3. Fine-fraction bulk isotopic analyses from Site 1218. Magnetochronology is shown on the right.

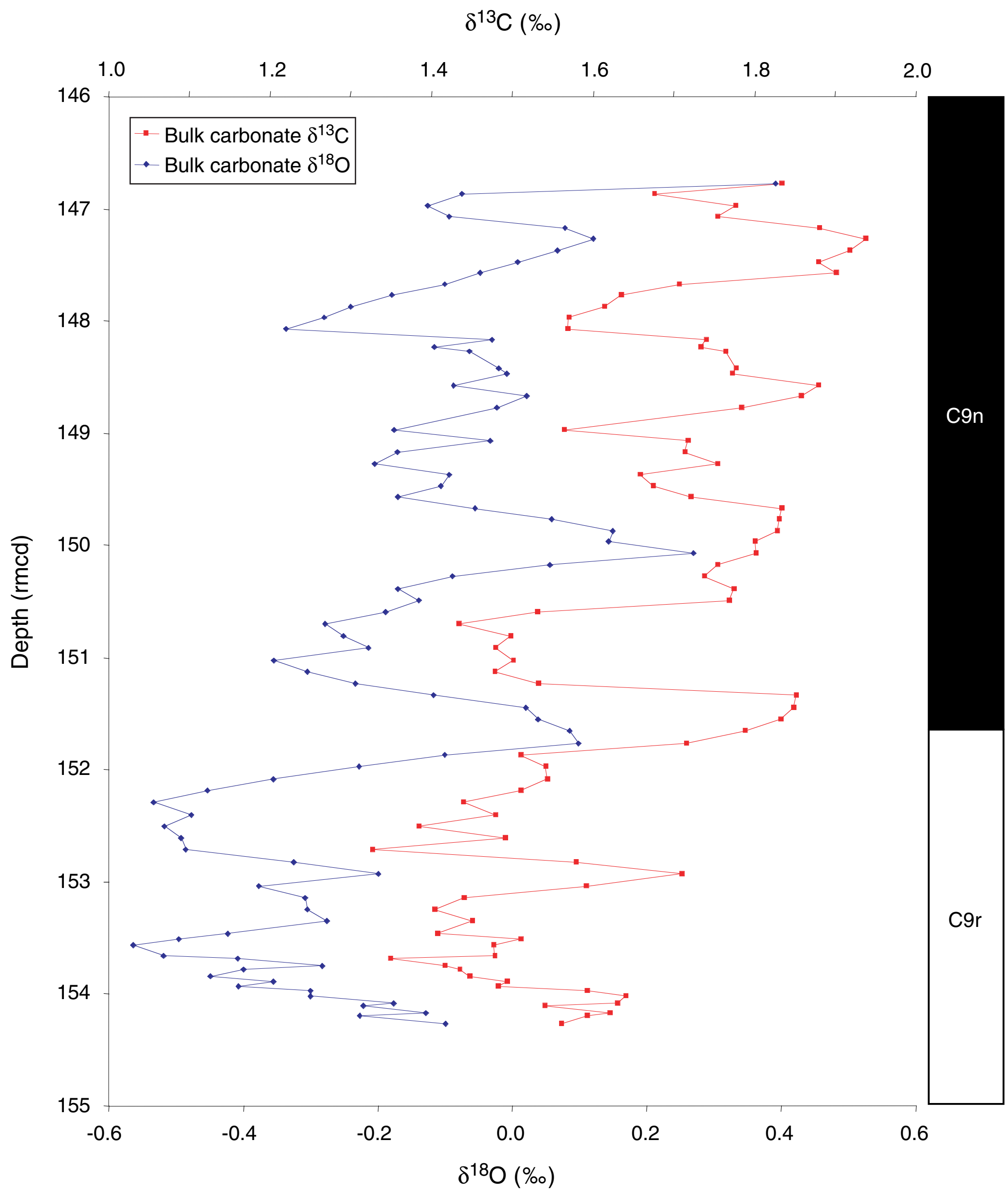

Table T1. Planktonic foraminifer (*Globoquadrina venezuelana*) stable isotope data, Site 1218.

Core, section, interval (cm)*	Depth			Age (Ma)		$\delta^{13}C$	$\delta^{18}O$
	(mbsf)	(mcd)	(rmcd)	CK1995	Calibrated	(‰)	(‰)
199-1218A-							
14H-2, 80	123.00	138.42	138.51	27.105	26.474	0.57	0.68
14H-1, 90	123.10	138.52	138.60	27.111	26.480	0.64	0.15
14H-1, 100	123.20	138.62	138.69	27.117	26.486	0.56	0.30
14H-1, 110	123.30	138.72	138.78	27.123	26.492	0.63	0.51
14H-1, 120	123.40	138.82	138.88	27.129	26.498	0.66	0.16
14H-1, 130	123.50	138.92	138.97	27.135	26.504	0.73	0.65
14H-1, 140	123.60	139.02	139.06	27.141	26.510	0.75	0.24
14H-2, 0	123.70	139.12	139.15	27.147	26.519	1.00	0.62
14H-2, 10	123.80	139.22	139.24	27.153	26.527	1.02	0.38
14H-2, 20	123.90	139.32	139.34	27.160	26.536	1.07	0.36
14H-2, 40	124.10	139.52	139.52	27.172	26.553	1.11	0.50
14H-2, 50	124.20	139.62	139.62	27.178	26.562	1.06	0.34
14H-2, 60	124.30	139.72	139.72	27.185	26.571	0.98	0.46
14H-2, 80	124.50	139.92	139.92	27.198	26.589	0.92	0.30
14H-2, 80	124.50	139.92	139.92	27.198	26.589	0.91	0.64
14H-2, 90	124.60	140.02	140.02	27.205	26.599	0.94	0.30
14H-2, 100	124.70	140.12	140.12	27.211	26.608	0.99	0.51
14H-2, 110	124.80	140.22	140.22	27.218	26.617	0.94	-0.08
14H-2, 120	124.90	140.32	140.32	27.225	26.626	0.98	0.53
14H-3, 0	125.20	140.62	140.62	27.244	26.651	1.32	-0.03
14H-3, 10	125.30	140.72	140.72	27.251	26.660	1.51	-0.02
14H-3, 20	125.40	140.82	140.82	27.258	26.668	1.27	0.54
14H-3, 30	125.50	140.92	140.92	27.264	26.676	1.39	-0.02
14H-3, 40	125.60	141.02	141.02	27.271	26.685	1.36	0.08
14H-3, 40	125.60	141.02	141.02	27.271	26.685	1.38	0.20
14H-3, 50	125.70	141.12	141.12	27.277	26.693	1.39	0.17
14H-3, 60	125.80	141.22	141.22	27.284	26.701	1.45	0.29
14H-3, 70	125.90	141.32	141.32	27.291	26.709	1.55	0.57
14H-3, 70	125.90	141.32	141.32	27.291	26.709	1.29	0.08
14H-3, 80	126.00	141.42	141.42	27.297	26.717	1.48	0.57
14H-3, 90	126.10	141.52	141.52	27.304	26.725	1.55	0.39
14H-3, 100	126.20	141.62	141.62	27.310	26.733	1.67	-0.29
14H-3, 100	126.20	141.62	141.62	27.310	26.733	1.34	0.55
14H-3, 110	126.30	141.72	141.72	27.317	26.741	1.43	0.50
14H-3, 120	126.40	141.82	141.82	27.324	26.749	1.34	0.40
14H-3, 130	126.50	141.92	141.92	27.330	26.757	1.31	0.60
14H-3, 140	126.60	142.02	142.02	27.337	26.765	1.35	0.56
14H-4, 0	126.70	142.12	142.12	27.344	26.773	1.36	0.54
14H-4, 10	126.80	142.22	142.22	27.350	26.781	1.46	0.34
14H-4, 20	126.90	142.32	142.32	27.357	26.789	1.57	0.28
14H-4, 30	127.00	142.42	142.42	27.363	26.797	1.57	-0.26
14H-4, 40	127.10	142.52	142.52	27.370	26.805	1.48	0.02
14H-4, 50	127.20	142.62	142.62	27.377	26.812	1.20	0.33
14H-4, 60	127.30	142.72	142.72	27.383	26.818	1.24	0.32
14H-4, 70	127.40	142.82	142.82	27.390	26.824	1.11	0.13
14H-4, 90	127.60	143.02	143.02	27.403	26.836	1.00	0.30
14H-4, 110	127.80	143.22	143.22	27.416	26.848	1.04	0.33
14H-4, 130	128.00	143.42	143.42	27.429	26.860	0.80	0.72
14H-4, 140	128.10	143.52	143.52	27.436	26.867	0.92	0.44
14H-5, 0	128.20	143.62	143.62	27.443	26.874	1.20	0.73
14H-5, 10	128.30	143.72	143.72	27.449	26.882	1.13	0.46
14H-5, 20	128.40	143.82	143.82	27.456	26.889	1.17	0.36
14H-5, 40	128.60	144.02	144.02	27.469	26.904	1.45	0.53
14H-5, 50	128.70	144.12	144.12	27.476	26.910	1.21	0.73
14H-5, 80	129.00	144.42	144.42	27.496	26.931	1.38	0.27
14H-5, 90	129.10	144.52	144.52	27.502	26.937	1.19	0.24
14H-5, 100	129.20	144.62	144.62	27.509	26.944	0.93	0.33
14H-5, 110	129.30	144.72	144.72	27.515	26.951	0.90	0.29
14H-5, 120	129.40	144.82	144.82	27.522	26.958	1.02	-0.12
14H-5, 130	129.50	144.92	144.92	27.529	26.965	0.91	0.47
14H-6, 0	129.70	145.12	145.12	27.542	26.979	0.99	0.05

Notes: * = top. CK1995 = Cande and Kent, 1995. Only a portion of this table is available here. The complete table is available in ASCII.

Table T2. Benthic foraminifer stable isotope data, Site 1218.

Core, section, interval (cm)*	Depth (mbsf)	Depth (mcd)	Depth (rmcd)	Age (Ma) CK1995	Age (Ma) Calibrated	δ13C (‰)	δ18O (‰)	Adjusted δ18O (‰)	Species
199-1218A-									
14H-1, 15	122.35	137.77	137.91	27.065	26.434	0.35	1.89	2.53	GRIM
14H-1, 15	122.35	137.77	137.91	27.065	26.434	0.50	1.95	2.59	HAV
14H-1, 25	122.45	137.87	138.00	27.071	26.440	0.72	1.96	2.60	HAV
14H-1, 35	122.55	137.97	138.09	27.077	26.446	0.82	1.95	2.59	GRIM
14H-1, 35	122.55	137.97	138.09	27.077	26.446	0.73	2.01	2.65	HAV
14H-1, 45	122.65	138.07	138.18	27.083	26.453	0.80	1.90	2.54	GRIM
14H-1, 45	122.65	138.07	138.18	27.083	26.453	0.63	1.86	2.50	GRIM
14H-1, 55	122.75	138.17	138.28	27.090	26.459	0.87	2.06	2.70	GRIM
14H-1, 55	122.75	138.17	138.28	27.090	26.459	0.55	2.15	2.79	HAV
14H-1, 65	122.85	138.27	138.37	27.096	26.465	0.48	1.87	2.51	GRIM
14H-1, 65	122.85	138.27	138.37	27.096	26.465	0.76	1.75	2.39	HAV
14H-1, 75	122.95	138.37	138.46	27.102	26.471	0.46	2.03	2.67	GRIM
14H-1, 85	123.05	138.47	138.55	27.108	26.477	0.61	2.28	2.92	GRIM
14H-1, 95	123.15	138.57	138.65	27.114	26.483	0.63	2.02	2.66	GRIM
14H-1, 105	123.25	138.67	138.74	27.120	26.489	0.31	1.80	2.44	GRIM
14H-1, 115	123.35	138.77	138.83	27.126	26.495	0.80	1.85	2.49	GRIM
14H-1, 115	123.35	138.77	138.83	27.126	26.495	0.64	1.98	2.62	HAV
14H-1, 125	123.45	138.87	138.92	27.132	26.501	0.66	2.12	2.76	GRIM
14H-1, 135	123.55	138.97	139.01	27.138	26.507	0.46	2.06	2.70	GRIM
14H-1, 145	123.65	139.07	139.11	27.144	26.515	0.54	2.26	2.90	GRIM
14H-1, 145	123.65	139.07	139.11	27.144	26.515	0.20	2.21	2.85	HAV
14H-2, 5	123.75	139.17	139.20	27.150	26.523	0.70	2.24	2.88	GRIM
14H-2, 5	123.75	139.17	139.20	27.150	26.523	0.86	2.19	2.83	HAV
14H-2, 15	123.85	139.27	139.29	27.157	26.531	0.93	2.33	2.97	GRIM
14H-2, 15	123.85	139.27	139.29	27.157	26.531	0.64	2.15	2.79	HAV
14H-2, 25	123.95	139.37	139.38	27.163	26.540	0.42	2.05	2.69	HAV
14H-2, 35	124.05	139.47	139.47	27.169	26.548	0.85	1.99	2.63	HAV
14H-2, 35	124.05	139.47	139.47	27.169	26.548	0.83	1.89	2.53	GRIM
14H-2, 45	124.15	139.57	139.57	27.175	26.557	0.80	2.01	2.65	GRIM
14H-2, 45	124.15	139.57	139.57	27.175	26.557	0.58	2.22	2.86	HAV
14H-2, 55	124.25	139.67	139.67	27.182	26.566	0.89	2.38	3.02	GRIM
14H-2, 55	124.25	139.67	139.67	27.182	26.566	0.59	1.92	2.56	HAV
14H-2, 65	124.35	139.77	139.77	27.188	26.576	0.71	1.87	2.51	GRIM
14H-2, 65	124.35	139.77	139.77	27.188	26.576	0.62	2.15	2.79	HAV
14H-2, 75	124.45	139.87	139.87	27.195	26.585	0.92	1.73	2.37	GRIM
14H-2, 85	124.55	139.97	139.97	27.201	26.594	0.64	2.00	2.64	GRIM
14H-2, 85	124.55	139.97	139.97	27.201	26.594	0.54	2.13	2.77	GRIM
14H-2, 85	124.55	139.97	139.97	27.201	26.594	0.62	1.86	2.50	HAV
14H-2, 95	124.65	140.07	140.07	27.208	26.603	0.43	1.77	2.41	GRIM
14H-2, 95	124.65	140.07	140.07	27.208	26.603	0.77	1.83	2.47	HAV
14H-2, 115	124.85	140.27	140.27	27.221	26.622	0.63	1.55	2.19	GRIM
14H-2, 115	124.85	140.27	140.27	27.221	26.622	0.59	1.42	2.06	HAV
14H-2, 125	124.95	140.37	140.37	27.228	26.630	0.69	1.80	2.44	GRIM
14H-2, 145	125.15	140.57	140.57	27.241	26.647	0.87	1.71	2.35	GRIM
14H-2, 145	125.15	140.57	140.57	27.241	26.647	0.84	1.94	2.58	HAV
14H-3, 5	125.25	140.67	140.67	27.248	26.655	0.83	1.87	2.51	HAV
14H-3, 5	125.25	140.67	140.67	27.248	26.655	1.06	2.08	2.72	GRIM
14H-3, 15	125.35	140.77	140.77	27.254	26.664	0.88	2.00	2.64	GRIM
14H-3, 15	125.35	140.77	140.77	27.254	26.664	0.65	2.05	2.69	HAV
14H-3, 15	125.35	140.77	140.77	27.254	26.664	0.65	1.91	2.55	GRIM
14H-3, 25	125.45	140.87	140.87	27.261	26.672	0.59	1.80	2.44	HAV
14H-3, 35	125.55	140.97	140.97	27.268	26.681	0.83	2.03	2.67	GRIM
14H-3, 45	125.65	141.07	141.07	27.274	26.689	0.71	2.33	2.97	GRIM
14H-3, 55	125.75	141.17	141.17	27.281	26.697	0.78	1.96	2.60	HAV
14H-3, 65	125.85	141.27	141.27	27.287	26.705	0.91	1.99	2.63	HAV
14H-3, 75	125.95	141.37	141.37	27.294	26.713	1.08	2.16	2.80	HAV
14H-3, 75	125.95	141.37	141.37	27.294	26.713	0.91	2.05	2.69	GRIM
14H-3, 85	126.05	141.47	141.47	27.301	26.721	1.08	2.17	2.81	HAV
14H-3, 95	126.15	141.57	141.57	27.307	26.729	0.81	2.13	2.77	GRIM
14H-3, 95	126.15	141.57	141.57	27.307	26.729	0.75	2.25	2.89	HAV
14H-3, 105	126.25	141.67	141.67	27.314	26.737	0.91	2.13	2.77	HAV
14H-3, 115	126.35	141.77	141.77	27.320	26.745	1.00	2.04	2.68	GRIM
14H-3, 125	126.45	141.87	141.87	27.327	26.753	0.62	2.19	2.83	GRIM

Notes: * = top. CK1995 = Cande and Kent, 1995. GRIM = *Cibicidoides grimsdalei*, HAV = *Cibicidoides havanensis*. Only a portion of this table is available here. The complete table is available in **ASCII**.

Table T3. Fine fraction bulk isotope analyses, Site 1218. (See table note. Continued on next page.)

Core, section, interval (cm)*	Depth (mbsf)	Depth (mcd)	Depth (rmcd)	Age (Ma) CK1995	Age (Ma) Calibrated	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
199-1218B-							
15H, 2, 5	128.95	146.77	146.77	27.651	27.100	0.39	1.83
15H, 2, 5	129.05	146.87	146.87	27.657	27.105	–0.08	1.68
15H, 2, 25	129.15	146.97	146.97	27.664	27.110	–0.13	1.78
15H, 2, 35	129.25	147.07	147.07	27.671	27.115	–0.09	1.75
15H, 2, 45	129.35	147.17	147.17	27.677	27.121	0.08	1.88
15H, 2, 55	129.45	147.27	147.27	27.684	27.126	0.12	1.94
15H, 2, 65	129.55	147.37	147.37	27.690	27.131	0.07	1.92
15H, 2, 75	129.65	147.47	147.47	27.697	27.136	0.01	1.88
15H, 2, 85	129.75	147.57	147.57	27.704	27.144	–0.05	1.90
15H, 2, 95	129.85	147.67	147.67	27.710	27.152	–0.10	1.71
15H, 2, 105	129.95	147.77	147.77	27.717	27.160	–0.18	1.63
15H, 2, 115	130.05	147.87	147.87	27.724	27.167	–0.24	1.61
15H, 2, 125	130.15	147.97	147.97	27.730	27.175	–0.28	1.57
15H, 2, 135	130.25	148.07	148.07	27.737	27.183	–0.34	1.57
15H, 2, 145	130.35	148.17	148.17	27.743	27.191	–0.03	1.74
15H, 3, 1	130.41	148.23	148.23	27.747	27.195	–0.12	1.73
15H, 3, 5	130.45	148.27	148.27	27.750	27.198	–0.06	1.76
15H, 3, 20	130.60	148.42	148.42	27.760	27.210	–0.02	1.78
15H, 3, 25	130.65	148.47	148.47	27.763	27.214	–0.01	1.77
15H, 3, 35	130.75	148.57	148.57	27.770	27.220	–0.09	1.88
15H, 3, 45	130.85	148.67	148.67	27.776	27.225	0.02	1.86
15H, 3, 55	130.95	148.77	148.77	27.783	27.231	–0.02	1.78
15H, 3, 75	131.15	148.97	148.97	27.796	27.242	–0.18	1.56
15H, 3, 85	131.25	149.07	149.07	27.803	27.249	–0.03	1.72
15H, 3, 95	131.35	149.17	149.17	27.809	27.255	–0.17	1.71
15H, 3, 105	131.45	149.27	149.27	27.816	27.262	–0.21	1.75
15H, 3, 115	131.55	149.37	149.37	27.823	27.269	–0.09	1.66
15H, 3, 125	131.65	149.47	149.47	27.829	27.276	–0.11	1.67
15H, 3, 135	131.75	149.57	149.57	27.836	27.282	–0.17	1.72
15H, 3, 145	131.85	149.67	149.67	27.842	27.289	–0.06	1.83
15H, 4, 5	131.95	149.77	149.77	27.849	27.296	0.06	1.83
15H, 4, 15	132.05	149.87	149.87	27.856	27.302	0.15	1.83
15H, 4, 25	132.15	149.97	149.97	27.862	27.309	0.14	1.80
15H, 4, 35	132.25	150.07	150.07	27.869	27.316	0.27	1.80
15H, 4, 45	132.35	150.17	150.17	27.876	27.323	0.06	1.75
15H, 4, 55	132.45	150.27	150.28	27.883	27.330	–0.09	1.74
15H, 4, 65	132.55	150.37	150.39	27.890	27.337	–0.17	1.77
15H, 4, 75	132.65	150.47	150.49	27.897	27.344	–0.14	1.77
15H, 4, 85	132.75	150.57	150.60	27.904	27.351	–0.19	1.53
15H, 4, 95	132.85	150.67	150.70	27.911	27.358	–0.28	1.43
15H, 4, 105	132.95	150.77	150.81	27.918	27.365	–0.25	1.50
15H, 4, 115	133.05	150.87	150.92	27.925	27.373	–0.21	1.48
15H, 4, 125	133.15	150.97	151.02	27.932	27.380	–0.35	1.50
15H, 4, 135	133.25	151.07	151.13	27.939	27.387	–0.31	1.48
15H, 4, 145	133.35	151.17	151.23	27.946	27.394	–0.23	1.53
15H, 5, 5	133.45	151.27	151.34	27.953	27.402	–0.12	1.85
15H, 5, 15	133.55	151.37	151.45	27.960	27.412	0.02	1.85
15H, 5, 25	133.65	151.47	151.55	27.967	27.421	0.04	1.83
15H, 5, 35	133.75	151.57	151.66	27.973	27.430	0.09	1.79
15H, 5, 45	133.85	151.67	151.76	27.979	27.439	0.10	1.72
15H, 5, 55	133.95	151.77	151.87	27.984	27.448	–0.10	1.51
15H, 5, 65	134.05	151.87	151.98	27.989	27.458	–0.23	1.54
15H, 5, 75	134.15	151.97	152.08	27.995	27.463	–0.36	1.54
15H, 5, 85	134.25	152.07	152.19	28.000	27.468	–0.45	1.51
15H, 5, 95	134.35	152.17	152.29	28.005	27.473	–0.53	1.44
15H, 5, 105	134.45	152.27	152.40	28.011	27.478	–0.48	1.48
15H, 5, 115	134.55	152.37	152.51	28.016	27.483	–0.52	1.38
15H, 5, 125	134.65	152.47	152.61	28.021	27.488	–0.49	1.49
15H, 5, 135	134.75	152.57	152.72	28.026	27.493	–0.49	1.33
15H, 5, 145	134.85	152.67	152.83	28.032	27.498	–0.33	1.58
15H, 6, 5	134.95	152.77	152.93	28.037	27.503	–0.20	1.71
15H, 6, 15	135.05	152.87	153.04	28.042	27.508	–0.38	1.59
15H, 6, 25	135.15	152.97	153.14	28.048	27.513	–0.31	1.44
15H, 6, 35	135.25	153.07	153.25	28.053	27.526	–0.31	1.40
15H, 6, 45	135.35	153.17	153.36	28.058	27.526	–0.28	1.45
15H, 6, 55	135.45	153.27	153.46	28.064	27.534	–0.42	1.41

Table T3 continued.

Core, section, interval (cm)*	Depth (mbsf)	Depth (mcd)	Depth (rmcd)	Age (Ma) CK1995	Age (Ma) Calibrated	$\delta^{18}O$ (‰)	$\delta^{13}C$ (‰)
15H, 6, 60	135.50	153.32	153.51	28.066	27.542	–0.50	1.51
15H, 6, 65	135.55	153.37	153.57	28.069	27.542	–0.56	1.48
15H, 6, 75	135.65	153.47	153.66	28.074	27.550	–0.52	1.48
15H, 6, 85	135.75	153.57	153.75	28.078	27.556	–0.28	1.42
15H, 6, 95	135.85	153.67	153.84	28.083	27.563	–0.45	1.45
15H, 6, 105	135.95	153.77	153.93	28.087	27.570	–0.41	1.48
15H, 6, 115	136.05	153.87	154.02	28.092	27.576	–0.30	1.64
15H, 6, 125	136.15	153.97	154.11	28.096	27.583	–0.22	1.54
15H, 6, 135	136.25	154.07	154.20	28.101	27.590	–0.23	1.59
199-1218C-							
9H, 5, 95	137.95	153.85	153.69	28.075	27.551	–0.41	1.35
9H, 5, 105	138.05	153.95	153.78	28.080	27.559	–0.40	1.43
9H, 5, 116	138.16	154.06	153.89	28.085	27.566	–0.36	1.49
9H, 5, 125	138.25	154.15	153.98	28.089	27.573	–0.30	1.59
9H, 5, 137	138.37	154.27	154.08	28.095	27.581	–0.18	1.63
9H, 5, 145	138.45	154.35	154.17	28.099	27.587	–0.13	1.62
9H, 6, 5	138.55	154.45	154.26	28.104	27.594	–0.10	1.56

Notes: * = top. CK1995 = Cande and Kent, 1995.