Data report: Pleistocene benthic foraminiferal oxygen and stable carbon isotopes and their application for age models, Hole U1352B, offshore New Zealand[1]

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Chapter contents

Abstract

Integrated Ocean Drilling Program Expedition 317 drilled progradational sequences on the continental shelf and upper slope in the offshore Canterbury Basin on the eastern margin of the South Island of New Zealand. We measured $\delta^{18}O$ and $\delta^{13}C$ values in benthic foraminifers (*Nonionella flemingi*) from the upper 550 meters below seafloor at slope Site U1352. The results of the oxygen isotope ratios in conjunction with nannofossil datum levels allow identification of most of the marine isotope stages (MIS) shown in the LR04 stack since MIS 63 (1.76 Ma).

Introduction

During Expedition 317, three sites were drilled on the continental shelf (84–122 m water depth) and one site was drilled on the upper slope (344 m water depth) (Fig. **F1**) from November 2009 to January 2010 using the D/V *JOIDES Resolution*. The expedition recovered Eocene to Holocene sediment with particular focus on the sequence stratigraphy of the Miocene to Holocene, when sea level change was dominated by glacioeustasy (see the **"Site U1352"** chapter [Expedition 317 Scientists, 2011]). Core recovery at the upper slope Site U1352 was excellent and reached nearly 100% at penetration depths shallower than 550 m core depth below seafloor (CSF-A). We picked tests of benthic foraminiferal species *Nonionella flemingi* from this interval and measured oxygen and stable carbon isotope values.

Oxygen isotope ratios of benthic foraminifers provide an excellent global record of glacial–interglacial cycles, especially since the Pliocene (e.g., LR04 $\delta^{18}O$ stack of Lisiecki and Raymo, 2005). We constructed an age model for Hole U1352B by correlating between the LR04 $\delta^{18}O$ stack and our $\delta^{18}O$ measurements.

Materials and methods

A total of 343 samples were taken from the upper 550 m in Hole U1352B. The cores consist mainly of unconsolidated mud intercalated with fine sand layers. Sediment was sampled using 20 cm^3 plastic tubes. Freeze-dried samples were washed over 125, 250, and 500 µm stacked sieves. From several to ~40 tests of benthic foraminifer *N. flemingi* were picked from subsamples of the medium to fine sand–size fraction (125–500 µm). Three to six well-

[1]Hoyanagi, K., Kawagata, S., Koto, S., Kamihashi, T., and Ikehara, M., 2014. Data report: Pleistocene benthic foraminiferal oxygen and stable carbon isotopes and their application for age models, Hole U1352, offshore New Zealand. *In* Fulthorpe, C.S., Hoyanagi, K., Blum, P., and the Expedition 317 Scientists, *Proc. IODP,* 317: Tokyo (Integrated Ocean Drilling Program Management International, Inc.).
doi:10.2204/iodp.proc.317.208.2014
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preserved tests were selected for isotope analysis from each sample and sonicated repeatedly in methanol for 1–2 min to remove clay-size particles. After removal of impurities from the surfaces of the tests, the tests were broken with a needle and sonicated in methanol to remove internal impurities.

Oxygen and stable carbon isotopic analyses were carried out at the Kochi Core Center using an IsoPrime mass spectrometer. Automated reaction with hot (90°C) phosphoric acid was performed on cleaned samples in individual vials, and the resulting purified CO_2 gas was fed directly into the mass spectrometer. Oxygen isotope results are expressed as per mil (‰) relative to the Vienna Peedee belemnite standard. We measured 21 samples for each measurement cycle. We measured four working standards (NBS 19; $\delta^{18}O$ = –2.2‰ and $\delta^{13}C$ = 1.95‰) at the beginning of each measurement cycle, one additional standard every seven samples, and three further standards at the end of the measurement cycle. Analytical precision is better than 0.14‰ for $\delta^{18}O$ and 0.07‰ for $\delta^{13}C$. We made 369 measurements on the 343 samples because we replicated measurements for 24 of the samples (Tables T1, T2).

Results and correlation with the LR04 stack

A plot of $\delta^{18}O$ versus depth shows a cyclic fluctuation between 1.32‰ and 4.11‰, whereas $\delta^{13}C$ shows a cyclic fluctuation between –1.95‰ and 0.77‰ (Fig. F2). No samples of *N. flemingi* were found from 10.7 to 63.3 m CSF-A, but good $\delta^{18}O$ and $\delta^{13}C$ results were obtained from the rest of the section to 550 m CSF-A at intervals of ~1.5 m. The average sedimentation rate within the upper 550 m is estimated as 22 cm/1000 y (see the "Site U1352" chapter [Expedition 317 Scientists, 2011]). As a result, 1.5 m represents ~7000 y, and we are therefore confident that we can recognize $\delta^{18}O$ and $\delta^{13}C$ fluctuations with cycle periods exceeding ~14,000 y.

Results from coring (see the "Site U1352" chapter [Expedition 317 Scientists, 2011]) suggested that an unconformity lies somewhere between 491.74 and 525.34 m CSF-F, with a hiatus from 1.8 to 2.7 Ma. We use this correlation, together with the seven Pleistocene nannofossil datum levels that fall within the measured section (Table T3; see also the "Site U1352" chapter [Expedition 317 Scientists, 2011]), to correlate the $\delta^{18}O$ record (Fig. F3A) to the global benthic foraminiferal $\delta^{18}O$ LR04 stack of Lisiecki and Raymo (2005) (Fig. F3B) and to plot the Expedition 317 $\delta^{18}O$ record versus age (Fig. F3C). Ultimately, we recognize all of the marine isotope stages (MIS) of the LR04 stack (Lisiecki and Raymo, 2005) except for MIS 3 and 4, which are expected to lie within the interval between 10.7 and 63.3 m CSF-A where *N. flemingi* was absent (Fig. F3C).

A depth-age curve (age model), based on the isotopic correlations, was generated using AnalySeries 2.0.4.3 software (Fig. F4) and indicates that the average sedimentation rate in the upper ~500 m of Hole U1352B is ~28 cm/1000 y. However, sedimentation rates fluctuate; the maximum rate is ~60 cm/1000 y, and the minimum is <10 cm/1000 y.

Acknowledgments

This research used samples and data provided by the Integrated Ocean Drilling Program (IODP). We acknowledge IODP Expedition 317 Co-Chief Scientist Craig Fulthorpe, Staff Scientist Peter Blum, shipboard scientists, technical staff and the captain and crew of the *JOIDES Resolution*. We are grateful to the reviewer, Kenneth Miller, for his helpful comments. Oxygen isotopic measurements were performed under the cooperative research program of the Center for Advanced Marine Core Research, Kochi University (Numbers 10B037, 11A022, 11A020, 12A017, and 12B015). Funding for this research was provided by the Center for Deep Earth Exploration of the Japan Agency for Marine-Earth Science and Technology, Japan Society for the Promotion of Science (Grants in Aid for Scientific Research Number 23340154), and Shinshu University.

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Initial receipt: 14 February 2014
Acceptance: 15 April 2014
Publication: 6 June 2014
MS 317-208

Figure F1. Location of Integrated Ocean Drilling Program Expedition 317 drill sites. This paper focuses on slope Site U1352. Shelf Sites U1351, U1353, and U1354 are also shown together with Ocean Drilling Program (ODP) Site 1119 (Leg 181) and the Clipper exploration well.

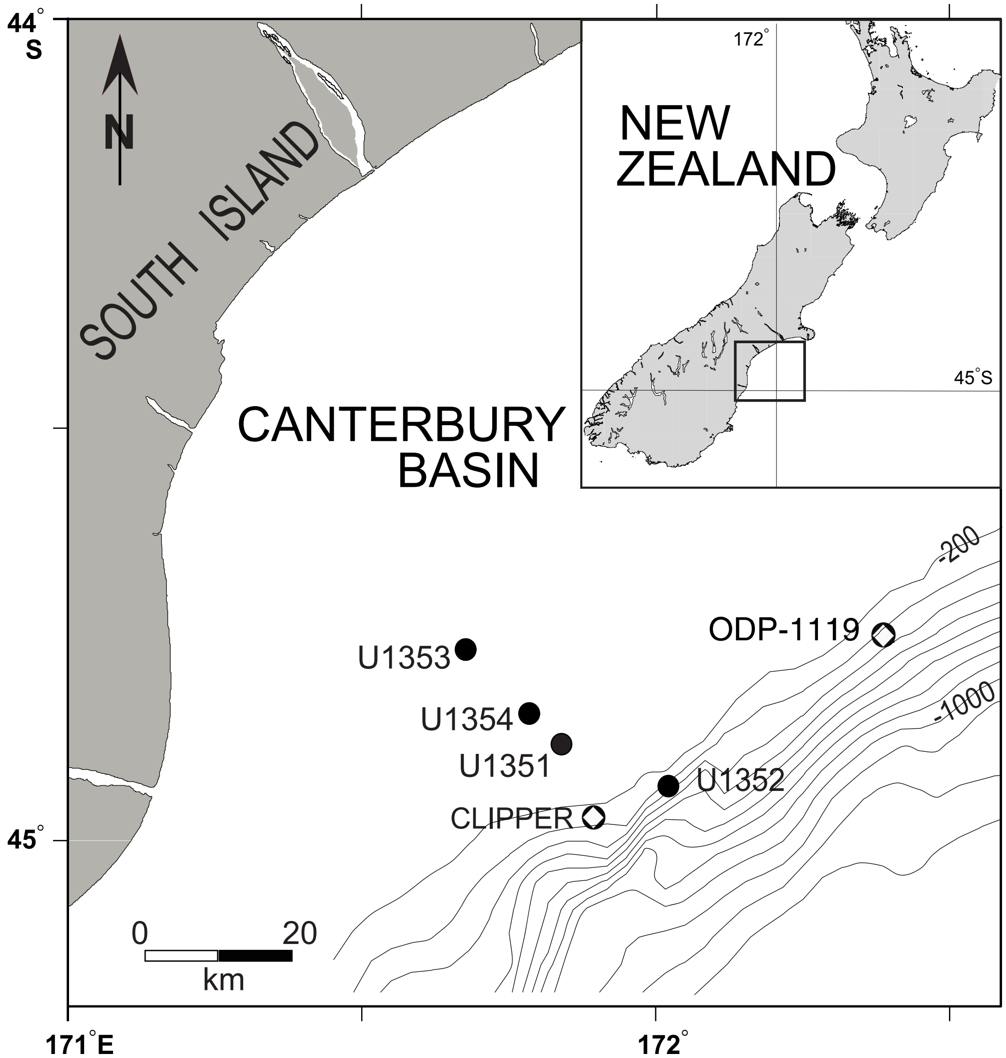

Figure F2. Depth plots of the oxygen and carbon isotope ratios of foraminifer *Nonionella flemingi* tests, Hole U1352B. VPDB = Vienna Peedee belemnite.

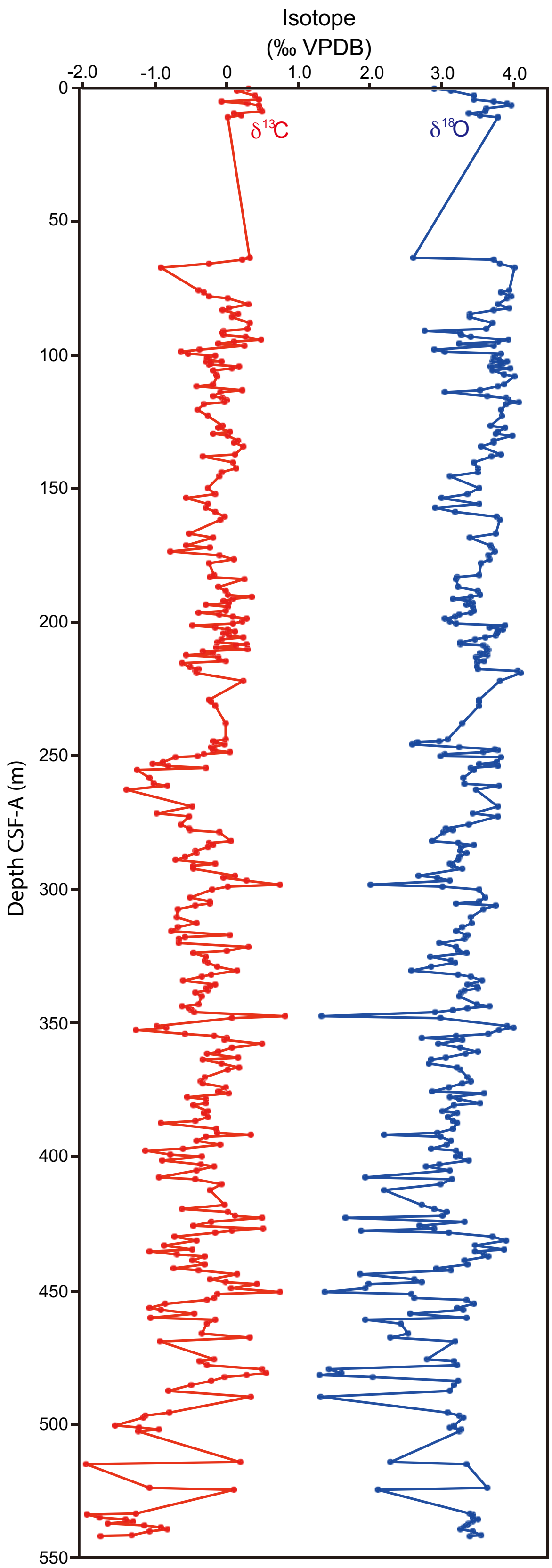

Figure F3. A. Oxygen isotope variations vs. depth from the interval above 550 m CSF-A at Site U1352. Shaded areas indicate nannofossil datum with ages. **B.** Oxygen isotope curve of the LR04 stack (Lisiecki and Raymo, 2005). **C.** Oxygen isotope variations vs. age at Site U1352 rescaled using AnalySeries 2.0.4.3 software.

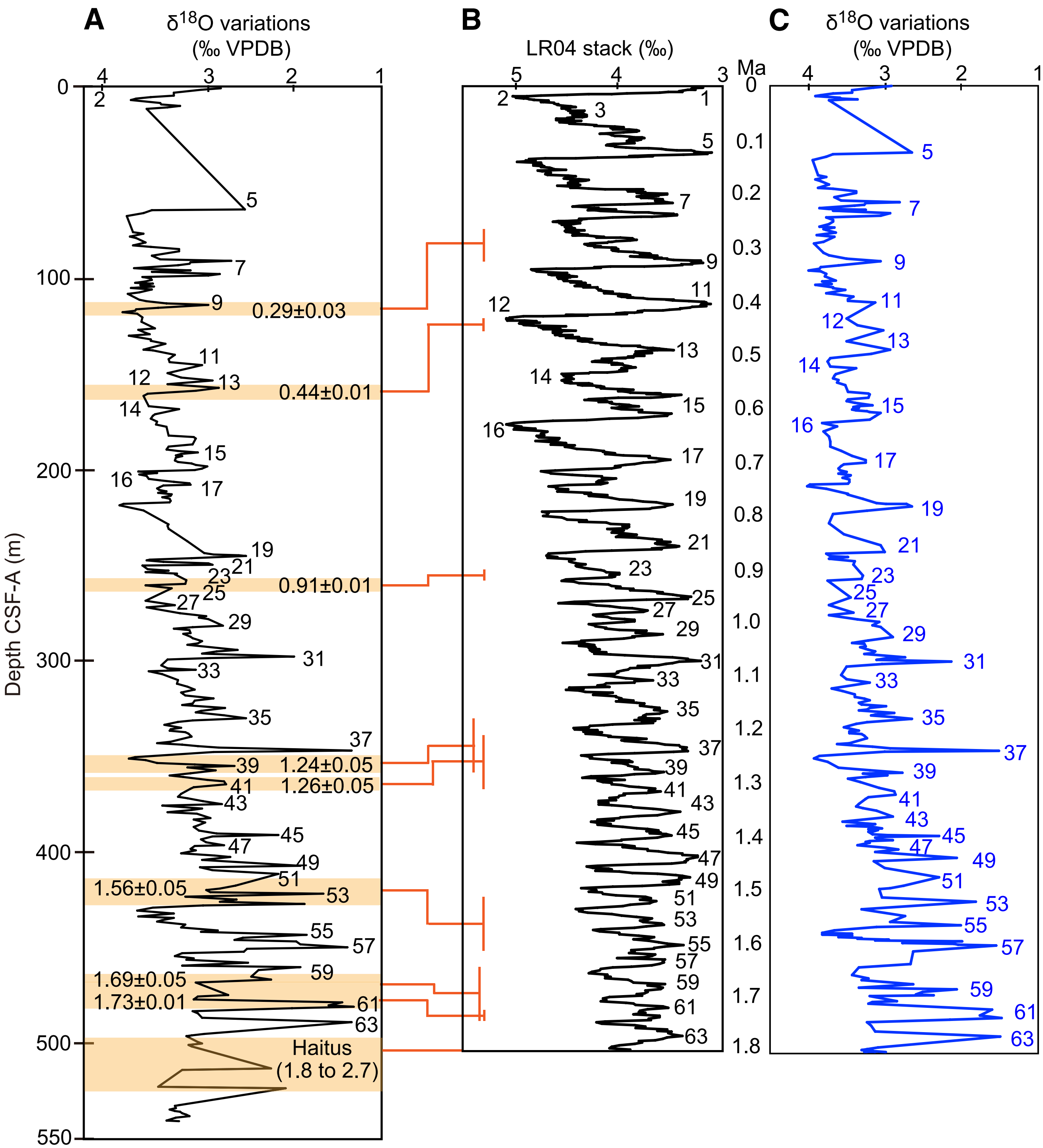

Figure F4. Sedimentation rate curve produced using AnalySeries 2.0.4.3 software, Hole U1352B.

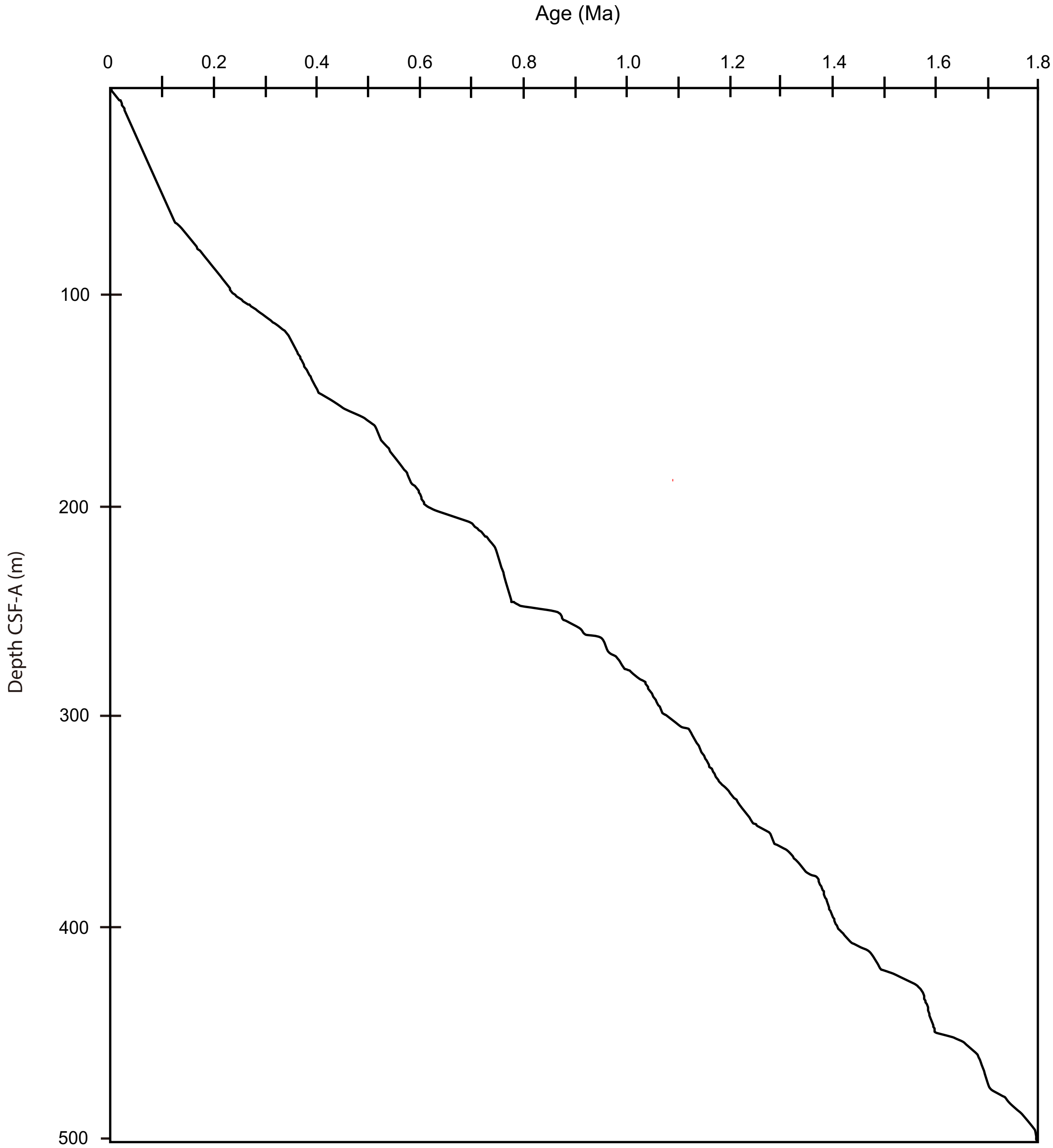

Table T1. Values of oxygen isotope ratio and stable carbon isotope ratio, Hole U1352B. (Continued on next four pages.)

Core, section, interval (cm)	Top depth CSF-A (m)	Middle depth CSF-A (m)	Bottom depth CSF-A (m)	$\delta^{13}C$ (‰ VPDB)	$\delta^{18}O$ (‰ VPDB)	Number of measurements
317-U1352B-						
1H-1, 19–21	0.10	0.20	0.30	0.320	2.918	1
1H-1, 94–96	0.85	0.95	1.05	0.161	3.161	1
1H-2, 94–186	2.35	2.45	2.55	0.407	3.484	1
1H-3, 94–96	3.85	3.95	4.05	0.469	3.480	1
1H-4, 19–21	4.60	4.70	4.80	–0.054	3.762	1
1H-4, 94–96	5.35	5.45	5.55	0.315	3.941	1
1H-5, 19–21	6.10	6.20	6.30	0.472	4.005	1
1H-6, 19–21	7.50	7.60	7.70	0.483	3.651	1
2H-1, 19–21	8.30	8.40	8.50	0.517	3.638	1
2H-1, 94–96	9.05	9.15	9.25	0.122	3.408	1
2H-2, 20–22	9.81	9.91	10.01	0.219	3.561	1
2H-2, 94–96	10.55	10.65	10.75	0.037	3.811	1
7H-6, 19–21	63.30	63.40	63.50	0.332	2.625	1
7H-6, 94–96	64.05	64.15	64.25	0.233	3.751	1
8H-1, 19–21	65.30	65.40	65.50	–0.229	3.847	1
8H-2, 20–22	66.81	66.91	67.01	–0.897	4.046	1
9H-1, 94–96	75.55	75.65	75.75	–0.373	3.973	1
9H-2, 19–21	76.30	76.40	76.50	–0.298	3.853	1
9H-3, 19–21	77.80	77.90	78.00	–0.228	4.007	1
9H-3, 94–96	78.55	78.65	78.75	0.030	3.939	1
9H-5, 19–21	80.80	80.90	81.00	0.321	3.818	1
9H-6, 18–20	82.29	82.39	82.49	0.044	3.980	1
9H-6, 92–94	83.03	83.13	83.23	–0.047	3.757	1
10H-1, 19–21	84.30	84.40	84.50	0.180	3.416	1
10H-2, 95–97	85.32	85.42	85.52	0.091	3.421	1
10H-4, 19–21	87.56	87.66	87.76	0.338	3.746	1
10H-5, 94–96	89.81	89.91	90.01	0.317	3.649	1
10H-6, 19–21	90.56	90.66	90.76	–0.021	2.788	1
10H-6, 94–96	91.31	91.41	91.51	–0.040	3.283	1
10H-7, 20–22	92.07	92.17	92.27	–0.024	3.299	1
10H-7, 94–96	92.81	92.91	93.01	0.279	3.434	1
11H-1, 51–53	94.12	94.22	94.32	0.498	3.964	1
11H-1, 94–96	94.55	94.65	94.75	0.119	3.819	1
11H-2, 16–18	95.27	95.37	95.47	–0.095	3.280	1
11H-2, 94–96	96.05	96.15	96.25	0.273	3.754	1
11H-3, 94–96	97.55	97.65	97.75	–0.368	2.927	1
11H-4, 22–24	98.31	98.41	98.51	–0.626	3.073	1
11H-4, 94–96	99.03	99.13	99.23	–0.517	3.862	1
11H-5, 19–21	99.78	99.88	99.98	–0.142	3.766	1
11H-5, 94–96	100.53	100.63	100.73	–0.261	3.751	1
11H-6, 19–21	101.28	101.38	101.48	–0.236	3.827	1
11H-6, 94–96	102.03	102.13	102.23	–0.057	3.950	1
11H-7, 19–21	102.28	102.38	102.48	–0.274	3.738	1
11H-7, 92–94	103.01	103.11	103.21	–0.198	3.890	1
12H-1, 19–21	103.30	103.40	103.50	–0.236	3.864	1
12H-1, 94–96	104.05	104.15	104.25	0.198	3.718	1
12H-2, 19–21	104.80	104.90	105.00	0.097	3.996	1
12H-2, 94–96	105.55	105.65	105.75	–0.170	3.745	1
12H-3, 94–96	107.01	107.11	107.21	–0.128	3.899	1
12H-4, 19–21	107.76	107.86	107.96	–0.119	4.041	1
12H-6, 19–21	110.76	110.86	110.96	–0.174	3.897	1
12H-6, 94–96	111.51	111.61	111.71	–0.403	3.809	1
13H-1, 19–21	112.80	112.90	113.00	0.243	3.569	1
13H-1, 93–95	113.54	113.64	113.74	–0.073	3.072	1
13H-2, 94–96	115.03	115.13	115.23	–0.173	3.673	1
13H-3, 19–21	115.78	115.88	115.98	–0.042	3.934	1
13H-3, 94–96	116.53	116.63	116.73	0.023	3.953	1
13H-4, 19–21	117.28	117.38	117.48	–0.013	4.104	1
13H-4, 94–96	118.03	118.13	118.23	–0.299	3.930	1
13H-6, 19–21	120.28	120.38	120.48	–0.384	3.860	1
14H-1, 19–21	122.30	122.40	122.50	–0.247	3.879	1
14H-3, 94–96	126.05	126.15	126.25	–0.037	3.712	1
14H-4, 19–21	126.80	126.90	127.00	–0.102	3.915	1
14H-5, 19–21	128.30	128.40	128.50	0.060	3.819	1
14H-5, 94–96	129.05	129.15	129.25	–0.168	3.779	1
14H-6, 19–21	129.80	129.90	130.00	0.034	4.023	1
15H-1, 19–21	131.80	131.90	132.00	0.179	3.757	1

Table T1 (continued). (Continued on next page.)

Core, section, interval (cm)	Top depth CSF-A (m)	Middle depth CSF-A (m)	Bottom depth CSF-A (m)	$\delta^{13}C$ (‰ VPDB)	$\delta^{18}O$ (‰ VPDB)	Number of measurements
15H-1, 84–86	132.45	132.55	132.65	0.123	3.757	1
15H-2, 89–91	134.00	134.10	134.20	0.251	3.578	1
15H-4, 94–96	136.98	137.08	137.18	0.129	3.852	1
15H-5, 19–21	137.60	137.70	137.80	–0.312	3.733	1
15H-6, 94–96	139.85	139.95	140.05	0.108	3.472	1
16H-1, 94–96	142.05	142.15	142.25	0.147	3.542	1
16H-2, 94–96	143.55	143.65	143.75	–0.060	3.534	1
16H-3, 94–96	145.02	145.12	145.22	–0.086	3.143	1
16H-6, 93–95	149.51	149.61	149.71	–0.251	3.553	1
17H-1, 93–95	151.54	151.64	151.74	–0.147	3.395	1
17H-2, 94–96	153.05	153.15	153.25	–0.550	3.022	1
17H-4, 90–92	155.30	155.40	155.50	–0.238	3.553	1
18H-1, 94–96	157.05	157.15	157.25	–0.269	2.937	1
18H-2, 92–94	158.53	158.63	158.73	–0.148	3.216	1
18H-3, 93–95	160.04	160.14	160.24	–0.017	3.801	1
18H-5, 94–96	161.45	161.55	161.65	–0.073	3.844	1
19H-1, 95–97	166.56	166.66	166.76	–0.501	3.790	1
19H-2, 94–96	168.05	168.15	168.25	–0.165	3.418	1
19H-4, 94–96	171.05	171.15	171.25	–0.558	3.715	1
19H-5, 19–21	171.80	171.90	172.00	–0.216	3.730	1
19H-6, 19–21	173.27	173.37	173.47	–0.767	3.766	1
20H-1, 19–21	174.80	174.90	175.00	–0.087	3.686	1
20H-2, 19–21	176.30	176.40	176.50	0.113	3.698	1
20H-3, 19–21	177.48	177.58	177.68	–0.237	3.573	1
21H-2, 94–96	182.05	182.15	182.25	–0.161	3.547	1
21H-3, 19–21	182.80	182.90	183.00	–0.220	3.242	1
21H-3, 94–96	183.55	183.65	183.75	0.269	3.224	1
21H-5, 94–96	186.55	186.65	186.75	–0.097	3.252	1
21H-6, 94–96	188.05	188.15	188.25	0.001	3.542	1
22H-1, 19–21	189.30	189.40	189.50	0.032	3.568	1
22H-1, 94–96	190.05	190.15	190.25	0.371	3.437	1
22H-2, 19–21	190.80	190.90	191.00	0.101	3.189	1
22H-2, 94–96	191.55	191.65	191.75	–0.027	3.399	1
22H-3, 19–21	192.30	192.40	192.50	0.040	3.464	1
22H-3, 93–95	193.04	193.14	193.24	–0.281	3.379	1
22H-4, 19–21	193.80	193.90	194.00	0.036	3.457	1
22H-5, 19–21	195.30	195.40	195.50	–0.003	3.476	1
22H-5, 95–97	196.06	196.16	196.26	–0.371	3.427	1
22H-6, 19–21	196.80	196.90	197.00	–0.085	3.270	1
22H-6, 94–96	197.55	197.65	197.75	0.105	3.219	1
22H-7, 19–21	198.30	198.40	198.50	0.292	3.076	1
23H-1, 94–96	199.55	199.65	199.75	0.243	3.145	1
23H-2, 19–21	200.30	200.40	200.50	0.099	3.235	1
23H-2, 94–96	201.05	201.15	201.25	–0.468	3.916	1
23H-3, 19–21	201.80	201.90	202.00	–0.141	3.690	1
23H-3, 94–96	202.55	202.65	202.75	0.039	3.893	1
23H-4, 19–21	203.30	203.40	203.50	0.131	3.808	1
23H-4, 95–97	204.06	204.16	204.26	–0.028	3.798	1
23H-5, 19–21	204.80	204.90	205.00	0.041	3.791	1
23H-5, 94–96	205.55	205.65	205.75	0.245	3.644	1
23H-6, 19–21	206.30	206.40	206.50	–0.061	3.489	1
23H-6, 94–96	207.05	207.15	207.25	–0.107	3.295	1
23H-7, 19–21	207.80	207.90	208.00	0.289	3.281	1
24H-1, 19–21	208.30	208.40	208.50	0.144	3.609	1
24H-1, 94–96	209.05	209.15	209.25	–0.124	3.646	1
24H-2, 19–21	209.80	209.90	210.00	0.317	3.687	1
24H-2, 93–95	210.54	210.64	210.74	–0.313	3.663	1
24H-3, 19–21	211.30	211.40	211.50	–0.171	3.568	1
24H-3, 94–96	212.05	212.15	212.25	–0.546	3.670	1
24H-4, 19–21	212.80	212.90	213.00	–0.106	3.506	1
24H-4, 94–96	213.55	213.65	213.75	–0.089	3.522	1
24H-5, 18–20	214.29	214.39	214.49	0.005	3.619	1
24H-5, 94–96	215.05	215.15	215.25	–0.608	3.529	1
24H-6, 94–96	216.55	216.65	216.75	–0.491	3.525	1
24H-7, 18–20	217.29	217.39	217.49	–0.382	3.537	1
25H-1, 19–21	217.80	217.90	218.00	–0.427	4.089	1
25H-1, 94–96	218.55	218.65	218.75	–0.411	4.138	1
25H-3, 94–96	221.55	221.65	221.75	0.248	3.849	1
26H-2, 19–21	228.72	228.82	228.92	–0.230	3.551	1
26H-2, 94–96	229.47	229.57	229.67	–0.196	3.558	1

Table T1 (continued). (Continued on next page.)

Core, section, interval (cm)	Top depth CSF-A (m)	Middle depth CSF-A (m)	Bottom depth CSF-A (m)	δ^{13}C (‰ VPDB)	δ^{18}O (‰ VPDB)	Number of measurements
26H-3, 95–97	230.98	231.08	231.18	–0.141	3.549	1
27H-1, 94–96	237.55	237.65	237.75	0.002	3.317	1
27H-5, 94–96	243.55	243.65	243.75	0.004	3.118	1
27H-6, 19–21	244.30	244.40	244.50	–0.165	2.999	1
27H-6, 64–66	244.75	244.85	244.95	–0.148	2.696	1
27H-7, 19–21	245.30	245.40	245.50	–0.013	2.619	1
28H-1, 19–21	246.30	246.40	246.50	–0.201	3.274	1
28H-1, 94–96	247.05	247.15	247.25	–0.160	3.768	1
28H-2, 19–21	247.73	247.83	247.93	–0.173	3.810	1
28H-2, 94–96	248.48	248.58	248.68	0.065	3.603	1
28H-3, 19–21	249.23	249.33	249.43	–0.306	3.070	1
28H-3, 94–96	249.98	250.08	250.18	–0.390	3.011	3
28H-4, 17–19	250.21	250.31	250.41	–0.694	3.856	1
29H-1, 94–96	252.05	252.15	252.25	–0.875	3.796	1
29H-2, 19–21	252.80	252.90	253.00	–1.025	3.544	2
29H-2, 94–96	253.55	253.65	253.75	–0.802	3.821	1
29H-3, 19–21	254.30	254.40	254.50	–0.268	3.441	1
29H-3, 94–96	255.05	255.15	255.25	–1.241	3.472	2
30H-1, 17–19	257.78	257.88	257.98	–1.066	3.333	2
30H-2, 94–96	260.05	260.15	260.25	–1.011	3.340	1
30H-3, 19–21	260.80	260.90	261.00	–0.808	3.828	1
30H-4, 18–20	262.29	262.39	262.49	–1.389	3.506	1
31H-2, 19–21	268.80	268.90	269.00	–0.462	3.821	1
31H-5, 18–20	271.10	271.20	271.30	–0.963	3.470	1
32H-1, 19–22	272.31	272.41	272.51	–0.512	3.815	1
32H-3, 19–21	275.30	275.40	275.50	–0.628	3.404	1
32H-4, 19–21	276.80	276.90	277.00	–0.503	3.091	1
32H-4, 94–96	277.55	277.65	277.75	–0.500	3.183	3
32H-5, 19–21	278.25	278.35	278.45	–0.089	3.061	1
33H-1, 19–21	281.80	281.90	282.00	0.083	2.897	1
33H-1, 93–95	282.54	282.64	282.74	–0.233	3.254	2
33H-2, 19–21	283.21	283.31	283.41	–0.172	3.481	1
33H-3, 19–21	283.98	284.08	284.18	–0.248	3.297	1
33H-4, 94–96	285.49	285.59	285.69	–0.416	3.287	1
33H-5, 19–21	286.24	286.34	286.44	–0.407	3.371	1
33H-6, 19–21	287.72	287.82	287.92	–0.563	3.280	1
34H-2, 19–21	288.56	288.66	288.76	–0.693	3.252	1
34H-3, 18–20	289.98	290.08	290.18	–0.147	3.147	1
34H-4, 23–25	290.91	291.01	291.11	–0.450	3.188	1
34H-5, 97–99	292.02	292.12	292.22	–0.448	3.314	1
35H-2, 19–21	294.44	294.54	294.64	0.140	2.710	1
36H-1, 19–21	295.40	295.50	295.60	–0.023	2.966	1
36H-2, 19–21	296.60	296.70	296.80	0.296	3.137	1
37X-1, 94–96	297.85	297.95	298.05	0.767	2.035	3
37X-2, 19–21	298.60	298.70	298.80	0.035	3.043	1
37X-CC, 19–21	299.65	299.75	299.85	–0.184	3.556	1
38X-1, 19–21	302.70	302.80	302.90	–0.487	3.635	1
38X-2, 19–21	304.20	304.30	304.40	–0.217	3.553	1
38X-2, 94–96	304.95	305.05	305.15	–0.212	3.223	1
38X-3, 19–21	305.70	305.80	305.90	–0.426	3.782	1
38X-4, 19–21	307.20	307.30	307.40	–0.666	3.616	1
38X-6, 19–21	310.20	310.30	310.40	–0.683	3.434	1
39X-1, 19–21	312.30	312.40	312.50	–0.407	3.446	1
39X-2, 19–21	313.80	313.90	314.00	–0.673	3.313	1
39X-3, 19–21	315.30	315.40	315.50	–0.760	3.229	1
39X-4, 19–21	316.80	316.90	317.00	0.066	3.390	1
39X-4, 94–96	317.55	317.65	317.75	–0.563	3.368	2
39X-5, 19–21	318.30	318.40	318.50	–0.652	3.341	1
39X-6, 19–21	319.80	319.90	320.00	–0.656	2.999	1
39X-7, 19–21	321.10	321.20	321.30	0.323	3.235	1
40X-1, 94–96	322.75	322.85	322.95	0.022	3.261	1
40X-2, 19–21	323.50	323.60	323.70	–0.450	3.383	1
40X-3, 19–21	325.00	325.10	325.20	–0.275	2.864	1
40X-4, 19–21	326.50	326.60	326.70	–0.286	3.156	1
40X-4, 94–96	327.25	327.35	327.45	–0.243	3.215	1
40X-5, 94–96	328.75	328.85	328.95	–0.119	2.880	1
40X-6, 94–96	330.25	330.35	330.45	0.161	2.607	1
41X-1, 19–21	331.60	331.70	331.80	–0.207	3.258	1
41X-1, 94–96	332.35	332.45	332.55	–0.328	3.429	1
41X-2, 94–96	333.85	333.95	334.05	–0.600	3.595	1

Table T1 (continued). (Continued on next page.)

Core, section, interval (cm)	Top depth CSF-A (m)	Middle depth CSF-A (m)	Bottom depth CSF-A (m)	δ13C (‰ VPDB)	δ18O (‰ VPDB)	Number of measurements
41X-3, 94–96	335.35	335.45	335.55	–0.141	3.389	1
41X-4, 19–21	336.10	336.20	336.30	–0.222	3.521	1
41X-4, 94–96	336.85	336.95	337.05	–0.278	3.530	1
41X-5, 19–21	337.60	337.70	337.80	–0.239	3.346	1
41X-5, 94–96	338.35	338.45	338.55	–0.423	3.308	1
41X-6, 94–96	339.85	339.95	340.05	–0.326	3.273	1
42X-2, 19–21	342.70	342.80	342.90	–0.377	3.524	2
42X-2, 94–96	343.45	343.55	343.65	–0.610	3.690	1
42X-3, 19–21	344.20	344.30	344.40	–0.501	3.385	1
42X-3, 94–96	344.95	345.05	345.15	–0.472	3.187	1
42X-4, 19–21	345.70	345.80	345.90	–0.439	2.940	1
42X-5, 18–20	347.19	347.29	347.39	0.837	1.345	2
42X-5, 94–96	347.95	348.05	348.15	0.092	3.008	1
43X-1, 20–22	350.81	350.91	351.01	–0.962	3.950	1
43X-1, 95–97	351.56	351.66	351.76	–0.836	4.028	1
43X-2, 19–21	352.30	352.40	352.50	–1.254	3.828	1
43X-3, 19–21	353.80	353.90	354.00	–0.560	3.679	2
43X-3, 94–96	354.55	354.65	354.75	–0.152	3.230	1
43X-4, 19–21	355.30	355.40	355.50	0.021	2.753	1
43X-4, 94–96	356.05	356.15	356.25	–0.010	3.324	1
43X-5, 94–96	357.55	357.65	357.75	0.521	2.977	1
43X-6, 94–96	359.05	359.15	359.25	0.092	3.282	1
44X-1, 19–21	360.50	360.60	360.70	–0.106	3.535	1
44X-1, 94–96	361.25	361.35	361.45	–0.257	3.365	1
44X-2, 94–96	362.75	362.85	362.95	0.178	3.081	1
44X-3, 19–21	363.50	363.60	363.70	–0.312	2.876	1
44X-4, 19–21	365.00	365.10	365.20	–0.060	2.854	1
44X-5, 19–21	366.50	366.60	366.70	0.189	3.239	1
44X-5, 94–96	367.25	367.35	367.45	0.036	3.281	1
45X-1, 19–21	370.10	370.20	370.30	–0.296	3.392	1
45X-2, 19–21	371.60	371.70	371.80	–0.340	3.432	1
45X-2, 94–96	372.35	372.45	372.55	–0.319	3.318	1
45X-3, 94–96	373.85	373.95	374.05	0.002	3.134	1
45X-4, 94–96	375.35	375.45	375.55	–0.100	2.899	1
45X-5, 19–21	376.10	376.20	376.30	0.045	3.628	1
45X-6, 19–21	377.60	377.70	377.80	–0.540	3.141	1
45X-6, 94–96	378.35	378.45	378.55	–0.279	3.272	1
46X-1, 19–21	379.70	379.80	379.90	–0.274	3.560	1
46X-1, 94–96	380.45	380.55	380.65	–0.446	3.204	1
46X-3, 19–21	382.68	382.78	382.88	–0.243	3.046	1
46X-3, 94–96	383.43	383.53	383.63	–0.302	3.247	1
46X-4, 94–96	384.93	385.03	385.13	–0.240	3.106	1
46X-5, 94–96	386.43	386.53	386.63	–0.426	3.193	1
46X-6, 19–21	387.18	387.28	387.38	–0.900	3.245	1
47X-1, 18–20	389.29	389.39	389.49	–0.132	3.183	1
47X-2, 19–21	390.80	390.90	391.00	–0.108	2.967	2
47X-2, 93–95	391.54	391.64	391.74	0.349	2.217	1
47X-3, 19–21	392.30	392.40	392.50	–0.269	3.018	1
47X-4, 18–20	393.79	393.89	393.99	–0.406	3.156	1
47X-5, 18–20	395.29	395.39	395.49	–0.074	3.096	1
47X-6, 18–20	396.79	396.89	396.99	–0.591	2.883	1
47X-6, 93–95	397.54	397.64	397.74	–1.125	3.230	1
48X-1, 19–21	398.80	398.90	399.00	–0.772	3.286	1
48X-1, 94–96	399.55	399.65	399.75	–0.331	3.223	1
48X-2, 94–96	401.05	401.15	401.25	–0.882	3.401	1
48X-3, 94–96	402.55	402.65	402.75	–0.351	2.993	2
48X-4, 19–21	403.30	403.40	403.50	–0.161	2.806	1
48X-5, 19–21	404.80	404.90	405.00	–0.404	3.140	1
48X-7, 19–21	407.60	407.70	407.80	–0.936	1.957	1
49X-1, 19–21	408.40	408.50	408.60	–0.419	3.168	1
49X-2, 19–21	409.90	410.00	410.10	–0.059	3.013	1
49X-3, 93–95	412.14	412.24	412.34	–0.214	2.224	1
50X-1, 19–21	418.00	418.10	418.20	–0.012	2.741	1
50X-2, 19–21	419.50	419.60	419.70	–0.611	2.930	2
50X-2, 98–100	420.29	420.39	420.49	0.033	3.098	2
50X-3, 94–96	421.75	421.85	421.95	0.138	3.041	2
50X-4, 19–21	422.50	422.60	422.70	0.520	1.682	1
50X-5, 19–21	424.00	424.10	424.20	–0.195	3.348	1
50X-6, 19–21	425.50	425.60	425.70	–0.450	2.721	1
50X-7, 19–21	426.80	426.90	427.00	0.527	2.925	2

Table T1 (continued).

Core, section, interval (cm)	Top depth CSF-A (m)	Middle depth CSF-A (m)	Bottom depth CSF-A (m)	$\delta^{13}C$ (‰ VPDB)	$\delta^{18}O$ (‰ VPDB)	Number of measurements
51X-1, 19–21	427.60	427.70	427.80	0.087	1.903	1
51X-1, 95–97	428.36	428.46	428.56	–0.140	3.127	1
51X-2, 95–97	429.86	429.96	430.06	–0.718	3.734	1
51X-3, 95–97	431.36	431.46	431.56	–0.400	3.924	1
51X-4, 94–96	432.85	432.95	433.05	–0.852	3.489	1
51X-5, 95–97	434.36	434.46	434.56	–0.467	3.906	1
51X-6, 19–21	435.10	435.20	435.30	–1.066	3.488	1
51X-7, 19–21	436.30	436.40	436.50	–0.689	3.620	1
52X-1, 19–21	437.20	437.30	437.40	–0.286	3.679	1
52X-2, 19–21	438.70	438.80	438.90	–0.467	3.348	1
52X-3, 19–21	440.20	440.30	440.40	–0.296	3.397	2
52X-4, 19–21	441.70	441.80	441.90	–0.726	2.957	1
52X-4, 94–96	442.45	442.55	442.65	–0.380	3.157	1
52X-5, 93–95	443.94	444.04	444.14	0.167	1.882	1
52X-6, 94–96	445.45	445.55	445.65	–0.213	2.647	1
53X-1, 19–21	446.80	446.90	447.00	–0.001	2.749	1
53X-1, 95–97	447.56	447.66	447.76	0.442	2.004	1
53X-2, 94–96	449.05	449.15	449.25	0.071	1.953	1
53X-3, 94–96	450.55	450.65	450.75	0.760	1.388	1
53X-4, 19–21	451.30	451.40	451.50	–0.115	2.605	1
53X-5, 19–21	452.80	452.90	453.00	–0.160	2.641	2
53X-5, 94–96	453.55	453.65	453.75	–0.262	3.383	1
53X-6, 95–97	455.03	455.13	455.23	–0.848	3.474	1
54X-1, 19–21	456.40	456.50	456.60	–1.060	3.248	1
54X-1, 94–96	457.15	457.25	457.35	–0.895	3.335	1
54X-2, 94–96	458.65	458.75	458.85	–0.437	2.588	1
54X-3, 94–96	460.15	460.25	460.35	–1.053	3.379	1
54X-4, 19–21	460.90	461.00	461.10	–0.137	1.962	1
54X-5, 19–21	462.40	462.50	462.60	–0.264	2.460	1
55X-1, 19–21	466.00	466.10	466.20	–0.326	2.551	1
55X-2, 17–19	467.48	467.58	467.68	0.340	2.305	1
55X-3, 19–21	469.00	469.10	469.20	–0.912	3.217	1
56X-1, 19–21	475.60	475.70	475.80	–0.155	2.825	1
56X-1, 94–96	476.35	476.45	476.55	–0.364	3.195	1
56X-2, 94–96	477.85	477.95	478.05	–0.264	3.240	1
56X-3, 94–96	479.35	479.45	479.55	0.520	1.455	1
56X-4, 94–96	480.85	480.95	481.05	0.568	1.621	1
56X-5, 19–21	481.60	481.70	481.80	0.298	1.319	1
56X-5, 94–96	482.35	482.45	482.55	–0.017	2.057	1
56X-6, 94–96	483.85	483.95	484.05	–0.194	3.256	1
57X-1, 19–21	485.20	485.30	485.40	–0.482	3.198	1
57X-2, 94–96	487.45	487.55	487.65	–0.805	3.140	1
57X-4, 19–21	489.70	489.80	489.90	0.353	1.338	1
58X-2, 94–96	495.77	495.87	495.97	–0.779	3.117	1
58X-3, 19–21	496.52	496.62	496.72	–1.122	3.269	1
58X-3, 94–96	497.27	497.37	497.47	–1.157	3.337	1
58X-5, 95–97	500.28	500.38	500.48	–1.539	3.194	1
58X-6, 19–21	501.02	501.12	501.22	–1.203	3.143	1
58X-6, 94–96	501.77	501.87	501.97	–0.931	3.306	1
58X-7, 19–21	502.52	502.62	502.72	–1.217	3.274	1
60X-1, 18–20	513.99	514.09	514.19	0.205	2.312	1
60X-CC, 19–20	514.71	514.81	514.91	–1.952	3.381	1
61X-1, 19–21	523.60	523.70	523.80	–1.067	3.674	1
61X-2, 19–21	524.60	524.70	524.80	0.127	2.129	1
62X-1, 19–21	533.20	533.30	533.40	–1.248	3.418	1
62X-1, 84–86	533.85	533.95	534.05	–1.937	3.466	1
62X-2, 19–21	534.70	534.80	534.90	–1.757	3.464	2
62X-2, 94–96	535.45	535.55	535.65	–1.392	3.533	1
62X-3, 19–21	536.20	536.30	536.40	–1.294	3.466	1
62X-3, 94–96	536.95	537.05	537.15	–1.648	3.403	1
62X-4, 19–21	537.70	537.80	537.90	–1.130	3.377	2
62X-4, 94–96	538.45	538.55	538.65	–0.898	3.332	2
62X-5, 19–21	539.20	539.30	539.40	–0.821	3.293	1
62X-5, 94–96	539.95	540.05	540.15	–1.064	3.464	2
62X-6, 94–96	541.45	541.55	541.65	–1.308	3.577	2
62X-7, 19–21	541.70	541.80	541.90	–1.744	3.414	1

Values are plotted on each middle depth in Figures F2 and F3. VPDB = Vienna Peedee belemnite.

Table T2. Samples on which multiple measurements were made and their values of $\delta^{18}O$ and $\delta^{13}C$, Hole U1352B.

Core, section, interval (cm)	$\delta^{18}O$ (‰ VPDB)				$\delta^{13}C$ (‰ VPDB)			
	1	2	3	Average	1	2	3	Average
317-U1352B-								
28H-3, 94–96	2.993	2.899	3.140	3.011	–0.576	–0.294	–0.298	–0.390
29H-2, 19–21	3.602	3.485		3.544	–0.972	–1.078		–1.025
29H-3, 94–96	3.522	3.421		3.472	–1.152	–1.329		–1.241
30H-1, 17–19	3.326	3.340		3.333	–1.120	–1.011		–1.066
32H-4, 94–96	3.117	3.082	3.350	3.183	–0.583	–0.506	–0.412	–0.500
33H-1, 93–95	3.315	3.193		3.254	–0.211	–0.255		–0.233
37X-1, 94–96	2.128	1.956	2.020	2.035	0.579	0.859	0.862	0.767
39X-4, 94–96	3.257	3.479		3.368	–0.588	–0.538		–0.563
42X-2, 19–21	3.391	3.657		3.524	–0.322	–0.431		–0.377
42X-5, 18–20	1.328	1.362		1.345	0.856	0.818		0.837
43X-3, 19–21	3.661	3.698		3.679	–0.556	–0.565		–0.560
47X-2, 19–21	2.880	3.054		2.967	–0.138	–0.077		–0.108
48X-3, 94–96	2.922	3.065		2.993	–0.327	–0.375		–0.351
50X-2, 19–21	2.877	2.983		2.930	–0.622	–0.601		–0.611
50X-2, 98–100	3.065	3.130		3.098	0.130	–0.063		0.033
50X-3, 94–96	2.979	3.103		3.041	0.073	0.202		0.138
50X-7, 19–21	2.920	2.930		2.925	0.480	0.574		0.527
52X-3, 19–21	3.286	3.507		3.397	–0.203	–0.389		–0.296
53X-5, 19–21	2.350	2.932		2.641	–0.265	–0.054		–0.160
62X-2, 19–21	3.455	3.473		3.464	–1.730	–1.783		–1.757
62X-4, 19–21	3.390	3.364		3.377	–1.099	–1.161		–1.130
62X-4, 94–96	3.356	3.308		3.332	–0.882	–0.914		–0.898
62X-5, 94–96	3.378	3.549		3.464	–0.896	–1.232		–1.064
62X-6, 94–96	3.511	3.643		3.577	–1.577	–1.038		–1.308

Averages of the multiple measurement values are shown in Table T1. VPDB = Vienna Peedee belemnite.

Table T3. Nannofossil bioevents, Hole U1352B.

Datum (Ma)	Bioevent and hiatus	Depth CSF-A (m)		Core, section	
		Top	Bottom	Top	Bottom
				317-U1352B-	317-U1352B-
0.29 (±0.03)	LO *Emiliania huxleyi* (Zone NN21 base)	112.82	121.1	12H-CC	13H-CC
0.44 (±0.01)	HO *Pseudoemiliana lacunosa* (Zone NN20 base)	155.99	164.18	17H-CC	18H-CC
0.91 (±0.01)	HCO *Reticulofenestra asanoi*	257.09	266.92	29H-CC	30H-CC
1.24 (±0.05)	HO *Gephyrocapsa* >6.5 µm	348.59	360.08	42X-CC	43X-CC
1.26 (±0.05)	HO *Gephyrocapsa* >5.5 µm	360.08	369.96	43X-CC	44X-CC
1.56 (±0.05)	LO *Gephyrocapsa* >5.5 µm	412.3	427.34	49X-CC	50X-CC
1.69 (±0.05)	HO *Gephyrocapsa* >4 µm	463.67	469.84	54X-CC	55X-CC
1.73 (±0.01)	LO *Gephyrocapsa caribbeanica*	469.84	484.83	55X-CC	56X-CC
1.8–2.8	Hiatus	491.74	525.34	57X-CC	61X-CC
2.78 (±0.1)	HO *Reticulofenestra ampla*	525.34	542.58	61X-CC	62X-CC

Bioevent data (see the "Site U1352" chapter [Expedition 317 Scientists, 2011]) is used to constrain oxygen isotope stages correlation presented in Figure F3. LO = lowest occurrence, HO = highest occurrence, HCO = highest common occurrence.