Data report: benthic foraminiferal stable isotope records at Site U1344, Integrated Ocean Drilling Program Expedition 323[1]

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Chapter contents

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Abstract

A high-resolution benthic carbon and oxygen stable isotope record for marine isotope Stages (MIS) 1–6 at Site U1344 in the Bering Sea is presented here. In addition, a low-resolution record is provided for the remaining part of the stratigraphic section recovered at the site, which spans the past 1.9 My. Sediment samples were analyzed from Holes U1344A, U1344D, and U1344E, which were cored proximal to the Beringian continental slope (59°03′N, 179°12′W; 3184 m water depth) during Integrated Ocean Drilling Program Expedition 323. Primarily, two benthic foraminiferal species, *Uvigerina senticosa* and *Elphidium batialis* (both shallow infauna) were used for isotopic measurements. In their absence, *Valvulineria sadonica, Globobulimina pacifica,* and *Nonionella labradorica* were used. An offset of 0.9‰ in the oxygen isotopic composition between *U. senticosa* and *E. batialis* was observed. The average sedimentation rate for the last two glacial–interglacial cycles (upper 64 m core composite depth below seafloor [CCSF-A]) was ~40 cm/ky regardless of its water depth (>3000 m).

Introduction

Oxygen isotope stratigraphy has been widely used in paleoceanographic studies to determine relative ages of sediments by comparison of benthic foraminiferal oxygen isotope ($\delta^{18}O$) data to the composite LR04 global stack curve (Lisiecki and Raymo, 2005). In general, the subarctic Pacific and its marginal seas are known to have poor $CaCO_3$ preservation in sediments. During Integrated Ocean Drilling Program (IODP) Expedition 323, seven sites (U1339–U1345) were drilled in the Bering Sea along a depth transect ranging from ~800 to 3200 meters below seafloor (mbsf) and covering three different regions of the marginal sea: the Umnak Plateau, the Bowers Ridge, and the Bering lower slope region (see the **"Expedition 323 summary"** chapter [Expedition 323 Scientists, 2011a]). Of these, we targeted Site U1344 for this study because a continuous record of benthic foraminifers was documented during onboard biostratigraphic work (see the "**Expedition 323 summary**" chapter [Expedition 323 Scientists, 2011a). At ~3200 m water depth, Site U1344 is the deepest site drilled during Expedition 323. It is located along the small summit of a submarine-canyon interfluvial proximal to the Beringian continental slope north of the Aleutian Basin (59°03′N, 179°12′W). The site presently lies below the oxygen minimum zone (OMZ) and is both the coldest in temperature and the highest in dissolved oxygen among the sites cored during Expedition 323 (see the "Site U1344" chapter [Expedition 323 Scientists, 2011b]; see the "Expedition 323 summary" chapter [Expedition 323 Scientists, 2011a). Furthermore, Site U1344 lies under an area of high biological sea-surface productivity near the maximum extent of present-day seasonal sea-ice cover. These parameters play an important role in supplying nutrients to the seafloor and to benthic organisms (see the "Site U1344" chapter [Expedition 323 Scientists, 2011b]; Alvarez Zarikian, in press). Carbon isotopes ($\delta^{13}C$) of benthic foraminiferal shells reflect the carbon isotopic composition of dissolved inorganic carbon in deep/pore water, in which the shell calcified (McCorckle et al., 1990; Ravelo and Hillaire-Marcel, 2007), recording their microhabitat.

For this data report, carbon and oxygen ($\delta^{13}C$ and $\delta^{18}O$) stable isotopes were measured in the shells of benthic foraminifers to establish an oxygen isotope stratigraphy for Site U1344. The established record consists of a high-resolution portion extending from the seafloor to 64 m core composite depth below seafloor (CCSF-A) (equivalent to the past ~140 ky) and a low-resolution portion from this depth to the bottom of the Site U1344 record (~750 mbsf in Hole U1344A). The complete stratigraphic section recovered at Site U1344 spans the past ~1.9 My (see the "Site U1344" chapter [Expedition 323 Scientists, 2011b]).

Methods and materials

0–64 m CCSF-A (MIS 1–6)

A total of 336 subsamples (40 cm³) were taken from Cores 323-U1344A-1H through 6H, 323-U1344D-1H through 7H, and 323-U1344E-1H through 6H following the site's composite depth scale (0–64 m CCSF-A) at a sample spacing of 10 cm. Sediment samples were freeze-dried and washed on a 63 µm mesh sieve and then dried in an oven at 40°C. Dry samples were sieved through a 250 µm mesh. Two benthic foraminiferal species, *Uvigerina senticosa* and *Elphidium batialis,* were picked for isotope measurements. Both species are shallow infauna (Bubenshchikova et al., 2008; Asahi et al., in press). Three specimens of each species were used for each measurement. Brownish shells were excluded.

64–750 m CCSF-A (Pleistocene)

A total of 145 samples with an individual volume of 30–40 cm³ and spanning the overall stratigraphic section recovered at Site U1344 (746.6 m) were taken from Holes U1344A and U1344D at a sampling resolution of four samples per core (each core is approximately 9.5 m long). Shipboard results (see the "Site U1344" chapter [Expedition 323 Scientists, 2011b]) suggested that multiple species would be necessary to obtain a complete and continuous isotope record spanning the ~750 m section recovered from Hole U1344A because not a single benthic foraminifer species occurred abundantly and uninterruptedly throughout the cored sediment sequence. Therefore, the two most ubiquitous and abundant foraminifers (*E. batialis* and *Valvulineria sadonica*) were used to generate the isotope record. In samples where these taxa are absent or occur in very low abundance, the species *U. senticosa, Globobulimina pacifica,* and *Nonionella labradorica* were selected. Planktonic foraminifers are present and very low in abundance overall, and a planktonic oxygen isotope stratigraphy could not be established.

Cleaning procedures and stable isotopic analyses

Stable isotopic analyses were carried out at two different laboratories: the Center for Advanced Marine Core Research at Kochi University, Japan (KOCHI), and the Stable Isotope Geoscience Facility at Texas A&M University, USA (TAMU).

Cleaning of benthic foraminiferal shells followed a conventional procedure: crushing and cleaning by ultrasonification with 99.5% methyl alcohol and Milli-Q water (Asahi et al., in press). The cleaning steps were repeated two times. After confirming under a stereo microscope that all dirt had been removed, shells were rinsed in Milli-Q water and dried in an oven at 40°C overnight.

Dried samples used for the high-resolution section were analyzed using IsoPrime mass spectrometry with the Multicarb preparation system at Kochi University along with part of the samples from the low-resolution section. Analyses were calibrated to the NBS-19 standard ($\delta^{13}C$ = +1.95‰, Vienna Peedee belemnite [VPDB]; $\delta^{18}O$ = –2.20‰, VPDB), and the average analytical errors for $\delta^{13}C$ and $\delta^{18}O$ were less than 0.06‰ and 0.10‰, respectively. Benthic foraminifer samples used from the low-resolution section were measured on a KIEL IV carbonate device coupled to a 10 kV Thermo Scientific MAT 253 isotope ratio mass spectrometer at TAMU. The external precisions of the KIEL IV for $\delta^{13}C$ and $\delta^{18}O$ are 0.03‰ and 0.07‰, respectively.

The oxygen isotope species–specific offset between *U. senticosa* and *E. batialis* at Site U1344 was calculated at 0.9‰ ± 0.2‰ (1σ, N = 127), which is very close to the offset (0.82‰ ± 0.22‰) calculated between these species at nearby Site U1343 (Asahi et al., in press). Therefore, to correct the species-specific offset, $\delta^{18}O$ values of *E. batialis* were adjusted by +0.9‰.

Age model

The age model for the uppermost 64 m CCSF-A at Site U1344 was established by correlating the derived composite $\delta^{18}O$ record to the LR04 global stack (Lisiecki and Raymo, 2005). The comparison was made using the dynamic "MATCH 2.3" program (Lisiecki and Lisiecki, 2002). Prior to matching, all data were normalized. No biostratigraphic- or magnetostratigraphic-based age-depth tie points were provided prior to the matching process. The age model for the remaining part of the record (from ~64 to ~800 mbsf) is from shipboard stratigraphy (see the **"Site U1344"** chapter [Expedition 323 Scientists, 2011b]).

Results

Carbon and oxygen stable isotope records derived from the benthic foraminifers at Site U1344 are shown in Figures **F1** and **F2.** Data are provided in Table **T1.**

Abundance of benthic foraminifers at Site U1344 drops significantly downhole with no single species occurring continuously throughout the record. Noticeably, *Uvigerina*, which is relatively abundant in the upper 270 m CCSF-A of the stratigraphic section, is absent from all examined samples below that depth to the base of the record (~1.9 Ma) (see the **"Site U1344"** chapter [Expedition 323 Scientists, 2011b]). In samples where neither *U. senticosa* nor *E. batialis* are present, specimens of *V. sadonica, G. pacifica,* or *N. labradorica* were picked and analyzed. Analysis of different benthic foraminifer species allowed us to compare the stable isotopic composition of these species (Fig. **F2**) and infer their microhabitat preferences. Previous studies show a direct correlation between microhabitat depth within the sediment and the $\delta^{13}C$ composition of benthic foraminifers (McCorckle et al., 1990; Ravelo and Hillaire-Marcel, 2007). Deep-dwelling infaunal species are generally isotopically lighter than species living at the sediment/water interface. Figure **F2** shows the relationship between the $\delta^{18}O$ and $\delta^{13}C$ composition of *U. senticosa, E. batialis, V. sadonica, G. pacifica,* and *N. labradorica*. Of these, *U. senticosa* exhibits the highest and most narrow range of $\delta^{13}C$ values of the four species (approximately –1.0‰), whereas *E. batialis* shows the lightest values (average = –2.9‰) and widest $\delta^{13}C$ range. Both *Uvigerina* spp. and *E. batialis* are known as shallow infaunal species (e.g., Bubenshchikova et al., 2008; Asahi et al., in press), whereas *V. sadonica* and *G. pacifica* are considered intermediate infaunal species (Bubenshchikova et al., 2008). However, the lightest $\delta^{13}C$ values in *E. batialis* found at Site U1344 suggest that this species may live deeper in the sediment than previously known or may preferentially feed on more degraded organic matter such as phytodetritus.

The correlation of the Site U1344 composite benthic $\delta^{18}O$ record with the LR04 global stack curve (Lisiecki and Raymo, 2005) provides a high-resolution age model at Site U1344 for the last 140 ky. (Figs. **F3, F4;** Table **T2**). The interval of marine isotope Stages (MIS) 1–6 were identified on the composite $\delta^{18}O$ record from the seafloor to 64 m CCSF-A (Fig. **F4**). The age-depth plot (Fig. **F5**) reveals high sedimentation rates with an average of ~46 cm/ky at Site U1344 over the last ~120 ky. During MIS 6 and 5e, relatively low sedimentation rates (~30 cm/ky) were observed (Fig. **F5**). Because of scarce $\delta^{18}O$ data, the chronology during MIS 5d and 5e is ambiguous (Fig. **F5**).

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Figure F1. Downhole records of benthic foraminiferal stable isotope records, Site U1344. **A.** δ^{13}C data. **B.** δ^{18}O data. VPDB = Vienna Peedee belemnite.

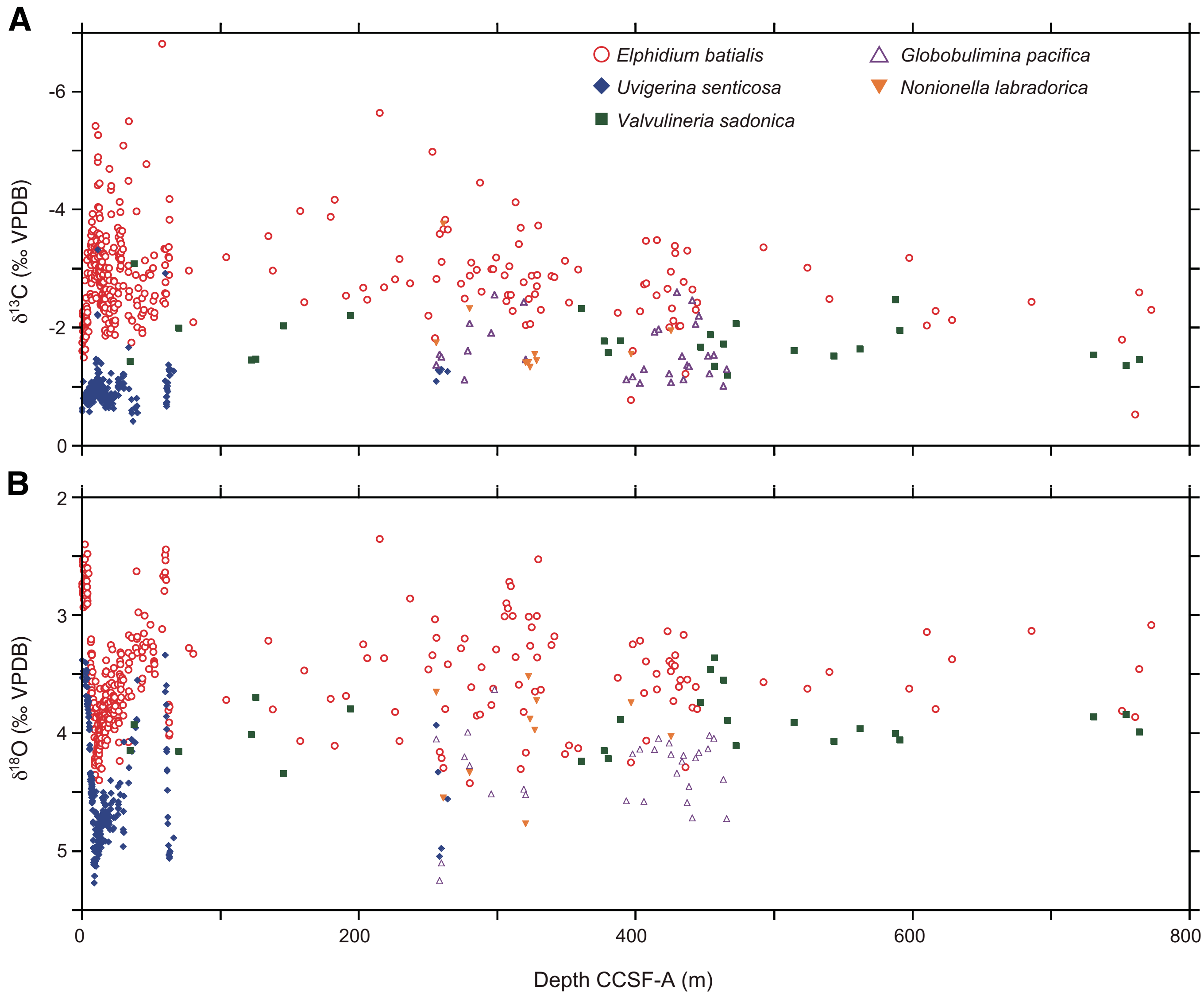

Figure F2. Relationship between the $\delta^{13}C$ and $\delta^{18}O$ isotopic compositions of benthic foraminifers, Site U1344. VPDB = Vienna Peedee belemnite.

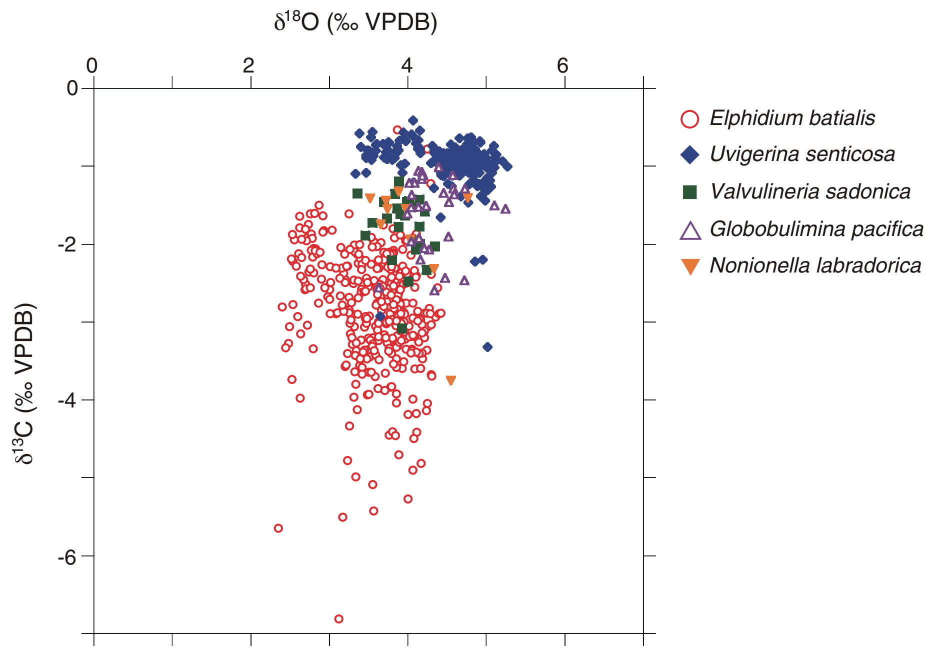

Figure F3. Benthic foraminiferal stable isotope records for the uppermost 64 m CCSF-A, Site U1344. **A.** $\delta^{13}C$ data. **B.** $\delta^{18}O$ data. **C.** Composite $\delta^{18}O$ data. VPDB = Vienna Peedee belemnite.

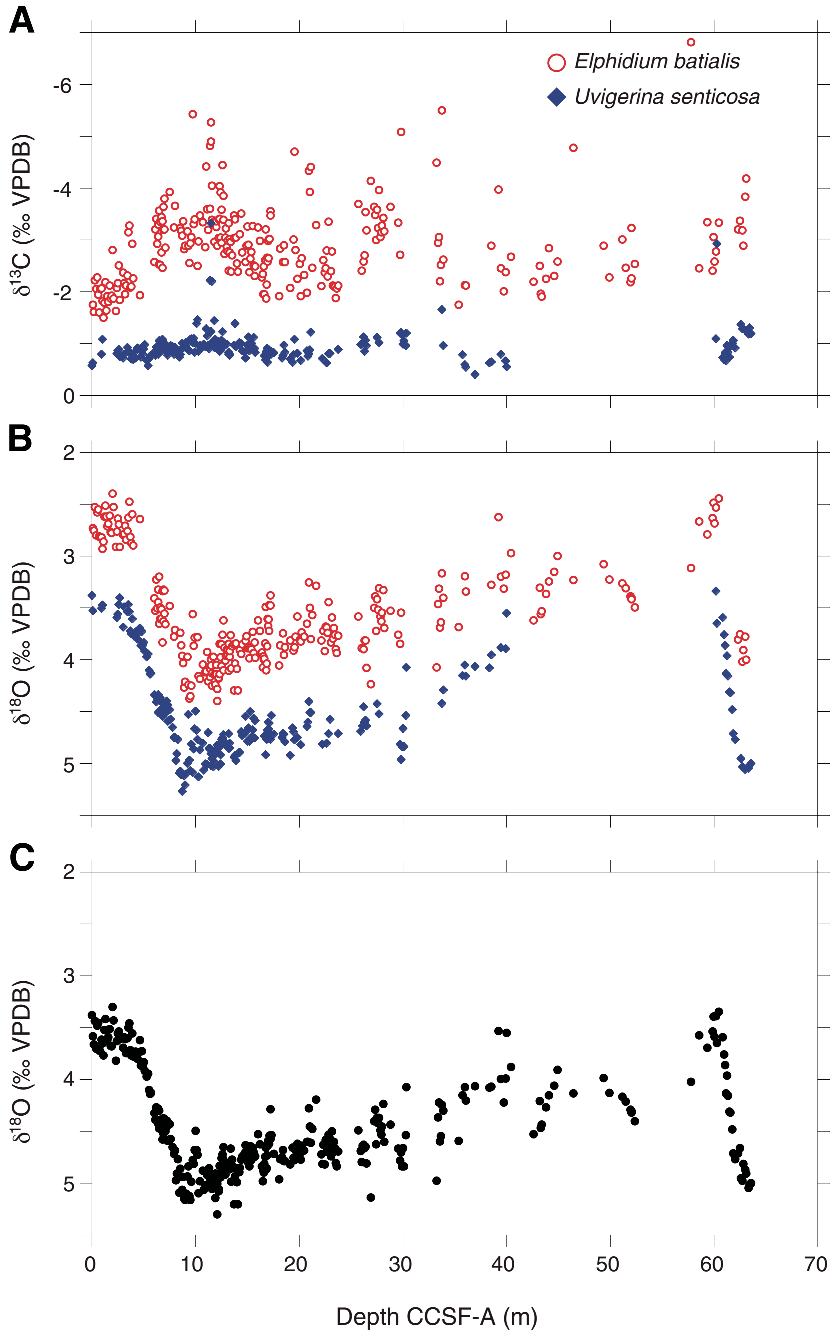

Figure F4. $\delta^{18}O$ stratigraphy for the uppermost 64 m CCSF-A (black line) correlated to the LR04 global stack (gray line), Site U1344. See Lisiecki and Raymo (2005). MIS = marine isotope stage, VPDB = Vienna Peedee belemnite.

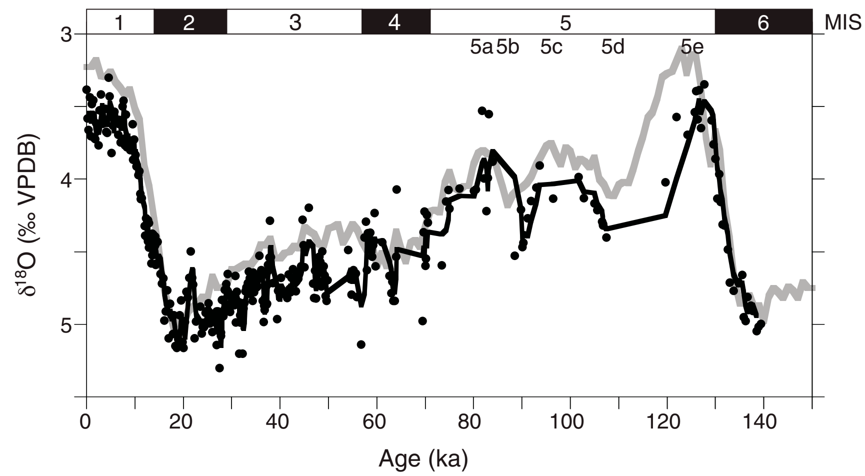

Figure F5. Depth-age plot for the uppermost 64 m CCSF-A based on $\delta^{18}O$ stratigraphy, Site U1344.

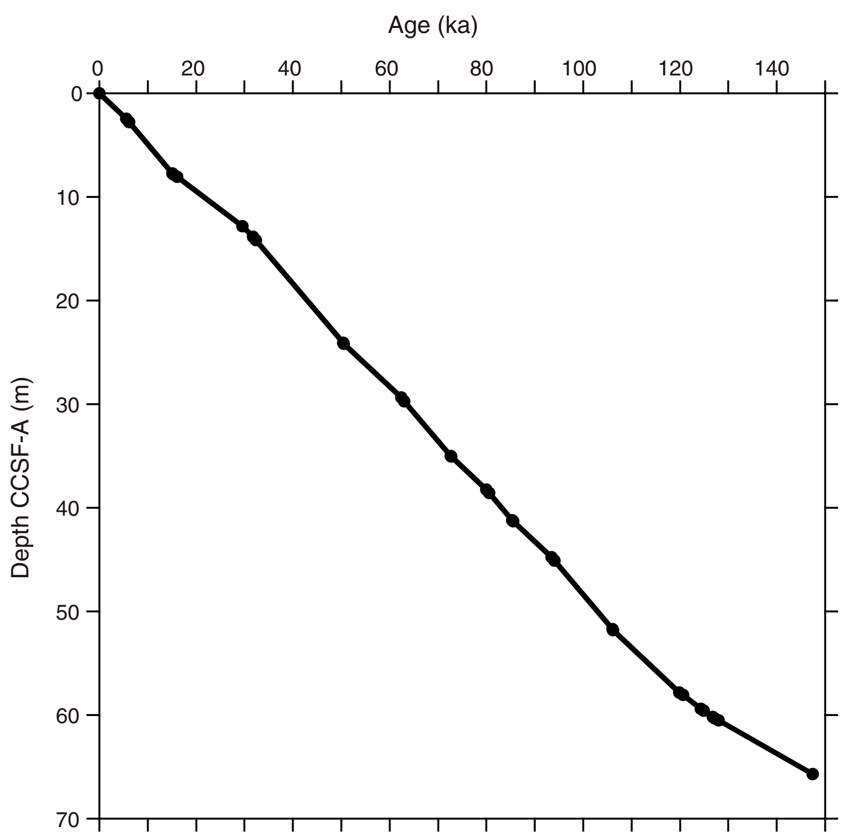

Table T1. Carbon and oxygen isotope records of benthic foraminiferal species, Site U1344.

Core, section, interval (cm)	Depth (mbsf)	Depth CCSF-A (m)	*Elphidium batialis* (‰ VPDB)		*Uvigerina senticosa* (‰ VPDB)		*Valvulineria sadonica* (‰ VPDB)		*Globobulimina pacifica* (‰ VPDB)		*Nonionella labradorica* (‰ VPDB)		Composite (‰ VPDB)	Laboratory
			$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	
323-U1344A-														
1H-1, 0	0.01	0.01			3.382	–0.577							3.382	KOCHI
1H-1, 10	0.11	0.11	2.731	–1.745	3.528	–0.625							3.582	KOCHI
1H-1, 20	0.21	0.21	2.757	–1.606									3.662	KOCHI
1H-1, 30	0.31	0.31	2.530	–2.216									3.435	KOCHI
1H-1, 40	0.41	0.41	2.801	–2.050									3.706	KOCHI
1H-1, 50	0.51	0.51	2.578	–2.279									3.483	KOCHI
1H-1, 60	0.61	0.61	2.550	–1.938									3.456	KOCHI
1H-1, 70	0.71	0.71	2.813	–1.602									3.718	KOCHI
1H-1, 80	0.81	0.81	2.821	–2.057									3.726	KOCHI
1H-1, 90	0.91	0.91	2.821	–2.061	3.504	–0.798							3.615	KOCHI
1H-1, 100	1.01	1.01	2.931	–1.825	3.473	–1.084							3.655	KOCHI
1H-1, 110	1.11	1.11	2.863	–1.496									3.769	KOCHI
1H-1, 120	1.21	1.21	2.620	–1.787									3.525	KOCHI
1H-1, 130	1.31	1.31	2.513	–2.187									3.418	KOCHI
1H-1, 140	1.41	1.41	2.623	–1.638									3.528	KOCHI
1H-2, 0	1.51	1.51	2.714	–1.914									3.619	KOCHI
1H-2, 10	1.61	1.61	2.691	–1.803									3.596	KOCHI
1H-2, 20	1.71	1.71	2.610	–2.121									3.516	KOCHI
1H-2, 30	1.81	1.81	2.770	–1.864									3.676	KOCHI
1H-2, 40	1.91	1.91	2.778	–1.921									3.683	KOCHI
1H-2, 50	2.01	2.01	2.397	–2.803									3.302	KOCHI
1H-2, 60	2.11	2.11	2.526	–1.872									3.432	KOCHI
1H-2, 80	2.31	2.31	2.914	–1.629									3.819	KOCHI
1H-2, 90	2.41	2.41	2.766	–2.078	3.596	–0.801							3.633	KOCHI
1H-2, 100	2.51	2.51	2.642	–2.169	3.563	–0.869							3.555	KOCHI
1H-2, 110	2.61	2.61	2.696	–2.505	3.469	–0.890							3.535	KOCHI
1H-2, 120	2.71	2.71	2.913	–1.844	3.404	–0.751							3.611	KOCHI
1H-2, 125	2.75	2.76	2.739	–2.353									3.644	TAMU
1H-3, 0	3.01	3.01	2.797	–2.366	3.688	–0.716							3.695	KOCHI
1H-3, 10	3.11	3.11	2.787	–2.160	3.491	–0.797							3.592	KOCHI
1H-3, 20	3.21	3.21	2.708	–1.952									3.613	KOCHI
1H-3, 30	3.31	3.31	2.841	–2.120									3.746	KOCHI
1H-3, 40	3.41	3.41	2.758	–2.317	3.537	–0.919							3.600	KOCHI
1H-3, 50	3.51	3.51	2.629	–3.146	3.467	–0.861							3.501	KOCHI
1H-3, 60	3.61	3.61	2.478	–3.272	3.536	–0.825							3.460	KOCHI
1H-3, 70	3.71	3.71	2.814	–2.080	3.720	–0.820							3.720	KOCHI
1H-3, 80	3.81	3.81	2.877	–2.100	3.751	–0.705							3.767	KOCHI
1H-3, 90	3.91	3.91	2.598	–2.928	3.607	–0.715							3.555	KOCHI
1H-3, 100	4.01	4.01	2.900	–2.262	3.756	–0.692							3.781	KOCHI
1H-3, 110	4.11	4.11			3.773	–0.822							3.773	KOCHI
1H-3, 120	4.21	4.21			3.731	–0.724							3.731	KOCHI
1H-3, 138	4.39	4.39			3.802	–0.917							3.802	KOCHI
1H-4, 0	4.51	4.51			3.741	–0.907							3.741	KOCHI

KOCHI = Kochi University, TAMU = Texas A&M University. Only a portion of this table appears here. The complete table is available in **ASCII**.

Table T2. Age model for the uppermost 64 m CCSF-A based on $\delta^{18}O$ stratigraphy, Site U1344.

Age (ka)	Depth CCSF-A (cm)
0	1.0
5.6	245.8
6.2	278.8
15.2	774.9
15.3	781.6
16.1	808.0
29.6	1284.3
31.8	1383.5
32.4	1416.6
50.4	2408.8
50.6	2415.4
62.4	2938.0
63.0	2971.1
72.6	3500.3
72.8	3506.9
80.0	3824.4
80.6	3857.5
85.4	4122.1
85.5	4128.7
93.5	4479.3
94.1	4512.3
106.1	5173.8
106.2	5180.4
119.9	5782.4
120.6	5808.9
124.4	5941.2
125.0	5961.0
126.8	6020.5
127.2	6033.8
128.0	6053.6
139.4	6355.9

All depth-age tie points are from oxygen isotope stratigraphy.