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56. *DATA REPORT:* CARBON ISOTOPE STRATIGRAPHY OF PALEOGENE BULK SEDIMENTS, HOLE 762C (EXMOUTH PLATEAU, EASTERN INDIAN OCEAN)[1]

E. Thomas,[2] N. J. Shackleton,[3] and M. A. Hall[3]

ABSTRACT

Carbon isotope measurements were made on bulk sediments from the Paleogene calcareous sequence recovered at Ocean Drilling Program Site 762 (Hole 762C) on the central Exmouth Plateau, eastern Indian Ocean. The very positive $\delta^{13}C$ values that characterize the early/late Paleocene boundary and the very rapid trend toward lighter values in the latest Paleocene, as observed at other sites worldwide, are clearly present in the record from Hole 762C, as is the short excursion to extremely light values close to the Paleocene/Eocene boundary. The highest values in the upper Paleocene maximum at Site 762 are close to those at mid-latitude South Atlantic sites on Walvis Ridge, but slightly lower than those from the high latitude Sites 689 and 690 (65°S; Maud Rise, Weddell Sea). These $\delta^{13}C$ events will be of value in long-distance stratigraphic correlations; especially the short, but extreme excursion at the end of the Paleocene may be useful in clearing up the stratigraphic correlation problems for that interval. Site 762 values for the upper Eocene resemble the pattern at Walvis Ridge more closely than do the values for Sites 689 and 690 (Maud Rise); the latter showed a positive excursion in that interval. The bulk carbon isotopic record seems to be more similar between low- and mid-latitude sites, even in different ocean basins, than between low and high latitudes.

INTRODUCTION

Site 762 (19°53.23′S, 112°15.24′E) was drilled in about 1360 m water on the western flank of the central Exmouth Plateau. Well-preserved Cenozoic nannofossil oozes and chalks were recovered, and recovery with the extended core barrel (XCB) was reasonably good but not excellent (66.8% for the Paleogene chalk interval studied). The microfossils studied indicate a low-latitude, open-ocean environment of deposition through the Cenozoic (Haq, von Rad, O'Connell, et al., 1990). Despite the great burial depth of the Paleogene section (Table 1), the sediments appear to have preserved a reliable carbon isotope signal.

For most purposes stable isotope analyses of bulk sediments are of very little value, and one has to analyze monospecific or at least monogeneric assemblages of benthic foraminifers and size-controlled, monospecific samples of planktonic foraminifers (e.g., Berger et al., 1978). It is useful, however, to analyze bulk sediment to obtain appropriate data to contribute to our understanding of the history of the oceanic carbon budget (e.g., Shackleton, 1987). In this report we present a data set from Site 762, at low latitudes in the eastern Indian Ocean, to add to and compare with data sets from low latitudes in the Pacific (Shackleton et al., 1985), the mid-latitudes in the southern Atlantic (Renard et al., 1983; Shackleton and Hall, 1984; Shackleton, 1986), and high latitudes (Shackleton and Hall, 1990).

There are significant spatial variations in $\delta^{13}C$ in ocean surface waters today (Kroopnick et al., 1977), but the spatial variability in the $\delta^{13}C$ content of surface sediments is small compared with the range of values observed for the Cenozoic (Shackleton, 1987), which suggests that the bulk sediment record of $\delta^{13}C$ may be useful in stratigraphic correlations. This additional data set can help evaluate the stratigraphic use of bulk $\delta^{13}C$ data.

ANALYTICAL DATA AND CONCEPTS

Samples from Hole 762C, weighing a few milligrams, were taken from Cores 122-762C-2X through -41X (171 to 540 mbsf, corresponding to about 35–65 Ma), then dried and vacuum roasted at 400°C to remove any organic contaminants. The samples were then reacted with 100% phosphoric acid at 90°C using a VG Isotech Isocarb common acid bath system. The evolved carbon dioxide was analyzed in a VG Isotech SIRA series II mass spectrometer. The results were calibrated to PDB by repeated analysis of a carbonate standard. Analytical accuracy is better than 0.08‰.

Measurements are listed in Table 1. As an aid to preliminary evaluation of the data and comparison with records from other sites, each sample is assigned an age based on the magnetostratigraphic record in Galbrun (this volume, chapter 42) and the calcareous nannofossil record in Siesser and Bralower (this volume). The numerical ages follow Berggren et al. (1985), with the nannofossil zone boundary corrections in Aubry et al. (1988). The age tie-points are listed in Table 2.

DISCUSSION

Figure 1 shows the $\delta^{13}C$ record for Hole 762C plotted vs. depth, and on the time scale obtained from Table 2. The pronounced upper Paleocene peak in $\delta^{13}C$ values around 60 Ma (time scale of Berggren et al., 1985) is clearly present, as is the rapid decline in values at around the Paleocene/Eocene boundary. The peak values of $\delta^{13}C$ at around 60 Ma are very similar to those at mid-latitude Deep Sea Drilling Project (DSDP) Sites 525, 527, and 528 (Walvis Ridge; Shackleton and Hall, 1984), but lower than those at high-latitude Sites 689 and 690 (Shackleton and Hall, 1990). It has been demonstrated for data from the Maud Rise on planktonic and benthic foraminifers (Stott et al., 1990; Kennett and Stott, 1990, 1991), as well as in bulk values (Shackleton and Hall, 1990), that there is a short "overshoot" to very light $\delta^{13}C$ values at the end of this long-term decline in $\delta^{13}C$ values. A coeval negative excursion was observed in sediments from Site 738 (Antarctic Indian

[1] von Rad, U., Haq, B. U., et al., 1992. *Proc. ODP, Sci. Results*, 122: College Station, TX (Ocean Drilling Program).

[2] University of Cambridge, Department of Earth Sciences, Downing Street, Cambridge CB2 3EQ, United Kingdom.

[3] University of Cambridge, Subdepartment of Quaternary Research, Godwin Laboratory, Free School Lane, Cambridge CB2 3RS, United Kingdom.

Table 1. Stable isotope analyses, Hole 762C.

Sample (Hole762C)	Depth (mbsf)	Age (Ma)	type	$\delta^{18}O$	$\delta^{13}C$
2X-1,128-130	171.28	35.383	bulk	1.09	1.83
2X-4, 85- 87	175.35	35.576	bulk	0.67	1.94
3X-1, 23- 25	179.73	35.784	bulk	0.63	2.25
3X-4, 72- 74	184.72	36.021	bulk	0.22	2.01
4X-1, 27- 29	189.27	36.236	bulk	0.07	1.73
4X-4, 72- 74	194.22	36.471	bulk	0.08	1.30
5X-1,128-130	199.78	36.735	bulk	-0.12	1.50
6X-1,132-134	209.32	37.187	bulk	0.14	1.78
6X-4, 77- 79	213.27	37.374	bulk	0.06	1.85
7X-1, 22- 24	217.72	37.585	bulk	-0.19	1.72
7X-4, 72- 74	222.72	37.830	bulk	-0.59	1.77
8X-1, 48- 50	227.48	38.138	bulk	-0.48	1.89
8X-4, 71- 73	232.21	38.443	bulk	-0.01	1.62
9X-1, 73- 75	237.23	38.768	bulk	-0.07	1.63
10X-1, 79- 81	246.79	39.386	bulk	0.10	1.81
10X-4, 72- 74	251.22	39.898	bulk	0.31	1.86
11X-1,132-134	256.82	40.830	bulk	-0.01	2.01
11X-4, 71- 73	260.71	41.478	bulk	-0.05	2.41
12X-1,131-133	266.31	42.410	bulk	0.28	1.87
12X-4, 72- 74	270.22	43.061	bulk	0.14	1.97
13X-1,129-131	275.79	44.020	bulk	-0.21	1.88
14X-1,130-132	285.30	45.518	bulk	0.45	1.88
14X-4, 70- 72	289.20	46.131	bulk	0.08	1.86
15X-1,123-125	294.73	46.740	bulk	0.36	1.77
15X-CC,13- 15	297.50	47.040	bulk	0.21	1.54
16X-1,121-123	304.21	47.765	bulk	0.36	1.81
16X-3, 79- 81	306.79	48.043	bulk	0.05	1.90
17X-2, 32- 34	314.32	48.857	bulk	0.09	1.79
17X-5,131-133	319.81	49.450	bulk	-0.22	1.70
18X-1, 77- 79	322.77	49.716	bulk	-0.40	1.61
18X-2, 79- 81	324.29	49.934	bulk	-0.23	1.83
18X-3, 79- 81	325.79	50.096	bulk	-0.23	1.85
18X-4, 71- 73	327.21	50.249	bulk	-0.32	1.92
18X-5, 80- 82	328.80	50.445	bulk	-0.44	1.32
18X-6, 79- 81	330.29	50.654	bulk	-0.51	1.80
19X-1, 82- 84	332.32	50.939	bulk	-0.61	1.77
19X-2, 71- 73	333.71	51.134	bulk	-0.62	1.79
19X-4, 72- 74	336.72	51.556	bulk	-0.73	1.48
20X-1, 82- 84	341.82	52.074	bulk	-0.83	0.77
20X-2, 71- 73	343.21	52.149	bulk	-1.23	1.63
20X-3, 78- 80	344.78	52.234	bulk	-1.03	0.73
20X-4, 51- 53	346.01	52.301	bulk	-0.93	1.14
21X-1, 78- 80	351.28	52.586	bulk	-0.94	1.07
21X-2, 67- 69	352.67	52.705	bulk	-0.86	1.16
22X-1, 72- 74	360.72	53.598	bulk	-0.99	1.12
22X-2, 71- 73	362.21	53.763	bulk	-0.74	1.24
22X-3, 60- 62	363.60	53.917	bulk	-0.90	0.93
22X-4, 66- 68	365.16	54.090	bulk	-0.71	1.11
22X-5, 67- 69	366.67	54.258	bulk	-1.15	0.83
22X-6, 72- 74	368.22	54.430	bulk	-1.08	1.07
23X-1, 67- 69	370.17	54.663	bulk	-0.90	1.04
23X-2, 66- 68	371.66	54.811	bulk	-1.03	0.99
23X-3, 54- 56	373.04	54.964	bulk	-1.01	0.76
24X-1, 57- 59	379.57	55.593	bulk	-1.03	0.96
24X-CC, 8- 10	380.50	55.662	bulk	-1.02	1.25
25X-1, 70- 72	389.20	55.957	bulk	-0.73	1.20
25X-2, 78- 80	390.78	56.011	bulk	-0.90	1.46

Table 1 (continued).

Sample (Hole762C)	Depth (mbsf)	Age (Ma)	type	$\delta^{18}O$	$\delta^{13}C$
25X-3, 70- 72	392.20	56.059	bulk	-0.78	1.53
25X-4, 80- 82	393.80	56.114	bulk	-0.92	1.48
25X-5, 35- 37	394.85	56.164	bulk	-0.78	0.64
26X-1, 15- 16	398.15	56.437	fine	-0.88	1.26
26X-1, 75- 77	398.75	56.514	bulk	-0.85	1.15
26X-2, 15- 16	399.65	56.595	fine	-1.13	1.22
26X-2, 68- 70	400.18	56.642	bulk	-0.84	1.16
26X-3, 15- 16	401.16	56.730	fine	-0.95	1.26
26X-3, 67- 69	401.67	56.776	bulk	-0.81	1.40
26X-4, 15- 16	402.65	56.863	fine	-0.52	1.47
27X-1, 15- 16	402.66	56.864	fine	-0.89	1.30
27X-1, 63- 65	403.13	56.907	bulk	-0.93	1.25
26X-4, 65- 67	403.15	56.908	bulk	-0.81	1.37
26X-5, 15- 16	404.15	56.998	fine	-0.55	1.37
27X-2, 15- 16	404.16	56.999	fine	-0.82	1.33
27X-2, 61- 63	404.61	57.039	bulk	-0.78	1.51
26X-5, 68- 70	404.68	57.046	bulk	-0.79	1.34
27X-3, 15- 16	405.66	57.134	fine	-0.89	1.69
26X-CC, 6- 8	405.86	57.151	bulk	-0.88	1.41
27X-3, 65- 67	406.15	57.177	bulk	-1.04	1.41
27X-4, 15- 16	407.16	57.267	fine	-1.01	1.73
27X-4, 55- 57	407.55	57.303	bulk	-0.87	1.49
27X-CC,15- 16	408.79	57.414	fine	-1.09	1.84
28X-1, 15- 16	412.16	57.716	fine	-0.92	1.80
28X-1, 65- 67	412.65	57.760	bulk	-1.20	1.02*
28X-CC,15- 16	413.88	57.868	fine	-1.28	1.29
28X-CC,23- 25	413.95	57.877	bulk	-0.81	2.33
29X-1, 15- 16	421.65	58.567	fine	-0.94	2.67
29X-1, 64- 66	422.14	58.611	bulk	-1.03	2.05
29X-2, 16- 17	423.16	58.848	fine	-0.92	3.43
29X-2, 65- 67	423.65	58.999	bulk	-0.76	2.81
29X-3, 15- 16	424.65	59.249	fine	-0.83	3.07
29X-3, 77- 79	425.27	59.275	bulk	-0.68	2.80
29X-CC,15- 16	426.10	59.311	fine	-0.83	3.28
30X-1, 15- 16	431.15	59.527	fine	-0.74	2.99
30X-1, 63- 65	431.63	59.547	bulk	-0.47	3.11
30X-2, 15- 16	432.65	59.510	fine	-0.63	3.19
30X-2, 57- 59	433.07	59.609	bulk	-0.51	3.01
30X-3, 15- 16	434.15	59.655	fine	-0.65	3.28
30X-3, 66- 68	434.66	59.677	bulk	-0.35	2.94
30X-4, 15- 16	435.65	59.719	fine	-0.61	3.15
30X-4, 57- 59	436.07	59.737	bulk	-0.49	2.88
30X-CC,15- 16	436.67	59.763	fine	-0.45	3.23
31X-1, 74- 76	441.24	59.959	bulk	-0.69	2.56
31X-2, 72- 74	442.72	60.022	bulk	-0.07	3.11
31X-3, 74- 76	444.24	60.087	bulk	-0.33	3.11
31X-4, 76- 78	445.76	60.152	bulk	-0.61	3.06
31X-5, 75- 77	447.25	60.216	bulk	-0.55	3.07
31X-6, 74- 76	448.74	60.280	bulk	-0.46	2.67
32X-1, 75- 77	450.75	60.366	bulk	-0.44	2.69
32X-2, 68- 70	452.18	60.427	bulk	-0.25	2.80
32X-CC,34- 36	453.75	60.494	bulk	-0.59	2.42
33X-1, 74- 76	460.24	60.772	bulk	-0.70	2.72
33X-2, 71- 73	461.71	60.835	bulk	-0.52	2.45
33X-3, 66- 68	463.16	60.897	bulk	-0.80	2.60
33X-4, 68- 70	464.68	60.962	bulk	-0.75	2.39
33X-5, 70- 72	466.20	61.027	bulk	-0.61	2.18

Note: *End Paleocene benthic foraminiferal extinction

Table 1 (continued).

Sample (Hole762C)	Depth (mbsf)	Age (Ma)	type	$\delta^{18}O$	$\delta^{13}C$
33X-6, 76- 78	467.76	61.094	bulk	-0.62	2.40
34X-1, 73- 75	469.73	61.178	bulk	-0.74	2.47
34X-2, 69- 71	471.19	61.241	bulk	-0.83	2.22
34X-3, 75- 77	472.75	61.308	bulk	-0.60	2.08
34X-4, 79- 81	474.29	61.374	bulk	-0.60	2.13
34X-5, 70- 72	475.70	61.434	bulk	-0.42	2.17
35X-1, 61- 63	479.11	61.580	bulk	-0.73	1.93
35X-2, 63- 65	480.63	61.645	bulk	-0.51	1.89
36X-CC,34- 36	488.60	61.986	bulk	-0.74	1.67
37X-1, 78- 80	498.28	62.401	bulk	-0.62	1.67
37X-4, 77-79	502.77	62.593	bulk	-0.80	1.92
38X-1, 73- 75	507.73	62.805	bulk	-0.56	1.91
38X-4, 76- 78	512.26	62.999	bulk	-0.87	1.69
39X-1, 76- 78	517.26	63.410	bulk	-0.75	1.49
39X-4, 69- 71	521.69	64.374	bulk	-1.10	1.29
40X-1, 73- 75	526.73	64.587	bulk	-1.00	1.13
40X-4, 73- 75	531.23	64.766	bulk	-0.98	1.43
41X-1, 77- 79	536.27	64.956	bulk	-1.11	1.34
41X-4, 73- 75	540.73	65.146	bulk	-1.07	1.44

Note: Age estimates after Galbrun (this volume, chapter 42) and Siesser and Bralower (this volume); Table 2.

Table 2. Age tie-points used to determine the ages of samples, as shown in Table 1.

Datum	Depth, mbsf	Age, Ma
NP20/NP21	199.05	36.7
NP20/NP19	222.25	37.8
C16R/C17N	249.01	39.53
C19N/C19R	273.46	43.60
C19R/C20N	276.01	44.06
C20N/C20R	289.45	46.17
C20R/C21N	310.22	48.75
C21N/C21R	328.05	50.34
C21R/C22N	339.53	51.95
C22N/C22R	351.90	52.62
C24N-1/C24R-1	376.70	55.37
C24R-1/C24N-2	380.44	55.66
C24N-2/C24R-2	394.58	56.14
C24R-2/C25N	422.46	58.64
C25N/C25R	424.45	59.24
C26R/C27N	512.98	63.03
C27N/C27R	518.73	63.54
C27R/C28N	519.59	64.29
C28R/C29N	540.39	66.50

Ocean; Barrera and Keller, 1991) and from the Walvis Ridge (Thomas and Shackleton, unpubl. data). This short negative peak occurs at the same level as the extinction of many species of deep-sea benthic foraminifers, including *Gavelinella beccariiformis* (Thomas, 1990; Kennett and Stott, 1991). At Site 762 there is a similar but less extreme drop in $\delta^{13}C$ values of bulk carbonate at the extinction of *G. beccariiformis* (Fig. 2). This short-lived event could thus be a valuable tool for high-precision stratigraphic correlation in the interval around the Paleocene/Eocene boundary, where stratigraphy is extremely difficult because of the brackish character of the type sections of the Paleocene (Aubry et al., 1986, 1988).

At high-latitude Sites 689 and 690 there is an interval of highly positive $\delta^{13}C$ values in the uppermost Eocene (around 37–39 Ma). This interval is not present at Site 762 and is likewise absent at the mid-latitude Walvis Ridge sites (Shackleton and Hall, 1984; 1990). Thus it appears that the bulk carbon isotope record can be very useful in some parts of the geological record, but it needs to be interpreted with care.

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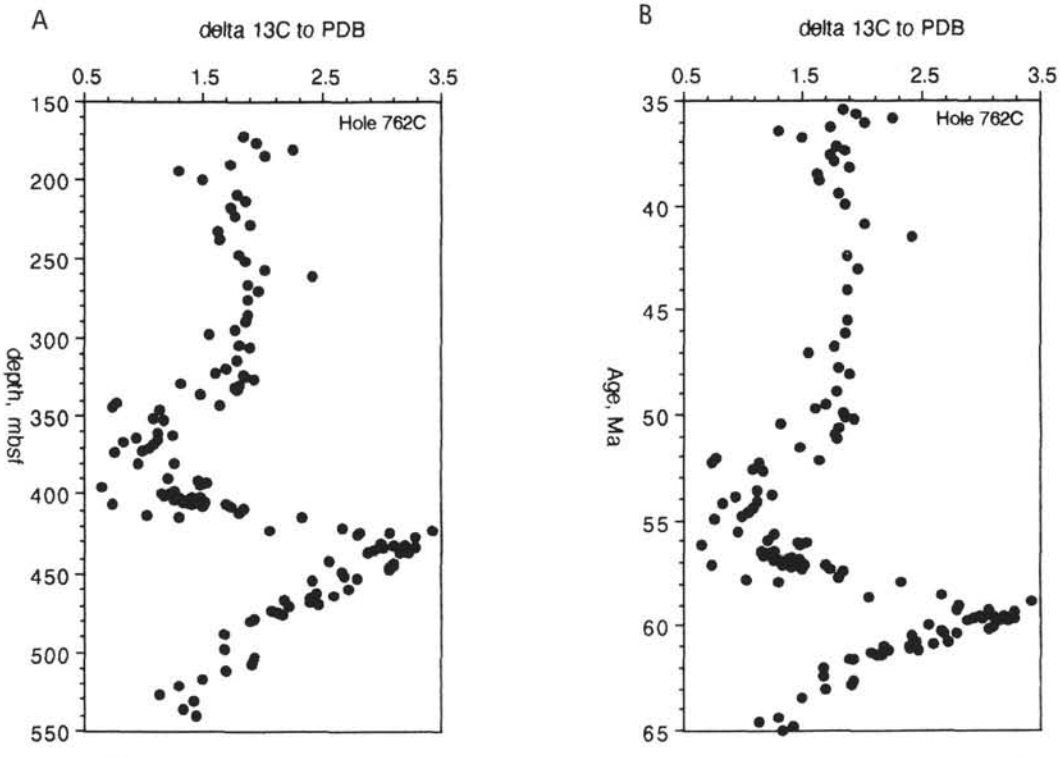

Figure 1. $\delta^{13}C$ data for bulk sediment in Hole 762C. **A.** Data plotted against depth in meters below seafloor (mbsf). **B.** Data plotted against numerical age. Time scale after Siesser and Bralower (this volume) and Galbrun (this volume, chapter 42).

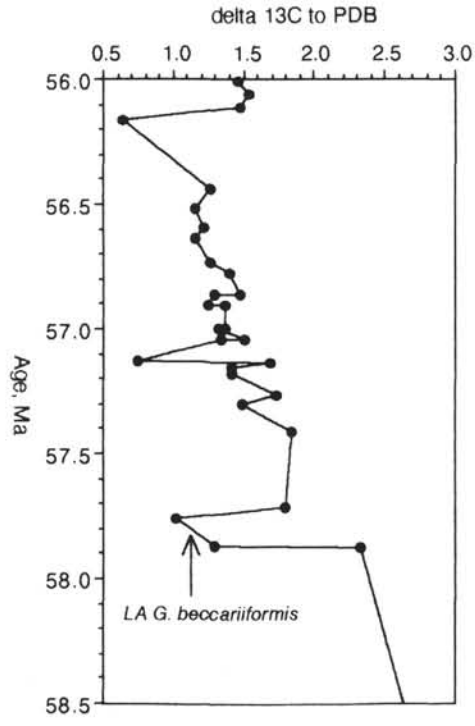

Figure 2. $\delta^{13}C$ data for bulk sediment in Hole 762C, for the interval between 56.0 and 58.5 Ma. The level of last appearance (LA) of *Gavelinella beccariiformis* is indicated.