

DATA REPORT: OXYGEN AND CARBON STABLE ISOTOPE RECORDS OF THE MIOCENE CALCAREOUS MICROFOSSILS FROM ODP LEG 189 SITES 1170 (SOUTH TASMAN RISE) AND 1172 (EAST TASMAN PLATEAU)¹

Atsuhito Ennyu^{2,3} and Michael A. Arthur²

INTRODUCTION

Downcore oxygen and carbon stable isotope records of planktonic and benthic foraminifers and fine-fraction carbonate from the southern high latitudes provide critical paleohydrographic constraints on the evolution of the Southern Ocean climate. In particular, the potential effects of an intensified Antarctic Circumpolar Current on the thermal isolation and cooling of the southern high latitudes, production of cold deep waters, and, ultimately, accumulation of continental ice on Antarctica in the middle Miocene are matters of interest. Using sediment materials from Ocean Drilling Program Leg 189 Sites 1170 and 1172 off Tasmania, Ennyu and Arthur [N1] established the surface- and deepwater stable isotope records in the Southern Ocean across the middle Miocene event of the east Antarctic ice sheet expansion and discussed the paleoclimate proxy records in terms of the thermal evolution of the southern high latitudes and its effect on deepwater circulation.

This report provides data tables and other supporting information relevant to discussions presented in Ennyu and Arthur [N1]. Items included in this report are (1) the oxygen and carbon stable isotope data measured on the Miocene bulk fine-fraction (i.e., <63 µm, primarily polyspecific nannofossil assemblage) carbonate and planktonic and

¹Ennyu, A., and Arthur, M.A., 2004. Data report: Oxygen and carbon stable isotope records of the Miocene calcareous microfossils from ODP Leg 189 Sites 1170 (South Tasman Rise) and 1172 (East Tasman Plateau). *In* Exon, N.F., Kennett, J.P., and Malone, M.J. (Eds.), *Proc. ODP, Sci. Results*, 189, 1–12 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/189_SR/VOLUME/CHAPTERS/112.PDF>. [Cited YYYY-MM-DD]

²Department of Geosciences, The Pennsylvania State University, University Park PA 16802, USA.

³Present address: Division of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Sapporo, Hokkaido 060-0810, Japan. aennyu@nature.sci.hokudai.ac.jp

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benthic foraminifers from Holes 1170A and 1172A and (2) the Miocene depth-age models for the two sites.

MATERIALS AND METHODS

Core samples from Holes 1170A and 1172A were obtained aboard the *JOIDES Resolution* during Leg 189 (Exon, Kennett, Malone, et al., 2001). Each sample consists of two 10-cm³ tubes that occupy a downcore interval of ~4 cm. Miocene sections at the two sites are entirely composed of nannofossil ooze and chalk (Site 1170 bulk carbonate content = >90 wt% and Site 1172 = >85 wt%) that contains moderately to well-preserved planktonic and benthic foraminiferal tests (except for the condensed intervals of the lower Miocene, in which planktonic foraminiferal tests are moderately infilled).

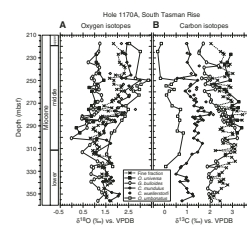
Sediment samples were disaggregated with distilled-deionized (DDI) water and wet sieved through a 63- μm screen. The <63- μm fraction was oven-dried at ~60°C and processed for stable isotope analyses. Separated coarse-fraction (>63 μm) samples were soaked in a 3% hydrogen peroxide solution for a day, rinsed and heated in hot (~90°C) DDI water, ultrasonicated, and repeatedly rinsed in DDI water until adhering material on the surface of foraminiferal tests was removed. The coarse-fraction samples were then sieved into 250-, 354-, and 420- μm fractions, and well-preserved foraminiferal specimens from the 250- to 354- μm and 354- to 420- μm fractions were hand picked. For each sample, multiple foraminifer specimens (i.e., typically 5–10 specimens for benthic foraminifers and 10–15 specimens for planktonic foraminifers) of the same species were separated, crushed between two glass slides, brush-cleaned in methanol to remove remaining adhering particles from inner shell walls, when present, and processed for stable isotope analyses.

Separated foraminifers and bulk fine-fraction (<63 μm) samples were reacted with 100% anhydrous phosphoric acid at 90°C in an automated common acid bath carbonate device coupled to a Finnigan MAT 252 mass spectrometer for carbon and oxygen stable isotope analyses in the Penn State Stable Isotope Biogeochemistry Laboratory. Stable isotopic values are reported in per mil (‰) notation relative to the Vienna Peedee belemnite (VPDB) standard. Analytical precision for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values is 0.05‰ and 0.08‰, respectively, and was monitored through multiple analyses of NBS-19 standard.

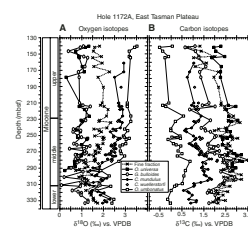
STABLE ISOTOPE DATA

Results of stable isotope analyses of planktonic and benthic foraminifers and the bulk fine-fraction carbonate from Holes 1170A and 1172A are shown in Figures F1 and F2, respectively, and are reported in Table T1. Foraminiferal species analyzed include *Globigerina bulloides* and *Orbulina universa* for the planktonic foraminifers and *Cibicidoides mundulus*, *Cibicidoides wuellerstorfi*, and *Oridorsalis umbonatus* for the benthic foraminifers. Interpretations and discussion on the stable isotope data are presented in Ennyu and Arthur [N1].

F1. Oxygen and carbon stable isotopes, Hole 1170A, p. 5.



F2. Oxygen and carbon stable isotopes, Hole 1172A, p. 6.



T1. Oxygen and carbon stable isotopes, p. 8.

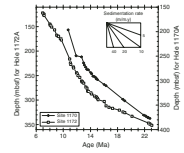
AGE MODELS

Figure F3 shows the depth-age models for Holes 1170A and 1172A employed in Ennyu and Arthur [N1] to convert sample depths into numerical ages. The depth-age models are constructed using selected magnetostratigraphic and biostratigraphic datums from Stickley et al. (this volume) that are calibrated to the geomagnetic polarity timescale of Cande and Kent (1995) and the magnetobiochronologic timescale of Berggren et al. (1995). The event datums employed to plot Figure F3 are presented in Table T2. Each sample depth was converted to numerical age by linearly interpolating between the two consecutive datum depths immediately below and above the sample depth. The calculated numerical age for each sample depth is reported in Table T1.

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F3. Depth-age models, p. 7.



T2. Miocene magnetic polarity and biostratigraphy datum events, p. 11.

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Figure F1. (A) Oxygen and (B) carbon stable isotope records of planktonic and benthic foraminifers and the fine-fraction carbonate from Hole 1170A. Isotope data are reported in Table T1, p. 8. VPBD = Vienna Pee Dee belemnite standard.

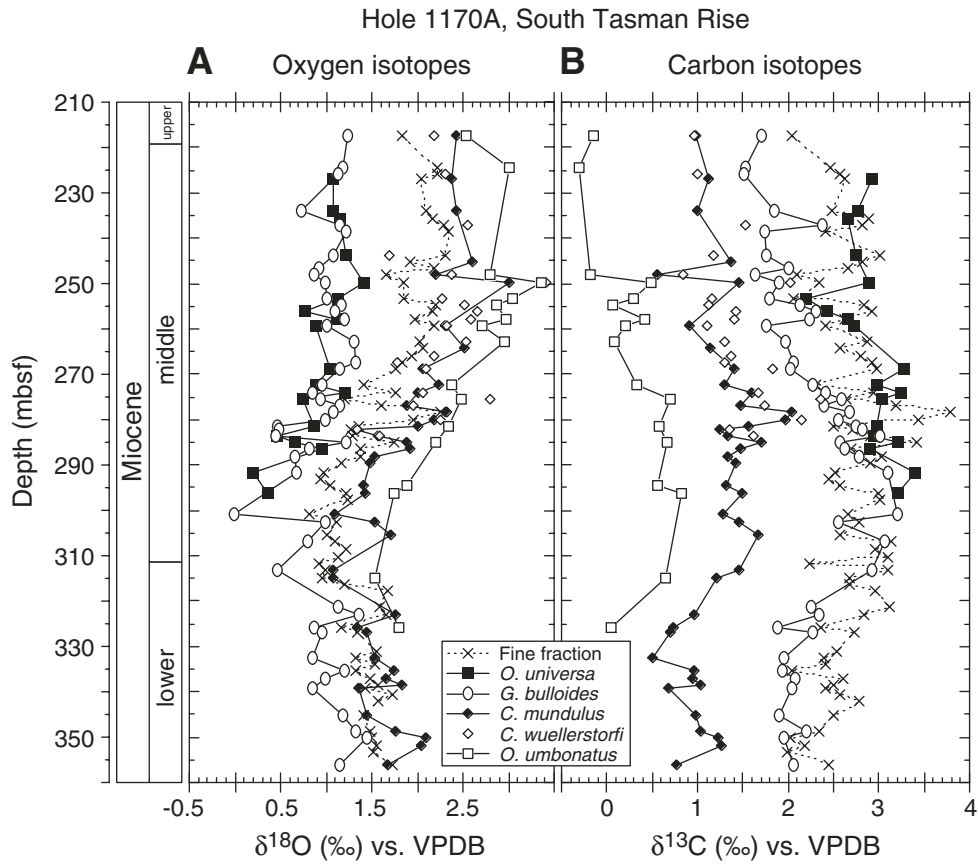


Figure F2. (A) Oxygen and (B) carbon stable isotope records of planktonic and benthic foraminifers and the fine-fraction carbonate from Hole 1172A. Isotope data are reported in Table T1, p. 8. VPBD = Vienna Pee Dee belemnite standard.

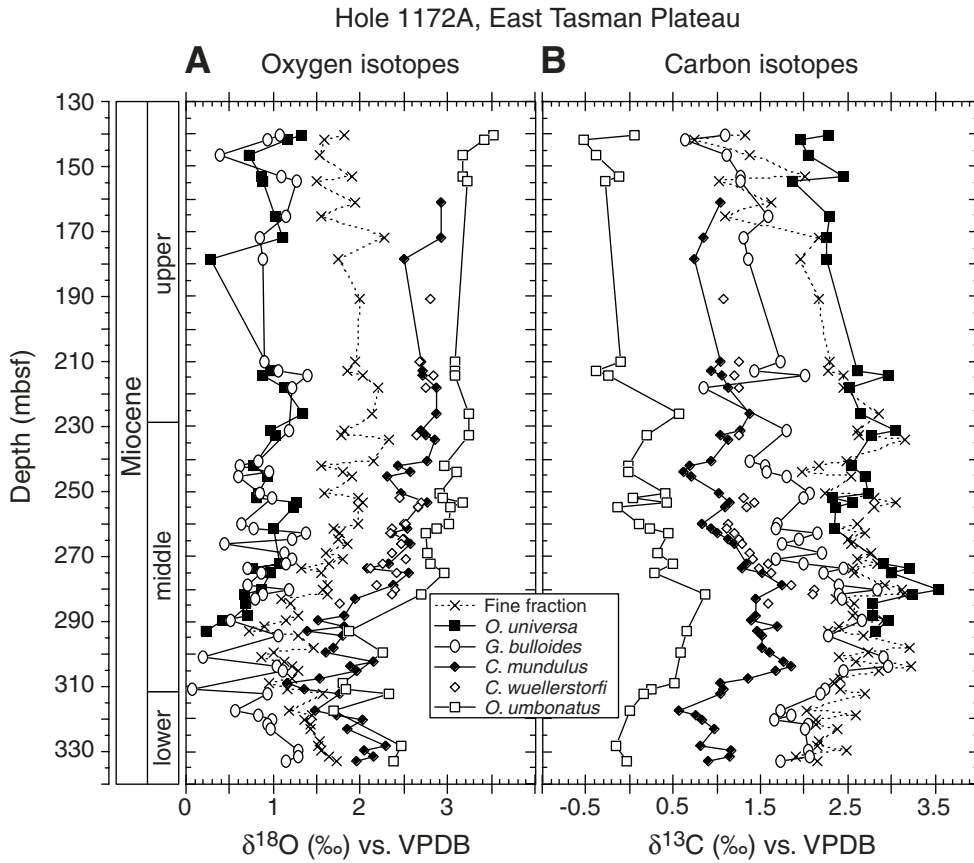


Figure F3. Depth-age models for the Miocene in Holes 1170A and 1172A. Selected geomagnetic polarity and biostratigraphy event datums from [Stickley et al.](#) (this volume) plotted in this diagram are presented in Table T2, p. 11. Inset shows slopes for sedimentation rates.

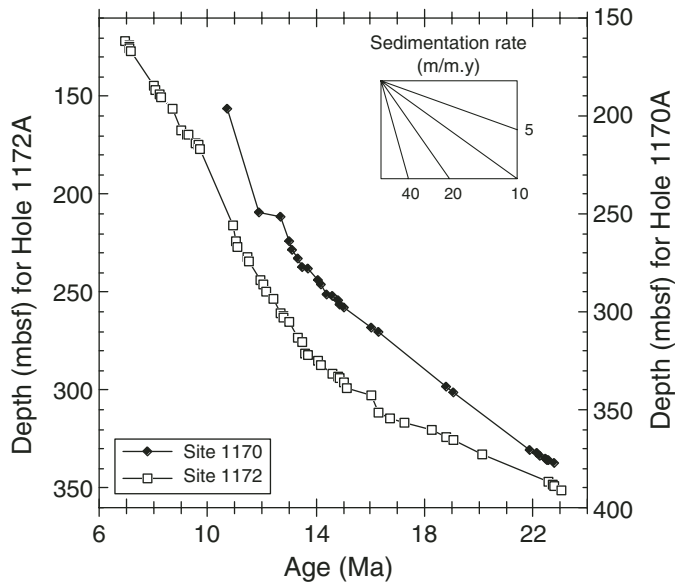


Table T1. Oxygen and carbon stable isotopes (in permil) of calcareous microfossils, Holes 1170A and 1172A. (Continued on next two pages.)

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Fine fraction		<i>Globigerina bulloides</i>		<i>Orbulina universa</i>		<i>Cibicoides mundulus</i>		<i>Cibicoides wuellerstorfi</i>		<i>Oridorsalis umbonatus</i>	
			$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
189-1170A-														
25X-2, 105-110	217.25	11.17	2.04	1.83	1.70	1.23			0.98	2.42	0.96	2.18	-0.14	2.53
26X-1, 18-22	224.48	11.33	2.47	2.23	1.53	1.19					1.00	2.30	-0.30	3.00
26X-2, 18-22	225.98	11.37	2.58	2.22	1.52	1.12								
26X-3, 18-22	226.98	11.39	2.62	2.05			2.92	1.08	1.13	2.38				
27X-1, 18-22	234.08	11.55	2.48	2.09	1.85	0.73	2.76	1.08	1.01	2.44				
27X-2, 18-22	235.58	11.59	2.88	2.16			2.66	1.15						
27X-3, 18-22	237.08	11.62	2.82	2.30	2.38	1.15					1.53	2.55		
27X-4, 18-22	238.58	11.66	2.41	2.34	1.74	1.21								
28X-1, 18-22	243.68	11.77	3.01	2.30	1.77	1.08	2.75	1.22			1.17	1.69		
28X-2, 18-22	245.18	11.81	2.82	1.92					1.38	2.60				
28X-3, 18-22	246.68	11.84	2.65	2.18	2.00	0.92								
28X-4, 18-22	248.18	11.87	2.10	1.65	1.64	0.87			0.57	2.20	0.84	2.37	-0.17	2.80
28X-5, 18-22	249.68	12.01	2.34	1.85	1.91	0.99	2.88	1.41	1.46	3.01	2.02	3.42	0.48	3.36
29X-1, 18-22	253.28	12.74	2.06	1.85	1.79	1.01	2.20	1.14			1.17	2.28	0.30	3.05
29X-2, 18-22	254.78	12.78	2.84	2.20	2.12	1.17					1.12	2.52	0.07	2.88
29X-3, 18-22	256.28	12.81	2.92	2.17	2.30	1.09	2.43	0.76			1.43	2.66		
29X-4, 18-22	257.78	12.85	2.62	1.97	2.23	1.21	2.67	1.12			1.40	2.59	0.42	2.98
29X-5, 18-22	259.28	12.88	2.41	2.19	1.77	1.02	2.73	0.89	0.91	2.31	1.10	2.32	0.20	2.70
30X-1, 18-22	262.88	12.97	2.87	2.03	1.98	1.31					1.30	2.54	0.08	2.95
30X-2, 18-22	264.38	13.00	2.57	2.06					1.13	2.51				
30X-3, 18-22	265.88	13.05	2.80	1.94							1.37	2.18		
30X-4, 18-22	267.38	13.10	2.92	1.84	2.05	1.32					1.30	1.78		
30X-5, 18-22	268.88	13.15	2.98	1.76	2.02	1.16	3.28	1.05	1.41	2.06	1.82	2.09		
31X-1, 18-22	272.48	13.28	2.30	1.41	2.26	0.96	2.97	0.88	1.30	2.23			0.33	2.37
31X-2, 18-22	273.98	13.35	2.94	1.77	2.41	0.86	3.25	1.21	1.60	2.01	1.68	2.06		
31X-3, 18-22	275.48	13.43	2.64	1.20	2.59	0.95	3.03	0.75			2.36	2.79	0.70	2.48
31X-4, 18-22	276.98	13.51	3.19	1.61	2.39	1.14			1.48	1.89	1.74	1.95		
31X-5, 18-22	278.48	13.74	3.78	2.25	2.68	1.08			2.05	2.33				
31X-6, 18-22	279.98	13.84	3.43	1.96	2.55	0.98			1.97	2.18	2.15	2.25		
31X-7, 18-22	281.48	13.94	2.50	1.36	2.75	0.47	2.97	0.88	1.56	2.01			0.58	2.34
32X-1, 18-22	282.08	13.98	2.71	1.27	2.81	0.48			1.25	1.32	1.36	1.35		
32X-2, 18-22	283.58	14.08	2.91	1.29	3.01	0.44	2.93	0.47	1.34	1.57	1.61	1.58		
32X-3, 18-22	285.08	14.14	3.43	1.74	2.56	1.21	3.21	0.66	1.71	1.89			0.66	2.21
32X-4, 18-22	286.58	14.20	2.70	1.37	2.63	0.81	2.90	0.96	1.47	1.92				
32X-5, 18-22	288.08	14.26	3.04	1.38	2.79	0.66			1.34	1.54				
32X-6, 18-22	289.42	14.31	2.90	1.16					1.43	1.48				
33X-1, 18-22	291.68	14.48	2.51	0.98	3.11	0.67	3.39	0.19						
33X-2, 18-22	293.18	14.72	2.45	0.93										
33X-3, 18-22	294.68	14.83	2.58	1.05					1.32	1.41			0.56	1.88
33X-4, 18-22	296.18	14.91	3.00	1.22			3.20	0.35	1.50	1.43			0.82	1.74
33X-5, 18-22	297.68	15.05	3.01	1.24										
34X-1, 18-22	300.98	15.36	2.66	0.81	3.21	-0.01			1.29	1.10				
34X-2, 18-22	302.48	15.50	2.78	1.11	2.55	0.99			1.46	1.53				
34X-4, 18-22	305.48	15.78	2.58	1.00					1.67	1.72				
34X-5, 18-22	306.98	15.92	3.13	1.10	3.07	0.81								
34X-6, 18-22	308.48	16.07	2.96	1.22										
35X-1, 18-22	310.28	16.27	3.10	1.13										
35X-2, 18-22	311.78	16.41	2.24	0.92										
35X-3, 18-22	313.28	16.54	3.10	0.99	2.93	0.47			1.47	1.07				
35X-4, 18-22	314.78	16.68	2.68	0.95					1.21	1.08			0.65	1.53
35X-5, 18-22	316.28	16.82	2.69	1.21										
35X-6, 18-22	317.78	16.95	2.95	1.68										
36X-2, 18-22	321.38	17.28	3.12	1.58	2.26	1.13								
36X-3, 18-22	322.88	17.41	2.84	1.66	2.34	1.36			0.97	1.76				
36X-5, 18-22	325.88	17.68	2.36	1.16	1.88	0.87			0.73	1.35			0.05	1.79
36X-6, 18-22	326.88	17.77	2.73	1.34	2.27	0.96			0.71	1.44				
37X-2, 18-22	330.98	18.15	2.54	1.56										
37X-3, 18-22	332.48	18.28	2.40	1.32	1.95	0.85			0.51	1.54				
37X-4, 18-22	333.98	18.42	2.41	1.53										
37X-5, 18-22	335.48	18.55	2.03	1.33	1.94	1.21			0.97	1.74				
37X-6, 18-22	336.98	18.69	2.61	1.49	2.08	0.99			0.95	1.66				
37X-7, 18-22	338.48	18.82	2.50	1.57					1.04	1.83				
38X-1, 18-22	339.08	18.88	2.40	1.43	2.04	0.84			0.68	1.37				
38X-2, 18-22	340.58	19.01	2.56	1.73										
38X-3, 18-22	342.08	19.15	2.78	1.57										
38X-5, 18-22	345.08	19.44	2.49	1.41	1.90	1.18			0.99	1.44				

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Fine fraction		<i>Globigerina bulloides</i>		<i>Orbulina universa</i>		<i>Cibicoides mundulus</i>		<i>Cibicoides wuellerstorfi</i>		<i>Oridorsalis umbonatus</i>	
			$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
36X-2, 110-114	328.30	19.42	2.14	1.51					0.81	2.29			-0.16	2.47
36X-3, 110-114	329.80	19.64	2.49	1.54	2.04	1.30			1.17	2.04				
36X-4, 113-115	331.33	19.87	1.90	1.65	2.07	1.28			1.15	2.15				
36X-5, 110-114	332.80	20.09	2.16	1.73	1.73	1.15			0.90	1.95			-0.04	2.38

Table T2. Miocene magnetic polarity and biostratigraphy datum events used to construct depth-age models, Holes 1170A and 1172A.

Hole	Datum	Event	Mean depth (mbsf)	Age (Ma)	Hole	Datum	Event	Mean depth (mbsf)	Age (Ma)	
1170A	M	Termination 5n.1n	190.00	9.74	M	Termination 5n.1n		176.70	9.74	
	D	LO <i>Denticulopsis dimorpha</i>	196.56	10.70	M	Onset 5n.2n		216.00	10.95	
	N	LO <i>Cyclicargolithus floridanus</i>	249.36	11.90	M	Termination 5r.1n		224.30	11.05	
	R	LO <i>Actinocyclus ingens</i> var. <i>nodus</i>	251.80	12.71	M	Onset 5r.1n		226.90	11.10	
	M	Termination C5AAn	264.00	12.99	M	Termination 5r.2n		232.10	11.48	
	M	Onset C5AAn	268.50	13.14	M	Onset 5r.2n		234.30	11.53	
	M	Termination C5ABn	273.00	13.30	M	Termination 5An.1n		243.80	11.94	
	M	Onset C5ABn	277.00	13.51	M	Onset 5An.1n		246.30	12.08	
	M	Termination C5ACn	278.00	13.70	M	Termination 5An.2n		250.00	12.18	
	M	Onset C5ACn	283.50	14.08	M	Onset 5An.2n		253.20	12.40	
	M	Termination C5ADn	286.00	14.18	M	Termination 5Ar.1n		260.40	12.68	
	D	FO <i>Actinocyclus ingens</i> var. <i>nodus</i>	291.42	14.38	M	Onset 5Ar.1n		260.90	12.71	
	M	Onset C5ADn	292.00	14.61	M	Termination 5Ar.2n		262.00	12.78	
	M	Termination C5Bn.1n	294.00	14.80	M	Onset 5Ar.2n		263.20	12.82	
	M	Onset C5Bn.1n	296.00	14.89	M	Termination 5AAn		265.30	12.99	
	M	Termination C5Bn.2n	297.50	15.03	M	Termination 5ABn		273.60	13.30	
	M	Termination C5Cn.1n	308.00	16.01	M	Onset 5ABn		275.70	13.51	
	M	Onset C5Cn.1n	310.50	16.29	N	LO <i>Sphenolithus heteromorphus</i>		281.50	13.60	
	M	Onset C5En	338.00	18.78	M	Termination 5ACn		282.20	13.70	
	M	Termination C6n	341.00	19.05	M	Onset 5ACn		285.20	14.08	
	M	Onset C6AAn	370.50	21.86	M	Termination 5ADn		287.30	14.18	
	M	Termination C6AAr.1n	372.20	22.15	M	Onset 5ADn		291.90	14.61	
	M	Onset C6AAr.1n	373.60	22.25	M	Termination 5Bn.1n		293.30	14.80	
	M	Termination C6AAr.2n	374.90	22.46	M	Onset 5Bn.1n		293.90	14.89	
	M	Onset C6AAr.2n	375.40	22.49	M	Termination 5Bn.2n		296.30	15.03	
	M	Termination C6Bn.1n	375.80	22.59	M	Onset 5Bn.2n		298.80	15.16	
	M	Termination C6Bn.2n	377.40	22.80	M	Termination 5Cn.1n		302.30	16.01	
	1172A	M	Termination 3Bn	121.50	6.94	P	FO <i>Praeorbulina curva</i>		311.36	16.30
		M	Onset 3Bn	124.20	7.09	M	Onset 5Cn.3n		314.10	16.73
		P	FO <i>Globorotalia conomiozea</i>	125.00	7.12	M	Termination 5Dn		316.90	17.28
		M	Termination 3Br.1n	125.40	7.14	M	Termination 5En		320.20	18.28
		M	Onset 3Br.1n	126.80	7.17	M	Onset 5En		324.00	18.78
P		LO <i>Paragloborotalia continuosa</i>	144.51	8.00	M	Termination 6n		325.80	19.05	
M		Onset 4n.2n	146.90	8.07	M	Onset 6n		333.10	20.13	
M		Termination 4r.1n	149.20	8.23	M	Termination 6Bn.1n		346.70	22.59	
M		Onset 4r.1n	150.30	8.26	M	Onset 6Bn.1n		348.40	22.75	
M		Termination 4An	156.20	8.70	M	Termination 6Bn.2n		349.10	22.80	
M		Onset 4An	167.00	9.03	M	Onset 6Bn.2n		350.90	23.07	
M		Termination 4Ar.1n	169.80	9.23						
M		Onset 4Ar.1n	169.90	9.31						
M		Termination 4Ar.2n	174.00	9.58						
M		Onset 4Ar.2n	175.00	9.64						

Notes: M = magnetic polarity, P = planktonic foraminifer, R = radiolarian, N = nannofossil. LO = last occurrence, FO = first occurrence.

CHAPTER NOTE*

- N1. Ennyu, A., and Arthur, M.A., submitted. Early to middle Miocene paleoceanography in the southern high latitudes off Tasmania. *In* Exon, N.F., Kennett, J.P., and Malone, M.J. (Eds.), *Climate Evolution in the Southern Ocean and Australia's Cenozoic Flight Northward from Antarctica*. Geophys. Monogr.

*Dates reflect file corrections or revisions.