Data Respository Material: Shelf-open ocean calcareous phytoplankton assemblages across the Paleocene-Eocene Thermal Maximum: Implications for global productivity gradients

by **Gibbs et al.**

Appendix DR1: Supplementary Information on methods and materials

Material, chronology and correlation

The PETM section at Wilson Lake (39°39.35N, 75°02.52W) is highly expanded and continuous, except for two disconformities in the uppermost part of the PETM interval. The upper disconformity at 95 m has removed the first occurrence (FO) of *Discoaster diastypus*, suggesting that the upper part of the section is above the recovery phase of the PETM. The interval between the peak excursion and the lower of the two disconformities includes the FO of *Rhomboaster bramlettei* at 105.70-105.51 which marks the NP9/NP10 boundary (Martini, 1971). The FO of *Tribrachiatus orthostylus* at 94.40-93.83 m places the uppermost four metres in NP11. At ODP Site 1209 (32°39.11N, 158°30.36E; water depth 2387 m), a stratigraphically complete PETM section is marked by a 25 cm thick clay-rich ooze which sharply overlies and grades up into nannofossil ooze (Bralower et al., 2002). The pre-event, onset/peak and recovery intervals at both sites are defined based on the $\delta^{13}C$ records (Zachos et al., 2003). The recovery interval is distinguished from the onset/peak as the point where $\delta^{13}C$ values start to increase. The assigned ages follow Zachos et al. (2003) who based their end-recovery ages on PETM duration estimates of Röhl et al. (2000) and Farley & Eltgroth (2003).

Taxonomy and data collection

For Wilson Lake, species-level, whole assemblage counts were performed on 74 closely samples between 364.15 and 300.23 feet (110.99 and 91.51 m) at a sampling interval of 10 cm through the onset and peak of the CIE, increasing to 20-70 cm above that level. For ODP Site 1209, 66 samples were investigated at 1 cm intervals through the onset and peak, and at 3-5 cm above and below. Quantitative counts (percent abundances) for all taxa present were made on routine smear slides based on the counting strategy of Bralower (2002). Two counts were made for each sample. The first count recorded the first 500 specimens encountered and the second recorded the next 300 'uncommon' taxa. Taxonomic concepts follow morphological-based taxonomies (see Bown, 2005, and references therein). As with any relative (and also, in many cases, absolute) abundances, there are intrinsic 'closed sum' problems, therefore we deliberately do not over-interpret individual species trends but instead look for general trends in multiple taxa and diversity records, as highlighted by correlation coefficients. We also compare these trends to non-ecological records, in particular dissolution, to address secondary influences. However, irrespective of closed sum effects, the co-varying trends still reflect significant change in assemblage character through time, even if it is impossible to determine which taxa increased or decreased in absolute rather than relative abundance.

Quality of records

We used a number of quantitative indicators of nannofossil preservation to assess the level of dissolution: 1. The ratio of indeterminate *Toweius* to identifiable *Toweius* which reflects the etching of dissolution-sensitive central area structure necessary for species-level identification. 2. Nannofossil fragmentation, which was measured in two ways. At Wilson Lake we determined the number of nannofossils fragments per 100 whole nannofossils. At Shatsky, where fragmentation was greater, we estimated the percent of nannofossil fragments relative to total carbonate particles per field of view. 3. Foraminiferal fragmentation, which was counted as the number of foraminiferal fragments per mm^2. 4. Percent $CaCO_3$ records (Colosimo et al., 2005; WL data courtesy of J. Zachos and co-workers) which can reflect both variation in carbonate dissolution and production.

Nannofossil assemblages at Wilson Lake are, for the most part, exceptionally well-preserved. Quantitative indicators of nannofossil preservation suggest only low levels of restricted dissolution. Nannofossil fragmentation, the abundance of identifiable *Toweius*, and percent carbonate all suggest increased dissolution during the onset and peak of the event followed by very little dissolution. Relatively high abundances of robust taxa (e.g., *Discoaster*, *Fasciculithus,* and *Sphenolithus*) in samples from the lower part of the PETM onset (~110.4-111.0 m) potentially reflect increased dissolution, however, delicate taxa are present and even common in these levels (e.g., *Hornibrookina arca, Calciosolenia aperta*). Intervals of high carbonate dissolution in the onset and peak were excluded from analysis. At ODP Site 1209, the record suggests peak dissolution during the event onset and peak. Although fragmentation of nannofossils decreased, rather than increased, in this interval, increased dissolution likely led to complete dissolution (as discussed for foraminiferal fragmentation, Le & Shackleton, 1992). The abundance of foraminiferal fragments shown here is very similar to the record of foraminiferal fragmentation counted by more traditional techniques in Zachos et al. (2003) and Colosimo et al. (2005).

Additional references

Colosimo, A.B., Bralower, T.J., and Zachos, J.C., in press, Evidence for lysocline shoaling at the Paleocene/Eocene Thermal Maximum on Shatsky Rise, Northwest Pacific: Proceedings of the Ocean Drilling Program, Scientific Results, v. 198.

Farley, K.A. and Eltgroth, S.F., 2003, An alternative age model for the PETM using extraterrestrial ^{3}He: Earth and Planetary Science Letters, v. 208, p. 135-148.

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Martini, E., 1971, Standard Tertiary and Quaternary calcareous nannoplankton zonation, in Farinacci, A., ed., Proceedings II Planktonic Conference: Rome, Edizioni Tecnoscienza, p. 739–785.

Röhl, U, T.J. Bralower, R.D. Norris, and G. Wefer, 2000, New chronology for the late Paleocene thermal maximum and its environmental implications: Geology, v. 28, p. 927-930.

Table DR 1. Average nannofossil percent abundances at USGS Wilson Lake and ODP Site 1209 across the PETM. Small placoliths refer to combined *Toweius* and *Coccolithus* <3 ∝m. *Not discussed in the text as only present in significant abundances in 3 samples.

TABLE DR 1. AVERAGE NANNOFOSSIL PERCENT ABUNDANCES

Wilson Lake			Site 1209b		
Taxon	% abundance	cumulative	Taxon	% abundance	cumulative
Small placoliths	40.1	40	*Coccolithus pelagicus*	49.2	49
Total *Toweius*	29.1	69	Total *Toweius*	14.5	64
Coccolithus pelagicus	14.7	84	Total *Sphenolithus*	10	74
Coronocyclus bramlettei	2.6	87	Total *Fasciculithus*	7.3	81
*Hornibrookina arca**	1.9	88	Total *Discoaster*	5.1	86
Total *Discoaster*	1.6	90	*Zygrhablithus bijugatus*	4.1	90
Total *Fasciculithus*	1.4	91	Total *Campylosphaera*	4	94
Total *Neochiastozygus*	1.3	93	Calcareous dinoflagellates	2.2	96
Total *Chiasmolithus*	1.2	94	Total *Cruciplacolithus*	0.81	97
Total *Neococcolithes*	0.95	95	Total *Chiasmolithus*	0.67	98
Calcareous dinoflagellates	0.86	96	Total *Neocrepidolithus*	0.24	98
Total *Ellipsolithus*	0.76	97	*Zeugrhabdotus sigmoides*	0.23	98
Total *Campylosphaera*	0.5	97			
Total *Zygodiscus*	0.39	97			
Total *Pontosphaera*	0.35	98			
Total *Sphenolithus*	0.3	98			
Total *Cruciplacolithus*	0.26	98			

Table DR 2. Correlation coefficients for taxa at a) USGS Wilson Lake and b) ODP Site 1209. Positive and negative values indicate co-varying and inversely co-varying taxon pairs respectively. Note that correlation coefficients only highlight which taxa demonstrate similar or dissimilar trends, whether as a result of closed sum, ecological or dissolution controls, and need to be interpreted with these controls in mind.

TABLE DR 2. CORRELATION COEFFICIENTS

a) Wilson Lake

taxon	*Coronocyclus nitescens*	*total Discoaster*	*total Fasiculithus*	*total Neochiastozygus*	*total Neococcolithes*	*total Pontosphaera*	*total Sphenolithus*	small placoliths	*Zeughrabdotus sigmoides*	*total Zygodiscus*
Coronocyclus nitescens	x	-0.59	-0.74	0.13	0.55	-0.12	-0.59	0.66	-0.47	-0.34
total *Discoaster*		x	0.49	0.01	-0.42	-0.09	0.5	-0.31	0.18	0.13
total *Fasciculithus*			x	-0.1	-0.49	-0.1	0.49	-0.53	0.45	0.17
total *Neochiastozygus*				x	-0.14	0.51	-0.52	0.3	-0.46	-0.46
total *Neococcolithes*					x	-0.17	-0.47	0.6	-0.4	-0.17
total *Pontosphaera*						x	-0.31	0.2	-0.34	-0.29
total *Sphenolithus*							x	-0.57	0.51	0.5
small placoliths								x	-0.39	-0.18
Zeughrabdotus sigmoides									x	0.67
total *Zygodiscus*										x

b) Site 1209

taxon	total *Campylosphaera*	*Chiasmoltihus californicus*	total *Chiasmolithus*	*Coronocyclus nitescens*	total *Cruciplacolithus*	*Discoaster mohleri*	total *Discoaster*	total *Ellipsolithus*	total*Fasciculithus*	total *Neochiastozygus*	total *Sphenolithus*
total *Campylosphaera*	x	-0.4	0.27	0.33	0.48	-0.4	-0.18	-0.41	-0.84	0.3	-0.21
Chiasmoltihus californicus		x	0.32	-0.23	-0.33	0.51	0.29	0.35	0.45	-0.34	0.31
total *Chiasmolithus*			x	0.08	0.05	0.17	0.12	-0.31	-0.18	0.18	0.46
Coronocyclus nitescens				x	0.26	0	-0.3	-0.29	-0.16	0.25	-0.04
total *Cruciplacolithus*					x	-0.16	-0.04	-0.53	-0.48	0.14	-0.1
Discoaster mohleri						x	0.37	0.08	0.47	-0.32	0.28
total *Discoaster*							x	-0.06	0.04	0.02	0.02
total *Ellipsolithus*								x	0.5	-0.38	-0.05
total *Fasciculithus*									x	-0.49	0.27
total *Neochiastozygus*										x	-0.04
total *Sphenolithus*											x

Table DR 3. ODP Site 1209 samples and corresponding meters composite depth (mcd), meters below sea-floor (mbsf), and cms above PETM (from Colosimo et al., in press) for ease of comparison with other publications.

TABLE DR 3. ODP SITE 1209 SAMPLES AND DEPTHS

Site	hole	core	type	sec	interval (cm)	mcd	mbsf	cm above PETM
1209	B	22	H	1	46	215.47	195.56	89
1209	B	22	H	1	49	215.5	195.59	86
1209	B	22	H	1	52	215.53	195.62	83
1209	B	22	H	1	55	215.56	195.65	80
1209	B	22	H	1	58	215.59	195.68	77
1209	B	22	H	1	61	215.62	195.71	74
1209	B	22	H	1	64	215.65	195.74	71
1209	B	22	H	1	67	215.68	195.77	68
1209	B	22	H	1	70	215.71	195.8	65
1209	B	22	H	1	73	215.74	195.83	62
1209	B	22	H	1	75	215.76	195.85	60
1209	B	22	H	1	78	215.79	195.88	57
1209	B	22	H	1	81	215.82	195.91	54
1209	B	22	H	1	84	215.85	195.94	51
1209	B	22	H	1	86	215.87	195.96	49
1209	B	22	H	1	89	215.9	195.99	46
1209	B	22	H	1	92	215.93	196.02	43
1209	B	22	H	1	95	215.96	196.05	40
1209	B	22	H	1	97	215.98	196.07	38
1209	B	22	H	1	99	216	196.09	36
1209	B	22	H	1	101	216.02	196.11	34
1209	B	22	H	1	103	216.04	196.13	32
1209	B	22	H	1	105	216.06	196.15	30
1209	B	22	H	1	107	216.08	196.17	28
1209	B	22	H	1	109	216.1	196.19	26
1209	B	22	H	1	110	216.11	196.2	25
1209	B	22	H	1	112	216.13	196.22	23
1209	B	22	H	1	114	216.15	196.24	21
1209	B	22	H	1	116	216.17	196.26	19
1209	B	22	H	1	118	216.19	196.28	17
1209	B	22	H	1	119	216.2	196.29	16
1209	B	22	H	1	120	216.21	196.3	15
1209	B	22	H	1	121	216.22	196.31	14
1209	B	22	H	1	122	216.23	196.32	13
1209	B	22	H	1	123	216.24	196.33	12
1209	B	22	H	1	124	216.25	196.34	11
1209	B	22	H	1	125	216.26	196.35	10
1209	B	22	H	1	127	216.28	196.37	8
1209	B	22	H	1	128	216.29	196.38	7
1209	B	22	H	1	129	216.3	196.39	6
1209	B	22	H	1	130	216.31	196.4	5
1209	B	22	H	1	131	216.32	196.41	4
1209	B	22	H	1	132	216.33	196.42	3
1209	B	22	H	1	133	216.34	196.43	2
1209	B	22	H	1	134	216.35	196.44	1
1209	B	22	H	1	135	216.36	196.45	0
1209	B	22	H	1	136	216.37	196.46	-1
1209	B	22	H	1	137	216.38	196.47	-2
1209	B	22	H	1	138	216.39	196.48	-3
1209	B	22	H	1	139	216.4	196.49	-4
1209	B	22	H	1	140	216.41	196.5	-5
1209	B	22	H	1	141	216.42	196.51	-6
1209	B	22	H	1	143	216.44	196.53	-8
1209	B	22	H	1	144	216.45	196.54	-9
1209	B	22	H	1	146	216.47	196.56	-11
1209	B	22	H	1	149	216.5	196.59	-14
1209	B	22	H	2	2	216.53	196.62	-17
1209	B	22	H	2	5	216.56	196.65	-20
1209	B	22	H	2	8	216.59	196.68	-23
1209	B	22	H	2	11	216.62	196.71	-26
1209	B	22	H	2	14	216.65	196.74	-29
1209	B	22	H	2	17	216.68	196.77	-32
1209	B	22	H	2	20	216.71	196.8	-35
1209	B	22	H	2	23	216.74	196.83	-38
1209	B	22	H	2	26	216.77	196.86	-41
1209	B	22	H	2	29	216.8	196.89	-44

Figure DR 1. Preservation records at (a) USGS Wilson Lake (meters below surface) and (b) ODP Site 1209 (meters composite depth, see Table DR 3). Refer to DR1 for details.

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