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5. Data Report: Tropical and Equatorial Calcareous Nannofossil Pleistocene Biostratigraphy, ODP Leg 202[1]

José-Abel Flores,[2] Wuchang Wei,[3] Gatsby E. López-Otálvaro,[2]
Carmen Alvarez,[2] and Francisco J. Sierro[2]

INTRODUCTION

During Ocean Drilling Program (ODP) Leg 202, Pleistocene calcareous nannofossils were recovered from several sites situated between 16°S and 8°N latitude. These sites are under the influence of coastal or equatorial upwelling and offer the opportunity to refine biostratigraphic patterns using alternative events from those used in "standard" zonations (Martini, 1971; Okada and Bukry, 1980).

Differences in the positions of the studied sites (Fig. F1) determine changes in sedimentation rates, which range from ~0.8 to 6 cm/k.y. (Shipboard Scientific Party, 2003). These differences are due to the proximity to the continent and to organic production.

The analyzed sites for this study are Sites 1237, 1238, 1240, 1241, and 1242; geographical situation and water depths are listed in Table T1.

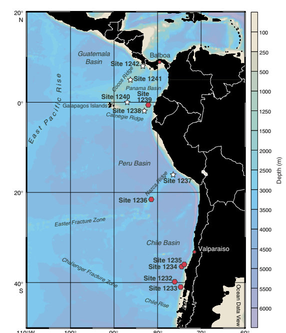
MATERIAL AND METHODS

One to two samples per section were systematically analyzed. For the last 500 k.y., a finer sampling resolution of 10–30 cm was used.

Smear slides were made directly from unprocessed samples and examined with a cross-polarized light microscope at 1000× resolution.

The total abundance of calcareous nannofossils for each sample was estimated as follows:

F1. Geographical situation of Leg 202 drill sites, p. 6.



T1. Situation and water depths of studied sites, p. 7.

[1] Flores, J.-A., Wei, W., López-Otálvaro, G.E., Alvarez, C., and Sierro, F.J., 2006. Data report: tropical and equatorial calcareous nannofossil Pleistocene biostratigraphy, ODP Leg 202. *In* Tiedemann, R., Mix, A.C., Richter, C., and Ruddiman, W.F. (Eds.), *Proc. ODP, Sci. Results,* 202: College Station, TX (Ocean Drilling Program), 1–10. doi:10.2973/odp.proc.sr.202.214.2006
[2] Departamento de Geología, Universidad de Salamanca, 37008 Salamanca, Spain. Correspondence author: **flores@usal.es**
[3] Scripps Institution of Oceanography, University of California, San Diego, Geoscience Research Division, La Jolla CA 92093-0244, USA.

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V = very abundant, >100 nannoliths per field of view.
A = abundant, 10–100 nannoliths per field of view.
C = common, 1–10 nannoliths per field of view.
F = few, <1 nannoliths per field of view.

Additionally, the abundance of calcareous nannofossil species in each sample was estimated as follows:

D = dominant, >50% of the total assemblage.
A = abundant, >10%–50% of the total assemblage.
C = common, >1%–10% of the total assemblage.
F = few, 0.1%–1% of the total assemblage.
R = rare, <0.1% of the total assemblage.

In regard to nannofossil preservation, etching and overgrowth are the most important features. In order to establish a ranking of preservation, we followed previous coding systems such as that used by Shipboard Scientific Party Leg 177 (1999), considering both effects (etching and overgrowth):

G = good (little or no evidence of dissolution and/or secondary overgrowth of calcite; diagnostic characters fully preserved).
M = moderate (dissolution and/or secondary overgrowth; partially altered primary morphological characteristics; however, nearly all specimens can be identified at species level).

Table T2 shows the semiquantitative results of this study. Only samples close to biostratigraphic events are displayed.

T2. Pleistocene calcareous nannofossil abundance, p. 8.

RESULTS

Calcareous Nannofossil Taxonomy

The species considered in this study are mainly included within the family Noelaerhabdaceae (placoliths including the genera *Emiliania, Pseudoemiliania, Gephyrocapsa,* and *Reticulofenestra*) (Thierstein et al., 1977; Pujos-Lamy, 1977; Wei, 1993; Raffi et al., 1993; Weaver and Thomson, 1993). The taxonomy of this group is complex and confusing, mainly because of a proliferation of species names and morphotypes. Here, we adopted the ideas of Raffi et al. (1993) and Flores et al. (2000) for the morphological features of gephyrocapsids, using readily identifiable features under cross-polarized light such as coccolith diameter, bridge angle, and so on.

Calcareous Nannofossil Events

First Occurrence of *Emiliania huxleyi*

The first occurrence (FO) of *E. huxleyi* was dated by Thierstein et al. (1977) at 268 ka (late in marine isotope Stage [MIS] 8). At Sites 1237, 1238, 1240, and 1241, this species is very scarce and sometimes difficult to identify. Dissolution may also make identification difficult, especially at Site 1242.

Last Common Occurrence of *Gephyrocapsa caribbeanica*

The last common occurrence of *G. caribbeanica* is close to the FO of *E. huxleyi,* proposed as an alternative event for midresolution biostratigraphic studies when *E. huxleyi* is scarce or absent (Flores and Marino, 2002). A clear reduction in the abundance of *G. caribbeanica* occurs in all the studied sites just after the FO of *E. huxleyi,* although it is possible to find some specimens of the morphotype *G. caribbeanica* until the most recent samples, especially in samples from Sites 1240, 1241, and 1242.

Last Occurrence of *Pseudoemiliania lacunosa*

Thierstein et al. (1977) identified the globally synchronous last occurrence (LO) of *P. lacunosa* within MIS 12. This event is clearly identified in all the studied sites. To be consistent, we considered the LO when the record of *P. lacunosa* is <1% in abundance. It is common to find specimens of this species close to the FO of *E. huxleyi,* interpreted here as reworked.

First Common Occurrence of *G. caribbeanica*

A clear increase in the abundance of *G. caribbeanica* can be identified within MIS 13 (Matsuoka and Okada, 1990; Pujos and Giraudeau, 1993; Bollmann et al., 1998; Flores et al., 1999), although prior to this dominance, this species increased progressively from MIS 15. This event is easy to identify at Sites 1237 and 1238, recorded just before the LO of *P. lacunosa*. It is difficult to see the signal of this species at Sites 1240, 1241, and 1242; the low sampling resolution contributed to this fact.

Last Occurrence of *Reticulofenestra asanoi*

The LO of *R. asanoi* is known to be a synchronous event in low and relatively high latitudes and occurred late in MIS 22 (Sato and Takayama, 1992; Wei, 1993). In this study, we considered under the denomination *R. asanoi* specimens larger than 6 µm, and the signal is very well identified in all the studied sites.

Reentry of Medium-Sized *Gephyrocapsa*

Raffi et al. (1993) reported the reentry of so-called medium *Gephyrocapsa* between MIS 29 and 16, with a marked degree of diachronism. This event was identified at all the studied cores, although it is difficult to identify at Sites 1241 and 1242.

First Occurrence of *R. asanoi*

The FO of *R. asanoi* is not easy to identify owing to the occurrence of intermediate forms between this species and small reticulofenestrids. Wei (1993) observed the FO of the species between MIS 35 and 29. Sato and Takayama (1992) dated the event at 1.06 Ma (~MIS 30) in the northeast Atlantic (ODP Leg 94) and the Boso Peninsula (west Pacific). Flores and Marino (2002) identified this event in the Atlantic Southern Ocean at the top of Subchron C1r.2r. We clearly observed this event at all the studied cores, considering specimens with maximum diameters >6 µm, following the original description of Sato and Takayama (1992).

Last Occurrence of *Gephyrocapsa* (>5.5 µm)

The LO of the large *Gephyrocapsa* morphotype (large *Gephyrocapsa* sp. B-Matsuoka and Okada, 1990; LG, Raffi et al., 1993) is a globally synchronous event that has been recorded in MIS 37 (Raffi et al., 1993; Wei, 1993). In our material, this event is identified at all sites, although the abundance is sometimes <1%.

First Occurrence of *Gephyrocapsa* (>5.5 µm)

The FO of large *Gephyrocapsa* is a diachronous event. Raffi et al. (1993) placed this event between MIS 46 and 49, and Wei (1993) observed the same event from MIS 47 to 51. As in the mentioned FO of this morphotype, their identification in our material is easy, although maximum abundance is habitually <1%.

Last Occurrence of *Calcidiscus macintyrei*

Raffi et al. (1993) and Wei (1993) dated this event between 1.59 and 1.64 Ma (MIS 55–57), although it is sometimes absent because of ecological restrictions (Flores and Marino, 2002). In our material this species is always scarce but present enough to identify the event, which occurs always immediately after the LO of *Discoaster broweri,* close to the Olduvai/Matuyama boundary (Wei, 1993).

COMMENTS

In this study we identified a total of 11 calcareous nannofossil events at five ODP sites in the tropical and equatorial Pacific (Table T3). Although we discussed assigned ages for these events, as well as the degree of diachronity at different latitudes and oceans, we do not provide a final calibration of these events in the region. This paper constitutes a first attempt; in the future, when paleomagnetic and isotope stratigraphies become refined, they will be compared against these results.

T3. Location of calcareous nannofossil events, p. 10.

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Figure F1. Geographical situation of Leg 202 drill sites. Stars = sites used in this study.

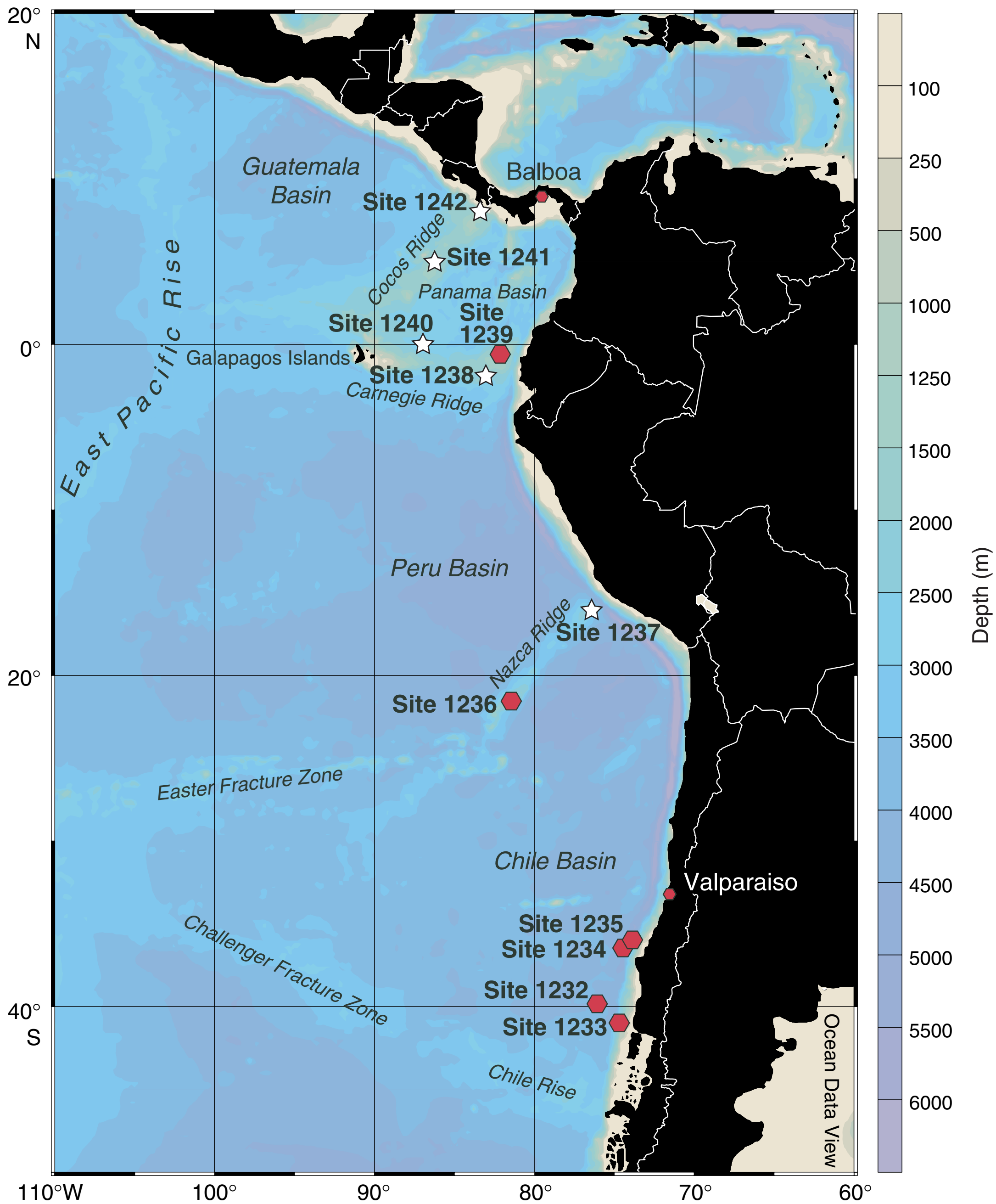

Table T1. Situation and water depth of studied sites.

Site	Longitude	Latitude	Water depth (m)	Average sedimentation rate (cm/k.y.)
202-				
1237	76°22.69′W	16°0.42′S	3212	1.5
1238	82°46.93′W	1°52.31′S	2203	4.5
1240	86°27.76′W	0°01.31′N	2921	10.0
1241	86°26.68′W	5°50.57′N	2027	2.0
1242	83°36.42′W	7°51.35′N	1364	14.0

Table T2. Pleistocene calcareous nannofossil abundance of selected Pleistocene species and morphotypes. (See table notes. Continued on next page.)

Hole, core, section, interval (cm)	Depth (mcd)	Abundance	Preservation	*Emiliania huxleyi*	*Pseudoemiliania lacunosa*	*Gephyrocapsa caribbeanica*	Medium *Gephyrocapsa*	*Reticulofenestra asanoi*	*Gephyrocapsa* >5.5 µm	*Calcidiscus macintyrei*	*Discoaster broweri*
202-											
1237D-1H-2, 108	4.89	A	M	F			F				
1237D-1H-2, 117	4.98	A	M	F			F				
1237D-1H-2, 126	5.07	A	M	F		C	F				
1237D-1H-2, 135	5.16	A	M	F		C	F				
1237D-1H-2, 144	5.25	A	M	F		C	F				
1237D-1H-3, 1	5.31	A	M	F		C	F				
1237D-1H-3, 9	5.40	A	M			C	F				
1237C-2H-4, 63	13.34	A	G			C	F				
1237C-2H-4, 72	13.43	A	G		F	C	F				
1237C-2H-4, 81	13.52	A	G		R	C	F				
1237C-2H-4, 90	13.61	A	G		F	C	F				
1237C-2H-5, 54	14.75	A	G		C	A	F				
1237C-2H-5, 63	14.84	A	G		C	A	F				
1237C-2H-5, 72	14.93	A	G		F		F				
1237D-2H-2, 1	15.00	A	G		F		F				
1237B-3H-4, 60	21.23	A	G		F		F				
1237B-3H-5, 60	22.74	A	G		F		F	C			
1237B-3H-CC, 19	26.10	A	G		F		F	C			
1237B-4H-1, 75	29.55	A	G		F						
1237B-4H-2, 75	31.06	A	G		F				F		
1237B-4H-3, 75	32.57	A	G		F						
1237B-5H-5, 75	35.60	A	G		F						
1237B-4H-6, 75	37.71	A	G		F					F	
1237B-5H-1, 75	38.20	A	G		F					F	R
1237B-5H-2, 75	39.54	A	G		F					F	F
1238A-2H-3, 100	9.62	A	G	F			F				
1238A-2H-3, 125	9.87	A	G	F			F				
1238A-2H-4, 1	10.13	A	G	F		C	F				
1238A-2H-4, 25	10.38	A	G	F		C	F				
1238A-2H-4, 50	10.63	A	G	F		C	C				
1238A-2H-4, 75	10.88	A	G	F		C	C				
1238A-2H-4, 100	11.13	A	G			C	C				
1238A-2H-4, 125	11.38	A	G			C	C				
1238B-3H-5, 100	27.04	A	G			C	C				
1238B-3H-5, 125	27.29	A	G			C	C				
1238B-3H-6, 5	27.59	A	G		R	A	C				
1238B-3H-6, 25	27.79	A	G		R	A	F				
1238C-4H-4, 50	29.77	A	G		F	A	F				
1238C-4H-4, 75	30.02	A	G		F	D	F				
1238C-4H-4, 100	30.27	A	G		F		F				
1238C-4H-4, 125	30.52	A	G		F		F				
1238A-5H-CC, 19	48.24	V	G		F		C				
1238A-6H-1, 75	50.60	V	G		F			F			
1238A-7H-6, 75	68.09	V	G		F			F			
1238A-7H-CC, 0	68.95	V	G		F				C		
1238A-8H-1, 75	70.75	V	G		F				C		
1238A-8H-5, 75	76.79	V	G		F				F		
1238A-8H-6, 75	78.30	V	G		F						
1238A-9H-3, 76	81.68	V	G		F						
1238A-9H-4, 75	83.19	A	G		F					F	
1238A-10H-CC, 33	98.20	A	G		F					R	
1238A-11H-1, 75	99.65	A	G		F					R	R
1240C-2H-3, 122	16.27	A	G	F			F				
1240C-2H-4, 82	17.37	A	G	F		R	F				
1240D-2H-4, 122	20.04	A	G	C		R	F				
1240B-3H-1, 82	20.37	A	M	F		R	F				
1240B-3H-1, 122	20.77	A	M			F	F				
1240B-3H-5, 98	26.55	A	M			F	F				
1240D-3H-2, 98	28.49	A	M			C	F				
1240C-4H-5, 98	41.60	A	M			C	F				
1240B-5H-3, 98	44.14	A	M		F	C	F				
1240C-5H-2, 50	48.06	A	M		C	C	F				
1240A-7H-CC, 22	68.40	A	M		F		F				
1240A-9H-1, 75	79.90	A	M		F		F	C			
1240A-9H-4, 75	84.42	A	M		F		C	F			
1240A-9H-6, 75	87.44	A	M		F		C	F			
1240A-9H-7, 40	88.59	A	M		F			F			
1240A-10H-CC, 9	98.63	A	M		F			F			
1240A-11H-1, 75	99.92	A	M		F						
1240A-11H-7, 40	108.50	A	M		F				F		
1240A-11H-CC, 8	108.99	A	M		F				F		
1240A-13H-1, 75	121.60	A	M		F				F		
1240A-13H-2, 75	123.10	A	M		F						
1240A-14H-3, 75	134.41	A	M		F						
1240A-14H-4, 75	135.91	A	M		F						
1240A-14H-5, 75	137.42	A	M		F					R	
1240A-14H-CC, 18	140.60	A	M		F					R	
1240A-15H-CC, 21	151.94	A	M		F					R	R
1241B-1H-3, 65	3.65	A	M	F			F				
1241B-1H-3, 110	4.10	A	M	F		F	F				
1241B-1H-3, 125	4.25	A	M	F		F	F				
1241B-1H-4, 65	5.15	A	M	F		F	F				
1241B-1H-4, 80	5.30	A	M	R		F	F				
1241B-1H-4, 95	5.45	A	M			F	F				
1241B-1H-4, 125	5.75	A	G			C	F				
1241A-2H-2, 95	7.30	A	G			C	F				
1241A-2H-3, 110	8.95	A	G		R	C	F				
1241A-2H-3, 125	9.10	A	G		F	C	F				
1241A-2H-4, 50	9.85	A	G		F	C	F				
1241A-2H-4, 110	10.45	A	G		F	C	F				
1241A-3H-3, 75	18.91	A	G		F		F				
1241A-3H-4, 75	20.41	A	G		F		F	R			
1241A-3H-5, 75	21.91	A	G		F		F	F			
1241A-3H-6, 75	23.42	A	G		F			F			
1241A-3H-7, 40	24.58	A	G		F						
1241A-3H-CC, 1	24.76	A	G		F						
1241A-4H-1, 75	27.59	A	G		F				F		
1241A-4H-2, 75	29.09	A	G		F						
1241A-4H-CC, 1	36.51	A	G		F						
1241A-5H-1, 75	37.87	A	G		F					R	
1241A-6H-1, 75	48.82	A	G		F					R	
1241A-6H-2, 75	50.33	A	G		F					R	F
1242A-3H-2, 61	21.02	A	M	F			F				
1242A-3H-6, 61	27.07	A	M	F		F	F				
1242C-4H-2, 61	32.22	A	M	F		C	F				
1242C-4H-3, 61	33.73	A	M	R		C	F				
1242C-4H-4, 61	35.24	A	M			C	F				
1242C-4H-6, 61	38.25	A	M			C	F				
1242A-6H-2, 61	51.62	A	M			C	F				
1242A-6H-3, 61	53.13	A	M		R	C	F				
1242C-6H-4, 61	57.02	A	M		F	C	F				
1242C-6H-5, 61	58.52	A	M		F	A	F				
1242B-7H-5, 61	65.51	A	M		F		F				
1242A-11H-3, 75	103.62	A	M		F		F				
1242A-11H-4, 75	105.12	A	M		F		F				
1242A-13H-4, 75	125.69	A	M		F		R				
1242A-13H-5, 75	127.19	A	M		F		R	R			
1242A-13H-CC, 26	130.39	A	M		F			R			
1242A-14H-1, 75	131.93	A	M		F						
1242A-17H-CC, 17	174.77	A	M		F						
1242A-18H-CC, 68	186.81	A	M		F				R		

Table T2 (continued).

Hole, core, section, interval (cm)	Depth (mcd)	Abundance	Preservation	*Emiliania huxleyi*	*Pseudoemiliania lacunosa*	*Gephyrocapsa caribbeanica*	Medium *Gephyrocapsa*	*Reticulofenestra asanoi*	*Gephyrocapsa* >5.5 µm	*Calcidiscus macintyrei*	*Discoaster broweri*
1242A-19H-3, 40	191.99	A	M		F				R		
1242A-19H-4, 40	192.64	A	M		F						
1242A-20X-CC, 24	204.34	C	M		F						
1242A-21X-CC, 28	215.23	C	M		F					R	
1242A-25X-5, 75	257.48	C	M		F					R	
1242A-25X-6, 75	258.98	F	M		F					R	F

Notes: V = very abundant, A = abundant. G = good, M = moderate. D = dominant, A = abundant, C = common, F = few, R = rare.

Table T3. Location of calcareous nannofossil events.

	Event depth (mcd)										
Site	LCO *Gephyrocapsa caribbeanica*	FO *Emiliania huxleyi*	LO *Pseudoemiliania lacunosa*	FCO *Gephyrocapsa caribbeanica*	LO *Reticulofenestra asanoi*	RE Medium *Gephyrocapsa*	FO *Reticulofenestra asanoi*	LO *Gephyrocapsa* >5.5 µm	FO *Gephyrocapsa* >5.5 µm	LO *Calcidiscus macintyrei*	LO *Discoaster broweri*
202-											
1237	5.03	5.35	13.38	14.88	21.98	27.82	27.82	30.30	31.81	36.61	37.90
1238	10.00	11.00	27.44	30.15	49.42	49.42	68.52	68.52	77.54	82.43	98.92
1240	16.80	20.52	42.87	74.15*	85.93	88.01	99.27	108.74	122.35	136.65	145.77
1241	3.85	5.37	8.12	14.68*	21.16	22.66	24.00	26.17	28.34	37.19	49.57
1242	29.64	34.48	52.37	62.01*	126.44	128.79	131.16	180.79	192.31	209.78	258.23

Notes: * = depth is approximate. LCO = last common occurrence, FO = first occurrence, LO = last occurrence, FCO = first common occurrence, RE = reentrance.