Bralower, T.J., Premoli Silva, I., and Malone, M.J. (Eds.)
Proceedings of the Ocean Drilling Program, Scientific Results Volume 198

5. Data Report: Planktonic Foraminiferal Biostratigraphy across the Cretaceous/Paleocene Boundary at Shatsky Rise (ODP Leg 198, Northwest Pacific)[1]

Isabella Premoli Silva,[2] Maria Rose Petrizzo,[2] and Daniele Melloni[2]

INTRODUCTION

During Leg 198, the Cretaceous/Paleocene (K/P) boundary was recovered in a remarkable set of cores in nine separate holes at Sites 1209, 1210, 1211, and 1212 on the Southern High of Shatsky Rise. The boundary succession includes an uppermost Maastrichtian white to very pale orange, slightly indurated nannofossil ooze overlain by lowermost Paleocene grayish orange foraminiferal ooze. The boundary between the uppermost Maastrichtian and the lowermost Paleocene is clearly bioturbated. The contact surface is irregular, and pale orange burrows extend 10 cm into the white Maastrichtian ooze.

Preliminary investigations conducted on board revealed that the deepest sections of these burrows yielded highly abundant, minute planktonic foraminiferal assemblages dominated by *Guembelitria* with rare *Hedbergella holmdelensis* and *Hedbergella monmouthensis,* possibly attributable to the lowermost Paleocene Zone P0. The substantial thickness of the uppermost Maastrichtian *Micula prinsii* (CC26) nannofossil Zone and the lowermost Danian *Parvularugoglobigerina eugubina* (Pα) foraminiferal Zone suggested that the K/P boundary was rather expanded compared to the majority of deep-sea sites (see Bralower, Premoli Silva, Malone, et al., 2002).

[1] Premoli Silva, I., Petrizzo, M.R., and Melloni, D., 2005. Data report: Planktonic foraminiferal biostratigraphy across the Cretaceous/Paleocene boundary at Shatsky Rise (ODP Leg 198, Northwest Pacific). *In* Bralower, T.J., Premoli Silva, I., and Malone, M.J. (Eds.), *Proc. ODP, Sci. Results,* 198, 1–15 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/198_SR/VOLUME/CHAPTERS/111.PDF>. [Cited YYYY-MM-DD]
[2] Dipartimento di Scienze della Terra "Ardito Desio," via Mangiagalli 34, 20133 Milano, Italy. Correspondence author: **Isabella.Premoli@unimi.it**

Initial receipt: 04 March 2004
Acceptance: 27 January 2005
Web publication: 6 December 2005
Ms 198SR-111

This data report concerns the planktonic foraminiferal biostratigraphy across the K/P boundary in Hole 1209C, the shallowest site (2387 m water depth), and in Hole 1211C, the deepest site (2907 m water depth), where the foraminiferal record across the boundary appeared to be best preserved.

METHODS

A total of 100 samples in Hole 1209C and 81 in Hole 1211C were investigated. In both holes, 1 m across the visible boundary was sampled every centimeter using the U-channel sampling device. Sampling was extended below and above this interval where samples were taken every 5 to 10 cm. A few samples taken randomly and studied on board the ship around this interval were reexamined. Unfortunately, the U-channel sampling method was not totally suitable for collecting clean samples for a very high resolution study, as several samples were contaminated from either older or younger layers.

All samples were washed through 38-µm mesh sieves to retain the very minute specimens of the earliest Paleocene fauna. The distributions of planktonic foraminifers from both holes are shown in Tables T1 and T2. These tables also include the abundance estimate of single planktonic foraminiferal species, and total benthic foraminifers, as well as other organic/inorganic components of the washed residues, which are annotated as follows:

AA = very abundant (>50%).
A = abundant (30%–50%).
C = common (10%–30%).
F = few (5%–10%).
R = rare (1%–5%).
VR = very rare (1–5 specimens).
P = present.

The state of preservation is annotated as follows:

VG = very good (no evidence of breakage or dissolution).
G = good (>90% of specimens unbroken).
M = moderate (30%–90% of the specimens unbroken).
P = poor (strongly recrystallized or dominated by fragments and broken or corroded specimens).
VP = very poor (>90% of specimens broken).

Mineral and other components are abbreviated as follows:

ox = iron oxides.
sph = spherules.
py = pyrite.

Quantitative analysis was performed on planktonic foraminiferal assemblages from the U-channel samples in both holes. The quantitative data will be published elsewhere.

T1. Planktonic foraminiferal distribution, Hole 1209C, p. 11.

T2. Planktonic foraminiferal distribution, Hole 1211C, p. 14.

BIOSTRATIGRAPHY

The interval investigated spans four foraminiferal biozones, (1) the uppermost Maastrichtian *Abathomphalus mayaroensis* Zone, defined by the first occurrence (FO) of the nominate taxon to the last occurrence (LO) of most Cretaceous taxa; (2) the lowermost Paleocene Zone P0, defined by the LO of most Cretaceous taxa to the FO of *P. eugubina;* (3) the lower Paleocene Zone Pα, defined by the total range of *P. eugubina;* and (4) the lower part of the lower Paleocene Subzone P1a of Zone P1, defined by the LO of *P. eugubina* to the FO of *Subbotina triloculinoides* (see Olsson et al., 1999).

Hole 1209C

Total interval studied: Samples 198-1209C-15H-4, 5–6 cm, to 15H-2, 70–71 cm (235.48–233.2 meters below seafloor [mbsf]). Based on planktonic foraminiferal distribution, few intervals can be identified (from bottom to top).

Top Sections 198-1209C-15H-4 to 15H-3, 88 cm (235.48–234.88 mbsf): in the uppermost Maastrichtian white ooze, the assemblage is highly diversified and belongs to the *A. mayaroensis* Zone with large (>250 µm) specimens of *Globotruncanita stuarti, Globotruncanita stuartiformis, Globotruncanella havanensis, Globotruncanella petaloidea, Pseudoguembelina excolata, Pseudoguembelina hariaensis, Pseudotextularia elegans, Racemiguembelina fructicosa, H. holmdelensis,* and *H. monmouthensis,* and common *Guembelitria* occur in the small-sized fraction (<150 µm). Faunal preservation through this interval is very variable, ranging from fair to progressively poorer approaching the top of the Cretaceous; faunas, although unevenly preserved from layer to layer, become chalky in aspect, tend to dissolve, and specimens are highly fragmented.

Pale orange burrows extend up to 10 cm into the irregular surface of the white uppermost Cretaceous ooze; washed residues of carefully taken samples from the bottom of the deepest burrows contain minute (<75 µm), well-preserved planktonic foraminiferal assemblages consisting of almost 100% *Guembelitria* and rare, very small sized hedbergellids (*H. holmdelensis* and *H. monmouthensis*) attributable to the lowermost Paleocene Zone P0. However, in washed residues from U-channel samples, this minute fauna is mixed with the poorly preserved, chalky broken specimens from the surrounding uppermost Maastrichtian white ooze.

Foraminiferal assemblages from the top part of the burrows and/or small depressions on the white ooze irregular surface comprise the same species described above along with very rare, minute five-chambered *P. eugubina*. At the same level, rare yellow-brown spherules are first noted and range up to Sample 198-1209C-15H-3, 83–84 cm (234.82 mbsf) in Zone Pα.

In Sample 198-1209C-15H-3, 87–88 cm (234.86 mbsf), *P. eugubina* is still rare, and then it rapidly increases in size and abundance. Important components of the assemblage include hedbergellids, *Guembelitria, Chiloguembelina morsei, Chiloguembelina midwayensis,* and *Woodringina hornerstownensis,* whereas *Woodringina claytonensis* is slightly subordinate. *Eoglobigerina eobulloides, Eoglobigerina edita, Eoglobigerina fringa,* and *Globoconusa daubjergensis* are very rare. *Guembelitria* and chiloguembelinids display an opposite trend in abundance.

In the interval from Sample 198-1209C-15H-3, 83–84 cm (234.82 mbsf), upward, *P. eugubina* becomes very abundant and reaches the maximum abundance in Sample 198-1209C-15H-3, 81–82 cm (234.80 mbsf), whereas hedbergellids decrease in abundance abruptly and disappear in Sample 198-1209C-15H-3, 73–74 cm (234.72 mbsf). Important components of the assemblages include *C. midwayensis* and woodringinids.

In Sample 198-1209C-15H-3, 72–73 cm (234.71 mbsf), *P. eugubina* starts to decrease in abundance and is last recorded in Sample 198-1209C-15H-3, 51–52 cm (234.50 mbsf). In this interval the faunal assemblage is dominated by the genera *Guembelitria, Chiloguembelina,* and *Woodringina*. *Eoglobigerina eobulloides* and *Globanomalina archeocompressa* are very rare and occur sporadically.

In Sample 198-1209C-15H-3, 59–60 cm (234.58 mbsf), *Parasubbotina pseudobulloides* appears first and is followed by *Praemurica pseudoinconstans* slightly above, even though their presence is sporadic across the Pα/P1a zonal boundary.

Subzone P1a starts in Sample 198-1209C-15H-3, 50 cm (234.49 mbsf); the record of *P. pseudobulloides* and *P. pseudoinconstans* is still scattered, and only few specimens are present. *Guembelitria* shows a marked increase in abundance in Sample 198-1209C-15H-3, 49–50 cm (234.48 mbsf), which is balanced by a decrease of *C. midwayensis*. However, the other biserial heterohelicids remain more or less stable in abundance.

The presence of *P. pseudobulloides* and, to a minor extent, *P. pseudoinconstans,* even rarer still, becomes more constant in Sample 198-1209C-15H-3, 37–38 cm (234.36 mbsf and above). From Samples 198-1209C-15H-3, 25–26 cm (234.24 mbsf), to 15H-3, 9–10 cm (234.08 mbsf), *E. eobulloides* is also better represented in the assemblages.

At the top of Section 198-1209C-15H-3 (233.99 mbsf), the abundance of *Guembelitria* decreases markedly and the assemblage is dominated by heterohelicids (mainly *Chiloguembelina* and woodringinids and by a lesser amount of *Guembelitria*) representing almost 100% of the total specimens. The trochospiral taxa (*P. pseudobulloides* and *P. pseudoinconstans*) represent only 3%–6%, and *E. eobulloides* is absent.

Section 198-1209C-15H-2, sampled every 5 cm (233.9–233.5 mbsf), yields a fauna similar to the top of Section 15H-3, dominated by biserial taxa, whereas *Guembelitria* decreases significantly upcore.

Above Sample 198-1209C-15H-2, 100–101 cm (233.50 mbsf), chiloguembelinids, especially *C. morsei,* further increase in abundance.

From Sample 198-1209C-15H-2, 95–96 cm, to 15H-2, 70–71 cm (233.45–233.20 mbsf), *P. pseudobulloides* and *P. pseudoinconstans* significantly increase in abundance (>25%); in addition, the assemblages comprise ~45% of *C. morsei* alone and ~15% woodringinids, whereas *Guembelitria* is almost absent.

The faunal assemblage from the few samples investigated in Holes 1209A, 1209B, and 1210A supports the distribution and evolution of planktonic foraminiferal taxa recorded in Hole 1209C across the K/P boundary.

Hole 1211C

Total interval studied: Samples 198-1211C-15H-5, 22–23 cm, to 15H-3, 80–81 cm (135.02–132.61 mbsf). Samples 198-1211C-15H-3, 150 cm, to 15H-3, 81 cm (133.3–132.62 mbsf), were taken in 1-cm intervals using the U-channel sampling device; Section 198-1211C-15H-4 was sampled every 10 cm. Data from a few samples studied on board were also incorporated.

Shore-based study of the interval across the K/P boundary in Hole 1211C revealed that the succession is much more disturbed and complex with respect to that recovered in Hole 1209C.

In Hole 1211C, Cretaceous faunas are poorly preserved and strongly affected by dissolution and well-preserved, recognizable specimens are very rare or even missing in some samples.

Moreover, characteristic features of the succession in Hole 1211C are

1. The remarkable abundance of benthic foraminifers from Sample 198-1211C-15H-4, 80–81 cm (134.10 mbsf), up to 15H-3, 111–112 cm (132.92 mbsf). Above this level, the abundance of benthic foraminifers becomes moderate for a few centimeters and then scarce as expected.
2. The washed residues from Samples 198-1211C-15H-4, 80–81 cm (134.10 mbsf), to 15H-3, 147–148 cm (133.26 mbsf), contain very few planktonic specimens, ranging from 89 total specimens in Sample 15H-4, 25–26 cm (133.55 mbsf), to 0 specimens in Sample 15H-4, 35–36 cm (133.65 mbsf). Larger numbers of specimens are recorded only from Sample 15H-3, 146–147 cm (124 specimens), upcore.
3. Fish remains, which are common in the most depauperate residues.
4. Spherules and iron oxides, recorded in two separate intervals, Samples 198-1211C-15H-3, 143–144 cm (133.24 mbsf), to 15H-3, 141–142 cm (133.22 mbsf), and more abundantly from Samples 15H-3, 127–128 cm (133.08 mbsf), to 15H-3, 118–119 cm (132.99 mbsf).

As shown in Table T2, the interval in which *P. eugubina* was observed is twice as long as the range of *P. eugubina* in Hole 1209C and extends well below the level where the K/P boundary was previously placed (Bralower, Premoli Silva, Malone, et al., 2002). Moreover, Cretaceous taxa are scattered over a longer interval but are concentrated in the middle of the *P. eugubina* range, whereas very few of them were found in the samples thought to belong to the top of the Cretaceous section.

Sample 198-1211C-15H-5, 22–23 cm (135.02 mbsf), corresponds to the uppermost sample investigated that definitely belongs to the uppermost Cretaceous *A. mayaroensis* Zone.

Sample 198-1211C-15H-4, 9–10 cm (133.39 mbsf), yields a lowermost Paleocene *P. eugubina* fauna that already contains common to abundant *P. eugubina* (including multiple morphotypes), common woodringinids, few *Guembelitria,* rare *E. eobulloides,* and very rare fragments of Cretaceous taxa. A similar assemblage is also present in the underlying Sample 198-1211C-15H-4, 25–26 cm (133.55 mbsf).

Based on these data, the base of the U-channel sample set at the bottom of Section 198-1211C-15H-3 lies well above the oldest Paleocene faunas. Moreover, comparing faunal composition from the lower part of the section in Sample 198-1211C-15H-4, 80–81 cm (134.10 mbsf), with that from Hole 1209C, it looks likely that the K/P boundary in Hole 1211C was probably lying in the unrecovered lower part of Section 15H-4 (below 134.10 mbsf).

The top of Zone Pα is also difficult to place. The LO of *P. eugubina* recorded in Sample 198-1211C-15H-3, 88–89 cm (132.69 mbsf), may correspond to its true extinction level, as *P. eugubina* co-occurs with *P.*

pseudobulloides and *P. pseudoinconstans* in the upper part of its range. However, the latter species are much more common than in the corresponding interval in Hole 1209C. Also anomalous is the presence of common hedbergellids along with common *P. eugubina* (including multiple morphotypes) in Samples 198-1211C-15H-3, 110–111 cm (132.91 mbsf), to 15H-3, 97–98 cm (132.78 mbsf), as the hedbergellids should disappear in the lower half of the range of *P. eugubina*.

From the anomalous distribution of both uppermost Cretaceous and lowermost Paleocene taxa, we can conclude that the succession across the K/P boundary in Hole 1211C is affected by significant reworking or, alternatively, by intensive bioturbation. The latter possibility, however, may apply to the upper part of Section 198-1211C-15H-3 but is unlikely for the lower Section 15H-4, where burrows are not evident. We also considered the possibility that one or more layers were repeatedly slumped downslope into the normal succession. However, the faunal record does not show any repeated trend, as the assemblages are very mixed. Apparently, reworking, or mixing by bioturbation, extends up at least to Sample 198-1211C-15H-3, 96–97 cm (132.77 mbsf), as suggested by the highest occurrence of hedbergellids.

ACKNOWLEDGMENTS

This research used samples provided by the Ocean Drilling Program (ODP). ODP is sponsored by the U.S. National Science Foundation (NSF) and participating countries under management of Joint Oceanographic Institutions (JOI), Inc. Funding for this research was provided by MIUR-COFIN 2001 and 2003 to I.P.S.

REFERENCES

Bralower, T.J., Premoli Silva, I., Malone, M.J., et al., 2002. *Proc. ODP, Init. Repts.,* 198 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station TX 77845-9547, USA.

Olsson, R.K., Hemleben, C., Berggren, W.A., and Huber, B.T. (Eds.), 1999. *Atlas of Paleocene Planktonic Foraminifera*. Smithson. Contrib. Paleobiol., Vol. 85.

APPENDIX

Species List (in alphabetical order)

Cretaceous

***Abathomphalus* Bolli, Loeblich, and Tappan, 1957**

Abathomphalus intermedius (Bolli) = *Globotruncana intermedia* Bolli, 1951

***Contusotruncana* Korchagin, 1982**

Contusotruncana contusa (Cushman) = *Pulvinulina arca* var. *contusa* Cushman, 1926

***Globigerinelloides* Cushman and ten Dam, 1948**

Globigerinelloides messinae (Broennimann) = *Globigerinella messinae messinae* Broennimann, 1952

Globigerinelloides subcarinatus (Broennimann) = *Globigerinella messinae subcarinata* Broennimann, 1952

***Globotruncanella* Reiss, 1957**

Globotruncanella havanensis (Voorwijk) = *Globotruncana havanensis* Voorwijk, 1937

Globotruncanella petaloidea (Gandolfi) = *Globotruncana* (*Rugoglobigerina*) *petaloidea* Gandolfi, 1955

***Globotruncanita* Reiss, 1957**

Globotruncanita stuarti (de Lapparent) = *Rosalina stuarti* de Lapparent, 1918

Globotruncanita stuartiformis (Dalbiez) = *Globotruncana elevata stuartiformis* Dalbiez, 1955

***Gublerina* Kikoine, 1948**

Gublerina cuvillieri Kikoine, 1948

***Heterohelix* Ehrenberg, 1843**

Heterohelix globulosa (Ehrenberg) = *Textularia globulosa* Ehrenberg, 1840

Heterohelix planata (Cushman) = *Guembelina planata* Cushman, 1938

***Kuglerina* Broennimann and Brown, 1956**

Kuglerina rotundata (Broennimann) = *Rugoglobigerina rugosa rotundata* Broennimann, 1952

***Pseudoguembelina* Broennimann and Brown, 1953**

Pseudoguembelina excolata (Cushman) = *Guembelina excolata* Cushman, 1926

Pseudoguembelina hariaensis Nederbragt, 1990

***Pseudotextularia* Rzehak, 1891**

Pseudotextularia elegans (Rzehak) = *Cuneolina elegans* Rzehak, 1891

***Racemiguembelina* Montanaro Gallitelli, 1957**

Racemiguembelina fructicosa (Egger) = *Guembelina fructicosa* Egger, 1902

***Rugoglobigerina* Broennimann, 1952**

Rugoglobigerina rugosa (Plummer) = *Globigerina rugosa* Plummer, 1926

***Schackoina* Thalmann, 1932**

Schackoina sp.

Ventilabrella Cushman, 1928

Ventilabrella multicamerata de Klasz, 1953

Cretaceous to Paleocene

Guembelitria Cushman, 1933

Guembelitria cretacea Cushman, 1933

Hedbergella Broennimann and Brown, 1958

Hedbergella holmdelensis Olsson, 1964

Hedbergella monmouthensis (Olsson) = *Globorotalia monmouthensis* Olsson, 1960

Zeouvigerina Finlay, 1939

Zeouvigerina waiparaensis (Jenkins) = *Chiloguembelina waiparaensis* Jenkins, 1965

Paleocene

Chiloguembelina Loeblich and Tappan, 1956

Chiloguembelina midwayensis (Cushman) = *Guembelina midwayensis* Cushman, 1940

Chiloguembelina morsei (Kline) = *Guembelina morsei* Kline, 1943

Eoglobigerina Morozova, 1959

Eoglobigerina edita (Subbotina) = *Globigerina edita* Subbotina, 1953

Eoglobigerina eobulloides (Morozova) = *Globigerina* (*Eoglobigerina*) *eobulloides* Morozova, 1959

Eoglobigerina fringa (Subbotina) = *Globigerina fringa* Subbotina, 1953

Globanomalina Haque, 1956, emended

Globanomalina archeocompressa (Blow) = *Globorotalia* (*Turborotalia*) *archeocompressa* Blow, 1979

Globanomalina planocompressa (Shutskaya) = *Globorotalia planocompressa planocompressa* Shutskaya, 1965

Globoconusa Khalilov, 1956

Globoconusa daubjergensis (Broennimann) = *Globigerina daubjergensis* Broennimann, 1953

Parasubbotina Olsson, Hemleben, Berggren, and Liu, 1992

Parasubbotina pseudobulloides (Plummer) = *Globigerina pseudobulloides* Plummer, 1926

Parvularugoglobigerina Hofker, 1978

Parvularugoglobigerina eugubina (Luterbacher and Premoli Silva) = *Globigerina eugubina* Luterbacher and Premoli Silva, 1964

Parvularugoglobigerina alabamensis (Liu and Olsson) = *Guembelitria*? *alabamensis* Liu and Olsson,1992

Praemurica Olsson, Hemleben, Berggren, and Liu, 1992

Praemurica pseudoinconstans (Blow) = *Globorotalia* (*Turborotalia*) *pseudoinconstans* Blow, 1979

Praemurica taurica (Morozova) = *Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961

Subbotina Brotzen and Pozaryska, 1961

Subbotina trivialis (Subbotina) = *Globigerina trivialis* Subbotina, 1953

Woodringina Loeblich and Tappan, 1957

Woodringina claytonensis Loeblich and Tappan, 1957

Woodringina hornerstownensis Olsson, 1960

Table T1. Planktonic foraminiferal distribution, Hole 1209C. (See table notes. Continued on next two pages.)

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Guembelitria cretacea*	*Hedbergella monmouthensis*	*Hedbergella holmdelensis*	*Globotruncanita stuartiformis*	*Pseudotextularia elegans*	*Globotruncanella havanensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Schackoina* spp.	*Kuglerina rotundata*	*Heterohelix globulosa*	*Contusotruncana contusa*	*Parvularugoglobigerina eugubina*	*Chiloguembelina morsei*	*Globotruncanita stuarti*	*Chiloguembelina midwayensis*	*Woodringina hornerstownensis*	*Rugoglobigerina rugosa*	*Woodringina claytonensis*	*Eoglobigerina eobulloides*	*Eoglobigerina fringa*	*Gublerina cuvillieri*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parvularugoglobigerina eugubina* morph.	*Parvularugoglobigerina alabamensis*	*Globoconusa daubjergensis*	*Globanomalina archeocompressa*	*Zeauvigerina waiparaensis*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	*Subbotina trivialis*	*Praemurica taurica*	Zone	Age
198-1209C-																																							
15H-2, 70–71	233.2		G		VR													A		C	F		F											F	C				
15H-2, 75–76	233.25		G		VR													A		C	F		F											C	C				
15H-2, 80–81	233.3		G		VR													A		F	C		C											F	C				
15H-2, 85–86	233.35		G															A		C	F		C											F	C				
15H-2, 90–91	233.4		G		VR													A		F	C		C											F	C				
15H-2, 95–96	233.45		G		R													A		C	C		F											F	C				
15H-2, 100–101	233.5		G		F													A		C	C		C											R	R				
15H-2, 105–106	233.55		G		F													A		C	C		R											R	F				
15H-2, 110–111	233.6		G		F													A		C	C		C											VR	R				
15H-2,115–116	233.65		G		F													A		F	C		F											R	R				
15H-2, 120–121	233.7		G		F		VR											A		F	C		F											R	R				
15H-2, 125–126	233.75		G		C		VR											A		C	C		C											R	VR				
15H-2, 130–131	233.8		G		F													A		F	C		C											R	VR				
15H-2, 135–136	233.85		G		C													A		F	C		C											R	R				
15H-2, 140–141	233.9		G		C													C		F	C		C											R	VR				
15H-3, 0–1	233.99		P		C													C		C	C		R											F					
15H-3, 1–2	234.00	R	G		A													C		C	C		R											R					
15H-3, 2–3	234.01		G		A													C		C	C		F											R					
15H-3, 3–4	234.02	R	G	ox	A													C		C	C		R											R				P1a	early Paleocene
15H-3, 4–5	234.03		G		A													C		C	C		F											R					
15H-3, 5–6	234.04	R	G		A													C		C	C		C											R	VR				
15H-3, 6–7	234.05		G		A													C		C	C		F											R	R				
15H-3, 7–8	234.06		G		A													C		C	C		R																
15H-3, 8–9	234.07	R	G		A													C		C	C		F										R	R	R				
15H-3, 9–10	234.08		G		A													C		C	C		F											VR			VR		
15H-3, 10–11	234.09		G		A													C		C	C		F	R										R					
15H-3, 11–12	234.10		G		A													C		C	C		C	VR									R	VR					
15H-3, 12–13	234.11		G		A													C		C	C		C	VR									VR	VR					
15H-3, 13–14	234.12		G		A													C		C	C		C	R										R			VR		
15H-3, 14–15	234.13		G		A													C		C	C		C	R										VR					
15H-3, 15–16	234.14		G		C												VR	C		C	F		F	R										R			VR		
15H-3, 16–17	234.15		G		A												VR	C		C	C		F	R										R	VR				
15H-3, 17–18	234.16		G		C													C		C	C		C	VR										VR	R				
15H-3, 18–19	234.17		M		C													C		C	C		C										VR	R	VR				
15H-3, 19–20	234.18		M		A													C		C	C		C											VR	VR				
15H-3, 20–21	234.19		M		A													C		C	C		F												R				
15H-3, 21–22	234.20	R	M		A													C		C	C		F	VR										VR	R				

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Guembelitria cretacea*	*Hedbergella monmouthensis*	*Hedbergella holmdelensis*	*Globotruncanita stuartiformis*	*Pseudotextularia elegans*	*Globotruncanella havanensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Schackoina* spp.	*Kuglerina rotundata*	*Heterohelix globulosa*	*Contusotruncana contusa*	*Parvularugoglobigerina eugubina*	*Chiloguembelina morsei*	*Globotruncanita stuarti*	*Chiloguembelina midwayensis*	*Woodringina hornerstownensis*	*Rugoglobigerina rugosa*	*Woodringina claytonensis*	*Eoglobigerina eobulloides*	*Eoglobigerina fringa*	*Gublerina cuvillieri*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parvularugoglobigerina eugubina* morph.	*Parvularugoglobigerina alabamensis*	*Globoconusa daubjergensis*	*Globanomalina archeocompressa*	*Zeauvigerina waiparaensis*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	*Subbotina trivialis*	*Praemurica taurica*	Zone	Age
15H-3, 22–23	234.21	R	M		A													C		C	C		C	VR										VR	VR				
15H-3, 23–24	234.22	R	M		A													C		F	C		R	R										R	R				
15H-3, 24–25	234.23	R	M		A													C		F	C		F	R										R	R				
15H-3, 25–26	234.24		M		A													C		C	C		F	VR										R	VR				
15H-3, 26–27	234.25		M		A													C		F	C		F											VR					
15H-3, 27–28	234.26		M		A													C		F	C		F																
15H-3, 28–29	234.27		M		A													C		F	C		F	VR						VR			VR	R					
15H-3, 29–30	234.28		M		A													C		F	C		C											VR	VR				
15H-3, 30–31	234.29		M		A													A		F	C		F											R	VR				
15H-3, 31–32	234.30		M		C													A		F	C		F												VR				
15H-3, 32–33	234.31		M		A													A		F	C		F											R	R				
15H-3, 33–34	234.32		M		A													C		F	C		F										VR	VR	VR	VR			
15H-3, 34–35	234.33		M		A													C		C	C		F											VR					
15H-3, 35–36	234.34		M		A													C		F	C		F										VR	VR				P1a	
15H-3, 36–37	234.35	R	M		A													C		F	C		F											VR					
15H-3, 37–38	234.36		M		A													C		F	C		F											VR	VR				
15H-3, 38–39	234.37		VP	ox																VR	VR																		
15H-3, 39–40	234.38		M		A													C		R	C		C	VR															
15H-3, 40–41	234.39	R	P		A													C		F	C		C										VR						
15H-3, 41–42	234.40		M		A													A		F	C		F										VR	VR		VR			early Paleocene
15H-3, 42–43	234.41		M		A													C		C	C		F																
15H-3, 43–44	234.42		M		A													C		C	C		C											VR		VR			
15H-3, 44–45	234.43	R	M		A													C		C	F		C										VR						
15H-3, 45–46	234.44		M		A													C		C	F		F											VR					
15H-3, 46–47	234.45	R	M		A													C		C	C		F																
15H-3, 47–48	234.46	R	M		A													C		F	C		F																
15H-3, 48–49	234.47		M		A													C		C	C		F											VR					
15H-3, 49–50	234.48		M		A													C		C	C		F																
15H-3, 50–51	234.49	R	M		C													C		C	C		F	VR									VR	VR					
15H-3, 51–52	234.50	R	M		C												VR	C		C	C		F	VR															
15H-3, 52–53	234.51		P		C												VR	C		C	C		C										R			VR			
15H-3, 53–54	234.52	R	M		C													C		C	C		C										VR			VR			
15H-3, 54–55	234.53	R	M		C												R	C		C	C		F										VR						
15H-3, 55–56	234.54	R	M		AA												R	C		C	F		R											VR		VR		Pα	
15H-3, 56–57	234.55	R	M		C												R	C		C	F		F											R					
15H-3, 57–58	234.56		M		C												F	C		C	F		F	R						VR			VR	R					
15H-3, 58–59	234.57		P		C												R	C		A	F		F	VR								VR		R	VR				
15H-3, 59–60	234.58		P		C												F	C		C	C		C										R	VR					
15H-3, 60–61	234.59		VP		C	VR											F/C	C		C	C		F										R						

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Guembelitria cretacea*	*Hedbergella monmouthensis*	*Hedbergella holmdelensis*	*Globotruncanita stuartiformis*	*Pseudotextularia elegans*	*Globotruncanella havanensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Schackoina* spp.	*Kuglerina rotundata*	*Heterohelix globulosa*	*Contusotruncana contusa*	*Parvularugoglobigerina eugubina*	*Chiloguembelina morsei*	*Globotruncanita stuarti*	*Chiloguembelina midwayensis*	*Woodringina hornerstownensis*	*Rugoglobigerina rugosa*	*Woodringina claytonensis*	*Eoglobigerina eobulloides*	*Eoglobigerina fringa*	*Gublerina cuvillieri*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parvularugoglobigerina eugubina* morph.	*Parvularugoglobigerina alabamensis*	*Globoconusa daubjergensis*	*Globanomalina archeocompressa*	*Zeouvigerina waiparaensis*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	*Subbotina trivialis*	*Praemurica taurica*	Zone	Age
15H-3, 62–63	234.61	R	M		C												F/C	C		C	R		F										VR						
15H-3, 63–64	234.62		M		C												F/C	C		C	F		F								VR		R						
15H-3, 64–65	234.63	R	M		C												F/C	C		C	F		R										VR						
15H-3, 65–66	234.64		M		C												F/C	C		C	F		F	p				VR											
15H-3, 66–67	234.65		M		C												F/C	C		C	R		F									VR							
15H-3, 67–68	234.66		M		C			VR									F/C	C		C	R		R	P					F		VR	VR	VR						
15H-3, 68–69	234.67	R	M	py	C												F/C	C		C	F		F									VR							
15H-3, 69–70	234.68		M		C												F/C	C		C	R		F	R	VR					VR			R						
15H-3, 70–71	234.69		M		C												F/C	C		C	R		F									VR							
15H-3, 71–72	234.70		M		C												F/C	C		C	R		F	VR							VR								
15H-3, 72–73	234.71	R	M		C												F/C	C		A	R		R	VR				P											
15H-3, 73–74	234.72	R	P		C	VR											C	C		C	F		F								VR								
15H-3, 74–75	234.73		P		C	VR											C	C		C	F		F																
15H-3, 75–76	234.74		P		C	R	R										C	C		C	F		F								VR								
15H-3, 76–77	234.75		P		F	R	VR										C	C		C	F		F							VR									
15H-3, 77–78	234.76	R	P	py	C	VR	R										C	C		C	F		F	VR						VR								Pα	early Paleocene
15H-3, 78–79	234.77	R	P		C	R	R										C	C		C	F		R																
15H-3, 79–80	234.78	R	P		C	R	R										C	C		C	F		R	VR															
15H-3, 80–81	234.79		P		C	F	R										C	C		C	F		F	VR				P	F										
15H-3, 81–82	234.80		P		C	R	R										C	C		C	R		R	R			VR												
15H-3, 82–83	234.81		P		C	F	R										C	C		C	F		F	R			R												
15H-3, 83–84	234.82		P–M	sph	C	F	F										C	C		C	F		F	R	R		R												
15H-3, 84–85	234.83	F	P–M	sph	C	C	C										C	C		F	F		R	R			R												
15H-3, 85–86	234.84	F	P–M	sph	C	C	C										C	C	VR	F	F		R	R	R		R												
15H-3, 86–87	234.85	F	P–M	sph	C	C	C	VR		VR						VR	F	F	VR	R	R		VR	R	R														
15H-3, 87–88	234.86	F	P–M	sph	C	C	C		R								R	F	VR	R	R		R	R	R	R													
15H-3, 88–89	234.87	F	P–M	sph	C	A	C		R			VR			R				VR		VR		VR																
15H-3, 89–90	234.88	F	P–M	sph	C	A	A	VR	R			VR							R		VR	VR																	
15H-3, 90–91	234.89	F	P–M	sph	C	C	C			R							F	C		F																			
15H-3, 91–92	234.90	F	P–M	sph	C	C	C	R	R	R	R	R	R				R	F	R																				
15H-3, 92–93	234.91	F	P–M	sph	C	C	A	VR	R	R	R	R						F	VR																				
15H-3, 93–94	234.92	F	P–M	sph	C	C	C	VR	F	F	F	C	VR				VR	C	R																				
15H-4, 5–6	235.48	F	VP		A	P	P	P	P	?	P	P	P	P	P	P																						*A. mayar.*	L. Cretaceous

Notes: Abundance: AA = very abundant (>50%), A = abundant (30%–50%), C = common (10%–30%), F = few (5%–10%), R = rare (1%–5%), VR = very rare (1–5 specimens), P = present. Preservation: VG = very good (no evidence of breakage or dissolution), G = good (>90% of specimens unbroken), M = moderate (30%–90% of the specimens unbroken), P = poor (strongly recrystallized or dominated by fragments and broken or corroded specimens), VP = very poor (>90% of specimens broken). Mineral and other components: ox = iron oxides, sph = spherules, py = pyrite. Morph. = multiple morphotypes. *A. mayar.* = *Abathomphalus mayaroensis.*

Table T2. Planktonic foraminiferal distribution, Hole 1211C. (**See table notes.** Continued on next two pages.)

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Globigerinelloides messinae*	*Schackoina* spp.	*Racemiguembelina fructicosa*	*Abathomphalus intermedius*	*Guembelitria cretacea*	*Heterohelix planata*	*Heterohelix globulosa*	*Globigerinelloides subcarinatus*	*Guembelitria cretacea*	*Chiloguembelina morsei*	*Parvularugoglobigerina eugubina*	*Globotruncanella havanensis*	*Woodringina hornerstownensis*	*Chiloguembelina midwayensis*	*Hedbergella holmdelensis*	*Woodringina claytonensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Rugoglobigerina rugosa*	*Globotruncanita stuartiformis*	*Ventilabrella multicamerata*	*Pseudoguembelina hariaensis*	*Eoglobigerina eobulloides*	*Parvularugoglobigerina eugubina* morph.	*Hedbergella monmouthensis*	*Contusotruncana contusa*	*Globotruncanita stuarti*	*Pseudotextularia elegans*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	Zone	Age
198-1211C-																																						
15H-3, 80–81	132.61	R	P										AA	A			R/F											?										
15H-3, 81–82	132.62	R	P										C	A			C	F		F																		
15H-3, 82–83	132.63	R	P										C	A			C	R		C															VR			
15H-3, 83–84	132.64	R	P										C	A			C	F		C															VR		P1a	
15H-3, 84–85	132.65	R	P										C	A			C	C		C																		
15H-3, 85–86	132.66	R	P										C	A			C	C		F																VR		
15H-3, 86–87	132.67	R	P										C	A			C	F		C															VR	R		
15H-3, 87–88	132.68	R	P										C	A			C	F		F																VR		
15H-3, 88–89	132.69	R	P										C	A	R		C	F		F							VR									VR		
15H-3, 89–90	132.70	R	P										C	A	VR		C	F		F																VR		
15H-3, 90–91	132.71	R	P										R	A	VR		C	C		C							VR								R	R		
15H-3, 91–92	132.72	R	P										F	A	R		C	C		C															VR	VR		
15H-3, 92–93	132.73	R	P										C	A	VR		C	C		F															VR			
15H-3, 93–94	132.74	R	P										C	A	R		C	C		F							VR								R	R		
15H-3, 94–95	132.75	R	P										F	A	R		C	C		C															VR			
15H-3, 95–96	132.76	R	P										C	A	R		C	C		F							R								R			
15H-3, 96–97	132.77	R	P										F	A	R		C	C		C							R		VR						R			early Paleocene
15H-3, 97–98	132.78	R	P										C	A	R		C	C	R	C							R		R						R			
15H-3, 98–99	132.79	R	P										F	C	F		C	C	R	F							R	F	R						R			
15H-3, 99–100	132.80	R	P										F	A	C		C	C	R	R							R	F	R						R			
15H-3, 100–101	132.81	R	P										C	C	C		C	C	R	R							R	F	R						R		Pα	
15H-3, 101–102	132.82	R	P										C	C	C		C	F	R	R							R	F	R						R			
15H-3, 102–103	132.83	R	P										C	C	F		C	F	R	F							R	R	R						R			
15H-3, 103–104	132.84	R	P										C	C	F		C	F	R	F							R	R	R						R			
15H-3, 104–105	132.85	R	P										C	C	F		C	F	R	F							?	R	R				P		R			
15H-3, 105–106	132.86	R	P										C	C	F		C	F	R	F								R	R						R			
15H-3, 106–107	132.87	F	P										C	C	F		C	F	R	F								F	R						R			
15H-3, 107–108	132.88	F	P										C	C	F		C	F	R	F								F	R						R			
15H-3, 108–109	132.89	F	P										C	C	F		C	F	R	F								F	R						VR			
15H-3, 109–110	132.90	F	P										C	C	F		C	F	R	F								F	R									
15H-3, 110–111	132.91	F	M										C	C	F		C	R	R	R								C	R									
15H-3, 111–112	132.92	C	M										C	C	C		C	R	VR	F								C	VR					VR				
15H-3, 112–113	132.93	C	M										C	C	F		C	R		F								F	VR									

Table T2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Globigerinelloides messinae*	*Schackoina* spp.	*Racemiguembelina fructicosa*	*Abathomphalus intermedius*	*Guembelitria cretacea*	*Heterohelix planata*	*Heterohelix globulosa*	*Globigerinelloides subcarinatus*	*Guembelitria cretacea*	*Chiloguembelina morsei*	*Parvularugoglobigerina eugubina*	*Globotruncanella havanensis*	*Woodringina hornerstownensis*	*Chiloguembelina midwayensis*	*Hedbergella holmdelensis*	*Woodringina claytonensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Rugoglobigerina rugosa*	*Globotruncanita stuartiformis*	*Ventilabrella multicamerata*	*Pseudoguembelina hariaensis*	*Eoglobigerina eobulloides*	*Parvularugoglobigerina eugubina* morph.	*Hedbergella monmouthensis*	*Contusotruncana contusa*	*Globotruncanita stuarti*	*Pseudotextularia elegans*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	Zone	Age
15H-3, 113–114	132.94	C	M	sph									C	C	F		C	C		R								F										
15H-3, 114–115	132.95	C	M										C	C	F		C	C	VR	R								F										
15H-3, 115–116	132.96	C	G										C	C	F		C	C	VR	R							VR	F	VR									
15H-3, 116–117	132.97	C	G										C	C	C		C	F	VR	R								C	R									
15H-3, 117–118	132.98	C	M	sph									C	C	C		C	F	R	F							VR		R									
15H-3, 118–119	132.99	C	M	sph, ox									C	C	C		C	F	R	R							VR		R									
15H-3, 119–120	133.00	C	P	sph, ox									C	C	C		C	F	R	R							VR		R				R					
15H-3, 120–121	133.01	C	P	sph, ox									C	C	A		C	F	R	R									R									
15H-3, 121–122	133.02	C	M	sph, ox									C	C	A	VR	C	F	R	R		VR		VR					R		VR							
15H-3, 122–123	133.03	C	M	sph, ox									C	C	C		C	F	R	F				VR					R									
15H-3, 123–124	133.04	C	M	sph, ox									C	C	A		C	F	VR	R		VR		VR					R		VR							
15H-3, 124–125	133.05	C	M	sph, ox	R								C	C	C		C	F	R	F		R	R	VR					R	VR	VR	VR						
15H-3, 125–126	133.06	C	M	sph, ox	R								C	C	C	VR	C	F	R	F		VR	VR	VR					R	VR	VR	VR						
15H-3, 126–127	133.07	C	M	sph, ox	R								C	C	C	VR	C	F	R	R		R	R	R					R		VR							
15H-3, 127–128	133.08	C	M		R								C	C	C	R	F	F	F	R		VR	R	R					R	VR	R							
15H-3, 128–129	133.09	C	M		R								C	C	C	R	C	F	R	R		VR	R	VR	VR				R		VR							
15H-3, 129–130	133.10	C	M		R	P							C	C	C	R	C	R	R	F	P	R	R	VR	P	P			R	VR	VR							
15H-3, 130–131	133.11	C	M		R								C	C	C	R	C	R	R	F	VR	R	R	R					R	VR	R	VR					Pα	early Paleocene
15H-3, 131–132	133.12	C	M		R								C	F	C	F	C	R	F	F	R	R	R	R	VR				R	VR	VR	R						
15H-3, 132–133	133.13	C	M		R								C	F	C	R	F	R	F	F		R	R	VR	VR				R	VR	VR	VR						
15H-3, 133–134	133.14	C	P		R								C	C	F	F	C	R	F	R		VR	R	R					R	VR	R	R						
15H-3, 134–135	133.15	C	P		R								F	R	F	R	F	VR	R				R	VR						VR	R							
15H-3, 135–136	133.16	C	P		R								C	C	C	R	C	R	F	R			R						R	VR	VR							
15H-3, 136–137	133.17	C	P										F	R	F		F	VR	R	R				VR					R			VR						
15H-3, 137–138	133.18	C	P										C	C	C	R	C	F	F	F			VR						R	VR	R	VR						
15H-3, 138–139	133.19	C	P		R								C	F	C		C	R	R	F									R	P								
15H-3, 139–140	133.20	C	P		VR								C	C	C		C	C	R	F									VR									
15H-3, 140–141	133.21	C	P		VR								C	C	C		C	C	R	F				p					R									
15H-3, 141–142	133.22	C	P	ox	R								C	C	C		R	C	C	R		VR							F									
15H-3, 142–143	133.23	C	P	sph	R								C	C	C		R	C	F	R		VR							C									
15H-3, 143–144	133.24	C	P	ox	R								C	C	C	R	R	F	C	VR		R	VR						C									
15H-3, 144–145	133.25	A	P		R								C	F	F	VR		F	F										C									
15H-3, 145–146	133.26	A	P										C	F	C	R		F	F				VR						F									
15H-3, 146–147	133.27	A	P										C	F	C	R		R	R										R									

Table T2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Benthic foraminifers	Preservation	Inorganic grains	*Globigerinelloides messinae*	*Schackoina* spp.	*Racemiguembelina fructicosa*	*Abathomphalus intermedius*	*Guembelitria cretacea*	*Heterohelix planata*	*Heterohelix globulosa*	*Globigerinelloides subcarinatus*	*Guembelitria cretacea*	*Chiloguembelina morsei*	*Parvularugoglobigerina eugubina*	*Globotruncanella havanensis*	*Woodringina hornerstownensis*	*Chiloguembelina midwayensis*	*Hedbergella holmdelensis*	*Woodringina claytonensis*	*Globotruncanella petaloidea*	*Pseudoguembelina excolata*	*Rugoglobigerina rugosa*	*Globotruncanita stuartiformis*	*Ventilabrella multicamerata*	*Pseudoguembelina hariaensis*	*Eoglobigerina eobulloides*	*Parvularugoglobigerina eugubina* morph.	*Hedbergella monmouthensis*	*Contusotruncana contusa*	*Globotruncanita stuarti*	*Pseudotextularia elegans*	*Eoglobigerina edita*	*Globanomalina planocompressa*	*Parasubbotina pseudobulloides*	*Praemurica pseudoinconstans*	Zone	Age
15H-3, 147–148	133.28	A	P										R	R	F	VR		R	R										R									
15H-3, 148–149	133.29	A	P										F	F	R	R		R	VR			VR							VR		VR							
15H-3, 149–150	133.30	A	P										R	R	F	R	R	R	R	VR									R									
15H-4, 9–10	133.39	R	VP	?		P					P		F		C		C		R	C	P	P	VR	VR	P	P	P	C										
15H-4, 12–13	133.42	A	VP									R								VR	R	VR																
15H-4, 25–26	133.55	A	VP									R	F	C		VR	R	R																				
15H-4, 35–36	133.65	A	VP																																		Pα	early Paleocene
15H-4, 45–46	133.75	A	VP									R	VR	VR		VR																						
15H-4, 60–61	133.90	A	VP										C	F	R																							
15H-4, 70–71	134.00	A	VP										C	F	VR																							
15H-4, 80–81	134.10	A	VP									R	VR	R																								
15H-5, 22–23	135.02	F							R	P	P	P																										
15H-7, 110–111	138.30	C	VP		P	P	R	VR																														

Notes: Abundance: AA = very abundant (>50%), A = abundant (30%–50%), C = common (10%–30%), F = few (5%–10%), R = rare (1%–5%), VR = very rare (1–5 specimens), P = present. Preservation: VG = very good (no evidence of breakage or dissolution), G = good (>90% of specimens unbroken), M = moderate (30%–90% of the specimens unbroken), P = poor (strongly recrystallized or dominated by fragments and broken or corroded specimens), VP = very poor (>90% of specimens broken). Mineral and other components: ox = iron oxides, sph = spherules, py = pyrite. Morph. = multiple morphotypes.