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3. Data Report: Paleocene–Early Oligocene Calcareous Nannofossil Biostratigraphy, ODP Leg 198 Sites 1209, 1210, and 1211 (Shatsky Rise, Pacific Ocean)[1]

Timothy J. Bralower[2]

ABSTRACT

A relatively complete lower Paleocene to lower Oligocene sequence was recovered from the Southern High of Shatsky Rise at Sites 1209, 1210, and 1211. The sequence consists of nannofossil ooze and clay-rich nannofossil ooze. Samples from these sites have been the target of intensive calcareous nannofossil biostratigraphic investigations. Calcareous nannofossils are moderately preserved in most of the recovered sequence, which extends from nannofossil Zones CP1 to CP16. Most traditional zonal markers are present; however, the rarity and poor preservation of key species in the uppermost Paleocene and lower Eocene inhibits zonal subdivision of part of this sequence.

INTRODUCTION

Ocean Drilling Program Leg 198 addresses the causes and consequences of Cretaceous and Paleogene global warmth. Eight sites were drilled along a broad depth transect on Shatsky Rise, a medium-sized large igneous province in the west-central Pacific. The depth transect was designed to characterize changes in the nature of surface and deep waters during the greenhouse climate interval, as well as during abrupt climatic events such as the Paleocene/Eocene Thermal Maximum (PETM).

[1]Bralower, T.J., 2005. Data report: Paleocene–early Oligocene calcareous nannofossil biostratigraphy, ODP Leg 198 Sites 1209, 1210, and 1211 (Shatsky Rise, Pacific Ocean). *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/115.PDF>. [Cited YYYY-MM-DD]
[2]Department of Geosciences, The Pennsylvania State University, University Park PA 16802, USA.
bralower@geosc.psu.edu

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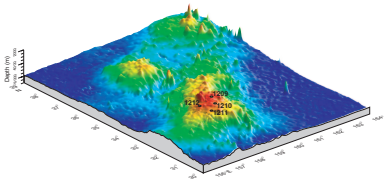
A high-quality collection of sedimentary records through the Paleogene was obtained at four different sites on the Southern High of Shatsky Rise: Sites 1209, 1210, 1211, and 1212 (Fig. F1). This investigation concerns the calcareous nannofossil biostratigraphy of the first three sites. Sites 1209 and 1211 were triple cored, and Site 1210 was double cored. The biostratigraphy of Site 1212 is described in Bralower, Premoli Silva, Malone, et al. (2002) and is not discussed further in this chapter.

A precise biostratigraphic framework is a fundamental prerequisite for the interpretation of the depositional and paleoceanographic history of Shatsky Rise. Shipboard Paleogene biostratigraphic investigation was largely limited to core catcher samples except around critical boundaries. The resolution of this investigation is increased to one sample per core section or more. This higher resolution allows more precise determination of the ranges of key taxa and placement of zonal boundaries. Biostratigraphic interpretation is not without difficulty, however. Several traditionally used Paleogene zonal markers are absent or rare in sediments at the three sites. Overgrowth obscures other markers and renders their ranges difficult to determine. Similar problems have been encountered in other Paleogene sequences (e.g., Monechi, 1985; Pospichal and Wise, 1990). At Site 865 in the equatorial Pacific, Bralower and Mutterlose (1995) determined the stratigraphic ranges of >100 secondary markers. This investigation seeks to determine the stratigraphic potential of some of these markers by observing their position relative to other sections, as well as their abundance and taxonomic distinctiveness near the ends of their ranges.

F1. Map of sites investigated, p. 6.



METHODS AND PROCEDURES

This biostratigraphic investigation is based on observations of about one sample in each core section of the composite splice at each site. The number of samples observed is higher close to the Paleocene/Eocene boundary. Biostratigraphic investigations were conducted using the light microscope with 1000× magnification under cross-polarized light. Discoasters were observed under phase-contrast illumination. Most samples were observed on two separate occasions for a total of 30 min. A greater amount of time was devoted to samples close to the ends of species ranges and especially near zonal boundaries, where samples were sometimes observed for 1 hr.

Relative abundance of nannofossils was determined in the following fashion: a species was termed abundant if, on average, >10 specimens could be observed in a field of view at 1000× magnification; it was termed common if 1–9 specimens could be observed in each field; it was termed few if 1–9 specimens could be observed in every 10 fields of view; and it was termed rare, if, on average, >10 fields were required to observe one specimen. All taxa observed were tabulated at Sites 1209 and 1210 (Tables T1, T2). At Site 1211 only zonal markers and other stratigraphically significant taxa were listed (Table T3). In addition, more detailed sampling was conducted near the PETM at all three sites. Ranges of key taxa were observed in these samples (Tables T4, T5, T6), although they have not been compiled in the range charts (Tables T1, T2, T3).

For most taxa, generally accepted taxonomic concepts are applied (e.g., Aubry, 1984, 1988, 1989, 1990; Perch-Nielsen, 1985; Bralower and Mutterlose, 1995). Certain groups of nannofossils, particularly the dis-

T1. Calcareous nannofossil range chart, Site 1209, p. 7.

T2. Calcareous nannofossil range chart, Site 1210, p. 8.

T3. Calcareous nannofossil range chart, Site 1211, p. 9.

T4. Zonal and other key datums, Site 1209, p. 10.

T5. Zonal and other key datums, Site 1210, p. 12.

T6. Zonal and other key datums, Site 1211, p. 14.

coasters, proved to be difficult to study, as this group is incompletely categorized and often obscured by overgrowth in the studied samples.

RESULTS

Range charts showing the distribution of all species observed are presented in Tables **T1, T2,** and **T3.** Zonal and other key datums for the three sites are compiled in Tables **T4, T5,** and **T6** using meters composite depth (mcd) from Bralower, Premoli Silva, Malone, et al. (2002) and revised meters composite depth (rmcd) from **Westerfeld and Röhl** (this volume).

Preservation

Calcareous nannofossil preservation is generally moderate in the Paleocene to lower Oligocene section at Sites 1209, 1210, and 1211. Most samples show signs of slight etching and moderate overgrowth. Overgrowth has masked whole specimens, making it difficult to distinguish consistently among species of *Nannotetrina*, for example, and to consistently interpret the ray form of discoasters. Etching, for example, often removes the central area of *Toweius*. A few samples distributed randomly through the sections have good preservation. In general, preservation deteriorates from the Paleocene to the Eocene and nannofossils in a number of Eocene samples are marked by moderate to high amounts of etching as a result of dissolution. There is no systematic increase in overgrowth or dissolution with depth; thus, preservation appears to be related to alteration at or near the seafloor.

Application of Standard Paleogene Zonations

The standard zonation of Bukry (1973, 1975), emended by Okada and Bukry (1980), was developed in low-latitude oceanic sections. Hence, this scheme is primarily applied here. The zonation of Martini (1971), on the other hand, was established in land sequences largely from the continents. Generally, many of the zones of both schemes and the subzones of Okada and Bukry (1980) could be determined at Sites 1209, 1210, and 1211 with a fair amount of confidence (Tables **T4, T5, T6**). However, a number of these units could not be determined due to taxonomic difficulties or paucity of key species. For example, the base of Zone CP7 could not be determined because of the rarity of *Discoaster nobilis*. The base of Zone CP3 was difficult to determine with precision as a result of the rarity of *Ellipsolithus macellus* near the onset of its range. In addition, the base of Zone CP14 (Subzone CP14a) was difficult to determine because of the sporadic distribution of *Reticulofenestra umbilicus* near the base of its range. Finally, the base of Subzone CP16b, defined by the base of the acme of *Ericsonia subdisticha,* is also difficult to determine precisely, as this species is rarely abundant in samples investigated. The significance of the zonal markers and other datums that have potential as zonal markers will be discussed in detail in Bralower (unpubl. data).

Nannofossil biostratigraphy suggests extremely slow sedimentation or unconformities at all sites. At Sites 1209 and 1210, the uppermost Eocene and lowermost Oligocene interval is extremely condensed, with multiple datums concentrated within a few meters (~137–141 mcd at both sites; Tables **T1, T2, T4, T5**). The upper part of the middle Eocene

(Subzones CP13b–CP14a; ~98 mcd) at Site 1211 appears to be condensed (Tables T3, T6). In addition, the lowermost Eocene (Zone CP9) at Sites 1209 (~208 mcd), 1210 (~201 mcd), and 1211 (~136 mcd) appears to be highly condensed. More detailed investigation is required to determine if unconformities are present in these intervals. Reworked nannofossils have not been observed, except in the upper Eocene where markers are observed significantly above the termination of their ranges (Tables T1, T2, T3).

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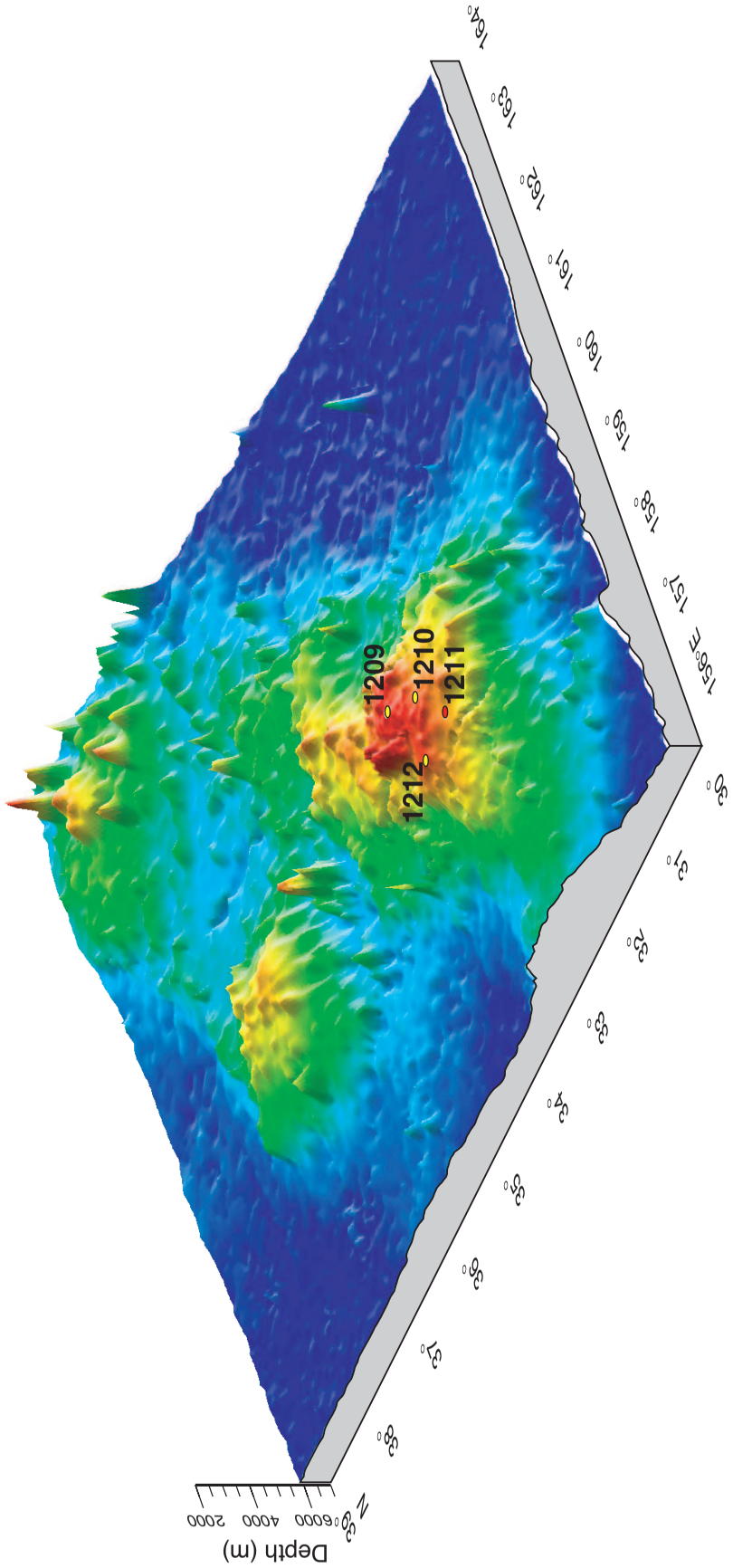

Figure F1. Map of sites investigated.

Table T1. Calcareous nannofossil range chart for composite splice at Site 1209. (This table is available in an **oversized format.**)

Table T2. Calcareous nannofossil range chart for composite splice at Site 1210. (This table is available in an **oversized format.**)

Table T3. Calcareous nannofossil range chart for composite splice at Site 1211. (This table is available in an **oversized format.**)

Table T4. Zonal and other key datum, Site 1209. (**See table notes.** Continued on next page.)

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
LAD *E. formosa*	**1209C-3H-2, 30–31**	**130.145**	**130.455**	**1209C-3H-3, 30–31**	**131.645**	**131.955**	**CP16c**	**NP22**	**130.895**	**131.205**
Base acme *E. subdisticha*	**1209C-3H-6, 30–31**	**136.145**	**136.455**	**1209A-14H-4, 30–31**	**137.195**	**139.005**	**CP16b**		**136.670**	**137.730**
LAD *D. barbadiensis*	**1209C-3H-6, 30–31**	**136.145**	**136.455**	**1209A-14H-4, 30–31**	**137.195**	**139.005**	**CP16a**		**136.670**	**137.730**
LAD *C. grandis*	**1209C-3H-6, 30–31**	**136.145**	**136.455**	**1209A-14H-4, 30–31**	**137.195**	**139.005**	**CP15**		**136.670**	**137.730**
FAD *S. predistentus*	1209A-14H-4, 30–31	137.195	139.005	1209A-14H-5, 30–31	138.695	140.445			137.945	139.725
LAD *D. saipanensis*	1209A-14H-5, 30–31	138.695	140.445	1209A-14H-6, 30–31	140.195	141.725		NP21	139.445	141.085
FAD *S. pseudoradians*	1209A-14H-5, 30–31	138.695	140.445	1209A-14H-6, 30–31	140.195	141.725		NP20	139.445	141.085
LAD *C. dela*	1209B-15H-1, 144–145	141.000	142.445	1209B-15H-2, 107–108	142.130	143.575			141.565	143.010
LAD *C. solitus*	**1209B-15H-4, 110–111**	**145.165**	**146.518**	**1209B-15H-5, 110–111**	**146.665**	**147.803**	**CP14b**	**NP17**	**145.915**	**147.161**
FAD *D. bisectus*	1209B-15H-5, 110–111	146.665	147.803	1209B-15H-6 20–21	147.265	148.350			146.965	148.077
FAD *D. scrippsae*	1209B-16H-1, 0–5	147.490	151.895	1209B-16H-2, 50–51	149.490	153.875			148.490	152.885
FAD *S. obtusus*	1209B-16H-2, 50–51	149.495	153.875	1209B-16H-3, 50–51	150.995	155.375			150.245	154.625
LAD *N. fulgens*	1209B-16H-3, 50–51	150.995	155.375	1209A-16H-1, 45–46	151.220	155.855			151.108	155.615
FAD *R. umbilicus*	**1209B-16H-3, 50–51**	**150.995**	**155.375**	**1209A-16H-1, 45–46**	**151.220**	**155.855**	**CP14a**		**151.108**	**155.615**
LAD *C. gigas*	**1209A-16H-2, 45–46**	**152.010**	**156.645**	**1209A-16H-3, 45–46**	**153.510**	**158.145**	**CP13c**		**152.760**	**157.395**
FAD *S. furcatolithoides*	1209A-17H-1, 45–46	162.395	166.175	1209A-17H-2, 45–46	163.895	167.675			163.145	166.925
FAD *C. gigas*	**1209A-17H-3, 45–46**	**165.395**	**169.175**	**1209A-17H-4, 50–51**	**166.945**	**170.725**	**CP13b**		**166.170**	**169.950**
FAD *S. spiniger*	1209A-17H-6, 50–51	169.945	173.725	1209B-18H-2, 50–52	170.730	174.335			170.338	174.030
FAD *N. fulgens*	**1209B-18H-2, 50–52**	**170.720**	**174.335**	**1209B-18H-3, 50–52**	**172.220**	**175.835**	**CP13a**	**NP15**	**171.470**	**175.085**
LAD *C. crassus*	1209B-18H-2, 50–52	170.720	174.335	1209B-18H-3, 50–52	172.220	175.835			171.470	175.085
LAD *C. cribellum*	1209A-18H-3, 82–83	175.000	180.625	1209A-18H-4, 45–46	176.130	181.755			175.565	181.190
LAD *R. inflata*	1209B-19H-1, 120–121	179.860	185.005	1209A-18H-6, 45–46	178.420	180.153	CP13a		179.140	182.579
FAD *Nannotetrina* sp.	1209B-19H-4, 100–102	184.170	189.300	1209B-19H-5, 0–2	184.670	189.810			184.420	189.555
FAD *T. carinatus*	1209B-19H-4, 100–102	184.170	189.300	1209B-19H-5, 0–2	184.670	189.810			184.420	189.555
LAD *T. orthostylus*	1209A-19H-4, 45–46	187.180	192.355	1209A-19H-5, 45–46	188.680	193.855		NP13	187.930	193.105
FAD *R. dictyoda*	1209A-19H-5, 45–46	188.680	193.855	1209A-19H-6, 45–46	190.180	195.355			189.430	194.605
FAD *R. inflata*	**1209A-19H-6, 45–46**	**190.180**	**195.355**	**1209B-20H-2, 100–102**	**190.550**	**197.870**	**CP12b**		**190.365**	**196.613**
LAD *L. nascens*	1209B-20H-2, 100–102	190.560	197.870	1209B-20H-3, 100–102	192.060	199.360			191.310	198.615
FAD *C. grandis*	1209B-20H-3, 100–102	192.060	199.370	1209B-20H-4, 100–102	193.560	200.870			192.810	200.120
FAD *D. sublodoensis*	**1209B-20H-5, 100–102**	**195.060**	**202.370**	**1209A-20H-4, 45–46**	**196.300**	**203.315**	**CP12a**	**NP14**	**195.680**	**202.843**
FAD *C. crassus*	**1209A-20H-6, 45–46**	**199.300**	**206.315**	**1209C-10H-1, 110–111**	**199.890**	**204.574**	**CP11**		**199.595**	**205.445**
LAD *D. multiradiatus*	1209C-10H-2, 100–102	201.291	206.375	1209C-10H-3, 100–102	202.800	208.032			202.046	207.204
FAD *C. cribellum*	1209C-10H-4, 100–102	204.290	209.300	1209C-10H-5, 100–102	205.790	210.595			205.040	209.948
FAD *Chiphragmalithus* spp.	1209C-10H-5, 100–102	205.800	210.595	1209C-10H-6, 100–102	207.300	211.968			206.550	211.282
FAD *D. lodoensis*	**1209C-10H-6, 100–102**	**207.290**	**211.969**	**1209C-11H-2, 0–2**	**208.410**	**215.192**	**CP10**	**NP12**	**207.850**	**213.581**
FAD *S. radians*	1209C-10H-6, 100–102	207.290	211.969	1209C-11H-2, 0–2	208.410	215.192			207.850	213.581
FAD *T. orthostylus*	1209C-10H-6, 100–102	207.290	211.969	1209C-11H-2, 0–2	208.410	215.192			207.850	213.581
FAD *S. editus*	1209C-10H-6, 100–102	207.290	211.969	1209C-11H-2, 0–2	208.410	215.192			207.850	213.581
FAD *D. barbadiensis*	1209C-10H-6, 100–102	207.290	211.969	1209C-11H-2, 0–2	208.410	215.192			207.850	213.581
LAD *F. tympaniformis*	1209B-21H-CC, 0	208.560	215.580	1209B-22H-1, 12	210.030	216.683			209.295	216.132
FAD *C. eograndis*	1209B-21H-CC, 0	208.560	215.580	1209B-22H-1, 12	210.030	216.683			209.295	216.132
FAD *D. diastypus*	**1209B-22H-1, 64**	**210.550**	**217.254**	**1209B-22H-1, 70**	**210.610**	**217.319**	**CP9**		**210.580**	**217.287**
FAD *Z. bijugatus*	1209B-22H-1, 127	211.180	217.945	1209B-22H-1, 132	211.230	218.000			211.205	217.973
LAD *C. tenuis*	1209B-22H-1, 127	211.180	217.945	1209B-22H-1, 132	211.230	218.000			211.205	217.973
FAD *C. eodela*	**1209A-22H-3, 46–47**	**215.860**	**223.105**	**1209A-22H-4, 46–47**	**217.360**	**224.605**	**CP8b**		**216.610**	**223.855**
FAD *D. multiradiatus*	**1209C-12H-2, 50–52**	**220.070**	**227.300**	**1209C-12H-3, 50–52**	**221.570**	**228.800**	**CP8a**	**NP9**	**220.820**	**228.050**
LAD *H. kleinpellii*	1209C-12H-5, 50–52	224.580	231.800	1209C-12H-6, 50–52	226.080	233.225			225.330	232.513
FAD *D. mohleri*	**1209C-12H-6, 50–52**	**226.070**	**233.225**	**1209A-23H-3, 45–46**	**226.800**	**234.213**	**CP6**		**226.435**	**233.719**
FAD *H. kleinpellii*	**1209A-23H-4, 45–46**	**228.305**	**235.713**	**1209A-23H-5, 45–46**	**229.805**	**237.256**	**CP5**	**NP6**	**229.055**	**236.485**

Table T4 (continued).

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
FAD *S. anarrhopus*	1209A-23H-4, 45–46	228.300	235.713	1209A-23H-5, 45–46	229.800	237.256			229.050	236.485
FAD *F. tympaniformis*	**1209C-13H-5, 100–102**	**235.840**	**243.260**	**1209C-13H-6, 100–102**	**237.340**	**244.760**	**CP4**	**NP5**	**236.590**	**244.010**
FAD *Fasciculithus* spp.	1209C-13H-6, 100–102	237.340	244.760	1209C-13H-7, 0-2	237.840	245.270			237.590	245.015
FAD *C. bidens*	1209C-13H-7, 0–2	237.850	245.270	1209A-24H-5, 45–46	238.685	248.435			238.268	246.853
FAD *S. primus*	1209A-24H-6, 45–46	240.185	249.935	1209A-24H-7, 45–46	241.685	251.256			240.935	250.596
FAD *T. pertusus*	1209A-24H-7, 45–46	241.680	251.256	1209C-14H-3, 115–116	241.810	251.550			241.745	251.403
FAD *E. macellus*	**1209C-14H-4, 100–102**	**243.180**	**252.822**	**1209C-14H-5, 100–101**	**244.680**	**254.294**	**CP3**	**NP4**	**243.930**	**253.558**
FAD *C. danicus*	**1209C-14H-7, 0–2**	**246.660**	**256.395**	**1209A-25H-3, 110–111**	**247.090**	**257.042**	**CP2**	**NP3**	**246.875**	**256.719**
FAD *C. tenuis*	**1209A-25H-5, 110–111**	**250.080**	**260.085**	**1209A-25H-6, 100–101**	**251.480**	**261.485**	**CP1b**	**NP2**	**250.780**	**260.785**
K/T boundary	**1209C-15H-3, 96**	**251.590**	**261.580**				**CP1a**	**NP1**	**251.590**	**261.580**

Notes: LAD = last appearance datum, FAD = first appearance datum. Bold = zonal markers or primary events. OB80 = Okada and Bukry, 1980, M71 = Martini, 1971.

Table T5. Zonal and other key datum, Site 1210. (**See table notes.** Continued on next page.)

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
LAD *E. formosa*	**1210B-13H-2, 70-71**	**130.015**	**130.015**	**1210B-13H-3, 70-71**	**131.515**	**131.515**	**CP16c**	**NP22**	**130.765**	**130.765**
Base acme *E. subdisticha*	**1210B-13H-7, 21-22**	**137.025**	**137.025**	**1210A-14H-2, 144-145**	**136.335**	**136.335**	**CP16b**		**136.680**	**136.680**
LAD *D. barbadiensis*	**1210B-13H-7, 21-22**	**137.025**	**137.025**	**1210A-14H-2, 144-145**	**136.335**	**136.335**	**CP16a**		**136.680**	**136.680**
LAD *C. grandis*	**1210A-14H-2, 144-145**	**137.335**	**137.335**	**1210A-14H-3, 45-46**	**137.835**	**137.835**	**CP15**		**137.585**	**137.585**
FAD *S. predistentus*	1210A-14H-3, 45-46	137.835	137.835	1210A-14H-4, 45-46	139.335	139.335			138.585	138.585
LAD *D. saipanensis*	1210A-14H-3, 45-46	137.835	137.835	1210A-14H-4, 45-46	139.335	139.335		NP21	138.585	138.585
FAD *S. pseudoradians*	1210A-14H-4, 45-46	139.335	139.335	1210A-14H-5, 45-46	140.835	140.835		NP20	140.085	140.085
LAD *C. dela*	1210A-14H-4, 45-46	139.335	139.335	1210A-14H-5, 45-46	140.835	140.835			140.085	140.085
LAD *C. solitus*	**1210A-15H-1, 45-46**	**146.565**	**146.825**	**1210A-15H-2, 45-46**	**148.065**	**148.325**	**CP14b**	**NP17**	**147.315**	**147.575**
FAD *D. bisectus*	1210A-15H-2, 45-46	148.065	148.325	1210A-15H-3, 45-46	149.565	149.825			148.815	149.075
FAD *D. scrippsae*	1210A-15H-5, 1-2	152.125	152.385	1210B-15H-2, 100-102	152.700	152.960			152.413	152.673
LAD *N. fulgens*	1210A-15H-5, 1-2	152.112	152.385	1210B-15H-2, 100-102	152.700	152.960			152.406	152.673
FAD *S. obtusus*	1210B-15H-2, 100-102	152.700	152.960	1210B-15H-3, 50-51	153.695	153.955			153.198	153.458
FAD *R. umbilicus*	**1210B-15H-3, 50-51**	**153.695**	**153.955**	**1210B-15H-4, 0-1**	**154.695**	**154.955**	**CP14a**		**154.195**	**154.455**
LAD *C. gigas*	**1210B-15H-4, 0-1**	**154.695**	**154.955**	**1210B-15H-5, 50-51**	**156.695**	**156.955**	**CP13c**		**155.695**	**155.955**
FAD. *S. furcatolithoides*	1210A-16H-3, 45-46	160.215	160.475	1210A-16H-4, 45-46	161.715	161.975			160.965	161.225
FAD *C. gigas*	**1210B-16H-3, 50-51**	**164.075**	**164.335**	**1210B-16H-4, 100-101**	**166.075**	**166.335**	**CP13b**		**165.075**	**165.335**
LAD *C. crassus*	1210B-16H-5, 50-51	167.075	167.335	1210B-16H-6, 50-51	168.575	168.835			167.825	168.085
FAD *S. spiniger*	1210B-16H-5, 50-51	167.075	167.335	1210B-16H-6, 50-51	168.575	168.835			167.825	168.085
FAD *N. fulgens*	**1210A-17H-2, 45-46**	**169.005**	**169.492**	**1210A-17H-3, 45-46**	**170.505**	**170.992**	**CP13a**	**NP15**	**169.755**	**170.242**
LAD *C. cribellum*	1210A-17H-4, 45-46	172.005	172.626	1210A-17H-5, 45-46	173.505	174.125			172.755	173.376
LAD *R. inflata*	1210A-17H-4, 45-46	172.005	172.626	1210A-17H-5, 45-46	173.505	174.125	CP13a		172.755	173.376
FAD *T. carinatus*	1210A-18H-2, 45-46	179.385	179.875	1210A-18H-3, 45-46	180.885	181.505			180.135	180.690
LAD *T. orthostylus*	1210A-18H-4, 45-46	182.385	183.005	1210A-18H-5, 45-46	183.885	184.505		NP13	183.135	183.755
FAD *Nannotetrina* sp.	1210A-18H-5, 45-46	183.885	184.505	1210B-18H-2, 140-141	184.445	185.065			184.165	184.785
FAD *R. inflata*	**1210B-18H-2, 140-141**	**184.445**	**185.065**	**1210B-18H-3, 100-101**	**185.545**	**186.165**	**CP12b**		**184.995**	**185.615**
FAD *R. dictyoda*	1210B-18H-2, 140-141	184.445	185.065	1210B-18H-3, 100-101	185.545	186.165			184.995	185.615
FAD *C. grandis*	1210B-18H-4, 100-101	187.045	187.665	1210B-18H-5, 100-101	188.545	189.165			187.795	188.415
LAD *L. nascens*	1210B-18H-4, 100-101	187.045	187.665	1210B-18H-5, 100-101	188.545	189.165			187.795	188.415
FAD *D. sublodoensis*	**1210A-19H-2, 48-49**	**190.275**	**191.095**	**1210A-19H-3, 47-48**	**191.765**	**192.585**	**CP12a**	**NP14**	**191.020**	**191.840**
FAD *C. crassus*	**1210A-19H-3, 47-48**	**191.765**	**192.585**	**1210A-19H-4, 47-48**	**193.265**	**194.085**	**CP11**		**192.515**	**193.335**
FAD *Chiphragmalithus* spp.	1210B-19H-3, 50-51	195.845	196.665	1210B-19H-4, 50-51	197.345	198.165			196.595	197.415
LAD *D. multiradiatus*	1210B-19H-3, 50-51	195.845	196.665	1210B-19H-4, 50-51	197.345	198.165			196.595	197.415
FAD *C. cribellum*	1210B-19H-4, 50-51	197.345	198.165	1210B-19H-5, 50-51	198.845	199.665			198.095	198.915
FAD *S. radians*	1210B-19H-5, 50-51	198.845	199.665	1210B-19H-6, 50-51	200.345	201.165			199.595	200.415
FAD *D. lodoensis*	**1210B-19H-6, 50-51**	**200.345**	**201.165**	**1210A-20H-3, 45-46**	**201.195**	**203.305**	**CP10**	**NP12**	**200.770**	**202.235**
FAD *T. orthostylus*	1210B-19H-6, 50-51	200.345	201.165	1210A-20H-3, 45-46	201.195	203.305			200.770	202.235
FAD *S. editus*	1210B-19H-6, 50-51	200.345	201.165	1210A-20H-3, 45-46	201.195	203.305			200.770	202.235
FAD *D. barbadiensis*	1210B-19H-6, 50-51	200.345	201.165	1210A-20H-3, 45-46	201.195	203.305			200.770	202.235
FAD *D. diastypus*	**1210B-20H-1, 50-52**	**201.790**	**203.904**	**1210B-20H-2, 50-52**	**203.290**	**205.380**	**CP9**		**202.540**	**204.642**
LAD *F. tympaniformis*	1210B-20H-2, 10	202.910	204.990	1210B-20H-2, 90	203.710	205.790			203.310	205.390
FAD *Z. bijugatus*	1210B-20H-3, 100	205.280	207.390	1210B-20H-3, 110	205.380	207.490			205.330	207.440
FAD *C. eodela*	**1210B-20H-6, 0-1**	**208.785**	**209.995**	**1210A-21H-2, 48-49**	**209.325**	**211.432**	**CP8b**		**209.055**	**210.714**
FAD *D. multiradiatus*	**1210B-21H-3, 100-102**	**214.950**	**217.060**	**1210B-21H-4, 100-102**	**216.450**	**218.560**	**CP8a**	**NP9**	**215.700**	**217.810**
LAD *H. kleinpellii*	1210B-21H-5, 100-102	217.950	220.060	1210B-21H-6, 50-51	218.945	221.055			218.448	220.558
FAD *D. mohleri*	**1210A-22H-2, 45-46**	**220.035**	**222.145**	**1210A-22H-2, 118**	**220.760**	**222.870**	**CP6**		**220.398**	**222.508**
FAD *S. anarrhopus*	1210A-22H-3, 42-43	221.505	223.615	1210A-22H-4, 45-46	223.035	225.145			222.270	224.380
FAD *H. kleinpellii*	**1210A-22H-3, 60**	**221.680**	**223.790**	**1210A-22H-3, 70**	**221.780**	**223.890**	**CP5**	**NP6**	**221.730**	**223.840**
FAD *F. tympaniformis*	**1210B-22H-5, 100-102**	**229.080**	**231.190**	**1210B-22H-6, 0-2**	**229.580**	**231.690**	**CP4**	**NP5**	**229.330**	**231.440**

Table T5 (continued).

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
FAD *Fasciculithus* spp.	1210A-23H-2, 47-48	230.855	232.965	1210A-23H-3, 93-94	232.815	234.925			231.835	233.945
FAD *E. macellus*	**1210A-23H-2, 47-48**	**230.855**	**232.965**	**1210A-23H-3, 93-94**	**232.815**	**234.925**	**CP3**	**NP4**	**231.835**	**233.945**
FAD *C. bidens*	1210A-23H-2, 47-48	230.855	232.965	1210A-23H-3, 93-94	232.815	234.925			231.835	233.945
FAD *S. primus*	1210A-23H-3, 93-94	232.815	234.925	1210A-23H-4, 27-28	233.655	235.765			233.235	235.345
FAD *T. pertusus*	1210A-23H-3, 93-94	232.815	234.925	1210A-23H-4, 27-28	233.655	235.765			233.235	235.345
FAD *C. danicus*	**1210B-23H-4, 100-102**	**238.590**	**240.700**	**1210B-23H-5, 100-102**	**240.090**	**242.200**	**CP2**	**NP3**	**239.340**	**241.450**
FAD *C. tenuis*	**1210A-24H-2, 45-46**	**241.305**	**243.325**	**1210A-24H-3, 45-46**	**242.805**	**244.825**	**CP1b**	**NP2**	**242.055**	**244.075**
K/T Boundary	**1210A-24H-4, 51**	**244.360**	**246.380**				**CP1a**	**NP1**	**244.36**	**246.380**

Notes: LAD = last appearance datum, FAD = first appearance datum. Bold = zonal markers or primary events. OB80 = Okada and Bukry, 1980, M71 = Martini, 1971.

Table T6. Zonal and other key datum, Site 1211. (See table notes. Continued on next page.)

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
LAD *E. formosa*	**1211C-8H-7, 30–31**	**79.955**	**79.955**	**1211-9H-3, 100–101**	**80.435**	**80.435**	**CP16c**		**80.195**	**80.195**
Base acme *E. subdisticha*	**1211C-9H-4, 52–53**	**85.895**	**85.895**	**1211C-9H-5, 102–103**	**87.895**	**87.895**	**CP16b**		**86.895**	**86.895**
LAD *D. barbadiensis*	**1211C-9H-4, 52–53**	**85.895**	**85.895**	**1211C-9H-5, 102–103**	**87.895**	**87.895**	**CP16a**		**86.895**	**86.895**
FAD *S. predistentus*	1211C-9H-5, 102–103	87.895	87.895	1211C-9H-6, 22–23	88.595	88.595			88.245	88.245
LAD *D. saipanensis*	1211C-9H-5, 102–103	87.895	87.895	1211C-9H-6, 22–23	88.595	88.595		NP21	88.245	88.245
LAD *C. grandis*	**1211A-10H-1, 105–106**	**89.005**	**87.924**	**1211-10H-2, 133–134**	**90.835**	**89.665**	**CP15**		**89.920**	**88.795**
FAD *S. pseudoradians*	1211A-10H-3, 107–108	92.025	90.945	1211-10H-4, 108–109	93.535	92.005		NP20	92.780	91.475
LAD *C. dela*	1211A-10H-6, 45–46	95.905	93.928	1211-10H-7, 45–46	96.905	94.878			96.405	94.403
FAD *D. bisectus*	1211C-10H-4, 120–121	97.195	96.045	1211C-10H-5, 0–1	97.495	96.365			97.345	96.205
FAD *S. obtusus*	1211C-10H-5, 0–1	97.495	96.365	1211C-10H-5, 100–101	98.495	97.345			97.995	96.855
LAD *C. solitus*	**1211C-10H-5, 100–101**	**98.495**	**97.345**	**1211C-10H-6, 0–1**	**98.995**	**97.845**	**CP14b**	**NP17**	**98.745**	**97.595**
LAD *N. fulgens*	1211C-10H-5, 100–101	98.495	97.345	1211C-10H-6, 0–1	98.995	97.845			98.745	97.595
FAD *R. umbilicus*	**1211C-10H-5, 100–101**	**98.495**	**97.345**	**1211C-10H-6, 0–1**	**98.995**	**97.845**	**CP14a**		**98.745**	**97.595**
FAD *D. scrippsae*	1211C-10H-5, 100–101	98.495	97.345	1211C-10H-6, 0–1	98.995	97.845			98.745	97.595
LAD *C. gigas*	**1211C-10H-5, 100–101**	**98.495**	**97.345**	**1211C-10H-6, 0–1**	**98.995**	**97.845**	**CP13c**		**98.745**	**97.595**
FAD. *S. furcatolithoides*	1211C-10H-6, 50–51	99.495	98.345	1211-11H-2, 45–46	99.745	98.852			99.620	98.599
FAD *C. gigas*	**1211A-11H-2, 45–46**	**99.745**	**98.852**	**1211-11H-3, 45–46**	**101.245**	**100.345**	**CP13b**		**100.495**	**99.599**
LAD *R. inflata*	**1211A-11H-2, 45–46**	**99.745**	**98.852**	**1211-11H-3, 45–46**	**101.245**	**100.345**	**CP13a**		**100.495**	**99.599**
FAD *S. spiniger*	1211A-11H-3, 45–46	101.245	100.345	1211-11H-4, 45–46	102.745	101.834			101.995	101.090
FAD *N. fulgens*	**1211A-11H-3, 45–46**	**101.245**	**100.345**	**1211-11H-4, 45–46**	**102.745**	**101.834**	**CP13a**	**NP15**	**101.995**	**101.090**
LAD *C. crassus*	1211A-11H-3, 45–46	101.245	100.345	1211-11H-4, 45–46	102.745	101.835			101.995	101.09
LAD *C. cribellum*	1211A-11H-4, 45–46	102.745	101.834	1211-11H-5, 45–46	104.245	103.155			103.495	102.495
FAD *T. carinatus*	1211B-11H-5, 45–46	106.795	105.740	1211B-11H-6, 45–46	108.295	107.141			107.545	106.441
LAD *T. orthostylus*	1211B-11H-7, 20–21	108.845	107.610	1211C-11H-5, 100–101	109.235	108.555		NP13	109.040	108.083
FAD *R. inflata*	**1211C-11H-6, 50–51**	**110.235**	**109.555**	**1211-12H-3, 45–46**	**111.175**	**111.085**	**CP12b**		**110.705**	**110.32**
FAD *Nannotetrina* sp.	1211C-11H-6, 50–51	110.235	109.555	1211-12H-3, 45–46	111.175	111.085			110.705	110.32
FAD *R. dictyoda*	1211A-12H-3, 45–46	111.175	111.085	1211-12H-4, 45–46	112.675	112.585			111.925	111.835
LAD *L. nascens*	1211A-12H-5, 45–46	114.175	113.893	1211-12H-6, 45–46	115.675	115.272			114.925	114.583
FAD *D. sublodoensis*	**1211A-12H-6, 45–46**	**115.675**	**115.272**	**1211B-12H-5, 45–46**	**116.935**	**116.845**	**CP12a**	**NP14**	**116.305**	**116.059**
FAD *C. grandis*	1211A-12H-6, 45–46	115.675	115.272	1211B-12H-5, 45–46	116.935	116.845			116.305	116.059
FAD *C. crassus*	**1211B-12H-5, 45–46**	**116.935**	**116.845**	**1211B-12H-6, 45–46**	**118.435**	**118.288**	**CP11**		**117.685**	**117.567**
FAD *Chiphragmalithus* spp.	1211C-12H-5, 100–101	120.065	120.365	1211C-12H-6, 97–98	121.535	121.869			120.800	121.117
LAD *D. multiradiatus*	1211C-12H-5, 100–101	120.065	120.365	1211C-12H-6, 97–98	121.535	121.869			120.800	121.117
FAD *C. cribellum*	1211C-12H-6, 97–98	121.535	121.869	1211C-12H-7, 0–1	121.565	121.903			121.550	121.886
FAD *S. editus*	1211A-13H-4, 40–42	123.700	123.870	1211-13H-5, 102–104	125.820	125.990			124.760	124.93
FAD *D. lodoensis*	**1211A-13H-5, 102–104**	**125.820**	**125.990**	**1211-13H-6, 101–103**	**127.160**	**127.276**	**CP10**	**NP12**	**126.490**	**126.633**
FAD *D. barbadiensis*	1211A-13H-5, 102–104	125.820	125.990	1211-13H-6, 101–103	127.160	127.276			126.490	126.633
FAD *S. radians*	1211A-13H-5, 102–104	125.820	125.990	1211-13H-6, 101–103	127.160	127.276			126.490	126.633
FAD *T. orthostylus*	1211A-13H-5, 102–104	125.820	125.990	1211-13H-6, 101–103	127.160	127.276			126.490	126.633
LAD *F. tympaniformis*	1211A-13H-6, 1	126.150	126.320	1211-13H-6, 5	126.190	126.360			126.170	126.34
FAD ***D. diastypus***	1211A-13H-6, 1	126.150	126.320	1211-13H-6, 5	126.190	126.360	CP9		126.170	126.34
FAD *Z. bijugatus*	1211A-13H-6, 10	126.240	126.410	1211-13H-6, 13	126.270	126.440			126.255	126.425
FAD *C. eodela*	**1211C-13H-6, 0–1**	**131.185**	**130.933**	**1211-14H-2, 45–46**	**131.755**	**131.795**	**CP8b**		**131.470**	**131.364**
FAD *D. multiradiatus*	**1211A-14H-2, 45–46**	**131.755**	**131.795**	**1211-14H-3, 45–46**	**133.255**	**133.295**	**CP8a**	**NP9**	**132.505**	**132.545**
LAD *H. kleinpellii*	1211A-14H-4, 45–46	134.755	134.795	1211-14H-5, 45–46	136.255	136.295			135.505	135.545
FAD *D. mohleri*	**1211A-14H-5, 45–46**	**136.255**	**136.295**	**1211-14H-6, 45–46**	**137.755**	**137.769**	**CP6**		**137.005**	**137.032**
FAD *H. kleinpellii*	**1211B-14H-4, 55–56**	**137.495**	**137.595**	**1211B-14H-4, 57–58**	**137.515**	**137.615**	**CP5**	**NP6**	**137.505**	**137.605**
FAD *S. anarrhopus*	1211B-14H-4, 60–61	137.545	137.645	1211B-14H-5, 60–61	139.045	139.145			138.295	138.395
FAD *F. tympaniformis*	**1211B-14H-6, 60–61**	**140.545**	**140.645**	**1211B-14H-7, 10–11**	**141.545**	**141.645**	**CP4**	**NP5**	**141.045**	**141.145**

Table T6 (continued).

Event	Upper core, section, interval (cm)	Upper depth (mcd)	Upper depth (rmcd)	Lower core, section, interval (cm)	Lower depth (mcd)	Lower depth (rmcd)	Zone OB80	Zone M71	Datum mean (mcd)	Datum mean (rmcd)
FAD *Fasciculithus* spp.	1211A-15H-1, 45–46	142.015	141.571	1211-15H-2, 45–46	143.515	143.085			142.765	142.328
FAD *S. primus*	1211A-15H-1, 45–46	142.015	141.571	1211-15H-2, 45–46	143.515	143.085			142.765	142.328
FAD *C. bidens*	1211A-15H-1, 45–46	142.015	141.571	1211-15H-2, 45–46	143.515	143.085			142.765	142.328
FAD *E. macellus*	**Indeterminable**			**Indeterminble**			**CP3**	**NP4**		
FAD *C. danicus*	**1211A-15H-2, 45–46**	**143.515**	**143.085**	**1211-15H-3, 45–46**	**145.015**	**144.585**	**CP2**	**NP3**	**144.265**	**143.835**
FAD *T. pertusus*	1211A-15H-2, 45–46	143.515	143.085	1211-15H-3, 45–46	145.015	144.585			144.265	143.835
FAD *C. tenuis*	**1211A-15H-3, 45–46**	**145.015**	**144.585**	**1211-15H-4, 45–46**	**146.515**	**146.085**	**CP1b**	**NP2**	**145.765**	**145.335**
K/T Boundary	**1211A-15H-4, 146**	**147.52**	**147.09**				**CP1a**	**NP1**	**147.52**	**147.09**

Notes: LAD = last appearance datum, FAD = first appearance datum. Bold = zonal markers or primary events. OB80 = Okada and Bukry, 1980, M71 = Martini, 1971.