

10. CRETACEOUS AND EARLY TERTIARY FORAMINIFERS FROM DEEP SEA DRILLING PROJECT LEG 62 SITES IN THE CENTRAL PACIFIC¹

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INTRODUCTION

During DSDP Leg 62, foraminifers were recovered from four holes in the central North Pacific. At Site 463, in the Mid-Pacific Mountains (21°21'N, 174°40'E; water depth 2525 m), the Cretaceous section included Aptian-Albian to Maastrichtian sediments. Paleogene faunas occurred in a mixed zone in three cores from strata unconformably overlying the Cretaceous. Recovery was very poor at Site 464 (39°51'N, 173°53'E; water depth 4637 m), on the northern flank of Hess Rise. Twenty-four cores of Cretaceous material encompassed the Cenomanian-Albian. Site 465 (Hole 465A) on southern Hess Rise (33°49'N, 178°55'E) was drilled at a depth of 2161 meters. The Cretaceous section includes upper Albian to uppermost Maastrichtian. The Cretaceous/Tertiary boundary was recovered in Hole 465A, and the combined Paleocene sections from both sites spanned all zones of the Paleocene. A mixed zone of Paleogene sediments overlies the Paleocene at Site 465. Because of the abundance of chert, only core catchers were recovered in many instances. Poor recovery characterized the Cretaceous section also at Site 466, on southern Hess Rise (34°11'N, 179°15'E; water depth of 2665 m). The Cretaceous section includes 24 cores, of which half contain only core catchers; only the Campanian was successfully cored. Four overlying cores contain mixed Paleogene and Cretaceous materials, thus representing the commonly occurring Paleogene "mixed zone" of the central Pacific (Table 1; Figs. 1 and 2).

Both planktonic and benthic foraminifers were present in nearly every sample younger than Aptian. Preservation varied from generally poor in most Albian samples at each site to very good in most of the Campanian-Maastrichtian section. Paleogene sequences were generally well preserved, except in the mixed zone, where dissolution and recrystallization were common.

METHODS

Cretaceous planktonic foraminifers were zoned according to the zonation and time scale of van Hinte (1976). Faunas were surveyed, selected species were identified, and relative abundances of those species are tabulated in Figures 3 and 4. Because the author is not a specialist in Cretaceous planktonics, not all species could be identified; faunal lists, therefore, are not inclusive.

Paleogene planktonic foraminifers were zoned according to the zonation and time scale of Hardenbol and Berggren (1978). Relative abundances of Paleocene species are tabulated in Figure 5.

Table 1. Geographic position of DSDP Leg 62 sites in the central Pacific today.

Leg	Site	Latitude	Longitude	Water Depth (m)
6	47	32°26'N	157°42'E	2689
6	45	25°15'N	198°30'E	4508
6	44	19°18'N	169°00'E	1478
32	305	32°13'N	157°51'E	2903
32	310	36°52'N	176°54'E	3516
32	313	20°10'N	170°57'E	3484
17	171	19°07'N	169°27'E	2295
20	200	12°50'N	156°46'E	1879
20	202	12°48'N	156°57'E	1515
30	288	5°58'N	161°49'E	3000
30	289	0°29'N	158°30'E	2206
6	51	33°28'N	153°24'E	5981
17	167	7°04'N	176°49'E	3176
20	199	13°30'N	156°10'E	6100
62	463	21°21'N	174°40'E	2525
62	464	39°51'N	173°53'E	4637
62	465	33°49'N	178°55'E	2161
62	466	34°11'N	179°15'E	2665

BIOSTRATIGRAPHY

Site 463

Site 463 was continuously cored, and sediments were recovered from the Aptian-Albian to the Maastrichtian. Significant hiatuses include the Coniacian-Campanian, and the latest Maastrichtian.

Preservation

No foraminifers were found in samples below Core 66, presumably because of the very poor preservation of the material. Late Aptian-Albian faunas were only occasionally preserved; foraminifers are uncommon in the radiolarian oozes. Recognizable foraminifers are tiny and recrystallized. Middle to late Albian (Cores 55-48) faunas are slightly better preserved, but still recrystallized, and apertures are often obscured. Preservation improves in the Cenomanian (Cores 46-40), although intense dissolution is present in Core 43. Preservation is better in the Turonian, although foraminifers are very rare in some intervals (Cores 36 and 37). Moderate preservation characterizes most of the upper Turonian and Coniacian, until in Core 30 foraminifers are entirely recrystallized and cemented together. Campanian sediments are generally well-preserved, except for intervals of moderate to intense dissolution accompanied by chert in Cores 24, 23, 22, and one section of 21. In some

¹ Initial Reports of the Deep Sea Drilling Project, Volume 62.

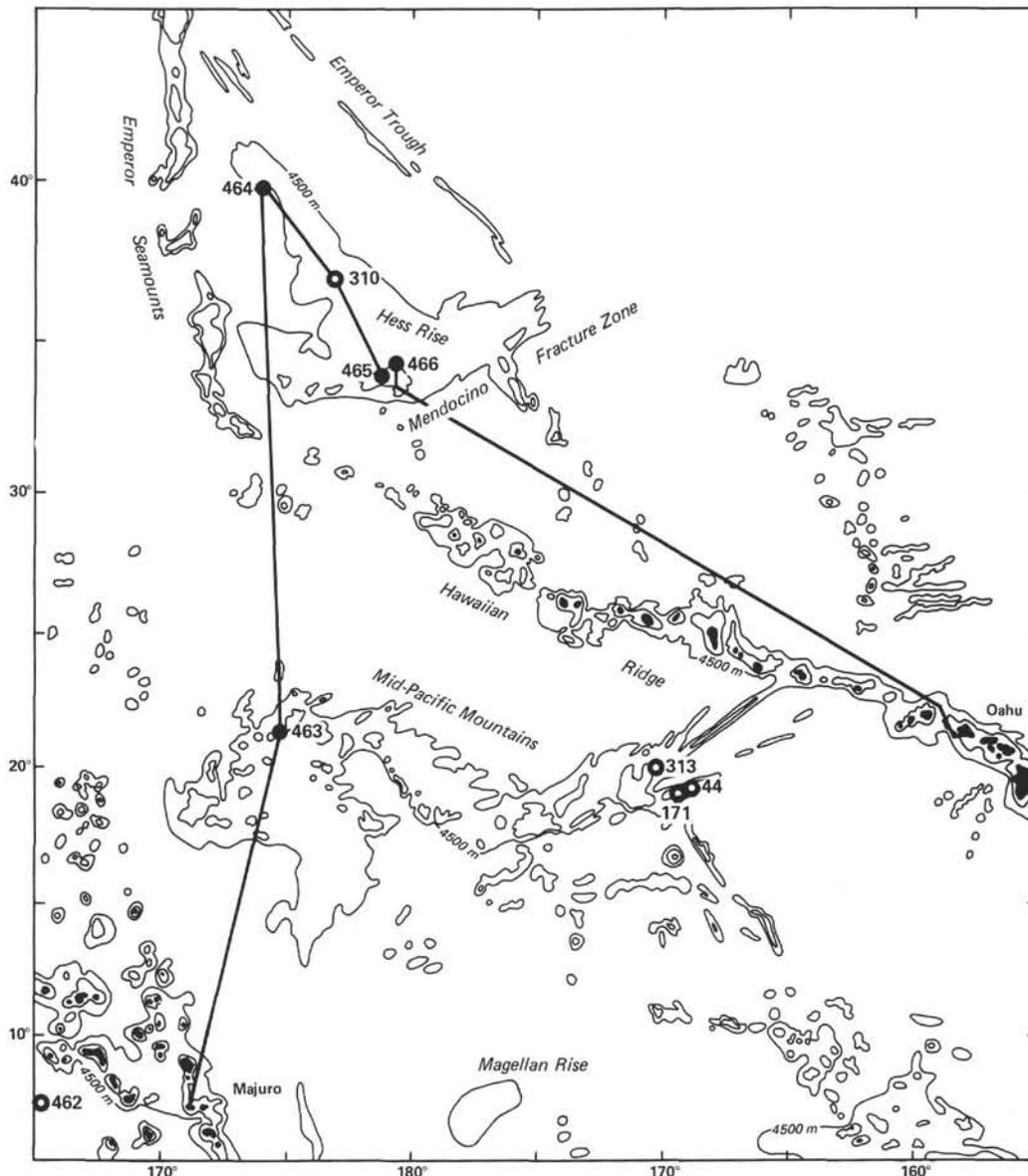


Figure 1. Locations of sites drilled on DSDP Leg 62 in the central Pacific.

faunas, most of the large specimens have been removed by dissolution. Good preservation characterizes the Maastrichtian, except where dissolution has altered faunas in sections of Cores 18, 17, 16, 12, 11, and 9. Re-crystallization of foraminifers occur in two isolated instances in Core 10 and in one section of Core 13.

Foraminifer Faunas

Aptian-Albian faunas (66-2 to 53,CC) have only been roughly zoned, since the poor preservation and infrequent faunas make zonal assignment difficult. The co-occurrence of *Ticinella bejaouaensis* and *Hedbergella planispira* in Cores 64 and 65 suggests that the samples are located in the uppermost *T. bejaouaensis* Zone and may be Albian. The presence of *Ticinella primula* in 56,CC and *Ticinella breggiensis* in 53,CC suggests subdivision of this interval into two middle Albian zones, but faunas are not well enough preserved.

Slightly more-diverse faunas allow recognition of the *Rotalipora ticinensis*-*Planomalina buxtorfi* Zone (52 to 50,CC) by the overlap of the nominate taxa. *Ticinella* species become larger and more diverse in this zone, and *Planomalina buxtorfi* is large and abundant at one level.

The first appearance of *Rotalipora apenninica*, accompanied by *Rotalipora evoluta*, before the appearance of *Rotalipora gandolfi*, despite the absence of *P. buxtorfi*, suggests that Cores 49,CC to 48-2 belong to the latest Albian *P. buxtorfi*-*R. apenninica* Zone. *Rotalipora apenninica* and *Praeglobotruncana stephani* are common along with *H. planispira* and *Hedbergella delrioensis*, but *Ticinella* spp. are less frequent. *Clavihedbergella* was not seen; *Shackoina* occurs only in 48,CC.

The first appearance of *Rotalipora gandolfi* (48-1) marks the base of the *Rotalipora gandolfi*-*Rotalipora greenhornensis* Zone (48-1 to 44,CC). Rotaliporids, *P. stephani* and the hedbergellids occur commonly. The

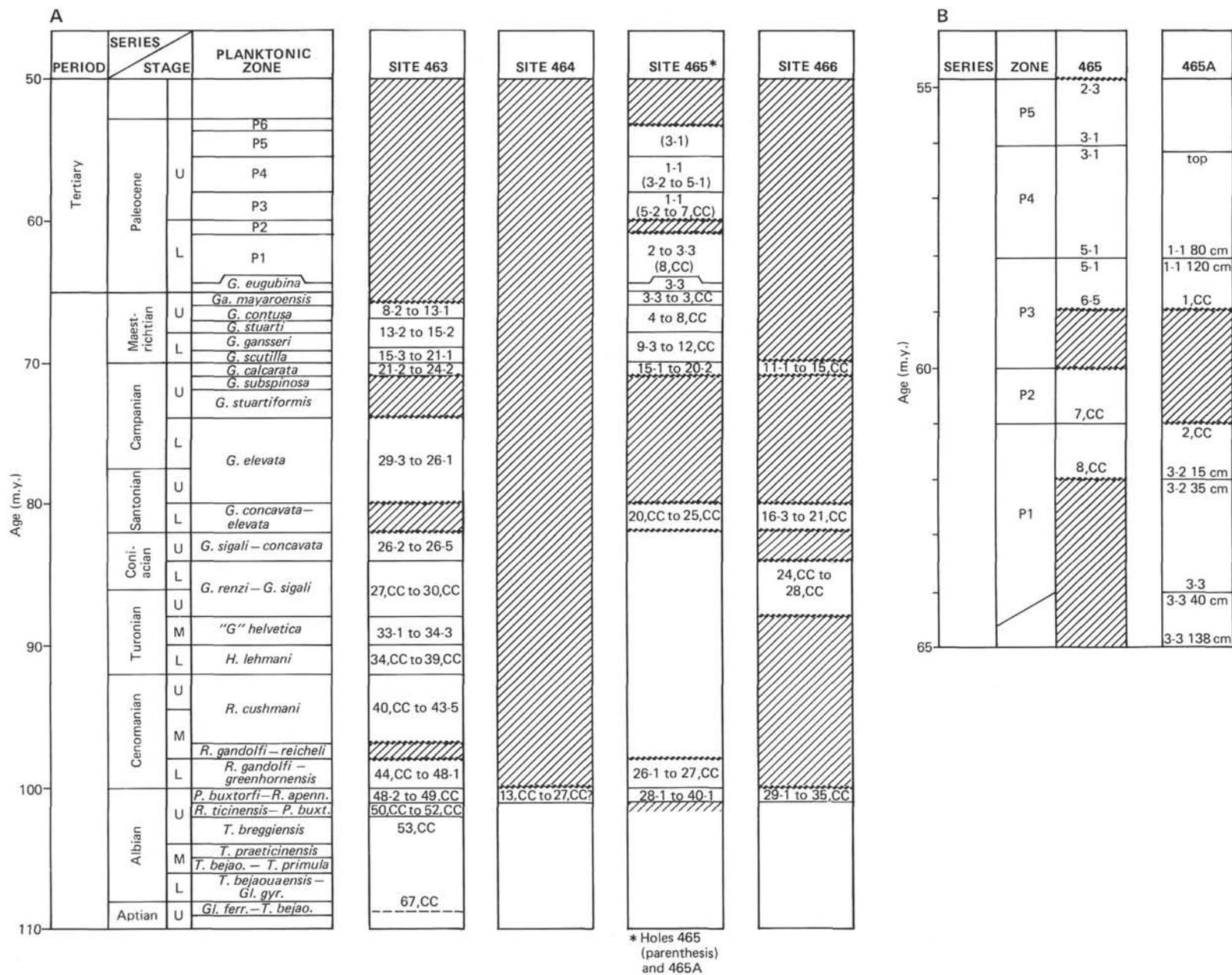


Figure 2. Biostratigraphic summary of Leg 62 sites according to planktonic foraminifers. Planktonic-foraminifer zonation and time scale for the Cretaceous by van Hinte (1976); Paleogene time scale, by Hardenbol and Berggren (1978). Core levels within a zone shown beside the appropriate zone; hiatuses are hachured.

Site 465

This site was continuously cored, and faunas from the late Albian to the latest Maastrichtian were retrieved. The Cretaceous/Tertiary boundary was recovered in Hole 465A, Core 3. Hiatuses in this section occurred in the Cenomanian to Santonian, the Santonian to Campanian, and in the Maastrichtian.

Preservation

Recrystallization is intense in the Albian (Cores 40-34), above which preservation improves, except that the fossils are squashed. Preservation deteriorates again in Cores 30 to 28, where dissolution and recrystallization are common at most levels. By the Cenomanian (27,CC to 25,CC), sediments are slightly less recrystallized. Above the hiatus to the Santonian, fossils are better preserved, but dissolution is intense in Cores 24 and 25. The Campanian sediments (20 to 12,CC) are generally moderately well preserved, except for dissolution intervals connected with chert in Cores 20 to 16 and 12. Maastrichtian faunas are well preserved, except for an episode of dissolution associated with chert just below the Cretaceous/Tertiary boundary in Core 3.

Foraminifer Faunas

Poor preservation dominates the *P. buxtorfi*-*R. apenninica* Zone (40-1 to 27,CC). Foraminifers are dolomitized in the lower cores, and diluted by abundant radiolarians in some samples. Both the fossils and the faunas are small in most samples. Hedbergellids are the most common components of the faunas, but small, infrequent specimens of *Rotalipora apenninica* in Core 40 and a fossil related to *Planomalina buxtorfi* in 37-1 locate these faunas in the *P. buxtorfi*-*R. apenninica* Zone. In Core 34-1 there is a major change in the faunas; all fossils become larger, *Ticinella* spp. increase in abundance, and radiolarians occur only in discrete interlayers. In Core 32, tiny praebuliminids become a very common component of the faunas. Smaller faunas and individuals return as preservation worsens in Cores 31 and 30. In Core 28, there is a notable increase in the rotalid benthics; abundant plant fibers, fish debris, and brown clay occur in 27, along with some mollusk fragments.

The *Rotalipora gandolfi*-*R. greenhornensis* Zone is located in Core 27 by the appearance of *R. gandolfi*. Hedbergellids, rotaliporids, and size-sorted mollusk debris are common in this core. Bad preservation renders the fossils barely recognizable in some sections.

The *Gtr. concavata*-*Gtr. elevata* Zone (Cores 25 to 20-2) is recognized on the basis of the overlap of the *D. concavata* group and *Gtr. elevata*. *Globotruncana arca*, *Gtr. stuartiformis*, and *Hx. striata* all occur in this interval. Some faunas are depleted because of dissolution or sorting, so that only *Heterohelix* spp., *Globigerinelloides* spp., and *Gtr. elevata* are common. The first *Nuttalides truempyi* accompanies radiolarians, dolomite rhombs, and pyrite among the foraminifers in 21-4.

With the first occurrence in abundance of *Gtr. calcarata* (20-2), the zone of that name is recognized (20-2

to 12,CC). *Globotruncana calcarata* is accompanied by *Gtr. subspinoso*. Very high-spired *Gtr. calcarata* occurs in 18-2. *Globotruncana fornicata* is less abundant in Cores 21, 19, 16, and 15. The heterohelicids are the most abundant component of most faunas; *R. rugosa* is infrequent in most samples at this site. *Globigerinelloides asperus* is often common, but the smoother *G. prairiehillensis* is rare or absent at this site. The first rugotruncanids occur in 17-2, but they are not common. The most common globotruncanids are *Gtr. tricarinata*, *Gtr. stuartiformis*, and *Gtr. fornicata*, *Gtr. arca* being slightly less abundant in most samples. The benthic *Aragonia* first occurs in 16,CC.

The disappearance of *Gtr. calcarata*, and the presence of the *Gtr. scutilla* faunas, including *Psg. costulata*, characterize the *Gtr. scutilla* Zone. However, the lack of *Gtr. gansseri*, and the presence of *Psg. excolata* in 9-3, suggests that that fauna could belong to the *Gtr. gansseri* Zone, in which it is tentatively placed here (12,CC to 8,CC). Faunas are dominated by *Gtr. stuartiformis* and the heterohelicids, although heterohelicids other than *Heterohelix* are not common at this site. *Gublerina* first occurs in 11,CC. In 9,CC, *Inoceramus* prisms and other invertebrate debris are relatively frequent. In 9-3, both *Gtr. fornicata* and the rugotruncanids increase in abundance, ornamentation becomes more pronounced, and many individuals are higher-spired than in previous samples.

The first *Globotruncana contusa* occurs in 8,CC, thus defining the base of the zone of that name. The *Gtr. contusa* Zone (8,CC to 3,CC) includes the most abundant levels of *Globotruncanella havanensis* (8-1), as well as one specimen of *Gtr. gansseri* (6-4). *Globotruncana contusa*, *Gtr. stuarti*, *R. rotundata*, and *R. fructifera* are typical components of the faunas.

Abathomphalus mayaroensis occurs abundantly in Core 3, thus defining the *Ga. mayaroensis* Zone. Faunas are depleted because of intense dissolution, so that benthic faunas are enriched in many levels by the loss of the planktonics; *Psg. excolata* is the most common planktonic foraminifer. Chert is very common in this interval.

Site 465

Three cores of the Late Cretaceous *Ga. mayaroensis* Zone were retrieved from Hole 465. Faunas are well preserved and belong to the upper part of the *Ga. mayaroensis* Zone. *Globotruncana cretacea*, common in Core 10-1, was not found in nearby Hole 465A, suggesting better preservation of sediment in 465 (Sliter, 1971). *Globigerinelloides asperus*, rugotruncanids, and the *Gtr. stuarti*-*Gtr. stuartiformis* groups are the most common constituents in 10-4; *Globotruncana contusa* is more abundant in 9,CC.

Site 466

The Cretaceous section recovered at this site includes lower Maastrichtian and upper Campanian to upper Albian sediments. Hiatuses span the Cenomanian, and parts of the Turonian, Coniacian, and Maastrichtian. Most of the samples below the lower Maastrichtian to

upper Campanian are only core-water samples, so the faunas are highly reduced in size, size-sorted, and lack globotruncanids in many instances, making zonal assignment difficult. Preservation of the Upper Cretaceous material is only moderate, and Albian faunas are generally poorly preserved.

Sediments of the *P. buxtorfi*-*R. apenninica* Zone (Cores 29 to 35) contain partially recrystallized planktonic foraminifers. *Rotalipora apenninica* is present throughout the section, but *P. buxtorfi* was not found. By reference to the *R. apenninica* interval of Luterbacher (1975), this interval is placed in the upper Albian.

The *Globotruncana renzi*-*Gtr. sigali* Zone (Cores 28 to 24) lacks most index fossils, but does contain specimens of *M. renzi*, *Gtr. fornicata*, and *Gtr. lapparenti*. The lack of *D. concavata* suggests that these faunas then belong to the *Gtr. renzi*-*Gtr. sigali* Zone. Within these samples, pyrite, radiolarians, chert, and glauconite are common, while the larger planktonic foraminifers are not. One broken piece of an orbitoidal foraminifer was found in Core 25; this may indicate redeposition from a shelf-depth environment.

The *Gtr. concavata*-*Gtr. elevata* Zone was recognized in Cores 21 to 16. *Globotruncana fornicata*, *D. concavata*, *D. assymetrica*, *G. asperus*, and *Rugoglobigerina pilula* were all found in 21,CC; fine fractions in other samples contain abundant *Heterohelix* spp., *G. asperus*, *G. prairiehillensis*, and *Clavihedbergella*. In 16,CC the radiolarians are beautifully preserved, whereas the planktonic foraminifers are heavily bored. *Planoglobulina glabrata* was also found in this sample.

Cores 15 to 10 have been ascribed to the upper Campanian *Gtr. calcarata* Zone, despite the lack of the nominate taxon, because of the abundance of Campanian faunas and *R. subcircumnodifer*, but the lack of typical lower Maastrichtian rugotruncanids as seen at nearby Site 465. Faunas typically consist of *Globotruncana stuartiformis*, *Gtr. elevata*, *Gtr. fornicata*, *Gtr. tricarinata*, *R. rugosa*, *S. multispina*, *Psg. costulata*, and *R. subcircumnodifer*. Preservation is usually only moderate, and dissolution removal of faunal elements intense. Fragments of benthic foraminifers, chunky carbonate, glauconite, and large rock fragments occur in 14,CC; all but the rock fragments occur occasionally in all other samples of this zone. Eocene planktonic foraminifers are found mixed with faunas of Core 10.

Paleogene

Paleogene sediments were recovered at Sites 463, 465, and 466. At all sites, part of the section comprises a "mixed zone," with fossils of Oligocene through Campanian age admixed in varying proportions. The thickness and character of the mixed zone varies from site to site.

At Site 463, Cores 5 through 8 contain mixed faunas; levels include pure Cretaceous dissolved faunas, pure Eocene faunas in Cores 7 and 8, and mixed Cretaceous, Eocene, and Oligocene faunas in Cores 7 through 5.

At Site 465, only a small section of Core 2 contains mixed faunas of Cretaceous, Eocene, and Oligocene

age. These faunas are underlain by a continuous Paleocene section. At Site 466, the only Paleogene material occurs in Cores 7 through 10. At the top of the section, Campanian and upper Maastrichtian fossils are mixed with middle Eocene and some upper Eocene and middle Oligocene foraminifers. At the bottom of the section, Eocene and upper Maastrichtian fossils are mixed with phillipsite, glauconite, manganese, and fish debris. Eocene fossils dominate in all samples.

Site 463

Paleogene sediments occur in Cores 8 to 5-1. The upper Oligocene *G. ampliapertura* Zone and the middle Eocene *Globigerinatheka kugleri* Zone (6,CC) are present at discrete levels; all other levels contain mixed Cretaceous, Eocene, and Oligocene sediments. The percentage of Oligocene sediments is greater in Cores 5-1 to 6-5; faunas included *Chiloguembelina cubensis*, *Globigerina ampliapertura*, *Hantkenina alabamensis*, *Catapsydrax dissimilis*, *Globoquadrina venezuelana*, and *Globigerina tripartita*. Eocene and Upper Cretaceous fossils are more common in Cores 7 and 8. Levels of Cretaceous material only are intercalated in levels of Eocene with few Cretaceous fossils in Core 7. Eocene fossils of the *Morozovella formosa formosa* Zone (8-2), including *M. formosa*, *A. quetra*, *M. aragonensis*, *C. wilcoxensis*, *A. primitiva*, and *T. pseudotopilensis*, were found in one pure layer.

Site 465

The Paleocene was continuously cored at Site 465 (Hole 465, Cores 2 to 9; and Hole 465A, Cores 1 to 3-3). The section ranges from late Paleocene Zone P5 to Zone P1 in 8,CC. Preservation of all samples is good; slight recrystallization is evidenced by microcrystals of calcite on the tests of the morozovellids, particularly on their peripheries.

Fossils of Zone P1 age (8,CC) include *Chiloguembelina midwayensis*, *Planorotalites compressa*, *Subbotina pseudobulloides*, and a rare multi-chambered form resembling *Morozovella trinidadensis*, but possibly related to *Hedbergella monmouthensis*. In the Atlantic, this form indicates Zone P1 below the appearance of *M. trinidadensis*.

Zone P2 fossils, determined by the presence of *Morozovella uncinata*, occurred in 7,CC. *Chiloguembelina* dominated the faunas, followed in abundance by the morozovellids and *Woodringina*. *Chiloguembelina midwayensis* is often large and occasionally spinose, and shows a tendency to develop small terminal chambers and accessory apertures.

Fossils of Zone P3b, the *Morozovella pusilla pusilla* Zone, occur in Cores 6-5 and 5. Common fossils include *Morozovella pusilla*, *M. conicotruncata*, and *Acarinina spiralis*. *Subbotina pseudobulloides* is infrequent, and chiloguembelinids are rare. Morozovellids are tightly coiled, with closed umbilici.

Cores 3 to 5-1 are ascribed to the upper Paleocene *Planorotalites pseudomenardii* Zone. *Chiloguembelina* is infrequent, as morozovellids dominate the faunas. *Morozovella velascoensis*, *Acarinina coalingsensis*, *Plan-*

orotalites pseudomenardii, *Acarinina primitiva*, and *M. pusilla* are all present. Eocene fossils of Zone P6 occur at the top of Core 3 and at the base of Core 2, where they are mixed with middle Eocene and Pliocene fossils.

The Cretaceous/Tertiary boundary is contained in Core 3-3 of Hole 465A (Fig. 6). Cretaceous sediments at the bottom of the section are stark white, with occasional splotches of black material identified as pyrite. Chert fragments are common in this sediment, which is chalky and contains dissolved foraminifer faunas. At 140 cm, white Cretaceous material is streaked through the center of a grayish sediment of Paleocene age. The contact between the streak of Cretaceous and the Paleocene is sharp, so that it is possible to sample pure faunas of either age at this level. Above 110 cm, no further white sediment is seen, and the black pyrite splotches do not occur.

Because of dissolution of the Cretaceous sediment, it is not possible to determine if the uppermost Cretaceous is present. The basal "*Globigerina*" *eugubina* Zone is present at 138 cm; it is very well preserved and contains faunas similar to the "*G.*" *eugubina* Zone at other DSDP sites, except for the greater abundance of *Chiloguembelina* and *Guembelitria* at some levels. *Hedbergella monmouthensis*, which occurs in the "*Globigerina*" *eugubina* Zone faunas of Atlantic Sites 356 and 384, and in cores from Agulhas Plateau, is present also at this site.

Zone P1a is present above the *G. eugubina* Zone in Core 3; faunas include *Chiloguembelina morsei*, *Subbotina pseudobulloides*, *Hedbergella monmouthensis*, *Morozovella inconstans*, and *G. cretacea*. Upper Zone P1 is found in Core 3-1 through Core 2. *Chiloguembelina midwayensis* is abundant, accompanied by *S. pseudobulloides*, *M. inconstans*, *H. monmouthensis*, *H. sp. cf. H. monmouthensis* (resembling *M. trinidadensis*), and striate chiloguembelinids. Core 1, CC contains fossils of the Zone P3b. The dominant element of the faunas has changed from *Chiloguembelina* spp. to *Morozovella pusilla*. *Morozovella velascoensis* and *Planorotalites chapmani* are also common; acarininids and subbotinids are less common in these faunas.

Site 466

Cores 7 through 10 contain mixed assemblages of Cretaceous, Eocene, and Oligocene planktonic foraminifers. Oligocene fossils dominate in Core 7, whereas Eocene faunas predominate in Cores 8 to 10. Preservation is selective: fragile Oligocene species are not found in the upper core, whereas the robust morozovellids and acarininids predominate in lower faunas. Some of the in-mixed Cretaceous fossils are better preserved in these levels than in the *in situ* Cretaceous below. In some Eocene levels, middle Eocene fossils are recrystallized, whereas lower Eocene specimens are not.

Included in Core 7 are *Globoquadrina venezuelana*, *Turborotalia opima*, *Chiloguembelina cubensis*, *Gtr. elevata*, *Gtr. fornicata*, and *R. fructifera*. The core catcher of 7 contains more Cretaceous than Eocene or Oligocene fossils. By contrast, 10, CC is largely composed of Eocene fossils, with little in-mixed Cretaceous.

Fossils include *M. aragonensis*, *A. soldadoensis*, *G. kugleri*, *Gtr. contusa*, *Psg. excolata*, and *Gtr. calcarata*. The presence of *Gtr. calcarata* in Core 10, CC is important, because this fossil is not found in sediment of that age in the *in situ* Cretaceous below.

COMPARISON WITH OTHER CENTRAL PACIFIC DSDP SITES

Cretaceous and Paleogene sediments have been recovered at 13 other central Pacific DSDP sites (Luterbacher, 1975; Caron, 1975; Toumarkine, 1975; Fleischer, 1975; McNulty, 1976; Douglas, 1971, 1973; Kraushennikov, 1971, 1973) (Table 1). The biostratigraphy of these sites is briefly recapitulated below to allow comparison with sections of Leg 62. Zonal names from these reports are retained.

Cretaceous

Site 305

Upper Cretaceous sediments are well preserved, except those from the *A. mayaroensis* Zone, which are very dissolved. Beginning in the upper Campanian, dissolution becomes intense again and continues so down to the Aptian. Black shales are reported in the Aptian here, as well as at Site 306.

Site 310

The only Maastrichtian fossils are redeposited, overlying a good interval belonging to the *Gtr. concavata* Zone, the Coniacian, the *P. helvetica* Zone, and the *R. apenninica* Zone of the Cenomanian. Black shales in the Cenomanian are reported at this site from only one fragment in a core catcher.

Site 313

This site contains well-preserved lower to middle Maastrichtian sediments, below which preservation declines rapidly through the upper and lower Campanian.

Site 51

Only the *Gtr. concavata* Zone and *Ticinella* from the Albian are recorded here.

Site 47

The *A. mayaroensis* Zone is inferred from the nanofossil *M. mura* Zone. Underlying this zone, there is a nanofossil chalk and ooze with *Inoceramus*, belonging to the *Gtr. gansseri* Zone.

Site 169

This site contains upper Cenomanian pink to white chalks.

Site 170

This site lacks the upper Maastrichtian, but begins in the lower Maastrichtian *R. subcircumnodifer* Zone. Below are ashy, cherty, zeolitic mudstones, which contain identifiable fossils of the *R. evoluta* Zone.

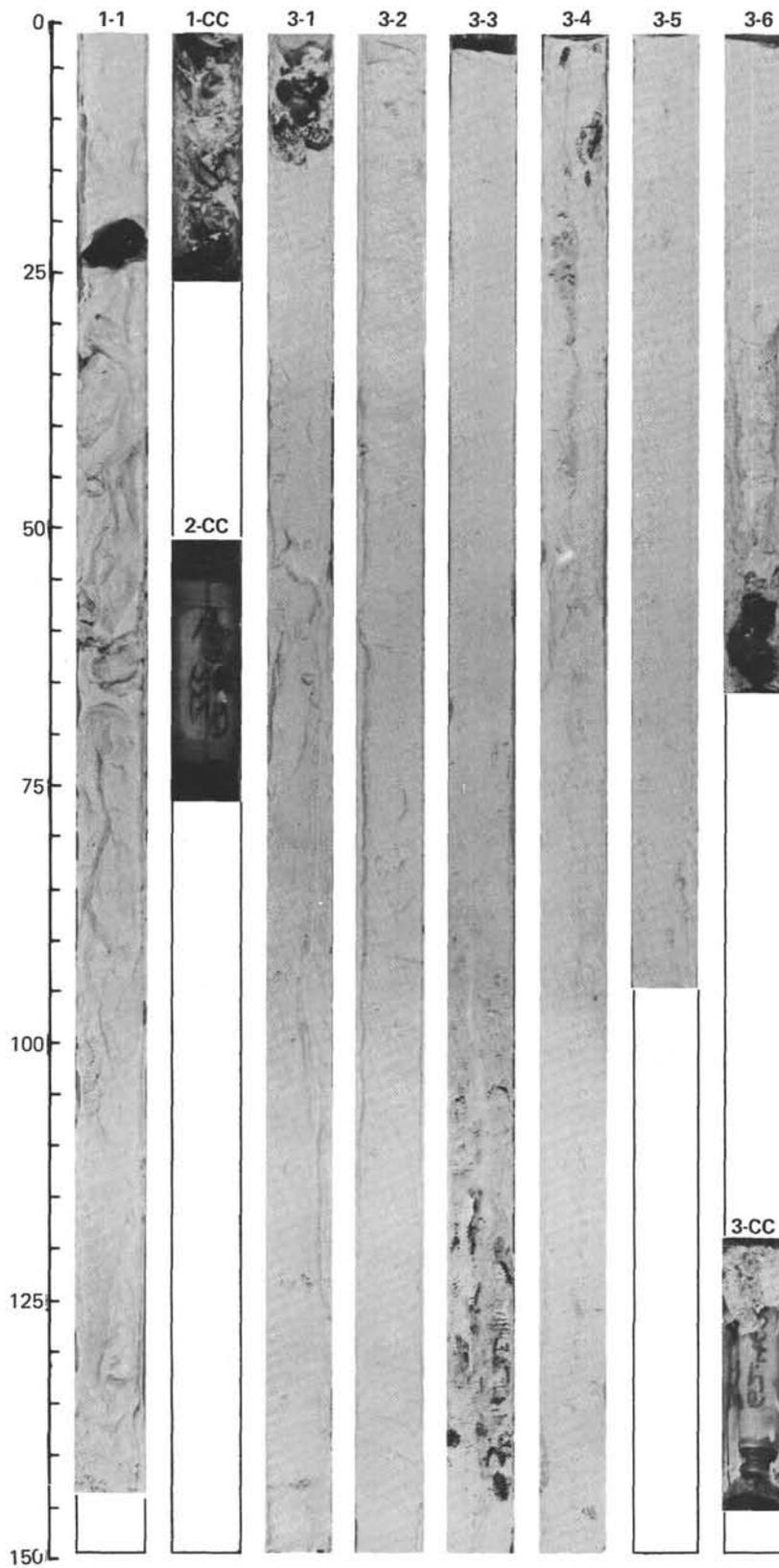


Figure 6. Photograph of Cores 1, 2, and 3 from Hole 465A. The Cretaceous/Tertiary boundary occurs at 3-3, 138-140 cm. The white stringer at the base of this section is the Cretaceous material which has been spread into the Paleocene section during the drilling process. Black splotches are pyrite. The disturbed Late Cretaceous zone of chert and dissolved carbonate can be seen from Section 4 to the core catcher.

Site 171

This site contains a complete section of Maastrichtian and upper Campanian, underlain by a hiatus from the *Gtr. calcarata* to *Gtr. concavata* Zones. The *M. renzi* and *P. helvetica* Zones overlies a volcanic siltstone of Cenomanian age.

Site 167

This site includes a complete Maastrichtian and Campanian section. Santonian fossils below are dissolved, so that only the nannofossil zones can be recognized. The Santonian-Coniacian contains primarily neritic benthics. The Aptian at this site is brownish-yellow cherty limestone.

Site 199

This site contains badly dissolved *A. mayaroensis* Zone fossils.

Site 288

There is a 30-meter coring gap between the Danian and the *Gtr. gansseri* Zone, so that the *A. mayaroensis* Zone may have been present, but uncored. The lower Maastrichtian is present, but between the *M. subcircumnodifer* Zone and the Cenomanian the foraminifers are dissolved, and there are few nannofossils. Improved preservation allows recognition of the Cenomanian *R. greenhornensis* Zone; the section bottoms in the Albian/Aptian.

Site 289

There is a 20-meter coring gap between the Danian and the *Gtr. gansseri* Zone at this site. However, the nannofossil *M. mura* Zone is present, suggesting that the *A. mayaroensis* Zone was deposited, but the zonal marker removed. The lower Maastrichtian and upper Campanian are represented, but from the lower Campanian to the Aptian there is a hiatus. Aptian sediments are pinkish-gray, siliceous limestones.

Site 45

This site contains a greenish-gray Cenomanian level.

Paleogene**Site 305**

This site produced heavily dissolved Oligocene sediments, a dissolved and impoverished middle Eocene fauna, and a well-preserved Paleocene section. The lower middle Eocene is considered missing, and there is a hiatus across the Cretaceous/Tertiary boundary. The *M. subbotinae* Zone is missing, but all other Eocene to upper Paleocene zones are present; the Danian was not reported. *Morozovella formosa* is heavily ornamented, tending to *M. crater*.

Site 310

Dissolution was so strong that the Oligocene to Maastrichtian section could not be zoned. Only the *G. ampliapertura* Zone was recognized. Sedimentation

rates were reportedly low in the middle Eocene and the Oligocene; there is a hiatus in the upper Oligocene.

Site 313

The Oligocene contains only the *G. opima* and *G. ciproensis* Zones; there is a dissolution hiatus between the lower Oligocene and the middle Eocene; the *M. subbotinae* Zone is present, but most of the Eocene is heavily contaminated with Paleogene reworking. Most of the Paleocene is missing, as on the Magellan Rise and Horizon Guyot.

Site 44

The section is nearly continuous from the middle Eocene through the lower Oligocene; all zones except P15 are identified, but sedimentation rates were very low.

Site 167

The upper Oligocene is missing; however, all zones of the lower Oligocene through the middle Eocene Zone P13 are represented. Chert and a hiatus occupy what would be the middle Eocene, followed by a hiatus spanning the upper Paleocene.

Site 171

There is a hiatus between the lower Oligocene and the middle Eocene Zone P14; Zone P13 is found, followed by a second gap to the Cretaceous.

Site 199

This site contains the Paleocene, but not the Danian.

Site 200

Only the *M. formosa* Zone can be recognized; morozovellids and acariniids display a surprising abundance of secondary sutural apertures; high accumulation rates are reported in the upper Paleocene and lower Eocene.

Site 202

This site contains poorly preserved fossils from the *O. beckmani* Zone.

Site 288

The Oligocene (Zones P22 and P19) are well represented, followed by a coring gap and hiatus to the upper Paleocene; the Paleocene section extends to the Danian.

Site 289

A long Oligocene, including Zones P22, an extended P21, and a part of P19, is followed by a hiatus to the upper Eocene P16. Upper Eocene Zone P15 and middle Eocene Zone P14 are present above the chert, which makes zonation below indefinite. Zone P11 was identified overlying fossils of Zone P8; the section continues from Zone P7 to P3, only Zone P6 being absent.

Site 47

This site contains a hiatus from the upper Miocene nannofossil *C. tricorniculatus* Zone to the middle Eo-

cene *G. bullbroki* Zone (P11). The section below Zone P8 contains all Eocene and Paleocene zones, including the "*G.*" *eugubina* Zone.

Site 45

This site contains only an upper Eocene ash deposit, containing the nannofossil *D. barbadiensis*, and a part of the Oligocene in one core.

Hiatuses

There are multiple reported hiatuses in the various Pacific Paleogene and Cretaceous sites discussed above. Lancelot and Larson (1975) report that the Paleocene-lower Eocene hiatus is widespread in the Pacific, although they speculate that it may be unique to plateau regions in the highly productive equatorial zone. They also suggest that hiatuses are longer in the deeper middle-latitude sites. The previous summary of the hiatuses reported in the Paleogene and Cretaceous suggests that the times of extensive loss of material (or non-deposition) are the late Eocene, the early Eocene to late Paleocene, the Cretaceous/Tertiary boundary (including part of the *Ga. mayaroensis* Zone), and part of the Campanian to Santonian. The generally poor preservation of most Cretaceous sediments older than the Campanian makes it difficult to assess actual hiatuses in these sections.

Significant exceptions are the middle Eocene to lower Oligocene section at Site 44, the complete lower Eocene through Paleocene section at Site 47, the complete Paleocene section at Site 465, the Paleocene section at Site 47, and the upper Eocene section at Site 289.

The Cretaceous/Tertiary boundary is marked by a disturbed zone in the most complete sections, Site 47 and 465. It is absent at other central Pacific sites.

The most widespread Cretaceous hiatus spans large parts of the *Ga. mayaroensis* Zone at seven sites. Parts of the lower Campanian are missing at three sites. That the hiatuses supposed to develop as sites cross the equatorial zone (Lancelot and Larson, 1975) should not necessarily be synchronous between sites may explain the scattered distribution of hiatuses through Cretaceous sections.

SEDIMENTATION RATES

Sedimentation rates for the four Leg 62 sites in the Cretaceous are plotted in Figure 7. Particularly high rates common among Sites 463, 465, and 466 occur in the Maastrichtian *Gtr. contusa* Zone and the *Gtr. calcarata* Zone of the late Campanian. Low rates at all the sites are typical through the Coniacian and early Cenomanian.

At Site 463, high rates through the Maastrichtian probably occurred as the site entered the equatorial high-productivity zone; however, radiolarians are not abundant through these levels. Stratigraphic uncertainties concerning the presence or absence of the *Gtr. stuarti* Zone may add to the inflated rates in general. The low value in the *Gtr. gansseri* Zone should be accurate, as this taxon is a tropical index species and should occur through its full range at Site 463. Low

rates in the Turonian, Coniacian, Cenomanian, and Santonian may partially result from transformation of sediment into chert, as well as from erosion. The low rate in the *P. buxtorfi*-*R. apenninica* Zone is surprising in view of high late Albian rates at many other Pacific and Atlantic DSDP sites.

The sections at Sites 465 and 466 are very similar except that sediment removal, presumed to be caused by the equatorial crossing in the Turonian, ceased earlier at Site 466. High rates in the late Campanian to early Maastrichtian and late Albian are apparently ocean-wide phenomena at intermediate-depth sites in middle to low latitudes. The low rates in the Cenomanian are probably the partial result of erosional truncation of parts of those sections at both sites, as well as of chertification of some sediment. The low Cenomanian rate at Site 465 is surprising, as this site is supposed to have received clastic influx at this time. Rates of pelagic sedimentation must have been very low (or erosion of material very active) to produce such low rates even in a turbidite sequence in the high-productivity zone.

REDEPOSITED SEDIMENTS

Redeposited Paleogene sediments from the so-called "mixed zone" are common at Sites 463, 465 and 465. The differing composition of the nannofloras and planktonic-foraminifer faunas from the same sample suggest not only differential erosion and redeposition of sediments from nearby areas, but also derivation from several different sources.

Redeposited sediments at Site 465 occur primarily in the early Cenomanian and late Albian. Along with the small-sized planktonic foraminifers and neritic benthics were abundant detrital minerals, plant debris, and size-sorted mollusk fragments. The benthic foraminifers and small rotaliporids in these samples suggest a neritic depth of deposition; the mineral and plant debris suggest a shallow shelf to subaerial source for the redeposited sediments.

At Site 466, two modes of redeposition prevailed in the Cretaceous and Paleogene. The Paleogene "mixed zone" at this site contains redeposited Cretaceous and Paleogene planktonic foraminifers, as well as detrital and authigenic minerals, redeposited benthic foraminifers, fish debris, and glauconite. These sediments represent a high-productivity dissolution interval, as well as episodes of normal sedimentation, mixed together. Late Cretaceous samples contain rock fragments, volcanic glass, bryozoans, redeposited benthic foraminifers, and some reworked Eocene fossils. This regime suggests erosion of Eocene sediments from a volcanic source and shallow-shelf environment into normal pelagic accumulations.

Older Cretaceous samples at this site were mainly derived from core water and contained only the fine fractions of the mineral and foraminifer components, along with prisms of *Inoceramus*. In Core 25, one fragment of a large orbitoidal benthic foraminifer typical of reefs was found mixed with pelagic sediments of Cretaceous age; a few reworked Eocene planktonic foraminifers were also present. The contents of this sample sug-

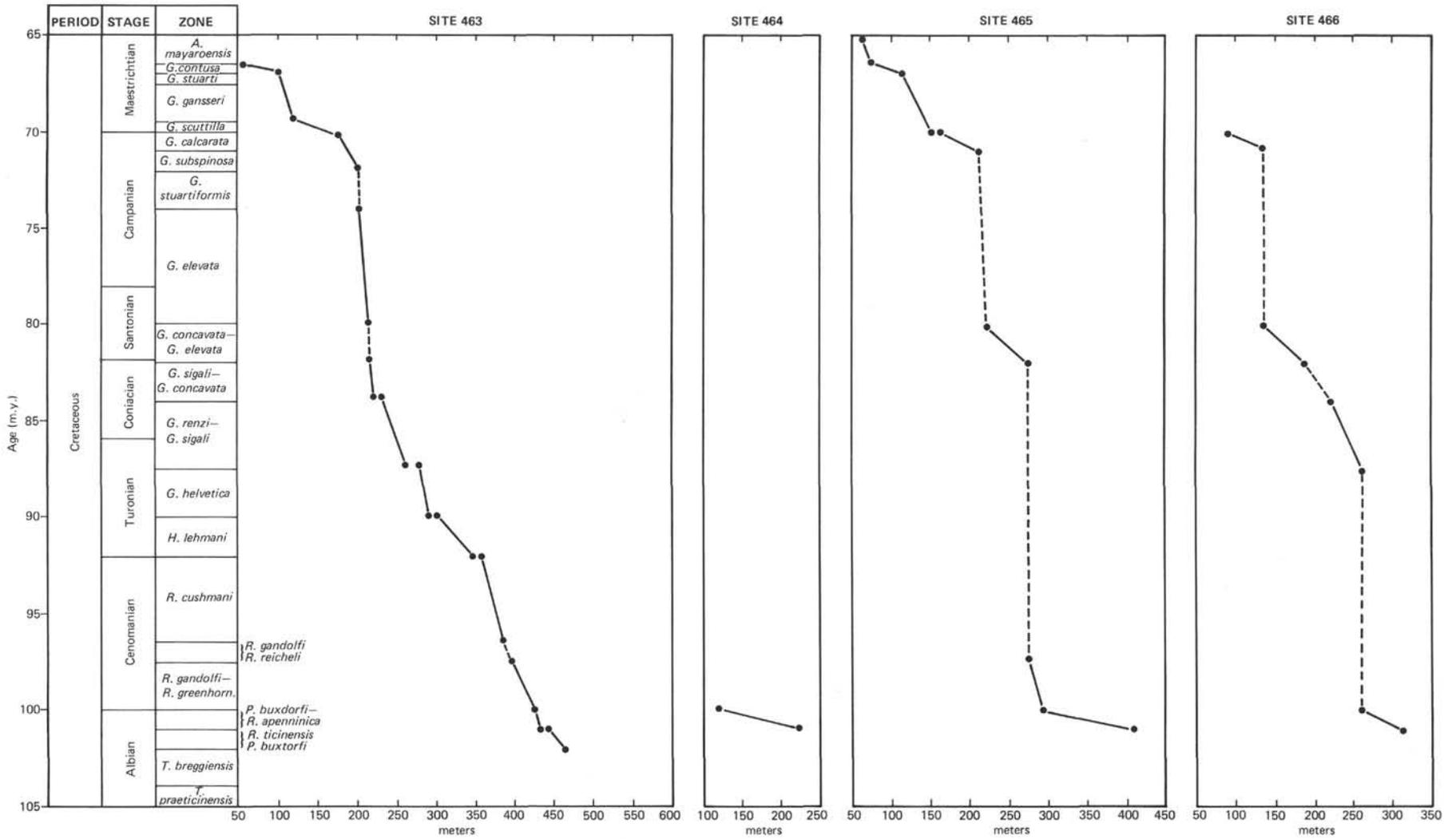


Figure 7. Sedimentation rates in meters per million years at Sites 463, 464, 465, and 466. Horizontal scale is meters in sub-bottom depth at the sites. Vertical scale follows the time-scale of van Hinte (1976). Dotted lines indicated hiatuses in the section. Separate dots at the same levels indicate some intervening sedimentation of indeterminate age.

gest that the core-water samples were misleading, and that the sedimentation regime of the late Campanian sediments may have occurred back through the Coniacian and Santonian.

Cenomanian sediments at Site 466 roughly resemble those at Site 465, except that the siliceous and phosphatic contents are higher at Site 466. Radiolarians, chert, fish debris, and normal pelagic sediment at this site are found with detrital minerals, plant debris, and some volcanic glass suggesting distal turbidite deposition, similar to that at nearby Site 465.

The two major periods of redeposition, the Paleogene and late Albian to Cenomanian, differ not only in the types of sediments, but also in probable cause. Turbidite processes, possibly related to the lower sea levels in the early Cenomanian, were responsible for the redeposited materials at Sites 465 and 466. Erosion of a volcanic and shallow-water sediments produced the sediment pattern at Site 466 during the later Cretaceous. Extreme erosion of pelagic carbonate sediments and redeposition from several sources is the suggested mechanism producing the "mixed zone" faunas of the Paleogene in the central Pacific.

SUMMARY OF SEDIMENTATION HISTORY AT MID-PACIFIC MOUNTAINS SITES

The Mid-Pacific Mountains Sites 171, 313, 44, and 463 (Table 1; Fig. 8) all contain substantial hiatuses in the Paleogene. The so-called "mixed zone" is present at all the deeper sites, but not mentioned at Site 44, which apparently contains short, sporadic hiatuses in the Oligocene to middle Eocene, which was not continuously cored. The mixed zone is thickest at Site 463 (Cores 4 to 7-3) and 171 (Cores 5 to 9), but very thin at the deepest Site 313 (Core 2), where dissolution effects are common (Toumarkine, 1975).

The Eocene/Oligocene boundary is identified at Site 44, but faunas are highly dissolved (Blow, 1971). At all other sites, this interval has been removed. Roughly similar Eocene levels are preserved intact at these sites, although mixing is intense at Site 463. Middle Eocene Zones P13 and P14 are best preserved; radiolarians occur commonly in the early and middle Eocene at Sites 171 and 313, but are not found at Site 463. Whereas some early Eocene faunas are found at Sites 463 and 313, most of the early Eocene and Paleocene is missing from the Mid-Pacific Mountains holes.

Only Sites 463, 171, and 313 recovered Cretaceous sections, all of which have short hiatuses in the uppermost Maastrichtian. At that time all of these sites are presumed to have crossed the equatorial zone (Lancelot and Larson, 1975). The middle Maastrichtian to upper Campanian sequence is continuous and well preserved; hiatuses below the *Gtr. calcarata* Zone occur at Sites 171 and 463, whereas preservation only deteriorates at Site 313; subsequently, this sequence was interrupted by an episode of volcanism and turbidite deposition masking whether the erosional event at Sites 463 and 171 also occurred here. Site 313 bottoms in lower Campanian, overlying basalt.

Sites 171 and 463 contain hiatuses below the upper Campanian *Gtr. calacrata* Zone; more material is removed from the section at the more-easterly Site 171, which contains a telescoped Santonian to Coniacian section. At Site 463, smaller, discrete portions of the lower Campanian and upper Coniacian are missing. The lower Coniacian and upper Turonian are represented at both sites; however, the section at Site 463 is relatively complete from the Turonian to the Aptian, whereas sediments of this age at Site 171 are poorly preserved and dominated by volcanic input and shallow water fossils.

SUMMARY OF SEDIMENTATION HISTORY AT HESS RISE SITES

Four Sites, 464, 465, 466, and 310 (Table 1, Fig. 7), have been drilled on Hess Rise. The deepest site (464) contains a 90-m.y. hiatus, so that only Albian to Aptian sediments were recovered. Site 310, drilled near 3500 meters, contains a more complete section riddled with intense dissolution intervals and numerous Paleogene and Cretaceous hiatuses.

All Paleogene material is absent from Site 464. Dissolution is very intense at Site 310, whereas hiatuses and redeposition of material resulting in "mixed zone" faunas are typical at Sites 465 and 466. Deviations from this regime include a complete Paleocene section recovered at Site 465, and coherent lower Eocene at Site 310. Paleogene radiolarians and zeolites are common in the sediments of the deeper Site 310, more affected by dissolution, whereas foraminifers and no radiolarians were found at the shallower sites.

The Cretaceous sections are different at each site, and comparison of the section is difficult, because the intense dissolution of faunas at Site 310 has removed many standard index species and required a more local zonation to be used (Caron, 1975). Site 465 contains a complete Maastrichtian sequence; no *in situ* Maastrichtian is reported from either Site 466 or 310. The upper Campanian *Gtr. calacrata* Zone is found at Sites 465 and 466, but *Gtr. calcarata* was not identified at Site 310—only *Gtr. subspinosa*, which does represent the upper Campanian. A thick lower Campanian section is found at Site 310, but not at the other sites, which contain the late Santonian *Gtr. concavata*–*Gtr. elevata* Zone, only part of which spans the Santonian/Campanian boundary; it may in part be equivalent to the lowermost part of the section at Site 310. Site 466 contains lower Coniacian, possibly equivalent to the Coniacian *Gtr. primitiva* Zone at Site 310; but this entire interval is lacking at Site 465. At both Sites 465 and 466, the Turonian and most of the Cenomanian are spanned by a hiatus, presumably representing the crossing of the equatorial region. The mid-Turonian *Gtr. helvetica* Zone, however, is preserved at Site 310, which should have been in the northern subtropical belt at that time. The lower Cenomanian to upper Albian *P. buxtorfi*–*R. apenninica* interval is present at Site 465 and 466; this interval identified at Site 310 may be slightly younger in the Cenomanian, as indicated by the various types of praeglobotruncanids. Site 465 bottoms on volcanic

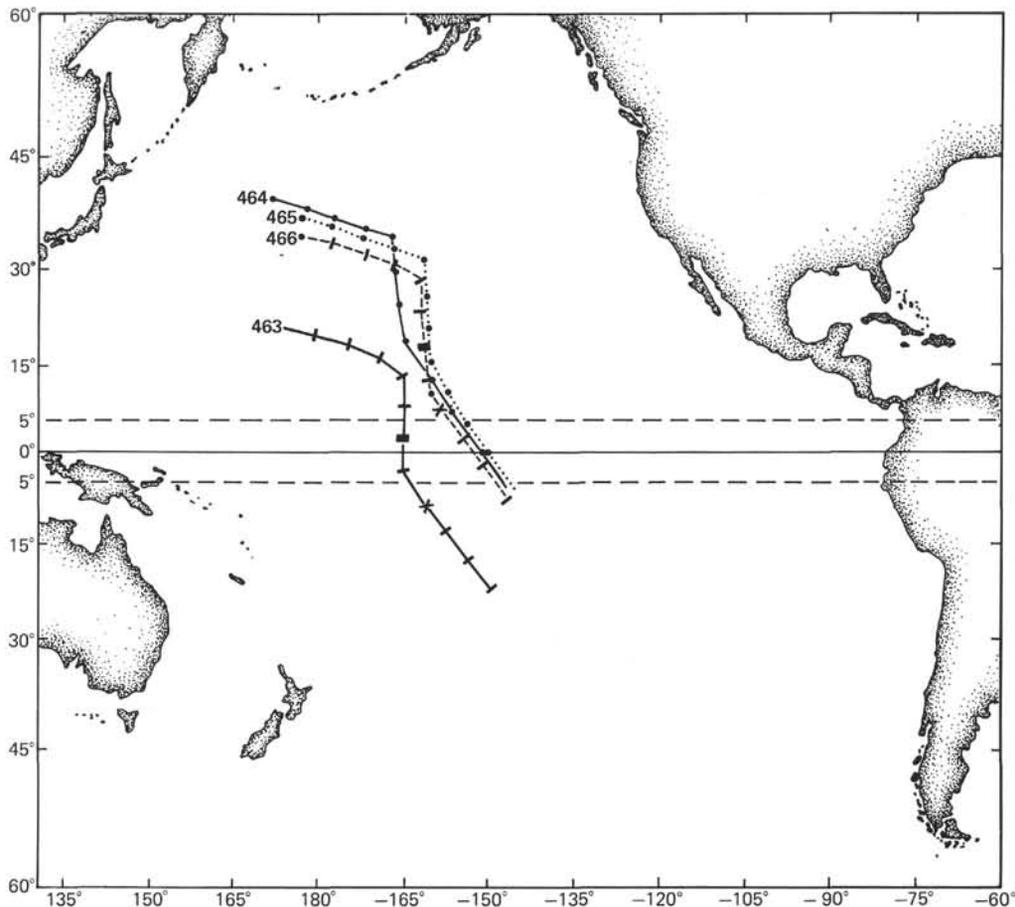


Figure 8. Paleolatitudinal reconstructions of the geographic location of Leg 62 sites in the central Pacific according to the rotational reconstruction model of Lancelot and Larson (1975). Bars along the site path indicate increments of 10 m.y. The heavy bars indicate the position of each site at 60 m.y. ago, and the cross the position at 80 m.y. ago.

rock, overlain by Albian fossils and shallow-water detrital fossils and redeposited clastic sediment of a hemipelagic nature. The amount of redeposited shallower-water materials and sediment is less at Site 466.

Foraminifers of Albian age are preserved at Site 464, which presumably lay above the CCD in the equatorial zone between 100 and 110 m.y. ago. Siliceous fossils, benthic invertebrate fossils, and some redeposited benthic foraminifers are present, and sedimentation rates are very high.

CRETACEOUS PLANKTONIC FORAMINIFER PALEOECOLOGY

Leg 62 Cretaceous faunas all lived in the Tethyan belt (Sliter, 1972) of the Pacific. Faunas at Site 465 are most similar to those reported from the latitudinally equivalent Shatsky Rise (Douglas, 1971; Caron, 1978), and dissimilar to the other Hess Rise site (310), which was at a slightly higher latitude. Site 463 faunas resemble southern Tethyan faunas, but lack *Gtr. falsostuarti* and abundant *Globigerinelloides* (Caron, 1978; Olsson, 1964; Pessagno, 1960, 1962; Said and Kenawy, 1956; Bolli, 1957). Comparison of faunas between Sites 463 and 465 is shown in Figures 3, 4, and 9. The frequent episodes of dissolution make comparison of faunas dif-

ficult, so that the relative frequencies of each taxon throughout the stage or zone are compared. The absence of *Gtr. havanensis* at many levels at both sites suggests that some dissolution has occurred. The presence of *Gtr. cretacea* at 465, but not at coeval levels at 465, indicates removal of species from 465 faunas. Concentration of the resistant species *Gtr. arca* and *Gtr. stuartiformis* (Sliter, 1972) at Site 465, in the Campanian-Maastrichtian, then, may be the result of dissolution of other taxa. By contrast, concentration of the dissolution-susceptible species *Gtr. ventricosa* (Sliter, 1972) at 463 suggests better preservation at this site. There are, however, levels at Site 465 (8,CC and 8-2) where dissolution becomes more pronounced and *Gtr. havanensis* is enriched, indicating that more study of dissolution of Cretaceous planktonics is warranted.

While coeval faunas at Sites 463 and 465 share nearly all species in common (*Gtr. gansseri* is the exception), relative abundances and morphotypic expression differ between the two sites. Species such as *Gtr. stuarti*, *Gtr. ventricosa*, *R. subpennyi*, and some *Globigerinelloides* spp. are larger at Site 463 and apparently higher-spired. Rugotruncanids and rugoglobigerinids are much more abundant at Site 463, as are the rotaliporids in the Cenomanian. The endemic Tethyan forms *A. intermedius*,

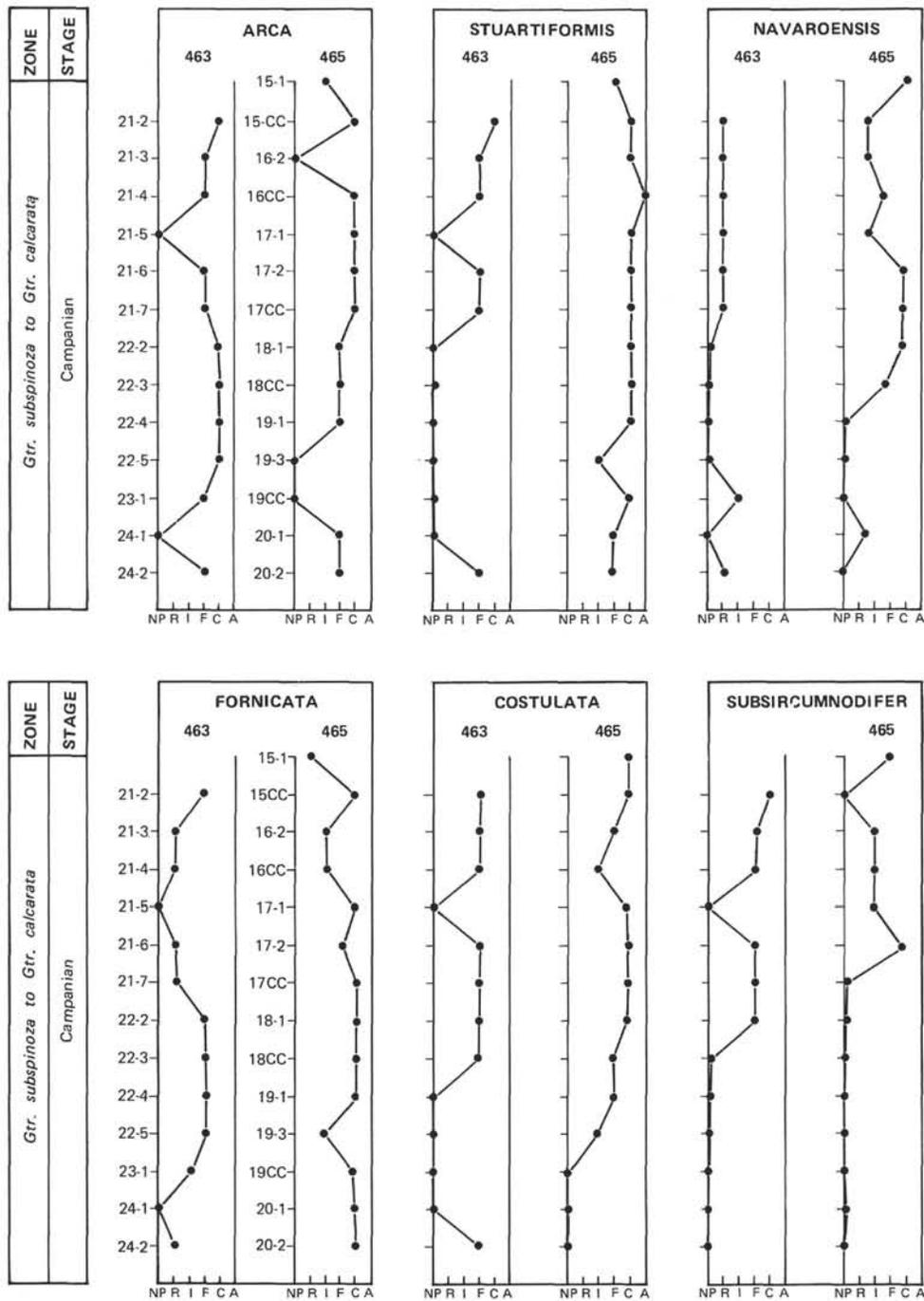


Figure 9. Relative frequencies of six Cretaceous planktonic-foraminifer species at Sites 465 and 463 during the late Campanian. Data are taken from Figures 3 and 4. Symbols include: NP, not present; R, rare; I, infrequent; F, frequent; C, common; and A, abundant. The charts demonstrate the greater overall abundance of these species at most levels at Site 465.

Gtr. gansseri, *Gtr. stuarti*, and *R. subcircumnodifer* overall abundance at Site 463, whereas *Gtr. contusa*, (Sliter, 1972) appear more consistently and in greater also a Tethyan endemic in Sliter's 1972 scheme, is more common at Site 465. During deposition of the *Gtr. contusa* Zone, Site 465 should have been located near 15°N, while Site 463 lay at the equator; their positions suggest that *Gtr. contusa* is indicative of the central Pacific sub-

tropical belt, rather than the equatorial fauna. *Globotruncana arca*, which can penetrate into the boreal zones (Sliter, 1971), was more abundant at Site 463, along with the endemic Tethyan faunas.

Equatorial and Subtropical Faunas

According to the rotational reconstruction model of Lancelot and Larson (1975) the times of equatorial

crossing for Sites 463 and 465 are estimated at 65 to 70 and 95 to 90 m.y. ago, respectively (Fig. 8). Faunas deposited at this time could constitute the equatorial-water-mass faunas, distinct from those of the subtropics. From 70 to 80 m.y. ago, Site 465 lay just within the northern subtropical belt, while Site 463 was situated in the southern subtropics; faunas might be expected to show a high degree of correspondence.

Site 465 was situated at the equator at approximately 90 m.y. ago; there is a hiatus at this site corresponding to that time. Just before arriving at the equator, Site 465 accumulated sediments of early Cenomanian age, which are poorly preserved. These sediments were probably deposited in slope-depth water, and are accompanied by clastic sediments, redeposited, size-sorted mollusk fragments, and plant fiber. Radiolarians, common in older samples, are absent in the Cenomanian, although small stringers of chert do punctuate the limestones. The planktonic foraminifers are small; common elements include *Rotalipora apenninica*, *R. gandolfi*, *Hd. delrioensis*, *Hd. amabilis*, *Hd. planispira*, and *G. caseyi*. Although deposited close to the equator, these faunas are strongly affected by the local depositional environment and cannot be used to describe the equatorial fauna of the Cenomanian.

Reconstructions place Site 463 at the equator 65 to 70 m.y. ago. As at Site 465, the equatorial crossing is marked by a hiatus. Maastrichtian faunas often bear evidence of dissolution and etching; chert is infrequent to frequent in some samples, but no radiolarians were found. Sedimentation rates for the early Maastrichtian are high, however. Planktonic-foraminifer faunas commonly contain *Gtr. stuartiformis*, *Gtr. arca*, *R. subcircumnodifer*, other rugotruncanids, *R. rugosa*, *Psg. costulata*, and *Psg. excolata*. In low abundance we find *Gtr. fornicata*, *Gtr. elevata*, *Gtr. gansseri*, and *P. elegans*. *Planoglobulina glabrata* is generally rare. High-spired morphotypes of *Gtr. gansseri*, *Gtr. ventricosa*, and *R. subpennyi* typify these faunas. Particularly large individuals of *Gtr. ventricosa*, *R. subpennyi*, *Globigerinelloides* spp., *H. navarroensis*, and later, *Gtr. stuarti* are common. *Heterohelix navarroensis* variants are pronouncedly nodose, whereas at some levels *P. elegans* has spinose striae. The ridges on *Psg. excolata* are particularly wide and platy at this site. Spinose ornament is highly developed on *R. scotti* and *R. rugosa*.

Northern and southern subtropical faunas of late Campanian age differ between the two sites. Site 463 (5 to 10°S) contains the same species as Site 465 (5 to 10°N); only the relative proportions of taxa differ, as does the state of preservation of the sediments at some levels.

At Site 463, common species include *Gtr. arca*, *Gtr. elevata*, *Gtr. subspinosa*, *Gtr. calcarata*, *Gtr. tricarinata*, and (at the top of the section) the rugotruncanids. Less frequent are *Gtr. fornicata*, *R. rugosa*, *Gtr. stuartiformis*, and *Psg. costulata*. *Globigerinelloides* spp., *P. glabrata*, *H. navarroensis*, *P. elegans*, and *A. intermedia* are generally rare.

By contrast, *Gtr. arca*, *Gtr. elevata*, *Gtr. subspinosa*, *Gtr. calcarata*, and the rugotruncanids are relatively un-

common at Site 465. More-common species include *Gtr. fornicata*, *Globigerinelloides* spp., *Gtr. stuartiformis*, *Psg. costulata*, and *H. navarroensis*; *Abathomphalus intermedia* and *P. glabrata* are generally rare. Differences between the two sites are even more pronounced in the Maastrichtian.

Dissolution has in part selectively altered faunas at the two sites; however, many dissolution-susceptible taxa persist in Campanian faunas. Furthermore, the process has concentrated different species (both solution-resistant and solution-susceptible) at the two sites. Thus, it appears that there are recognizable differences between the northern and southern subtropical faunas, as well as between the central Pacific equatorial and subtropical faunas.

Solution-Susceptible Species

Reports on solution susceptibility of Cretaceous planktonic foraminifers (Sliter, 1972, 1976; Douglas, 1971; Caron, 1975; Olsson, 1964) are conflicting. The globotruncanids, heavily ornamented heterohelicids, *Abathomphalus*, *Gublerina*, rugoglobigerinids, and "Gtr." *havanensis* are reported to be solution-resistant, whereas hedbergellids, *Gtr. cretacea*, *Globigerinelloides* spp., *Guembelitria*, smoother heterohelicids, and non-keeled juveniles are most solution-susceptible. Nevertheless, Caron (1975) reported Maastrichtian dissolved faunas containing only hedbergellids, *Globigerinelloides*, and heterohelicids from the central Pacific.

At Site 465, dissolved faunas include concentrations of *H. globulosa*, *R. rugosa*, *P. glabrata*, *H. pulchra*, *Gtr. arca*, *Gtr. stuartiformis*, *H. striata*, *Psg. costulata*, *H. navarroensis*, and *Gtr. tricarinata* (12-1, 60 cm). In 12-CC, both *Gtr. arca* and *Gtr. stuartiformis* are concentrated by dissolution, and in 19-3 *Gtr. fornicata* and *H. striata* occur in abundance with *Gtr. stuartiformis* and *Gtr. tricarinata*. In the dissolved zone below the Cretaceous/Tertiary boundary, *Psg. excolata* is sometimes the only species present. In one very heavily dissolved sample, *Gtr. havanensis* is concentrated.

BENTHIC-FORAMINIFER PALEOECOLOGY

Benthic-foraminifer populations were identified at selected intervals through the Cretaceous at Sites 465 and 466. The faunas were compared to those identified by Sliter (1972, 1975, 1976), and paleoenvironments were assigned according to his criteria.

Albian to early Cenomanian faunas from this area consistently contain *Gavelinella intermedia*, *Osangularia* sp. ex. gr. *O. utaturensis*, *Patellina australis*, *Praebulimina* sp. (of Scheibnerova, 1974), and *Neobulimina* sp. (of Gradstein, 1978). *Gavelinella intermedia* is particularly abundant at Sites 463 and 465; the buliminids appear in floods at Site 465 (34-1), and occasionally at Site 466 in the Albian. The faunas at Site 465 are generally low in diversity and high in dominance of the gavelinellids or buliminids. At Site 466, diversity is higher, and the gavelinellids less abundant.

At Site 465, Cenomanian benthic faunas are more diverse; rotalids continue to predominate in the faunas, but *Praebulimina* sp. is common to abundant at some

levels. Addition of *Anomalina*, *Bolivina*, *Gyroidinoides* and several buliminids occurs in the Coniacian (25,CC), and diversity increases markedly. By the Santonian, *Nuttalides truempyi*, *Pullenia*, pleurostomellids, and several lagenids occur in the faunas. Small buliminids occur abundantly throughout the section. Campanian faunas include two species of *Aragonia*, and by the Maastrichtian the buliminids, *N. truempyi*, *A. velascoensis*, *G. beccariformis*, *Stilostomella*, and the pleurostomellids are common. *Uvigerina taurica* first occurs in the "G." *eugubina* Zone of the earliest Paleocene.

A simple diagram representing the probable depositional depths at Site 465 is shown in Figure 10. This site bottoms in volcanic trachyte, overlain by sediments containing the benthic foraminifers mentioned above, and planktonic faunas containing individuals of *R. apenninica* which are very small; they may be juveniles from near-surface waters over the shelf area, or they may be smaller because of water chemistry. Accompanying sediments contain plant fibers, mollusk fragments, and clays interpreted as a turbidite. The most abundant benthic, *G. intermedia*, is reported from Albian slope-depth environments of Australia (Scheibnerova, 1974), the Blake Nose (Gradstein, 1978), Site 259 in the Indian

Ocean (Scheibnerova, 1974), the Falkland Plateau (Sliter, 1976), and the Shatsky Rise (Luterbacher, 1975).

Gradual deepening, as more genera are added, follows the scheme of Sliter (1976). By Maastrichtian time, the site lay close to its present depth.

REFERENCES

Blow, W. H., 1971. Deep Sea Drilling Project, Leg 6, foraminifera from selected samples. In Fischer, A. G., Heezen, B. C., et al., *Init. Repts. DSDP*, 6: Washington (U.S. Govt. Printing Office), 1013-1027.

Bolli, H. M., 1957. The genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in the Upper Cretaceous of Trinidad. *Bull. U.S. National Mus.*, 215:51-60.

Caron, M., 1975. Late Cretaceous planktonic foraminifera from the northwest Pacific, Leg 32 of the DSDP. In Larson, R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 710-724.

_____, 1978. Cretaceous planktonic foraminifera from Deep Sea Drilling Project 40, southeast Atlantic Ocean. In Bolli, H. M., Ryan, W. B. F., et al., *Init. Repts. DSDP*, 40: Washington (U.S. Govt. Printing Office), 651-678.

Douglas, R. G., 1971. Cretaceous foraminifera from the northwest Pacific Ocean: Leg 6, Deep Sea Drilling Project. In Fischer, A. G., Heezen, B. C., et al., *Init. Repts. DSDP*, 6: Washington (U.S. Govt. Printing Office), 1027-1053.

_____, 1973. Planktonic foraminifera biostratigraphy in the central North Pacific Ocean. In Winterer, E. L., Ewing, J. I., et al., *Init. Repts. DSDP*, 17: Washington (U.S. Govt. Printing Office), 673-675.

Fleischer, R. L., 1975. Oligocene planktonic foraminiferal biostratigraphy, central north Pacific Ocean, Deep Sea Drilling Project Leg 32. In Larson, R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 753-765.

Gradstein, F., 1978. Biostratigraphy of lower Cretaceous Blake Nose and Blake-Bahama Basin foraminifera, DSDP Leg 44, western north Atlantic Ocean. In Benson, W. E., Sheridan, R. E., et al., *Init. Repts. DSDP*, 44: Washington (U.S. Govt. Printing Office), 663-701.

Hardenbol, J., and Berggren, W. A., 1978. A new Paleogene numerical time scale. *Am. Assoc. Petrol. Geol. Stud. Geol.*, 6:213-234.

Krashenninikov, V., 1971. Cenozoic foraminifera. In Fischer, A. G., Heezen, B. C., et al., *Init. Repts. DSDP*, 6: Washington (U.S. Govt. Printing Office), 1055-1079.

Lancelot, Y., and Larson, R., 1975. Sedimentary and tectonic evolution of the northwestern Pacific. In Larson, R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 925-941.

Luterbacher, H., 1975. Paleocene and early Eocene planktonic foraminifera, Leg 32, Deep Sea Drilling Project. In Larson, R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 725-735.

McNulty, C., 1976. Smaller Cretaceous foraminifera of Leg 43, Deep Sea Drilling Project. In Tuholke, B. E., Vogt, P. R., et al., *Init. Repts. DSDP*, 43: Washington (U.S. Govt. Printing Office), 487-504.

Olsson, R. K., 1964. Late Cretaceous planktonic foraminifera from New Jersey and Delaware. *Micropaleont.*, 10:157-188.

Pessagno, E. A., 1960. Stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puerto Rico. *Micropaleont.*, 6:1-18.

_____, 1962. The upper Cretaceous stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puerto Rico. *Micropaleont.*, 8:349-368.

Said, R., and Kenawy, A., 1956. Upper Cretaceous and Lower Tertiary foraminifera from northern Sinai, Egypt. *Micropaleont.*, 2:105-173.

Scheibnerova, V., 1974. Aptian-Albian benthonic foraminifera from DSDP Leg 27, Sites 259, 260, and 263, eastern Indian Ocean. In Veivers, J. J., Heirtzler, J. R., et al., *Init. Repts. DSDP*, 27: Washington (U.S. Govt. Printing Office), 679-741.

Sliter, W. V., 1972. Cretaceous foraminifers—depth habitats and their origin. *Nature*, 239:514-515.

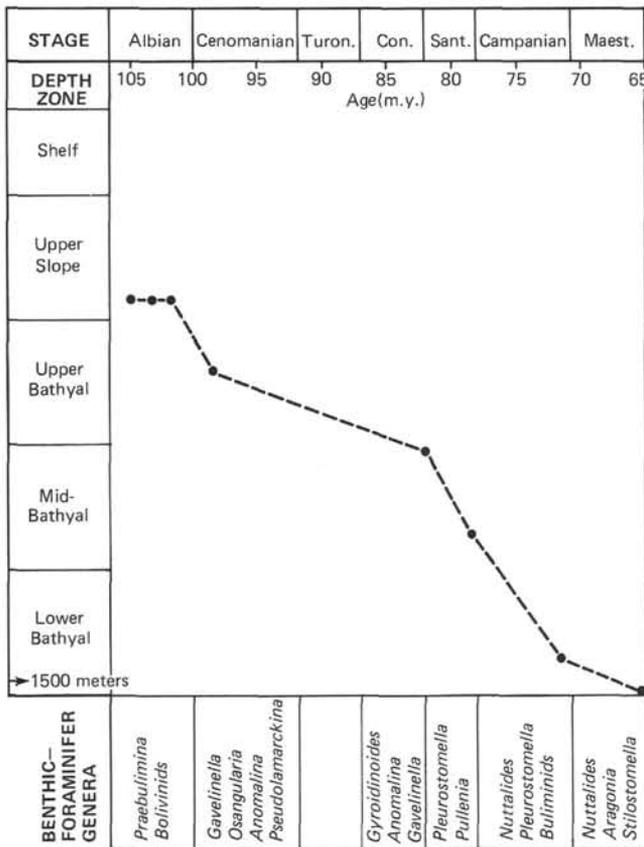


Figure 10. The relative depositional depth of Site 465 through the course of the late Cretaceous, as indicated by benthic-foraminifer faunas at the site. Dominant genera in samples through the Late Cretaceous are shown along the bottom of the diagram. The depth indications of these faunas are inferred from the scheme of Sliter (1976).

- _____, 1975. Foraminiferal life and residue assemblages from Cretaceous slope deposits. *Geol. Soc. Am. Bull.*, 86:897-906.
- _____, 1976. Cretaceous foraminifers from the southwestern Atlantic Ocean, Leg 36, Deep Sea Drilling Project. In Barker, D. F., Dalziel, I. W. D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 519-545.

- Toumarkine, M., 1975. Middle and late Eocene planktonic foraminifera, from the northwestern Pacific, Leg 32 of the Deep Sea Drilling Project. In Larson, R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 735-753.
- van Hinte, J., 1976. A Cretaceous time-scale. *Bull. Am. Assoc. Petrol. Geol.*, 60:498-516.