9. PALEOGENE PLANKTONIC FORAMINIFERS FROM DEEP SEA DRILLING PROJECT LEG 62 SITES AND ADJACENT AREAS OF THE NORTHWEST PACIFIC[1]

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ABSTRACT

Paleogene carbonate sediments, with planktonic foraminifers, of the western Mid-Pacific Mountains (Deep Sea Drilling Project Site 463) and Hess Rise (Sites 465 and 466) contain numerous hiatuses. Materials of previous DSDP legs (Sites 44, 47, 171, 192, 305, 310, 313) were used to expand knowledge of the Paleogene stratigraphy of the northwest Pacific and to construct a zonal stratigraphy of Paleogene deposits for this region based on planktonic foraminifers.

INTRODUCTION

Before the beginning of deep-sea drilling, the character of Paleogene planktonic foraminifers of the northwest Pacific was poorly known, because the Paleogene of Japan is composed of geosynclinal terrigenous and volcanogenic sediments containing poor assemblages of planktonic foraminifers, and in the U.S.S.R. (Kamchatka Peninsula, Sakhalin Island) geosynclinal terrigenous facies are also characteristic of the Paleogene; the poverty of planktonic foraminifers therein may be related to location in high latitudes (50–60°).

Deep-sea drilling in the northwest Pacific changed this situation. As early as DSDP Leg 6 (1969), Paleogene calcareous sediments were penetrated on Shatsky Rise (Site 47; Paleocene to lower Eocene) and on Horizon Guyot (Site 44; middle to upper Eocene and Oligocene) (Krasheninnikov, 1971a, b). On Leg 17, again on Horizon Guyot (Site 171), middle Eocene and Oligocene deposits were identified (Douglas, 1973); on Leg 19, at the northwest end of the Emperor Seamounts (Site 192), Eocene and Oligocene sediments were discovered (Echols, 1973); on Leg 32, Paleocene, Eocene, and Oligocene sediments were found on Shatsky Rise (Site 305), and lower and middle Eocene and Oligocene sediments were found on Hess Rise (Site 310) and in the eastern Mid-Pacific Mountains (Site 313) (Luterbacher, 1975; Toumarkine, 1975; Fleisher, 1975). Finally, on Leg 62 lower and middle Eocene and Oligocene sediments were penetrated in the western Mid-Pacific Mountains (Site 463), and Paleocene and middle Eocene sediments were penetrated on Hess Rise (Sites 465 and 466). Unfortunately, all of these sections are stratigraphically incomplete and are commonly marked by one or more hiatuses. Where the sections are continuous (Site 47, for instance), they represent only part of the Paleogene.

Through the courtesy of the Deep Sea Drilling Project, the author received samples of Paleogene sediments from Leg 17 (Site 171), Leg 19 (Site 192), and Leg 32 (Sites 305, 310, 313). The combination of data on the stratigraphy of Paleogene sediments from Legs 6, 17, 19, 32, and 62 permits recognition of the main peculiarities of planktonic-foraminifer assemblages and Paleogene zonal stratigraphy of the northwest Pacific. Subdivision of the Paleogene sediments follows the zonal scheme of Bolli (1957a, b), with some modifications (Blow 1969; Premoli-Silva and Bolli, 1973). Information is presented here in correspondence with descending latitude, from the northern sections (Emperor Seamounts) to the southern ones (Mid-Pacific Mountains).

STRATIGRAPHY OF PALEOGENE SEDIMENTS AT THE SITES

In the northwest Pacific Ocean, Paleogene carbonate sediments containing planktonic foraminifers are present between 53° and 19° north latitude.

The Emperor Seamounts

The most northern hole is 192A, on the top of Meiji Guyot, at the northwest end of the Emperor Seamounts (53°00.57′N, 164°42.81′E; water depth 3014 m). In this hole the middle Maastrichtian nannofossil chalk is unconformably overlain by about 85 meters of gray to white nannofossil chalk and dark-gray calcareous and nannofossil-rich claystone, the lower part of which (Sample 192A-4-3, 124–126 cm to Sample 192A-4-4, 120–122 cm) is characterized by rare, small *Acarinina pentacamerata*, *A. interposita*, *A. pseudotopilensis*, *A.* sp. aff. *A. soldadoensis*, *A.* sp., *Globigerina senni*, *G. eocaenica*, and *G.* sp. aff. *G. pseudoeocaena* and is assigned to the lower Eocene. Overlying sediments (Sample 192A-1-4, 50–52 cm to Sample 192A-4-3, 30–32 cm) contain only sporadic, small *Pseudohastigerina micra*, *Globigerina* sp. aff. *G. pseudoeocaena*, and *G.* sp., and can be assigned to the middle–upper Eocene. At the top of this sequence (Sample 192A-1-2, 50–52 cm), the planktonic-foraminifer assemblage is somewhat more diverse, containing *Globigerinita unicava*, *Globorotaloides suteri*, *Globigerina praebulloides*, *G. ouachitaensis*, *G. angiporoides*, and *Globorotalia permicra*. Joint occurrence of the two last species shows

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that the sediments belong to the uppermost upper Eocene to lower Oligocene. The nannofossil chalk is overlain by gray and greenish claystones (Hole 192), devoid of organic remains, and the age is thus unclear.

Unfortunately, the lower Eocene to lower Oligocene planktonic foraminifers are poorly preserved, and their precise identification is difficult.

Hess Rise

Site 310 (36°52.11′N, 176°54.09′E; water depth 3516 m) provided scant information on the biostratigraphy of Paleogene sediments.

Maastrichtian nannofossil ooze is unconformably overlain by zeolitic nannofossil ooze and nannofossil-bearing zeolitic pelagic clay of the uppermost lower Eocene to the basal middle Eocene. Planktonic foraminifers were subjected to strong selective dissolution, and are represented by single or rare *Globigerina senni*, *G. pseudoeocaena*, *G. higginsi*, *G.* sp., *Acarinina pseudotopilensis*, and *A.* sp. aff. *A. bullbrooki* (Sample 310-11-1, 122–124 cm to Sample 310-11-5, 100–102 cm).

Higher in the section are lower Oligocene nannofossil oozes with a hiatus. They contain richer assemblages of planktonic foraminifers: *Globigerina prasaepsis*, *G. tapuriensis*, *G. galavisi*, *G. corpulenta*, *G. praebulloides*, *G. angiporoides*, *G. gortanii*, *Globigerinita unicava*, *G. riveroae*, *G. pera*, *Globorotaloides suteri*, *Globorotalia permicra*, and *G. gemma* (Sample 310-10-1, 100–102 cm to Sample 310-10-6, 20–22 cm). This microfauna enables us to attribute the sediments to the *Globigerina tapuriensis* Zone, but it must be borne in mind that some index species may have been destroyed by selective dissolution. Dissolution is extremely pronounced, and, although unbroken tests are present, many are fragmented.

At this site, Paleogene deposits are 19-meters thick and are overlain unconformably by middle Miocene deposits.

The investigations of Leg 62 produced important new information on the stratigraphy and geological history of Hess Rise. A complete Paleocene section was penetrated at Site 465, and middle Eocene sediments were recognized at Site 466.

At Site 465 (33°49.23′N, 178°55.14′E; water depth 2161 m) the Upper Cretaceous (Maastrichtian, *Abathomphalus mayaroensis* Zone) passes into the Paleogene by a gradual transition. The Paleogene is represented by Paleocene deposits unconformably overlain by Pliocene deposits. The Paleocene is composed of nannofossil ooze and foraminifer-nannofossil ooze with interbeds of gray chert; the thickness is 54 meters. The Paleocene is subdivided into the following zones by means of planktonic foraminifers.

The *Globigerina eugubina* Zone was recognized at 465A-3-3, but no samples from this interval were at the author's disposal.

The *Globigerina pseudobulloides* Zone (*Globigerina taurica* Zone or *Globigerina eobulloides* Zone according to various zonal schemes) contains great numbers of *Guembelitria irregularis* and *Chiloguembelina taurica*, and rarer *Globigerina eobulloides*, *G. tetragona*, *G. fringa*, and *Globorotalia* sp. aff. *G. pseudobulloides* (Sample 465A-3-2, 90–92 cm).

The *Globorotalia trinidadensis* Zone contains numerous specimens of the index species, and *G. pseudobulloides; Chiloguembelina taurica*, *Globigerina trivialis*, and *Globorotalia compressa* are common, whereas *Globigerina varianta*, *G. edita*, and *Guembelitria irregularis* are rare (Sample 465A-3-1, 90–92 cm). Sample 465-8,CC likely belongs to the same zone; its assemblage of planktonic foraminifers consists of rare *Globorotalia trinidadensis* and *G. pseudobulloides*.

The three above-mentioned zones constitute the Danian Stage in the strict sense.

The *Acarinina uncinata* Zone, with numerous *A. uncinata*, *A. praecursoria*, and *A. inconstans*, accompanied by *Globorotalia pseudobulloides*, *G. compressa*, *Chiloguembelina taurica*, *Ch.* sp., and rarer *Acarinina spiralis*, *Globigerina varianta* and *G. trivialis* (Sample 465-7,CC), together with the three aforementioned zones constitutes the Danian Stage in the broad sense.

The *Globorotalia angulata* Zone in the strict sense has not been recognized at Site 465; presumably, its absence is related to poor recovery; only one sample (465-7,CC) was taken in which the *Acarinina uncinata* Zone was recognizable.

The *Globorotalia conicotruncata* Zone (or the *Globorotalia pusilla* Zone), with abundant *G. conicotruncata*, accompanied by *G. pusilla*, *G. cubanensis*, *G. angulata*, and *G. ehrenbergi*, rarer *G. quadrata*, *Globigerina varianta*, *G. trivialis*, *Acarinina tadjikistanensis djanensis*, and sporadic *Globigerina triloculinoides*, is present from Sample 465-6-1, 90–92 cm to Sample 465-6-5, 90–92 cm. In Sample 465-6-1, 90–92 cm, a transition to sediments of the *Globorotalia pseudomenardii* Zone is observed. Here are specimens of highly specialized *Globorotalia conicotruncata*, characterized by large dimensions, a great number of chambers (8–10), ornamented umbilical end of the chambers, and an even peripheral margin with a thin, distinct keel; they are accompanied by rare specimens of *Globorotalia occlusa*, *Globigerina nana*, and *G. velascoensis*, which become more abundant in the overlying sediments.

The *Globorotalia pseudomenardii* Zone contains extremely rare specimens of the index species, abundant *Globorotalia velascoensis*, *G. occlusa*, *G. laevigata*, and *G. convexa*, and rarer *Globorotalia pasionensis*, *G. imitata*, *Globigerina nana*, *G. velascoensis*, and *G. quadritriloculinoides*. The upper part of the zone contains abundant *Acarinina mckannai* and *A. aquiensis*, and sporadic specimens of *A. acarinata*. In Hole 465A, this zone includes Sample 465A-1-1, 90–92 cm; it should be attributed to the very base of the *Globorotalia pseudomenardii* Zone, because in its assemblage of planktonic foraminifers rather abundant *Globorotalia conicotruncata* are still present. In Hole 465, this zone corresponds to the interval from Sample 465-4-2, 90–92 cm to Sample 465-5-6, 30–32 cm. The first of these samples contains rare specimens of *Acarinina acarinata*, *A. soldadoensis*, *A. esnaensis*, *Globorotalia acuta*, *G. aequa*, and *G. hispidicidaris* (transition to the *Globorotalia velascoensis* Zone). In the second sample, rare specimens of *Globorotalia conicotruncata* were recognized, which indicate a transition to the *Globorotalia conicotruncata* Zone.

The *Globorotalia velascoensis* Zone, with *G. velascoensis*, *G. occlusa*, *G. acuta*, *G. aequa*, *G. convexa*, *G. hispidicidaris*, *G. pasionensis*, *G. imitata*, *Acarinina acarinata*, *A. soldadoensis*, *A. primitiva*, *A. esnaensis*, *A. mckannai*, *Globigerina velascoensis*, *G. nana*, *G. quadritriloculinoides*, and *G. compressaformis*, is present from Sample 465-3-1, 90–92 cm to Sample 465-4-1, 90–92 cm.

At Site 466 (34°11.46′N, 179°15.34′E; water depth 2665 m), the Paleogene section is markedly different: neither Paleocene or lower Eocene sediments are present. Instead, upper Campanian to lower Maastrichtian deposits are directly overlain by about 23 meters of middle and upper Eocene nannofossil oozes, with chert interbeds in the lower part.

In the basal layers of the middle Eocene, the planktonic-foraminifer assemblage consists of *Acarinina bullbrooki*, *A. pentacamerata*, *A. aspensis*, *A. triplex*, *Globorotalia aragonensis*, *G. caucasica*, *G. marksi*, *Globigerina pseudoeocaena*, and *G. senni* (Sample 466-9-4, 90–92 cm to Sample 466-10,CC). Higher in the section (Sample 466-9-1, 90–92 cm to Sample 466-9-3, 90–92 cm), the same species persist, but specimens of *Acarinina bullbrooki* are abundant, and *Globorotalia boweri* appears as well. These sediments are assigned to the base of the middle Eocene (*Hantkenina aragonensis* Zone in the broad sense). Along with the middle Eocene microfauna, numerous redeposited planktonic foraminifers of the Upper Cretaceous and rare ones of the upper Paleocene are identified.

The sediments from Sample 466-8-1, 90–92 cm to Sample 466-8-6, 90–92 cm were conditionally attributed to the Eocene; only rare benthic foraminifers were recovered here. In Sample 466-7-7, 20–22 cm, the planktonic-foraminifer assemblage consists of an admixture of Upper Cretaceous, lower and middle Eocene (*Globorotalia caucasica*, *G. aragonensis*, *Acarinina bullbrooki*, *A. rotundimarginata*, *Globigerapsis index*, and *G. kugleri*), and Oligocene (*Globigerina sellii*) species. These carbonate turbidites are likely younger (late Oligocene to Neogene). They are overlain by lower Pliocene sediments.

Shatsky Rise

The best Paleogene sections in the northwest Pacific appear to be on Shatsky Rise (Sites 47 and 305).

Site 47 is on the northwest slope of the rise (32° 26.09′N, 157°42.07′E; water depth 2689 m). Here, nannofossil and foraminifer-nannofossil chalk and oozes of the Paleocene, lower Eocene, and lowermost middle Eocene rest conformably on the Upper Cretaceous (Maastrichtian, *Abathomphalus mayaroensis* Zone), and are unconformably overlain by upper Miocene sediments. Their thickness is insignificant, about 44 meters. The excellently preserved planktonic foraminifers record the entire succession of Paleocene and lower Eocene zones, testifying to continuity of the section. Unfortunately, the sediments were strongly deformed by drilling, and in places they were soupy. This makes exact definition of the stratigraphic boundaries difficult, a fact disregarded by some authors studying foraminifers from Site 47 (for instance, Hofker, 1978). Of the three holes drilled at Site 47, Hole 47.2 proved most successful and will be discussed below.

In the interval from Sample 47.2-11-4, 10–12 cm to Sample 47.2-11-6, 145–147 cm, the planktonic foraminifer assemblages are a mixture of Maastrichtian and Danian species (*Acarinina uncinata* Zone); sometimes they are accompanied by upper Paleocene species (the thickness of sediments deformed by drilling is not less than 4.5 m). *Globigerina eugubina*, *G. minutula*, *G. sabina*, and *G. trifolia*, observed here with abundant *Chiloguembelina* and *Guembelitria*, suggest that the Danian Stage begins with the *Globigerina eugubina* Zone.

The *Globigerina taurica* Zone (or the *Globigerina pseudobulloides* Zone) includes sediments with abundant *Chiloguembelina taurica*, *C. morsei*, *C. midwayensis*, and *Guembelitria irregularis*, accompanied by *Globigerina daubjergensis*, *G. taurica*, *G. eobulloides*, *G. tetragona*, *G. pentagona*, *G. fringa*, *G. theodosica*, *G. hemisphaerica*, and *Globorotalia* sp. aff. *G. pseudobulloides* (Sample 47.2-11-3, 145–147 cm). Mechanical admixture of Maastrichtian forms is not great here. The observed specimens of *Globigerina sabina* and *G. minutula* are probably components of the paleocoenosis of foraminifers of this zone.

The *Globorotalia trinidadensis* Zone is characterized by numerous specimens of the index species, *G. pseudobulloides*, *Globigerina daubjergensis*, *Chiloguembelina midwayensis*, *C. taurica*, *C. morsei*, and *Guembelitria irregularis*, and rarer *Globorotalia compressa*, *Globigerina trivialis*, *G. varianta*, and *G. edita; Globigerina triloculinoides* and *Globorotalia planocompressa* are sporadic (47.2-11 (top) to Sample 47.2-11-3, 10–12 cm).

An extremely rich assemblage of planktonic foraminifers of the *Acarinina uncinata* Zone consists of *A. uncinata*, *A. inconstans*, *A. indolensis*, *A. spiralis*, *A. praecursoria*, *A. schachdagica*, *A. multiloculata*, *Globorotalia pseudobulloides*, *G. compressa*, *G. quadrata*, *Globigerina trivialis*, *G. varianta*, and *G. triloculinoides;* representatives of heterohelicids are rare (Sample 47.2-10-4, 120–122 cm to Sample 47.2-10,CC).

The *Globorotalia angulata* Zone in the strict sense contains numerous *G. angulata* and rare *G. ehrenbergi;* they are accompanied by *Acarinina multiloculata*, *Globorotalia quadrata*, *G. pseudobulloides*, *Globigerina varianta*, *G. trivialis*, and *G. triloculinoides* (Sample 47.2-10-3, 110–112 cm to Sample 47.2-10-4, 80–82 cm). The exact positions of the lower and upper boundaries of this zone are obscure, because of deformation of sediments by drilling.

The *Globorotalia conicotruncata* Zone contains the index species, *G. pusilla*, *G. cubanensis*, and *Acarinina tadjikistanensis djanensis*, associated with *Globorotalia angulata*, *G. ehrenbergi*, *Globigerina varianta*, and *G. trivialis* (47.2-10 (top) to Sample 47.2-10-3, 1–3 cm).

The *Globorotalia pseudomenardii* Zone contains the index species in abundance, associated with *G. velascoensis*, *G. occlusa*, *G. pasionensis*, *G. laevigata*, *G. con-*

vexa, *G. imitata*, *Acarinina mckannai*, *Globigerina velascoensis*, *G. nana*, *G. bacuana*, *G. quadritriloculinoides*, and *G. pileata* (Sample 47.2-8-5, 114–115 cm to Sample 47.2-9,CC).

The *Globorotalia velascoensis* Zone contains an extremely diverse assemblage of planktonic foraminifers: *G. velascoensis*, *G. pasionensis*, *G. occlusa*, *G. aequa*, *G. acuta*, *G. hispidicidaris*, *G. apanthesma*, *G. trichotrocha*, *G. parva*, *G. tortiva*, *G. imitata*, *Acarinina acarinata*, *A. esnaensis*, *A. soldadoensis*, *A. primitiva*, *A. mckannai*, *A. tribulosa*, *Globigerina nana*, *G. velascoensis*, *G. chascanona*, and *G. compressaformis* (Sample 47.2-8-4, 73–75 cm to Sample 47.2-8-5, 66–68 cm).

It is also difficult to define the exact position of the Paleocene/Eocene boundary, because of mechanical deformation of sediments by drilling (within 1.5 m). However, the succession of zonal assemblages of planktonic foraminifers in the lower Eocene is perfectly distinct. The following zones are distinguished:

The *Globorotalia subbotinae* Zone contains the index species and *G. aequa*, *G. wilcoxensis*, *G. quetra*, *G. elongata*, *Acarinina pseudotopilensis*, *A. camerata*, *A. triplex*, *A. esnaensis*, *A. soldadoensis*, *A. gravelli*, *A. primitiva*, *Globigerina compressaformis*, *G. prolata*, and *G. collactea;* specimens of *Pseudohastigerina wilcoxensis* are sporadic. In the upper part of the zone are *Globorotalia marginodentata*, *G. formosa gracilis*, and *Acarinina broedermanni* (Sample 47.2-8-3, 81–82 cm to Sample 47.2-8-4, 23–25 cm).

The *Globorotalia formosa formosa* Zone contains the index taxon, *G. formosa gracilis*, *G. lensiformis*, *G. marginodentata*, *G. quetra*, *G. wilcoxensis*, *G. naussi*, *Acarinina decepta*, and *Heterohelix wilcoxensis*. *Acarinina pseudotopilensis*, *A. triplex*, *A. broedermanni*, *A. gravelli*, *A. soldadoensis*, *Globigerina compressaformis*, and *G. prolata* are common ranging up from the underlying deposits (47.2-8 (top) to Sample 47.2-8-3, 30–32 cm).

The *Globorotalia aragonensis* Zone has numerous specimens of the index species, accompanied by *G. marksi*, *Acarinina interposita*, *A. pentacamerata*, *Globigerina eocaenica*, *G. pseudoeocaena*, *G. inaequispira*, and rare *Globorotalia caucasica*. Still present here are *Acarinina triplex*, *A. pseudotopilensis*, *A. broedermanni*, *A. decepta*, *A. soldadoensis*, *A. gravelli*, *Pseudohastigerina wilcoxensis*, and *Globorotalia quetra*, with comparatively rare *G. lensiformis* and *G. formosa formosa* (Sample 47.2-7-5, 25–27 cm to Sample 47.2-7,CC).

The *Globorotalia palmerae* Zone (or the *Acarinina pentacamerata* Zone) is characterized by abundant *A. pentacamerata*, *A. aspensis*, *Globigerina senni*, and *Globorotalia caucasica*. Other species are *Globorotalia planoconica*, *G. aragonensis*, *G. marksi*, *G. naussi*, *Globigerina higginsi*, *G. pseudoeocaena*, *G. inaequispira*, *G. turgida*, *G. taroubaensis*, *G. prolata*, *G. eocaena*, *Acarinina interposita*, *A. triplex*, *A. pseudotopilensis*, *A. soldadoensis*, *A. broedermanni*, and *Pseudohastigerina wilcoxensis* (Sample 47.2-7-2, 128–130 cm to Sample 47.2-7-4, 110–112 cm).

The basal middle Eocene is represented by the *Hantkenina aragonensis* Zone in the broad sense, with numerous *Acarinina bullbrooki*, *A. pentacamerata*, *A. aspensis*, and *Globorotalia caucasica*, along with *Globorotalia boweri*, *G. spinulosa*, *G. renzi*, *G. aragonensis*, *Globigerina senni*, *G. pseudoeocaena*, and *Pseudohastigerina micra* (Samples 47.2-7-2, 85–87 cm and 47.2-7-2, 23–25 cm). Younger sediments of the middle Eocene were eliminated by underwater erosion, evidenced by redeposited *Globigerapsis index*, *Globigerinatheca barri*, and *Truncorotaloides topilensis* in the basal deposits of the upper Miocene.

Site 305 is on the southwest slope of Shatsky Rise (32°00.13′N, 157°51.00′E; water depth 2903 m). Although the distance from Site 47 is insignificant, and the water depth is only 214 meters more, the Paleogene deposits and planktonic foraminifers are very different here. The Paleogene is represented by monotonously uniform foraminifer-nannofossil ooze, 76 meters thick, separated from the Upper Cretaceous (Maastrichtian, *Abathomphalus mayaroensis* Zone) by a hiatus.

The Paleocene begins with the *Globorotalia conicotruncata* Zone, in which common specimens of the index species are accompanied by rare *G. pusilla and G. angulata* (Samples 305-14-4, 120–122 cm and 305-14-5, 120–122 cm). Thus, the section is devoid of five zones from the *Globigerina eugubina* Zone to the *Globorotalia angulata* Zone in the strict sense. From the data of Luterbacher (1975), who found in Sample 305-14,CC pieces of sediments with foraminifer assemblages of the *Globorotalia trinidadensis*, *Acarinina uncinata*, and *Globorotalia angulata* Zones, it would appear that the sediments bearing these forms have been destroyed by underwater erosion.

The *Globorotalia pseudomenardii* Zone is characterized by abundant *Acarinina mckannai*, associated with rare *Globorotalia occlusa* and *G. trichotrocha*, and extremely rare *G. velascoensis*, *G. pseudomenardii*, and *Globigerina velascoensis* (Sample 305-13-6, 120–122 cm to Sample 305-14-3, 120–122 cm).

The *Globorotalia velascoensis* Zone contains abundant *Acarinina acarinata*, accompanied by *A. primitiva*, *A. soldadoensis*, *A. esnaensis*, *A. mckannai*, and very rare *Globorotalia acuta*, *G. aequa*, *G. velascoensis*, and *G. occlusa*, (Sample 305-13-1, 118–120 cm to Sample 305-13-5, 117–119 cm).

Paleocene assemblages of planktonic foraminifers of Site 305 underwent strong selective dissolution: many species of keeled *Globorotalia* were destroyed by dissolution; tests of the remaining planktonic foraminifers have an etched surface; there are numerous fragments of planktonic foraminifers; and the foraminifer assemblages are enriched in benthic forms. As a result of these subsequent changes, the assemblages of Paleocene planktonic foraminifers at Site 305 differ sharply from those at Site 47, displaying considerable similarity to the natural subtropical-temperate assemblages of Paleocene planktonic foraminifers of the northern Caucasus. Here, biostratigraphic units synchronous with the *Globorotalia pseudomenardii* and *Globorotalia velascoen-*

sis Zones bear the names *Acarinina subsphaerica* (synonym of *A. mckannai*) and *Acarinina acarinata* Zones. The Paleocene acarininids, which reached their peak in the subtropical and temperate climatic belts, are highly resistant to selective dissolution.

The Eocene is separated from the Paleocene by a hiatus, as indicated by the absence of the *Globorotalia subbotinae* Zone.

In the lower Eocene, the assemblages of planktonic foraminifers are as rich as at Site 47, although the features of selective dissolution are rather obvious here as well. The following zones are identified:

The *Globorotalia formosa formosa* Zone, with numerous specimens of the index species, *G. lensiformis*, *G. formosa gracilis*, *Acarinina pseudotopilensis*, *A. esnaensis*, *A. gravelli*, *A. acarinata*, *A. triplex*, *A. soldadoensis*, and *A. camerata* (Sample 305-12-1, 125–127 cm to Sample 305-12-5, 126–128 cm);

The *Globorotalia aragonensis* Zone contains the index species, *G. lensiformis*, *Acarinina interposita*, *A. soldadoensis*, *A. triplex*, *A. pseudotopilensis*, and rare *A. pentacamerata* (Samples 305-11-5, 120–122 cm and 305-11-6, 130–132 cm);

The *Globorotalia palmerae* Zone (or the *Acarinina pentacamerata* Zone) contains numerous *A. pentacamerata*, *A. aspensis*, and *A. interposita*, in association with rarer *Globorotalia aragonensis*, *Globigerina senni*, *G. higginsi*, *G. pseudoeocaena*, *Acarinina pseudotopilensis*, and *A. triplex*, and sporadic *Globorotalia caucasica* (Sample 305-11-1, 94–96 cm to Sample 305-11-4, 130–132 cm).

Selective dissolution heavily affected planktonic foraminifers of the middle and upper Eocene and Oligocene, making zonation of these deposits difficult.

The middle Eocene includes rare *Globigerapsis index*, *Globigerinatheca barri*, *Acarinina bullbrooki*, *Truncorotaloides topilensis*, *T. rohri*, *Globigerina senni*, *G. pseudoeocaena*, and *Globorotalia spinulosa* (Sample 305-10-4, 22–24 cm to Sample 305-10-5, 120–122 cm). Undoubtedly these sediments represent only part of the middle Eocene.

The upper Eocene is characterized by rare *Globigerapsis semiinvoluta*, *G. tropicalis*, *G. index*, *Globigerina corpulenta*, *G. galavisi*, *Hantkenina* sp., and *Globorotalia cerroazulensis* (Sample 305-9-3, 97–99 cm to Sample 305-10-3, 47–49 cm).

In the Oligocene sediments, only the following can be tentatively outlined:

The lower part (within the *Globigerina tapuriensis* and *Globigerina sellii* Zones) contains *G. officinalis*, *G. galavisi*, *G. prasaepis*, *G. pseudovenezuelana*, *Globigerinita unicava*, *G. pera*, *G. riveroae*, *Globorotaloides suteri*, *Globorotalia gemma*, *G. permicra*, and very rare *Globigerina ampliapertura* and *Pseudohastigerina* sp. (Sample 305-8-3, 102–104 cm to Sample 305-9-2, 70–72 cm).

The middle part (likely the *Globigerina ampliapertura* Zone) contains *G. prasaepis*, *G. galavisi*, *Globigerinita unicava*, *G. pera*, *Globorotaloides suteri*, *Globorotalia gemma*, and very rare *Globigerina ampliapertura* (Sample 305-8-1, 100–102 cm to Sample 305-8-2, 96–98 cm).

The upper part (within the *Globorotalia opima* and *Globigerina ciperoensis* Zones) contains *Globorotalia* sp. aff. *G. opima*, *G. nana*, *G. gemma*, *Globorotaloides suteri*, *Globigerina prasaepis*, *G. galavisi*, and *Globigerinita unicava* (Sample 305-6-6, 118–120 cm to Sample 305-7-6, 50–52 cm).

The Oligocene is unconformably overlain by sediments of the lower Miocene *Globigerinita dissimilis* Zone (Sample 305-6-6, 30–32 cm).

It is noteworthy that at Site 306, at the base of the southwest slope of Shatsky Rise (water depth 3399 m), the Paleogene is entirely missing. Here, Lower to Upper Cretaceous (Albian–Cenomanian) deposits are directly overlain by Quaternary sediments.

Mid-Pacific Mountains

Paleogene deposits are penetrated by holes on opposite ends of this sublatitudinal range, on the west at Site 463, and on the east at Sites 44, 171,and 313.

At Site 463 (21°21.01′N, 174°40.07′E; water depth 2525 m), the Paleogene is composed of nannofossil oozes and foraminifer-nannofossil oozes of little thickness (13 m), with some interval hiatuses. The Paleogene rests with erosional unconformity on chalks of the middle Maastrichtian (*Globotruncana gansseri* Zone). The basal layers of the section are assigned to the *Globorotalia palmerae* Zone (= *Acarinina pentacamerata* Zone) of the lower Eocene. The rich assemblage of planktonic foraminifers consists of *Globorotalia caucasica*, *G. aragonensis*, *G. quetra*, *Acarinina pentacamerata*, *A. aspensis*, *A. triplex*, *A. pseudotopilensis*, *A. broedermanni*, *Globigerina senni*, *G. pseudoeocaena*, *G. inaequispira*, and *Pseudohastigerina wilcoxensis* (Sample 463-7-1, 135–137 cm to Sample 463-7-3, 10–12 cm).

Higher in the section, following a gap, are sediments of the *Globorotalia lehneri* Zone (middle Eocene), with numerous *Globigerapsis index*, *G. kugleri*, *Globigerinatheca barri*, *Truncorotaloides topilensis*, *T. rohri*, *Globorotalia spinulosa*, *Acarinina bullbrooki*, and *Globigerina senni*, rarer *Globorotalia lehneri*, *G. frontosa*, and *Globigerina pseudoeocaena*, and very rare *Acarinina rotundimarginata*, *Hantkenina* sp. aff. *H. alabamensis* and *Globorotalia aragonensis* (Sample 463-6-6, 50–52 cm).

The Oligocene is also separated from the middle Eocene by a hiatus. Its lower part appears to be attributable to the *Globigerina sellii* Zone judging from the abundance of the index species, *G. tripartita*, *G. tapuriensis*, *G. ouachitaensis*, *G. prasaepis*, *G. angustiumbilicata*, *G. turritilina*, *Cassigerinella chipolensis*, *Globorotalia gemma*, *G. permicra*, and *Chiloguembelina cubensis*, with very rare specimens of *Pseudohastigerina micra* (Samples 463-6-4, 90–92 cm and 463-6-5, 90–92 cm).

A similar assemblage of planktonic foraminifers was observed in overlying sediments as well, where *Globigerina pseudovenezuelana*, *G. galavisi*, *Globigerinita unicava*, *Globorotalia nana*, and rare *Globigerina ampliapertura* were identified. Representatives of *Pseudohastigerina* are missing here. This places the deposits in the *Globigerina ampliapertura* Zone (Sample 463-5-1, 90–92 cm to Sample 463-6-3, 90–92 cm). The Oligocene is unconformably overlain by upper Miocene deposits.

Oligocene sediments contain abundant redeposited tests of planktonic foraminifers of the Upper Cretaceous, Paleocene (*Globorotalia trinidadensis*, *Acarinina uncinata*, *Globorotalia pseudomenardii*, and *Globorotalia velascoensis* Zones), lower Eocene (*Globorotalia subbotinae*, *Globorotalia aragonensis*, and *Acarinina pentacamerata* Zones), and middle Eocene. The section of Paleogene sediments in the vicinity of Site 463 appears to have been originally more complete stratigraphically, but many of its intervals have been removed by erosion.

Two holes (Sites 44 and 171) were drilled at Horizon Guyot, in the eastern Mid-Pacific Mountains. The Cretaceous/Paleogene contact was recovered in Hole 171 (19°07.9′N, 169°27.6′W; water depth 2290 m). The middle Eocene here unconformably overlies Upper Cretaceous deposits (Maastrichtian, *Abathomphalus mayaroensis* Zone). The Paleogene is composed of foraminifer-nannofossil ooze to nannofossil-foraminifer ooze, with chert intercalations at the base, and is about 95 meters thick. Sporadic sampling of cores prevents estimation of the continuity of the stratigraphic succession.

The middle Eocene begins with the *Orbulinoides beckmanni* Zone, with extremely rare specimens of the zonal species, accompanied by *Acarinina bullbrooki*, *Truncorotaloides rohri*, *T. topilensis*, *Globigerapsis kugleri*, *G. index*, *Globigerinatheca barri*, *Globorotalia centralis*, *G. spinulosa*, and *Globigerina pseudovenezuelana* (Sample 171-9-2, 30–32 cm to Sample 171-9-3, 120–122 cm).

In the sediments of the overlying *Truncorotaloides rohri* Zone, the index species together with *Globigerina pseudoeocaena compacta*, *G. pseudovenezuelana*, *Globigerapsis index*, and *Globorotalia spinulosa* were found (Sample 171-8-3, 48–50 cm to Sample 171-8-6, 48–50 cm). Middle Eocene sediments contain abundant redeposited foraminifers of the Upper Cretaceous, upper Paleocene (*Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones), and lower Eocene (*Globorotalia subbotinae* and *Globorotalia formosa* Zones).

The upper Eocene was not identified in Hole 171, probably because of poor recovery (an 8-m interval had no core at all). The base of the Oligocene is marked by the *Ericsonia subdisticha* Zone (Sample 171-7,CC); upward, there is a break in sampling (about 15 m) which probably corresponds to the *Globigerina tapuriensis* and *Globigerina sellii* Zones. Above, the entire Oligocene zonal succession is established:

The *Globigerina sellii* Zone contains the index species, *Globigerina tapuriensis*, *G. galavisi*, *G. tripartita*, *G. prasaepis*, *G. pseudovenezuelana*, *G. ouachitaensis*, *G. praebulloidoes*, *Globorotalia gemma*, *Chiloguembelina cubensis*, and *Pseudohastigerina barbadoensis* (Sample 171-6-2, 125–127 cm).

The *Globigerina ampliapertura* Zone contains a similar assemblage of planktonic foraminifers, but without representatives of *Pseudohastigerina* (Sample 171-6-2, 34–36 cm).

The *Globorotalia opima* Zone contains abundant *G. opima* and *G. nana*, accompanied by *G. gemma*, *Globigerina pseudovenezuelana*, *G. ciperoensis*, *G. angulisuturalis*, *G. angustiumbilicata*, *G. tripartita*, *G. sellii*, *G. galavisi*, *G. prasaepis*, *Globigerinita unicava*, and *Globorotaloides suteri* (Sample 171-4-6, 52–54 cm to Sample 171-5-6, 52–54 cm).

The *Globigerina ciperoensis* Zone contains abundant, small *G. ciperoensis*, *G. angustiumbilicata*, and *G. angulisuturalis*, together with *Globorotalia pseudokugleri*, *Globigerinita unicava*, *Globigerina tripartita*, *G. pseudovenezuelana*, and *Globorotaloides suteri* (Sample 171-4-1, 52–54 cm to Sample 171-4-5, 52–54 cm).

Abundant redeposited Upper Cretaceous, Paleocene, lower Eoecene and (less frequently) middle Eocene planktonic foraminifers were found in the Oligocene sediments (particularly in the *Globorotalia opima* Zone).

Following a 9-meter break in core sampling, Oligocene sediments are succeeded by the lower Miocene *Globigerinita dissimilis* Zone (Sample 171-3-6, 50–52 cm).

At Site 44 (19°18.5′N, 169°00.9′W; water depth 1478 m) a similar succession of middle Eocene to Oligocene sediments was cored, although the contact with underlying deposits was not discovered. However, the upper Eocene is well represented there, and reworked Cretaceous and Paleocene foraminifers are absent, which permits more-distinct foraminifer zonation.

The middle Eocene is composed of nannofossil-foraminifer chalk with chert interbeds, whereas the upper Eocene and Oligocene comprise nannofossil–foraminifer chalk and ooze; thickness is about 40 meters.

Two zones were recognized in the middle Eocene:

The *Orbulinoides beckmanni* Zone contains numerous *O. beckmanni*, *Globorotalia centralis*, *G. renzi*, *G. bolivariana*, *G. spinulosa*, *Globigerapsis index*, *G. kugleri*, *Globigerinatheca barri*, *Truncorotaloides rohri*, *T. topilensis*, *Globigerina pseudoeocaena compacta*, and *G. pseudovenezuelana*, rarer *Globorotalia frontosa*, *Globigerinita echinata*, *Acarinina rotundimarginata*, and *Pseudohastigerina micra*, and extremely rare *Hantkenina alabamensis*, *H. lehneri*, and *Globorotalia lehneri* (Sample 44-4-5, 130–132 cm to Sample 44-4,CC).

The *Truncorotaloides rohri* Zone contains abundant *T. rohi*, *Pseudohastigerina micra*, *Globorotalia centralis*, *Globigerina pseudoeocaena compacta*, *Globigerapsis index*, and *Chiloguembelina* sp., accompanied by *Truncorotaloides topilensis*, *Globorotalia renzi*, *G. spinulosa*, *Globigerinatheca barri*, and rare *Hantkenina alabamensis* and *Globorotaloides suteri*. *Hantkenina longispina*, *Globigerapsis tropicalis*, *Globorotalia cerroazulensis*, and *Globigerina posttriloculinoides* appear here for the first time (Sample 44-3-5, 135–137 cm to Sample 44-4-4, 98–100 cm).

The upper Eocene is subdivided into two zones:

The *Globigerapsis semiinvoluta* Zone contains the index species, *G. tropicalis*, *G. index*, *Globigerinatheca barri*, *Globorotalia cerroazulensis*, *G. centralis*, *Globigerina corpulenta*, *G. pseudovenezuelana*, *G. incretacea*, *G. pseudocorpulenta*, *G. praebulloides*, *G. tri-*

partita, *Globigerinita howei*, *G. pera*, *Pseudohastigerina micra*, *Hantkenina suprasuturalis*, and *H. alabamensis* (Sample 44-2-5, 140–142 cm to Sample 44-3-4, 40–42 cm).

The *Globorotalia cocoaensis* Zone contains the same assemblage of planktonic foraminifers (except *Globigerapsis semiinvoluta*), together with typical *Globorotalia cocoaensis* and *Cribrohantkenina inflata* (44-2 (top) to Sample 44-2-4, 122–24 cm).

The upper Eocene/Oligocene relation is not clear (Core 1 is incomplete): presumably, they are separated by a small gap. In any case, the lowest part of the Oligocene belongs to the *Globigerina sellii* Zone, which is characterized by the index species, *G. tapuriensis*, *G. tripartita*, *G. pseudovenezuelana*, *G. praebulloides*, *G. ampliapertura*, *G. angustiumbilicata*, *G. ouachitaensis*, *G. prasaepis*, *G. turritilina*, *Cassigerinella chipolensis*, *Globorotalia gemma*, *Globigerinita unicava*, *Pseudohastigerina barbadoensis*, and *P. micra* (Sample 44-1-2, 30–35 cm to Sample 44-1,CC).

The youngest Oligocene sediments of Hole 44 belong to the *Globigerina ampliapertura* Zone, in which the index species is very common, but representatives of *Pseudohastigerina* are absent (44-1 (top) and Sample 44-1-1, 104–106 cm).

The age of overlying sediments is unknown here, because the upper 40 meters of the section were drilled without coring.

Site 313 (20°10.52′N, 170°57.15′W; water depth 3484 m) is north of Horizon Guyot, in a small basin surrounded by seamounts. Here the Paleogene is composed of deeper-water sediments than on Horizon Guyot. The middle Maastrichtian (*Globotruncana gansseri* Zone) and lower Eocene are separated by an interval (9.5 m) where sediments (hard layer) were not recovered. The lower and middle Eocene are represented by nannofossil chalk, foraminifer-nannofossil chalk, and radiolarian foraminifer-nannofossil chalk, with chert intercalations; the Oligocene consists of foraminifer-nannofossil ooze. The thickness of the Paleogene exceeds 150 meters. The deep-water character of the sediments is manifested by abundant radiolarians in the lower Eocene and by very strong dissolution of planktonic-foraminifer tests in the middle Eocene and Oligocene. Commonly the latter are represented by the most-resistant species, their fragments being numerous. In conjunction with the dissolution of planktonic foraminifers, sediments are enriched in benthic foraminifers.

Poor recovery and discontinuous coring do not permit tracing the entire succession of foraminifer zones, and only some were identified.

Planktonic-foraminifer assemblages are exceedingly rich in the lower part of the lower Eocene. The *Globorotalia subbotinae* Zone is characterized by numerous specimens of the index species, *G. wilcoxensis*, *G. formosa gracilis*, *Acarinina nitida*, *A. pseudotopilensis*, and *A. soldadoensis*, rarer *A. camerata* and *A. triplex*, and sporadic *A. primitiva*, *A. esnaensis*, and *Globorotalia aequa*. In the upper part of the zone, specimens of *Globorotalia marginodentata* are common. Globigerinids (*Globigerina compressaformis*, and *G. nana*) are very sporadic. It is interesting to note that shells of some species of *Acarinina* on their spiral side (along the spiral suture) have additional openings resembling additional apertures of the genus *Truncorotaloides* (Sample 313-12-5, 52–54 cm to Sample 313-13-6, 118–120 cm).

Sediments in the interval from Sample 313-12-1, 135–137 cm to Sample 313-12-4, 52–54 cm apparently have to be assigned to the *Globorotalia formosa formosa* Zone. The planktonic-foraminifer assemblage is similar to that of underlying sediments, but contains rare *Globorotalia* sp. aff. *G. formosa formosa*, *G. lensiformis*, and *G. quetra*, and common *G. marginodentata*.

Data on the upper part of the lower Eocene are scarce, because of poor recovery; from an interval of about 20 meters, only 0.5 meters of sediments were obtained, with abundant radiolarians and sporadic *Globorotalia aragonensis*, *Acarinina pentacamerata*, *A. interposita*, *A. pseudotopilensis*, and *A. soldadoensis* (Sample 313-9-1, 127–129 cm). These sediments are assignable to the undifferentiated *Globorotalia aragonensis* and *Globorotalia palmerae* Zones.

The lower and middle Eocene are also separated by an interval (9.5 m) without recovery. Perhaps this explains why the basal middle Eocene belongs to the *Globorotalia lehneri* Zone, with extremely rare specimens of the index species and more common *Acarinina bullbrooki*, *A. rotundimarginata*, *Truncorotaloides rohri*, *T. topilensis*, *Globigerapsis index*, *G. kugleri*, *Globigerinatheca barri*, *Globorotalia spinulosa*, *G. frontosa*, *Globigerina senni*, and *Globorotaloides carcoselleensis* (Sample 313-7-2, 70–72 cm to Sample 313-7-6, 130–132 cm). This microfauna is accompanied by abundant redeposited planktonic foraminifers of the Upper Cretaceous, upper Paleocene (*Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones), and lower Eocene (*Globorotalia aragonensis* Zone). Usually the reworked foraminifers are very well sorted and well preserved, whereas the *in situ* middle Eocene planktonic foraminifers bear traces of strong selective dissolution, especially the planktonic foraminifers from the upper part of the middle Eocene (Sample 313-5-1, 125–127 cm to Sample 313-6-1, 130–132 cm), where only sporadic specimens of *Globigerina senni*, *Globigerapsis index*, *Acarinina bullbrooki*, and *Globorotaloides carcoselleensis* were encountered (together with benthic foraminifers and abundant redeposited Upper Cretaceous, upper Paleocene and lower Eocene planktonic foraminifers).

The middle Eocene and Oligocene are separated by a hiatus which presumably corresponds to the upper Eocene. The Oligocene is characterized by impoverished assemblages of planktonic foraminifers bearing distinct traces of selective dissolution, but divisible into the following zones:

The *Globigerina ampliapertura* Zone contains rare specimens of the index species and more abundant frequent *G. prasaepis*, *G. tripartita*, *G. pseudovenezuelana*, *G. angustiumbilicata*, *G. pseudoampliapertura*, *G. sellii*, *G. tapuriensis*, *Globigerinita unicava*, *G. riveroae*, *G. pera*, *Globorotaloides suteri*, *Globorotalia gemma*, *G. nana*, and *G. clemenciae* (Sample 313-4-2, 20–22 cm to Sample 313-5-1, 20–22 cm). Reworked Upper Cretaceous planktonic foraminifers are not numerous here.

In the *Globorotalia opima* Zone, specimens of the index species are mainly present as the most resistant to the dissolution. Other species are extremely rare: *Globigerina prasaepis*, *G. tripartita*, *Globigerinita unicava*, *Globorotaloides suteri* (Sample 313-3-2, 50–52 cm to Sample 313-3-6, 117–119 cm).

The *Globigerina ciperoensis* Zone contains rare *G. venezuelana*, *G. sellii*, *G. prasaepis*, and *Globigerinita unicava* (Sample 313-3-1, 70–72 cm). This zone is determined conditionally, because of the absence of *Globorotalia opima*.

Upward, following an interval of 28.5 meters without recovery, middle Miocene sediments are identified.

MAIN FEATURES OF PALEOGENE STRATIGRAPHY OF THE NORTHWESTERN PACIFIC, BASED ON PLANKTONIC FORAMINIFERS

Figure 1, which summarizes data of the preceding text, shows that complete sections of Paleocene calcareous sediments are absent in the northwest Pacific. Only Site 465 (Hess Rise) and Sites 47 and 305 (Shatsky Rise) display complete or almost complete sections of the Paleocene and lower Eocene. For the upper part of the middle Eocene, upper Eocene, and Oligocene, the most important sites are 44 and 171 (Horizon Guyot). Thus, only a combination of all sites permits reconstruction of the characteristics of the planktonic foraminifer faunas and the zonal stratigraphy of the Paleogene.

Most of the sites, including those of Leg 62, are between 19 and 36° north latitude, i.e., within modern tropical–subtropical climatic belts; Site 192 is an exception, well to the north (53°). Naturally, the Paleogene planktonic-foraminifer assemblages bear a tropical character. In the Paleocene and lower and middle Eocene, keeled *Globorotalia*, the genera *Truncorotaloides* and *Orbulinoides*, and various species of *Globigerapsis* and *Globigerinatheca* are widely developed. The upper Eocene is characterized by *Globigerapsis semiinvoluta*, *Cribrohantkenina*, and the *Globorotalia cerroazulensis* group; large *Globigerina* are abundant in the Oligocene. In contrast, in the Paleocene and lower and middle Eocene, representatives of *Acarinina* and *Globigerina* are subordinate. In the middle and upper Eocene, some species of *Globigerina* and *Hantkenina* which are typical of contemporaneous sediments of subtropical and temperate belts are rare. *Acarinina* species are numerous in sediments of the *Acarinina uncinata* and *Globorotalia palmerae* Zones of Sites 47, 305, and 465. Nevertheless, planktonic-foraminifer assemblages of these zones have a definitely tropical character and differ strongly from those developed in synchronous sediments of the subtropical–temperate belts; in the latter case, *Globigerina* species dominate in the *Acarinina uncinata* Zone, and in the *Globorotalia palmerae* Zone they constitute an essential component of planktonic assemblages. At Site 313, some specimens of lower Eocene *Acarinina pseudotopilensis*, *A. nitida*, *A. primitiva*, and *A. interposita* possess additional apertural openings on the spiral side of tests, a feature apparently typical of tropical forms of *Acarinina* (Krasheninnikov and Hoskins, 1973). All these data testify that calcareous sediments of Hess Rise, Shatsky Rise, and, most of all, the Mid-Pacific Mountains were formed in some southern areas closer to the equatorial belt, and subsequently were shifted to the north-northwest as a result of motion of the Pacific Plate, as suggested by many scientists (e.g., Lancelot and Larson, 1975).

Typical subtropical and temperate faunas of planktonic foraminifers are now very well studied in the countries of the Mediterranean Sea, Central Europe, and southern regions of the U.S.S.R. (Crimea, Caucasus, Transcaspian), and also in the North Atlantic, i.e., Bay of Biscay and Rockall Plateau (Berggren, 1972; Krasheninnikov, 1979). Unfortunately, in the northwest sector of the Pacific Ocean they are still unknown, because between 36 and 53° north latitude there is an insufficient number of holes that penetrated calcareous sediments of the Paleogene. The paleoclimatological significance of Paleogene planktonic foraminifers at Site 192 is difficult to interpret; their impoverishment and poor preservation is likely the result of selective dissolution. Paleogene shallow-water carbonate sediments with rare planktonic foraminifers were discovered on Leg 55 at Suiko (Site 433), Nintoku (Site 432), and Ojin (Site 430) Seamounts (Emperor Seamounts chain), but studies of these materials have not yet been published. When the bands of Paleogene calcareous sediments with tropical, subtropical, and temperate planktonic-foraminifer assemblages have been delineated, it will be possible to give a more-detailed paleoclimatological reconstruction of Paleogene time, and to outline with more precision stages of motion of the Pacific Plate to the northwest.

Determination of the paleoclimatic affinity of planktonic-foraminifer assemblages is complicated by selective dissolution, which hampers identification. Certainly, Paleogene calcareous sediments at all sites under consideration were formed above the CCD, but sediments of some sites were deposited below the foraminifer lysocline.

Sedimentation of pelagic nannofossil-foraminifer ooze took place above the foraminifer lysocline during the Paleocene to early Eocene at Site 47, the middle to late Eocene and Oligocene at Site 44, the Paleocene at Site 465, the early to middle Eocene and Oligocene at Site 463, and the middle Eocene and Oligocene at Site 171 (modern water depths 1500–2700 m). In each case, planktonic foraminifers are characterized by high species diversity and excellent preservation.

Precipitation of foraminifer-nannofossil ooze below the foraminifer lysocline took place during the early to middle Eocene and Oligocene at Site 310, the Paleocene, Eocene, and Oligocene at Site 305, and the early to middle Eocene and Oligocene at Site 313 (modern water depths 2900–3500 m). During the middle to late Eocene at Site 466 (modern water depth 2665 m), sedimentation took place at or near the foraminifer lysocline. Planktonic-foraminifer assemblages at these sites are distinguished by the following characteristics: low diversity;

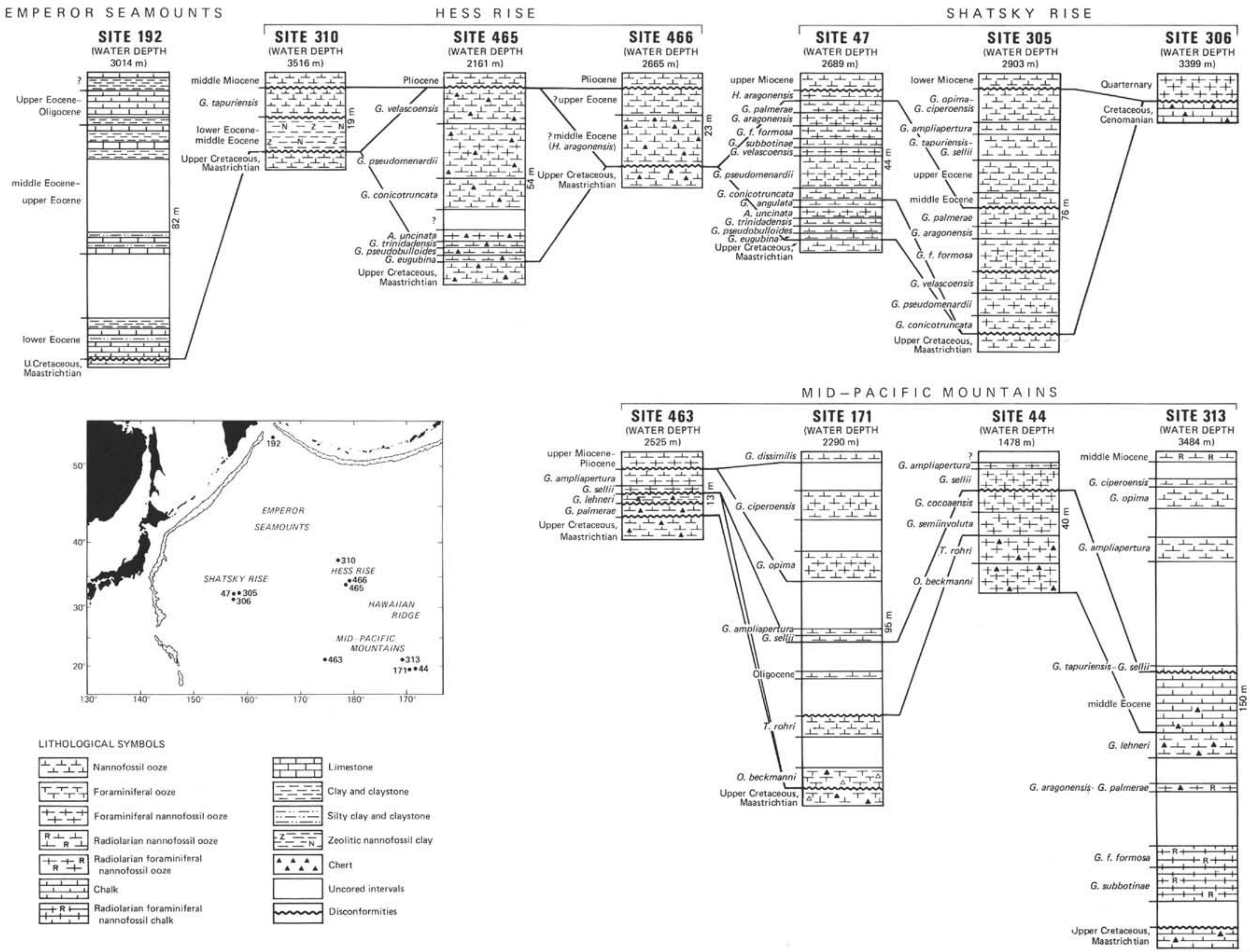

Figure 1. Sections of Paleogene sediments of the Emperor Seamounts, Hess Rise, Shatsky Rise, and Mid-Pacific Mountains.

absence of some easily dissolved species; enrichment of sediments in the most-resistant species, i.e., *Acarinina* spp., *Globigerina senni*, *G. pseudoeocaena*, *G. prasaepis*, *G. pseudovenezuelana*, *G. sellii*, *Globigerapsis index*, *Globorotalia frontosa*, *G. nana*, *G. opima*, *Globigerinita unicava*, *G. pera*, *Globorotaloides suteri*, etc.; etched shell surfaces; abundant shell debris; enrichment of the microfauna in benthic foraminifers. These assemblages reflect only in part their original composition.

In the upper Paleocene, dissolution is pronounced (Site 305); in the lower Eocene it is weak, and planktonic-foraminifer assemblages are rather rich (Sites 305, 313); very strong dissolution is evident in the middle and upper Eocene (Sites 310, 466, 305, 313); in the Oligocene it is again somewhat weaker (Sites 310, 305, 313). Such variations of selective dissolution reflect oceanic subsidence, the rise of the foraminifer lysocline in accordance with removal of the Pacific Plate from the equatorial belt, and fluctuations of the lysocline during Paleogene time.

Above all, we must consider the appearance and existence of resistant planktonic microfauna on the whole. Deterioration of climate in Oligocene time might have caused the distinct climatic differentiation of distribution of planktonic foraminifers, but assemblages with comparatively low species diversity and weak specialization do not yield as perfect a biogeographic picture as in the Eocene. They testify to a certain uniformity of Oligocene planktonic foraminifers, because even their assemblages from the temperate belt (North Atlantic: Bay of Biscay and Rockall Plateau) are essentially similar to more-southern assemblages. We may suggest that Oligocene planktonic foraminifers in general were more tolerant both to climatic conditions and to selective dissolution. Without doubt, careful estimation of the influence of dissolution on the composition of planktonic-foraminifer assemblages will help avoid mistakes in determining their paleoclimatic peculiarities.

Insofar as Paleogene planktonic foraminifers of the Mid-Pacific Mountains, Shatsky Rise, and Hess Rise bear a distinctly tropical character, the zonal scheme of Bolli (1957 a, b), with some subsequent modifications (Blow, 1969; Premoli-Silva and Bolli, 1973) can be applied to the Paleogene sediments.

In the Paleocene the following zones were identified: *Globigerina eugubina* (Sites 47, 465), *Globorotalia pseudobulloides* (Sites 47, 465), *Globorotalia trinidadensis* (Sites 47, 465), *Acarinina uncinata* (Sites 47, 465), *Globorotalia angulata* (Site 47), *Globorotalia conicotruncata* (Sites 47, 305, 465), *Globorotalia pseudomenardii* (Sites 47, 305, 465), *Globorotalia velascoensis* (Sites 47, 305, 465).

The lower Eocene contains these zones: *Globorotalia subbotinae* (Sites 47, 313), *Globorotalia formosa formosa* (Sites 47, 305, 313), *Globorotalia aragonensis* (Sites 47, 305), *Globorotalia palmerae* (Sites 47, 305, 463).

The middle Eocene contains these zones: *Hantkenina aragonensis* in the broad sense (Sites 47, 466), *Globorotalia lehneri* (Sites 313, 463), *Orbulinoides beckmanni* (Sites 44, 171), *Truncorotaloides rohri* (Sites 44, 171).

The upper Eocene contains these zones: *Globigerapsis semiinvoluta* (Site 44), *Globorotalia cocoaensis* (Site 44).

The Oligocene includes these zones: *Globigerina tapuriensis* (Site 310), *Globigerina sellii* (Sites 44, 171, 463), *Globigerina ampliapertura* (Sites 44, 171, 305, 313, 463), *Globorotalia opima* (Sites 171, 313), *Globigerina ciperoensis* (Sites 171, 313).

Hence, only two zones have not been identified: the *Globigerapsis kugleri* Zone in the middle Eocene, and the *Globigerina gortanii–Globorotalia centralis* Zone at the top of the upper Eocene. Their absence appears to be related to gaps in the sedimentary record, dissolution effects, and poor recovery.

The most important feature of the regional stratigraphy of the Paleogene deposits of the northwest Pacific is heterogeneity of sections of calcareous sediments on the elevations (Emperor Seamounts, Shatsky Rise, Hess Rise, Mid-Pacific Mountains) (Fig. 1). For example, on Hess Rise at Site 465 there is a continuous Paleocene section, but the Eocene and Oligocene are missing. At neighboring Sites 310 and 466, the Paleocene is absent, but the Eocene and Oligocene are represented by some intervals. On Shatsky Rise at Site 47, the Paleocene and lower Eocene are very well developed, but the middle to upper Eocene and Oligocene are not present. At Site 305, the basal Paleocene and basal lower Eocene are missing, but the middle to upper Eocene, and especially the Oligocene, are well represented. At Sites 48 and 306, the Paleogene is entirely lacking. On the Mid-Pacific Mountains, the Paleocene is missing, and the basal parts of sections are composed of sediments of the lowermost lower Eocene (Site 313), uppermost lower Eocene (Site 463), and upper middle Eocene (Site 171). At Site 463, only some intervals of the middle Eocene and Oligocene were encountered, whereas at Sites 171, 44, and 313, sections of the middle to upper Eocene and Oligocene are comparatively complete.

Certainly the inconstant and changeable nature of the Paleogene sedimentary cover on the various elevations lays an imprint on the Paleogene stratigraphy of the whole realm. Nevertheless, there are hiatuses which can be traced rather constantly within the area in question.

At all sites except 47 and 465, the Mesozoic and Cenozoic are separated by a gap. The Upper Cretaceous is overlain by sediments of the middle Paleocene (*Globorotalia conicotruncata* Zone, Site 305); lower Eocene (*Globorotalia subbotinae* Zone, Site 313; *Globorotalia palmerae* Zone, Site 463); middle Eocene (*Hantkenina aragonensis* Zone, Site 466; *Orbulinoides beckmanni* Zone, Site 171). Thus, this hiatus does not represent a narrow stratigraphic interval (not equivalent, for instance, to the Maastrichtian/Danian boundary). In general, it corresponds to the interval from the base of the Paleocene to the middle middle Eocene. At Site 48, the Maastrichtian is overlain by the upper Miocene, and at Site 306 by the Quaternary.

There are scanty data on the character of the Paleocene/Eocene relation—at Site 47 the contact is gradual, at Site 305 it is disconformable.

The middle Eocene is separated from underlying sediments by a hiatus as a rule; it rests on Maastrichtian (Sites 310, 466, 171) and lower Eocene (Sites 305, 463) sediments. Only at Site 47 is the contact conformable.

The upper Eocene is recognized reliably only at Sites 44 and 305, where it passes into the middle Eocene by a gradual transition.

The Oligocene is separated by a gap from the middle Eocene (Sites 310, 463, 313) or upper Eocene (Site 44). The normal upper Eocene/Oligocene contact is observed only at Site 305.

A gradual transition from Oligocene to Miocene is suggested only at Site 171. At all other sites, there is a hiatus, but again it does not represent a narrow stratigraphic interval (not upper Oligocene to lower Miocene, for example). This gap separates different subdivisions of the Paleogene and Neogene: lower Miocene and upper Oligocene (Site 305); middle Miocene and upper Oligocene (Site 313) or lower Oligocene (Site 310); upper Miocene and lower Oligocene (Site 463) or middle Eocene (Site 47); Pliocene and upper Eocene (Site 466) or Paleocene (Site 465).

The nature of these gaps can be clarified if the distribution of reworked planktonic foraminifers and, especially, calcareous turbidites is analyzed. Redeposited planktonic foraminifers and turbidites have not been found in Paleogene sediments of Sites 192, 44, 47, 465, and 310 (although the condensed Paleogene section of Site 310 contains some hiatuses). At Site 305, sediments of the *Globorotalia conicotruncata* Zone includes pieces of nannofossil ooze with planktonic-foraminifer assemblages belonging to older zones of the Paleocene (*Globorotalia angulata*, *Acarinina uncinata*, and *Globorotalia trinidadensis* Zones).

Turbidites are well developed at Sites 171, 463, 313, and 466, where they alternate with normal pelagic sediments. At Site 171, the middle Eocene contains abundant planktonic foraminifers from the Upper Cretaceous and from some intervals of the upper Paleocene and lower Eocene. The Oligocene at Site 171 contains species reworked from the Upper Cretaceous, upper Paleocene, and lower and middle Eocene. At Site 463, the lower and middle Eocene are without turbidites, but the Oligocene contains a mass accumulation of foraminifers redeposited from the Upper Cretaceous, upper Paleocene, and lower and middle Eocene. At Site 313, the lower Eocene is marked by ooze, whereas the middle Eocene is marked by turbidites with abundant planktonic foraminifers reworked from the Upper Cretaceous and all zones of the upper Paleocene and lower Eocene; at this site the Oligocene is again represented by pure pelagic ooze. At Site 466, middle Eocene sediments contain common reworked foraminifers from the upper Cretaceous and lower Eocene. The upper Eocene does not contain redeposited microfaunas; the basal layers of the Neogene include abundant foraminifers redeposited from the upper Cretaceous, lower and middle Eocene, and Oligocene.

Thus, the Paleogene sections at Hess Rise, Shatsky Rise, and the Mid-Pacific mountains (or at least neighboring sections) have been at one time much more complete stratigraphically than they are now. In the area of Site 305, it is necessary to admit the primary existence of lower Paleocene sediments (including the Danian Stage); in the region of Site 171 sediments of the upper Paleocene, lower Eocene, and lower middle Eocene originally existed; in the area of Site 463, sediments of the upper Paleocene, and some zones of the lower and middle Eocene were present; in the vicinity of Site 313, sediments of the upper Paleocene and all zones of the lower Eocene existed; near Site 466, sediments of the upper Paleocene, lower and middle Eocene, and Oligocene were present. In these areas, primary hiatuses corresponded to more narrow stratigraphic intervals. The universal distribution of a reworked upper Paleocene microfauna (*Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones) may indicate that the gap between Mesozoic and Cenozoic is confined to the lower Paleocene.

Analysis of hiatuses and foraminifer assemblages of turbidities allows the conclusion that the gaps mainly represent repeated erosion of sediments, not non-deposition. This submarine erosion apparently has resulted from a combination of general causes (eustatic fluctuations of sea level, paleogeographic variations, and changes in bottom currents) and local causes (slides of unconsolidated sediments, turbidity currents off highs, etc.). It is probable that intensification of erosion on rises of the northwest Pacific at the Cretaceous/Paleogene boundary, in the middle Eocene, in the Oligocene, and at the Oligocene/Neogene boundary reflects a phenomenon of general rank. The comparatively small number of sites in this realm of the Pacific Ocean permits for the present only preliminary conclusions.

The peculiarities of the regional stratigraphy of Paleogene calcareous sediments on the Mid-Pacific Mountains, Shatsky Rise, and Hess Rise—numerous breaks in sedimentation, turbidites, dissolution facies, etc.—is compelling evidence that the thickness of sediments as an indication of biological productivity and the paleogeography of a given region must be used with care.

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