33. CENOZOIC FORAMINIFERA

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INTRODUCTION

Cenozoic foraminifera were found in 18 of 34 holes drilled on Leg 6. Planktonic forms are far more abundant than benthonic forms.

Abundant planktonic foraminifera are typical in Cenozoic white chalk oozes occurring in present water depths of 1500 to 3300 meters (Hole 44.0 on Horizon Ridge, Holes 47.0, 47.1, 47.2, 48.2 on Shatsky Rise, Holes 55.0, 56.2, 57.0, 57.1, 57.2 on Caroline Ridge). Numerous planktonic foraminifera also occur in light brownish-calcareous and marly oozes in Holes 58.1 and 58.2 (northeast of the Caroline Ridge) where the present water depth is 4500 meters. The foraminifera here are associated with abundant radiolarians and spicules of siliceous sponges.

Oligocene and Neogene sediments recovered from present water depths of 4600 to 5500 meters are characterized by a very poor fauna. These sediments include slightly calcareous clay and volcanic ash of the Philippine basin (Sites 53 and 54), zeolitic clays, diatom and radiolarian oozes of the Mariana basin (Site 59). Planktonic foraminifera are rare, being represented by a few small specimens whose shells often show traces of dissolution.

Foraminifera are absent in the Cenozoic reddish-brown zeolitic clay covering the abyssal portions of the Pacific Ocean (5500 to 6000 meters). Sediments of this type were drilled at Sites 45 and 46 in the Marcus-Necker basin and at Sites 51 and 52 between the Shatsky Rise and the Japan Trench.

The cores obtained during Leg 6 represent an almost continuous sequence of foraminiferal Cenozoic chalk oozes. Small stratigraphic gaps occur only in the middle part of the Middle Eocene (*Globorotalia lehneri* Zone) and in the middle part of the Oligocene (*Globorotalia opima* Zone). However, because these holes do not overlap completely, it is possible these are not actual breaks in the stratigraphic succession.

The sequence of foraminiferal-rich Cenozoic deposits in the northwest Pacific Ocean is of a great practical and theoretical importance.

Can the same zonal scheme for a stratigraphic subdivision of Cenozoic sediments be applied to both continental and oceanic areas? If so, what are the characteristic features of such synchronous assemblages?

The planktonic biostratigraphy of Cenozoic deposits in the northwestern and western part of the Pacific province is poorly known. This is due to the fact that the Paleogene and Neogene of Japan, Taiwan Island, Philippines, Caroline and Marianas Islands, and New Guinea are represented by thick sequences of terrigenous and volcanic rocks with a very poor fauna of planktonic foraminifera, or shallow-water deposits which contain only benthonic foraminifera. Even when the Paleogene and Neogene are represented by relatively deep-water marls, clays or clayey limestones, as for example in the Solomon Islands, the sequence of planktonic foraminiferal assemblages still cannot be studied in detail here owing to poor exposures, complicated tectonics, and stratigraphic gaps.

Carbonate sediments with abundant planktonic foraminifera on Shatsky Rise, Horizon Ridge, and Caroline Ridge therefore offer excellent possibilities for establishing a zonal stratigraphic scale for the Paleogene and Neogene and comparing it to analogous scales of the Caribbean basin, Mediterranean and Crimea-Caucasian area.

Several difficulties of a stratigraphic and paleontological character require comment before describing the material from Leg 6.

In this paper the term "zone" refers to a chronostratigraphic unit of an oppel-zone type. It may be defined as follows: "A zone is a deposit, usually world wide, formed during the existence of a certain assemblage of planktonic foraminifera which represent a particular level of evolutionary development." The zone is defined by an assemblage of foraminifera, but is named for the species which is most characteristic. Locally, then, climatic and ecological conditions may be such that although a particular assemblage is present, the index-species of that zone is lacking. Zone, defined thus, is the smallest unit of the International Stratigraphic Scale and is equal to stage (Krasheninnikov, 1969).

The subdivision of the Paleogene in the northwest Pacific is less detailed than in some other areas. However, all the identified zones (and evidently most of the subzones) are chronostratigraphic subdivisions and occur in the same succession as they do in tropical and subtropical areas from 50°-45°N (i.e., the latitude of Southern France, Northern Italy, Switzerland, Crimea and Caucasus) to 45°S (i.e., latitude of the southern part of New Zealand).

In Miocene deposits of the Eastern Mediterranean (Syria, UAR), five zones can be distinguished that are about equivalent to stages (Krasheninnikov, 1966, 1968, 1969). These zones (stages) are well traced in the Mediterranean, the basins of the Pacific and Atlantic Oceans. They will be used for stratigraphical subdivision of Miocene sediments from the northwestern part of the Pacific Ocean.

Tables 1 and 2 give a correlation of zonal scales for Paleogene and Neogene deposits of the Northwest Caribbean, Mediterranean, and the USSR (Crimean-Caucasian region), as well as definitions of series and subseries in these different regions.

PALEOGENE

Paleogene deposits were discivered in three regions: The Shatsky Rise (Paleocene-basal beds of Middle Eocene), the Horizon Ridge (Middle Eocene-Oligocene) and the Caroline Ridge (Upper Oligocene). The lack of stratigraphic overlap between the three areas makes it impossible to trace the influence of climatic belts on the composition of planktonic foraminifera within any zone, although the Shatsky Rise and the Caroline Ridge are separated by a considerable distance (about 24° of latitude).

Paleocene

In this paper the Danian Stage is regarded as belonging to the Paleocene. Without any signs of a stratigraphic break the Paleocene of Shatsky Rise rests on the upper part of the Maestrichtian Stage (the *Abathomphalus mayaroensis* Zone). Unfortunately, the Maestrichtian Stage and basal beds of the Danian Stage (the *Globigerina taurica* Zone) are separated by sediments that are a mechanical admixture of both. Therefore, pelagic sediments of the Pacific Ocean show the same catastrophically rapid change of plankton at the Upper Cretaceous-Paleogene boundary that is observed in synchronous deposits on continents.

Paleocene deposits are divided into the following five zones (from oldest to youngest): *Globigerina taurica, Globorotalia trinidadensis, Acarinina uncinata* and *Globorotalia velascoensis* (with two subzones).

The *Globigerina taurica* Zone is characterized by an abundance of minute globigerines with a thin, smooth shell wall: *Globigerina taurica* Moroz., *G. theodosica* Moroz., *G. tetragona* Moroz., *G. pentagona* Moroz., *G. hemisphaerica* Moroz., *G. fringa* Subb., *G. sabina* Lut. et Premoli Silva and *G. minutula* Lut. et Premoli Silva. The species of *Globigerina* described by Morozova (1958, 1961) were assigned by her to the new subgenus *Eoglobigerina. Globigerina daubjergensis* Bronn., *Gumbelitria irregularis* Moroz., *Chilogumelina moresei* (Kline), *C. taurica* Moroz. and *C. midwayensis* (Cushm.) are represented by numerous specimens. *Globorotalia pseudobulloides* (Plumm.) also appears in this zone. The zone is 1.3 meters thick. However, it may include some of the 4.5 meters of Maestrichtian and Danian chalk oozes mixed by drilling. The recognition of this zone in Cenozoic sediments on the Shatsky Rise indicates that it is a chronostratigraphical zone.

The *Globorotalia trinidadensis* Zone is characterized by numerous specimens of *Globorotalia pseudobulloides* (Plumm.), *G. trinidadensis* Bolli, *Globigerina daubjergensis* Bronn., *Gumbelitria irregularis* Moroz., *Chilogumbelina midwayensis* (Cushm.), *C. morsei* (Kleine) and *C. taurica* Moroz. Less abundant are specimens of *Globorotalia compressa* (Plumm.), *Globigerina trivialis* Subb., *G. varianta* Subb. and *G. edita* Subb. Relatively scarce is *G. triloculinoides* Plumm. In the basal part of the zone, *Globigerina tetragona* Moroz., *G. pentagona* Moroz. and *G. theodosica* Moroz. are common, whereas *Acarinina uncinata* (Bolli) appears in the top. The zone is about 3.5 meters thick.

The assemblage of planktonic foraminifera of the *Acarinina uncinata* Zone includes abundant *Acarinina uncinata* (Bolli), *A. praecursoria* Moroz., *A. indolensis* Moroz., *A. schachdagica* Chalil., associated with usual *Acarinina inconstans* (Subb.), *A. apiralis* Bolli, *Globorotalia compressa* (Plumm.), *G. quadrata* (White), and less common *Globigerina varianta* Subb., *G. trivialis* Subb., *G. triloculinoides* Plumm. and *Globorotalia pseudobulloides* (Plumm.). The number of specimens of acarininas clearly prevail over those of globigerinas; representatives of *Chilogumbelina* are quite scarce. In the upper part of the zone there appear a few, small *Globorotalia angulata* (White), *G. ehrenbergi* Bolli and *Acarinina multiloculata* Moroz. This zone is 3 meters thick.

Limestones and marls of the Danian Stage stratotype in Denmark contain an impoverished assemblage of planktonic foraminifera. Yet the author believes that the *Globigerina taurica* and *Globorotalia trinidadensis* Zones correspond to the stratotype of the Danian Stage. In the Soviet Union many micropaleontologists, including the author, attribute the *Acarinina uncinata* Zone to the Danian Stage too, i.e., the *Acarinina inconstans* Zone (Danian s.l.). This is because the assemblages of globigerinas from the *Globorotalia trinidadensis* and *Acarinina uncinata* Zones are more or less similar in specific composition, whereas acarininas usually common in the Paleocene and Eocene, are replaced by globigerinas in the *Acarinina uncinata* Zone in the USSR. Pelagic chalk oozes of the *Acarinina uncinata* Zone on

TABLE 1
Correlation of Some Paleogene Zonal Scales Based on Planktonic Foraminifera

Stratigraphical Scale of the Paleogene of the Mediterranean and Caribbean Region		Northwest Pacific Ocean		Trinidad	Mediterranean (Syria)		USSR (Crimea and Caucasus)		Stratigraphical Scale of the Paleogene of the USSR	
		Zones	Subzones	Zones	Zones	Subzones	Zones			
Oligocene		Globigerina ciperoensis		Globigerina ciperoensis	Globigerina ciperoensis		Maikop formation			Oligocene
		Globorotalia opima (absent)		Globorotalia opima	Globorotalia opima					
		Globigerina ampliapertura		Globigerina ampliapertura	Globigerina ampliapertura					
Eocene	Upper	Globigerina corpulenta	Globorotalia cerroazulensis	Globorotalia cerroazulensis	Globigerina corpulenta	Globorotalia cerroazulensis	Bolivina		Upper	Eocene
							"Globigerinoides conglobatus" and large globigerinas			
			Globigerapsis semiinvoluta	Globigerapsis semiinvoluta		Globigerapsis semiinvoluta				
	Middle	Truncorotaloides rohri		Truncorotaloides rohri	Truncorotaloides rohri		Globigerina turcmenica			
		Orbulinoides beckmanni		Porticulasphaera mexicana	Hantkenina alabamensis		Hantkenina alabamensis			
		Acarinina rotundimarginata (absent)		Globorotalia lehneri	Acarinina rotundimarginata		Acarinina rotundimarginata			
		Acarinina bullbrooki		Globigerapsis kugleri	A. bullbrooki	G. kugleri	Acarinina "crassaformis"		Middle	
				Hantkenina aragonensis		H. aragonensis				
	Lower	Globorotalia aragonensis	Acarinina pentacamerata	Globorotalia palmerae	G. aragonensis and A. pentacamerata	A. pentacamerata	Globorotalia aragonensis			
			Globorotalia aragonensis	Globorotalia aragonensis		G. aragonensis				
		Globorotalia marginodentata		Globorotalia formosa	Globorotalia subbotinae	G. marginodentata	Globorotalia subbotinae	G. marginodentata	Lower	
		Globorotalia subbotinae		Globorotalia rex		G. subbotinae		G. subbotinae		
Paleocene	Upper	Globorotalia velascoensis	Globorotalia velascoensis	Globorotalia velascoensis	Globorotalia velascoensis	Upper subzone	Acarinina subsphaerica	A. acarinata	Upper	Paleocene
			Globorotalia pseudomenardii	Globorotalia pseudomenardii		Lower subzone		A. subsphaerica		
	Lower	Globorotalia angulata	Globorotalia conicotruncata	Globorotalia pusilla	Globorotalia angulata	G. conicotruncata	Globorotalia angulata	G. tadjikistanensis		
			Globorotalia angulata			G. angulata		G. conicotruncata	Lower	
								G. angulata		
		Acarinina uncinata		Globorotalia uncinata	Acarinina uncinata		Acarinina inconstans		Danian Stage	
Danian Stage	Lowermost	Globorotalia trinidadensis		Globorotalia trinidadensis	G. triloculinoides and G. pseudobulloides		Globigerina trivialis			Upper Cretaceous
		Globigerina taurica		?	Globigerina eobulloides		Globigerina taurica			
Upper Cretaceous	Maestrichtian Stage	Abathomphalus mayaroensis		Abathomphalus mayaroensis	Abathomphalus mayaroensis		Abathomphalus mayaroensis		Maestrichtian Stage	

TABLE 2
Correlation of Some Neogenes Zonal and Stage Scales Based on Planktonic Foraminifera

Stratigraphical Scale of the Neogene Sediments of the Northwest Pacific Ocean Used in This Paper: Series	Subseries	Stage	Zone	Subzone	Trinidad (Bolli, 1957)	Mediterranean (Syria, Krasheninnikov, 1966)	Caribbean, Pacific, Mediterranean (Banner and Blow, 1965; Blow, 1969)			
Pliocene	Upper part	?	?	*Globorotalia tosaensis*		Pliocene	N 21. *Globorotalia tosaensis*	Astian-Zanclian		Pliocene
	Lower part			*Sph. dehiscens-G. altispira-G. obliquiloculata*			N 20. *G. multicamerata-P. obliquiloculata*			
							N. 19. *Sph. dehiscens-G. altispira*			
Miocene	Upper	Messinian	*Globorotalia miocenica*	*G. tumida-Sph. paenedehiscens*		Messinian	N 18. *G. tumida tumida-Sph. paenedehiscens*			
				G. plesiotumida			N 17. *G. tumida plesiotumida*	Messinian Tortonian		Late Miocene
	Middle	Tortonian	*Globorotalia menardii*	*G. acostaensis-G. continuosa*	*G. menardii*	Tortonian	N 16. *G. acostaensis-G. merotumida*			
							N 15. *G. continuosa*			
				G. mayeri	*G. mayeri*		N 14. *G. nepenthes-G. siakensis*	Langhian		Middle Miocene
		?	*Globorotalia fohsi*		*G. fohsi robusta*	? (lower part of Middle Miocene)	N 13. *Sph. subdehiscens-Globigerina druryi*			
					G. fohsi lobata		N 12. *G. fohsi*			
					G. fohsi fohsi		N 11. *G. praefoshi*			
							N 10. *G. peripheroacuta*			
					G. fohsi barisanensis		N 9. *O. suturalis-G. peripheroronda*			
	Lower	Burdigalian	*Globigerinatella insueta*	*P. glomerosa* *G. bisphaerica*	*Globigerinatella insueta*	Burdigalian	N 8. *G. insueta-G. sicanus*	Burdigalian	Girondian	Early Miocene
				G. dehiscens			N 7. *G. insueta-G. trilobus*			
		"Aquitanian"	*Globigerinita dissimilis*		*G. stainforthi*	"Aquitanian"	N 6. *G. insueta-G. dissimilis*			
					G. dissimilis		N 5. *G. praedehiscens-G. dehiscens*	Aquitanian		
			Globorotalia kugleri		*Globorotalia kugleri*	absent	N 4. *Globorotalia kugleri-Globigerinoides primordius*			
Upper Oligocene		Chattian (?)	*Globigerina ciperoensis*		*Globigerina ciperoensis*	*Globigerina ciperoensis*	N 3. *Globigerina angulisuturalis*	Bormidian (Chattian)		Oligocene

the Shatsky Rise, however, are characterized by abundant and various acarininas. These data indicate that the top of *Globorotalia trinidadensis* Zone is the upper boundary of the Danian Stage, and the *Acarinina uncinata* Zone comprises part of the superadjacent Stage that unfortunately has no generally accepted name.

The *Globorotalia angulata* Zone is determined by numerous *Globorotalia angulata* (White), *G. conicotruncata* (Subb.), *G. pusilla* Bolli, *G. ehrenbergi* Bolli, *G. Kubanensis* Shutzk., *G. simulatilis* (Schw.), *Acarinina multiloculata* Moroz. and *A. schachdagica* Chalil. Less common are *Globorotalia quadrata* (White), *Acarinina spiralis* (Bolli), *Globigerina varianta* Subb., *G. trivialis* Subb., and quite rare *Globigerina triloculinoides* (Plumm.), *G. colchidica* Moroz. and *Acarinina praecursoria* Moroz. This zone is 6 meters thick.

The *Globorotalia angulata* Zone is subdivided into two subzones. In the lower *Globorotalia angulata* Subzone the index-species reaches its acme; *Acarinina praecursoria* is still abundant, whereas *Globorotalia pusilla* is relatively scarce. The upper *Globorotalia conicotruncata* Subzone is characterized by an abundance of the index-species combined with numerous *Globorotalia pusilla, G. simulatilis, G. tadjikistanensis* N. Bykova; in its upper part appears *Globigerina bacuana* Chalil. and *G. quadritriloculinoides* Chalil., which are typical for overlying sediments.

Planktonic foraminifera of the *Globorotalia velascoensis* Zone are extremely diverse. The assemblage consists of *Globorotalia velascoensis* (Cushm.), *G. parva* Rey, *G. occlusa* Loebl. et Tapp., *G. laevigata* Bolli, *G. tortiva* Bolli, *G. apanthesma* Loebl. et Tapp., *G. hispidicidaris* Loebl. et Tapp., *G. imitata* Subb., *G. convexa* Subb., *G. trichotrocha* Loebl. et Tapp., *G. pseudomenardii* Bolli, *G. pasionensis* Berm., *G. elongata* Glaessn., *G. acuta* Toulm., *G. aequa* Cushm. et Renz, *Acarinina mckannai* (White), *A. acarinata* Subb., *A. tribulosa* (Loebl. et Tapp.), *A. primitiva* (Finl.), *A. irrorata* (Loebl. et Tapp.), *A. intermedia* Subb., *A. strabocella* (Loebl. et Tapp.), *A. soldadoensis* (Bronn.), *A. esnaensis* (LeRoy), *Globigerina velascoensis* Cushm., *G. quadritriloculinoides* Chalil., *G. bacuana* Chalil., *G. nana* Chalil., *G. chascanona* Loebl. et Tapp., *G. pileata* Chalil. *G. aquiensis* Loebl. et Tapp., *G. linaperta* Finl. and *G. compressaformis* Chalil. The thickness of the zone is rather significant–about 13 meters.

The *Globorotalia velascoensis* Zone is subdivided into two subzones. The lower subzone (thickness of 7 meters) is characterized by the occurrence of *Globorotalia laevigata* and *G. tortiva.* In the upper subzone (thickness of 6 meters) there is considerable increase in the number of specimens of *Acarinina primitiva* and *Globorotalia elongata;* also, *Globigerina compressaformis, Acarinina soldadoensis, Globorotalia acuta* and *G. aequa* appear for the first time and become typical. The number of specimens of *G. aequa* increases rapidly from the bottom to the top of the subzone.

The sequence of planktonic foraminifera within the *Globorotalia velascoensis* Zone of the Shatsky Rise allows correlation of the lower and upper subzones, respectively, with the *Globorotalia pseudomenardii* and *G. velascoensis* Zones of Trinidad, and the *Acarinina subphaerica* (junior synonym of *A. mckannai*) and *A. acarinata* Zones of the USSR. Apparently all these zonal names cannot be regarded as valid since in the *Globorotalia velascoensis* Zone of the Shatsky Rise *Globorotalia pseudomenardii, G. velascoensis, Acarinina acarinata* and *A. mckannai* are found in abundance throughout the zone. In the given paper the lower subzone bears the name the *Globorotalia pseudomenardii* Subzone, the upper one the *G. velascoensis* Subzone; in the future, however, these terms should be replaced by others.

The *Globorotalia subbotinae* Zone is characterized by abundance of *Globorotalia subbotinae* Moroz. (junior synonym of this species is *G. rex* Martin), *G. wilcoxensis* Cushm. et Pont., *Acarinina soldadoensis* (Bronn.), *A. pseudotopilensis* Subb., *A. camerata* Chalil., *Globigerina nana* Chalil. and *C. compressaformis* Chalil.; to the common species belong: *Globorotalia quetra* Bolli, *G. elongata* Glaessn., *G. reissi* Loebl. et Tapp., *Acarinina triplex* Subb., *A. primitiva* (Finl.), *A. esnaensis* (LeRoy), *A. gravelli* (Bronn.), *Globigerina collactea* Finl. and *G. prolata* Bolli. In the lower part of the zone there are many *Globorotalia aequa* Cushm. et Renz, and scarce *Globorotalia velascoensis* (Cushm.), *G. acuta* Toulm., *G. pasionensis* Berm., *G. hispidicidaris* Loebl. et Tapp., *G. occlusa* Loebl. et Tapp., *Globigerina quadritriloculinoides* Chalil. were met. Occasionally *Globorotalia marginodentata* Subb. and *G. formosa gracilis* Bolli occur in the top of the zone. Only in one sample were found specimens of *Pseudohastigenia wilcoxensis* (Cushm. et Pont). Very scarce are also *Acarinina broedermanni* (Cushm. et Berm.). This zone is about 2.5 meters thick on Shatsky Rise.

The planktonic foraminiferal assemblage of the *Globorotalia marginodentata* Zone includes abundant *Globorotalia marginodentata* Subb., *G. formosa formosa* Bolli, *Acarinina triplex* Subb., *A. soldadoensis* (Bronn.), *A. pseudotopilensis* Subb. and *Globigerina compressaformis* Chalil. in association with less developed *Globorotalia formosa gracilis* Bolli, *G. quetra* Bolli, *G. reissi* Loebl. et Tapp., *G. naussi* Mart., *Acarinina primitiva* (Finl.), *A. decepta* (Mart.), *A. nitida* (Mart.), *A. gravelli* (Bronn.), *A. broedermanni* (Cushm. et Berm.), *Globigerina prolata* Bolli and *Heterohelix wilcoxensis* (Cushm. et Pont.). Many *Globorotalia subbotinae* Moroz. are observed in the lower part of the zone, whereas in its upper part appear *Globorotalia lensiformis* Subb. Rare specimens of *Globorotalia aragonensis* Nutt., *G. marksi* Mart., *Acarinina interposita* Subb. and *A. pentacamerata* (Subb.) were met in the top of the zone. This zone is 3.5 meters thick on Shatsky Rise.

The *Globorotalia aragonensis* Zone is characterized by numerous *Globorotalia aragonensis* Nutt., *G. marksi* Mart., *G. caucasica* Glaessn., *G. planoconica* Subb., *Acarinina pentacamerata* (Subb.), *A. interposits* Subb., *A. triplex* Subb., *A. pseudotopilensis* Subb., *A. soldadoensis* (Bronn.), *A. aspensis* (Colom.), *Globigerina pseudoeocaena* Subb., *G. turgida* Finl., *G. taroubaensis* Bronn., *G. senni* (Beckm.) and *G. prolata* Bolli; and, less frequent are *Globorotalia naussi* Mart., *G. quetra* Bolli, *Acarinina decepta* (Mart.), *A. gravelli* (Bronn.), *A. nitida* (Mart.), *Globigerina eocaena* Gumb., *G. eocaenica* Terq., *G. inaequispira* Subb. and *Pseudohastigerina eocaena* Gumb., *G. eocaenica* Terq., *G. inaequispira* Subb. and *Pseudohastigerina wilcoxensis* (Cushm. et Pont.). This zone is 6.5 meters thick on Shatsky Rise.

The *Globorotalia aragonensis* Zone includes two subzones. The lower *Globorotalia aragonensis* Subzone (thickness of 3 meters) is characterized by abundance of the index-species and *Acarinina interposita; Globorotalia lensiformis* Subb. and *G. formosa* Bolli continue existing here. In the upper *Acarinina pentacamerata* Subzone (thickness of 3.5 meters) the index-species and *Globorotalia caucasica* develop to its maximum; often observed are *Acarinina aspensis* and *Globigerina senni;* there appears *Acarinina bullbrooki* (Bolli). In the upper part of the subzone scarce specimens of *Globigerina higginsi* (Bolli), *Globorotalia renzi* Bolli and *Pseudohastigerina micra* (Cole) may be found.

The *Globorotalia aragonensis* and *Acarinina pentacamerata* Subzones of the Shatsky Rise correspond with like subzones of lower Eocene of Syria, to the *Globorotalia aragonensis* and *Globorotalia palmerae* Zones of the Trinidad Lower Eocene. Analogues of these subzones may be found in the USSR Eocene deposits as well (Crimea, Caucasus). However, planktonic foraminiferal assemblages of the *Globorotalia aragonensis* and *Acarinina pentacamerata* Subzones are so much similar that only one zone is often distinguished: *Globorotalia aragonensis* (USSR, Bulgaria, USA, Australia, Italy, Madagascar island), *Globorotalia aragonensis* and *Acarinina pentacamerata* (Syria, Yugoslavia, UAR), *Globorotalia aragonensis–G. palmerae* (Cuba), *Globorotalia pseudoscitula* (south India) and *Globorotalia crater* (New Zealand).

New microfaunal elements of the *Acarinina bullbrooki* Zone that begins the Middle Eocene are numerous *Acarinina bullbrooki* (Bolli), *Pseudohastigerina micra* (Cole) and considerably more scarce *Globorotalia spinulosa* Cushm., *G. renzi* Bolli, *Globigerina boweri* Bolli, *G. higginsi* (Bolli), *Globigerapsis index* (Finl.) and *Globigerinatheca barri* Bronn. These are accompanied by numerous *Acarinina pentacamerata* (Subb.), *A. aspensis* (Colom.), *Globorotalia caucasica* Glaessn., *Globigerina senni* (Beckm.), *G. pseudoeocaena* Subb., *G. eocaena* Gumb., *G. turgida* Finl., and sporadic *Globorotalia aragonensis* Nutt., *G. marksi* Mart. and *Acarinina broedermanni* (Cushm. et Berm.) passing from underlying deposits. The composition of planktonic foraminifera shows clearly that the *Acarinina bullbrooki* Zone is represented by basla beds whose thickness totals one meter only. In the examined section of Shatsky Rise the basal layers of the Middle Eocene are covered by sediments of the Upper Miocene.

As mentioned before, chalk oozes with foraminifera of the *Globorotalia lehneri* Zone (the *Acarinina rotundimarginata* Zone of the USSR Eocene deposits) were not discovered by drilling on Leg 6. However, in the lowermost part of the *Orbulinoides beckmanni* Zone of Horizon Ridge, the *Globorotalia lehneri* Cushm. et Jarv. and *Acarinina rotundimarginata* Subb. are rather common. This suggests that the *Globorotalia lehneri* Zone as an independent stratigraphical subdivision exists in the sections of Eocene deposits of the northwestern part of the Pacific Ocean.

Among planktonic foraminifera of the *Orbulinoides beckmanni* Zone prevail: *O. beckmanni* Blow et Saito, *Globigerapsis kugleri* Bolli, Loebl. et Tapp., *G. index* (Finl.), *Globigerinatheca barri* Bronn., *Globigerina pseudoeocaena* Subb., *Pseudohastigerina micra* (Cole), *Truncorotaloides topilensis* (Cushm.), *T. rohri* Bronn. et Berm., *Globorotalia centralis* Cushm. et Berm., *G. armenica* Saak.-Ges., *G. spinulosa* Cushm. and *G. renzi* Bolli. They are accompanied by *Hantkenina alabamensis* Cushm., *Globorotalia spinuloinflata* (Bandy), *G. bolivariana* (Petters), *Globorotaloides suteri* Bolli, *Globigerinita echinata* (Bolli), *Globigerina frontosa* Subb., *G. posttriloculinoides* Chalil. and *G. pseudovenezuelana* Bann. et Blow. Mainly in the lower part of the zone there occur *Globorotalia lehneri* Cushm. et Jarv., *Acarinina rotundimarginata* Subb. and very scarce *Hantkenina lehneri* Cushm. et Jarv. The zone is 12 meters thick on Horizon Ridge.

Four distinct paleocoenoses, reflecting variations in bionomic conditions, can be distinguished in the *Orbulinoides beckmanni* Zone on the Horizon Ridge: 1) with abundant *Orbulinoides beckmanni* and *Globigerinatheca barri* in the lower part of the zone; in the upper part *Orbulinoides beckmanni* disappears almost completely; 2) with numerous *Truncorotaloides topilensis* and *T. rohri*; 3) with wide prevalence of *Globorotalia centralis* and *G. armenica*; and 4) with abundant large globigerinas–*Globigerina pseudovenezuelana, G. pseudoeocaena compacta.*

Microfauna of the *Truncorotaloides rohri* Zone is characterized by a wide distribution of globigerinas–*Globigerina pseudovenezuelans* Bann. et Blow, *G.*

praebulloides Blow, *G. azerbaijanica* Chalil., *G. pseudocorpulenta* Chalil., *G. incretacea* Chalil., *G. turcmenica* Chalil. combined with minute *Truncorotaloides rohri* Bronn. et Berm., *Acarinina rugosoaculeata* Subb., *Heterohelix* sp., *Pseudohastigerina micra* (Cole) and *Hantkenina longispina* Cushm. Also common are *Globigerina howei* Bann. et Blow, *G. pera* (Todd), *G. unicava* (Bolli, Loebl. et Tapp.), *Globorotalia centralis* Cushm. et Berm., *G. armenica* Saak.-Ges., *G. bolivariana* (Petters), *Globorotaloides suteri* Bolli, *Globigerapsis index* (Finl.) and *G. tropicalis* Bann. et Blow. A few *Truncorotaloides topilensis* (Cushm.), *Globorotalia spinulosa* Cushm., *G. lehneri* Cushm. et Jarv., *Hantkenina alabamensis* Cushm., and in the very top of the zone–*Cribrohantkenina inflata* (Howe) were seen. The zone is 6 meters thick on Horizon Ridge.

The assemblage of planktonic foraminifera of the Upper Eocene *Globigeirna corpulenta* Zone consists of numerous *Globigerina corpulenta* Subb., *G. pseudovenezuelana* Bann. et Blow, *G. tripartita* Koch, *G. praebulloides* Blow, *Pseudohastigerina micra* (Cole), *Globigerinita unicava* (Bolli, Loebl. et Tapp.), *Globorotalia centralis* Cushm. et Berm., *G. armenica* Saak-Ges., *Hantkenina suprasuturalis* Bronn., *Cribrohantkenina inflata* (Howe) associated with more scarce *Globigerapsis tropicalis* Bann. et Blow and single *Hantkenina alabamensis* Cushm. and *Globorotalia increbescens* (Bandy). The zone is 9 meters.

The *Globigerina corpulenta* has two subzones. The lower one being *Globigerapsis semiinvoluta* (Keijz.); sporadic *G. index* (Finl.) also occur, and in the base of the subzone one *Truncorotaloides rohri* Bronn. et Berm. was found. In the upper *Globorotalia cerroazulensis* Subzone *G. cerroazulensis* (Cole) and *Globigerina gortanii* Bors. (= *G. turritilina* Bann. et Blow) occur invariably in the upper part; *Globorotalia pseudoampliapertura* Bann. et Blow, *G. postcretacea* (Mjatl.), *Globigerina officinalis* Subb., *G. ampliapertura* Bolli are common.

Lower Oligocene deposits (the *Globigerina ampliapertura* Zone) were penetrated on Horizon Ridge (Site 44). Planktonic foraminifera are represented by numerous *Globigerina ampliapertura* Bolli, *G. ampliapertura auapertura* Jenk., *G. pseudovenezuelana* Bann. et Blow, *G. officinalis* Subb., *G. ouachitaensis* Howe et Wall., *G. angustiumbilicata* Bolli, *G. praebulloides* Blow, *G. sellii* Bors. (= *G. oligocaenica* Bann. et Blow), *Globorotalia postcretacea* (Mjatl.), *Cassigerinella chipolensis* (Cushm. et Pont.), *Chiloguembelina cubensis* (Palm.), *Pseudohastigerina barbadoensis* Blow, less distributed *Globigerina tripartita* Koch, *G. tapuriensis* Bann. et Blow, *Globigerinita unicava* (Bolli, Loebl. et Tapp.), *Globorotalia opima nana* Bolli, *G. increbescens* (Bandy) and scarce *Globigerina ciperoensis* Bolli, *G. senilis* Bandy, *G. gortanii* Bors. and *G. pseudoampliapertura* Bann. et Blow. A minimum thickness for this zone is 9 meters on Horizon Ridge, but the upper boundary was not cored.

Upper Oligocene deposits (the *Globigerina ciperoensis* Zone) have been recognized on the Caroline Ridge (Holes 56.2, 57.0, 57.1). The assemblage consists of abundant *Globigerina ciperoensis* Bolli, *G. angulisuturalis* Bolli, *G. angustiumbilicata* Bolli, *G. ouachitaensis* Howe et Wall., *G. praebulloides* Blow, *G. pseudoedita* Subb., *Globorotalia brevispira* (Subb.), *Cassigerinella chipolensis* Cushm. et Pont.), with less common *Globorotalia opima nana* Bolli, *G. inaequiconica* Subb., *Globigerina senilis* Bandy and *G. tripartita* Koch. Scarce *Globorotalia opima* Bolli occur in basal beds and in the upper part–*Globorotalia pseudokugleri* Blow, *G. siakensis* (LeRoy), and *Globigerina woodi* Jenk. At the very top *Globigerinoides trilobus promordius* Bann. et Blow occurs rarely. The zone is 22 meters thick; however, its lower boundary was not seen.

No Middle Oligocene sediments were discovered in the northwest Pacific.

NEOGENE

There are many interpretations of where the Paleogene-Neogene boundary should be placed. Two are worthy of special consideration: the top of the *Globorotalia kugleri* Zone (Bolli, 1957c) and the bottom of the *Globorotalia kugleri* Zone (Bronniman and Rigassi, 1963, Blow, 1969). The rich fauna of planktonic foraminifera in Oligocene and Miocene chalk oozes of the northwest Pacific indicate that the second alternative is more favorable. This is because across the boundary of the *Globigerina ciperoensis/Globorotalia kugleri* Zones the change of planktonic foraminiferal fauna is more abrupt than across the *Globorotalia kugleri/ Globigerinita dissimilis* Zone. Many new species appear at the *G. ciperoensis/G. kugleri* boundary and then persist through the *Globigerinita dissimilis* Zone of undoubtedly Miocene age–*Globigerina juvenilis* Brady, *G. woodi* Jenk., *G. bradyi* Wiesn., *G. venezuelana* Hedb., *Globigerinita dissimilis* (Cushm. et Berm.), *Globoquadrina praedehiscens* Bann. et Blow and *Globorotalia siakensis* (LeRoy). Some of them (*G. juvenilis, G. bradyi, G. woodi*) are most numerous in the *Globorotalia kugleri* Zone; others (*G. venezuelana, G. dissimilis, G. praedehiscens*) reach their acme in the *Globigerinita dissimilis* Zone. Beginning from the *Globorotalia kugleri* Zone, *Globigerinoides trilobus primordius* Bann. et Blow becomes a stable but small element of the microfauna. This is exactly the position where *Globigerinoides* datum-plane should be placed. On the other hand, *Globigerina ciperoensis* Bolli and *G. angulisuturalis* Bolli, so typical of the Oligocene, barely cross the bottom of the *Globorotalia kugleri* Zone.

Further confirmation for placing the Paleogene/Neogene boundary here should be sought in the fauna of smaller and larger (Nummulitidae, Miogypsimidae) benthonic foraminifera.

In a recently published zonal scheme of the Mediterranean Miocene (Cati *et al.,* 1968) the Paleogene-Neogene boundary is drawn in the middle part of the *Globorotalia kugleri* Zone of the Caribbean where representatives of *Globigerinoides* begin to appear. This author cannot agree with this point of view because in Oligocene and Miocene deposits of the Caroline Ridge *Globigerinoides trilobus* is known already in the top of the *Globigerina ciperoensis* Zone, whereas at its contact with the *Globorotalia kugleri* Zone a change of the whole complex of planktonic foraminifera takes place.

Miocene

Subdivision of the Miocene into subseries is based on a more standard variant: the lower boundary of the Middle Miocene is considered the datum-plane of *Candorbulina universa* (= *Orbulina suturalis*), the upper boundary of Middle Miocene is drawn along the top of the Tortonian Stage. In this case Lower Miocene includes three zones–*Globorotalia kugleri, Globigerinita dissimilis* and *Globigerinatella insueta* (with three subzones); Middle Miocene two zones–*Globorotalia fohsi* and *Globorotalia menardii* (with two subzones); and, one zone *Globorotalia miocenica* corresponds to Upper Miocene.

Lower Miocene

Deposits of the *Globorotalia kugleri* Zone were found on the Caroline Ridge at present water depths of 2850 to 3300 meters (Holes 55.0, 56.2, 57.0, 51.1), at the foot of the Ridge, where the depths reach 4500 meters (Holes 58.1, 58.2), and on the abyssal plain of the Pacific Ocean eastwards from Guam at a depth of 5547 meters (Hole 58.2).

Chalk oozes of the Caroline Ridge are characterized by abundant *Globorotalia kugleri* Bolli, *Globigerina bradyi* Wiesn., *G. juvenilis* Bolli, *G. angustiumbilica* Bolli, *G. praebulloides* Blow, *Globigerinita unicava* (Bolli, Loebl. et Tapp.) and *Cassigerinella chipolensis* (Cushm. et Pont.). Less common are *Globorotalia brevispira* (Subb.), *G. siakensis* (LeRoy), *Globigerina venezuelana* Hedb., *G. tripartita* Koch, *G. woodi* Jenk., *G. pseudoedita* Subb., *Globoquadrina praedehiscens* Bann. et Blow, and rather rare are *Globigerinita dissimilis* (Cushm. et Berm.), *G. naparimaensis* Bronn., *Globigerina ouachitaensis* Howe et Wall., *Globorotalia opima nana* Bolli, *G. obesa* Bolli and *G. increbescens* (Bandy). In the lower part of the zone there are many *Globorotalia pseudokugleri* Blow, and sporadic *Globigerina ciperoensis* Bolli and *G. angulisuturalis* Bolli.

A few specimens of *Globigerinoides trilobus primordius* Bann. et Blow appear in basal beds of the *Globorotalia kugleri* Zone. Distribution of this species is sporadic. In Hole 56.2, *Globigerinoides trilobus primodius* was found in all the samples; a few were found in Holes 55.0 and 57.1, and none were found in Hole 57.0.

Gray and light red-brown marl ooze, with abundant Radiolaria and sponge spicules was penetrated at Site 58 at the foot of the Caroline Ridge. This marl contains a poor fauna of planktonic foraminifera. Only in some interbeds are foraminifera relatively numerous–*Globorotalia kugleri, G. siskensis, Globigerina bradyi, G. juvenilis, G. angustiumbilicata, Globigerinita unicava, Cassigerinella chipolensis*, but even here they are subordinate to Radiolaria. *Globigerinoides trilobus* was not observed at all.

There are almost no planktonic foraminifera in red-brown clays and radiolarian oozes of the abyssal plain of the Pacific Ocean (Hole 59.2) attributed to the *Globorotalia kugleri* Zone. *Globorotalia kugleri, Globigerina bradyi, G. praebulloides, G. angustiumbilicata, Cassigerinella chipolensis* were seen rarely.

The contact between *Globorotalia kugleri* and *Globigerina ciperoensis* was seen in Holes 56.2, 57.0, and 57.1, and between *Globorotalia kugleri* and *Globorotalia dissimilis* in Hole 55.0. However, the top and bottom of the *Globorotalia kugleri* Zone were not seen in the same hole. Therefore the total thickness of the zone is unknown, but in Hole 56.2 it must have a maximum thickness of about 50 meters.

The *Globigerinita dissimilis* Zone was only penetrated in Hole 55.0 on the Caroline Ridge. Chalk oozes of this zone are 12 meters thick here. The zone is defined by the development of *Globigerina venezuelana* Hedb., *Globigerinita dissimilis* (Cushm. et Berm.), *G. stainforthi* (Bolli, Loebl. et Tapp.), *Globoquadrina praedehiscens* Bann. et Blow, *G. altispira globosa* Bolli, *Globorotalia siakensis* (LeRoy) and *G. minutissima* Bolli. Together with them may be found *Globigerina bradyi* Wiesn., *G. juvenilis* Bolli, *G. angustiumbilicata* Bolli, *G. pseudoedita* Subb., *Cassigerinella chipolensis* (Cushm. et Pont.) and scarce *Globigerina woodi* Jenk. and *Globigerinita unicava* (Bolli, Loebl. et Tapp.) passing from underlying deposits. In all samples *Globigerinoides trilobus trilobus* (Reuss) only occurs rarely.

Basal beds of the *Globogerinita dissimilis* Zone are characterized by scarce *Globigerina tripartita* Koch and sporadic *Globorotalia kugleri* Bolli. The latter species disappears very suddenly at the boundary of the *Globorotalia kugleri*/*Globigerinita dissimilis* Zones. The upper part of the zone is distinguished by *Globigerina foliata* Bolli, *Globoquadrina altispira altispira* (Cushm. et Jarv.) and *G. dehiscens* (Chapm., Parr et Coll.). This may correspond to the *Globigerinita stainforthi* Zone of Trinidad that was separated by Bolli (1957c). However, subdivision of the *Globigerinita dissimilis* Zone of the Caroline Ridge into two independent stratigraphic units (the *Globigerinita dissimilis* and *G. stainforthi* Zones as interpreted by Bolli) is extremely difficult, since these two index-species occur in equal numbers throughout.

The *Globigerinatella insueta* Zone at the top of the Lower Miocene was seen in Hole 55.0 on the Caroline Ridge, where it reaches a thickness of 27 meters. Among planktonic foraminifera prevail *Globigerinoides trilobus* (Reuss), *G. subquadratus* Bronn., *G. diminuta* Bolli, *Globoquadrina altispira* (Cushm. et Jarv.), *G. dehiscens* (Chapm., Parr et Coll.), *G. quadraria* (Cushm. et Ell.), *G. langhiana* Cita et Gel., *Globigerina foliata* Bolli, *G. falconensis* Blow, *G. bollii* Cita et Premoli Silva, *G. juvenilis* Bolli, *Globorotalia obesa* Bolli and *G. siakensis* (LeRoy); less numerous are *Globorotalia peripheroronda* Bann. et Blow, *G. minutissima* Bolli, *Globigerina angustiumbilicata* Bolli and *Cassigerinella chipolensis* (Cushm. et Pont.). The zonal species–*Globigerinatella insueta* Cushm. et stainf. was found throughout the zone but only rarely. In the lower part of the zone are a few *Globoquadrina praedehiscens* Bann. et Blow, *Globigerinita stainforthi* (Bolli, Loebl. et Tapp.), *G. dissimilis* (Cushm. et Berm.), *Globigerina venezuelana* Hedb., *G. bradyi* Wiesn., and in the top of the zone there appears *Sphaeroidinellopsis grimsdalei* (Keijz).

Based on stratigraphical distribution of *Globigerinoides bisphaerica* Todd and *Praeorbulina transitoria* (Blow), deposits of the *Globigerinatella insueta* Zone of the Caroline Ridge may be subdivided into three parts: the lower subzone with various globoquadrinas, globigerinas and *Globigerinoides trilobus* (thickness about 8 meters); the middle subzone with *Globigerinoides bisphaerica* (thickness about 8 meters); the middle subzone with *Globigerinoides bisphaerica* (thickness about 7 meters); and, the upper subzone with *Praeorbulina transitoria* (thickness about 12 meters). Taking into consideration the terminology given in the paper by Cati, Bizon, *et al.* (1968), they may be named as *Globoquadrina dehiscens, Globigerinoides bisphaerica, Praeorbulina glomerosa* subzones, respectively. These stratigraphical units should be considered precisely as subzones. The Miocene deposits of the Caroline Ridge support this opinion. *Globigerinoides bisphaerica* is not abundant here, *Praeorbulina transitoria* is rare, and *Praeorbulina glomerosa glomerosa* absent so the boundaries of the subzones may only be drawn approximately.

Middle Miocene

Middle Miocene deposits (the *Globorotalia fohsi* and *Globorotalia menardii* Zones) were recovered from Holes 55.0 and 56.2 on the Caroline Ridge, Holes 53.0 and 54.0 in the Philippine Sea, and 60.0 east of Guam.

On the Caroline Ridge the *Globorotalia fohsi* Zone contains *Sphaeroidinellopsis grimsdalei* (Keijz) (this name seems to be a synonym of *S. seminulina* Schwager), *Sph. rutschi* Cushm. et Renz, *Globorotalia altispira* (Cushm. et Jarv.), *G. dehiscens* (Chapm. Parr et Coll.), *Globorotalia mayeri* Cushm. et Ell., *G. obesa* Bolli, *Globigerina concinna* Reuss, *G. foliata* Bolli, *G. falconensis* Blow, *Globigerinoides trilobus* (Ruess) and *G. subquadratus* Bronn. Considerably less abundant are *Candorbulina universa* Jedl. (= *Orbulina saturalis* Bronn.), *Globorotalia fohsi* Cushm. et Ell., *G. peripheroacuta* Bann. et Blow, *G. praemenardii* Cushm. et Stainf., *G. peripheronda* Bann. et Blow and *Globigerinoides irregularis* LeRoy, though it is these species that are important for the age determination of sediments. Quite sporadic are *Biorbulina bilobata* (d'Orb.), *Globigerinoides aguasayensis* Bolli, and in the lower part of the zone–*Globigerinoides bisphaerica* Todd, *Praeorbulina transitoria* (Blow) and *P. glomerosa* (Blow). The *Globorotalia fohsi* Zone has a total thickness of 23 meters in Hole 55.0.

In the Philippine Sea limy-clayey volcanic ashes are characterized by very rare and small planktonic foraminifera, though their specific composition is varied–*Candorbulina universa* Jedl., *Globorotalia obesa* Bolli, *G. praemenardii* Cushm. et Stainf., *G. scitula praescitula* Blow, *G. mayeri* Cushm. et Ell., *G. mohleri* Bolli et Berm., *Globigerinoides trilobus* (Reuss), *G. irregularis* LeRoy, *Globigerina parabulloides* Blow, *G. foliata* Bolli, *G. concinna* Reuss, *Globoquadrina dehiscens* (Champ., Parr et Coll.); *Globigerinoides bisphaerica* Todd, *Praeorbulina glomerosa* (Blow) and *P. transitoria* (Blow) are sporadic. Thickness of deposits of the *Globorotalia fohsi* Zone in the Philippine Sea exceeds 75 meters.

The *Globorotalia menardii* Zone of the Caroline Ridge is characterized by abundant *Orbulina universa* d'Orb., *Globorotalia menardii* (d'Orb.), *G. acostaensis* Blow, *G. merotumida* Bann. et Blow, *Globigerinoides obliquus* Bolli, *G. bollii* Blow, *G. aff. sacculifera* (Brady), *G. trilobus* (Reuss), *Globigerina nepenthes* Todd, *G. bulloides* d'Orb., *G. concinna* Reuss, *G. parabulloides* Blow, *G. aff. bradyi* Wiesn., *G. microstoma* Cita, Premoli Silva et Rossi, *Globoquadrina altispira* (Cushm. et Jarv.), *G. larmeui obesa* Akers, *Sphaeroidinellopsis subdehiscens* Blow, *S. grimsdalei* (Keiijz.) and *S. rutschi* Cushm. et Renz. Less frequently are observed *Globorotalia mayeri* Cushm. et Ell., *G. obesa* Bolli, *G. pseudopachyderma* Cita, Premoli Silva et Rossi, *G. continuosa* Blow, *Globigerinoides elongatus* (d'Orb.), *Globigerina bulbosa* LeRoy, *G. globorotaloidea* Colom, *G. decoraperta* Tak. et Saito, *Globoquadrina dehiscens* (Champ., Parr et Coll.) and *Globigerinita glutinata* (Egger). Relatively rare species of planktonic foraminifera are *Globorotalia scitula* (Brady), *G. lenguaensis* Bolli, *Globigerina apertura* Cushm., *G. quinqueloba* Natl. and *Hastigerina* *siphonifera* (d'Orb.). In the lower part of the zone sporadic *Candorbulina universa* Jedl. are observed, whereas at the very top *Globorotalia tumida plesiotumida* Bann. et Blow appears.

The *Globorotalia menardii* Zone may be subdivided into two subzones, the boundary between them being rather indistinct. In the lower subzone *Globorotalia mayeri* disappears, and in the upper subzone *Globorotalia acostaensis, G. continuosa* and *G. merotumida* appear. The rest of the planktonic foraminiferal species are common to both subzones. The total thickness of the *Globorotalia menardii* Zone is 18 meters in Hole 56.2. In Hole 55.0 the thickness increases to 23 meters.

The *Globorotalia menardii* Zone was seen in one sample from Hole 53.0. Though planktonic foraminifera are very rare and small here, their composition is rather diverse: *Orbulina universa, Globorotalia menardii, G. lenguaensis, G. mayeri, G. obesa, Sphaeroidinellopsis grimsdalei, S. rutschi, Globigerina nepenthes, G. bulloides, G. bulbosa, Globigerinoides trilobus, G. altiapertura, G. bolli, G. adriatica* (Forn.), *Globorotaloides variabilis* Bolli, *Globoquadrina altispira, G. larmeui, G. dehiscens* and *Biorbulina bilobata.*

Upper Miocene

Upper Miocene deposits (the *Globorotalia miocenica* Zone) were recognized on the Caroline Ridge (Holes 56.2 and 57.2) and on the Shatsky Rise (Holes 47.2, 48.1, 48.2). Different assemblages of Upper Miocene planktonic foraminifera occur in each area.

On the Caroline Ridge chalk oozes contain: *Globorotalia multicamerata* Cushm. et Jarv., *G. acostaensis acostaensis* Blow, *G. aconstaensis humerosa* Tak. et Saito, *G. tumida plesiotumida* Bann. et Blow, *G. tumida tumida* (Brady), *Globigerinoides obliquus* Bolli, *G. obliquus extremus* Bolli et Berm., *G. sacculifera* (Brady), *Globigerina nepenthes* Todd, *G. bulloides* d'Orb., *Globoquadrina altispira* (Cushm. et Jarv.), *Sphaeroidinellopsis subdehiscens* Blow, *S. subdehiscens paenedehiscens* Blow, *S. seminulina* (Schw.) and *Orbulina universa* d'Orb. Less common are *Globorotalia margaritae* Bolli et Berm., *G. menardii* (d'Orb.), *Globigerinoides trilobus* (Reuss), *Globigerina apertura* Cushm. and *G. microstoma* Cita, Premoli Silva et Rossi; and, rarely *Globorotalia miocenica* Palm., *Hastigerina siphonifera* (d'Orb)., *Biorbulina bilobata* (d'Orb.) and *Candorbulina* sp.

In Hole 57.1 *Pulleniatina primalis* Bann. et Blow is numerous, whereas in Hole 56.2 this species was rare.

The *Globorotalia miocenica* Zone of the Caroline Ridge is subdivided into two subzones: the *Globorotalia tumida plesiotumida* Zone where the index-species and *Sphaeroidinellopsis subdehiscens subdehiscens* may be often observed, and the upper *Globorotalia tumida tumida–Sphaeroidinellopsis subdehiscens praedehiscens* Subzone where two index-species are well developed. The thickness of Upper Miocene deposits on the Caroline Ridge is 9 meters, but none of the holes contained both the Middle Miocene and Pliocene contacts.

Predominant among planktonic foraminifera of the *Globorotalia miocenica* Zone of the Shatsky Rise are *Globorotalia miozea saphoae* Bizon accomplished by *G. margaritae* Bolli et Berm., *G. tumida plesiotumida* Bann. et Blow, *G. miroensis* Perc., *G. acostaensis* Blow, *G. gavalae* Perc., *G. incompta* (Cifelli), *Sphaeroidinellopsis subdehiscens* Blow, *S. seminulina* (Schw.), *Globigerina bulloides* d'Orb., *G. nepenthes* Todd, *G. microstoma* Cita, Premoli Silva et Rossi, *G. parabulloides* Blow, *Globoquadrina altispira* (Cushm. et Jarv.), *G. conglomerata* (Schw.), *Globigerinita glutinata* (Egger) and *Orbulina universa* d'Orb. The following species are found in small numbers: *Globorotalia miocenica* Palmer, *G. multicamerata* Cushm. et Jarv., *G. tumida tumida* (Brady), *Globigerinoides obliquus extremus* Bolli et Berm., *Globigerina apertura* Cushm., *Sphaeroidinellopsis subdehiscens paenedehiscens* Blow, and quite sporadic are *Globorotalia merotumida* Bann. et Blow, *Globoquadrina dehiscens* (Chapm., Parr et Coll.), *Hastigerina siphonifera* (d'Orb.) and *Biorbulina bilobata* (d'Orb.).

In Upper Miocene deposits of the Shatsky Rise the *Globorotalia tumida tumida plesiotumida* and *Globorotalia tumida tumida–Sphaeroidinellopsis subdehiscens paenedehiscens* Subzones can be observed very indistinctly, since the index-species are rare. The *Globorotalia miocenica* Zone of the Shatsky Rise is about 17 meters thick. The *Globorotalia miocenica* Zone of the northwest Pacific corresponds to the Messinian Stage of the Mediterranean. However, the Messinian deposits of northern Italy, Greece and Syria contain a more varied fauna.

Pliocene

Pliocene sediments occur on Shatsky Rise (Holes 47.2 and 48.2) and Caroline Ridge (Holes 55.0 and 57.2). The assemblages of planktonic foraminifera differ considerably in each place.

Pliocene planktonic foraminifera have undergone great changes as compared to the Upper Miocene ones. Their specific composition, however, remains almost constant throughout the Pliocene. The Pliocene of the northwest Pacific can be divided into a lower and upper part with similar assemblages.

Chalk oozes of the Caroline Ridge are characterized by abundant *Sphaeroidinella dehiscens* (Park. et Jon.), *Globorotalia tumida tumida* (Brady), *G. cultrata* (d'Orb.), *G. acostaensis humerosa* Tak. et Saito, *G. multicamerata* Cushm. et Jarv., *Pulleniatina obliquiloculata* (Park. et Jon.), *Globigerinoides conglobatus* (Brady), *G. sacculifera* (Brady), *G. ruber* (d'Orb.), *G. fistulosus* (d'Orb.), *Orbulina universa* d'Orb. and *Globigerina eggeri* Rhumb. They are accompanied by less frequent *Globorotalia crassaformis* Gall. et Wissl., *G. crassaformis oceanica* Cushm. et Berm., *G. inflata* (d'Orb.), *G. dutertrei* (d'Orb.), *G. ungulata* Berm., *Globoquadrina conglomerata* (Schw.) and sporadic *Globorotalia hirsuta* (d'Orb.), *Hastigerina siphonifera* (d'Orb.) and *Candeina nitida* d'Orb.

In the lower part of the Pliocene *Globorotalia acostaensis pseudopima* Blow are common, and Miocene *Globoquadrina altispira* (Cushm. et Jarv.) becomes extinct. In the upper part of the Pliocene *Globorotalia tosaensis* Tak. et Saito is developed, and *G. inflata* (d'Orb.) and *G. crassaformis* Gall. et Wissl. become more common.

The lower part of the Pliocene seems to correspond to the *Sphaeroidinella dehiscens–Globoquadrina altispira* and *Globorotalia multicamerata–Pulleniatina obliquiloculata* Zones of the stratigraphic scale compiled by Blow (1969), whereas the upper part corresponds to the *Globorotalia tosaensis tenuitheca* Zone. Since the differences between the planktonic foraminiferal assemblages from the lower and upper parts of the Pliocene are not significant, it would be more expedient to regard these subdivisions as zones or even subzones; in addition, the boundary between them is not distinct enough because the stratigraphic intervals of the *Globoquadrina altispira* and *Globorotalia tosaensis* overlap one another to a certain extent. A minimum thickness for Pliocene deposits on the Caroline Ridge is 18 meters.

Lower Pliocene deposits on the Shatsky Rise have not been established with certainty. They are either completely absent, or considerably reduced in thickness. Chalk oozes from the Upper Pliocene are characterized by abundant *Globorotalia crassaformis oceanica* Cushm. et Berm., *G. crassaformis crassaformis* Gall. et Wissl., *G. crassaformis ronda* Blow, *Globigerina bulloides* d'Orb., *G. parabulloides* Blow, *G. apertura* Cushm., *G. concinna* Reuss. These species are accompanied by *Globorotalia tumida tumida* (Brady), *G. cultrata* (d'Orb.), *G. multicamerata* Cushm. et Jarv., *G. inflata* (d'Orb.), *G. ungulata* Berm., *Globigerinoides conglobatus* (Brady), *G. ruber* (d'Orb.), *G. sacculifera* (d'Orb.), *Orbulina universa* d'Orb., *Globigerinita glutinata* (Egger), *Sphaeroidinella dehiscens* (Park. et Jon.) and sporadic *Globorotalia tosaensis* Tak. et Saito. Pliocene deposits reach a thickness of 21 meters on Shatsky Rise.

QUATERNARY DEPOSITS

Chalk oozes and limey clays with abundant planktonic foraminifera of Quaternary age were penetrated by holes on Shatsky Rise (47.0, 47.2, 49.1) and Caroline Ridge (55.0 and 58.1). The specific composition in the two regions was somewhat different.

On the Caroline Ridge most numerous are: *Pulleniatina obliquiloculata* (Park. et Jon.), *Globorotalia tumida* (Brady), *G. cultrata* (d'Orb.), *G. truncatulinoides* (d'Orb.), *G. acostaensis humerosa* Tak. et Saito, *Sphaeroidinella dehiscens* (Park. et Jon.), *S. dehiscens excavata* Blow, *Globigerinoides conglobatus* (Brady), *G. ruber* (d'Orb.) and *G. sacculifera* (Brady). Together with them may be found less common *Globorotalia crassaformis* Gall. et Wissl., *G. ungulata* Berm., *G. puncticulata* (Deh.), *G. inflata* (d'Orb.), *G. dutertrei* (d'Orb.), *Globigerina bulloides* d'Orb., *G. eggeri* Rhumb., *G. calida praecalida* Park., *G. digitata praedigitata* Park., *Orbulina universa* d'Orb., *Hastigerina siphonifera* (d'Orb.), *Globigerinoides fistulosus* (d'Orb.) and rare *Globorotalia hirsuta* (d'Orb.) and *Candeina nitida* d'Orb.

In chalk oozes of Shatsky Rise *Globorotalia truncatulinoides, G. puncticulata, G. inflata, G. bulloides, G. concinna, G. quinqueloba, Globigerinita glutinata* and sometimes *Globorotalia crassaformis oceanica,* and *G. crassaformis crassaformis* predominate. Other foraminiferal species are less common–*Sphaeroidinella dehiscens, Pulleniatina obliquiloculata, Globorotalia tumida, G. cultrata, G. hirsuta, G. acostaensis humerosa, Globigerinoides ruber, G. sacculifera,* etc.

The same annual distribution pattern seen in the Pliocene persists into the Quaternary on the Shatsky Rise and Caroline Ridge. These microfaunistic differences were seen as far back as the Upper Miocene (for older sediments, no comparative data is available).

The lower boundary of Quaternary deposits is drawn along the datum-plane of wide distribution of *Globorotalia truncatulinoides.* The stratigraphic intervals *G. truncatulinoides* and *G. tosaensis* overlap one another slightly. The latter species occurs in the basal part of Quaternary deposits, but as isolated specimens. The Quaternary deposits reach 18 meters in thickness.

THE MAIN RESULTS

The excellent Paleogene and Neogene sections containing abundant planktonic foraminifera recorded from the Northwest Pacific permit us to draw certain stratigraphic conclusions. The conclusions are of a great importance not only in understanding the Cenozoic stratigraphy of the northwest Pacific, but also in helping to establish a universally accepted zonation for the Cenozoic.

1. The Paleogene and Neogene planktonic foraminiferal faunas in the cores recovered from the northwest Pacific are characterized by the same species

assemblage and faunal succession as reported from other areas in the Pacific, Caribbean, Mediterranean, Indian and Crimean-Caucasian region.

It is noteworthy that the Paleogene fauna present in the Pacific contains the species described by Subbotina, Morozova, Myatlyuk, Shutskaya, Chalilov, Bykova, Saakyan-Gezalyan that are very seldom mentioned in micropaleontological studies outside the USSR. These species are not endemic as might at first appear from the literature. To such species belong: *Globigerina taurica, G. eobulloides, G. theodosica, G. tetragona, G. pentagona, G. hemisphaerica, G. fringa, G. trivialis, G. varianta, G. edita, G. bacuana, G. quadritriloculinoides, G. nana, G. pileata, G. compressaformis, G. pseudoeocaena, G. inaequispira, G. frontosa, G. posttriloculinoides, G. azerbaijanica, G. pseudocorpulenta, G. incretacea, G. turcmenica, G. corpulenta, G. officinalis, G. pseudoendita, Acarinina praecursoria, A. indolensis, A. schachdagica, A. inconstans, A. multioculata, A. acarinata, A. intermedia, A. pseudotopilensis, A. triplex, A. camerata, A. interposita, A. pentacamerata, A. rotundimarginata, A. rugosoaculeata, Globorotalia conicotruncata, G. kubanensis, G. kolchidica, G. takjikistanensis, G. imitata, G. convexa, G. subbotinae, G. marginodentata, G. lensiformis, G. caucasica, G. planoconica, G. armenica, G. postcretacea, G. brevispira, G. inaequiconica, Gumbelitria irregularis* and *Chilogumbelina taurica.* The foraminifera of the northwest Pacific are not provincial and consequently provide an excellent framework for world-wide correlation. Evolution within the faunas of the tropical-subtropical belts proceeded synchronously and on a world-wide basis. It follows, therefore, that there is no need for a speical zonation of the Pacific Cenozoic.

In the future it is necessary to unify the chronostratigraphic zonal units of the universal zonal scale.

2. In the monotonous chalk oozes of the Shatsky Rise, Caroline Ridge and Horizon Ridge, the boundaries between stratigraphic subdivisions are gradual and one frequently finds mixed or transitional faunas at zonal boundaries. Foraminifera characteristic or restricted to one zone may also appear at the very top of the underlying zone. However, the transitional layers are much thinner than adjacent zones.

In continental sections, faunal changes are also gradual in monotonous lithologic sections. However, lithological boundaries frequently coincide with chronostratigraphic ones, and a change in the planktonic microfauna appears very abrupt.

Continuous sections of pelagic chalk oozes present an "ideal model" for working out a universal zonation of the Paleogene and Neogene because of the abundance of planktonic foraminifera and the excellent preservation of their shells. It is this type of zonation that may serve as a basis for a generally accepted scale of stages, series and sub-series. Of special importance in biostratigraphy are the oceanic sediments which correspond to the time span of tectonic movements and regressions on the continents.

In the Mediterranean and Europe continuous sequences of marine deposits of Upper Oligocene-Lower Miocene with rich planktonic foraminifera are extremely rare. For this reason serious controversies exist over the Paleogene-Neogene boundary. The pelagic chalk ooze of the Caroline Rise shows clearly that the bottom of the Neogene should be drawn at the base of the *Globorotalia kugleri* Zone.

Excellent data on Upper Miocene planktonic foraminifera have been obtained from the sites on the Shatsky Rise and Caroline Ridge. This greatly helps in making up the deficiency elsewhere in the world where similar sediments are represented by continental or shallow water sediments.

3. Continuous sequences of pelagic chalk oozes only approach an "ideal model." In the sections examined from the northwest Pacific, species that play a very important role in subdividing the Paleogene and Neogene deposits on the continents are absent or very rare. The *Globorotalia subbotinae* Zone of the Lower Eocene, for instance, practically lack *Pseudohastigerina wilcoxensis* (the lower boundary of Eocene is determined by the *Pseudohastigerina* datum-plane). There is no *Globorotalia palmerae* in the *Globorotalia aragonensis* Zone of Lower Eocene (the upper part of this zone being named by Bolli as the *G. palmerae* Zone). The *Globigerinatella insueta* Zone (Burdigalian Stage) is characterized by rare *Globigerinoides bisphaerica* and *Praeorbulina transitoria,* whereas *P. glomerosa* is absent almost completely. Therefore, the subdivision of the *Globigerinatella insueta* Zone into subzones in sections on the Caroline Ridge is rather difficult, whereas the subzones can be easily recognized in the Lower Miocene deposits of the Caribbean and Mediterranean. The bottom of the Middle Miocene can usually be determined by abundant *Candorbulina universa* and *Hastigerina siphonifera,* but in the sections of Miocene deposits of the Caroline Ridge they occur sporadically, as though being replaced by the *Sphaeroidinellopsis* species.

Therefore, when establishing zones and subzones, complete planktonic foraminiferal assemblages must be considered, not just their index species. Furthermore, a universal zonal scale of Cenozoic deposits should be based on planktonic foraminifera from both continents and oceans.

4. Local assemblages of planktonic foraminifera reflect the influence of local bionomic conditions.

The assemblages of foraminifera from the Paleogene pelagic oozes of the Shatsky Rise are characterized by: (1) An extremely high percentage of planktonic forms (benthonic foraminifera make up less than 1 per cent of total); (2) very large shell size for a given foraminiferal species; (3) sculptural ornamentation of shell-spinosity, thickened keel and sometimes septal sutures, ornamented umbilical ends of chambers, such as the high-conical shells of *Globorotalia velascoensis, G. acuta, G. conicotruncata, G. aragonesis, G. caucasica;* (4) a different combination of foraminiferal species than is present in the Paleogene on continents. Globorotalias and carininas usually prevail over globigerinas, and in the *Acarinina uncinata* Zone *A. incinata, A. praecursoria, A. schachdagica* dominate; in the *Globorotalia angulata* Zone, *Acarinina multiloculata* is abundant; *G. pasionesis, G. hispidicidaris, G. apanthesma* are abundant in the *Globorotalia velascoensis* Zone.

Such an assemblage (outlined in (4) above) from the Shatsky Rise is quite different from that obtained in chalky limestones and marls of Syria, UAR, and the Crimean-Caucasian region. This indicates that the formation of chalky limestones and marls in marginal parts of the African, Arabian and Russian Platforms took place at considerably lesser depths than in the northwest Pacific.

5. The planktonic foraminifera in any zone change as a function of geographical latitude. It is difficult to analyze these changes in Paleogene and Neogene deposits from the continents because the local conditions of sedimentation can obscure the influence of climatic zonation. Pelagic sediments of the oceans enable us to study the effect of climatic belts on specific composition without any interference from other sources.

The Paleogene and Neogene deposits of Shatsky Rise and Caroline Ridge are separated (along meridian) by a distance of over 3000 kilometers. These sections, however, do not overlap one another stratigraphically, but supersede one another except for the Upper Miocene and Pliocene deposits. Consequently, comparison of Upper Miocene and Pliocene planktonic foraminifera of the Shatsky Rise and Caroline Ridge reveals certain differences which seem to depend purely upon climatic conditions.

The list of planktonic foraminifera for the Upper Miocene of the two given regions is similar. But in the sections of the Caroline Ridge, *Globorotalia multicamerata, G. tumida tumida, G. tumida plesiotumida, G. acostaensis humerosa, Globigerinoides sacculifera, Sphaeroidinellopsis subdehiscens paenedehiscens, Pulleniatina primalis* predominate. On the Shatsky Rise the common species are: *Globorotalia miozea saphoae, G. margaritae, G. miroensis, Sphaeroidinellopsis subdehiscens, Globigerina bulloides, G. microstoma, G. parabulloides* and *Globigerinita glutinata;* more frequent are *Globorotalia miocenica.*

The same is also true of Pliocene planktonic foraminifera. Especially numerous on the Caroline Ridge are: *Sphaeroidinella dehiscens, Pulleniatina obliquiloculata, Globigerinoides conglobatus, G. fistulosus, Globorotalia tumida tumida, G. acostaensis humerosa, G. multicamerata* and not frequently may be observed *Candeina nitida.* On the Shatsky Rise *Globorotalia crassaformis crassaformis, G. crassaformis oceanica* are abundant, and various species of *Globigerina, Globorotalia inflata* become more common.

On the whole, the Upper Miocene and Pliocene microfauna of the Shatsky Rise is more similar to that of the Mediterranean than planktonic foraminifera of the equatorial region of the Caroline Ridge.

6. The paleoecological characteristics were very stable throughout the Cenozoic in the northwest Pacific. A continuous section on the Shatsky Rise includes deposits from the Maestrichtian up to the basal layers of the Middle Eocene. However, benthonic foraminifera invariably make up one per cent or less of the specimens, being always represented by the deep-sea species *Pullenia, Sphaeroidina, Lenticulina, Nodosaria, Eponides, Cassidulina, Bulimina* and *Uvigerina.* Within this interval all changes in the specific composition of planktonic foraminifera are caused by evolutionary factors, not by the influence of local bionomic conditions as the water depth is considerable (2700 meters).

A similar picture can be observed on Horizon Ridge where a continuous section of Middle Eocene-Lower Oligocene was discovered. Benthonic foraminifera make up a constant 4 to 6 per cent of the total foraminiferal content. Sedimentation appears to have taken place at shallower depth (1400 meters), and local bionomic conditions on the Horizon Seamount have undergone slight changes. This resulted in variations of planktonic foraminiferal assemblages in the *Orbulinoides beckmanni* Zone. Variously *Orbulinoides beckmanni, Truncorotaloides,* or large globigerines, or *Globorotalia centralis* and *G. armenica* predominate. However, in the *Truncorotaloides rohri, Globigerina corpulenta* and *Globigerina ampliapertura* Zones the specific composition of the planktonic foraminifera is very constant.

The paleoecological constancy of the paleocoenoses of planktonic foraminifera and the monotony of Maestrichtian, Paleocene, Eocene and Oligocene sediments on the Shatsky Rise and Horizon Ridge indicate a constant depth of this part of the Pacific.

On the Caroline Ridge (present water depth 2900 to 3000 meters) radiolarians are more numerous in the Oligocene and Lower Miocene than in the Middle and

Upper Miocene. Also, either radiolarians or planktonic foraminiferas predominate in some layers. If radiolarians predominate, then the foraminiferas are impoverished in their specific composition. Evidently the depth of the ocean here was subject to fluctuations in the Oligocene and Miocene. The percentage of benthonic foraminifera is extremely small, and all of them are represented by inhabitants of great depths (species of *Laticarinina, Pullenia, Sphaeroidina, Uvigerina, Cassidulina, Pyrgo, Lenticulina*). Also, radiolarians are always found together with numerous planktonic foraminifera, thereby eliminating the possibility of sediment accumulation below the carbonate compensation depth. Therefore the fluctuations in water depth were only minor.

7. Disconformities and stratigraphic hiatuses also have been discovered in some of these relatively continuous sequences.

The largest hiatus was discovered on the western slope of Shatsky Rise where Upper Miocene rests on the basal beds of Middle Eocene (Hole 47.2). To the southwest Upper Miocene sediments rest on Cretaceous sediments. On the crest of the Rise the relation of Upper Miocene to underlying sediments is not known. The seismic profile, however, shows that a sequence of sediments of considerable thickness occurs here between Lower Eocene and Middle Miocene. Chalk oozes of Lower Pliocene age appear to be absent in Hole 47.2 as well.

On the Caroline Ridge in Hole 55.0, the Tortonian deposits are succeeded by Pliocene ones, and the Upper Miocene (Messinian Stage) is missing in the section; in the neighboring Hole 56.2, it is well represented.

Without further work it is difficult to estimate the extent of these stratigraphic breaks and suggest a mechanism for their formation.

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