17. MIDDLE AND LATE CENOZOIC PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY OF THE SOUTHWEST PACIFIC–DSDP LEG 21

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ABSTRACT

Planktonic foraminifera have been examined from eight DSDP sites in the southwest Pacific from the late Early Miocene to the Recent. The traverse of sites examined ranges from tropical to cool subtropical (temperate) regions. The stratigraphic ranges of the planktonic foraminifera of Middle to Late Cenozoic age in six of these sites are presented here. Large paleoenvironmental differences between the sites have made it necessary to use separate zonal schemes in cool subtropical (temperate), warm subtropical, and tropical areas. The planktonic foraminiferal zonations for the cool subtropical and warm subtropical regions are new. For the tropical sites the zonation scheme is that of Banner and Blow (1965) and Blow (1969). Species of *Globorotalia* represent the most useful forms for zonal subdivision and correlation with the region. In cool subtropical areas a valuable evolutionary bioseries is represented by gradation from *Globorotalia miozea conoidea* to *G. conomiozea* to *G. puncticulata* to *G. inflata.* In warm subtropical areas the evolution can also be observed from *G. puncticulata* to *G. inflata.* The ranges of numerous planktonic foraminifera differ markedly between the different regions because of the distinct environmental controls.

Sphaeroidinella dehiscens is of no value in the determination of the Miocene-Pliocene boundary throughout the area because it does not appear until the Middle Pliocene. In cool subtropical areas the first evolutionary appearance of *Globorotalia puncticulata* marks the boundary, while in warm subtropical areas this species appears later. In the warmer sites the first appearance of *Globorotalia margaritae* seems to be a reliable indication of the Miocene-Pliocene boundary.

The Pliocene-Pleistocene boundary is placed at the first appearance of *Globorotalia truncatulinoides.* In several sites the evolution of *G. truncatulinoides* from *G. tosaensis* near the boundary is not a simple continuum, but is marked by reversals in evolutionary trend that may be partly environmentally controlled.

Most of the important forms are illustrated by scanning electron micrographs.

INTRODUCTION

During Leg 21 of the Deep Sea Drilling Project, a total of eight sites cored yielded 1388 meters of core in the southwest Pacific (Figure 1). The coring of a series of sites ranging from present-day southern tropical latitudes (14°-15°S) to temperate latitudes (37°S) has provided Late Cenozoic sequences containing assemblages that are in large part able to be correlated with those of the tropical and temperate regions. A high proportion of continuous coring and a high rate of core recovery at several sites have provided an excellent basis for detailed biostratigraphic and related studies. The rather shallow-water location of several sites has assured that the section contains rich assemblages of well-preserved foraminifera.

The stratigraphic distribution of Cenozoic to Late Cretaceous sediments recovered during Leg 21 is shown in Figure 2. Paleogene and Neogene sediments were recovered at all sites. The general planktonic foraminiferal biostratigraphy at each site is presented in Part I (this volume), Site Reports. The planktonic foraminiferal sequence of the Paleogene is disrupted by disconformities and sampling

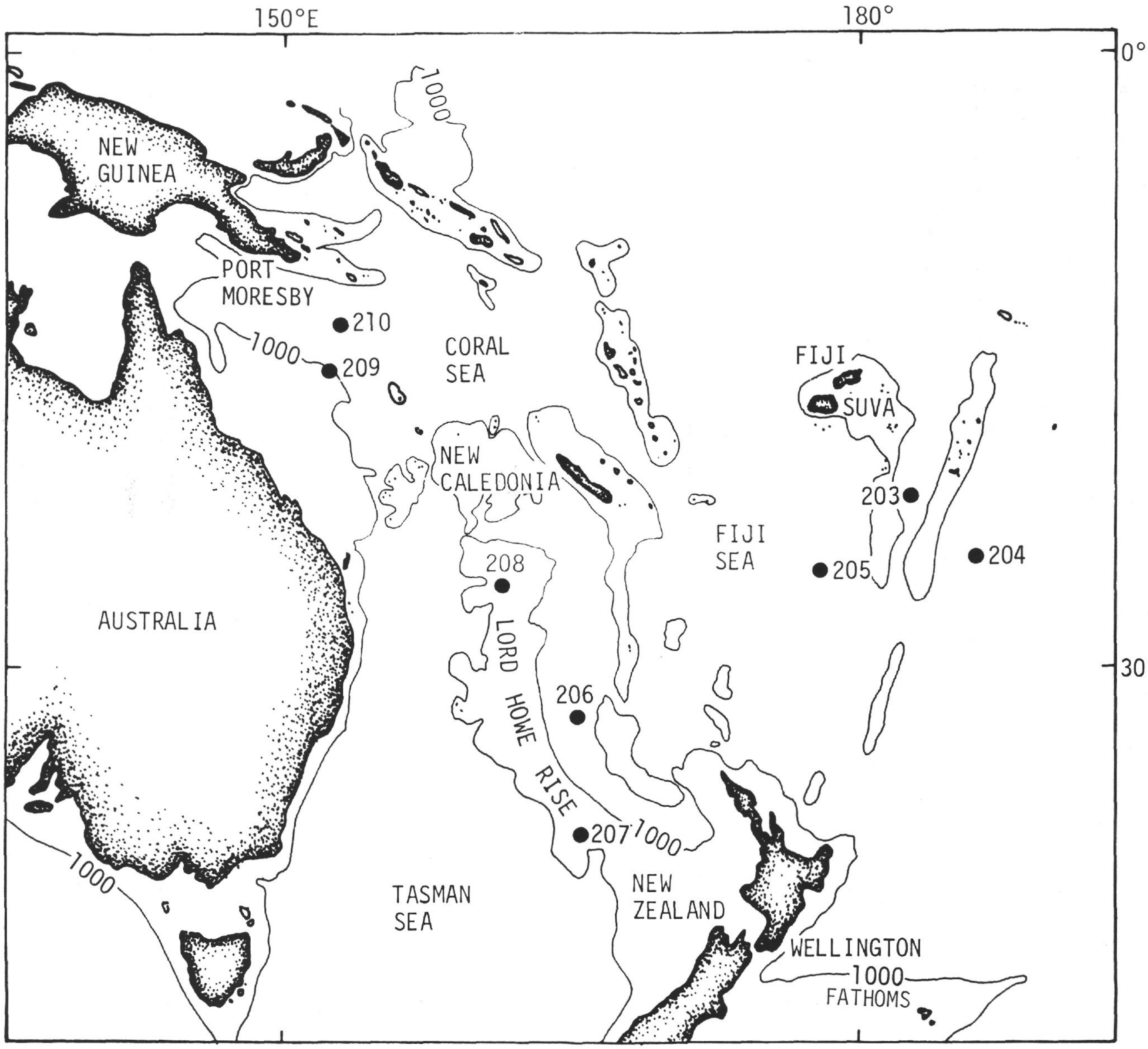

Figure 1. *Location of DSDP Leg 21 sites.*

gaps. In addition, planktonic foraminiferal preservation is commonly poor because of dissolution at various levels. In contrast, the Neogene sequences are typically continuous, contain rich calcareous assemblages, and have fewer sedimentary breaks.

This paper presents an account of the planktonic foraminiferal biostratigraphy from the late Early Miocene to the Recent. The stratigraphic ranges of species are charted for six of the eight sites (Figures 3 to 8), and the biostratigraphy is discussed. Regional trends of the planktonic foraminifera are discussed, and zonal schemes are presented for the three distinct water-mass regions cored.

Late Cenozoic planktonic foraminifera were recovered at all sites except Site 204 which is too deep for preservation of calcareous foraminifera. Locations and water depths of the other DSDP sites are shown in Table 1.

TABLE 1
Location and Water Depth of Sites, Leg 21

Site	Latitude	Longitude	Depth (m)
203	22°09.22'S	177°32.77'W	2720
205	25°30.99'S	177°53.95'E	4320
206	32°00.75'S	165°27.15'E	3196
207	36°57.75'S	165°26.06'E	1389
208	26°06.61'S	161°13.27'E	1545
209	15°56.19'S	152°11.27'E	1428
210	13°45.99'S	152°53.78'E	4643

GENERAL ASPECTS OF MIDDLE-LATE CENOZOIC OF SITES

The planktonic foraminiferal biostratigraphy for each site is summarized in Part I (Site Summaries). General

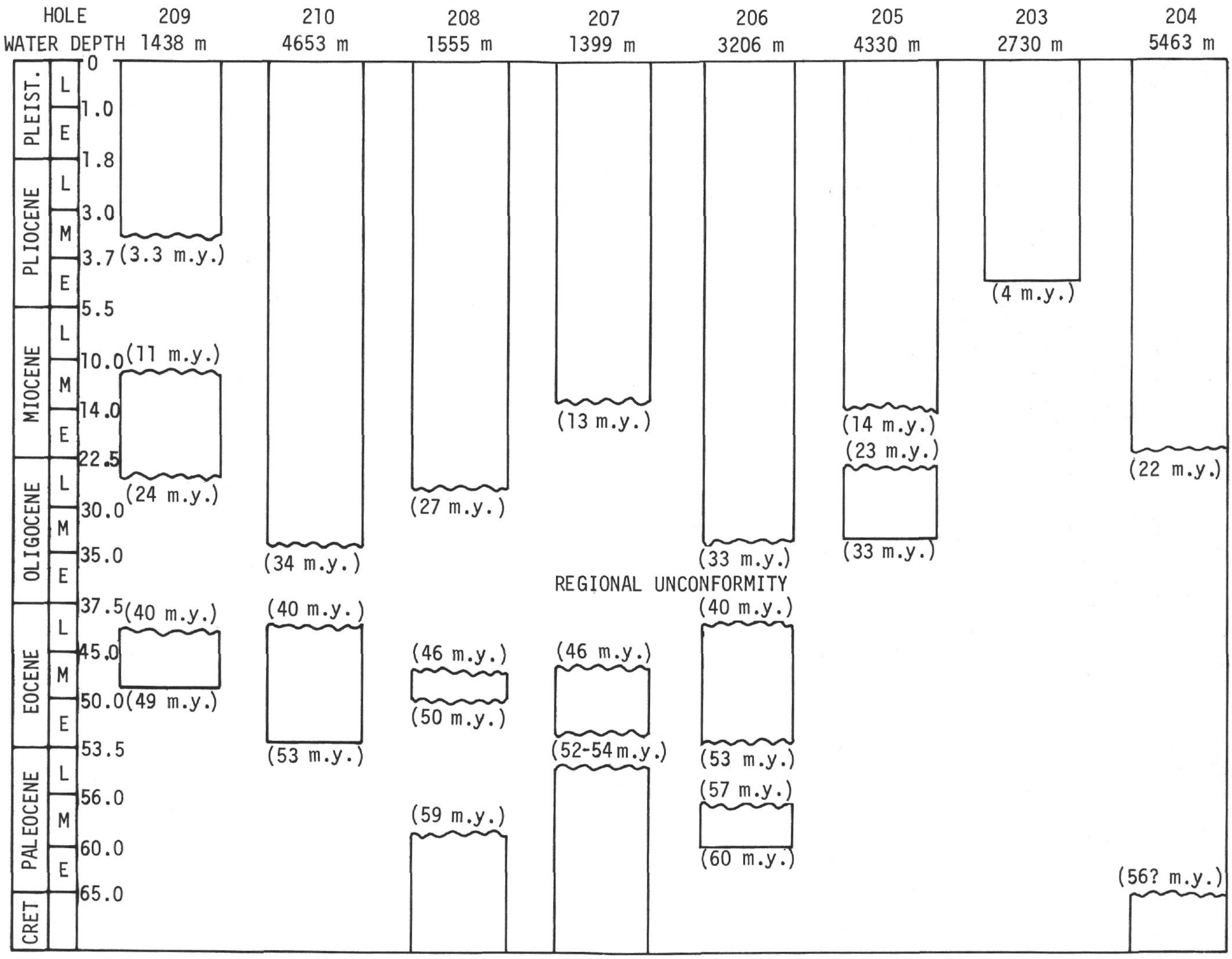

Figure 2. *Stratigraphic distribution of sediments cored on Leg 21.*

aspects of the Late Cenozoic are presented here. In almost all sites the Late Miocene to Recent was continuously cored and hence, is represented by remarkably complete sections. Sites 208, 206, and 207-207A are among the most valuable Late Cenozoic sections in the southern hemisphere, planktonic foraminifera being abundant and well preserved throughout. Site 210 also yielded abundant foraminifera, and though much deeper and affected by dissolution of tests, revealed important biostratigraphic information. Six sites were studied in detail. Disconformities were found in four of the sites, being minor in two cases (Sites 206 and 208), but major in the other two cases (Sites 207 and 209).

Site 203

Planktonic foraminifera are abundant and moderately well preserved in all five cores obtained from Site 203 which range in age from the Middle Pliocene to Recent. The assemblages are almost exclusively made up of tropical elements. The section if very thick (400 meters) owing to extensive nearby volcanism which provided abundant volcanic debris.

Site 204

This site at a depth of 5354 meters was of no value in this study because planktonic foraminifera are absent throughout due to dissolution.

Site 205

Pliocene to Pleistocene planktonic foraminiferal faunas are absent due to intense dissolution in the upper few meters of sediment in Site 205. The youngest planktonic foraminiferal faunas present (at 205-3-3, 115 cm) are of Late Miocene age. Planktonic foraminifera occur in varying frequencies with moderate to good preservation in the Middle and Late Miocene down to Core 205-22. A summary of planktonic foraminiferal biostratigraphy for this site is given in Part I, this volume. No detailed studies of the planktonic foraminiferal biostratigraphy of this site were attempted because of the limited time to prepare this report.

Site 206

The late Early Miocene (Section 206-33-1) to Recent of this section is represented by about 300 meters of

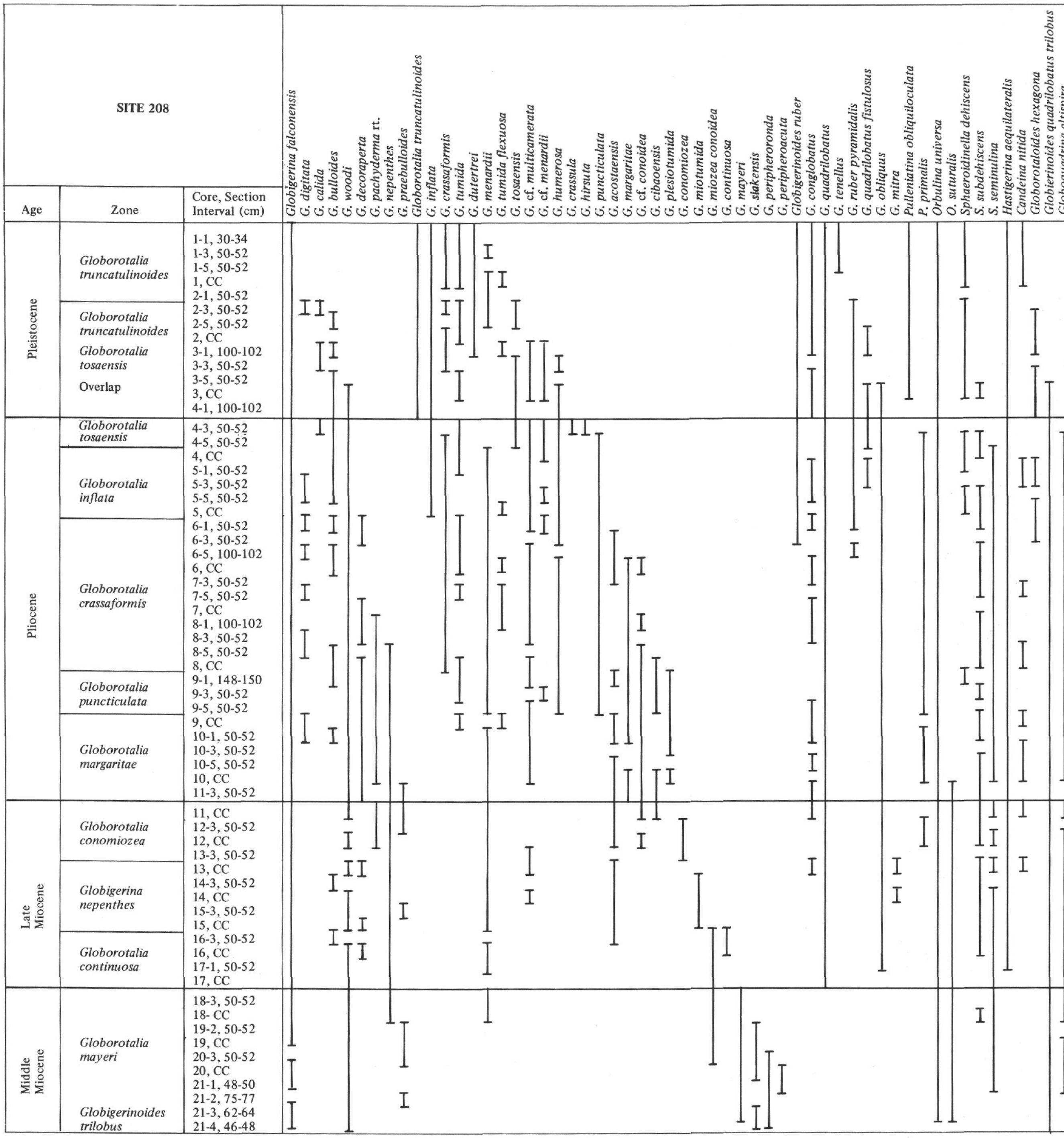

Figure 3. *Distribution of planktonic foraminifera and zonation at Site 208.*

foraminiferal-rich nanno oozes. Planktonic foraminifera are abundant and well preserved throughout. The section is one of the most continuous Middle to Late Cenozoic planktonic foraminiferal sequences in the southern hemisphere, one of the few available biostratigraphic sections in waters intermediate between tropical and temperate areas, and one of the finest Neogene deep-sea biostratigraphic sequences in the world. Faunas present throughout include both tropical forms (e.g., *Globorotalia menardii* and *G. tumida*) and temperate forms (e.g., *G. inflata* and *Globigerina bulloides*). One distinct disconformity occurs at the Miocene-Pliocene boundary, while a less distinct disconformity occurs between the Early and Middle Miocene. Particularly high sedimentation rates (6 cm/1000 years) characterize the Pleistocene which is thus potentially useful for detailed biostratigraphy.

Site 207-207A

The upper 120 meters (Cores 207-1 to 207-5 and 207A-1 to 207A-8) at Site 207 is an apparently continuous Late Miocene to Recent section. This interval is represented by foraminiferal-rich nanno ooze containing abundant, well-preserved planktonic foraminifera. It represents the most continuous, cool subtropical (temperate) Late Cenozoic section described in the southern hemisphere. Temperate elements are dominant, while tropical elements are quite rare.

Site 208

At Site 208 an apparently continuous Middle Miocene to Recent section of foraminiferal-rich nanno ooze is 320 meters thick (208-1-1, 10 cm to 208-21-3, 62 cm) and provides the most complete Middle to Late Cenozoic planktonic foraminiferal sequence available in warm subtropical waters in the southern hemisphere. Planktonic foraminifera are abundant and well preserved throughout. Site 208 is of particular importance because the faunas are intermediate between tropical and temperate regions. A relatively minor disconformity separates Early and Middle Miocene faunas.

Site 209

At Site 209 an excellent biostratigraphic sequence of about 50 meters extends unbroken from the Middle Pliocene to the Recent (209-1-1 to 209-5-CC). Planktonic foraminifera are very well preserved throughout, with solution-susceptible forms remaining well preserved. The faunas are exclusively tropical. A disconformity separates Middle Pliocene from late Middle Miocene sediments. Low sample recovery in the Miocene prevented useful biostratigraphic studies on faunas of this age.

Site 210

At this site a very thick, apparently continuous, turbidite sequence (450 m) represents the Late Miocene to Recent. No detailed planktonic foraminiferal studies were carried out in material older than the Late Miocene at Section 210-29-CC. The Pleistocene to Late Miocene contains abundant to common and well to moderately well preserved planktonic foraminifera. However, because of the considerable depth of deposition (4643 meters), much dissolution has affected those planktonic foraminiferal tests not reworked from shallower water. Reworked assemblages are generally well preserved although characteristically highly sorted. Because of the reworking and dissolution, the planktonic foraminiferal biostratigraphy is not reliable.

REGIONAL DISTRIBUTION PATTERNS

The Late Cenozoic planktonic foraminiferal faunas of the southwest Pacific deep-sea drilling sites demonstrate distributional patterns that are clearly related to environmental differences throughout the area. Stratigraphic ranges of numerous species are obviously related to general differences in water masses between sites and water-mass fluctuations at each site in the past. Because the sites studied range from cool-subtropical (Site 207-207A) through warm subtropical (Sites 206 and 208) to tropical areas (Sites 209, 210, 203), a complex relationship is revealed between the evolution of species in various water masses, subsequent migration to other water masses, and environmental influences on their stratigraphic ranges and frequencies.

Middle Miocene

The Middle Miocene is best represented in the two warm subtropical sites (Sites 206 and 208). Important forms at both of these sites are *Globigerina woodi, Globigerina nepenthes, Globorotalia mayeri, Globorotalia miozea conoidea, Sphaeroidinella seminulina, Globoquadrina altispira, Orbulina universa,* and *Globigerinoides quadrilobatus trilobus.* Within the Middle Miocene, *Globorotalia mayeri* grades upward into *Globorotalia continuosa* with both forms being consistent throughout their respective ranges. It is important to note that the Middle Miocene faunas of the warm subtropical sites are similar to those of the cool subtropical site (Site 207-207A). Furthermore, even the tropical Middle Miocene fauna represented at Site 209 is similar to those further south except for the addition of *Globorotalia menardii* and *Globorotalia siakensis.* Thus, the Middle Miocene faunas of the region are rather uniform. This uniformity of planktonic foraminiferal faunas throughout the region decreases markedly in younger strata with increased biogeographic provincialism. Increasing provincialism probably reflects a narrowing of faunal belts after the Middle Miocene or an increasing tropical influence after the Middle Miocene due to northward drift of the Tasman Sea region associated with the Cenozoic northward drift of Australia.

Late Miocene

The Late Miocene is represented at four of the sites studied (Sites 207-207A, 206, 208, and 210), ranging from temperate to tropical. At Site 206 a disconformity has cut out the latest Miocene. Temperate faunas characteristically contain *Globigerina nepenthes, Globigerina bulloides, Globigerina falconensis, Globigerina woodi,* and *Globigerina decoraperta* throughout. *G. woodi* and *G. decoraperta* are particularly important elements in the Late Miocene and become much less dominant in the Pliocene (particularly Late Pliocene) and the Pleistocene, while *G. bulloides* and *G. falconensis* become more important. An important element in the early Late Miocene is *Globorotalia continuosa.* This species is replaced in the late Late Miocene by *Globigerina pachyderma.* An important and conspicuous evolutionary change within the upper Miocene is that from *Globorotalia miozea conoidea* to *Globorotalia conomiozea.* Both forms are consistent elements of the fauna throughout their respective ranges.

Further to the north is Site 206, which is the cooler of the two warm subtropical sites. The presence of *Globigerinoides quadrilobatus sacculifer, Sphaeroidinella subdehiscens,* and *Globorotalia menardii* in the Late Miocene reflects warmer conditions than the temperate faunas further south. Otherwise the faunas are rather similar.

Still further to the north within the warm subtropical region (Site 208), the cooler forms, *Globigerina woodi* and

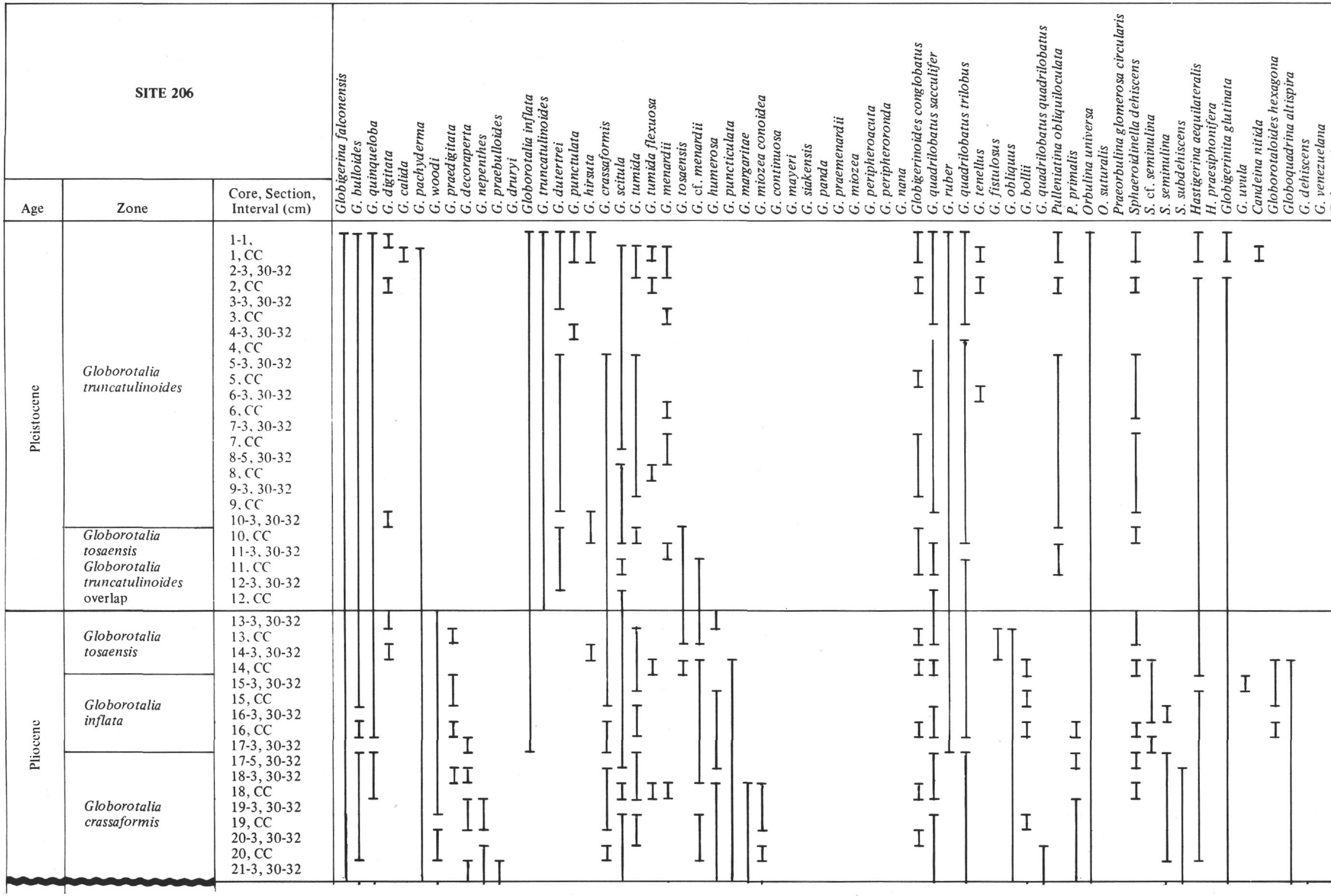

Figure 4. *Distribution of planktonic foraminifera and zonation at Site 206.*

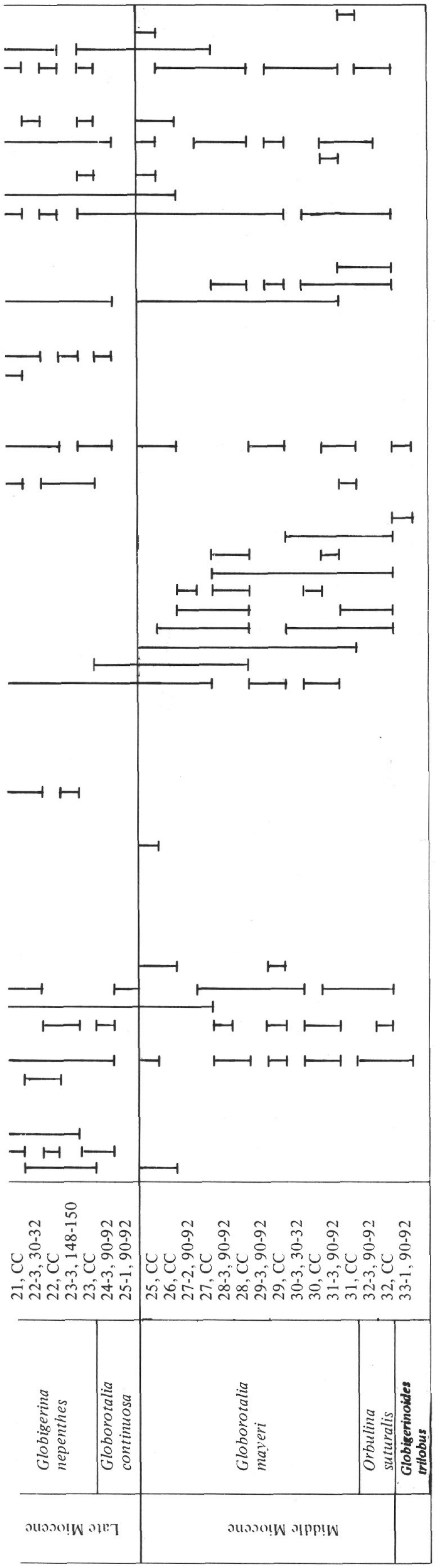

Figure 4. *(Continued)*

Globigerina bulloides, become less consistent; *G. menardii* becomes more important; and *Globorotalia acostaensis* appears. In addition, the presence of *Globigerinoides quadrilobatus sacculifer, Pulleniatina primalis, Sphaeroidinella subdehiscens, Candeina nitida, Globoquadrina altispira, Globigerinoides obliquus*, and *Globigerinoides conglobatus* reflects the warmer conditions at these latitudes.

In the tropical belt (Site 210) cool-water species such as *Globigerina bulloides* and *Globigerina woodi* are very rare. Instead the fauna is made up almost exclusively of abundant warm-water forms including *Globorotalia menardii, Globorotalia tumida, Globigerinoides quadrilobatus sacculifier*, and *Pulleniatina primalis. Globorotalia conomiozea* and other members of the *G. "miozea"* group that are typical of the cooler waters to the south are absent.

Pliocene

The Pliocene is well represented in Leg 21 material, occurring in all six sites examined. The temperate Pliocene fauna contains important *G. woodi, G. falconensis, G. bulloides*, and *Globigerina pachyderma*. Coiling direction changes in *G. pachyderma* reflect oscillations in water masses over the region during the Pliocene. The Late Pliocene is marked by increased frequencies of *G. bulloides* and *G. falconensis* and decreased frequencies of *G. woodi* and *G. decoraperta*. The Miocene-Pliocene boundary is marked by the evolutionary transition from *Globorotalia conomiozea* to *Globorotalia puncticulata. G. puncticulata* is an important element throughout the Early Pliocene in both temperate and warm subtropical areas and in turn evolves into *Globorotalia inflata* in the Late Pliocene in both areas. In the temperate site, warm-water forms such as *Sphaeroidinella, Globorotalia tumida, Globorotalia margaritae*, and *Globorotalia cibaoensis* are generally rare when present. *Globorotalia tosaensis* occurs only rarely in the late Pliocene.

Further to the north at Site 206, similar cooler-water forms prevail, although warm-water forms such as *G. tumida, G. humerosa, G. sacculifer, S. dehiscens*, and *S. subdehiscens* appear within their respective ranges. In addition *G. margaritae* is more common in the Early Pliocene.

The Pliocene at Site 208 contains even fewer cooler-water forms, while warm-water forms are more common within their respective ranges. Warm-water forms present include *Globorotalia tumida, Globorotalia menardii, Globorotalia margaritae, Globorotalia humerosa, Globorotalia acostaensis, Globorotalia cibaoensis, Globigerinoides conglobatus, Pulleniatina primalis, Sphaeroidinella subdehiscens*, and *Sphaeroidinella seminulina*. The evolution of *G. crassaformis* to *G. tosaensis* is recorded in the Late Pliocene of Site 208. *G. tosaensis* is more important in the warmer Pliocene sequences.

In the tropical Pliocene, *G. puncticulata* and *G. inflata* are virtually absent, while *G. tumida, S. dehiscens*, and *P. primalis* increase even more in importance.

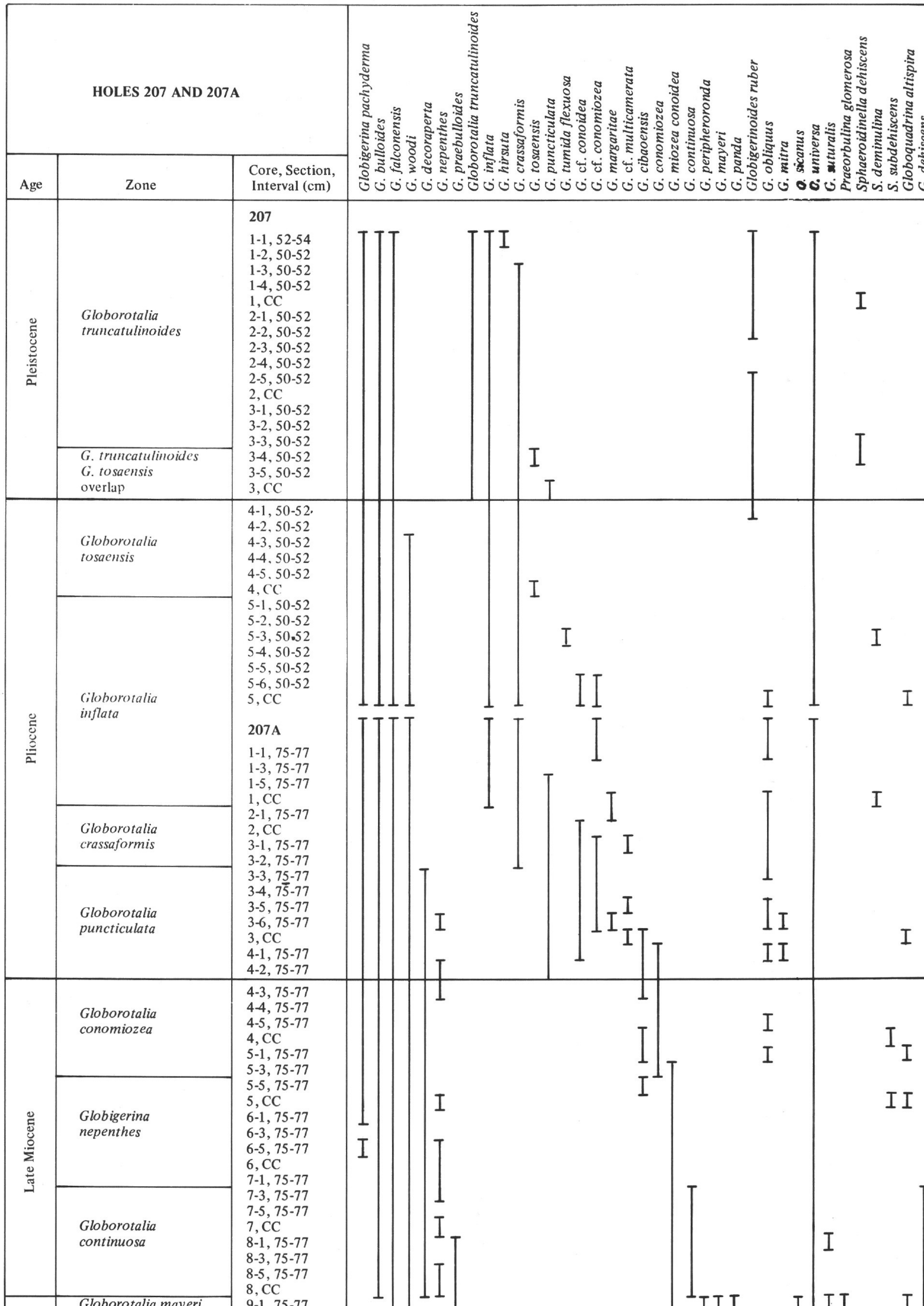

Figure 5. *Distribution of planktonic foraminifera and zonation at Site 207-207A.*

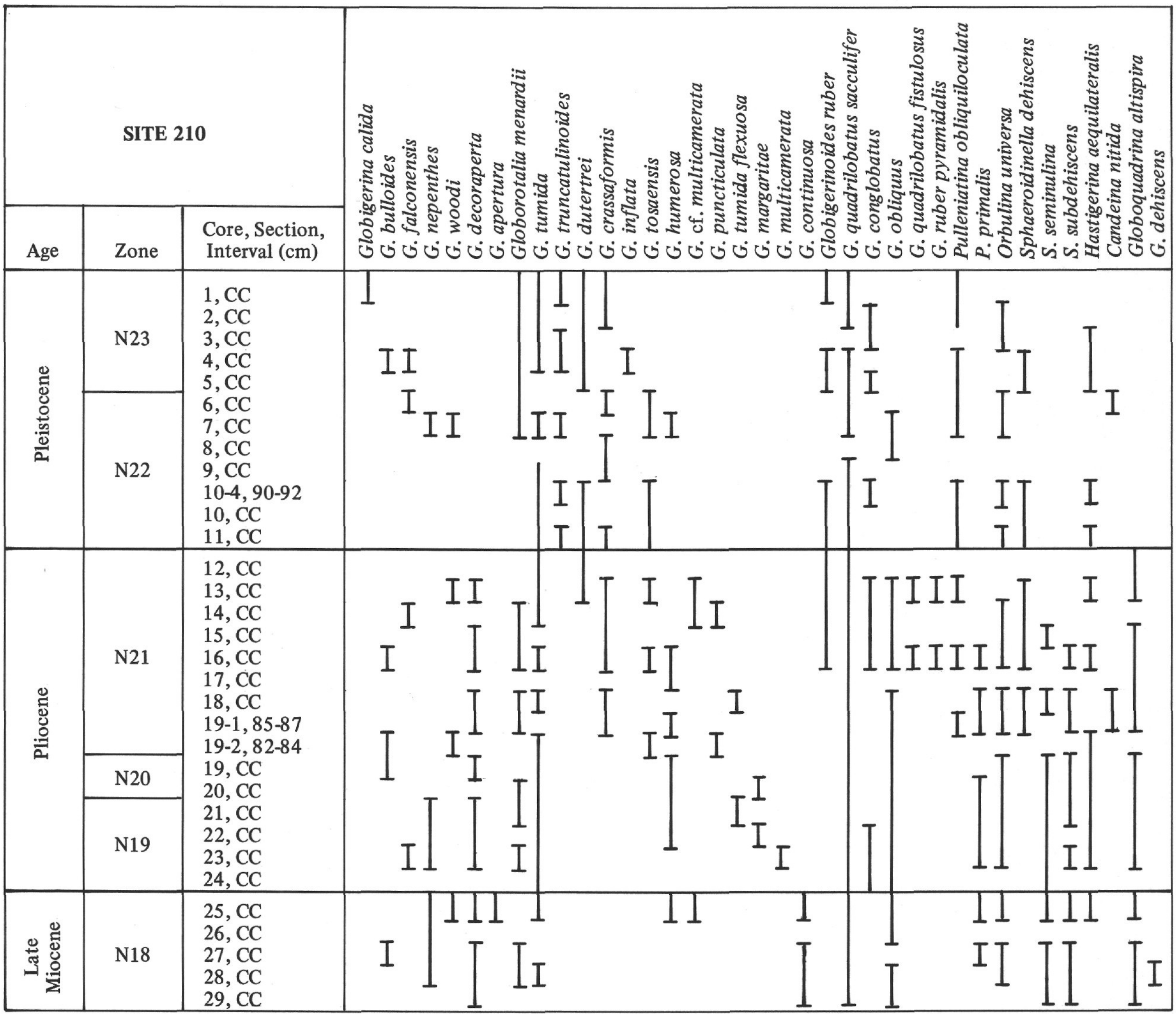

Figure 6. *Distribution of planktonic foraminifera and zonation at Site 210.*

Pleistocene

Important elements in the temperate faunas of the Pleistocene (Site 207-207A) include *Globigerina bulloides, G. falconensis,* and *G. pachyderma,* while *G. crassaformis, G. truncatulinoides,* and *O. universa* are consistently present. At these latitudes, fluctuations in coiling directions with *G. pachyderma* and large fluctuations in frequency of *Globigerinoides ruber* reflect large-scale fluctuations of the subtropical water mass. At this latitude, tropical and warm subtropical forms such as *G. tumida, G. menardii, Sphaeroidinella,* and *Pulleniatina* are absent or very rare.

Further to the north at Site 206, cooler forms are still dominant, although tropical forms such as *G. tumida, G. menardii, P. obliquiloculata,* and *Sphaeroidinella* are present in low frequencies at several intervals. *G. pachyderma* is represented almost exclusively by right-coiling forms reflecting warmer conditions at these latitudes during the Pleistocene than in areas to the south.

In the warm subtropical Site 208, cooler forms are either greatly reduced or absent. *G. pachyderma* (right coiling) is very rare and *G. bulloides* is infrequent or rare. On the other hand, the tropical forms such as *Sphaeroidinella dehiscens, Pulleniatina obliquiloculata,* and *Globorotalia tumida* are more important. Alternations in relative abundance can be detected between the cooler forms *G. inflata* and *G. falconensis* and the warm forms *G. tumida, G. menardii,* and *P. obliquiloculata.* As in the Gulf of Mexico these alternations reflect interglacial-glacial episodes (Kennett and Huddlestun, 1972).

In the tropical sites, even *G. inflata* is virtually eliminated, while the usual tropical forms are overwhelmingly predominant.

PLIOCENE-PLEISTOCENE BOUNDARY

The Pliocene-Pleistocene boundary, in all of the Leg 21 sites examined, has been placed at the first appearance of

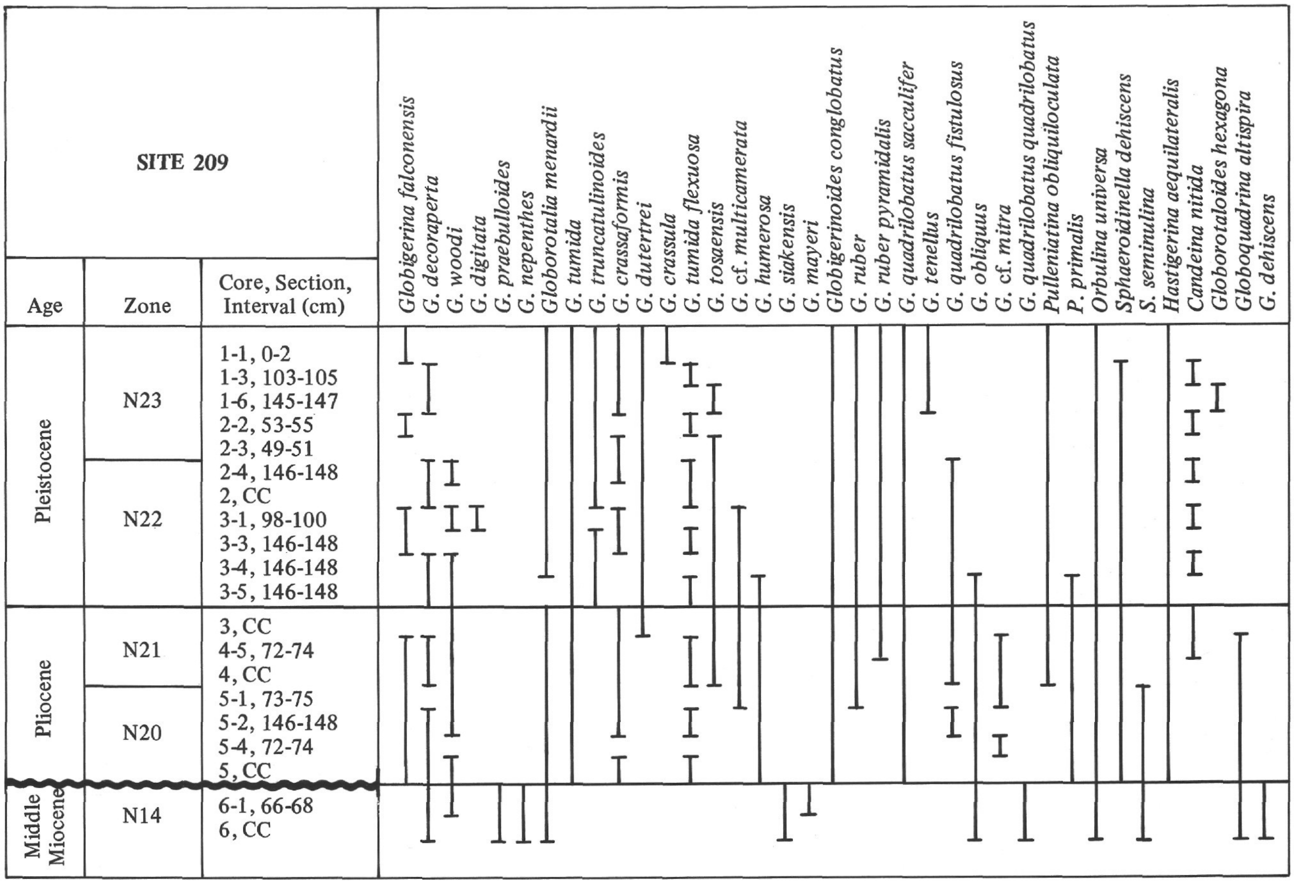

Figure 7. *Distribution of planktonic foraminifera and zonation at Site 209.*

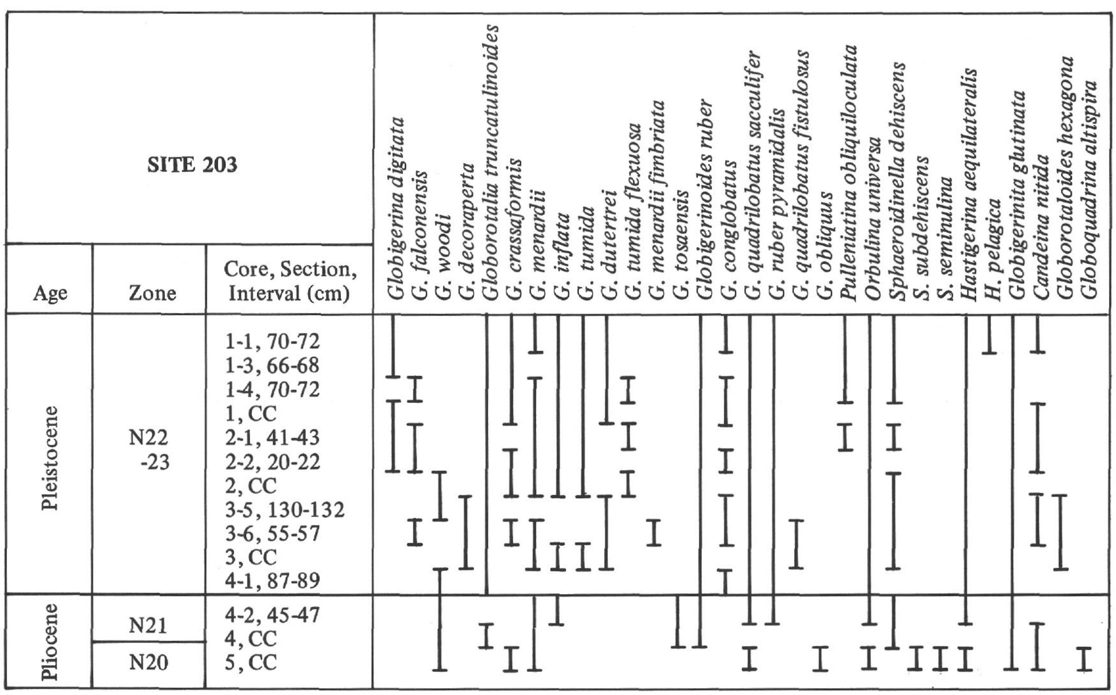

Figure 8. *Distribution of planktonic foraminifera and zonation at Site 203.*

Globorotalia truncatulinoides (Figures 3 to 8), in approximate agreement with the first appearance of *G. truncatulinoides* within the type basal Pleistocene Calabrian Stage at Santa Maria Catanzaro in southern Italy (Bayliss, 1969). The first appearance of *G. truncatulinoides* and hence, the Plio-Pleistocene boundary in tropical deep-sea cores is associated with the major normal event in the Matuyama (Berggren et al., 1967; Phillips et al., 1968; Glass et al., 1967) which has been variously called the Olduvai (Opdyke, 1972) or the Gilsa (Watkins, 1972) the base of which is 1.79 m.y. B.P.

The southwest Pacific cores do not all exhibit a simple gradational bioseries like that described by Berggren et al. (1967). In Site 207 (cool subtropical), *G. truncatulinoides* appears abruptly and is continuously present throughout the Pleistocene, while *G. tosaensis* is very rare. No gradation was observed between *G. tosaensis* and *G. truncatulinoides.* Further to the north in Site 206 (warm subtropical), a fairly simple gradation occurs between *G. tosaensis* and *G. truncatulinoides.* The transition is dominated by right-coiling forms.

In Site 208 the transition from *G. tosaensis* to *G. truncatulinoides* is not a simple gradational evolutionary change with steadily increasing abundances of the morphotype of *G. truncatulinoides.* Instead, the relative abundance of the two forms fluctuates significantly within the interval of overlap. In tropical Site 209, the interrelationship is even more complex. In this site, large fluctuations in the relative abundance of both forms occur throughout almost the entire interval of overlap of the two forms (from Cores 3-4 to 2-4). Alternations of *G. tosaensis* and *G. truncatulinoides* have also been described in a late Pliocene-Early Pleistocene core in the southwest Pacific (Kennett and Gietzenauer, 1969) and shown to be related to paleooceanographic oscillations. In summary, the evolution of *G. truncatulinoides* from *G. tosaensis* is complex with the two forms, at least in part related to particular oceanographic conditions in various water masses during the Plio-Pleistocene transition. Because of these complexities, it is possible that the earliest appearance of *G. truncatulinoides* was not simultaneous in various water masses.

MIOCENE-PLIOCENE BOUNDARY

The type Miocene-Pliocene boundary in Italy is at the boundary between the Late Miocene Messinian Stage and the overlying "trubi" Marl of the Zanclian Stage considered to be of Early Pliocene age. Blow (1969) found that the first appearance of *Sphaeroidinella dehiscens,* which marks the N18/N19 boundary, is 13 meters above the Miocene-Pliocene boundary in Italy. Furthermore, Cita (1973) considers that *Globorotalia margaritae* first appears slightly above the Miocene-Pliocene boundary in Mediterranean deep drilled sites and ranges to the upper part of the Early Pliocene.

Hays et al. (1969) discovered that *S. dehiscens* increases greatly in abundance within the Mammoth Reversed Event (3.0 m.y. B.P.) in tropical Pacific cores, although they show that it ranges as rare specimens throughout the Gilbert and lower Gauss epochs (approximately 5 to 3 m.y. B.P.). Bandy et al. (1971) treated the level of increased abundance of *S. dehiscens* as the *S. dehiscens* datum and correlated it with the N18/N19 boundary and the Miocene-Pliocene boundary, which they dated as 3.0 m.y. B.P. because of its relation to the Mammoth Event.

The ranges of *S. dehiscens, G. margaritae,* and other species such as *Globorotalia puncticulata* and *Globorotalia crassaformis* in the Leg 21 sites shed further light on the Miocene-Pliocene boundary problem. In these sites *G. margaritae* occurs earlier than *S. dehiscens* (Figures 3 to 8). In fact, the two species are mutually exclusive with *G. margaritae* in Sites 206, 208, and 210 occurring in the Early Pliocene and *S. dehiscens* appearing in the Middle Pliocene after the extinction of *G. margaritae* and ranging to the present day. Thus, the first appearance of *S. dehiscens* is later than in tropical north Pacific cores (Hays et al., 1969) and in the type Italian section (Blow, 1969) and, instead, reflects the level of widespread increased abundance that took place in the Middle Pliocene. The first appearance of *S. dehiscens* does not represent a true datum level because, like many species, its range varies between different water masses. It appears likely that the first appearance of *G. margaritae* represents a more reliable datum level, approximating the Miocene-Pliocene boundary over a wider range of water masses.

The relations between the Miocene-Pliocene boundary as used in the Leg 21 sites and the traditional position of the New Zealand Miocene-Pliocene boundary may also be considered. As previously mentioned, *S. dehiscens* is of no value in the correlation of the Miocene-Pliocene boundary in this area. In New Zealand the Miocene-Pliocene boundary has been placed between the Kapitean and Opoitian stages and is based on the first evolutionary appearance of nonkeeled *Globorotalia* variously called *G. inflata* (Jenkins, 1971); *G. crassaformis* (Kennett, 1966c); and *G. puncticulata* (Hornibrook and Edwards, 1971; Kennett and Watkins, 1972). I now consider the earliest form to be *G. puncticulata.* This form was derived in an evolutionary bioseries from *G. conomiozea* (previously called the *G. crassaformis* bioseries by Kennett, 1966c). This evolution is clearly shown in Site 207 by very abundant specimens. The Miocene-Pliocene boundary in this site has been placed at the first appearance of *G. puncticulata* (*G. puncticulata* also includes *G. sphericomiozea*, Walters) as in New Zealand (Kennett 1966a; b; c; 1967). In Site 207 *G. margaritae* has not been found lower than the first appearance of *G. puncticulata* and thus, no positive biostratigraphic evidence yet exists to indicate that the Miocene-Pliocene boundary in New Zealand is younger than the type boundary in Italy.

In Site 206 *G. puncticulata, G. margaritae,* and *G. crassaformis* appear together because of the presence of a disconformity that has eliminated the earliest Pliocene and latest Miocene biostratigraphic sequence. This core, thus, does not assist much in correlation of the Miocene-Pliocene boundary in different water masses.

In Site 208, the evolutionary bioseries from *G. conomiozea* to *G. puncticulata* is not represented. Instead, *G. puncticulata* appears later than the last appearance of *G. conomiozea* and the first appearance of *G. margaritae*

(Figure 3). The first appearance of *G. puncticulata* in this site is considered to reflect later migration to warmer waters after its initial evolutionary appearance in cooler waters to the south. Thus, the Miocene-Pliocene boundary in Site 208 is placed at the first appearance of *G. margaritae* rather than *G. puncticulata* like that in the Mediterranean deep drilled sites (Cita, 1973). Furthermore, because the last appearance of *G. conomiozea* coincides with the first appearance of *G. margaritae* in Site 208, it appears that the New Zealand Miocene-Pliocene boundary is similar to that in Europe.

PLANKTONIC FORAMINIFERAL ZONES

General

As a result of the wide latitudinal spread of the DSDP Leg 21 sites in the southwest Pacific (13°45'S to 36°57'S), sites were drilled in three distinct water-mass areas; cool subtropical (temperate); warm subtropical; and tropical. At present each of these areas is marked by fairly distinct planktonic foraminiferal assemblages. A trend towards a more and more restricted latitudinal distribution of many planktonic foraminiferal species began in the Late Eocene and Oligocene and became progressively more pronounced during the Miocene, Pliocene, and Pleistocene (Bolli, 1970). This distribution has led to the development of distinct Late Cenozoic zonations for the tropical areas (e.g., Bolli, 1970; Banner and Blow, 1965; Blow, 1969; Jenkins, 1972) and temperate areas (e.g., Jenkins, 1966; 1967). No zonal schemes have been established for areas intermediate between tropical and temperate. As a result, there has been great difficulty in correlating the zonal schemes between the two areas. During the progress of this work it was found that differences in stratigraphic ranges of important taxa in these various regimes meant that it was indeed necessary to establish a zonal scheme for the water mass between tropical and cool subtropical (temperate) regions which in this report is called the warm subtropical area.

Three zonal schemes have been utilized in this study. For the tropical sites the zonation of Banner and Blow (1965) and Blow (1969) has been utilized (Figures 6 to 8). The other two zonal schemes are new and are defined in this study. One of these has been established using the sites from the warm subtropical area (Figures 3, 4, and 9), while the other has been established on the basis of stratigraphic ranges in Site 207-207A adjacent to northern New Zealand in cool subtropical conditions (Figures 5 and 10). The only planktonic foraminiferal zonation established for the Late Cenozoic of New Zealand is that of Jenkins (1966; 1967). This zonation was found to be too broad for application to Leg 21 material. In particular, Jenkins established only one zone (*Globorotalia inflata* Zone) to encompass the entire Pliocene and Pleistocene, while a number of subzones were established on coiling direction changes in *Globigerina pachyderma.* Hornibrook and Edwards (1971) also have pointed out a series of foraminiferal and nannofossil datum levels for the Late Cenozoic of New Zealand. Figure 11 shows the correlation between the two new zonal schemes with the zonal scheme of Jenkins (1967; 1971) and the New Zealand Middle-Late Cenozoic stages.

In defining these two new zonal schemes, an attempt has been made to utilize species with similar ranges in both the warm and cool subtropical areas. As a result, the zonations are quite similar (Figure 11), although it is important to note that differences do exist in the definition of several of the zones with the same names. For example, the *Globorotalia tosaensis* Zone (Figure 11) in the warmer subtropical areas is defined at the first *evolutionary* appearance of *G. tosaensis* from *Globorotalia crassaformis.* In the cooler subtropical area this species has less consistent occurrence throughout its range because of cooler water conditions. Furthermore, its evolution from *G. crassaformis* is not represented. Hence, the base of the zone is determined in one case on the first evolutionary appearance and in the other case by its first cryptogenetic appearance. It is possible that additional work may demonstrate that the base of the zone is indeed equivalent in both areas. Another example involves the *Globorotalia puncticulata* zones in both areas. In cooler subtropical areas the evolution of *G. puncticulata* from *Globorotalia conomiozea* is clear and widespread (Kennett, 1966c), and the base of the *G. puncticulata* Zone is marked by the first evolutionary appearance of *G. puncticulata.* In the warmer subtropical area, the evolutionary bioseries is not represented, and the first appearance of *G. puncticulata* occurs later than the extinction of *G. conomiozea* and the first appearance of the Early Pliocene form *Globorotalia margaritae.* Hence, the base of the zone is different in age in the two areas.

By far the most useful forms for zonation of the Late Cenozoic in this area are species of *Globorotalia* because they evolved rapidly, are usually common and consistent elements of the planktonic foraminiferal faunas, and in some cases evolutionary changes transgress both the cool and warm subtropical areas. In the Late Miocene to Late Pliocene cool subtropical area a continuous evolutionary lineage proceeds from *Globorotalia miozea conoidea* (previously *G. miozea* of Kennett, 1966c) to *G. conomiozea* to *G. puncticulata* (previously *G. crassaformis* of Kennett, 1966c) to *G. inflata.* This lineage forms the foundation of the Late Miocene to Pliocene zonation.

The summary of correlations of the zones between each site is shown in Figure 12.

Zonal Characteristics

Warm Subtropical Planktonic Foraminiferal Zones

Globorotalia truncatulinoides Zone

Definition:
Top: Not defined, but the zone includes all faunas above the extinction of *Globorotalia tosaensis* Takayangi and Saito.
Base: Extinction of *Globorotalia tosaensis* Takayangi and Saito.

Age: Late Pleistocene-Recent.

Taxa:
Extinctions within zone:
Globorotalia tumida flexuosa

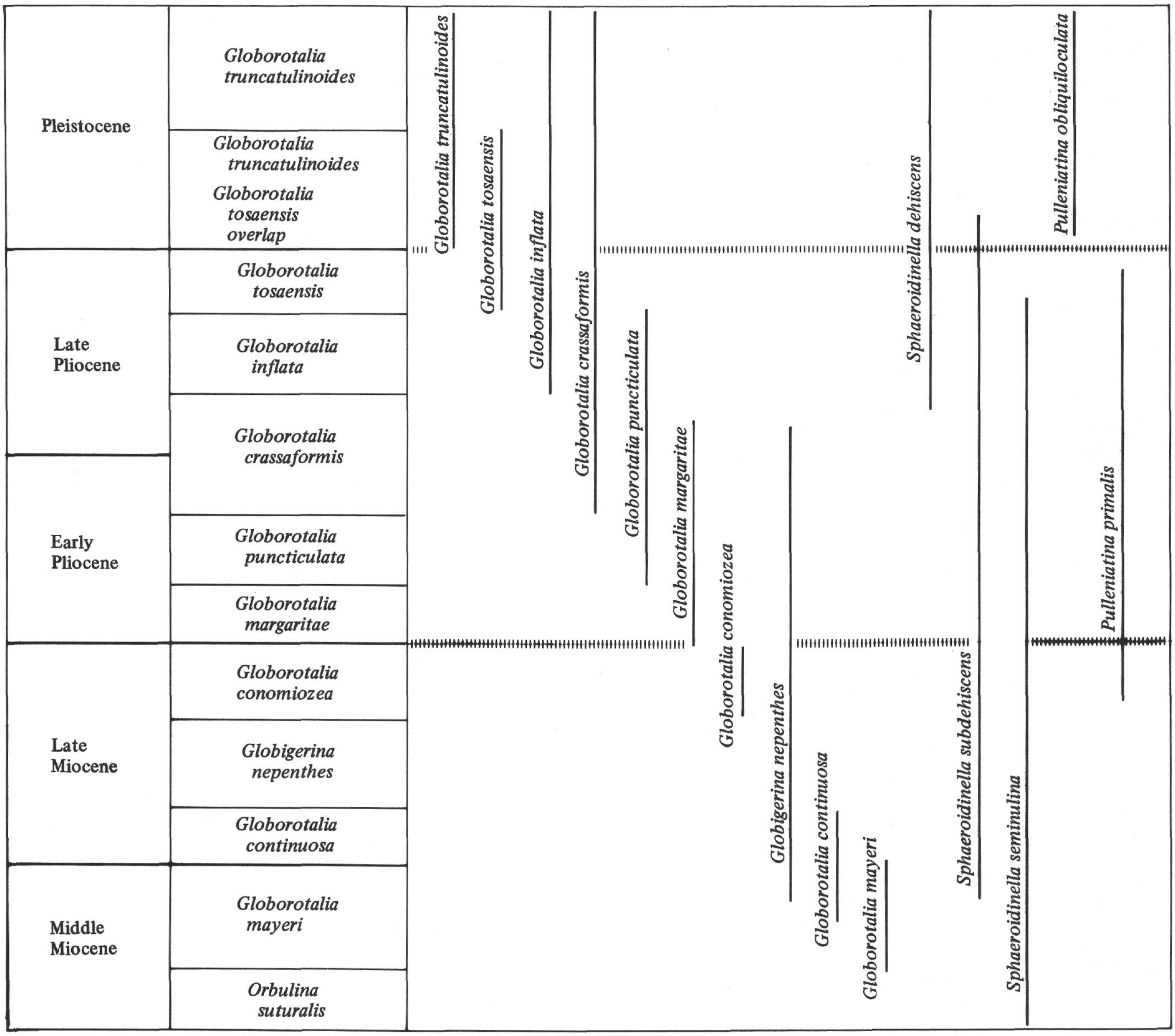

Figure 9. *Range distribution of key planktonic foraminifera in the warm-subtropical deep-sea sequences of the southwest Pacific.*

Initial appearances within zone:
Globigerinoides tenellus

Important species ranging throughout zone:

Candeina nitida	*Globigerinoides ruber*
Globigerina falconensis	*G. conglobatus*
G. bulloides	*G. quadrilobatus sacculifer*
Globorotalia truncatulinoides	*G. quadrilobatus trilobus*
	Pulleniatina obliquiloculata
G. inflata	*Orbulina universa*
G. crassaformis	*Sphaeroidinella dehiscens*
G. tumida	*Hastigerina aequilateralis*
G. menardii	

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Sites 206 and 208.

Correlation: Broadly equivalent to the uppermost part of Zone N22 and including N23 (Banner and Blow, 1965; Blow, 1969) and to N22 of Parker (1967). Broadly equivalent to the upper part of *G. truncatulinoides truncatulinoides* Zone (Bolli, 1970) and the upper part of *Pulleniatina obliquiloculata* Zone (Jenkins, 1972).

Globorotalia truncatulinoides-Globorotalia tosaensis Overlap Zone

Definition:
Top: Extinction of *Globorotalia tosaensis* Takayangi and Saito.

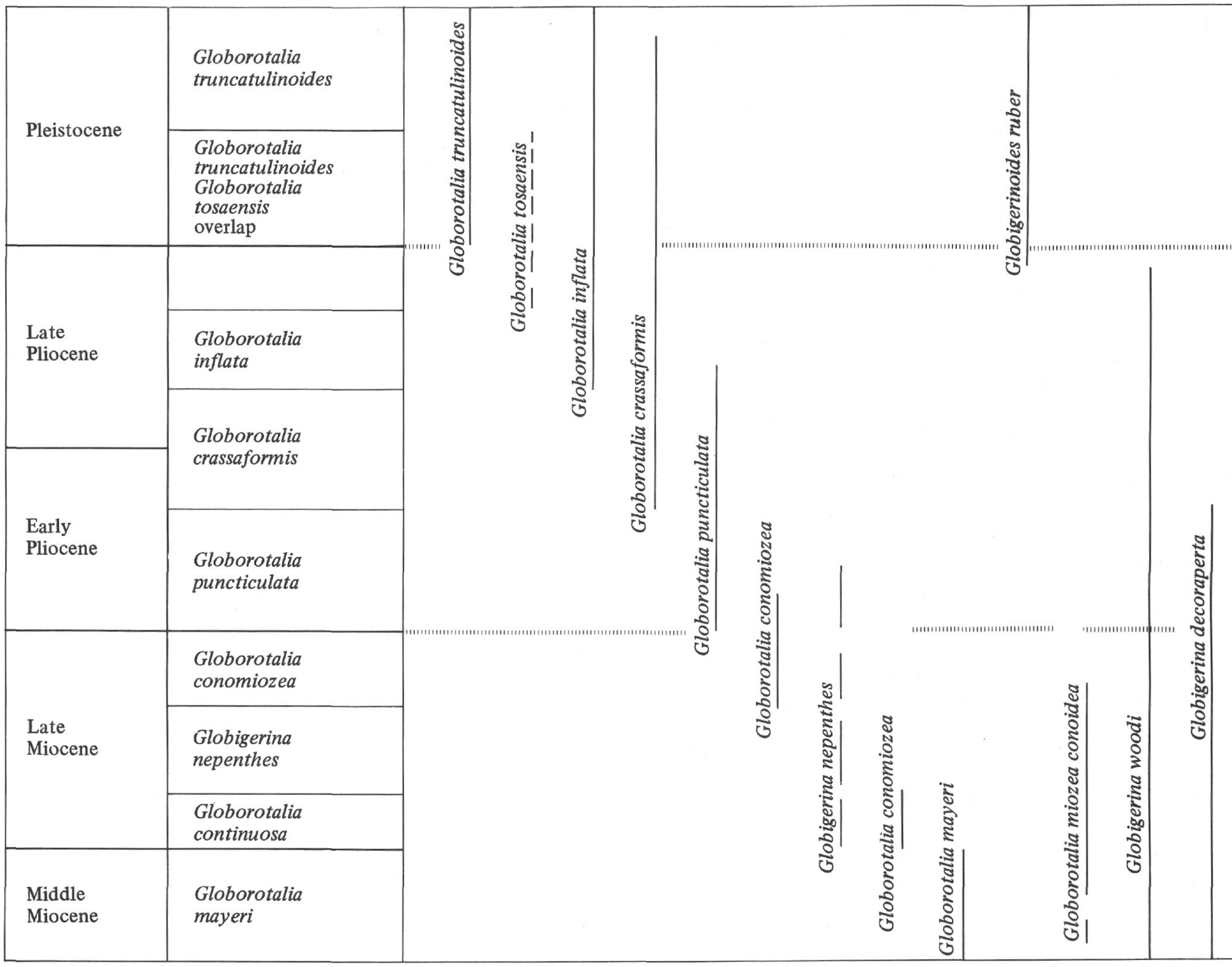

Figure 10. *Range distribution of key planktonic foraminifera in the cool-subtropical deep-sea sequence (Site 207-207A) in the southwest Pacific.*

Base: Initial evolutionary appearance of *Globorotalia truncatulinoides* (d'Orbigny). (First appearance of morphotype)

Age: Early Pleistocene.

Taxa:
Extinctions within zone:
Globigerina woodi
Globorotalia humerosa
Globorotalia cf. *multicamerata*
Globigerinoides quadrilobatus fistulosus
Globigerinoides obliquus
Sphaeroidinella subdehiscens

Initial appearances within zone:
Globorotalia dutertrei
Pulleniatina obliquiloculata

Important species ranging throughout zone:
Globigerina falconensis
G. bulloides
Globorotalia inflata
G. crassaformis
G. truncatulinoides
G. tosaensis
Globigerinoides ruber
G. conglobatus
G. quadrilobatus trilobus
Orbulina universa
Sphaeroidinella dehiscens
Hastigerina aequilateralis

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Sites 206 and 208.

Correlation: Broadly equivalent to Zone N22 (Banner and Blow, 1965; Blow, 1969) and to the lower part of N22 of Parker (1967). Broadly equivalent to the lower part of *G. truncatulinoides truncatulinoides* Zone (Bolli, 1970) and the lower part of *Pulleniatina obliquiloculata* Zone (Jenkins, 1972).

Age	DSDP Leg 21		New Zealand Zones (Jenkins, 1971)	New Zealand Stages
	Warm Subtropical Planktonic Foraminiferal Zones	Cool Subtropical Planktonic Foraminiferal Zones		
Pleistocene	*Globorotalia truncatulinoides*	*Globorotalia truncatulinoides*		
	Globorotalia truncatulinoides Globorotalia tosaensis overlap	*Globorotalia truncatulinoides Globorotalia tosaensis* overlap		
Late Pliocene	*Globorotalia tosaensis*	*Globorotalia tosaensis*		
	Globorotalia inflata	*Globorotalia inflata*		
	Globorotalia crassaformis	*Globorotalia crassaformis*	*Globorotalia inflata*	*Opoitian*
Early Pliocene	*Globorotalia puncticulata*	*Globorotalia puncticulata*		
	Globorotalia margaritae			
Late Miocene	*Globorotalia conomiozea*	*Globorotalia conomiozea*	*Globorotalia miozea sphericomiozea*	*Kapitean*
	Globigerina nepenthes	*Globigerina nepenthes*	*Globorotalia miotumida miotumida*	*Tonga-porutuon*
	Globorotalia continuosa	*Globorotalia continuosa*		
Middle Miocene	*Globorotalia mayeri*	*Globorotalia mayeri*	*Globorotalia mayeri mayeri*	*Waiauan – Lillburnian*
	Orbulina suturalis		*Orbulina suturalis*	
Early Miocene	*Globigerinoides trilobus*			

Figure 11. *Correlation of Leg 21 cool-subtropical and warm-subtropical foraminiferal zones.*

Globorotalia tosaensis Zone

Definition:

Top: Initial evolutionary appearance of *Globorotalia truncatulinoides* (d'Orbigny). (First appearance of morphotype.)

Base: Initial evolutionary appearance of *Globorotalia tosaensis* Takayanagi and Saito.

Age: Late Pliocene.

Taxa:

Extinctions within zone:

Globorotalia puncticulata
Pulleniatina primalis
Globoquadrina altispira

Important species ranging throughout zone:

Globigerina falconensis	*Globigerinoides ruber*
G. bulloides	*G. quadrilobatus sacculifer*
G. woodi	*G. quadrilobatus trilobus*

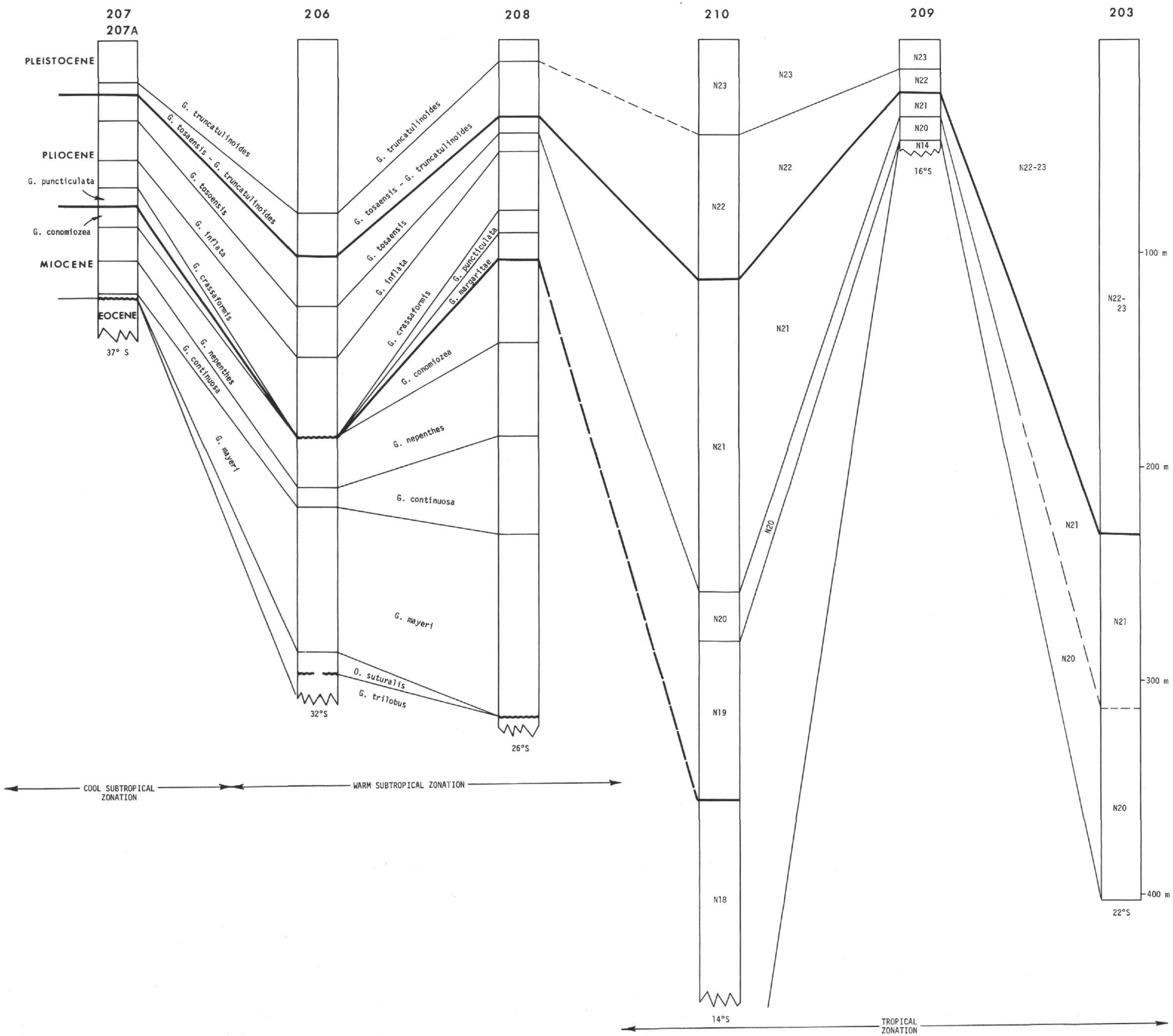

Figure 12. *Correlation and distribution of planktonic foraminiferal zones in Leg 21 sites.*

Globorotalia inflata	*Orbulina universa*
G. crassaformis	*Sphaeroidinella dehiscens*
G. tosaensis	*Hastigerina aequilateralis*
G. tumida	

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Sites 206 and 208.

Correlation: Equivalent to Zone N21 (Banner and Blow, 1965; Blow, 1969; Parker, 1967). Equivalent to *Globorotalia truncatulinoides tosaensis* Zone of Bolli (1970).

Globorotalia inflata Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia tosaensis* Takayanagi and Saito.
Base: Initial evolutionary appearance of *Globorotalia inflata* (d'Orbigny).

Age: Late Pliocene.

Taxa:
Extinctions within zone:
Globigerina decoraperta
Sphaeroidinella seminulina

Initial appearances within zone:
Globigerinoides quadrilobatus fistulosus

Important species ranging throughout zone:

Globigerina falconensis	*G. quadrilobatus sacculifer*
G. bulloides	*G. quadrilobatus trilobus*
G. woodi	*G. obliquus*
Globorotalia crassaformis	*Pulleniatina primalis*
G. inflata	*Orbulina universa*
G. tumida	*Sphaeroidinella dehiscens*
G. humerosa	*S. subdehiscens*
G. puncticulata	*S. seminulina*
Globigerinoides ruber	*Hastigerina aequilateralis*
G. conglobatus	*Globoquadrina altispira*

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Sites 206 and 208.

Globorotalia crassaformis Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia inflata* (d'Orbigny).
Base: Initial appearance of *Globorotalia crassaformis* (Galloway and Wissler).

Age: Early-Late Pliocene.

Taxa:
Extinctions within zone:
Globigerina nepenthes
Globorotalia acostaensis
G. cibaoensis
G. margaritae
G. cf. *miozea conoidea*

Initial appearances within zone:
Globigerinoides ruber
Sphaeroidinella dehiscens as consistent element

Important species ranging throughout zone:

Globigerina falconensis	*Pulleniatina primalis*
G. bulloides	*Orbulina universa*
G. woodi	*Sphaeroidinella seminulina*
G. decoraperta	*S. subdehiscens*
Globorotalia tumida	*Hastigerina aequilateralis*
G. crassaformis	*Globoquadrina altispira*
G. humerosa	
Globigerinoides conglobatus	
G. quadrilobatus sacculifer	
G. quadrilobatus trilobus	
G. obliquus	

Reference Section: Site 208: 26°06.61'S, 161°13.27°E.

Occurrence of Zone: Continuously cored at Sites 206 and 208. At Site 206 the base of the zone is a disconformity, and the base of the zone may be missing.

Correlation: Includes the upper part of *Globorotalia margaritae* Zone and lower part of *Globorotalia exilis/Globorotalia miocenica* Zone of Bolli (1970). Includes upper part of N19 of Banner and Blow (1965), Blow (1969), and Parker (1967).

Globorotalia puncticulata Zone

Definition:
Top: Initial appearance of *Globorotalia crassaformis* (Galloway and Wissler).
Base: Initial appearance of *Globorotalia puncticulata* (Deshayes) (not evolutionary).

Age: Early Pliocene.

Taxa:
Initial appearance within zone:
Globorotalia humerosa

Important species ranging throughout zone:

Globigerina falconensis	*Globigerinoides quadrilobatus sacculifer*
G. bulloides	*G. quadrilobatus trilobus*
G. woodi	*G. obliquus*
G. decoraperta	*Pulleniatina primalis*
G. nepenthes	

Globorotalia tumida
G. menardii
G. cf. *miozea conoidea*
G. puncticulata
G. cibaoensis
Orbulina universa
Sphaeroidinella subdehiscens
S. seminulina
Hastigerina aequilateralis
Globoquadrina altispira

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Site 208, missing in disconformity at Site 206.

Correlation: Includes part of N19 of Banner and Blow (1965), Blow (1969), and Parker (1967) and part of *Globorotalia margaritae* Zone of Bolli (1970).

Globorotalia margaritae Zone

Definition:
Top: Initial appearance of *Globorotalia puncticulata* (Deshayes) (not evolutionary).
Base: Initial appearance of *Globorotalia margaritae* Bolli and Bermudez.
Age: Early Pliocene.
Taxa:
Extinctions within zone:
Globigerina praebulloides
Orbulina suturalis

Initial appearances within zone:
Globigerina digitata
Globorotalia tumida
G. tumida flexuosa
G. margaritae

Important species ranging throughout zone:
Globigerina falconensis
G. woodi
G. decoraperta
G. nepenthes
Globorotalia menardii
G. cf. *multicamerata*
G. acostaensis
G. cf. *miozea conoidea*
Globigerinoides conglobatus
G. quadrilobatus sacculifer
G. quadrilobatus trilobus
G. obliquus
Pulleniatina primalis
Orbulina universa
Sphaeroidinella subdehiscens
S. seminulina
Hastigerina aequilateralis
Globoquadrina altispira

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Site 208, missing in disconformity at Site 206.

Correlation: Includes lower part of N19 of Banner and Blow (1965), Blow (1969), and Parker (1967) and lower part of *Globorotalia margaritae* Zone of Bolli (1970).

Globorotalia conomiozea Zone

Definition:
Top: Initial appearance of *Globorotalia margaritae* Bolli and Bermudez.
Base: Initial evolutionary appearance of *Globorotalia conomiozea* Kennett.

Age: Late Miocene.

Taxa:
Initial Appearance within zone:
Pulleniatina primalis

Important species ranging throughout zone:
Globigerina falconensis
G. bulloides
G. nepenthes
Globorotalia menardii
G. acostaensis
G. cf. *miozea conoidea*
G. conomiozea
Globigerinoides quadrilobatus sacculifer
G. quadrilobatus trilobus
G. obliquus
Orbulina universa
O. suturalis
Sphaeroidinella subdehiscens
S. seminulina
Hastigerina aequilateralis
Globoquadrina altispira

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Site 208, missing in disconformity at Site 206.

Correlation: Broadly equivalent to Zone N18 (Banner and Blow, 1965; Blow, 1969; Parker, 1967) and to *Globorotalia dutertrei* Zone of Bolli (1970). Equivalent to *Globorotalia miozea sphericomiozea* Zone of Jenkins (1971).

Globigerina nepenthes Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia conomiozea* Kennett.
Base: Extinction of *Globorotalia continuosa* Blow.

Age: Late Miocene.

Taxa:
Initial appearances within zone:
Globigerina pachyderma
Globorotalia cf. *multicamerata*
Candeina nitida

Important species ranging throughout zone:
Globigerina falconensis
G. woodi
G. nepenthes
Globorotalia menardii
G. miozea conoidea
G. acostaensis
Globigerinoides quadrilobatus sacculifer
G. quadrilobatus trilobus
G. obliquus
Orbulina universa
O. suturalis
Sphaeroidinella subdehiscens
S. seminulina
Hastigerina aequilateralis
Globoquadrina altispira
G. dehiscens

Reference Section: Site 208: 26°06.61'S, 161°13.27'E.

Occurrence of Zone: Continuously cored at Sites 206 and intermittently cored at Site 208. At Site 206 the top of the zone is a disconformity, and the top of the zone may be missing.

Correlation: Broadly equivalent to Zone N17 (Banner and Blow, 1965; Blow, 1969; Parker, 1967) and partly equivalent to *Globorotalia acostaensis* Zone of Bolli (1970). Broadly equivalent to *Globorotalia plesiotumida* Zone of Jenkins (1972) and upper part of *Globorotalia miotumida miotumida* Zone of Jenkins (1971).

Globorotalia continuosa Zone

Definition:
Top: Extinction of *Globorotalia continuosa* Blow
Base: Extinction of *Globorotalia mayeri* Cushman and Ellisor.

Age: Late Miocene.

Taxa:
Initial appearances within zone:
Globigerinoides quadrilobatus sacculifer
G. obliquus

Important species ranging throughout zone:

Globigerina falconensis	*Orbulina universa*
G. woodi	*O. suturalis*
G. nepenthes	*Sphaeroidinella seminulina*
Globorotalia menardii	*Hastigerina aequilateralis*
G. miozea conoidea	*Globoquadrina dehiscens*
Globigerinoides quadrilobatus trilobus	

Reference Section: Site 208: 26°06.61′S, 161°13.27′E.

Occurrence of Zone: Continuously cored at Site 206 and intermittently cored at Site 208.

Correlation: Broadly equivalent to the lower part of *Globorotalia miotumida miotumida* Zone of Jenkins (1971).

Globorotalia mayeri Zone

Definition:
Top: Extinction of *Globorotalia mayeri* Cushman and Ellisor.
Base: Initial evolutionary appearance of *Globorotalia mayeri* Cushman and Ellisor.

Age: Middle Miocene

Taxa:
Extinctions within zone:
Globorotalia siakensis
G. panda
G. praemenardii
G. miozea
G. peripheroronda
G. peripheracuta
Praeorbulina glomerosa circularis

Initial appearances within zone:
Globorotalia miozea conoidea
Orbulina universa
Sphaeroidinella subdehiscens

Important species ranging throughout zone:

Globigerina woodi	*Globigerinoides quadrilobatus trilobus*
G. decoraperta	*Sphaeroidinella seminulina*
Globorotalia mayeri	*Globoquadrina altispira*
Orbulina universa	*G. dehiscens*

Reference Section: Site 208: 26°06.61′S, 161°13.27′E.

Occurrence of Zone: Continuously cored at Site 206 and intermittently cored at Site 208. At Site 208 the base of the zone is a disconformity, and the base of the zone may be missing.

Correlation: Equivalent to *Globorotalia mayeri mayeri* Zone of Jenkins (1971).

Orbulina suturalis Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia mayeri* Cushman and Ellisor.
Base: Because of a possible disconformity at Site 206, the base of the zone could not be defined. It is likely that additional work will show that the base of the zone is best placed at the extinction of *Praeorbulina glomerosa curva* as in the New Zealand Miocene zonation (Jenkins, 1971).

Age: Middle Miocene.

Taxa:
Important species ranging throughout zone:

Globigerina woodi	*Orbulina suturalis*
Globorotalia siakensis	*Praeorbulina glomerosa circularis*
G. panda	*Sphaeroidinella seminulina*
G. miozea	*Globoquadrina altispira*
G. peripheroronda	

Reference Section: Site 206: 32°00.75′S, 165°27.15′E.

Occurrence of zone: Continuously cored at Site 206. Missing in disconformity at Site 208. At Site 206 the base of the zone is possibly a disconformity, and the base of the zone is not represented.

Correlation: Equivalent to *Orbulina suturalis* Zone of Jenkins (1971).

Globigerinoides trilobus Zone

Not formerly designated. The zone is assumed to be equivalent to the *Globigerinoides trilobus* Zone of Jenkins (1971), the top of which is defined at the initial evolutionary appearance of *Praeorbulina.*

Cool Subtropical Planktonic Foraminiferal Zones

Globorotalia truncatulinoides Zone

Definition:
Top: Not defined, but the zone includes all faunas above the extinction of *Globorotalia tosaensis* Takayanagi and Saito.
Base: Extinction of *Globorotalia tosaensis* Takayanagi and Saito.

Age: Late Pleistocene–Recent.

Taxa:
Important species ranging throughout zone:

Globigerina pachyderma	*G. inflata*
G. bulloides	*G. crassaformis*
G. falconensis	*Globigerinoides ruber*
Globorotalia truncatulinoides	*Orbulina universa*

Reference Section: Site 207: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207.

Correlation: Equivalent to the *Globorotalia truncatulinoides* Zone in sites of DSDP Leg 21 from the warm subtropical region (Figure 11).

Globorotalia truncatulinoides-Globorotalia tosaensis Overlap Zone

Definition:
Top: Extinction of *Globorotalia tosaensis* Takayanagi and Saito.
Base: Initial evolutionary appearance of *Globorotalia truncatulinoides* (d'Orbigny). (First appearance of morphotype.)

Age: Early Pleistocene

Taxa:
Important species ranging throughout zone:

Globigerina pachyderma	*G. inflata*
G. bulloides	*G. crassaformis*
G. falconensis	*Globigerinoides ruber*
Globorotalia truncatulinoides	*Orbulina universa*

Reference Section: Site 207: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207.

Correlation: Equivalent to the *Globorotalia truncatulinoides-Globorotalia tosaensis* Overlap Zone in sites of Leg 21 from the warm subtropical region (Figure 11).

Globorotalia tosaensis Zone

Definition:
Top: Initial appearance of *Globorotalia truncatulinoides* (d'Orbigny). (First appearance of morphotype).
Base: Initial appearance of *Globorotalia tosaensis* Takayanagi and Saito.

Age: Late Pliocene

Taxa:
Extinction within zone:
Globigerina woodi

Initial appearance within zone:
Globigerinoides ruber

Important species ranging throughout zone:

Globigerina falconensis	*Globorotalia inflata*
G. bulloides	*G. crassaformis*
G. falconensis	*Orbulina universa*

Reference Section: Site 207: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207.

Correlation: Broadly equivalent to the *Globorotalia tosaensis* Zone in sites of Leg 21 from the warm subtropical region (Figure 11). Exact definition differs, however, because *G. tosaensis* is rare as the result of cooler oceanographic conditions, and the first appearance of both *G. tosaensis* and *G. truncatulinoides* were not observed as evolutionary appearances.

Globorotalia inflata Zone

Definition:
Top: Initial appearance of *Globorotalia tosaensis* Takayanagi and Saito.
Base: Initial evolutionary appearance of *Globorotalia inflata* (d'Orbigny).

Age: Late Pliocene.

Taxa: Extinctions within zone:
Globorotalia cf. *miozea conoidea*
G. cf. *conomiozea*
Globigerinoides obliquus
Sphaeroidinella seminulina
Globoquadrina altispira

Important species ranging throughout zone:

Globigerina pachyderma	*Globorotalia inflata*
G. bulloides	*G. crassaformis*
G. falconensis	*Orbulina universa*
G. woodi	

Reference Section: Site 207 (upper part) and 207A (lower part): 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207-207A

Correlation: Broadly equivalent to *Globorotalia inflata* Zone in sites of Leg 21 from the warm subtropical region (Figure 11). Exact definition of top of zone differs because the first appearance of *G. tosaensis* at Site 207 does not necessarily coincide with the initial evolutionary appearance as observed in Sites 206 and 208.

Globorotalia crassaformis Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia inflata* (d'Orbigny).

Base: Initial appearance of *Globorotalia crassaformis* (Galloway and Wissler).

Age: Early–Late Pliocene.

Taxa:
Important species ranging throughout zone:

Globigerina pachyderma	*G. puncticulata*
G. bulloides	*G.* cf. *miozea conoidea*
G. falconensis	*Globigerinoides obliquus*
G. woodi	*Orbulina universa*
Globorotalia crassaformis	

Reference Section: Site 207A: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to *Globorotalia crassaformis* Zone in sites of Leg 21 from the warm subtropical region (Figure 11).

Globorotalia puncticulata Zone

Definition:
Top: Initial appearance of *Globorotalia crassaformis* (Galloway and Wissler).
Base: Initial evolutionary appearance of *Globorotalia puncticulata* (Deshayes).

Age: Early Pliocene.

Taxa:
Extinctions within zone:
Globigerina decoraperta
G. nepenthes
Globorotalia cibaoensis
G. conomiozea

Important species ranging throughout zone:

Globigerina falconensis	*Globorotalia puncticulata*
G. bulloides	*G.* cf. *miozea conoidea*
G. woodi	*Orbulina universa*

Reference Section: Site 207A: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to both the *Globorotalia margaritae* and *Globorotalia puncticulata* Zones in sites of Leg 21 from the warm subtropical region (Figure 11). It is important to note that the *Globorotalia puncticulata* Zones in both these areas are distinct. *Globorotalia puncticulata* in Site 207A first appears in evolutionary succession from *Globorotalia conomiozea* while in warmer waters to the north this species appears later and not in evolutionary succession. The base of the zone is thus diachronous.

Globorotalia conomiozea Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia puncticulata* (Deshayes).
Base: Initial evolutionary appearance of *Globorotalia conomiozea* Kennett.

Age: Late Miocene.

Taxa:
Extinction within zone:
Globorotalia miozea conoidea

Initial appearance within zone:
Globigerinoides obliquus

Important species ranging throughout zone:

Globigerina pachyderma	*Globorotalia conomiozea*
G. bulloides	*Orbulina universa*
G. falconensis	

Reference Section: Site 207A: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to the *Globorotalia miozea sphericomiozea* Zone of Jenkins (1971). Broadly equivalent to the *Globorotalia conomiozea* Zone in sites of Leg 21 from the warm subtropical region (Figure 11).

Globorotalia continuosa Zone

Definition:
Top: Extinction of *Globorotalia continuosa* Blow.
Base: Extinction of *Globorotalia mayeri* Cushman and Ellisor.

Age: Late Miocene.

Taxa:
Extinction within zone:
Orbulina suturalis

Important species ranging throughout zone:

Globigerina bulloides	*Globorotalia miozea conoidea*
G. falconensis	*G. continuosa*
G. woodi	*Orbulina universa*
G. decoraperta	*Globoquadrina dehiscens*

Reference Section: Site 207A: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to the *Globorotalia continuosa* Zone in sites of Leg 21 from the warm subtropical region (Figure 11). Broadly equivalent to the lower part of the *Globorotalia miotumida miotumida* Zone of Jenkins (1971).

Globigerina nepenthes Zone

Definition:
Top: Initial evolutionary appearance of *Globorotalia conomiozea* Kennett.
Base: Extinction of *Globorotalia continuosa* Blow.

Age: Late Miocene.

Taxa:
Extinction within zone:
Globoquadrina dehiscens

Initial appearance within zone:
Globigerina pachyderma

Important species ranging throughout zone:

Globigerina bulloides	*G. decoraperta*
G. falconensis	*Globorotalia miozea conoidea*
G. woodi	*Orbulina universa*

Reference Section: Site 207A: 36°57.75′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to the *Globigerina nepenthes* Zone in sites of Leg 21 from the warm subtropical region (Figure 11). Broadly equivalent to the upper part of *Globorotalia miotumida miotumida* Zone of Jenkins (1971).

Globorotalia mayeri Zone

Definition:
Top: Extinction of *Globorotalia mayeri* Cushman and Ellisor.
Base: Initial evolutionary appearance of *Globorotalia mayeri* Cushman and Ellisor.

Age: Middle Miocene.

Taxa:
Extinctions within zone:
Globorotalia peripheroronda
G. panda
Praeorbulina glomerosa circularis

Important species occurring within zone:

Globigerina falconensis	*Orbulina universa*
G. woodi	*O. suturalis*
G. praebulloides	*Globoquadrina dehiscens*
Globorotalia miozea conoidea	

Reference Section: Site 207A: 36°57′S, 165°26.06′E.

Occurrence of Zone: Continuously cored at Site 207A.

Correlation: Equivalent to *Globorotalia mayeri mayeri* Zone of Jenkins (1971). Equivalent to the upper part of *Globorotalia mayeri* Zone in sites of Leg 21 from the warm subtropical region (Figure 11).

Tropical Planktonic Foraminiferal Zones

Late Cenozoic foraminiferal biostratigraphy was examined in three sites (210, 209, 203) in the tropical region. At two of these sites (209 and 203) the Late Cenozoic is represented by only the Pleistocene and Pliocene. In Site 210 stratigraphic ranges of planktonic foraminifera were examined from the Late Miocene to the present day. The planktonic foraminiferal zonation of Banner and Blow (1965) and Blow (1969) is suitable for biostratigraphic subdivision of these sites (Figures 6 to 8 and 11 and 12). Although no detailed discussion is made here of the biostratigraphy of the tropical sites, the following conclusions have been made.

Pleistocene

1) The Pleistocene is marked by fairly consistent occurrence of *Globorotalia truncatulinoides.*

2) The early Pleistocene differs from the late Pleistocene by containing *Globigerinoides quadrilobatus fistulosus* (in Sites 203 and 209); *Globorotalia tosaensis* (in Sites 209 and 210); and *Globigerina woodi* (in Sites 203, 209, and 210).

3) The range of *Globorotalia dutertrei* approximates the Pleistocene, although in Site 210 this species extends from the latest Pliocene to the present day (upper part of N21 to present day).

Pliocene

1) The Late Pliocene Zone N21 is marked by the occurrence of *G. tosaensis* and the absence of *G. truncatulinoides.*

2) *Pulleniatina obliquiloculata* does not extend lower than the base of N21 (Late Pliocene) in the three sites.

3) *Globoquadrina altispira* becomes extinct at or near the Pliocene-Pleistocene boundary, and in none of the sections does this species overlap with *Globorotalia truncatulinoides.* The extinction of *Globigerinoides obliquus* is also close to the Pliocene-Pleistocene boundary.

4) *Globigerinoides ruber* ranges from the uppermost part of N20 to the Recent.

5) *Pulleniatina primalis* overlaps with *P. obliquiloculata* within Zone N21 (Late Pliocene) in Sites 209 and 210. *P. primalis* was not observed in Site 203.

6) In Site 210, the first appearance of *Sphaeroidinella dehiscens* and *Globorotalia crassaformis* occurs near the base of N21 (Late Pliocene). Despite solution concentration in Site 210, *S. dehiscens* was not observed in the Early Pliocene.

7) The presence of *Globorotalia margaritae* marks the Early Pliocene in Site 210 where *S. dehiscens* is not present. *G. margaritae* appears to be a much more reliable indicator for the Early Pliocene than *S. dehiscens*, particularly in cooler areas away from the equator.

8) In Site 210, the Miocene-Pliocene boundary is difficult to place, but is tentatively placed at the extinction of *Globorotalia continuosa* and before the first appearance of *G. margaritae.*

ACKNOWLEDGMENTS

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PLATE 1

Figures 1-4	*Candeina nitida* d'Orbigny, side views. 1. 21-206-1, CC; X67. 2. 21-208-9, CC; X73. 3. 21-208-13-5, 50-52 cm; X82. 4. 21-208-13-5, 50-52 cm; X82.
Figures 5, 6	*Globigerina pachyderma* (Ehrenberg), left coiling form. 5. Umbilical view; X165. 6. 21-207-4-1, 50-52 cm; Spiral view; X158.
Figures 7-11	*Globigerina pachyderma* (Ehrenberg), right coiling form. 7. Umbilical view; X148. 8. Spiral view; X147. 9. Umbilical view; X171. 10. Umbilical view; X152. 11. 21-206-18, CC; Side view; X152.
Figures 12-14	*Globigerina bulloides* d'Orbigny. 12. Umbilical view; X111. 13. 21-206-14, CC; Spiral view; X147. 14. 21-207A-10-2, 75-77 cm; Umbilical view; X58.

PLATE 1

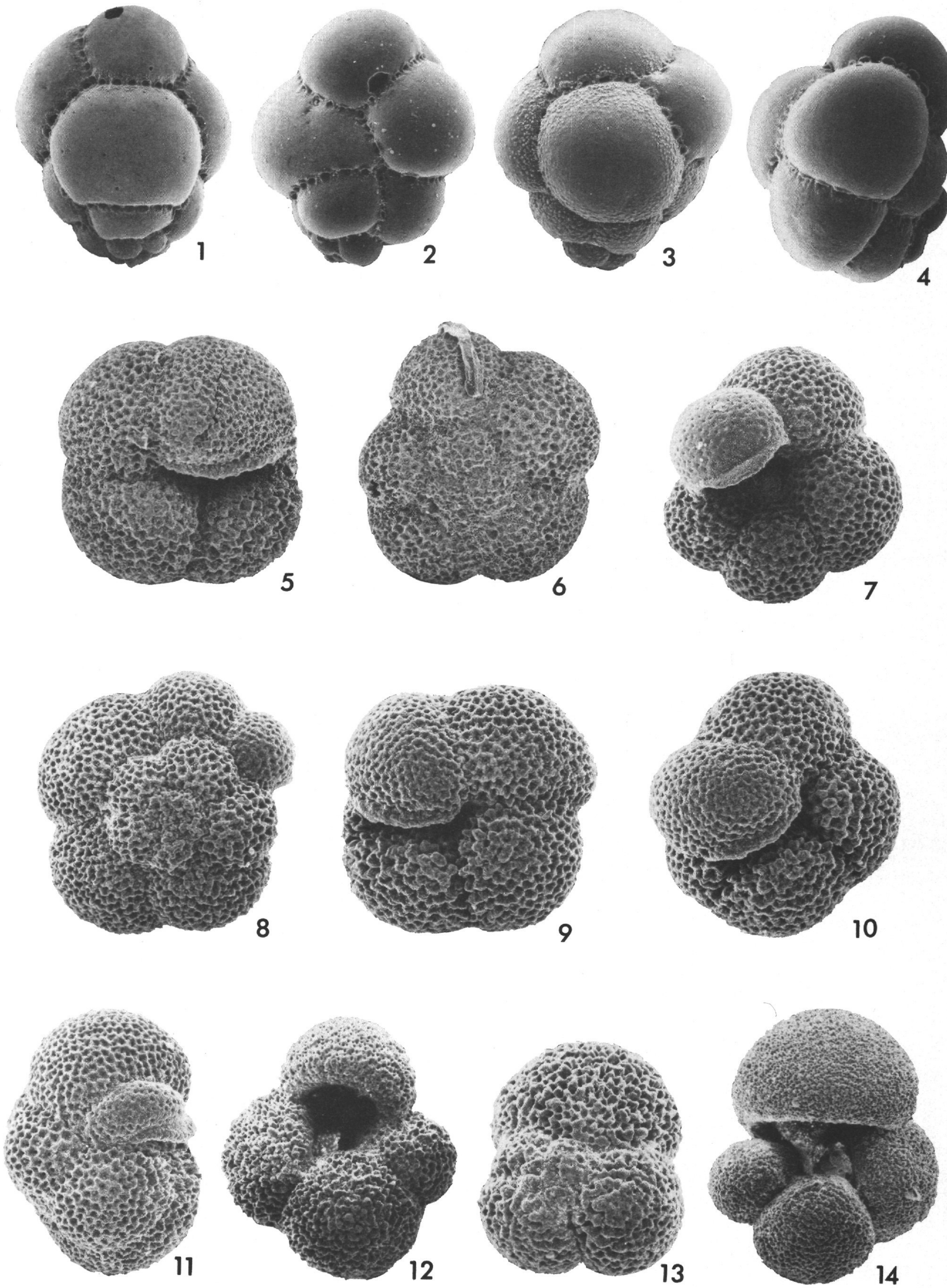

PLATE 2

Figure 1	*Globigerina* sp., 21-207A-10-2, 75-77 cm; Umbilical view; X86.
Figure 2	*Globorotalia obesa* Bolli; 21-208-20-2, 50-52 cm; Umbilical view; X69.
Figures 3, 4	*Globigerina falconensis* Blow. 3. Umbilical view; X127. 4. 21-206-12-3, 30-32 cm; Spiral view; X130.
Figures 5-8	*Globigerina woodi* Jenkins. 5. 21-206-14, CC; Umbilical view; X179. 6. 21-206-23, CC; Spiral view; X132. 7. 21-206-23, CC; Umbilical view; X166. 8. 21-206-27, CC; Umbilical view; X136.
Figures 9, 10	*Globigerina decoraperta* Takayanagi and Saito. 9. Umbilical view; X200. 10. 21-207A-7, CC; Spiral view; X175.
Figures 11-14	*Globigerina nepenthes* Todd. 11. Umbilical view; X141. 12. 21-206-21, CC; Umbilical view; X132. 13. Umbilical view, X133. 14. 21-206-24, CC; Spiral view; X135.
Figures 15, 16	*Globigerina druryi* Akers. 15. 21-206-28, CC; Umbilical view; X140. 16. 21-206-25, CC; Spiral view; X143.

PLATE 2

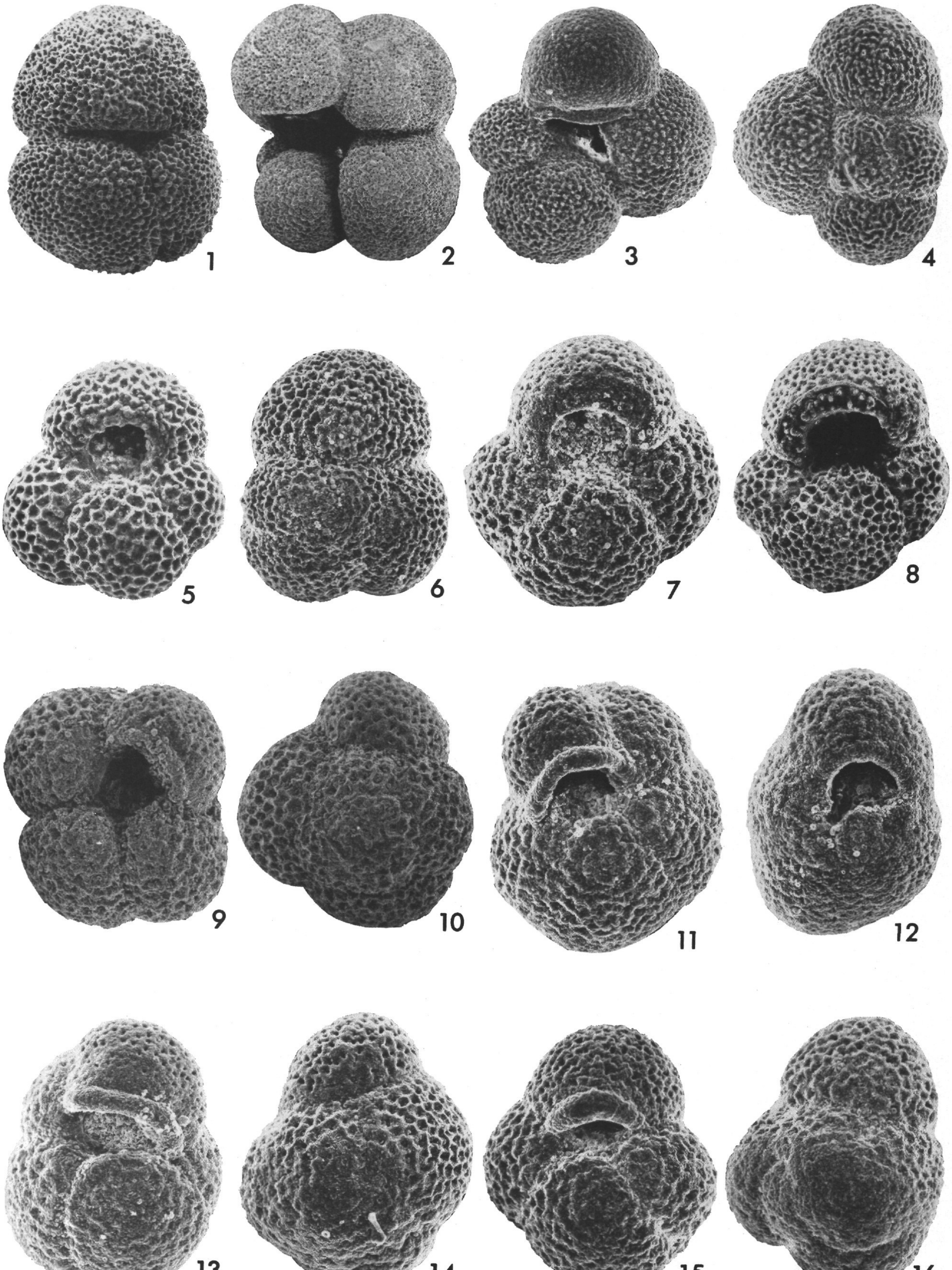

PLATE 3

Figures 1-3	*Globoquadrina altispira* (Cushman and Jarvis). 1. Umbilical view; ×98. 2. Spiral view; ×106. 3. 21-206-18, CC; Side view; ×108.
Figures 4, 5	*Globigerina digitata* Brady. 4. Umbilical view; ×106. 5. 21-206-13, CC; Spiral view; ×111.
Figure 6	*Globigerina praedigitata* Parker. 21-208-13-5; 50-53 cm; Umbilical View; ×111.
Figures 7-9	*Globigerina angulisuturalis* Bolli. 7. Spiral view; ×211. 8. Umbilical view; ×183. 9. 21-209-13, CC; Spiral view; ×202.
Figure 10	*Globigerinoides bolli* Blow. 21-206-18, CC; Umbilical view; ×187.
Figures 11, 13	*Globigerinoides obliquus* Bolli. 11. 21-206-13, CC; Spiral view; ×60. 13. 21-206-13, CC; Umbilical view; ×62.
Figures 12,14,15	*Globigerinoides conglobatus* (Brady). 12. 21-206-7, CC; Spiral view; ×71. 14. 21-209-1, CC; Umbilical view; ×63. 15. 21-206-14, CC; Umbilical view; ×60.

PLATE 3

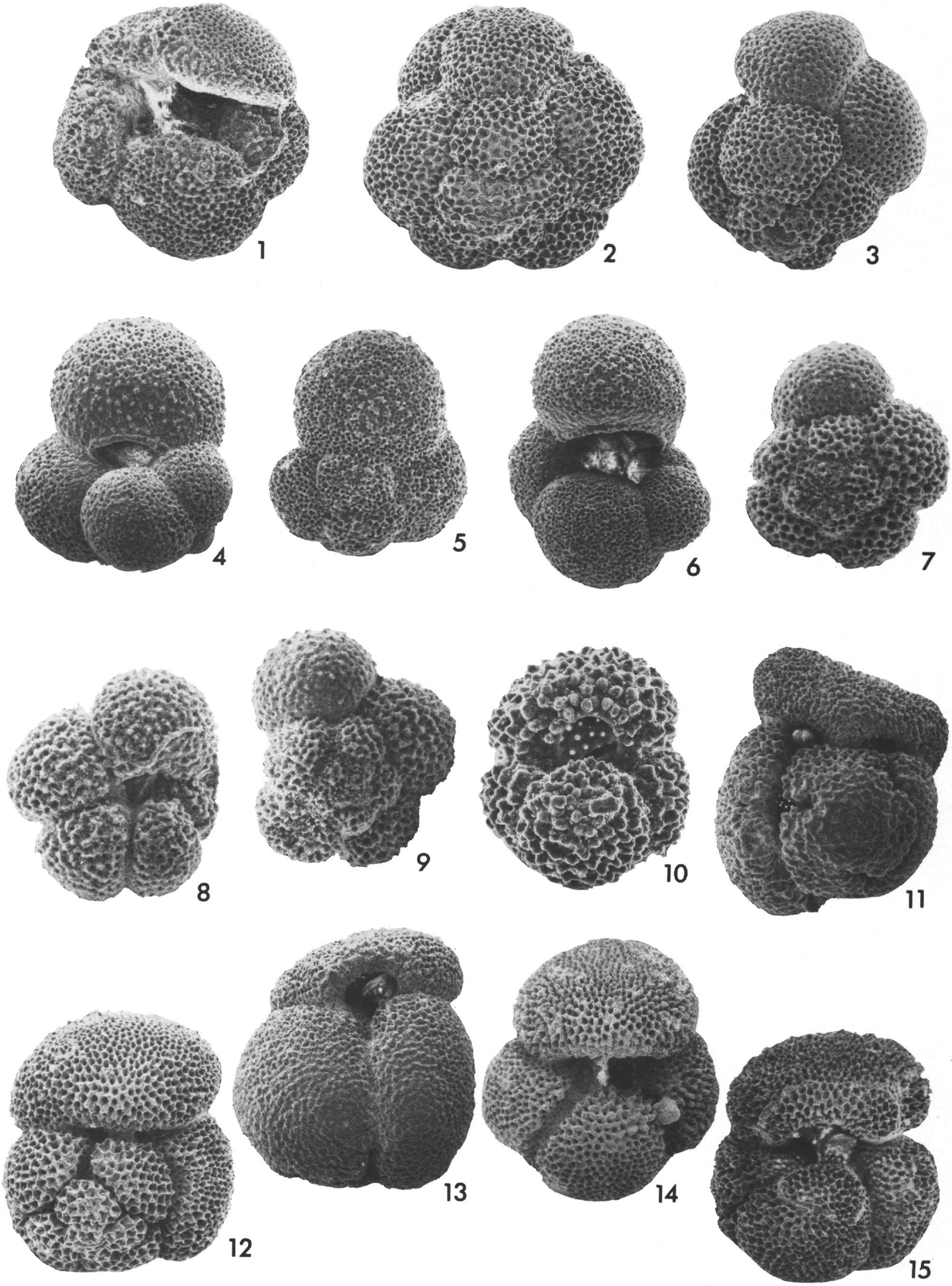

PLATE 4

Figure 1	*Globigerinoides* cf. *mitra* Todd. 21-208-14-1, 50-52 cm; Spiral view; X67.
Figures 2-5	*Globigerinoides obliquus* Bolli. 2. 21-206-13, CC; Umbilical view; X147. 3. 21-206-14, CC; Umbilical view; X140. 4. 21-206-18, CC; Spiral view; X107. 5. 21-206-14, CC; Spiral view; X134.
Figures 6, 7	*Globigerinoides ruber* (d'Orbigny) umbilical views. 6. 21-206-11, CC; X122. 7. 21-206-14, CC; X128.
Figure 8	*Globigerinoides* sp. 21-206-11, CC; Spiral view; X129.
Figure 9	*Globigerinoides* sp. 21-206-14, CC; Umbilical view; X111.
Figure 10	*Globigerinoides ruber pyramidalis* (vanden Broeck). 21-206-13, CC; Side view; X116.
Figure 11, 12	*Globigerinoides* cf. *quadrilobatus trilobus* (Reuss). 11. 21-207A-9-5, 75-77 cm; Umbilical view; X86. 12. 21-207A-10-1, 110-112 cm; Spiral view; X134.
Figures 13-16	*Globigerinoides transitoria* Blow. 13. Spiral view; X96. 14. Umbilical view; X118. 15. Umbilical view; X85. 16. 21-207A-9-4, 75-77 cm; Umbilical view; X105.

PLATE 4

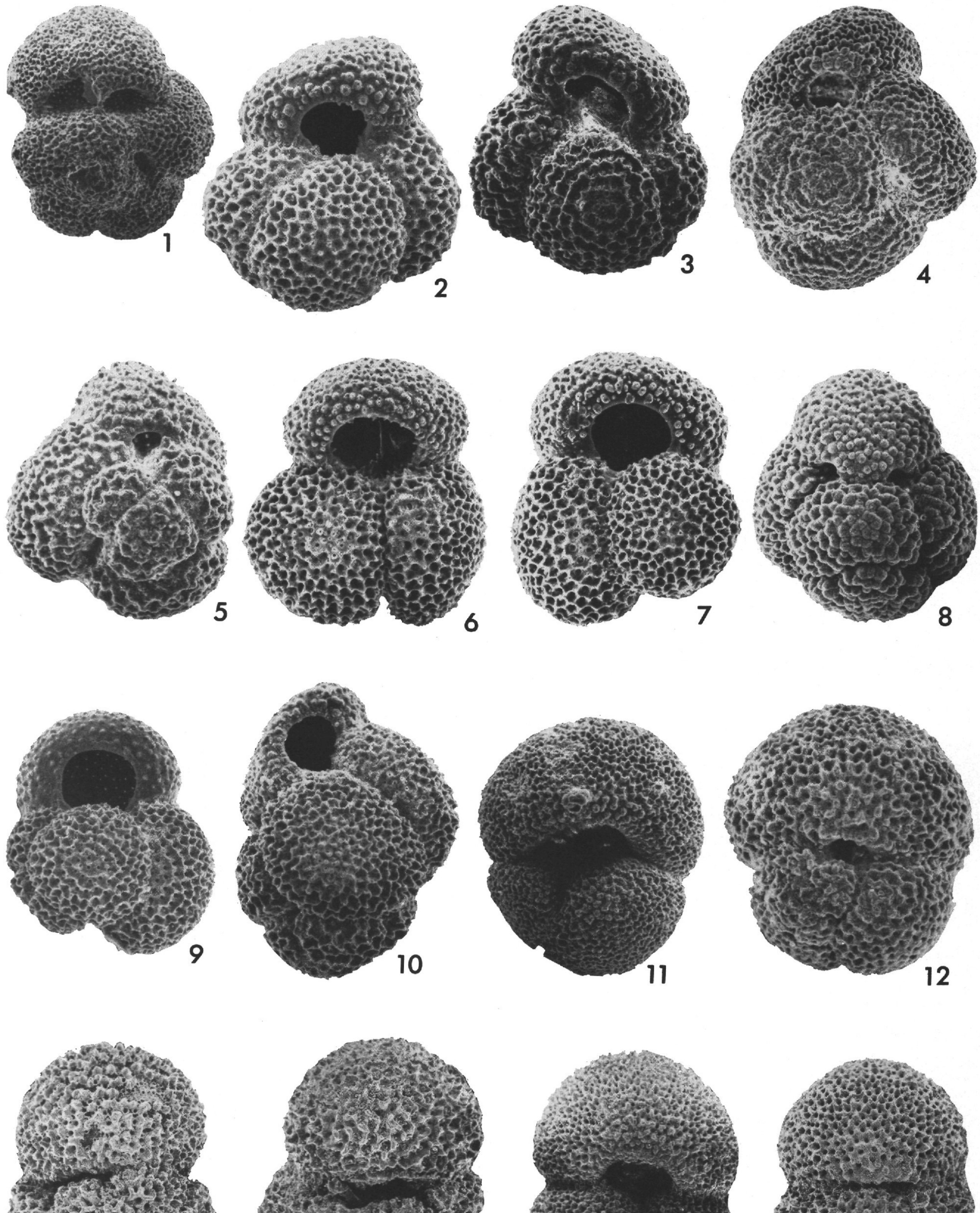

PLATE 5

Figures 1-5	*Globigerinoides quadrilobatus trilobus* (Reuss). 1. Spiral view, X137. 2. Umbilical view; X148. 3. Umbilical view; X144. 4. 21-207A-9-4, 75-77 cm; Umbilical view; X125. 5. 21-206-11, cc; Umbilical view; X136.
Figures 6, 7	*Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny) 6. Umbilical view; X67. 7. 21-208-1-1, 52-54 cm; Spiral view; X59.
Figure 8	*Globigerinoides quadrilobatus sacculifer* (Brady) 21-206-31, CC; Umbilical view; X108.
Figure 9	*Globigerinoides* sp. 21-207A-9-5, 75-77 cm; Umbilical view; X78.
Figures 10-13	*Globigerinoides quadrilobatus sacculifer* (Brady). 10. 21-206-18, CC; Umbilical view; X85. 11. 21-206-18, CC; Spiral view; X52. 12. 21-206-13, CC; Umbilical view; X83. 13. 21-206-13, CC; Spiral view; X83.
Figures 14, 15	*Globigerinoides fistulosus* (Schubert) spiral views. 14. 21-208-2, CC; X39. 15. 21-208-30, CC; X39.

PLATE 5

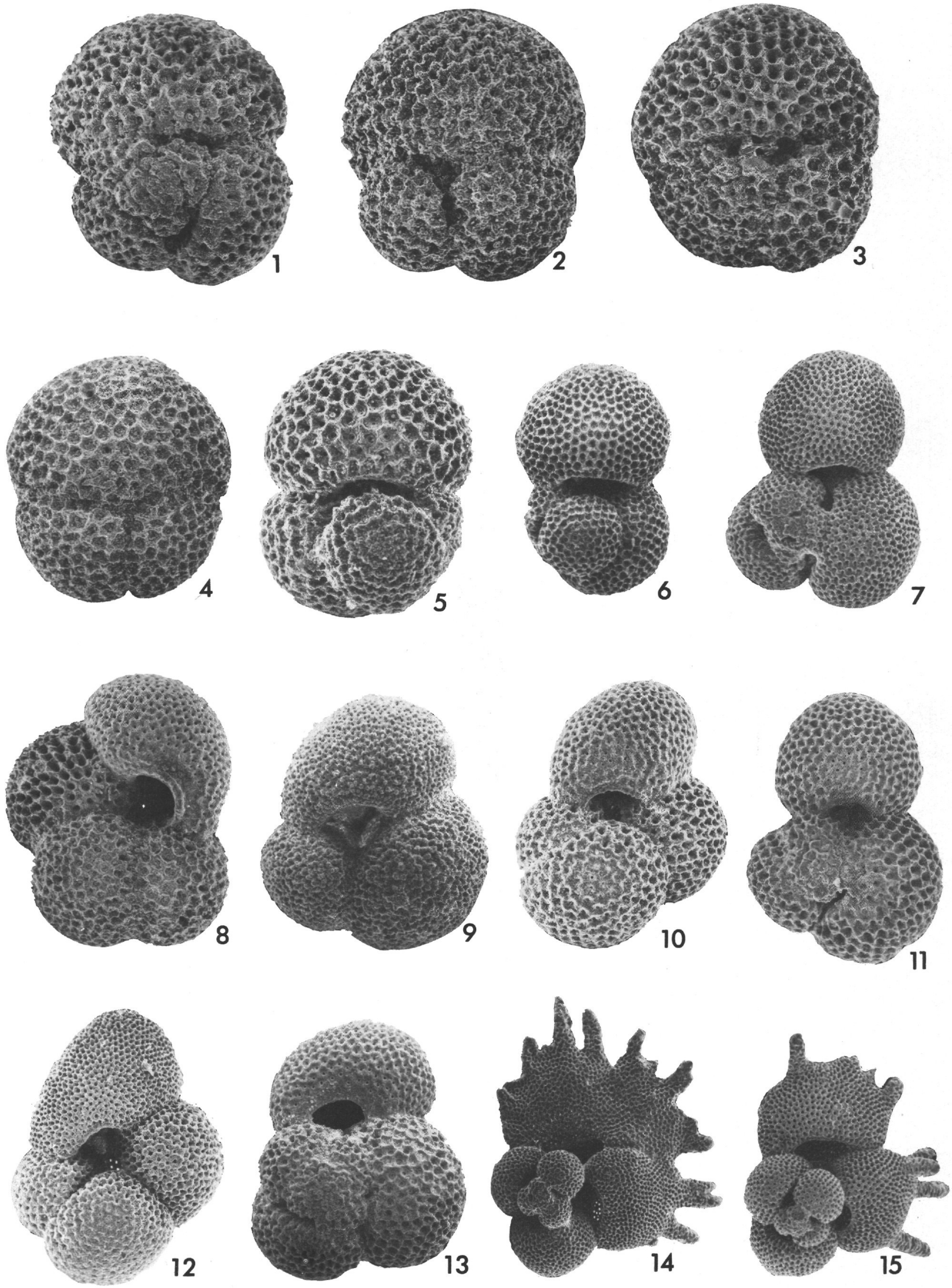

PLATE 6

Figure 1	*Globigerinoides quadrilobatus sacculifer* (Brady). 21-209-1, CC; Umbilical view.
Figures 2-11	*Globigerinoides quadrilobatus fistulosus* (Schubert). Simpler forms at end of evolutionary bioseries. Changes within range of bioseries shown on Plates 6 to 8. Younger samples at top of plate. 2. 21-209-2-4, 146-148 cm; Umbilical view; X49. 3. Umbilical view; X60. 4. Umbilical view; X62. 5. 21-209-3-1, 98-100 cm; Spiral view; X70. 6. Spiral view; X68. 7. Umbilical view; X49. 8. 21-209-3-3, 148 cm; Spiral view; X82. 9. Umbilical view; X71. 10. Umbilical view; X54. 11. 21-209-3-4, 146-148 cm; Umbilical view; X75.

PLATE 6

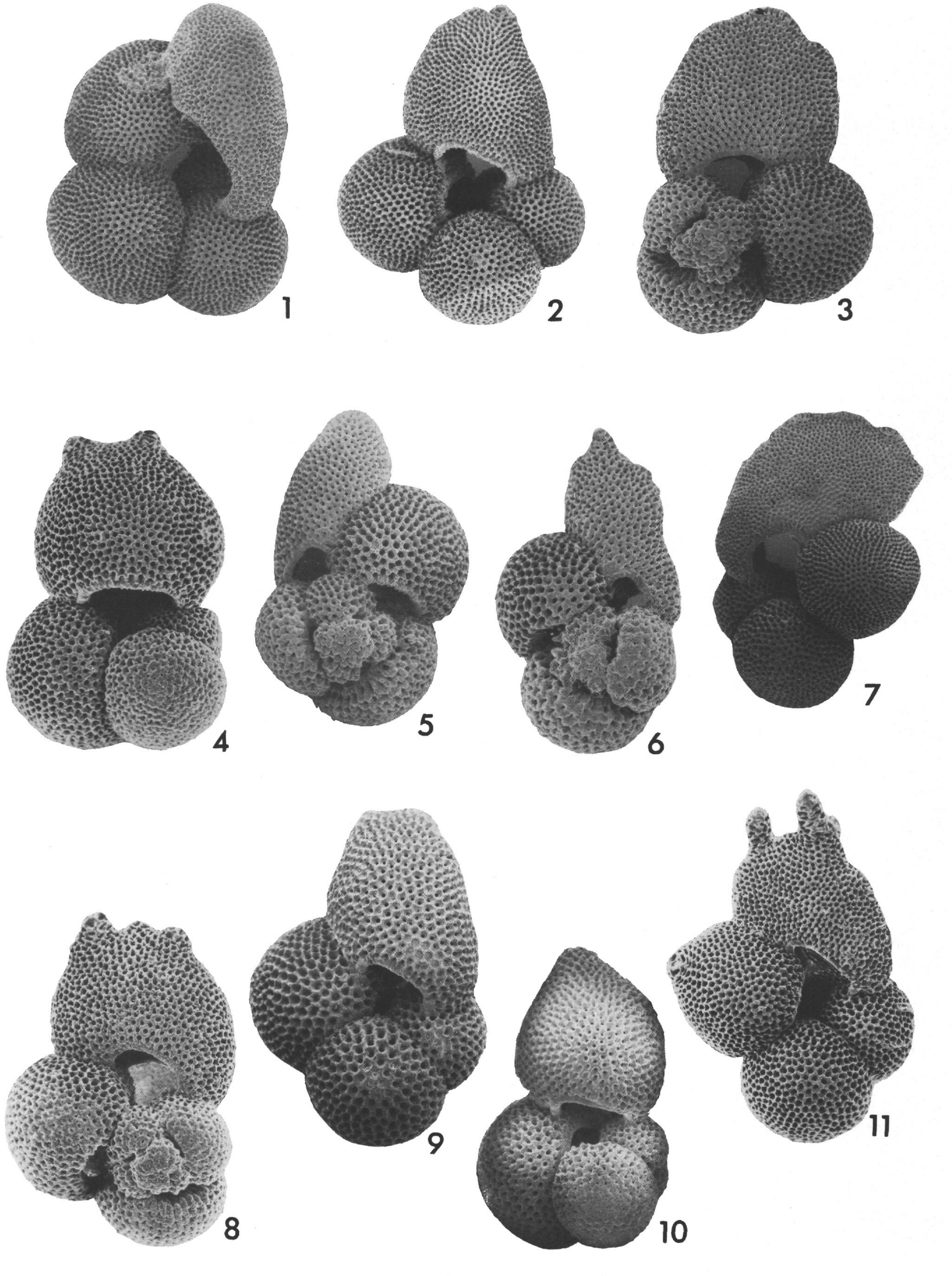

PLATE 7

Figures 1-13 *Globigerinoides quadrilobatus fistulosus* (Schubert). More complex forms in middle part of evolutionary bioseries. Younger samples at top of plate.

1. 21-209-3-5, 146-148 cm; Umbilical view; X67.
2. Spiral view; X54.
3. Spiral view; X40.
4. Spiral view; X36.
5. 21-209-3, CC; Spiral view; X43.
6. Spiral view; X58.
7. Spiral view; X48.
8. Spiral view; X42.
9. 21-209-4-5, 72-74 cm; Spiral view; X54.
10. Spiral view; X43.
11. Umbilical view; X39.
12. Spiral view; X61.
13. 21-209-4, CC; Umbilical view; X50.

PLATE 7

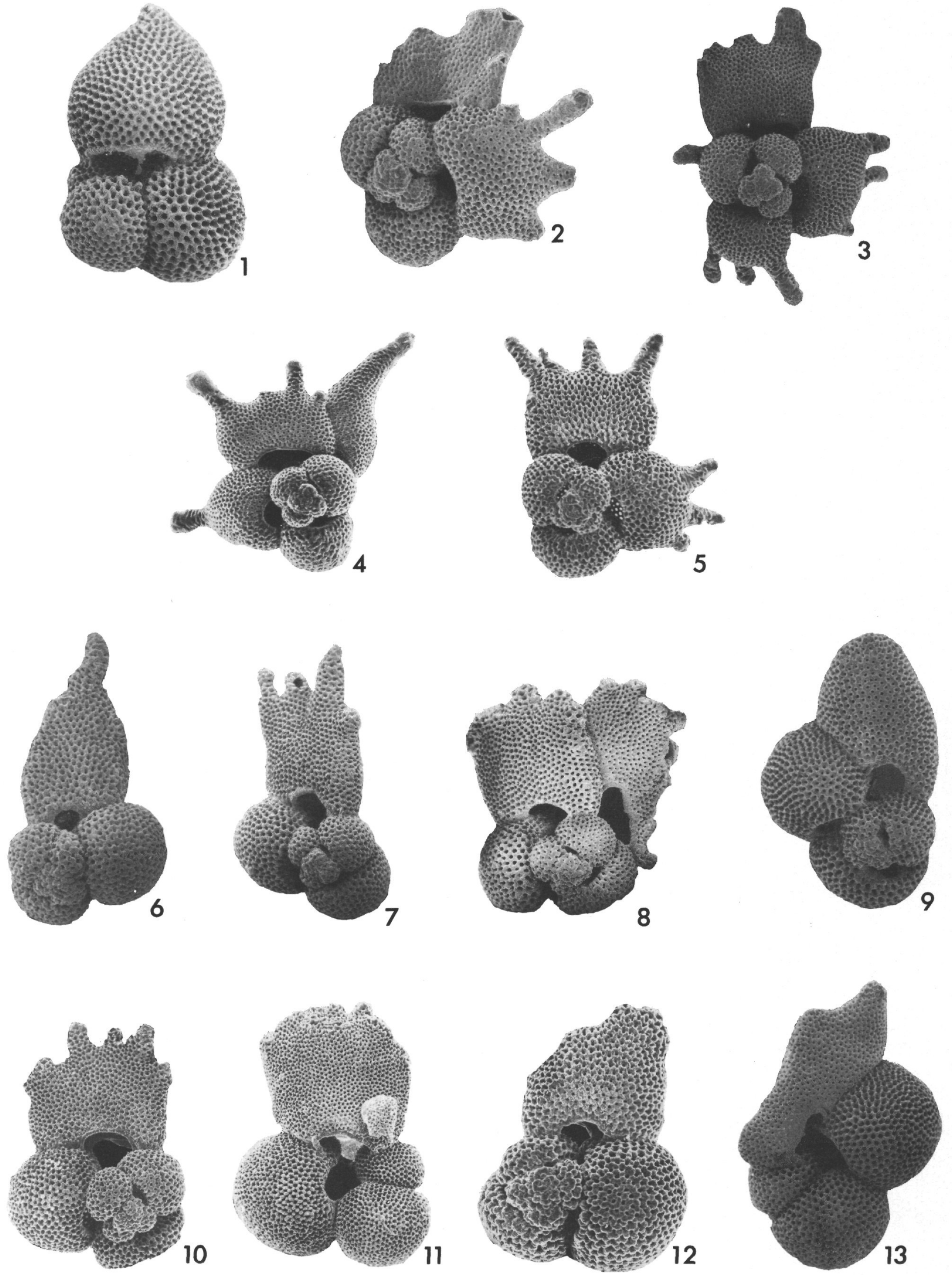

PLATE 8

Figures 1-10 *Globigerinoides quadrilobatus fistulosus* (Schubert)
Simpler forms at beginning of evolutionary bioseries. Younger samples at top of plate.

1. Umbilical view; X69.
2. Spiral view; X58.
3. Spiral view; X57.
4. Spiral view; X52.
5. 21-209-5-1, 73-75 cm; Umbilical view; X49.
6. Umbilical view; X63.
7. Umbilical view; X73.
8. Spiral view; X47.
9. Spiral view; X68.
10. 21-209-5-2, 146-148 cm; Umbilical view; X56.

Figures 11-14 *Globigerinoides quadrilobatus sacculifer* (Brady)
Forms immeidately preceding evolutionary bioseries of *G. quadrilobatus fistulosus.*

11. Spiral view; X61.
12. Spiral view; X82.
13. Umbilical view; X59.
14. 21-209-5-4, 72-74 cm; Spiral view; X72.

PLATE 8

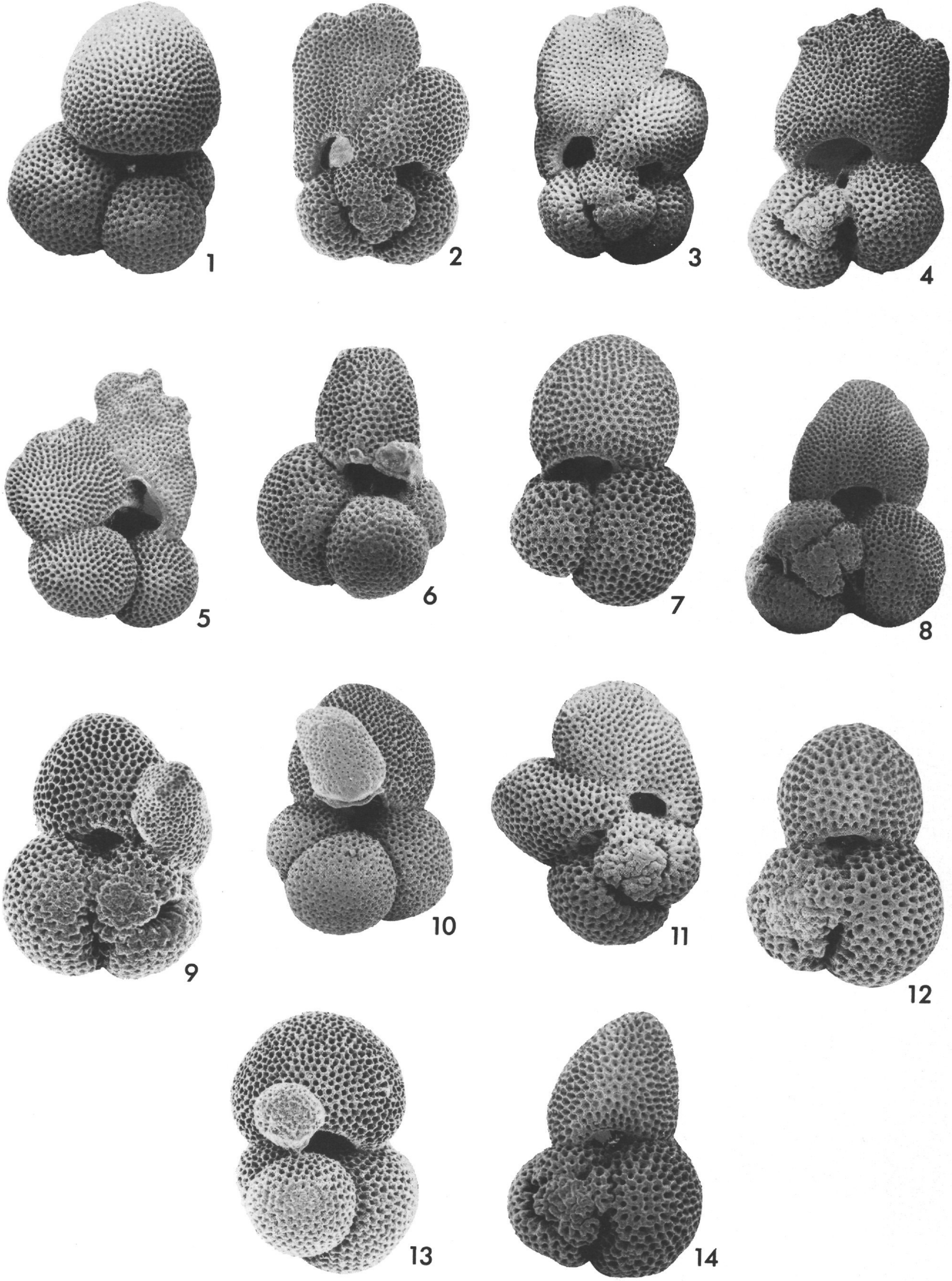

PLATE 9

Figures 1-5	*Hastigerina aequilateralis* (Brady). 1. Spiral view; X79. 2. Umbilical view; X71. 3. Side view; X76. 4. 21-206-13, CC; Side view; X76. 5. 21-206-25, CC; Umbilical view; X148.
Figures 6, 7	*Hastigerina pelagica* (d'Orbigny). 6. Apertural view; X63. 7. 21-203-1-1, 70-72 cm; Side view; X67.
Figure 8	*Catapsydrax dissimilis* (Cushman and Bermudez). 21-206-41, cc; X88.
Figures 9-13	*Globoquadrina dehiscens* (Chapman, Parr, and Collins) 9. Spiral view; X68. 10. Umbilical view; X61. 11. Side view; 21-208-17-1, 50-52 cm; Side view; X79. 12. 21-206-32, cc; Umbilical biew; X105. 13. 21-206-24, cc; Spiral view; X108.
Figures 14, 15	*Globoquadrina venezuelana* (Hedberg). 14. 21-206-25, CC; Spiral view; X67. 15. 21-206-23, CC; Umbilical view; X69.

PLATE 9

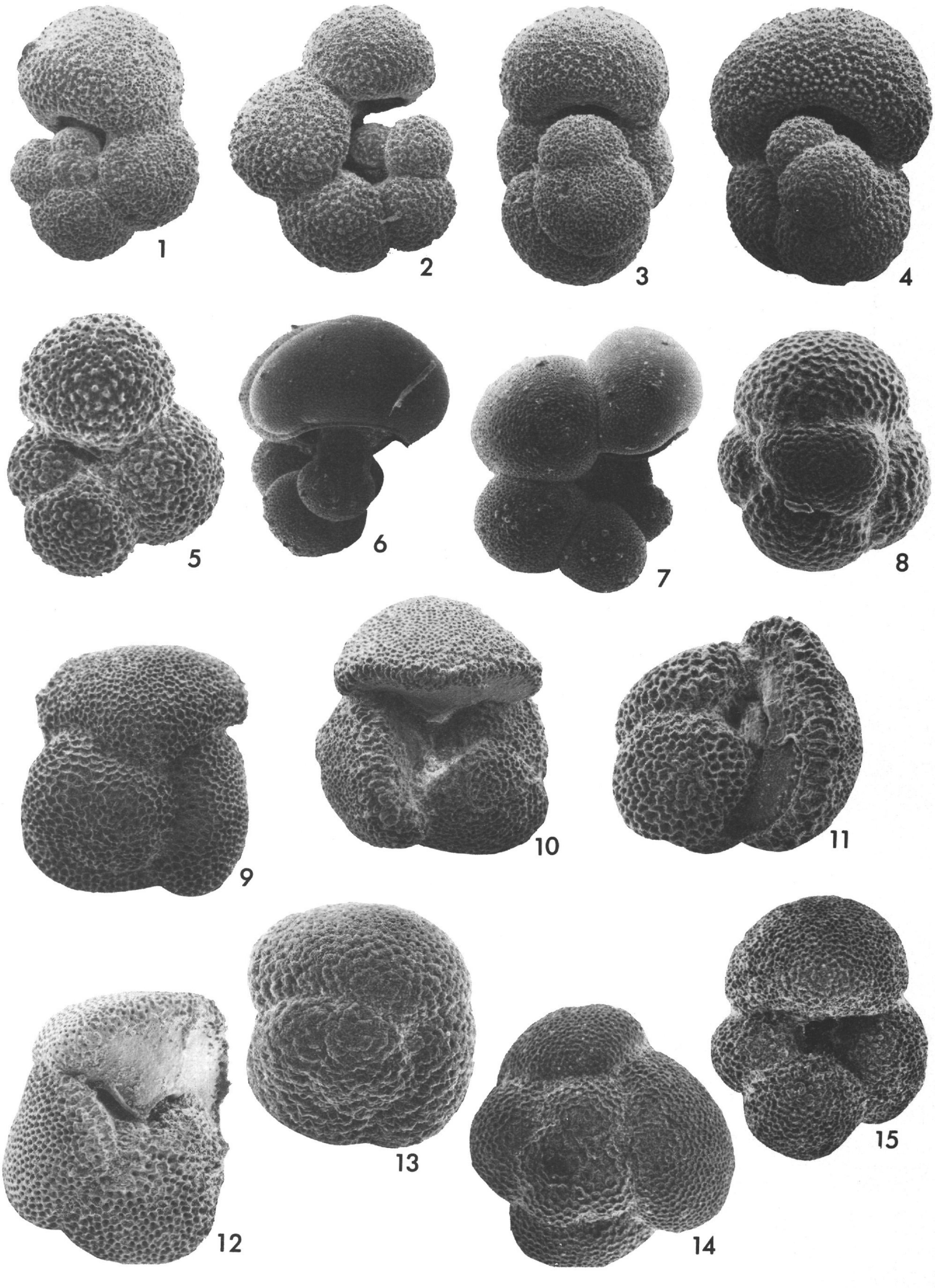

PLATE 10

Figures 1-4 *Globoquadrina* cf. *altispira* (Cushman and Jarvis)
1. Umbilical view; X 118.
2. Spiral view; X 136.
3. Umbilical view; X 109.
4. 21-206-31, CC; Spiral view; X 138.

Figures 5-7 *Globorotalia dutertrei* (d'Orbigny).
5. 1-208-1-1, 52-54 cm; Umbilical view; X69..
6. Spiral view; X 79.
7. 21-206-11-3, 30-32 cm; Side view; X97.

Figures 8, 9 *Globorotalia humerosa* Takayanagi and Saito.
8. Umbilical view; X 114.
9. 21-206-13, CC; Side view; X 101.

Figures 10-13 *Globorotalia acostaensis* Blow.
10. Umbilical view, X 100.
11. Side view; X95.
12. Umbilical view; X 100.
13. 21-208-13-1, 50-52 cm; Spiral view; X 101.

PLATE 10

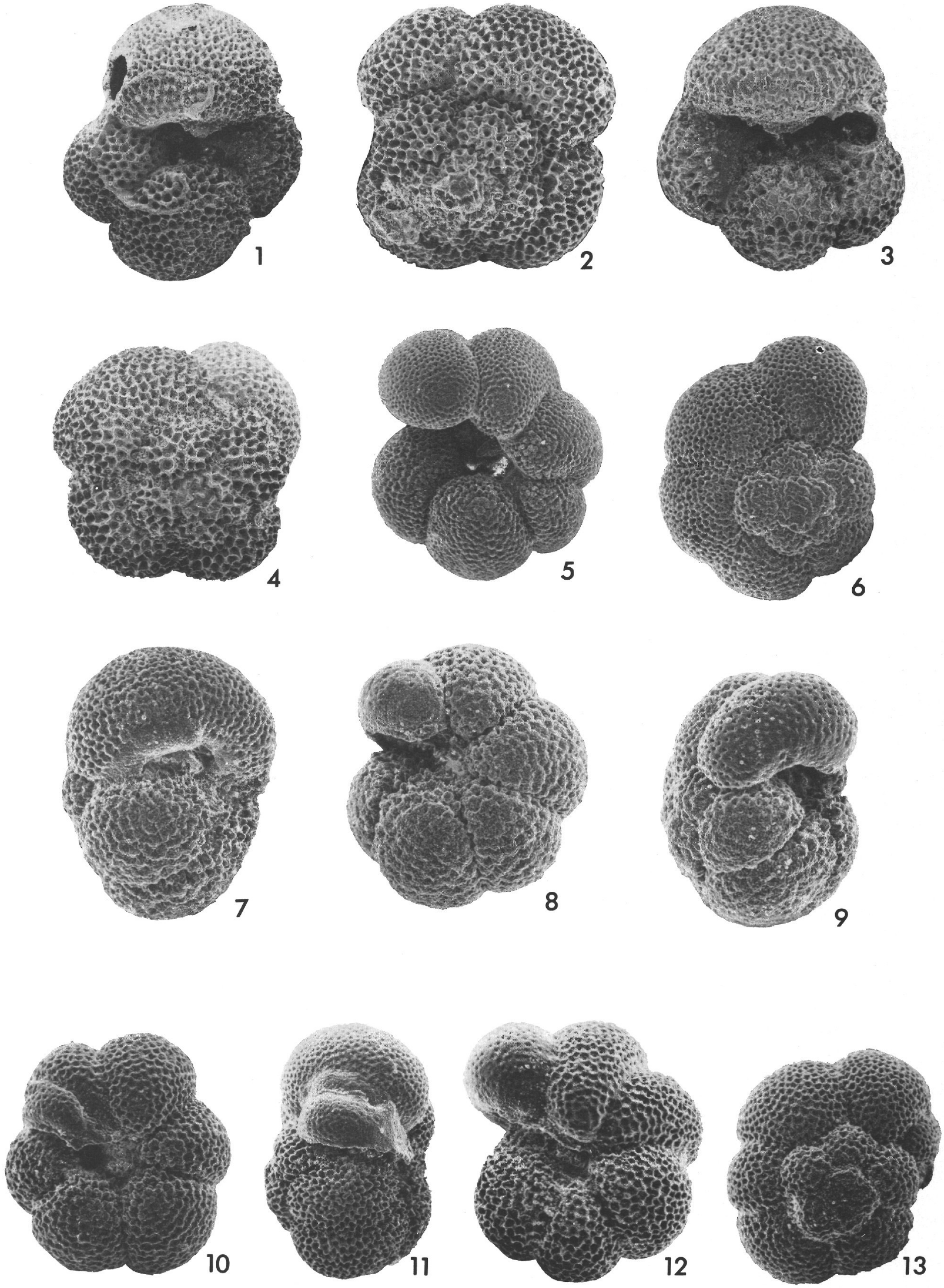

PLATE 11

Figures 1-3, 5	*Globoquadrina altispira* (Cushman and Jarvis). 1. Umbilical view; X95. 2. Spiral view; X93. 3. Umbilical view; X92; 5. 21-207A-9-3, 75-77 cm; Side view; X66.
Figure 4	*Globoquadrina* cf. *altispira* (Cushman and Jarvis). 21-208-8 CC; Side view; X98.
Figures 6-9	*Globorotalia panda* Jenkins. 6. 21-206-27, CC; Spiral view; X87. 7. 21-206-27-2, 90-92 cm; Side view; X101. 8. 21-207A-10-2, 75-77 cm; Umbilical view; X107. 9. 21-206-31, CC; Umbilical view; X91.
Figures 10-12	*Globorotalia margaritae* Bolli and Bermudez. 10. Spiral view; X132. 11. Umbilical view; X113. 12. 21-208-8, CC; Side view; X115.
Figures 13, 14	*Globorotalia cibaoensis* Bermudez. 13. Umbilical view; X89. 14. 21-208-8, CC; Spiral view; X88.
Figures 15, 16	*Globorotalia scitula* (Brady). 15. Umbilical view; X82. 16. 21-206-6, CC; Spiral view; X67.

PLATE 11

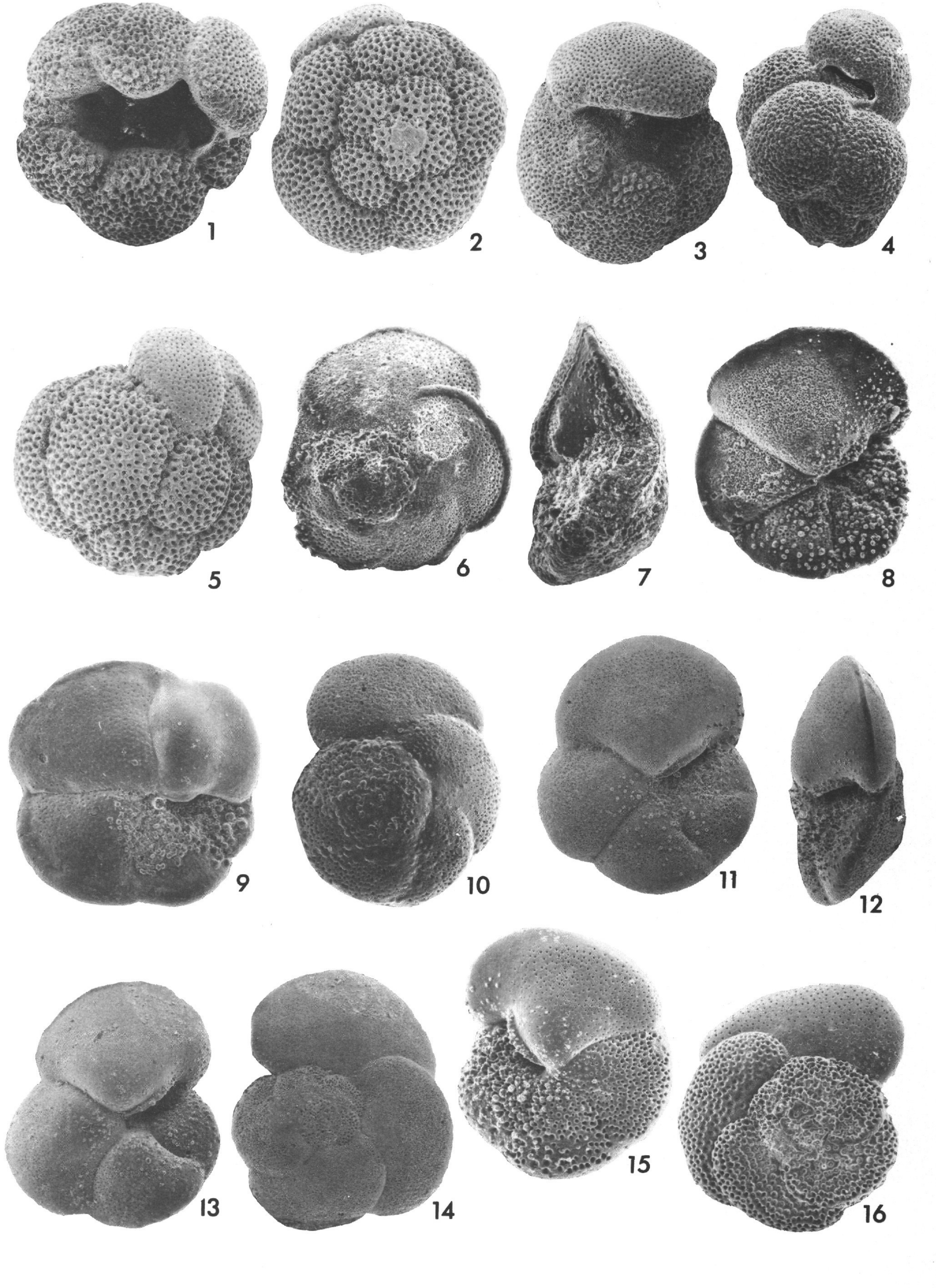

PLATE 12

Figures 1-4	*Globorotalia* cf. *menardii* (Parker, Jones, and Brady). 1. 21-206-13, CC; Spiral view; X61. 2. 21-206-13, CC; Umbilical view; X73. 3. 21-206-14, CC; Umbilical view; X94. 4. 21-206-13, CC; Side view; X79.
Figures 5-9	*Globorotalia menardii* (Parker, Jones, and Brady). 5. 21-206-7, CC; Spiral view; X40. 6. 21-209-1, CC; Umbilical view; X48. 7. 21-206-18, CC; Spiral view; X66. 8. 21-209-1, CC; Side view; X43. 9. 21-206-8, CC; Side view; X64.
Figures 10, 11	*Globorotalia tumida flexuosa* (Koch). 10. Side view; X42. 11. 21-206-1, CC; Umbilical view; X48.
Figures 12-16	*Globorotalia tumida* (Brady). 12. 21-206-8, CC; Spiral view; X47. 13. 21-206-14, CC; Side view; X45. 14. 21-206-3-3, 148-50 cm; Umbilical view; X41. 15. 21-206-8, CC; Umbilical view; X42. 16. 21-206-6, CC; Umbilical view; X43.

PLATE 12

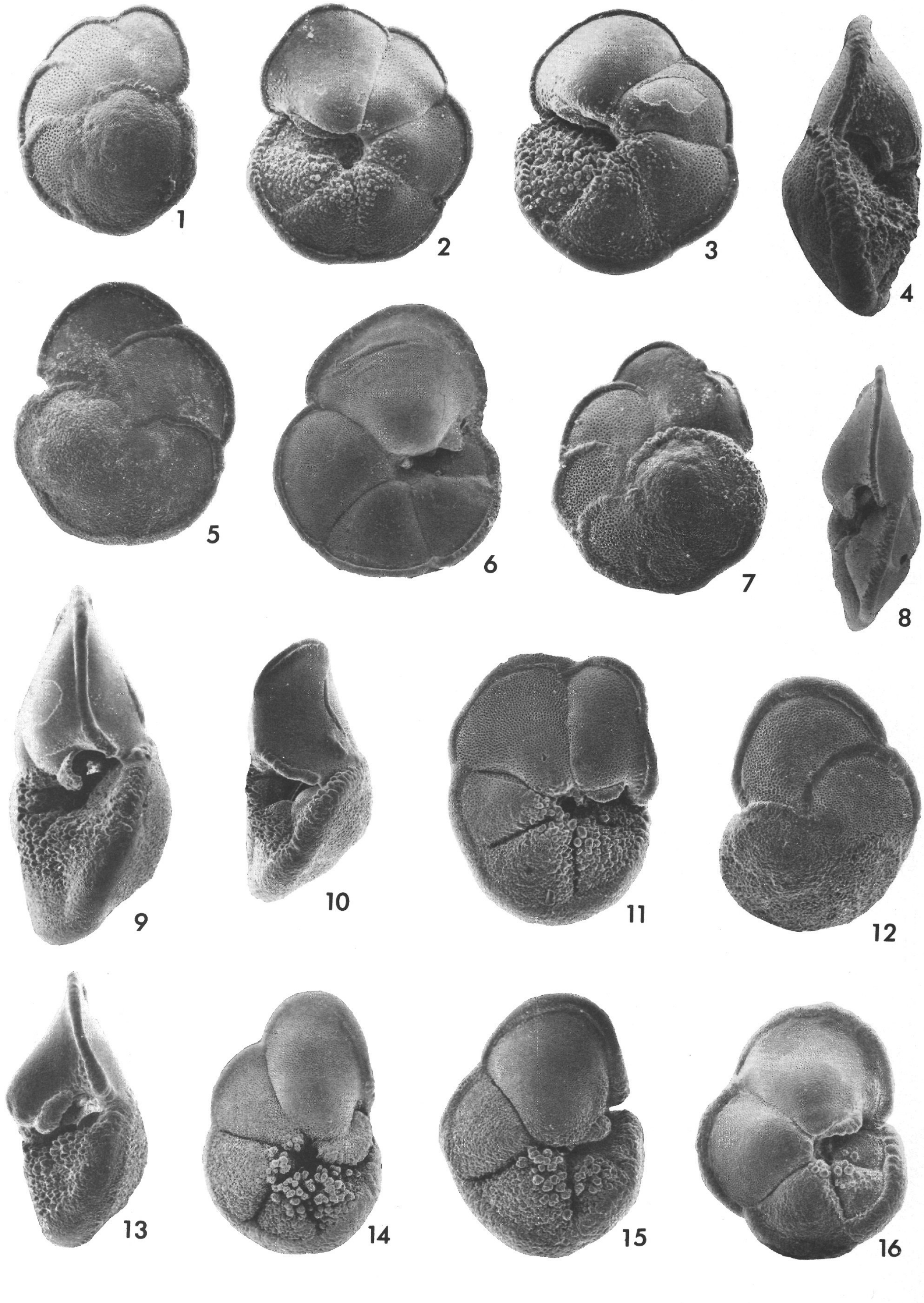

PLATE 13

Figures 1, 2 — *Globorotalia multicamerata* Cushman and Jarvis.
1. Umbilical view; X51.
2. 21-206-3-3, 148-150 cm; Spiral view; X49.

Figures 3-5 — *Globorotalia praemenardii* Cushman and Stainforth.
3. 21-206-27, CC; Side view; X132.
4. 21-206-27, CC; Umbilical view; X89.
5. 21-206-28, CC; Umbilical view; X104.

Figures 6-8 — *Globorotalia peripheroronda* Blow and Banner.
6. 21-207A-10-1, 110-112 cm; Spiral view; X143.
7. 21-207A-10-2, 75-77 cm; Umbilical view; X128.
8. 21-206-31, CC; Side view; X141.

Figures 9-11 — *Globorotalia perpheroacuta* Blow and Banner.
9. 21-206-32, CC; Umbilical view; X92.
10. 21-208-20, CC; Side view; X111.
11. 21-206-28, CC; Spiral view; X113.

Figures 12-16 — *Globorotalia mayeri* Cushman and Ellisor.
12. 21-207A-10-1, 110-112 cm; Umbilical view; X143.
13. 21-206-28, CC; Spiral view; X123.
14. 21-207A-10-1, 110-112 cm; Spiral view; X79.
15. 21-206-28, CC; Side view; X121.
16. 21-206-28, CC; Umbilical view; X128.

PLATE 13

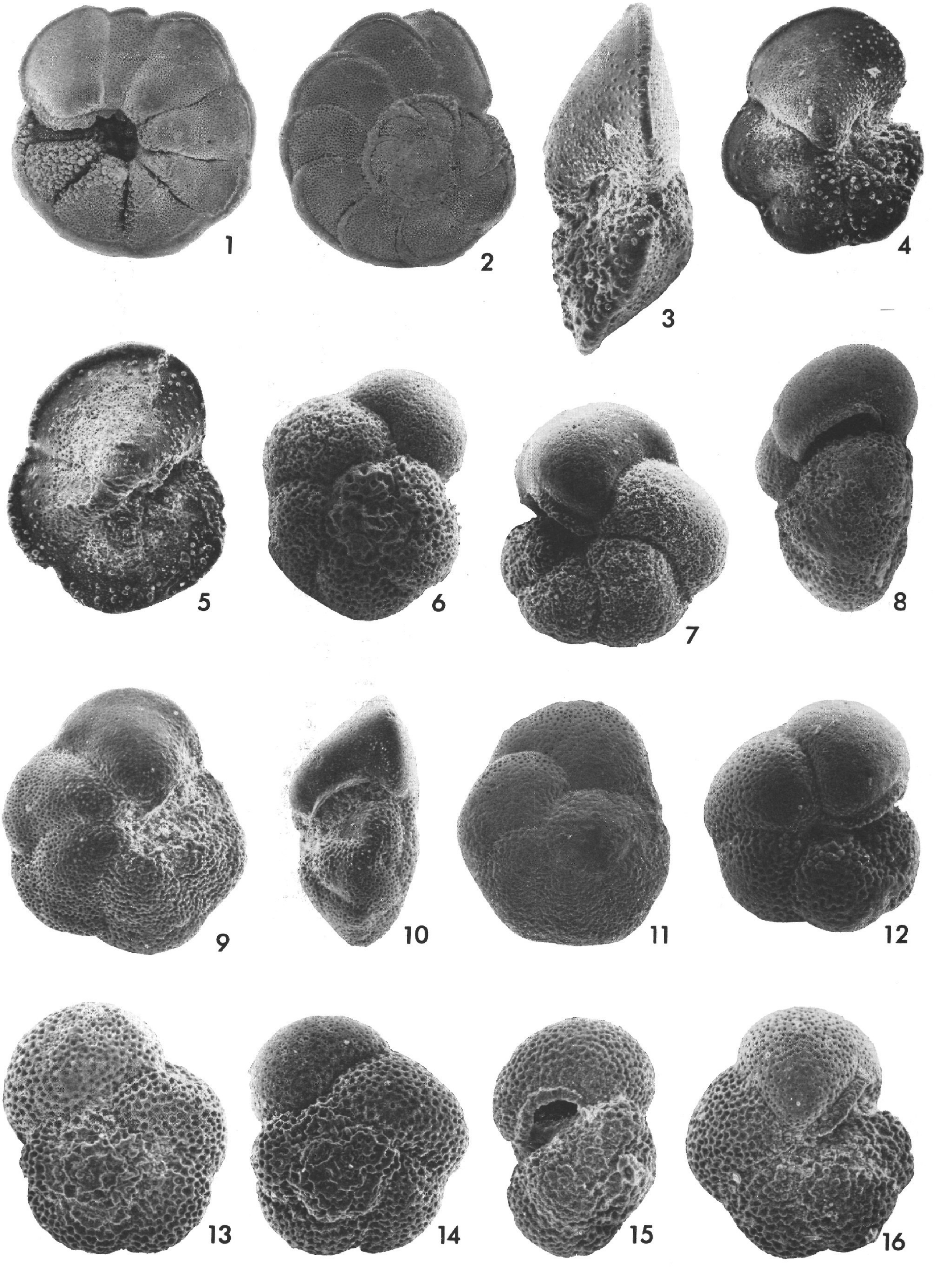

PLATE 14

Figures 1, 2	*Globorotalia siakensis* (LeRoy). 1. Umbilical view; X115. 2. 21-206-31, CC; Spiral view; X133.
Figures 3-6	*Globorotalia continuosa* Blow. 3. Side view; X205. 4. Umbilical view; X220. 5. 21-206-24, CC; Spiral view; X206. 6. 21-206-26, CC; Umbilical view; X170.
Figures 7-14	*Globorotalia crassaformis* Galloway and Wissler. 7. 21-206-18, CC; Umbilical view; X86. 8. 21-206-18, CC; Umbilical view; X72. 9. 21-206-11-3, 30-32 cm; Spiral view; X97. 10. 21-206-14, CC; Umbilical view; X79. 11. 21-206-18, CC; Spiral view; X95. 12. 21-206-18, CC; Side view; X93. 13. 21-206-12-3, 30-32 cm; Close-up of edge showing keel; X322. 14. 21-206-13, CC; Close-up of edge showing rounded porous periphery; X269.

PLATE 14

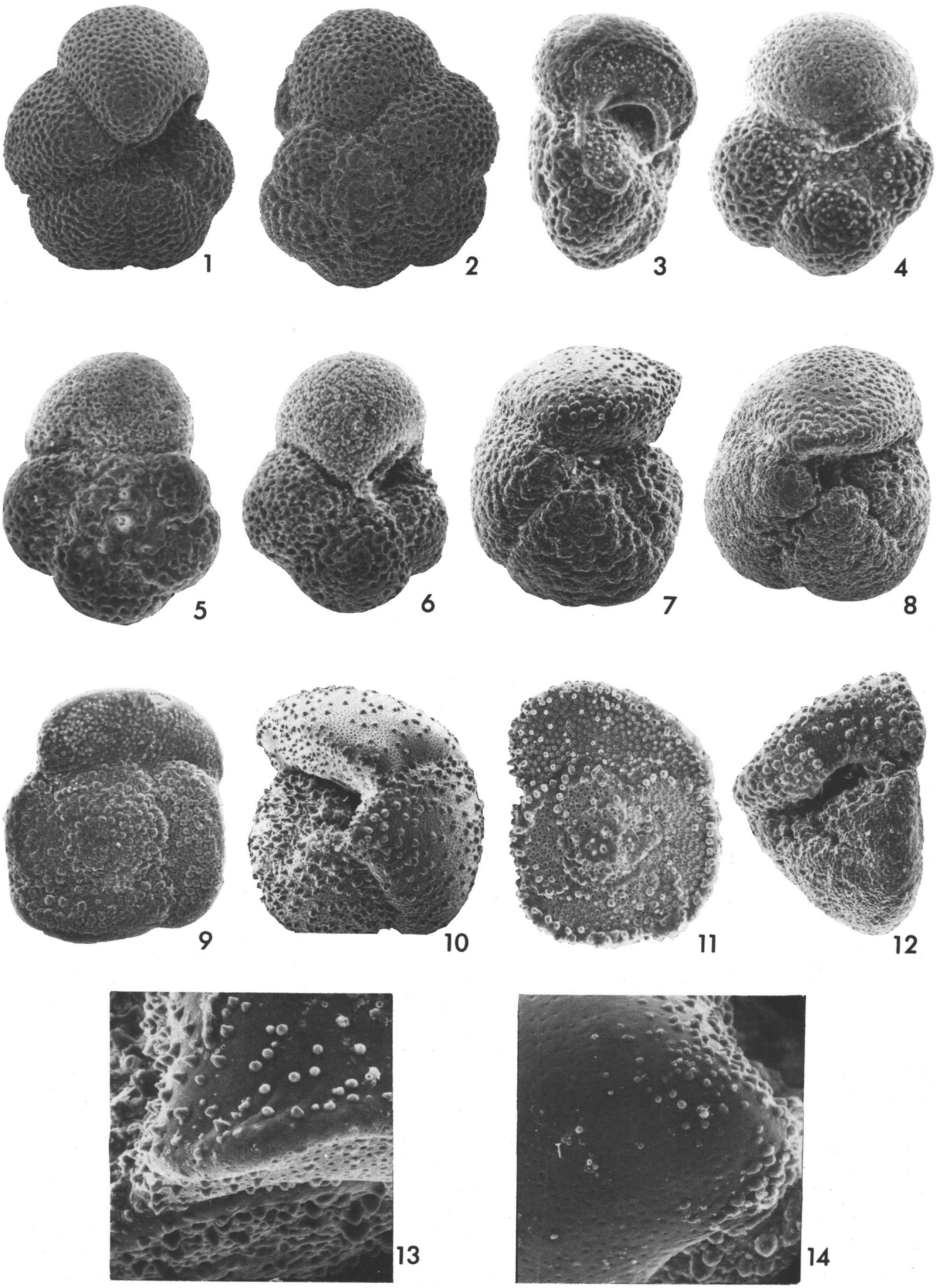

PLATE 15

Figures 1-4 — *Globorotalia crassaformis* Galloway and Wissler X *G. tosaensis* Takayanagi and Saito. Form transitional between these two species at beginning of evolution of *G. tosaensis.*

1. Side view, X100.
2. Umbilical view; X92.
3. Spiral view, X79.
4. 21-206-13, CC; Edge view; X267.

Figures 5-14 — *Globorotalia tosaensis* Takayanagi and Saito.

5. Umbilical view; X94.
6. 21-206-12-3, 30-32 cm; Spiral view; X79.
7. Spiral view; X86.
8. Side view; X89.
9. Umbilical view; X117.
10. Edge view; X272.
11. Edge view; X275.
12. 21-206-13, CC; Edge view; X278.
13. Edge view; X278.
14. 21-206-12-3, 30-32 cm; Edge view; X328. These close-up views of the peripheral edge show the gradation that occurs between porous nonkeeled to non-porous keeled margins.

PLATE 15

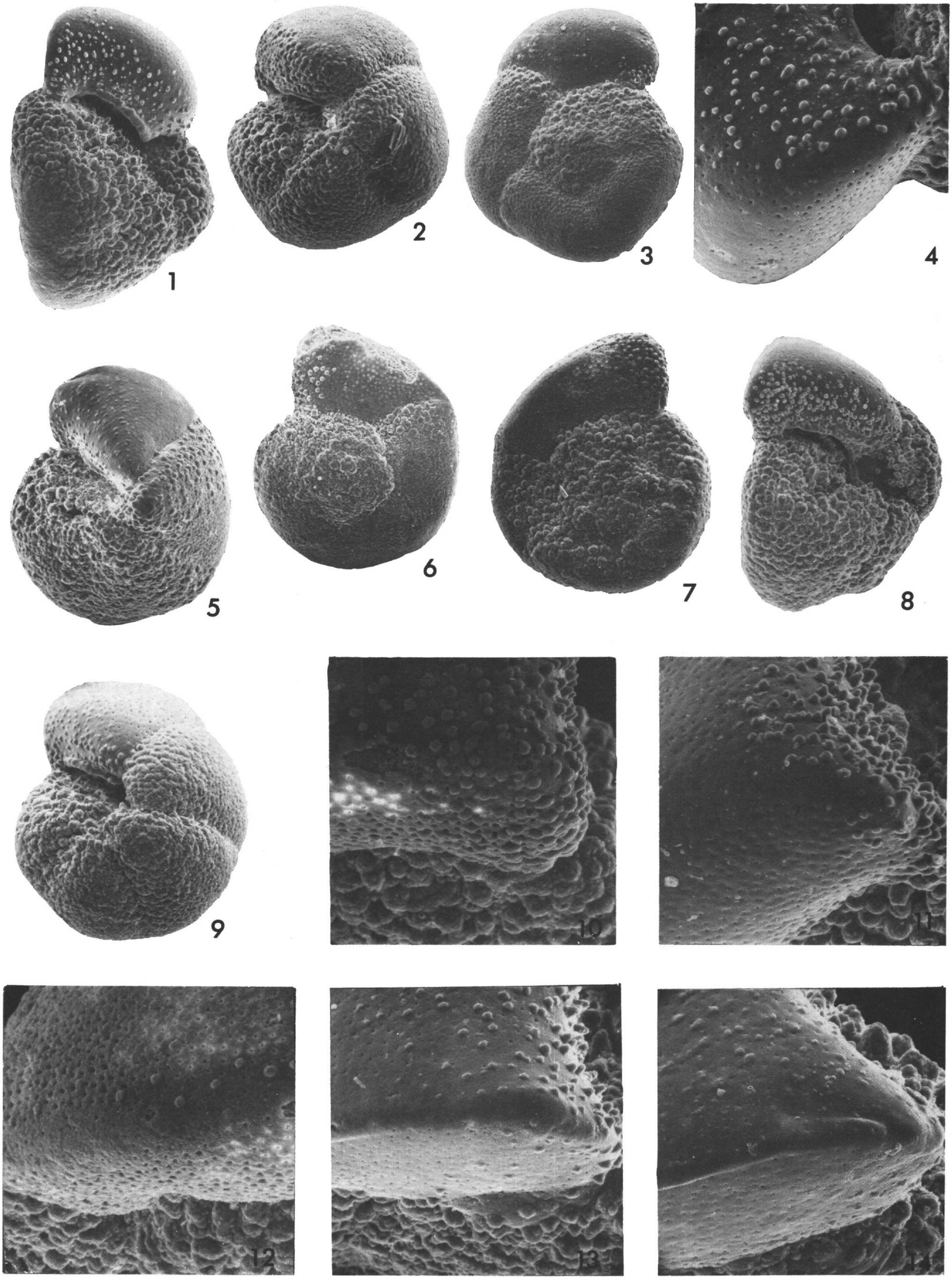

PLATE 16

Figures 1-3 *Globorotalia truncatulinoides* (d'Orbigny).
1. Umbilical view; X71.
2. Side view; X79.
3. 21-206-6, CC; Spiral view; X80;

Figures 4-11 *Globorotalia miozea conoidea* Walters.
4. 21-206-31, CC; Spiral view; X109.
5. Umbilical view; X77.
6. Spiral view; X72.
7. Umbilical view; X75.
8. 21-207A-5-3, 75-77 cm; Umbilical view; X57.

Early part of evolutionary bioseries to *Globorotalia conomiozea* Kennett.
9. Side view; X70.
10. Spiral view; X63.
11. 21-206-21, CC; Umbilical view; X69.

PLATE 16

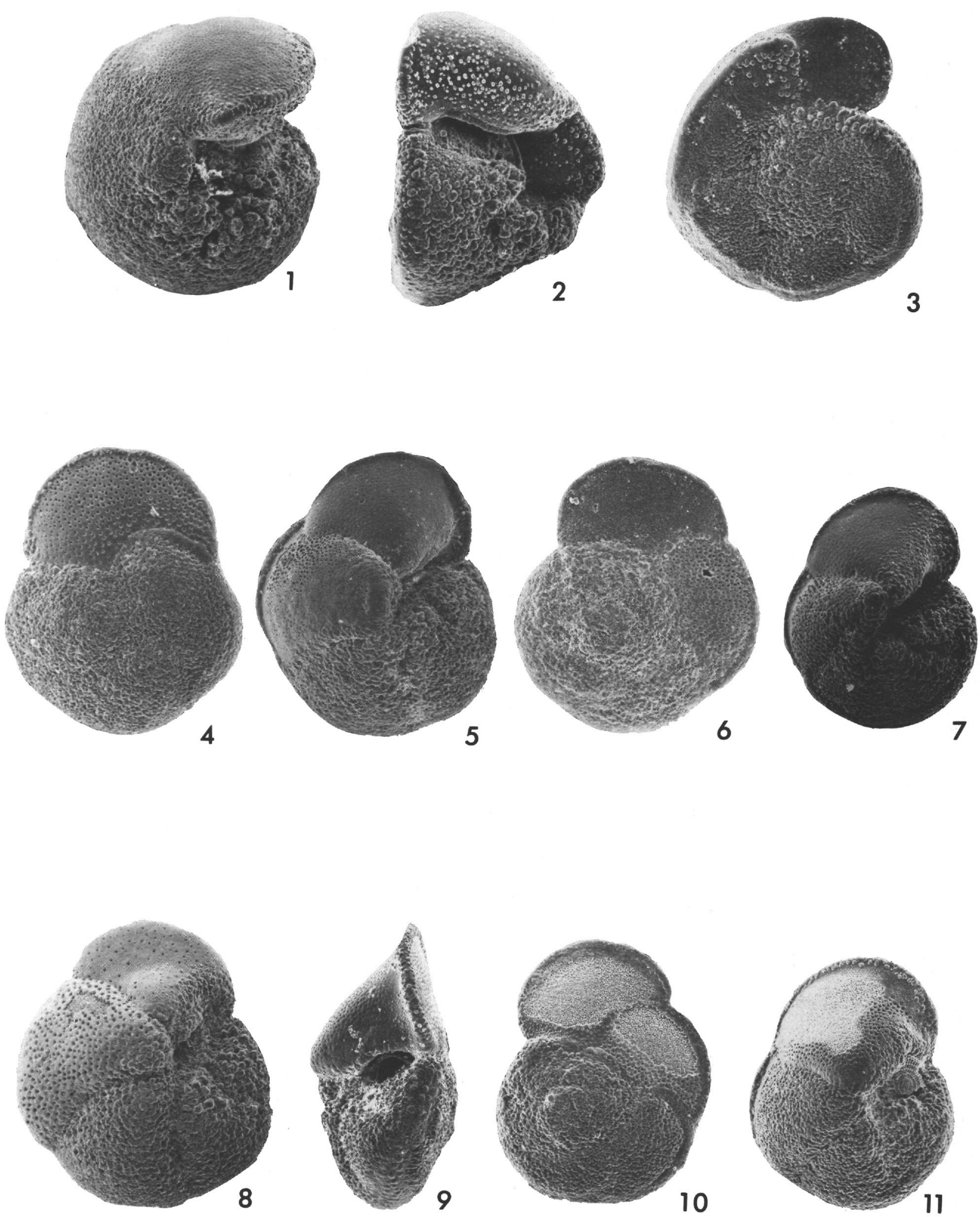

PLATE 17

Figures 1-3 — *Globorotalia miozea conoidea* Walters.

1. Spiral view; X 100.
2. Umbilical view; X 93.
3. 21-207A-5-3, 75-75 cm; Side view; X 80.

Early part of evolutionary bioseries to *Globorotalia conomiozea* Kennett.

Figures 4-13 — *Globorotalia conomiozea* Kennett. Specimens from within evolutionary bioseries. Younger sample in bottom half of plate.

4. Side view; X 74.
5. Spiral view; X 83.
6. Side view; X 88.
7. 21-207A-5-3, 75-77 cm; Side view; X 74.
8. Spiral view; X 99.
9. Side view; X 83.
10. Side view; X 116.
11. Umbilical view; X 78.
12. Side view; X 111.
13. 21-207A-4, CC; Spiral view; X 134.

PLATE 17

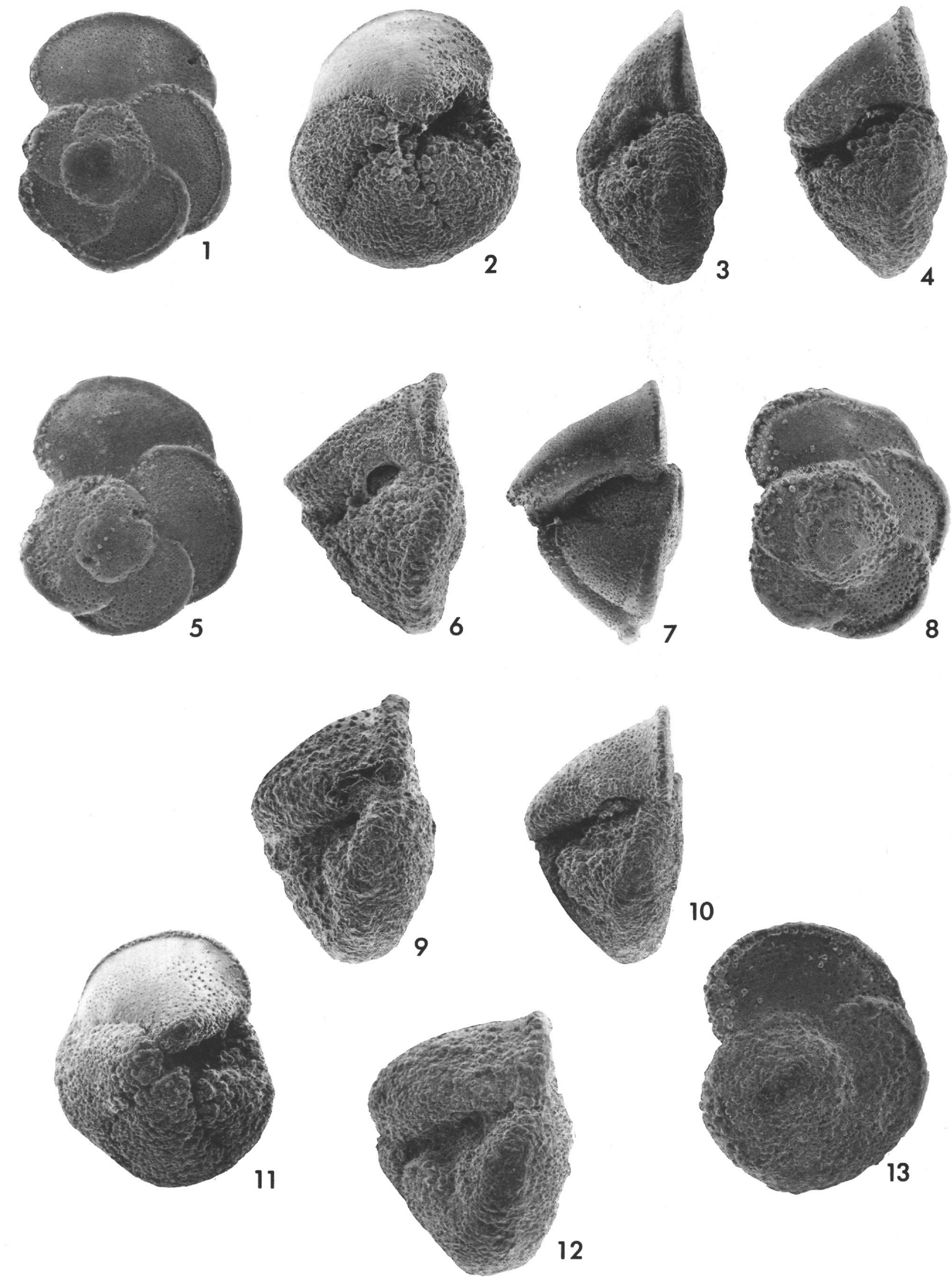

PLATE 18

Figure 1	*Globorotalia conomiozea* Kennett. 21-207A-4-1, 75-77 cm; Side view; X113. Intermediate form between *G. conomiozea* and *G. puncticulata.*
Figures 2-11	*Globorotalia punticulata* (d'Orbigny). 2-7. Early forms derived from *G. conomiozea.* 8-11. Advanced forms leading to *Globorotalia inflata.* 2. Umbilical view; X115. 3. Side view; X127. 4. Side view; X132. 5. Spiral view; X146. 6. Side view; X114. 7. 21-207A-4-1, 75-77 cm; Umbilical view; X134. 8. Side view; X103. 9. 21-206-18, CC; Umbilical view; X98. 10. Spiral view; X106. 11. 21-206-14, CC; Side view; X150.
Figures 12-16	*Globorotalia inflata* (d'Orbigny). 12. Spiral view; X75. 13. Umbilical view; X79. 14. 21-206-11, CC; Side view; X92. 15. 21-206-13, CC; Umbilical view; X144. 16. 21-206-11, CC; Umbilical view; X92.

PLATE 18

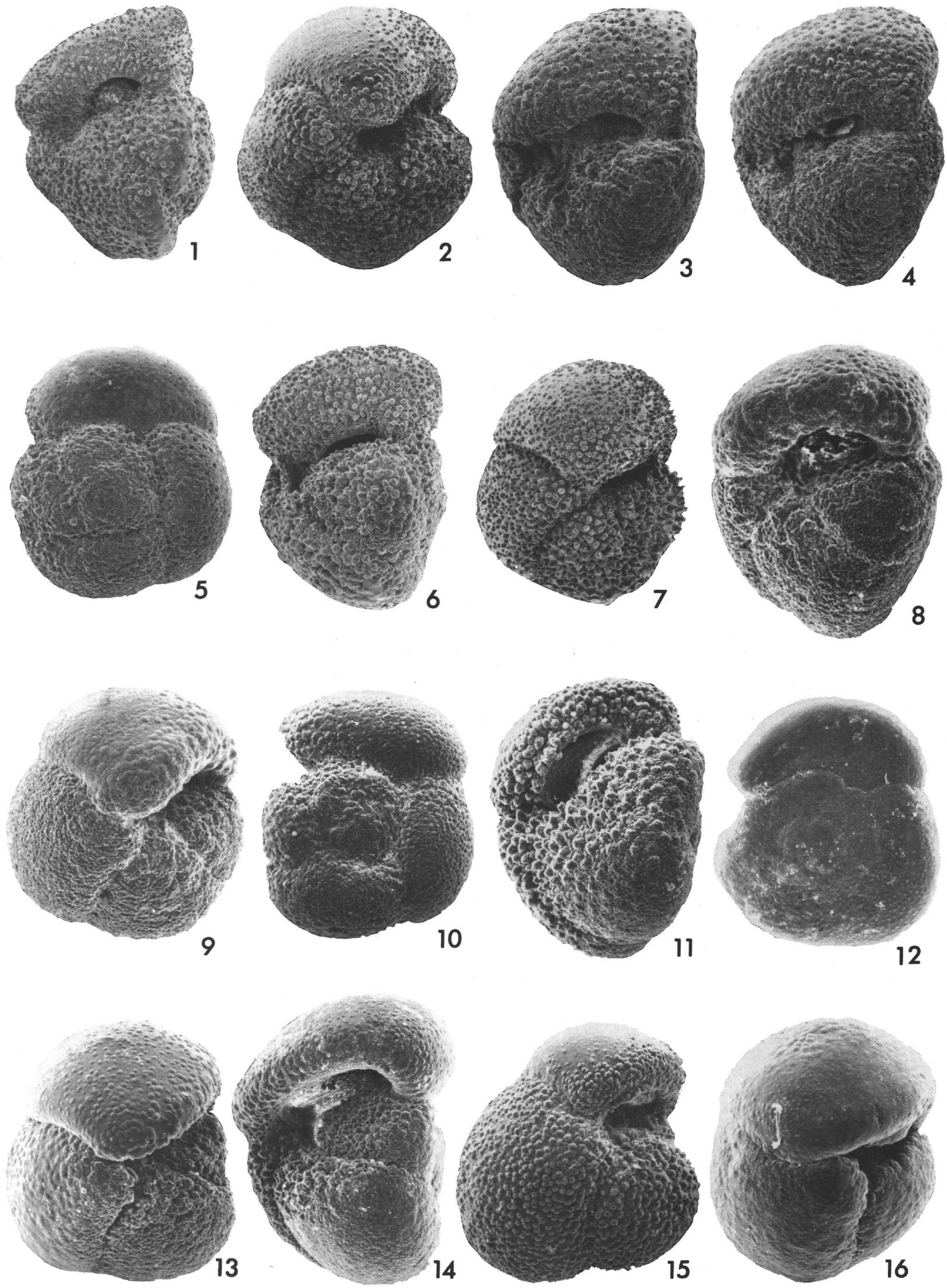

PLATE 19

Figures 1-3	*Globorotalia pseudokugleri* Blow. 1. Umbilical view; X196. 2. Side view; X213. 3. 21-206-41, CC; Spiral view; X200.
Figures 4-6	*Globorotaloides hexagona* (Natland). 4. Umbilical view; X200. 5. Umbilical view; X159. 6. 21-206-14, CC; Spiral view; X167.
Figure 7	*Globigerinoides sicanus* De Stefani. 21-207A-9-4, 75-77 cm; Spiral view; X104.
Figures 8-11	*Praeorbulina glomerosa circularis* (Blow). 8. 21-207A-9-3, 75-77 cm; X151. 9. X128. 10. X77. 11. 21-207A-9-2, 75-77 cm; X82.
Figures 12, 13	*Orbulina suturalis* Bronnimann. 12. X64. 13. 21-208-13-5, 50-52 cm; X69.

PLATE 19

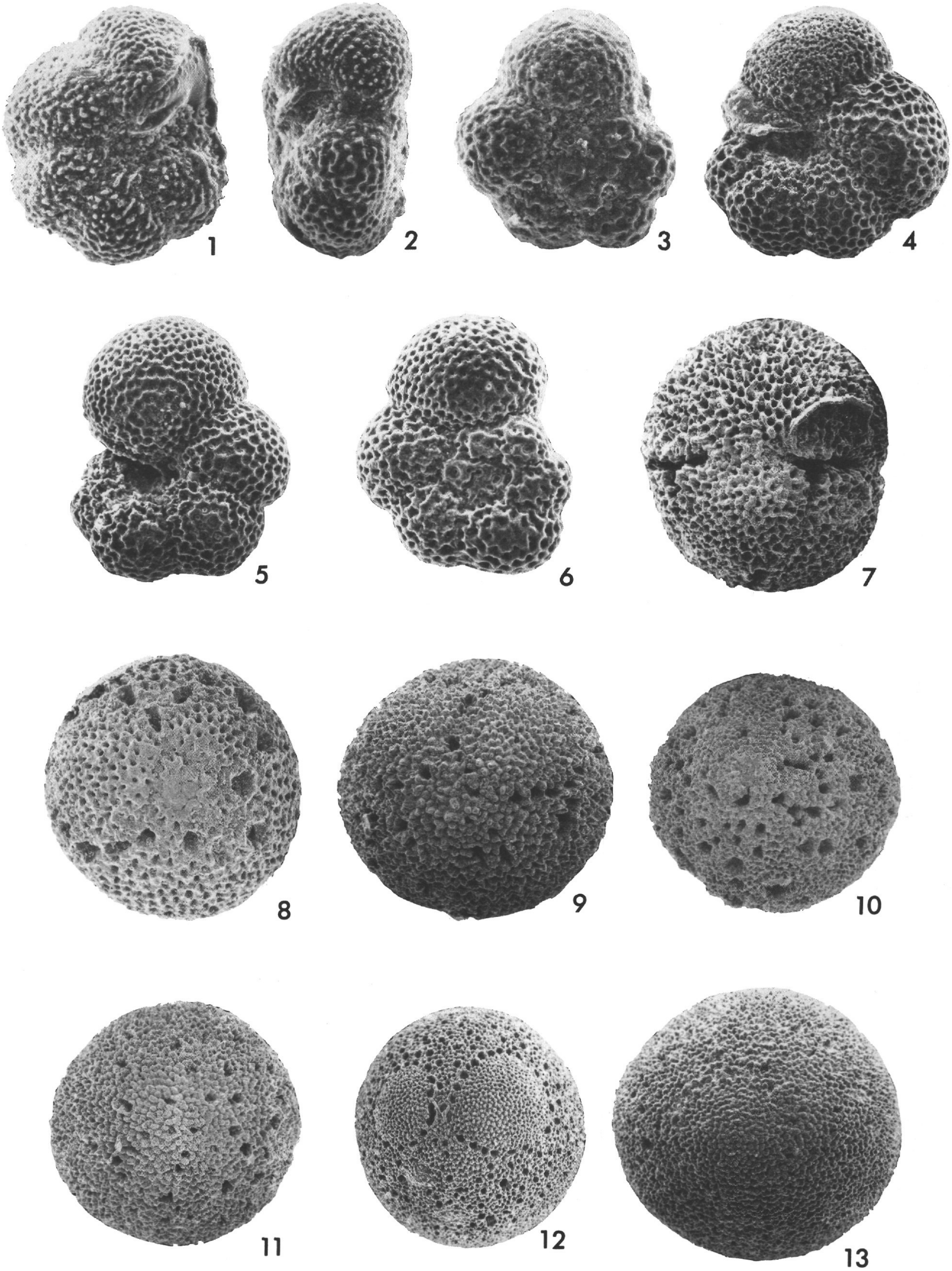

PLATE 20

Figures 1-6	*Orbulina suturalis* Bronnimann. 1. Internal view; X72. 2. Internal view; X70. 3. Spiral view of initial trochospiral stage; X173. 4. Internal view; X61. 5. Internal view; X61. 6. 21-208-13-5, 50-52 cm; Internal view; X90.
Figure 7	*Orbulina universa* d'Orbigny. 21-208-8, CC; X44.
Figures 8, 9	*Pulleniatina obliquiloculata* (Parker and Jones). 8. Side view; X66. 9. 21-206-7, CC; Spiral view; X75.
Figures 10-12	*Pulleniatina primalis* Banner and Blow. 10. 21-206-17-5, 30-32 cm; Spiral view; X93. 11. 21-206-19, CC; Umbilical view; X106. 12. 21-206-21, CC; Spiral view; X117.

PLATE 20

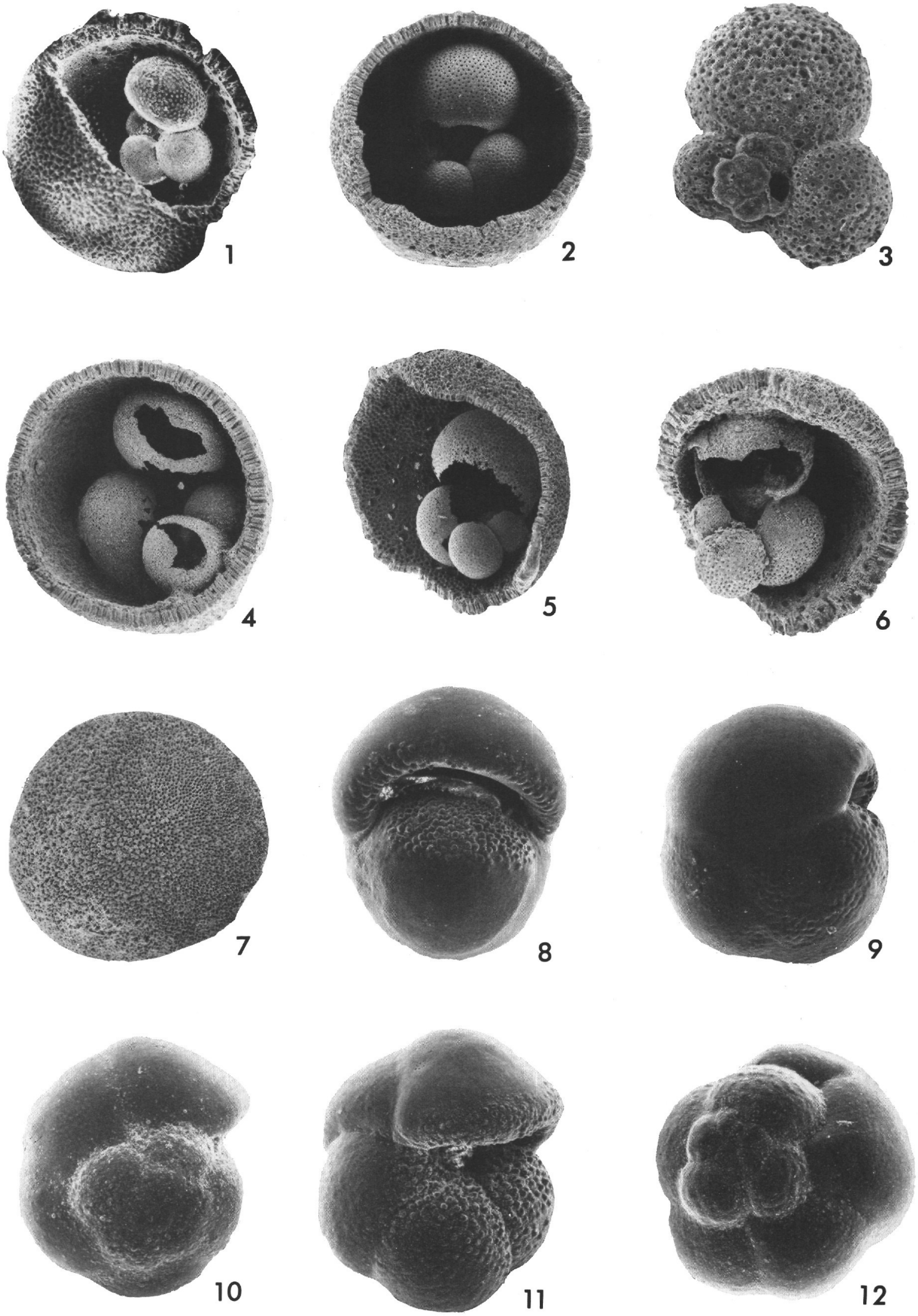

PLATE 21

Figure 1	*Pulleniatina primalis* Banner and Blow. 21-206-21-3, 30-32 cm; Side view; X94.
Figures 2-6	*Sphaeroidinella dehiscens* (Parker and Jones). 2. 21-206-13, CC; Side view; X63. 3. 21-206-21, CC; Apertural view; X64. 4. 21-206-3-3, 148-150 cm; Side view; X44. 5. 21-206-6, CC; Apertural view; X68. 6. 21-206-14, CC; Side view; X62.
Figure 7	*Sphaeroidinella seminulina* (Schwager) 21-210-19, CC; Umbilical view; X100;
Figures 8-10	*Sphaeroidinella subdehiscens* Blow. 8. Umbilical view; X60. 9. Spiral view; X98. 10. 21-210-19, CC; Spiral view; X104.
Figure 11	*Sphaeroidinella* sp. 21-206-14, CC; Umbilical view; X104.
Figures 12-15	*Sphaeroidinella seminulina* (Schwager). 12. Umbilical view; X104. 13. Umbilical view; X126. 14. Umbilical view; X70. 15. 21-206-14, CC; Spiral view; X83.

PLATE 21