4. PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY OF NEOGENE AND QUATERNARY OF SITE 398 OF DSDP LEG 47B

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INTRODUCTION

This paper deals with the planktonic foraminiferal biostratigraphy of the Neogene and Quaternary sediments of DSDP Site 398.

Site 398 is located on the continental margin south of Vigo Seamount, 90 km off the western coast of the Iberian Peninsula (40°57.6'N, 10°43.1'W). The interval from the base of the Neogene (Section 398D 12-6) to the top of the Quaternary is represented by a non-continuously cored, 518-meter sedimentary sequence. The recovery was generally good (> 90%) except for a few cores in which the recovery was poor to void (398-1, 398D-2, 398D-10, 398D-11).

Four holes were drilled: 398 (Cores 1-4), 398A (Cores 1-2), 398B (Core 1), and 398D (Cores 2-12) yielding 235 samples, investigated in this study. On the average, 2 to 3 samples per section were taken; only in Core 398D-6 was a greater number collected (up to 7 for each section).

The main lithotypes in this interval are bioturbated calcareous biogenic oozes and rhythmically interbedded chalks. Lithologic changes generally are gradual and characterized by an overall trend towards decreasing carbonate content downhole. Superimposed on this trend is an input of biogenic silica mainly in the form of sponge spicules and radiolarian tests in the earliest Neogene sediments (Cores 398D-12 to 398D-8).

In spite of the numerous samples studied, the biostratigraphic and (consequently) chronostratigraphic results were disturbed by several factors.

FACTORS DISTURBING THE BIOSTRATIGRAPHIC RECORD

Several factors related to drilling operations, sedimentary processes, and/or the evolution of water masses in the northern Atlantic affected the distribution of planktonic foraminifers. These factors interfere with the biostratigraphic resolution, which offers the best results when based on the normal succession of the evolutionary foraminiferal trends.

The factors here briefly commented upon are: coring discontinuity, drilling operation disturbances, bioturbation, dissolution effects, and temperature of the water masses.

Coring Discontinuity

Since Neogene and Quaternary sediments were not the main objective of Site 398, time constraints did not allow their being continuously cored. The thickness of the uncored intervals ranges from 76 meters (between Cores 398-3 and 398-4) to 9 meters. Therefore, it was not possible to identify all the stratigraphic boundaries.

Drilling Operation Disturbances

Cores 398D-2 and 398B-1 exhibit some degree of drilling disturbances. As noted in the following pages, the study of the planktonic foraminiferal fauna of this interval pointed out an anomalous biostratigraphic sequence (Figures 1 and 2). Specifically, in the three sections recovered (3.5 m thick) in Core 398D-2, early Pliocene (Zone M Pl 3) and late Pliocene (Zones M Pl 5 and M Pl 6) sediments were recognized. Abrupt changes were recorded in the foraminiferal assemblages and also in the sediment color (from light gray to dark gray) of closely adjacent samples. Easily visible is the change occurring at Sample 398D-2-2, 40 cm (see core photographs in Site Report), which marks the boundary between early Pliocene and late Pliocene zones. Moreover, the sediments of Core 398D-2 are younger than those of Core 398A-2 (201.0 to 210.5 m) and in part than those of overlying Cores 398A-1 and 398-4. Also, Sections 4 to 1 of Core 398B-1 (from 233.5 to 229.5 m) are younger than Core 398A-2.

According to shipboard sedimentologists (see Lithological Report, this volume), the presence of slumps in this interval can be excluded. Therefore, this anomalous stratigraphic succession is possibly due to sediments displaced during drilling operations.

Dissolution

The entire Neogene sequence of Site 398 is affected by calcium carbonate dissolution. Dissolution is strong and evident in the Miocene, and less intense and limited to a few levels in the Pliocene. The degree of dissolution of the foraminiferal tests varies greatly from complete dissolution of delicate forms accompanied by concentration of the most resistant species, somewhat advanced fragmentation, and decalcification of the tests.

In the Miocene, planktonic microfossils are limited both in species and specimens. Taxa of subspherical shape like *Globigerina venezuelana* (Plate 1, Figures 1 and 2), *G. nepenthes* (Plate 1, Figure 10), *Globoquadrina dehiscens* (Plate 8, Figures 1, 2 and 5), *Globigerinita dissimilis* (Plate 2, Figures 17, 18, and 20), *G. unicava* (Plate 2, Figure 19), and small individuals of other species, known for their high resistance to disso-

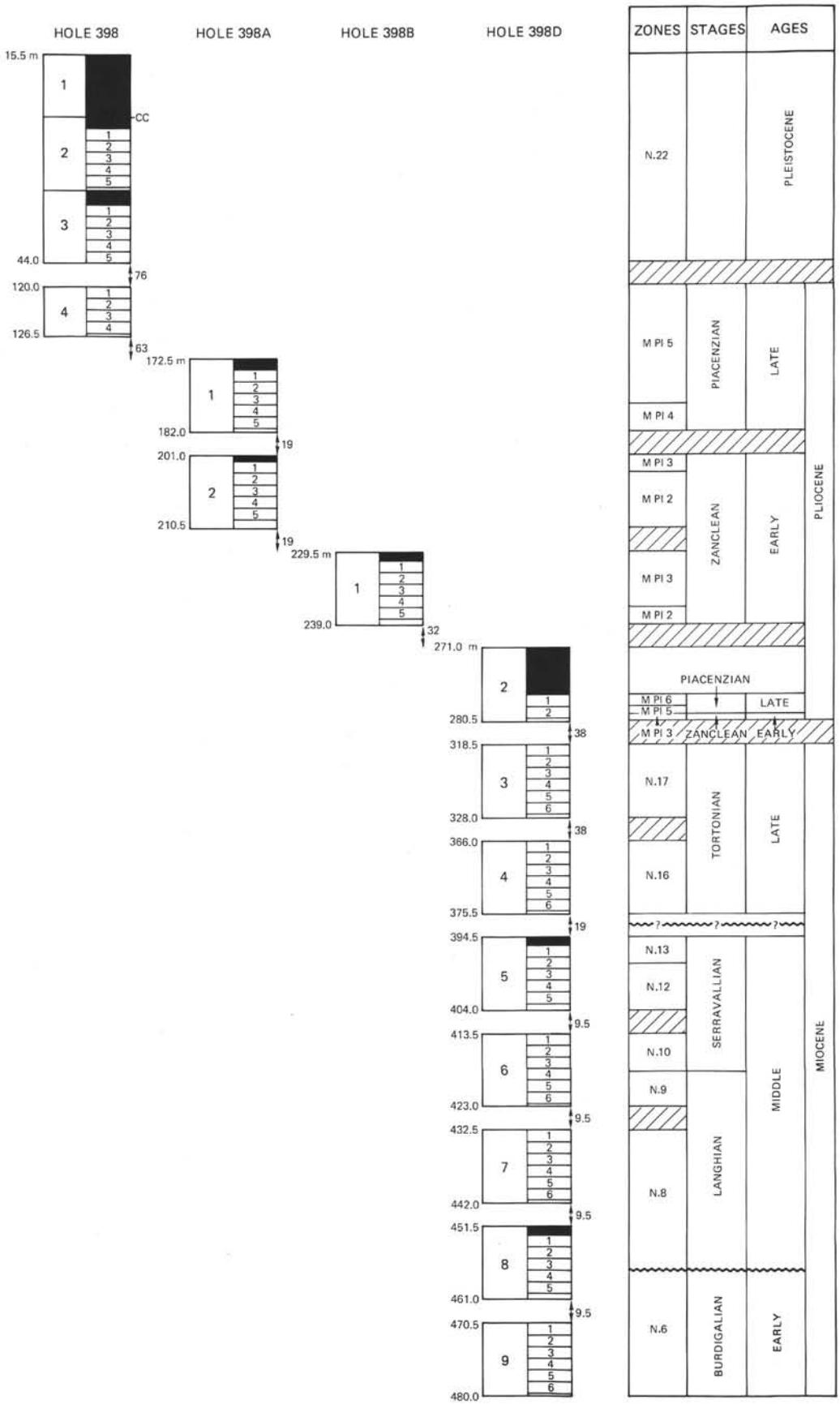

Figure 1. *Neogene and Quaternary stratigraphy at Site 398. The numbers to the right of the arrows indicate the thickness of the uncored intervals.*

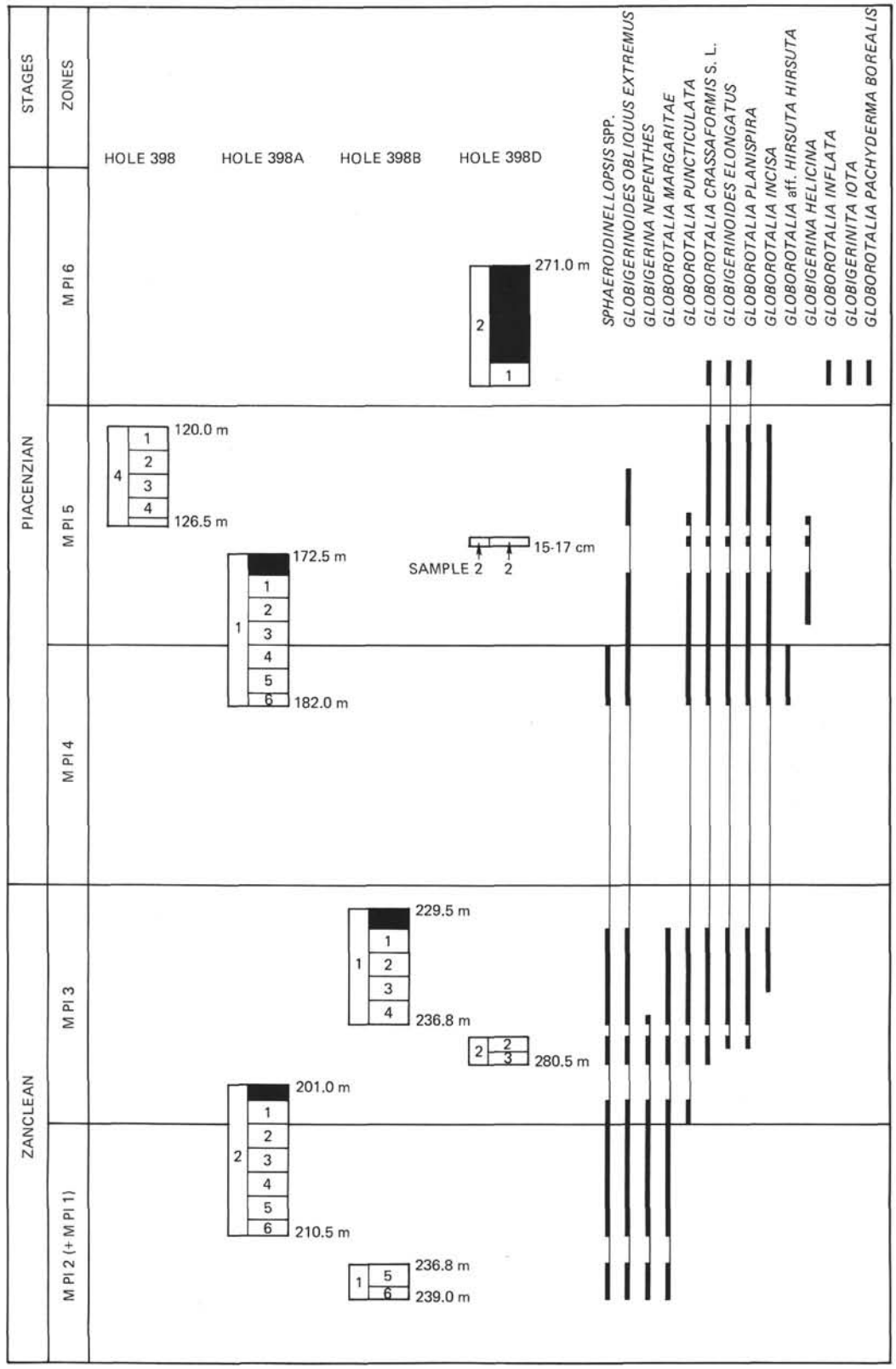

Figure 2. *Stratigraphic position of Cores 398D-2 to 398-4 in comparison with the Pliocene biostratigraphy. The cores have been positioned against the zones on the basis of their qualitative and quantitative planktonic foraminiferal content. The distribution of selected significant taxa plotted on the right of the figure emphasizes the stratigraphic location of the cores.*

lution (Cita, 1971; Berger and von Rad, 1972) are dominant. Keeled Globorotalias (like *G. praemenardii praemenardii, G. cultrata*), *Globigerinoides* and *Orbulina* (the latter being always small) are generally rare and represented by a few unbroken specimens.

In the Pliocene interval, the assemblages are generally well preserved and diversified. However, intense fragmentation of the planktonic foraminiferal tests observed in a few levels suggests fluctuations in the CCD.

Following the distribution patterns of foraminiferal solution facies (FS) given by Berger and von Rad (1972), the range of FS values is very narrow in Miocene sediments (FS 6). This indicates similar states of dissolution. These values are larger within Pliocene sediments, where well-preserved assemblages alternate with poor (FS4-2). In relation to the dissolution facies, fossil preservation is good to excellent in the Quaternary and good to moderate in the Pliocene and Miocene.

On the basis of the CCD fluctuation curve for the North Atlantic (Berger and von Rad, 1972), the CCD was relatively shallow throughout the Miocene, reached a minimum depth (3600 to 3700 m) during the middle-early Miocene, and then dropped rapidly at the end of the Miocene. Though the curve is primarily based on data from Leg 14 (off northwestern Africa), the estimation made for Miocene sediments at Site 398 is in fairly good agreement with the distribution of dissolution facies at Site 139, Leg 14.

Bioturbation

Different types of bioturbation, such as mottling and burrows (see Site Report, this volume), affected intensely, at times, the stratigraphic succession from the Quaternary to the Miocene. Such bioturbations testify that limivorous organisms reworked the sediments, crumbling the fossil tests. Therefore, part of the fragmentation of foraminiferal tests at Site 398 could be related to these sedimentary structures.

Temperature of the Water Masses

Besides dissolution, the temperature of the water masses also played an important role in controlling the distribution of foraminifers at Site 398, mainly in the qualitative and quantitative composition of the assemblages. Without a paleoclimatic study which would reveal the role of temperature, it is difficult to clearly separate dissolution effects from those induced by climatic changes. This is particularly true for the more intensely etched Miocene sediments. Relative to the Pliocene and especially the Quaternary succession, the specific selection due to temperature is undoubtedly more evident.

Typical forms of tropical and subtropical water masses are rare (Bé and Tolderlund, 1971), e.g., *Globorotalia cultrata* s.l., *Globorotalia miocenica, G. tumida, Pulleniatina* spp., *Sphaeroidinella dehiscens, Globigerinoides conglobatus, G.* gr. *quadrilobatus*, and *Neogloboquadrina dutertrei* s.s.. By contrast, the high frequency of *Globorotalia inflata, G. puncticulata, G. pachyderma* (dextral coiling), *Globigerina bulloides, Turborotalita quinqueloba, Globorotalia borealis* (sinistral coiling), and *Globorotalia truncatulinoides* (dextral coiling) suggest a transition towards the Arctic Zone. This is consistent with the location of Site 398 (about 41°N), which falls in the Transition Zone of Bradshaw (1959).

BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY

For the reasons outlined above, not all the biozones of the Neogene and the Quaternary at Site 398 were recorded or clearly recognized.

The standard zonation of Blow (1969) was adopted for the Miocene and Pleistocene intervals. Such zonations, as well as those recently proposed by Berggren (1971, 1972), Bolli and Premoli Silva (1973), and Stainforth et al. (1975), could not be utilized for the Pliocene interval because the zonal markers are missing. In spite of minor difficulties, the zonation most suitable for this stratigraphic interval is that proposed by Cita (1973, amended 1975) in the Mediterranean region.

According to Cita's early Pliocene zonation, two different intervals are easily recognizable, within the range of *Globorotalia margaritae* and before the FAD of *G. puncticulata*. The first one (Zone M Pl 1 = *Sphaeroidinellopsis* Acme Zone) is very short in duration; the second one (Zone M Pl 2 = *G. margaritae* Interval Zone) is longer. They differ on the basis of the frequency of the zonal markers. In extra-Mediterranean areas in which *Sphaeroidinellopsis* (and also *G. margaritae*) may occur frequently also in Miocene sediments, the distinction between the two intervals cannot be made. The Pliocene interval,[1] in which *G. margaritae* occurs without *G. puncticulata*, is considered in the present study as belonging to Zone M Pl 2 (including Zone M Pl 1).

The biostratigraphy and chronostratigraphy of Site 398 are depicted in Figure 1. Reference is made to the range chart (Figures 3a, b, c, d — in back pocket) and to Plates 1 through 9 for documentation of the planktonic foraminifers recorded from early Miocene to Quaternary. Brief comments about some taxa are reported in the taxonomical notes. From bottom to top, the succession is as follows.

Cores 398D-12 to 398D-9 (518 to 470.5 m sub-bottom)

In Core 398D-12, the foraminiferal assemblages are mostly dissolved (FS 6-7). Radiolarians and sponge spicules are generally very common. Benthic foraminifers, ostracodes, and fish remains occur sporadically.

Among the scattered planktonic species recorded in this interval *Globigerinita dissimilis* s.l., *G. unicava uni-*

[1] The Pliocene age of this interval also is based on calcareous nannofossils (Blechshmidt, this volume).

cava, Globigerina venezuelana, and *Globoquadrina dehiscens praedehiscens* are constantly present. *Globoquadrina dehiscens dehiscens* was first noted in Sample 398D-12-1 104-106 cm.

Cores 398D-11 and 398D-10 had no recovery. Core 398D-9 is affected by considerable dissolution (FS 6); radiolarians and sponge spicules are still common. Benthic foraminifers, echinoid remains, and fish teeth are scarce. Among the planktonic foraminifers, the most common are *Globorotalia siakensis, G.* sp. 1, *Globigerina praebulloides, Globigerinita dissimilis* s.l., and *Globoquadrina dehiscens* s.l. ("*praedehiscens*" is better represented in the lower part, as is "*dehiscens*" s.s. in the upper part of the core).

Cassigerinella chipolensis, Globigerina venezuelana, Globorotalia aff. *birnageae, G. obesa*, and *G. acrostoma* are rare. *Globoquadrina altispira* s.l., *G. baroemoenensis*, and *Globigerinoides quadrilobatus* s.l. (the only representative of the genus and of small size) were recorded sporadically.

With reference to Blow's zonation, Zone N.6 was recognized in Core 398D-9. The base of this zone is marked by the first appearance of *Globigerinatella insueta*, the top by the disapperance of *Globigerinita dissimilis* s.l. and *G. unicava*.

The co-occurrence through the core of *Globigerinita dissimilis* s.l., *G. unicava unicava*, and *Globoquadrina dehiscens praedehiscens* (which according to Blow, 1969, disappear within Zone N.6), and of *Globorotalia continuosa, Globigerinoides quadrilobatus trilobus*, and *G. quadrilobatus succulifer* (which first appear within Zone N.6) supports this zonal designation even in the absence of the marker *Globigerinatella insueta*.

The underlying Cores 398D-10 to 398D-12, in the absence of significant taxa and particularly of the genus *Globigerinoides* which provides a valuable datum for the recognition of the earliest Miocene zones, cannot be placed into a precise biostratigraphic interval. The only significant biostratigraphic event recorded in this interval is the occurrence of *Globoquadrina dehiscens dehiscens* (Sample 398D-12-1, 104-106 cm) which, according to Blow, appears first in the upper part of Zone N.4. Therefore, it is assumed that Cores 398D-12 to 398D-10 fall within Zones N.4 to N.6.

Cores 398D-8 to 398D-7 (461 to 432.5 m sub-bottom)

The preservation of planktonic foraminiferal assemblages of these two cores is referable to FS 6 of Berger and von Rad (1972).

Taxa common or frequent in both cores include *Globoquadrina dehiscens dehiscens, G. baroemoenensis, Globigerina praebulloides, Globorotalia siakensis*, and *G. praescitula. Globigerinoides quadrilobatus* s.l., *Globigerina venezuelana*, and *Globorotalia miozea miozea* are also found in some levels.

Other taxa commonly recorded are *Globorotalia acrostoma* in Core 398D-8, and *Globigerina druryi, G. falconensis*, and *Globoquadrina* s.l. in Core 398D-7.

Rare to sparse in both the cores are *Cassigerinella chipolensis, Globigerinatella insueta, Praeorbulina transitoria, P. glomerosa curva, Globigerinoides sicanus, G. subquadratus, Globorotalia peripheroronda, G. obesa, G.* cf. *praemenardii archeomenardii, Hastigerina siphonifera praesiphonifera, Sphaeroidinellopsis disjuncta*, and *Globoquadrina langhiana*.

The sediments between Samples 398D-8, CC and 398D-8-4, 133-135 cm yield *Globigerinita dissimilis* s.l. and *G. unicava unicava*. In terms of Blow's zonation, this interval is referable to Zone N.6. The interval from Sample 398D-8-3, 104-106 cm to the top of Core 398D-7 is referable to Zone N.8 because it yields *Globigerinoides sicanus*, which defines the lower boundary of the zone. Additional supporting evidence is provided by the occurrence of *Praeorbulina transitoria, P. glomerosa curva*, and specimens ex-interc *Globorotalia praescitula—G. praemenardii archeomenardii* (*G.* cf. *praemenardi archeomenardii* in the range chart; Plate 4, Figure 3).

It follows that biostratigraphic gap at least spanning Zone N.7 occurs between Sections 398D-8-4 and 398D-8-3.

Cores 398D-6 to 398D-5 (423 to 394.5 m sub-bottom)

Cores 398D-6 and 398D-5 are strongly affected by dissolution (FS 6-5). Benthic foraminifers, radiolarians, sponge spicules, ostracodes, and fish teeth are scarce.

The most common taxa include *Globoquadrina dehiscens dehiscens, Globorotalia miozea*, and in some samples, *Sphaeroidinellopsis disjuncta, Globigerina praebulloides, G. druryi, G. woodi woodi, Globorotalia praemenardii praemenardii, G. peripheroronda, G. continuosa, G. siakensis, Orbulina* spp., *Globoquadrina altispira* s.l., *G. baroemoenensis, Globigerinoides quadrilobatus* s.l., *Globigerina falconensis*, and *Globorotalia scitula. Globigerina venezuelana, G. parabulloides, Globorotalia obesa*, and *Globigerinopsis aguasayensis* were occasionally recorded.

Praeorbulina glomerosa circularis, Orbulina suturalis, O. bilobata, O. universa, Globorotalia praemenardii praemenardii, and *G. scitula* group were first recorded in Core 398D-6. *Sphaeroidinellopsis subdehiscens* and *Globorotalia partimlabiata* first appeared in Core 398D-5.

Praeorbulina glomerosa circularis and *Globorotalia praescitula* last occur in the lower part of Core 398D-6; *Globorotalia peripheroronda* last occurs in the upper part of the same core.

In terms of Blow's zonal scheme, the sedimentary sequence from Cores 398D-6 to 398D-5 includes the interval from Zone N.9 (upper part) to Zone N.13 (lower part). The co-occurrence of *Orbulina* spp. and *Praeorbulina glomerosa circularis* only in the lower portion of Core 398D-6 (up to Sample 398D-6-4, 119-121 cm) suggests the upper part of Zone N.9. The FAD of *Sphaeroidinellopsis subdehiscens* marking the Zone N.12/N.13 boundary occurs in Section 398D-5-2.

The lineage *G. peripheroronda-G. fohsi* (upon which the N.9/N.10, N.10/N.11, and N.11/N.12 boundaries are based) was not recorded at Site 398 (except for *G. peripheroronda*). Since *G. peripheroacuta* is absent, the

most reliable event marking the N.9/N.10 boundary is the first appearance of *G. praemenardii praemenardii*. The evolutionary development from its immediate ancestor, *G. praemenardii archeomenardii*, was not recognized at Site 398. However, its appearance in Sample 398D-6-4, 57-59 cm could coincide with its FAD, if we take into account the distribution of *G. praescitula* and *Praeorbulina glomerosa circularis*.

In conclusion, we tentatively assign from Samples 398D-6, CC to 398D-6-4, 89-91 cm as being in Zone N.9; from Sample 398D-6-4, 57-59 cm to the top as being in Zone N.10; from Samples 398D-5, CC to 398D-5-2, 124-126 cm as being in Zone N.12; and from Sample 398D-5-2, 53-55 cm to the top as being in Zone N.13.

Cores 398D-4 to 398D-3 (375.5 to 318.5 m sub-bottom)

Cores 398D-4 and 398D-3 are referable to FS 5 and FS 6, respectively. Benthic foraminifers, echinoid remains, and ostracodes are consistently rare. Generally abundant taxa include *Globorotalia acostaensis* and mainly *Globigerina nepenthes*. *Orbulina* spp., *Globototalia cultrata* s.l., *Globigerina bulloides, G. calida praecalida*, and *Globoquadrina dehiscens dehiscens* (very rare in Core 398D-3) are only occasionally common. *Globigerina decoraperta, G. digitata praedigitata, G. falconensis, G. praebulloides, G. parabulloides, Globorotalia scitula* and related forms, *G. miozea miozea* (atypical in Core 398D-3), *G. merotumida*, and *Globoquadrina altispira* s.l. are rare to sporadic. *Globigerinoides* is generally rare in Core 398D-4 (only *G. obliquus obliquus* and *G. bollii* are common in several samples) and very scarce in Core 398D-3.

Also recorded in Core 398D-4 are *Globorotaloides falconarae* (usually rare), *Globorotalia continuosa* (frequent), and *G.* aff. *lenguaensis* (common in some levels). In Core 398D-3, we found *Sphaeroidinellopsis seminulina seminulina, Globorotalia miozea conoidea* (both common in a few samples), and *Globorotaloides* sp. (only in two samples where it is abundant).

The planktonic assemblage of Core 398D-4 yields elements significant of zones younger than N.15 (like *Globorotalia acostaensis, Globigerina bulloides, G. digitata praedigitata*, and *G. calida praecalida*). *Globorotalia merotumida* occurs here without its descendant *G. tumida plesiotumida* (in the keeled *Globorotalia* populations, quite rich in this core), thus indicating Zone N.16. In particular, the presence of transitional forms *Globorotalia continuosa-G.acostaensis* and the absence of "*extremus*" in the *Globigerinoides obliquus* populations suggest the lower part of Zone N.16. This is confirmed by the occurrence of *Globorotaloides falconarae*, typical specimens of *Globorotalia continuosa*, and forms close to *G. lenguaensis*. The latter taxa are very common in this biostratigraphic interval of Mediterranean and extra-mediterranean sections (D'Onofrio et al., 1975; Salvatorini and Cita, this volume, Part 1; Colalongo et al., 1976; El-Bied Rakich et al., in preparation). Additional evidence is provided by the coiling direction of *Globorotalia acostaensis*, which is consistently dextral from the base of Core 398D-4, up to Sample 398D-4-1, 126-128 cm; it becomes sinistral from Sample 398D-4-1, 35-37 cm up to Core 398D-3. Bossio et al. (1976), Salvatorini and Cita (this volume, Part 1), El-Bied Rakich et al. (in preparation), Colalongo et al. (1976) show that *G. acostaensis* generally has a dextral coiling in the lower part of Zone N.16 before the first appearance of *Globigerinoides obliquus extremus*; afterwards, it is consistently sinistral for a long range (including part of Zones N.16 and N.17) to again become dextral within Zone N.17 after the appearance of *Globorotalia conomiozea* and shortly before the FAD of *G. margaritae*. The latter coiling direction change can be related to the one recorded by Zachariasse (1975) and Stainforth et al. (1975) in the latest Miocene of the Mediterranean area, and by Saito et al. (1975) in Equatorial Pacific piston cores at the base of paleomagnetic Epoch 5.

Reliable taxa are not found which could prove useful in precisely placing Core 398D-3 in the standard zonation of Blow. We placed this core in the lower part of Zone N.17 based on the following considerations. Salvatorini and Cita (this volume, Part I) illustrate the evolutionary trend of the *Sphaeroidinellopsis* plexus from early Miocene to early Pliocene at Site 397. According to them, *Sphaeroidinellopsis subdehiscens* evolves in the lower part of Zone N.17 (i.e., the upper part of Zone N.16 as amended by these authors), into *S. seminulina seminulina*, from which *S. seminulina paenedehiscens* elevated to zonal marker of the homonymous zone develops. Core 398D-3, which yields only *S. subdehiscens* (in the lower part) and *S. seminulina seminulina*, is assigned to the lower part of Zone N.17 following the taxonomical concepts of Salvatorini and Cita.

Cores 398D-2 to 398-4 (280.5 to 120.0 m sub-bottom)

This stratigraphic interval generally is scarcely affected by dissolution (FS 2-3) and the planktonic assemblages are well preserved and diversified. Nevertheless, the regular sequence of biostratigraphic events has not been found owing to collapses of different portions of the sedimentary succession. In Figure 2, the position of the cores in comparison with the biostratigraphy emphasizes this irregularity.

According to Cita's zonation, the following biozones were recognized (from oldest to youngest).

Zone M Pl 2 (including M Pl 1) was recognized in Core 398B-1 (CC to Section 5) and Core 398A-2 (CC. to Section 2). *Globorotalia margaritae, G. acostaensis, G. scitula, Globigerina nepenthes, G. bulloides, G. decoraperta, Orbulina* spp., and *Globigerinoides obliquus extremus* (only at some levels) are common to frequent. *Sphaeroidinellopsis seminulina* s.l., *Globigerinoides obliquus obliquus, G. quadrilobatus* s.l., *Globigerina falconensis, G. digitata praedigitata*, and *G. calida praecalida* are usually rare. Taxa occasionally recorded include *Globoquadrina altispira* s.l., *Globorotalia humerosa, G. pachyderma* s.s., *Globigerinoides conglobatus*, and *Hastigerina siphonifera siphonifera*.

Zone M Pl 3, defined as the interval of co-occurrence of *Globorotalia margaritae* and *G. puncticulata*, was recognized in Cores 398D-2 (CC to Section 2, 130-132 cm), 398B-1 (Sections 4 to 1) and 398A-2 (Section 1). In Sample 398B-1, 22-24 cm, *G. margaritae* is replaced by common specimens of *G.* aff. *hirsuta hirsuta* frequently found in the overlying Zone M Pl 4 (the top of the core is very unlikely in place).

Globorotalia margaritae, G. puncticulata, G. acostaènsis, G. crassaformis s.l., *Globigerinoides quadrilobatus* s.l., *Orbulina* spp., *Globigerina decoraperta*, and *G. bulloides* are consistently recorded. Taxa common in some levels also include *Globorotalia scitula, Globigerinoides obliquus extremus, Hastigerina siphonifera siphonifera, Globigerina apertura, G. falconensis, G. calida praecalida*, and *G. nepenthes* (the latter is almost completely missing in Core 398B-1); *Sphaeroidinellopsis seminulina* s.l., *Globigerinoides elongatus, Globigerina digitata praedigitata, Globoquadrina altispira* s.l., *Globorotalia pachyderma* s.s., *G. planispira* and *G. incisa* (only in Core 398B-1) are rare to sporadic.

Zone M Pl 4, defined as the interval from the last occurrence of *Globorotalia margaritae* to the last occurrence of the genus *Sphaeroidinellopsis*, was recognized in Core 398A-1 (CC to Section 4). The most common taxa include *Globorotalia puncticulata, Globigerinoides elongatus, Orbulina universa* and, subordinately, *O. suturalis, Globigerina decoraperta, G. bulloides, G. falconensis, G. apertura, G. calida praecalida, Globigerinoides quadrilobatus* s.l., *G. obliquus extremus* (in the lowest part), *Globorotalia acostaensis, G. scitula*, and *G. incisa* (only in some samples). *Sphaeroidinellopsis seminulina* s.l., *Globigerina digitata praedigitata, Globorotalia planispira, G.* aff. *hirsuta hirsuta* are rare. Sporadically recorded were *Globorotalia crassaformis* s.l., *G. bononiensis, Globigerinoides ruber, G. conglobatus, Globoquadrina altispira globosa*, and *Hastigerina siphonifera siphonifera.*

Zone M Pl 5 is defined as the interval from the last occurrence of *Sphaeroidinellopsis* to the population decrease of *Globigerinoides obliquus extremus.* In this study, we considered the first appearance of *Globorotalia inflata* as the upper boundary of the zone (virtually coinciding with the boundary as defined by Cita, 1973). This decision is based on the following: (1) the coring discontinuity and drilling disturbances do not allow us to follow continuously the quantitative variations of *Globigerinoides obliquus extremus;* (2) at Site 398, *Globigerinoides* and mainly *G. obliquus extremus* are generally rare or absent in samples from zones older than M Pl 5; and (3) *Globorotalia inflata*, on the contrary is consistently frequent. Zone M Pl 5 (as above considered) was recognized in Sample 398D-2, 15-17 cm, in Sections 398A-1-3 to 398A-1-1, and in Core 398-4.

Globorotalia puncticulata, G. incisa, G. planispira, G. crassaformis, G. scitula, Globigerina bulloides, G. calida praecalida, and *Orbulina universa* are the best-represented taxa. At some levels, *Globigerina helicina, G. apertura*, and *Hastigerina siphonifera siphonifera* are also common.

Globigerina decoraperta, G. falconensis, G. digitata praedigitata, and the *Globorotalia acostaensis-incompta* group are usually rare. *Globorotalia pachyderma* s.s., *Globigerina microfoliata*, and the *Globigerinoides* (including *G. obliquus extremus, G. ruber, G. conglobatus, G. quadrilobatus* s.l.) are occasionally recorded; only *G. elongatus* is common in several samples of Core 398-4. *Globorotalia bononiensis* occurs in Section 398A-1-3.

Zone M Pl 6, defined at the base by the population decrease of *Globigerinoides obliquus extremus* (almost coinciding with the first appearance of *Globorotalia inflata*) and at the top by the first occurrence of *Globorotalia truncatulinoides*, was recognized in Section 398D-2-2 directly overlying Zone M Pl 3. Taxa found in abundance include *Globorotalia inflata, G. crassaformis* s.l., *G. planispira, Globigerinoides elongatus, Globigerina bulloides, G. calida praecalida, Neogloboquadrina atlantica, Hastigerina siphonifera siphonifera, Turborotalita humilis, T. quinqueloba,* and *Orbulina universa.* Rare to sparse are *Globorotalia scitula, G. pachyderma* s.l., *Pulleniatina obliqueloculata obliqueloculata, Globigerinita iota, Globigerionides conglobatus, G. ruber, Globigerina falconensis* and *G. digitata praedigitata.*

Cores 398-3 to 398-1 (44.0 to 15.5 m sub-bottom)

The planktonic foraminiferal assemblages are generally rich and not affected by dissolution (FS 2). Only in Sample 398-2-3, 47-49 cm and particularly in Sample 398-3-1, 124-126 cm, do the assemblages consist of a limited number of species. A significant detrital supply is evident in these samples, possibly connected with continental glaciation in northern Europe (Poore and Berggren, 1975). Benthic foraminifers are consistently present but rare. Echinoid, fish remains, ostracodes, and radiolarians are present occasionally.

The Globorotalias are well represented throughout the interval, in particular with *G. truncatulinoides* and *G. inflata; G. scitula* is common; *G. crassaformis* s.l., *G. bermudezi, G. incompta*, and *G. pachyderma* s.l. are sometimes found. *G. tumida tumida* and *G. hirsuta hirsuta* are very rare and limited to the upper part of the interval, while *G. planispira* is represented by rare, small, and atypical specimens and disappears in Core 398-3.

The genus *Globigerinoides* is frequent only in some samples and essentially with *G. elongatus. G. ruber* and *G. tenellus* are only occasionally common. *G. conglobatus* and *G. quadrilobatus* s.l. are seldom recorded. The genus *Globigerina* is mainly represented by *G. bulloides* and *G. megastoma cariacoensis*, while *G. falconensis, G. digitata* s.l., and *G. calida* s.l. are common only at some levels.

Among the other taxa, we have consistently recorded *Orbulina universa, Globigerinita iota, Turborotalita quinqueloba*, and in some samples *T. humilis* and *Hastigerina siphonifera siphonifera. Pulleniatina obliqueloculata obliqueloculata, Sphaeroidinella dehiscens dehiscens*, and *Turborotalita cristata* are occasionally present.

The interval encompassing Core 398-3 to 398-1 (only the core catcher material was recovered from Core 398-1) is attributable to Zone N.22. The base of the zone is defined by the first evolutionary appearance of *Globorotalia truncatulinoides* and the top by the first occurrence of *Globigerina calida calida* and *Sphaeroidinella dehiscens excavata.*

The occurrence from the lowest part of Core 398-3 of *Globorotalia truncatulinoides* associated with *Globigerina digitata digitata, Globigerinoides tenellus*, and *Turborotalita cristata* allows us to exlude zones older than Zone N.22. Significant taxa of Zone N.23 are not present. For *Hastigerina adamsi* and *Sphaeroidinella dehiscens excavata*,[2] if one could suggest ecological control, this would be less justified for *Globigerina calida calida* (*sensu* Blow, 1969). *G. calida* s.l. is in fact not infrequent in the interval. In particular, from Section 398-2-3 upwards, *G. calida praecalida - G. calida calida* (*G.* cf. *calida calida* in Figure 3) are well-represented transitional specimens. Moreover, Zone N.23 has been documented only in the topmost part of deep-sea cores.

On the basis of what has been described, biostratigraphic zones from early Miocene to Pleistocene were recognized in the sedimentary sequence of Site 398.

Cores 398D-12 to 398D-10 fall within the Zone N.4 to N.6 interval. Inability to precisely determine their biostratigraphic position does not allow us to define their exact chronostratigraphic setting. However, according to the correlation of Blow's zonation with the early Miocene stages (Anglada, 1971a, b; Demarcq et al., 1974; Poignant and Pujol, 1976), this interval could correlate partly with the Aquitanian and partly with the Burdigalian. Core 398D-9 to Section 398D-8-4, yielding Zone N.6 assemblages, are firmly referable to the Burdigalian Stage. Considering the results of Cita and Blow (1969) and Ryan et al. (1974), there is an unquestionable correlation of Section 398D-8-3 to Sample 398D-6-4, 89-91 cm (which include Zones N.8 and N.9) with the Langhian, and of Sample 398D-6-4, 57-59 cm to Core 398D-5 (Zones N.10 to N.13) with the Serravallian. The recognition of the lower part of Zone N.16 in Core 398D-4 allows us to correlate it to the lower part of the Tortonian (Cita and Blow, 1969; Ryan et al., 1974).

Zone N.17 (lower part), which straddles the Tortonian and Messinian stages, was recognized in Core 398D-3. According to what was discussed above, the core postdating the FAD of *Sphaeroidinellopsis seminulina seminulina* and predating the FAD of *S. seminulina paenedehiscens* is referable to the Tortonian. At Site 397, the interval placed between the two events (Cores 55 to 52) is correlatable to the middle-late Tortonian both on the basis of the planktonic foraminiferal content (Salvatorini and Cita, this volume, Part 1) and of the calcareous nannofossils (Mazzei et al., this volume, Part 1).

[2] *Hastigerinella digitata*, which according to Blow (1969) represents one of the fundamental taxa of Zone N.23, has been recently recorded in the Tortonian (Cita et al., in press) and Messinian sediments (Giannelli et al., 1976) in the Mediterranean Basin.

Cores 398D-2 to 398-4 include Zones M Pl 2 to M Pl 6 which are recognized in standard Pliocene stages. Considering the relationships between the zones and the stages of the Pliocene, as given by Cita (1973, 1975), Cita and Gartner (1973), Cita and Decima (1975), and the recommendations of the VI R.C.M.N.S. Congress about the stages which have to be adopted, and following Mazzei et al. (this volume, Part 1), Cores 398D-2 to 398-4 are zonated as follows:

Zanclean: Samples 398D-2, CC to 398D-2-2, 130-132 cm (M Pl 3); Samples 398B-1, CC to 398B-1-1, 86-88 cm (M Pl 2 and M Pl 3); Sample 398A-2, CC to Sample 398A-2-1 (M Pl 2 and M Pl 3).

Piacenzian: Samples 398D-2-2, 15-17 cm to 398D-2-1, 53-55 cm (M Pl 5 and M Pl 6); Samples 398A-1, CC to 398A-1-1, 9-11 cm (M Pl 4 and M Pl 5); Samples 398-4, CC to 398-4-1, 90-92 cm (M Pl 5).

The Pleistocene was recognized in Core 398-3 to Sample 398-1, CC, in which Zone N.22 was identified.

CONCLUSIONS

Site 398 is not suitable for accurate biostratigraphic resolution because of factors disturbing the biostratigraphic record (coring discontinuity, drilling disturbances, dissolution, bioturbation, and temperature of water masses).

The sporadic distribution and/or absence of several significant taxa in some cases have limited a reliable application of adopted zonal schemes.

The following biozones from early Miocene to Pleistocene were recognized (Figures 1 and 2).

Early Miocene

Zone N.4 (?) to Zone N.6—Aquitanian (?) to Burdigalian: Core 398D-12 to Sample 398D-8-4, 73-75 cm.

Middle Miocene

Zone N.8—Langhian: Samples 398D-8-3, 104-106 cm to 398D-7-1, 42-44 cm.

Zone N.9—Langhian: Samples 398D-6, CC to 398D-6-4, 89-91 cm.

Zone N.10—Serravallian: Samples 398D-6-4, 36-38 cm to 398D-6-1, 20-22 cm.

Zone N.12—Serravallian: Samples 398D-5, CC, 398D-5-2, 124-126 cm.

Zone N.13—Serravallian: Samples 398D-5-2, 53-55 cm to 398D-5-1, 35-37 cm.

Late Miocene

Zone N.16—Tortonian: Samples 398D-4-6, 141-143 cm to 398D-4-1, 35-37 cm.

Zone N.17—Tortonian: Samples 398D-3, CC to 398D-3-1, 78-80 cm.

Early Pliocene

Zone M Pl 2 (including Zone M Pl 1)—Zanclean: Samples 398B-1, CC to 398B-1-5, 14 cm; Samples 398A-2, CC to 398A-2-2, 30-32 cm.

Zone M Pl 3—Zanclean: Samples 398D-2, CC to 398D-2-2, 130-132 cm; Samples 398B-1-4, 106-108 cm to

398B-1-1, 86-88 cm; Samples 398A-2-1, 139-141 cm to 398A-2-1, 64-66 cm.

Late Pliocene

Zone M Pl 4—Piacenzian: Samples 398A-1, CC to 398A-1-4, 20-22 cm.

Zone M Pl 5—Piacenzian: Samples 398D-2-2, 15-17 cm; Samples 398A-1-3, 107-109 cm to 398-4-1, 90-92 cm.

Zone M Pl 6—Piacenzian: Samples 398D-2-1, 126-128 cm to 398D-2-1, 53-55 cm.

Pleistocene

Zone N.22: Samples 398-3, CC to 398-1, CC.

In the Miocene sequence, a biostratigraphic gap including at least Zone N.7 and part of Zone N.8 was documented between Section 4 (Zone N.6) and Section 3 (Zone N.8, post *Praeorbulina datum*) within Core 398D-8.

Another gap may have interrupted the sedimentary sequence between Cores 398D-5 and 398D-4, as it is difficult for Zones N.13 (pars) through N.15 to occur in this uncored 19-meter-thick interval. Middle Miocene hiatuses are known from other deep-sea cores of the eastern North Atlantic (Sites 397, 135, 136, 139, and 140).

The anomalous biostratigraphic succession recovered in the Pliocene was attributed to drilling disturbances. Displaced sediments were recorded in Core 398B-1 (Sections 4 to 1) and Core 398D-2, in which abrupt qualitative and quantitative changes occur in the planktonic foraminiferal assemblages. Such sediments belong to zones younger than the ones recognized in shallower cores (Cores 398A-2 to 398-4) as illustrated in Figures 1 and 2. Drilling disturbances did not affect Cores 398B-1, CC to Section 5), 398A-2, 398A-1, and 398-4, where the zonal boundaries seem stratigraphically normal and the zonal succession, in comparison with the coring depth, appears to be regular. We suggest that latest Miocene sediments occur at the depth from which Core 398D-2 (271 to 280 m) was recovered. In fact, at the top of Core 398D-3 (38 m deeper than Core 398D-2), sediments of middle-late Tortonian occur.

Taxonomical Notes

In the present paper, the taxonomical concepts and terminology of Blow (1969) have been utilized as far as possible. The following comments are added here to clarify the writers' approach to some controversial species.

Globigerina helicina d'Orbigny (Plate 8, Figures 10 and 11, See Banner and Blow, 1960, p. 13, pl. 2, fig. 5 (lectotype figured).

Globigerina megastoma cariacoensis Rögl and Bolli (Plate 8, Figures 12 and 13). Rögl and Bolli, 1973, p. 564, pl. 4, fig. 10 to 12, and text-fig. 4.

Globigerina microfoliata Brönnimann and Resig (Plate 1, Figures 5 and 6). Brönnimann and Resig, 1971, p. 1267, pl. 6, fig. 4 to 6; pl. 43, fig. 1.

Globigerina regina Crescenti (Plate 1, Figure 8). Crescenti, 1966, p. 34, pl. 2, fig. 6 and 7, and text-fig. 4. See also Salvatorini and Cita, this volume, Part 1, pl. 7, fig. 16 to 18.

Globigerina umbilicata Orr and Zaitzeff. Orr and Zaitzeff, 1971, p. 18, pl. 1, fig. 1 to 3.

Globorotalia acrostoma Wezel (Plate 3, Figures 7 and 8). Wezel, 1966, p. 1298, pl. 101, fig. 1 to 12, and text-fig. 1. See also Salvatorini and Cita, this volume, Part 1, pl. 9, fig. 19 to 21.

Globorotalia bella Jenkins. Jenkins, 1967, p. 1069, fig. 3, nos. 1 to 6. See also Salvatorini and Cita, this volume, Part 1, pl. 9, fig. 5 to 8.

Globorotalia bononiensis Dondi and Papetti (Plate 7, Figures 1 to 3). Dondi, 1963, p. 162, fig. 41, 1.

Globorotalia incisa Brönnimann and Resig (Plate 7, Figure 6). Brönnimann and Resig, 1971, p. 1278, pl. 45, fig. 5 and 7; pl. 46, fig. 1 to 8. See also Salvatorini and Cita, this volume, Part 1, pl. 8, fig. 20 to 22.

Globorotalia partimlabiata Ruggieri and Sprovieri (Plate 3, Figure 9). Ruggieri and Sprovieri, 1970, p. 22, text-fig. 3 and 4b. See also in Giannelli and Salvatorini, 1976, p. 167-168, text-fig. 1; see also Salvatorini and Cita, this volume, Part 1, pl. 9, fig. 11, 17 and 18.

Globorotalia planispira Brönnimann and Resig (Plate 7, Figures 12 to 14, 19, and 20). Brönnimann and Resig, 1971, p. 1282, pl. 36, fig. 4 and 6; pl. 44, fig. 1 to 5, 7, and 8. See also Stainforth et al., 1975, p. 394, fig. 193, nos. 1 to 6.

Turborotalia atlantisae (Cifelli and Smith) (Plate 7, Figures 25 and 26). Cifelli and Smith, 1970, p. 17, pl. 1, fig. 1 to 3 (given as *Globigerina atlantisae*).

Globorotaloides falconarae Giannelli and Salvatorini (Plate 2, Figure 16). Giannelli and Salvatorini; 1976, p. 170, pl. 2, fig. 1 to 6. See also Cita et al., (1978), pl. 4, fig. 12 and 13; see also Salvatorini and Cita, this volume, Part 1, pl. 4, fig. 5 to 7.

Hastigerinella riedeli Rögl and Bolli (Plate 8, Figures 14 and 15). Rögl and Bolli, 1973, p. 567, pl. 4, fig. 1 to 5; pl. 14, fig. 1 to 3; text-fig. 5.

The species and subspecies listed below must be considered "sensu lato," i.e., including the taxa s.s. and the taxa indicated here between parentheses.

Globigerina nepenthes Todd (Plate 1, Figure 10), (*G. nepenthes delicatula* Brönnimann and Resig, *G. picassiana* Perconig).

Globigerina praebulloides Blow (Plate 1, Figure 7), (*G. praebulloides leroyi* Banner and Blow, *G. praebulloides occlusa* Banner and Blow).

Globoquadrina dehiscens dehiscens (Plate 8, Figure 3), (Chapman, Parr, and Collins) (*G. quadraria advena* Bermudez).

Globorotalia cultrata (d'Orbigny) (Plate 4, Figures 11 and 12), *G. menardii* (Parker, Jones, and Brady), *G. limbata* (Fornasini).

Globorotalia margaritae Bolli and Bermudez (Plate 5, Figures 1 and 2), (*G. margaritae evoluta* Cita, *G. margaritae primitiva* Cita).

Globorotalia truncatulinoides (d'Orbigny) (Plate 5, Figure 15), (*G. truncatulinoides pachytheca* Blow).

Globigerinita glutinata (Egger), *G. ambitacrema* (Loeblich and Tappan), *G. naparimaensis* Brönnimann, *G. incrusta* Akers).

Globorotalia scitula group. Only *G. praescitula* Blow (Plate 3, Figures 5 and 6), *G. scitula* (Brady) (Plate 5, Figure 16), and *G. bermudezi* Rögl and Bolli (Plate 7, Figures 5 and 9) have been distinguished. Of the other forms of this group which were found at Site 398, those not clearly referable to known species have been lumped into the "*G. scitula* group."

Globorotalia crassaformis s.l.: We have not tried to split the group into the numerous morphotypes recognized in the literature: e.g., "*crassaformis*" (Galloway and Wissler) (Plate 6, Figures 1 and 2), "*oceanica*" Cushman and Bermudez (Plate 6, Figures 5 to 7), "*ronda*" Blow (Plate 6, Figures 3 and 4) "*viola*" Blow (Plate 6, Figures 9, 10, and 13), "*conomiozea*" Blow (Plate 6, Figures 11, 14, and 15), "*hessi*" Bolli and Premoli Silva "*aemiliana*" Colalongo and Sartoni (Plate 5, Figures 13 and 14), "*crotonensis*" Conato and Follador, "*crassacrotonensis*" Conato and Follador, and "*crassula*" Cushman and Stewart (Plate 6, Figures 8 and 12). These morphotypic distinctions were not made because of the difficulty of these subdivisions and, consequently, their limited stratigraphic value. In Plates 5 and 6, several morphotypes belonging to this group are documented.

Globigerina bulloides s.l. *Globigerina bulloides* d'Orbigny, and *G. apertura* Cushman (Plate 1, Figure 11) were considered here as species rather than subspecies (Blow, 1969). The structure and the morphology of *G. apertura* are quite different from that of *G. bulloides*, while they appear to be similar to those of *G. decoraperta* Takayanagi and Saito (Plate 1, Figure 15), from which *G. apertura* could have evolved.

Globigerina digitata s.l.: The subdivision of *Globigerina digitata digitata* Brady from *G. digitata praedigitata* is based on broader criteria than those followed by Blow (1969). In *G. digitata digitata* (Plate 1, Figures 12 and 13), we included taxa which have the ultimate and the penultimate chamber showing distinct radial elongation even without the conical termination, characteristic of the subspecies according to Blow (1969). We followed Blow's criteria in distinguishing *G. digitata praedigitata* (Plate 1, Figures 17 and 18). In the Pleistocene Cores 398-3 to 398-1, small individuals (type *praedigitata*) commonly occur; they probably represent juvenile forms of *G. digitata digitata*. These forms, as well as the larger ones having less distinct radial elongation in the final chambers than *G. digitata digitata*, are lumped together in *G. digitata* s.l.

Globigerina cf. *calida calida* Parker (Plate 1, Figures 19 and 21). A form very similar to *G. calida calida* Parker (as amended by Blow, 1969) occurs upwards from Section 398-2-3 showing less distinct radial elongation of the less sharply separated chambers and slightly more-elevated coiling; it could represent a transitional form from *G. calida praecalida* Blow to *G. calida* s.s. It is here defined as *G.* cf. *calida calida*. It differs from "*praecalida*" (Plate 1, Figure 20) in having final chambers more separated and slightly radially elongated.

Sphaeroidinellopsis plexus: The plexus of *Sphaeroidinellopsis* is extensively discussed by Salvatorini and Cita (this volume, Part 1) who propose an extensive revision. All the taxa recognized by these authors occur at Site 398: *S. disjuncta* (Finlay), (Plate 9, Figures 1 and 3); *S. subdehiscens* (Blow), (Plate 9, Figures 4 and 5); *S. seminulina seminulina* (Schwager), (Plate 9, Figures 6 and 7); *S. seminulina paenedehiscens* Blow, (Plate 9, Figures 7 and 8).

Globorotalia pachyderma s.l.: In the Pleistocene interval (Cores 398-3 upwards) and in Sample 398D-2-2, 82-84 cm, two morphotypes are easily recognizable within the populations of *Globorotalia pachyderma*. These morphotypes are *G. pachyderma* (Ehrenberg) (Plate 7, Figures 10 and 11) and *Globigerina borealis* Brady (i.e., *G. bulloides* var. *borealis* Brady as lectotypified by Banner and Blow (1960), (Plate 7, Figures 15 to 18). The latter differs from the former mainly in having a less coarsely textured surface and a more ovate equatorial profile. Moreover, the chambers increase more rapidly in size and are more radially elongated, particularly the last one (or the penultimate when the last one is abortive). The apertural rim in "*borealis*" is broader and more thickened than in "*pachyderma*." The different coiling direction facilitates the distinction of the two forms; thus, *borealis* is constantly sinistral, and "*pachyderma*" consistently coils dextrally. At Site 398, the "*borealis*" morphotypes appear to have a distribution more limited than the "*pachyderma*" type (from the latest Pliocene and from the early Pliocene, respectively). This is consistent with the observations of Blow (1969) that "forms identical to the lectotype range from within Zone N.20 to Zone N.23" (p. 316). The above-mentioned differences in both morphology and stratigraphic range support the subdivision into two subspecies.

G. aff. *hirsuta hirsuta* d'Orbigny (Plate 5, Figures 3 to 6): We indicated as *G.* aff. *hirsuta hirsuta* a taxon having features quite similar to those indicated by d'Orbigny (1839, in Barker-Webb and Berthelot, Hist, Nat. Iles Canaries, v. 2, p. 131, pl. 1, fig. 37-39). *G.* aff. *hirsuta hirsuta* has been recorded only from the Zone M Pl 4, where it occurs frequently. This form differs from *G. hirsuta hirsuta* as neotypified by Blow (1969, p. 398, pl. 8, fig. 1 to 3), in having more appressed umbilical coiling and more closed, less petaloid chambers. *G.* aff. *hirsuta hirsuta* differs from *G. margaritae* in having a less concave-convex test, a more square equatorial periphery, and only four chambers in the final whorl (which are, moreover, less petaloid and tangentially longer). Furthermore, the coiling direction is consistently dextral, while sinistral in *G. margaritae*. It dif-

fers from *G. aemiliana* Colalongo and Sartoni in having a thin but distinct keel and a more compressed and dorsally convex test.

Globorotalia aff. *lenguaensis* Bolli (Plate 3, Figures 15 and 20): We indicated as *G.* aff. *lenguaensis*, taxa quite similar to the types of Bolli; they differ in having less typical features.

Globorotalia sp. 1 (Plate 3, Figures 1 to 4): This form, recorded only in Core 398D-9 (Zone N.6), is very similar to the Oligocene species *Globorotalia opima opima* Bolli. It differs consistently in having a well-developed apertural lip.

Globorotalia sp. 2: It is a small taxon recorded from Zone N.9 to N.17 (see *Globorotalia* sp. in Salvatorini and Cita, pl. 8, fig. 16 to 19, this volume).

Globorotaloides sp. (Plate 2, Figures 14 and 15): This taxon, encountered only in a short interval of Core 398D-3 (lower part of Zone N.17) is similar to *G. falconarae* Giannelli and Salvatorini (Plate 2, Figure 16) from which it differs in being larger and having a more inflated test.

Turborotalita sp. 1 (Plate 7, Figures 27 to 29): This form is comparable to *Globorotalia parkerae* Brönnimann and Resig. It was recorded in Core 398-3 (Zone N.22).

Turborotalita sp. 2 (Plate 7, Figures 22 to 24): This form is comparable to *Globanomalina praepumilio* Parker. It was recorded in Cores 398B-1 (Zone M Pl 3) and 398-4 (Zone M Pl 5).

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PLATE 1

Figures 1, 2 — *Globigerina venezuelana* Hedberg, 100×.
1. Umbilical view. Sample 398D-8-4, 133-135 cm. Zone N.6.
2. Umbilical view. Sample 398D-7-2, 131-133 cm. Zone N.8.

Figure 3, 4 — *Globigerina druryi* Akers, 100×.
3,4. Umbilical view. Sample 398D-5-4, 61-63 cm. Zone N.12.

Figures 5, 6 — *Globigerina microfoliata* Brönnimann and Resig, 100×.
5. Umbilical view.
6. Spiral view. Sample 398A-1-3, 107-109 cm. Zone M Pl 5.

Figure 7 — *Globigerina praebulloides* Blow, 100×.
Umbilical view. Sample 398D-6-5, 67-69 cm. Zone N.9.

Figure 8 — *Globigerina regina* Crescenti, 100×.
Umbilical view. Sample 398D-6-4, 36-38 cm. Zone N.10.

Figure 9 — *Globigerina woodi woodi* Jenkins, 100×.
Umbilical view. Sample 398D-6-3, 33-35 cm. Zone N.10.

Figure 10 — *Globigerina nepenthes* Todd, 100×.
Oblique-lateral view. Sample 398D-3-6, 25-27 cm. Zone N.17.

Figure 11 — *Globigerina apertura* Cushman, 100×.
Umbilical view. Sample 398A-1-3, 22-24. Zone M Pl 5.

Figures 12, 13 — *Globigerina digitata digitata* Brady, 100×.
12. Umbilical view. Sample 398-3-5, 130-132 cm. Zone N.22.
13. Umbilical view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figure 14 — *Globigerina falconensis* Blow, 100×.
Umbilical view. Sample 398A-1-5, 30-32 cm. Zone M Pl 4.

Figure 15 — *Globigerina decoraperts* Takayanagi and Saito, 100×.
Umbilical view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.

Figure 16 — *Globigerina rubescens* Hofker, 166×.
Umbilical view. Sample 398-4-3, 50-52 cm. Zone M Pl 5.

Figures 17, 18 — *Globigerina digitata praedigitata* Parker, 100×.
17. Umbilical view. Sample 398B-1-4, 59-61 cm. Zone M Pl 3.
18. Umbilical view. Sample 398D-2-1, 82-84 cm. Zone M Pl 3.

Figures 19, 21 — *Globigerina* cf. *calida calida* Parker, 100×.
19. Spiral view.
21. Umbilical view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figure 20 — *Globigerina calida praecalida* Blow, 100×.
Umbilical view. Sample 398A-1-3, 107-109 cm. Zone M Pl 5.

PLATE 1

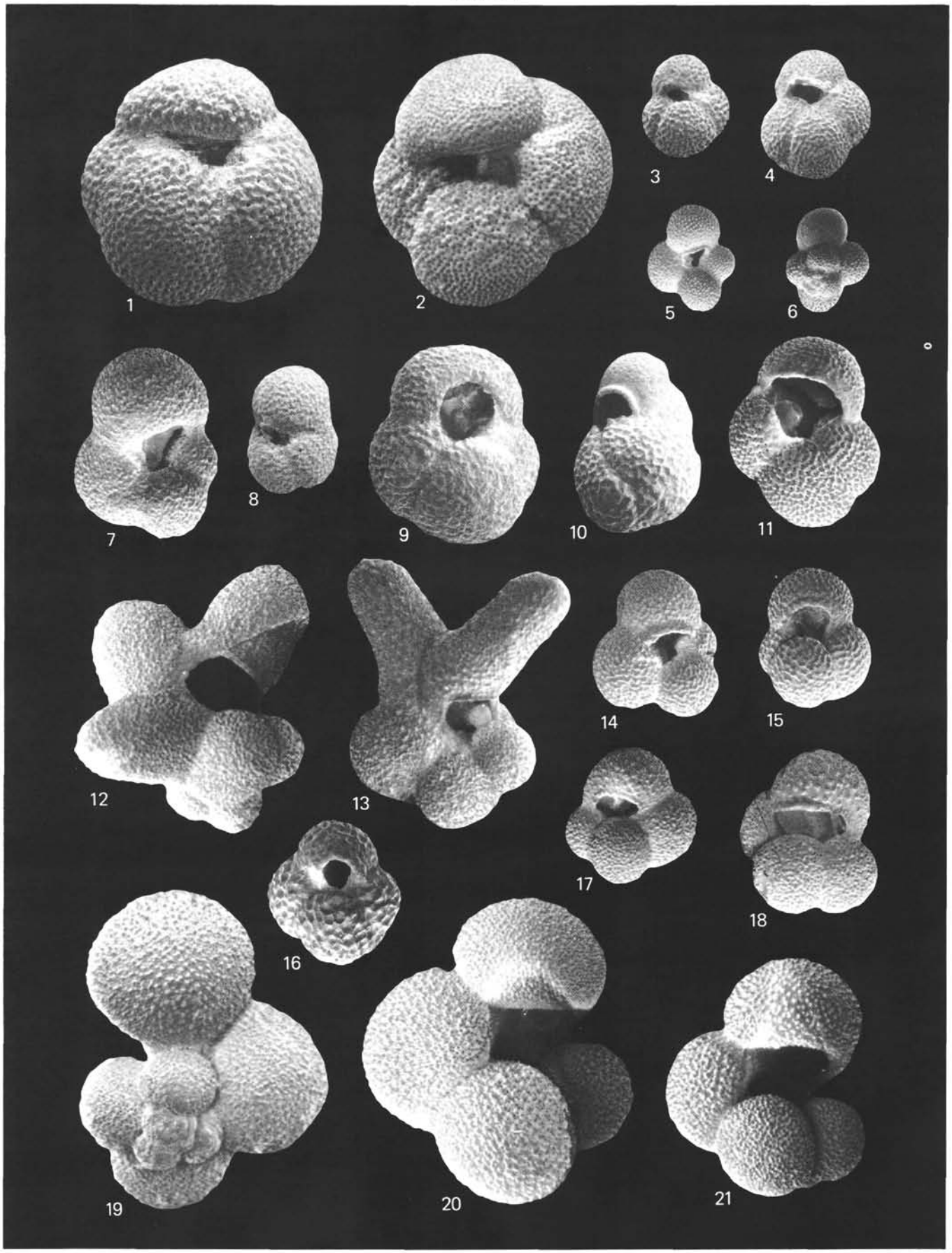

PLATE 2
100×

Figure 1 — *Globigerinoides sicanus* De Stefani.
Sample 398D-7-3, 9-11 cm. Zone N.8.

Figure 2 — *Globigerinoides subquadratus* Brönnimann.
Spiral view. Sample 398D-7-2, 41-43 cm. Zone N.8.

Figures 3, 4 — *Globigerinoides* cf. *quadrilobatus altiaperturus* Bolli.
3. Lateral view. Sample 398D-8, CC. Zone N.6.
4. Umbilical view. Sample 398D-8-3, 104-106 cm. Zone N.8.

Figure 5 — *Globigerinoides bollii* Blow.
Umbilical view. Sample 398D-4-2, 36-38 cm. Zone N.16.

Figure 6 — *Globigerinoides obliquus obliquus* Bolli.
Umbilical view. Sample 398B-1-4, 59-61 cm. Zone M Pl 3.

Figure 7 — *Globigerinoides obliquus extremus* Bolli and Bermudez.
Umbilical view. Sample 398B-1-2, 25-27 cm. Zone M Pl 3.

Figure 8 — *Globigerinoides ruber* (d'Orbigny).
Spiral view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figure 9 — *Globigerinoides elongatus* (d'Orbigny).
Spiral view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figures 10, 11 — *Globigerinoides tenellus* Parker.
10. Spiral view.
11. Umbilical view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figure 12 — *Globigerinoides conglobatus conglobatus* (Brady).
Spiral view. Sample 398A-1-6, 56-58 cm. Zone M Pl 4.

Figure 13 — *Globorotaloides hexagona* (Natland).
Umbilical view. Sample 398-3, CC. Zone N.22.

Figures 14, 15 — *Globorotaloides* sp.
14. Umbilical view.
15. Spiral view. Sample 398D-3-6, 25-27 cm. Zone N.17.

Figure 16 — *Globorotaloides falconarae* Giannelli and Salvatorini.
Umbilical view. Sample 398D-4-1, 35-37 cm. Zone N.16.

Figures 17, 18 — *Globigerinita dissimilis dissimilis* (Cushman and Stainforth).
Umbilical view. Sample 398D-9-2, 36-38 cm. Zone N.6.

Figure 19 — *Globigerinita unicava unicava* (Bolli, Löeblich and Tappan).
Umbilical view. Sample 398D-9-6, 127-129 cm. Zone N.6.

Figure 20 — *Globigerinita dissimilis ciperoensis* Blow and Banner.
Umbilical view. Sample 398D-9-6, 127-129 cm. Zone N.6.

PLATE 2

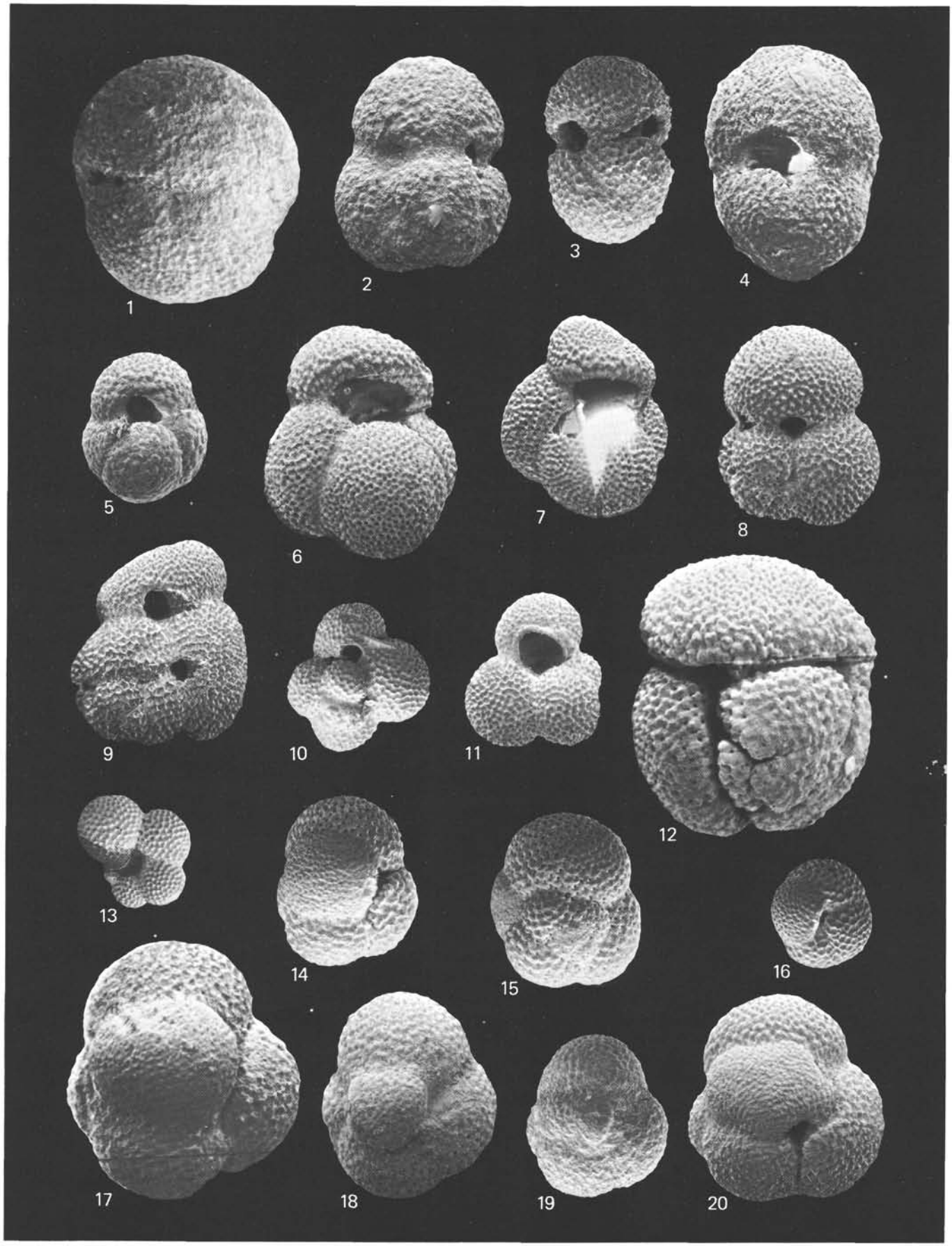

PLATE 3
100 ×

Figures 1-4 *Globorotalia* sp. 1.
1,2,4. Umbilical view.
3. Lateral view. Sample 398D-9-2, 36-38 cm. Zone N.6.

Figures 5, 6 *Globorotalia praescitula* Blow.
5. Lateral view.
6. Spiral view. Sample 398D-8-2, 70-72 cm. Zone N.8.

Figures 7, 8 *Globorotalia acrostoma* Wezel.
7. Umbilical view.
8. Lateral view. Sample 398D-8-3, 104-106 cm. Zone N.8.

Figure 9 *Globorotalia partimlabiata* Ruggieri and Sprovieri.
Umbilical view. Sample 398D-5-2, 53-55 cm. Zone N.13.

Figures 10, 14 *Globorotalia siakensis* Le Roy.
10. Umbilical view.
14. Spiral view. Sample 398D-5-5, 26-28 cm. Zone N.12.

Figures 11-13 *Globorotalia peripheroronda* Blow and Banner.
11. Umbilical view.
12. Lateral view.
13. Spiral view. Sample 398D-6-5, 67-69 cm. Zone N.9.

Figures 15, 20 *Globorotalia* aff. *lenguaensis* Bolli.
15. Spiral view.
20. Umbilical view. Sample 398D-4-2, 36-38 cm. Zone N.16.

Figures 16, 17 *Globorotalia continuosa* Blow.
16. Spiral view.
17. Umbilical view. Sample 398D-4-5, 34-36 cm. Zone N.16.

Figure 18 *Globorotalia acostaensis* Blow.
Umbilical view. Sample 398D-4-4, 16-18 cm. Zone N.16.

Figure 19 *Globorotalia obesa* Bolli.
Umbilical view. Sample 398D-7-3, 122-124 cm. Zone N.8.

Figure 21 *Globorotalia humerosa* Takayanagi and Saito.
Umbilical view. Sample 398B-1-3, 107-109 cm. Zone M Pl 3.

Figures 22, 23 *Globorotalia incompta* (Cifelli).
22. Lateral view.
23. Umbilical view. Sample 398-4, CC. Zone M Pl 5.

PLATE 3

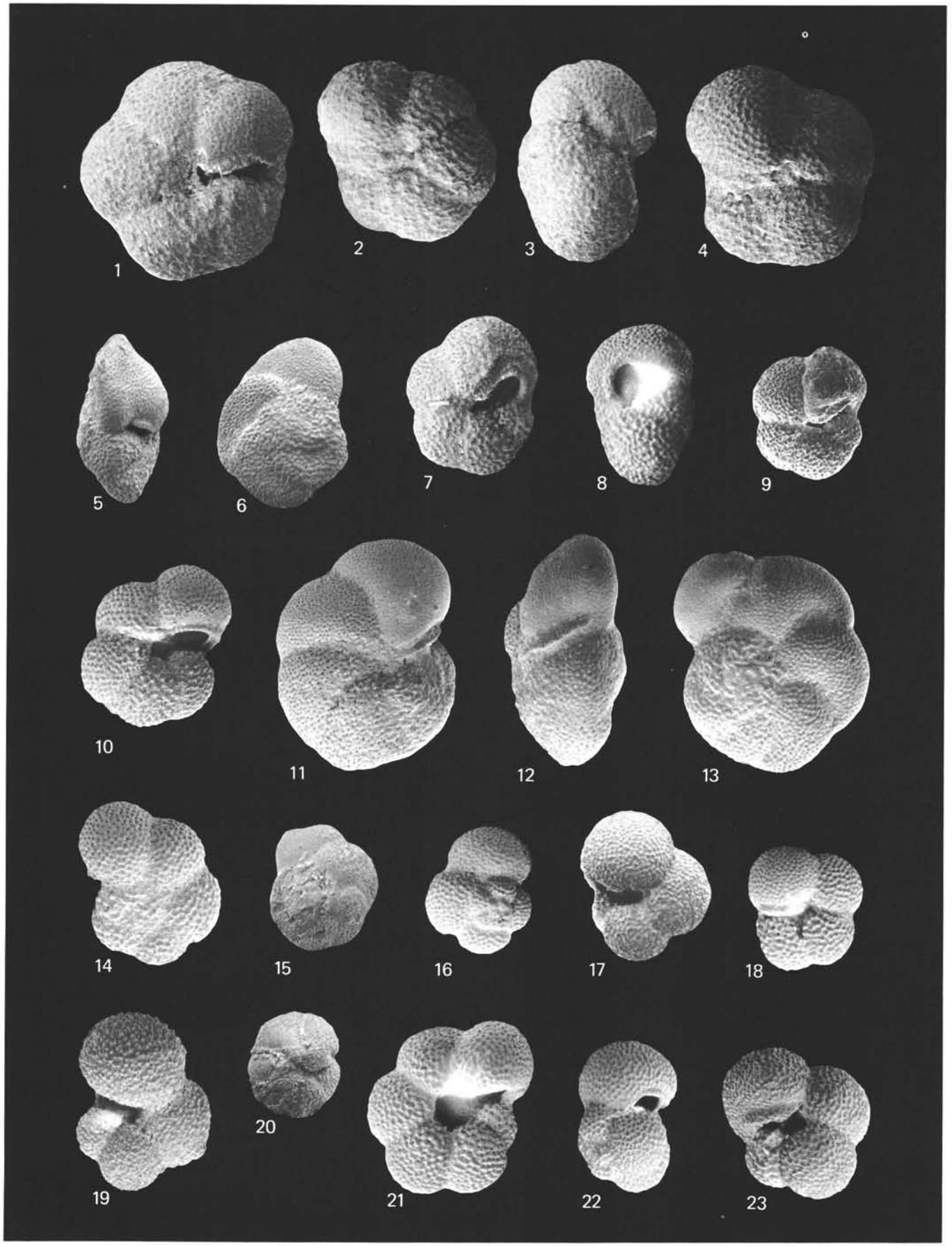

PLATE 4
100×

Figures 1, 2, 5 *Globorotalia miozea miozea* Finlay.
1. Spiral view. Sample 398D-8-3, 76-78 cm. Zone N.8.
2. Umbilical view.
5. Lateral view. Sample 398D-8-3, 104-106 cm. Zone N.8.

Figure 3 *Globorotalia* cf. *praemenardii archeomenardii* Bolli.
Spiral view. Sample 398D-8-2, 70-72 cm. Zone N.8.

Figure 4 *Globorotalia miozea conoidea* Jenkins.
Lateral view. Sample 398D-3-5, 31-33 cm. Zone N.17.

Figures 6-8 *Globorotalia praemenardii praemenardii* Cushman and Stainforth.
Spiral view. Sample 398D-5-5, 26-28 cm. Zone N.12.

Figures 9, 10, 13 *Globorotalia merotumida* Blow and Banner.
9. Umbilical view.
10. Lateral view.
13. Spiral view. Sample 398D-4-4, 16-18 cm. Zone N.16.

Figures 11, 12 *Globorotalia cultrata* s.l.
Spiral view. Sample 398D-4-2, 36-38 cm. Zone N.16.

Figures 14-16 *Globorotalia miozea cibaoensis* Bermudez.
14. Spiral view.
15. Lateral view.
16. Umbilical view. Sample 398D-1, CC. Zone M Pl 2.

PLATE 4

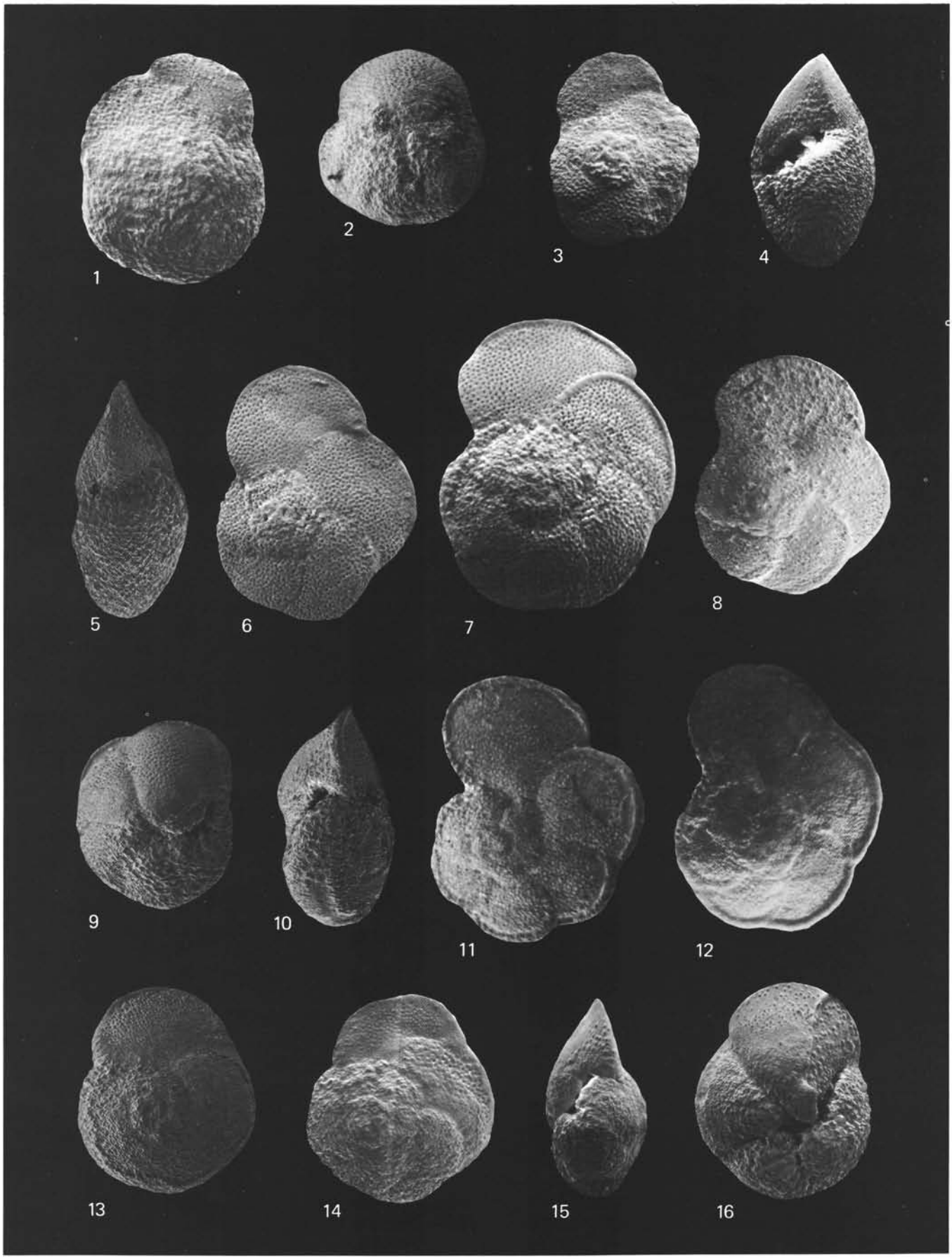

PLATE 5

Figures 1, 2 — *Globorotalia margaritae* Bolli and Bermudez, 100×.
1. Spiral view.
2. Lateral view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.

Figures 3-6 — *Globorotalia* aff. *hirsuta hirsuta* (d'Orbigny), 100×.
3,6. Spiral view.
4. Umbilical view.
5. Lateral view. Sample 398A-1, CC. Zone M Pl 4.

Figures 7, 10 — *Globorotalia hirsuta hirsuta* (d'Orbigny), 100×.
7. Spiral view.
10. Lateral view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figures 8, 11, 12 — *Globorotalia tumida tumida* (Brady).
8,12. Lateral view, 100×.
11. Spiral view, 40×. Sample 398-2-3, 138-140 cm. Zone N.22.

Figure 9 — *Globorotalia crassaformis* s.l., 100×.
Umbilical view. Sample 398-2-1, 140-142 cm. Zone N.22.

Figures 13, 14 — *Globorotalia crassaformis* s.l. (type *aemiliana* Colalongo and Sartoni), 100×.
13. Lateral view. Sample 398B-1-2, 86-88 cm. Zone M Pl 3.
14. Spiral view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.

Figure 15 — *Globorotalia truncatulinoides* (d'Orbigny), 100×.
Lateral view. Sample 398-2, CC. Zone N.22.

Figure 16 — *Globorotalia scitula* (Brady), 100×.
Spiral view. Sample 398-4-4, 20-22 cm. Zone M Pl 5.

PLATE 5

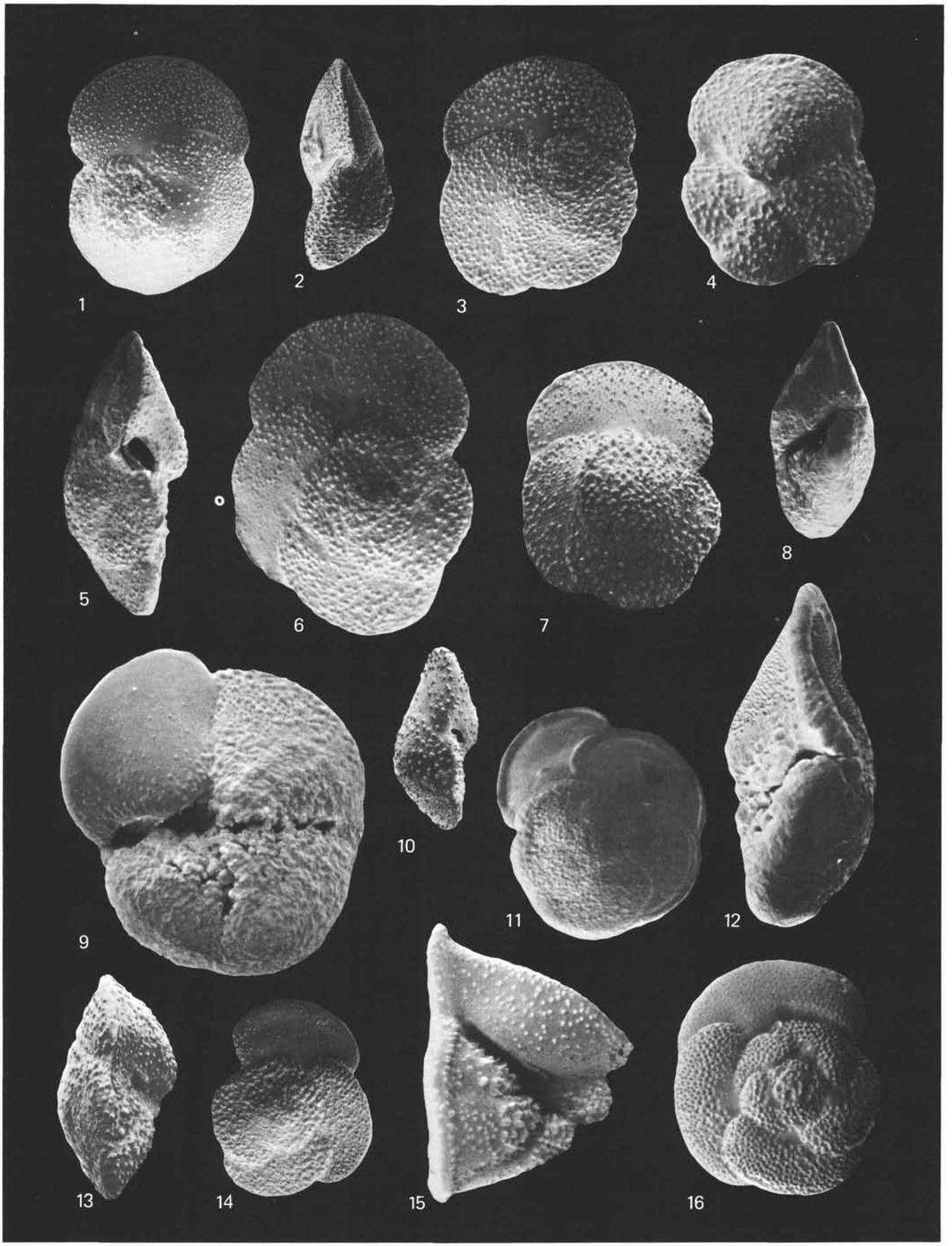

PLATE 6
100×

Figures 1, 2 *Globorotalia crassaformis* s.l. (type *crassaformis* Galloway and Wissler).
1. Lateral view.
2. Umbilical view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.

Figures 3, 4 *Globorotalia crassaformis* s.l. (type *ronda* Blow).
3. Lateral view.
4. Umbilical view. Sample 398A-1-3, 107-109 cm. Zone M Pl 5.

Figures 5-7 *Globorotalia crassaformis* s.l. (type *oceanica* Cushman and Stainforth).
5. Umbilical view.
6. Lateral view.
7. Spiral view. Sample 398B-1-4, 59-61 cm. Zone M Pl 3.

Figures 8, 12 *Globorotalia crassaformis* s.l. (type *crassula* Cushman and Stewart).
8. Spiral view.
12. Umbilical view. Sample 398-4, CC. Zone M Pl 5.

Figures 9, 10, 13 *Globorotalia crassaformis* s.l. (type *viola* Blow).
9. Umbilical view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.
10. Umbilical view. Sample 398-2, CC. Zone N.22.
13. Spiral view. Sample 398B-1-1, 131-133 cm. Zone M Pl 3.

Figures 11, 14, 15 *Globorotalia crassaformis* s.l. (type *conomiozea* Blow not Kennett).
11. Lateral view.
14. Umbilical view.
15. Spiral view. Sample 398A-1-3, 22-24 cm. Zone M Pl 5.

PLATE 6

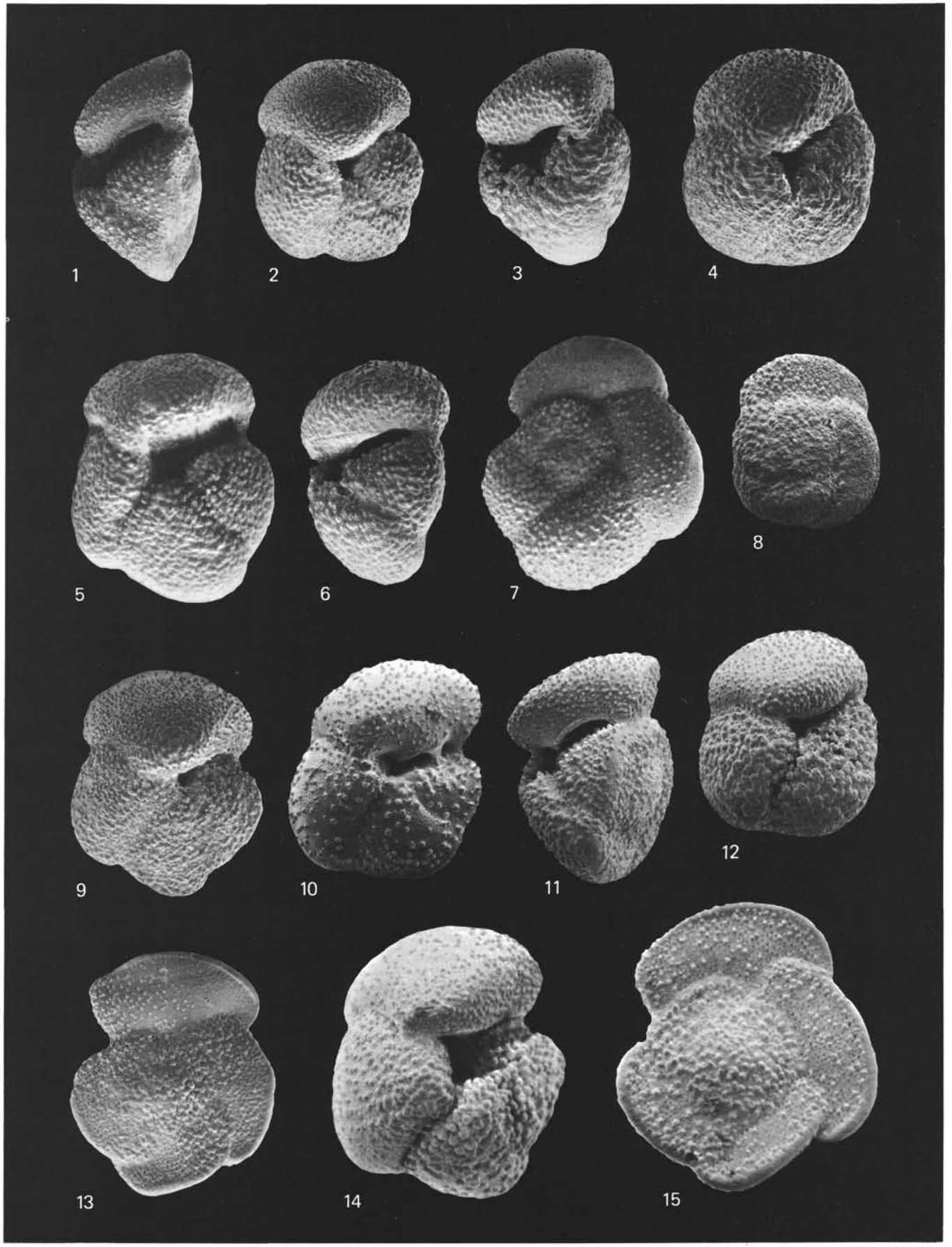

PLATE 7

Figures 1-3 *Globorotalia bononiensis* Dondi and Papetti, 100×.
1. Umbilical view.
2. Lateral view.
3. Spiral view. Sample 398A-1-3, 107-109 cm. Zone M Pl 5.

Figure 4 *Globorotalia puncticulata* (Deshayes), 100×.
Umbilical view. Sample 398B-1-3, 107-109 cm. Zone M Pl 3.

Figures 5, 9 *Globorotalia bermudezi* Rögl and Bolli, 100×.
5. Lateral view. Sample 398-3-5, 130-132 cm. Zone N.22.
9. Umbilical view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figure 6 *Globorotalia incisa* Brönnimann and Resig, 100×.
Umbilical view. Sample 398A-1-1, 82-84 cm. Zone M Pl 5.

Figures 7, 8 *Globorotalia inflata* (d'Orbigny), 100×.
7. Lateral view.
8. Spiral view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figures 10, 11 *Globorotalia pachyderma pachyderma* (Ehrenberg), 100×.
10. Spiral view. Sample 398A-2-1, 139-141 cm. Zone M Pl 3.
11. Umbilical view. Sample 398-2-3, 47-49 cm. Zone N.22.

Figures 12-14, 19, 20 *Globorotalia planispira* Brönnimann and Resig, 100×.
12,13. Umbilical view.
14. Spiral view.
19. Spiral view. Sample 398D-2-2, 15-17 cm. Zone M Pl 5.
20. Lateral view. Sample 398-4-5, 22-24 cm. Zone M Pl 3.

Figures 15-18 *Globorotalia pachyderma borealis* (Brady), 100×.
15,16,18. Umbilical view.
17. Spiral view. Sample 398-2-3, 138-140 cm. Zone N.22.

Figure 21 *Turborotalita iota* (Parker), 166×.
Umbilical view. Sample 398-2-3, 138-140 cm. Zone N.22.

Figures 22-24 *Turbortalita* sp. 2, 166×
22. Spiral view.
23. Umbilical view. Sample 398B-1-3, 107-109 cm. Zone M Pl 3.
24. Umbilical view. Sample 398-4, CC. Zone M Pl 5.

Figures 25, 26 *Turborotalita atlantisae* (Cifelli), 100×.
25. Spiral view. Sample 398-2-3, 30-32 cm. Zone N.22.
26. Umbilical view. Sample 398-3-5, 80-82 cm. Zone N.22.

Figures 27-29 *Turborotalita* sp. 1, 166×.
27. Umbilical view.
28,29. Spiral view. Sample 398-3, CC. Zone N.22.

Figures 30, 31 *Turborotalita cristata* (Heron-Allen and Earland).
30. Umbilical view, 166×.
31. Spiral view, 250×. Sample 398-2-3, 30-32 cm. Zone N.22.

PLATE 7

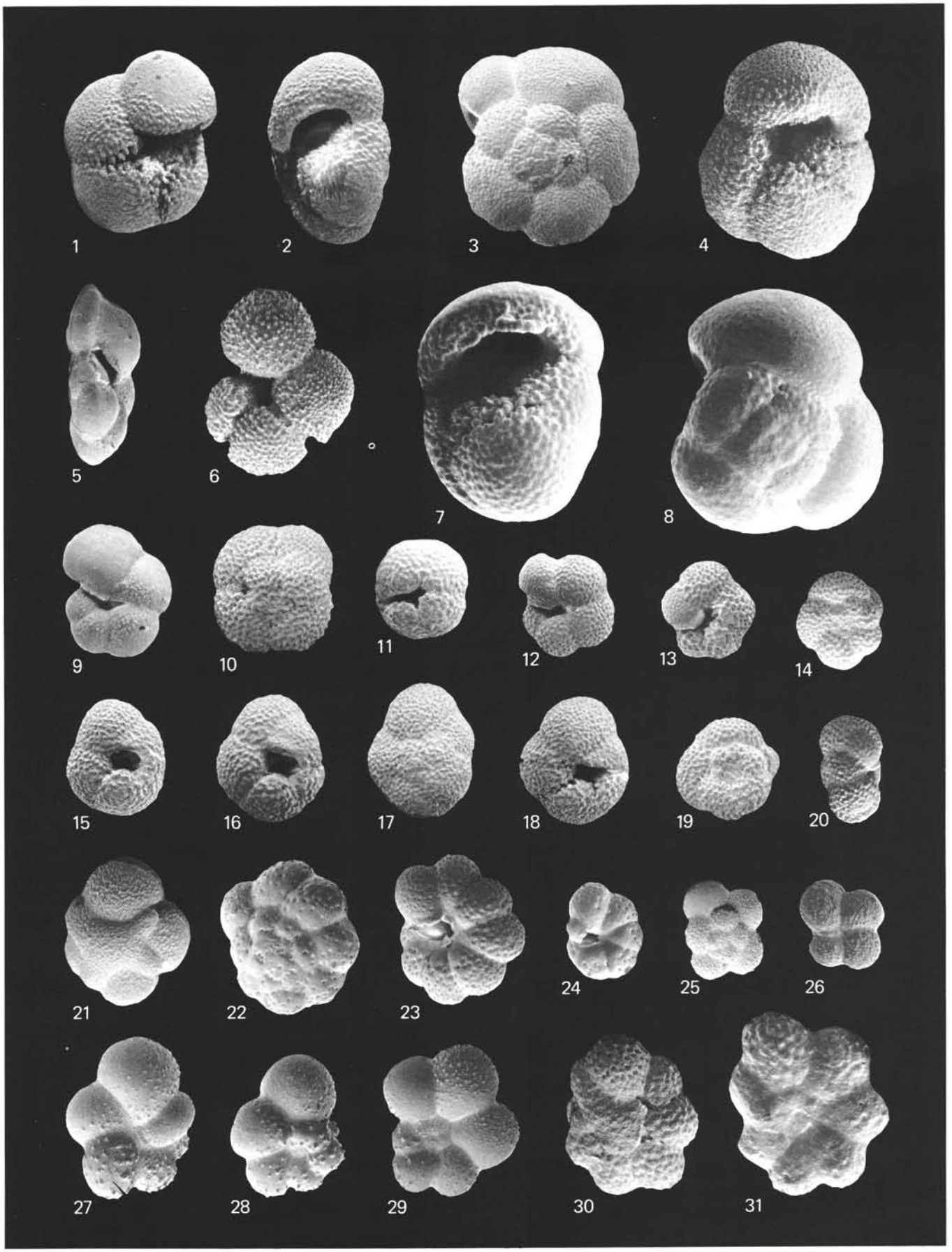
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PLATE 8
100×

Figures 1, 2 *Globoquadrina dehiscens praedehiscens* Blow and Banner.
1. Spiral view. Sample 398D-9-6, 127-129 cm. Zone N.6.
2. Umbilical view. Sample 398D-9, CC. Zone N.6.

Figure 3 *Globoquadrina baroemoenensis* (Le Roy).
Umbilical view. Sample 398D-7-3, 122-124 cm. Zone N.8.

Figure 4 *Globoquadrina langhiana* Cita and Gelati.
Umbilical view. Sample 398D-7-3, 122-124 cm. Zone N.8.

Figure 5 *Globoquadrina dehiscens dehiscens* (Chapman, Parr, and Collins).
Umbilical view. Sample 398D-6, CC. Zone N.9.

Figure 6 *Globoquadrina altispira altispira* (Cushman and Jarvis).
Lateral view. Sample 398D-6, CC. Zone N.9.

Figure 7 *Globoquadrina altispira globosa* Bolli.
Umbilical view. Sample 398D-9-6, 127-129 cm. Zone N.6.

Figure 8 *Globigerinatella insueta* Cushman and Stainforth.
Sample 398D-7-3, 9-11 cm. Zone N.8.

Figure 9 *Neogloboquadrina dutertrei* (d'Orbigny).
Umbilical view. Sample 398-2-2, 136-138 cm. Zone N.22.

Figures 10, 11 *Globigerina helicina* d'Orbigny).
10. Lateral view.
11. Umbilical view. Sample 398A-1-1, 9-11 cm. Zone M Pl 5.

Figures 12, 13 *Globigerina megastoma cariacoensis* Rögl and Bolli.
12. Lateral view.
13. Umbilical view. Sample 398-2-3, 30-32 cm. Zone N.22.

Figures 14, 15 *Hastigerinella riedeli* Rögl and Bolli.
Umbilical view. Sample 398-2-1, 140-142 cm. Zone N.22.

Figure 16 *Hastigerina siphinifera siphonifera* (d'Orbigny).
Umbilical view. Sample 398-3, CC. Zone N.22.

PLATE 8

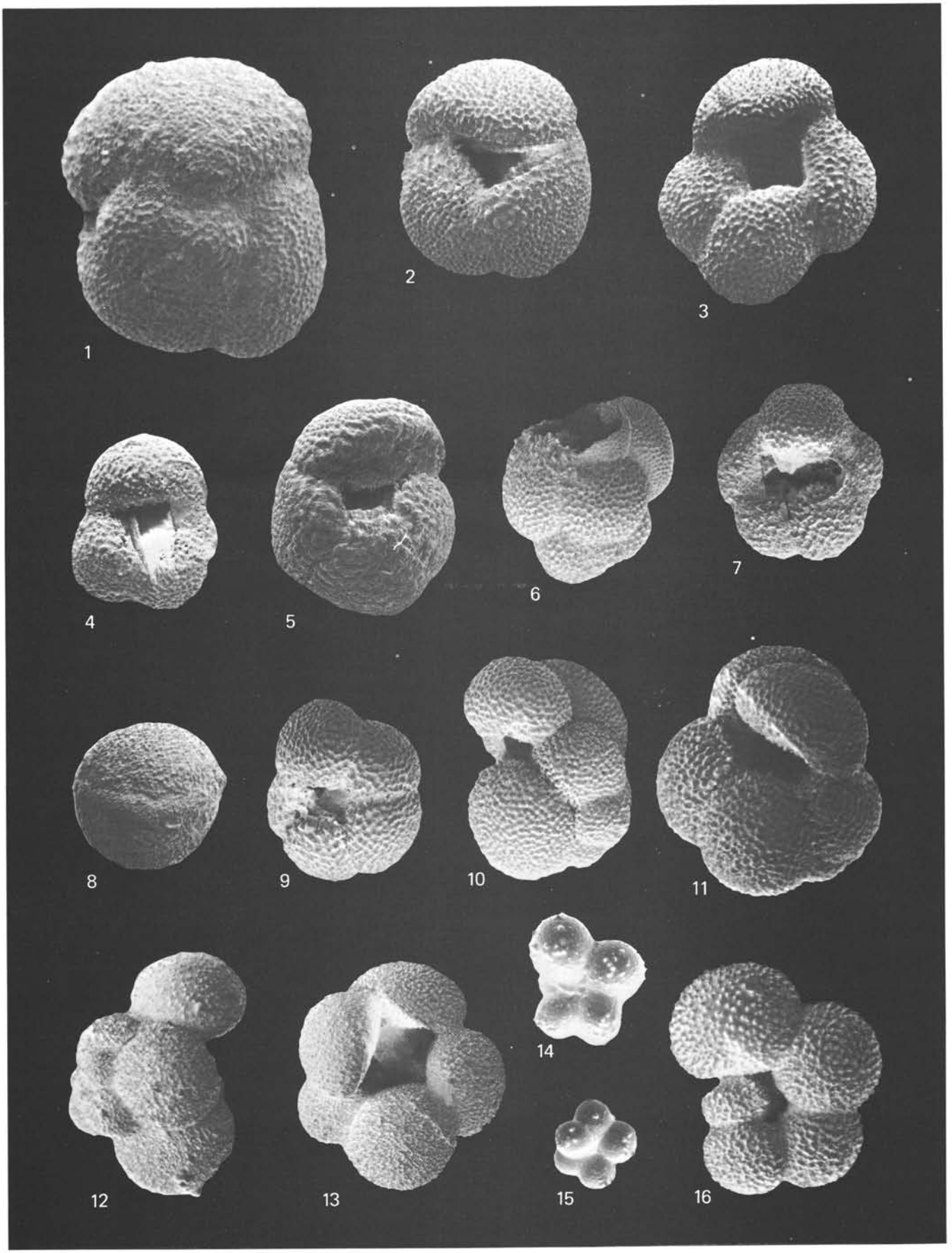

PLATE 9
100×

Figures 1-3 *Sphaeroidinellopsis disjuncta* Jenkins.
Umbilical view. Sample 398D-6, CC. Zone N.9.

Figures 4, 5 *Sphaeroidinellopsis subdehiscens* Blow.
Umbilical view.
4. Sample 398D-3-5, 31-33 cm. Zone N.17.
5. Sample 398D-5-2, 53-55 cm. Zone N.13.

Figures 6, 7 *Sphaeroidinellopsis seminulina seminulina* (Schwager).
Umbilical view. Sample 398D-3-6, 25-27 cm. Zone N.17.

Figures 8, 9 *Sphaeroidinellopsis seminulina paenedehiscens* Blow.
Umbilical view. Sample 398A-1, CC. Zone M Pl 4.

Figure 10 *Sphaeroidinella dehiscens dehiscens* (Parker and Jones).
Umbilical view. Sample 398-2, CC. Zone N.22.

Figure 11 *Pulleniatina obliqueloculata obliqueloculata* (Parker and Jones).
Spiral view. Sample 398-2, CC. Zone N.22.

PLATE 9