

## 8. MIOCENE FORAMINIFERAL STRATIGRAPHY, DSDP SITE 397 (CAPE BOJADOR, NORTH ATLANTIC)

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### ABSTRACT

Biostratigraphic investigations have been conducted on planktonic foraminiferal assemblages from a 627-meter thick interval encompassing Cores 33 to 97 of Hole 397. The upper part of the section consists of hemipelagic sediments yielding rich and well-diversified faunas. From Section 397-57-3 to Core 397-61, slumps are frequent and disturb the biostratigraphic record. Evidence of dissolution at depth is recorded, especially in the upper Miocene. Turbidites and debris flows are also present; the latter representing the dominant transport mechanism for sediments from Core 397-78 downwards, and the fossil assemblages are often sparse and/or poorly preserved.

All the biozones known from the time interval encompassing the Burdigalian, Langhian, Serravallian, Tortonian, Messinian, and Zanclean stages have been recognized. Zone N.16 is here emended, and two new biozones are defined: *Sphaeroidinellopsis seminulina paenedehiscens* Partial-Range-Zone and *Globigerina nepenthes* Interval-Zone.

A strongly condensed sequence, with at least two biostratigraphically identifiable hiatuses, is recorded in the interval from Cores 397-71 to 77, which is middle Miocene (Serravallian).

The Tortonian/Messinian and Messinian/Zanclean boundaries could be identified with accuracy in the hemipelagic sequence post-dating the slump interval, and these boundaries are correlated with stratotype sections in the Mediterranean area. The duration of the "salinity crisis" could also be precisely defined: it falls entirely within paleomagnetic Epoch 5.

Several evolutionary lineages could be followed, and are documented with SEM photographs. New observations on the evolutionary trends recorded in representatives of the genus *Sphaeroidinellopsis* are provided.

The Miocene succession continuously cored at DSDP Site 397 is the thickest and the most complete recovered so far from the eastern North Atlantic. Despite its upper continental rise setting and the occurrence of sediment types such as debris flows (in the lower Miocene) and volcanoclastic sandstones (in the middle Miocene), the biostratigraphic succession is relatively little disturbed and no major gaps are recorded within the Neogene. Consequently, we can consider the Cape Bojador section as a reference section for the North Atlantic, especially with regard to upper Neogene sediments.

### INTRODUCTION

The present paper reports the results of biostratigraphic research carried out on the Miocene succession continuously cored at DSDP Site 397, located on the upper continental rise off Cape Bojador (eastern North Atlantic, lat 26°50.7' N, long. 15°10.8' W). The samples investigated total 231, beginning with Core 397-33, which is early Pliocene in age and postdates the

FAD<sup>1</sup> of *Globorotalia puncticulata* (M P1 2/M P1 3 zonal boundary of Cita, 1975b), to Core 397-97, which is early Miocene in age (Zone N.7 of Blow, 1969). Cores 98 to 102 at Hole 397 had little or no recovery. The early Miocene succession penetrated at Hole 397A, extending for some 313 meters below the level corre-

<sup>1</sup> FAD = First appearance datum.

lated with Core 397-102, is not discussed here in detail, but is considered in the part of this contribution devoted to correlations.

Though the purpose of the present paper is primarily to elucidate the Miocene biostratigraphy of planktonic foraminifers, we extend our observations several dozens of meters into the Pliocene, in order to establish precise biostratigraphic reference points for the correlation of the Miocene/Pliocene boundary, and to correlate accurately the latest Miocene (Messinian) stage. This time interval is characterized in the Mediterranean by a basin-wide "salinity crisis" (Ruggieri, 1967; Ryan, et al., 1974; Cita, 1972). We were curious to study a correlative biostratigraphic interval of the Messinian in an eastern North Atlantic setting at about the same latitude as the Mediterranean, and to utilize new observational data to check the duration of the salinity crisis as previously put forward by Ryan et al. (1974).

#### FACTORS WHICH DISTURB THE BIOSTRATIGRAPHIC SUCCESSION

Several factors, mainly sedimentary processes and the evolution of water masses in the eastern North Atlantic, affect the distribution of planktonic foraminiferal assemblages. They result in "noise" superimposed over the normal evolution of foraminiferal assemblages, as a function of time (biostratigraphic signal). Disturbing factors include (a) slumping, (b) reworking from older formations, (c) downslope displacement, (d) dissolution at depth, (e) preservation, and (f) submarine erosion.

The most effective of these factors in this section are (a) and (f). Slumping is recorded, especially in the interval from Sections 397-57-3 to 397-61-5; lower in the section (as far as Core 397-72), slumps are occasionally recorded. Biostratigraphic evidence of submarine erosion was found between Cores 397-70 and 71. Core 71 yields foraminiferal faunas of Zone N.14 age (based on the recorded co-occurrence of *Globigerina nepenthes* and of *Globorotalia siakensis*). Core 70 yields *Globorotalia acostaensis*, the zonal marker of Zone 16. There is no evidence of Zone N.15 which, therefore, signifies a hiatus.

Another hiatus can be inferred between Cores 397-77 and 78. At the top of Core 78, several taxa disappear simultaneously, including *Praeorbulina* spp., *Globigerinoides sicanus*, *Globorotalia praescitula*, *G. praemenardii arachaeomenardii*, and *Cassigerinella chipolensis*, whereas several species first occur in the lower part of Core 77: *Orbulina universa*, *Globorotalia peripheroacuta*, *G. praemenardii praemenardii*, and *Globigerinopsis aguasayensis*. The reader is referred to the Site Chapter (this volume) for details on the other disturbing factors.

#### COMMENTS ON SOME LINEAGES OF PLANKTONIC FORAMINIFERS

Several evolutionary lineages of planktonic foraminifers are known from the interval under discussion. Some could be followed step-by-step in the succession

penetrated at Site 397. In the lower part of the section, where the majority of the sediments are allochthonous, we looked for intervals most likely to yield undisturbed fossil assemblages for dating purposes.

Figures 1 through 5 show SEM photographs illustrating relationships between various steps of five discrete evolutionary lineages, and the ranges recorded in the cores investigated. A few comments follow.

*Praeorbulina-Orbulina* lineage (Figure 1). This well-known lineage, which originates from *Globigerinoides sicanus*, has been thoroughly documented by Blow (1956). Sparse, small-sized specimens are recorded down to the core catcher of Core 397-97. We consider these lowermost occurrences dubious (*G. cf. sicanus* of the range chart), and prefer to locate the FAD *G. sicanus* in Sample 397-8, CC, where the first really typical and fully developed specimens appear. The FAD of *G. sicanus* is used by Blow (1969) to identify the Zone N.7/N.8 boundary, however other authors, including Brönimann and Resig (1971) and Stainforth et al. (1975), record the taxon as low in Zones N.6 and N.7, respectively.

The second step of the lineage is represented by the FAD of *Praeorbulina*, which occurs in the lower part of Zone N.8 and characterizes the base of the Langhian stage of the middle Miocene. In agreement with other data available in the current literature, the first two species of this genus are *P. transitoria* and *P. glomerosa curva*. Their joint occurrence in Core 397-89 might be artificial, since this core had a poor recovery. *P. glomerosa glomerosa* is first recorded in Sample 397-84, CC, and *P. glomerosa circularis* in Section 397-79-2. The first evolutionary appearances of these two subspecies occur with Zone N.8 and within the Langhian stage/age.

The third step is represented by the FAD of *Orbulina suturalis*, evolving from *P. glomerosa circularis*, which event marks the N.8/N.9 boundary. This FAD is recorded in Section 397-78-2, along with the FAD of *O. bilobata* (evolving from *P. transitoria*).

The fourth and final step is represented by the FAD of *Orbulina universa*, which occurs slightly above the FAD of *O. suturalis*. Although this biostratigraphic event is recorded at the base of Core 397-77, it cannot be considered as a first evolutionary appearance because it follows a biostratigraphic gap corresponding to most of Zone N.9 and to Zone N.10, or part of it.

*Globorotalia peripheroronda-G. fohsi* lineage (Figure 2). This lineage, which is well known (Bolli, 1950, 1957; Blow and Banner, 1966; Olsson, 1972), represents a basic tool in biostratigraphy and correlation of middle Miocene successions from tropical areas. Any discrepancies essentially involve the taxonomical nomenclature applied to the consecutive steps of this evolutionary sequence (see Jenkins, 1966; Bolli, 1967; Cifelli, 1968; Blow, 1969; Beckmann et al., 1969; Olsson, 1972; Stainforth et al., 1975). In the present paper, we follow Blow and Banner (1966).

The first step of the lineage is represented by *G. peripheroronda*, which is recorded from the lowermost sample investigated. Indeed, we recorded this taxon as

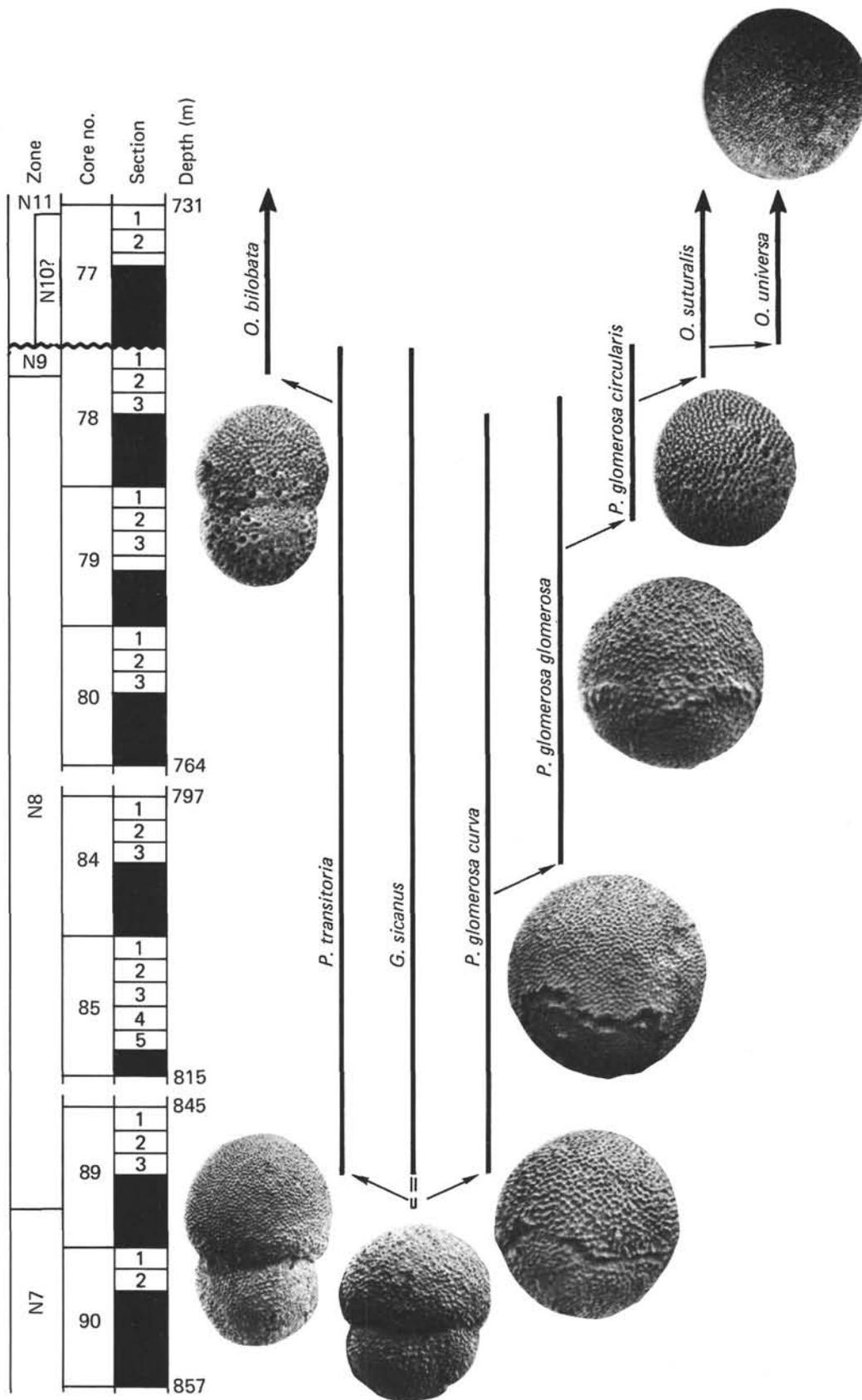


Figure 1. Praeorbulina-Orbulina lineage as recorded at DSDP Site 397.

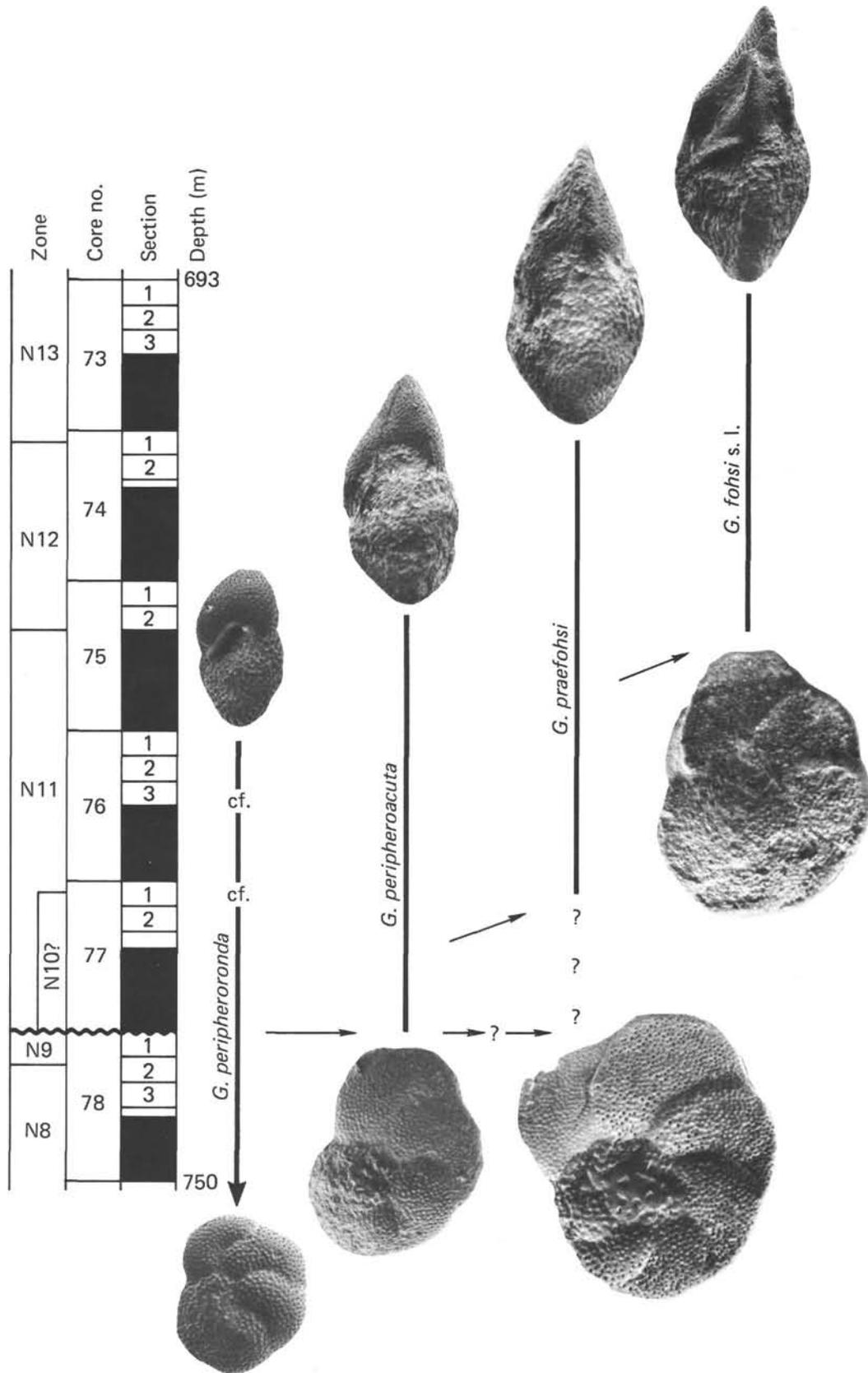


Figure 2. *Globorotalia peripheroronda*-*G. foehsi s.l.* lineage as recorded at DSDP Site 397.

low as Core 397A-12, which means approximately 100 meters lower in the stratigraphic column. In Section 397-78-1, within the population of *G. peripheroronda*, specimens were found which display more compressed (though not yet acute) chambers in their peripheral part; this is an evolutionary trend towards *G. peripheroacuta*, the second step of the lineage. The latter taxon occurs starting from Sample 397-77, CC in its typical form. A minor hiatus between the two samples interrupts the trend.

The third clear step we can recognize is represented by *G. praefohsi*, first recorded in Section 397-77-1. In the interval immediately underlying this section, this group of forms is extremely rare; also, the poor preservation prevents detailed observations. Consequently, we cannot exclude that the FAD of *praefohsi* could actually occur earlier (see Biochronology). Starting from Core 397-77 upwards, *G. peripheroronda* decreases in abundance and progressively loses its diagnostic characteristics (*G. cf. peripheroronda* of the range chart), disappearing at the top of Core 397-76.

The fourth step is represented by *G. fohsi* s. str., whose FAD is in Sample 397-75, CC. After an interval devoid of *Globorotalias* referable to this plexus, which encompasses part of Cores 397-74 and 75, *G. fohsi* s. str. reappears, along with *G. fohsi* forma *lobata* (from Section 397-74-1) and *G. fohsi* forma *robusta* (from Section 397-73-2). The (minor) discrepancies recorded in the relative distribution of these taxa in the Cape Bojador succession and in Blow's generalized zonal scheme might be accounted for partly by the interval being one of sediments unfavorable to planktonic foraminifers and partly by incomplete core recovery.

*Globorotalia fohsi* s.l. becomes extinct after Core 397-73-1. Higher occurrences of one or other taxon of this lineage are accounted for either by reworking, or by slumping.

*Globorotalia praescitula*-*G. cultrata* s.l. lineage (Figure 3). The first step of the lineage *G. praescitula* is recorded through Cores 397-78 to 97.

The FAD of the second step, represented by *G. praemenardii archaeomenardii* occurs in Sample 397-81, CC, which we referred to Zone N. 8. According to our observations on the specimens from Site 397, the evolution of fully keeled, younger forms from non-keeled, older forms occurs exactly as described by Blow (1959, 1969). In Core 397-84 we observed specimens ex interc "praescitula"-*archeomenardii*" (*G. cf. praemenardii* of the range chart) with a faint peripheral keel in the last or occasionally in the penultimate chamber; they have a larger, more compressed test than *G. praescitula*.

The evolution leading from *G. praemenardii archaeomenardii* to *G. praemenardii praemenardii* (the third step) cannot be followed because of the already-mentioned hiatus below Core 397-77. According to Blow (1969), the evolutionary passage should occur in the latest part of Zone N.9, whereas *G. praemenardii* s.s. first occurs in Core 397-77, which we refer to Zone N.11 (or latest part of N.10).

The fourth step of this lineage is represented by *G. cultrata* s.l. (including *G. cultrata cultrata*, *G. cultrata menardii*, and *G. cultrata limbara*). This taxon is recorded with typical specimens starting from Core 397-73 upwards.

The evolution from *G. praemenardii praemenardii* to *G. cultrata* s.l. involves the following trends: increase in the size of the test and the umbilicus; the peripheral keel becomes stronger, and both the intercameral and the spiral sutures become limbated; the chambers of the last-formed whorl increase in number; and tests tend to become flatter and to display a subcircular, instead than a somewhat elongated, equatorial periphery. Reference is made to Cita et al. (1978) where the taxonomy of the transitional forms was discussed and documented by SEM micrographs, while describing the Miocene succession at DSDP Site 372 in the western Mediterranean. In the present paper, *G. ex cultrata* group of Cita et al. (that is to say with a sutural limbation extended to the whorls preceding the last one, but with a general morphology still resembling *praemenardii*; see Plate 13, Figures 15-21) has been included in the concept of *G. praemenardii praemenardii*. As a consequence, the latter taxon has a wider stratigraphic distribution than indicated by Blow (1969); indeed, it is recorded at Site 397 as high as in Zone N.14.

The later steps of the *G. menardii* lineage, with the development of *G. miocenica*, *G. exilis*, and related taxa, are recorded in the Pliocene succession of Site 397 but are not discussed here.

*Globigerina druryi*-*G. nepenthes* lineage. Both taxa are here considered in a broad sense: *G. druryi* (see Plate 1, Figures 9, 13, and 14) includes *G. pseudo-druryi* and *G. nepenthoides*, both described by Brönnimann and Resig (1971). *G. nepenthes* (Plate 1, Figure 19; Plate 2, Figures 1 and 2) includes *G. picasiana* Perconig and *G. nepenthes delicatula* Brönnimann and Resig. The creation of all these taxa seems to us weakly justified, taking into account the remarkable variability of the plexus. The ancestral species *G. druryi*, as here intended, is recorded from the base of the section investigated (Zone N.7). This range is stratigraphically lower than that recorded by Blow (1969), but is consistent with the findings from the equatorial Pacific reported from DSDP Leg 7 (Brönnimann and Resig, 1971), with reference to *G. pseudodruryi* and *G. nepenthoides*, which we lump together with *G. druryi*.

The development of *G. nepenthes* is quite gradual: transitional forms are recorded through a long range encompassing Zone N.11 to N.13 (see also Cita et al., 1978). The FAD of *G. nepenthes* is used to identify the N.13/N.14 zonal boundary and is calibrated to the paleomagnetic stratigraphy (Ryan et al., 1974); we, therefore, paid special attention to locate it precisely. As recorded in Section 397-72-2, it corresponds to the first common occurrence of typical, well-developed specimens.

*Globorotalia continuosa*-*G. humerosa humerosa* lineage (Figure 4). *Globorotalia continuosa*, which represents the first step of this evolutionary sequence, is re-

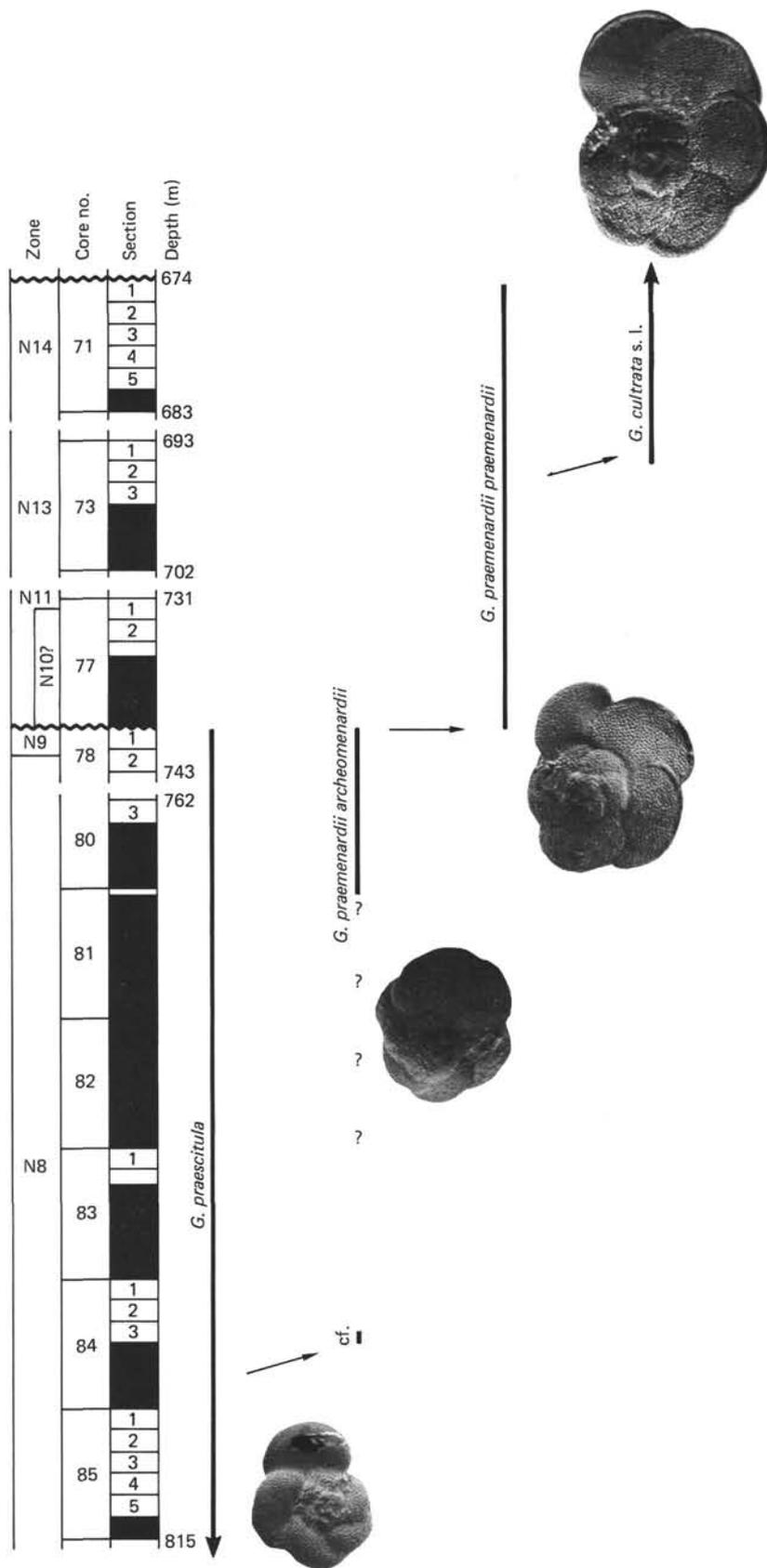


Figure 3. *Globorotalia praescitula*-*G. cultrata s.l.* lineage as recorded at DSDP Site 397.

corded in its typical form only from Section 397-76-3 (Zone N.11). This long-ranging species co-occurs with *G. acostaensis* from Cores 397-57 to 70 (Zone N.16). At Site 397, however, it is impossible to locate the LAD<sup>2</sup> of *G. continuosa*, because of the slumpings and reworking recorded from Section 397-57-3 to Core 397-61.

The FAD of *G. acostaensis*, the second step of this lineage and zonal boundary N.15/N.16, is recorded in Core 397-70 after a hiatus comprising Zone N.15 and probably part of Zone N.14. As a consequence, we have no record of the transition from *G. continuosa* to *G. acostaensis*. According to the most qualified literature, the third step in the evolution is represented by *G. humerosa* s.l., however, discrepancies exist between the various authors in pinpointing the first evolutionary appearance of this taxon (compare, for instance, the ranges and/or comments given by Blow, 1969; Bizon and Bizon, 1972; Bolli, 1970; Cita and Blow, 1969; Parker, 1967, 1973; Brönnimann and Resig, 1971; Catalano and Sprovieri, 1971; Ryan et al., 1974; Saito et al., 1975; d'Onofrio et al., 1975; Natori, 1976; Srinivasan and Kennett, 1976; etc). According to our observations on the faunal assemblages recorded at DSDP Site 397, the transition from *G. acostaensis* to *G. humerosa* s.l. is quite gradational. The morphological changes include (a) increasing number of chambers in the final whorl, from five in *acostaensis* to six or more in *humerosa* s.l.; (b) increasing size of the umbilical cavity small in *acostaensis* and large in *humerosa*; and (c) general size of the test much larger in *humerosa* s.l. (see Figure 4). We have recorded typical populations of *G. humerosa humerosa*, starting from Core 397-40, which is early Pliocene in age. However, starting from Section 397-63-1 (Zone N.16), or from levels predating the FAD of *Globigerinoides obliquus extremus*, we recorded rare specimens with five or six chambers in the last-formed whorl and with a fairly wide umbilical area; these forms display intermediate morphological features between *G. acostaensis* and *G. humerosa* s. s. We referred these forms to *G. humerosa praehumerosa*, following Natori (1976). The diagnosis of this species corresponds to that of the forms previously identified by the present authors as *G. humerosa* from the upper Miocene.

*Globorotalia margaritae* lineage. The evolution of *G. margaritae* (Plate 10, Figures 20 and 21) from a non-keeled form strictly related to *G. scitula* can be followed step-by-step within the upper Miocene from Cores 397-44 to 50, the FAD of *G. margaritae* being located in Section 397-45-1. At this level, we find forms typical in all regards, i.e., with reference to external morphology, wall structure, and dimensions in comparison with topotypes kindly made available by H. M. Bolli and P.

Bermudez. In the interval encompassing Cores 397-44 to 50, we recorded a complex stock of *Globorotalias* including several morphotypes rapidly evolving towards the typical *G. margaritae*. In this evolution, the carinal structure is acquired paligenetically, repeatedly, and heterochronously. Within the rich populations of *G. margaritae* s.l., we recognized an evolutionary trend in agreement with that described by Cita (1972) in the Mediterranean deep-sea record, also recognized by Bolli and Premoli Silva (1973) in the Caribbean (DSDP Leg 15). The three subspecies *G. margaritae margaritae*, *G. margaritae primitiva*, and *G. margaritae evoluta* have been identified at Site 397; however, in the range chart, we did not plot them separately. References to the *G. margaritae* lineage are found in numerous papers (including Blow, 1969; Berggren and Amdurer, 1973; Berggren and Haq, 1976; Stainforth et al., 1975; Parker, 1967, 1973; Cita, 1972, 1975b; Zocchi, 1974; Colalongo and Sartoni, 1967; Wernli, 1977; Catalano and Sprovieri, 1971; and Bossio et al., 1976), but we consider the problem still open, and plan to study it in the near future.

*Sphaeroidinellopsis* lineage (Figure 5). The genus *Sphaeroidinellopsis* is ubiquitous in the Cape Bojador section, ranging from Cores 397-33 to 97. This circumstance allowed us to follow its evolutionary trends through most of the Miocene and the early Pliocene. The evolution of this plexus has been investigated by Blow (1969), who delineated a lineage starting from *S. seminulina seminulina* (Zone N.6 to N.21) and leading to *S. subdehiscens paenedehiscens* (N.17 to N.20), via *S. subdehiscens subdehiscens* (N.13-N.19?). The distinctive criteria, the terminology, and the distribution of individual taxa was given by Blow (1956) only partially agree with our observations on the Site 397 populations. According to us, the importance of the number of chambers in the last-formed whorl has been overemphasized as a taxonomic character in the past: much more meaningful features which display distinctive evolutionary trends are (a) structure of the cortex and (b) characters of the umbilical margin. In every step of the lineage, forms with three or four or more chambers are consistently associated. Transitional forms are present throughout, which cannot be distinguished on the basis of features unrelated to the architecture deriving from the number of chambers, i. e., general shape of the test, peripheral lobation, and width of the umbilicus. We consider the forms with more than three chambers in the last-formed whorl of marginal value since the terminal chamber is often aberrant. According to these criteria, the evolution of the group is delineated as follows.

The first step is represented by *S. disjuncta* which is recorded from Core 397-97 upwards. This form displays a very coarse external cortex (neither smooth nor hyaline), a globular test, and subspherical chambers separated by deeply incised sutures. The umbilicus in the three-chambered specimens is narrow, the "aperture" consists of a low slit and is umbilical-extraumbil-

<sup>2</sup> LAD = Last appearance datum.

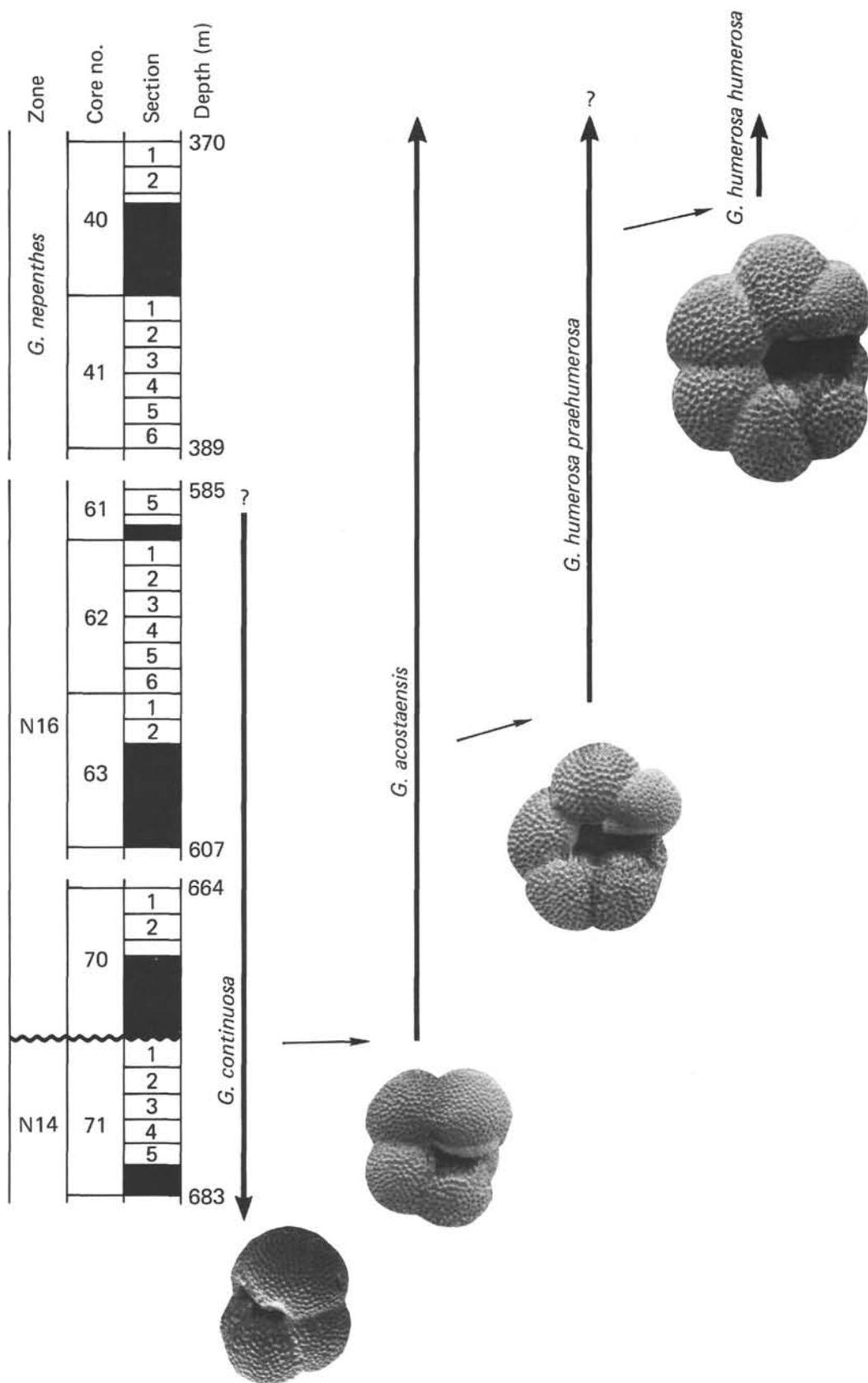


Figure 4. *Globorotalia continua*-*G. humerosa humerosa* lineage as recorded at DSDP Site 397.

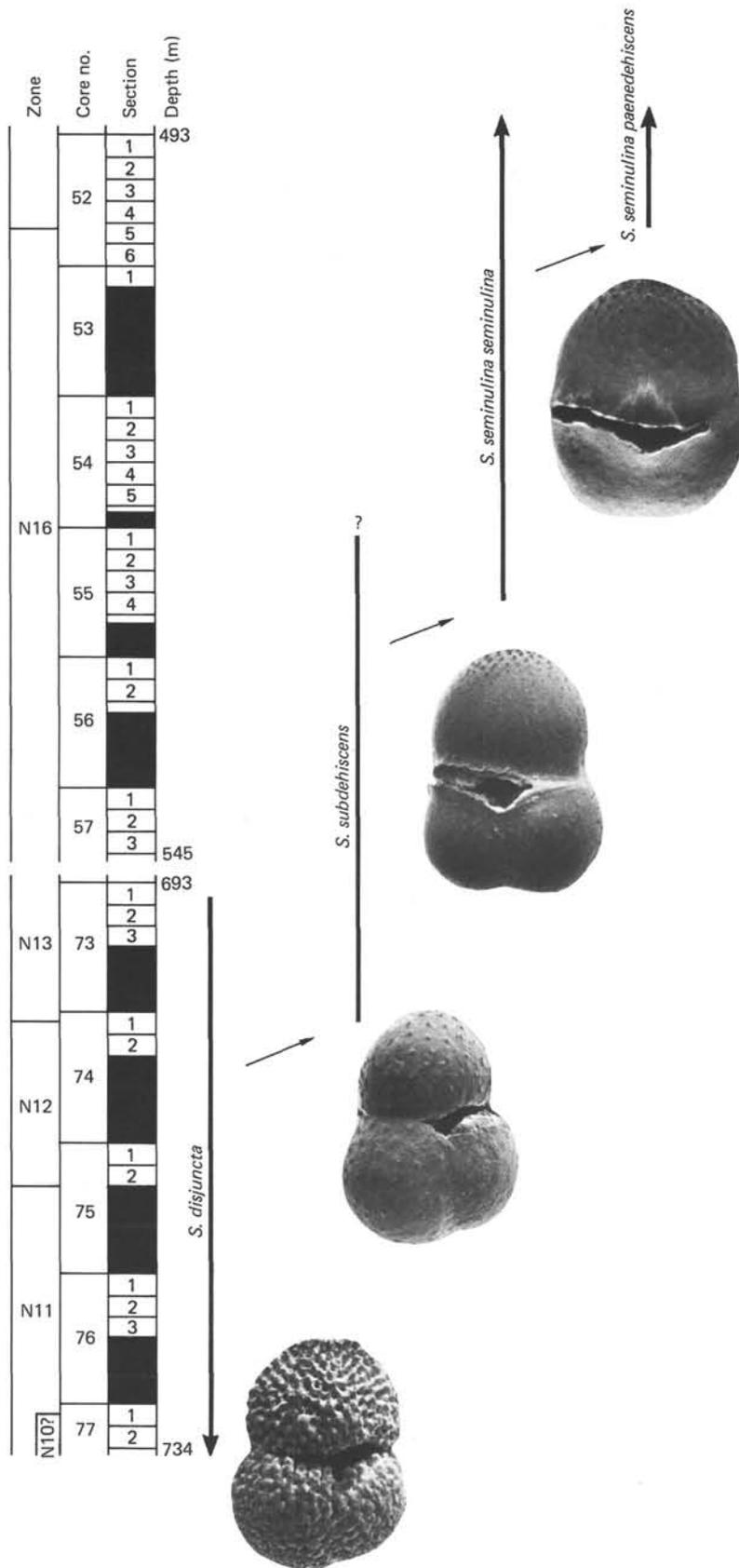


Figure 5. *Sphaeroidinellopsis* lineage as recorded at DSDP Site 397.

ical in position, and the umbilical margins of the chambers are devoid of lips or flanges. The umbilicus in the four-chambered specimens is wider, the "aperture" less extended laterally and often entirely umbilical in position, with a higher arc; the last-formed chamber is often aberrant, smaller than the preceding one, slightly more compressed, and occasionally sacculiform; its ventral margin may develop a thickened and fimbriate edge. We identify this first step with *S. disjuncta*, originally described from the lower Miocene of New Zealand (Finlay, 1940; see also Hornibrook, 1958; and Jenkins, 1971). Though the holotype is a four-chambered specimen, the author originally also included three-chambered forms in the taxon under discussion. Several authors, including Brönnimann and Resig and Banner and Blow (1969) consider Finlay's species as a younger synonym of *S. seminulina seminulina*. With reference to Jenkins (1971), we do not accept this synonymy: the main differences between the two taxa concern external morphology, apertural characters, and wall structure. The assumption that the coarse-wall structure is related to decortication of the test is discarded because (a) the character is persistent, also in levels where there is no evidence of dissolution at depth, and (b) a gradual evolution of the biocharacter is observed leading to the second step of the lineage (see below). We consider it likely that "*Globigerina*" *grimsdalei* Keijzer from the Oligocene-Miocene of Cuba is a younger synonym of Finlay's species; the wall structure, the apertural characters, as well as the general morphology are identical to those observed in some variants of *S. disjuncta*. The range of *S. disjuncta* is from Cores 397-73 (N.13) to 97 (Zone N.7), predating the LAD of *G. foehsi* s.l. This range agrees well with that recorded in the type area of the taxon (New Zealand; see Jenkins, 1971).

The second step of the lineage is represented by *S. subdehiscens*. In Cores 397-73 to 78, we record a gradual trend: the first two chambers of the final whorl tend to become smoother. Starting from Core 397-76, the last chamber also becomes partially smooth. In this interval, the tests are less globular, slightly compressed laterally, the chambers are less spherical, and the sutures only slightly depressed. The ventral edges of the chambers gradually tend to be rimmed by a narrow, smooth, flat area. This holds true for both the three-chambered specimens and the four-chambered ones. Starting from Section 397-74-1, the test becomes entirely smooth and has a glassy and polished appearance. Due to the importance that we attribute to the external cortex with respect to other biocharacters, we thus locate the second step in Section 397-74-1. The morphological features (discussed above) correspond to the definition of *S. dehiscens subdehiscens* Blow (1959), originally described from the middle Miocene *Globorotalia mayeri* Zone, *G. mayeri*-*G. linguaensis* Subzone of the Pozon Formation, Venezuela, later referred by Blow (1969) to Zone N.13. *S. dehiscens subdehiscens* was considered by Blow (1969) as zonal marker of Zone N.13. With reference to the relative

range of other species, including the *Globorotalia foehsi* and *G. cultrata* groups, we consider that the taxon under discussion very likely can be considered diagnostic of Zone N.13 also according to our own interpretation. The range of *S. subdehiscens* is from Core 397-55 (Zone N.17) to Section 397-74-1 (Zone N.13), in good agreement with the range given by Blow (1969).<sup>3</sup>

The third step of the lineage is represented by *S. seminulina seminulina*. From the FAD of *S. subdehiscens* to the top of the interval under discussion, we did not record any appreciable change in the structure of the cortex, which is persistently glassy and "polished." However, the following successive modifications of the free umbilical margins could be observed with the range *S. subdehiscens*: (a) in both the three-chambered and four-chambered specimens, the terminations of the chambers towards the umbilicus become increasingly developed and fringed, whereas the proximal edge of the last-formed chamber is like in *S. subdehiscens*; (b) the edge of the terminal chamber becomes more extended, and the fringed margins of the chambers preceding the last one tend to be projected outwards; (c) in both the three-chambered and four-chambered forms, the proximal edge of the last chamber displays a tendency to become projected outwards and crenulated (see Figure 5). The third characteristic (c) is shown clearly starting from Section 397-55-4; consequently, we locate here the third step of the lineage, which we identify with *S. seminulina seminulina*.<sup>4</sup> The range of the taxon extends beyond the stratigraphic interval considered in the present study.

The fourth step is represented by *S. seminulina paenedehiscens*. *S. seminulina seminulina* initially retains the general morphological features proper of *S. subdehiscens* (test and chambers slightly compressed, equatorial periphery faintly lobulated, intercameral sutures slightly depressed). However, soon afterwards two groups of specimens become distinguishable. One maintains the characters of *S. seminulina seminulina* to the top of the interval considered, the only difference consisting of a more accentuated extension of the proximal edges of the chambers of the last whorl. A second

<sup>3</sup> We consider it highly likely that Blow's species is a younger synonym of "*Sphaeroidinella*" *rutschi* Cushman and Renz, inasmuch as the four-chambered paratype figured by Renz (1948, pl. 10, fig. 1c) is put by Blow (1969) in the synonymy of *S. subdehiscens*. Both the holotype and paratype of *S. rutschi* are from a level of the Pozon formation referred by Renz (1948) to the *Marginulinopsis basispinosus* Zone, and subsequently referred by Blow (1959, 1969) to the interval encompassing Zones N.14 to N.16. Though *S. rutschi* has priority, we keep the name *subdehiscens* because (a) the latter taxon has been widely used in the last decade, and (b) unlike the former, it has been described and figured with accuracy.

<sup>4</sup> This taxon has been neotypified by Banner and Blow (1960). Unfortunately, these authors selected from the metatypic collection a specimen with four chambers in the last-formed whorl, which is not diagnostic according to our observations. However, both the neotype and the holotype (which is three-chambered) correspond to the features which we consider characteristic of our third evolutionary step. The holotype is from the Neogene of Kar Nikobar. The neotype, which is from the same locality, is late Miocene (?) in age according to Banner and Blow (1960).

group, along with a further development of umbilical flanges, displays a tendency of the test to become sub-globular, less lobulated, and with less depressed sutures. Starting from Section 397-52-5 upwards, the morphological differences between the two groups are clearly evident: specimens referable to the second group (here identified as *S. seminulina paenedehiscens*) display ovated, inflated test, strongly globular chambers, superficial and indistinct intercameral sutures. Only specimens with more than three chambers in the last whorl have slightly lobulated equatorial periphery, and depressed sutures in the terminal part.<sup>5</sup>

The holotype of *S. seminulina paenedehiscens* Blow is from Zone N.19 (Bowden Formation, Jamaica). *S. sphaeroides* Lamb is a junior synonym of the former, as pointed out also by Stainforth et al. (1975). *S. seminulina paenedehiscens* ranges from Sections 397-33-1 (Zone N.19) to 397-52-5 (Zone N.17). During this range, an increase in the size of the test is recorded. In large-sized specimens, the free umbilical margins of the first and last chamber of the terminal whorl extend laterally so that they reach the dorsal peripheral shoulder.

An important step in this lineage consists in the acquisition of a supplementary aperture, which coincides with the FAD of the genus *Sphaeroidinella* (Zone N.18/N.19 boundary), a biostratigraphic criterion used to identify the Miocene/Pliocene boundary (see Blow, 1969; Cita and Blow, 1969; Cita, 1975a).

The first local occurrence of *Sphaeroidinella dehis-cens forma immatura*, as recorded in Sample 397-35, CC, does not coincide with the FAD of *Sphaeroidinella*; it occurs close to the FAD of *Globorotalia puncticulata*, well within Zone N.19. Representatives of the *Sphaeroidinellopsis* lineage are sporadically represented in the Cape Bojador drill site through Cores 397-35 to 45, so that we could not use this criterion to identify the Miocene/Pliocene boundary (see Chronostratigraphy).

## BIOCHRONOLOGY

The zonal subdivision adopted here follows Blow's zonal scheme, which is generally accepted as a standard zonation for the Neogene, and is usually followed in DSDP volumes. The greatest difficulties in applying this zonation have been encountered in the upper Miocene and in the lower Pliocene, with special reference to the recognition of the N.16/N.17, N.17/N.18, and N.18/N.19 zonal boundaries. The first two boundaries are defined on the basis of *Globorotalia tumida* evolutionary lineage, which is incompletely developed at Site 397. Moreover, Zones N.16 and N.17 are both long duration zones (see Ryan et al., 1974) and the criterion on which their distinction is established is sub-

ject to a certain degree of uncertainty, resulting from (a) the very gradational transition from *G. merotumida* to *G. tumida plesiotumida*, as already pointed out by several authors; and (b) the difficulty in discriminating the taxa under discussion from other keeled *Globorotalias*. On the other hand, we could not apply the detailed zonation recently proposed for the late Miocene of the Mediterranean by d'Onofrio et al. (1975), due to the recorded absence of the zonal markers.

The N.18/N.19 zonal boundary could not be pinpointed due to the delayed entrance of *Sphaeroidinella dehis-cens forma immatura* at Site 397, as already mentioned.

As a result of (1) the difficulties in applying Blow's zonation to the succession of Cape Bojador, and (2) the inherent weakness of this zonation for the interval encompassing the upper Miocene and lower Pliocene, we are here introducing two new biozones as substitutes of Zones N.17, N.18, and part of N.19 of the standard zonation. The new biozones are here defined. They link Blow's zonation, which is excellent and can be easily applied for the rest of the Miocene with Cita's zonation (1972, emended 1975b) which also can be applied for the Pliocene outside the Mediterranean, the area for which Cita's zones were established.

Zone N.16: *Globorotalia (Turborotalia) acostaensis acostaensis* G. (*G.*) *merotumida*. Partial-Range Zone of Blow (1969), here emended. Interval from the first evolutionary appearance of *G. acostaensis* to the FAD of *Sphaeroidinellopsis seminulina paenedehiscens*.

*Sphaeroidinellopsis seminulina paenedehiscens* Partial-Range Zone, here proposed. Interval with the zonal marker from the FAD of the nominal taxon to the FAD of *Globorotalia margaritae* s. s.

*Globigerina nepenthes* Interval-Zone, here proposed. Interval with the nominal taxon from the FAD of *Globorotalia margaritae* s. s. to the FAD of *G. puncticulata*.

The biozones are briefly discussed here from bottom to top, with comments on the peculiarities, anomalies, and deficiencies they present in the section investigated. Reference is made to the general range chart (Figure 6) for a documentation of the taxa recorded in the over 230 samples investigated, and to Plates 1 to 14 for illustration of the stratigraphically most interesting, or most common, or rare but meaningful taxa. No taxonomical notes are included here, besides those already discussed and limited to a single evolutionary lineage.

Zone N.7: *Globigerinatella insueta-Globigerinoides quadrilobatus trilobus*. From Samples 397-97-1, CC to 397-90-2, 90-93 cm (922.3 to 856.9 m sub-bottom).

The lower boundary of this biozone is defined by the LAD of *Globigerinita dissimilis* s.l., which has not been recorded in any of the samples investigated. The upper boundary coincides with the FAD of *Globigerinoides sicanus* (see Plate 6, Figures 8 and 11; Plate 7, Figures 1 through 3). The latter taxon, however, has been recorded from earlier horizons of the early Miocene, starting from Zone N.6 (Brönnimann and Resig,

<sup>5</sup> We considered *seminulina* and *paenedehiscens* at a subspecific level since the characters to which we attribute the greatest taxonomic importance in the *Sphaeroidinellopsis* lineage, i.e., structure of the cortex and apertural characters, are almost identical.

CHRONOSTRATIGRAPHY		LOWER MIOCENE																							
		BURDIGALIAN										LANGHIAN													
BIOSTRATIGRAPHY		ZONE N 7										ZONE N 8													
		LEG 47		CORE		97	96	95	94	93	92	91	90	89	88	87	86	85	84	83					
SITE 397		SECTION		CC	1	5	2	1	3	3	2	1	CC	2	4	2	5	4	4						
		INTERVAL (cm)		40-43	45-48	51-53	15-17	22-24	35-37	125-128	117-119	34-37	CC	CC	26-29	102-108	38-42	15-18	126-128	10-14	CC	4	2	1	
<i>Globigerina angustumiliolata</i>																									
<i>Turborotalita quinqueloba</i> group																									
<i>G. apertura</i>																									
<i>G. bulloides</i>																									
<i>G. calida praecalida</i>																									
<i>G. decoraperta</i>																									
<i>G. digitata praedigitata</i>																									
<i>G. druryi</i>																									
<i>G. eamesi</i>																									
<i>G. falconensis</i>																									
<i>G. foliata</i>																									
<i>G. nepenthes</i>																									
<i>G. aff. ouachitaensis ciproensis</i>																									
<i>G. parbulloides</i>																									
<i>G. praebulloides</i>																									
<i>G. regina</i>																									
<i>G. venezuelana</i>																									
<i>Globigerinoides bollii</i>																									
<i>G. bulloideus</i>																									
<i>G. conglobatus conglobatus</i>																									
<i>G. dimidiatus</i>																									
<i>G. elongatus</i>																									
<i>G. emeisi</i>																									
<i>G. fragilis</i>																									
<i>G. mitra</i>																									
<i>G. obliquus extremus</i>																									
<i>G. obliquus obliquus</i>																									
<i>G. quadrilobatus altiaperturus</i>																									
<i>G. quadrilobatus quadrilobatus</i>																									
<i>G. quadrilobatus saeculifer</i>																									
<i>G. quadrilobatus trilobus</i>																									
<i>G. seigliei</i>																									
<i>G. sicarus</i>																									
<i>G. subquadratus</i>																									
<i>Globigerinita bradyi</i>																									
<i>G. glutinata</i>																									
<i>G. juvenilis</i>																									
<i>Globigerinotula insueta</i>																									
<i>Præorbulina glomerosa circularis</i>																									
<i>P. glomerosa curva</i>																									
<i>P. glomerosa glomerosa</i>																									
<i>P. transitoria</i>																									
<i>Orbulina bilobata</i>																									
<i>O. suturalis</i>																									
<i>O. universa</i>																									
<i>Candeina nitida nitida</i>																									
<i>C. nitida praenitida</i>																									
<i>Sphaeroidinella dehiscens f. immatura</i>																									
<i>Sphaeroidinellopsis diijuncta</i>																									
<i>S. seminulina paenedehiscens</i>																									
<i>S. seminulina seminulina</i>																									
<i>S. subdehiscens</i>																									
<i>Globobulimina altispira altispira</i>																									
<i>G. altispira globulosa</i>																									
<i>G. baromoensis</i>																									
<i>G. dehiscens dehiscens</i>																									
<i>G. langhiana</i>																									
<i>G. larmei larmei</i>																									
<i>Neoglobobulimina dutertrei s. l.</i>																									
<i>Globobulimina acostaensis</i>																									
<i>G. acostoma</i>																									
<i>G. bella</i>																									
<i>G. bermudezi</i>																									
<i>G. birnagae</i>																									
<i>G. clemenciae</i>																									
<i>G. continua</i>																									
<i>G. crassaformis s. l.</i>																									
<i>G. cultrata s. l.</i>																									
<i>G. fonsi s. l.</i>																									
<i>G. humerosa praeumerosa</i>																									
<i>G. humerosa humerosa</i>																									
<i>G. incisa</i>																									
<i>G. languaensis</i>																									
<i>G. margaritae s. l.</i>																									
<i>G. mayeri</i>																									
<i>G. merotumida</i>																									
<i>G. minacea</i>																									
<i>G. miotumida</i>																									
<i>G. miozea miozea</i>																									
<i>G. multicamerata</i>																									
<i>G. obesa</i>																									
<i>G. partimlabiata</i>																									
<i>G. peripheroacuta</i>																									
<i>G. peripheroronda</i>																									
<i>G. praefonsi</i>																									
<i>G. praemenardii archeomenardii</i>																									
<i>G. praemenardii praemenardii</i>																									
<i>G. praescitula</i>																									
<i>G. punctulata</i>																									
<i>G. scitula</i> group																									
<i>G. skakensis</i>																									
<i>G. tumida plesiotumida</i>																									
<i>G. tumida tumida</i>																									
<i>G. aff. unguata</i>																									
<i>G. sp.</i>																									
<i>G. spp.</i>																									
<i>Turborotalita sp.</i>																									
<i>Globobulimina falconariae</i>																									

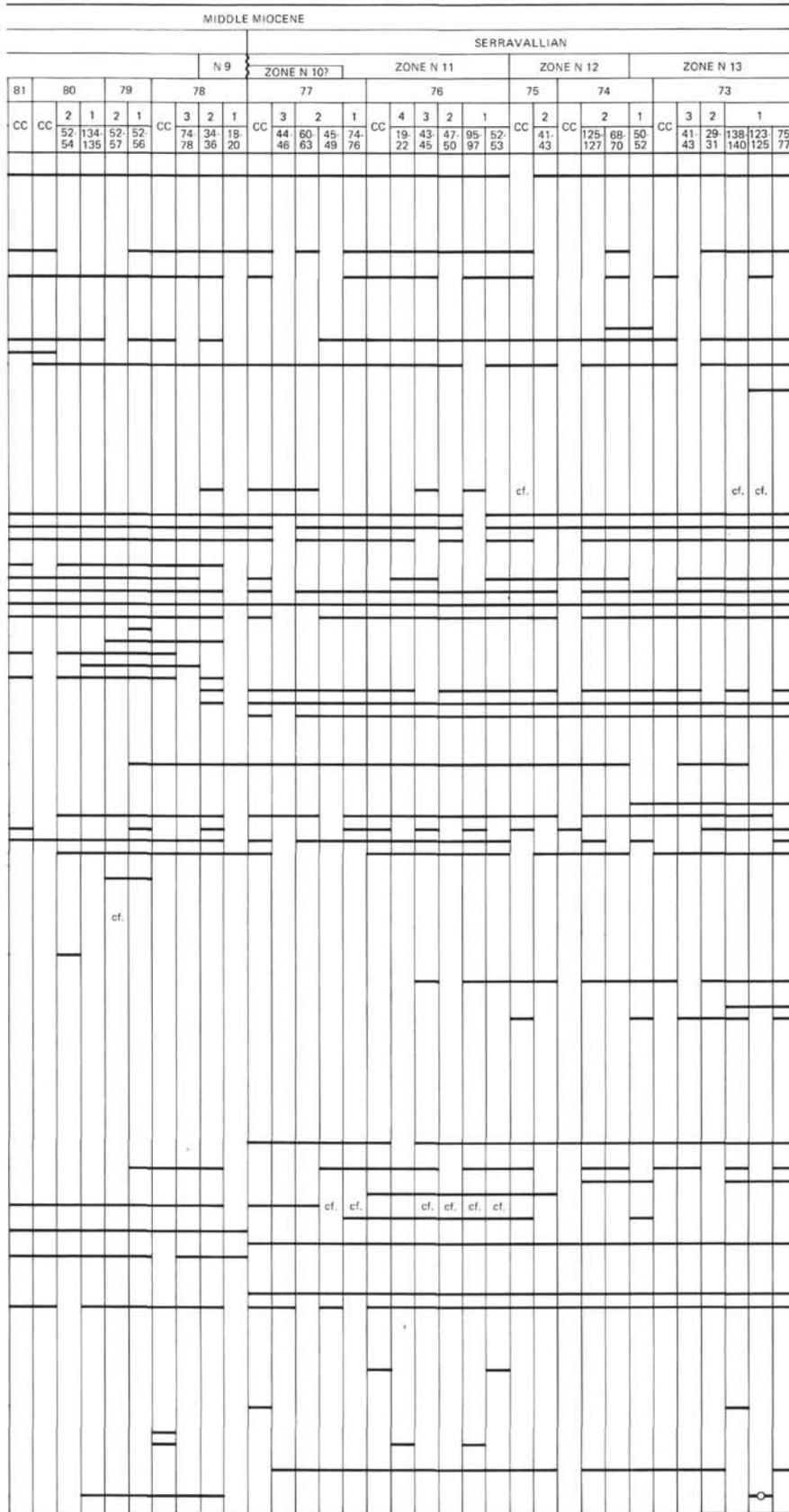


Figure 6. (Continued).

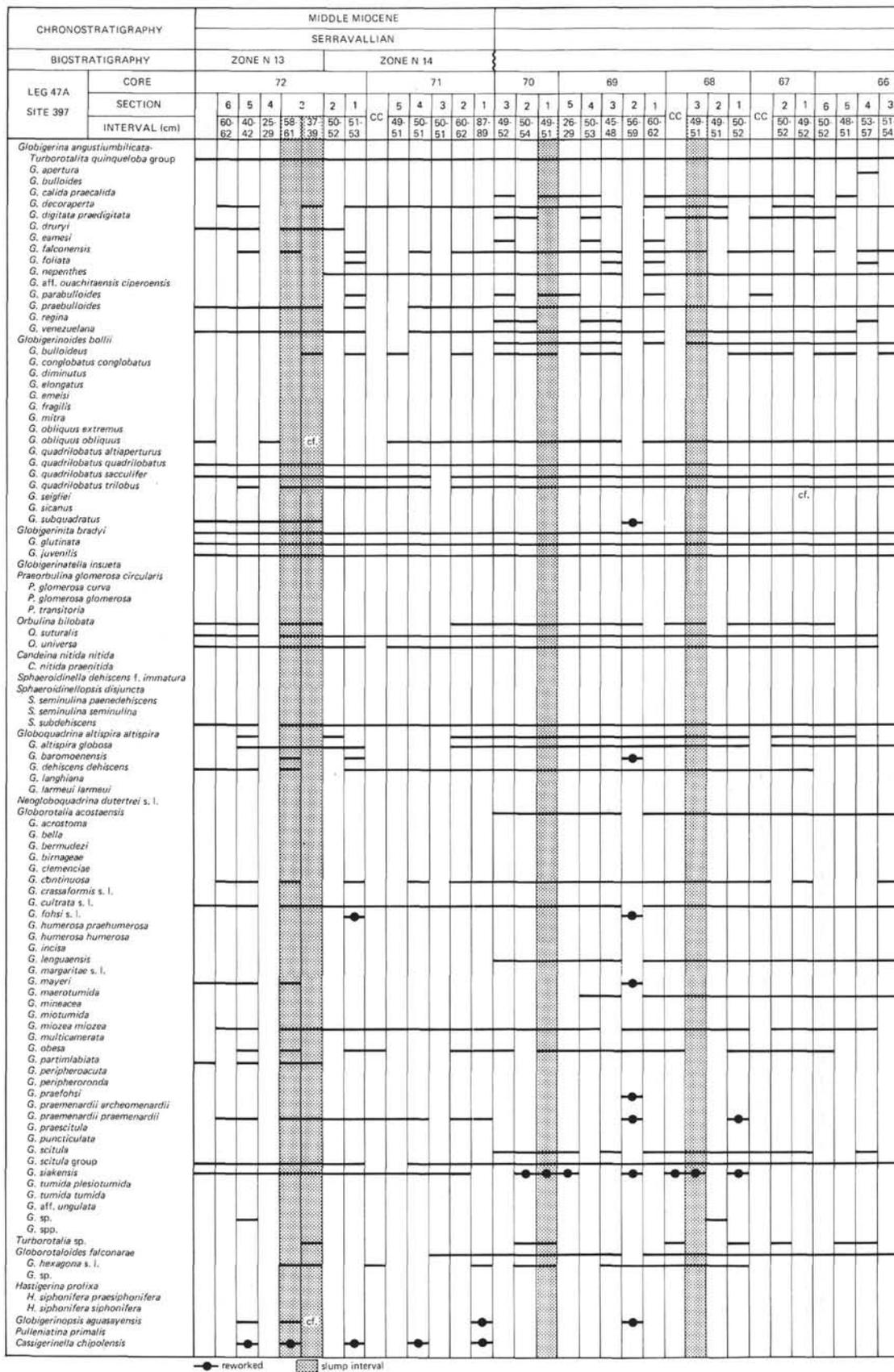


Figure 6. (Continued).

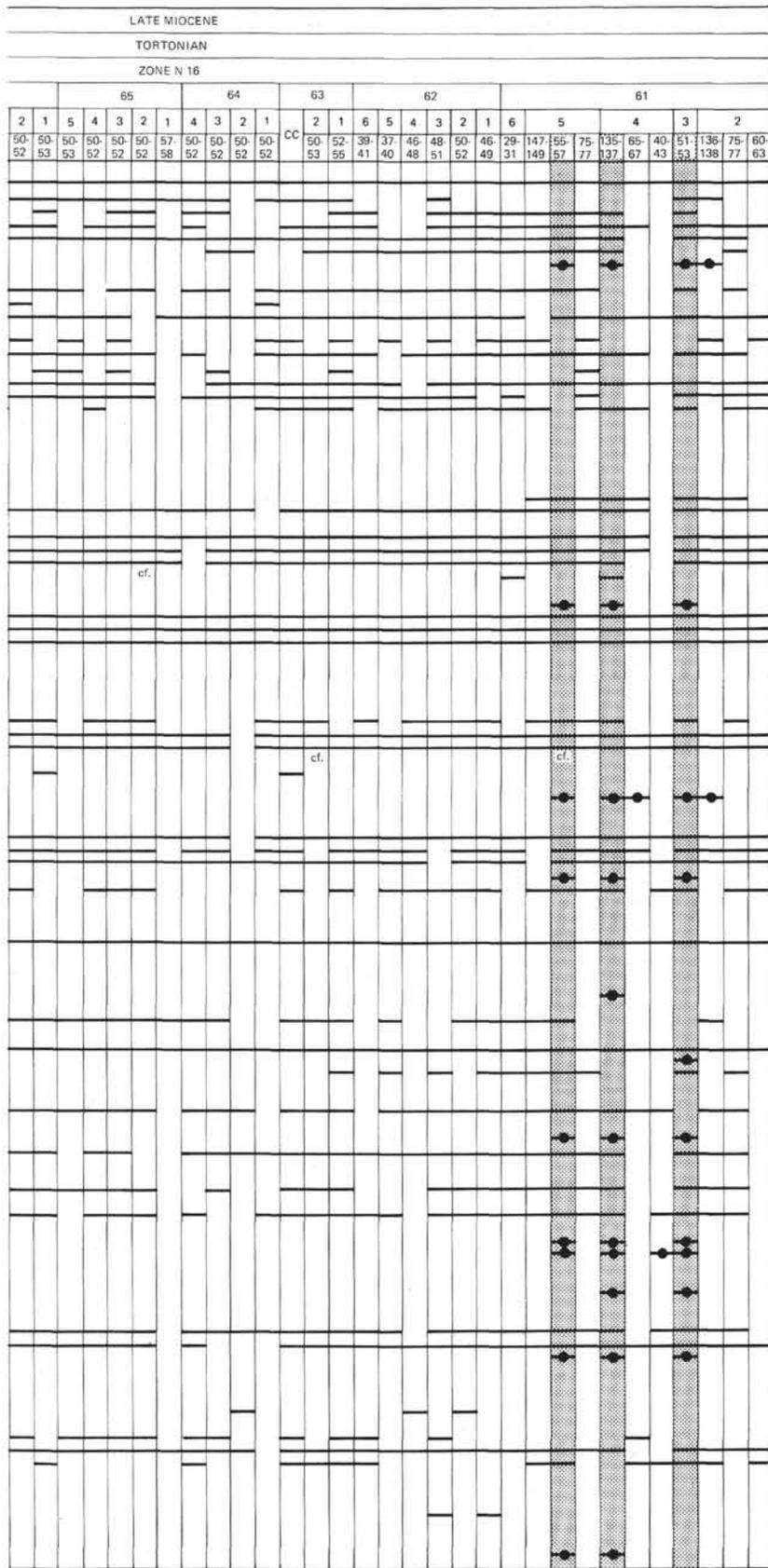


Figure 6. (Continued).

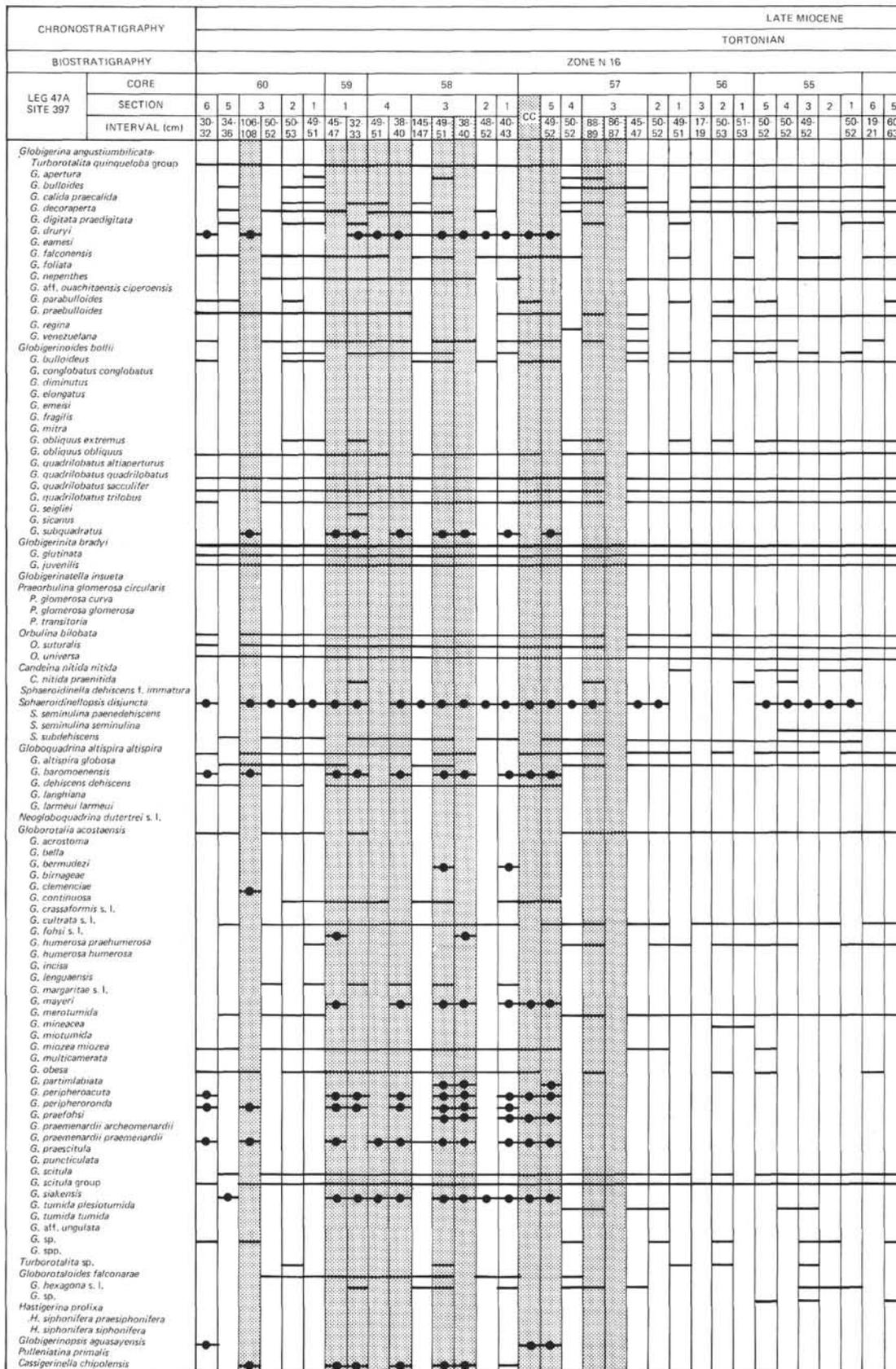


Figure 6. (Continued).

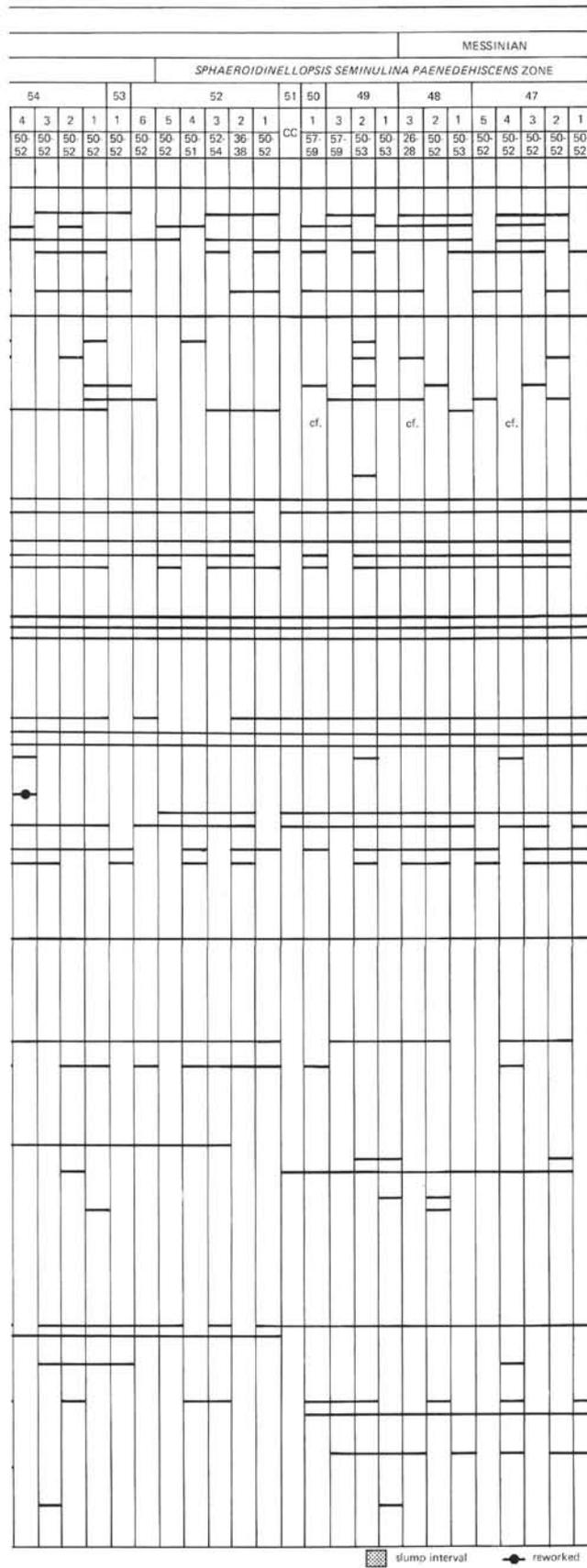


Figure 6. (Continued).





1971), or from levels correlated with Zone N.7 (Stainforth et al., 1975). In the present paper, we locate the N.7/N.8 zonal boundary in coincidence with the FAD of the oldest typical specimens referable to *G. sicanus*, i.e., Sample 397-89-3, CC. Consequently, the underlying interval is referred to N.7. Rare, small specimens of *Globigerinoides* with three chambers in the last whorl, which can be compared with *G. sicanus* (*G. cf. sicanus* of Figure 6), are recorded well below Core 397-89, down to Section 397-A-17-3 which is 230 meters lower (see Site Report, this volume). The recorded occurrence, from Core 397-97 upwards, of *Globorotalia birnageae* (Plate 9, Figures 10, 15, and 16) and of *Globigerinoides diminutus* (Plate 8, Figures 14 and 15), both taxa first occurring in Zone N.7 according to Blow (1969), excludes an attribution to zones older than N.7.

One more item of supporting evidence is provided by the occurrence of *Globigerinoides altiapertura* (Plate 8, Figures 6 through 9), which ranges up to Core 397-94. According to Blow (1969) this taxon disappears in the lower part of N.7. Taxa commonly recorded from this interval include the *Globigerinoides quadrilobatus* group; *G. subquadratus* (Plate 8, Figures 1 and 2); *Globigerina praebuloides* (Plate 1, Figure 5); *Globorotalia praescitula* (Plate 13, Figures 5 through 8); *G. peripheroronda* (Plate 11, Figures 1 through 3); *Cassigerinella chipolensis* (Plate 14, Figure 21); and (in some levels) *Globoquadrina altispira* s.l. and *G. baromoenesis* (Plate 3, Figure 15). Rare or sporadic are *Globigerinatella insueta* (Plate 2, Figure 16). *Globoquadrina dehiscens dehiscens* (Plate 3, Figure 11 including forma "advena"). *Globigerinoides obliquus obliquus* (Plate 8, Figure 4; often non-typical, and indicated with cf. in the range chart); *G. diminutus*, *G. altiapertura*, *Globigerina falconensis* (Plate 2, Figure 15); *G. druryi* (Plate 1, Figures 9, 13, and 14); *G. venezuelana* (Plate 1, Figures 1, 2, and 4); *Sphaeroidinellopsis disjuncta* (Plate 4, Figures 13 through 17); *Globorotalia siakensis* (Plate 10, Figures 1 through 13); *G. obesa* (Plate 9, Figure 1); *G. birnageae*, *G. clemenciae* (Plate 8, Figures 23 and 24); *G. cf. miozea* (Plate 12, Figure 18; Plate 13, Figure 1; also, *G. cf. praescitula* of Walters, 1965); *G. acrostoma* (Plate 9, Figures 10 through 21); *G. bella*, *Globoquadrina larmei* (Plate 3, Figures 4 and 5); *G. langhiana* (Plate 3, Figure 9).

Zone N.8: *Globigerinoides sicanus-Globigerinatella insueta*. From Samples 397-89-3, CC to 397-78-3, 74-77 cm (848.5 to 744.2 m sub-bottom).

The lower boundary of Zone N.8 coincides with the FAD of *Globigerinoides sicanus*; the upper boundary, with the FAD of *Orbulina suturalis*. Within this biozone, we recorded two parallel evolutionary lineages, one leading from *Praeorbulina glomerata curva* (Plate 6, Figures 2, 3, and 5) to *Orbulina suturalis*, the other one from *Praeorbulina transitoria* (Plate 6, Figures 1 and 4) to *O. bilobata* (Figure 1). Also observed in this interval is the evolutionary trend leading from *Globorotalia praescitula* to *G. praemenardii archaomenardii* (Plate 13, Figures 9 through 13). Taxa commonly recorded from this biozone include *Globigeri-*

*noides sicanus*, *G. subquadratus*, *G. quadrilobatus* s.l., *Globigerina falconensis*, *G. praebuloides*, *G. venezuelana*, *Globorotalia siakensis*, *G. praescitula*, *Praeorbulina* spp., *Globoquadrina altispira* s.l., *G. baromoenesis*, and (in some samples) *Sphaeroidinellopsis disjuncta*, *Cassigerinella chipolensis*, *Globoquadrina dehiscens dehiscens*, *Globigerina druryi*, *Globorotalia birnageae*, *G. peripheroronda*. Usually rare are *Globigerinatella insueta*, *Globorotalia praemenardii archaomenardii* (Plate 13, Figures 9 through 13), *G. cf. miozea*, *G. clemenciae*, and *G. acrostoma*. Occasionally recorded are *Hastigerina siphonifera praesiphonifera* (Plate 2, Figures 23 and 24); *Bolliella prolata* (Plate 2, Figures 5 and 6); *Globigerinoides diminutus*, *G. obliquus obliquus*, *Globoquadrina larmei*, and *G. langhiana*.

Zone N.9: *Orbulina suturalis-Globorotalia (Turborotalia) peripheroronda*. From Samples 397-78-2, cm to 397-78-1, 18-20 cm (742.3 to 740.6 m sub-bottom).

The lower boundary of Zone N.9 coincides with the FAD of *Orbulina suturalis*; the upper boundary, with the FAD of *Globorotalia peripheroacuta* (Plate 11, Figures 4 through 6, and 10). At Site 397, this latter taxon is recorded starting from Sample 397-77, CC. Consequently, only Sections 1 and 2 of Core 397-78 are referable to Zone N.9. The extremely small thickness of this biozone, given the high sedimentation rate type of this setting at the foot of a continental slope, is suggestive of a hiatus. Additional biostratigraphic observations supporting the existence of a hiatus immediately beneath Core 397-77 are discussed in the Site Report (this volume). This hiatus probably corresponds to the greatest part of Zone N.9 and to most of Zone N.10.

In this short interval, we recorded the first occurrence of *Orbulina bilobata*. *Globorotalia peripheroronda* (Plate 11, Figures 1 through 3) shows a tendency to develop a compressed periphery in the last few chambers. Among the Praeorbulinas, only *P. glomerata circularis* (frequent; see Plate 6, Figure 10) and *P. transitoria* (rare) persist, along with the last specimens referable to *Cassigerinella chipolensis*, *Globigerinoides sicanus*, *Globorotalia praemenardii archaomenardii*, and *G. praescitula*. Some of these taxa have been recorded from younger levels; however, they are interpreted as either reworked, or involved in slumps.

Zone N.11: *Globorotalia (G.) praefohsi*. From samples 397-77-1, 74-76 cm to 397-76-1, 52-56 cm (731.7 to 722.5 m sub-bottom).

The lower boundary is defined by the FAD of *G. praefohsi* (Plate 11, Figures 7 through 9), evolving from its ancestor, *G. peripheroacuta* (Plate 11, Figures 4 through 6, and 10); the upper boundary by the FAD of *G. fohsi* s. s. These two biostratigraphic events have been recorded, respectively, in Samples 397-77-1, 74-76 cm, and 397-75, CC. The interval immediately underlying, from Samples 397-77-2, 45-49 cm, to 397-77, CC (an interval yields *G. peripheroacuta* without *G. praefohsi*), should be referred to Zone N.10. This attribution, however, is very uncertain because this interval is very unfavorable to the investigations on this lineage of *Globorotalias*: specimens referable to the *Globorotalia fohsi* plexus (Plate 11, Figures 11 through

16 and 19) are sparse and poorly preserved. Consequently, we cannot rule out the possibility that the zonal boundary lies somewhat lower, in Core 397-77. A purely paleontological argument supporting this doubt is the recorded occurrence of a highly evolved form of *G. praemenardii* (i.e., with limbated spiral and intracameral sutures in the penultimate whorl) starting from Sample 397-77-3, CC. According to Blow (1969), the acquisition of this biocharacter in the lineage under discussion is realized within Zone N.11. In conclusion, we refer to Zone N.11 as the interval from Samples 397-77-1, 76 cm to 397-76-1, 52 cm, but allow that all of Core 397-77 may fall within this biozone.

Within this interval, we record the first local appearance of *Globorotalia praemenardii praemenardii* (Plate 13, Figures 14 through 21; Plate 14, Figure 1), *Orbulina universa*, *G. continuosa* (Plate 10, Figures 3 and 4), and *Globigerinopsis aguasayensis* (Plate 3, Figures 1 through 3); *Globorotalia peripheroronda*, on the contrary, becomes progressively rare and less typical, disappearing at the top of the zone. Taxa common or frequent include *Orbulina* spp., *Globoquadrina baromoensis*, *G. altispira* s.l., *Globigerinoides quadrilobatus* s.l., *Globigerina druryi*, *G. venezuelana*, *Sphaeroidinellopsis disjuncta*, *Globorotalia siakensis*, *G. praemenardii praemenardii*, *G. miozea miozea* (typical from this interval upwards; see Plate 13, Figures 2 through 4), and *G. scitula* group. Also common in some levels are *Globoquadrina dehiscens dehiscens*, *Globigerina praebuloides*, *Globorotalia peripheroacuta* (in the later part of the interval), and *Globigerinopsis aguasayensis*. *Globigerinoides subquadratus*, *Globigerina falconensis*, and *Globorotalia praefohsi* are rare; *Hastigerina siphonifera praesiphonifera* and *Globigerinoides obliquus obliquus* are sporadic.

Zone N.12: *Globorotalia (G.) fohsi*. From samples 397-75, CC to 397-74-2, 68-70 cm (715.1 to 704.6 m sub-bottom).

The FADs of *Globorotalia fohsi* s.s. and of *Sphaeroidinellopsis subdehiscens* (Plate 4, Figures 18 through 20) characterize, respectively, the lower and upper boundary of this biozone. The FAD of the latter taxon has been recorded in Sample 397-74-1, 50-52 cm. We acknowledge that our interpretation of this taxa of the *Sphaeroidinellopsis* lineage differs in part from that of Blow (1969), but we believe that our position does not affect the biostratigraphic interpretation of this interval. The above assumption is supported by the range of *Globorotalia praefohsi* (Plate 11, Figures 17 and 18), *G. fohsi*, *G. praemenardii praemenardii*, *G. cultrata* s.l. (Plate 14, Figures 2 through 4, and 6), *Globigerina decoraperta* (Plate 1, Figures 11 and 12). In other words, we consider the N.12/N.13 boundary as defined by Blow (1969).

The preservation of foraminiferal tests is poor in most cases; the best represented taxa include *Globorotalia siakensis*, *G. praemenardii praemenardii*, *G. scitula* group, *Globigerina venezuelana*, *Globigerinoides quadrilobatus* s.l., and *Orbulina* spp. In some samples, we also recorded an abundance of *Globoquadrina dehiscens dehiscens*, *G. altispira* s.l., *Globigerina druryi*, *G.*

*falconensis*, *G. praebuloides*, *Sphaeroidinellopsis disjuncta* (with transitional forms to *S. subdehiscens*). *G. miozea miozea*, and *G. continuosa*. Within this interval, *Globorotalia peripheroacuta* disappears; taxa of the *G. fohsi* lineage, *Globigerinoides subquadratus*, and *Globoquadrina baromoensis* are seldom recorded; and *Globorotalia partimlabiata* (Plate 9, Figures 11, 17, and 18) first appears.

Zone N.13: *Sphaeroidinellopsis subdehiscens subdehiscens-Globigerina druryi*. From Samples 397-74-1, 50-52 cm to 397-72-3, 37-39 cm (703 to 686.3 m sub-bottom).

The lower boundary of this zone is defined by the FAD of *S. subdehiscens*; the upper one, by the FAD of *Globigerina nepenthes* (Plate 1, Figure 19; Plate 2, Figures 1 and 2). Within this interval, specimens ex interc *G. druryi-G. nepenthes* (very close to the latter taxon) are recorded. As previously mentioned, we located the FAD of *G. nepenthes* (i.e., Zone N.13/N.14 boundary) where typical, well-developed specimens are commonly recorded. *Globorotalia siakensis*, *G. scitula* group, *G. partimlabiata*, *Sphaeroidinellopsis subdehiscens*, *Globigerinopsis aguasayensis*, *Orbulina* spp., *Globigerinoides quadrilobatus*, and occasionally *Globorotalia continuosa*, *G. miozea miozea*, *Globigerina venezuelana*, *G. druryi*, *Globoquadrina altispira* s.l. are common to abundant. *Globigerinoides obliquus obliquus* and *G. bulloides* are sporadic.

Within this interval, we recorded the FADs of *Globorotalia cultrata* s.l. and of *Globigerina decoraperta*. Taxa which disappear within Zone N.13 are *Globorotalia fohsi* (Plate 11, Figures 11 through 16, and 19; Plate 12, Figures 1, 2, and 5) with the forms "lobata" and "robusta," *G. praefohsi*, *Sphaeroidinellopsis disjuncta*, *Globorotalia partimlabiata*, *Globigerinoides subquadratus*, and *Globigerinopsis aguasayensis*. Typical specimens of *Globorotalia mayeri* (Plate 9, Figures 5, 9, and 12 through 14) were recorded only from this interval.

Zone N.14: *Globigerina nepenthes/Globorotalia siakensis*. From Samples 397-72-2, 50-52 cm to 397-71-1, 87-89 cm (685.5 to 674.8 m sub-bottom).

This biozone is defined at its base by the FAD of *G. nepenthes* and at its top by the LAD of *G. siakensis*. In our cores, we also recorded *G. siakensis* from Cores 397-70 to 68. We referred these cores to Zone N.16 because of the occurrence of *Globorotalia acostaensis* (see discussion under Reworking in the Site Report, this volume). *G. siakensis* is interpreted as being reworked.

*Globorotalia cultrata* s.l. (Plate 14, Figures 2 through 4, and 6). *G. siakensis*, *G. miozea miozea*, *Globigerina nepenthes*, *Globoquadrina dehiscens*, *Sphaeroidinellopsis subdehiscens*, *Globigerina praebuloides*, *Globigerinoides quadrilobatus* s.l., and *Orbulina* spp. are the most common taxa. Rare are *Globigerina decoraperta*, *G. falconensis*, *Globorotalia continuosa*, *Globigerinoides obliquus obliquus*, *G. bulloideus* (Plate 8, Figures 10 and 11), and *Globoquadrina altispira* s.l. Within this interval, we recorded the last occurrence of *Globigerina druryi* and *Globoquadrina baromoensis*,

and the first occurrence of *Globorotaloides falconarae* (Plate 4, Figures 5 through 7).

Zone N.16: *Globorotalia* (*Turborotalia*) *acostaensis acostaensis-Globorotalia* (*T.*) *merotumida*. From Samples 397-70-3, 49-52 cm to 397-52-6, 50-52 cm (668.4 to 501.5 m sub-bottom).

This zone, defined by Blow (1969) as the interval from the FAD of *G. acostaensis* to the FAD of *G. tumida plesiotumida*, is here amended in its upper limit, which is defined by the FAD of *Sphaeroidinellopsis seminulina paenedehiscens* (Plate 5, Figures 3, and 5 through 11). This taxon is easily recognizable and the interval with transitional forms “*seminulina* s.s.”-“*paenedehiscens*” is very short. The FAD of the latter taxon slightly postdates that of *Globorotalia tumida plesiotumida* (Plate 12, Figures 10 through 14, and 19), but the reliability of the specific identification is by far larger.

A hiatus occurs between Cores 397-71 and 70; consequently, the FAD of *G. acostaensis* (Plate 10, Figures 5 and 6) is not really controlled on an evolutionary lineage. Specimens transitional from *G. continua* to *G. acostaensis* are recorded in Cores 397-70 and 69; therefore, if the record of Zone N.16 is incomplete at its base, the missing part should be extremely short.

The interval referred to Zone N.16 is strongly affected by slumps (Cores 397-70, 68, and especially 61 to 57). Samples from slump intervals are shaded in the range chart (Figure 6). Reworking also has been noticed at various intervals. Many taxa, due to their biochronological significance, certainly have to be considered allochthonous: they are indicated with ● in the range chart.

Several first occurrences are recorded in this interval. From bottom to top they are *Globerigina digitata praedigitata* (Plate 1, Figures 7 and 8); *G. calida praealida* (Plate 1, Figures 3 through 6); *Globorotalia linguaensis* (Plate 9, Figures 2 through 4); *G. scitula* s.s., *Globigerinoides bollii* (from the base of the interval; see Plate 8, Figures 12 and 13); *Globigerina apertura* (Plate 1, Figures 10 and 15); *G. bulloides* (Plate 2, Figure 3); *Candeina nitida praenitida* (Plate 3, Figure 12); *Globorotalia humerosa praeumerosa* (Plate 10, Figures 7 and 8); *Globigerinoides seiglei* (Plate 7, Figures 12 and 13); *Gl. obliquus extremus* (Plate 8, Figure 3); *Globorotalia tumida plesiotumida*, *Candeina nitida nitida*, *Globorotalia mineacea* (Plate 10, Figures 14 and 15); *Sphaeroidinellopsis seminulina seminulina*, and *Globorotalia miotumida* (Plate 12, Figures 3, 4, and 9). Some of these have to be considered as local occurrences, others as first evolutionary appearances; the latter include *G. nitida nitida* (Plate 3, Figure 13), *G. obliquus extremus*, and *G. bulloides*.

Taxa common to frequent in this interval include *Globorotalia acostaensis* (rare in the earlier part only), *G. cultrata* s.l., *G. linguaensis* (limited to the lower part), *Sphaeroidinellopsis subdehiscens*, *Globigerina decoraperta*, *G. nepenthes*, *G. falconensis*, *Globigerinoides bulloideus*, *G. obliquus obliquus*, *G. quadrilobatus*

s.l., and *Globoquadrina altispira* s.l. *Globorotalia continua*, *G. mineacea*, *Globigerina venezuelana*, *G. apertura*, *Globigerinoides bollii*, *G. bulloideus*, and *Globorotaloides falconarae* are only occasionally common. Other taxa recorded from this interval are rare or sparse.

Several species *Globorotalia linguaensis*, *G. continua* and *Globorotaloides falconarae* disappear in the middle part of this interval. The precise location of their last occurrences, however, cannot be recognized because of the slumps. *Globorotalia miozea miozea* and *Sphaeroidinellopsis subdehiscens* disappear in the latest part of the interval.

The coiling direction of *G. acostaensis* in Zone N. 16 is initially dextral (Cores 397-70 to 67), then consistently sinistral with two short duration reversals within Cores 397-64 and 61.

*Sphaeroidinellopsis seminulina paenedehiscens* Zone (here proposed). From Samples 397-52-5, 50-52 cm to 397-45-2, 50-52 cm (500 to 419 m sub-bottom).

FAD of *G. margaritae* coincides with the first occurrence of typical specimens, definitely keeled and sinistral. Specimens similar to *G. margaritae* (fully keeled but consistently right-coiling) are recorded several meters deeper, within the bioseries leading to *G. margaritae*.

This interval is affected by strong dissolution; as a consequence the assemblages are often poorly diversified and usually sparse. Taxa recorded with a certain abundance are *Globigerina nepenthes* and *Globorotalia acostaensis*. In the interval from Sections 397-50-1 to 47-3 *Globorotalia miotumida* is also consistently recorded. *Globigerinoides obliquus extremus*, *G. obliquus obliquus*, *G. bulloideus*, *G. quadrilobatus* s.l., *Globoquadrina altispira* s.l., *Globigerina decoraperta*, *G. falconensis*, *Orbulina* spp., and *Sphaeroidinellopsis seminulina paenedehiscens* are only occasionally common in this interval. The last form increases gradually in size.

Within this interval, *Globorotalia miotumida*, *G. merotumida* (Plate 12, Figures 15 through 17), and *Globigerinoides bulloideus* disappear; *Globorotalia multicamerata* (Plate 14, Figures 5, 7, and 8) and *Globigerinoides conglobatus* (Plate 7, Figures 10 and 11) first occur. From Core 397-50 upwards we recorded a stock of *Globorotalias* which gradually evolve to *G. margaritae* (Plate 10, Figures 20 and 21). A change in coiling direction (from left-coiling to right-coiling) is recorded in *G. acostaensis*, which is consistently dextral in the later part of the interval, from Section 397-47-2 upwards.

*Globigerina nepenthes* Zone (here proposed). From Samples 397-45-1, 50-52 cm to 397-36-1, 50-52 cm (418 to 332.5 m sub-bottom).

This interval, which we have defined previously as spanning from the FAD of *G. margaritae* to the FAD of *G. punctitulata*, is strongly affected by dissolution at depth.

Among the best represented taxa are *Globorotalia acostaensis*, *G. cultrata* s.l., *G. margaritae*, *G. humerosa*

s.s., *Globigerina nepenthes*, *G. falconensis*, *G. bulloides*, *Globigerinoides obliquus extremus*, *G. quadrilobatus*, and *Orbulina* spp.

*Sphaeroidinellopsis seminulina paenedehiscens*, *Globorotalia scitula* s.s., *G. multicamerata*, *Hastigerina siphonifera* s.s., *Globigerina calida praecalida*, and *Globoquadrina altispira* (group) are only occasionally common. Rare are *Sphaeroidinellopsis seminulina seminulina*, *Globorotalia mineacea*, and *G. tumida plesiotumida*; sparse are *Candeina nitida nitida*, *Globigerinoides conglobatus*, *G. mitra*, *Globigerina apertura*, *G. venezuelana*, and *G. digitata praedigitata*.

The following first occur within this interval, from bottom to top: *Neogloboquadrina dutertrei* s.l. (Plate 10, Figures 16 through 18); *Globorotalia* cf. *tumida tumida*, *G. humerosa* s.s. (Plate 10, Figures 9 and 10); *Globigerinoides emeisi* (Plate 8, Figure 5); *Globorotalia* aff. *ungulata* (Plate 12, Figures 6 through 8); *G. incisa* (Plate 8, Figures 20 through 22); and *Pulleniatina primalis* (Plate 4, Figures 10 through 12).

In the lower part of this zone, the following disappear: *Globigerinoides bollii*, *G. tumida plesiotumida*, and the plexus of *Globorotalia* spp. (Plate 8, Figures 16 through 19).

M PI 3 Zone (of Cita, 1975b): *Globorotalia margaritae*-*G. puncticulata* Concurrent-Range Zone. From Sample 397-51, CC to Section 397-33-1, i.e., to the top-most part of the interval considered here (323.1 to 304 m sub-bottom). At the base of the interval, along with *G. puncticulata* (Plate 9, Figures 22 through 24), the following first occur: *G. crassaformis* (Plate 9, Figure 25); *Globigerinoides elongatus* (Plate 7, Figures 4 through 7); and *Sphaeroidinella dehiscens immatura* (Plate 5, Figure 12). Since Core 397-35 has a very limited recovery, the contemporaneous appearance of several taxa (which in itself is suggestive of a hiatus) might be misleading. The best-represented taxa in this interval include *G. puncticulata*, *G. margaritae* cum var., *G. cultrata* s.l. (Plate 4, Figures 2 through 4, 6); *G. acostaensis*, *G. humerosa* (Plate 10, Figures 9, 10); *G. scitula* (Plate 10, Figure 19); *Sphaeroidinellopsis seminulina paenedehiscens*, *Globigerina apertura*, *G. decoraperta*, *G. calida praecalida*, *G. bulloides*, *Globigerinoides obliquus extremus*, *G. quadrilobatus*, and *Orbulina* spp. Rare to sparse are *Pulleniatina primalis*, *Candeina nitida nitida*, *Globorotaloides hexagona* (Plate 4, Figures 8, 9), *Globoquadrina altispira altispira*, *Globigerinoides conglobatus*, *G. elongatus*, *Globigerina venezuelana*, *G. digitata praedigitata*, *Sphaeroidinella dehiscens immatura*, and *Globorotalia* aff. *ungulata*.

### CHRONOSTRATIGRAPHY

The Cape Bojador succession here considered is correlatable with the following standard stages of the Neogene, listed from bottom to top:

Burdigalian: from Sample 397-97, CC (Zone N.7) to Section 397-90-2 (Zone N.7)

Langhian: from Sample 397-89, CC Zone N.8) to Section 397-78-1 (Zone N.9),

Serravallian: from Sample 397-77, CC (Zone N.10, pars, or N.11) to Section 397-71-1 (Zone N.14),

Tortonian: from Section 397-70-3 (Zone N.16) to Section 397-49-1 (*S. seminulina paenedehiscens* Zone),

Messinian: from Section 397-48-3 (*S. seminulina paenedehiscens* Zone) to Section 397-43-2 (*Globigerina nepenthes* Zone),

Zanclean: from Section 397-42-2 (*G. nepenthes* Zone) to Section 397-33-1 (M PI 3 Zone).

The correlation as indicated above is easy and immediate if we consider the results of the following investigations on the stratotype sections: Demarcq et al. (1974) for the Burdigalian; Cita and Blow (1969) and Ryan et al. (1974) for the Langhian, Serravallian, Tortonian, and Messinian; Cita (1972, 1975a), Cita and Gartner (1973), Cita and Decima (1975) for the Zanclean.

The positioning of the stratotype sections of these stages with reference to the standard foraminiferal zonation has been thoroughly discussed by Cita and Blow (1969) and by Ryan et al., (1974).

Figure 7 shows the calibration of the standard foraminiferal zones (represented in time-equivalent spacing in the central column) to the paleomagnetic stratigraphy (column to the left). The different inclinations of the lines connecting the foraminiferal zonal boundaries, from the time-equivalent spacing to their actual position recorded in the continuously cored succession penetrated at Site 397, permit the identification of minor hiatuses related to submarine erosion.

Special attention has been paid to the correlation of the Tortonian/Messinian and Messinian/Zanclean (i.e., Miocene/Pliocene) boundary: they define a time interval during which the Mediterranean was affected by a basin-wide salinity crisis. The problem of the Tortonian/Messinian boundary, which for years was subject to controversy even after the designation of a neostatotype section in Sicily (Selli, 1960; d'Onofrio, 1964) recently has been examined by d'Onofrio et al. (1975). After investigations of several sections collected in Italy, these authors showed that the FAD of *Globorotalia conomiozea* was a most significant and readily recognizable biostratigraphic event, and the most important event occurring close to that boundary. Other biostratigraphic criteria used to correlate the boundary are the FADs of *Globorotalia mediterranea*,<sup>6</sup> *G. saheliana*, and *G. saphoe*.

However, none of these criteria could be applied to the Cape Bojador succession, because of the absence of these species, which either are endemic to the Mediterranean (i.e., the last three species mentioned above have never been recorded outside the Mediterranean) or might be climatically excluded (e.g., *G. conomiozea*).

The Tortonian/Messinian boundary was located at Site 397 by means of calcareous nannofossils: first evolutionary appearance of *Amaurolithus delicatus*, re-

<sup>6</sup>While the present paper was in press, a publication by W. H. Berggren (Marine Micropaleontology, v. 2, p. 265-313) showed that *G. mediterranea* is present also in the South Atlantic, thus refuting the first alternative.

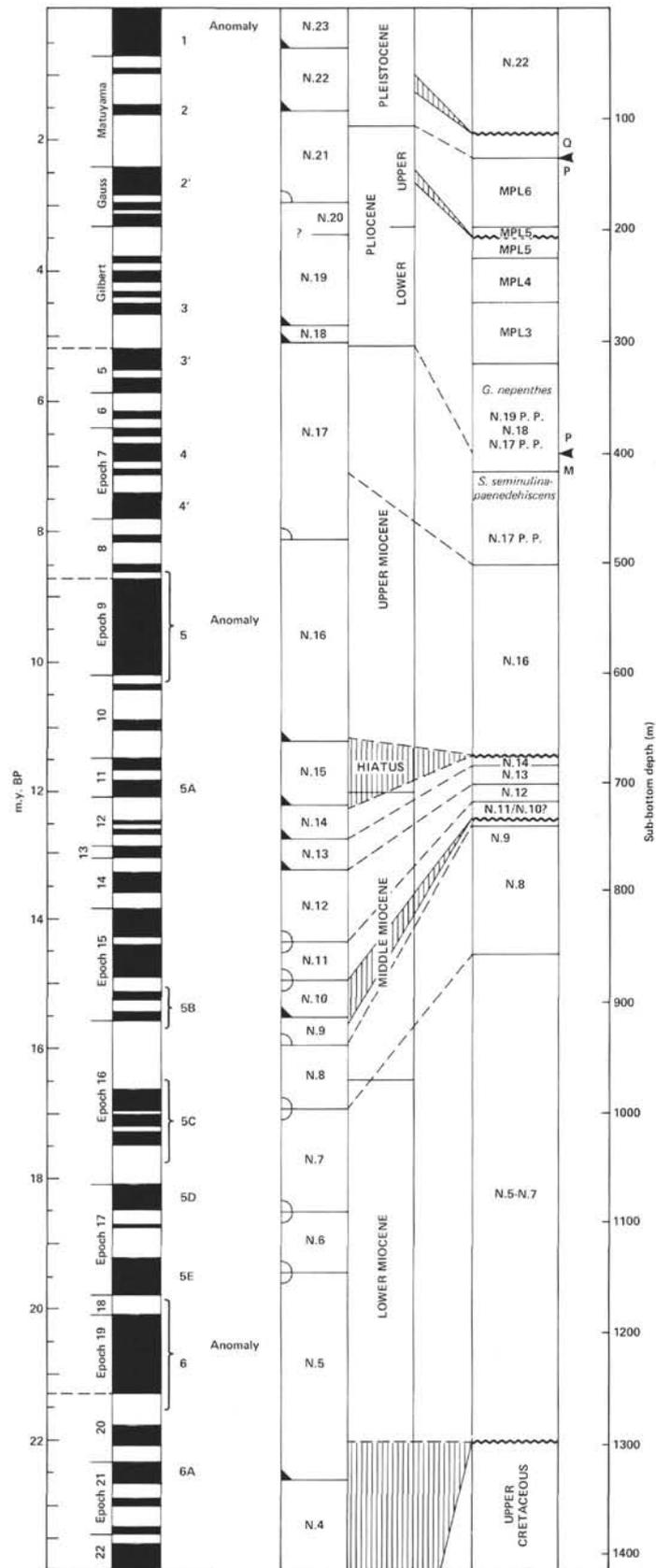


Figure 7. Calibration of the Neogene section continuously cored at DSDP Site 397 with the time-scale of Ryan et al. (1974) by means of planktonic foraminiferal zonal boundaries.

corded at the base of Core 397-48, and correlated with the Bou Regreg section of Morocco (Bossio et al., 1976) at approximately the same level where *G. conomiozea* first occurs in that section (see Mazzei et al., this volume). A biostratigraphic event which proved very useful for correlation is a sudden coiling change observed in *Globorotalia acostaensis* from sinistral (below) to dextral (above). This datum was already known in the Mediterranean. It has been recorded at the base of the Messinian from Crete, Sicily, and northern Algeria by Zachariasse (1975); in the "Tripoli" Formation immediately underlying the first evaporitic beds in Sicily (Stainforth et al., 1975); in the uppermost Miocene of southern Spain (Montenant et al., 1976); and a few meters beneath the basal evaporites in the Riba dello Zolfo section from Piedmont (Bossio et al., 1976). In equatorial Pacific piston cores, this same event has been recognized by Saito et al. (1975) as occurring at the base of paleomagnetic Epoch 5, exactly at the same position where it is recorded at Site 397 (i.e., between Sections 3 and 2 in Core 397-47). The coiling change also has been noticed in the Bou Regreg section (Bossio et al., 1976) where it postdates the FAD of *G. conomiozea* and predates the FAD of *G. margaritae*.

Relative to the Miocene/Pliocene boundary, a boundary stratotype recently has been designated at the base of the "Trubi" Formation at Cape Rossello, Sicily (Cita, 1975a). The boundary stratotype falls within the range of *Globorotalia margaritae* and of *Amaurolithus tricorniculatus*. It is near the FAD of *Sphaeroidinella* and prior to the FAD of *Ceratolithus acutus*; thus, it is in the latter part of Zone N.18, and in the earlier part of Zone NN 13 of Martini's (1971) standard nannofossil zonation. It postdates the LAD of *Discoaster quinqueramus* and lies close to the Gilbert/Epoch 5 boundary of paleomagnetic stratigraphy. Taking into account all these correlation criteria, the best location of the Miocene/Pliocene boundary at Site 397 is within Core 397-42 (see also Mazzei et al., this volume).

#### CORRELATION WITH OTHER MIOCENE SUCCESIONS FROM THE CONTINENTAL MARGIN OF NORTHWEST AFRICA AND ADJACENT BASINS

Table 1 indicates the location and water depth of twelve DSDP sites from the same general area (latitudinal range from 5°N to 35°N; longitudinal range from 27°W to 10°W) with which we established a correlation (see Figure 8). Figure 9 shows a more precise correlation, zone by zone, of the only three of the above sites with a continuous coring throughout the Neogene, i.e., DSDP Sites 397, 369, and 366. Site 369 is close to 397, located on the continental slope off Cape Bojador; Site 366 is 21° latitude to the south, on the Sierra Leone Rise, with water depth comparable to that at Site 397 (2853 and 2900 m, respectively).

The biostratigraphic correlations indicated in Figure 9 permit a comparison which overcomes any difficulty resulting from the foraminiferal zonation followed in

TABLE 1  
Coordinates and Water Depth of the DSDP Sites From the Eastern North Atlantic, Discussed in the Correlation With Site 397

Leg	Site	Latitude (N)	Longitude (W)	Water Depth (m)
2	12 C (Cape Verde)	19° 41.73'	26° 00.03''	4557
14	135	35° 20.80'	10° 25.46''	4152
14	136	34° 10.13'	16° 18.19'	4169
14	137	25° 55.53'	27° 03.64'	5361
14	138	25° 55.37'	25° 33.79'	5288
14	139	23° 31.14'	18° 42.26'	3047
14	140	21° 44.97'	21° 47.52'	4483
41	366	5° 40.7'	19° 51.1'	2853
41	Sierra Leone 367	12° 29.2'	20° 02.8'	4748
41	C. Verde Basin 368	17° 30.4'	21° 21.2'	3366
41	C. Verde Rise 369	26° 35.5'	14° 59.9'	1752
41	Spanish Sahara 370	32° 50.2'	10° 46.6'	4214
	Moroccan Basin			

Lancelot and Seibold (1977) which differs partly from that used here.

The Miocene succession cored on the slope (Site 369) is highly condensed and contains a number of stratigraphic gaps. The Sierra Leone Rise (Site 366) section is of special interest since it supports the assumption that the biostratigraphically documented gaps at Site 397 are not a local phenomenon related to a peculiar setting (inter-canyon base-of-slope), but a wide-ranging phenomenon. The approximately 170-meter-thick Miocene section of the Sierra Leone Rise displays two well-defined hiatuses: one near the base of Zone N.16, another one within Zone N.10, i.e., at exactly the same biostratigraphic horizons we recorded at Cape Bojador.

Though not yet fully understood, the wide extent of this middle Miocene (Serravallian) erosional phase(s) must be emphasized and further investigated.

The Miocene succession penetrated at Site 397 is the thickest and the most complete recovered to date from the eastern North Atlantic. Despite its upper continental rise setting and the occurrence of sediment types such as debris flows (in the lower Miocene) and volcanoclastic sandstones (in the middle Miocene), the biostratigraphic succession is relatively little disturbed and no major gaps are recorded within the Neogene. Consequently, we can consider the Cape Bojador section as a reference section for the eastern North Atlantic, with special regard to the upper Neogene.

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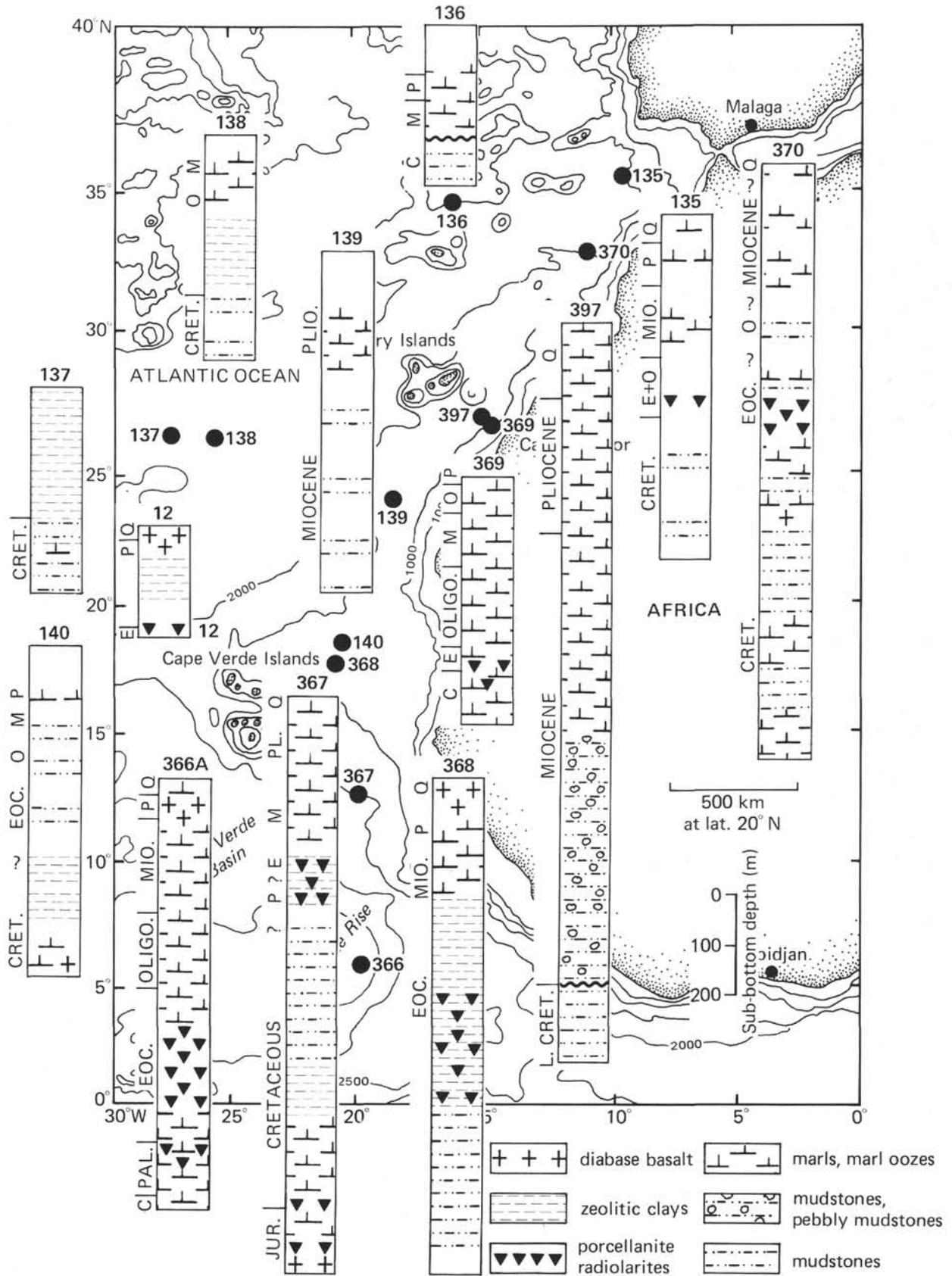


Figure 8. Stratigraphic columns of eastern North Atlantic DSDP Miocene sediments.

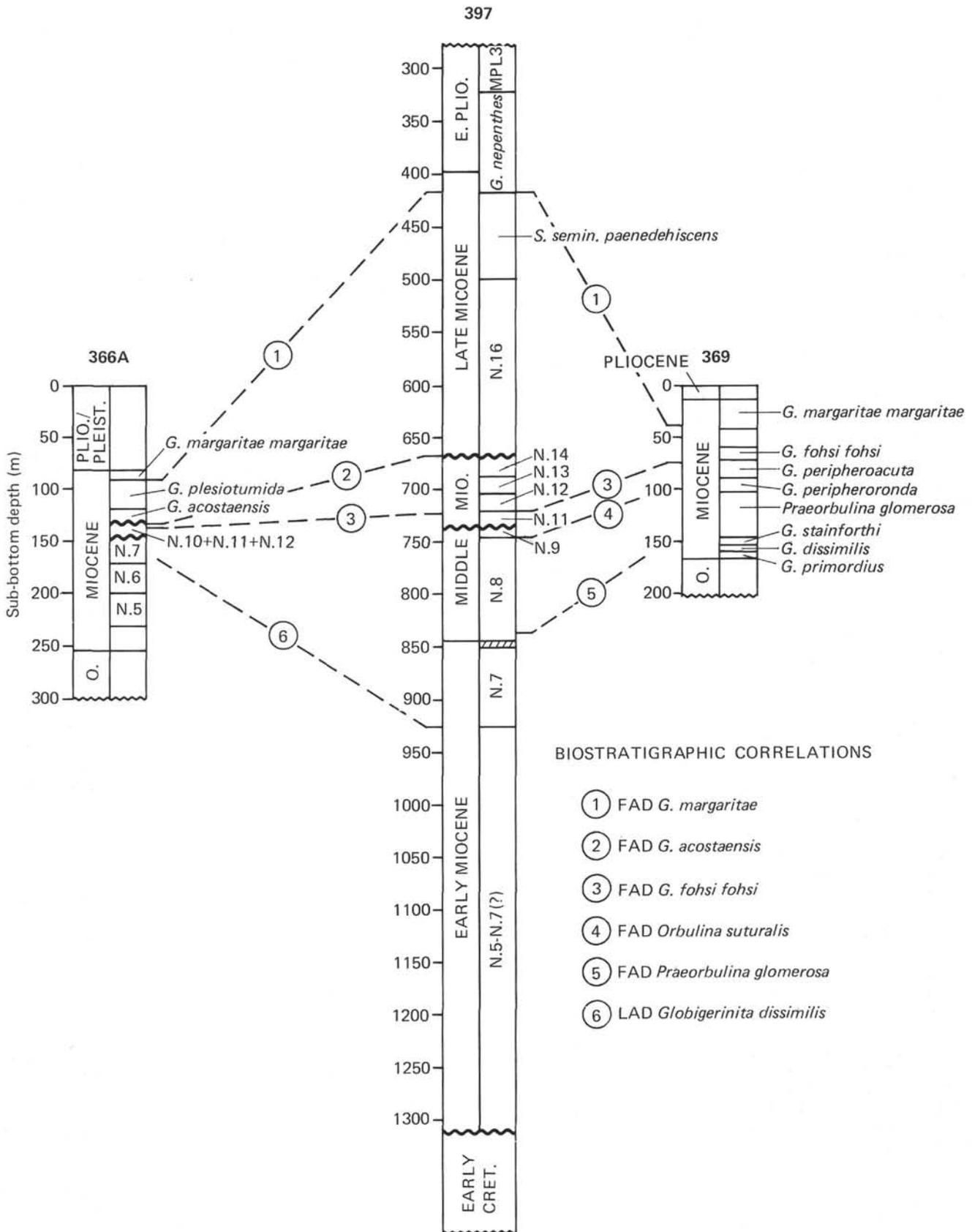


Figure 9. Biostratigraphic correlation of the Miocene successions penetrated at DSDP Sites 366 (Sierra Leone Rise), 397 (upper continental rise off Cape Bojador), and 369 (continental slope off Cape Bojador).

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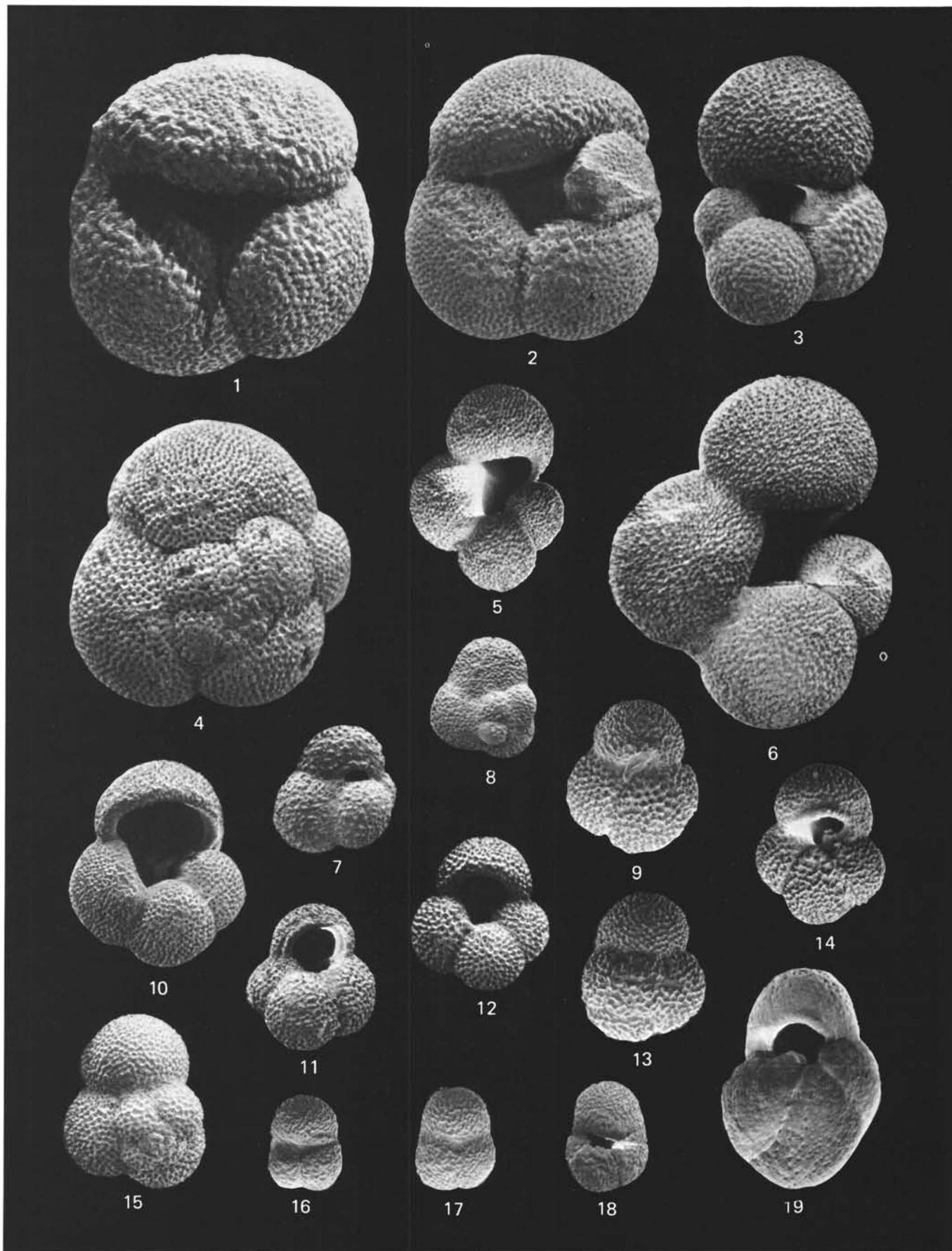
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PLATE 1

- Figures 1, 2, 4 *Globigerina venezuelana* Hedberg.  
1. Umbilical view,  $\times 100$ .  
Sample 397-41-6, 25-27 cm. *Globigerina nepenthes* Zone, Zanclean.  
2. Umbilical view,  $\times 100$ .  
4. Spiral view,  $\times 100$ .  
Sample 397-70-3, 49-52 cm. Zone N.16, Tortonian.
- Figures 3, 6 *Globigerina calida praecalida* Blow.  
Umbilical views,  $\times 100$ .  
Sample 397-33-4, 49-52 cm. Zone M Pl 3, Zanclean.
- Figure 5 *Globigerina praebulloides* Blow.  
Umbilical view,  $\times 100$ .  
Sample 397-94-1, 22-24 cm. Zone N.7, Burdigalian.
- Figures 7, 8 *Globigerina digitata praedigitata* Parker.  
7. Umbilical view,  $\times 100$ .  
8. Spiral view,  $\times 100$ .  
Sample 397-34-3-50-53 cm. Zone M Pl 3, Zanclean.
- Figures 9, 13, 14 *Globigerina drury* Akers.  
9. Umbilical view,  $\times 100$ .  
Sample 397-94-1, 22-24 cm. Zone N.7, Burdigalian.  
13. Spiral view,  $\times 100$ .  
Sample 397-97-1, 40-43 cm. Zone N.7, Burdigalian.  
14. Umbilical view,  $\times 100$ .  
Sample 397-76, CC. Zone N.11, Serravalian.
- Figures 10, 15 *Globigerina apertura* Cushman.  
10. Umbilical view,  $\times 100$ .  
15. Spiral view,  $\times 100$ .  
Sample 397-34-5, 50-53 cm. Zone M Pl 3, Zanclean
- Figures 11, 12 *Globigerina decoraperta* Takayanagi and Saito.  
Umbilical views,  $\times 100$ .  
Sample 397-34-1, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 16-18 *Globigerina regina* Crescenti.  
16, 18. Umbilical views,  $\times 100$ .  
17. Spiral view,  $\times 100$ .  
Sample 397-66-4, 53-57 cm. Zone N.16, Tortonian.
- Figure 19 *Globigerina nepenthes* Todd.  
Umbilical view,  $\times 100$ .  
Sample 397-66-4, 53-57 cm. Zone N.16, Tortonian.

PLATE 1



## PLATE 2

- Figures 1, 2 *Globigerina nepenthes* Todd.  
 1. Umbilical view,  $\times 100$ . Sample 397-55-1, 50-52 cm. Zone N.16, Tortonian.  
 2. Umbilical view,  $\times 100$ . Sample 397-50-1, 57-59 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone, Tortonian.
- Figure 3 *Globigerina bulloides* d'Orbigny.  
 Umbilical view,  $\times 100$ . Sample 397-36-2, 50-53 cm. *Globigerina nepenthes* Zone, Zanclean.
- Figures 4, 10 *Globigerina paraboloides* Blow.  
 Umbilical views,  $\times 100$ . Sample 397-63, CC. Zone N.16, Tortonian.
- Figures 5, 6 *Hastigerina proluxa* (Lipps). Two views of the same specimen.  
 5. Equatorial view,  $\times 100$ .  
 6. Umbilical view,  $\times 100$ . Sample 397-85, CC. Zone N.8, Langhian.
- Figures 7-9 *Globigerina eamesi* Blow.  
 7. Spiral view,  $\times 100$ .  
 9. Umbilical view,  $\times 100$ . Sample 397-69-4, 50-53 cm. Zone N.16, Tortonian.  
 8. Umbilical view,  $\times 100$ . Sample 397-69-1, 60-62 cm. Zone N.16, Tortonian.
- Figures 11, 12 *Globigerina* aff. *ouachitaensis ciperensis* Bolli.  
 11. Umbilical view,  $\times 100$ . Sample 397-92-1, 34-37 cm. Zone N.7, Burdigalian.  
 12. Spiral view,  $\times 100$ . Sample 397-94-1, 22-24 cm. Zone N.7, Burdigalian.
- Figures 13, 14 *Globigerina foliata* Bolli.  
 13. Umbilical view,  $\times 100$ .  
 14. Spiral view,  $\times 100$ . Sample 397-69-1, 60-62 cm. Zone N.16, Tortonian.
- Figure 15 *Globigerina falconensis* Blow.  
 Umbilical view,  $\times 100$ . Sample 397-34-1, 50-53 cm. Zone M PI 3, Zanclean.
- Figure 16 *Globigerinatella insueta* Cushman and Stainforth.  
 Umbilical view,  $\times 100$ . Sample 397-85, CC. Zone N.8, Langhian.
- Figures 17-20 *Turborotalita* sp.  
 17. Umbilical view,  $\times 100$ . Sample 397-55-3, 49-52 cm. Zone N.16, Tortonian.  
 18. Side view,  $\times 100$ . Sample 397-63-1, 52-55 cm. Zone N.16, Tortonian.  
 19. Umbilical view,  $\times 100$ . Sample 397-60-6, 30-32 cm. Zone N.16, Tortonian.  
 20. Spiral view,  $\times 100$ . Sample 397-61-4, 65-67 cm. Zone N.16, Tortonian.
- Figures 21, 22 *Hastigerina siphonifera siphonifera* (d'Orbigny).  
 21. Umbilical view,  $\times 100$ .  
 22. Equatorial view,  $\times 100$ . Sample 397-39-2, 50-52 cm. *Globigerina nepenthes* Zone, Zanclean.
- Figures 23, 24 *Hastigerina siphonifera praesiphonifera* Blow.  
 23. Umbilical view,  $\times 100$ . Sample 397-90-2, 90-93 cm. Zone N.7, Burdigalian.  
 24. Equatorial view,  $\times 100$ . Sample 397-84, 10-14 cm. Zone N.8, Langhian.

PLATE 2

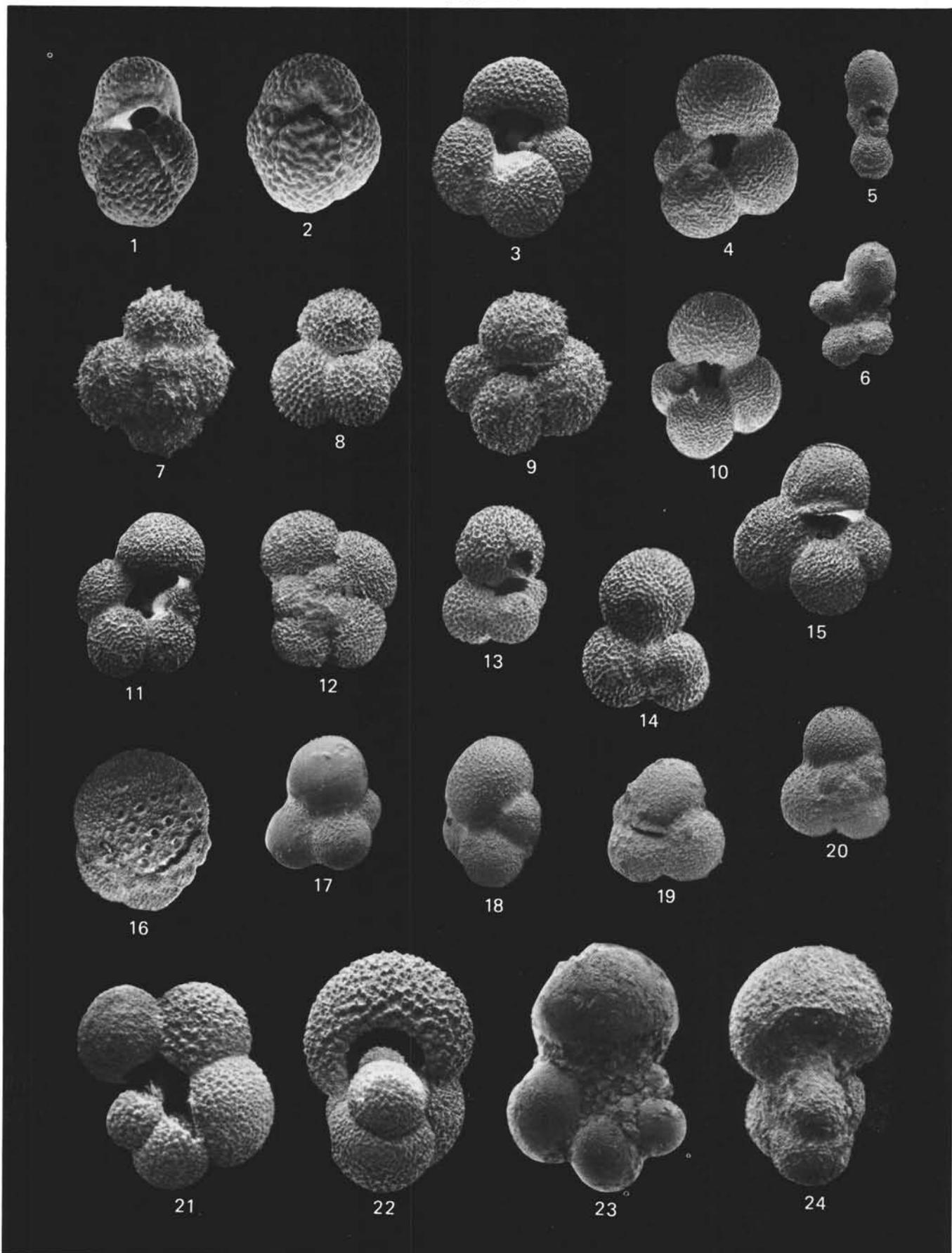


PLATE 3

- Figures 1-3 *Globigerinopsis aguasayensis* Bolli.  
1. Umbilical view,  $\times 100$ . Sample 397-76-1, 95-97 cm. Zone N.11, Serravallian.  
2. Side oblique view,  $\times 100$ .  
3. Spiral view,  $\times 100$ . Sample 397-57, CC. Slump within Zone N.16.
- Figures 4, 5 *Globoquadrina larmei larmei* Akers.  
4. Umbilical view,  $\times 100$ .  
5. Spiral view,  $\times 100$ . Sample 397-92, CC. Zone N.7, Burdigalian.
- Figures 6-8 *Globorotalia bermudezi* (Bolli).  
Three views of the same specimen:  
6. Umbilical view,  $\times 100$ .  
7. Spiral view,  $\times 100$ .  
8. Side view,  $\times 100$ .  
Sample 397-61-4, 135-137 cm. Slump within Zone N.16.
- Figure 9 *Globoquadrina langhiana* Cita and Gelati.  
Umbilical view,  $\times 100$ . Sample 397-97, CC. Zone N.7, Burdigalian.
- Figures 10, 14 *Globoquadrina altispira altispira* (Cushman and Jarvis).  
10. Umbilical view,  $\times 100$ .  
14. Side view,  $\times 100$ . Sample 397-47-3, 50-52 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone, Messinian.
- Figure 11 *Globoquadrina dehiscens dehiscens* (Chapman, Parr, and Collins).  
Umbilical view,  $\times 100$ .  
Sample 397-83-1, 41-43 cm. Zone N.8, Langhian.
- Figure 12 *Candeina nitida praenitida* Blow.  
Spiral oblique view showing the antepenultimate intercameral suture (pointed out by the arrows), without supplementary apertures,  $\times 100$ . Sample 397-56-1, 51-53 cm. Zone N.16, Tortonian.
- Figure 13 *Candeina nitida nitida* d'Orbigny.  
Spiral oblique view showing the antepenultimate intercameral suture (pointed out by the arrows), with supplementary apertures,  $\times 100$ . Sample 397-39-2, 50-52 cm. *Globigerina nepenthes* Zone, Zanclean.
- Figure 15 *Globoquadrina baromoenensis* (Le Roy).  
Umbilical view,  $\times 100$ . Sample 397-72-1, 51-53 cm. Zone N.14, Serravallian.
- Figure 16 *Globoquadrina altispira globosa* Bolli.  
Umbilical view,  $\times 100$ . Sample 397-68-1, 50-52 cm. Zone N.16, Tortonian.

PLATE 3

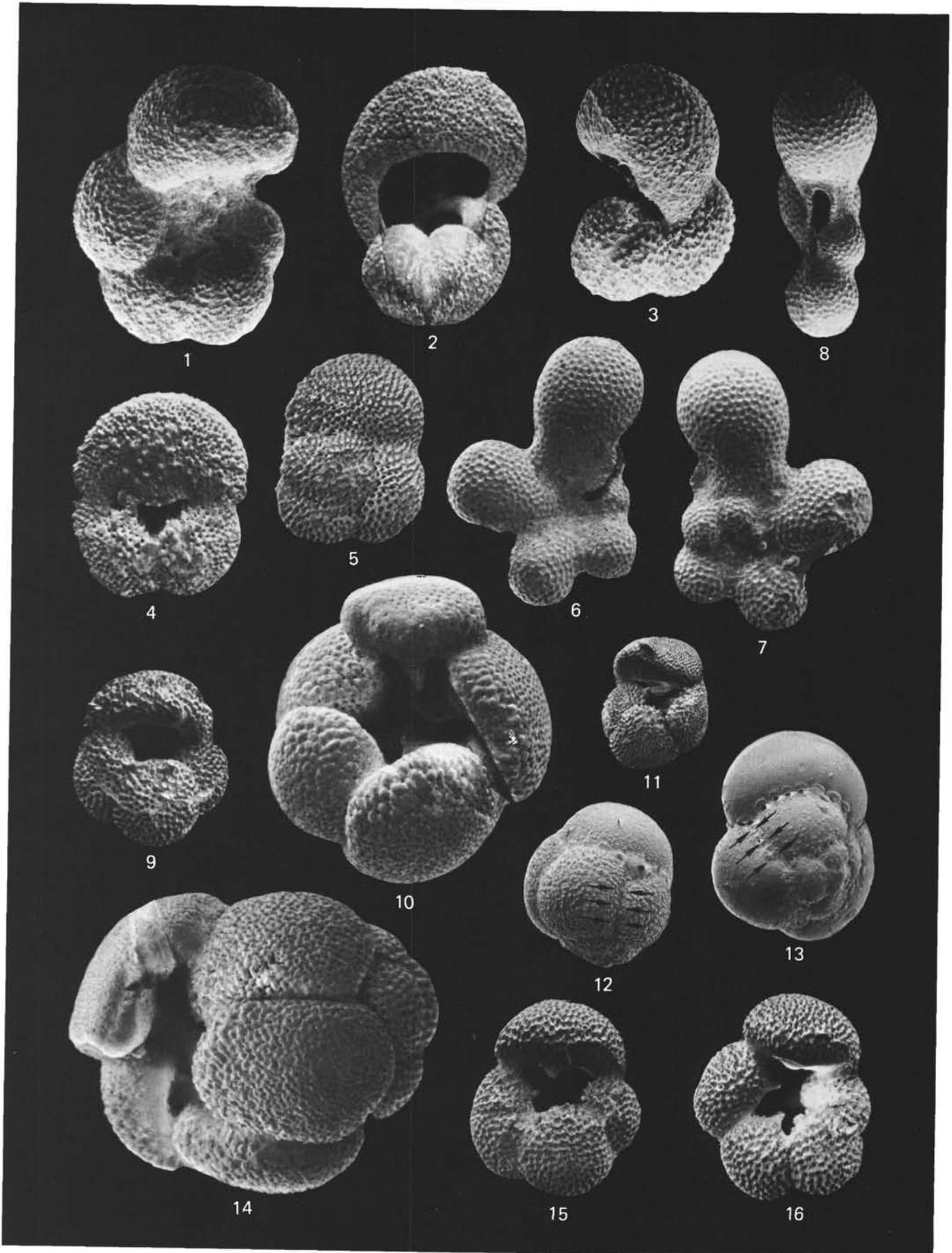


PLATE 4

- Figures 1-4 *Globorotaloides* sp.  
1,2. Umbilical views,  $\times 100$ .  
3. Side view,  $\times 100$ .  
4. Spiral view,  $\times 100$ .  
Sample 397-55-3, 49-52 cm. Zone N.16, Tortonian.
- Figures 5-7 *Globorotaloides falconarae* Gioannelli and Salvatorini.  
5, 6. Umbilical views,  $\times 100$ .  
7. Spiral view  $\times 100$ .  
Sample 397-63-1, 52-55 cm. Zone N.16, Tortonian.
- Figures 8, 9 *Globorotaloides hexagona* s.l.  
Umbilical views,  $\times 100$ .  
Sample 397-34-3, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 10-12 *Pulleniatina primalis* Banner and Blow.  
10. Umbilical view,  $\times 100$ .  
Sample 397-34-2, 50-53 cm. Zone M Pl 3. Zanclean.  
11. Spiral view,  $\times 100$ .  
12. Side view,  $\times 100$ .  
Sample 397-34-1, 50-52 cm. Zone M Pl 3 Zanclean.
- Figures 13-17 *Sphaeroidinellopsis disjuncta* (Finlay).  
13,17. Umbilical view,  $\times 100$ .  
Sample 397-92, CC.  
14,16. Umbilical views,  $\times 100$ .  
15. Detail of Figure 14,  $\times 250$ .  
Sample of 397-90, CC. Zone N.7, Burdigalian.
- Figures 18-20 *Sphaeroidinellopsis subdehiscens* (Blow).  
Umbilical views,  $\times 100$ .  
Sample 397-65-4, 50-52 cm. Zone N.16, Tortonian.
- Figure 21 *Cassigerinella chipolensis* (Cushman and Ponton).  
Umbilical view,  $\times 150$ .  
Sample 397-94-1, 22-24 cm. Zone N.7, Burdigalian.

PLATE 4

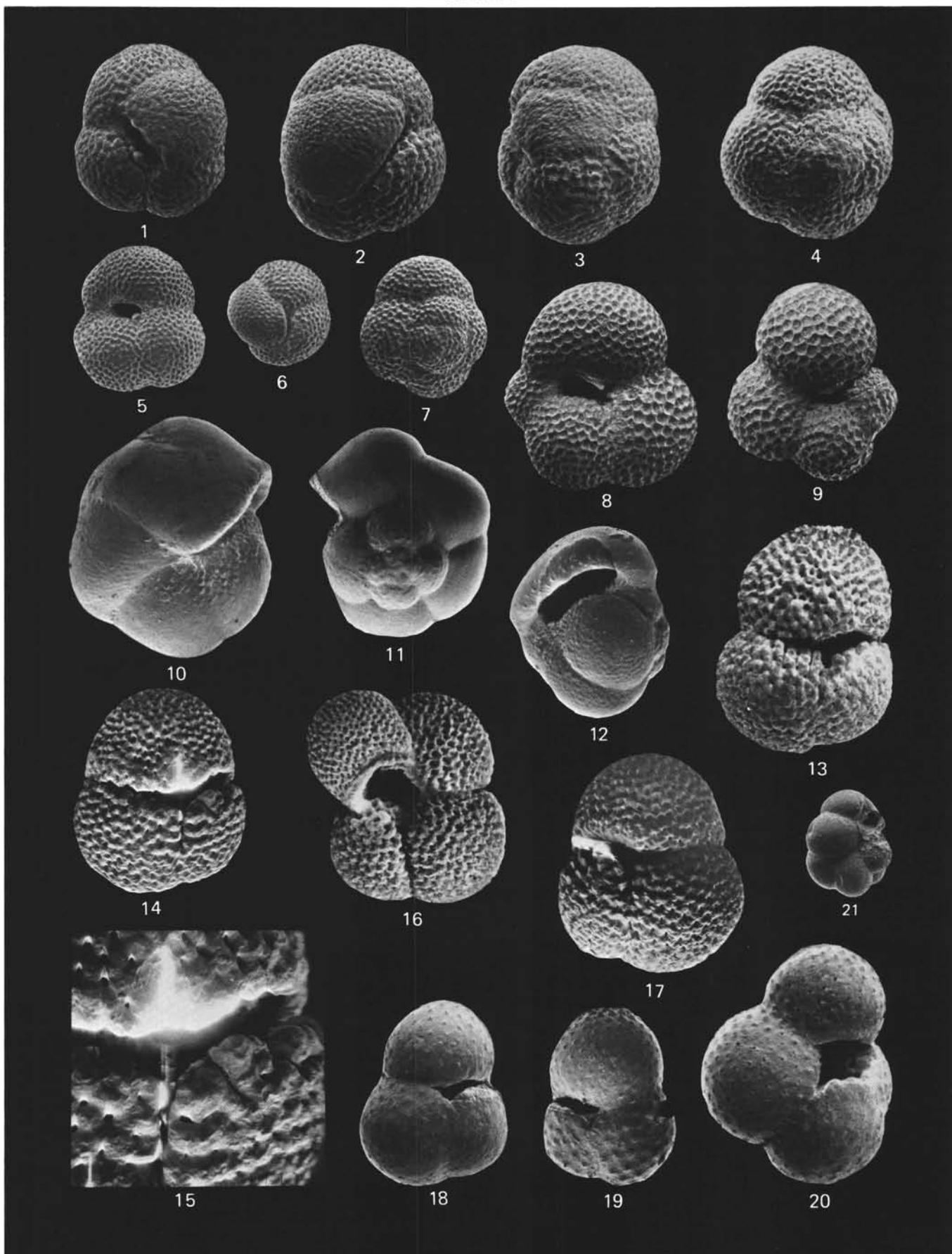


PLATE 5

- Figures 1, 2, 4 *Sphaeroidinellopsis seminulina seminulina* (Schwager).  
1,4. Umbilical views,  $\times 100$ .  
Sample 397-39-2 50-51 cm. *Globigerina nepenthes* Zone, Zanclean.  
2. Umbilical view,  $\times 100$ .  
Sample 397-55-3, 49-52 cm. Zone N.16, Tortonian.
- Figures 3, 5-11 *Sphaeroidinellopsis seminulina paenedehiscens* Blow.  
3,7,8. Umbilical views,  $\times 100$ .  
5. Spiral view,  $\times 100$ . Sample 397-41-3, 50-53 cm. *Globigerina nepenthes* Zone, Zanclean.  
6. Umbilical view,  $\times 100$ .  
Sample 397-37-4, 45-48 cm. *Globigerina nepenthes* Zone, Zanclean.  
9,11. Umbilical views,  $\times 100$ .  
10. Details of Figure 11,  $\times 250$ .  
Sample 397-34-1, 50-53 cm. Zone M Pl 3, Zanclean.
- Figure 12 *Sphaeroidinella dehiscens dehiscens* forma *immatura* (Cushman).  
Spiral view,  $\times 100$ .  
Sample 397-34-3, 50-53 cm. Zone M Pl 3, Zanclean.

PLATE 5

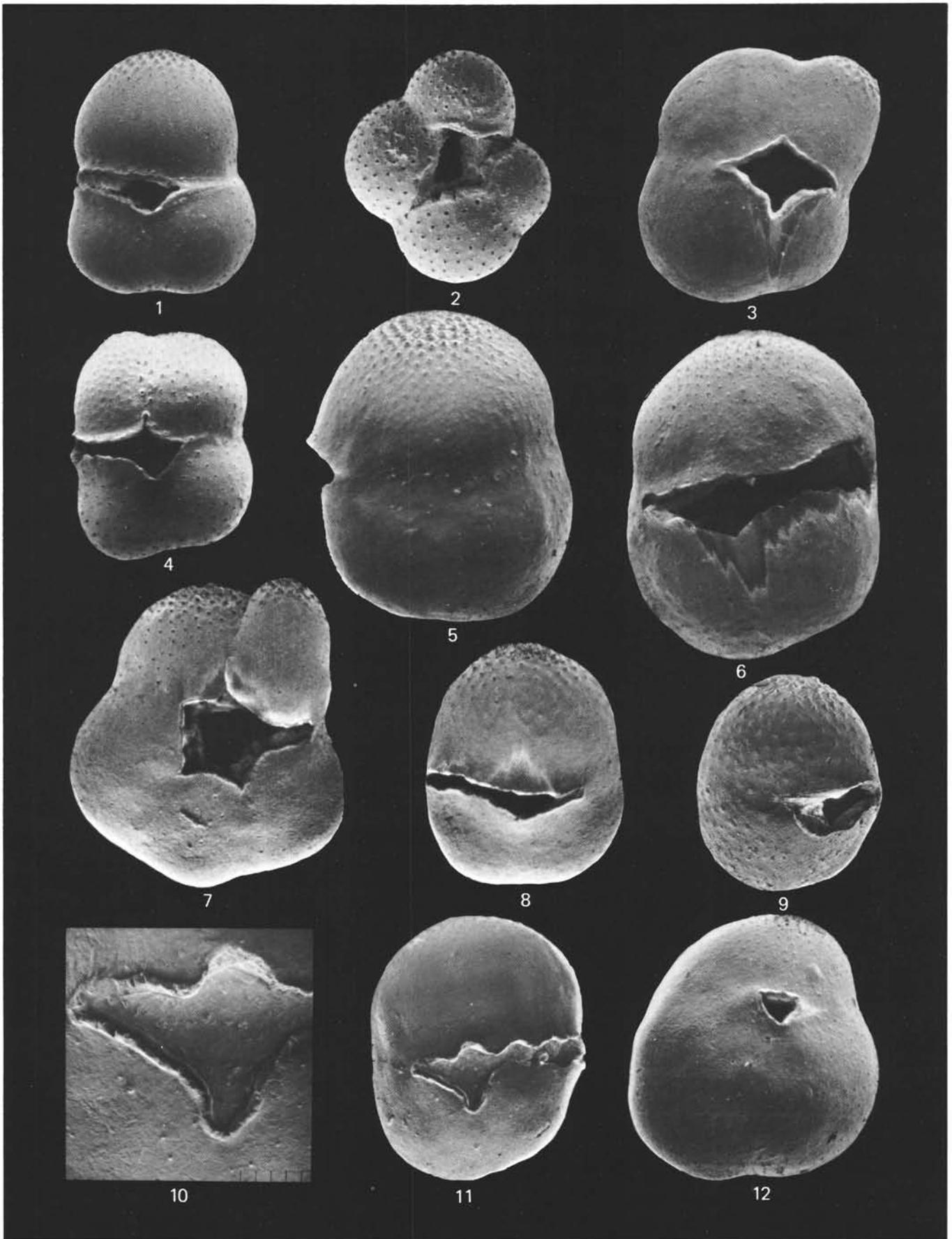


PLATE 6

- Figures 1, 4 *Praeorbulina transitoria* (Blow).  
Spiral views,  $\times 100$ .  
Sample 397-84, 10-14 cm. Zone N.8, Langhian.
- Figures 2, 3, 5 *Praeorbulina glomerosa curva* (Blow).  
2. Spiral oblique view,  $\times 100$ .  
3,5. Side views,  $\times 100$ .  
Sample 397-84-4, 10-14 cm. Zone N.8, Langhian.
- Figures 6, 7, 9 *Praeorbulina glomerosa glomerosa* (Blow).  
6. Spiral view,  $\times 100$ .  
Sample 397-78-3, 74-78 cm. Zone N.8, Langhian.  
7. Side view,  $\times 100$ .  
Sample 397-80-1, 134-135 cm. Zone N.8, Langhian.  
9. Side view,  $\times 100$ .  
Sample 397-84-4, 10-14 cm. Zone N.8, Langhian.
- Figure 10 *Praeorbulina glomerosa circularis* (Blow).  
Side view,  $\times 100$ .  
Sample 397-78-2, 34-36 cm. Zone N.9, Langhian.
- Figures 8, 11 *Globigerinoides sicanus* De Stefani.  
Umbilical views,  $\times 100$ .  
Sample 397-84-4, 10-14 cm. Zone N.8, Langhian.

PLATE 6

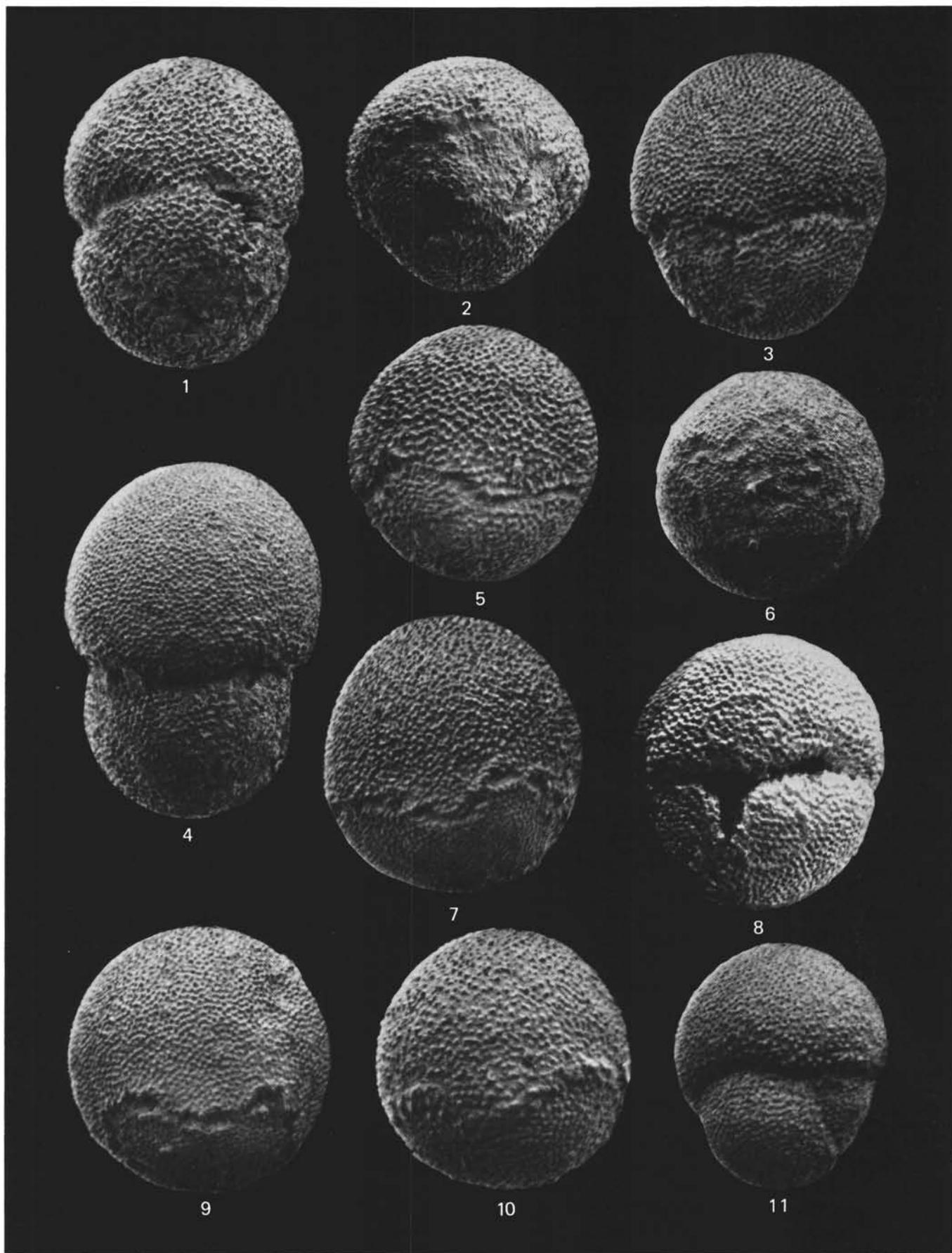


PLATE 7

- Figures 1-3 *Globigerinoides sicanus* De Stefani.  
1,2. Umbilical views,  $\times 100$ .  
Sample 397-84-4, 10-14 cm. Zone N.8,  
Langhian.  
3. Spiral view,  $\times 100$ .  
Sample 397-88, CC. Zone N.8, Langhian.
- Figures 4-7 *Globigerinoides elongatus* (d'Orbigny).  
4. Spiral view,  $\times 100$ .  
5. Spiral view,  
Sample 397-33-1, 50-53 cm. Zone M Pl 3,  
Zanclean.  
6,7. Umbilical views,  $\times 100$ .  
Sample 397-33-3, 50-53 cm. Zone M Pl 3,  
Zanclean.
- Figures 8, 9 *Globigerinoides fragilis* Borsetti and Cati.  
8. Umbilical view,  $\times 100$ .  
9. Spiral view,  $\times 100$ .  
Sample 397-49-2, 50-53 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone,  
Tortonian.
- Figures 10, 11 *Globigerinoides conglobatus conglobatus* (Brady).  
10. Spiral view,  $\times 100$ .  
11. Umbilical view,  $\times 100$ .  
Sample 397-34-1, 50-53 cm. Zone M Pl 3,  
Zanclean.
- Figures 12, 13 *Globigerinoides seigliei* Bermudez and Bolli.  
Two views of the same specimen:  
12. Umbilical view,  $\times 100$ .  
13. Spiral view,  $\times 100$ .  
Sample 397-61-6, 29-31 cm. Zone N.16,  
Tortonian.

PLATE 7

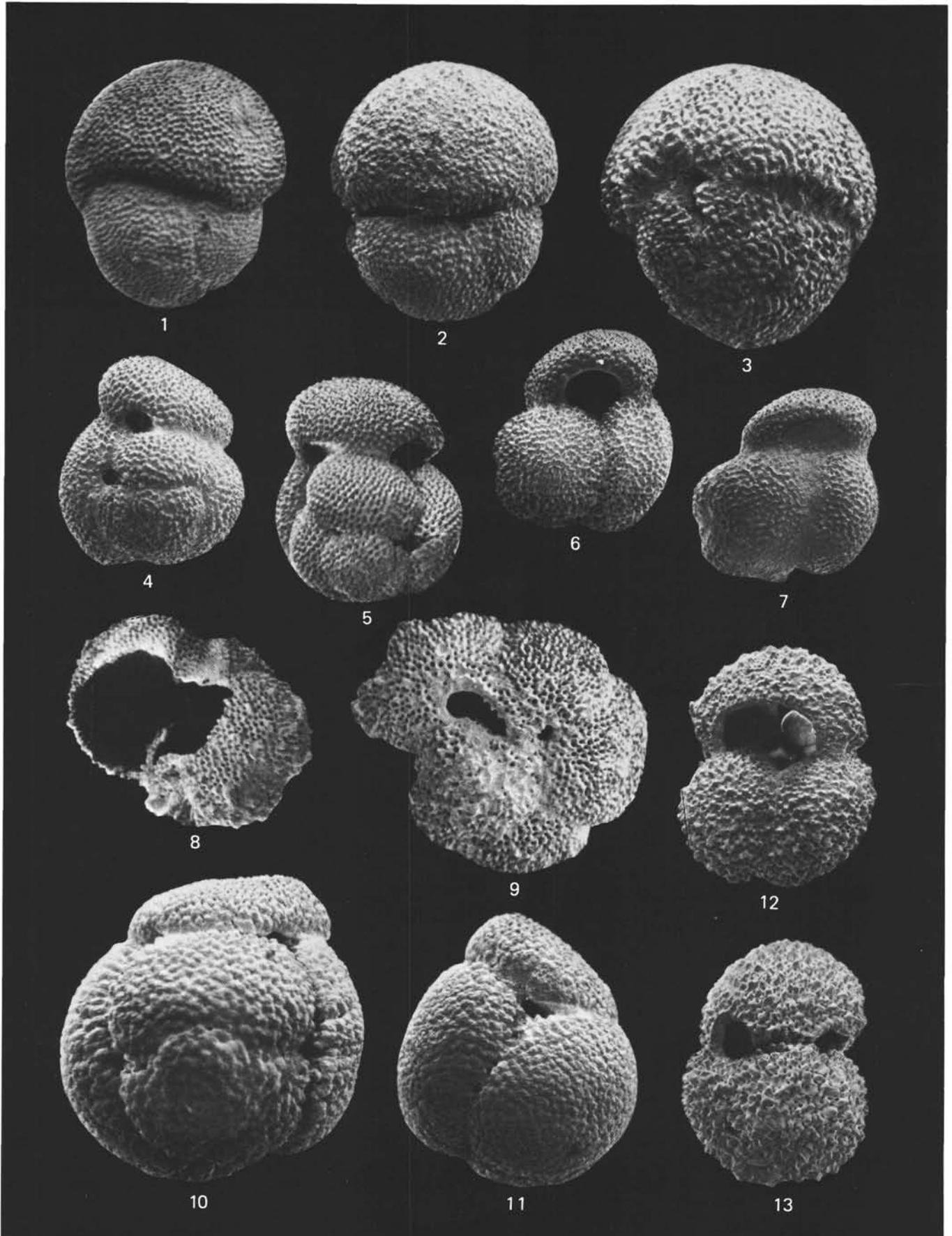


PLATE 8

- Figures 1, 2 *Globigerinoides subquadratus* Brönnimann.  
1. Umbilical view,  $\times 100$ .  
2. Spiral view,  $\times 100$ . Sample 397-92, CC. Zone N.7, Burdigalian.
- Figure 3 *Globigerinoides obliquus extremus* Bolli and Bermúdez, Umbilical view,  $\times 100$ .  
Sample 397-38-5, 50-53 cm. *Globigerina nepenthes* Zone, Zanclean.
- Figure 4 *Globigerinoides obliquus obliquus* Bolli.  
Umbilical view,  $\times 100$ . Sample 397-70-3, 49-52 cm. Zone N.16, Tortonian.
- Figure 5 *Globigerinoides emeisi* Bolli.  
Umbilical view,  $\times 100$ . Sample 397-34-3, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 6-9 *Globigerinoides quadrilobatus altiaperaturus* Bolli.  
6. Umbilical view,  $\times 100$ . Sample 397-97, CC. Zone N.7, Burdigalian.  
7. Umbilical view,  $\times 100$ . Sample 397-94-1, 2-24 cm. Zone N.7, Burdigalian.  
Two views of the same specimen:  
8. Spiral view,  $\times 100$ .  
9. Side view,  $\times 100$ . Sample 397-97-1, 40-43 cm. Zone N.7, Burdigalian.
- Figures 10, 11 *Globigerinoides bulloideus* Crescenti.  
10. Umbilical view,  $\times 100$ .  
11. Spiral view,  $\times 100$ . Sample 397-54-6, 19-21 cm. Zone N.16, Tortonian.
- Figures 12, 13 *Globigerinoides bollii* Blow.  
12. Umbilical view,  $\times 100$ . Sample 397-60-2, 50-53 cm. Zone N.16, Tortonian.  
13. Spiral view,  $\times 100$ . Sample 397-66-4, 53-57 cm. Zone N.16, Tortonian.
- Figures 14, 15 *Globigerinoides diminutus* Bolli.  
14. Umbilical view,  $\times 100$ . Sample 397-90, CC. Zone N.7, Burdigalian.  
15. Side oblique view,  $\times 100$ . Sample 397-92-3, 125-128 cm. Zone N.7, Burdigalian.
- Figures 16-19 *Globorotalia* sp.  
16. Umbilical view,  $\times 100$ . Sample 397-60-3, 106-108 cm. Zone N.16, Tortonian.  
17. Umbilical view,  $\times 100$ .  
19. Side view,  $\times 100$ . Sample 397-57-4, 50-52 cm. Zone N.16, Tortonian.  
18. Spiral view,  $\times 100$ . Sample 397-56-2, 50-53 cm. Zone N.16, Tortonian.
- Figures 20-22 *Globorotalia incisa* Brönnimann and Resig.  
Umbilical views,  $\times 100$ . Sample 397-34-3, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 23, 24 *Globorotalia clemenciae* Bermúdez.  
23. Umbilical view,  $\times 100$ . Sample 397-60-3, 106-108 cm. Slump within Zone N.16.  
24. Spiral view,  $\times 100$ . Sample 397-86-1. 38-42 cm. Zone N.8, Langhian.

PLATE 8

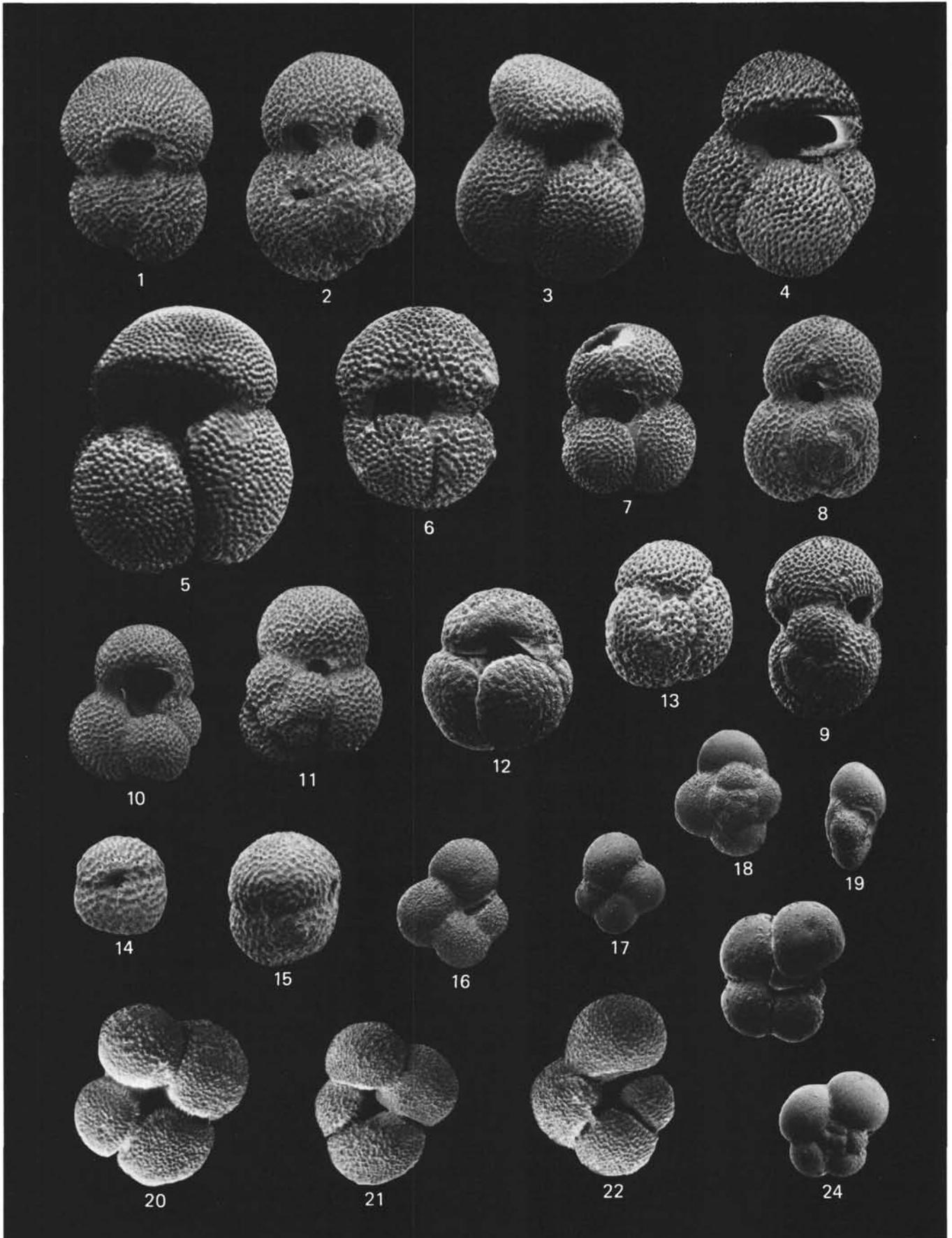


PLATE 9

- Figure 1 *Globorotalia obesa* Bolli.  
Spiral view,  $\times 100$ . Sample 397-68, CC. Zone N.16, Tortonian.
- Figures 2-4 *Globorotalia linguaensis* Bolli.  
2. Umbilical view,  $\times 100$ . Sample 397-58-1, 40-43 cm. Zone N.16, Tortonian.  
3. Umbilical view,  $\times 100$ .  
4. Spiral view,  $\times 100$ . Sample 397-63, CC. Zone N.16, Tortonian.
- Figures 6-8 *Globorotalia bella* Jenkins.  
Three views of the same specimen.  
6. Umbilical view,  $\times 100$ .  
7. Spiral view,  $\times 100$ .  
8. Side view,  $\times 100$ . Sample 397-87, CC. Zone N.8. Langhian.
- Figures 5, 9, 12-14 *Globorotalia mayeri* Cushman and Ellisor.  
5. Side view,  $\times 100$ .  
9. Umbilical view,  $\times 100$ .  
12. Spiral view,  $\times 100$ . Sample 397-61-5, 55-57 cm. Slump within Zone N.16.  
Two views of the same specimen:  
13. Umbilical view,  $\times 100$ .  
14. Spiral view,  $\times 100$ . Sample 397-72, CC. Zone N.13, Serravallian.
- Figures 10, 15, 16 *Globorotalia birnageae* Blow.  
10, 15. Umbilical views,  $\times 100$ . Sample 397-94-1, 22-24 cm. Zone N.7, Burdigalian.  
16. Spiral view,  $\times 100$ . Sample 397-84-4, 10-14 cm. Zone N.8, Langhian.
- Figures 11, 17, 18 *Globorotalia partimlabiata* Ruggieri and Sprovieri.  
11. Side view,  $\times 100$ .  
17. Umbilical view,  $\times 100$ .  
18. Spiral view,  $\times 100$ . Sample 397-58-3, 38-40 cm. Slump within Zone N.16.
- Figures 19-21 *Globorotalia acrostoma* Wezel.  
19. Umbilical view,  $\times 100$ . Sample 397-87, CC. Zone N.8, Langhian.  
20. Umbilical view,  $\times 100$ . Sample 397-97-1, 40-43 cm. Zone N.7, Burdigalian.  
21. Spiral view,  $\times 100$ . Sample 397-90, CC. Zone N.7, Burdigalian.
- Figures 22-24 *Globorotalia puncticulata* (Deshayes).  
22. Umbilical view,  $\times 100$ . Sample 397-34-5, 50-53 cm. Zone M Pl 3, Zanclean.  
Two views of the same specimen:  
23. Spiral view,  $\times 100$ .  
24. Side view,  $\times 100$ . Sample 397-34-5, 50-53 cm. Zone M Pl 3, Zanclean.
- Figure 25 *Globorotalia crassaformis crassaformis* (Galloway and Wissler).  
Umbilical view,  $\times 100$ . Sample 397-34-5, 50-53 cm. Zone M Pl 3, Zanclean.

PLATE 9

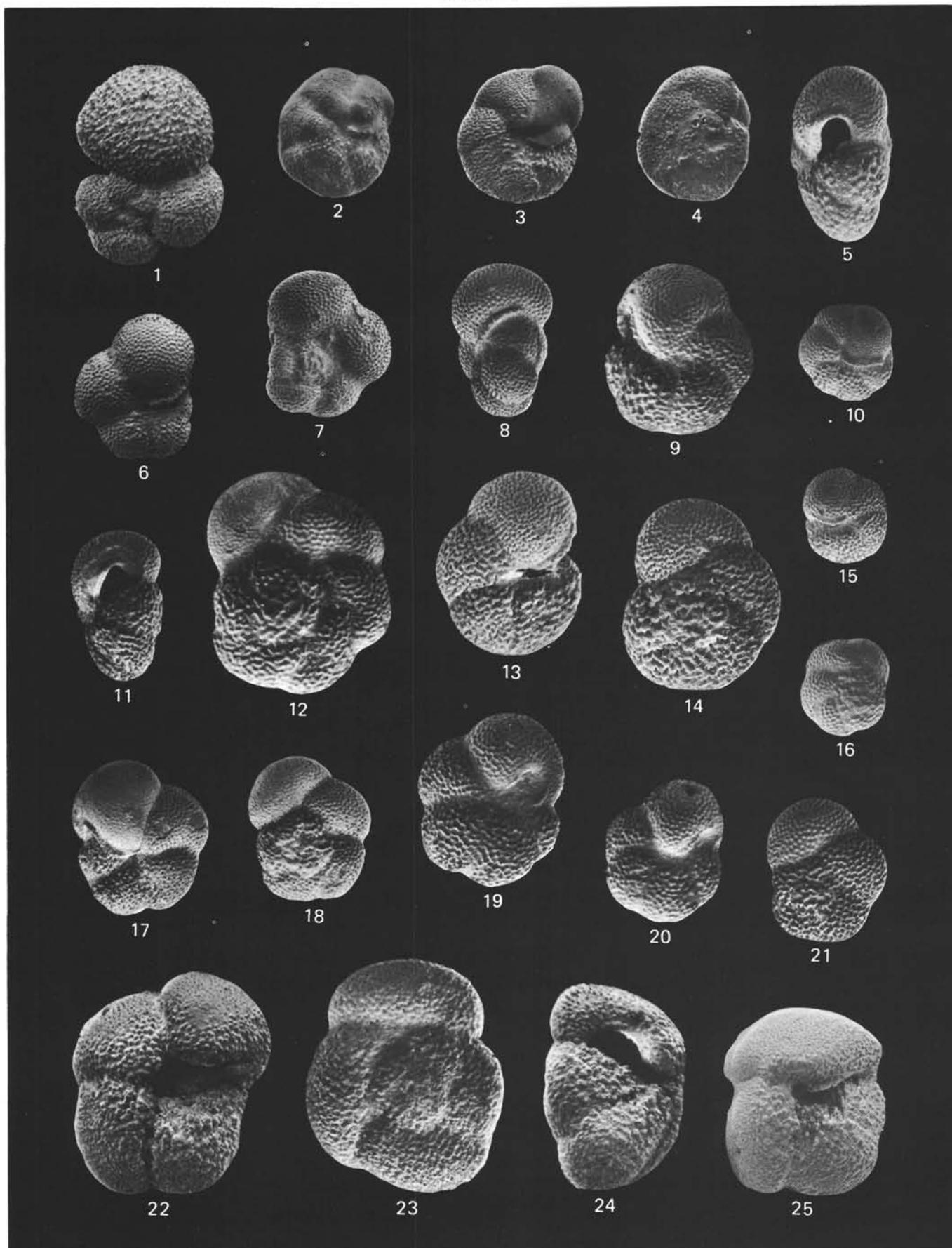


PLATE 10

- Figures 1, 2 *Globorotalia crassaformis crassaformis* (Galloway and Wissler).  
Two views of the same specimen:  
1. Spiral view,  $\times 100$ .  
2. Side view,  $\times 100$ . Sample 397-34-5, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 3, 4 *Globorotalia continuosa*.  
3. Umbilical view,  $\times 100$ .  
4. Side view,  $\times 100$ . Sample 397-69-4, 50-53 cm. Zone N.16, Tortonian.
- Figures 5, 6 *Globorotalia acostaensis* Blow.  
5. Umbilical view,  $\times 100$ . Sample 397-66-2, 50-52 cm. Zone N.16, Tortonian.  
6. Umbilical view,  $\times 100$ . Sample 397-70-1, 49-51 cm. Zone N.16, Tortonian.
- Figures 7, 8 *Globorotalia humerosa praeumerosa* natori.  
Umbilical views,  $\times 100$ . Sample 397-61-5, 15-17 cm. Zone N.16, Tortonian.
- Figures 9, 10 *Globorotalia humerosa humerosa* Takayanagi and Saito.  
Umbilical views,  $\times 100$ . Sample 397-34-4, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 11-13 *Globorotalia siakensis* Le Roy.  
11. Umbilical view,  $\times 100$ . Sample 397-61-4, 135-137 cm. Slump within Zone N.16.  
12. Umbilical view of a reworked specimen,  $\times 100$ . Sample 397-69-2, 56-59 cm. Zone N.16, Tortonian.  
13. Umbilical view,  $\times 100$ . Sample 397-72-1, 51-53 cm. Zone N.14, Serravallian.
- Figures 14, 15 *Globorotalia mineacea* Bermúdez and Bolli.  
14. Umbilical view,  $\times 100$ .  
15. Spiral view,  $\times 100$ . Sample 397-43-2, 40-43 cm. *Globigerina nepenthes* Zone, Messinian.
- Figures 16-18 *Negloboquadrina dutertrei* s.l.  
16,17. Umbilical views,  $\times 100$ . Sample 397-41-3, 50-53 cm. *Globigerina nepenthes* Zone, Zanclean.  
18. Umbilical view,  $\times 100$ . Sample 397-34-6, 40-43 cm. Zone M Pl 3, Zanclean.
- Figure 19 *Globorotalia scitula* (Brady).  
Umbilical view,  $\times 100$ . Sample 397-39-2, 50-52 cm. *Globigerina nepenthes* Zone, Zanclean.
- Figures 20, 21 *Globorotalia margaritae margaritae* Bolli and Bermúdez.  
20. Umbilical view,  $\times 100$ . Sample 397-37-3, 51-53 cm. *Globigerina nepenthes* Zone, Zanclean.  
21. Spiral view,  $\times 100$ . Sample 397-35 CC. Zone M Pl 3, Zanclean.

## PLATE 10

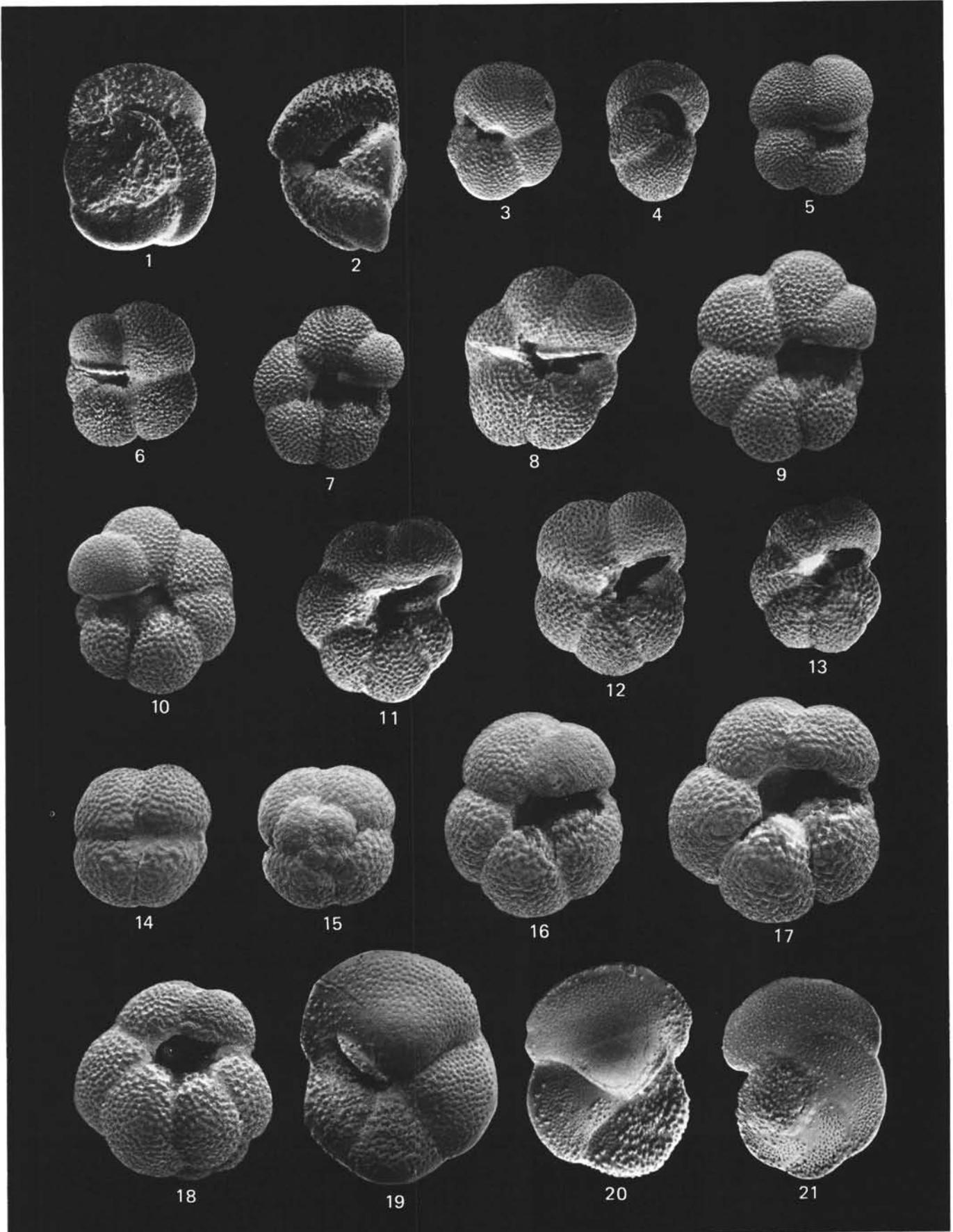


PLATE 11

- Figures 1-3 *Globorotalia peripheroronda* Blow and Banner.  
1. Umbilical view,  $\times 100$ .  
2. Spiral view,  $\times 100$ . Sample 397-85, CC. Zone N.8, Langhian.  
3. Side view,  $\times 100$ . Sample 397-90, CC. Zone N.7, Burdigalian.
- Figures 4-6, 10 *Globorotalia peripheroacuta* Blow and Banner.  
4. Umbilical view,  $\times 100$ .  
5. Side view,  $\times 100$ . Sample 397-77-3, 44-46 cm. Zone N.11 (N.10?), Serravallian.
- Two views of the same specimen:  
6. Side view,  $\times 100$ .  
10. Spiral view,  $\times 100$ . Sample 397-76-3, 43-45 cm. Zone N.11, Serravallian.
- Figures 7-9 *Globorotalia praefohsi* Blow and Banner.  
7. Side view,  $\times 100$ . Sample 397-76, CC. Zone N.11, Serravallian.
- Two views of the same specimen:  
8. Umbilical view,  $\times 100$ .  
9. Side view,  $\times 100$ . Sample 397-76, CC. Zone N.11, Serravallian.
- Figures 11-16, 19 *Globorotalia fohsi* s.l.  
Two views of the same specimen:  
11. Umbilical view,  $\times 100$ .  
12. Side view,  $\times 100$ . Sample 397-73-1, 138-140 cm. Zone N.13, Serravallian.
- Two views of the same specimen:  
13. Spiral view,  $\times 100$ .  
14. Side views,  $\times 100$ . Sample 397-73-1, 138-140 cm. Zone N.13, Serravallian.
- Two views of the same specimen:  
15. Side view,  $\times 100$ .  
16. Umbilical view,  $\times 100$ . Sample 397-74-1, 50-52 cm. Zone N.13, Serravallian.  
19. Spiral view,  $\times 100$ . Sample 397-74-1, 50-52 cm. Zone N.13, Serravallian.
- Figures 17, 18 *Globorotalia praefohsi* Blow and Banner.  
Two views of the same specimen:  
17. Umbilical view,  $\times 100$ .  
18. Spiral view,  $\times 100$ .  
Sample 397-58-3, 38-40 cm. Slump within Zone N.16.

PLATE 11

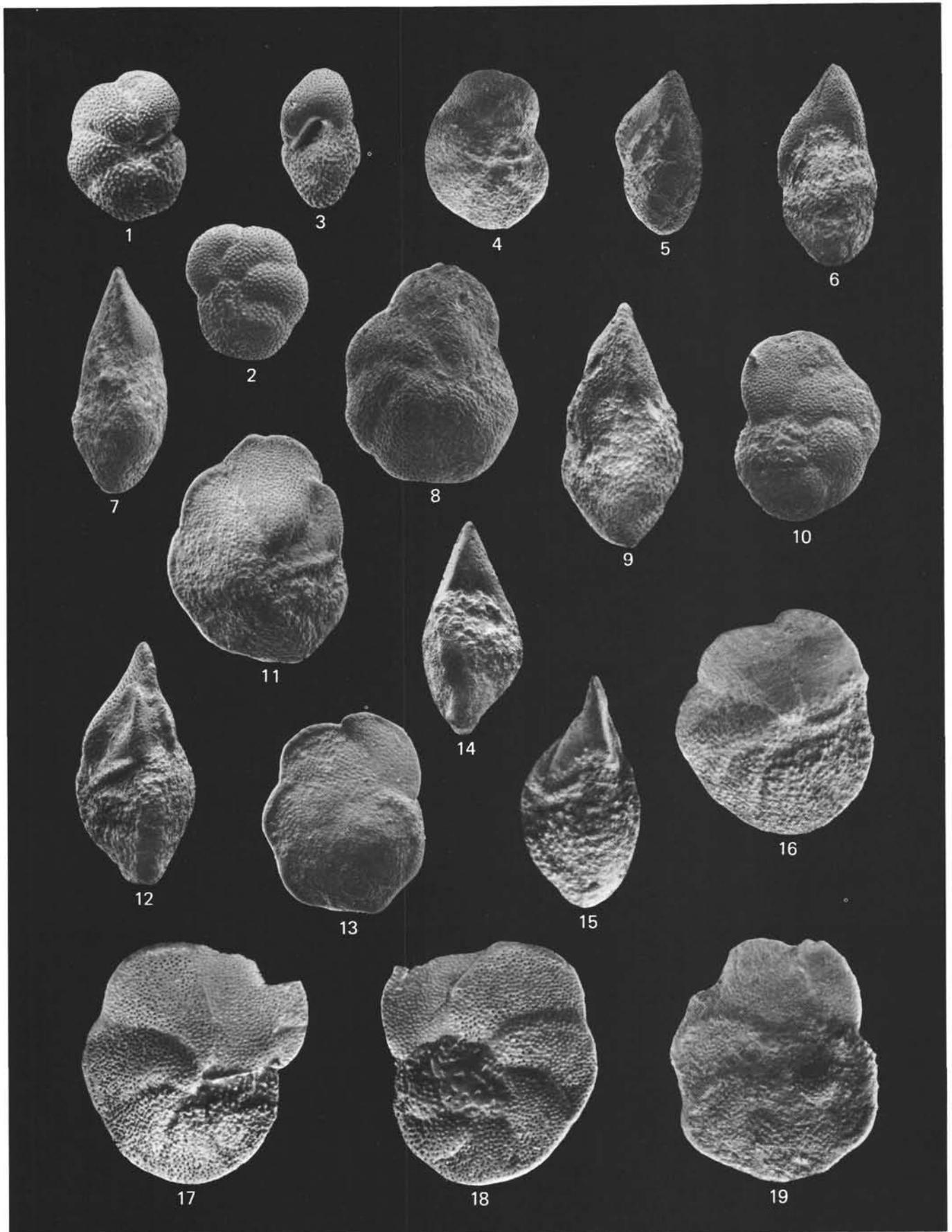


PLATE 12

- Figures 1, 2, 5 *Globorotalia fohsi*.  
1. Spiral view of the specimens in Figures 11 and 12 of Plate 11,  $\times 100$ . Sample 397-73-1, 138-140 cm. Zone N.13, Serravallian.  
2. Spiral view,  $\times 100$ .  
5. Spiral view,  $\times 100$ . Sample 397-58-3, 38-40 cm. Slump within Zone N.16.
- Figures 3, 4, 9 *Globorotalia miotumida* Jenkins.  
3. Umbilical view,  $\times 100$ .  
9. Spiral view,  $\times 100$ . Sample 397-48-3, 26-28 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone, Messinian.  
4. Side view,  $\times 100$ . Sample 397-47-2, 50-52 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone, Messinian.
- Figures 6-8 *Globorotalia* aff. *ungulata* Bermúdez.  
Three views of the same specimen:  
6. Umbilical view,  $\times 100$ .  
7. Side view,  $\times 100$ .  
8. Spiral view,  $\times 100$ . Sample 397-34-3, 50-53 cm. Zone M Pl 3, Zanclean.
- Figures 10-14, 19 *Globorotalia tumida plesiotumida* Blow and Banner.  
Three views of the same specimen:  
10. Umbilical view,  $\times 100$ .  
14. Spiral view,  $\times 100$ .  
19. Side view,  $\times 100$ . Sample 397-47-4, 50-52 cm. *Sphaeroidinellopsis seminulina paenedehiscens* Zone, Messinian.  
Two views of the same specimen:  
11. Umbilical view,  $\times 100$ .  
13. Side view,  $\times 100$ . Sample 397-43-6, 40-43 cm. *Globigerina nepenthes* Zone, Messinian.  
12. Spiral view,  $\times 100$ . Sample 397-43-6, 40-43 cm. *Globigerina nepenthes* Zone, Messinian.
- Figures 15-17 *Globorotalia merotumida* Blow and Banner.  
Three views of the same specimen:  
15. Umbilical view,  $\times 100$ .  
16. Spiral view,  $\times 100$ .  
17. Side view,  $\times 100$ . Sample 397-67-2, 50-52 cm. Zone N.16, Tortonian.
- Figure 18 *Globorotalia* cf. *miozea miozea* Finlay.  
Spiral view,  $\times 100$ . Sample 397-85-4, 126-128 cm. Zone N.8, Langhian.

PLATE 12



PLATE 13

- Figure 1 *Globorotalia cf. miozea miozea* Finlay.  
Umbilical view,  $\times 100$ .  
Sample 397-93-3, 3-5 cm. Zone N.7, Burdigalian.
- Figures 2-4 *Globorotalia miozea miozea* Finlay.  
2. Umbilical view,  $\times 100$ .  
3. Spiral view,  $\times 100$ .  
4. Side view,  $\times 100$ .  
Sample 397-77-2, 60-63 cm. Zone N.11 (N.10?),  
Serravallian.
- Figures 5-8 *Globorotalia praescitula* Blow.  
5. Umbilical view,  $\times 100$ .  
Sample 397-86-1, 38-42 cm. Zone N.8, Langhian.  
Three views of the same specimen:  
6. Umbilical view,  $\times 100$ .  
7. Spiral view,  $\times 100$ .  
8. Side view,  $\times 100$ .  
Sample 397-86-1, 38-42 cm. Zone N.8, Langhian.
- Figures 9-13 *Globorotalia praemenardii archeomenardii* Bolli.  
9. Umbilical view,  $\times 100$ .  
10. Side view,  $\times 100$ .  
Sample 397-80-2, 52-54 cm. Zone N.8, Langhian.  
11. Spiral view,  $\times 100$ .  
Sample 397-78, CC. Zone N.8, Langhian.  
Two views of the same specimen:  
12. Spiral view,  $\times 100$ .  
13. Side view,  $\times 100$ .  
Sample 397-78, CC. Zone N.8, Langhian.
- Figures 14-21 *Globorotalia praemenardii praemenardii* Cushman and Stainforth.  
14. Spiral view,  $\times 100$ .  
Sample 397-75, CC. Zone N.12, Serravallian.  
Three views of the same specimen:  
15. Umbilical view,  $\times 100$ .  
16. Spiral view,  $\times 100$ .  
17. Side view,  $\times 100$ .  
Sample 397-74-2, 68-70 cm. Zone N.12, Serravallian.  
18. Spiral view,  $\times 100$ .  
Sample 397-76-3, 43-45 cm. Zone N. 11, Serravallian.  
Three views of the same specimen:  
19. Umbilical view,  $\times 100$ .  
20. Side view,  $\times 100$ .  
21. Spiral view,  $\times 100$ .  
Sample 397-76-1, 95-97 cm. Zone N.11, Serravallian.

PLATE 13

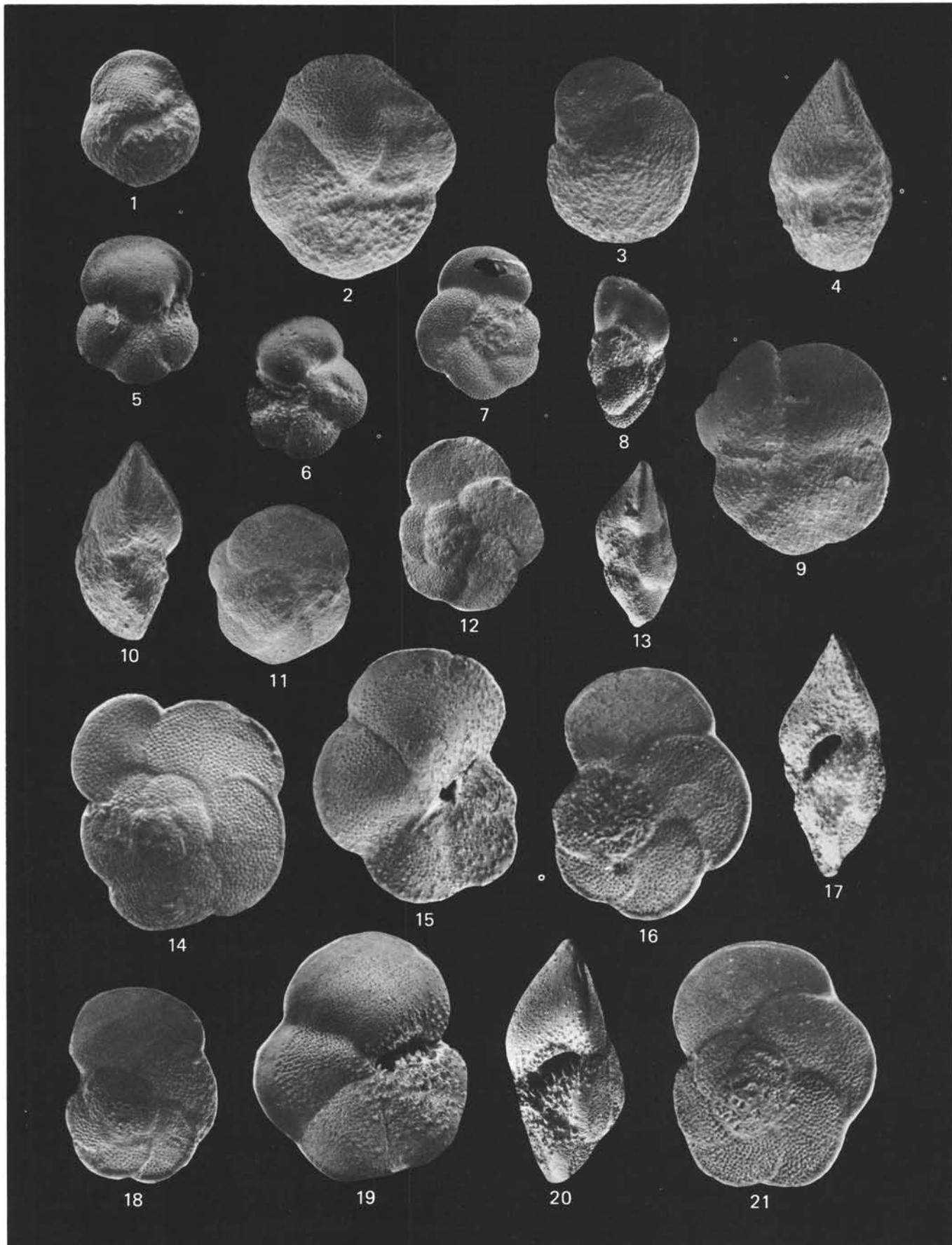


PLATE 14

- Figure 1 *Globorotalia praemenardii praemenardii* Cushman and Stainforth.  
Spiral view,  $\times 100$ .  
Sample 397-77, CC. Zone N.11 (N.10?), Serravallian.
- Figures 2-4, 6 *Globorotalia cultrata* s.l.  
Three views of the same specimen:  
2. Spiral view,  $\times 100$ .  
3. Side view,  $\times 100$ .  
6. Umbilical view,  $\times 100$ .  
Sample 397-67-1, 49-52 cm. Zone N.16, Tortonian.  
4. Spiral view,  $\times 50$ .  
Sample 397-61-2, 60-63 cm. Zone N. 16, Tortonian.
- Figures 5, 7, 8 *Globorotalia multicamerata* Cushman and Jarvis.  
5. Spiral view,  $\times 100$ .  
8. Umbilical view,  $\times 100$ .  
Sample 397-34-1, 50-53 cm. Zone M Pl 3, Zanclean.  
7. Spiral view,  $\times 100$ .  
Sample 397-38-5, 50-53 cm. *Globigerina nepenthes* Zone, Zanclean.

PLATE 14

