28. QUATERNARY PLANKTONIC FORAMINIFERS OF THE SOUTHWESTERN ATLANTIC (RIO GRANDE RISE) DEEP SEA DRILLING PROJECT LEG 72[1]

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ABSTRACT

Quaternary sediments were recovered at all four Sites at Leg 72. Planktonic foraminifers were abundant and well preserved, especially in the holes shielded from Antarctic Bottom Water (AABW) influence. The fauna belonged to the subtropical province marked by *Globigerinoides ruber* and to a lesser extent by *Globorotalia inflata*. Thirty planktonic foraminiferal species were distinguished, and a detailed study of the Site 517 stratigraphy was made.

The Quaternary sequence of the Rio Grande Rise was subdivided slightly differently from the Bolli and Premoli Silva (1973) pattern. Five subzones were identified but some difficulties arose when a precise correlation became necessary in the subzones of the tropical provinces. Correlations could nevertheless be made, particularly with respect to the earliest Quaternary.

Quaternary faunal data have been dated by isotopic stratigraphy (Vergnaud Grazzini et al., this volume) and partially contradict results previously published for this part of the Atlantic (Williams and Ledbetter, 1979).

By studying the occurrence of planktonic foraminifers, we obtained more information about hydrologic variations during the Quaternary sequence of Hole 517; two broad periods were recognized. Finally, we identified the interaction between the Brazil Current and the subtropical convergence.

INTRODUCTION

During the Deep Sea Drilling Project Leg 72, Quaternary sediments were recovered for 4 sites off the Brazilian coast (Fig. 1, Table 1).

These different sites were selected in order to examine a range of paleodepths around the Rio Grande Rise for analysis of changes in paleoenvironments in the southwestern Atlantic. The profile of sites includes Site 516 on the upper part of the Rio Grande Rise (water depth 1313 m), Site 517 on the west flank (depth 2963 m), Site 518 (depth 3944 m), and Site 515 in the Brazil Basin (depth 4250 m). The sites are situated within transition zones between major water masses and at the "core" of North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW). Site 516 was positioned between the Antarctic Intermediate Water (AAIW) and NADW, Site 517 in NADW, Site 518 between the NADW and AABW, and finally Site 515 was located in the AABW.

The deep-sea environment, particularly depth and water aggressivity, determines indirectly the degree of dissolution of calcareous deposits and the distribution of biologic remains on the sea floor. The Quaternary sediments recovered in the uppermost lithologic units of these holes were mainly biogenic oozes, with the exception of the dominance of gray brown terrigenous mud at Site 515. In the shallower holes (Sites 516 and 517), planktonic foraminifers are abundant and well preserved. At Site 515, and to a less degree at Site 518, the dissolution of planktonic microfauna is so strong that it is difficult to make any definitive interpretations.

For several reasons, Site 517 was chosen as a reference for analyzing marine Quaternary sediments of Leg 72. First, this site has the best continuous sedimentary series of about 25 m length. Secondly, the planktonic foraminifers are abundant and well preserved. Lastly, this site is located in the present NADW (Reid and others, 1977).

The purpose of this study of planktonic foraminifers is to explore the Quaternary sequences of the southwestern Atlantic, in order to determine the biostratigraphy of these series and interpret hydrologic and paleoclimatic factors from Site 517.

BIOSTRATIGRAPHIC INVESTIGATION

METHODS

In our standard section (Site 517), a 10-cm^3 sample was taken every 10 cm. In Sites 515, 516, and 518, the core catcher and only one sample for each section were examined. These samples were washed, coarse-fraction dried, and separated for planktonic microfaunal analysis. For each level the residue was microsplit and 4 groups of percentages were established: rare (0–4%), few (5–9%), common (10–29%), and abundant (more than 30%).

Planktonic Foraminifers

Due to the geographic position of the sites, the uppermost foraminiferal assemblages can be attributed to the subtropical province. Nowadays, the dominant living species (Bé, 1977) are: *Globigerinoides ruber* and to a lesser extent *Globigerina bulloides*. The same species occur in the superficial sediments (Boltovskoy, 1973), but with a considerable increase in the relative abundance of the transitional species and/or winter subtropical species *Globorotalia inflata* and *Globigerina pachyderma*.

The following species of planktonic foraminifers occur in the Quaternary sediments: *Candeina nitida, Globigerina bulloides, G. calida, G. digitata, G. eggeri, G. falconensis, G. pachyderma* left coiling, *G. pachyderma* right coiling, *G. quinqueloba, G. rubescens* group, *Glo-*

[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

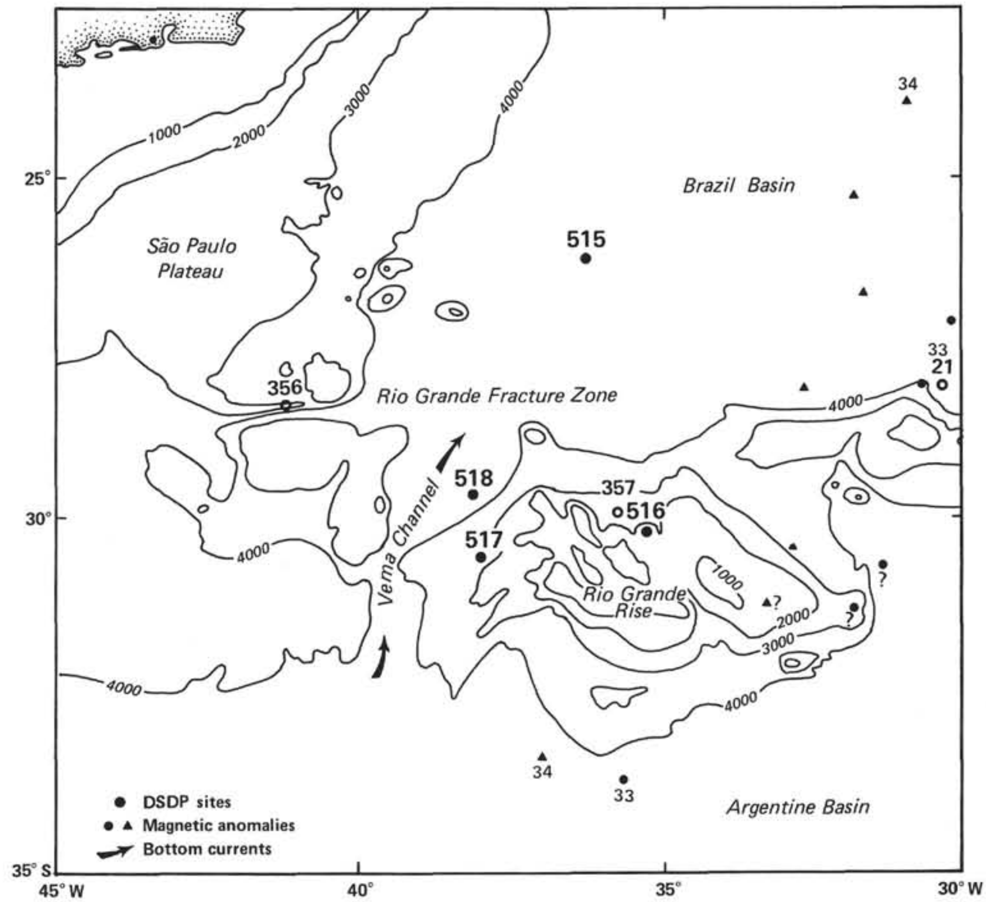

Figure 1. Location map showing Leg 72 sites.

Table 1. Data on the Quaternary sequences of Leg 72 Holes.

Holes	Latitude (S)	Longitude (W)	Water depth (m)	Drilled in Quaternary (m)	No. of samples used
515	26°14′33	36°30′17	4250.4	49.0	6
515A	26°14′31	36°30′17	4252.0	42.0	21
516	30°16′58	35°17′11	1313.0	7.2	11
516A	30°16′59	35°17′12	1313.0	12	8
517	30°56′81	38°02′47	2963.0	24	100
518	29°58′42	38°08′12	3944.0	19	20

bigerinita glutinata, Globigerinoides conglobatus, G. ruber (white), *G. ruber* (pink), *G. trilobus, G. sacculifer, Globorotalia crassaformis* group, *G. crassula, G. hirsuta, G. inflata, G. menardii* group, *G. scitula, G. tosaensis, G. triangula, G. truncatulinoides* left-coiling, *G. truncatulinoides* right-coiling, *Globorotaloides hexagona, Hastigerina siphonifera, Orbulina universa, Pulleniatina obliquiloculata, Sphaeroidinella dehiscens.* Some of them are differentiated in morphotypes, whereas others are grouped together.

Quaternary Zonation

Establishment of the biostratigraphic scale based on planktonic foraminifers depends upon several criteria (Hedberg, 1972), mainly the extinctions and/or appearances of taxa. In the Quaternary, the faunal stock of the lower Pleistocene persists even today (Berggren, 1969). The faunal frequency changes, and disappearances and appearances reflect environment modifications (Pujol, 1981). The extinction and nonevolutionary appearances of planktonic foraminifers are time transgressive from one ocean basin to another (Kennett, 1970).

Investigations of the Quaternary marine section in recent years has led to the creation of subdivisions (Blow, 1969; Lamb and Beard, 1972; Bolli and Premoli Silva, 1973). Several zonal patterns have in fact, been suggested for subdivisions of sediments of this age. The quality of the sample and the elements used determine the differences in these biozonations. In fact, biostratigraphic subdivisions of Quaternary sediments formed during a short geologic period (1.8 m.y.) could be considered only as *Globorotalia truncatulinoides* s.l. Zone. This zone is then subdivided into 2 subzones: *G. truncatulinoides* Partial Range Zone (N22) and *Globigerina calida calida–Sphaeroidinella excavata* Assemblage Zone (N23). This zonation scheme has been applied to much of the deep-sea drilling data. But when the sampling sequence is studied in detail, it is very difficult within temperate sites to discern the boundary between N23 and N22 zones.

With abundant Quaternary sediment, Bolli and Premoli Silva (1973) established the *Globorotalia truncatulinoides* Zone and its five subzones: *G. crassaformis viola, G. crassaformis hessi, Globigerina calida calida, G. bermudezi,* and *Globorotalia fimbriata.* These subzones have since been applied to sedimentary sections from the Mid-Atlantic Ridge (DSDP Legs 45 and 46; Krasheninnikov, 1978); near the western African coast (Leg 41; Pflaumann and Krasheninnikov, 1978) and in the Indian Ocean (Leg 27; Rögl, 1974). Such a wide geographic extension underlines the subzones' chronostratigraphic nature. A precise correlation with a Quaternary time scale is, however, hazardous, especially with the species *G. fimbriata* or *Globigerina bermudezi.* The juxtaposition of different biogenic variations (FAD = first appearance datum, or LAD = last appearance datum) with isotopic curves seems to have good stratigraphic value, especially in the upper part of the Quaternary (Berggren et al., 1980; Pujol, 1980).

Biozonation

The distribution of some taxa helped us to divide the *Globorotalia truncatulinoides* zone into five different subzones (Fig. 2). Variations in the frequency and in the coiling trends for this species provide some environmental indications but emphasize the subdivisions. This differentiation is based principally on 10-cm sampling intervals at Site 517. A comparison is then made with the other Leg 72 sites.

Subzone A

Definition. Range of *Globorotalia hirsuta.*

Remarks. *G. hirsuta* is a descendant of *G. praehirsuta* (Blow, 1969): "*G.* (*G.*) *hirsuta praehirsuta* gives rise to *G.* (*G.*) *hirsuta hirsuta* within the earlier parts of Zone N21". Yet, in the Quaternary sequences of the northeastern Atlantic, this species is only observed in the upper part of the Quaternary. It first appeared near the LAD of *Pseudoemiliania lacunosa* (Pujol, 1980), dated around 0.45 Ma (Thierstein et al., 1977).

The first *G. hirsuta* occurrence at Site 517 is in Sample 517-2-1, 120–122 cm. This level corresponds to Isotopic Stage 11 (Vergnaud Grazzini et al., this volume). Acceptance of the isotopic stratigraphy leads to an age estimate of about 400,000 yr. If only core catchers are analyzed, the LAD of *Pseudoemiliania lacunosa* is recognized in Core 517-2,CC (see site chapter, Site 517, this volume). Even through the FAD of *G. hirsuta* is located in Stage 11, its relative abundance increases in Sample 516-1-2, 80–82 cm. This level is situated in Isotopic Stage 7 (Vergnaud Grazzini et al., this volume), as is the FAD of this species in the Vema Channel (Williams and Ledbetter, 1979). The reason for stratigraphic difference is not clear, but it could be a result of the particular paleooceanography of the Vema Channel (Johnson et al., 1977; Ledbetter and Johnson, 1976).

The coiling trend of *G. hirsuta* also gives some biostratigraphic information (Pujol, 1975; Pujol and Duprat, 1977; Pujol, 1980). Today, this species shows a preference for a right coiling; in the last glacial stages (Isotopic Stages 2 and 4) it was dominantly left coiling, and between the LAD of *Pseudoemiliania lacunosa* and Isotopic Stage 5, it again shows a right-coiling dominance.

Only a right-coiling population occurs at Site 517. The absence of the left-coiling specimens in the upper cores could be due either to the nonrecovery of uppermost sediment or to the nonrecognition of the isotopic stages because of broad sampling. The first assumption seems to be the most probable one. The absence of *G. fimbriata* and *Globigerina bermudezi* (index taxon of the more recent subzones of Bolli and Premoli Silva, 1973) could suggest missing surficial sediment, but we think that this absence is only ecological. The biogeographic area of this species is located near the equator.

Subzone B

Definition. Interval between the decrease of the frequency of *Globorotalia crassaformis* and the first occurrence of *G. hirsuta.*

Remarks. In the Vema Channel, *G. crassaformis* disappears in Isotopic Stage 5 (120,000 yr. ago) (Williams and Ledbetter, 1979). This species occurs in the upper part of the Leg 72 holes. In Cores 517-1 and 517-2, the distribution of *G. crassaformis* is sporadic and its frequency very low, so it is difficult, if not impossible, to compare this distribution to the time scale given by Williams and Ledbetter (1979). Again, an increase of velocity of the AABW flowing through the Vema Channel could cause the disappearance of *G. crassaformis* in Isotopic Stage 5 (Ledbetter, 1979).

Subzone C

Definition. Interval between the LAD of *Globigerina eggeri* and the decrease of *Globorotalia crassaformis* group.

Remarks. As in the preceding subzone definition, the datum of this subzone base probably marks an ecozone.

Subzone D

Definition. Interval between the LAD of *Globorotalia crassula* (= *G. crassaformis viola*) and the last occurrence of *Globigerina eggeri.*

Remarks. Both *Globorotalia inflata* and *G. crassaformis* increase in relative abundance. This subzone is comparable to the *G. crassaformis hessi* Subzone (base) of Bolli and Premoli Silva (1973) and may reflect environmental conditions.

Subzone E

Definition. Interval between the FAD of *Globorotalia truncatulinoides* and the LAD of *G. crassula* (= *G. crassaformis viola*).

Remarks. *Globorotalia triangula* is present, and *G. tosaensis* is rare. Our definition of *G. crassula* also includes *G. crassaformis viola;* this subzone is biostratigraphically equivalent to the *G. crassaformis viola* Subzone of Bolli and Premoli Silva (1973).

Correlation of Leg 72 Sites

Recognition of the different subzones defined for Site 517 is difficult for the other sites of Leg 72, because of: 1) the low abundance of planktonic microfauna and/or their bad preservation (Holes 515, 515A, and 518); 2) low Quaternary sedimentation rate; 3) the restricted number of samples examined. Nonetheless, Figure 3 shows the distribution of subzones in the other holes.

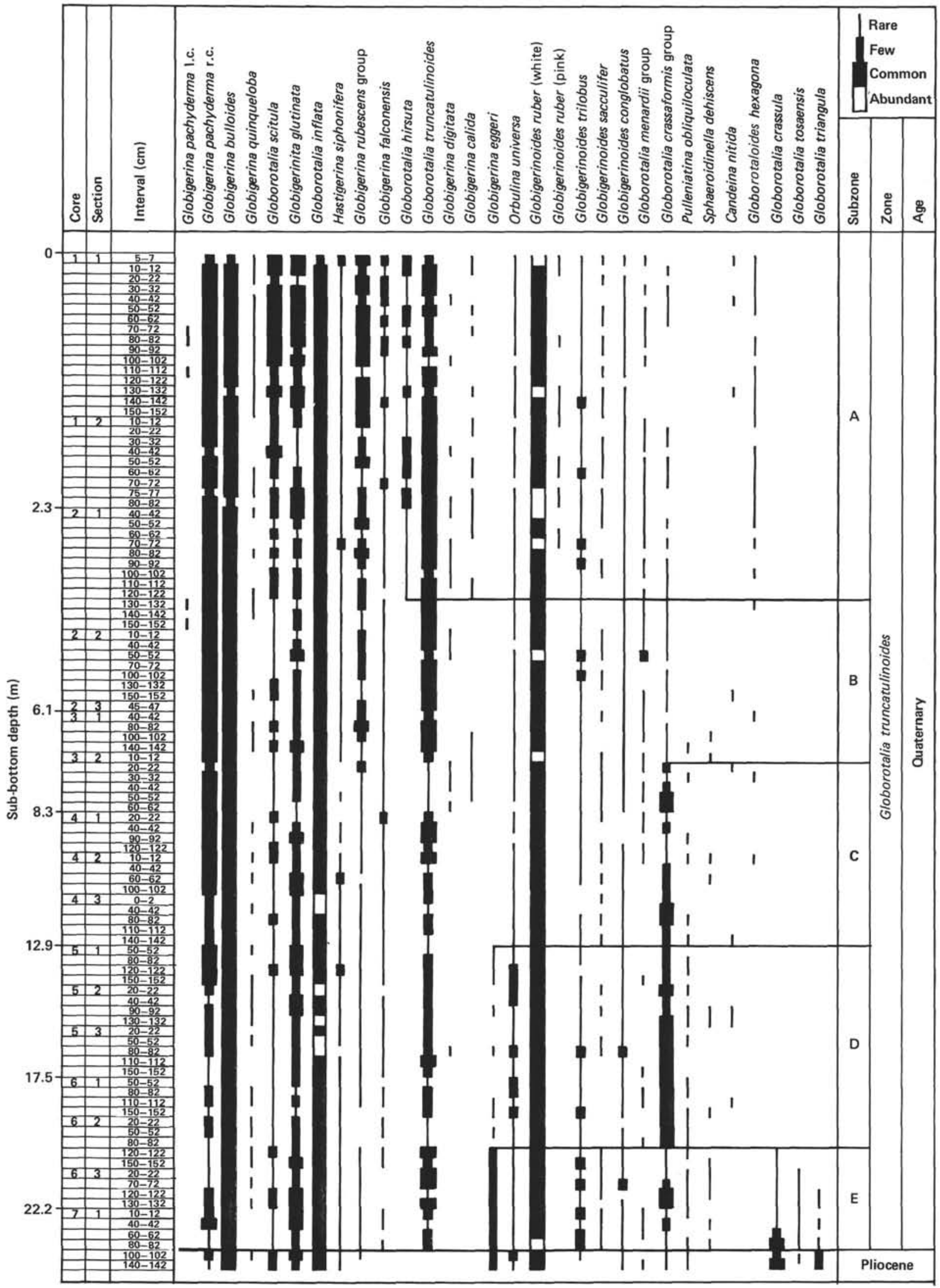

Figure 2. Quaternary biostratigraphy and planktonic foraminifers of Site 517 (Leg 72; southwestern Atlantic). Voids are excluded from the depth scale. l.c. = left coiling; r.c. = right coiling.

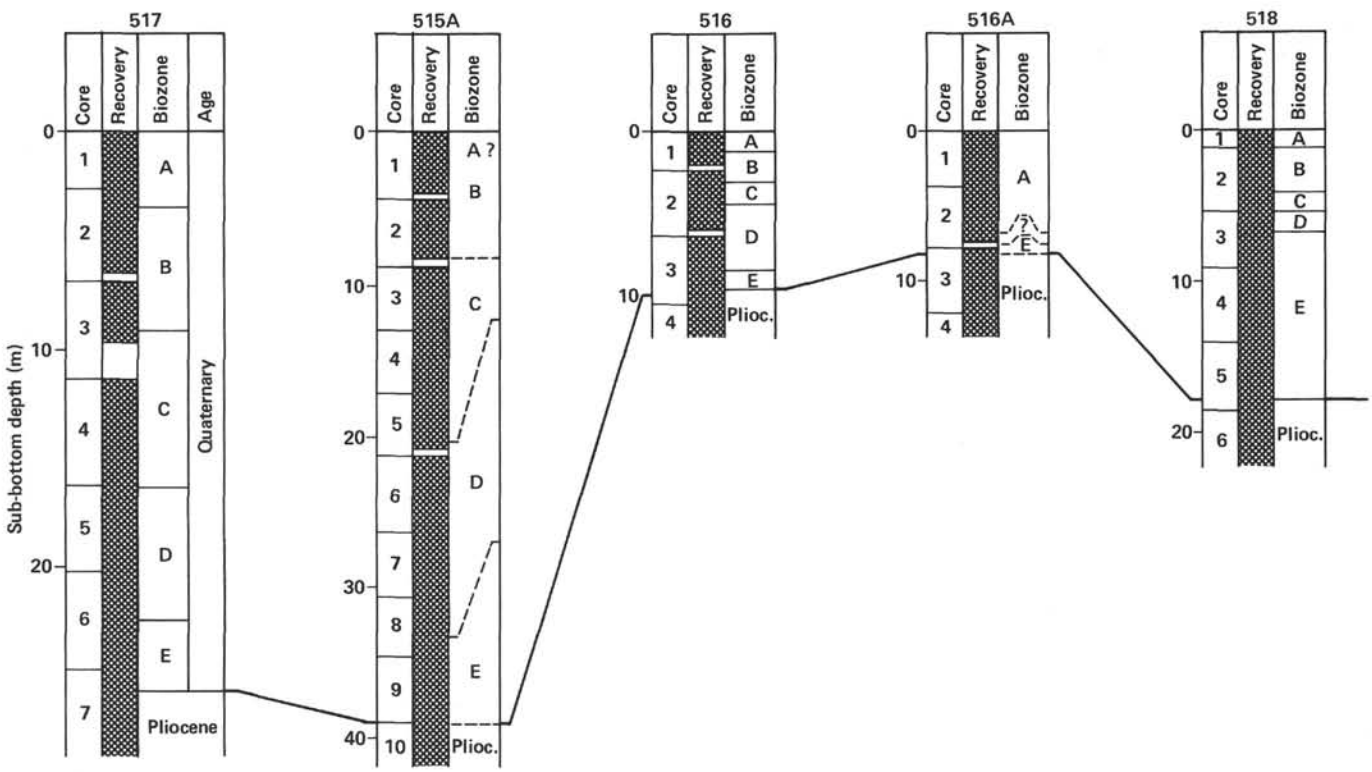

Figure 3. Biostratigraphic correlation of the Quaternary sequence in the southwestern Atlantic (Rio Grande Rise, Leg 72). (Plioc. = Pliocene.)

On the Rio Grande Rise (Holes 516 and 516A), *Globorotalia truncatulinoides* appears at Samples 516-3-2, 30–32 cm and 516A-2,CC (some contamination in Sample 516A-3,CC). Subzone A is recognized in the two holes. The planktonic microfauna are abundant, and the surface sediment contains many pteropods. Subzones B, C, and D do not occur in Hole 516A, but these three subzones can be recognized in Hole 516. *G. truncatulinoides* is left coiling in Subzones B and C but shows random coiling in Subzone D. *G. crassula* is observed in Section 516-3-2; *G. truncatulinoides* is again left coiling. The Quaternary sequence is about 9 m thick at Site 516, but is thicker on the west flank of the Rio Grande Rise (Site 517). *G. truncatulinoides* appears at about 25.3 m sub-bottom depth or 23 m depth if we take into account the percentage of sample recovered (Sample 517-7-1, 80–82 cm). The different subzones defined for Site 517 are adjusted to exclude the void spaces (Fig. 3).

In the southern Brazil Basin (Site 518), a good Quaternary sequence was retrieved from Core 518-1 to Sample 518-5-3, 70–72 cm. Some probable contamination exists in samples from Section 518-6-1, but the different subzones are identified. Planktonic foraminifers are abundant to common, and the preservation is generally good to moderate. Dissolution is low to high. It is especially high in Subzones D and E and at the base of Subzone A.

Within the Brazil Basin, Quaternary sediments were recovered in Holes 515 and 515A by the hydraulic piston corer (HPC). Assemblages in these cores are strongly dissolved. On the basis of the FAD *G. truncatulinoides*, Cores 515-1 and 515-2 are assessed to be Quaternary. Core 515-2 could belong to Subzone E (*G. triangula*). In Hole 515A, Cores 1 to 10 are Quaternary (42 m of sediment). Biostratigraphic differentiation is not possible.

Stratigraphic Interpretation

All subzones defined and based on planktonic foraminifers are correlated with Zones N22/N23 of Blow (1969). The appearance of *Globorotalia truncatulinoides* defines the base of the Quaternary. Because of the definition of the N22/N23 boundary, it is impossible to translate it in subzone terms. In fact, the definition of Zone N23 seems to contain some regional restrictions. When comparing established subzones with those of Bolli and Premoli Silva (1973), we can make some hypothetical correlations on the basis of species distribution. Our lower Quaternary Subzone E could be equivalent to the *G. crassaformis viola* Subzone. The frequency of the *G. crassaformis* group and the appearance of *Globigerina calida* at the base of Subzone E allow correlation of Subzones C and D to the *Globorotalia hessi* Subzone. Finally, Subzones A and B could be equivalent to the *Globigerina calida calida* Subzone. This implies the absence of the *G. bermudezi* and *Globorotalia fimbriata* Subzones, at least in Site 517.

Core 517-1 probably penetrated the sea floor interface at least 4 times before its retrieval, based on a repeated lithologic succession of gray pteropod-foraminiferal ooze. Sampling was avoided whenever there was repetition of coarse sand pteropod-rich laminae. This coring problem is perhaps a reason for the absence of the upper part of the Quaternary at Site 517 and for the difficulty in recognizing the last glacial stages, especially those marked by left-coiling *G. hirsuta*. Abundance of pink *Globigerinoides ruber* and pteropods, however, indicate that the surface sediment is Recent.

The combination of the sequence of species occurrence and oxygen isotope stratigraphy allows some age estimations. The first occurrence of *Globorotalia hirsuta* in Sample 517-2-1, 120–122 cm is near the LAD of *Pseudoemiliania lacunosa* (see site chapter, Site 517, this volume), indicating an age of about 400,000 yr. The increase of *G. hirsuta* slightly higher (Sample 517-1-2, 81–82 cm) probably correlates with its FAD in the Vema Channel beginning with Isotopic Stage 7 (Williams and Ledbetter, 1979). The presence of *Globorotaloides hexagona* in the surface sample and an apparent absence of left-coiling *Globorotalia hirsuta* indicate the absence of the last glacial sediment or mechanical coring perturbation of that deposit.

Oxygen isotope stratigraphy provides an additional stratigraphic framework. Emiliani (1955, 1966) numbered Quaternary planktonic foraminiferal Isotopic Stages 1 to 15, and Shackleton and Opdyke (1973, 1976) increased that number to 23 stages. Oxygen and carbon isotope analyses of benthic as well as planktonic foraminifers (Vergnaud Grazzini et al., this volume) also provided a good stratigraphic frame for Site 517. Thirty-seven isotopic stages corresponding to 19 glacial cycles have been identified. Our faunal zonation is directly related neither to these cycles nor to surface temperatures. Some major faunal changes, such as that of *G. crassaformis*, however, might correspond to important glacial advances (Isotopic Stage 22). Subzone E (Samples 517-7-1, 100 cm to 517-6-2, 110 cm) is also related to a time of minor glacial effect. Subzone D (Samples 517-6-2, 110 cm to 517-4-3, 150 cm) corresponds to Stages 34 to 25. An increase from 4 to about 5‰ in the $\delta^{18}O$ values occurs progressively throughout this subzone, reaching a maximum in Stage 22 at the base of the Subzone C (Samples 517-4-3, 140 cm to 517-3-2, 20 cm). Subzone B (Samples 517-3-2, 10 cm to 517-2-1, 120 cm) and A (Samples 517-2-1, 110 cm to 517-1-, 0–2.5 cm) are related to the last glacial cycle, to Stages 15 to 12, and Stages 11 to 1, respectively.

The paleomagnetic study of Hamilton and others (this volume) further refines a precise time scale of our biozonation and its correlation with the isotopic stratigraphy. The reversed interval immediately below 25 m sub-bottom correlates with the lower part of the Matuyama Epoch, defining Subzone E as the base of the Pleistocene. At about 15 m sub-bottom (Core 517-4), another change of polarity could represent the base of the Jaramillo, dated at about 0.94 Ma (Berggren et al., 1980). If we accept the isotopic stratigraphy (Vergnaud Grazzini et al., this volume), the Jaramillo Event should bracket Isotopic Stage 24; this estimate permits a more precise assignment of this age to the interval between Samples 517-4-3, 100 cm and 517-4-3, 180 cm.

The Brunhes-Matuyama (0.73 Ma) reversal is placed between Cores 517-3 and 517-4 (Hamilton et al., this volume). But the location of the Brunhes/Matuyama boundary at the transition from Stage 19 to Stage 20 permits us to assign this age to Sample 517-4-2, 10 cm (Vergnaud Grazzini et al., this volume), and to calculate an average sedimentation rate of 1–3 cm/10^3 yr. for the upper part of the sequence. These results are summarized in Figure 4 and are in good agreement with the placement of events proposed by Hamilton and others (this volume.

ENVIRONMENTAL INVESTIGATIONS

Oceanographic Setting

The circulation in the South Atlantic Ocean includes large subtropical anticyclonic gyre roughly similar to that seen in other oceans. This gyre is bounded on the east by the Benguela Current, on the north by the South Equatorial Current, on the west by the Brazil Current, and on the south by Westwind Drift.

The different sites of Leg 72, particularly Site 517 from which a detailed study of planktonic foraminifers is made, are located in the Brazil Current (Fig. 5). The Brazil Current transports South Equatorial Water southward along the east coast of South America. It meets the cold, northward-flowing Falkland Current at approximately 35°S, and the two swing eastward to form the South Atlantic Current. Thus, at about 35 to 38°S, the Brazil Current reaches the subtropical convergence.

The temperature of the surface water of the Brazil Current near the Rio Grande Rise varies throughout the year between 20 and 25°C, but at a depth of about 100 m, it remains at a constant 20°C. Surface salinity is 36.5‰ in January and 36‰ in August and is stable at about 36‰ at 100 m depth.

Principally, a subtropical microfauna with a low percentage of subantarctic elements inhabit the surface waters of the Leg 72 study area today. Species typical of subtropical waters are: *Globigerinoides trilobus, G. ruber, Globorotalia menardii*, and *Hastigerina siphonifera* (Boltovskoy, 1970; Lena and Watanabei, 1981). In waters near the Brazil coast or in those forming the prolongation of the Falkland Current *Globigerinoides ruber* increases and *H. siphonifera* decreases in relative abundance (Boltovskoy, 1970).

Different studies of the plankton collected in the South Atlantic (Bé and Tolderlund, 1971; Bé, 1977; Boltovskoy, 1968, 1970, 1976) spot the absence and occurrence of the more important species. Among the key species not present in the biocenose of this area are the Antarctic species *Globigerina pachyderma* (left-coiling varieties) and the sub-Antarctic species *G. pachyderma* (right-coiling), *G. bulloides*, and *G. quinqueloba.*

Northern subtropical species present in the region include: *Globorotalia inflata* (<5%), *Globigerinita glutinata* (<5%), *Orbulina universa* (<5%), *Hastigerina siphonifera* (<5%), *Globorotalia hirsuta* (<5%), and *G. truncatulinoides* (<5%, ratio of coiling: random to left-coiling dominant).

Southern subtropical and tropical species include: *Globigerinoides ruber* (>50%), *Globorotalia crassaformis* (<5%), *Globigerinoides conglobatus* (<5%), *Globorotalia menardii* <5%), *Pulleniatina obliquiloculata* (<5%), and *Globigerinoides trilobus* (20–50%).

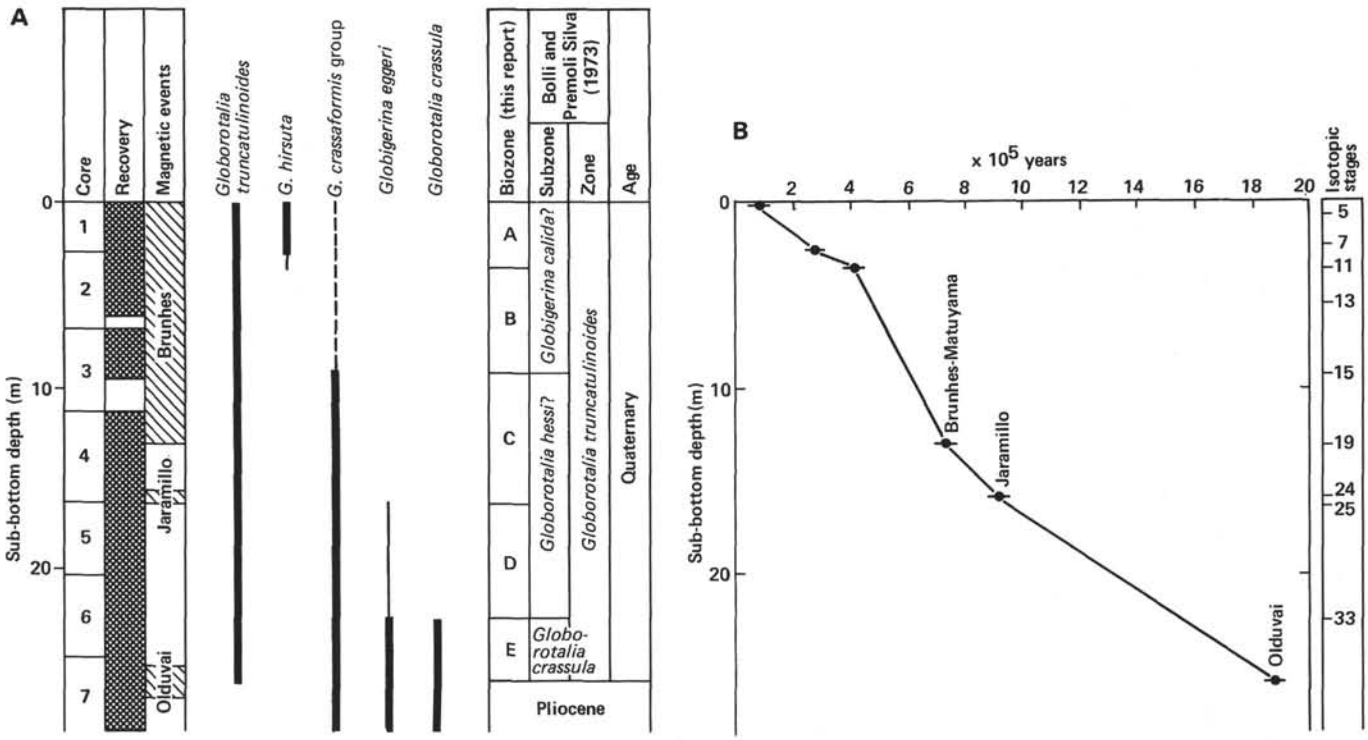

Figure 4. A. Biostratigraphic summary of Site 517 (Leg 72). Hypothetical time scale of the Quaternary sequence and rate of sedimentation presumed. B. Quaternary biozonation scheme and datum levels; isotopic stages from Vergnaud Grazzini and others (this volume); magnetic reversal epoch boundaries from Hamilton and others (this volume).

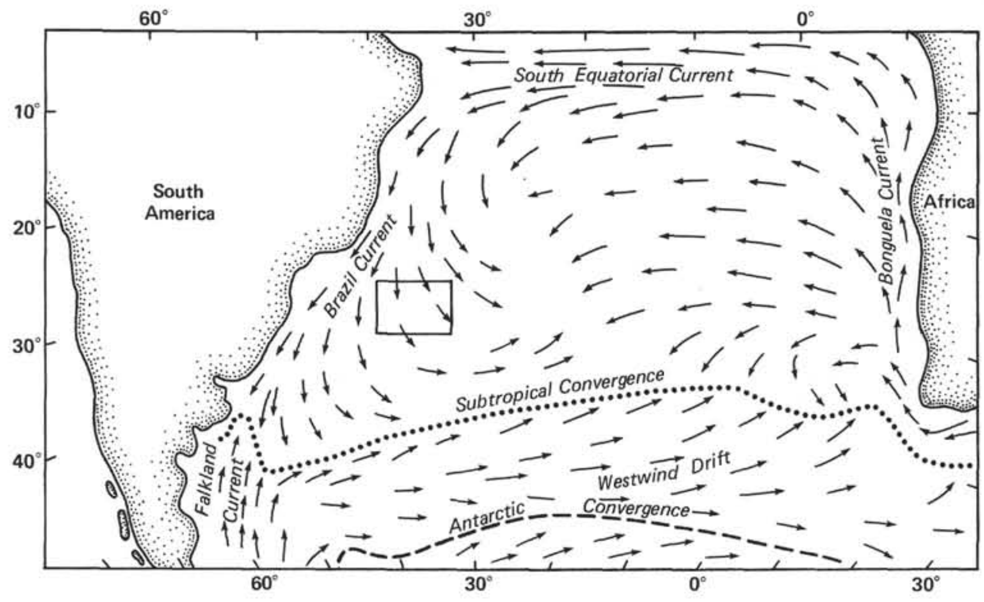

Figure 5. Hydrologic setting for the Leg 72 study area.

The spatial distribution of the more important species and their frequency are given in Figure 6. The distribution of these species reflects the structure of the surface waters of the region. Sub-Antarctic species (*Globigerina pachyderma, G. bulloides*) are bounded by the antarctic convergence, and subtropical species (e.g., *Globigerinoides ruber*) are bounded by the subtropical convergence. The transitional species *Globorotalia inflata* has an intermediate position, and the distribution of left-coiling and right-coiling populations of *G. truncatulinoides* show a gradual succession between a southern left-dominated population and northern right-dominated population (Fig. 6E).

METHODS

We used the present-day ecological responses of these species of planktonic foraminifers to investigate the hydrologic variations during the Quaternary. This approach is based on the eventual displacement of the different water masses and particularly the subtropical

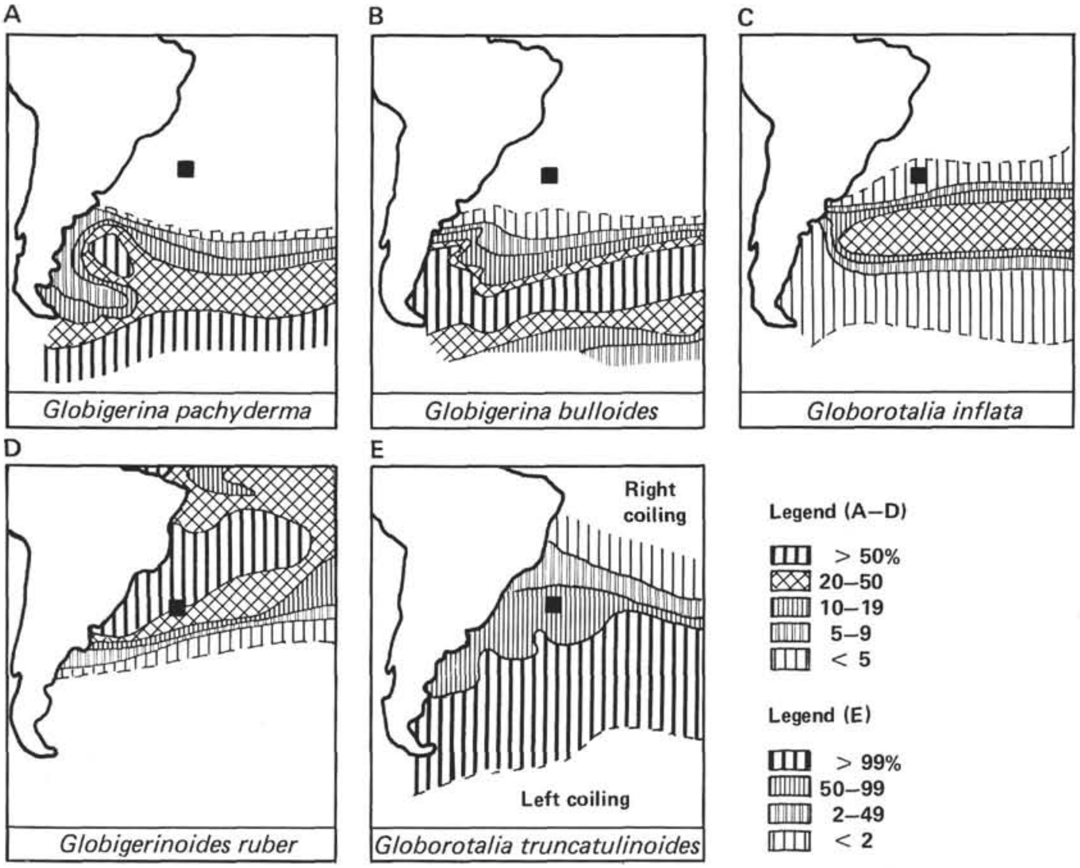

Figure 6. Distribution and frequency of some planktonic foraminifers in the surface waters near Site 517 (southwestern Atlantic, Leg 72); from Bé (1977); Bé and Tolderlund (1971). Percentage ratios of left-coiling versus right-coiling species.

convergence, variations that could be reflected by frequency variations of the planktonic foraminifers.

Irregularities of the faunal composition in surface waters and on the sea floor can be related to changes in temperature. Despite demonstrations that the distribution of planktonic species is not solely determined by temperature (Cifelli, 1971), this type of investigation can depict the paleohydrology. In this way, pertinent data for climatologic analyses were obtained from publications dealing with the ecology of planktonic foraminifers. A good approach to studying climatic variations would be the identification and classification of species according to temperature range (for instance, cold-water indicators or warm-water indicators). The matrix of percentage of the different species for each sample from Site 517 are factor analyzed, in order to arrange the species in groups objectively.

Environmental Interpretation of Site 517

This interpretation is made from the base to the top of the Quaternary sequence (Samples 517-7-1, 80–82 cm to 517-1-1, 0–2.5 cm) and in the succession of each subzones. The investigations are based on three sorts of data. First, their climatic values are considered and the species frequencies are arranged from left to right, cold species on the left side and warm on the right (Fig. 2). The figure, used previously for biostratigraphy, shows the increase or decrease through the sequence of temperature-ordered species.

A detailed analysis of variations of these 30 species is complicated; therefore, for the second type of data, we factor-analyzed this data in order to deduce the number of dimensions of the matrix. The results of this Q-mode analysis form our second data base. The analysis of the percentages of the 30 different species observed in 100 samples from Site 517 are condensed to 10 categories for a cumulative variance of 99.63%. We interpret these categories as representing assemblages of planktonic foraminifers. We retained three factor-assemblages with a variance of 31.7%, 38.4%, and 26.1%, respectively (Fig. 7, Tables 2 and 3).

In Factor 1, right-coiling *Globigerina pachyderma* and, to a lesser extent, left-coiling *Globorotalia truncatulinoides* are the dominant forms. The distribution of these species suggests a displacement of the subtropical convergence from south to north.

Factor 2 is an intermediate assemblage in which *G. inflata* and, to a lesser degree, *Globigerina bulloides* are the most important species. It can probably account for the displacement from the south (40–45°S) to the north (30°S) of the South Atlantic Current.

A single species, *Globigerinoides ruber*, dominates Factor 3 and represents the subtropical influence of the Brazil Current.

The coiling ratio of *Globorotalia truncatulinoides* is a key paleoenvironmental indicator. In present subtropical surface water of the site location, the population of *G. truncatulinoides* is composed of about 50% left-coiling form. Following this distribution (Fig. 8), we think that Quaternary fluctuations of the hydrologic regime will also produce changes in the populations of *G.*

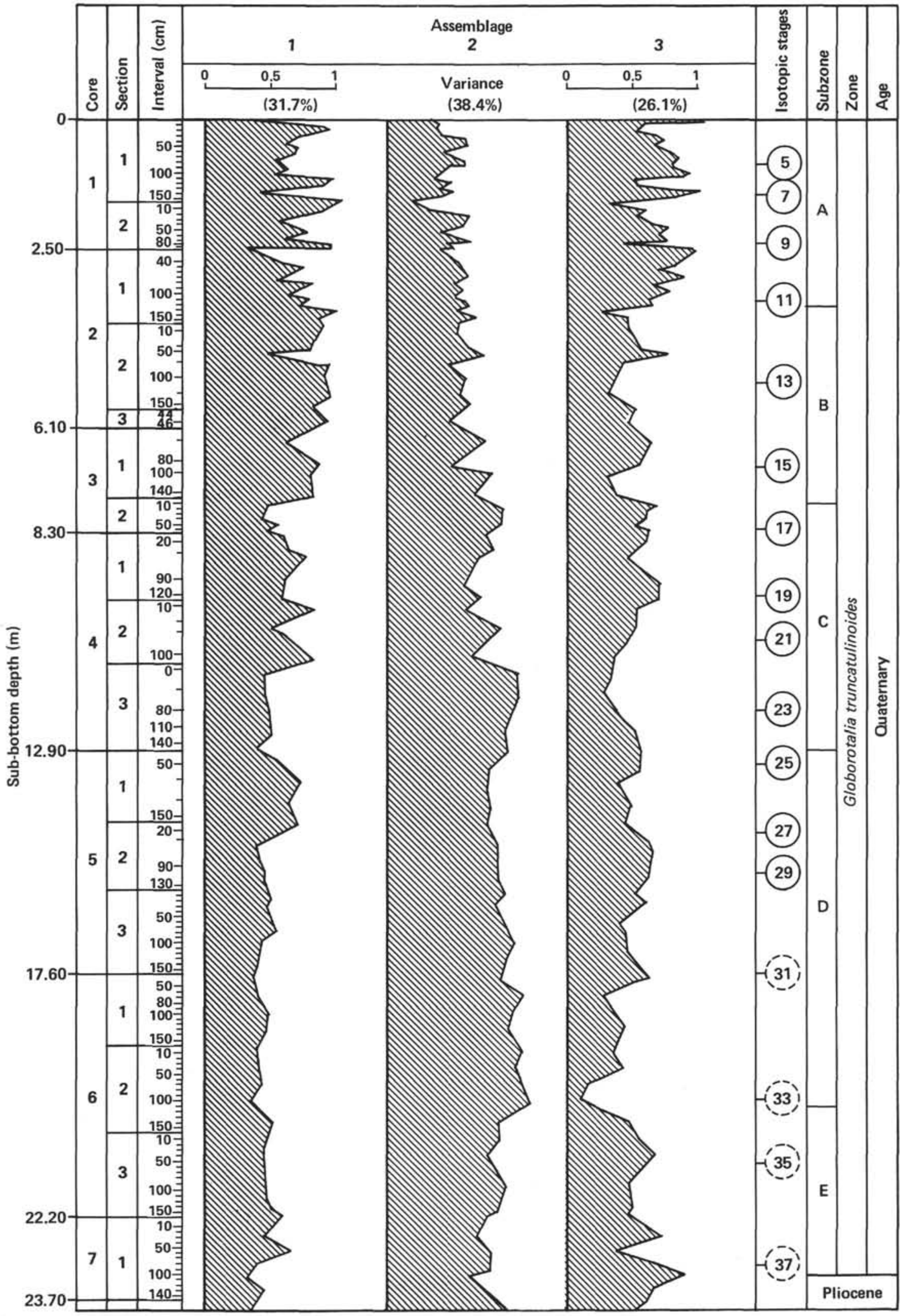

Figure 7. Varimax assemblage derived from factor analysis of planktonic foraminiferal frequency in Site 517. Voids are excluded from the depth scale. Isotopic stages from Vergnaud Grazzini and others (this volume).

Table 2. Varimax factor matrix from factor analysis of Hole 517.

Sample no.	Core-section (depth in cm)	Communality	Factor-assemblages 1	2	3
1	1-1, 5	0.998	0.322	−0.268	−0.893
2	1-1, 10	0.998	0.783	−0.325	−0.498
3	1-1, 20	0.998	0.810	−0.322	−0.432
4	1-1, 30	0.998	0.630	−0.338	−0.581
5	1-1, 40	0.992	0.539	−0.514	−0.614
6	1-1, 50	0.995	0.597	−0.530	−0.545
7	1-1, 60	0.991	0.586	−0.372	−0.682
8	1-1, 70	0.993	0.477	−0.409	−0.720
9	1-1, 80	0.992	0.508	−0.492	−0.677
10	1-1, 90	0.996	0.554	−0.418	−0.698
11	1-1, 100	0.993	0.451	−0.348	−0.786
12	1-1, 110	0.998	0.851	−0.305	−0.413
13	1-1, 120	0.997	0.782	−0.401	−0.461
14	1-1, 130	0.996	0.355	−0.330	−0.862
15	1-1, 140	0.992	0.555	−0.410	−0.710
16	1-1, 150	0.996	0.922	−0.152	−0.265
17	1-2, 10	0.997	0.804	−0.267	−0.509
18	1-2, 20	0.998	0.689	−0.549	−0.454
19	1-2, 30	0.999	0.619	−0.533	−0.547
20	1-2, 40	0.994	0.487	−0.508	−0.631
21	1-2, 50	0.997	0.661	−0.347	−0.601
22	1-2, 60	0.996	0.524	−0.538	−0.641
23	1-2, 70	0.994	0.835	−0.392	−0.372
24	1-2, 75	0.997	0.298	−0.462	−0.823
25	1-2, 80	0.999	0.365	−0.338	−0.844
26	2-1, 40	0.999	0.519	−0.458	−0.690
27	2-1, 50	0.997	0.651	−0.480	−0.566
28	2-1, 60	0.996	0.553	−0.517	−0.643
29	2-1, 70	0.997	0.459	−0.438	−0.744
30	2-1, 80	0.997	0.706	−0.458	−0.534
31	2-1, 90	0.998	0.625	−0.498	−0.577
32	2-1, 100	0.997	0.589	−0.454	−0.649
33	2-1, 110	0.997	0.679	−0.501	−0.525
34	2-1, 120	0.994	0.632	−0.534	−0.540
35	2-1, 130	0.998	0.859	−0.461	−0.209
36	2-1, 140	0.998	0.752	−0.584	−0.289
37	2-1, 150	0.997	0.790	−0.475	−0.370
38	2-2, 10	0.996	0.766	−0.465	−0.391
39	2-2, 40	0.998	0.695	−0.532	−0.471
40	2-2, 50	0.994	0.395	−0.620	−0.651
41	2-2, 70	0.997	0.819	−0.384	−0.358
42	2-2, 100	0.997	0.793	−0.496	−0.292
43	2-2, 130	0.998	0.798	−0.462	−0.279
44	2-2, 150	0.998	0.698	−0.562	−0.425
45	2-3, 45	0.998	0.800	−0.396	−0.408
46	3-1, 40	0.996	0.518	−0.626	−0.554
47	3-1, 80	0.998	0.767	−0.424	−0.473
48	3-1, 100	0.998	0.689	−0.660	−0.251
49	3-1, 140	0.997	0.726	−0.585	−0.328
50	3-2, 10	0.998	0.415	−0.679	−0.583
51	3-2, 20	0.997	0.377	−0.766	−0.509
52	3-2, 30	0.997	0.384	−0.764	−0.499
53	3-2, 40	0.996	0.467	−0.762	−0.427
54	3-2, 50	0.997	0.405	−0.717	−0.546
55	3-2, 60	0.996	0.500	−0.666	−0.512
56	4-1, 20	0.994	0.531	−0.705	−0.434
57	4-1, 40	0.996	0.664	−0.615	−0.402
58	4-1, 90	0.997	0.529	−0.525	−0.592
59	4-1, 120	0.996	0.504	−0.611	−0.590
60	4-2, 10	0.996	0.722	−0.520	−0.428
61	4-2, 40	0.998	0.448	−0.757	−0.445
62	4-2, 60	0.995	0.540	−0.685	−0.421
63	4-2, 100	0.997	0.723	−0.562	−0.312
64	4-3, 0	0.998	0.405	−0.849	−0.296
65	4-3, 40	0.999	0.405	−0.867	−0.233
66	4-3, 80	0.999	0.427	−0.821	−0.354
67	4-3, 110	0.996	0.436	−0.779	−0.439
68	4-3, 140	0.998	0.366	−0.791	−0.482
69	5-1, 50	0.997	0.525	−0.681	−0.478
70	5-1, 80	0.997	0.648	−0.662	−0.321
71	5-1, 120	0.993	0.571	−0.683	−0.418
72	5-1, 150	0.996	0.615	−0.671	−0.377
73	5-2, 20	0.997	0.420	−0.719	−0.526
74	5-2, 40	0.995	0.337	−0.730	−0.575
75	5-2, 90	0.992	0.394	−0.743	−0.519
76	5-2, 130	0.999	0.416	−0.771	−0.450
77	5-3, 20	0.997	0.426	−0.720	−0.515
78	5-3, 50	0.998	0.470	−0.788	−0.334
79	5-3, 80	0.994	0.385	−0.831	−0.382
80	5-3, 110	0.991	0.353	−0.815	−0.394
81	5-3, 150	0.998	0.327	−0.768	−0.535
82	6-1, 50	0.997	0.364	−0.892	−0.237
83	6-1, 80	0.998	0.422	−0.840	−0.330
84	6-1, 110	0.997	0.414	−0.819	−0.372
85	6-1, 150	0.992	0.338	−0.876	−0.311
86	6-2, 20	0.997	0.360	−0.851	−0.370
87	6-2, 50	0.997	0.361	−0.899	−0.173
88	6-2, 80	0.999	0.299	−0.938	−0.091
89	6-2, 120	0.998	0.449	−0.755	−0.409
90	6-2, 150	0.997	0.418	−0.762	−0.450
91	6-3, 20	0.995	0.396	−0.674	−0.578
92	6-3, 70	0.991	0.400	−0.804	−0.400
93	6-3, 120	0.996	0.454	−0.751	−0.430
94	6-3, 130	0.997	0.507	−0.666	−0.414
95	7-1, 10	0.989	0.385	−0.605	−0.615
96	7-1, 40	0.997	0.555	−0.701	−0.320
97	7-1, 60	0.996	0.355	−0.701	−0.577
98	7-1, 80	0.995	0.302	−0.544	−0.747
99	7-1, 100	0.997	0.380	−0.666	−0.590
100	7-1, 140	0.996	0.322	−0.788	−0.445
		Variance	31.675	38.447	26.114
		Cumulative variance	31.675	70.122	96.236

Table 3. Varimax factor score matrix (species matrix) from factor analysis of Hole 517.

Species	Factor-assemblage 1	2	3
Globigerina pachyderma (left-coiling)	0.005	0.002	0.001
G. pachyderma (right-coiling)	0.809	0.217	0.093
G. bulloides	0.197	−0.354	0.021
G. quinqueloba	0.006	0.005	−0.014
Globorotalia scitula	0.065	0.087	−0.216
Globigerinita glutinata	0.044	−0.040	−0.159
Globorotalia inflata	0.194	−0.819	0.165
Hastigerina siphonifera	0.007	−0.020	−0.034
Globigerina rubescens	0.097	0.144	−0.270
G. falconensis	0.055	0.034	−0.065
Globorotalia hirsuta	−0.013	0.048	−0.132
G. truncatulinoides (right coiling)	−0.000	−0.004	−0.068
G. truncatulinoides (left coiling)	0.480	0.092	0.111
Globigerinoides ruber (white)	0.124	−0.223	−0.872
Globigerina digitata	−0.000	0.001	−0.005
Orbulina universa	−0.017	−0.049	−0.032
Globigerinoides ruber (pink)	−0.001	0.007	−0.017
G. conglobatus	−0.000	−0.021	−0.025
G. trilobus	0.008	−0.018	−0.063
G. sacculifer	0.000	0.002	−0.021
Globigerina eggeri	−0.016	−0.018	−0.006
Globigerinoides tenellus	−0.000	−0.000	−0.000
Globigerina calida	−0.002	0.004	−0.016
Globorotalia crassaformis group	−0.065	−0.248	0.106
G. menardii group	0.006	0.005	−0.020
Pulleniatina obliquiloculata	−0.004	−0.014	0.005
G. tumida	−0.000	−0.000	−0.000
Sphaeroidinella dehiscens	−0.002	−0.005	0.001
Turborotalita humilis	−0.000	−0.000	−0.000
Candeina nitida	−0.001	−0.000	−0.003
G. tosaensis	−0.003	−0.004	−0.001
G. triangula	−0.001	−0.001	0.000
Globorotaloides hexagona	0.005	0.012	−0.019

truncatulinoides. The variation of the frequency of left-coiling and right-coiling individuals of this species in the Quaternary sequence is interpreted in this way: increase of the left-coiling form corresponds to an amplification of the southern hydrologic influence (cold); increase of the right-coiling individuals suggests an intensification of the warm Brazil Current.

Two broad intervals can be differentiated within the Quaternary sequence. From the base to Subzone C, the first one is characterized by the importance of Factor 2 (*G. inflata* principally) and by a certain monotony of the frequency of the other species. The dominance of Factor 2 in Subzones C (lower half), D, and E reflects the lack of important hydrologic change in the investigated area during the periods of the subzones.

The second episode corresponds to the upper Subzones A, B, and C and is differentiated by the increase of Factor 1 and by rapid fluctuations between cold species such as *Globigerina pachyderma* (Factor 1) and warm species such as *Globigerinoides ruber* (Factor 2). These three upper subzones seem to represent a conflicting period between the warm Brazil Current influence and the rise of a southern hydrologic influence. The boundary between these two broad periods is situated in the middle of Subzone C. It could be underlined by rapid and strong pulsations of left-coiling *Globorotalia truncatulinoides*. Indeed, from the base of the Quaternary to the middle of Subzone C (approximately Section

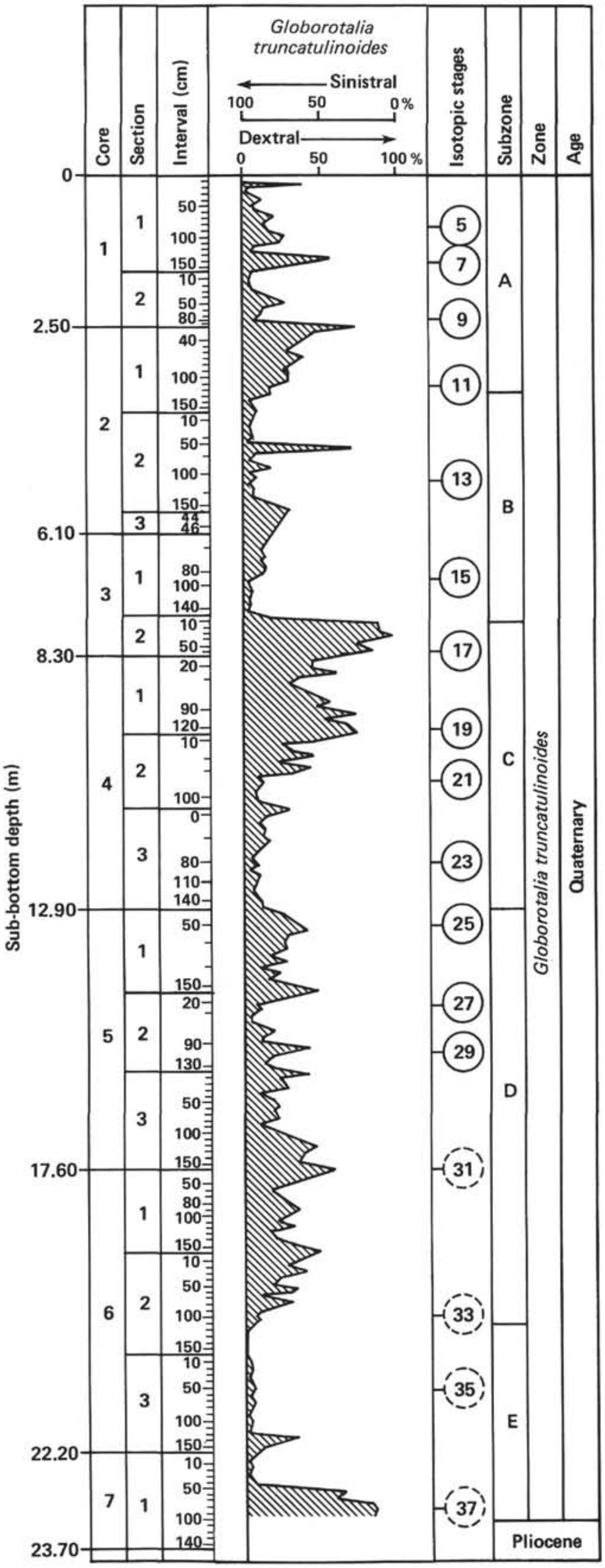

Figure 8. Coiling ratio of *Globorotalia truncatulinoides* in the Quaternary of Site 517 (southwestern Atlantic, Leg 72). Voids are excluded from the depth scale. Isotopic stages from Vergnaud Grazzini and others (this volume).

517-4-2) the *G. truncatulinoides* population is dominantly left coiling, with few right-coiling pulsations. These pulsations appear in the upper part of Subzone C and again in Subzones A and B.

CONCLUSIONS

The Quaternary sequence of the Rio Grande Rise area records two hydrologic periods. The more recent one begins at Isotopic Stage 19 (Brunhes Event) and corresponds to an interval with rapid fluctuations between the warm Brazil Current and the cold Falkland Current or extension of the subtropical convergence, in turn indicating more rapid or more differentiated climatic cycles. The older period is clearly different and shows only a few variations, and these have low amplitude. This pattern corresponds to the results of the $\delta^{18}O$ record (Van Donk, 1976), indicating that many of the glacial stages (especially before 1 Ma) are less pronounced than the more recent glacial maximum. The occurrence of this differentiation near the Jaramillo magnetic reversal event goes with the polarity assignment at Site 517 (Hamilton et al., this volume). That contrast was seen by Huang and Watkins (1977) between the Brunhes and Matuyama as caused by bottom-water activity in the South Pacific.

Three important pulsations of right-coiling *Globorotalia truncatulinoides* occur in the upper part of the Quaternary, indicating a cyclic variation of the surface hydrologic details. Considering the low sedimentation rate, details with regard to the chronology and the magnitude of the fluctuations are very difficult to obtain. Bioturbation, moreover, does introduce some distortion, but that is integrated into the general trends of the paleoclimatic response of sea surface temperature and atmospheric circulation, intensified during glacial periods. During glacial stages, the general atmospheric circulation of the winter seasons was intensified because of the increasing thermal gradient between the equator and poles, and, consequently, the oceanic circulation was strengthened (Climap Project Members, 1976). In Site 517, this fact is represented, but it is difficult to give a precise interpretation of the different stages.

PALEONTOLOGIC LIST

In this section we discuss the different species observed; we include some indications about the nomenclature retained in the investigation, the abundance and the occurrence of each species in the Quaternary sequence, and their paleoclimatic values. The different specimens are deposited in the paleontologic collection of the Institut de Géologie du Bassin d'Aquitaine of the Université de Bordeaux (France).

Genus *CANDEINA* d'Orbigny, 1839

Candeina nitida **d'Orbigny**
(Plate 1, Figs. 1–2)

Candeina nitida d'Orbigny, 1839b, p. 108, pl. 2, Figs. 27–28; Bé, 1967, fig. 31.

This tropical species is almost rare and has a sporadic distribution.

Genus *GLOBIGERINA* d'Orbigny, 1826

Globigerina bulloides **d'Orbigny**
(Plate 1, Figs. 3–5)

Globigerina bulloides d'Orbigny, 1826, p. 277, no. 1, modèles no. 17 (juvenile), no. 76 (adult); Banner and Blow, 1960, p. 3, pl. 1, figs. 1 (lectotype), 4; Be, 1967, Fig. 14.

It would appear that occurrence and distribution of some subspecies or varieties depend upon ecological factors. Figures 3–5 of Plate 1 show the variability of the population accepted in this species.

Globigerina bulloides is considered as an epipelagic species and temperate-water and cool-water inhabitant. It is always common (10 to 20%) in the Quaternary sequence.

Globigerina calida **Parker**
(Plate 1, Figs. 6–7)

Globigerina calida Parker, 1962, p. 221, pl. 1, figs. 9–11, Blow, 1969, p. 317, pl. 13, figs. 9–10.

Range according to Bolli and Premoli Silva (1973) from the base of the *Globigerina calida calida* Subzone to present day. Here it appears at the base of Subzone B. Almost rare and sporadic in Subzones A and B.

Globigerina digitata **Brady**
(Plate 1, Figs. 8–9)

Globigerina digitata Brady, 1879, p. 286; Brady, 1884, p. 599, pl. 80, figs. 6–10; Bé, 1967, fig. 9.

This subtropical species is very rare.

Globigerina eggeri **Zobel**
(Plate 2, Figs. 1–4)

Globigerina dutertrei forma eggeri Zobel, 1968, pp. 109–110, fig. 2.

This form differs essentially from *Globigerina dutertrei* because of lack of teeth in the ombilic. In the variability of its population we accept the *Globigerina "pachyderma-dutertrei intergrade"* recognized by Kipp, 1976. This species disappears at the top of Subzone D.

Globigerina falconensis **Blow**
(Plate 2, Figs. 5–6)

Globigerina falconensis Blow, 1959, p. 177, pl. 9, figs. 40–41; Parker, 1962, p. 224, pl. 1, figs. 14, 16–19; Malmgren and Kennett, 1977, pl. 1, figs. 3–6.

This species could enter in the variability of the *G. bulloides* populations. But its geographic distribution in biocenosis (Cifelli and Smith, 1970) is slightly different from that of *G. bulloides*, implying another ecological control. In this Quaternary sequence, this species shows a frequency increase in Subzone A.

Globigerina pachyderma **(Ehrenberg)**
(Plate 2, Figs. 7–10)

Globigerina pachyderma Ehrenberg, 1861, p. 277, 278, 303; Ehrenberg, 1872, pl. 1, fig. 4.

Globigerina pachyderma (Ehrenberg). Brady, 1884, p. 600, pl. 114, figs. 19–20; Parker, 1962, p. 224, pl. 1, figs. 26–35, pl. 2, figs. 1–6; Bé, 1967, fig. 11.

No distinction is made between this and *Globigerina incompta*. Left-coiling specimens are very rare; right-coiling *G. pachyderma* increases from the upper part of Subzone D. This group is considered as the most important cool-water indicator.

Globigerina quinqueloba **Natland**
(Plate 3, Figs. 1–2)

Globigerina quinqueloba Natland, 1938, p. 149, pl. 6, fig. 7; Bé, 1967, fig. 10.

We regard this species also as a distinct cool-water indicator. Its average size is around 150 μm in diameter. So the frequency indication and perhaps its occurrence in all Quaternary sequences should be more important.

Globigerina rubescens **Hofker**
(Plate 3, Figs. 3–4)

Globigerina rubescens Hofker, 1956, p. 234, pl. 35, figs. 18–21.

This typical and small species is rare in the lower Quaternary and becomes common in Subzone A. Its average diameter is generally around 200 μm, so statistically it is often omitted.

Genus *GLOBIGERINITA* Brönnimann, 1951

Globigerinita glutinata **(Egger)**
(Plate 3, Figs. 5–6)

Globigerinita glutinata Egger, 1893, p. 371, figs. 19–21.

Globigerinita glutinata (Egger). Parker, 1962, p. 246, pl. 9, figs. 1–6; Bé, 1967, fig. 18.

The bulla is often not present. This species is scarce to common in the Pleistocene.

Genus *GLOBIGERINOIDES* Cushman, 1927

Globigerinoides conglobatus **(Brady)**
(Plate 3, Figs. 7–8)

Globigerina conglobata Brady, 1879, p. 286; Brady, 1884, pl. 80, figs. 1–5; Banner and Blow, 1960, p. 6, pl. 4, fig. 4 (lectotype).

Globigerinoides conglobatus (Brady). Parker, 1962, p. 229, pl. 3, figs. 1–5; Bé, 1967, fig. 4a–b.

Globigerinoides conglobatus is a very thick-walled species that is treated as more resistant against dissolution than the other species of *Globigerinoides*. It is rare to scarce from the Pliocene to Present.

Globigerinoides ruber **(d'Orbigny)**
(Plate 3, Figs. 9–10; Plate 4, Figs. 1–3)

Globigerina rubra d'Orbigny, 1839, pl. 4, figs. 12–14.

Globigerinoides ruber (d'Orbigny) Bé, 1967, figs. 5a–c.

A differentiation is made between the pink and white forms. The white form is almost common to abundant. It seems to be one of the typical species of the southwestern Atlantic association. The pink form is rare and present only in Subzone A. A few *pyramidilis* forms (Plate 4, Fig. 3) are added in our statistics.

Globigerinoides sacculifer **(Brady)**
(Plate 4, Figs. 4–5)

Globigerina sacculifer Brady, 1877, p. 535; Brady, 1884, p. 604, pl. 80, figs. 11–17, pl. 82, fig. 4.

Globigerinoides sacculifer (Brady) Bé, 1967, fig. 6a.

Rare and sporadic in all Quaternary sequences.

Globigerinoides tenellus **Parker**
(Plate 4, Figs. 6–7)

Globigerinoides tenellus Parker, 1958, pl. 6, figs. 7–11.

This small species is very similar to *Globigerina rubescens* but differs in the presence of the supplementary aperture on the spiral side. It occurs in minor abundances. Taking into account its scarcity, we have added this species to *G. rubescens* (*G. rubescens* group) in the statistics.

Globigerinoides trilobus **(Reuss)**
(Plate 4, Figs. 8–9)

Globigerina triloba Reuss, 1850, p. 374, pl. 47, fig. 11.

This form associated by some workers with the *sacculifer forma* either as *sacculifer* species (Bé, 1977) or as "*trilobus*" species (Cifelli, 1965) is considered here as a distinct species. It occurs often in the same sample as *G. sacculifer* does, but it is more common.

Genus *GLOBOROTALIA* Cushman, 1927

Globorotalia crassaformis **(Galloway and Wissler)**
(Plate 5, Figs. 1–4, 9–10)

Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, figs. 12a–c.

Globigerina crassaformis crassaformis (Galloway and Wissler) Rögl, 1974, p. 763, pl. 3, figs. 1–5.

No distinction is made in this broad group. It is scarce to common in the lower Quaternary, but its frequency decreases from the top of Subzone C.

Globorotalia viola **Blow**
(Plate 5, Figs. 5–8)

Globorotalia (*Globorotalia*) *crassula viola* Blow, 1969, pp. 397–398, pl. 5, figs. 4–9.

This form seems to be an ecological variation of *Globorotalia crassula sensu* Berggren (1977). Its occurrence is the same. This illustrated form is added to *G. crassula* in the statistics.

Globorotalia crassula **Cushman and Stewart**
(Plate 5, Figs. 11-12)

Globorotalia crassula Cushman and Stewart, 1930, p. 77, pl. 7, fig. 1; Blow, 1969, p. 361, pl. 9, figs. 1-3 (holotype refigured).

This form disappears at the top of Subzone E. It is common and typical in the uppermost Pliocene.

Globorotalia hirsuta **(d'Orbigny)**
(Plate 6, Figs. 1-2)

Rotalina hirsuta d'Orbigny, 1839, p. 131, pl. 2, figs. 37-39.
Globorotalia hirsuta (d'Orbigny) Parker, 1962, p. 236, pl. 5, figs. 10-15; Bé, 1967, fig. 27a-c.

This species seems to have a short occurrence in the Quaternary. Its appearance is noted at the LAD of *Pseudoemiliania lacunosa*, as in the North Atlantic. Future analyses should confirm this fact. In Site 517, its frequency increases in the upper part of Subzone A. This fact may be compared to the occurrence shown by Williams and Ledbetter (1979) from about 240,000 yr. ago.

Globorotalia inflata **(d'Orbigny)**
(Plate 6, Figs. 3-4)

Globigerina inflata d'Orbigny, 1839, p. 134, pl. 2, figs. 7-9.
Globorotalia inflata (d'Orbigny) Parker, 1962, p. 236, pl. 5, figs. 6-9; Bé, 1967, fig. 24.

This species is common to abundant from the Subzone E to the middle part of the Subzone C. Its frequency does not vary considerably. Above Subzone C, the frequency becomes common with some variations. We treat *G. inflata* as belonging to the temperate zones with significant preference for high nutrient concentration.

Globorotalia menardii **(d'Orbigny)**
(Plate 6, Figs. 5-6)

Rotalia menardii d'Orbigny, 1826, modèle no. 10, unpublished plate, pl. 11, fig. 1.
Globorotalia menardii (d'Orbigny) Le Calvez, 1977, pp. 109-110, figs. 1-2.

Always rare, this species is less sporadic in the upper part of the Quaternary sequence.

Globorotalia scitula **(Brady)**
(Plate 6, Fig. 7-10)

Pulvinulina scitula Brady, 1882, pp. 716-717; Banner and Blow, 1960, p. 27, pl. 5, fig. 5 (lectotype).
Globorotalia scitula (Brady) Parker, 1962, p. 238, pl. 6, figs. 4-6; Bé, 1967, fig. 28.

In this population we accept *Globorotalia bermudezi* as a term of the specific variation in the *G. scitula* species. It is rare to common. Its frequency increases in Subzone A.

Globorotalia triangula **Theyer**
(Plate 7, Figs. 1-2)

Globorotalia inflata triangula Theyer, 1973, pp. 200-201, pl. 1, figs. 1-7.

Very few specimens are observed in Subzone E.

Globorotalia truncatulinoides **(d'Orbigny)**
(Plate 7, Figs. 3-4)

Rotalia truncatulinoides d'Orbigny, 1839a, p. 132, pl. 2, figs. 25-27.
Globorotalia truncatulinoides (d'Orbigny) Bé, 1967, fig. 24.

This species is common in this section. Its coiling direction is often random. But we can observe few right-coiling pulsations regarded as a modification of the hydrologic setting during the Quaternary.

Globorotalia tumida **(Brady)**
(Plate 7, Figs. 5-6)

Pulvinulina menardii (d'Orbigny) var. *tumida* Brady, 1877, p. 535; Brady, 1884, p. 692, pl. 103, figs. 4-6; Banner and Blow, 1960, p. 26, pl. 5, fig. 1 (lectotype).
Globorotalia tumida (Brady) Parker, 1962, p. 239, pl. 6, figs. 8-10.

This rare species is added to *Globorotalia menardii* in our statistics.

Genus *HASTIGERINA*

Hastigerina siphonifera **(d'Orbigny)**
(Plate 7, Fig. 7)

Globigerina siphonifera d'Orbigny, 1839, pl. 4, figs. 15-18.
Globigerinella aequilateralis (Brady) Bé, 1967, fig. 16.
Hastigerina siphonifera (d'Orbigny) Loeblich and Tappan, 1964, fig. 531,1; Le Calvez, 1977, pp. 33-34, fig. 6.

Rare to scarce in all sections.

Genus *ORBULINA*

Orbulina universa **d'Orbigny**
(Plate 7, Fig. 8)

Orbulina universa d'Orbigny, 1839b, p. 3, fig. 1; Bé, 1967, fig. 3a.

Rare to low occurrence.

Genus *PULLENIATINA*

Pulleniatina obliquiloculata **(Parker and Jones)**
(Plate 7, Figs. 9-10)

Pullenia sphaeroides (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, pp. 365, 368 pl. 19, figs. 4a-b; Banner and Blow, 1960, p. 25, pl. 7, fig. 4 (lectotype).
Pulleniatina obliquiloculata (Parker and Jones) Parker, 1962, p. 234, pl. 4, figs. 13-16, 19, 22; Bé, 1967, Fig. 23.

Very rare specimens in the lower Quaternary (Subzones C, D, E).

Genus *SPHAEROIDINELLA*

Sphaeroidinella dehiscens **(Parker and Jones)**
(Plate 7, Fig. 11)

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones, 1865, p. 369, pl. 19 fig. 5; Banner and Blow, 1960, p. 35, pl. 7, fig. 3 (lectotype).
Sphaeroidinella dehiscens (Parker and Jones) Parker, 1962, p. 234, pl. 5, figs. 1-2; Bé, 1967, fig. 7a-c.

Rare specimens occur in Subzones C to E.

Genus *GLOBOROTALOIDES*

Globorotaloides hexagona **(Natland)**

Globigerina hexagona Natland, 1938, p. 149, pl. 7, figs. 1a-c.

This species is present sporadically from Subzone C to the top of Site 517. It disappears at the beginning of the last glacial in the Atlantic province.

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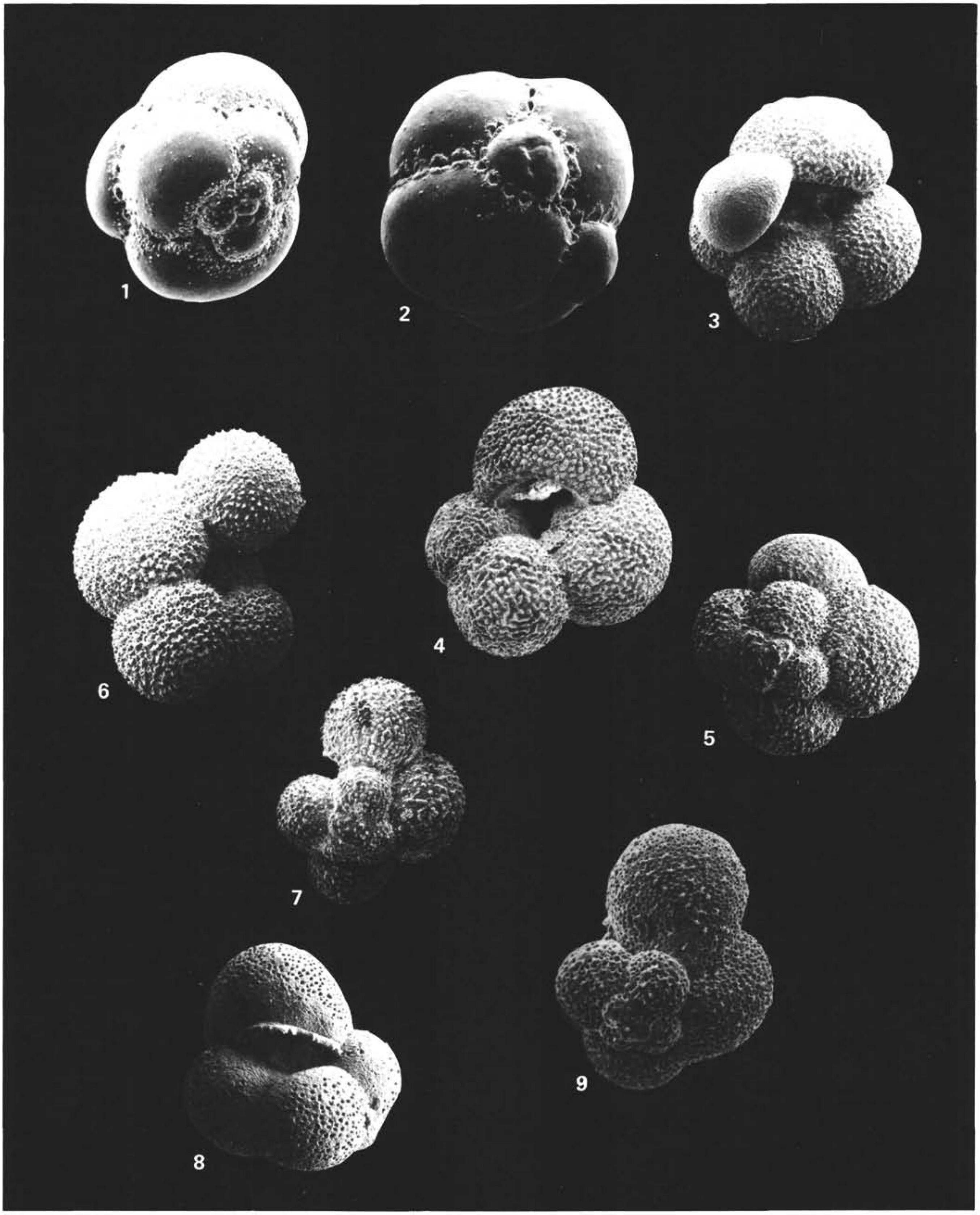

Plate 1. (Specimens magnified ×120 unless otherwise indicated.) **1–2.** *Candeina nitida* d'Orbigny, Sample 517-1-1, 0–2.5 cm, ×80, (1) spiral view, (2) umbilical view. **3–5.** *Globigerina bulloides* d'Orbigny, (3) Sample 517-3-1, 40 cm, umbilical view, ×100, (4) Sample 517-3,CC, umbilical view, (5) Sample 517-3-1, 40 cm, spiral view. **6–7.** *G. calida* Parker, Sample 517-1-1, 0–2.5 cm, ×100, (6) umbilical view, (7) spiral view. **8–9.** *G. digitata* Brady, Sample 517-4-2, 50 cm, (8) umbilical view, (9) spiral view.

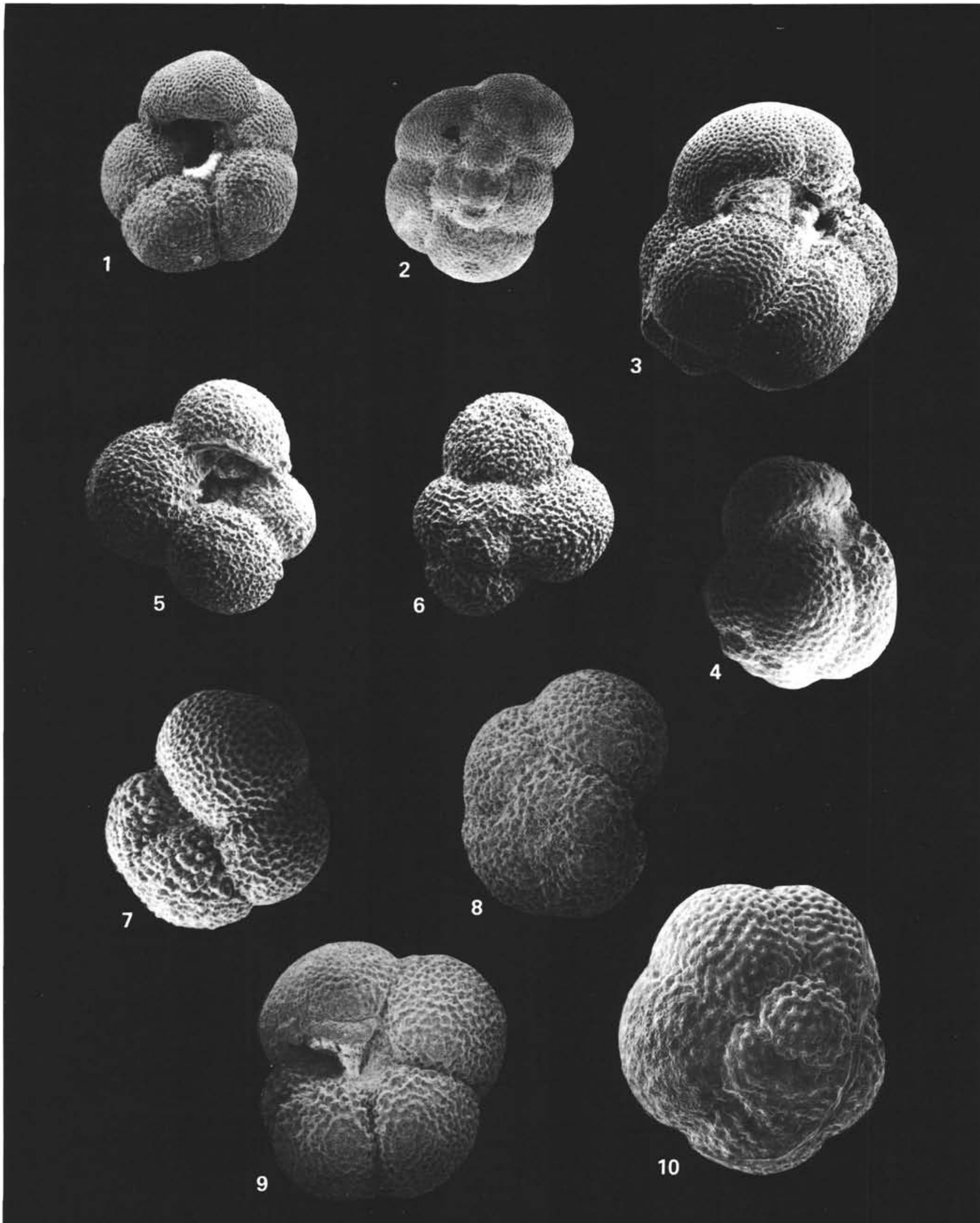

Plate 2. (Specimens magnified ×120 unless otherwise indicated.) **1-4.** *Globigerina eggeri* Zobel, (1-2) Sample 517-7-1, 10 cm, ×60, (1, umbilical view; 2, spiral view), (3-4) Sample 517-7-1, 50 cm, (3, umbilical view, ×80; 4, peripheral view, ×60). **5-6.** *G. falconensis* Blow, Sample 517-3,CC, (5) umbilical view, (6) spiral view. **7-10.** *G. pachyderma* (Ehrenberg), (7) Sample 517-1,CC, umbilical view, (8) Sample 517-2-1, 0-2.5 cm, spiral view, ×140, (9) Sample 517-2-1, 0-2.5 cm, umbilical view, (10) Sample 517-1-1, 0-2.5 cm, spiral view, ×140.

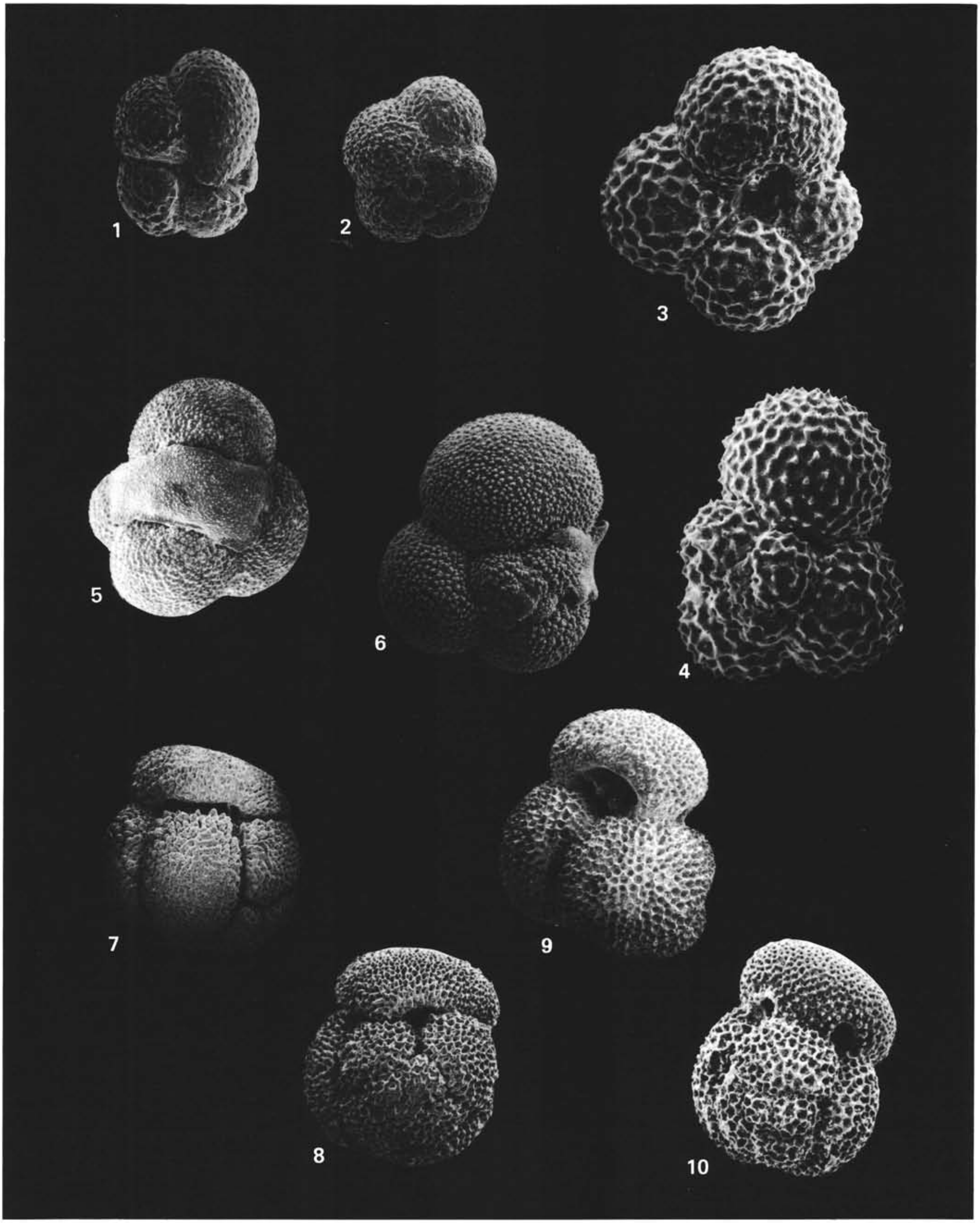

Plate 3. **1–2.** *Globigerina quinqueloba* Natland, Sample 517-1,CC, ×180, (1) umbilical view, (2) spiral view. **3–4.** *G. rubescens* Hofker, Sample 517-1-1, 0–2.5 cm, ×200, (3) umbilical view, (4) spiral view. **5–6.** *Globigerinita glutinata* (Egger), Sample 517-1-1, 0–2.5 cm, ×160, (5) umbilical view; (6) spiral view. **7–8.** *Globigerinoides conglobatus* (Brady), Sample 517-1-1, 0–2.5 cm, (7) umbilical view, ×60, (8) spiral view, ×80. **9–10.** *G. ruber* (d'Orbigny) white variety, Sample 517-1-1, 0–2.5 cm, ×100, (9) umbilical view, (10) spiral view.

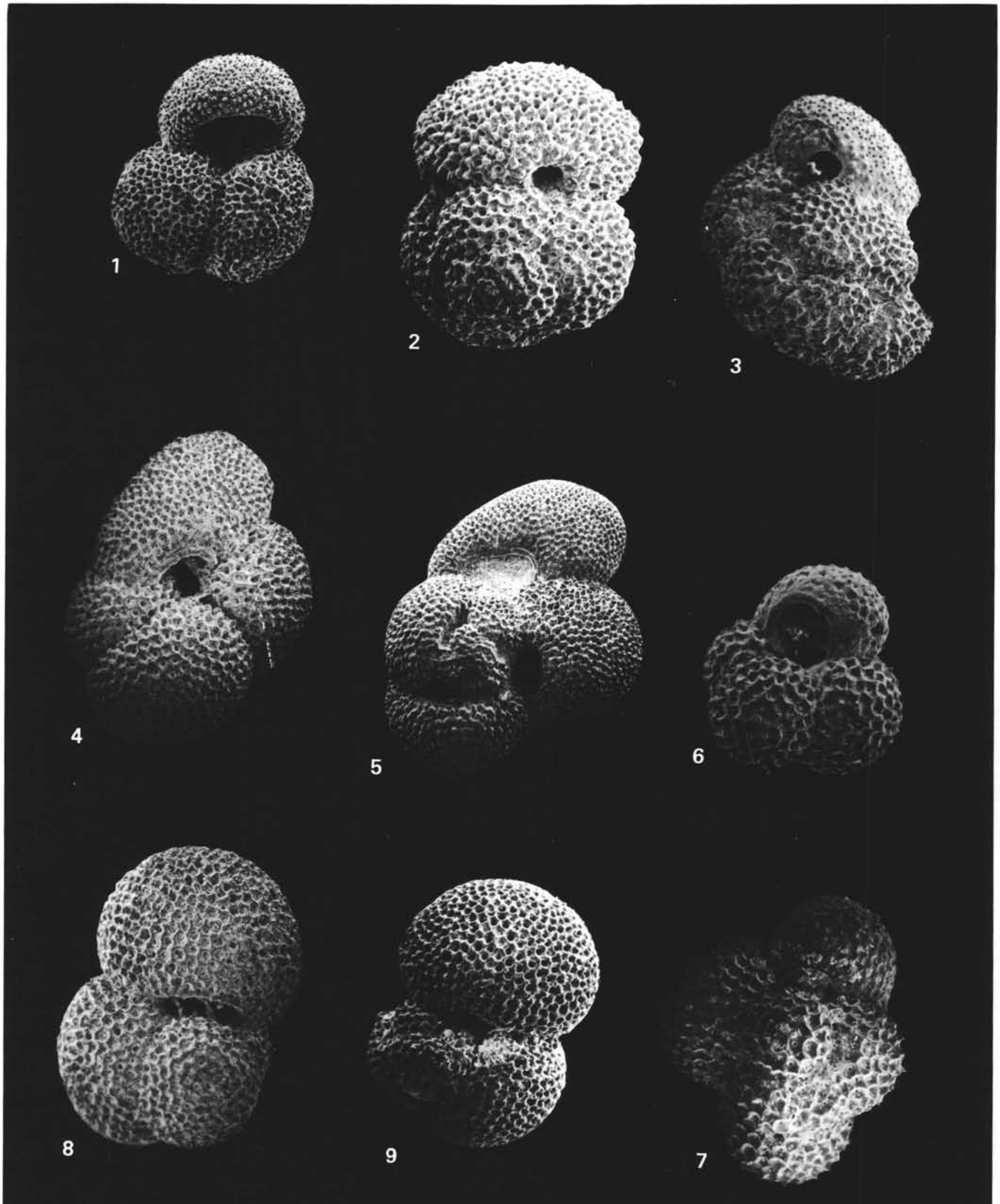

Plate 4. (Specimens magnified ×80 unless otherwise indicated.) **1–2.** *Globigerinoides ruber* (d'Orbigny) pink variety, (1) Sample 517-1-1, 0–2.5 cm, umbilical view, (2) Sample 517-1-2, 10 cm, ×120, spiral view. **3.** *G. ruber* (d'Orbigny) *pyramidilis*, Sample 517-4-2, 50 cm, ×20, spiral view. **4–5.** *G. sacculifer* (Brady), Sample 517-1-2, 10 cm, (4) umbilical view, (5) spiral view, ×60. **6–7.** *G. tenellus* Parker, Sample 517-1-1, 0–2.5 cm, ×160, (6) umbilical view, (7) spiral view. **8–9.** *G. trilobus* (Reuss), Sample 517-1-1, 0–2.5 cm, (8) umbilical view, ×100, (9) spiral view.

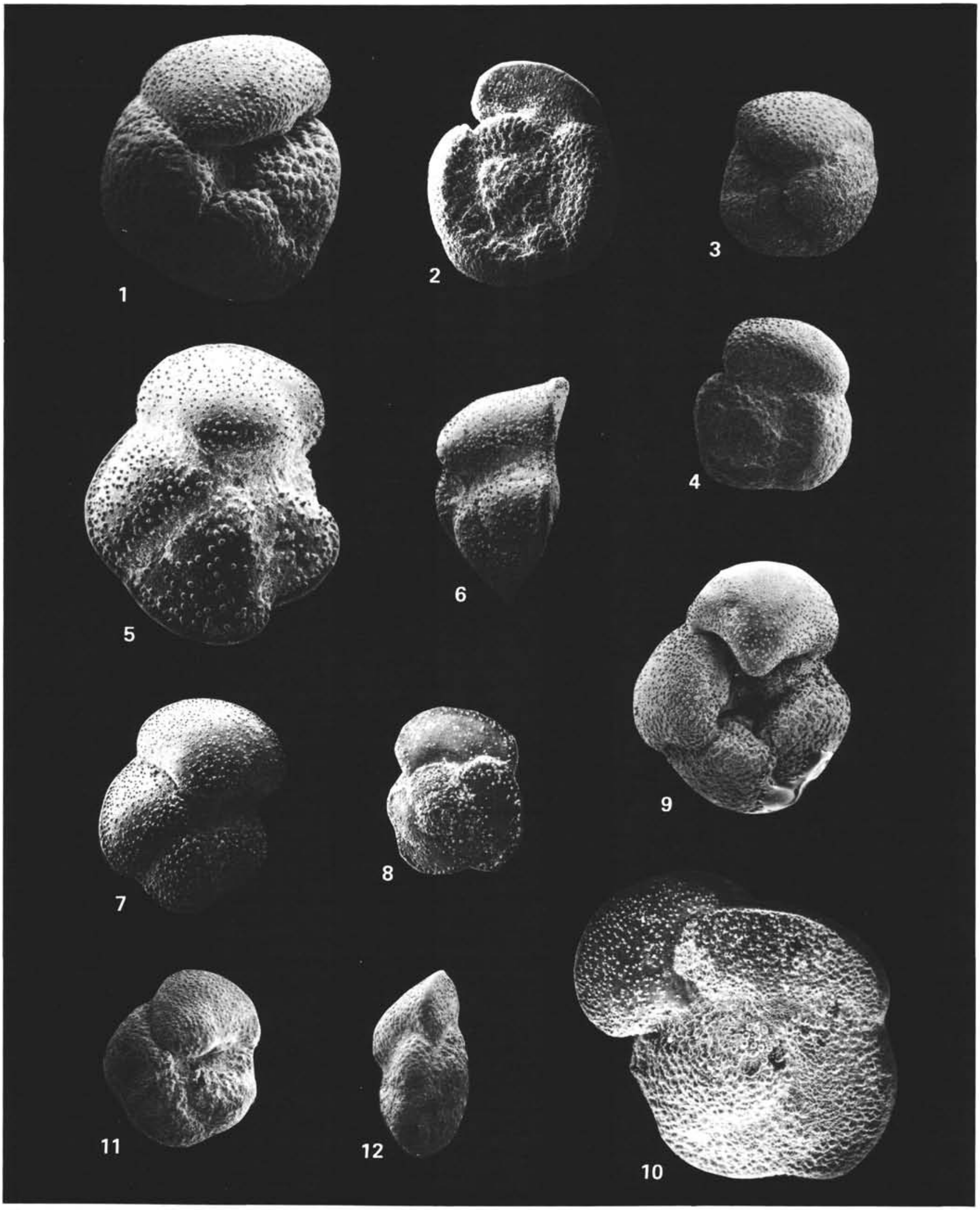

Plate 5. (Specimens magnified ×60 unless otherwise indicated.) **1-4.** *Globorotalia crassaformis* (Galloway and Wissler), (1-2) Sample 517-7-3, 50 cm, (1, umbilical view, ×80; 2, spiral view), (3-4) Sample 517-6,CC, (3, umbilical view; 4, spiral view). **5-8.** *G. viola* Blow, Sample 517-7-1, 50 cm, (5) umbilical view, ×80, (6) peripheral view, (7) umbilical view, (8) spiral view. **9-10.** *G. crassaformis* (Galloway and Wissler), (9) Sample 516-6,CC, umbilical view, (10) Sample 517-7-1, 50 cm, spiral view, ×80. **11-12.** *G. crassula* Cushman and Stewart, Sample 517-7-1, 50 cm, (11) umbilical view, (12) peripheral view.

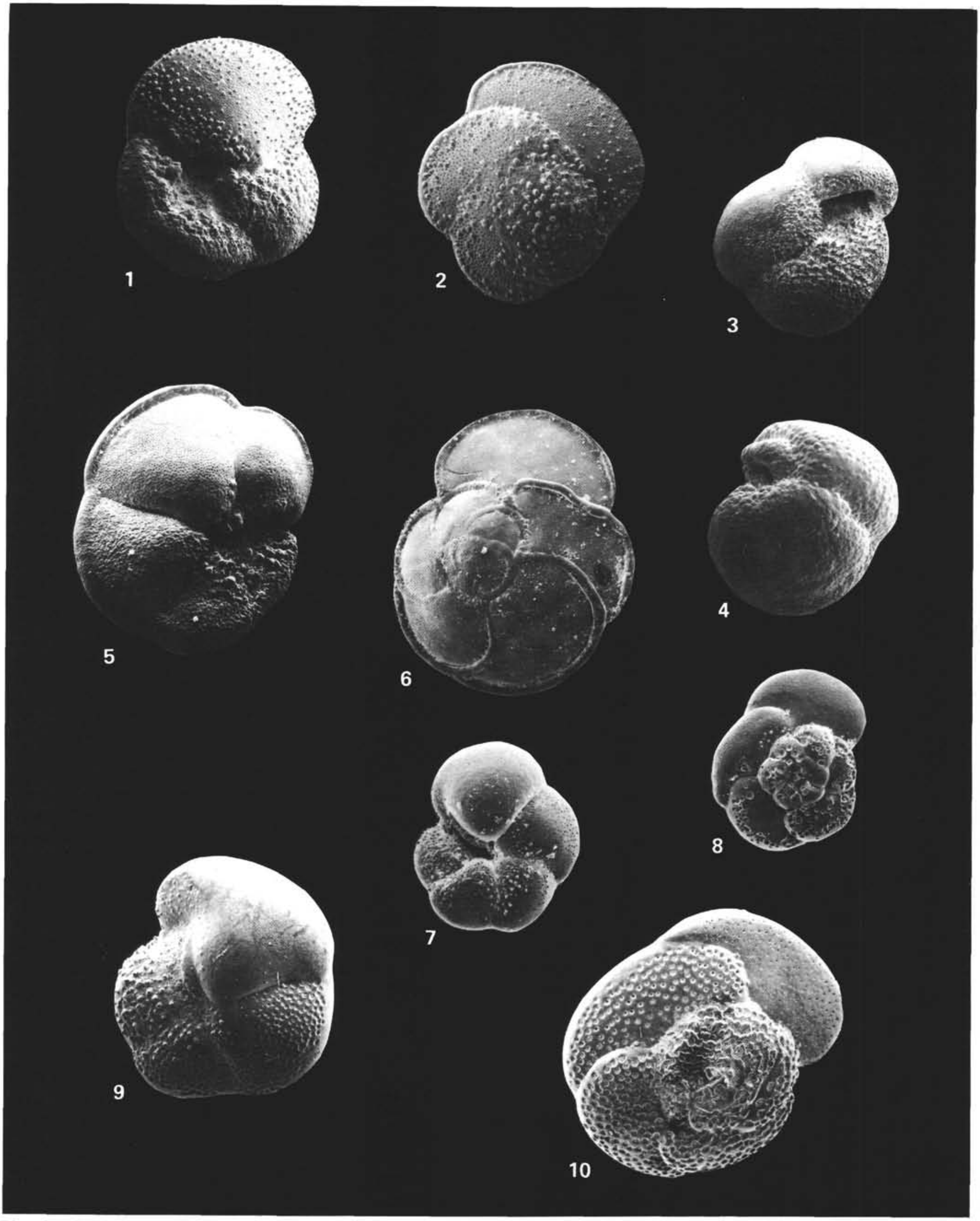

Plate 6. (Specimens magnified ×80 unless otherwise indicated.) **1–2.** *Globorotalia hirsuta* (d'Orbigny), Sample 517-1-1, 0–2.5 cm, (1) umbilical view, ×60; (2) spiral view. **3–4.** *G. inflata* (d'Orbigny), Sample 517-1-1, 0–2.5 cm, (3) umbilical view, (4) spiral view, ×100. **5–6.** *G. menardii* (d'Orbigny), Sample 517-1-1, 0–2.5 cm, ×60, (5) umbilical view, (6) spiral view. **7–10.** *G. scitula* (Brady), (7–8) Sample 517-1-1, 0–2.5 cm, ×120, (7, umbilical view; 8, spiral view), (9–10) Sample 517-7,CC, (9, umbilical view; 10, spiral view).

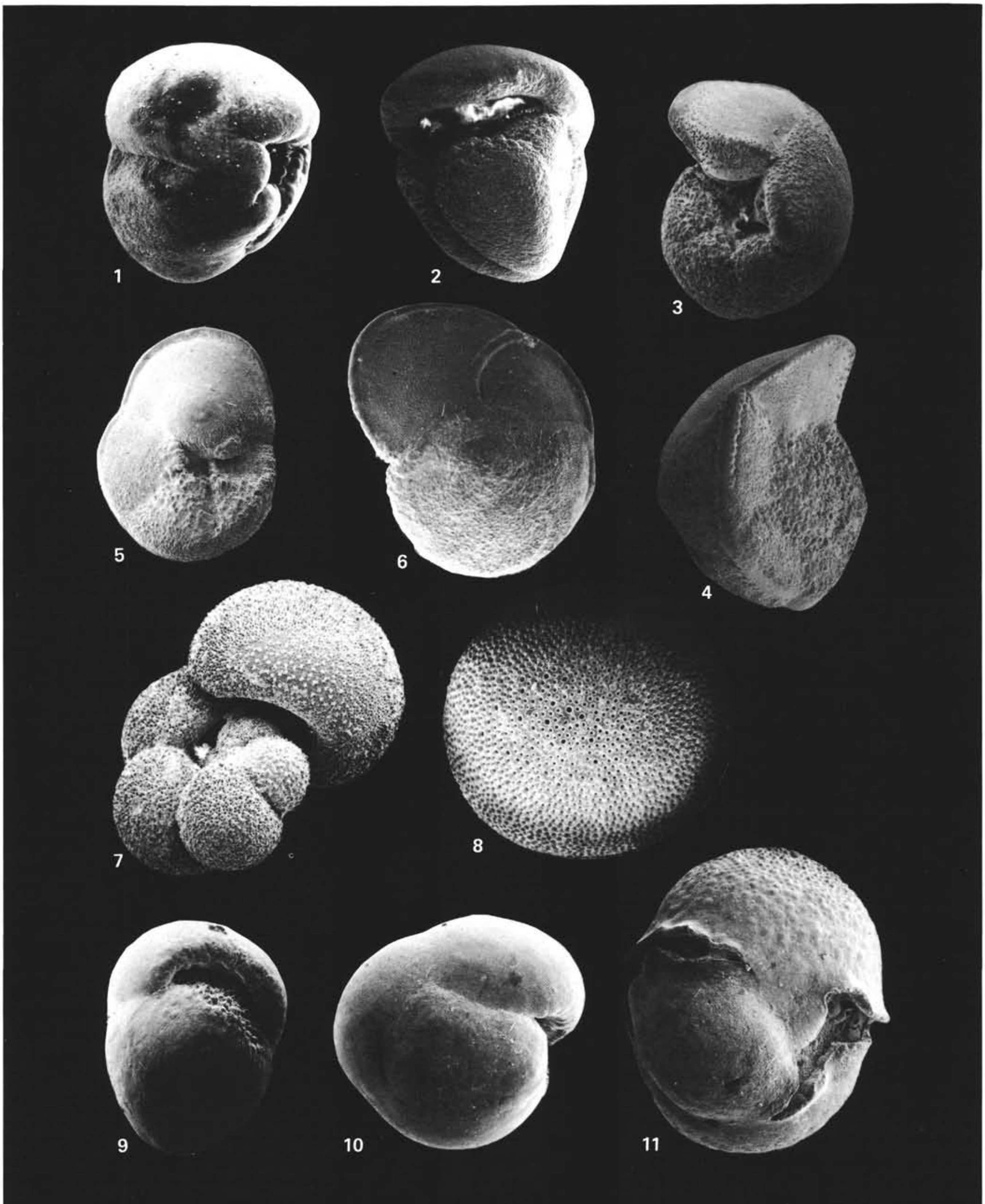

Plate 7. (Specimens magnified ×70 unless otherwise indicated.) **1–2.** *Globorotalia triangula* Theyer, Sample 517-7-3, 50 cm, (1) umbilical view, (2) peripheral view, ×50. **3–4.** *G. truncatulinoides* (d'Orbigny), Sample 517-1-1, 0–2.5 cm, (3) umbilical view, ×50, (4) spiral view. **5–6.** *G. tumida* (Brady), Sample 517-7-1, 50 cm, ×50, (5) umbilical view, (6) spiral view. **7.** *Hastigerina siphonifera* d'Orbigny, Sample 517-4-2, 50 cm, peripheral view. **8.** *Orbulina universa* d'Orbigny, Sample 517-1-1, 0–2.5 cm. **9–10.** *Pulleniatina obliquiloculata* (Parker and Jones), Sample 517-4-2, 50 cm, (9) umbilical view, (10) spiral view. **11.** *Sphaeroidinella dehiscens* (Parker and Jones), Sample 517-5-3, 10 cm, spiral view.