25. THE FORAMINIFERA OF SITES 23-31, LEG 4

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CONTENTS

1. INTRODUCTION

While carrying out investigations on the foraminifera during the Leg 4 cruise of *Glomar Challenger* it became increasingly apparent to the author that the shipboard paleontologist should be obliged eventually to present more than only a preliminary investigation, as was required for this first report. From the experience gained during drilling operations, it was seen again and again how much the outcome of the work is dependent upon an intimate knowledge of the cores. This concerns their general aspect including possible disturbances caused by the coring operations, such as, diapyric intrusion of sediments into the core barrel, and observations on lithologic changes. Most important is the recognition of contaminated portions of the cores, particularly for faunal distribution and biostratigraphic studies. The amount of contamination from higher parts of the section can be considerable, in particular along the surface of the cores. Great care has to be taken, therefore, when sampling to avoid such contaminated areas. This, and sampling at the lithologically most promising levels, greatly influences the value of the resulting investigations. Naturally, cores can be re-examined in this sense and sampled again at the depository, but the paleontologist engaged in a certain study is often unable to do this personally, and instead has to rely on core descriptions and samples taken by others. It is not possible then for him to be aware of many of the above mentioned aspects seen by "the man on the spot."

It is for these considerations that an effort has been made to present here a more comprehensive picture of Sites 23 to 31 than originally envisaged. This goes not only for the foraminiferal fauna, including their quantitative and stratigraphic distribution, coiling ratios of some species, their preservation in respect to the effects of calcium carbonate solution and their application to biostratigraphy, but in a more general way also for some other microfossils and inorganic components retained in the sieves through which the samples were washed. With this it is thought to provide a sufficiently wide base for further studies on the foraminiferal faunas. By adding a column "nature of residue" on each site chart, information is also given on certain sedimentological features of the penetrated beds.

2. ACKNOWLEDGEMENTS

The writer wishes to thank the Deep Sea Drilling Project for having given him the opportunity to participate in Leg 4 of the *Glomar Challenger* cruise from Rio de Janeiro to Panama. This included drilling in the Caribbean Sea, an area where the writer worked for many years and in which he continues to take a strong interest. The Swiss Federal Institute of Technology, Zürich has kindly granted to the writer the necessary leave of absence. After the cruise, the Geology Department of this institution put at the writer's disposal laboratory facilities, help for sample preparation, faunal identification and distribution, drawing and photographing of charts, photographing of specimens by means of the scanning electron microscope, X-ray identification of certain minerals, and clerical work.

It would not have been possible to complete this report in the form presented here in the short time of only about six months after termination of Leg 4 without the able help of the following persons: Drs. Vera Bertolino, Monique Toumarkine and J.P. Beckmann assisted the writer in the investigation of the foraminiferal faunas; Drs. Bertolino and Toumarkine complemented the author's shipboard work on the Caribbean Sites 29, 30 and 31; Dr. Beckmann worked on Sites 23, 24 and 25. In addition to planktonic foraminifera, Dr. Beckmann determined the larger foraminifera of Sites 23 and 24, some smaller benthonic forms of Site 28, prepared the text for Sites 23, 24 and 25, and discussed the manuscript and many aspects of the work with the author. Mrs. Beatrice Lüthi of the Mineralogy Department made the X-ray analysis of a number of minerals. For the correlation of the Caribbean Sites 29 through 31 with land based sections, the writer discussed with Drs. E. Robinson and P. Jung many stratigraphic and faunal aspects of the Jamaica Neogene and with Dr. P.J. Bermudez and Mr. V. Hunter problems that concern coastal Venezuela, in particular the state of Falcon. Messrs. F.C. Fetter, who also prepared samples, P.H. Roth and J. Kuhn took upon themselves the execution of the numerous charts which were photographed and prepared for publication by Mrs. Verena Glarner and Miss Verena Wepfer of the Photographic Institute. The scanning electron microscope micrographs were taken by Mr. R. Wessiken of the Mineralogy Department and Mr. H.E. Franz of the Geology Department. The manuscript and parts of the charts were typed by Miss Denise Landolt. The writer wishes to express his sincere thanks to them all.

3. REMARKS ON LEG 4 UPPER MIOCENE TO PLEISTOCENE PLANKTONIC FORAMINIFERAL SPECIES AND SUBSPECIES

In the short time at disposal to prepare this report it was not possible to present a complete analysis of the planktonic foraminifera in Sites 23 to 31. Though not every collected sample could be analyzed in detail, it is believed that sample spacing in critical intervals is sufficiently close that bottoms and tops of most species are determined with reasonable accuracy. First, the faunas retained in the 80 mesh sieve were investigated, while the smaller fraction of $> 230 < 80$ was examined only in a tentative way. Particular attention was paid to the stratigraphically important species and subspecies. Pre-Miocene species were encountered only very sporadically and mostly reworked in younger sediments. The listed forms of this age are sufficiently well known from many publications so that no further discussions or illustrations are needed here.

Composition and distribution of the planktonic foraminiferal fauna of the Lower and Middle Miocene (*Globorotalia kugleri* to *Globorotalia menardii* Zone) proved to be the same as published by Bolli, 1957c, from Trinidad. Reference is made to this publication for description and illustrations of the species and subspecies concerned.

In comparison to the older faunas of the tropical Atlantic and Caribbean, those from the Upper Miocene to Pleistocene have been less extensively described and figured. Several forms were encountered in the Pliocene and Pleistocene of Leg 4 Sites that could not be included in known taxa, and their morphological features appear sufficiently distinct to justify the erection of new subspecies. However, this report is not considered the right medium to present new taxa. They are therefore given a capital letter affix after the species name and are briefly characterized in the notes which follow on species and subspecies. Their actual description as new subspecies will be given in a separate publication. Scanning electron microscope micrographs of selected and stratigraphically important species and subspecies are attached to the present report.

The greater part of the Upper Miocene to Recent species and subspecies mentioned in this report are well known, but the following comments are given to explain how some of them are interpreted here.

Genus *Globigerina*

Globigerina species are in general not common, though certain species, such as, *G. bulloides* (d'Orbigny) s.l., *G. nepenthes* Todd, *G. tetracamerata* Bolli and Bermudez, may become quite frequent locally. No further comments on the *Globigerina* species recognized in the various stations appear necessary. They are all well known, described and figured in various publications. *G. bulloides* (d'Orbigny) s.l. contains typical representatives as well as closely related forms separated by certain authors into distinct subspecies.

Genus *Globigerinita*

The genus has been plotted as such and no individual species are distinguished in this report.

Genus *Globigerinoides*

An attempt was made to distinguish between *Globigerinoides conglobatus* (Brady) and its presumed ancestral form *G. canimarensis* Bermudez. However, no clear boundary between the two forms could be seen, and both are plotted as *G. conglobatus* (Brady) s.l.

Globigerinoides obliquus obliquus (Bolli) (Plate 1, Figures 18 and 19) and *G. obliquus extremus* Bolli (Plate 1, Figures 20 and 21) were found to have distinct ranges and it appears that especially the latter is a valuable guide fossil in the Pliocene.

Globigerinoides ruber (d'Orbigny) shows considerable variation in size, height of spire and shape of final chamber. All specimens are here included in *G. ruber* (d'Orbigny) s.l. (Plate 1, Figures 22 and 23). Only specimens that have retained their original red color are plotted under a separate heading to check to what sediment depth or stratigraphic age the pigment may be preserved.

The basal Miocene *Globigerinoides primordius* Blow and Banner, the ancestor of *G. trilobus* (Reuss) s.l., is shown on Plate 1, Figures 1 and 2. *G. trilobus* (Reuss) s.l. (Plate 1, Figures 3 and 4) includes the two subspecies *G. trilobus trilobus* (Reuss) and *G. trilobus immaturus* Le Roy. Separately plotted are *G. trilobus sacculifer* (Brady) (Plate 1, Figure 5), *G. trilobus fistulosus* (Schubert) (Plate 1, Figures 8 through 11), *G. trilobus* cf. *fistulosus* (Schubert) (with only rudimentary fistules, Plate 1, Figures 6 and 7) and *G. trilobus* A (Plate 1, Figures 12 through 17). The fistules of form A are not arranged in a line as is the case in *G. trilobus fistulosus* (Schubert), but are placed in irregular positions at the end of the chambers.

Records available indicate that the form A has a very restricted distribution in the *Globorotalia truncatulinoides truncatulinoides* Zone and thus occurs after the extinction of the typical *G. trilobus fistulosus.*

Genus *Globorotalia*

Globorotalia acostaensis Blow (Plate 2, Figures 1, 2 and 3): Specimens compare well with those described originally from Eastern Falcon, Venezuela (Blow, 1959).

Globorotalia crassaformis (Galloway and Wissler): This species originally described from the Pleistocene of California is part of a lineage that appears in the Lower Pliocene and displays considerable variability that resulted in the erection by various authors of a number of separate species and subspecies. Some relations within the *G. crassaformis* lineage are briefly discussed in Cati *et al.*, 1968. The following subdivision of the *G. crassaformis* group is made in this report:

> *Globorotalia crassaformis* s.l. (Galloway and Wissler) (Plate 3, Figures 10, 11 and 12): Rather small specimen with rounded to subangular periphery. Chambers slightly inflated, spiral side flat, umbilical side high. The primitive forms of the *G. crassaformis* lineage are included here.
> Coiling: predominantly sinistral.
> Distribution: First appearance in the *Globorotalia*

margaritae Zone, continuing into the *Globorotalia exilis*/*Globorotalia miocenica* Zone, exceedingly scarce to absent in younger strata.

Globorotalia crassaformis crassaformis (Galloway and Wissler) (Plate 3 Figures 7, 8 and 9): This form apparently develops from *G. crassaformis* s.l. already in the *Globorotalia margaritae* Zone. It is more distinctly conical and angular to even slightly keeled, in particular the last chamber.
Coiling: sinistral.
Distribution: Upper part *Globorotalia margaritae* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone, becoming scarce in the upper part of its range.

Globorotalia crassaformis viola Blow (Plate 3, Figures 1, 2 and 3): This is the very angular and comparatively large form with a distinct peripheral keel and flat spiral side as described by the original author (Blow, 1969).
Coiling: sinistral.
Distribution: *Globorotalia exilis*/*Globorotalia miocenica* Zone.

Globorotalia crassaformis cf. *viola* Blow (Plate 3, Figures 4, 5 and 6): Here are included forms that differ from the typical ones in that the spiral side is slightly convex and the periphery not as distinctly acute.
Coiling: sinistral.
Distribution: *Globorotalia margaritae* Zone to *Globorotalia truncatulinoides* cf. *tosaensis* Zone.

Globorotalia crassaformis A (Plate 4, Figures 17 through 20): Robust, fairly large form, smooth surface, flat spiral side, very high and inflated umbilical side. Rounded periphery. Characteristic for the form is an extension of the last chamber almost completely across the umbilicus. The inclusion of this form in *G. crassaformis* is tentative.
Coiling: sinistral.
Distribution: *Globorotalia exilis*/*Globorotalia miocenica* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone, lower part.

Globorotalia crassaformis Aa (Plate 4, Figures 21 through 24): Similar to *G. crassaformis* A but the final chamber is not overlapping the narrow umbilicus. This form appears to be the ancestral form of *G. crassaformis* A.
Coiling: sinistral.
Distribution: *Globorotalia exilis*/*Globorotalia miocenica* Zone.

Globorotalia crassaformis B (Plate 4, Figures 13 through 16): Robust form, rough surface, quite inflated with rounded periphery. Larger specimens show indications of a peripheral keel and a distinctly angular periphery in the last chamber. The surface of the spiral wall in the last whorl tends to be somewhat offset between successive chambers.
Coiling: sinistral.
Distribution: *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia dutertrei (d'Orbigny): Under this name are included a great variety of apparently closely interrelated forms that range from true, rounded *Globorotalia* (with umbilical-extraumbilical aperture) to *Globigerina* (with umbilical aperture) and *Globoquadrina* (umbilical aperture with elongated tooth-like projections). The following forms are distinguished in this report:

Globorotalia dutertrei humerosa Takayanagy and Saito (Plate 2, Figures 4, 5 and 6): Mostly 5-chambered, low spiralled forms appear already in the Upper Miocene. They are regarded here as ancestral forms of the *G. dutertrei* complex. In Site 25 it was possible to separate *G. humerosa* from the later (typical) more variable *G. dutertrei* s.l. Because of the effects of solution depth in Sites 29, 30 and 31 or widely spaced coring, this subspecies could not be separated there.
Coiling: dextral.
Distribution: *Globorotalia dutertrei* s.l. Zone.

Globorotalia dutertrei (d'Orbigny), high spired (Plate 2, Figures 13, 14 and 15): An attempt was made to separate the distinctly high spired *G. dutertrei* to check whether their stratigraphic distribution was more restricted. Results indicate that though they appear to come in slightly later than the low spired forms, the picture is not sufficiently clear and may be influenced by environmental factors.
Coiling: dextral.
Distribution: *Globorotalia margaritae* to *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia dutertrei pseudopima Blow (Plate 2, Figures 7, 8 and 9): 4-chambered form described by Blow as *G. acostaensis pseudopima*. In the present material, they appear to be linked more closely to the *G. dutertrei* group, both in their morphology and in their distribution pattern.
Coiling: dextral.
Distribution: *Globorotalia margaritae* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone. This is a more extended range than originally given by Blow, 1969 (N20-N23).

Globorotalia dutertrei (d'Orbigny) s.l. (Plate 2, Figures 10-12, 16-19): Included here are the majority of specimens which form a variable group characterized by large, low spiralled tests with 5 or more

chambers in the last whorl.
Coiling: dextral.
Distribution: *Globorotalia margaritae* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia exilis Blow (Plate 7, Figures 9 through 13): Blow, 1969, described this species as subspecies of *G. cultrata.* The Leg 4 investigations showed that *G. exilis* is not only a very distinct form of stratigraphically restricted distribution but also coils dextrally throughout its range, as does the concurring *G. miocenica. G. menardii* subspecies and *G. tumida* subspecies at the same level prefer sinistral coiling. Furthermore, it was observed in some of the Leg 4 sites that when *G. exilis* and *G. miocenica* occur together, in the zone named after these species, representatives of the *G. menardii* complex are practically absent. The same was observed in the *Globorotalia margaritae* Zone, where *G. multicamarata, G. pseudomiocenica* and *G. exilis* A, all coiling dextral, replace typical representatives of the *G. menardii* complex.
Coiling: dextral.
Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone, slightly extending into the older *Globorotalia margaritae* Zone.

Globorotalia exilis A (Plate 7, Figures 14, 15 and 16): Forms close to *G. exilis* but with chambers on the spiral side shorter and less inflated, and with a more pronounced peripheral keel, particularly in the early part of the last whorl. Number of chambers in the last whorl 6 to 8 against 5 to 6 in *G. exilis. G. exilis* A may be regarded as ancestral form of *G. exilis.*
Coiling: dextral.
Distribution: *Globorotalia margaritae* Zone, basalmost part of *Globorotalia exilis/Globorotalia miocenica* Zone.

Globorotalia inflata (d'Orbigny): The variability in chamber shape and growth as added allows the distinction of the following forms:

> *Globorotalia inflata* (d'Orbigny) (Plate 4, Figures 4, 5, and 6): Here are included specimens that appear to come closest to the original concept of the species, i.e. forms with 3 to 4 chambers in the last whorl, which are closely appressed and show a tendency to become very slightly subangular.
> Coiling: sinistral.
> Distribution: *Globorotalia exilis/Globorotalia miocenica* to *Globorotalia truncatulinoides truncatulinoides* Zone.
>
> *Globorotalia* cf. *inflata* (d'Orbigny) (Plate 4, Figures 7, 8 and 9): These forms differ from *G. inflata* in their more inflated, globular chambers.
> Coiling: sinistral.
> Distribution: *Globorotalia exilis/Globorotalia miocenica* to *Globorotalia truncatulinoides truncatulinoides* Zone.
>
> *Globorotalia inflata* A (Plate 4, Figures 1, 2 and 3): Comparatively small forms with chambers increasing in size more rapidly, 4 to 5 in the last whorl. Periphery more lobate. This form may be regarded as ancestral to the others.
> Coiling: sinistral.
> Distribution: *Globorotalia margaritae* to *Globorotalia exilis/Globorotalia menardii* Zone.

Globorotalia juanai Bermudez and Bolli (Plate 8, Figures 22, 23 and 24): Specimens are present in a center bit sample of Site 30, probably from the *Globorotalia acostaensis* Zone. This compares well with the nearby Cubagua-1 subsurface section where the species is restricted to this Zone.
Coiling: dextral.

Globorotalia margaritae Bolli and Bermudez (Plate 8, Figures 1 through 7): Specimens compare well with the original description. In the upper part of the *Globorotalia margaritae* Zone of Sites 29 and 31, they have a tendency to grow larger by adding one or two more chambers (Plate 8, Figures 5, 6 and 7).
Coiling: sinistral.
Distribution: *Globorotalia margaritae* Zone.

Globorotalia menardii (Parker, Jones and Brady): The *G. menardii* complex contains a wide variety of forms. Authors treat this group in different ways, and some place the species into synonymy with *G. cultrata.* Here, the older name *G. menardii* is maintained and a number of subspecies are distinguished. It has been observed in the Leg 4 sites, and in many other samples that in the tropical-subtropical Pliocene/Pleistocene two forms are usually present that can be separated:

1) A comparatively thick walled form with robust peripheral keel. The size is variable, ranging from small to very large forms.
2) Thin walled, often somewhat elongate forms with a delicate peripheral keel. The size is also variable but is usually small to medium.

The following *G. menardii* subspecies are distinguished:

> *Globorotalia menardii menardii* (Parker, Jones and Brady) (Plate 5, Figures 8, 9 and 10): This is the name used in this report for the thick walled forms. They seem to compare in their characteristics with Banner and Blow's lectotype published in 1960.
> Coiling: sinistral.
> Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone.
>
> *Globorotalia menardii cultrata* (d'Orbigny) (Plate 5, Figures 11, 12 and 13): These are the thin walled, delicate forms, relying on d'Orbigny's original figure and Banner and Blow's neotype figure, which shows

the same delicately built test, in contrast to the more robust appearance of the *G. menardii* neotype.
Coiling: sinistral.
Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia menardii A (Plate 5, Figures 1 through 4): It was found that the early representatives of the *G. menardii* group in the Middle to Upper Miocene are distinctly smaller and show a slower increase in chamber size. These forms are here separated as *G. menardii* A and are present e.g. in the Lengua Formation of Trinidad (see Bolli, 1957c).
Coiling: variable, may switch from sinistral to dextral and vice versa as in the Lengua Formation of Trinidad, Bolli 1950.
Distribution: *Globorotalia acostaensis* to *Globorotalia margaritae* Zone.

Globorotalia menardii B (Plate 5, Figures 5, 6 and 7): These are larger forms than *G. menardii* A. Further studies may show whether this form is an intermediate between *G. menardii* A and *G. multicamerata* or possibly closely related to *G. exilis* A and an ancestor of *G. exilis* s.l. Most specimens are quite distinctly convex spirally as is also typical for *G. multicamerata.* From *G. exilis* A they differ in a more robust peripheral keel and the more convex spiral side.
Coiling: variable, though predominantly sinistral.
Distribution: *Globorotalia acostaensis* to *Globorotalia margaritae* Zone of Site 25.

Globorotalia menardii fimbriata (Brady): Specimens that show very fine peripheral spines were found in the top sample of Site 31.
Coiling: sinistral.
Distribution: *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia miocenica Palmer (Plate 7, Figures 4 through 8): Very distinct specimens occur only in the *Globorotalia exilis/Globorotalia miocenica* Zone, occasionally also in the uppermost part of the *Globorotalia margaritae* Zone. Most specimens in the latter zone are smaller and display a slightly convex spiral side and are for that reason placed in *G. pseudomiocenica.*
Coiling: dextral.
Distribution: upper part of *Globorotalia margaritae* Zone, *Globorotalia exilis/Globorotalia miocenica* Zone.

Globorotalia multicamerata Cushman and Jarvis (Plate 7, Figures 17 through 20): The species is characterized by the high number of chambers in the last whorl, 7 to 9 and occasionally more, and the rather convex spiral side.
Coiling: dextral.
Distribution: *Globorotalia margaritae* Zone and lower part of *Globorotalia exilis/Globorotalia miocenica* Zone.

Globorotalia pseudomiocenica Bolli and Bermudez (Plate 7, Figures 1, 2 and 3): See remarks under *Globorotalia miocenica.*
Coiling: dextral.
Distribution: *Globorotalia margaritae* Zone.

Globorotalia cf. *puncticulata* (Deshayes) (Plate 4, Figures 10, 11 and 12): The specimens differ from *G. inflata* in that the chambers are somewhat more angular and higher umbilically.
Coiling: sinistral.
Distribution: *Globorotalia truncatulinoides truncatulinoides* Zone (Site 25 only).

Globorotalia scitula (Brady) (Plate 8, Figures 19, 20 and 21): No distinction of the published subspecies has been attempted. The species has a long range and was found in small numbers in practically all Miocene to Pleistocene samples containing planktonic foraminifera.
Coiling: dextral.
Distribution: *Globorotalia acostaensis* to *Globorotalia truncatulinoides truncatulinoides* Zone (in Leg 4 sites).

Globorotalia subcretacea (Lomnicki) (Plate 8, Figures 16, 17 and 18): Scarce specimens attributable to this species occur throughout the Miocene to Pleistocene. According to Dr. T. Saito (personal communications) the specimens attributed here to *G. subcretacea* are close to or identical with *G. hexagona.*
Coiling: not investigated.

Globorotalia truncatulinoides (d'Orbigny): Blow, 1969, distinguishes two evolutionary lineages:

1. *G. ronda - G. tosaensis tosaensis - G. truncatulinoides pachytheca.*
2. *G. oceanica - G. tosaensis tenuitheca - G. truncatulinoides truncatulinoides.*

The first lineage is characterized primarily by thicker, "sheathed" walls obstructing the original perforation. The second group has normal, perforated walls. Blow's two endforms can be recognized, e.g. in Recent Pacific samples (example: Downwind BG-121, 27° 09'S, 109° 50'W, depth 3320 meters). A distinction of the earlier stages of the proposed lineages is apparently more difficult. Because of the scarceness of specimens in the Leg 4 sites, the presence of these two separate lineages could not be verified.

The *G. truncatulinoides* complex is here treated like the Miocene *G. fohsi* group (see Bolli 1967). A number of subspecies are distinguished that allow for a differentiation of several stages from early rounded forms to a keeled endform. Though the early, rounded subspecies in the Leg 4 sites are only poorly represented, they are here included in *G. truncatulinoides* to show their probable close relationship.

The following subspecies are distinguished:

Globorotalia truncatulinoides cf. *ronda* Blow (Plate 3, Figures 13, 14 and 15): These are specimens that are very close to and possibly identical with Blow's species. Their range is however found to be much more restricted in the Caribbean sites than postulated from elsewhere by Blow. It appears that the subspecies has given rise to *G. truncatulinoides* cf. *tosaensis*.
Coiling: variable (random, dextral, sinistral).
Distribution: *Globorotalia margaritae* Zone.

Globorotalia truncatulinoides cf. *tosaensis* Takayanagy and Saito (Plate 3, Figures 16, 17 and 18): Diverging views exist on the variability and stratigraphic range of *G. tosaensis*. The holotype figures and paratypes seen from the Nobori Formation of Japan are more angular, thinner-walled, and have less inflated side walls than specimens attributed to this taxon by e.g. Berggren, 1968. In comparison, Berggren's forms are distinctly inflated umbilically and possess a more robust shell. Such specimens are here included in *G. truncatulinoides* cf. *tosaensis*.
Coiling: dextral.
Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone to *Globorotalia truncatulinoides* cf. *tosaensis* Zone. Where present in the Caribbean sites they appear within the *Globorotalia exilis/Globorotalia miocenica* Zone and become practically extinct with the first *Globorotalia truncatulinoides truncatulinoides*. This compares well with their distribution in the Chain 61 section of Berggren 1968.

Globorotalia truncatulinoides tosaensis Takayanagy and Saito (Plate 3, Figures 19, 20 and 21): Here are included forms that compare closely with the figured specimens of Takayanagy and Saito and paratypes received from these authors. They appear almost simultaneously with keeled forms referable to *G. truncatulinoides truncatulinoides*, with which they concur during the lower part of the range of that subspecies. It was therefore not possible to recognize a distinct *Globorotalia truncatulinoides tosaensis* Zone in the sense of an occurrence of the subspecies without *G. truncatulinoides truncatulinoides*. The subspecies may however be used to recognize an interval of joint occurrence of *G. truncatulinoides tosaensis* and *G. truncatulinoides truncatulinoides* in the lower part of the present *Globorotalia truncatulinoides truncatulinoides* Zone.
Coiling: variable (random, dextral, sinistral).
Distribution: Lower part of *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia truncatulinoides truncatulinoides (d'Orbigny) (Plate 3, Figures 22, 23 and 24): Here are included keeled specimens regardless of wall structure. (*G. truncatulinoides truncatulinoides* and *G. truncatulinoides* Zone.)
Coiling: variable (random, dextral, sinistral).
Distribution: *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia tumida (Brady): The species displays considerable variability during evolution and is apparently affected by environmental conditions. It makes a late appearance in Site 25 and in the Caribbean Sites 29, 30 and 31, probably because of adverse ecological factors. The early part of the evolutionary sequence with *G. tumida plesiotumida* has not been seen. This subspecies is however present sporadically in the *Globorotalia dutertrei* Zone of the nearby Cubagua-1 well section (Bolli in Bermudez 1966).

The following subspecies are distinguished:

Globorotalia tumida tumida (Brady) (Plate 6, Figures 4, 5 and 6):
Coiling: sinistral.
Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone (very rare) to *Globorotalia truncatulinoides truncatulinoides* Zone.

Globorotalia tumida flexuosa (Koch) (Plate 6, Figures 7 through 12): This form is regarded as a variant of *G. tumida tumida*. Figures 7, 8 and 9 show transitional forms. Under favorable conditions it may appear anywhere during the range of that subspecies.
Coiling: sinistral
Distribution: *Globorotalia truncatulinoides truncatulinoides* Zone. In Bodjonegoro-1, for example, the subspecies makes a short appearance as far down as the *Globorotalia margaritae* Zone.

Globorotalia cf. *tumida* (Brady) (Plate 6, Figures 1, 2 and 3): Here are included specimens that do not have the typical *G. tumida* shape. They are forms somehow half way in test shape between *G. menardii menardii* and *G. tumida tumida*, and seem to be bound to certain environmental conditions.
Coiling: sinistral.
Distribution: *Globorotalia margaritae* Zone (very scarce), *Globorotalia exilis/Globorotalia miocenica* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone.

Pulleniatina obliquiloculata s.l. (Parker and Jones): In Sites 29, 30 and 31 the genus first appears only in the upper part of the *Globorotalia exilis/Globorotalia miocenica* Zone, in Site 25 at the base of that zone. In well Cubagua-1 of coastal Venezuela, primitive forms make a limited appearance in the *Globorotalia margaritae* Zone (Bolli in Bermudez, 1966); in Bodjonegoro well 1 of Java the genus comes in already in the upper part of the *Globorotalia dutertrei* s.l. Zone (Bolli, 1966a). This

latter appearance is in agreement with that of *P. primalis* as given by Blow, 1969, in the upper half of his N17 (= *Globorotalia dutertrei* s.l. Zone). The late appearance in the mentioned Leg 4 sites must therefore be due to ecological factors that prevented the genus from living in these areas. No attempt is made in the present study to subdivide the species into existing subspecies.
Coiling: dextral throughout in Site 25 and in the *Globorotalia truncatulinoides truncatulinoides* Zone of Sites 29, 30 and 31. Dextral, random, and sinistral in the *Globorotalia truncatulinoides* cf. *tosaensis* and *Globorotalia exilis/Globorotalia miocenica* Zones of Sites 29, 30 and 31 (for details see charts).
Distribution: *Globorotalia exilis/Globorotalia miocenica* Zone to *Globorotalia truncatulinoides* Zone.

Sphaeroidinella dehiscens s.l. (Parker and Jones) (Plate 8, Figures 8 through 11): The species occurs in the Pliocene and Pleistocene of Sites 25, 29, 30 and 31. Whereas the outer shell remains intact, the inner portion is usually incomplete or entirely missing in specimens from samples affected by calcium carbonate solution (see Plate 8, Figure 8). This gives to these specimens—regardless of stratigraphic position—an "excavate" aspect.
Distribution: *Globorotalia margaritae* Zone to *Globorotalia truncatulinoides truncatulinoides* Zone. Occasional specimens present in samples below the *Globorotalia margaritae* Zone are considered to be the result of contamination.

Sphaeroidinellopsis seminulina A (Plate 8, Figures 12 through 15): This is recognized in addition to *S. seminulina* (Schwager) and *S. subdehiscens* Blow. The form has 5 to 6 chambers in the last whorl and differs from *S. seminulina* in its less extended ultimate chambers, the tendency to a convex spiral side and a less lobate periphery. It seems to represent an endform of the genus.
Distribution: *Globorotalia margaritae* Zone.

No comments appear necessary for the other planktonic species that are present in the Pliocene-Pleistocene and which include *Beella digitata, Candeina nitida, Hastigerina pelagica, H. siphonifera, Globoquadrina altispira, Orbulina* sp. and others.

4. THE ZONATION OF LEG 4 STATIONS BASED ON PLANKTONIC FORAMINIFERA

The zonal schemes of Bolli 1957, a,b,c, and of Bolli and Bermudez 1965, compiled and partly revised by Bolli 1966, are used here for the dating in terms of planktonic foraminiferal zones of the sediments penetrated in Sites 23 through 31. The schemes can be applied successfully wherever planktonic foraminifera are present, with some exceptions in the Pliocene-Pleistocene to be discussed below.

It is well known that planktonic foraminiferal zones in the Cretaceous and Paleogene are valid over geographically much wider areas, in particular to higher latitudes, than in the Miocene to Recent. The trend towards a more and more restricted latitudinal distribution of many planktonic foraminiferal species—apparently related primarily to changes in water temperatures—began already during the late Eocene and Oligocene, and became progressively more pronounced in the Miocene, Pliocene and Pleistocene. Zonations established for younger Tertiary strata and based on tropical-subtropical species could therefore be applied only with difficulty to areas outside the tropical belt such as the Mediterranean or New Zealand. Thus, it became necessary to establish complementary zonal schemes for temperate areas. As examples, publications by Cati *et al.*, 1968, for the Mediterranean area, and Jenkins, 1967, for New Zealand may be cited. By means of intermediate sections, certain widely distributed species, or by other microfossils such as nannoplankton, it should be possible eventually to correlate the different zonal schemes based on tropical, temperate and cold water faunas.

Cretaceous to Miocene

In the samples of Leg 4, Upper Cretaceous and Paleocene planktonic foraminifera occurred only sporadically and sparsely. Usually, they were either reworked in younger sediments, or were recovered from center bit or bit samples where depth and type of sediment could not be determined accurately, for instance in Site 28. The Middle Eocene to Oligocene planktonic foraminifera of Sites 23, 24 and 27 are all reworked in the Lower Miocene *Globorotalia kugleri* Zone.

No difficulties were encountered in placing the faunas of Miocene age of Sites 23, 24, 25, 29, 30 and 31 into the zonal scheme of Bolli and Bermudez, 1965.

Pliocene-Pleistocene

While agreement exists on most ranges of Cretaceous to Miocene planktonic species, this is not the case for some Pliocene to Recent forms. The conflicting findings e.g. by Bolli and Bermudez, 1965, Banner and Blow, 1965, Bolli 1964, 1966a, Bolli in Bermudez, 1966, Bolli *et al.*, 1967, and Blow, 1969, can be cited as examples. It appears that discrepancies in the interpretation of species ranges are due not so much to diverging species concepts, faunal mixing, or reworking, as to the fact that the presence or absence of certain species was determined—even locally—by climatic fluctuations. Glacial and interglacial periods affected the temperatures or circulation of tropical and subtropical waters sufficiently to control the distribution of planktonic species. The changing water temperatures caused by glaciation periods thus led to a complex lateral and vertical distribution pattern of many species.

This would explain why the various authors mentioned above, who based their findings on different areas and sections, are often not in full agreement. Many of the apparent discrepancies can be bridged as was shown by Bolli, 1966, who correlated in Table 3 the Banner and Blow, 1965, scheme with that of Bolli and Bermudez, 1965. On the other hand, Blow, 1969, Figure 15, was led to the statement that the "younger zones proposed originally by Bolli and Bermudez, 1965, cannot be directly correlated with Zones N16 to N23." Neither Banner and Blow, 1965, nor Blow, 1969, offer sufficient documentation on the sections they used, nor do they make available detailed distribution charts of the sections on which they base their zonal scheme. This makes it difficult to evaluate their zonal schemes and correlate them with others. In the case of Blow, 1969, this applies particularly also to the distribution of the planktonic foraminifera species and subspecies as shown on his Figures 1 through 13.

Difficulties in correlating Pliocene-Pleistocene sections within the tropical belt on the basis of certain planktonic species were previously experienced by the writer in 1964 (and summarized there on p. 551) when he compared species ranges from sections in Java, the Philippines and Venezuela.

Remarks on the Distribution of Some Index Fossils in the Tropical Pliocene and Pleistocene

How variable the ranges in the Pliocene-Pleistocene of certain species can be—as a result of ecological changes, kind of section investigated, and also partly because of reworking effects—is shown by the following two examples.

First, *Globorotalia tumida* s.l. is a species restricted today, and apparently also in the past, to the tropical belt. The ancestral form *G. tumida pleisotumida* appears, according to Blow, 1969, in his N17 Zone or in the late Miocene. This corresponds with the *G. dutertrei* s.l. Zone of Bolli and Bermudez and agrees with the occurrence of this subspecies in well Bodjonegoro-1 of Java, Bolli, 1966a, and in well Cubagua-1 of Venezuela, Bolli in Bermudez, 1966. Whereas the evolution of *G. tumida plesiotumida* into *G. tumida tumida* could be followed practically without interruption in Bodjonegoro-1, beginning in the *G. dutertrei* s.l. Zone, this was not so in Cubagua-1. Here *G. tumida plesiotumida* occurs only over a very restricted interval and typical *G. tumida tumida* never makes an appearance at all, apparently for ecological reasons. In Sites 29, 30 and 31, drilled in the relative proximity of Cubagua-1, *G. tumida tumida* is restricted to the *G. truncatulinoides truncatulinoides* Zone. Other species in Sites 29, 30 and 31 with similar irregular distribution patterns in the Pliocene-Pleistocene include *G. menardii cultrata, G. menardii menardii, G.* cf. *tumida,* and *Pulleniatina* s.l.

Second, the question of a possible overlap of *Globoquadrina altispira* and *Globorotalia truncatulinoides* has recently caused some controversy. Before entering into a discussion on this it must be made clear that *Globorotalia tosaensis* is now regarded by the writer as the ancestral form of *G. truncatulinoides.* In his earlier publications, he did not separate these two forms (for explanation of the relationship see discussions on *G. truncatulinoides* under Remarks on Upper Miocene to Pleistocene Species and Subspecies).

When Bolli and Bermudez, 1965, proposed a *Globoquadrina altispira altispira/Globorotalia truncatulinoides* Zone it was based on samples received from the Manchioneal Formation of Jamaica, and on cores from the Nicaragua Rise, Bolli *et al.,* 1968. It was already noted by these authors that such overlaps were not known from coastal Northeastern Venezuela nor in the Bodjonegoro-1 section of Java, Bolli 1966a. Periods of adverse ecological conditions were thought at that time to have accounted for this. The concept of an overlap of *G. altispira* and *G. truncatulinoides* s.l. found support in the papers by Akers, 1965, and Poag and Akers, 1967, who reported such concurrences from cored sections in the Northern Gulf of Mexico and the Gulf Coast. In their zonal scheme of 1965 which was published shortly after that of Bolli and Bermudez, 1965, Banner and Blow do not only reject an overlap of *G. altispira* with *G. truncatulinoides* (their N22) or *Globorotalia tosaensis* (their N21) but assume an actual gap between extinction of *G. altispira* and first occurrence of *G. tosaensis.* This interval is defined by them as Zone N20 or as *Globorotalia multicamerata-Pulleniatina obliquiloculata* (s.s.) Zone. An overlap of *G. altispira* and *G. truncatulinoides* was also maintained as unlikely by Robinson, 1967, who cited evidence against it from Jamaica itself, from just where Bolli and Bermudez had taken their original proof for such an overlap. According to Robinson, field evidence and the study of many samples indicate that all joint occurrences of these two species in Jamaica must be due to reworking (see also p. 595 of this paper). In his Pliocene-Pleistocene zonal scheme of 1969, which is partially altered from that of Banner and Blow, 1965, Blow explains at some length that contrary to Banner and Blow's views of 1965, a gap between *G. altispira* and *G. tosaensis* does not only not exist but even allows for a concurrence of these two species at least in some areas. This he observed in unspecified deep sea cores from the northern Caribbean and from the Central and North Atlantic. In parts of the Indo-Pacific Province, on the other hand, he regards such occurrences of *G. altispira* in younger sediments as not autochthonous (again without documentation).

It is now known that *Globoquadrina altispira* and *Globorotalia truncatulinoides tosaensis* distinctly overlap in at least some parts of the Indo-Pacific (see remarks in this paper on Bodjonegoro-1 and deep sea cores,

p. 600. It would thus appear that *G. altispira* became extinct somewhat earlier in at least some parts of the Caribbean and Atlantic compared with the Indo-Pacific region.

In none of the three Caribbean sites (29, 30 and 31) does there exist an overlap of *G. altispira* with typical *G. truncatulinoides tosaensis* or *G. truncatulinoides truncatulinoides.* On the contrary, their top or bottom occurrences were in each section separated by an interval of varying thickness. This is in agreement with the views of Banner and Blow, 1965, and Robinson, 1967, but refutes the opinions of Bolli and Bermudez, 1965, and Blow, 1969.

In summarizing it may be said that where in documented Caribbean sections *G. altispira* and *G. truncatulinoides tosaensis* or *G. truncatulinoides truncatulinoides* concur (such as in the Manchioneal Formation of Jamaica or the Nicaragua Rise section), evidence is strong that *G. altispira* is reworked or that the faunas became mixed during or subsequent to coring operations. Regarding other localities with a reported overlap such as those mentioned by Akers, 1965, Poag and Akers, 1967, and Blow, 1969, no detailed descriptions of sections and faunas were given. Before accepting them as proof for a possible natural overlap, they will first have to be carefully investigated for possible reworking and/or mixing of faunas. If the fully documented evidences only of the above cited authors are taken into consideration, one therefore arrives at the conclusion that *G. altispira* and *G. truncatulinoides tosaensis* and *G. truncatulinoides truncatulinoides* not only do not overlap but are separated in the Caribbean/Gulf Coast region by a certain interval. This interval may be characterized by forms here named *G. truncatulinoides* cf. *tosaensis* and present e.g. in Sites 29 and 31 or in Chain 61, Berggren, 1968. A slight overlap of *G. altispira* with *G. truncatulinoides* cf. *tosaensis* is indicated in Site 31, Core 3, 2 to 4 centimeters. See p. 583 for a discussion of *G. truncatulinoides tosaensis* and *G. truncatulinoides* cf. *tosaensis.*

The practical absence of typical *Globorotalia truncatulinoides tosaensis* prior to the first keeled *G. truncatulinoides truncatulinoides* and the absence or only very erratic presence of *Globoquadrina altispira* above the *G. margaritae* Zone makes these species unsuitable as Pliocene index fossils at least in the area of Sites 29, 30, and 31. This and the total lack of an overlap are the prime reasons why a new zonal definition in the Caribbean region for the interval above the *G. margaritae* Zone and below the *G. truncatulinoides truncatulinoides* Zone of Bolli and Bermudez 1965 had to be found. An application of the 1969 zonal scheme of Blow in the Caribbean Sites 29 to 31 and also in Site 25 is prevented for the following reasons:

1. The virtual absence, apparently for environmental reasons, of his postulated evolutionary series from *Globorotalia merotumida* via *G. plesiotumida* to *G. tumida tumida.* (See also p. 585).
2. His zonal marker *Globorotalia multicamerata* has a much more restricted range, extending only very slightly above the *Globorotalia margaritae* Zone.
3. The lower part of the *Pulleniatina* lineage is missing, apparently for environmental reasons.
4. No overlap of *Globoquadrina altispira* and *Globorotalia truncatulinoides tosaensis,* as discussed above.

Fortunately, the faunal distribution in Sites 25, 29, 30 and 31 above the *G. margaritae* Zone is such that a distinct subdivision of the higher Pliocene/Pleistocene is possible on the ranges of a number of characteristic species. They include: *Globorotalia margaritae, G. miocenica, G. exilis, G. truncatulinoides* cf. *tosaensis, G. truncatulinoides tosaensis, G. truncatulinoides truncatulinoides* and also *G. multicamerata, Globigerinoides trilobus fistulosus, G. obliquus extremus* and *Sphaeroidinella dehiscens.* Based on the distribution of these species, it is possible to propose for the Central Atlantic and Caribbean area the following two tentative zones between the *Globorotalia margaritae* Zone below and the *G. truncatulinoides truncatulinoides* Zone above:

Globorotalia exilis/Globorotalia miocenica Zone

Definition:	Interval with *G. exilis* and/or *G. miocenica* between the extinction of *Globorotalia margaritae* and the extinction of the two zonal markers.
Author:	Bolli, in this paper.
Type Locality:	JOIDES Site 31, Beata Ridge, Caribbean Sea (14°56.00'N, 72°01.63'W). Core 3, Section 3. The zone ranges in Site 31 from Core 6, core catcher (at 318 feet) to Core 3, Section 1, 50 centimeters (at 200 feet).
Remarks:	The zone is nearly identical with the total range of the zonal markers, which develop in the uppermost part of the *Globorotalia margaritae* Zone from *G. pseudomiocenica* and from a form called here *Globorotalia exilis* A (see notes on species). Typical *Globorotalia multicamerata* may continue from the *Globorotalia margaritae* Zone into the *Globorotalia exilis/Globorotalia miocenica* Zone but appear to be restricted to its lower part. Typical *Globigerinoides trilobus fistulosus* is restricted to the lower part of the zone. *G. obliquus extremus* continues from the *Globorotalia margaritae* Zone into the *Globorotalia exilis/Globorotalia margaritae* Zone where frequent and typical forms become extinct almost simultaneously with *G. trilobus fistulosus. Pulleniatina* s.l. makes its first appearance within the zone (for ecological reasons) and so does

Globorotalia truncatulinoides cf. *tosaensis*. *Globoquadrina altispira* is seen only very sporadically. The zone could be further subdivided, on the basis of the first appearance and extinction of several of the mentioned species. The zone is provisionally given a double name to prevent its confusion with the Mediterranean *Globorotalia miocenica* s.l. Zone of Cati *et al.,* 1968.

Globorotalia truncatulinoides cf. *tosaensis* Zone

Definition:	Interval with zonal marker from extinction of *Globorotalia exilis/Globorotalia miocenica* to the first occurrence of *G. truncatulinoides truncatulinoides.*
Author:	Bolli, in this paper.
Type Locality:	JOIDES Site 29, Central Venezuelan Basin, Caribbean Sea (14° 47.11'N, 69° 19.36'W). Core 2, Section 3, 146 to 148 centimeters. The zone ranges in Site 29 within Core 2 from Section 3, 148 centimeters, to Section 2, 139 centimeters.
Remarks:	Eventually, cf. *tosaensis* may have to be replaced by a new subspecies name.

Outside the *Glomar Challenger* Sites 25, 29, 30 and 31, the modified zonal scheme can also be applied to the deep sea core Chain 61 in the south central North Atlantic (Berggren, 1968), to at least some sections of Legs 1, 2 and 3 of the Deep Sea Drilling Project and to land-based sections in Jamaica. The geographic area within which the faunal distribution leading to the newly defined zones can be observed includes at present parts of the Caribbean, large parts of the tropical/subtropical Atlantic province, and parts at least of the Gulf of Mexico area. So far, the characteristic species *Globorotalia exilis, G. miocenica, G. multicamerata* have not been found in the land-based sections of Venezuela and Trinidad; they have not been reported from the Pacific province either.

The Pliocene-Pleistocene boundary is placed here at the first occurrence of *Globorotalia truncatulinoides truncatulinoides.* This does not quite agree with Blow, 1969, who places the boundary within the upper part of his N21 Zone; according to his range charts, at approximately this level 14 planktonic species and subspecies become extinct. Such a mass extinction at about the same time, and affecting the index forms *Globorotalia multicamerata, G. miocenica, G. exilis, Globoquadrina altispira, Globigerinoides trilobus fistulosus* and *G. obliquus extremus,* would indeed point to a major event. However, no such distinct level of extinction of so many forms could be seen in the Leg 4 sites. On the contrary, and as can be seen from the charts, and the remarks under the description of the *Globorotalia exilis/Globorotalia miocenica* Zone, some of these forms became extinct at quite different levels. It must be stressed that this is based entirely on observations in the cited Leg 4 sections. Blow, 1969, gives no documentation for his ranges but announces its publication in a future work. Some of his ranges at least those that do not check with those found in the Caribbean sites may be the result of a different environment or may be based on deep sea cores which are often referred to in his text. If such cores were piston cores they must be of limited length and the sedimentary sequences of these reaching into Pliocene or older sediments must be strongly condensed or incomplete (see also p. 601). Consequently, faunal distributions based on such cores must be similarly affected.

5. SITES 23-31: PLANKTONIC FORAMINIFERA, OTHER MICROFOSSILS, NATURE OF RESIDUE, ZONE, AGE

Explanations on the fauna, nature of residue, zonal subdivision and age for individual stations are being kept brief here; only the essential features are mentioned. The details can be obtained from charts prepared for each station. They contain the following information for each sample included in the present study:

1) Columns on the left indicate the depth below sea floor, core number, section number and the interval in centimeters from the top of the section. Each core, which at full recovery contains a maximum of 30 feet of sediment, is divided into sections of 150-centimeter lengths, or a maximum of 6 per core.
2) The planktonic foraminifera are plotted in alphabetical order. A number of species are listed out of order in Sites 30 and 31. For reasons of space, it was necessary to prepare two separate charts each for Sites 29, 30 and 31, one for the Upper Miocene–Pleistocene, the other for the Oligocene–Middle Miocene. In Holes 26 and 26A, planktonic foraminifera and reworked planktonic foraminifera are listed separately. The planktonic foraminifera of Hole 27 and 27A are grouped according to age into Pliocene–Recent, Lower Miocene, Eocene and Cretaceous.
3) Benthonic genera and species are plotted in alphabetical order in Sites 23, 24 and 28 where they were investigated in some detail. In the other sites their presence is merely listed as "benthonic foraminifera" under the heading "other microfossils."
4) The presence of echinoid spines, fish teeth/bones, plant remains, Radiolaria, sponge spicules, etc. are listed in addition to the benthonic foraminifera under "other microfossils."
5) The composition of the residue retained in 230 and larger mesh sieves is given under "nature of residue." Listed here are also nonfossil remains

such as sediment fragments and minerals. The following minerals were determined by the X-ray refraction method:

Barite	(Hole 24A, Core 2; Hole 28, Core 9, core catcher)
Calcite	(Hole 28, several samples from lower part of section)
Dolomite	(Hole 23, Core 2, Section 1, 65 centimeters; Hole 27, Core 2, Section 3, bottom of core; Hole 28, Core 2, Section 2, 100 to 101 centimeters)

6) The following four frequency grades for planktonic foraminifera, benthonic foraminifera, other microfossils and nature of residue are distinguished. They are based on rough estimates and refer to sediment samples of approximately 10 to 20 cc:

● abundant (more than 100)
● common (about 26 to 100)
• few (about 6 to 25)
• very few (1 to about 5)

7) The column "compensation depth" indicates for some stations whether and to what degree the planktonic foraminifera are damaged or completely destroyed by the effects of calcium carbonate solution. The legend for this column reads as follows:

not affected (left blank)
/ slightly damaged
X strongly damaged
* destroyed

8) Abbreviation of genus names

Gg = *Globigerina*
Gs = *Globigerinoides*
Gq = *Globoquadrina*
Gr = *Globorotalia*
Pu = *Pulleniatina*
Sa = *Sphaeroidinella*
Ss = *Sphaeroidinellopsis*

9) Zone and age determinations are found at the right of each chart.

10) "c" indicates contamination.

Distribution of *Globorotalia* Species and Selected other Planktonic Foraminifera in the Upper Miocene to Pleistocene

Separate charts showing the distribution in stratigraphic order of the more important Upper Miocene to Pleistocene species and subspecies are given for Holes 25, 25A, 29, 29B, 30 and 31.

Direction of Coiling in *Globorotalia, Globoquadrina,* and *Pulleniatina*

For the same sites and on the same charts as mentioned above are indicated preferred coiling directions for the *Globorotalia* species and subspecies, for *Globoquadrina altispira* and *Pulleniatina obliquiloculata* s.l.

6. SITE 23

Site 23 lies near the outer edge of the continental slope off Recife (Brazil) at a water depth of 5079 meters (16,664 feet). The sediments recovered in the cores represent mostly deep-sea clays which are poor in calcium carbonate except for some pockets of foraminiferal ooze and sandy beds of probable turbidites.

Cores 1, 2 and 3 recovered mostly red clay type sediments. In Core 1, irregularly distributed pockets and lenses of calcareous ooze contained a mixed Pliocene-Pleistocene fauna (*Globorotalia truncatulinoides* s.s. associated with older forms such as *Globoquadrina altispira, Globorotalia crassaformis viola, G. miocenica, G. multicamerata, G. margaritae, Globigerinoides fistulosus* and others). Possibly the foraminiferal oozes of Core 1 represent slump masses of predominantly Pliocene material which were embedded in the red clays of Site 23 during the Pleistocene.

Core 2 contains a poor fauna of probable Upper Miocene age (strongly affected by calcium carbonate solution), whereas the sediments of Core 3 were apparently formed well below the "compensation depth."

Cores 4 and 5 recovered greenish-gray clays with interbedded quartz sands and calcareous sandstones. The quartz is angular to subangular. The clays and some of the sands appear to be nonfossiliferous, but several sandy-calcareous beds include well preserved planktonic foraminifera of the *G. kugleri* Zone (Lower Miocene), associated with larger and smaller benthonic foraminifera (including: *Miogypsina tani* and *M. "gunteri-tani"* transitional forms, *Lepidocyclina anellei, Heterostegina antillea* and sp., *Amphistegina* cf. *taberana*). It is remarkable that *Miogypsina tani* is concentrated in the bottom of Core 4 and in Core 5, whereas the presumably more primitive transition forms *M. gunteri-tani* are well represented in the upper part of Core 4. This reversal, together with the fact that such typically shallow water forms occur now at a water depth of over 5000 meters (16,400 feet), indicates that sometime during the Miocene these Lower Miocene fossils were eroded, carried downwards in submarine slumps, or turbidity currents, and re-deposited in the deep sea. This applies probably also to the planktonic foraminifera of Cores 4 and 5, since they are irregularly distributed and mostly concentrated in the sandy beds. Core 5 (clay) and Core 6 (basalt) did not provide conclusive data, because of poor recovery and the absence of diagnostic fossils.

7. SITE 24

Site 24 lies close to Site 23 (off Brazil), at a water depth of 5148 meters (16,889 feet).

Cores 1 to 4 of Site 24 show a close resemblance, both lithologically and faunally, to Cores 4 and 5 (? also 6) of Site 23. It appears that the section of Site 24 is slightly older in age (but still within the *Globorotalia kugleri* Zone). This was first suggested in the Shipboard Report, based on the relative scarcity of *Globigerinoides trilobus primordius,* and is now confirmed by the presence of *Miogypsina gunteri* (the ancestor of *M. tani* of Site 23), *Pararotalia* cf. *mexicana* and *Miogypsinella* sp. Furthermore, the specimens of *Globorotalia kugleri* have generally a more rounded periphery (approaching that of *G. pseudokugleri* Blow) in Site 24 than in Site 23, a character which indicates the lower part of the *G. kugleri* Zone. Rare reworked Eocene forms such as *Globorotalia crassata* group, *G.* cf. *formosa, Truncorotaloides* sp. and *Hantkenina* sp. are found in Cores 1 and 2.

Hole 24A was drilled on the same site as Hole 24 in order to evaluate the deeper sediments down to the "basement." It penetrated clays and sandy mudstones containing mainly Radiolaria indicative of Upper Cretaceous, probably Campanian. A few *Globorotalia* of possible Paleocene age occur in Core 1. No diagnostic foraminifera could be recovered from Cores 2 to 4.

8. SITE 25

Site 25 is situated on top of a submarine ridge off the northeast coast of Brazil, at a water depth of 1916 meters (6284 feet); from the sea bottom to a drilling depth of 120 feet, a nearly continuous section of Quaternary to Upper Miocene sediments was penetrated (Cores 1 to 3). The Pleistocene fauna of Core 1 is followed in Core 2 by a mixed Pliocene/Pleistocene assemblage. The question is here left open as to whether this mixing is natural (due to slumping and/or reworking as in Site 23), or whether it was artificially produced during the coring operations ("telescoping effect"). The incomplete recovery of Core 2 suggests that some kind of mechanical disturbance might have taken place. Cores 3 and 4, on the other hand, show a straightforward sequence from Lower Pliocene to Upper Miocene, with some obvious contamination from above in Core 4.

Below a depth of about 150 feet some hard rocks were encountered which, according to the drilling report, alternated with softer beds. Recovery from this section was very poor and consisted of a few small pieces of hard limestone (Cores 5 and 7) with minor quantities of chalky ooze (Core 5). The soft rocks of Core 5 contain a somewhat heterogeneous assemblage with a predominance of Middle Miocene forms (association of the *Globorotalia menardii* Zone of Bolli, 1957c, with *G. fohsi* s.l., *G. mayeri,* and *G.* cf. *kugleri*). Thin sections of the hard limestone in the same core show a poorly preserved planktonic fauna which is mostly undeterminable but seems to include some pre-Miocene (probably Eocene) elements. Core 7 recovered only a piece of limestone which includes abundant calcareous algae (*Cymopolia* cf. *mayaensis* Johnson and Kaska, *Trinocladus* (?) sp., *Halimeda* sp., *Archaeolithothamnium* sp. and unidentified *Corallinaceae*). Foraminifera are rare and include *Eofabiania* (and *Fabiania?*) sp., *Amphistegina* cf. *lopeztrigoi* Palmer, a spinose *Rotalia* species and undetermined smaller forms. Such an assemblage must have lived in very shallow water (back-reef shoal environment). The majority of the fossils suggest an Eocene (Lower Eocene?) age, although a few of the melobesian algae have rather an Oligo-Miocene aspect.

A second hole (25A) was drilled in an attempt to get deeper penetration, but only one core was recovered. It contains a rich planktonic fauna of Miocene age which, based on biostratigraphic evidence, would be placed between Cores 4 and 5 of Hole 25. This arrangement is, however, in conflict with the reported drilling depths. In addition, some limestone pebbles were recovered from the core catcher. Two of these were thin sectioned; they include few poorly preserved microfossils, amongst them *Globigerinas,* possibly also Globorotalids (unkeeled *Globorotalia, Truncorotaloides?*), remains of melobesian algae, and rare fragments of *Discocyclina.* The latter are valuable indicators of an Eocene (to Paleocene) age.

The significance of these hard rocks with distinctive Eocene elements in both holes is not fully understood, especially since they were recovered together with Miocene planktonic foraminifera. The limestones are usually fine crystalline, and partially impregnated with silica and an unidentified ore mineral. Either they are reworked pebbles in the Miocene, or they indicate that the well approached a hard surface of Eocene (?) rocks.

9. SITE 26

The site lies in the *Vema* Fracture Zone, a narrow east-west trending trough which cuts through the Mid-Atlantic Ridge. Water depth is 5169 meters (16,954 feet). The sediments penetrated consist of turbidites: mainly clays, and occasionally thin layers of fine to medium and rarely coarse sands; and layers rich in mainly fine plant debris. Graded bedding is present. The sands consist mainly of angular to subangular colorless quartz; red quartz (hematite films) and mica can be frequent. Also present are blue quartz and other minerals.

The foraminiferal faunas encountered are almost exclusively planktonic and of Pleistocene to Recent age, with occasional smaller benthonic species present in some samples. The fauna is usually poor to very poor and often almost completely absent. The whole fauna is presumed to be allochthonous, that is, transported together with the sediment components. This assumption is based on:

a) Depth of Site 26, which is 5169 meters (16,954 feet) and therefore below compensation depth. An autochthonous planktonic fauna would therefore be dissolved before it could accumulate whereas specimens transported relatively rapidly in suspension with above mentioned turbiditic particles are buried quickly once the turbidites come to rest and are little or not at all affected by calcium carbonate solution.
b) The faunas are very poor compared with open-sea foraminiferal oozes from levels above compensation depth.
c) The faunas are size sorted, i.e., clays are almost barren, silts and sands contain foraminiferal tests in size corresponding to grains.
d) Some of the faunas have a heterogeneous aspect; few Middle to Lower Eocene planktonic foraminifera occur to Core 5, Section 4, interval 24 to 26 centimeters. Shallow water faunas such as crab claws, byrozoa, pelecypod fragments, gastropods, were found in the samples of Hole 26A. The benthonic foraminifera such as Miliolids, *Cassidulina, Bolivina, Bulimina,* etc. are also considered to have been carried along with the sediments.

It is assumed that most of the sediments penetrated at Site 26, in particular the coarser levels consisting mainly of quartz and plant fragments, have their origin in the Amazon river. On their way to the Demerara Abyssal Plain and the *Vema* Fracture Zone, these turbidity currents loaded with Amazon material picked up the shallow water forms (molluscs, bryozoans, some foraminifera, etc.) on the inner continental shelf and the planktonic foraminifera on the outer shelf and on the shelf slope (Amazon cone). It appears that older sediments are exposed in the slope canyons. This would explain the presence of the few Eocene planktonic foraminifera in Core 5, Section 4, 24 to 26 centimeters.

Some of the *Globigerinoides ruber* have retained their red color even in the deepest cores. This is an indication that the sediments are extremely young, and, considering their thickness, have been laid down at a considerable rate. It appears that the layers rich in plant remains which measure up to 2 centimeters in length reflect flooding periods of the Amazon.

Hole 26A did not recover any cores because the bit and some drill collars twisted off while drilling between 1500 and 2000 feet. Sediment material was recovered, however, from inside the remaining drill collars and from outside the deepest pipes. It is assumed that this material, rich in mineral grains (mainly quartz), plant fragments and also planktonic foraminifera, comes from a depth between 1800 and 2000 feet, thus from below the deepest core obtained from Hole 26. It is for this reason that the faunas recovered from Hole 26A are included on the distribution chart.

10. SITE 27

The site lies in the western part of the Atlantic Basin, about 250 miles east of the Lesser Antilles Island Arc and northeast of Barbados, in a water depth of 5251 meters (17,223 feet).

The sediments penetrated to a depth of 1240 feet (374 meters) are of turbidite nature, consisting largely of clays practically barren of microfauna but with occasional thin layers of very small plant fragments. Some silt/sand encountered in Core 3, from 772 to 802 feet, and again in a center bit sample between Cores 5 and 6, at 1240 to 1488 feet (374 to 452 meters) (possibly representing contamination from Core 3) contain a fairly rich, predominantly planktonic foraminiferal fauna of heterogeneous composition. The bulk of the fauna is of *Globorotalia kugleri* age, including *G. kugleri* and *Globigerinoides trilobus primordius,* with a scarce Middle Eocene component consisting of such species as: *Globorotalia lehneri, Truncorotaloides rohri,* and *T. topilensis.* In addition, a single specimen of the Upper Cretaceous *Globotruncana fornicata* was found in the center bit sample. Cores 5, 6 and 7 are virtually void of foraminifera. Their age could however be determined as Oligocene to Middle-Late Eocene by the presence of nannoplankton and Radiolaria. Cores 6 and 7, from 1488 to 1518 feet (453 to 463 meters) and 1554 to 1557 feet (473 to 474 meters), can be correlated both faunally and lithologically with the Oceanic Formation of Barbados.

It is thought that the turbidites, including the plant fragments, consist largely of material carried by the Orinoco River. The foraminiferal faunas of varying age must have been picked up by the turbidity currents from the shelf slope where, at the time, sediments of Cretaceous and Lower Tertiary age were outcropping. Whether the planktonic foraminifera of *Globorotalia kugleri* Zone age were also carried as fossils or represent the true age of the sediment in which they occur remains to be determined.

11. SITE 28

The site lies on the Outer Ridge north of the north wall of the Puerto Rico Trench, about 150 miles north of San Juan, drilled in a water depth of 5521 meters (18,109 feet).

The general character of sediments penetrated is from top to bottom: clay (partly red), greenish and white clay and light colored chalky radiolarian oozes; clays, chalks, argillite of various colors, partly rich in dolomite, chert.

The foraminiferal faunas recovered from Site 28 are extremely poor and are of two distinct types:

1. Scarce *Bathysiphon* specimens are present in the Eocene Cores 3 through 7, in particular in Core 3. A Bathysiphon A, B, and C is distinguished on the enclosed distribution chart. A is a fairly large, flattened fine grained and light colored form. B is small, rounded, often irregular, coarse and darker in color. C is rounded, of medium size and possessing fine to medium grains. These *Bathysiphon* occur in clays and chalks often rich in Radiolaria, diatoms and sponge spicules. It is assumed that the beds with these faunas were laid down below compensation depth. As a result a possible existing calcareous foraminiferal fauna was dissolved. Nannoplankton which is still present seems to have been less affected by the solution effects.
2. A fairly poor but well developed heterogeneous calcareous fauna was retrieved from the center bit between Cores 8 and 9 and from inside the bit which drilled below Core 9. This fauna consists primarily of planktonic foraminifera, mainly *Rotalipora apenninica* and associated planktonics of the Lower Cenomanian. Several specimens are of Santonian to Campanian age (*Globotruncana fornicata, G. arca* s.l.) and one specimen of *Truncorotaloides* sp. from the center bit sample is indicative for Middle Eocene. Several benthonic genera are, as shown on the distribution chart, also present in these two samples. The known ranges of some of them are:
   Arenobulimina sp. (Senonian)
   Clavulina sp. (Senonian-Tertiary)
   Epistominella sp. (aff. "*Eponides" guayabalensis-patelliformis:* Upper Cretaceous-Eocene-Oligocene)
   Gyroidina globosa (Upper Cretaceous-?Eocene)
   Karreriella cf. *subcylindrica* (Eocene-Oligocene)
   Marssonella oxycona (Senonian-?Paleocene)
   small *Marssonella* sp. (mostly Cretaceous, probably Upper)
   Planulina sp. (Eocene-Oligocene)
   Vulvulina sp. (Eocene-Oligocene)

The stratigraphic ages of these benthonic species agree with those of the planktonic foraminifera. Reference is made to Todd and Low, 1964, who have previously reported an apparently homogeneous Cenomanian fauna consisting of predominantly planktonic foraminifera from a dredge sample between 3200 and 3500 fathoms on the north slope of the Puerto Rico Trench.

More frequent than the foraminifera in these two samples are Radiolaria and nannoplankton. Other non-foraminiferal microfossils which may be mentioned are small fish teeth and bone fragments in Core 2, which is barren of any other faunas. Their lone presence indicates a deposition below compensation depth of these sediments.

12. THE CARIBBEAN SITES 29 THROUGH 31

One of the prime objectives of the Caribbean sites was to recover continuous or near continuous cored sections for biostratigraphic investigations from an area where uninterrupted sedimentation was supposed to have taken place. For several reasons, this goal was achieved in a limited way only. Continuous coring could be carried out at limited intervals only in sites 30 and 31. In addition, drilling was brought to an early halt in Site 29 by a Middle Eocene chert layer which could not be penetrated by the drill. With the upper part incompletely cored, Site 30 had to be abandoned in the Lower Miocene because of positioning difficulties. Site 31, also incompletely cored, could not be terminated as was projected for time reasons. Not foreseen when selecting the sites were the effects of calcium carbonate solution in fossil beds. Though the water depth of even the deepest site, at 13,933 feet (4247 meters), is above the solution depth of today, it turned out that part of the Pliocene and almost all of the Miocene foraminiferal fauna was partially or completely destroyed, especially in Holes 29 and 29B and, to a much lesser degree, in Hole 31.

Despite the fact that the original objectives could not be fully met because of these adverse factors, results still remain remarkable. As explained in this report under "The zonation of Leg 4 stations based on planktonic foraminifera," new findings on planktonic foraminifera and their stratigraphic distribution are practically restricted to the Pliocene/Pleistocene. It is pointed out there that existing zonal schemes could not readily be applied to the Middle and Upper Pliocene. As a result, a *Globorotalia exilis/Globorotalia miocenica* Zone and a *Globorotalia truncatulinoides* cf. *tosaensis* Zone had to be proposed, thus, replacing the interval previously taken by the *Globoquadrina altispira altispira* Zone of Bolli 1966.

One of the most remarkable results is the strongly changing thicknesses of the Pliocene/Pleistocene sediments in Sites 29, 30 and 31. This is clearly visible on the chart correlating these three stations (Figure 17). At first sight, the thickness seems to be controlled by water depth. In Site 29, the deepest station (13,933 feet) (4217 meters), the Pliocene/Pleistocene amounts to slightly less than 120 feet (36.5 meters). In Site 31–11,049 feet (3369 meters) it is about 350 feet (106 meters); and, in Site 30–3994 feet (1217 meters)– it increases to about 1100 feet (335 meters). It may be thought that calcium carbonate solution increasing with water depth would be largely responsible for this. However, the great thickness of the Pliocene/Pleistocene in Site 30 depends at least partially, on the accumulation of volcanic minerals and ashes. These were carried in from nearby Lesser Antilles volcanoes and occur throughout the section. Considerable accumulation of glauconite at certain levels contributes further to the thickness. In comparison, the Pliocene/Pleistocene of Site 25, drilled in only 6286 feet (1916 meters) of water on a narrow ridge at the base of the continental slope off Northeastern Brazil, measures less than 90 feet (27.4 meters) in thickness. In this case, it must be assumed that the rate of sedimentation there was considerably slowed down or was partially even interrupted by currents.

In contrast to the Pliocene/Pleistocene, the Miocene of Sites 29 to 31, as far as recovered and determinable, is much more uniform in thickness. This can again be clearly seen on Figure 17. Part of the Lower Miocene and the entire Oligocene is absent in Site 29, where the *Catypsydrax dissimilis* Zone lies with a hiatus on the Upper Eocene radiolarian oozes. Cores 9 (*Globorotalia kugleri* Zone) and 10 (*?Globorotalia opima opima* Zone) indicate that the Lower Miocene and at least part of the Oligocene are present in Site 31 which lies about 200 miles west of Site 29. Site 30 did not reach below the uppermost Lower Miocene (*Praeorbulina glomerosa* Zone). The Eocene radiolarian oozes of Site 29 are void of foraminifera.

Remark to Figure 8:	The specimens indicated in Core 2 of Hole 29B as *Globorotalia menardii menardii* are to be included in *G. menardii* B.

13. SITE 29

The site is situated in the central part of the Venezuela Basin in the Caribbean Sea in a water depth of 4247 meters (13,933 feet). Five major types of lithology (foraminiferal ooze, clay, chalk, radiolarian ooze and chert) were encountered in the three Holes 29, 29B and 29C, which represent in combination a continuously cored section from the sea floor to a depth of 813 feet (248 meters). Hole 29A which drilled down to 283 feet (86 meters) apparently entered the original Hole 29. With its very poor and unreliable recovery it is excluded from this study. Rich planktonic foraminiferal faunas are present in the upper approximately 120 feet (36 meters) of Hole 29, representing the Pliocene and Pleistocene. In the basal part of Cores 4, 5 and 6, 120 to 180 feet (36 to 54 meters), this fauna becomes very reduced numerically, with the remaining forms often corroded by the effects of calcium carbonate solution. The interval from 187 to approximately 300 feet (57 to approximately 91 meters) in Hole 29B shows the same picture: very poor or void in foraminifera. Often the only fossil remains in these sediments where calcium carbonate has been dissolved are small fish teeth and bone fragments. The interval from approximately 120 to 300 feet (57 to approximately 91 meters) (with the clays containing few or no calcareous fossil remains) represents the Middle and Upper Miocene (approximately *Globorotalia fohsi peripheroronda* to *Globorotalia dutertrei* Zone). It is only poorly and incompletely documented by planktonic foraminifera.

The foraminiferal fauna indicative of Lower Miocene becomes frequent again between approximately 300 to 400 feet (91 to 121 meters) (Cores 4, 5 and 6 of Hole 29B, Core 7 of Hole 29). The lithology gets increasingly chalky towards the lower part of this interval. From 400 to about 750 feet (121 to 328 meters) the sediments consist of a uniform, pure radiolarian ooze of middle Eocene age, void of foraminifera. Chert and cherty limestone, apparently interbedded with softer layers of probable radiolarian ooze, finally brought drilling to a halt at a depth of 813 feet (248 meters) (Hole 29C).

A considerable hiatus exists between the top of the radiolarian ooze and the overlying chalky beds. It apparently includes the upper Eocene, the whole Oligocene and the lower part of the Lower Miocene (*Globorotalia kugleri* Zone).

14. SITE 30

The location of Site 30 is on Aves Ridge in the eastern Caribbean, about 130 miles west of the Grenadines and in a water depth of 1218 meters (3994 feet). This station was selected for its shallow position to avoid the effects of calcium carbonate solution (in fossil beds) as were encountered in the Miocene of Site 29. Rich foraminiferal faunas were recovered throughout, ranging in age from Pleistocene to the upper part of the Early Miocene (*Praeorbulina glomerosa* Zone). Volcanic minerals, volcanic ash and, in particular in the lower part also glauconite have contributed considerably to the greatly increased sediment thickness in comparison to Sites 29 and 31.

The first objective of Site 30 was to obtain a continuous record of the Miocene and Oligocene sediments which were largely missed in Site 29. The Pleistocene and Pliocene were, therefore, only sporadically cored (Cores 1 through 8). As soon as the Miocene was reached, coring operations became continuous (Cores 9 through 16) with the result that a complete zonal sequence from the *Globorotalia acostaensis* down into the *Praeorbulina glomerosa* Zone could be recovered. It compares well with land based sections such as known from Trinidad (Cipero and Lengua Formations) and Eastern Falcon, Venezuela (Pozon Formation).

The thickness of the Miocene in Site 30, measuring only about 200 feet (60 meters), is very much reduced compared with the mentioned land based sections. This is despite the high percentage of volcanic minerals and ash, and glauconite. Positioning difficulties unfortunately prevented drilling below the *Praeorbulina glomerosa* Zone and also a re-entry to recover a more completely cored Pliocene/Pleistocene.

15. SITE 31

This site is located in a region of rough topography in the southeastern part of the Beata Ridge, Caribbean Sea at a water depth of 3369 meters (11,049 feet). The prime objective was to penetrate sediments below Horizon "A" (mid-Eocene chert layer). Though this was not achieved, valuable results were obtained, in particular in the Pliocene part of the section, which was almost completely cored and is closely comparable with the corresponding interval of Site 29.

In an attempt to meet the prime objective, coring had to be widely spaced below the Pliocene. Here three more cores were recovered, one each of Middle Miocene *Globorotalia fohsi fohsi* Zone age, lowermost Miocene *Globorotalia kugleri* Zone age, and an Oligocene core of probably *Globorotalia opima opima* Zone age. The lithology of the two deepest cores is a fairly indurated chalk. Shortly below the last core and apparently still in the Oligocene, technical difficulties and time reasons terminated further drilling.

The water depth in which Site 31 was drilled is about 3000 feet (900 meters) less than in Site 29. Planktonic foraminifera were expected, therefore, to be affected less by calcium carbonate solution at corresponding stratigraphic levels. Unfortunately, coring in the Miocene was too widely spaced to obtain full proof of this, but it can be said that the fauna of the three cores recovered from the Miocene and Oligocene are not noticeably damaged. Only in Core 7 (lower part of the *Globorotalia margaritae* Zone, Lower Pliocene) were some solution effects apparent. From this it may be concluded that to obtain sections from the central Caribbean with little or no damage done to the planktonic fauna by calcium carbonate solution, sites should be selected in a water depth not exceeding about 10,000 feet (3000 meters).

16. CORRELATION OF THE CARIBBEAN SITES 29, 30 AND 31 WITH JAMAICA, COASTAL VENEZUELA AND TRINIDAD

A correlation of the strata penetrated in Sites 29, 30 and 31 with surrounding land based sections in Jamaica, coastal Venezuela and Trinidad (Figure 18) is presented on a number of charts (Figures 20, 21 and 22), which are largely self-explanatory. Some supplementary data from published and unpublished sources on age, lithology and faunal aspects are given in the following text. For a better understanding of the Caribbean Neogene sequence and the distribution of its planktonic foraminifera, it was found desirable to deal with Jamaica in some more detail (Figure 19). In addition to contributing to the knowledge of the geological history of the Caribbean area, these correlations are also thought to aid in the selection of additional sites which are expected to be drilled in the future in the Caribbean Sea by JOIDES.

Jamaica (Figures 19 and 20)

The Miocene to Pleistocene planktonic foraminifera of Sites 29 and 31 are compared with those of the Montpelier, Buff Bay, Bowden and Manchioneal Formations of Jamaica (Figure 20). From these formations, Blow, 1969, proposed a number of type localities, named by him "holo"- and "para"-type localities for several of his planktonic foraminiferal N-zones. On his Figures 29 and 30 are shown age, zones, formation names and lithology of the Bowden and Buff Bay Formations. It was thought convenient to quote this latest information on Jamaica Neogene planktonic foraminifera and use it as a base for the correlation with Sites 29 and 31.

Blow proposed the following of his holotype (HT) and paratype (PT) localities from Jamaica formations:

Formation	Age	N-Zone	Sample	Locality
Manchioneal	Pleistocene	22 HT	ER 143/24	Navy Island Member of Manchioneal Formation, San San Bay section
Bowden	Pliocene	20 HT	ER 156	Bowden type section
		PT	ER 193	Drivers River section (near Manchioneal Harbor)
		PT	ER 538	Folly Point section
		19 HT	ER 146/44	Buff Bay section
		PT	ER 300	Bowden section (Blow 1969, p. 254) spot sample at Arcadia Road (personal information, Dr. Robinson)

Formation	Age	N-Zone	Sample	Locality
	Miocene	18 HT	ER 146/41	Buff Bay section
		PT	WHB 181B	Buff Bay section
		PT	ER 143/7	San San Bay section (Buff Bay Formation of Robinson 1969a, b)
Buff Bay		17 HT	ER 146/40	Buff Bay type section
		PT	ER 305	Bowden type section (Blow 1969, Figure 29) spot sample at Arcadia Road (personal information, Dr. Robinson)
		16 PT	ER 146/37	Buff Bay type section
Montpelier	Miocene	13 PT	ER 143/4	San San Bay

The direct correlation of the planktonic foraminifera of Sites 29 and 31 with Blow's holo-and paratype localities of Jamaica was made possible through the courtesy of E. Robinson, who kindly supplied splits of the original samples used by Blow. Further, several other samples collected by E. Robinson and some duplicated ER (Robinson) samples collected by P. Jung were available for study. E. Robinson also provided the writer with valuable additional information essential for the interpretation of the Jamaica sections. This concerns, for example, the type section of the Bowden Formation as shown on Blow's Figure 29. According to E. Robinson, it should be restricted to what is shown on this figure as Zone N.20, and the underlying Bowden Shell Bed (uppermost N.19). The samples of Blow's Zones N.16-19, which on Figure 29 are included in a Lower Bowden Formation of the type section, are in fact from the Arcadia Road section about one mile from the actual type section and represent a series of spot samples. The lithology (brown clays and marls) of this lower part compares well with the Buff Bay Formation but contrasts with the sandy, silty Bowden Formation, which is rich in megafossils. Robinson, 1969a, therefore placed this interval into the Buff Bay Formation.

The following is a brief review of the Neogene Jamaica formations and their faunas. For more details reference is made to Robinson 1967, 1969a, b.

Montpelier Formation

The Miocene Montpelier Formation is the oldest formation discussed in the present context. It consists of light colored chalks with chert, and ranges from approximately the *Globorotalia kugleri* Zone to the *Globorotalia mayeri* Zone. The upper part of the formation lacks chert components in Eastern Jamaica, where it is known as Spring Graden Member of the Montpelier Formation. The formation contains rich planktonic foraminiferal faunas. In its upper part, such as in sample ER 143/4 from the San San Bay section, reworked older foraminifera occur frequently.

Buff Bay Formation

The calcareous clays and marls that constitute the Upper Miocene to Pliocene Buff Bay Formation are open sea deposits rich in planktonic foraminifera. The approximately 100 feet (30 meters) of the formation exposed at its type section at Buff Bay is subdivided into four planktonic foraminiferal zones (N14-N17) by Robinson, 1969b, or into the *Globorotalia mayeri, Globorotalia menardii, Globorotalia acostaensis* and *?Globorotalia dutertrei* s.l. Zones of the present writer. The approximately 300 feet (91 meters) exposed at San San Bay (upper part of the Buff Bay Formation, also known as San San Beds) represent the Zone N17-N19 in Robinson, 1969b, or *?Globorotalia dutertrei* s.l. and *Globorotalia margaritae* Zones of the writer.

Bowden Formation

The Pliocene Bowden Formation is a predominantly silty-sandy deposit unconformably overlying the calcareous clays of the Buff Bay Formation. It is rich in shallow water molluscs, corals, bryozoans and benthonic foraminifera. The megafossils are accumulated in shell beds such as the basal Bowden Shell Bed. Planktonic foraminifera may at certain levels also constitute a considerable part of the Bowden fauna and are in general indicative of the *Globorotalia exilis/Globorotalia miocenica* Zone. However, the basal part of the Bowden Formation at Buff Bay (Sample ER 146/41, *Globorotalia margaritae* Zone) appears to be of the same age as the upper part of the Buff Bay Formation at San San Bay. This indicates a short period of contemporaneous deposition of the two formations within the *Globorotalia margaritae* Zone which is equal to N.18 and N.19, rather than N.16 and N.17 as postulated by Blow, 1969, on his Figure 29. Sample ER 523 from the uppermost part of the Bowden Formation at the type section contains left coiling *Globorotalia* cf. *tumida* and *G. menardii* s.l. which may be indicative of a *Globorotalia truncatulinoides* cf. *tosaensis* Zone age, or approximately Zone

N.21, which is shown as missing in Jamaica on Blow's Figure 29. The lithologic appearance and fauna of the Bowden Formation is that of a fairly shallow water, coastal deposit, containing much detrital material and a predominance of shallow water megafossils and microfossils. The possibility of re-deposition in the Bowden Formation of the planktonic foraminifera from a now largely eroded younger part of the Buff Bay Formation should be investigated. Conversely, it may be postulated that the terrigenous components and the shallow water faunas were carried into greater depth by currents. In such a case the planktonic component of the fauna would be autochthonous. Until a possible heterogeneity of its fauna can be disproved, the Bowden Formation should not be used for the designation of type localities for faunal zones.

Manchioneal Formation

The Pleistocene Manchioneal Formation which unconformably overlies the Bowden or Buff Bay Formations consists largely of rubbly re-crystallized limestone, rich in coral fragments which are not in growth position, calcareous algae, and pebbles originating from the Oligocene-Miocene White Limestone Group.

It was the type locality area of the Manchioneal Formation which Bolli and Bermudez, 1965, selected as type section (type sample: RMS 19611) for their *Globoquadrina altispira altispira/Globorotalia truncatulinoides* Zone. Robinson, 1967, pointed out that the *Globoquadrina altispira altispira* must be reworked there when found in association with *Globorotalia truncatulinoides.* This conclusion is accepted here. In view of its faunal and lithological composition, indicating reworking, the Manchioneal Formation is no longer thought suitable as a type section or type locality for a planktonic foraminiferal zone.

Figure 19 shows the stratigraphic relations of the upper part of the Montpelier, Buff Bay, Bowden and Manchioneal Formations at Buff Bay, San San Bay, Manchioneal Harbor, Innes Bay and Bowden. It includes the zonation as applied by the writer, the numbers of the investigated ER samples and Blow's N-zones. Selected index fossils present in the examined ER samples are listed in the text below.

Index Species Present in ER Samples of Figure 19

Buff Bay Section

146/31: *Globorotalia mayeri, G. menardii,* A, *Globigerina nepenthes, Globigerinoides obliquus obliquus.*

146/32: Same as above.

146/34: *Globorotalia menardii* A, *G. lenguaensis, Globigerinoides obliquus obliquus*/transition towards *extremus.*

146/37: *Globorotalia menardii* s.l., *G. lenguaensis* (no *G. acostaensis* seen in the material examined), *Globigerinoides obliquus obliquus.*

146/40: *Globorotalia dutertrei* (small specimens), *G. acostaensis, G. menardii* A, *G. ?tumida* cf. *plesiotumida, G. lenguaensis, Globigerina nepenthes, Globigerinoides obliquus obliquus.*

146/41: *Globorotalia margaritae, G. multicamerata, G. pseudomiocenica,* (no *G. tumida* seen in the examined material), *Sphaeroidinellopsis seminulina* A, *Pulleniatina obliquiloculata primalis, Globigerinoides obliquus extremus.*

146/44: *Globorotalia exilis* A, *G.* cf. *exilis, G. miocenica, G. pseudomiocenica, G. dutertrei* s.l., *G. fohsi lobata* (reworked), *G. multicamerata, Sphaeroidinella dehiscens, Globigerinoides obliquus extremus, Globoquadrina altispira.*

San San Bay Section

143/4: *Globorotalia mayeri, G. menardii* A, *Globigerina nepenthes, Globigerinoides obliquus obliquus.*

143/5: *G.* cf. *margaritae, Globorotalia multicamerata, G. dutertrei* s.l., *G. menardii* B, *Globigerina nepenthes, Globigerinoides obliquus extremus, Globoquadrina altispira.*

143/7: *Globorotalia* cf. *margaritae, G.* cf. *multicamerata, G. dutertrei* s.l., *G. menardii* B, *Globigerina nepenthes, Globigerinoides obliquus extremus, Sphaeroidinellopsis seminulina* A, *Globoquadrina altispira.*

143/18: *Globorotalia margaritae, G. multicamerata, G. pseudomiocenica, G. dutertrei* s.l., *Globigerinoides obliquus extremus, Sphaeroidinellopsis seminulina* A, *Globoquadrina altispira.*

143/21: *Globorotalia margaritae, G. pseudomiocenica*/trans. to *miocenica, G. exilis, G. dutertrei* s.l., *Globigerinoides obliquus extremus, Sphaeroidinellopsis* sp., *Globoquadrina altispira.*

143/21A: *Globorotalia margaritae, G. pseudomiocenica.*

143/24: *Globorotalia truncatulinoides truncatulinoides.*

Manchioneal Harbor (Drivers River)

193: *Globorotalia exilis, G. miocenica, Globigerinoides trilobus fistulosus, G. obliquus extremus, Globoquadrina altispira, Sphaeroidinella dehiscens.*

Innes Bay

191: *Globorotalia multicamerata, Globigerinoides trilobus* cf. *fistulosus, G. obliquus extremus, Sphaeroidinella dehiscens.*

763: *Globorotalia margaritae, G. multicamerata, G. exilis* A, *G. dutertrei* s.l., *Globigerinoides trilobus fistulosus, G. obliquus extremus, Sphaeroidinella dehiscens, Globoquadrina altispira.*

752: *Globorotalia exilis, G. miocenica, G. dutertrei* s.l., *Globigerinoides trilobus ?fistulosus, G. obliquus extremus.*

762: *Globorotalia exilis* A, *G. miocenica, G. multicamerata, G. dutertrei, G. truncatulinoides ronda, G. truncatulinoides* cf. *tosaensis, Globigerinoides obliquus extremus, Sphaeroidinella dehiscens.*

Bowden

156: *Globorotalia exilis, G. miocenica, G. multicamerata* (scarce), *G. dutertrei* s.l., *Sphaeroidinella dehiscens, Pulleniatina* (scarce).

529: *Globorotalia exilis, G. miocenica, Globigerinoides trilobus fistulosus, G. obliquus extremus.*

530: No diagnostic species.

523: *Globorotalia* cf. *tumida* (left coiling), *G. menardii* s.l. (left coiling).

524: *Globorotalia truncatulinoides truncatulinoides, G.* cf. *tumida.*

In general, the faunal sequences in the Jamaica sections compare well with those of Sites 29 and 31. The distribution of certain species in both areas, apparently, is controlled in a similar sense by ecologic conditions. This applies, for instance, to the distribution of the *Globorotalia tumida* complex. In Sites 29 and 31, *Globorotalia tumida tumida* appears as late as, or even slightly after, the first occurrence of *Globorotalia truncatulinoides truncatulinoides.* Forms referred to *Globorotalia* cf. *tumida* appear sporadically in Site 31 in the upper part of the *Globorotalia exilis/Globorotalia miocenica* Zone and in Site 29 in the uppermost *Globorotalia margaritae* Zone. No *Globorotalia tumida tumida* were seen in the Jamaica samples examined here. Its occurrence there in the Pliocene, thus, must be very erratic. Living conditions in the Caribbean area for the *Globorotalia tumida* complex were obviously more unfavorable during most of the Pliocene than during the Pleistocene. The spotty occurrences in the Cubagua well sections are another indication that the complex succeeded only very occasionally in existing in the Caribbean area, particularly during pre-Pleistocene time. This picture is in sharp contrast with that of Bodjonegoro-1 on the island of Java (Bolli, 1966) where *Globorotalia tumida* is continuously present from the *Globorotalia margaritae* Zone onwards, and with typical *Globorotalia tumida flexuosa* already existing in that zone.

Pulleniatina is another form that makes a delayed appearance in Sites 29 and 31. It appears here only in the upper part of the *Globorotalia exilis/Globorotalia miocenica* Zone (very scarce specimens, possibly the result of contamination, occur in Site 31 as deep as the upper part of the *Globorotalia margaritae* Zone). In the Jamaica samples which were examined, their presence in the Pliocene is also very irregular.

ER 156 (holotype sample of N.20, *Globorotalia* (G.) *multicamerata-Pulleniatina obliquiloculata obliquiloculata* Zone) from the lower part of the Bowden type section (Figure 19) is the only examined Jamaica sample where the faunal composition is in disagreement with its stratigraphic position, in comparison with findings in Sites 29 and 31. ER 156 is rich in planktonic foraminifera and contains *Globorotalia exilis, G. miocenica,* scarce *G. multicamerata, G. crassaformis crassaformis, G. dutertrei* s.l., *G. dutertrei pseudopima, Sphaeroidinella dehiscens,* scarce *Pulleniatina,* but no *Globigerinoides trilobus fistulosus* nor *G. obliquus extremus.* These two species are restricted in Sites 29, 30 and 31 to the lower part of the *Globorotalia exilis/Globorotalia miocenica* Zone, but they are present in the Bowden type section in Sample ER 529 which overlies ER 156. The ER 156 fauna is typical for the upper part of the *Globorotalia exilis/Globorotalia miocenica* Zone of Sites 29 and 31. A younger age of ER 156 is further substantiated by the absence of *Globoquadrina altispira,* a species that disappears in Site 29 already within the *Globorotalia margaritae* Zone and in Sites 30 and 31 sometime before the top of the *Globorotalia exilis/Globorotalia miocenica* Zone. The position of ER 156 below the apparently older ER 529 as reported by Blow on his Figure 29 is an indication that the Bowden type section may be either disturbed or that, as already mentioned, the planktonic foraminifera could be reworked. Another explanation is that the Bowden type section, outcropping along the coast, is poorly exposed in particular in its lower part. ER 156 is from an artificial outcrop about 15 to 20 meters (49 to 66 feet) above sea level, whereas ER 529 is from near sea-level and approximately 250 meters (820 feet) further to the north. The poorly exposed beds dip very gently towards the north, and it is therefore possible that ER 156, in fact, lies stratigraphically above ER 529.

Lithologic Comparison

No close lithologic comparison is attempted here between Sites 29 and 31 and the Jamaica formations. It is noted, however, that Cores 5 through 8 of Hole 29B, Core 7 of Hole 29, and Cores 8, 9 and 10 of Hole 31 consist of chalky clay and chalk and compare not only in age but also in lithology with the Montpelier Formation. The calcareous clays of the Buff Bay Formation have their age equivalent in the fine, partly silty and often nonfossiliferous clays (effects of calcium carbonate solution) of Cores 4, 5 and 6 in Hole 29, Cores 1 through ?4 in Hole 29B, and Cores 6 and 7 in Site 31. The calcareous clays and oozes, rich in calcareous planktonic organisms, from the lower part of Core 2 to the upper part of Core 4 of Hole 29 and Cores 3, 4 and 5 of Hole 31 compare biostratigraphically with the silty-sandy Bowden Formation.

The calcareous clays and oozes of Core 1 and the upper part of Core 2 in Hole 29 and of Cores 1 and 2 of Hole 31 fall into the same Pleistocene *Globorotalia truncatulinoides truncatulinoides* Zone as the rubble beds that constitute the Manchioneal Formation.

Coastal Venezuela

The correlation with coastal Venezuela is based on published records, information obtained from P.J. Bermudez and V. Hunter–in particular on Falcon–and on the present writer's own investigations. The following text contains, with the exception of the Cubagua-1 and Cubagua-2 subsurface sections, only brief supplementary remarks to Figures 21 and 22. For a more complete discussion of the stratigraphy and paleontology of the Miocene-Pleistocene sediments of coastal Venezuela, reference is made to the paper "Correlation of the JOIDES Caribbean Stations 29, 30 and 31 with Jamaica, Venezuela and Trinidad," submitted by the writer to the 4th Venezuelan Geological Congress, November 16-22, 1969.

Western Venezuela (Figure 21)

Sites 29 and 31 are correlated with corresponding formations of eastern north-central and north-western Falcon. In particular the well described and rich foraminiferal faunas of the eastern Falcon Formations (Renz, 1948, Blow, 1959) allow for reliable correlations with Sites 29 and 31. Studies of the planktonic foraminifera in the Neogene sediments of the peninsulas of Paraguana and Guajira are still not advanced sufficiently to include the formations from these areas in the correlation scheme.

Central- and Eastern-Venezuela

Correlated with Site 30 are from west to east the isolated Upper Miocene to Pleistocene sediments of Cabo Blanco, La Sabana, Carenero and Cumana (Bermudez, 1966). Following Stainforth, 1969, the Playa Grande and Mare Formations of Cabo Blanco and the Cumaña Formation of eastern Venezuela hitherto regarded as Pliocene in age are here placed in the Pleistocene. Such a change is based largely on the occurrence in these formations of *Globorotalia truncatulinoides* var. *nana* Bermudez, which is a small but distinctly keeled representative of the *Globorotalia truncatulinoides* complex, and as such diagnostic for the Pleistocene. The age of the Miocene La Sabana beds is based on investigations by Bolli and Krause, 1964, that of the Carenero Formation on Bermudez, 1966 and on the writer's own investigations.

Thicker and stratigraphically more complete sedimentary sequences occur on the island of Margarita and in particular on the peninsula of Araya and the island of Cubagua.

Island of Cubagua

Reference is made to Bermudez (1966, p. 356-359) for a closer review of the geology and stratigraphy of this island. The two boreholes Cubagua-1 and Cubagua-2 drilled here provide through the many cores recovered an excellent record of the subsurface part of the Cubagua Formation and thus allow for a good correlation with Site 30. The distribution of the foraminifera in these sections is shown on four charts in Bermudez, 1966 (benthonic foraminifera by A.N. Fuenmayor, planktonic foraminifera by the present writer).

Blow, 1969, states on p. 286-287 and shows on Figures 31 and 32 that a thrust intersects the well Cubagua-2 at about 2900 feet (884 meters), causing a repeated section. The evidence given for such a thrust that repeats part of Blow's Zones N.16 and N.17 lies in the presence of a "fairly primitive form of *Globorotalia (G.) tumida plesiotumida* with advanced *Globorotalia (G.) merotumida*" immediately below his assumed thrust and an "early form of *Globorotalia (G.) merotumida*" immediately above it. The existence of such a thrust and consequent repetition of part of the strata can not be maintained here for the following reasons:

1. According to the original core description record no cores were taken between Core No. 101 at 2732 to 2742 feet (830 to 833 meters) and Core No. 102 at 3062 to 3072 feet (933 to 936 meters). It must therefore be assumed that Blow relied on ditch samples to determine his thrust at 2900 feet (884 meters). Ditch samples are vulnerable to contamination from higher levels and only really reliable for determining so-called "tops," i.e. highest occurrence of species. In the case of Cubagua-2 the presence of primitive *G. tumida plesiotumida* and advanced *Globorotalia merotumida* at about 2900 feet (884 meters) from a position where only ditch samples could exist is, therefore, likely to be due to contamination from higher parts of the section.
2. The distribution pattern of the benthonic and planktonic foraminifera as shown for Cubagua-2 on the charts in Bermudez, 1966, and based entirely on core samples shows no indication of a repetition.
3. The suspicion that Blow based at least part of his observations in the Cubagua-1 - Cubagua-2 correlation on ditch samples instead of cores is further indicated by his mention on Figure 31 of an "open sea fauna but transitional to biofacies seen immediately above" for the interval

> about 4200 to 5155 feet (1280 to 1571 meters) in Cubagua-2. The cores examined by the writer below Core 133, 4142 to 4162 feet (1262 to 1268 meters), were found to be virtually barren, as was the case with the cores of interval 2904 to 4220 feet (884 to 1286 meters) in Cubagua-1. Any faunas from this interval, if they are from ditch samples, must be regarded with caution.

Dr. Blow informed the writer on this matter that he used for his work a set of Cubagua-1 and Cubagua-2 foraminiferal slides and tubes containing residue which he had obtained from the Geological Laboratory of the then Trinidad Leaseholds Ltd., Pointe-a-Pierre, Trinidad, W.I. All these slides and tubes were—apparently by mistake—labeled as cores, which information was accepted and taken for granted by him. Dr. Blow was thus misled through no fault of his own. He intends to modify in print his views on the Cubagua-2 succession in question.

Remarks on Some Faunal Distributions and Correlations

The Pliocene fauna of Sites 29 and 31 is characterized in the lower part by such species as *Globorotalia margaritae* and *G. multicamerata* (*Globorotalia margaritae* Zone), and in the middle part by *G. exilis, G. miocenica*, and *Globigerinoides trilobus fistulosus* (*Globorotalia exilis/Globorotalia miocenica* Zone, within which *Globoquadrina altispira* and *Globigerinoides obliquus extremus* become extinct). The upper part of the Pliocene lacks all of these species as well as *Globorotalia truncatulinoides truncatulinoides*, but contains forms described here as *Globorotalia truncatulinoides* cf. *tosaensis* and sinistrally coiling specimens of the *Globorotalia menardii* and *tumida* complex. The Pleistocene in these sections is characterized by fully developed *Globorotalia truncatulinoides truncatulinoides.* As can be seen from the discussion on Jamaica, the same sequences of species are also present in the sediments of that island.

This is not entirely the case in Site 30, which is situated on Aves Ridge, considerably to the east of Sites 29 and 31. Apparently because of adverse conditions, no *Globorotalia margaritae* or typical *G. multicamerata* were seen there in the examined material, although other evidence indicates that the interval of their occurrence was cored. *Globorotalia miocenica,* is well represented again, but *G. exilis, G. truncatulinoides* cf. *tosaensis* and *Globigerinoides trilobus fistulosus* were found to be extremely scarce. *Globorotalia tumida* s.l., on the other hand, is well developed only in the Pleistocene, as in Sites 29 and 31.

The only sediment of Pliocene age studied in Falcon for planktonic foraminifera is the Punta Gavilan Formation. *Globorotalia dutertrei* is present and very scarce; *G. margaritae* has been noted from some levels of the Punta Gavilan Formation, whereas, *G. multicamerata* is absent. Not recognized so far in this formation are *Globorotalia exilis, G. miocenica* and *Globigerinoides trilobus fistulosus*, indicative of Middle Pliocene. Their absence in Falcon could be explained by either environmental or stratigraphic reasons.

The Pliocene part of the Cubagua Formation of Eastern Venezuela shows a similar faunal pattern. Though *Globorotalia margaritae* is frequent, in the Lower Pliocene part of the formation no *G. multicamerata, G. exilis, G. miocenica, Globigerinoides trilobus fistulosus* nor *Globorotalia truncatulinoides* cf. *tosaensis* were seen in the surface and subsurface samples studied. The specimens of the *Globorotalia menardii/G. pseudomiocenica* complex of the Cubagua-1 and -2 Miocene to Pliocene interval are—as is the whole planktonic fauna of the Cubagua Formation—comparatively small in size throughout. This is an indication that the planktonic fauna was affected by adverse conditions that kept the above mentioned index species out of the Araya-Cubagua-Margarita area, at least, and also largely, out of the area of Site 31. In the Caribbean the boundary of favorable conditions for these species lies somewhere between Site 29 and Site 30 to the east, west of Jamaica, between Site 29, Site 31, and the Colombian/Venezuelan coast to the south. The northern boundary probably lies north of the Greater Antillan islands. This is indicated by the presence of *Globorotalia multicamerata, G. exilis* A (and *G. margaritae*) in *Atlantis* Sample 2971, taken at 20° 32'N, 74° 24'W (Windward Passage, between Cuba and Hispanola).

Similar to Sites 29 through 31, and probably for the same reasons, *Globorotalia tumida plesiotumida* and *G. tumida tumida* occur only very sporadically in the Pliocene of coastal Venezuela, for example, *G. tumida plesiotumida* in the core interval 1627 to 1637 feet (495 to 498 meters) of Cubagua-1, and in some surface samples, such as, HMB 63/76 from the *Globorotalia dutertrei* s.l. Zone, Cerro Barrigon, Araya. *Globorotalia tumida tumida* becomes frequent in the Pleistocene of Sites 29 through 31, but is absent in the formations of the same age in coastal Venezuela, i.e. Playa Grande, Mare, Cumanà Formations.

The genus *Pulleniatina* is subject to a similar irregular distribution pattern in Sites 29 through 31 and in Jamaica. The same applies to coastal Venezuela where *Pulleniatina* is known from the *Globorotalia margaritae* Zone of the Cubagua Formation, but is absent from the younger parts of that formation, to re-appear again in the Pleistocene of the Playa Grande and Cumanà Formations. This very irregular distribution pattern of the *Globorotalia tumida* complex and of *Pulleniatina* in the Pliocene and Pleistocene of coastal Venezuela extended during the Pliocene northward to at least Jamaica and Sites 29 through 31.

Globorotalia truncatulinoides truncatulinoides is well developed in the Pleistocene to Recent of Sites 29, 30 and 31 and in the Manchioneal Formation of Jamaica. The same species, though smaller in size but still with a distinct peripheral keel, is present in the Pleistocene Playa Grande, Mare and Cumanà Formations of coastal Venezuela, where it was listed by Bermudez and Fuenmayor, 1962, as *Turborotalia truncatulinoides* var. *nana.* It is still difficult to determine where exactly in the Pleistocene these formations have to be placed, but in view of the overlying still younger sediments one may regard them as Lower Pleistocene. It is likely that the small size of the specimens is an indication of adverse living conditions, which not only dwarfed *Globorotalia truncatulinoides* but, to a similar degree, also the remainder of the planktonic foraminiferal fauna of the Playa Grande and Cumanà Formations.

No difficulties were encountered in correlating (based on planktonic foraminifera) the Oligocene/Miocene and the Lower Pliocene (*Globorotalia margaritae* Zone) sediments of coastal Venezuela with Sites 29, 30 and 31 and with Jamaica. The absence in the higher Pliocene of Venezuela of many index fossils, which are present in Sites 29 through 31 and in Jamaica, renders a direct comparison of this part more difficult. However, with the aid of additional species and criteria, such as, *Globoquadrina altispira, Globigerinoides obliquus extremus*, and the coiling pattern of the *Globorotalia menardii* complex, it is still possible to make reasonably reliable correlations. What Bermudez and Bolli, 1969, determine as the *Globoquadrina altispira altispira* Zone in Cubagua-1–258 to 849 feet (78 to 260 meters)–and in Cubagua-2–150 to 1326 feet (45 to 404 meters)–is here correlated with the *Globorotalia exilis/Globorotalia miocenica* Zone of Sites 29 through 31 and with the Bowden Formation of Jamaica. The reasons for this are: the persistence of *Globoquadrina altispira* and, in the lower part only, of *Globigerinoides obliquus extremus*, and dextral coiling of *Globorotalia menardii* s.l. during this interval, which lies immediately above the *Globorotalia margaritae* Zone.

Trinidad (Figure 22)

The lower part of the section penetrated in Site 30, from the *Globorotalia menardii* Zone to the *Praeorbulina glomerosa* Zone, correlates stratigraphically with the Lengua and the upper part of the Cipero Formation of Trinidad. To correlate the Upper Miocene to Pleistocene part of Site 30 with Trinidad strata becomes more problematical because of the almost complete absence of planktonic foraminifera in the Trinidad formations of corresponding age. That planktonic foraminifera at least temporarily invaded the Trinidad seas after the Middle Miocene is shown by their occasional and scarce appearance in, for example, the Upper Miocene to ?Pliocene Cruse and Forest Formations and the Pliocene Talparo Formation. Faunas including *Globorotalia margaritae, G. dutertrei, G. acostaensis, G. pseudomiocenica, G. tumida plesiotumida* and *Globigerinoides obliquus extremus* were recently discovered for the first time in Trinidad (personal information, B. Carr-Brown). They were found in samples from the Talparo Formation collected in the Guayaguayare area of southeastern Trinidad.

17. A PRELIMINARY REVISION OF THE UPPER MIOCENE/PLIOCENE IN WELL BODJONEGORO-1, JAVA

A preliminary comparison of the distribution of the Upper Miocene/Pliocene planktonic foraminifera (*Globorotalia margaritae* Zone and younger) of well Bodjonegoro-1 on the Island of Java (Bolli, 1966), with the new findings in the Caribbean and South Atlantic as presented in this paper, has resulted in the following changes for Bodjonegoro-1:

1. The *Globorotalia margaritae* Zone, from 305 to 354 meters (1000 to 1161 feet), is now regarded as Pliocene in age.
2. The interval of the *Globoquadrina altispira altispira/Globorotalia crassaformis* Zone, from 216 to 305 meters (708 to 1000 feet), with *Globoquadrina altispira, Globigerina venezuelana, Globigerinoides obliquus extremus, G. trilobus* cf. *fistulosus* and dextral coiling *Globorotalia menardii* s.l. and *G.* cf. *multicamerata* can probably be correlated with the lower part of the *Globorotalia exilis/Globorotalia miocenica* Zone of the Caribbean/tropical-subtropical Atlantic.
3. The interval determined as "?equivalent of *Globorotalia truncatulinoides/Globorotalia inflata* Zone," from 101 to 216 meters (331 to 708 feet), was cored at 101 meters (331 feet) and again between 204 and 216 meters (669 and 718 feet). *Globorotalia menardii* s.l. and *Globorotalia* cf. *multicamerata* continue to be present and to coil dextrally in these intervals; *Globigerinoides obliquus extremus* becomes extinct in the lower part of the interval. In comparison with the Caribbean/tropical-subtropical Atlantic region, the interval 101 to 216 meters (331 to 708 feet) of Bodjonegoro-1 could thus represent the upper part of the *Globorotalia exilis/Globorotalia miocenica* Zone.

A revision of the forms described from Bodjonegoro-1 as *Globorotalia crassaformis* in the light of newer investigations on the *Globorotalia truncatulinoides tosaensis-G. truncatulinoides truncatulinoides* complex has given the following results:

The left coiling specimens between 291 and 308 meters (954 and 1010 feet), the random forms at 286 meters

(938 feet) and the dextral coiling ones of cores at 272 and 278 meters (892 and 911 feet) are retained in the *Globorotalia crassaformis* group. The dextral coiling specimens between 204 and 255 meters (699 and 836 feet) have to be assigned to *Globorotalia truncatulinoides tosaensis.* This was confirmed by Dr. T. Saito, co-author of the subspecies. The sinistrally coiling specimens of the core at 101 meters (331 feet) are again typical *Globorotalia crassaformis*, and no *G. truncatulinoides* s.l. were seen in the available material from that depth. From this results a stratigraphic overlap in Bodjonegoro-1 of *Globoquadrina altispira altispira* and *Globorotalia truncatulinoides tosaensis* between 216 and 255 meters (708 and 836 feet), or of at least 39 meters (128 feet).

Parker, 1967, observed a co-occurrence of these two species in a number of deep sea cores from the Indo-Pacific.

CAP 38 BP (14° 16′S, 119° 11′W), Sample 491 to 493 centimeters (p. 133);

LSDH 78 P (4° 31′S, 168° 02′E), Samples 30 to 32 and 74 to 77 centimeters (p. 134); and,

DODO 57 P (15° 40′S, 112° 44′E), Sample 61 to 62 centimeters (p. 135).

The corresponding concurrences (2 centimeters to 47 centimeters) of the two species in these deep sea core sections are minimal compared with an overlap of at least 39 meters (118 feet) in Bodjonegoro-1. Zonal thicknesses and faunal ranges are bound to be strongly condensed in piston cores that comprise considerable stratigraphic intervals in only a few meters of section. Distinct faunal overlaps (for example, of *Globoquadrina altispira altispira/Globorotalia truncatulinoides tosaensis* in Bodjonegoro-1) may not at all or only barely be recognizable in such sections. As a good example of a condensed core may be cited the above listed CAP 38 BP which contains, according to Parker, in a length of only 862 centimeters, Quaternary Zones N.21, N.19, N.18 and N.17 of Banner and Blow, 1965 (Pleistocene to Upper Miocene). In comparison, the Pliocene part alone of this stratigraphic interval (base *Globorotalia margaritae* at 626 centimeters to base *G. truncatulinoides truncatulinoides* at 410 centimeters) measures in Bodjonegoro-1 at least 250 meters (820 feet) or over 100 times more. Following the redefinition of some N zones by Blow, 1969, and referring to his Figure 41 the CAP 38 BP core represents a complete late Miocene to Holocene sequence that includes ? N.16 and N.17 to N.23. The dangers of using faunal distributions obtained from such strongly condensed core sections to construct charts showing absolute ranges of species are evident.

The JOIDES deep sea drilling operations can now retrieve continuously cored sections from much thicker and undisturbed sedimentary sequences. Similar to those from many land based surface and subsurface profiles, they are much more valuable for faunal distribution studies than piston cores, such as those mentioned above.

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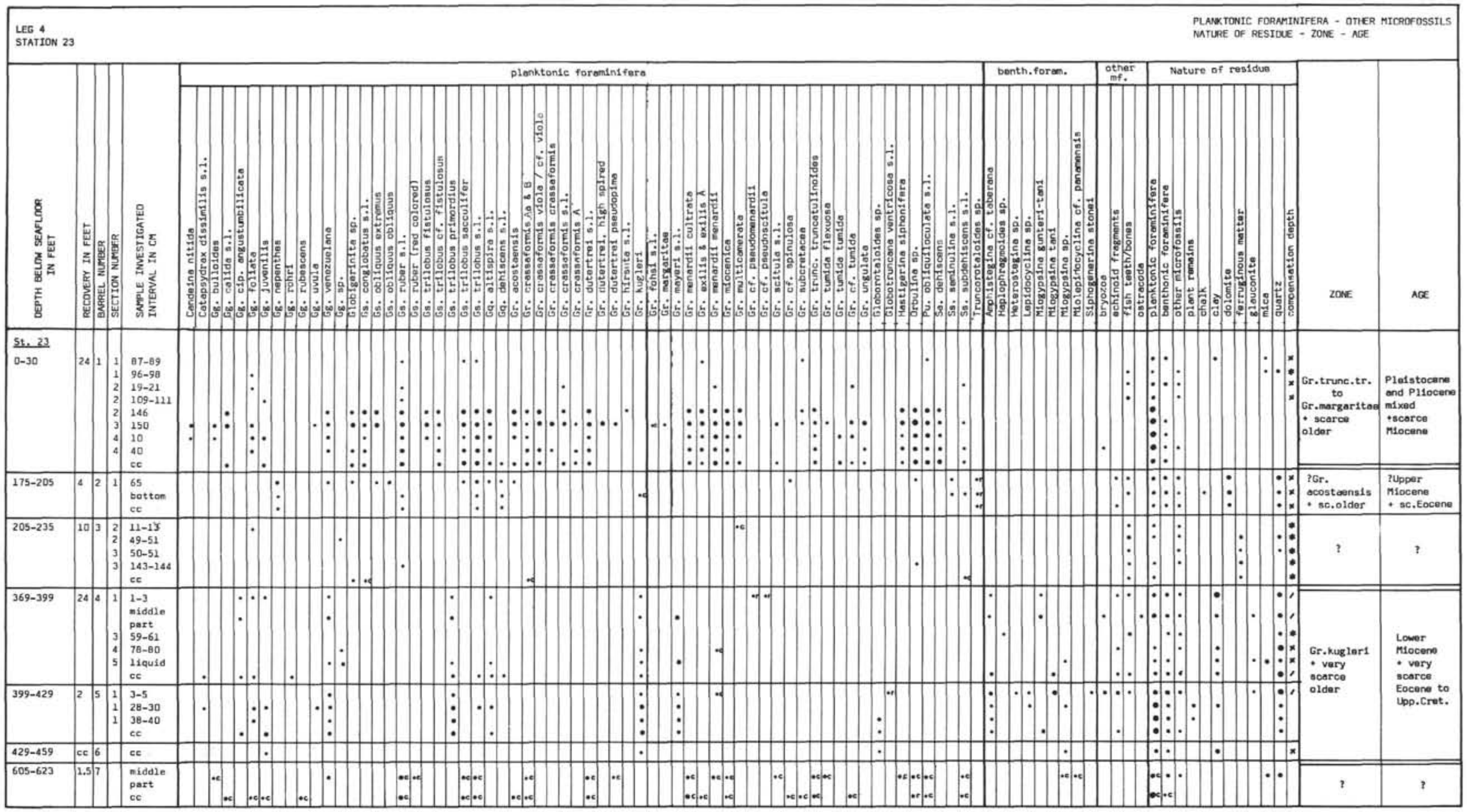


LEG 4
STATION 23

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW SEAFLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	ZONE	AGE
St. 23						
0-30	24	1	1 1 2 2 2 3 4 4	87-89 96-98 19-21 109-111 146 150 10 40 cc	Gr.trunc.tr. to Gr.margaritae + scarce older	Pleistocene and Pliocene mixed +scarce Miocene
175-205	4	2	1	65 bottom cc	?Gr. acostaensis + sc.older	?Upper Miocene + sc.Eocene
205-235	10	3	2 2 3 3	11-13 49-51 50-51 143-144 cc	?	?
369-399	24	4	1 3 4 5	1-3 middle part 59-61 78-80 liquid cc	Gr.kugleri + very scarce older	Lower Miocene + very scarce Eocene to Upp.Cret.
399-429	2	5	1 1 1	3-5 28-30 38-40 cc		
429-459	cc	6		cc		
605-623	1.5	7		middle part cc	?	?

planktonic foraminifera

Candeina nitida
Catapsydrax dissimilis s.l.
Gg. bulloides
Gg. calida s.l.
Gg. cip. angustumbilicata
Gg. foliata
Gg. juvenilis
Gg. nepenthes
Gg. rohri
Gg. rubescens
Gg. uvula
Gg. venezuelana
Gg. sp.
Globigerinita sp.
Gs. conglobatus s.l.
Gs. obliquus extremus
Gs. obliquus obliquus
Gs. ruber s.l.
Gs. ruber (red colored)
Gs. trilobus fistulosus
Gs. trilobus cf. fistulosus
Gs. trilobus primordius
Gs. trilobus sacculifer
Gs. trilobus s.l.
Gq. altispira s.l.
Gq. dehiscens s.l.
Gr. acostaensis
Gr. crassaformis Aa & B
Gr. crassaformis viola / cf. viola
Gr. crassaformis crassaformis
Gr. crassaformis s.l.
Gr. crassaformis A
Gr. dutertrei s.l.
Gr. dutertrei, high spired
Gr. dutertrei pseudopima
Gr. hirsuta s.l.
Gr. kugleri
Gr. fohsi s.l.
Gr. margaritae
Gr. mayeri s.l.
Gr. menardii cultrata
Gr. exilis & exilis A
Gr. menardii menardii
Gr. miocenica
Gr. multicamerata
Gr. cf. pseudomenardii
Gr. cf. pseudoscitula
Gr. scitula s.l.
Gr. cf. spinulosa
Gr. subcretacea
Gr. trunc. truncatulinoides
Gr. tumida flexuosa
Gr. tumida tumida
Gr. cf. tumida
Gr. ungulata
Globorotaloides sp.
Globotruncana ventricosa s.l.
Hastigerina siphonifera
Orbulina sp.
Pu. obliquiloculata s.l.
Ss. dehiscens
Ss. seminulina s.l.
Ss. subdehiscens s.l.
Truncorotaloides sp.

benth.foram.

Amphistegina cf. taberana
Haplophragmoides sp.
Heterostegina sp.
Lepidocyclina sp.
Miogypsina gunteri-tani
Miogypsina tani
Miogypsina sp.
Miolepidocyclina cf. panamensis
Siphogenerina stonei

other mf.

bryozoa
echinoid fragments
fish teeth/bones
ostracoda

Nature of residue

planktonic foraminifera
benthonic foraminifera
other microfossils
plant remains
chalk
clay
dolomite
ferruginous matter
glauconite
mica
quartz
compensation depth

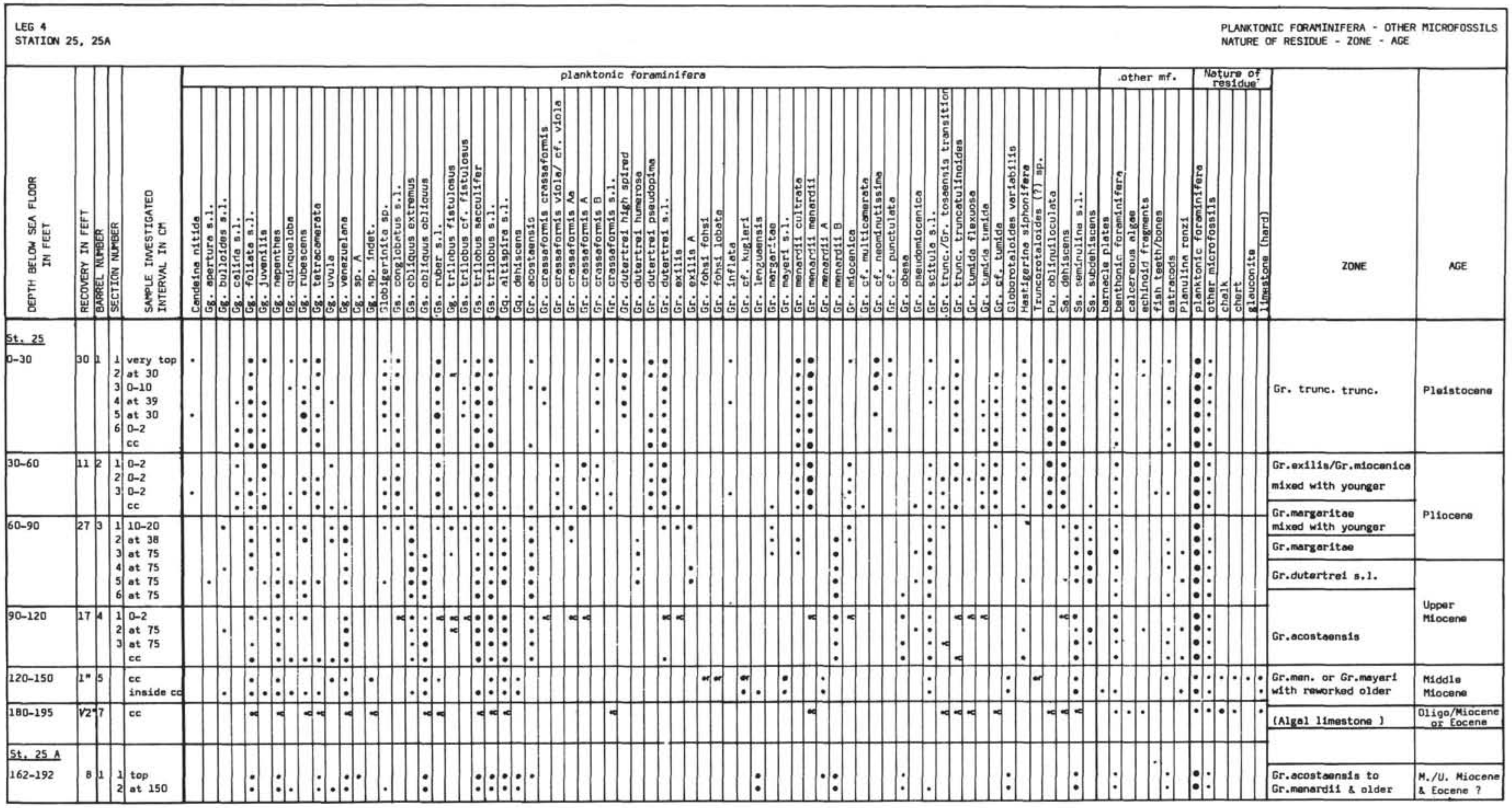
Figure 1.

LEG 4
STATION 24, 24A

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

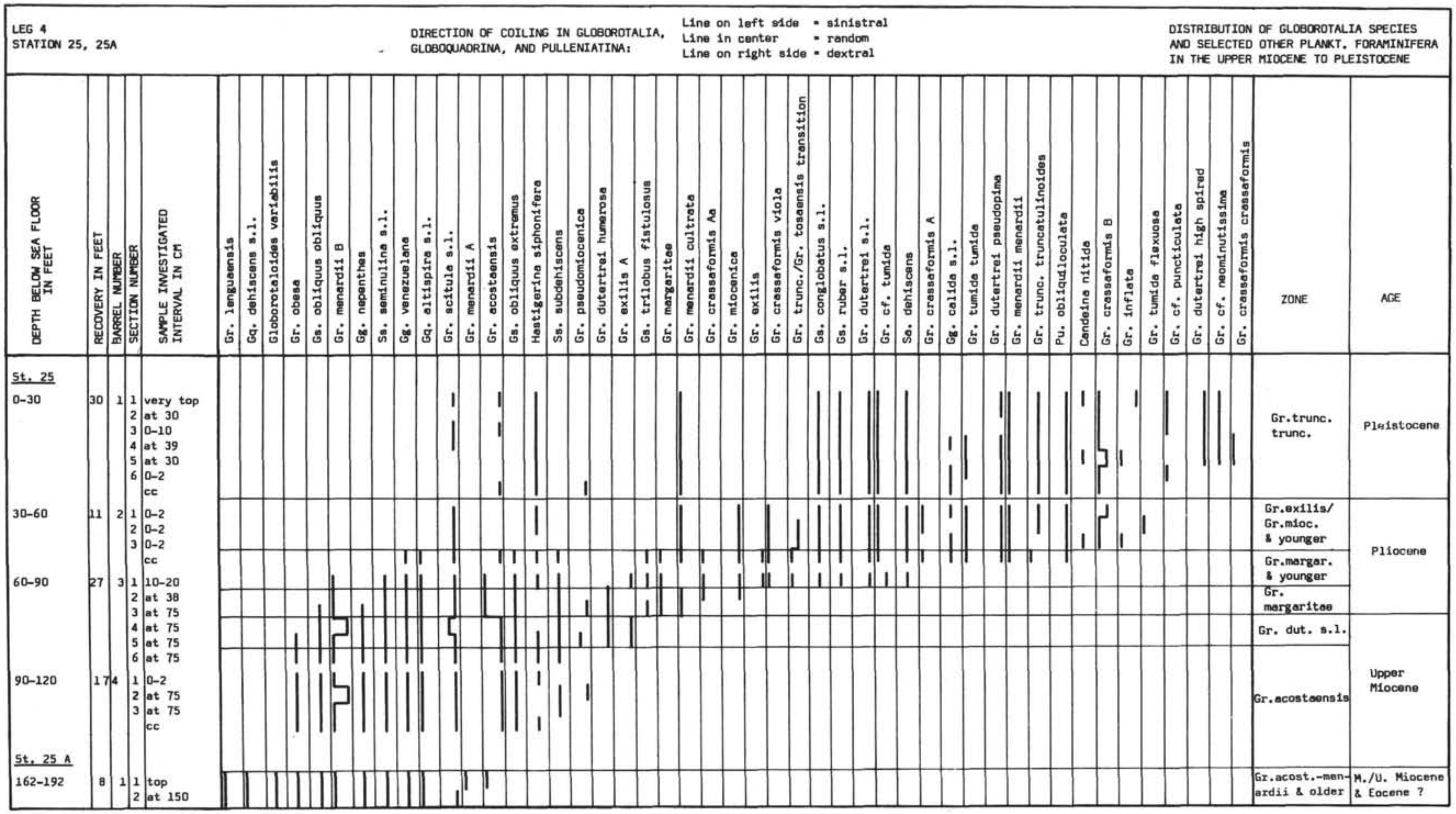
DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	plankt. foraminifera														benth. foraminifera															other mf.			Nature of residue										ZONE	AGE
					Catapsydrax dissimilis s.l.	Gg. cip. angustumbilicata	Gg. foliata	Gg. cf. trilocularis	Gg. venezuelana	Gs. trilobus primordius	Gr. kugleri	Gr. mayeri s.l.	Gr. opima opima	Gr. cf. pseudomenardii	Gr. cf. pusilla s.l.	Gr. sp.	Globorotaloides sp.	Hantkenina sp.	Ammodiscus sp.	Amphistegina cf. taberana	Bathysiphon sp.	Glomospira sp.	Heterostegina antillea	Heterostegina cf. israelskyi	Lepidocyclina canellei	Lepidocyclina sp.	Miogypsina gunteri	Miogypsina gunteri-tani	Miogypsina tani	Miogypsina sp.	Miogypsinella sp.	Miogypsinoides sp.	Pararotalia cf. mexicana	echinoid fragments	fish teeth/bones	radiolaria	planktonic foraminifera	benthonic foraminifera	other microfossils	plant remains	clay	glauconite	pyrite	quartz	barite	compensation depth		
St. 24																																																
650-680	1.4	1	1	6-8		•	•	•	•	●	●	●				•r	•			●				•		•	●					•					●	●				•		●		/	Gr.kugleri with reworked Eocene	Lower Miocene
			1	37	•	•			•	●	●		•			•r	•			●				•			•							•			●	●	•	•	•			●		/		
680-710	2.7	2	1	53-60	•				•	•	•		•			•r		•		•r			•	•	•		●							•			•	●	●		•		•	●		/		
			1	60-70					•	•										•			•	•		•			●			•		•			•	●	•			•		●				
			1	overall					•	•										•			•							•		•					●	●										
740-770	16	4	3	10-20			•	•															•							•		•	•		•		•	•	•		●	•		●		×	Gr.kugleri	
			3	14-15		•		•			•									•			•							•							•	•						●		×		
			3	71-73												•c			•																		•				•					✱		
			3	100-101	●				●	●	●															•		•		•	•						●	•						●		/		
				cc																																					●					✱		
St. 24 A																																																
1650-1676	0.8	1	1											•	•	•																			•	●	●		•		●					×	?Gr.pseudo-menardii to Gr. pusilla pusilla	?Paleocene
				loose chips																																•	•				●	•				✱		
				lighter col.shale																	•	•																•								×		
				dark shale																	•	•																•								×		
1676-1706	0.9	2																	•																•	●	•	•	•			•	•		•	×	?	?
1773-1803	2.9	3		bottom																																•					●					✱		
1803-1832	6	4		cc																																•					●	•	•			✱		

Figure 2.



Note: Fossils from limestone pebbles recovered from barrels 5 and 7 in Station 25 and from barrel 1 in hole 25A are listed in the text.

Figure 3.



Note: Barrels 5 and 7 of Station 25 have been omitted in order to preserve stratigraphic continuity.

Figure 4.

LEG 4
STATION 26, 26A

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CENTIMETER	planktonic foraminifera																																	reworked pl. Foram.											other mf.			Nat. of residue								ZONE	AGE
					Candeina nitida	Gg. bulloides s.l.	Gg. calida	Gg. foliata	Gg. quinqueloba	Gg. rubescens	Gg. uvula	Globigerinita sp.	Gs. conglobatus	Gs. ruber s.l.	Gs. ruber (red colored)	Gs. trilobus cf. fistul.	Gs. trilobus sacculifer	Gs. trilobus s.l.	Gr. acostaensis	Gr. crassaformis ocean.	Gr. crassaformis viola	Gr. crassaformis crass.	Gr. dutertrei high spir.	Gr. dutertrei s.l.	Gr. cf. inflata	Gr. menardii cultrata	Gr. menardii menardii	Gr. scitula s.l.	Gr. subcretacea	Gr. truncatulinoides tr.	Gr. tumida flexuosa	Gr. tumida tumida	Gr. cf. tumida	Hastigerina pelagica	Orbulina sp.	P. obliquiloculata	Sa. dehiscens s.l.	Gg. nepenthes	Gg. venezuelana	Gs. obliquus extremus	Gs. trilobus fistulosus	Gq. altispira s.l.	Gr. bullbrooki	Gr. crassaformis	Gr. lehneri	Gr. menardii saundersi	Gr. miocenica	Gr. multicamerata	benthonic foraminifera	echinoid spines	gastropods	planktonic foraminifera	other microfossils	plant remains	clay	manganese	mica	quartz	other minerals		
St. 26 315 - 345	11	1		top									•	•				●				•		•						•	•	●	•			•	•															●						●	●	Gr. trunc.trunc. (with reworked Pliocene to Middle Eocene)	Pleistocene
			1	148-150										•	•		•	●						●						•		●				•												•r		•			●		•				●	●		
			2	14-15										•	•		•	•				•		•		•				•	•	•	•			•														•			●	•					●	●		
				99-101										•				•																																			•			●						
			3	19-20																																																							•	•		
				90-120									•	●	•		•	●						•						•	•	●			•	•	•											•r											●			
				132-133																																																							•		
				147-148					●	●		•		•																																								●			●	●			
				bottom		•				•		•		•				•									•	•	•	•																			•			•		●				●	•		
345 - 375	6,5	2	1	110-111										•																																						•						•	•		
			2	3-4																																													•										•		
				143-144																																													•			•		●				●	•		
				cc						•		•		•				•												•																				•	•	•	•					•	●		
	Centre bit at 752' Top Bl. 3												•	•				●				•	•	●			●			●	•	●	•			•	•													•	•		●		•				●	●		
752-782	6	3	2	22-23																				•c																													•			•			•	•		
				95-96							•																																									•							●		
				cc																												•c																							•				•		
1315-1345	1	4	1	bottom								•		•										•												•																	•				•		●	●		
1564-1586	30	5	1	6-7														•														•					•																•						●	•		
				99-101	•							•	•	●		•	•	●				●		•						•					•		●	•r		•r		•r						•r	•r				●									
			2	15-16																																																•									
				101-102										•			•	•																																		•									
		5	3	46-48										•	•		•			•																																•									
				100-101									•	•			•	•							•																											•									
			4	24-26								•			•			•	•								•			•								•r				•r	•r		•r				•			•		●			•	●	•		
				28-29								•						•																															•			•		●			●	●	•		
				105-106			•			•			•	●				•		•				•				•		•		•		•		•																•									
				bottom																																																		•						
St. 26 A outside deepest pipes													•	•			●	●		•		•		●						•		●				●	•													•			•		●	●			•			
inside broken drill collar							•			•			●	•		•		•	•		•	•		●	•	●		•	•	●		●			•	●	•		•r			•r				•r			●			●	•	●	●			●			

Figure 5.

LEG 4
STATION 27, 27A

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

					Pliocene-Recent													planktonic foraminifera Lower Miocene														Eocene					C.	other mf.				Nature of residue												
DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	Globigerinita sp.	Gs. ruber s.l.	Gs. trilobus s.l.	Gr. crassaformis s.l.	Gr. dutertrei, high spir.	P. obliquiloculata s.l.	Ss. seminulina s.l.	Ss. subdehiscens s.l.	Ca. chipolensis	Cx. dissimilis s.l.	Gg. ciperoensis angulis.	Gg. ciperoensis cip.	Gg. praebulloides	Gg. rohri	Gg. cf. triloculatis	Gg. venezuelana	Gs. trilobus primordius	Gq. altispira s.l.	Gr. kugleri	Gr. mayeri s.l.	Gr. menardii A	Gr. obesa	Gr. opima nana	Gr. opima opima	Globorotaloides sp.	Gg. senni	Globigerapsis sp.	Gr. centralis	Gr. lehneri	Gr. spinulosa	Tr. rohri	Tr. topilensis	Gt. fornicata	Bathysiphon sp.	benthonic foraminifera	radiolaria	fish teeth/bones	planktonic foraminifera	other microfossils	plant remains	dolomite	clay	glauconite	manganese	mica	pyrite	quartz	other minerals	ZONE	AGE
St. 27 A																																																						
83-113	30	1	1	2-3																																					•											•	?	?
			4	100-101																																					•											•		
			5	100-101																																									•							•		
			6	100-101																																					•				•							•		
				cc						•																														•c	•	•			•	•						•		
147-177	10	2	3	4-5																																										●								
				81-82																																										•					•		•	•		
				cc																																			•c			•		•							•		
177-207	12	3	1	110-111																																					•				●	●					•	•		
			3	mid.pt.																																														●	●	●		
				cc																																			•c				•										
207-237	30	4	1	1-2																																					•										•	•		
			2	100-101																																					•								•		•	•		
			3	90-91							•																													•c		•		•								•		
				144-145																																								●					•	•				
			4	57-58																																									•				•		•	•		
			5	100-101																																					•					•					•	•		
			6	100-101																																					•					•					•	•		
				cc																																				•				•	•								
237-267	22	5	1	11-12																																					•										•	•		
			3	99-101																																					•				•									
			4	137-138																																															●		
			5	100-101																																					•					•								
				cc																																				•					•		•						
St. 27																																																						
275-305	30	1	1	2-3																																					•				•								?	?
			2	99-100																																					•											•		
			6	64-65																																					•				•	•								
				cc	•	•		•																																	•	•				•		•			•	•		
305-462	Centre bit betw. Bl. 1 & 2					•	•				•	•																											•		•	•			•						•	•		
462-492	12	2	1	90-100																																					•				•									
			3	102-104																																					•				●									
				bottom					•	•																															•	•			•						•	•		
772-802	10	3	1	4-5									•	•		•			•	•	•	•	•	•										•r	•r				•		•	●					•			•	●		Gr.kugleri (with reworked Eocene)	Lower Miocene
			2	100-101																																								•										
				cc							•c		•	•	•r	•r	•	•	•	•	●	•	•	●	•c	•	•		•r			•r	•r	•r	•r				•		•	●					•			●	•	•		
802-817	14	4	1	41-42																																											•							Lower Miocene (based on nannopl.)
			2	111-112																																											•							
			3	100-101																																				•						•									
				cc																																										•								
1210-1240	18	5	1	15-16																																														•				Upper Oligocene (based on nannopl.)
			2	100-101																																										•								
			3	100-101																																												•								
			4	3-4																																																			
				110-150																																					•c														
				cc																																											•								
1240-1488	Centre bit betw. Bl. 5 & 6													•	•r	•r	•	•	•	•	•	•	•	•			•r	•r	•r	•r	•r	•r	•r	•r	•r	•r	•r		•	•		●				•	•				•		pl. foram. contaminated from Barrel 3	
1488-1518	8	6	2	41-42																																					●						•								M. to U. Eocene (based on nannopl.)
			3	2-3																																					●						•								
				cc																																			•	•	●	•					•								
1554-1557	1,5	7		top																																					•						•								

Figure 6.

LEG 4
STATION 28

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW MUDLINE IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	plankt. foraminifera													bentnonic foraminifera														other mf.					Nature of residue													ZONE	AGE
					Clavihedbergella sp.	Globotruncana arca s.l.	Globotruncana fornicata	Globotruncana lapparenti s.l.	Hedbergella gautierensis	Hedbergella sp.	Planomalina turunensis	Planomalina sp.	Praeglobotruncana stephani	Pseudotextularia sp.	Rotalipora apenninica s.l.	Rugoglobigerina sp.	Truncorotaloides rohri s.l.	Ammodiscus sp.	Arenobulimina sp.	Clavulina sp.	Epistominella sp.	Gyroidina globosa	Karreriella cf. subcylindrica	Marssonella oxycona	Marssonella sp. small	Planulina sp.	Vaginulina sp.	Vulvulina sp.	Bathysiphon A	Bathysiphon B	Bathysiphon C	radiolaria	echinoid spines	fish teeth/bones	sponge spicules	micromolluscs	planktonic foraminifera	other microfossils	chalk	chert	clay	dolomite	glauconite	manganese	pyrite	quartz	calcite	baryte	other minerals		
St. 28																																																			
194-224	cc	1		cc																																					•					•					
224-253	15	2	2	2-3																														•								•	•									?	?
				100-101																														●								•	•								•		
			3	2-3																														•								•	•		•						•		
			4	2-3																														•								•	•		•								
				131-132																													•		•								•									•		
				cc																															•		•					•									•		
	Centre bit betw. Bls. 2 and 3																																●			•				●		●											
553-578	25	3	0	76-78																										•	•	•	•						•			•										?	Middle Eocene (based on nanno-plankton)
			1	3-4																										•	•	•	•						•			•											
				40-41																												•	●			●			•														
				100-101																											•	•	●			•			•														
				120-121																											•	•	●	•		•			•		•	•											
			2	2-3																													●	•		•					•	•											
				88-90																											•		•						•		•												
			3	4-6																											•		●			•			•														
				98-100																													●			●																	
				108-110																										•	•	•	●			•			•		•	●				•							
			4	2-4																													●			•						•				•							
				38-40																													●			●																	
				124-126																										•	•	•	●			•			•			•				•							
			5	7-9																										•	•		●						•			●				•							
				100-102																													•	•		•						•				•							
			6	0-2																										•			•						•			•											
				96-98																											•		●			•			•			•				•							
				cc																										•	•	•	●	•		●			•			●											
578-608	15	4		cc																													•			•						•											
774-803	cc	5		cc																										•			•						•	●												?	Lower Middle Eocene (based on nannool.)
	Centre bit betw. Bls. 5 and 6																															•									•	●	●	●											
917-927	cc	7		cc																											•		●						•	●	●												
	Centre bit betw. Bls. 8 and 9								•	•	•	•	•		•	•	•		•	•	•	•	•	•		•		•									•	•		•	●			•	•		•			predom. Rot.ap.apenninica Zone fauna (Cenomanian) + higher Cretaceous + Lower Tertiary	
1311-1326	cc	9		cc																													•							●	•			•		•		•	•			
	Inside bit, below Bl. 9				•	•	•	•	•	•	•	●	●	•	●	•		●			•	•			•		•										●	•		•	●	•			•		●				

Figure 7.

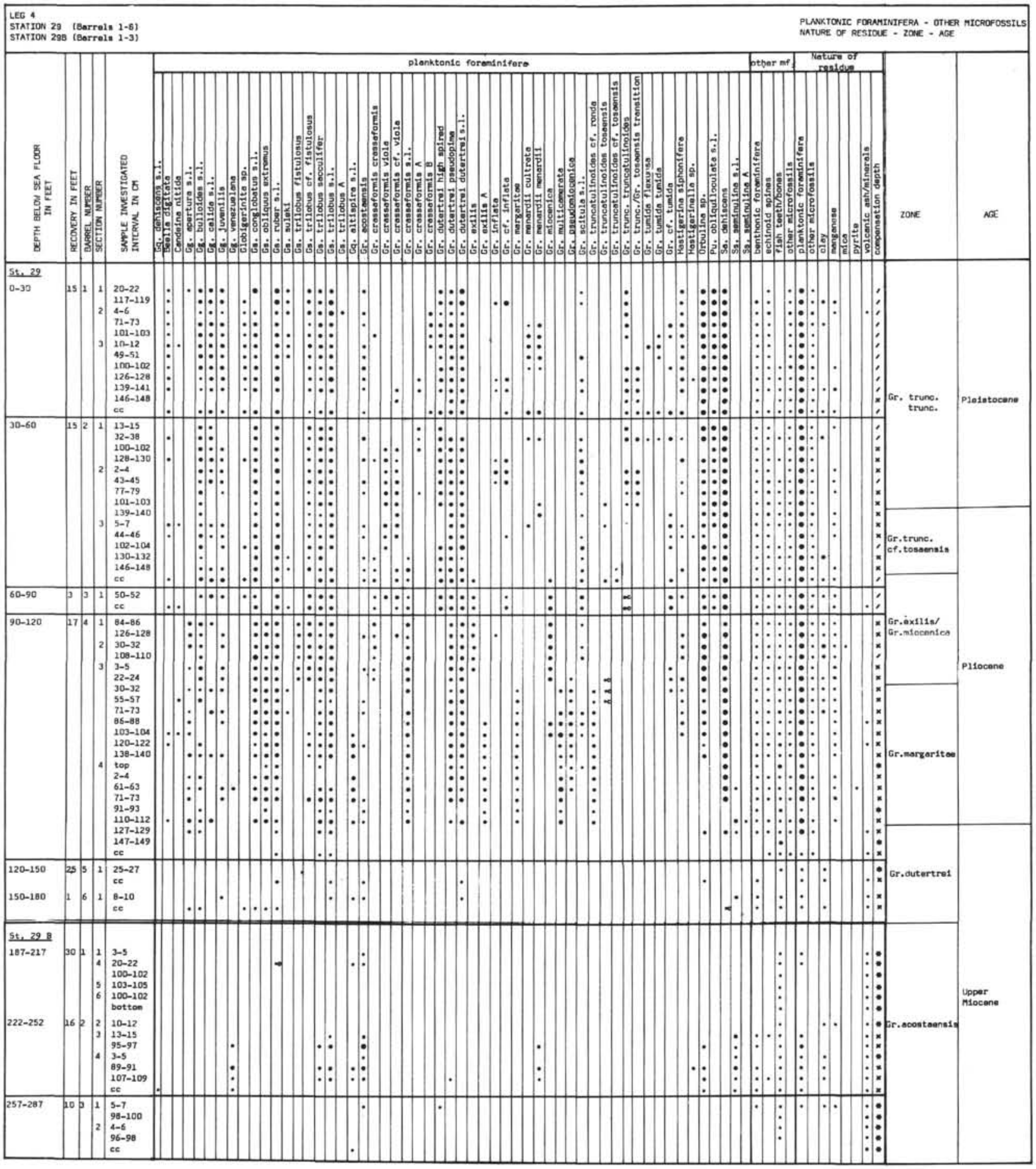

LEG 4
STATION 29 (Barrels 1-6)
STATION 29B (Barrels 1-3)
PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE
DEPTH BELOW SEA FLOOR IN FEET
RECOVERY IN FEET
BARREL NUMBER
SECTION NUMBER
SAMPLE INVESTIGATED INTERVAL IN CM
planktonic foraminifera
Gq. dehiscens s.l.
Beella digitata
Candeina nitida
Gg. apertura s.l.
Gg. bulloides s.l.
Gg. calida s.l.
Gg. juvenilis
Gg. venezuelana
Globigerinita sp.
Gs. conglobatus s.l.
Gs. obliquus extremus
Gs. ruber s.l.
Gs. sulcki
Gs. trilobus fistulosus
Gs. trilobus cf. fistulosus
Gs. trilobus sacculifer
Gs. trilobus s.l.
Gs. trilobus A
Gq. altispira s.l.
Gr. acostaensis
Gr. crassaformis crassaformis
Gr. crassaformis viola
Gr. crassaformis cf. viola
Gr. crassaformis s.l.
Gr. crassaformis A
Gr. crassaformis B
Gr. dutertrei high spired
Gr. dutertrei pseudopima
Gr. dutertrei dutertrei s.l.
Gr. exilis
Gr. exilis A
Gr. inflata
Gr. cf. inflata
Gr. margaritae
Gr. menardii cultrata
Gr. menardii menardii
Gr. miocenica
Gr. multicamerata
Gr. pseudomiocenica
Gr. scitula s.l.
Gr. truncatulinoides cf. ronda
Gr. truncatulinoides tosaensis
Gr. truncatulinoides cf. tosaensis
Gr. trunc. truncatulinoides
Gr. trunc./Gr. tosaensis transition
Gr. tumida flexuosa
Gr. tumida tumida
Gr. cf. tumida
Hastigerina siphonifera
Hastigerinella sp.
Orbulina sp.
Pu. obliquiloculata s.l.
Sa. dehiscens
Ss. seminulina s.l.
Ss. seminulina A
other mf.
benthonic foraminifera
echinoid spines
fish teeth/bones
other microfossils
Nature of residue
planktonic foraminifera
other microfossils
clay
manganese
mica
pyrite
volcanic ash/minerals
compensation depth
ZONE
AGE
St. 29
0-30
15
1
1
20-22
117-119
2
4-6
71-73
101-103
3
10-12
49-51
100-102
126-128
139-141
146-148
cc
30-60
15
2
1
13-15
32-38
100-102
128-130
2
2-4
43-45
77-79
101-103
139-140
3
5-7
44-46
102-104
130-132
146-148
cc
60-90
3
3
1
50-52
cc
90-120
17
4
1
84-86
126-128
2
30-32
108-110
3
3-5
22-24
30-32
55-57
71-73
86-88
103-104
120-122
138-140
4
top
2-4
61-63
71-73
91-93
110-112
127-129
147-149
cc
120-150
25
5
1
25-27
cc
150-180
1
6
1
8-10
cc
St. 29 B
187-217
30
1
1
3-5
4
20-22
100-102
5
103-105
6
100-102
bottom
222-252
16
2
2
10-12
3
13-15
95-97
4
3-5
89-91
107-109
cc
257-287
10
3
1
5-7
98-100
2
4-6
96-98
cc
Gr. trunc. trunc.
Pleistocene
Gr.trunc. cf.tosaensis
Gr.exilis/ Gr.miocenica
Pliocene
Gr.margaritae
Gr.dutertrei
Upper Miocene
Gr.acostaensis

Figure 8.

LEG 4
STATION 29 (Barrel 7)
STATION 29B (Barrels 4-7)

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE -AGE

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																											other mf.					Nature of residue								ZONE	AGE
					Catapsydrax dissimilis s.l.	Catapsydrax stainforthi	Gg. falconensis	Gg. foliata	Gg. rohri	Gg. uvula	Gg. venezuelana	Globigerinatella insueta	Globigerinita sp.	Gs. bispherica	Gs. diminutus	Gs. obliquus obliquus	Gs. ruber s.l.	Gs. transistorius	Gs. trilobus primordius	Gs. trilobus sacculifer	Gs. trilobus s.l.	Gq. altispira s.l.	Gq. dehiscens s.l.	Gr. archeomenardii	Gr. fohsi fohsi	Gr. fohsi peripheroronda	Gr. mayeri s.l.	Gr. subcretacea	Praeorbulina glomerosa s.l.	Ss. seminulina s.l.	Ss. subdehiscens s.l.	benthonic foraminifera	echinoid spines	fish teeth/bones	radiolaria	other microfossils	planktonic foraminifera	other microfossils	clay	manganese	mica	pyrite	volcanic ash/minerals	compensation depth		
St. 29 B																																														
287-317	21	4	1	10-12																										•							•		•	*	?	?
			2	5-7																										•							•		•	*		
			3	8-10																										•					•	•			•	*		
			4	4-6																										•						•			•	*		
				63-65							•											•	•		•		•			•		•		•			•	•	•			●	•		?Gr.fohsi fohsi	Middle Miocene
				100-102																		•	•				•			•		•		•			•		•		•					
				137-139							●	•	•	•			●	•		•	•	●	•						•			•					●								Praeorbulina glomerosa	Lower Miocene
				cc			●				●		•	●			●	•		•		●	●			●	●		•			•					●	•	•			•				
317-347	20	5	1	3-5																														•									•	*		
			2	18-20				•	•		●	•		●		•	●					●	●			●	●	•				•					•	•	•				•			
			3	50-52			•				●	●		•			•				●	●	●			•	●		•			•		•		•	●		•				•			
			4	115-117			●				●	●	•	●	●		●			•	●	●	●			●	•					•		•			●	•							Globigerinatella insueta	
				cc			•		●		●	●	•	●	•		•				●	●	●	•		●	●					•				•	●		•				•			
347-377	2	6		cc			●	•	•		●	•	•	●	●		●				•	●	●			●	•					•		•			●			•			•			
377-407	6"	7		cc																										●					●		•		●	*	?	
St. 29																																														
383-413	3	7	1	70-72		•	•					•	•	•			●				●	●	•	•		•	●					•	•	•	•		•				•		●		C.stainforthi	Lower Miocene
				108-110	•						•								•		•						•					•		•			•		•				•		Catapsydrax dissimilis	
				134-136	●						•												•				●					•		•		•	•		•							
				cc	●				•		•																●					•		•		•	•		•		•		•			

Figure 9.

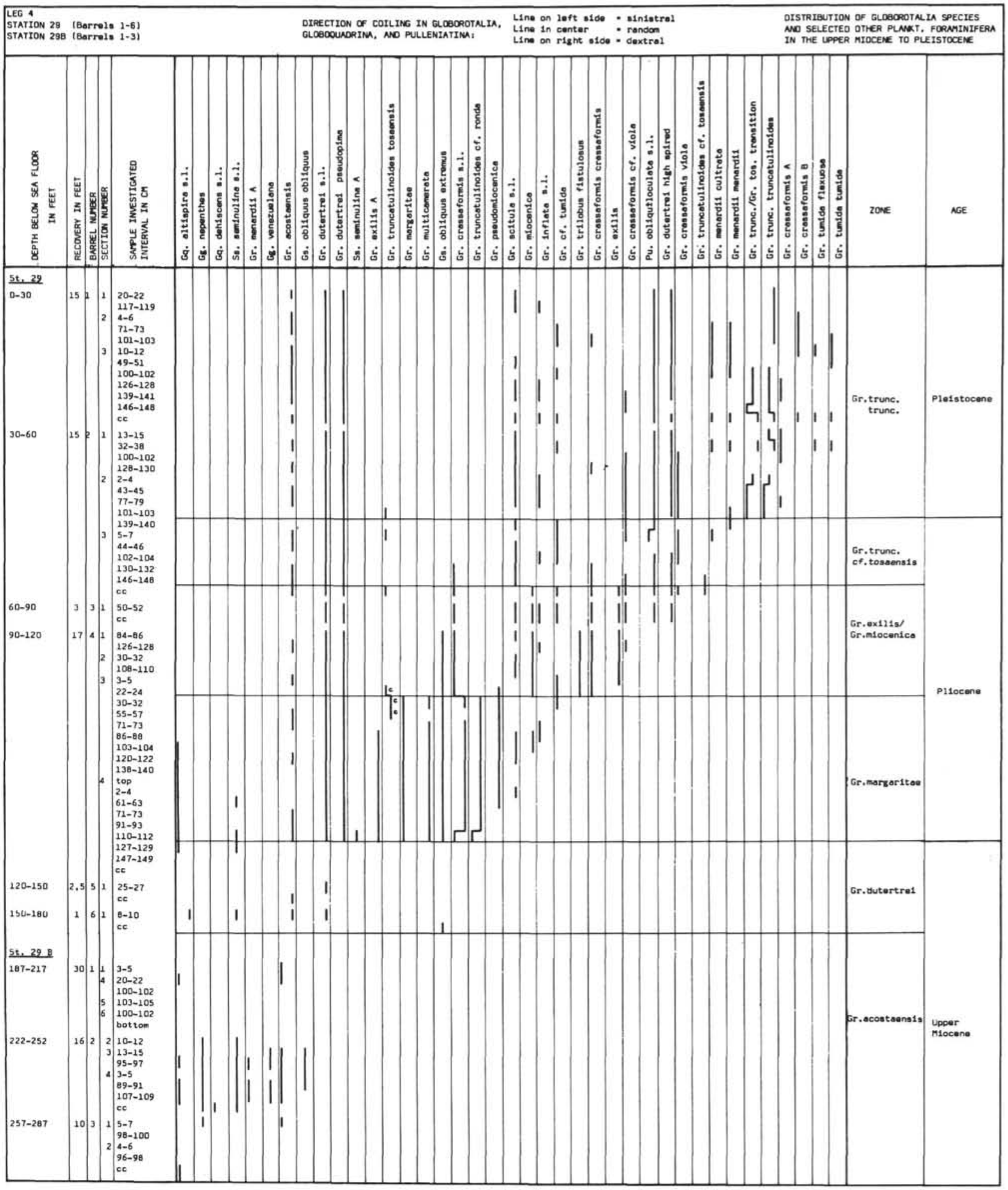

LEG 4
STATION 29 (Barrels 1-6)
STATION 29B (Barrels 1-3)
DIRECTION OF COILING IN GLOBOROTALIA, GLOBOQUADRINA, AND PULLENIATINA:
Line on left side = sinistral
Line in center = random
Line on right side = dextral
DISTRIBUTION OF GLOBOROTALIA SPECIES AND SELECTED OTHER PLANKT. FORAMINIFERA IN THE UPPER MIOCENE TO PLEISTOCENE
DEPTH BELOW SEA FLOOR IN FEET
RECOVERY IN FEET
BARREL NUMBER
SECTION NUMBER
SAMPLE INVESTIGATED INTERVAL IN CM
Gq. altispira s.l.
Gg. nepenthes
Gq. dehiscens s.l.
Ss. seminulina s.l.
Gr. menardii A
Gg. venezuelana
Gr. acostaensis
Gs. obliquus obliquus
Gr. dutertrei s.l.
Gr. dutertrei pseudopima
Ss. seminulina A
Gr. exilis A
Gr. truncatulinoides tosaensis
Gr. margaritae
Gr. multicamerata
Gs. obliquus extremus
Gr. crassaformis s.l.
Gr. truncatulinoides cf. ronda
Gr. pseudomiocenica
Gr. scitula s.l.
Gr. miocenica
Gr. inflata s.l.
Gr. cf. tumida
Gr. trilobus fistulosus
Gr. crassaformis crassaformis
Gr. exilis
Gr. crassaformis cf. viola
Pu. obliquiloculata s.l.
Gr. dutertrei high spired
Gr. crassaformis viola
Gr. truncatulinoides cf. tosaensis
Gr. menardii cultrata
Gr. menardii menardii
Gr. trunc./Gr. tos. transition
Gr. trunc. truncatulinoides
Gr. crassaformis A
Gr. crassaformis B
Gr. tumida flexuosa
Gr. tumida tumida
ZONE
AGE
St. 29
0-30 15 1 1 20-22
117-119
2 4-6
71-73
101-103
3 10-12
49-51
100-102
126-128
139-141
146-148
cc
30-60 15 2 1 13-15
32-38
100-102
128-130
2 2-4
43-45
77-79
101-103
139-140
3 5-7
44-46
102-104
130-132
146-148
cc
60-90 3 3 1 50-52
cc
90-120 17 4 1 84-86
126-128
2 30-32
108-110
3 3-5
22-24
30-32
55-57
71-73
86-88
103-104
120-122
138-140
4 top
2-4
61-63
71-73
91-93
110-112
127-129
147-149
cc
120-150 2,5 5 1 25-27
cc
150-180 1 6 1 8-10
cc
St. 29 B
187-217 30 1 1 3-5
4 20-22
100-102
5 103-105
6 100-102
bottom
222-252 16 2 2 10-12
3 13-15
95-97
4 3-5
89-91
107-109
cc
257-287 10 3 1 5-7
98-100
2 4-6
96-98
cc
c
c
c
Gr.trunc. trunc.
Gr.trunc. cf.tosaensis
Gr.exilis/ Gr.miocenica
Gr.margaritae
Gr.dutertrei
Gr.acostaensis
Pleistocene
Pliocene
Upper Miocene

Figure 10.

LEG 4
STATION 30
Barrels 1-9

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																																																	addit. pl. foram.					other mf.						Nature of residue						ZONE	AGE
					Beella digitata	Candeina nitida	Gg. apertura s.l.	Gg. bulloides s.l.	Gg. calida s.l.	Gg. foliata s.l.	Gg. juvenilis	Gg. nepenthes	Gg. tetracamerata	Gg. venezuelana	Globigerinita sp.	Gs. conglobatus s.l.	Gs. obliquus extremus	Gs. obliquus obliquus	Gs. ruber s.l.	Gs. ruber (red colored)	Gs. trilobus cf. fistulosus	Gs. trilobus sacculifer	Gs. trilobus s.l.	Gq. altispira s.l.	Gs. trilobus fistulosus	Gr. acostaensis	Gr. crassaformis B	Gr. crassaformis crassaformis	Gr. crassaformis viola	Gr. crassaformis cf. viola	Gr. crassaformis s.l.	Gr. dutertrei, high spired	Gr. dutertrei pseudopima	Gr. dutertrei s.l.	Gr. inflata	Gr. cf. inflata	Gr. menardii cultrata	Gr. menardii menardii	Gr. menardii A	Gr. miocenica	Gr. pseudomiocenica	Gr. scitula s.l.	Gr. subcretacea	Gr. trunc./Gr. tos. transition	Gr. trunc. truncatulinoides	Gr. tumida tumida	Gr. cf. tumida	Hastigerina siphonifera	Orbulina sp.	Pu. obliquiloculata s.l.	Sa. dehiscens s.l.	Ss. seminulina s.l.	Sa. subdehiscens s.l.	Gr. exilis	Gr. juanai	Gr. cf. multicamerata	Gr. trunc. cf. tosaensis	Ss. seminulina A	benthonic foraminifera	echinoid spines	fish teeth/bones	radiolaria	sponge spicules	other microfossils	planktonic foraminifera	other microfossils	glauconite	pyrite	volcanic ash/minerals	compensation depth		
St. 30																																																																								
165-195	23	1	1	77-79	·	·		•	•		•		•		·	●			●	•		•	●			●	•					•	•	●	●			·				•			●	·	·	•	●	●	•								•				•	•	●	•	·		•	/	Gr. trunc. trunc.	Pleistocene
			5	1-3	·	·		•	•		•		•		•	•			●	●		•	•			•	•		•	•		•	•	●	•			●				•	•		•	•	•	•	●	●	•								•	•			•	•	●				•	/		
				cc		·		·	·		·		•		·	•			●	●		•	•			·	•	•				•	•	●	•		•	●				•			•	•	•	•	●	●	·								•	•			•	•	●				●	/		
195-225	17	2	2	6-8	·	·		•	·		•		•		·	•			●	●	·	•	●			•						•	•	●	·		•	•				·			•	●	●	•	•	•	•								•	·				·	•	·	·		·	x		
			3	3-5				•	•		•		•		·	●			●	•	·		•			•	•					●	●	●	•		·	•				•			•	·	·	●	●	●	●								•	·			•	•	●	•	•		•	/		
			4	3-5	·			·	·		·		•			•			•	•		•	•			·	•					•	•	•								·			•			•	•	•	•								·	·				·	•	·			·	x		
				cc				•	•		•		•		·	●			·	·	·	•	•			•						·	•	●	·			·				•	·		•	·	·	·	●	●									·	•				·	●	·			•	/		
353-383	17	3	2	6-8				·			•		•		•	•			•	•		·	•			•	•	•				·	•	•			·	•				•	·			•	•	·		•	•								·	•				·	•				•	x		
				100-102		·	·	•	·		•		•		·		•		•		·	·	·			•	·	·					•	•	·							•		•	•				•	•	·								·					·	·				•	x		
			3	13-15			·	•			•		•		·	•	•		·		•	•	•			●	·	·	·	·		•	•	•			•	·				•					·	·	•	•	•								·	·				·	•	·			•	x		
			4	11-13				•	·		•		•		·	•	·		•			·	•			•	·	•				·	•	•				•				•		·	•		·	·	•	·	•								·	·				•	•	·			•	x		
				cc		·		•			·		·		·	·			●	·		·	·			•	●					·	•	•			·	·				·	·			·	·		·	·	·								·	•					•				•	x		
383-413	6	4	1	105-107			●	●	·		•		•			·	·		•			·	•			·	·		•	•		·	•	•			•	•				•		·	●				•	•	•								·	•				·	•	·			•	/		
			2	8-10			·	●	·		•		•		•	•	•		•			•	•			·	●					·	•	•			·	•				●		-				•	•	•	•								•	•				·	·	·			•	x		
			4	cc				●	·	·	•		•		•	•			●			·	•			•	•					•	●	●		•	·	●				•	•				·	·	●	●	•								•	•				·	●	·	●		•	/		
539-570	10	5	1	102-104		·	•	●	·		•		•			·			•			·	•			•			●	•		•	•	•								•		•	●			•	•	●	•								•	·				•	•				•	x		
			2	1-3			●	•			•		•			•			•			·	•			•			●	•		·	•	•								●		·	•			•	•	•	•								·	·				·	•	·		•	•	x		
				100-102			•	●		·	·		•			·			•			·	•			•			●	•		·	•	•			•	•				•					•	•	•	•	•								•	·	·			•	•				•	x	?Gr.trunc. cf. tosaensis	Pliocene
				cc				·			•		•		•	●	•		●	·	·	•	•			•	●		•	·		·	•	·			•	•				•	·				•	·		●	●								•	●				·	•	·	·		•	x		
570-585	15	6	1	14-16		·	•	•	·		·		•		·	•	·		•		·	•	•			·			•	•		·	•	•			·	·				•					·	·	•	•	•								•	·	•				•				·	x		
				62-64		·	•	•	•		•		•		·	•			·		·	•	•			•			•	•		·	•	•								●					•	·	•	·	•								•					·	●	·			•	x		
			2	10-12			•	•	·		·		•		·	·			·		·	·	•			•			·	·		·	•	•				·				·					·		·	·	·								·	·					•				·	x		
				70-72			·	•	·		•		•		·	•			•			•	•			·						·	•	•			·	·				·					·	·	·	•	•								·	·				·	•	·			·	x		
				102-104			·	•	·		•		·		·	·	·		•			·	•			·						·	•	•				·				·		•c	•c				·	·	·								·	·					•				•	x		
			3	7-9			·	·	·		·		·		·	·	·		•			·	•			·							•	•				·				·		•c	•c			·		·	·							•		·					·	•	·			●	x		
				cc		·		●	·		·		·		•	·			●	·		•	●			●			•	•		●	●	·	·			•				•		•c	•c		•	●	·										•	•				·	•	·			●	x		
853-883	5	7	1	3-5			•	•	·		•		•			·	•		•			•	•			•		•	·	·			•	•						•		·						·	•					•					·		•			·	•				●	x	Gr. exilis/ Gr. miocenica	
				71-73			•	•			•		•		·	•	•		•			·	•					·	•	•			•	•						•		·						·	•	·	·				•					·						·				·	x		
				114-116			·	·			•		·		·	·	•		•		·	·	•			•							•	•	·					•		·						·	·		·								·						•				●	x		
				cc			·	•			·		•		·	·	●		●		·	·	●	·	•	•			•	•		·	•	•	·					●		·						·	·										·	·				·	●	·		·	•	x		
1043-1073	1,5	8	1	3-5		·	·	•			·		•	·	·	·	•	•	·		·	·	·	·		•		•	•	•	•	·	●	•							●	·	·					·	·			·	●						•						•				•	x	Gr. margaritae or ?Gr. dut.	
				27-28			•	●		●	•		•	•	•	·	●	•	•		·	•	●	●		●		•	•	•	•	·	●	●							•	•	•					·	·			•	●			●			•						•				•	x		
				cc			●	●		•	•		●	•	·	•	●	•	•			•	•	●		•			•	•	•	·	●	●	·				·		•	•	·					·	·			•	●				•	•	•						•			·	•	x		
	Centre bit betw. Bls. 8 and 9						·	·			·	•	·		·		·	·				·	·	·		·													·		●	·							·				·		●					·					·	·	·			•	x		Upper Miocene
1200-1230	6	9	1	8-10				·				·					·	·				·	·	·		·													·										·										·				•	·	•	·	•		●	x	Gr. acostaensis	
			2	12-14			●	•			•	●	•	·			•	·					●	•		●													•			·							·			·	·						·				•		•		·		●	x		
				cc			·	·			·	●	·		·			●					•	·		·								•c					•			·										·	·						·			●	●		•		•		●	x		

Figure 11.

LEG 4
STATION 3o
Barrels lo-16

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																														other mf.						Nature of residue					ZONE	AGE
					Gg. foliata	Gg. juvenilis	Gg. nepenthes	Gg. rohri	Gg. uvula	Gg. venezuelana	Globigerinatella insueta	Globigerinita sp.	Gs. altiapertura	Gs. bisphaerica	Gs. obliquus obliquus	Gs. ruber s.l.	Gs. trilobus sacculifer	Gs. trilobus s.l.	Gq. altispira s.l.	Gq. dehiscens s.l.	Gr. archeomenardii	Gr. fohsi fohsi	Gr. fohsi lobata	Gr. fohsi peripheroronda	Gr. fohsi robusta	Gr. mayeri s.l.	Gr. menardii A	Gr. obesa	Gr. scitula s.l.	Gr. subcretacea	Orbulina sp.	Praeorbulina sp.	Ss. seminulina s.l.	Ss. subdehiscens s.l.	benthonic foraminifera	echinoid spines	fish teeth/bones	radiolaria	sponge spicules	other microfossils	planktonic foraminifera	other microfossils	glauconite	volcanic ash/minerals	compensation depth		
St. 30																																															
1230-1260	12	10		top	•	•	●			•		●			●		•	●	•	•						●	•		•		●		●	•	•			•	●	•	●	•	●	●	x	Gr. mayeri	Middle Miocene
			3	100-102			●			•					●			•		•						•	•		•		•		•	•	•	•		•	●	•	●	•	●	●	x		
				cc	•	•				•					•		•	•	•	•						•	•		•				•		•		•	●	●	•	•	•	●	●	x		
1260-1290	10	11	2	86-89		•				•					●	•		●		•					•	•			•				•		•		•	•		•	●	•	•	●	x	Gr. fohsi robusta	
				cc		●			•	●					•	●		●	●				•		•	●		•	•	•	•		•		●	•	•		•	•	●	•	•	●	/		
1290-1320	25	12	3	23-26		•				•		•				•	•	•	•				•			•			•	•	•		•		•		•		●	•	•	•	•	●	/	Gr. fohsi lobata	
				cc		●			•	●					•	●		●	●	●		•	•			●		•			•		●		●	•	•	•	●	•	●	•	●	●	/		
1320-1335	15	13	1	0-3						●					•	•	•	•	•	•		•	•			•					•		•		•				•	•	•	•	●	●	x		
				cc	•	•			•	•					●		•	●	●	•	•	●				●		•	•	•	•		●		•	•	•	●	●	•	●	•	●	●	/	Gr. fohsi fohsi	
1335-1351	5	14	1	103-105				•		●					●	•		●	●	●		●				●			•	•	●		•		•	•	•			•	●	•	•	●	x		
				cc	•	•		•	•	●			●		●	•	•	●	●	●	•	●		●		●		•			●		●			•	•			•	●	•	•	●	/		
1351-1381	23	15	1	80-83		•	•			●					●			●	●	•		●		•		•				•	●		•		•	•	•			•	●	•	●	●	x	Gr. fohsi peripheror.	
			3	8-11						●					●			●	●	●	•			●		●		•		•	•		•		•					•	●	•	•	●	x		
			5	0-3						●					•			●	●	•	●			•		●					•		•		•	•				•	●	•	●	●	x		
				cc		•			•	●	•		•	•		•		●	●	●	•			●		●			•			●			•	•				•	●	•	●	•	/	Praeorbulina glomerosa	Lower Miocene
1381-1411	4	16		cc		•			•	●	•			●		●	•	●	●	●				●		●				•		●	•		•	•	•			•	●	•	●	●	/		

Figure 12.

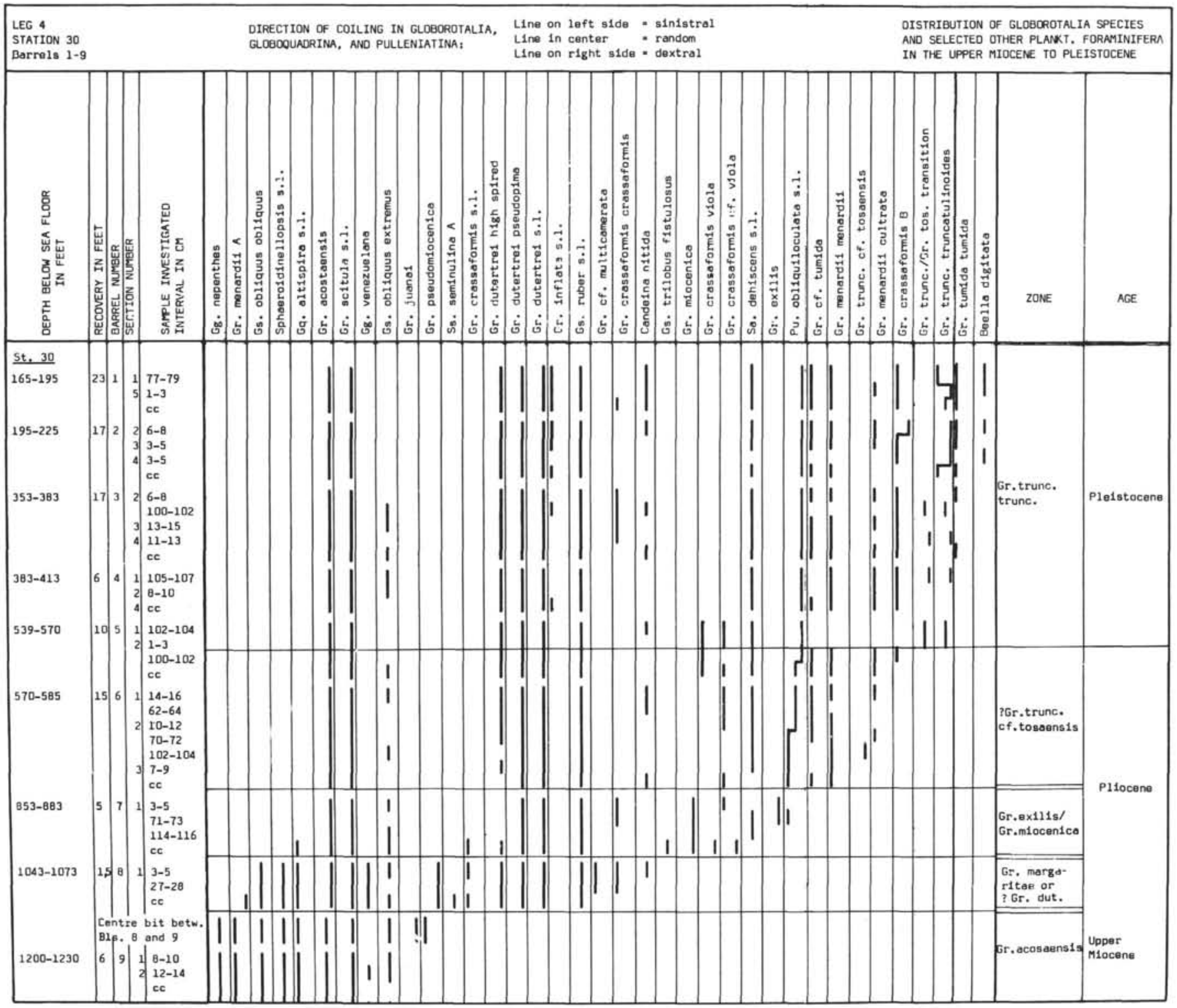

LEG 4
STATION 30
Barrels 1-9
DIRECTION OF COILING IN GLOBOROTALIA, GLOBOQUADRINA, AND PULLENIATINA:
Line on left side = sinistral
Line in center = random
Line on right side = dextral
DISTRIBUTION OF GLOBOROTALIA SPECIES AND SELECTED OTHER PLANKT. FORAMINIFERA IN THE UPPER MIOCENE TO PLEISTOCENE
DEPTH BELOW SEA FLOOR IN FEET
RECOVERY IN FEET
BARREL NUMBER
SECTION NUMBER
SAMPLE INVESTIGATED INTERVAL IN CM
Gg. nepenthes
Gr. menardii A
Gs. obliquus obliquus
Sphaeroidinellopsis s.l.
Gq. altispira s.l.
Gr. acostaensis
Gr. scitula s.l.
Gg. venezuelana
Gs. obliquus extremus
Gr. juanai
Gr. pseudomiocenica
Ss. seminulina A
Gr. crassaformis s.l.
Gr. dutertrei high spired
Gr. dutertrei pseudopima
Gr. dutertrei s.l.
Gr. inflata s.l.
Gs. ruber s.l.
Gr. cf. multicamerata
Gr. crassaformis crassaformis
Candeina nitida
Gs. trilobus fistulosus
Gr. miocenica
Gr. crassaformis viola
Gr. crassaformis cf. viola
Sa. dehiscens s.l.
Gr. exilis
Pu. obliquiloculata s.l.
Gr. cf. tumida
Gr. menardii menardii
Gr. trunc. cf. tosaensis
Gr. menardii cultrata
Gr. crassaformis B
Gr. trunc./Gr. tos. transition
Gr. trunc. truncatulinoides
Gr. tumida tumida
Beella digitata
ZONE
AGE
St. 30
165-195
23
1
1 77-79
5 1-3
cc
195-225
17
2
2 6-8
3 3-5
4 3-5
cc
353-383
17
3
2 6-8
100-102
3 13-15
4 11-13
cc
383-413
6
4
1 105-107
2 8-10
4 cc
539-570
10
5
1 102-104
2 1-3
100-102
cc
570-585
15
6
1 14-16
62-64
2 10-12
70-72
102-104
3 7-9
cc
853-883
5
7
1 3-5
71-73
114-116
cc
1043-1073
15
8
1 3-5
27-28
cc
Centre bit betw. Bls. 8 and 9
1200-1230
6
9
1 8-10
2 12-14
cc
Gr.trunc. trunc.
Pleistocene
?Gr.trunc. cf.tosaensis
Pliocene
Gr.exilis/ Gr.miocenica
Gr. margaritae or ? Gr. dut.
Gr.acosaensis
Upper Miocene

Figure 13.

LEG 4
STATION 31
Barrels 1-7

PLANKTONIC FORAMINIFERA   OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																			
					Beella digitata	Candeina nitida s.l.	Gg. apertura	Gg. bulloides s.l.	Gg. calida s.l.	Gg. foliata s.l.	Gg. juvenilis	Gg. nepenthes	Gg. tetracamerata	Gg. venezuelana	Globigerinita sp.	Gs. conglobatus s.l.	Gs. obliquus extremus	Gs. obliquus obliquus	Gs. ruber s.l.	Gs. ruber (red colored)	Gs. suleki	Gs. trilobus fistulosus	Gs. trilobus cf. fistulosus	Gs. trilobus sacculifer
St. 31																								
0-30	30	1	0	top		•		●	•		•		•		•	•			●	●	•		•	•
			1	top				•	•		•		•			•			•	•			•	•
				cc	•	•		•	•		•		•		•	•			●	●			•	•
105-135	1	2	1	top				•	•		•		•		•	•			•		•		•	•
				cc				•	•		•		•		•	•			●		•		•	•
198-228		3		2-4			•	•		•			•		•	•			•		•		•	•
				50-52	•	•		•	•	•	•		•		•	•			●		•		•	•
				100-102				•			•		•		•	•			•				•	•
			2	2-4				●	•		•		•		•	•			●				•	•
				50-52				•	•		•		•		•	•			•		•		•	•
				100-102				•	•		•				•	•							•	•
			3	2-4		•		•			•		•		•				•				•	•
				50-52		•		•			•		•		•	•			•		•		•	•
				105-107				•			•					•			•				•	•
			5	50-52		•		•	•		•		•		•	•			•				●	•
			6	50-52	•	•	●	●	•		•		•		•	•			•			•	•	•
				cc				●	•		•		•			•	•		•				•	•
228-258	10	4	1	50-52			•	•			•		•			•	•		•			•	•	•
			2	57-59		•	•	•	•		•		•			•	•		•			•	•	•
				cc		•	•	•			•		•			•	•		•				•	•
258-288	5	5	1	80-82	•		•	•			•		•			•	•		•			•	•	•
				cc		•	•	•			•		•		•	•	•		●			•	•	•
288-318	10	6	1	50-52		•	●	●					•	•		●	•		•					•
			2	50-52		•	•	●		•	•		●	●	•	●	•		●					●
				cc		•	●	•		•	●				●	•	•		●					•
318-348	5	7	1	36-38		•	●	●			●		•	●		●	●	●	●					•
				68-70		•	●	●			•		•		•	●	•	•	●				•	•
				109-111		•	●	●			•		•	●		•	•		●				•	●
				119-121			•	●				•	•		•	●	●	•	•				•	•
				131-132				•																
				139-142				●		•		●	•				•	•	•					•
				148-150				•				•				•	•	•						●
				cc			•	●			•	•		●		●	•	●	•					•

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																			
					Gs. trilobus s.l.	Gq. altispira s.l.	Gr. trunc. cf. ronda	Gr. acostaensis	Gr. crassaformis crassaformis	Gr. crassaformis B	Gr. crassaformis viola	Gr. crassaformis cf. viola	Gr. crassaformis s.l.	Gr. dutertrei, high spired	Gr. dutertrei pseudopima	Gr. dutertrei s.l.	Gr. inflata	Gc. inflata A	Gr. cf. inflata	Gr. margaritae	Gr. menardii cultrata	Gr. exilis	Gr. menardii menardii	Gr. exilis A
St. 31																								
0-30	30	1	0	top	●			•	•	•				●	•	•	•		•		•		•	
			1	top	•			•	•	•				•	•		•				•		•	
				cc	•				•	•				●	•	●	●				•		●	
105-135	1	2	1	top	●			•	•	•							•		●		•		•	
				cc	●			•						●	●	•	•				•		•	
198-228		3		2-4	●			•	•			•	•	•	•	•						•		
				50-52	•			•	•		•	•		•	•	•						•		
				100-102	●			•	•		•	•		•	•	•						•		
			2	2-4	●			•			•	•		•	•	●						●		
				50-52	●			•	•			•	•	•	•	●						•		
				100-102	•			•	•			•	•	•	•	•						•		
			3	2-4	•	•		•	•		•	•	•	•	•	●						•		
				50-52	●			•	•			•	•	•	•	●						•		
				105-107	•				•			•	•	•	•	•								
			5	50-52	●			•	•			•	•	●		●						•		
			6	50-52	●			•	•			•	•	•	•	●						•		
				cc	•	•		•	●			•	•		•	●		•				•		
228-258	10	4	1	50-52	•		•	•	•			•	•	•	•	•		•				•		
			2	57-59	●		•	•	•			•	•		•	•		●				•		
				cc	•	•	•		•			•	•		•	•		●				•		
258-288	5	5	1	80-82	•	•	•	•			•	●	•	•	●	●						•		•
				cc	•	•	•	•			•	●	●	•	●	●		•				•		•
288-318	10	6	1	50-52	•	•	•	•					•		•	●		•						•
			2	50-52	●	●	•	•		•			•	●	•	●		•						•
				cc	•	•	•	●					●	●	•	●		•						●
318-348	5	7	1	36-38	●	●								●	●	●		•		•				•
				68-70	●	●		●					•	•	●	●				•				•
				109-111	●	●		•	●				•	•	•	●				•				●
				119-121	●	●		●							●	●				•				
				131-132				•												•				
				139-142	●	●		•							●	•				•				
				148-150	●	•		•							•	•				•				
				cc	●	•		•					•		•	●				•				

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	planktonic foraminifera																
					Gr. miocenica	Gr. multicamerata	Gr. pseudomiocenica	Gr. scitula s.l.	Gr. trunc. cf. tosaensis	Gr. trunc. truncatulinoides	Gr. tumida flexuosa	Gr. tumida tumida	Gr. cf. tumida	Hastigerina pelagica	Hastigerina siphonifera	Gr. menardii fimbriata	Orbulina sp.	Pu. obliquiloculata s.l.	Sa. dehiscens s.l.	Ss. seminulina A	Sphaeroidinellopsis s.l.
St. 31																					
0-30	30	1	0	top				•		•	•	•	●	•	•	•	●	•	•		
			1	top				•		•	●	•	●		•		●	•	●		
				cc				•		•		•	•	•	●		●	•	•		
105-135	1	2	1	top				•		●			•		•		●	●	•		
				cc				•		●		•	•		●		●	•	•		
198-228		3		2-4				•	•						•		●	●	•		
				50-52	•			•	•				•		•		●	•	•		
				100-102	•			●	●				•		•		●	●	•		
			2	2-4	•			•	●						•		●	•	●		
				50-52	•			●									●		●		
				100-102	•												●		•		
			3	2-4	•	4°		●	•						•		●	•	•		
				50-52	•			•							•		●		●		
				105-107	•										•		●		●		
			5	50-52	•														●		
			6	50-52	●			•							•		●		●		
				cc	●			•							•		•	•	•		
228-258	10	4	1	50-52	•			•							•		●		●		
			2	57-59	●			•						•	•		●		•		
				cc	●	•		•									●	•	●		
258-288	5	5	1	80-82	●	•		•							•		●		●		
				cc	●	•		●							•		●		●		
288-318	10	6	1	50-52		●	•	•							•		●			•	●
			2	50-52		●	•	•							•		●			●	●
				cc		●	•	●						•			●		•	●	●
318-348	5	7	1	36-38		●	•	•							•		●	•	●	•	•
				68-70		•	●	•							•		●		●		•
				109-111		•	•	•							•		●			●	•
				119-121		•	•								•		●				●
				131-132		●	•														
				139-142		●	•								•		•				●
				148-150		●	•								•		•				●
				cc		●	•	•							•		●		fc		•

DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	other mf				Nature of residue							ZONE	AGE
					benthonic foraminifera	echinoid spines	fish teeth/bones	other microfossils	planktonic foraminifera	clay	manganese	pyrite	quartz	volcanic ash/minerals	compensation depth		
St. 31																	
0-30	30	1	0	top	•		•		●	•					/	Gr. trunc. trunc.	Pleistocene
			1	top	•	•	•	•	●	•					/		
				cc	•	•	•	•	●	•					/		
105-135	1	2	1	top	•	•	•	•	●		•			•	/		
				cc	•	•	•	•	●					•	/		
198-228		3		2-4	•	•		•	●	•					/	Gr.tr.cf.tos.	Pliocene
				50-52	•	•	•		●			•		•	/	Gr. exilis/ Gr. miocenica	
				100-102	•	•	•	•	●						/		
			2	2-4	•	•	•	•	●						/		
				50-52	•	•	•	•	●		•			•	/		
				100-102	•	•	•	•	●	•				•	/		
			3	2-4	•	•		•	●		•				/		
				50-52	•	•	•	•	●		•				/		
				105-107	•		•	•	●		•				×		
			5	50-52	•		•	•	●		•				×		
			6	50-52	•	•	•	•	●		•				×		
				cc	•			•	●		•			•	/		
228-258	10	4	1	50-52	•	•	•	•	●		•				/		
			2	57-59	•	•	•	•	●						/		
				cc	•	•	•	•	●		•	•			/		
258-288	5	5	1	80-82	•	•		•	●	●					/		
				cc	•	•	•		●		•				/		
288-318	10	6	1	50-52	•	•	•	•	●						/	Gr. margaritae	
			2	50-52	•		•	•	●						/		
				cc	•	•	•	•	●	•	•			•	/		
318-348	5	7	1	36-38	•	•	•	•	●						×		
				68-70	•	•	•	•	●		•				/		
				109-111	•	•	•	•	●		•	•		•	/		
				119-121	•	•	•	•	●				•	•	×		
				131-132	•		•	•	•				•		✱		
				139-142	•		•	•	●				•	•	×		
				148-150	•		•						•	•	×		
				cc	•		•	•	●				•	●	×		

Figure 14.

LEG 4
STATION 31
Barrels 8-lo

PLANKTONIC FORAMINIFERA - OTHER MICROFOSSILS
NATURE OF RESIDUE - ZONE - AGE

					planktonic foraminifera																					other mf.						Nature of residue							
DEPTH BELOW SEA FLOOR IN FEET	RECOVERY IN FEET	BARREL NUMBER	SECTION NUMBER	SAMPLE INVESTIGATED INTERVAL IN CM	Catapsydrax dissimilis s.l.	Gg. cip. angustumbilicata	Gg. juvenilis	Gg. rohri	Gg. venezuelana	Globigerinita sp.	Gs. obliquus obliquus	Gs. ruber s.l.	Gs. trilobus primordius	Gs. trilobus sacculifer	Gs. trilobus s.l.	Gq. altispira s.l.	Gq. dehiscens s.l.	Gr. archeomenardii	Gr. fohsi fohsi	Gr. kugleri	Gr. mayeri s.l.	Gr. obesa	Gr. opima s.l.	Orbulina sp.	Ss. seminulina sp.	benthonic foraminifera	echinoid spines	fish teeth/bones	radiolaria	sponge spicules	other microfossils	planktonic foraminifera	other microfossils	chalk	manganese	quartz	compensation depth	ZONE	AGE
St. 31 5o8-538	9	8	1	46-48					●	•	•	●			●	●	●	•	●		●			•	●	●	•	●			•	●			•			Gr. fohsi fohsi	Lower Miocene
			2	5o-52			•		●	•		●			●	●	•		●		●			●	●	●	●	●			●	●			•	•			
				cc			●		●	•	●	●		•	●	●	●	•	●		●	•				●	●	●				●	●	●	●				
696-726	11	9	2	1-4	●			●					●		●	●				•	●					•	•	•				●	•	●				Gr.kugleri	
			3	o-4	●			•	●											•	●					•		•	•	•	•	●		●					
886-916	25	lo	1	o-4	•			•	•												●					•			•			•		●			/	?Gr. opima opima	Oligocene
			3	o-3	•			●	●												●					•				●				●			/		
				cc	●	•			●												●		•					•	●	•		●		•			/		

Figure 15.

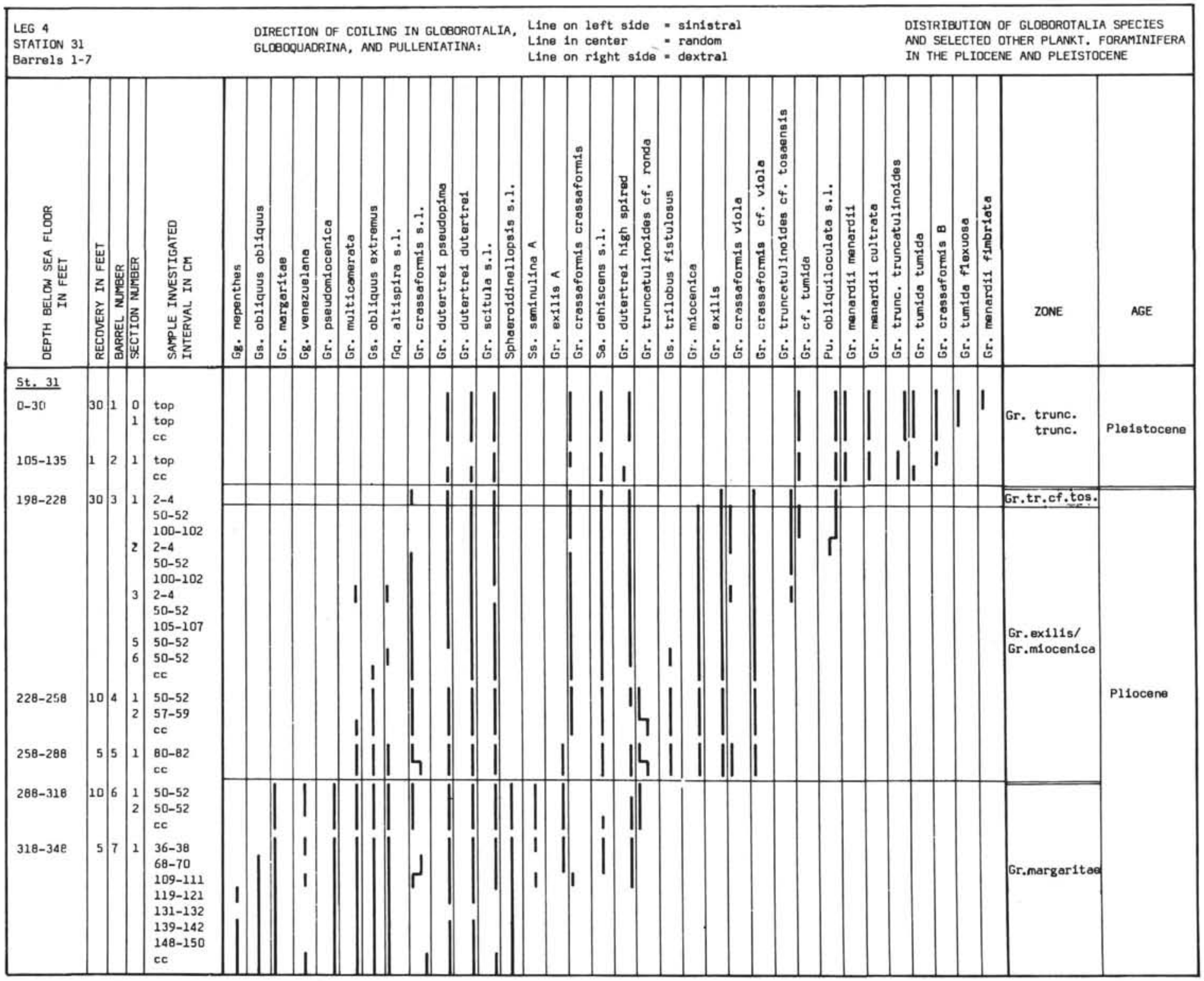

LEG 4
STATION 31
Barrels 1-7
DIRECTION OF COILING IN GLOBOROTALIA, GLOBOQUADRINA, AND PULLENIATINA:
Line on left side = sinistral
Line in center = random
Line on right side = dextral
DISTRIBUTION OF GLOBOROTALIA SPECIES AND SELECTED OTHER PLANKT. FORAMINIFERA IN THE PLIOCENE AND PLEISTOCENE
DEPTH BELOW SEA FLOOR IN FEET
RECOVERY IN FEET
BARREL NUMBER
SECTION NUMBER
SAMPLE INVESTIGATED INTERVAL IN CM
Gg. nepenthes
Gs. obliquus obliquus
Gr. margaritae
Gg. venezuelana
Gr. pseudomiocenica
Gr. multicamerata
Gs. obliquus extremus
Gq. altispira s.l.
Gr. crassaformis s.l.
Gr. dutertrei pseudopima
Gr. dutertrei dutertrei
Gr. scitula s.l.
Sphaeroidinellopsis s.l.
Ss. seminulina A
Gr. exilis A
Gr. crassaformis crassaformis
Sa. dehiscens s.l.
Gr. dutertrei high spired
Gr. truncatulinoides cf. ronda
Gs. trilobus fistulosus
Gr. miocenica
Gr. exilis
Gr. crassaformis viola
Gr. crassaformis cf. viola
Gr. truncatulinoides cf. tosaensis
Gr. cf. tumida
Pu. obliquiloculata s.l.
Gr. menardii menardii
Gr. menardii cultrata
Gr. trunc. truncatulinoides
Gr. tumida tumida
Gr. crassaformis B
Gr. tumida flexuosa
Gr. menardii fimbriata
ZONE
AGE
St. 31
0-30 30 1 0 top
1 top
cc
105-135 1 2 1 top
cc
198-228 30 3 1 2-4
50-52
100-102
2 2-4
50-52
100-102
3 2-4
50-52
105-107
5 50-52
6 50-52
cc
228-258 10 4 1 50-52
2 57-59
cc
258-288 5 5 1 80-82
cc
288-318 10 6 1 50-52
2 50-52
cc
318-348 5 7 1 36-38
68-70
109-111
119-121
131-132
139-142
148-150
cc
Gr. trunc. trunc.
Pleistocene
Gr.tr.cf.tos.
Gr.exilis/ Gr.miocenica
Pliocene
Gr.margaritae

Figure 16.

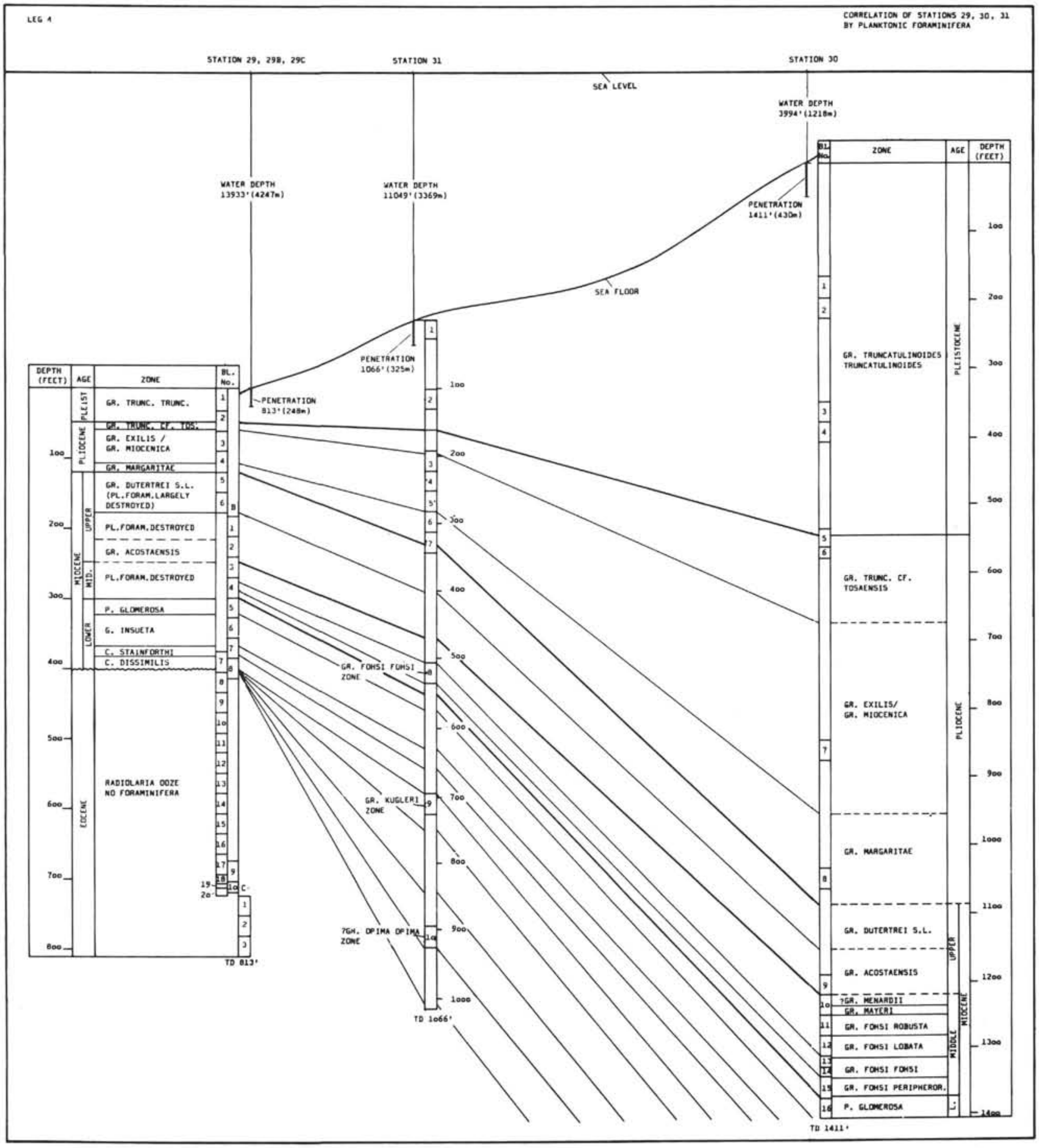

LEG 4
CORRELATION OF STATIONS 29, 30, 31
BY PLANKTONIC FORAMINIFERA
STATION 29, 29B, 29C
STATION 31
STATION 30
SEA LEVEL
WATER DEPTH
13933' (4247m)
WATER DEPTH
11049' (3369m)
WATER DEPTH
3994' (1218m)
SEA FLOOR
PENETRATION
813' (248m)
PENETRATION
1066' (325m)
PENETRATION
1411' (430m)
DEPTH (FEET)
AGE
ZONE
BL. No.
PLEIST
PLIOCENE
MIOCENE
UPPER
MID.
LOWER
EOCENE
GR. TRUNC. TRUNC.
GR. TRUNC. CF. TOS.
GR. EXILIS /
GR. MIOCENICA
GR. MARGARITAE
GR. DUTERTREI S.L.
(PL. FORAM. LARGELY
DESTROYED)
PL. FORAM. DESTROYED
GR. ACOSTAENSIS
PL. FORAM. DESTROYED
P. GLOMEROSA
G. INSUETA
C. STAINFORTHI
C. DISSIMILIS
RADIOLARIA OOZE
NO FORAMINIFERA
B
C
100
200
300
400
500
600
700
800
TD 813'
GR. FOHSI FOHSI
ZONE
GR. KUGLERI
ZONE
?GR. OPIMA OPIMA
ZONE
TD 1066'
GR. TRUNCATULINOIDES
TRUNCATULINOIDES
PLEISTOCENE
GR. TRUNC. CF.
TOSAENSIS
GR. EXILIS/
GR. MIOCENICA
PLIOCENE
GR. MARGARITAE
GR. DUTERTREI S.L.
GR. ACOSTAENSIS
?GR. MENARDII
GR. MAYERI
GR. FOHSI ROBUSTA
GR. FOHSI LOBATA
GR. FOHSI FOHSI
GR. FOHSI PERIPHEROR.
P. GLOMEROSA
UPPER
MIDDLE
L.
MIOCENE
1000
1100
1200
1300
1400
TD 1411'

Figure 17.

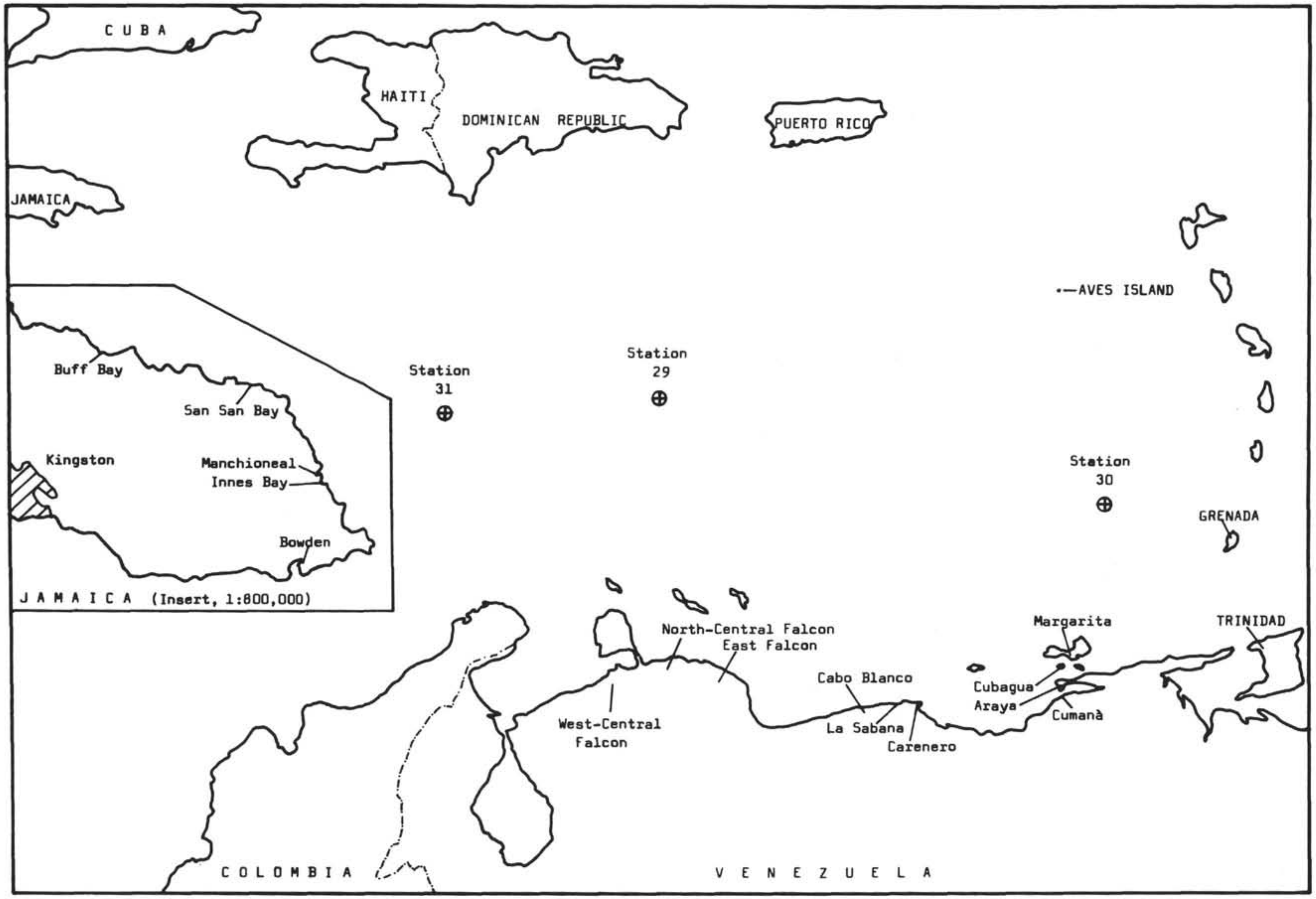

CUBA
HAITI
DOMINICAN REPUBLIC
PUERTO RICO
JAMAICA
AVES ISLAND
Station 31
Station 29
Station 30
GRENADA
Buff Bay
San San Bay
Kingston
Manchioneal
Innes Bay
Bowden
JAMAICA (Insert, 1:800,000)
North-Central Falcon
East Falcon
West-Central Falcon
Cabo Blanco
La Sabana
Carenero
Margarita
Cubagua
Araya
Cumanà
TRINIDAD
COLOMBIA
VENEZUELA

Figure 18.

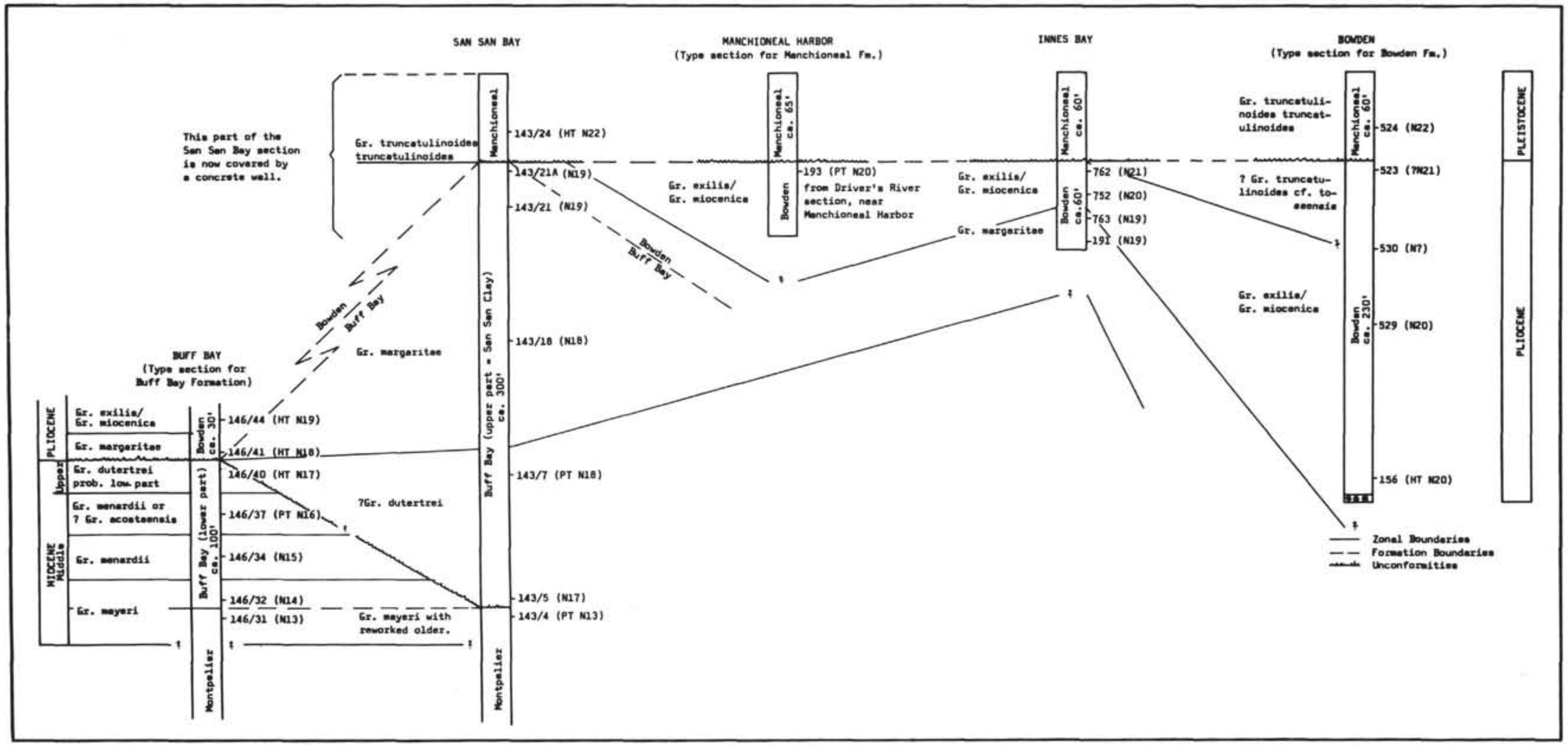

SAN SAN BAY
MANCHIONEAL HARBOR
(Type section for Manchioneal Fm.)
INNES BAY
BOWDEN
(Type section for Bowden Fm.)
This part of the San San Bay section is now covered by a concrete wall.
Gr. truncatulinoides truncatulinoides
Manchioneal
143/24 (HT N22)
143/21A (N19)
143/21 (N19)
Bowden
Buff Bay
Gr. margaritae
143/18 (N18)
Buff Bay (upper part = San San Clay) ca. 300'
143/7 (PT N18)
?Gr. dutertrei
143/5 (N17)
143/4 (PT N13)
Gr. mayeri with reworked older.
Montpelier
BUFF BAY
(Type section for Buff Bay Formation)
PLIOCENE
Upper
MIOCENE Middle
Gr. exilis/
Gr. miocenica
Gr. margaritae
Gr. dutertrei prob. low. part
Gr. menardii or ? Gr. acostaensis
Gr. menardii
Gr. mayeri
Bowden ca. 30'
Buff Bay (lower part) ca. 100'
Montpelier
146/44 (HT N19)
146/41 (HT N18)
146/40 (HT N17)
146/37 (PT N16)
146/34 (N15)
146/32 (N14)
146/31 (N13)
Manchioneal ca. 65'
Bowden
193 (PT N20)
from Driver's River section, near Manchioneal Harbor
Gr. exilis/
Gr. miocenica
Gr. exilis/
Gr. miocenica
Gr. margaritae
Manchioneal ca. 60'
Bowden ca. 60'
762 (N21)
752 (N20)
763 (N19)
191 (N19)
Gr. truncatuli-noides truncat-ulinoides
? Gr. truncatu-linoides cf. to-saensis
Gr. exilis/
Gr. miocenica
Manchioneal ca. 60'
Bowden ca. 230'
524 (N22)
523 (?N21)
530 (N?)
529 (N20)
156 (HT N20)
PLEISTOCENE
PLIOCENE
Zonal Boundaries
Formation Boundaries
Unconformities

Figure 19.

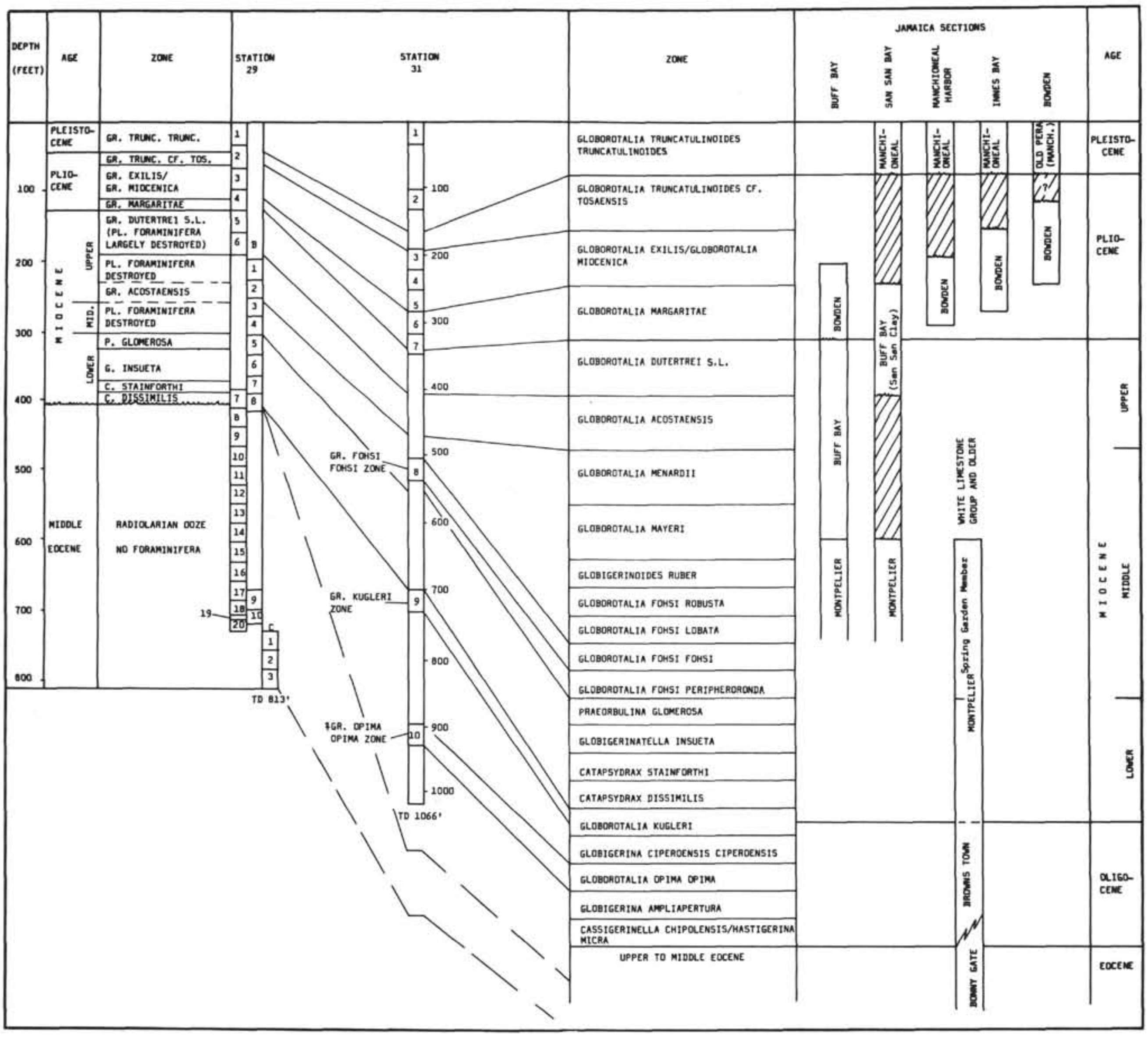

DEPTH (FEET)
AGE
ZONE
STATION 29
STATION 31
ZONE
JAMAICA SECTIONS
BUFF BAY
SAN SAN BAY
MANCHIONEAL HARBOR
INNES BAY
BOWDEN
AGE
100
200
300
400
500
600
700
800
PLEISTOCENE
PLIOCENE
MIOCENE
UPPER
MID.
LOWER
MIDDLE EOCENE
GR. TRUNC. TRUNC.
GR. TRUNC. CF. TOS.
GR. EXILIS/ GR. MIOCENICA
GR. MARGARITAE
GR. DUTERTREI S.L. (PL. FORAMINIFERA LARGELY DESTROYED)
PL. FORAMINIFERA DESTROYED
GR. ACOSTAENSIS
PL. FORAMINIFERA DESTROYED
P. GLOMEROSA
G. INSUETA
C. STAINFORTHI
C. DISSIMILIS
RADIOLARIAN OOZE NO FORAMINIFERA
19
20
TD 813'
GR. FOHSI FOHSI ZONE
GR. KUGLERI ZONE
*GR. OPIMA OPIMA ZONE
TD 1066'
1000
GLOBOROTALIA TRUNCATULINOIDES TRUNCATULINOIDES
GLOBOROTALIA TRUNCATULINOIDES CF. TOSAENSIS
GLOBOROTALIA EXILIS/GLOBOROTALIA MIOCENICA
GLOBOROTALIA MARGARITAE
GLOBOROTALIA DUTERTREI S.L.
GLOBOROTALIA ACOSTAENSIS
GLOBOROTALIA MENARDII
GLOBOROTALIA MAYERI
GLOBIGERINOIDES RUBER
GLOBOROTALIA FOHSI ROBUSTA
GLOBOROTALIA FOHSI LOBATA
GLOBOROTALIA FOHSI FOHSI
GLOBOROTALIA FOHSI PERIPHERORONDA
PRAEORBULINA GLOMEROSA
GLOBIGERINATELLA INSUETA
CATAPSYDRAX STAINFORTHI
CATAPSYDRAX DISSIMILIS
GLOBOROTALIA KUGLERI
GLOBIGERINA CIPEROENSIS CIPEROENSIS
GLOBOROTALIA OPIMA OPIMA
GLOBIGERINA AMPLIAPERTURA
CASSIGERINELLA CHIPOLENSIS/HASTIGERINA MICRA
UPPER TO MIDDLE EOCENE
MANCHIONEAL
OLD PERA (MANCH.)
?
BOWDEN
BUFF BAY
BUFF BAY (San San Clay)
MONTPELIER
WHITE LIMESTONE GROUP AND OLDER
MONTPELIER Spring Garden Member
BROWNS TOWN
BONNY GATE
PLEISTOCENE
PLIOCENE
MIOCENE
UPPER
MIDDLE
LOWER
OLIGOCENE
EOCENE

Figure 20.

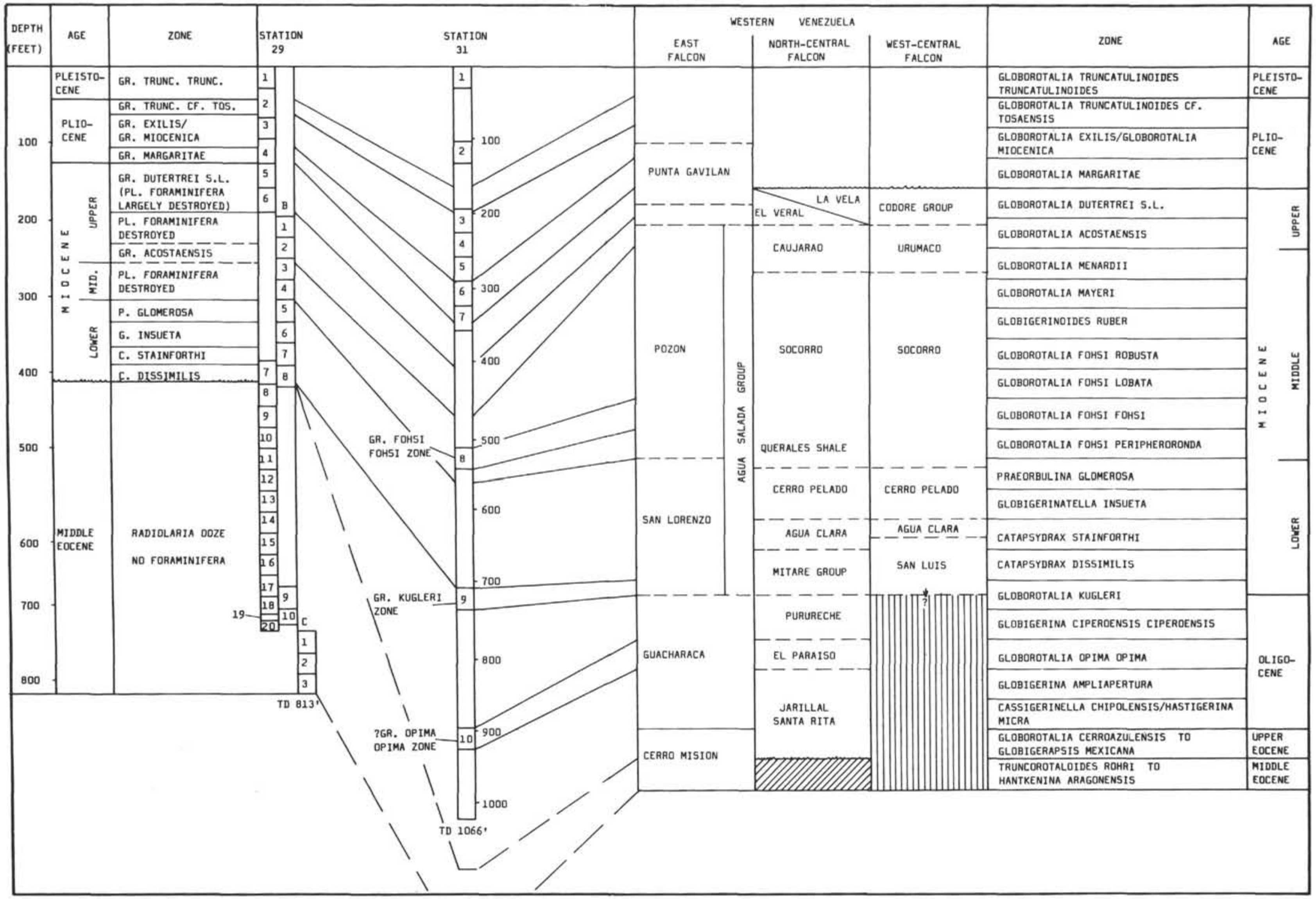

DEPTH (FEET)
AGE
ZONE
STATION 29
STATION 31
WESTERN VENEZUELA
EAST FALCON
NORTH-CENTRAL FALCON
WEST-CENTRAL FALCON
ZONE
AGE
100
200
300
400
500
600
700
800
PLEISTOCENE
PLIOCENE
MIOCENE
UPPER
MID.
LOWER
MIDDLE EOCENE
GR. TRUNC. TRUNC.
GR. TRUNC. CF. TOS.
GR. EXILIS/ GR. MIOCENICA
GR. MARGARITAE
GR. DUTERTREI S.L. (PL. FORAMINIFERA LARGELY DESTROYED)
PL. FORAMINIFERA DESTROYED
GR. ACOSTAENSIS
PL. FORAMINIFERA DESTROYED
P. GLOMEROSA
G. INSUETA
C. STAINFORTHI
C. DISSIMILIS
RADIOLARIA OOZE
NO FORAMINIFERA
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
B
C
TD 813'
GR. FOHSI FOHSI ZONE
GR. KUGLERI ZONE
?GR. OPIMA OPIMA ZONE
100
200
300
400
500
600
700
800
900
1000
TD 1066'
PUNTA GAVILAN
POZON
SAN LORENZO
GUACHARACA
CERRO MISION
LA VELA
EL VERAL
CAUJARAO
SOCORRO
QUERALES SHALE
CERRO PELADO
AGUA CLARA
MITARE GROUP
PURURECHE
EL PARAISO
JARILLAL
SANTA RITA
AGUA SALADA GROUP
CODORE GROUP
URUMACO
SOCORRO
CERRO PELADO
AGUA CLARA
SAN LUIS
?
GLOBOROTALIA TRUNCATULINOIDES TRUNCATULINOIDES
GLOBOROTALIA TRUNCATULINOIDES CF. TOSAENSIS
GLOBOROTALIA EXILIS/GLOBOROTALIA MIOCENICA
GLOBOROTALIA MARGARITAE
GLOBOROTALIA DUTERTREI S.L.
GLOBOROTALIA ACOSTAENSIS
GLOBOROTALIA MENARDII
GLOBOROTALIA MAYERI
GLOBIGERINOIDES RUBER
GLOBOROTALIA FOHSI ROBUSTA
GLOBOROTALIA FOHSI LOBATA
GLOBOROTALIA FOHSI FOHSI
GLOBOROTALIA FOHSI PERIPHERORONDA
PRAEORBULINA GLOMEROSA
GLOBIGERINATELLA INSUETA
CATAPSYDRAX STAINFORTHI
CATAPSYDRAX DISSIMILIS
GLOBOROTALIA KUGLERI
GLOBIGERINA CIPEROENSIS CIPEROENSIS
GLOBOROTALIA OPIMA OPIMA
GLOBIGERINA AMPLIAPERTURA
CASSIGERINELLA CHIPOLENSIS/HASTIGERINA MICRA
GLOBOROTALIA CERROAZULENSIS TO GLOBIGERAPSIS MEXICANA
TRUNCOROTALOIDES ROHRI TO HANTKENINA ARAGONENSIS
PLEISTOCENE
PLIOCENE
MIOCENE
UPPER
MIDDLE
LOWER
OLIGOCENE
UPPER EOCENE
MIDDLE EOCENE

Figure 21.

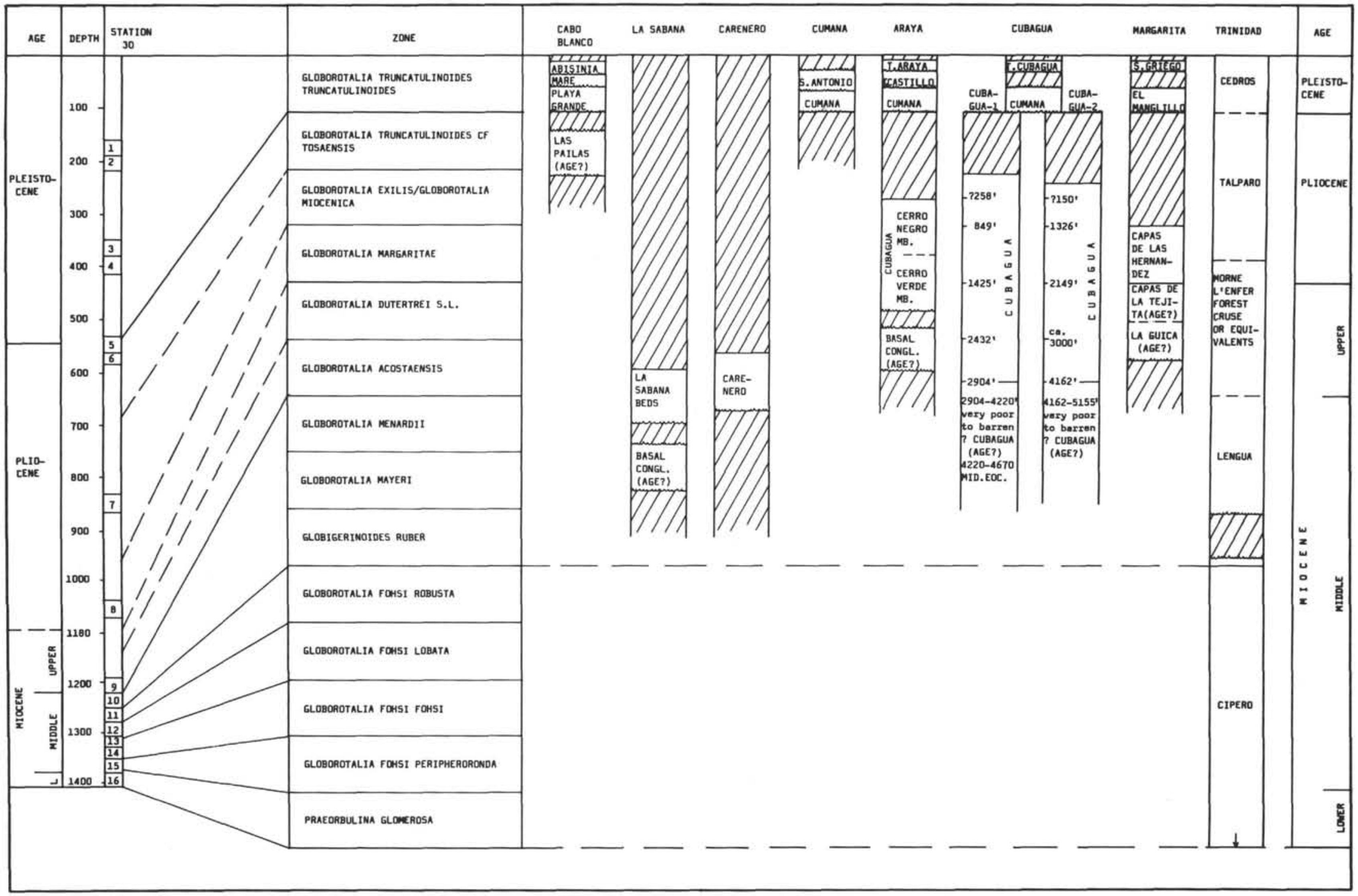

AGE
DEPTH
STATION 30
ZONE
CABO BLANCO
LA SABANA
CARENERO
CUMANA
ARAYA
CUBAGUA
MARGARITA
TRINIDAD
AGE
PLEISTO-CENE
PLIO-CENE
MIOCENE
UPPER
MIDDLE
L
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
GLOBOROTALIA TRUNCATULINOIDES TRUNCATULINOIDES
GLOBOROTALIA TRUNCATULINOIDES CF TOSAENSIS
GLOBOROTALIA EXILIS/GLOBOROTALIA MIOCENICA
GLOBOROTALIA MARGARITAE
GLOBOROTALIA DUTERTREI S.L.
GLOBOROTALIA ACOSTAENSIS
GLOBOROTALIA MENARDII
GLOBOROTALIA MAYERI
GLOBIGERINOIDES RUBER
GLOBOROTALIA FOHSI ROBUSTA
GLOBOROTALIA FOHSI LOBATA
GLOBOROTALIA FOHSI FOHSI
GLOBOROTALIA FOHSI PERIPHERORONDA
PRAEORBULINA GLOMEROSA
ABISINIA
MARE
PLAYA GRANDE
LAS PAILAS (AGE?)
LA SABANA BEDS
BASAL CONGL. (AGE?)
CARE-NERO
S. ANTONIO
CUMANA
T. ARAYA
CASTILLO
CUMANA
CUBAGUA
CERRO NEGRO MB.
CERRO VERDE MB.
BASAL CONGL. (AGE?)
T. CUBAGUA
CUBA-GUA-1
CUMANA
CUBA-GUA-2
?258'
849'
1425'
2432'
2904'
2904-4220' very poor to barren ? CUBAGUA (AGE?) 4220-4670 MID. EOC.
CUBAGUA
?150'
1326'
2149'
ca. 3000'
4162'
4162-5155' very poor to barren ? CUBAGUA (AGE?)
CUBAGUA
S. GRIEGO
EL MANGLILLO
CAPAS DE LAS HERNAN-DEZ
CAPAS DE LA TEJI-TA(AGE?)
LA GUICA (AGE?)
CEDROS
TALPARO
MORNE L'ENFER FOREST CRUSE OR EQUI-VALENTS
LENGUA
CIPERO
PLEISTO-CENE
PLIOCENE
UPPER
MIOCENE
MIDDLE
LOWER

Figure 22.

PLATES 1 - 9

Photographs by Scanning Electron Microscope

PLATE 1

Figures 1-2
Globigerinoides primordius Blow & Banner
1, Umbilical view. 2, Spiral view. × 56.
From Hole 27, Core 3, core catcher.
Globorotalia kugleri Zone, Lower Miocene.

Figures 3-4
Globigerinoides trilobus s.l. (Reuss)
3, Umbilical view. 4, Spiral view. × 56.
From Hole 31, Core 4, core catcher.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene.

Figure 5
Globigerinoides trilobus succulifer (Brady)
5, Spiral view. × 60.
From Hole 29, Core 1, core catcher.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 6-7
Globigerinoides trilobus cf. *fistulosus* (Schubert)
6, Spiral view. × 88. 7, Umbilical view. × 56.
From Hole 29, Core 2, Section 3, 146 to 148 centimeters.
Globorotalia truncatulinoides cf. *tosaensis* Zone, Pliocene.

Figures 8-11
Globigerinoides trilobus fistulosus (Schubert)
8-10, Spiral views. 11, Umbilical view. × 50.
From Hole 25, Core 1, Section 1, 10 to 20 centimeters.
Globorotalia margaritae Zone mixed with younger, Pliocene.

Figures 12-17
Globigerinoides trilobus A
12-13, Spiral views. 14, Umbilical view, with rudimentary end chamber. × 56.
15-17, Broken off final chambers showing the proliferation and irregular arrangement of the fistules. × 56.
From Hole 29, Core 1, Section 2, 4 to 6 centimeters.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 18-19
Globigerinoides obliquus obliquus Bolli
18, Spiral view. 19, Umbilical view. × 56.
From Hole 31, Core 7, Section 1, 148 to 150 centimeters.
Globorotalia margaritae Zone, Pliocene.

Figures 20-21
Globigerinoides obliquus extremus Bolli & Bermudez
20, Spiral view. 21, Umbilical view. × 56.
From Hole 31, Core 4, core catcher.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene.

Figures 22-23
Globigerinoides ruber (d'Orbigny)
22, Umbilical view. × 56.
From Hole 29, Core 1, core catcher.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.
23, Umbilical view, with oblique final chamber. × 56.
From Hole 31, Core 4, core catcher.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene.

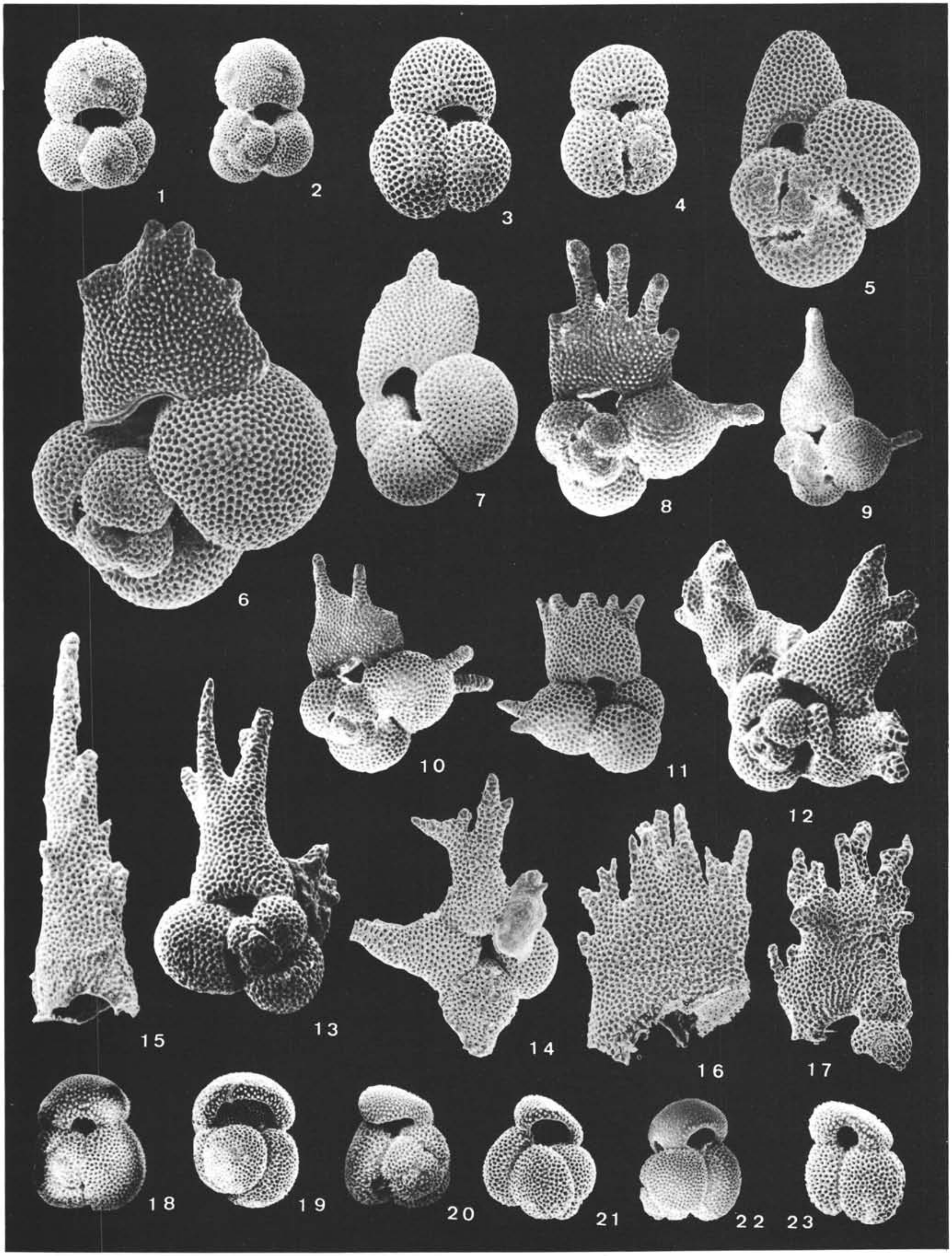


Plate 1.

PLATE 2

Figures 1-3	*Globorotalia acostaensis* Blow 1, Spiral view. 2, Side view. 3, Umbilical view. X 56. From Hole 29B, Core 2, Section 3, 13 to 15 centimeters. *Globorotalia acostaensis* Zone, Upper Miocene.
Figures 4-6	*Globorotalia dutertrei humerosa* Takayanagy & Saito 4, Spiral view. 5, Side view. 6, Umbilical view. X 63. From Hole 25, Core 3, Section 5, 75 centimeters. *Globorotalia dutertrei* s.l. Zone, Upper Miocene.
Figures 7-9	*Globorotalia dutertrei pseudopima* Blow 7, Spiral view. 8, Side view. 9, Umbilical view. X 60. From Hole 31, Core 4, core catcher. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figures 10-12	*Globorotalia dutertrei* (d'Orbigny) s.l. 10, Spiral view. 11, Side view. 12, Umbilical view. X 56. From Hole 31, Core 4, core catcher. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figures 13-15	*Globorotalia dutertrei* (d'Orbigny), high spired 13, Spiral view. 14, Side view. 15, Umbilical view with teeth. X 50. From Hole 30, Core 1, Section 5, 1 to 3 centimeters. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.
Figures 16-19	*Globorotalia dutertrei* (d'Orbigny) s.l. 16, Spiral view. 17, Side view. 18, Umbilical view. X 90. 19, Detail of Figure 18, showing umbilical tooth. X 550. From *Vema* V26, Core 119, 100 centimeters. Same location as JOIDES Hole 29 in the central Caribbean. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.
Remark:	See note in text on taxonomic position of *G. dutertrei.*

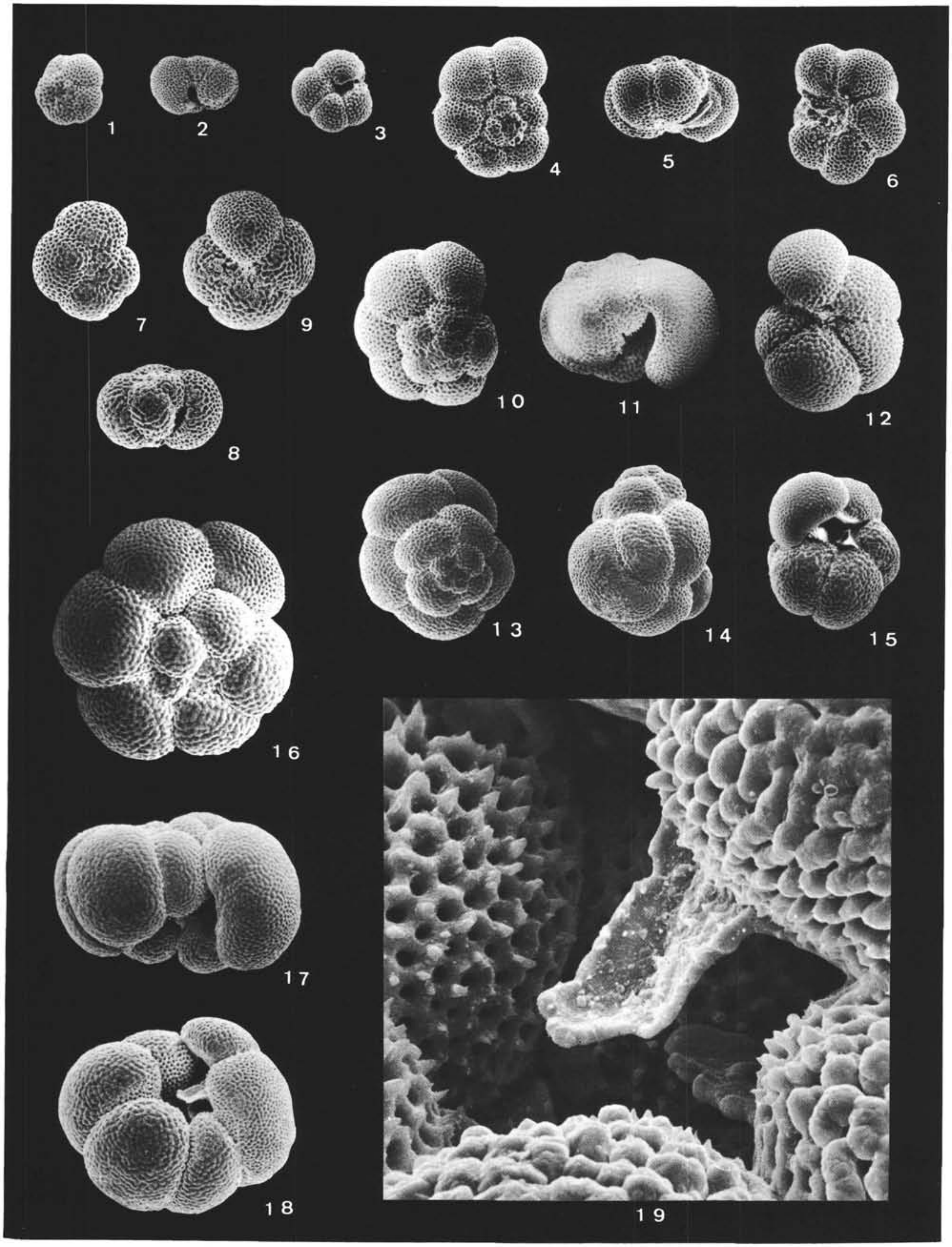


Plate 2.

PLATE 3

Figures 1-3
Globorotalia crassaformis viola Blow
1, Spiral view. 2, Side view. 3, Umbilical view. × 60.
From Hole 29, Core 3, Section 1, 50 to 52 centimeters.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene.

Figures 4-6
Globorotalia crassaformis cf. *viola* Blow
4, Spiral view. 5, Side view. 6, Umbilical view. × 60.
From Hole 29, Core 2, Section 3, 5 to 7 centimeters.
Globorotalia truncatulinoides cf. *tosaensis* Zone, Pliocene.

Figures 7-9
Globorotalia crassaformis crassaformis (Galloway & Wissler)
7, Spiral view. 8, Side view. 9, Umbilical view. × 80.
From Hole 31, Core 4, core catcher.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene.

Figures 10-12
Globorotalia crassaformis (Galloway & Wissler) s.l.
10, Spiral view. 11, Side view. 12, Umbilical view. × 56.
From Hole 29, Core 4, Section 4, 110 to 112 centimeters.
Globorotalia margaritae Zone, Pliocene.

Figures 13-15
Globorotalia truncatulinoides cf. *ronda* Blow
13, Spiral view. 14, Side view. 15, Umbilical view. × 60.
From Hole 29, Core 4, Section 3, 103 to 104 centimeters.
Globorotalia margaritae Zone, Pliocene.

Figures 16-18
Globorotalia truncatulinoides cf. *tosaensis* Takayanagy & Saito
16, Spiral view. 17, Side view. 18, Umbilical view. × 60.
From Chain 61, 535 to 539 centimeters (Berggren 1968).

Figures 19-21
Globorotalia truncatulinoides tosaensis Takayanagy & Saito
19, Spiral view. 20, Side view. 21, Umbilical view. × 60.
From Hole 29, Core 4, Section 3, 30 to 32 centimeters.
Globorotalia margaritae Zone, Pliocene (contamination from a higher level).

Figures 22-24
Globorotalia truncatulinoides truncatulinoides (d'Orbigny)
22, Spiral view. 23, Side view. 24, Umbilical view. × 45.
From Hole 31, Core 1, Section 1, top.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

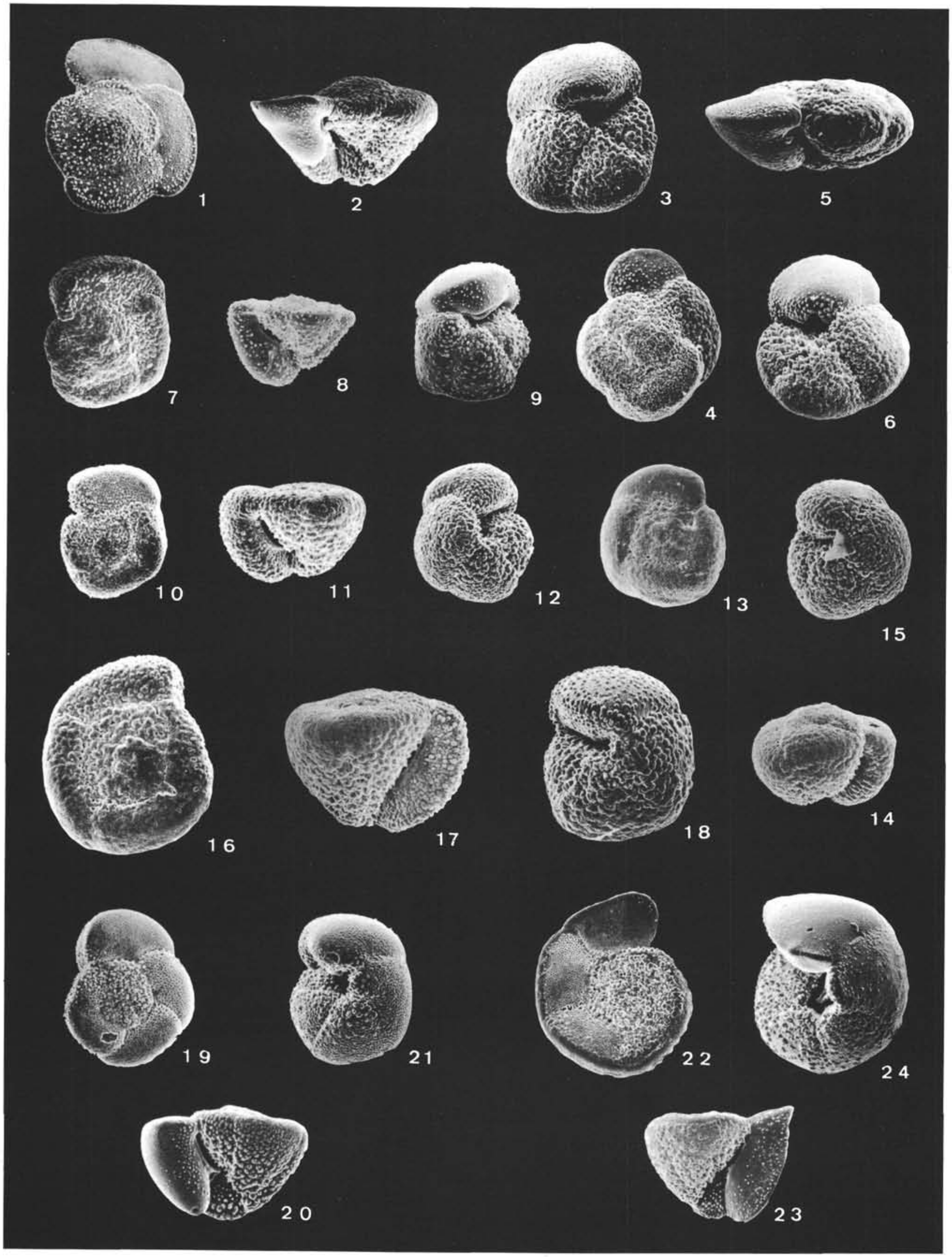


Plate 3.

PLATE 4

Figures 1-3
Globorotalia inflata A
1, Spiral view. 2, Side view. 3, Umbilical view. X 72.
From Hole 31, Core 6, Section 1, 50 to 52 centimeters.
Globorotalia margaritae Zone, Pliocene.

Figures 4-6
Globorotalia inflata
4, Spiral view. 5, Side view. 6, Umbilical view. X 60.
From Hole 31, Core 1, core catcher.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 7-9
Globorotalia cf. *inflata*
7, Spiral view. 8, Side view. 9, Umbilical view. X 52.
From Hole 31, Core 1, top.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 10-12
Globorotalia cf. *puncticulata*
10, Spiral view. 11, Side view. 12, Umbilical view. X 72.
From Hole 25, Core 1, Section 1, top.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 13-16
Globorotalia crassaformis B
13, 14, Spiral views. 15, Side view. 16, Umbilical view. X 56.
From Hole 29, Core 1, Section 3, 10 to 12 centimeters.
Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 17-20
Globorotalia crassaformis A
17, 18, Spiral views. 19, Side view. 20, Umbilical view. X 42.
From Hole 25, Core 2, Section 1, 0 to 2 centimeters.
Globorotalia exilis/Globorotalia miocenica Zone, Pliocene (mixed with younger).

Figures 21-24
Globorotalia crassaformis Aa
21, 22, Spiral views. 23, Side view. 24, Umbilical view. X 48.
From Hole 25, Core 3, Section 1, 10 to 20 centimeters.
Globorotalia margaritae Zone, Pliocene (mixed with younger).

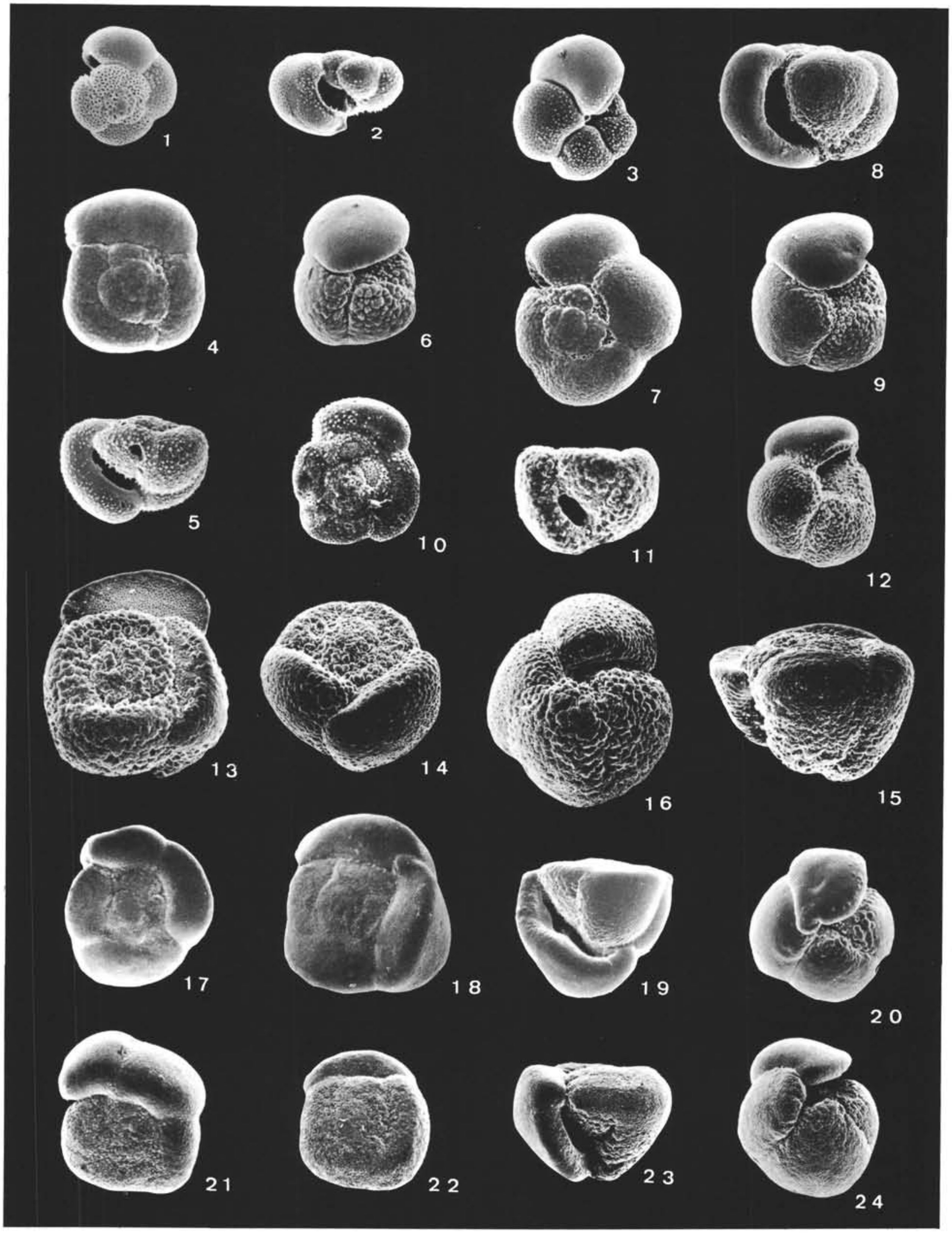


Plate 4.

PLATE 5

Figures 1-4	*Globorotalia menardii* A 1, Spiral view. 2, Side view. 3, 4, Umbilical views. × 48. From Hole 30, Core 10, Section 2, 56 to 58 centimeters. *Globorotalia mayeri* Zone, Middle Miocene.
Figures 5-7	*Globorotalia menardii* B 5, Spiral view. 6, Side view. 7, Umbilical view. × 50. From Hole 25, Core 3, Section 3, at 75 centimeters. *Globorotalia margaritae* Zone, Pliocene.
Figures 8-10	*Globorotalia menardii menardii* 8, Spiral view. 9, Side view. 10, Umbilical view. × 48. From Hole 29, Core 1, Section 2, 71 to 73 centimeters. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.
Figures 11-13	*Globorotalia menardii cultrata* 11, Spiral view. 12, Side view. 13, Umbilical view. × 50. From Hole 29, Core 1, Section 2, 71 to 73 centimeters. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.

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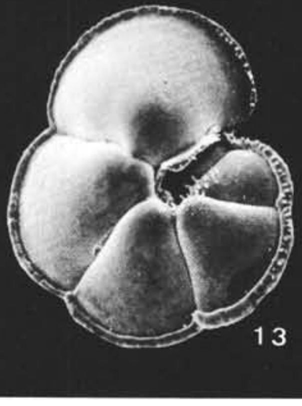

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Plate 5.

PLATE 6

Figures 1-3	*Globorotalia* cf. *tumida* (Brady) 1, Spiral view. 2, Side view. 3, Umbilical view. X 48. From Hole 29, Core 3, Section 1, 50 to 52 centimeters. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figures 4-6	*Globorotalia tumida tumida* (Brady) 4, Spiral view. 5, Side view. 6, Umbilical view. X 50. From Hole 29, Core 1, Section 3, 10 to 12 centimeters. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.
Figures 7-9	*Globorotalia tumida* (Brady) form transitional to *G. tumida flexuosa* (Koch) 7, Spiral view. 8, Side view. 9, Umbilical view. X 48. From Hole 29, Core 1, Section 3, 10 to 12 centimeters. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.
Figures 10-12	*Globorotalia tumida flexuosa* (Koch) 10, Spiral view. 11, Side view. 12, Umbilical view. X 52. From Hole 29, Core 1, core catcher. *Globorotalia truncatulinoides truncatulinoides* Zone, Pleistocene.

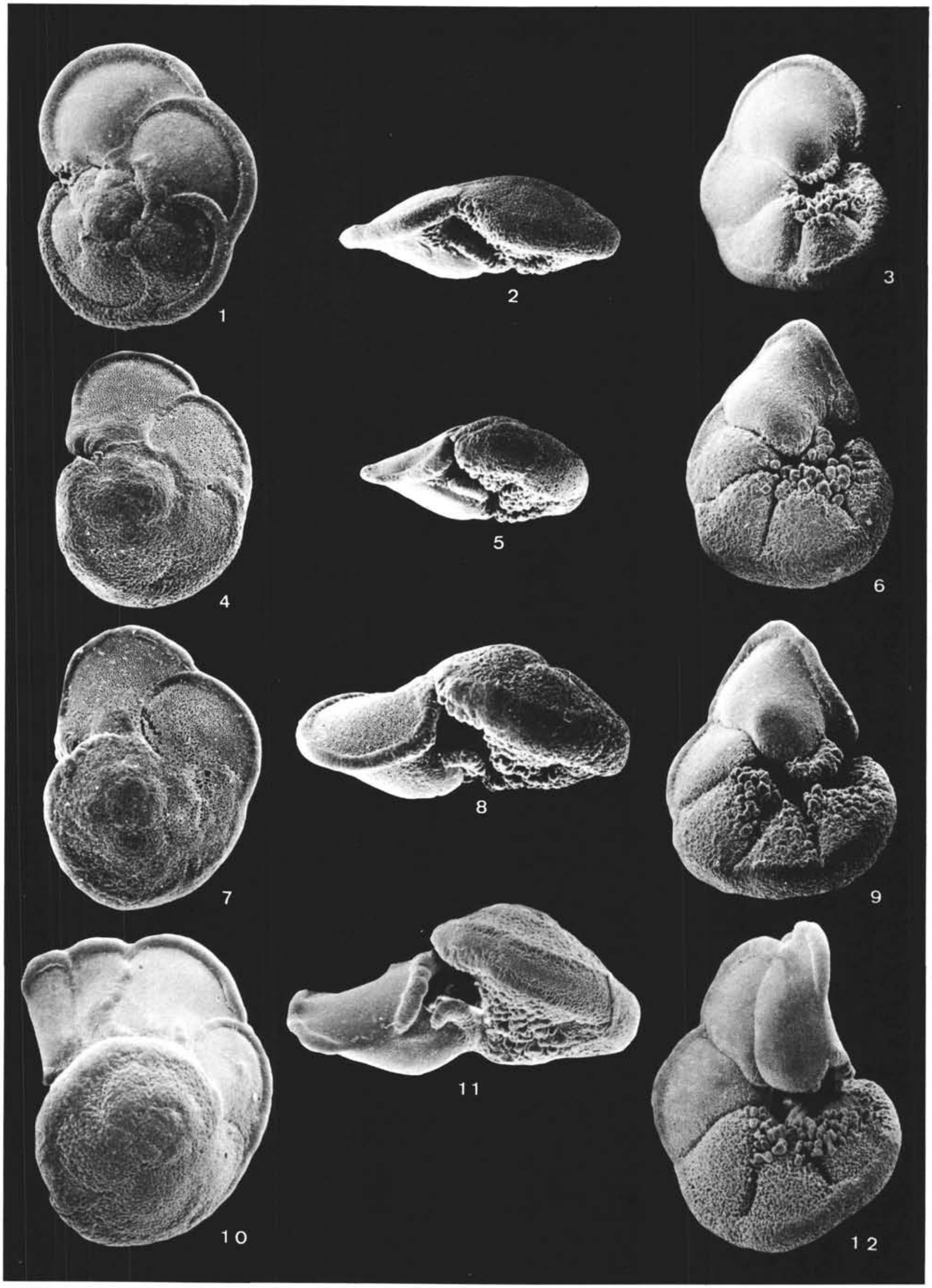

Plate 6.

PLATE 7

Figures 1-3	*Globorotalia pseudomiocenica* Bolli & Bermudez 1, Spiral view. 2, Side view. 3, Umbilical view. X 60. From Hole 29, Core 4, Section 3, 71 to 73 centimeters. *Globorotalia margaritae* Zone, Pliocene.
Figures 4-8	*Globorotalia miocenica* Palmer 4, 5, Spiral views. 6, Side view. 7, 8, Umbilical view. X 48. From Hole 30, Core 7, core catcher. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figures 9-12	*Globorotalia exilis* Blow 9, 10, Spiral views. 11, Side view. 12, Umbilical view. X 48. From Hole 31, Core 3, Section 2, 2 to 4 centimeters. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figure 13	*Globorotalia exilis* Blow Form transitional towards *G. exilis* A. Spiral view. X 45. From Hole 31, Core 3, Section 2, 2 to 4 centimeters. *Globorotalia exilis/Globorotalia miocenica* Zone, Pliocene.
Figures 14-16	*Globorotalia exilis* A 14, Spiral view. 15, Side view. 16, Umbilical view. X 60. From Hole 29, Core 4, Section 4, 110 to 112 centimeters. *Globorotalia margaritae* Zone, Pliocene.
Figures 17-20	*Globorotalia multicamerata* Cushman & Jarvis 17, 18, Spiral views. 19, Side view. X 60. 20, Umbilical view. X 44. 17, 18 from Hole 29, Core 4, Section 4, 110 to 112 centimeters. 19, 20 from Hole 31, Core 6, core catcher. *Globorotalia margaritae* Zone, Pliocene.


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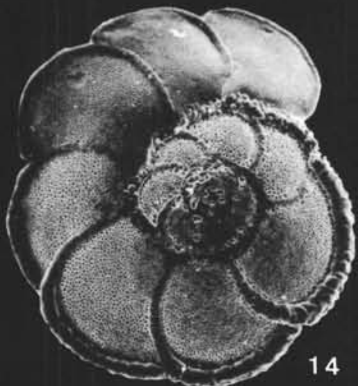
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Plate 7.

PLATE 8

Figures 1-7

Globorotalia margaritae Bolli & Bermudez

1, Spiral view. 2, Side view. 3, Umbilical view. × 57.

1, 3, From Hole 31, Core 7, Section 1, 139 to 142 centimeters. 2, From Hole 29, Core 4, Section 3, 120 to 122 centimeters.

4-7, Large size specimens: 4-5, Spiral view. 6, Side view. 7, Umbilical view. × 57.

From Hole 29, Core 4, Section 4, 110 to 112 centimeters.

Globorotalia margaritae Zone, Pliocene.

Figures 8-11

Sphaeroidinella dehiscens (Parker & Jones) s.l.

8, Specimen with completely dissolved inner part ($CaCO_3$ solution effect).

11, Same specimen as 8, turned 90° to the right. 10, Specimen with inner part partially dissolved. × 60.

From Hole 29, Core 2, Section 1, 100 to 102 centimeters.

Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 12-15

Sphaeroidinellopsis seminulina A

12, 13, Spiral views (12 possesses small spiral sutural apertures at the base of the last two chambers). 14, 15, Umbilical views. × 60.

From Hole 29, Core 4, Section 4, 110 to 112 centimeters.

Globorotalia margaritae Zone, Pliocene.

Figures 16-18

Globorotalia subcretacea (Lomnicki)

The figured specimens are probably closer to or identical with *G. hexagona* (Natland).

16, Spiral view. 17, Side view. 18, Umbilical view. × 80.

From Hole 23, Core 1, Section 3, 150 centimeters.

Globorotalia truncatulinoides truncatulinoides to *G. margaritae* Zone, Pliocene to Pleistocene.

Figures 19-21

Globorotalia scitula (Brady)

19, Spiral view. 20, Side view. 21, Umbilical view. × 52.

From Hole 29, Core 2, Section 1, 128 to 130 centimeters.

Globorotalia truncatulinoides truncatulinoides Zone, Pleistocene.

Figures 22-24

Globorotalia juanai Bermudez & Bolli (in press)

22, Spiral view. 23, Side view. 24, Umbilical view. × 72.

From Cubagua well 1 (Island of Cubagua), Core 2691 to 2703 feet.

Globorotalia acostaensis Zone, Upper Miocene.

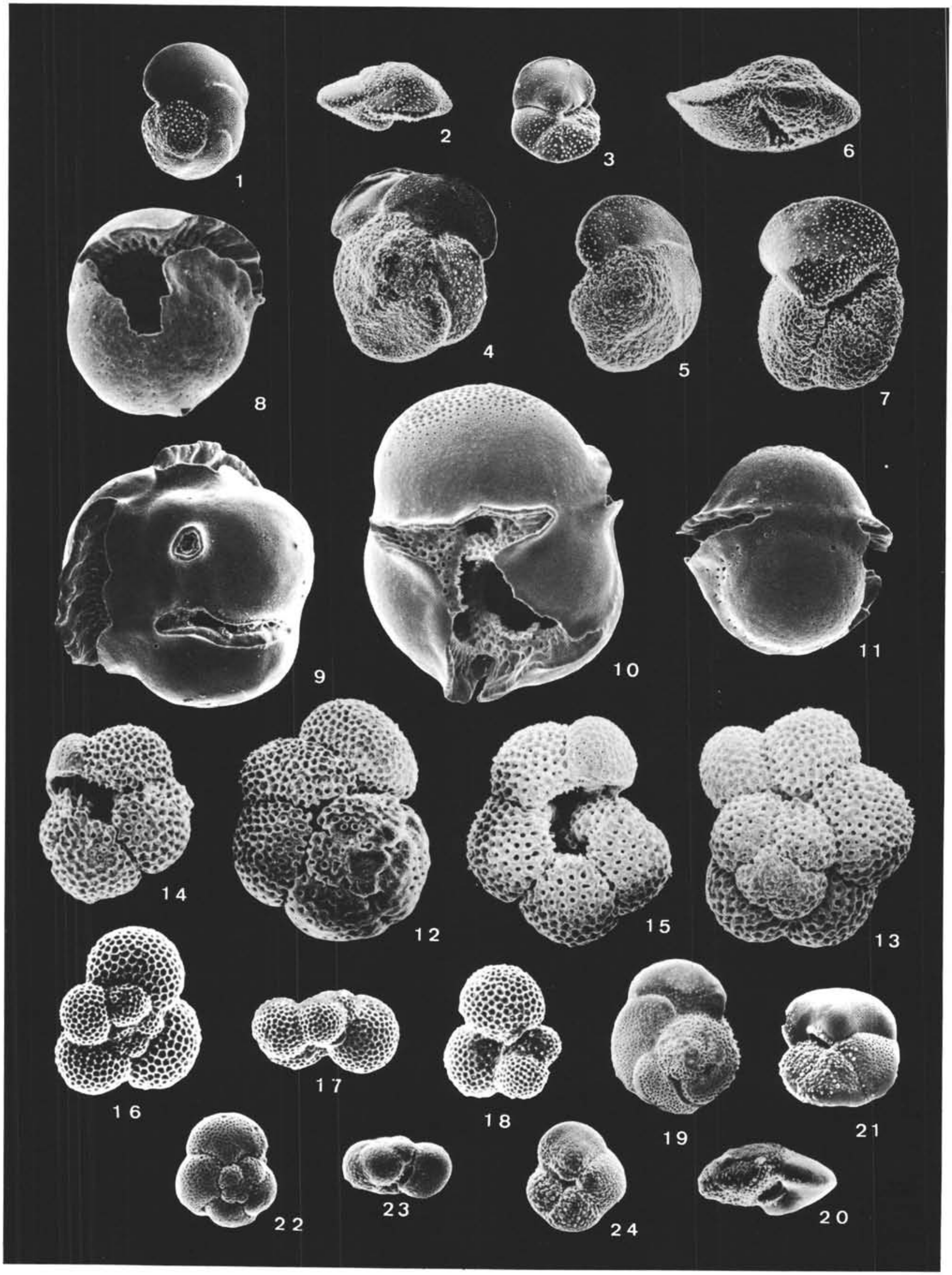
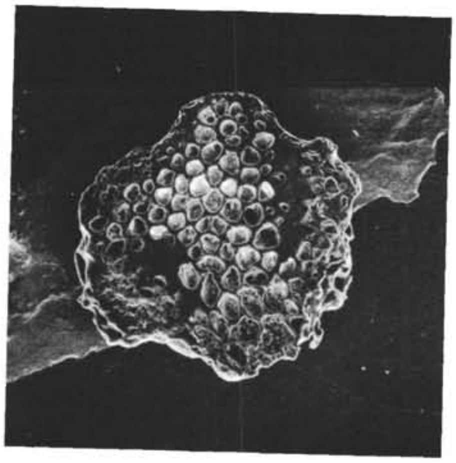


Plate 8.

PLATE 9

Figure 1	*Miogypsina gunteri* Cole Polished section through equatorial plane. X 30. Hole 24, Core 1, Section 1, 37 centimeters.
Figure 2	Same specimen as Figure 1, enlarged to show stolon passages. X 120.
Figure 3	*Miogypsinella* sp. Polished section through equatorial plane. X 60. Hole 24, Core 4, Section 3, 100 to 101 centimeters.
Figure 4	*Miogypsina tani* Drooger Polished section through equatorial plane. X 60. Hole 23, Core 5, Section 1, 3 to 5 centimeters.
Figure 5	*Miogypsina* sp. aff. *globulina* Polished section through equatorial plane. X 60. Hole 23, Core 7, middle part.
Figure 6	*Lepidocyclina canellei* Lemoine & R. Douville Polished cross section through proloculum. X 60. The marginal areas are invaded by mounting cement. Hole 24, Core 2, Section 1, 53 to 60 centimeters.



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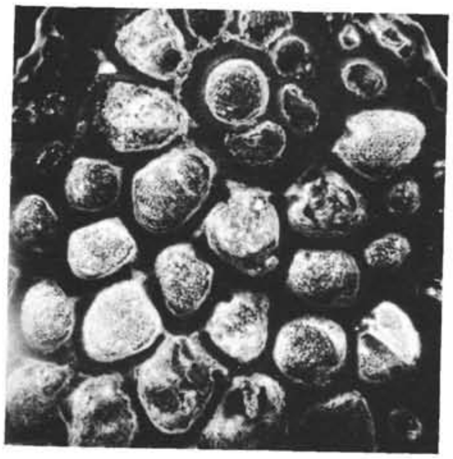

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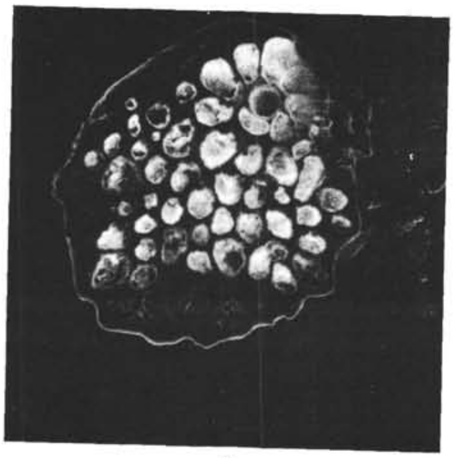

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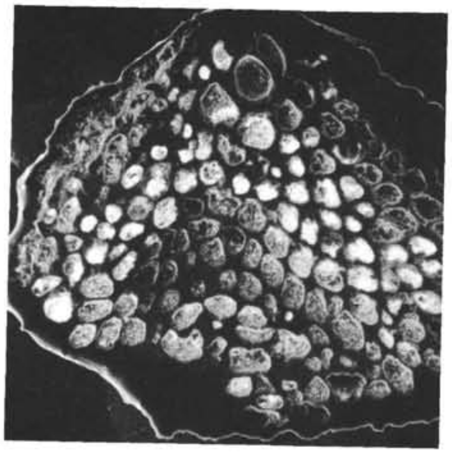

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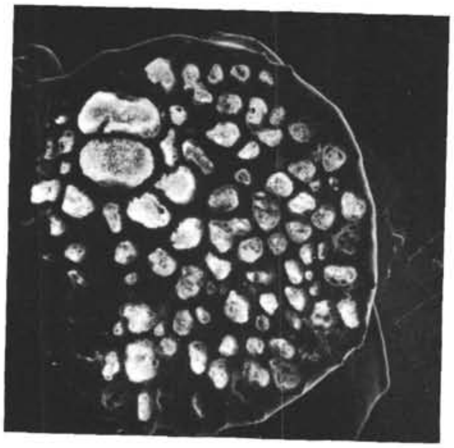

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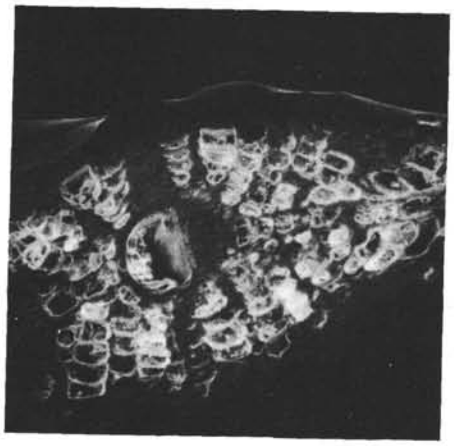

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Plate 9.