35. PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY IN THE WESTERN PHILIPPINE SEA, LEG 31 OF DSDP

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INTRODUCTION

During Leg 31 of the Deep Sea Drilling Project, 13 holes were drilled at nine sites located in the western Philippine Sea, bounded on the east by the Palau-Kyushu Ridge (Figure 1). Foraminiferal occurrence is nil or limited to certain levels in seven holes, with the exception of Sites 292 and 296. These latter two sites yield abundant and rather well-preserved foraminifera throughout the Pleistocene through Eocene and upper Oligocene sequences represented.

Every sample from Sites 292 and 296 was examined on the basis of 200-odd specimens of planktonic foraminifera which were picked out from the residue on the 100-mesh sieve. When necessary, additional specimens of age-determinant taxa were recovered and some fractions that passed through the 100-mesh screen were examined. As revealed previously (e.g., Ujiié and Miura, 1971), the total 200-odd specimens of planktonic foraminifera per sample are necessary and sufficient for recognition of faunal composition on a statistical basis, whereas analysis of the fractions coarser than 100 mesh are primarily effective for identification of age-determinant taxa.

BRIEF NOTES ON BIOSTRATIGRAPHIC RESULTS

Only 3 of the 13 holes drilled on Leg 31 yielded sufficient numbers of planktonic foraminifera for detailed analysis. This may be due in large part to the fact that many holes were drilled at depths exceeding the calcium carbonate compensation depth (CCD). However, calcareous nannofossils still persist in portions of some of these holes, probably because they are slightly more resistant to dissolution than foraminifera as suggested by McIntyre and McIntyre (1971) and Hay (1970); notwithstanding Berger's (1973) objection. In the Philippine Sea today, the CCD seems to lie somewhere between the depths of 4000 and 4500 meters, judging from the preliminary observation of 64 piston cores which were taken from all over the region in the nineteenth, twentieth, and twenty-first cruises of the R/V *Vema* of the Lamont-Doherty Geological Observatory (preserved at the National Science Museum of Tokyo in the form of vertical quarter portions). Figure 1 indicates location, approximate water depth (in km), and general lithology of these 64 piston cores along with the location of the holes of Leg 31.

Significantly, holes barren of foraminifera contain some reworked specimens, part of which are Upper Cretaceous or Paleocene species such as *Globotruncana* spp. from Samples 290-2A, CC, 293-1, CC; *Rugoglobigerina rugosa* (Plummer) from Sample 298-1A, CC;

Globorotalia perclara Loeblich and Tappan from Sample 295-3A, CC; *G. angulata* (White) from Sample 295-3A, CC; or *G.* aff. *angulata* from Sample 293-12, CC (see Plates 1 and 2). The Paleocene assemblage composed of *G. angulata, G. perclara,* and other indeterminant taxa from Site 295 is represented by a considerable number of specimens suggesting their source is close to the site. The other Cretaceous and Paleocene reworked species are represented only by one or two specimens showing poorer preservation, but *R. rugosa* represented by a fairly preserved specimen suggests contamination in laboratory work. Holes 290A, 293, and 294 containing reworked Paleocene to Cretaceous specimens are all located within, and near the margin of, the West Philippine Basin. Thus, these reworked species might have originated somewhere on the submarine slope of surrounding islands or submarine ridges; these species have never been reported from adjacent land sections of the area.

The bottoms of Holes 290, 291, 292, 294, 295, and 296 were dated as Oligocene or Eocene, whereas those of Site 293 nearest to the Central Basin "Fault" and Site 297 in the Shikoku Basin (northern extension of the Parece Vela Basin) were assigned to late Miocene and middle Miocene, respectively. The younger age of the basal sediments at Sites 293 and 297 reflecting the shallower depth of seismic "basement" in comparison with that of the adjacent area[1] implies that the Central Basin "Fault" area and the Parece Vela Basin might have spread later than the age considered by Uyeda and Ben-Avraham (1972) and Karig (1973).

Two biostratigraphic holes were drilled at water depths of 2943 meters on the southeastern flank of Benham Rise (Site 292) and 2920 meters on the west flank of the Palau-Kyushu Ridge (Site 296), both apparently above the CCD. Continuous coring at these sites penetrated nannofossil ooze through chalk until the basement of basalt or basalt breccia was reached. Recovery at these two sites averaged about 50%. The calcareous oozes and chalks are rich in well-preserved foraminifera and promise that these sites represent potential biostratigraphic reference sections for the western North Pacific region. However, both sites contain a significant disconformity within the Miocene portions of the column; namely, a gap of ca 7 m.y. between ca 20 m.y.B.P. and ca 13 m.y.B.P. at Site 292 and ca 1 m.y. gap between ca 12.5 m.y.B.P. and 13.5 m.y.B.P. at

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[1]According to Dr. Sadanori Murauchi, National Science Museum (personal communication).
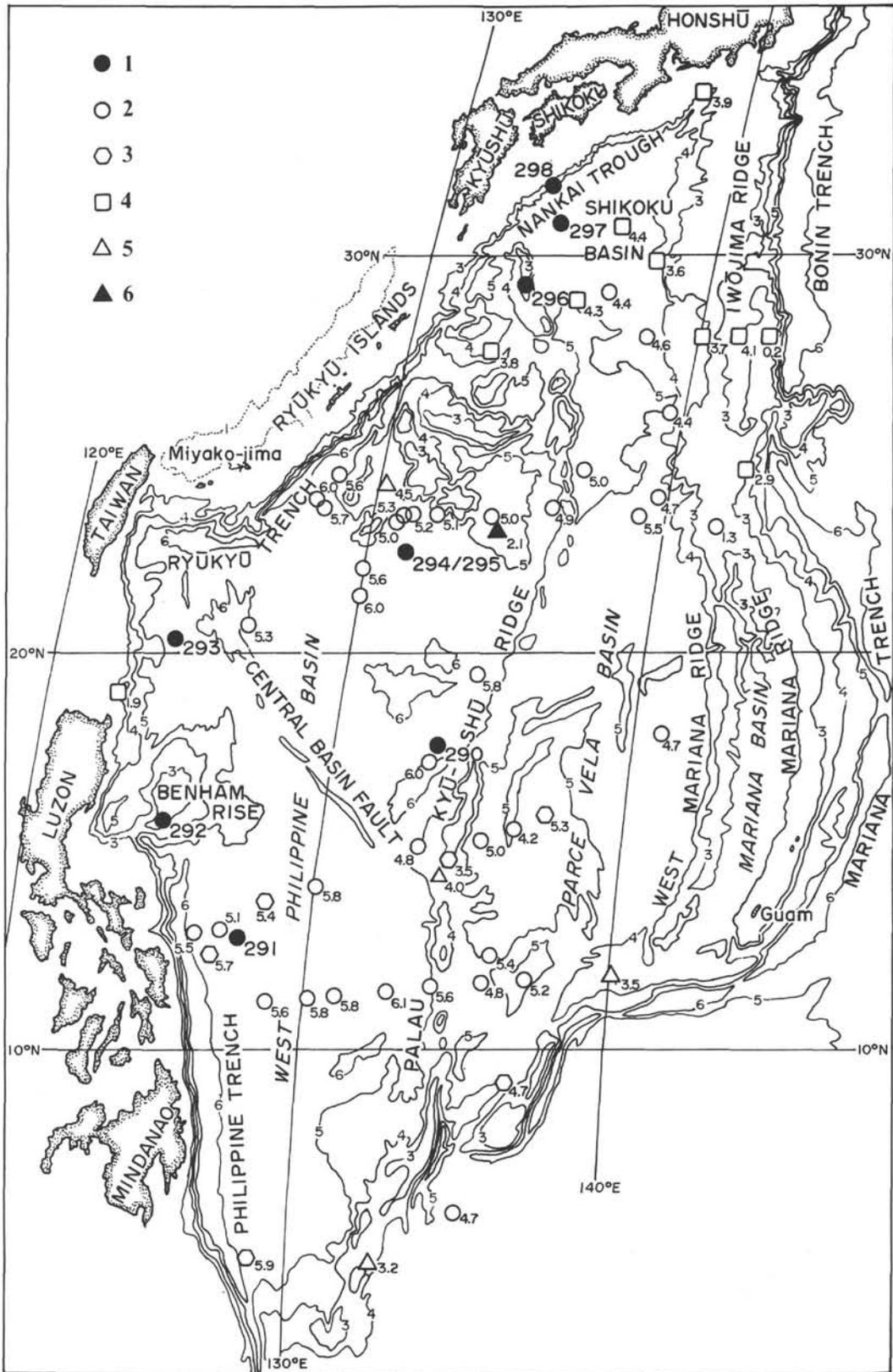
Figure 1. *Location map of drilling sites and the Lamont piston cores (bathymetry in km). 1: Sites of DSDP Leg 31, 2-6: Sites of the piston cores, 2: Brown clay predominant, 3: Brown clay in parts with diatomaceous ooze of gel-like appearance, 4: Blue mud predominant, 5: Calcareous ooze, 6: V21-98, calcareous ooze core studied by Ujiié and Miura (1971).*

Site 296, according to the time scale of Berggren and Van Couvering (1973). The large hiatus at Site 292 corresponds to a reflection level in the seismic profiler record. Absence of late early to early middle Miocene marine sediments may be recognized in land sections surrounding the Philippine Sea, such as those exposed on eastern Taiwan (Chang, 1967, 1969); the Ryukyu Islands (Ujiié and Saito, 1974); the Pacific coast of southwestern Japan (Ujiié, 1973); Mindanao (Ujiié and Samata, 1973); and probably other parts of the Philippines. Therefore, it is highly probable that the hiatus is the result of a regional tectonic movement associated with large-scale lowering of sea level.

Nannofossil age assignments at Sites 292 and 296 indicate that additional stratigraphic breaks may be expected in the holes, especially within the Neogene successions. However, no other breaks were recognized from the viewpoint of planktonic foraminiferal zonation, except for a presumed hiatus in the late Miocene portion of Site 292.

For the planktonic foraminiferal zonation, the writer utilized the N- or P-plus-numeral system proposed by Banner and Blow (1967) and Blow (1969) based on the datum plane of selected age-determinant taxa appearing first, or less frequently last, at a zone boundary. Use of any taxon name to nominate the zone was tentatively avoided here because the same name has sometimes been used for not entirely equivalent zones, giving rise to confusion in correlation. The subdivision of Blow's (1969) zones was not applied to Sites 292 and 296 at the present time, nor was an attempt made to subdivide the Pliocene as proposed by Berggren and Van Couvering (1973) during this study or during study of the Shimajiri Group of Miyako-jima, Ryukyu Islands (Ujiié and Oki, 1974).

Restricted ranges of many taxa were observed at Sites 292 and 296, and some of them may be significant for subdivision of Blow's zones. However, any stratigraphically more significant taxa than those used to define the datum planes of Blow (1969) have not yet been decided upon in post-Miocene faunas from the following western North Pacific sections: Mindanao, Philippines (Ujiié and Samata, 1973); Miyako-jima (Ujiié and Oki, 1974); a piston core, V21-98, from the branch of the Palau-Kyushu Ridge (Ujiié and Miura, 1971); and several land sections in southwestern Japan presently being studied by the writer and his colleagues. In many of those cases, short stratigraphic ranges can be attributed to local ecologic controls, and almost all the datum planes proposed by Blow (1969) have maintained their superiority here as worldwide planktonic events, except for the initial appearance of *Globorotalia (Turborotalia) acostaensis acostaensis* which defines the boundary between N.19 and N.20. This latter subspecies appears above the base of N.19 in the western Pacific (Brönnimann and Resig, 1971; Ujiié and Samata, 1973; Ujiié and Oki, 1974) so that N.20 does not exist any more, at least in its original sense.

The Oligocene succession in Hole 292 exhibits a remarkable continuity along with very clear contacts with accompanying earliest Miocene and late Eocene sediments. The range chart constructed for this Oligocene sequence indicates a considerable discrepancy to

the standardized zonation developed by Blow (1969) and Banner and Blow (in Eames et al., 1965) whose zonation scheme of the Oligocene succession essentially consists of two land sections in Tanganyika of East Africa and in southern Trinidad, West Indies. Douglas (1973) reported the occurrence of an Oligocene sequence similar to the "standard" at DSDP Hole 165A in the central North Pacific, although this sequence lacks the Miocene-Oligocene boundary. At Site 292, moreover, many "Oligocene taxa" show morphologic variations different from those described by Banner and Blow (1965) and Blow (1969), and contain several taxa hitherto undescribed. There is room for reexamination of type specimens of Oligocene taxa described by Banner and Blow at the British Museum (Natural History). At present, it is difficult to establish newly defined or subdivided zones of worldwide significance for the Oligocene based upon studies of Site 292 faunas, because the earliest Miocene to late Oligocene at Site 296 are somewhat different in the mode of occurrence due, in part, to a distance of about 14° in latitude between these two sites.

BIOSTRATIGRAPHIC SUMMARIES

Site 290

Hole 290 (lat 17°44.85'N, long 133°28.08'E, water depth 6062.5 m)

Hole 290A (lat 17°45.05'N, long 133°28.44'E, water depth 6062.5 m)

No foraminifera were recovered from any of the core samples at Site 290 with the exception of the drill-bit sample pulled up after completion of Hole 290A. The assemblage obtained from the bit sample consists of two poorly preserved specimens of Upper Cretaceous planktonic species (*Globotruncana* sp., Plate 1); considerable numbers of planktonic species of probable lower Pliocene age (N.19); and significant numbers of benthonic species some of which are characteristic of subtropical neritic environments as exemplified by *Elphidium* aff. *macellum*, "*Eponides*" *haidingeri*, *Amphistegina* sp., etc. The assignment of the Pliocene species to Zone N.19 is based on the joint occurrence of *Globorotalia* (s.s.) *tumida tumida* (Few), *Sphaeroidinella dehiscens* (s.l.) (F), *Globigerina nepenthes delicatula* (A), *Globigerinoides obliquus* (C), and *G. extremus*(C).

The association of the three types of foraminifera in the bit sample indicates the displacement of sediment to lower bathyal depths at Site 290 from neritic depths, most likely from the submarine slope of the Palau-Kyushu Ridge.

Site 291

Hole 291 (lat 12°48.43'N, long 127°49185'E, water depth 5217 m)

Hole 291A (lat 12°48.45'N, long 127°48.98'E, water depth 5217 m)

The core-catcher sample of Core 1 in Hole 291 contains many tiny planktonic foraminifera, nearly 78% of which are composed of *Globigerina quinqueloba* (41%) and *Globigerinita uvula* (37%). Adult individuals of these two species are regarded as representative of subboreal

to cool temperate regions in Recent seas. Although the other accompanying minor constituents (belonging to probably nine different species or subspecies) cannot be identified because of their juvenility, they do not include dwarf specimens of taxa characteristic of the tropical zone. In relation to the latitude of this site, this assemblage may reflect a cooling in a specific period of the post-Miocene; *G. uvula* and *G. quinqueloba* were not reported in pre-Pliocene sediments of the eastern North Pacific (e.g., Site 178; Ingle, 1973).

Numerous and well-preserved benthonic foraminifera were recovered from Section 2 and the core-catcher sample of Core 2, Hole 291. The faunal composition and preservation of these specimens indicate an abyssal to bathyal environment above the CCD. Several specimens of a single planktonic species, *Globorotaloides suteri* which ranges in age from late middle Eocene through Oligocene, are associated with the above-mentioned benthonic forms.

Assemblages similar to those of Core 2, Hole 291, were recognized in the core-catcher sample of Core 1 and the drill-bit sample of Core 2, Hole 291A, although in much less abundance in the former case implying up-hole contamination. In addition to *G. suteri,* rare specimens of *Globigerina venezuelana* (middle Eocene to Miocene) were also recovered in the latter two samples along with rare specimens of *G. linaperta* (late Paleocene to late Eocene) in the drill-bit sample. The ranges of the three planktonic species suggest a late Eocene age for the bit sample of Hole 291A.

Site 292 (lat 15° 49.11'N, long 124°39.05'E, water depth 2943 m)

Site 292 penetrated nannofossil ooze to chalk down to the depth of 367.5 meters below the sea bottom and provided a continuous sequence of planktonic foraminiferal faunas from Quaternary to late Eocene, except for a distinct hiatus between Cores 11 and 12 where middle early Miocene to early middle Miocene sediments are completely missing.

Utilizing either the first or last appearance of critical taxa at zone boundaries, a number of zones standardized by Blow (1969) were distinguished in this hole as summarized in Figure 2 and on which occurrence ranges of these critical taxa are depicted along with the time scale of Berggren and Van Couvering (1973) and Berggren (1971).

Significantly, a number of zone boundaries could not be recognized at Site 292 as discussed below.

1) N.23/N.22 boundary: The initial appearance of *Sphaeroidinella dehiscens excavata* which defines the base of N.23 was hardly distinguished in a continuous occurrence of *S. dehiscens*-plexus as there is a gradational change between morphologies of *S. dehiscens excavata* and forms such as "*S. dehiscens dehiscens* with a wide flange" defined by Berggren and Van Couvering (1973). This form appeared first near the base of N.21 at Site 292, somewhat differently from the case pointed out by Berggren and Van Couvering

(1973), who place the datum at the middle of N.19 allowing a twofold subdivision of N.19 into PL 1 and PL 2. The initial appearance of *Pulleniatina obliquiloculata finalis* and typical *Globigerina calida* may be used to approximately mark the N.23/N.22 boundary, instead of the appearance of *S. dehiscens excavata.*

2) N.18/N.17: The first appearance of *Globorotalia* (s.s.) *tumida tumida* was observed at the same level as that of *S. dehiscens*-plexus which marks the N.19/N.18 boundary. At Site 292, moreover, it does not accompany the preceding occurrence of the "direct ancestor," *Globorotalia* (s.s.) *tumida plesiotumida*, so that the first occurrence of *G.* (s.s.) *tumida tumida* is regarded as representing an ecological invasion into the region.

3) N.17/N.16: Since *G. tumida plesiotumida* was not recovered from the levels below the base of N.19, this boundary also cannot be detected at Site 292.

4) N.15/N.14: The occurrence of *Globorotalia (Turborotalia) siakensis* is continuous up to Section 3 of Core 11, namely, within N.12, before its phylogenetic extinction near the N.15/N.14 boundary.

5) N.14/N.13; This boundary was defined after a slight modification of the original definition, i.e., the initial appearance datum of *Globigerina nepenthes delicatula*. Brönnimann and Resig (1971) subdivided *G. nepenthes* (s.l.) into three subspecies including *G. nepenthes delicatula*, and established a homeomorphic species limited in occurrence from N.13 to N.6, i.e., *G. nepenthoides*. Excepting *G. nepenthes delicatula*, the two "subspecies" and *G. nepenthoides* show quite gradational changes of morphology so that any objective basis for taxonomic separation is hardly recognized, thus the whole range compiled together becomes much longer, probably extending from N.19 to N.6. In place of the initial appearance of *G. nepenthes* in the sense of Blow (1969), the writer applied that of *G. nepenthes delicatula* as the datum of N.14/N.13 boundary.

6) P.20/P.19: This boundary was defined originally by the extinction level of *Pseudohastigerina barbadoensis*. However, this minute-sized species could not be found at Site 292 and its occurrence seems to be restricted geographically. Another, but much more widely distributed species, *P. micra*, disappeared in Section 6 of Core 31, namely, within P.18, although these specimens are dwarf forms (smaller than 100 mesh of sieve).

7) P.18/P.17: The Oligocene-Eocene boundary should be determined by the first appearance of *Globigerina tapuriensis* according to Blow (1969). At Site 292, however, this species appeared initially within P.16 of late Eocene and seems to have persisted throughout the whole Oligocene. The occurrence range at Site 292 is thus different from that drawn by Blow (1969) who thought it to be limited in early Oligocene, P.18 and P.19, even though there might exist some discrepancy between taxonomic opinions of Blow (1969; Banner and Blow, 1962) and of the writer. At the present writing, the writer is inclined to consider that the definition of the P.18/P.17 boundary must be replaced by the extinction
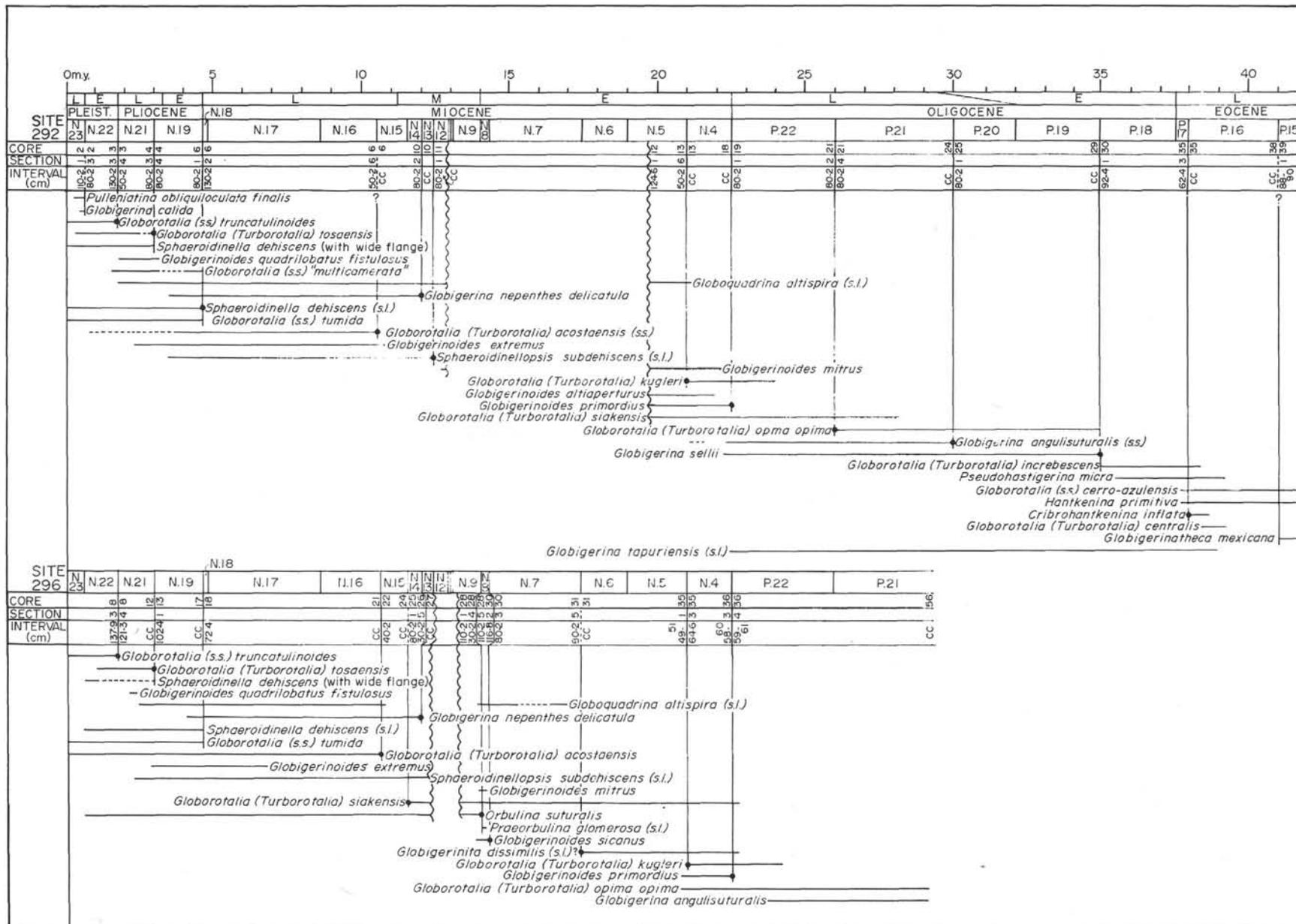
Figure 2. *Range charts of critical taxa at Sites 292 and 296. Time scale of Berggren (1971) and Berggren and Van Couvering (1973) is applied except for the Miocene-Pliocene boundary. The boundary is tentatively set at the N.19/N.18 boundary following to Blow (1969) instead of the N.18/N.17, on the basis of Ujiié and Oki's (1974) opinion: First or last appearance of critical taxon primarily to define the zone boundary.*

datum of *Hantkenina primitiva*, because of the ease of identification of this species and the fact that the occurrence of *Hantkenina* is recognized as limited to the Eocene on a worldwide basis. Blow (1969), however, recognized this datum plane slightly below the base of his P.18. Berggren (1971) also used this latter datum for the designation of the Oligocene-Eocene boundary as seen in Figure 2. This datum may be substantiated by the simultaneous extinction of a peculiar globorotalid, *Globorotalia* (s.s.) *cerro-azulensis*.

A biostratigraphic gap between Cores 11 and 12 is represented by the absence of N.11 through upper N.5 and, consequently, corresponds to a time gap of 7 m.y. according to the scale of Berggren and Van Couvering (1973). This disconformity may have been caused by submarine erosion rather than by mere nondeposition, and thereby reflected in lithologic change between the portions above and below the hiatus. All the cores above it are composed of calcareous ooze, whereas calcareous chalk begins to be developed from Core 12 downwards. Seismic reflection records also substantiates this lithologic hiatus as previously mentioned.

Another, though much more obscure, biostratigraphic gap might be expected within or below Core 6, judging from disproportionate relationship between a long time duration and a short core length inferred for Core 6. Whereas the N.19/N.18 boundary (ca 4.6 m.y.B.P.) was noted between Sections 1 and 2 of Core 6, the N.16/N.15 boundary (ca 10.5 m.y.B.P.) was set between Section 6 and the core-catcher sample of the same core. If these assignments are true, then a hiatus must be expected at some level between Sections 2 and 6. Nevertheless, the N.16/N.15 boundary in this case is tentative because it is based upon the "first appearance" of *Globorotalia (Turborotalia) acostaensis* (s.s.) unaccompanied by the preceding occurrence of its "ancestral species," *G. (T.) continuosa*. The initial appearance of *Globigerinoides conglobatus* (s.s.), indicative of the middle of N.17, was observed in the core-catcher sample of Core 8. When superiority is given to this originally subordinate datum instead of the apparent first appearance of *G. (T.) acostaensis* (s.s.), then the hiatus may well occur below Core 8 as seen in nannofossil zonation where a large hiatus is noted between Sample 8, CC and Section 1 of Core 9, equivalent to a time gap of about 5 m.y.

As stated before, the Oligocene succession at Site 292 represents a most important biostratigraphic section, and thorough documentation will be completed after comparison of specimens from Sites 292 and 296 and the holotypes of "Oligocene taxa" kept at the British Museum. Such a careful investigation will revise the upper and lower boundaries of Oligocene and the previous subdivisions of this stage, as anticipated in a brief discussion on the lower boundary mentioned above. It was noticed that many so-called Oligocene taxa persist into the earliest Miocene of Sites 292 and 296 and that, on the other hand, a new species of *Globigerinoides* occurs solely in the late Oligocene of Site 296.

Site 293 (lat 20°21.25′N, long 124°05.65′E, water depth 5599 m)

Small-sized specimens of shallow-water benthonic species such as *Ammonia beccarii*, *Elphidium* spp., and *Pseudononion japonicum* var. were recovered from the core catcher samples of Cores 1 through 5, and Cores 7 and 9, showing their displacement from the neighboring shelf.

Planktonic foraminifera in these samples, though absent in Sample 3, CC, are also tiny and with age indeterminate for nearly all. The assemblage from Sample 1, CC contains rarely reddish-colored *Globigerina rubescens* suggesting a Pleistocene-Holocene age (N.23). Sample 4, CC yields *Globorotalia (Turborotalia) tosaensis*, *Globigerinoides obliquus*, and *G. extremus*; the joint occurrence of the three species and absence of *Globorotalia (s.s.) truncatulinoides* and thus falls within the Pliocene (N.21).

Single, poorly preserved specimen of *Globotruncana* sp. (Late Cretaceous) and *Globorotalia* cf. *angulata* (late middle Paleocene) were found in the core-catcher samples of Cores 1 and 12, respectively. They are probably reworked from some submarine exposures adjacent to Luzon or Taiwan where these planktonic species have never been reported previously.

The cores at Site 293 are completely devoid of foraminifera except for those noted above and sometimes include framboidal pyrite rods (indication of axonic condition) as well as manganese micronodules or being carbonaceous.

Site 294 (lat 22°34.74′N, long 131°23.13′E, water depth 5784 m)

Only the core-catcher sample of Core 3 contains benthonic arenaceous species such as *Turritellella spectabilis*, *Glomospira gordialis*, *Involutina anguillae*, *Cyclammina* sp., and many other indeterminate astrorhizids, in the form of fragments or kinds of aggregations of several individuals. The mode of occurrence may suggest reworking from elsewhere.

Site 295 (lat 22°33.76′N, long 131°22.04′E, water depth 5802 m)

Only the core-catcher sample of Core 3A yielded foraminifera at this site. About 30 specimens were recovered within soupy mud, after treatment of some 50 cc of sample. All the individuals are reddish colored and heavily encrusted as seen in Plates 1 and 2, implying that they are of the same age and that they were reworked from somewhere close to the site. The majority of specimens are *Globorotalia angulata* and *G. perclara*, species restricted in their occurrence to the middle Paleocene and to the period from the earliest Paleocene to the earliest Eocene, respectively; the other components could not be identified because of their juvenility.

Site 296 (lat 29°20.41′N, long 133°31.52′E, water depth 2920 m)

A remarkably continuous succession of planktonic foraminifera spanning the Quaternary through the late Oligocene was obtained by the drilling at Site 296. Sediments at this site consist of nannofossil ooze and chalk with pyroclastic rocks forming the lower half of the sequence. The drill reached down to 1087 m below the sea bottom.

The results of foraminiferal zonation are also summarized in Figure 2 along with Site 292. Recognition of

the zonal boundaries of Blow (1969) was somewhat easier than at Site 292, but the following five boundaries were not recognized.

N.23/N.22 boundary: Neither primary nor subordinate datum planes could not be found for this boundary at Site 296.

N.17/N.18: At this site as well as at Site 292, the first appearance of *Globorotalia* (s.s.) *tumida tumida* defining the N.17/N.18 boundary occurs simultaneously with that of *Sphaeroidinella dehiscens*-plexus which is the datum for the base of N.19. "Ancestral form" of the former species, *G.* (s.s.) *tumida plesiotumida*, was scarcely recovered at a few levels within the basal N.19 and never below the base of N.19.

N.17/N.16: Typical specimens of *Globorotalia* (s.s.) *tumida plesiotumida* were very scarce in this hole as well as at many other localities in the western North Pacific region, raising doubts about the validity of the initial appearance datum of this subspecies to designate the N.17/N.16 boundary.

N.6/N.5: The occurrence of *Globigerinatella insueta* was so scarce and sporadic at this site that its initial datum defining this boundary could not be pinpointed.

P.22/P.21: Typical specimens of *Globorotalia* (*Turborotalia*) *opima opima* occur in much less abundance than at Site 292, thus the writer did not set the P.22/P.21 boundary.

Biostratigraphic gap was detected between the core-catcher sample of Core 27 and Section 1 of Core 28 within the middle Miocene. The corresponding time gap is estimated as about 1 m.y.; this age approximates a portion of the time gap observed at Site 292.

The relatively small thickness of sediments compared with time of deposition is apparent for N.17 and N.16 at Site 296 similar to events at Site 292. Therefore, the disconformity presumed within Core 6 or below Core 8 of Site 292 might be exaggerated by some overestimation of time duration for N.17 and N.16 so far as Berggren's (1971) and Berggren and Van Couvering's (1973) time scales can be applied. If such an overestimation is not expected, then the thin thickness of N.17 and N.16 might be ascribed to the slow rate of sedimentation immediately after the middle Miocene disconformity, at both sites.

Alternatively, the very thick succession of late Oligocene sediment (750 m in total) is evidently due to rapid sedimentation; the lower six-sevenths of the thickness is composed mainly of pyroclastics including volcanic lapilli. It was noticed that several specimens of *Lepidocyclina* (*Eulepidina*) sp. (Plate 3) are scattered over Cores 56 and 57, which consist of volcanic ash to lapilli, near the bottom of hole. Neritic environmental conditions can be inferred for sedimentation of these pyroclastics by the presence of this benthonic and neritic larger foraminifera. This genus also points to an early Miocene to Oligocene age, collaborating age assignment (P.21; late Oligocene) by planktonic foraminifera discovered from the core-catcher sample of Core 56. Foraminifera are absent below Core 57.

The detailed occurrences of planktonic foraminifera at this site and Site 292 will be documented and discussed thoroughly in another paper in the near future, along with descriptions of important taxa including several new ones.

Site 297 (lat 30°52.36′N, long 134°09.89′E, water depth 4458 m)

Age-diagnostic planktonic species occur in two intervals at this site, separated by a barren sequence in Cores 12, 13, and 14. Planktonic faunas of the upper portion from Cores 1 through 11 display a composition similar to those of N.22 observed at Site 296 with predominant *Globorotalia* (*Turborotalia*) *inflata*-plexus accompanied by significant occurrences of *G.* (*T.*) *tosaensis* and of *G.* (s.s.) *truncatulinoides*. Interestingly, *G.* (*T.*) *tosaensis* and transitional forms with *G.*(s.s.) *truncatulinoides* are only absent in Core 5 suggesting a younger age (upper N.22 to N.23) than the overlying cores. Therefore, the writer is inclined to suppose that planktonic foraminifera of Cores 1, 2, and 3 designated in age as lower N.22 may have been reworked from somewhere (foraminifera are absent in Core 4). This assumption seems to be supported by the heterogeneous lithology of those cores above Core 5.

The lower portion containing age-diagnostic species consists of Cores 15 through 18. Planktonic species found in their sequence include *Globorotalia* (s.s.) *miocenica*, *G.* (s.s.) aff. *cibaoensis* of Ujiié and Oki (1974), *G.* (s.s.) cf. *tumida plesiotumida*, *Globoquadrina altispira* (s.l.), *Globigerinoides obliquus*, *Globigerina nepenthes delicatula*, and *Sphaeroidinellopsis kochi*. The associated occurrence of these species indicates Zones N.18 to N.19 of the lower Pliocene. However, these faunas may represent displaced assemblages as documented by the paucity of specimens and the associated benthonic foraminifera characteristic of shallow water such as *Ammonia inflata*, *A. japonica*, *A. beccarii*, var., *A. takanabensis*, *Pararotalia nipponica*, *Buccella frigida*, *Cibicides cushmani*, quinqueloculines, and triloculines. Moreover, all of these cores include a considerable amount of sand.

Below Core 18, all the sediments consist of such fine-grained clay that no foraminifera were expected.

SITE 298

Hole 298 (lat 31°42.93′N, long 133°36.22′E, water depth 4628 m)

Hole 298A (lat 31°42.93′N, long 133°36.22′E, water depth 4628 m)

Planktonic foraminifera occur commonly in Cores 1 and 2, but rarely in Cores 4, 9 (Section 1, 70-73 cm; ash layer), and 12. All the assemblages contain typical specimens of *Globorotalia* (s.s.) *truncatulinoides* indicating a Quaternary age, probably Zone N.22. They are also frequently associated with the significant occurrences of shallow-water benthonic species such as *Pseudorotalia gaimardii*, *Ammonia ketienziensis*, *Hoeglundina elegans*, *Bolivinita quadrilatera*, *Triloculina trigonula*, *Nonion japonicum*, *Elphidium crispum*, etc.

A single fragile specimen of *Rugoglobigerina rugosa*, an Upper Cretaceous species, was recovered from the core-catcher sample of Core 1, Hole 298A. The preser-

vation of such a fragile shell implies contamination during laboratory work.

ACKNOWLEDGMENTS

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PLATE 1

(a: dorsal view, b: edge view of apertural side,
c: ventral view)

Figure 1   *Globotruncana* sp.
                 Sample 290A-2, CC; ×100

Figures 2, 3   *Globotruncana* sp.
                 Sample 293-1, CC; ×100.

Figure 4   *Globorotalia* aff. *angulata* (White), edge view.
                 Sample 293-12, CC; ×300.

Figure 5   *Globorotalia perclara* Loeblich and Tappan
                 Sample 295A-3, CC; ×100.

PLATE 1
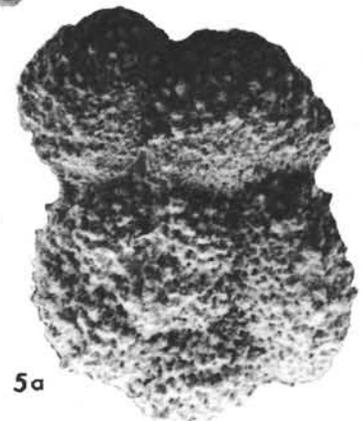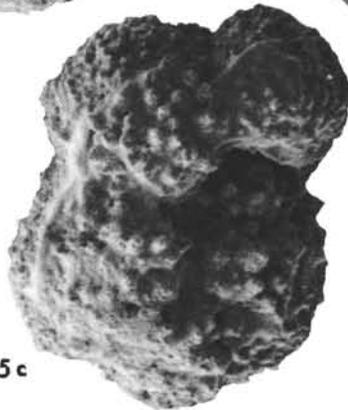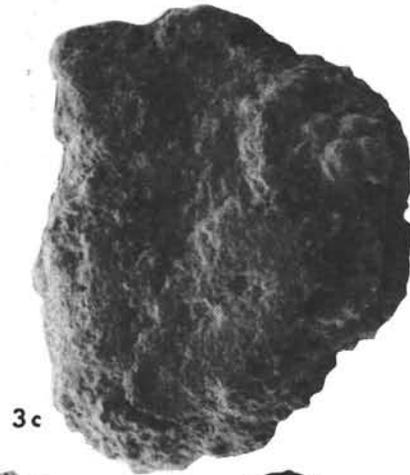
## PLATE 2

(a: dorsal view, b: edge view of apertural side,
c: ventral view)

Figure 1   *Globorotalia perclara* Loeblich and Tappan.
               Sample 295A-3, CC; ×100.

Figure 2   *Globorotalia angulata* (White).
               Sample 295A-3, CC; ×100.

Figure 3   *Rugoglobigerina rugosa* (Plummer), umbilical
               view.
   Sample 298A-1, CC; ×300.

PLATE 2
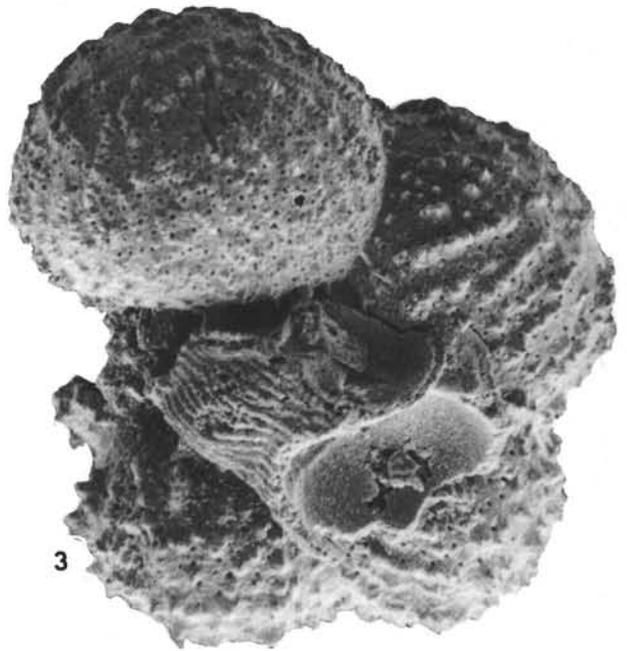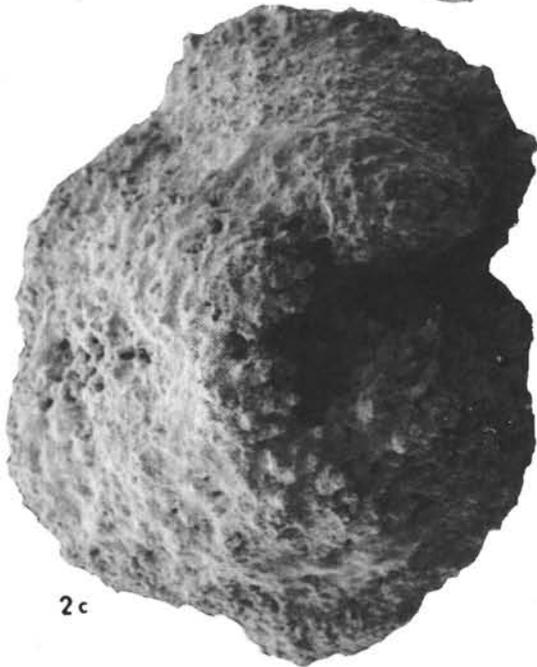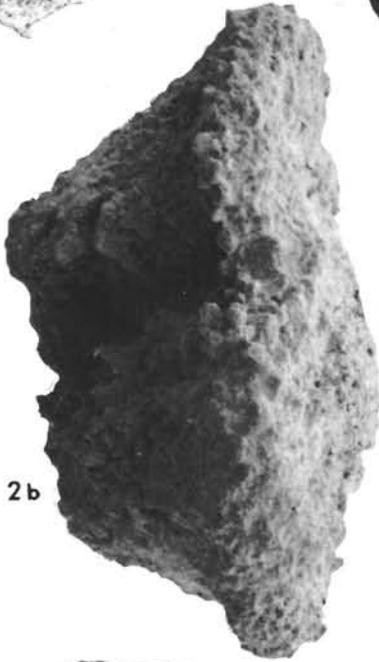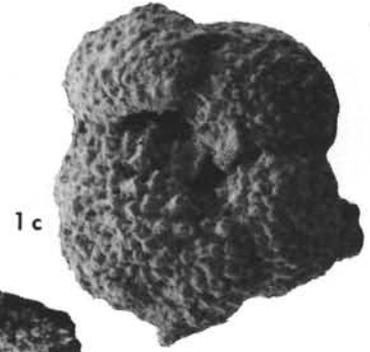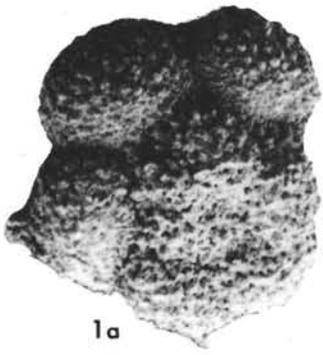
PLATE 3

Figures 1-3   *Lepidocyclina (Eulepidina)* sp.
1. External view of saddle-shaped test, whose surface is evenly scattered with small pustules. Sample 296-57-1, 107 cm; ×ca 7.
2. Equatorial section of the same specimen as figured above, showing embryonic apparatus characteristic of the subgenus, although the septum between protoconch and deuteroconch was broken in the course of preparation; ×20.
3. Vertical section through embryonic apparatus, showing the sinuous condition of intercameral wall in equatorial layer, which is characteristic feature of the subgenus. Sample 296-56-2, 137-139 cm; ×19.

Figures 4, 5   *Lepidocyclina (Eulepidina* ?) sp.
Tangential vertical sections, in which numerous pillars are evenly distributed suggesting similarity to some eulepidine species.
4. Sample 296-57-1, 52-57 cm; ×13.
5. Sample 296-57-1, 103-109 cm; ×19.

PLATE 3