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Planktonic Foraminifera from the Nobori Formation, Shikoku, Japan

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(With 5 plates, 2 text-figures, 1 table)

INTRODUCTION

Concerning the Neogene deposits developed along the eastern coast of Tosa Bay, Kochi Prefecture, Shikoku, many geological and paleontological works have been published since the earlier part of this century. In 1953 a result of the stratigraphical and paleontological studies was published by Katto, Nakamura and the senior author. In the work they classified the Neogene Tonohama group into three formations, as Nobori, Nahari and Ananai in ascending order, and considered that this group ranges from the early to middle Pliocene in age. Later, however, the age of the Nobori formation was determined to be Miocene on the basis of a re-study of megafossils (Katto and Ozaki, 1955), and the formation was excluded from the Tonohama group.

Recent progress in the studies on the planktonic Foraminifera of Japan enable the authors to give a sound conclusion concerning the geological age of the formation. In this work they re-examined the rock samples used in the former study (1953), and found many planktonic species. These consist of a characteristic assemblage correlative with a biostratigraphic zone established in Venezuela by Blow (1959). The present paper deals with the taxonomy of the planktonic Foraminifera and discusses the correlation with several important areas, from the view points of foraminiferal biostratigraphy.

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PREVIOUS WORKS CONCERNING THE NOBORI FORMATION

The Neogene sediments sporadically exposed along the coast of Tosa Bay have been investigated as to the geology and paleontology by many workers, among whom Ozawa (1930) and Asano (1937) reported on the smaller Foraminifera from the so-called Tonohama group then generally accepted as of Pliocene age. However the stratigraphical relationship between the isolated sediments was not fully clarified until 1953, when Katto, Nakamura and Takayanagi published on the biostratigraphy of the Tonohama group, and first established a detailed stratigraphic succession. Their classification is as follows:

Tonohama group	{	Ananai formation	Sandstone and conglomerate (marine)
		Unconformity
		Nahari formation	Siltstone, sandstone, conglomerate and lignite (non-marine)
		Unconformity
		Nobori formation	Siltstone and sandstone (marine)
		Unconformity
		Substratum :	Pre-Tertiary rocks

The Foraminifera of the two marine formations are quite different from one another. The abundant and characteristic species in the Nobori formation are: *Bolivina robusta* (Brady), *Uvigerina proboscidea* Schwager, *Cassidulina laevigata carinata* Cushman, *Nonion nicobarensis* Cushman, *Bolivinita quadrilatera* (Schwager), *Bulimina inflata* Seguenza, etc. And this assemblage has many species in common with the Miocene Foraminifera of the Kar Nicobar Islands. On the contrary the dominant species in the Ananai formation are: *Eponides praecinctus* (Karrer), *Robulus calcar* (Linnaeus), *Bolivina hanzawai* Asano, *Siphogenerina raphana* (Parker and Jones), and *Elphidium advenum* (Cushman). This assemblage shows close affinity with the Recent fauna of the Indo-Pacific Region, and seems to be equivalent to those of the lower to middle Pliocene foraminiferal assemblages previously known from the Pacific side of Central Japan. Accordingly whether the Nobori formation is Miocene or Pliocene is open to question. At that time, however, it was tentatively correlated with the lowermost Pliocene, because of the insufficient data. However, there is a remarkable break between the Nobori and Nahari formations. Aside from the angular unconformity separating the two formations, there are significant differences in their sedimentary environments as indicated by the difference of lithologic character, fossil contents, geological structures, and the present distribution of the formations. On the other hand, the unconformity between the Nahari and Ananai formations is less significant.

In 1955, Katto and Ozaki recollected the molluscan fossils from the Nobori formation, and among them found *Periploma pulchellum* Hatai and Nisiyama, a characteristic Miocene species of Japan. Further they recognized *Liquidamber* in the pollen flora of the Nobori but not in those of the other younger formations. From the molluscan assemblage and pollens, they concluded that the Nobori formation is Miocene in age. Furthermore Katto (1960) added a Miocene shark's tooth, *Carcharodon megalodon* (Charlesworth), to his megafaunal list from the Nobori formation. In the same paper he separated the Nahari formation from the Tonohama group, and renamed it as the Ropponmatsu formation to avoid phonetic confusion with the Eocene Naharigawa formation of the same province. Thus, the Tonohama group of 1953 was rearranged by him as follows:

Pliocene	{	Tonohama group (Including the Ananai formation and the Koe formation in Southwestern Shikoku)
	 Unconformity
		Ropponmatsu formation
	 Unconformity
Miocene		Nobori formation
	 Unconformity
		Substratum: Eocene Muroto formation

FORAMINIFERAL SAMPLES

The foraminiferal samples treated are from a cliff, 100 meters east of Nobori, Muroto City (formerly Hane-mura, Aki-gun) (IGPS loc. no. Ko-25; Lat. 33° 22'09" N., long. 134°03'33" E.). The Nobori formation is distributed in the vicinity of Nobori, being restricted because its northeastern part is in fault contact with the Ropponmatsu formation, and its southwestern is covered by the alluvial plain (text-figure 1). The formation consists mainly of homogeneous massive siltstone with no marker bed, though it is sandy above the basal coarse grained sandstone with pebbles derived from the older rocks. Therefore the stratigraphic position of the strata which yielded the fossils from the above-mentioned cliff can not be more exactly ascertained, even though it belongs to the upper

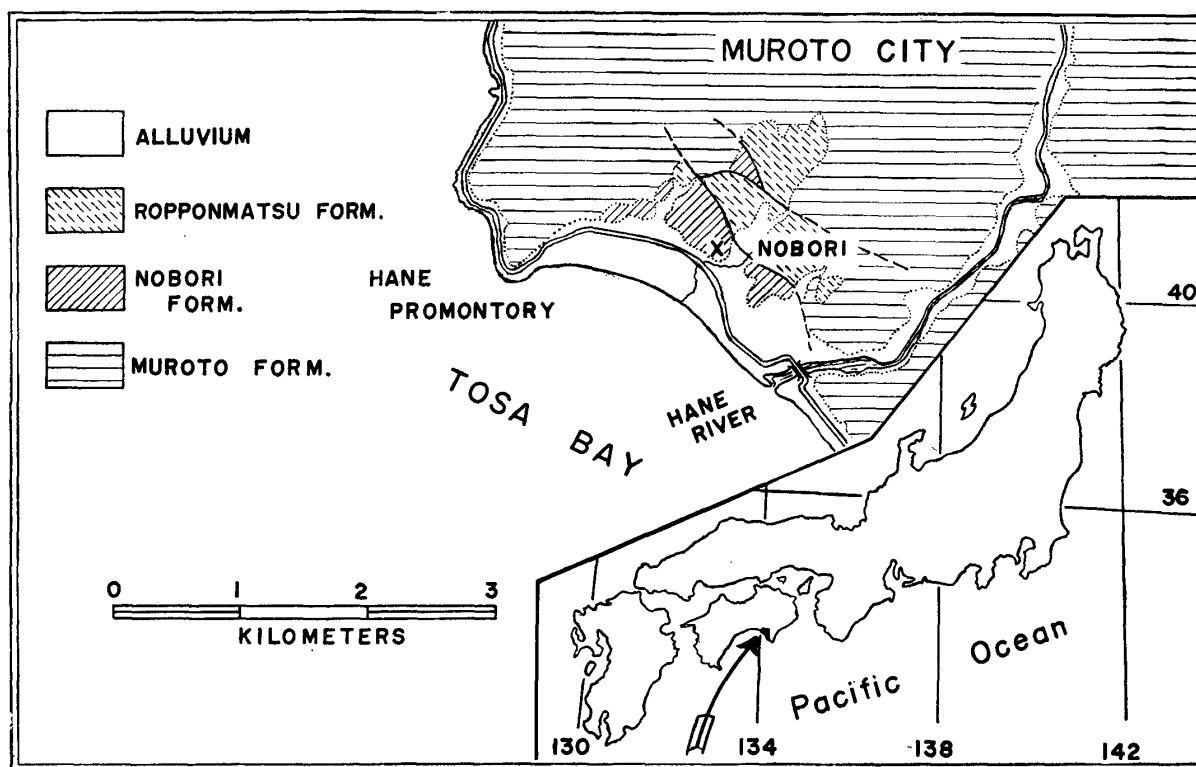


Fig. 1. Index and fossil locality maps of the Nobori area (reproduced in part from Katto *et al.*, 1953)

half of the about 80 meters thick Nobori formation. From this cliff 18 rock samples numbered from the lower upwards as A-1 to A-18 were collected from each 0.05 meters thick stratum, with stratigraphic intervals of one meter. And the foraminiferal samples used are the same as those of the previous report (Katto, *et al.*, 1953).

CONSIDERATIONS OF PLANKTONIC FORAMINIFERA

As a result of examination 50 forms including three new species and one new sub-species were distinguished, and their frequency is shown in Table 1. Being difficult to subdivide this foraminiferal assemblage vertically from the frequency distribution, it should be considered as comprising a single unit. To this planktonic assemblage, such terms as association or faunule that incorporate a more or less ecological meaning are difficult to be applied. Thus the strata of this assemblage is tentatively called the Nobori horizon to avoid confusion with any terms previously defined. By the procedure correlation of the Nobori horizon with zones recognized outside of Japan may be undertaken. Before going into the correlation, it may be better to mention the present status of the Miocene biostratigraphy by planktonic Foraminifera in Japan.

The junior author investigated the stratigraphy of the Kakegawa district of Central Japan, and found abundant planktonic Foraminifera (Saito, 1960). It was consequently proved that the sequence of the Zones from *Catapsydrax dissimilis* to *Globorotalia fohsi* are developed in the area. Although the component species of each zone are not the same as those of the Trinidad (Bolli, 1957a) or Venezuelan sequence (Blow, 1959), the first appearances of the diagnostic species of each zone agree well with those in the Caribbean sequence. The junior author also studied the planktonic assemblage associated with *Lepidocyclina* and *Miogypsina* in various parts of Japan, and has attained a consonant result with the Atlantic region, though it will appear at another occasion. Thus the

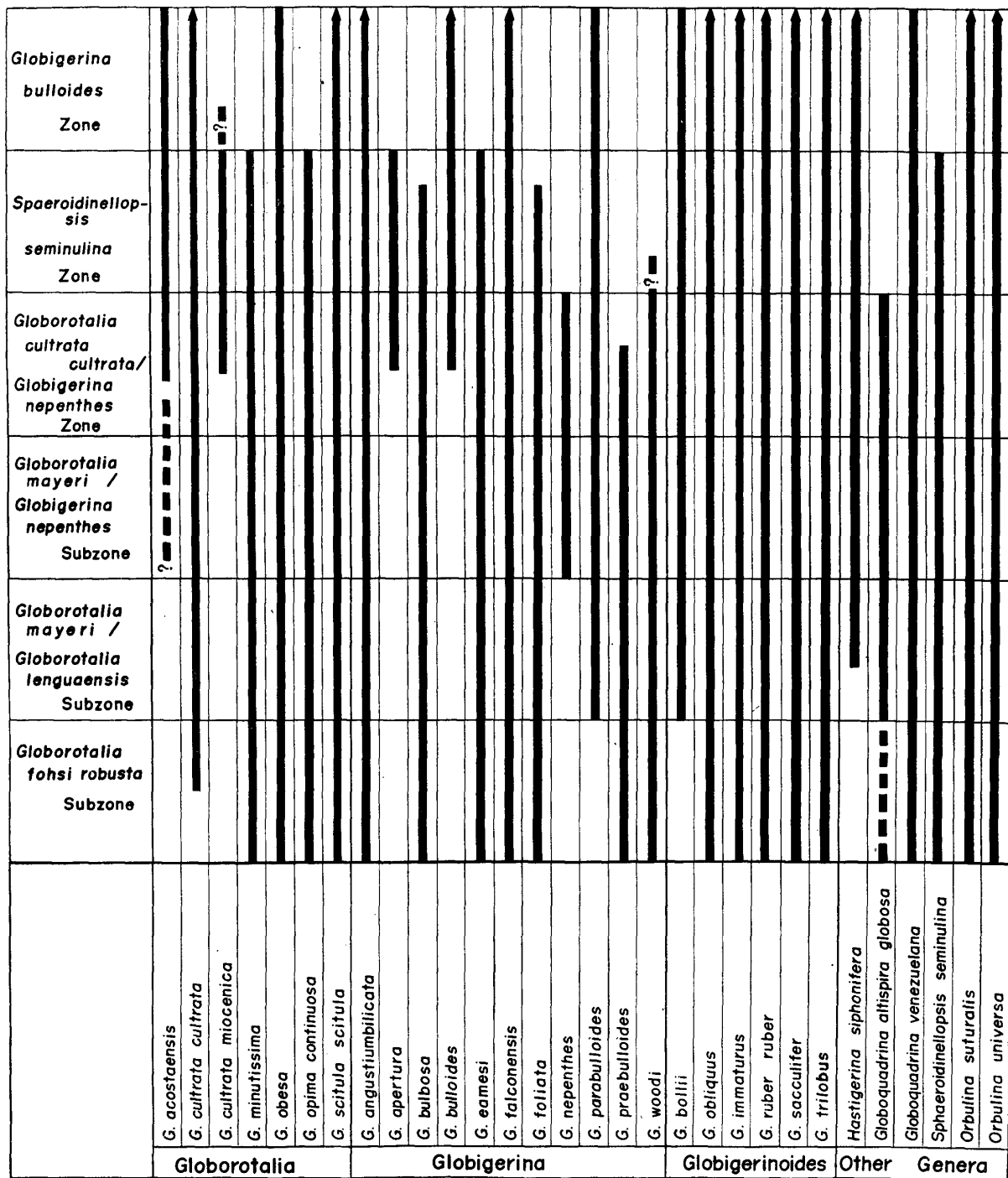


Fig. 2. Stratigraphic range of the characteristic species. (Zonation after Blow, 1959: zone name emended in part. Ranges of the species compiled from various records.)

bulloides d'Orbigny, and *Globorotalia cultrata miocenica* Palmer. The other is constituted by ones disappearing within the above-mentioned zone, they are *Globigerina nepenthes* Todd, *Globigerina praebulloides*, and *Globoquadrina altispira globosa* (Bolli). Therefore, the Nobori horizon can be safely correlated with the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone of Venezuela. If emphasis is given to the absence of *Globorotalia mayeri* Cushman and Ellis found in the lower to middle Miocene below this zone of Japan as well as in the Caribbean region, the Nobori horizon will also be correlative with the

Globorotalia menardii Zone (= *Globorotalia cultrata cultrata* Zone) of Trinidad (Bolli, 1957a). However, opinions diverge on the trans-Atlantic correlation of the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone. The controversy is tabulated below.

	Bolli (1957a, 1959)	Blow (1959)	Stainforth (1960)
<i>Globigerina bulloides</i> Zone		Sarmatian	
<i>Sphaeroidinellopsis seminulina</i> Zone			
<i>Globorotalia cultrata cultrata</i> / <i>Globigerina nepenthes</i> Zone	Helvetian	Tortonian	Tortonian
<i>Globorotalia mayeri</i> Zone	Burdigalian	Helvetian	Helvetian
<i>Globorotalia fohsi</i> Zone (s. l.)		Burdigalian	Burdigalian

Bolli (1957a, 1959) correlated his *Globorotalia menardii* Zone (= lower part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone of Blow) with the Helvetian, and defined the top of the *Globorotalia mayeri* Zone by the extinction of this species at the top of the Burdigalian. On the contrary, Blow (1959) correlated the *Globorotalia fohsi* Zone (s. l.) with the Burdigalian, and the zones from *Globorotalia mayeri* to *Globigerina bulloides*, as a whole, with Vindobonian to Sarmatian. Although not definitely stated in the same paper, he suggested that the Tortonian/Helvetian boundary may be placed at the top of the *Globorotalia mayeri* Zone, laying stress on the first appearance of *Globorotalia acostaensis* in the Tortonian. With which planktonic zones the Sarmatian/Tortonian boundary should be correlated, is beyond the object of the present study. But according to Banner and Blow (1959), it may be understood that they prefer to place this boundary at the level of extinction of *Globigerinoita* and *Globorotaloides*. But in the Venezuelan sequence, Blow (1959) recorded the top of the range of *Globigerinoita (morugaensis)* in the middle part of the "*Globorotalia menardii menardii*/*Globigerina nepenthes* Zone", and of *Globorotaloides (variabilis)* in the middle part of the "*Sphaeroidinella seminulina* Zone" (= *Sphaeroidinellopsis seminulina* Zone of the present study). There is thus considerable divergence as to the stratigraphic level of extinction of both genera. Their views on this boundary problem remain to be settled by concrete evidence.

In the next year, Stainforth (1960) expressed his view on the trans-Atlantic correlation problem, and supported Blow's opinion on the contemporaneity of the "*Globorotalia menardii menardii*/*Globigerina nepenthes* Zone" with the Tortonian by additional data. The studies by several Italian workers on the Tortonian Foraminifera are not available for the present study, except for the one by Dieci (1959). From Montegibbio and Ca' Spagnola di Castelvetro provinces in Italy, Dieci described 15 planktonic forms, namely: *Globigerina apertura* Cushman, *G. bulloides* d'Orbigny, *G. bulloides cryptomphala* Glaessner, *G. dubia* Egger, *G. dutertrei* d'Orbigny, *G. inflata* d'Orbigny, *G. quadrilatera* Galloway and Wissler, *Globigerinoides conglobatus* (Brady), *G. ruber* (d'Orbigny), *G. sacculifer* (Brady), *G. trilobus* (Reuss), *Orbulina suturalis* Bronnimann, *O. universa* d'Orbigny, *Globorotalia menardii* (d'Orbigny), and *G. scitula* (Brady). The joint occurrence of these species suggests that the Tortonian strata developed in the above provinces are younger than the *Globorotalia mayeri* Zone and older than the *Globigerina bulloides* Zone. However, conclusive data for further determination is desired.

Fortunately the present authors had an opportunity to examine a foraminiferal sample from the type Tortonian locality (Stazzano, Sant'Agata dei Fossili, Tortona, 20 kilometers east of Alessandria, Italy) deposited in the Institute of Geology and Paleontology,

Tohoku University. The planktonic Foraminifera identified are :

<i>Globorotalia scitula scitula</i> (Brady)	0.8 %
<i>Globigerina angustiumbilocata</i> Bolli	5.7
<i>Globigerina angustiumbilocata</i> Bolli var.	0.8
<i>Globigerina apertura</i> Cushman	2.4
<i>Globigerina bulloides</i> d'Orbigny	6.5
<i>Globigerina druryi</i> Akers <i>decoraperta</i> , n. subsp.	11.4
<i>Globigerina eamesi</i> Blow	0.8
<i>Globigerina falconensis</i> Blow	4.0
<i>Globigerina glutinata</i> Egger	1.6
<i>Globigerina nepenthes</i> Todd	19.4
<i>Globigerina pachyderma</i> (Ehrenberg)	0.8
<i>Globigerina woodi</i> Jenkins	3.2
<i>Globigerinoides bollii</i> Blow	17.0
<i>Globigerinoides obliquus</i> Bollii	3.2
<i>Globigerinoides immaturus</i> LeRoy	2.4
<i>Sphaeroidinellopsis seminulina</i> (Schwager)	4.0
<i>Orbulina universa</i> d'Orbigny	0.8
Miscellaneous	15.4
Total	100.0 %

The type Tortonian assemblage, though restricted in number of species, is marked by the co-existence of *Globigerina apertura*, *G. bulloides*, and *G. nepenthes*. This is assumed to be diagnostic to the assemblage of the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone. In addition, the occurrence of *Globigerina druryi decoraperta* n. subsp. and *Globigerina angustiumbilocata* var. will not only suggest faunal affinity between the type Tortonian and the Nobori assemblage, but also their contemporaneity.

According to Blow (1959), in the Tortonian of Sicily there are *Globorotalia acostaensis* Blow, *Sphaeroidinellopsis subdehiscens* (Blow), and *S. seminulina* (Schwager), but *Globigerina nepenthes* has not been found. Such differences among the three Tortonian assemblages in Italy and Sicily whether caused by local ecologic control on the distribution of the planktonic forms or phasic difference remains unknown. However as mentioned above, it seems to be probable to correlate both the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone and *Sphaeroidinellopsis seminulina* Zone with the Tortonian of Europe.

In the previous paper (Katto *et al.*, 1953), stress was laid upon that the Nobori assemblage had close affinity with the Miocene Foraminifera of the Kar Nicobar Islands. The latter assemblage has such planktonic forms as *Globigerina bulloides* d'Orbigny, *G. conglomerata* Schwager, *Sphaeroidinellopsis seminulina* (Schwager), *Orbulina universa* d'Orbigny, and *Globorotalia cultrata cultrata* (d'Orbigny) (Schwager, 1866). Taking into consideration the above stated features of the Tortonian, both assemblages may be nearly contemporaneous.

SYSTEMATIC DESCRIPTION

In the taxonomic study of the Nobori materials, the present authors endeavoured to place the forms in their proper systematic position, through considerations on : comparative morphology with topotype specimens as well as the forms described and illustrated in literature; variation in morphology, especially of the aperture, wall texture and coiling; ontogeny including position of the principal aperture, development of secondary apertures, surface ornamentation, morphological character of the final chamber, and of coiling form.

The character of the final chamber in ontogenic development seems to be an important and interesting problem in taxonomy and biology of the globigerines. Most

globigerines assume sometimes the so-called "aberrant" or abortive" form (Blow, 1959; Banner and Blow, 1960b) in their final chambers, and apertural characters change. But studies on the variation of individuals and of dissected specimens proved that such morphological changes usually are of no valuable criteria in taxonomy.

In some species of *Globigerina*, there are a number of specimens with variable shaped final chamber. *Globigerina angustiumbilitata* is the case in the present study. In dissected specimens, the variable shaped chambers are found to be appendages to the principal shell construction of *G. angustiumbilitata*, as clearly described and illustrated in later pages. Opinions may diverge as to whether the development of such a final chamber is a criterion distinguishing a taxon or merely a property of taxon. There is known no specimens with transformed penultimate chamber, and individuals with transformed final chamber do not always become full adults. Therefore the transformed final chamber may not be formed during full maturity, but develop in the reproductive phase or when individual growth is interrupted by some ecological causes. However, consideration must be given to that the form with transformed final chamber may occur during phylogenetic development of the taxon. The present authors here treated such forms as a variety of *G. angustiumbilitata*, because the mere development of a transformed chamber is not sufficient for specific distinction as already stated in earlier lines. Further, the presence or absence of such a chamber because intermediate forms have been found may not even be of specific or subspecific value.

Among *Globigerina angustiumbilitata* var., many specimens similar to *Globigerinita* were found. According to Loeblich and Tappan (1957) who emended the definition of *Globigerinita* Bronnimann and established the genus *Tinophodella*, *Globigerinita* includes forms with a modified final chamber and supplementary apertures, and *Tinophodella* differs in having a distinct umbilical plate (=bulla) with numerous small accessory apertures. In reality the bulla should be placed in a category different from the final chamber. A *Tinophodella* specimen removed of its bulla, however, does not differ from *Globigerina* as pointed out by Hofker (1959, p. 7). He considered *Globigerina naparimaensis* (= *Tinophodella ambitacrena*) as a form in the sporulation stage of *Globigerina* cf. *bulloides*, but it is more natural to consider it as *Globigerina juvenilis* (= *Globigerina glutinata* in the present study) with a bulla (Bolli, 1957a, p. 110). Both forms coexist in most of the previous records as well as in the Nobori formation. Blow (1959, p. 102) supposed a lineage from *Globigerina juvenilis* via "*Globigerinita naparimaensis incrusta*" to "*Globigerinita naparimaensis*", and considered that the third form is an offshoot from the first, the phenomenon being repeated several times throughout the Miocene in a repetitive and heterochronous manner. Biologically such a repetitive evolutionary process between species of different genera is out of question. His view may have been due to the misinterpretation that the bulla is a fundamental criterion in the taxonomy of the globigerines. As already interpreted by Hofker (1961, p. 66), it seems quite reasonable that the bulla is a closed cyst of the reproductive phase. Herein *Globigerina glutinata* with a bulla is tentatively classified as a variety of the species.

In this systematic part 50 forms found in the samples from the Nobori formation are described. Among these forms *Globorotalia humerosa*, *Globorotalia tosaensis*, *Globigerina druryi* Akers subsp. *decoraperta*, and *Candeina amacula* are described as new to science.

The arrangement of the families and genera is mainly based upon the suprageneric classification of Loeblich and Tappan (1961) and the generalized classification of planktonic Foraminifera of Bolli, Loeblich and Tappan (1957). Species of each genus are arranged in alphabetic order. In the description as a rule, diagnosis is given only to the forms which appear newly in the fauna, except where necessity arises. In the respective cases, the

catalogue- and sample-numbers of the types, remarks, occurrence analysed in the present study, and known stratigraphic range are given. The known stratigraphic ranges are principally expressed by the planktonic foraminiferal zones established in Trinidad and Venezuela (Bolli, 1957*a, b*; Blow, 1959). But some zone names are here emended owing to the recent taxonomic work by Banner and Blow (1960), namely, the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone is used for the previous *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, and the *Sphaeroidinellopsis seminulina* Zone for the *Sphaeroidinella seminulina* Zone. As already mentioned in the foregoing section, all of the samples treated are derived from a single locality (IGPS loc. no. Ko-25), and for the sake of brevity, it is not repeated in the description.

The types are deposited in the Institute of Geology and Paleontology, Tohoku University. The prefix IGPS for numbers of catalogue and locality is an abbreviation for Institute of Geology and Paleontology, Sendai.

Superfamily Globigerinacea

Family Hantkeninidae

Subfamily Hastigerininae

Genus *Hastigerina* Thomson, 1876

Hastigerina siphonifera (d'Orbigny), 1839

Pl. 24, figs. 1a, b

Globigerina siphonifera d'Orbigny, 1839, p. 83, pl. 4, figs. 15-18. (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina aequilateralis Brady, 1884, p. 605, pl. 80, figs. 18-21.

Hastigerina aequilateralis (Brady) var. *involuta* Cushman, 1917, p. 662; Cushman, 1921, p. 294, fig. 11.

Globigerinella aequilateralis (Brady). Cushman, 1927, p. 87, pl. 19, figs. 7a, b; LeRoy, 1944*a*, p. 40, pl. 3, figs. 24, 25, pl. 6, figs. 37, 38; Phleger and Parker, 1951, p. 35, pl. 19, fig. 14; Phleger, Parker and Peirson, 1953, p. 16, 17, pl. 2, figs. 9-11; Cushman, Todd and Post, 1954, p. 369, pl. 91, fig. 8; Todd, 1957, p. 279 (table), pl. 78, figs. 13a, b; Bé, 1956, pl. 1, figs. 19, 20, 27; Graham and Militante, 1959, p. 11, pl. 18, figs. 11a, b; Bradshaw, 1959, p. 38, pl. 7, figs. 1, 2.

Hastigerina aequilateralis (Brady). Bolli, Loeblich and Tappan, 1957, p. 29, pl. 3, figs. 4a, b; Chang, 1959, p. 60, 61, pl. 1, figs. 1-5.

Hastigerina cf. *aequilateralis* (Brady). Bolli, 1957*a*, p. 108, pl. 22, figs. 1a-2b; Jenkins, 1960, p. 349, pl. 1, figs. 1a-c.

Hastigerina aequilateralis aequilateralis (Brady). Blow, 1959, p. 171, pl. 8, figs. 31a, b.

Hastigerina aequilateralis involuta (Cushman). Blow, 1959, p. 171, 172, pl. 8, figs. 32a, b.

Hastigerina (*Hastigerina*) *siphonifera* (d'Orbigny). Banner and Blow, 1960*a*, p. 22, 23, text-figs. 2a-3b (lectotype designated).

Remarks : - This well known species occurs rarely in the present material. The Nobori specimens seem to be more tightly coiled and involute as compared with the forms previously illustrated. The size ranges from 0.45 to 0.47 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75076 from sample A-4.

Occurrence : - Rare.

Known range : - The *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to Recent.

Family Globorotaliidae

Subfamily Globorotaliinae

Genus *Globorotalia* Cushman, 1927

Globorotalia acostaensis Blow, 1959

Pl. 24, figs. 2a-c

Globorotalia acostaensis Blow, 1959, p. 208-210, pl. 17, figs. 106a-107; Jenkins, 1960, p. 358, pl. 4, figs. 1a-c.

Remarks : - Besides the typical forms of *Globorotalia acostaensis*, some variants are found in the Nobori formation. The shapes of the final chamber and the apertural lip appear to be fairly variable as stated in the description of the type (Blow, *loc. cit.*). However, it is marked by its thick test, usually with five chambers in the last whorl; small but deep umbilicus, visible when it is not covered with apertural lip; thick wall with finely cancellate surface; and a distinct, rather thick and broad apertural lip. It differs from *Globigerina pachyderma* (Ehrenberg) in having a large and thicker test with more inflated and rather separated chambers, aperture typically umbilical-extraumbilical in position, and finely cancellate wall surface. Coiling of tests is insistently in right direction. The size ranges from 0.24 to 0.34 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75063 from sample A-12.

Occurrence : - Rather common.

Known range : - Blow (*loc. cit.*) considered that it ranges from the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent (?). But subsequently Jenkins (*loc. cit.*) recorded it from the *Globorotalia mayeri* Zone. Therefore its first appearance is extended down to the latter zone.

Globorotalia cultrata cultrata* (d'Orbigny), 1839

Pl. 24, figs. 4a-c

Rotalina (*Rotalina*) *cultrata* d'Orbigny, in Ramon de la Sagra, 1839, p. 79, pl. 5, figs. 7-9 (*fide* Ellis and Messina, 1940 *et seq.*).

Rotalia (*Rotalie*) *menardii* d'Orbigny. Parker, Jones and Brady, 1856, p. 20, pl. 3, fig. 81 (*fide* Ellis and Messina, 1940 *et seq.*).

Globorotalia menardii (d'Orbigny). Bermudez, 1949, p. 286, 287, pl. 22, figs. 9-11; Bolli, 1957a, p. 120, pl. 29, figs. 6a-10b; Bradshaw, 1959, p. 44, pl. 8, figs. 3, 4; Chang, 1959, p. 69, pl. 5, figs. 10a-11c.

Globorotalia menardii menardii (d'Orbigny). Blow, 1959, p. 215, 216, pl. 18, figs. 119a-120c; Jenkins, 1960, p. 362, pl. 4, figs. 8a-c.

Globorotalia cultrata (d'Orbigny) Waller and Polski, 1959, pl. 10, figs. 3a-c.

Rotalia menardii Parker, Jones and Brady. Banner and Blow, 1960b, p. 31-33, pl. 6, figs. 2a-c (lectotype) [written as *Rotalia menardii* (Parker, Jones and Brady) ? = *Globorotalia cultrata* (d'Orbigny) in pl. 6].

Rotalina cultrata d'Orbigny. Banner and Blow, 1960b, p. 34, 35, pl. 6, figs. 1a-c (neotype) [written as *Rotalina cultrata* d'Orbigny 1839 = *Globorotalia cultrata* (d'Orbigny) in pl. 6].

Remarks : - Although this form has been referred to *Globorotalia menardii* by authors, in the present study it is identified with *Globorotalia cultrata cultrata* based upon the re-examination of the primary types of both species and their related species (Banner and Blow, *op. cit.*). Because it appears to be not a matter of opinion but of recorded fact that the taxon "*G. menardii* (d'Orbigny)" has never been validated, and is predated by the well described and illustrated *Rotalina cultrata* d'Orbigny (Banner and Blow, *op. cit.*, p. 32).

The species is characterized by its flattened subcircular test, five to six chambers in the last whorl, and lobulate periphery with a distinct imperforate carina. The aperture is furnished with a thin, rather broad lip, which never attain to that of *Globorotalia tumida* in size. Coiling of tests show a strong preference to the right direction, except for the samples from the two uppermost horizons in which some left-coiled specimens are found. The size ranges from 0.32 to 0.63 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75064 from sample A-17.

Occurrence : - Not common but found throughout.

Known range : - The middle part of the *Globorotalia fohsi robusta* Zone to Recent.

*- See uotatious given at end of References.

***Globorotalia cultrata miocenica* Palmer, 1945**

Pl. 24, figs. 5a-c

Globorotalia menardii (d'Orbigny) var. *miocenica* Palmer, 1945, p. 70, 71, pl. 1, figs. 10a-c; Bermudez, 1949, p. 287, pl. 22, figs. 12-14.

Globorotalia menardii miocenica Palmer. Blow, 1959, p. 216, 217, pl. 19, figs. 121a-c.

Globorotalia menardii (d'Orbigny) subsp. *miocenica* Palmer. Jenkins, 1960, p. 362, pl. 4, figs. 7a-c.

Remarks : - This subspecies is well defined by having a flat spiral side and a strongly vaulted umbilical side. The Nobori specimens show a less keeled test with rather coarsely hispid wall surface in the earlier stage, but a more keeled test with smooth and very finely perforate surface in the later stage. They have usually five chambers in the last whorl, though Palmer's typical form possesses about six chambers. The tendency in the direction of coiling is unsettled, because of the few specimens. The size ranges from 0.24 to 0.36 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75065 from sample A-7.

Occurrence : - Very rare.

Known range : - The *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to *Sphaeroidinellopsis seminulina* Zone.

***Globorotalia hirsuta* (d'Orbigny), 1839**

Pl. 26, figs. 1a-c

Rotalina hirsuta d'Orbigny, in Barker-Webb and Berthelot, 1839, p. 131, pl. 1, figs. 37-39 (*vide* Ellis and Messina, 1940 *et seq.*).

Pulvinulina canariensis (d'Orbigny). Brady, 1884, p. 692, pl. 103, figs. 8a-10b (not *Rotalina canariensis* d'Orbigny).

Globorotalia hirsuta (d'Orbigny). Cushman, 1931, p. 99, 100, pl. 17, figs. 6a-c; Phleger, Parker and Peirson, 1953, p. 19, pl. 4, figs. 1-7; Bradshaw, 1959, p. 44, pl. 8, figs. 1, 2; Bé, 1959, pl. 1, figs. 4, 8.

Globorotalia (Truncorotalia) hirsuta (d'Orbigny). Cushman and Bermudez, 1949, p. 36, 37, pl. 7, figs. 1-3.

Globorotalia canariensis (d'Orbigny). Wiseman and Ovey, 1950, p. 66, pl. 2, figs. 4a, b (not of d'Orbigny).

Globorotalia punctulata (d'Orbigny). Phleger, Parker and Peirson, 1953, p. 20, 21, pl. 4, figs. 8-12.

Remarks : - The concept of the taxon "*Globorotalia hirsuta*" has been in a long state of ambiguity as mentioned by Phleger *et al.* (*loc. cit.*). However the recent study of Banner and Blow, who examined the type of *Globigerina puncticulata* Deshayes, appears to throw light on this problem (1959, p. 15-17), and at least, a part of the forms previously referred to "*Globorotalia punctulata*", *e. g.*, of Phleger *et al.* seems to belong to the present species. The type illustrations of d'Orbigny show a plano-convex test consisting of about four chambers in the last whorl with a keeled periphery and hispid chamber walls. Such features are also the case with ones of Brady (*loc. cit.*) in the Challenger collection. However, the convexity of the sides seems to be very variable as evident through surveying various illustrations of this species by different authors. The Nobori specimens are much more convex on the umbilical side than on the spiral, just as the Cuban specimens (Cushman and Bermudez, *loc. cit.*). Further the hispidity on the surface of wall is also variable, though it develops more or less on almost all of the specimens. For such reason, the form identified with *Globorotalia canariensis* by Wiseman and Ovey is included into the synonymy. Coiling of the test examined is in left direction. The size ranges from 0.24 to 0.29 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75066 from sample A-17.

Occurrence : - Rare, only found in the uppermost horizon of the studied outcrop.

Known range : - Previously it has not been recorded from the Miocene, being known only from the Pliocene to Recent.

***Globorotalia humerosa* Takayanagi and Saito, n. sp.**

Pl. 28, figs. 1a-2b

Test low trochospiral, biconvex, but occasionally almost flat in spiral side, equatorial periphery lobate axial periphery rounded; chambers ovate, 10 to 14 arranged in about two whorls, usually six to seven in last whorl, chambers increasing in size in last whorl somewhat irregular, frequently last and/or penultimate chambers much reduced in size compared with preceding ones in last whorl; last chamber occasionally somewhat protruding and tending to be displaced towards umbilical side; sutures not limbate, radial to slightly curved, depressed on spiral side, radial to faintly curved, depressed on umbilical side; wall calcareous, thick, cancellate, surface granular in appearance; umbilicus fairly wide and deep, aperture medium to low arch, with a narrow distinct lip, interiomarginal, umbilical-extraumbilical, apertural openings of preceding chambers often connected with last one to make large channeled hollow; coiling of tests is mostly in right direction.

Maximum diameter of holotype 0.46 mm., maximum thickness 0.32 mm. Maximum diameter of paratype 0.44 mm., maximum thickness 0.31 mm.

Types : - Holotype, IGPS coll. cat. no. 75079 from sample A-16; paratype, IGPS coll. cat. no. 75078 from sample A-17.

Remarks : - In general appearance, this species resembles *Globigerina eggeri* Rhumbler, but is distinguished by having the aperture with a distinct lip being interiomarginal, umbilical-extraumbilical in position. It differs from *Globorotalia mayeri* Cushman and Ellis in having more inflated chambers, more convex spiral side, wider and deep umbilicus, and the thicker test with more granular appearance. It also differs from *Globorotalia acostaensis* Blow in having more chambers in the last whorl, usually with more than six chambers instead of five as in *G. acostaensis*, wider umbilicus, less developed apertural lip, and wider apertural opening. Moreover, it is distinguishable from *Globorotalia subcretacea* (Lomnicki) by possessing a less lobulate equatorial profile, more chambers in the last whorl, and rather irregularly developed last and/or penultimate chambers. The development of the reduced chambers in the adult stage may possibly be one of the characteristics of the new species. The specimen figured by Hamilton as *Globigerina subcretacea* Lomnicki (1953, pl. 30, fig. 32) seems to be closely related and referable to the present form in showing the much reduced last two chambers.

Occurrence : - Rather common.

***Globorotalia minutissima* Bolli, 1957**

Pl. 26, figs. 3a-c

Globorotalia minutissima Bolli, 1957a, p. 119, pl. 29, figs. 1a-c; Blow, 1959, p. 218, pl. 19, figs. 123a-c.

Remarks : - The small specimens referable to the present species are characterized by possessing a small test with equatorially lobate periphery; five to five and a half, ovate chambers in the last whorl; and a narrow slit-like aperture with a lip. Coiling of tests is almost in right direction. The size ranges from 0.13 to 0.26 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75067 from sample A-11.

Occurrence : - Sporadical.

Known range : - The *Catapsydrax stainforthi* Zone to the *Sphaeroidinellopsis seminulina* Zone.

***Globorotalia obesa* Bolli, 1957**

Pl. 24, figs. 7a-c

Globorotalia obesa Bolli, 1957, p. 119, pl. 29, figs. 2a-3; Blow, 1959, p. 218, pl. 19, figs. 124a-c; Jenkins, 1960, p. 364, pl. 5, figs. 2a-c.

Remarks : - The distinctly inflated, spherical and fewer chambers in the last whorl is a diagnostic of *Globorotalia obesa*. The Nobori specimens are well preserved and show finely hispid wall surface. The tendency in the direction of coiling is not ascertainable due to the few specimens, though both left- and right-coiled ones are found. The size ranges from 0.19 to 0.34 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75068 from sample A-5.

Occurrence : - Very rare.

Known range : - According to the previous records, it seems to range from the *Globigerina ampliapertura* Zone to the *Globigerina bulloides* Zone.

***Globorotalia* cf. *oceanica* Cushman and Bermudez**

Pl. 27, figs. 6a-12c

Compared with : *Globorotalia oceanica* Cushman and Bermudez, 1949, p. 43, 44, pl. 8, figs. 13-15.

Test low trochospiral, strongly convex on umbilical side, nearly flat to weakly convex on spiral side; equatorial periphery more or less slightly lobulate, axial periphery smoothly rounded with curvature variable to some extent; chambers about 11, arranged in about two and a half tightly coiled whorls, slightly inflated and partially embracing, gradually increasing in size in earlier whorls, but rapidly in last whorl consisting of four to four and a half chambers; sutures on umbilical side nearly radial, very narrowly depressed, not limbate, often incised near umbilicus, somewhat sinuous at midway between umbilicus and periphery; sutures on spiral side tangential, nearly straight, slightly depressed, not limbate; umbilicus small and not depressed in early stages, but becoming deep and distinctly depressed in last stage; aperture a fairly high, elongate arch, interiomarginal, umbilical-extraumbilical in position, in adult often restricted by a thickened rim covered with shelly granular substance; apertural face convex in early stage, later becoming slightly concave near base where aperture lies; wall calcareous, perforate, radial in structure, fairly thick, surface slightly hispid in early stage, later becoming smooth, but in umbilical side of last whorl surface of early chambers and of umbilical edge of penultimate chamber pustulose, except for final chamber being very smooth and often polished; coiling of tests abundantly in left direction. The size ranges from 0.13 to 0.63 mm. in maximum diameter.

Remarks : - As Barker cited (1960, p. 212), Phleger, Parker and Peirson (1953, p. 20, 21) gave a full account of contradiction of taxonomy among the various species, which had been erected by authors who placed Brady's "*Pulvinulina crassa*" of the Challenger Report (1884, p. 694, pl. 103, figs. 11, 12) in the synonymy. And Phleger *et al.* assigned this species to *Globorotalia punctulata* (d'Orbigny) (= *Globorotalia puncticulata* (Deshayes)), though their identification is to be reconsidered (see also *Globorotalia hirsuta* in the present paper). Leaving aside this question, *Globorotalia oceanica* is also a species proposed by the same procedure. The Nobori form, however, is most similar to *G. oceanica* than to any other species of the above-mentioned group, such as *Globigerina crassaformis* Galloway and Wissler, *Globorotalia crassula* Cushman and Stewart, and *Globorotalia pseudocrassa* Chapman and Parr. Although further taxonomic study is necessary, the Nobori form is tentatively referred to *G. oceanica*, and its diagnosis is given above to avoid more confusion. The present form shows much variation. During ontogenic development it changes usually

in axial profile from narrowly to broadly rounded. The juvenile specimens with narrowly rounded profile resembles *Globorotalia puncticulata*, but it attains more thickness and assume a broadly rounded appearance in the adult.

Hypotypes :— IGPS coll. cat. no. 75069a–g from sample A–11.

Occurrence :— Very common throughout.

Known range :— It has been recorded only from the type locality, off the north coast of Cuba.

Globorotalia opima continuosa Blow, 1959

Globorotalia opima continuosa Blow, 1959, p. 218, 219, pl. 19, figs. 125a–c; Jenkins, 1960, p. 366, pl. 5, figs. 4a–5c.

Remarks :— This species is somewhat similar to *Globigerina pachyderma* (Ehrenberg) in appearance, but differs in having the chambers increasing successively in size, and the last chamber attaining to the maximum size instead of subequally shaped chambers in the last whorl, and a comma-shaped aperture in side view. Coiling of tests shows a strong preference to right direction. The size ranges from 0.20 to 0.34 mm. in maximum diameter.

Occurrence :— Not common, but occurs throughout.

Known range :— Blow first recorded it from the *Catapsydrax stainforthi* Zone to the *Sphaeroidinellopsis seminulina* Zone of Venezuela, but later Jenkins extended the range down to the pre-*Globoquadrina dehiscens dehiscens* Zone of Australia (=lower part of the *Globigerina ampliapertura* Zone of Trinidad (Bolli, 1957a, p. 100)).

Globorotalia scitula scitula (Brady), 1882

Pl. 26, figs. 2a–c

Pulvinulina scitula Brady, 1882, p. 716, 717 (no figure given), (*vide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960b, p. 27, 29, pl. 5, figs. 5a–c (lectotype) [written as *Pulvinulina scitula* Brady 1882 = *Globorotalia* (*Turborotalia*) *scitula* (Brady) in pl. 5].

Pulvinulina patagonica (d'Orbigny). Brady, 1884, p. 693, pl. 103, figs. 7a–c (not *Rotalina patagonica* d'Orbigny).

Globorotalia scitula Brady. Cushman, 1927, p. 175.

Globorotalia scitula (Brady). Cushman and Henbest, 1940, p. 36, pl. 8, figs. 5a–c; Bradshaw, 1959, p. 44, pl. 8, figs. 5, 6.

Globorotalia canariensis (d'Orbigny). Renz, 1948, p. 136, pl. 11, figs. 3a, b (not *Rotalina canariensis* d'Orbigny).

Globorotalia scitula scitula (Brady). Blow, 1959, p. 219, 220, pl. 19, figs. 126a–c.

Remarks :— The general characters of the Nobori specimens agree well with the diagnosis of *Globorotalia scitula* (s. s.) given by Banner and Blow (*loc. cit.*). Most of them are very small and less than 0.35 mm. in maximum diameter. Coiling of tests is mostly in right direction, left-coiled ones are found only in the samples from the lowest two horizons of the studied outcrop. The size ranges from 0.16 to 0.37 mm. in maximum diameter.

Blow (*loc. cit.*) divides *Globorotalia scitula* (s. l.) into three subspecies, *viz.*, *G. scitula scitula*, *G. scitula praescitula* and *G. scitula gigantea*. In Japan the second subspecies, a vaulted form, was found in association with *Lepidocyclina*, but the third one has not been recognized to date. Accordingly the present authors refrain from comment on the relationship of *G. scitula scitula* and *G. scitula gigantea*, and whether they may be split into the subspecific rank. For the reasons, the previous references on the larger form of *G. scitula*, which might be *G. scitula gigantea*, are excluded from the above synonym list.

Hypotype :— IGPS coll. cat. no. 75071 from sample A–7.

Occurrence :— Rare and sporadic throughout.

Known range : - The uppermost part of the *Globorotalia fohsi barisanensis* Zone to Recent.

Globorotalia subcretacea (Lomnicki), 1901

Pl. 24, figs. 8a-c

Globigerina cretacea d'Orbigny? Brady, 1884, p. 596, pl. 82, figs. 10a-c (referred to *Globigerinella subcretacea* (Chapman) by Thalmann, 1932, p. 307).

Globigerina subcretacea Lomnicki, 1901, p. 17; Asano, 1957, p. 15, pl. 1, figs. 12, 13; Graham and Militante, 1959, p. 111, pl. 18, figs. 10a-c.

Globigerina subcretacea Chapman, 1902, p. 410, pl. 36, figs. 16a, b; Galloway and Wissler, 1927, p. 44, pl. 8, figs. 2a-c.

Hastigerina (?) *subcretacea* (Lomnicki). Barker, 1960, pl. 82, figs. 10a-c.

Remarks : - Although this species has been referred to various genera, its aperture is apparently umbilical-extraumbilical in position, thus it seems appropriate to place the species under the genus *Globorotalia*. This species is distinguished by having fairly thick cancellate wall, very low spiral arrangement of the test, parallel-sided in side view. The aperture is umbilical-extraumbilical in position and possesses a narrow lip. Last whorl consists usually of four to five subspherical chambers increasing rapidly in size. It differs from *Globorotalia acostaensis* in having more rapidly enlarging chambers, less distinct apertural lip, and less circular equatorial profile. The coiling of the tests is in right direction. The size ranges from 0.24 to 0.1 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75072 from sample A-7.

Occurrence : - Rather rare.

Known range - Lomnicki first recorded this species from the upper Miocene. It ranges probably from the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent.

Globorotalia tosaensis Takayanagi and Saito, n. sp.

Pl. 28, figs. 11a-12c

Test free, spiral side flat to slightly concave, umbilical side strongly convex, with rather deep and open umbilicus, periphery subacute, peripheral outline only slightly lobulate in adult, but more lobulate in younger tests; chambers low and broad on spiral side, increasing gradually in size as added, commonly with four chambers in final whorl, chambers on umbilical side sloping sharply outward to periphery from rounded umbilical shoulder, giving test a conical appearance; sutures somewhat indistinct on spiral side, gently curved, flush or very slightly depressed, sutures on umbilical side depressed, nearly radial in early part of whorl, later becoming somewhat sigmoidal; wall calcareous, finely perforate, surface generally spinose, especially in early chambers and umbilical shoulders of later chambers except for last formed one on umbilical side, resulting in a granular appearance; peripheral margin in early chambers rather smooth and transparent in appearance, but not forming a keel or marginal thickening; aperture a very low interiomarginal, umbilical-extraumbilical arch, bordered above by a narrow lip.

Maximum diameter of holotype 0.41 mm., maximum thickness 0.34 mm. Maximum diameter of paratype 0.39 mm., maximum thickness 0.29 mm.

Types : - Holotype, IGPS coll. cat. no. 75073 from sample A-17; paratype, IGPS coll. cat. no. 75077 from sample A-18.

Remarks : - *Globorotalia tosaensis* Takayanagi and Saito, n. sp. resembles *Globorotalia truncatulinooides* (d'Orbigny) in general appearance, but has less chambers in a whorl, and less acute periphery which is not keeled or thickened. In addition, *G. truncatulinooides* has an imperforate layer on the thickened margins of the last few chambers, besides the peripheral keel. These differences in character between both species are very similar to those among the subspecies of *Globorotalia fohsi* Cushman as pointed out by Banner and Blow (1959,

p. 21). They assumed the gradation from forms without keels to those with pseudocarinae, and from these to forms with true carinae is a distinct character generally seen in the evolutionary series of the Globorotaliids. The present relationship between *G. tosaensis* and *G. truncatulinoides* may be an analogous case. The latter species appears to have developed from *G. tosaensis* by attaining the characters mentioned above.

***Globorotalia tumida* (Brady), 1877**

Pl. 24, figs. 6a-c

Pulvinulina menardii (d'Orbigny) var. *tumida* Brady, 1877, p. 535 (no figure given); Banner and Blow, 1960b, p. 26, 27, pl. 5, figs. 1a-c (lectotype) [written as *Pulvinulina menardii* var. *tumida* Brady 1877 = *Globorotalia tumida* (Brady) in pl. 5].

Pulvinulina tumida Brady. Brady, 1884, p. 692, p. 103, figs. 4-6.

Globorotalia tumida (Brady). Cushman, 1927, p. 91, pl. 19, fig. 12 (after Brady); Phleger, Parker and Peirson, 1953, p. 22, 23, pl. 3, figs. 3, 6-8, 10, 11; Bolli, Loeblich and Tappan, 1957, p. 41, 42, pl. 10, figs. 2a-c; Todd, 1957, p. 279 (table), pl. 80, figs. 4a, b; Bradshaw, 1959, p. 47, pl. 8, figs. 9, 13.

Globorotalia menardii tumida (Brady). Chang, 1959a, p. 69, pl. 5, figs. 12a-13c.

Remarks: - The forms referred to this species is characterized by the tumid, nearly equally biconvex test with a periphery furnished with a massive, imperforate carina, being more developed on the earlier part of the last whorl. The aperture is interiomarginal, umbilical-extraumbilical in position, and possesses a marked lip. The apertural lip, extending usually from near the umbilicus to near the peripheral carina of the early part of the last whorl, is very thick, broad and linguiform, and its margin is decorated by a massive, granular, imperforate shell substance just the same as that composing the carinae. In addition, it often protrudes over the earliest chamber of the last whorl, so that the umbilicus becomes to be obscured. Further most of the present specimens have five chambers in the last whorl, and the chambers increase progressively in size, and the final chamber occupies about one third of the test. The above-mentioned features concerning the apertural lip and chambers are somewhat different in comparing with the syntype or lectotype illustrated by previous authors (Bolli *et al.*; Banner and Blow, *loc. cit.*). But these differences may be caused by local divergence due to the ecological condition, and not be an essential character to distinguish one from the other. The coiling of the tests is dominantly in the left direction. The size ranges from 0.47 to 0.68 mm. in maximum left diameter.

Hypotype: - IGPS coll. cat. no. 75074 from sample A-3.

Occurrence: - Sporadically found.

Known range: - Probably the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent.

Family Globigerinidae

Subfamily Globigerininae

Genus *Globigerina* d'Orbigny, 1826

***Globigerina angustiumbilitata* Bolli, 1957**

Pl. 28, figs. 3a-c

Globigerina ciproensis angustiumbilitata Bolli, 1959a, p. 109, pl. 22, figs. 12a-13c.

Globigerina angustiumbilitata (Bolli). Blow, 1959, p. 172, pl. 7, figs. 33a-34.

Globigerina angustiumbilitata Bolli. Jenkins, 1960, p. 350, pl. 1, figs. 2a-c.

Remarks: - The Nobori specimens are characterized by the four to five spherical chambers of the last whorl, radially depressed sutures on both sides, and a small umbilicus with a lipped aperture.

In this respect they are identical with *Globigerina angustiumbilitata*. Compared with

the typical ones, the present specimens are relatively larger in the last chamber, and some but not all of them show rather thick apertural lip. The coiling of the tests is generally towards the right, with three exceptions in 17 cases showing a slight preference to the left.

In addition to the above mentioned forms of *G. angustiumbilocata*, some variants with an aberrant chamber are found in the Nobori material. In the present study they are distinguished from the typical as a variety of this species, which description is given in the following (also see the early part of the systematic part). The size ranges 0.17 to 0.32 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75027 from sample A-11.

Occurrence : - Very common.

Known range : - The *Catapsydrax stainforthi* Zone to the *Globigerina bulloides* Zone.

***Globigerina angustiumbilocata* Bolli, var.**

Pl. 28, figs. 4a-9b

The variety differs from the typical in possessing an aberrant chamber supplemented to the final one. The chamber varies from a large thick lip-like to a bulla-like one covering the umbilicus, some of which are illustrated in the plate. Because of the presence of the bulla-like chamber it was once assumed to be allied to *Globorotaloides suteri* Bolli. However, precise examination indicates that it is not conspecific with that species but with *Globigerina angustiumbilocata*. It differs from the former species in retaining throughout a *Globigerina* stage except for the final chamber. In the manner of transformation of the final chamber there seems to be three main types. The first type is a large, simple apertural lip-like form attached to the penultimate chamber, and its aperture is naturally umbilical to extraumbilical in position. The second is an elongate and modified one extending onto the umbilical side to cover more or less the umbilical region, and the aperture is represented by one or more arched secondary apertures at the umbilical margin of the final chamber (*Globigerinita* type). The number of secondary apertures changes with the mode of fusing of the umbilical extension of the final chamber with the umbilical surface. The third type is a large and inflated form with two or more secondary apertures (*Globigerinita*-like type). In some extreme cases one of the secondary apertures is also found on the spiral side. In short, the position and number of such secondary apertures seem to change with the shape and position of the umbilical extension of the final chamber. All gradations are found between the typical *G. angustiumbilocata* and these variants. Most of tests are right coiling. The size ranges from 0.17 to 0.34 mm. in maximum diameter.

Hypotypes : - Hypotype (figs. 4a-c), IGPS coll. cat. no. 75028 from sample A-11; hypotype (figs. 5a-8b) IGPS coll. cat. no. 75029a-d from sample A-11; hypotype (figs. 9a, b), IGPS coll. cat. no. 75030 from sample A-9.

Occurrence : - Generally common throughout.

***Globigerina apertura* Cushman, 1918**

Pl. 24, figs. 9a-c

Globigerina apertura Cushman, 1918, p. 57, pl. 12, figs. 8a-c; Galloway and Wissler, 1927, p. 40, pl. 7, figs. 20a, b; Hamilton, 1953, p. 220, 221, pl. 32, fig. 12; Blow, 1959, p. 172, 173, pl. 8, figs. 35a, b; Dieci, 1959, p. 88, 89, pl. 7, figs. 20a, b.

Remarks : - This species is easily distinguished from the other related forms in having a larger, high-arched aperture with a distinct rim. The tests of the observed specimens show random coiling. The size ranges from 0.24 to 0.36 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75031 from sample A-1.

Occurrence : - Rather common.

Known range:—Upper part of *Globorotalia cultrata cultrata* Zone to *Sphaeroidinellopsis seminulina* Zone. It was exceptionally recorded from the Pleistocene San Pedro group in California (Galloway and Wissler, *loc. cit.*). Recent records (Cushman and Valentine, 1930, p. 28), are not reliable owing to lack of illustrations.

***Globigerina bulbosa* LeRoy, 1944**

Pl. 26, figs. 5a–c

Globigerina bulbosa LeRoy, 1944, p. 39, pl. 3, figs. 26, 27; Blow, 1959, p. 174, 175, pl. 9, figs. 37a–c.

Remarks:—The small form comprising four chambers in the last whorl with distinctly bulbous final chamber is referred to this species. The Nobori specimens are much smaller compared with the type illustrations given by LeRoy, and show a slight, thin apertural lip. These features well correspond with the Venezuelan specimens of Blow rather than the typical. The coiling of the tests is random. The size ranges from 0.15 to 0.17 mm.

Hypotype:—IGPS coll. cat. no. 75032 from sample A-7.

Occurrence:—Sporadical.

Known range:—The lower part of the *Globorotalia fohsi lobata* Zone to the *Sphaeroidinellopsis seminulina* Zone.

***Globigerina bulloides* d'Orbigny, 1826**

Pl. 24, figs. 12a–c

Globigerina bulloides d'Orbigny, 1826, p. 277 (no figure given), (*vide* Ellis and Messina, 1940 *et seq.*); Brady, 1884, p. 593, pl. 79, figs. 7a–c; Bolli, Loeblich and Tappan, 1957, p. 31, pl. 4, figs. 1a–c; Blow, 1959, p. 175, 176, pl. 9, figs. 38a–c; Dieci, 1959, p. 89, 90, pl. 7, fig. 21; Banner and Blow, 1960b, p. 3, 4, pl. 1, figs. 1a–c, 4a–c (lectotype designated).

Remarks:—This species differs from *Globigerina parabulloides* Blow, *G. praebulloides* Blow, and *G. diplostoma* Reuss in having a fairly large, arched aperture without a lip. The Nobori specimens show nearly random coiling, but with a slight preference to the left. The size ranges from 0.25 to 0.47 mm. in maximum diameter.

Hypotype:—IGPS coll. cat. no. 75033 from sample A-7.

Occurrence:—Not so common, but found throughout.

Known range:—The middle part of the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent.

***Globigerina conglomerata* Schwager, 1866**

Pl. 24, figs. 10a–c

Globigerina conglomerata Schwager, 1866, p. 255, pl. 7, fig. 113; Banner and Blow, 1960b, p. 7, 8, pl. 2, figs. 3a–c (neotype).

Remarks:—Rare but typical specimens in the present material are referred to this species. It has a coarsely and uniformly perforated thick wall. The surface of the test is granular and cancellate and furnished with strong short spines along the margins of umbilicus. Having no apertural lip, rim or tooth, this species differs from the genus *Globoquadrina*. The equatorial profile is subcircular and moderately embracing. Coiling of the test is probably random in direction. The size ranges from 0.39 to 0.49 mm. in maximum diameter.

Hypotype:—IGPS coll. cat. no. 75034 from sample A-1.

Occurrence:—Very rare.

Known range:—The *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to probably Recent.

***Globigerina diplostoma* Reuss, 1850**

Pl. 24, figs. 11a-c

Globigerina diplostoma Reuss, 1850, p. 373, pl. 47, figs. 9, 10, pl. 48, fig. 1, (*fide* Ellis and Messina, 1940 *et seq.*).

Globigerina concinna Reuss. Cushman, 1946 (part), p. 20, pl. 3, figs. 11a-12 (reproduced from Reuss, 1850) [not pl. 3, figs. 10a, b (=reproduced type figures of *Globigerina concinna* Reuss); pl. 4, figs. 11-13 (= *Globigerina concinna* Reuss), 14, 15 (= *Globigerina bulloides* d'Orbigny)].

Remarks : - In the Nobori specimens a form very similar to *Globigerina bulloides* d'Orbigny in general appearance except for a distinct apertural lip or thickened rim, is commonly found. Examining the topotype specimens of the latter species, Banner and Blow (1960b, believed that they are conspecific. However, so far as the type figures given by Reuss are concerned, it is obvious that *G. diplostoma* possesses a distinct lip or thickened rim at the aperture, though Reuss himself did not make mention of it.

The forms referred to *G. diplostoma* show four chambers in the last whorl of a low trochospiral test with much lobulate periphery in equatorial profile. The chambers are about nine, inflated, subglobular, and slightly embracing. The sutures are depressed, and nearly radial on both umbilical and spiral sides. The umbilicus is open and deep. The aperture is a moderately large, symmetrical arch in umbilical portion, and has a distinct, rather thick lip or thickened rim which often fuse with the penultimate apertural one and assumes a large hemi-circular aperture. Such apertural lip-like feature is also observed in the earlier stage of the ontogenetic development. The wall is very finely hispid. The final chamber often assumes an abortive shape and gives a subtriangular appearance. The abortive chamber has usually thinner and less hispid wall than the precedings, but always with a distinct lip. Therefore the statement (Blow, 1959, p. 176; Banner and Blow, 1960b, p. 4) that specimens of *Globigerina bulloides* which possess an aberrant final chamber appear similar to *G. diplostoma* seems to be inadequate.

The coiling of the tests shows a strong preference to the left direction in general. The size ranges from 0.26 to 0.46 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75035 from sample A-17.

Occurrence : - Common throughout.

Known range : - Exact range unknown, but probably Miocene to Recent.

***Globigerina druryi* Akers *decoraperta* Takayanagi and Saito, n. subsp.**

Pl. 28, figs. 10a-c

Test small, trochospiral, equatorial periphery lobulate, axial periphery broadly rounded; chambers spherical, about 12, arranged in about three whorls, increasing rather rapidly in size, last chamber somewhat protruded in radial direction; sutures rather distinct, depressed, nearly radial on both sides; wall calcareous, perforate, surface pitted; aperture a medium-sized, fairly high, symmetrical arch with a slightly thickened rim, interiomarginal and umbilical in position, placed rightly on opposite sides of antepenultimate chamber. Coiling of the tests is nearly random, but with slight preference to left in direction.

Maximum diameter of holotype 0.26 mm., thickness 0.19 mm. Other specimens range from 0.17 to 0.27 mm. in maximum diameter.

Holotype : - IGPS coll. cat. no. 75070 from sample A-16.

Remarks : - The new subspecies is distinguished from the typical *Globigerina druryi* by having a larger, high arched aperture with thickened rim instead of thin lip.

Occurrence : - Rather common.

***Globigerina eamesi* Blow, 1959**

Pl. 26, figs. 7a-c

Globigerina eamesi Blow, 1959, p. 176, 177, pl. 9, figs. 39a-c; Jenkins, 1960, p. 350, 351, pl. 1, figs. 7a-c.

Remarks: - The specimens referable to *Globigerina eamesi* are comparatively smaller than the typical one of Blow. This species is characterized by having rough to spinose wall, high trochospiral chamber arrangement, and narrow elongate slit-like aperture with a thin lip. The coiling of the tests is uncertain. The size ranges 0.22 to 0.29 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75036 from sample A-16.

Occurrence: - Very rare.

Known range: - Pre-*Globoquadrina dehiscens dehiscens* Zone of Jenkins (= *Globigerina ampliapertura* Zone of Bolli) to *Sphaeroidinellopsis seminulina* Zone.

***Globigerina falconensis* Blow, 1959**

Pl. 24, figs. 13a-c

Globigerina falconensis Blow, 1959, p. 177, pl. 9, figs. 40a-c, 41; Todd in Cole et al., 1960, p. 105, pl. 13, figs. 1a, b.

Remarks: - This species is distinguished from the allied forms in having a prominent apertural lip. The coiling of the tests is random in direction. The size ranges from 0.20 to 0.36 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75037 from sample A-12.

Occurrence: - Rather common.

Known range: - *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone to the *Globigerina bulloides* Zone or higher (?).

***Globigerina foliata* Bolli, 1957**

Pl. 25, figs. 1a-c

Globigerina foliata Bolli, 1957a, p. 111, pl. 24, figs. 1a-c; Blow, 1959, p. 177, 178, pl. 10, figs. 42a-c; ?
Globigerina foliata Bolli. Jenkins, 1960, p. 351, pl. 1, figs. 9a-c.

Remarks: - This species shows spherical and well-separate chambers increasing rapidly in size as added. The chamber arrangement is low trochospiral. The coiling of the tests is random in direction. The size ranges from 0.17 to 0.36 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75038 from sample A-15.

Occurrence: - Rather rare.

Known range: - Probably from the *Catapsydrax dissimilis* Zone to the upper part of the *Sphaeroidinellopsis seminulina* Zone. Jenkins (*loc. cit.*) recorded this species from his pre-*Globoquadrina dehiscens dehiscens* Zone (= *Globigerina ampliapertura* Zone of Bolli) to *Globorotalia menardii miotumida* Zone. However judging from his illustrations, the Australian forms appear to have an apertural lip and to be closely similar to *Globigerina falconensis*. For such reason, Jenkins' species is herein included into the synonymy with some doubt, and the record of occurrence prior to the *Catapsydrax dissimilis* Zone is reserved for further study.

***Globigerina glutinata* Egger, 1895**

Pl. 27, figs. 13a-c, 17a-c

Globigerina glutinata Egger, 1895, p. 371 (179), pl. 13, figs. 19-21; Rhumbler, 1909 (part), p. 148, 149, pl. 29, figs. 15-24, 26, pl. 34, fig. 1 (not pl. 29, figs. 14, 25).*Globigerinatella* aff. *insueta* Cushman and Stainforth. Bronnimann, 1950, p. 82, pl. 14, fig. 11.

- Globigerinita naparimaensis* Bronnimann, 1951a, (part), p. 18, text-figs. 3-14 (not text-figs. 1, 2); Bolli, Loeblich and Tappan, 1957 (part), p. 37, 38, pl. 8, figs. 2a-c (not figs. 1a-c).
Globigerinita glutinata (Egger). Phleger, Parker and Peirson, 1953, p. 16, pl. 2, figs. 12-15; Bradshaw, 1959, p. 40, pl. 7, figs. 7, 8.
Globigerinita incrusta Akers, 1955, p. 655, pl. 65, figs. 2a-d.
Globigerina juvenilis Bolli, 1957a, p. 110, pl. 24, figs. 5a-6; Blow, 1959, p. 178, pl. 10, figs. 43a, b; Jenkins, 1960, p. 351, 352, pl. 1, figs. 10a-11c.
Tinophodella ambitacrena Loeblich and Tappan, 1957, p. 114-116, figs. 2a-3c.
Globigerinita naparimaensis naparimaensis Bronnimann. Blow, 1959, p. 206, pl. 15, figs. 99a-c.
Globigerinita naparimaensis incrusta (Akers). Blow, 1959, p. 206, 207, pl. 15, figs. 100, 101.
Globigerinoides glutinata (Egger). Bandy, 1960a, p. 2.

Remarks: - The small and thin-walled forms are found to show usually three and a half inflated chambers in the last whorl, a small umbilicus, a low elongate umbilical aperture with a thin lip, and often the umbilical region is covered with an irregular shaped bulla with numerous accessory apertures. These features coincide well with the form previously referred to *Globigerina glutinata* by several authors. As Phleger *et al.* (*loc. cit.*) pointed out, Egger's illustrations are poor and he does not mention about the variation of the species. But Rhumbler's interpretation has been followed by adopting the opinion of Phleger *et al.* in this identification. In the Nobori materials a few specimens are found with secondary apertures just above the junction of the last intercameral suture and spiral suture on the spiral side. This feature has been recognized by some authors (Phleger *et al.*, Bradshaw, *loc. cit.*), and for such reason this species may be referable to the genus *Globigerinoides* (e. g. Bandy, *loc. cit.*). However, it is noticeable that the secondary aperture is not multiple as in *Globigerinoides* but always single, and is not present on the specimens with supplementary chambers (bulla) on the umbilical sides. Thus this species is not a true *Globigerinoides*. Owing to the frequent occurrence of the bullae the species has been referred to the genus "*Globigerinita*" (of authors = *Tinophodella* of Loeblich and Tappan). According to Phleger *et al.*,

"The occurrence of the secondary chambers is a variable feature; in some assemblages they are found in a large percentage of the specimens whereas in others they may be quite subordinate. The species may be easily defined, however from the general characters of the test."

Certainly the occurrence of the bulla is a remarkable feature in the present material, too. But the forms with bullae are not distinguishable from the forms without bullae in general outline, mode of coiling, wall texture, apertural character *etc.*, when the bullae are removed. Therefore both forms do not differ from one another in the principal shell construction but only in the presence or absence of bullae which is variable in grade of development.

Accordingly concentration must be given to the meaning of the bullae. On its physiological meaning, Hofker (1959, 1960) considered that the bulla is formed at the time of sporulation. Bandy followed him and added (1960a, p. 2):

"Fistulose and secondary apertural structures are not consistently present and they are mostly the simple expression of a reproductive phase or and ecologic manifestation; thus, they should not be used to establish a different generic category (*Globigerinita*) in planktonic Foraminifera."

Although Hofker's hypothesis has not been biologically verified, it seems to be a most probable interpretation. Meanwhile, the chronological relationship between the form with bulla and the one without bulla is as follows. According to the records by Bolli (1957a) and Blow (1959), the first appearance of *Globigerina juvenilis* (without bulla) is in the *Globorotalia kugleri* Zone, *Globigerinita naparimaensis* (with bulla) in the superjacent *Catapsydrax dissimilis* Zone, and *Globigerinita incrusta* in the higher superjacent *Catapsydrax stainforthi* Zone, though all the forms are herein referred to *Globigerina glutinata*. If these records are reliable, Blow's interpretation on evolutionary lineage from *Globigerina juvenilis* via *Globigerinita incrusta* to *Globigerinita naparimaensis* is contradictory to their re-

relationship chronologically as well as biologically (see the systematic part). Nevertheless they also assumed these forms as a closely allied group. Accordingly if it is necessary to separate them into specific or subspecific rank, it seems to be rather adequate to refer *juvenilis* to the lower population without bulla, *naparimaensis* to the middle one including the *juvenilis*-type and the *naparimaensis*-type, and *incrusta* to the upper one including the three types. But such chronologic relationship has not been settled in Trinidad and Venezuela.

The present authors believe the bulla to be an inconsistent character for definition of specific as well as generic categories, though its meaning and function require further research in ecology and physiology.

At the time of establishment of *Globigerina juvenilis*, Bolli did not make comparison with *Globigerina glutinata*, but mentioned that it represented possibly the juvenile stage of *Globigerina naparimaensis*. Further Loeblich and Tappan (*loc. cit.*) included a part of *Globigerina glutinata* of Rhumbler and of Phleger *et al.*, and paratypes of *Globigerinita naparimaensis* Bronnimann (with distinct bulla) into the synonymy of their *Tinophodella ambitacrena*. However these species together with the majority of forms excluded by Loeblich and Tappan are included here into the synonymy of *Globigerina glutinata* based on the above consideration. The holotype of *Globigerinita naparimaensis* seems to be conspecific with the present species, but it is reserved because of the abnormal appearance of its final chamber. Akers (*loc. cit.*) distinguished *Globigerinita incrusta* from *Globigerinita naparimaensis* by the accessory apertures of the bulla being restricted to the contact with the sutures of the primary chambers, and smaller size. But the bulla itself is essentially variable in form, and both *incrusta*- and *naparimaensis*-type (= *ambitacrena*-type) have been found in association with the type without bulla in foreign regions other than the Nobori formation. Moreover the bulla of the *incrusta*-type is not always confined to the small sized individuals. Furthermore, Blow (*loc. cit.*) observed an interesting phenomenon found during the examination of the samples from the Pozón-El Mene Road section. He wrote (p. 206):

“it was found that samples from a particular but fairly short interval often had a predominance of either *Globigerinita naparimaensis naparimaensis* or *Globigerinita naparimaensis incrusta* with a corresponding reduction in the prevalence of the other subspecies. This relative abundance is then often reversed in succeeding or preceding intervals. Furthermore, some intervals show forms apparently transitional from *Globigerina juvenilis* Bolli to *Globigerinita naparimaensis incrusta* but in other intervals these transitional form are either absent or scarce.”

Basing upon the above phenomenon, he established his hypothesis on the evolutionary lineage, but these forms belong to a single species. Accordingly *Globigerinita incrusta* is also included into the synonymy.

The form with bulla is here tentatively separated from the typical *Globigerina glutinata* as a variety of no taxonomic value, for the purpose of quantitative analysis.

The coiling of the tests is nearly random. The size ranges from 0.13 to 0.29 mm. in maximum diameter.

Hypotypes: - IGPS coll. cat. no. 75039a, b from sample A-11.

Occurrence: - Common throughout.

Known range: - The *Globorotalia kugleri* Zone to Recent.

***Globigerina glutinata* Egger, var.**

Pl. 27, figs. 14a-16c

As mentioned in the foregoing item, *Globigerina glutinata* with the bulla is treated as a variety of the species. The tests of the present species show commonly a random coiling, but exhibit a strong preference for right coiling in the specimens from upper

part of the studied outcrop. The size ranges from 0.12 to 0.22 mm. in maximum diameter.
Hypotypes: - IGPS coll. cat. no. 75061 from sample A-11; 75062a, b from sample A-17.
Occurrence: - Abundant throughout.

***Globigerina nepenthes* Todd, 1957**

Pl. 25, figs. 2a-c

Globigerina nepenthes Todd, 1957, p. 301, 302, pl. 78, figs. 7a, b; Bolli, 1957a, p. 111, pl. 24, figs. 2a-c; Blow, 1959, p. 178, 179, pl. 8, figs. 44, 45.

Remarks: - The Nobori specimens have been compared with the topotypes of this species from the Donni formation, Saipan Is. They show relatively thinner and smaller tests than the topotypes. This species is characterized by having its final chamber protruding and the others tending to be more strongly embracing. The coiling of the tests is random. The size ranges from 0.17 to 0.34 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75040 from sample A-4.

Occurrence: - Rather rare.

Known range: - The *Globorotalia mayeri*/*Globigerina nepenthes* Subzone to *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone.

***Globigerina pachyderma* (Ehrenberg), 1861**

Pl. 26, figs. 4a-c

Aristerospira pachyderma Ehrenberg, 1861, p. 276, 277, 303 (*vide* Ellis and Messina, 1940, *et seq.*); Ehrenberg, 1873, p. 386, pl. 1, fig. 4. (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina pachyderma (Ehrenberg). Brady, 1884, p. 600, pl. 114, figs. 19, 20; Cushman and Todd, 1947, p. 70, pl. 16, figs. 27, 28; Bradshaw, 1959, p. 36, pl. 6, figs. 20-23; Bé, 1960, p. 64-68, text-fig. 1; Bandy, 1960b, p. 671-681, text-fig. 1.

Remarks: - The specimens referred to this species are characterized by the equatorially subquadrate test consisting of about 11 chambers tightly coiled in two to two and a half whorls. In the last whorl about four chambers are visible, and the aperture at the interiomarginal portion of the last chamber is usually a long low arch or slit extending from umbilicus to near periphery and bordered by a distinctly thickened rim. In its ontogenetic development, the present form shows a remarkable change in its features as already pointed out by Bé (*op. cit.*). According to him, distinctly spherical chambers become progressively large and a relatively large aperture extends from umbilicus to periphery, but no prominent apertural ridge is visible in the early stages; in the final stage, subequally-sized chambers in the last whorl appear to coalesce due to crystalline thickening of the test, and the final chamber is equal in size or smaller than the penultimate chamber, in addition, the aperture with a prominent ridge is constricted and directed towards the umbilicus. These features well correspond with the Nobori specimens.

Banner and Blow (1960b, p. 4, 5) assumed *Globigerina pachyderma* of Brady (*loc. cit.*) to be a synonym of *Globigerina bulloides* d'Orbigny var. *borealis* Brady, and designated the lectotype of the latter species. In the description of the lectotype they stated that:

"The last formed apertures in forms with abortive final chambers are as variable in extent, size and shape as are the abortive chambers themselves; in such a form the aperture may be umbilical-extra-umbilical in position giving a *Turborotalia*-like appearance to the test. However, a study of the ontogenetic development of a form with an abortive final chamber and associated extraumbilical aperture shows that the earlier chambers possess purely umbilical apertures and the features is limited only to the final stage of development."

On the contrary, the Nobori specimens show that the apertures of the early chambers are not purely umbilical but a high arch extending from the umbilicus halfway to the periphery. Laying stress upon such difference, the present form is tentatively identified as *G.*

pachyderma previously referred to by many authors and *G. bulloides* var. *borealis* is retained, though the probability is reserved that it may be conspecific.

Coiling of the tests is predominantly towards the right. It seems to be adequate to compare this feature with the results of some authors (Ericson, 1959; Bandy, 1960b, etc.). Ericson stated, in his study on the distribution of *G. pachyderma* in the north Atlantic Ocean, that right coiling is dominant in specimens living in the water lying south of the April 7.2°C isotherm. Furthermore Bandy cited Green's contribution recording that the Recent right coiling population occur in tropical and temperate regions of the world. These facts may be in harmony that this species occurs in association with many typical warm water species in the Nobori formation. The size ranges from 0.17 to 0.31 mm. in maximum diameter.

Hypotype:—IGPS coll. cat. no. 75041 from sample A-11.

Occurrence:—Generally, common, and especially rich in the middle part of the studied outcrop.

Known range:—It has not been recorded from the Miocene, being previously known only from Pliocene to Recent.

Globigerina parabolloides Blow, 1959

Pl. 25, figs. 3a-c

Globigerina parabolloides Blow, 1959, p. 179, 180, pl. 10, figs. 46a-c.

Remarks:—This species is distinct from the allied forms as *G. bulloides* and *G. praebulloides*, in having a smaller umbilicus, a smaller aperture with a distinct but narrow rim or lip, and an elongate equatorial profile, as defined by Blow (*loc. cit.*). The aperture of the Nobori specimens is often cemented with clayey material, but its rim or lip is easily recognized in wet condition. The coiling of the tests is random, but with some preference towards the left. The size ranges from 0.26 to 0.41 mm. in maximum diameter.

Hypotype:—IGPS coll. cat. no. 75042 from sample A-16.

Occurrence:—Not common but found throughout the samples examined.

Known range:—The *Globorotalia mayeri*/*Globorotalia linguaensis* Zone to the *Globigerina bulloides* Zone.

Globigerina praebulloides Blow, 1959

Pl. 25, figs. 4a-c

Globigerina praebulloides Blow, 1959, p. 180, 181, pl. 8, figs. 47a-c, pl. 9, fig. 48; Jenkins, 1960, p. 352, pl. 2, figs. 1a-c.

Remarks:—The Nobori specimens agree well with Blow's species. It is characterized by having an elongate equatorial profile, slightly appressed chambers which increase rapidly in size, and fairly low arched aperture without lip. This species is closely related to *Globigerina woodi*, but it differs, as noted by Jenkins, in having smoother test ornamentation, not so depressed suture as to become U-shaped, and thinner test. This species also differs from *G. parabolloides* in having a less elongate equatorial profile, and not so restricted umbilical aperture, without distinct lip. The coiling of the tests is random. The size ranges from 0.24 to 0.43 mm. in maximum diameter.

Hypotype:—IGPS coll. cat. no. 75043 from sample A-18.

Occurrence:—Rather common.

Known range:—The pre-*Globoquadrina dehiscens dehiscens* Zone of Jenkins (= *Globigerina ampliapertura* Zone of Bolli) to the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone.

***Globigerina trilocularis* Deshayes, 1832**

Pl. 25, figs. 5a-c

Globigerina trilocularis d'Orbigny, 1826, p. 277 (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina trilocularis d'Orbigny (? : original designation of Deshayes unknown). Deshayes, 1832, p. 170 (*vide* Ellis and Messina, 1940 *et seq.*).

Globigerina trilocularis d'Orbigny. Fornasini, 1897, pl. 1, figs. 6-7a, p. 12, text-fig. (*vide* Ellis and Messina, 1940 *et seq.*).

Test low trochospiral with three chambers in last whorl, usually only three chambers visible in umbilical side; equatorial periphery lobate and profile subtriangular; chambers globular, inflated, increasing rapidly in size as added, large proportions of test occupied by last three chambers; aperture a low arch to sometimes an elongate slit, with a thin narrow lip; wall calcareous, perforate, thin and fragile, covered with fine spine.

Remarks : - Because of having no accessory aperture on the spiral side, this species belongs to the genus *Globigerina* not to *Globigerinoides*.

Under the name of *Globigerina trilocularis*, various forms have been recorded by different authors. To avoid confusion with those forms, the diagnosis of the present specimens is given.

According to the citation by Ellis and Messina (1940 *et seq.*), it seems that the first publication of this name by d'Orbigny (1826) has no taxonomic status. The first description applicable to this species seems to be that given by Deshayes in 1832. Consequently, although Fornasini published a description and the type figures of this taxon in 1897, the authorship of this species seems to belong not to him but to Deshayes. Further investigations as to the authorship of this taxon, could not be done by the present authors because of the inaccessibility of the type descriptions above cited. Apart from the problems discussed in the foregoing lines, the specimens referred to this species are closely related to the figured types of Fornasini.

This species differs from *G. woodi* in having thin and fragile wall, less arched aperture with thin lip, and less depressed suture. It differs also from *G. bulloides* in having a less arched and restricted aperture usually with thin lip, and a subtriangular, not sub-circular, equatorial profile. The coiling of the tests is random. The size ranges from 0.19 to 0.42 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75044 from sample A-5.

Occurrence : - Common.

Known range : - The total range of this species is not certain, but it is commonly seen in the Pliocene and Pleistocene deposits of Japan.

***Globigerina woodi* Jenkins, 1960**

Pl. 25, figs. 6a-c

Globigerina cf. trilocularis d'Orbigny. Bolli, 1957a, p. 110, pl. 22, figs. 8a-9c.

Globigerina woodi Jenkins, 1960, p. 352, pl. 2, figs. 2a-c.

Remarks : - The sutures of this species are radial and depressed on both umbilical and spiral sides, and often become distinctly U-shaped in specimens with thicker test. The wall is rather thick and usually coarsely pitted. In these features this species is easily distinguished from the other related forms as *Globigerina praebulloides* and *Globigerina trilocularis*. The coiling of the tests is random. The size ranges from 0.26 to 0.34 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75045 from sample A-16.

Occurrence : - Rather common.

Known range : - The *Catapsydrax dissimilis* Zone to *Globorotalia menardii miotumida* Zone

of Jenkins (= *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone) and probably higher in the geological column.

Genus *Globoquadrina* Finlay, 1947

Globoquadrina altispira altispira (Cushman and Jarvis), 1936

Pl. 25, figs. 7a, b

Globigerina altispira Cushman and Jarvis, 1936, p. 5, pl. 1, figs. 13a-c, 14; Bermudez, 1949, p. 277-278, pl. 21, fig. 43; Hamilton, 1953, p. 220, pl. 30, figs. 29, 30; Hamilton and Rex, 1959, p. 791, pl. 252, fig. 7.

Globoquadrina altispira (Cushman and Jarvis). Todd *et al.*, 1954, p. 677; Bolli, Loeblich and Tappan, 1957, p. 32, pl. 5, figs. 5a-c; Todd, 1957, p. 279 (table), pl. 79, figs. 11a, b; Chang, 1958, p. 52, pl. 4, figs. 7a, b; Chang, 1959a (part), p. 62, pl. 2, figs. 6-8c (not 9a-c); Todd *in* Cole *et al.*, 1960, p. 107, pl. 13, figs. 3-7.

Globoquadrina altispira altispira (Cushman and Jarvis), Bolli, 1957a, p. 11, pl. 24, figs. 7a-8b; Blow, 1959, p. 183, pl. 8, figs. 51a-c; Jenkins, 1960, p. 355, pl. 3, figs. 5a-c.

Remarks : - A single specimen with fairly high spired chamber arrangement is referred to this species. The coiling of the test is towards the right. The size of the test is 0.32 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75046 from sample A-9.

Occurrence : - Very rare.

Known range : - The *Catapsydrax stainforthi* Zone to *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone or higher (?).

Bolli (1957a) and Blow (1959) recorded the range of this species to be about the top of *Globorotalia fohsi* Zone in its upper limit, but in the present and the Donni material, this species occurs fairly commonly with *Globigerina nepenthes*. It seems, therefore, that the range of this species is longer in the Pacific regions than in the Mid-American regions. But further investigation is needed in this connection.

Globoquadrina altispira globosa Bolli, 1957

Pl. 25, figs. 8a, b

Globoquadrina altispira globosa Bolli, 1957a, p. 111, 112, pl. 24, figs. 9a-10c; Blow, 1959, p. 183, pl. 11, figs. 52a-c.

Globoquadrina altispira (Cushman and Jarvis). Chang, 1959a (part), p. 62, pl. 2, figs. 9a-c.

Remarks : - This species differs from *G. altispira altispira* by having more globular, less axially elongate chambers and low spiral arrangement in general. The coiling of the tests is towards the left. The size ranges from 0.29 to 0.31 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75047 from sample A-1.

Occurrence : - Very rare. Found only in the lower part of the outcrop.

Known range : - The *Catapsydrax dissimilis* Zone to the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone.

Globoquadrina venezuelana (Hedberg), 1937

Pl. 25, figs. 9a-c

Globigerina venezuelana Hedberg, 1937, p. 681, pl. 92, figs. 7a, b; Cushman and Stainforth, 1954, p. 67, pl. 12, figs. 13a-b; Bermudez, 1949, p. 280, pl. 21, figs. 39, 40; Phleger, Parker and Peirson, 1953, p. 14, pl. 1, figs. 24, 25; Bolli, 1957a, p. 110, pl. 23, figs. 6a-8b; Bolli, 1957b, p. 164, pl. 35, figs. 16a-17; Chang and Yen, 1958, p. 50, pl. 3, figs. 9a-c.

Globigerina conglomerata Schwager. Beckmann, 1954, p. 391, pl. 25, figs. 6-9, text-fig. 15 (not of Schwager).

Globoquadrina venezuelana (Hedberg). Blow, 1959, p. 186, pl. 11, figs. 58a-c, 59.

Remarks : - *Globigerina venezuelana* was referred to the genus *Globoquadrina* by Finlay

(1947, p. 291) at the time of its proposal. As noted by Blow (*loc. cit.*) and also in all of the present specimens, pointed umbilical teeth are observed, though the umbilical teeth are small, and in some cases indistinct owing to its more closed umbilicus. The coiling of the tests is random. The size ranges from 0.24 to 0.37 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75048 from sample A-3.

Occurrence: - Rare.

Known range: - The *Porticulasphaera mexicana* Zone to *Globigerina bulloides* Zone or higher.

Genus *Globigerinoides* Cushman, 1927

The species of this genus in the present materials are classified into two groups with respect to the position of the primary aperture. Group 1 shows the aperture to be above the two sutures between the three earlier chambers, and group 2 has it placed above the suture between the penultimate and antepenultimate chambers. The features of each group are shown in text-fig. 3.

Globigerinoides bollii Blow, 1959

Pl. 25, figs. 12a-c

Globigerinoides bollii Blow, 1959, p. 189-191, pl. 10, figs. 65a-c.

Remarks: - This species belongs to group 1. It is distinguished by having much embracing chambers, a small, almost circular primary aperture, and by showing no lateral and oblique compression in the last few chambers as found in *G. obliquus*. The coiling of the tests is uncertain owing to its rare occurrence. The size ranges from 0.17 to 0.34 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75049 from sample A-12.

Occurrence: - Very rare.

Known range: - The base of the *Globorotalia mayeri*/*Globorotalia linguaensis* Subzone to the *Globigerina bulloides* Zone.

Globigerinoides conglobatus (Brady), 1879

Pl. 25, figs. 11a-c

Globigerina conglobata Brady, 1879, p. 286 (no figures given), (*fide* Ellis and Messina, 1940 *et seq.*); Brady, 1884, p. 603, pl. 80, figs. 1-5, pl. 82, fig. 5; Banner and Blow, 1960b, p. 6-7, pl. 4, figs. 4a-c (lectotype) [written as *Globigerina conglobata* Brady 1879 = *Globigerinoides conglobatus* (Brady) in pl. 4).

Globigerinoides conglobatus (Brady). Thalmann, 1932, p. 307; Bé, 1959, pl. 2, figs. 7-12.

Globigerinoides conglobata (Brady). Phleger, Parker and Peirson, 1953, p. 15, pl. 2, figs. 1-3; Asano, 1957, p. 20, pl. 2, figs. 8, 9; Bradshaw, 1959, p. 40, pl. 7, figs. 5, 6; Chang, 1959b, p. 86, pl. 1, figs. 10a-11c.

Remarks: - *Globigerinoides conglobatus* belongs to group 1. The test wall is very thick and coarsely cancellated. Four comparatively large chambers are visible from the apertural side and they are so embracing as to show a "globe-like" outline. The apertures of the last chamber are bordered by thickened rim-like lips. The coiling of the tests is probably random. The size ranges from 0.31 to 0.49 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75050 from sample A-17.

Occurrence: - Very rare.

Known range: - Banner and Blow (*op. cit.*) considered this species to range probably from the early Pliocene to Recent, but typical specimens of this species are found in association with many Miocene forms in the Nobori formation. Hence the range is here extended

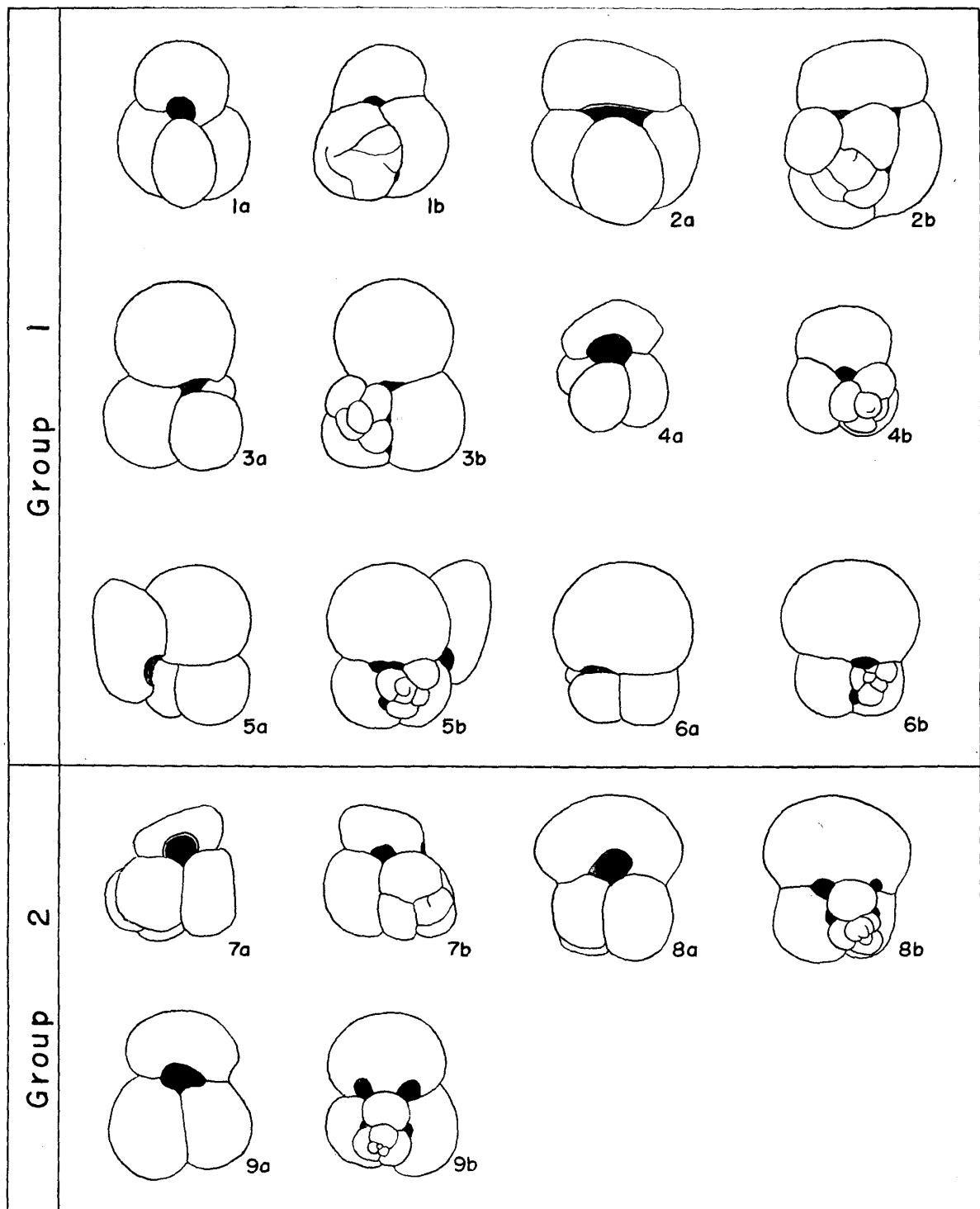


Fig. 3. Classification of the *Globigerinoides* by position of the aperture (a, umbilical view; b, spiral view): 1, *Globigerinoides bollii* Blow; 2, *Globigerinoides conglobatus* (Brady); 3, *Globigerinoides immaturus* LeRoy; 4, *Globigerinoides obliquus* Bolli; 5, *Globigerinoides sacculifer* (Brady); 6, *Globigerinoides trilobus* (Reuss); 7, *Globigerinoides elongatus* (d'Orbigny); 8, *Globigerinoides ruber cyclostomus* (Galloway and Wissler); 9, *Globigerinoides ruber ruber* (d'Orbigny)

downward to include the Nobori formation, *i.e.*, the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone.

***Globigerinoides elongatus* (d'Orbigny), 1826**

Pl. 26, figs. 8a-c

Globigerina elongata d'Orbigny, 1826, p. 277 (no figures given), (*vide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960b, p. 12, 13, figs. 10a-c (lectotype) [written as *Globigerina elongata* d'Orbigny 1826 = *Globigerinoides elongatus* (d'Orbigny) in pl. 3].

Globigerinoides elongata (d'Orbigny). Cushman, 1941, p. 40, pl. 10, figs. 20-23, pl. 11, fig. 3; Cushman, Todd and Post, 1954, p. 368, 369, pl. 91, fig. 5.

Remarks: - This species belongs to group 2. It differs from the *G. ruber* group in having the ultimate chamber laterally much compressed to show a sub-triangular outline in umbilical view. In spiral view, the chambers are reniform to sub-rectangular and tangentially elongated. The equatorial profile is sub-triangular to sub-quadrated. In general appearance, this species is closely related to *G. ruber cyclostomus* and forms transitional between those two species are found in the lower part of the studied outcrop. So far as the present authors investigated in the literature, this species is unknown from horizons older than the Nobori formation. This fact may suggest that it evolved from *Globigerinoides ruber ruber* via *G. ruber cyclostomus* at about this age. The coiling of the tests is random. The size ranges from 0.26 to 0.37 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75051 from sample A-8.

Occurrence: - Rather rare.

Known range: - The *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent.

***Globigerinoides immaturus* LeRoy, 1939**

Pl. 27, figs. 2a, b.

Globigerinoides sacculiferus (Brady) var. *immatura* LeRoy, 1939, p. 263, pl. 3, figs. 19-21 (*vide* Ellis and Messina, 1940 *et seq.*); LeRoy, 1941a, p. 44, pl. 1, figs. 37-39; LeRoy, 1941b, p. 87, pl. 7, figs. 16-18; LeRoy, 1941c, p. 118, pl. 3, figs. 31-33.

Globigerinoides triloba immatura LeRoy. Bolli, 1957a, p. 113, pl. 25, figs. 3a-4c, text-fig. 21 (2a, b); Blow, 1959, p. 188, pl. 11, figs. 62a, b; Jenkins, 1960, p. 354, pl. 2, figs. 7a-c.

Remarks: - This species belongs to group 1. It was originally defined as a subspecies of *G. sacculifer*, but *G. immaturus* is distinguished from *G. sacculifer* in not having a terminal elongate, sack-like chamber. Banner and Blow (1960b, p. 18, 19) designated the lectotype of *Globigerinoides quadrilobatus* (d'Orbigny) at the time of their re-investigations of specimens in A. d'Orbigny's collections, and considered *G. immaturus* as a subspecies of *G. quadrilobatus*. Accordingly, if their designation is correct, it appears to be very difficult to distinguish *G. immaturus* from *G. quadrilobatus* even subspecifically. It seems to be more preferable to assume the former as a junior synonym of the latter. However, the type figures of *Globigerina quadrilobata* given by d'Orbigny is not similar to the lectotype designated by Banner and Blow. Furthermore when they searched for the type specimen, they found that three specimens were missing from the tube labelled "*Globigerina quadrilobata*". Therefore, it seems to be questionable to conclude that the "*quadrilobata*" of a true *Globigerina* was not originally included among the three lost specimens. Pending further investigation on the validity of the lectotype of Banner and Blow, the Nobori specimens are here compared with *Globigerinoides immaturus* LeRoy. In the present specimens usually two apertures attach to the final chamber. The tests are nearly random in their coiling but with slight preference towards the left. The size ranges from 0.27 to 0.49 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75052 from sample A-11.

Occurrence: - Rather common.

Known range: - The *Globorotalia kugleri* Zone to Recent.

***Globigerinoides obliquus* Bolli, 1957**

Pl. 25, figs. 10a-c

Globigerinoides obliqua Bolli, 1957b, p. 113, pl. 25, figs. 9a-10c; Blow, 1959, p. 191, 192, pl. 11, figs. 68a, b.*Globigerinoides conglobatus* (Brady). Dieci, 1959, p. 92, pl. 7, fig. 27 (not of Brady).*Globigerinoides ruber* (d'Orbigny). Dieci, 1959, p. 93, pl. 7, figs. 28a, 29 (not of d'Orbigny).

Remarks: - This species belongs to group 1. It is distinguished by having the final chamber compressed in a laterally oblique manner and comparatively large, arched primary aperture. The coiling of the tests is random. The size ranges from 0.22 to 0.34 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75053 from sample A-11.

Occurrence: - Rather common.

Known range: - *Globorotalia kugleri* Zone to *Globigerina bulloides* Zone (or higher?).

***Globigerinoides ruber* (d'Orbigny), 1839**

This species belongs to group 2. It is characterized by having three fairly large tests in the last whorl, and the primary aperture is placed and shaped symmetrically with respect to the intercameral suture between the penultimate and antepenultimate chambers. The species included into this group can be classified into those of *sensu stricto* and of *sensu lato* as is given below.

***Globigerinoides ruber ruber* (d'Orbigny), 1839**

Pl. 26, figs. 9a-c

Globigerina rubra d'Orbigny, in Ramon de la Sagra, 1839, p. 82, 83, pl. 4, figs. 12-14 (plates published separately), (*fide* Ellis and Mssina, 1940 *et seq.*); Banner and Blow, 1960b, p. 19-21, pl. 3, figs. 8a, b (lectotype) [written as *Globigerina rubra* d'Orbigny 1839 = *Globigerinoides ruber* (d'Orbigny) in pl. 3].*Globigerina helicina* d'Orbigny. Brady, 1884, p. 603, pl. 81, figs. 4, 5 (not of d'Orbigny).*Globigerinoides rubra* (d'Orbigny). Cushman, 1927, p. 87, pl. 19, fig. 6; Phleger and Parker, 1951, p. 35, pl. 19, fig. 16; Phleger, Parker and Peirson, 1953, p. 15, pl. 2, figs. 4, 7; Bolli, 1957a (part), p. 113, 114, pl. 25, figs. 12a-c (not figs. 13a, b), text-fig. 21 (6a, b); Bradshaw, 1959, p. 42, pl. 7, figs. 12, 13; Jenkins, 1960 (part), p. 353, pl. 2, figs. 9a-c (not figs. 8a-c); Huang, 1960, p. 65, pl. 1, fig. 9.*Globigerinoides cyclostoma* (Galloway and Wissler). Natland, 1950, p. 36, pl. 10, figs. 4a-c (not Galloway and Wissler, 1927).*Globigerinoides ruber* (d'Orbigny). Graham and Militante, 1959, p. 111, 112, pl. 18, figs. 12a-c; Bé, 1959, pl. 2, figs. 16, 17.

Remarks: - In general morphology this subspecies is very similar to *Globigerinoides ruber cyclostomus*. But *G. ruber ruber* differs from *G. ruber cyclostomus* in having more lobulate equatorial periphery, less width of final chamber than of the two preceding chambers combined, rounded semi-circular final chamber in contrast to the subrectangular final chamber of *G. ruber cyclostomus*. In this subspecies, high spired forms frequently occur, but *G. cyclostomus* has a very low spiral arrangement.

A specimen possessing one more abnormal chamber analogous with the form figured by Brady under the name of *Globigerina helicina* (*loc. cit.*), is here referred to the present species. The coiling of the tests is random. The size ranges from 0.22 to 0.43 mm. in maximum diameter.

Hypotypes: - Figs. 9a-c; IGPS coll. cat. no. 75055 from sample A-17; figs. 10a, b, IGPS coll. cat. no. 75054 from sample A-18.

Occurrence: - Rather common.

Known range : – Bolli (*loc. cit.*) considered *Globigerinoides subquadratus* from the *Globigerinatella insueta* Zone as a synonym of this species. Blow (*loc. cit.*) followed this opinion. But Banner and Blow (*loc. cit.*) separated *G. subquadratus* from *G. ruber* (s. s.) as a subspecies, and herein their view is adopted. It ranges from the *Globorotalia fohsi* Zone to Recent.

***Globigerinoides ruber cyclostomus* (Galloway and Wissler), 1927**

Pl. 26, figs. 6a–c

Globigerina cyclostoma Galloway and Wissler, 1927, p. 42, pl. 7, figs. 8a–9c.

Remarks : – Galloway and Wissler distinguished this species from *G. ruber ruber* by “its much more compact method of coiling, less globular chambers, its more regularly formed trochoid coil and its small, circular aperture”. But in general outline, the chamber arrangement in the last whorl, position of the aperture, etc., this species is closely related to *G. ruber* (s. s.) and forms transitional between both often make it difficult to distinguish them from one another. Hence, *G. cyclostomus* is here treated as subspecies of *G. ruber*.

This subspecies is distinguished from *G. ruber* (s. s.) by having embracing subquadrate equatorial profile in contrast to the lobulate subtriangular one of *G. ruber* (s. s.), very low spiral arrangement, and large or nearly equal proportion of final chamber to the preceding two chambers combined. In addition, the shape of the final chamber is different between them, namely, *G. ruber* (s. s.) is inflated sub-circular and *G. ruber cyclostomus* is sub-rectangular. The coiling of the tests is random. The size ranges from 0.19 to 0.46 mm. in maximum diameter.

Hypotype : – IGPS coll. cat. no. 75056 from sample A-16.

Occurrence : – Fairly abundant.

Known range : – The *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone to Recent.

***Globigerinoides sacculifer* (Brady), 1877**

Pl. 26, figs. 11a–c

Globigerina sacculifera Brady, 1877, p. 535; Brady, 1884, p. 604, pl. 80, figs. 11–17, pl. 82, fig. 4; Banner and Blow, 1960b, p. 21–24, pl. 4, figs. 1a–2b (figs. 1a, b; lectotype : figs. 2a, b; ideotype) [written as *Globigerina sacculifera* Brady 1877 = *Globigerinoides quadrilobatus* (d'Orbigny) subsp. *sacculifer* (Brady) in pl. 4].

Globigerinoides sacculiferus (Brady). Thalmann, 1932, p. 307.

Globigerinoides sacculifera (Brady). Bermudez, 1952, p. 194, pl. 21, figs. 4–6; Phleger, Parker and Peirson, 1953, p. 16, pl. 2, figs. 5, 6; Cushman, Todd and Post, 1954, p. 369, pl. 91, fig. 7; Asano, 1957, p. 21, pl. 2, figs. 3–5; Bradshaw, 1959, p. 42, pl. 7, figs. 14, 15, 18.

Globigerinoides triloba sacculifera (Brady). Bolli, 1957a, p. 113, pl. 25, figs. 5a–6, text-fig. 21 (4a, b); Blow, 1959, p. 188, 189, pl. 11, figs. 63a, b; Chang, 1959a, p. 65, pl. 3, figs. 9–13.

Globigerinoides sacculifer (Brady). Graham and Militante, 1959, p. 112, 113, pl. 19, figs. 1a–2b; Bé, 1959, pl. 2, figs. 13–15; Dieci, 1959, p. 93, pl. 7, fig. 30; Bermudez, 1960, p. 73, 74, pl. 1, figs. 41, 42.

Remarks : – This species belongs to group 1. Usually two apertures are attached to the last chamber. This species is characterized by having an elongate, sack-like last chamber. Also in the case without sack-like chamber development, it may be distinguished by having a very lobulate, elongate last chamber. The coiling of tests is random. The size ranges from 0.34 to 0.51 mm. in maximum diameter.

Hypotype : – IGPS coll. cat. no. 75057 from sample A-11.

Occurrence : – Rather common.

Known range : – The *Globorotalia kugleri* Zone to Recent.

***Globigerinoides trilobus* (Reuss), 1850**

Pl. 27, figs. 4a, b

Globigerina triloba Reuss, 1850, p. 374, pl. 47, figs. 11a-d (*vide* Ellis and Messina, 1940 *et seq.*).*Globigerinoides triloba* (Reuss). Blow, 1956, p. 62, text-fig. 1 (1-3); Hamilton and Rex, 1959, p. 792, pl. 253, figs. 17-19.*Globigerinoides triloba triloba* (Reuss). Bolli, 1957a, p. 112, 113, pl. 25, figs. 2a-c, text-fig. 21 (1a, b); Blow, 1959, p. 187, pl. 11, figs. 6a, b; Chang, 1959a, p. 64, pl. 3, figs. 17a, b, pl. 4, figs. 1a, b; Jenkins, 1960, p. 353, pl. 2, figs. 5a-c.*Globigerinoides quadrilobatus trilobus* (Reuss). Banner and Blow, 1960b, p. 18.

Remarks : - This species belongs to group 1. *G. trilobus* differs from *G. immaturus* in having final chamber larger than all the earlier chambers combined. Two apertures (both primary and spiral) attach to the final chamber. The coiling of the tests is random. The size ranges from 0.27 to 0.54 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75058 from sample A-16.

Occurrence : - Rather common.

Known range : - The *Catapsydrax dissimilis* Zone to Recent.

Genus ***Pulleniatina*** Cushman, 1927***Pulleniatina obliquiloculata* (Parker and Jones), 1865**

Pl. 27, figs. 5a-c

Pullenia sphaeroides (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, p. 365, 368, pl. 19, figs. 4a, b; Banner and Blow, 1960b, p. 25, pl. 7, figs. 4a-c (lectotype) [written as *Pullenia sphaeroides* var. *obliquiloculata* Parker and Jones 1865 = *Pulleniatina obliquiloculata* (Parker and Jones) in pl. 7].

Pullenia obliquiloculata Parker and Jones. Brady, 1884, p. 618, pl. 84, figs. 16-20; Cushman, 1924, p. 43, pl. 8, fig. 10.

Pulleniatina obliquiloculata [*sic*] (Parker and Jones). Cushman, 1927, p. 90, pl. 19, figs. 5a-b; Bolli, Loeblich and Tappan, 1957, p. 33, pl. 4, figs. 3a-5.

Pulleniatina obliquiloculata (Parker and Jones). Cushman, 1933a, p. 266, pl. 27, figs. 5a, b; Cushman, 1933b, key-plate 35, figs. 1-3; LeRoy, 1941a, p. 44, 45, pl. 2, figs. 105-107; LeRoy, 1941b, p. 87, pl. 4, figs. 16-18; LeRoy, 1941c, p. 118, pl. 2, figs. 13-15; Coryell and Mossman, 1942, p. 239, pl. 36, fig. 31; Stainforth, 1948, p. 125, pl. 26, figs. 21-23; Bermudez, 1949, p. 283, pl. 22, figs. 5-7; Phleger and Parker, 1951, p. 35, pl. 19, figs. 19, 20; Phleger, Parker and Peirson, 1953, p. 17, pl. 2, figs. 16-18; Todd, 1957, p. 279 (table), pl. 79, figs. 9a, b; Asano, 1957, p. 7, 8, pl. 2, fig. 12; Bradshaw, 1959, p. 49, pl. 8, figs. 19, 20; Graham and Militante, 1959, p. 113, pl. 19, figs. 4a-c; Bermudez, 1960, p. 74, pl. 1, figs. 44, 45; Huang, 1960, p. 61, pl. 1, figs. 13, 14.

Remarks : - In addition to the typical specimens, there are several forms assumed to be immature in the Nobori formation. As to the immature forms of the living *Pulleniatina obliquiloculata*, Bradshaw (*loc. cit.*) stated that :

"Immature specimens of this species do not have the crescent-shaped aperture characteristic of the adult and are more lobulate and coarsely perforate."

Such features are identical with the Nobori specimens. Furthermore the ontogenetic development of the present specimens corresponds well with that of this species clearly described by Bolli *et al.* (*op. cit.*). Besides the streptospiral coiling, the thick, radially perforated later chamber-walls with smooth and brilliant surface seems to be diagnostic to the species. The coiling of the tests is almost towards the right.

Hypotype : - IGPS coll. cat. no. 75075 from sample A-6.

Occurrence : - Not common, almost restricted in the middle part of the studied outcrop.

Known range : - Some previous workers assumed this species to range from the Pliocene to Recent, and retained its records from the Miocene as doubtful. But so far as such

illustrations of the Miocene forms of authors are examined, it does not seem to be adequate to distinguish specifically these forms from the Recent ones. The first appearance of this species may probably be in the *Globorotalia cultrata cultrata*/*Globigerina nepenthes* Zone.

Subfamily Sphaeroidinellinae

Genus *Sphaeroidinella* Cushman, 1927

Sphaeroidinella dehiscens (Parker and Jones), 1865

Pl. 27, figs. 3a, b

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones, 1865, p. 369, pl. 19, figs. 5a-c; Banner and Blow, 1960b, p. 35, 36, pl. 7, figs. 3a, b (lectotype) [written as *Sphaeroidina bulloides* d'Orbigny var. *dehiscens* Parker and Jones 1865 = *Sphaeroidinella dehiscens* (Parker and Jones) in pl. 7].

Sphaeroidina dehiscens Parker and Jones. Brady, 1884, p. 621, pl. 84, figs. 8-11.

Sphaeroidinella dehiscens (Parker and Jones). Cushman, 1927, p. 90, pl. 19, figs. 2a, b; LeRoy, 1941b, p. 87, pl. 6, fig. 13; Phleger, Parker and Peirson, 1953, p. 18, pl. 2, fig. 19; Cushman, Todd and Post, 1954, p. 369, pl. 91, fig. 14; Bolli, Loeblich and Tappan, 1957, p. 32, 33, pl. 6, figs. 1-3, 5 (lectotype designated); Graham and Militante, 1959, p. 114, pl. 19, figs. 5a, b; Bradshaw, 1959, p. 49, pl. 8, figs. 21-23; Chang, 1959b, p. 88, pl. 2, fig. 11; Huang, 1960, p. 65, figs. 22, 26.

Remarks : - The specimens referred to this species are found throughout the present section. Comparing with the figured types of Parker and Jones (1865) or Banner and Blow (1960), the present specimens have a more narrow apertural opening. The size ranges from 0.34 to 0.54 mm. in maximum diameter.

Hypotype : - IGPS coll. cat. no. 75060 from sample A-7.

Occurrence : - Rather rare.

Known range : - It has been stated by Banner and Blow (*loc. cit.*) that this species was believed to range from the Sarmatian to Recent. Thus, it seems that the present occurrence may be its oldest.

Genus *Sphaeroidinellopsis* Banner and Blow, 1959

Sphaeroidinellopsis seminulina (Schwager), 1866

Pl. 26, figs. 12a-c

Globigerina seminulina Schwager, 1866, p. 256, pl. 7, fig. 112; LeRoy, 1941, p. 44, pl. 3, fig. 108.

Sphaeroidinella grimsdalei (Keijzer). Bolli, 1957a(part), p. 114, pl. 26, figs. 8-11 (not figs. 12a-c) [not *Globigerina grimsdalei* Keijzer].

Sphaeroidinella seminulina (Schwager). Todd, 1957, p. 279, pl. 79, figs. 7a, b; Chang, 1959a, p. 66, 67, pl. 4, figs. 5a-10b.

Sphaeroidinella seminulina seminulina (Schwager). Blow, 1959, p. 197-198, pl. 12, figs. 74-77c.

Remarks : - In the Nobori specimens such a distinct cortex as found in *Sphaeroidinella dehiscens* (Parker and Jones) is not observed, but they closely resemble various illustrated specimens of *Sphaeroidinellopsis seminulina seminulina* to which they are referred. With regard to the cortex of *Sphaeroidinella* Banner and Blow (1959, p. 15) stressed on its fragility, and it appears to be also the case with *Sphaeroidinellopsis*. The specimens are characterized by distinctly depressed sutures which are deeply incised near the umbilicus, and along which shiny narrow zones of shell material are often observed by reflected light. Such shell material is also usually seen around the apertural margins. These materials are considered to be the remain of the cortex. The last whorl of the present specimens is usually composed of three to three and a half chambers, but rarely of four. Many of them are more lobulated than the typical, and in this respect they are similar to *Sphaeroidinella multilobata* LeRoy and/ or the "second group" of *S. seminulina seminulina* of Blow (1959, *op. cit.*). Concerning this feature, however, all gradations are found between the typical

forms and these variant ones among the Nobori specimens. The tests of the observed specimens show nearly random coiling, but with somewhat preference towards the left. The size ranges from 0.19 to 0.31 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75059 from sample A-16.

Occurrence: - Rather common.

Known range: - The *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone to *Sphaeroidinellopsis seminulina* Zone.

Subfamily Orbulininae

Genus *Orbulina* d'Orbigny, 1839

Concerning the systematic relationship between *Orbulina* and its related genera as *Biorbulina* and *Candorbulina*, there has been some disagreement among different authors (Blow, 1956, 1959; Bronnimann, 1951; Banner and Blow, 1959; Bolli, Loeblich and Tappan, 1957; Jenkins, 1960). After examining these references, the present authors have inclined to the view stated by Blow, and Banner and Blow. They assume *Orbulina* and *Biorbulina* as distinct genera and *Candorbulina* as a junior synonymy of the former through laying stress on which chamber embraces all or nearly all of early test.

Orbulina suturalis Bronnimann, 1951

Pl. 24, fig. 3

Candorbulina universa Jedlitschka, 1934, p. 21, text-figs. 1-7, 19, 21-23 (*vide* Ellis and Messina, 1940 *et seq.*).

Orbulina suturalis Bronnimann, 1951b (part), p. 134, text-fig. 2, figs. 1-2, 5-8, 10-13; text-fig. 3, figs. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, figs. 2-4, 7-12, 15, 16, 19-22; Blow, 1956, p. 66-69, text-fig. 2, nos. 5-7; Bolli, 1957a, p. 115, pl. 27, fig. 4; Blow, 1959, p. 200, pl. 13, figs. 82a, b.

Remarks: - The general feature of the Nobori specimens coincides well with *Orbulina suturalis* of different authors. But the apertural pores are not distinctly observed over the area of the last chamber as well as along the sutures. The size ranges from 0.25 to 0.68 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75024 from sample A-11.

Occurrence: - Very rare.

Known range: - Uppermost part of the *Globigerinatella insueta* Zone to Recent.

Orbulina universa d'Orbigny, 1839

Pl. 27, fig. 1

Orbulina universa d'Orbigny in Ramon de la Sagra, 1839, p. 2, pl. 1, fig. 1 (*vide* Ellis and Messina, 1940 *et seq.*); Bermudez, 1949, p. 282, 283, pl. 22, fig. 3; Bronnimann, 1951b, p. 134, text-figs. 3 (12), 4 (1, 13, 14); Phleger, Parker and Peirson, 1953, p. 17, pl. 2, fig. 18; Blow, 1956, p. 66, text-fig. 2 (8, 9); Bolli, 1957a, p. 115, 116, pl. 27, fig. 5; Blow, 1959, p. 200, pl. 13, fig. 83; Jenkins, 1960, p. 356, pl. 3, fig. 12.

Orbulina universa universa d'Orbigny, Chang, 1959a, p. 67, pl. 4, figs. 13, 14.

Remarks: - As Bronnimann (*loc. cit.*) pointed out, the scattered large openings are not uniformly distributed over the area of the last chamber, but show a tendency to be concentrated on some area. The size ranges from 0.22 to 0.64 mm. in maximum diameter.

Hypotype: - IGPS coll. cat. no. 75025 from sample A-5.

Occurrence: - Rare.

Known range: - Notwithstanding the emphases by LeRoy (1948, 1952), Loeblich and Tappan (1961), etc., that the "*Orbulina* surface" as the middle Tertiary datum plane has not been fully accepted among the foraminiferalogists. But so far as the accurate records

from Japan are concerned, its first occurrence appears to be not older than the upper part of the *Globigerinatella insueta* Zone. On that account, it is appropriate to presume that *Orbulina universa* as well as the genus *Orbulina* range from the uppermost part of the *Globigerinatella insueta* Zone to Recent in Japan as well as in many other regions.

Genus *Candeina* d'Orbigny, 1839

Candeina amacula Takayanagi and Saito, n. sp.

Pl. 28, figs. 13a-c

Test free, subglobular, trochospiral, consisting of rapidly enlarging chambers in a low spire; chambers subglobular to hemi-spherical, all visible on spiral side, about four chambers in early whorl, later becoming three in final whorl, last-formed chamber strongly embracing and occupying nearly one half of final whorl; sutures distinct, slightly depressed, radial to slightly curved; wall calcareous, finely perforate, radial in structure, surface pitted; primary aperture in early stage interiomarginal, umbilical, later small supplementary sutural apertures develop on each side of primary aperture, in adult tests primary opening is replaced by small round to short slit-like ones situated at later sutures.

Maximum diameter of holotype 0.29 mm., maximum thickness 0.27 mm. Other specimens range from 0.17 to 0.22 mm. in maximum diameter.

Holotype: - IGPS coll. cat. no. 75026 from sample A-6.

Remarks: - This species is similar to *Candeina nitida* var. *triloba* Cushman in general outline and surface of the test which is rougher and more punctate than *C. nitida* d'Orbigny. However, according to Cushman (1921, p. 296), *C. nitida* var. *triloba* is distinguished from the typical by that the last three chambers composed the whole external surface of the test. In this respect, it is considered to be not adequate to include Cushman's variety under the genus *Candeina*, and *C. amacula*, n. sp. will be easily distinguished from the former by its chamber arrangement on spiral side.

Occurrence: - Very rare.

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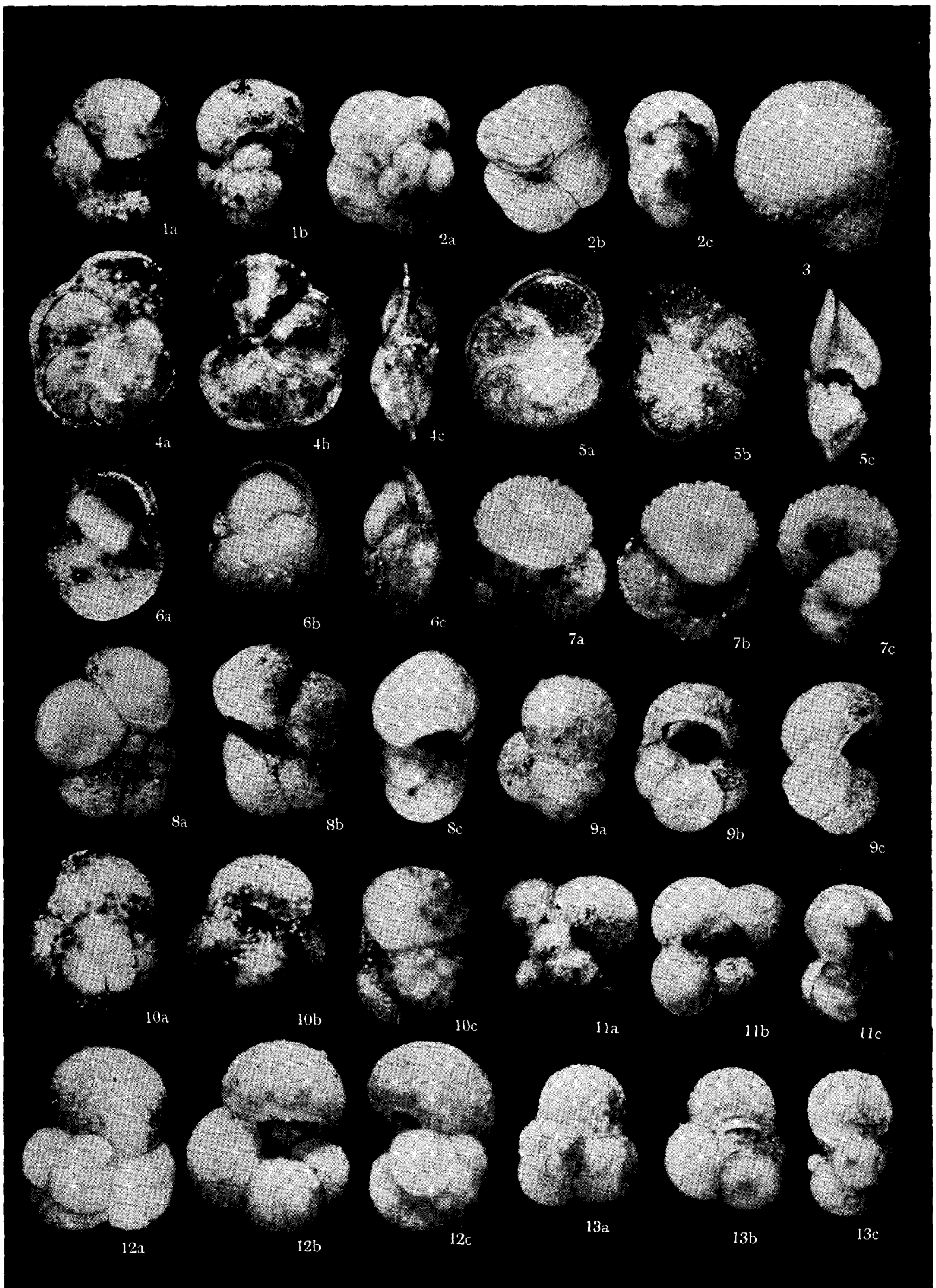
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While the present paper was in press, the writers noted an article by Ruth Todd, "On Selection of Lectotypes and Neotypes" (1961, *Cushman Found. Foram. Res., Contr.*, 12 (4), p. 121-122). In this paper she writes on the nomenclature of *Rotalina cultrata* d'Orbigny and *Rotalina menardii* d'Orbigny. According to her, from recommendations of the Draft Code (1958, 15th International Zoological Congress, London), the name of *Globorotalia menardii* (d'Orbigny) should be used and *Globorotalia cultrata* (d'Orbigny) should not be employed as done by Banner and Blow (1960, *Cushman Found. Foram. Res., Contr.*, 11 (1), p. 34-35). For this reason the writers wish to make notice that the above indicated name should be replaced by *Globorotalia menardii* (d'Orbigny) upon the view of Ruth Todd.

PLATE 24

- Figs. 1a, b. *Hastigerina siphonifera* (d'Orbigny) (p. 75). IGPS coll. cat. no. 75076, from sample A-4. ×54. a, equatorial; b, side view.
- Figs. 2a-c. *Globorotalia acostaensis* Blow (p. 75). IGPS coll. cat. no. 75063, from sample A-12. ×72. a, spiral; b, umbilical; c, side view.
- Fig. 3. *Orbulina suturalis* Bronnimann (p. 100). IGPS coll. cat. no. 75024, from sample A-12. ×75.
- Figs. 4a-c. *Globorotalia cultrata cultrata* (d'Orbigny) (p. 76). IGPS coll. cat. no. 75064, from sample A-17. ×78. a, spiral; b, umbilical; c, side view.
- Figs. 5a-c. *Globorotalia cultrata miocenica* Palmer (p. 77). IGPS coll. cat. no. 75065, from sample A-7. ×78. a, spiral; b, umbilical; c, side view.
- Figs. 6a-c. *Globorotalia tumida* (Brady) (p. 82). IGPS coll. cat. no. 75074, from sample A-3. ×48. a, umbilical; b, spiral; c, side view.
- Figs. 7a-c. *Globorotalia obesa* Bolli (p. 79). IGPS coll. cat. no. 75068, from sample A-5. ×79. a, spiral; b, umbilical; c, side view.
- Figs. 8a-c. *Globorotalia subcretacea* (Lomnicki) (p. 81). IGPS coll. cat. no. 75072 from sample A-7. ×74. a, spiral; b, umbilical; c, side view.
- Figs. 9a-c. *Globigerina apertura* Cushman (p. 83). IGPS coll. cat. no. 75031, from sample A-1. ×75. a, spiral; b, umbilical; c, side view.
- Figs. 10a-c. *Globigerina conglomerata* Schwager (p. 84). IGPS coll. cat. no. 75034, from sample A-1. ×53. a, spiral; b, umbilical; c, side view.
- Figs. 11a-c. *Globigerina diplostoma* Reuss (p. 85). IGPS coll. cat. no. 75035, from sample A-17. ×55. a, spiral (this species has no supplementary apertures); b, umbilical; c, side view.
- Figs. 12a-c. *Globigerina bulloides* d'Orbigny (p. 84). IGPS coll. cat. no. 75033, from sample A-7. ×85. a, spiral; b, umbilical; c, side view.
- Figs. 13a-c. *Globigerina falconensis* Blow (p. 86). IGPS coll. cat. no. 75037, from sample A-12, ×68. a, spiral; b, umbilical; c, side view.



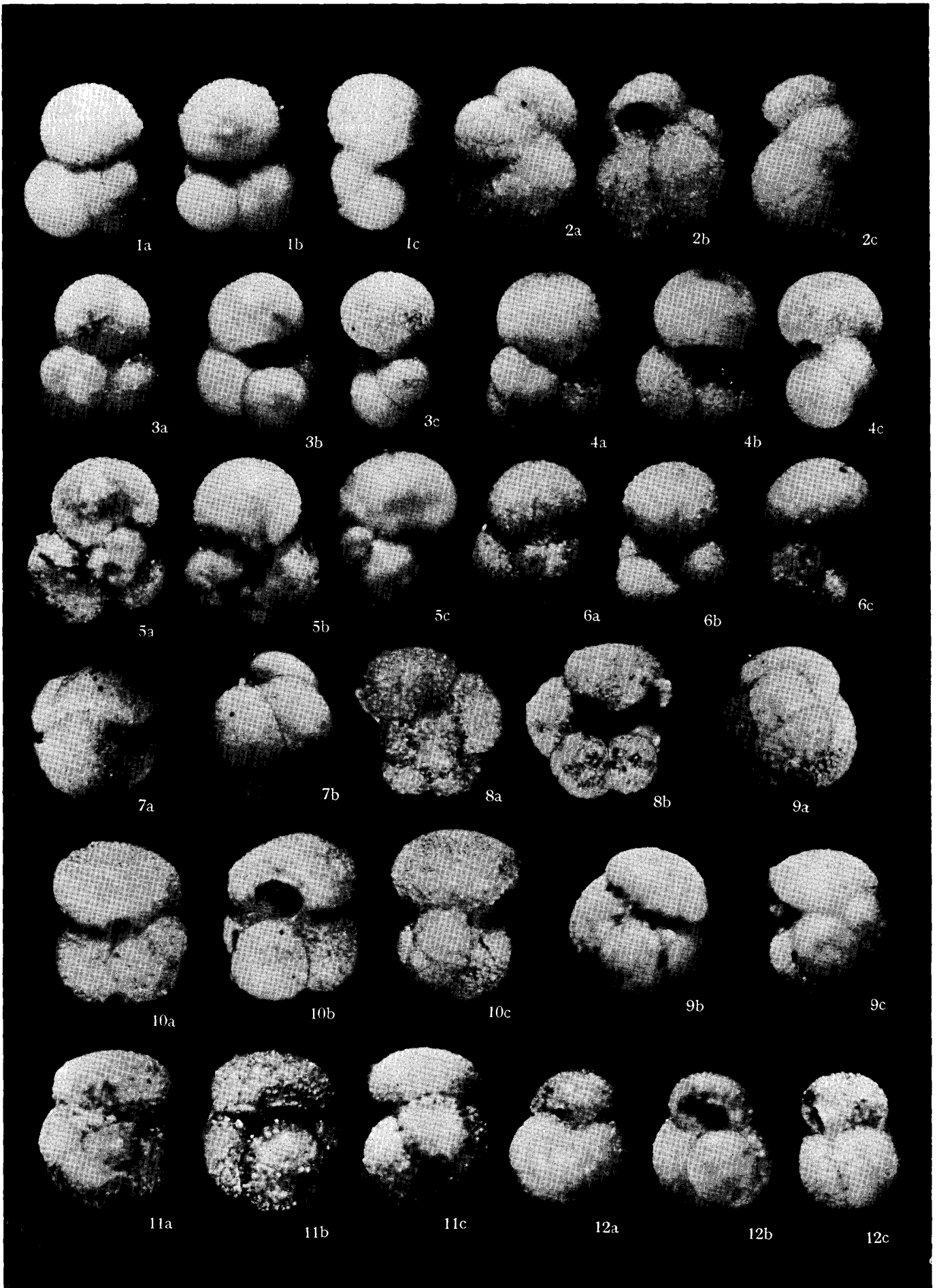
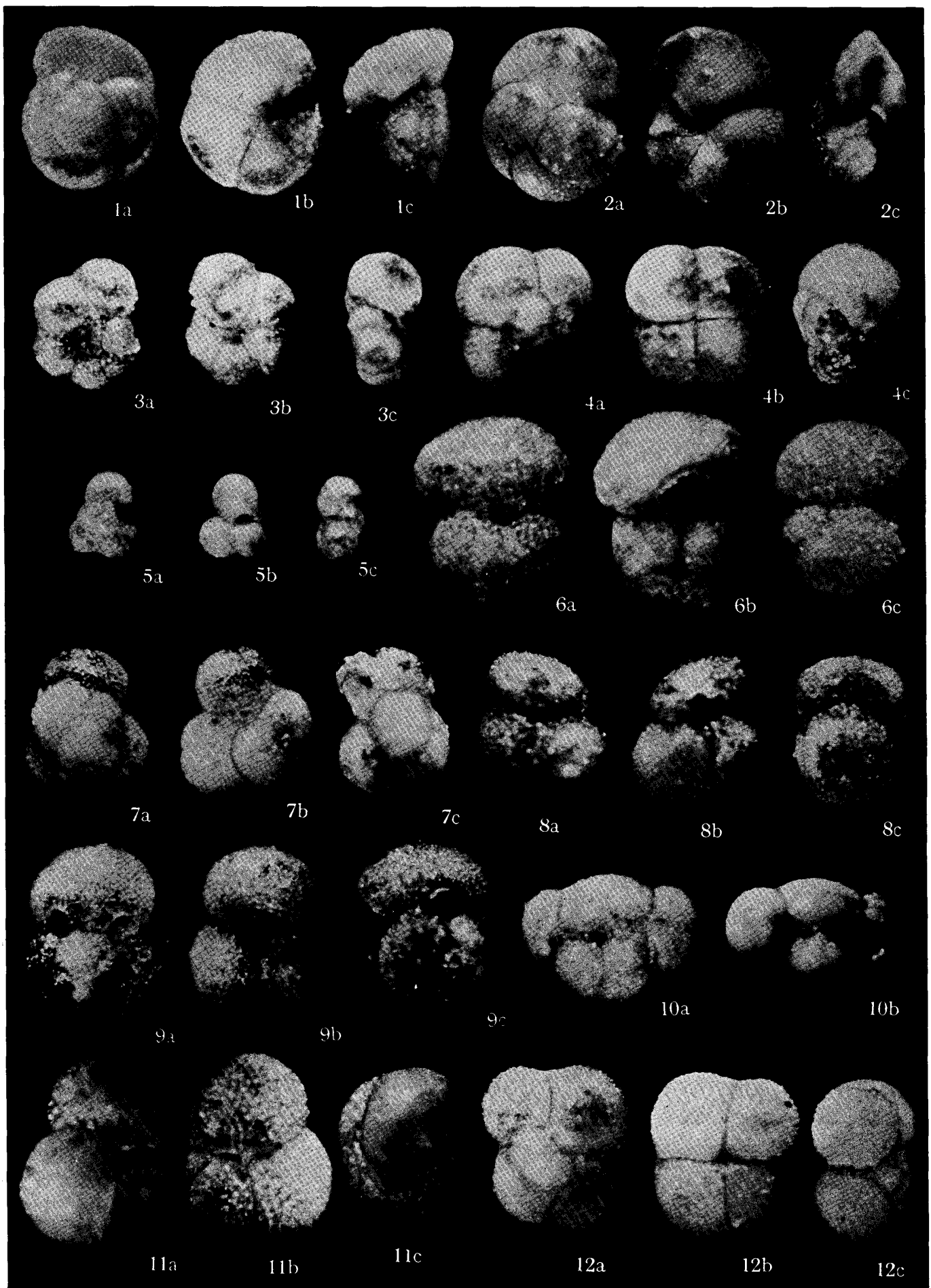


PLATE 25

- Figs. 1a-c. *Globigerina foliata* Bolli (p. 86). IGPS coll. cat. no. 75038, from sample A-15. ×73. a, spiral; b, umbilical; c, side view.
- Figs. 2a-c. *Globigerina nepenthes* Todd (p. 89). IGPS coll. cat. no. 75040, from sample A-4. ×104. a, spiral; b, umbilical; c, side view.
- Figs. 3a-c. *Globigerina paraboloides* Blow (p. 90). IGPS coll. cat. no. 75042, from sample A-16. ×67. a, spiral; b, umbilical; c, side view.
- Figs. 4a-c. *Globigerina praebuloides* Blow (p. 90). IGPS coll. cat. no. 75043, from sample A-18. ×70. a, spiral; b, umbilical; c, side view.
- Figs. 5a-c. *Globigerina trilocularis* Deshayes (p. 91). IGPS coll. cat. no. 75044, from sample A-5. ×70. a, spiral; b, umbilical; c, side view.
- Figs. 6a-c. *Globigerina woodi* Jenkins (p. 91). IGPS coll. cat. no. 75045, from sample A-16. ×68. a, spiral; b, umbilical, c, side view.
- Figs. 7a, b. *Globoquadrina altispira altispira* (Cushman and Jarvis) (p. 92). IGPS coll. cat. no. 75046, from sample A-9. ×73. a, umbilical; b, side view.
- Figs. 8a, b. *Globoquadrina altispira globosa* Bolli (p. 92). IGPS coll. cat. no. 75047, from sample A-1. ×82. a, spiral; b, umbilical view.
- Figs. 9a-c. *Globoquadrina venezuelana* (Hedberg) (p. 92). IGPS coll. cat. no. 75048, from sample A-3. ×73. a, spiral; b, umbilical; c, side view.
- Figs. 10a-c. *Globigerinoides obliquus* Bolli (p. 96). IGPS coll. cat. no. 75053, from sample A-11. ×82. a, spiral; b, umbilical; c, side view.
- Figs. 11a-c. *Globigerinoides conglobatus* (Brady) (p. 93). IGPS coll. cat. no. 75050, from sample A-17. ×55. a, spiral; b, umbilical; c, side view.
- Figs. 12a-c. *Globigerinoides bollii* Blow (p. 93). IGPS coll. cat. no. 75049, from sample A-12. ×78. a, spiral; b, umbilical; c, side view.

PLATE 26

- Figs. 1a-c. *Globorotalia hirsuta* (d'Orbigny) (p. 77). IGPS coll. cat. no. 75066, from sample A-17. $\times 117$. a, spiral; b, umbilical; c, side view.
- Figs. 2a-c. *Globorotalia scitula scitula* (Brady) (p. 80). IGPS coll. cat. no. 75071, from sample A-7. $\times 100$. a, spiral; b, umbilical; c, side view.
- Figs. 3a-c. *Globorotalia minutissima* Bolli (p. 78). IGPS coll. cat. no. 75067, from sample A-11. $\times 92$. a, spiral; b, umbilical; c, side view.
- Figs. 4a-c. *Globigerina pachyderma* (Ehrenberg) (p. 89). IGPS coll. cat. no. 75041, from sample A-11. $\times 96$. a, spiral; b, umbilical; c, side view.
- Figs. 5a-c. *Globigerina bulbosa* LeRoy (p. 84). IGPS coll. cat. no. 75032, from sample A-7. $\times 100$. a, spiral; b, umbilical; c, side view.
- Figs. 6a-c. *Globigerinoides ruber cyclostomus* (Galloway and Wissler) (p. 97). IGPS coll. cat. no. 75056, from sample A-16. a, $\times 70$. spiral; b, umbilical; c, side view.
- Figs. 7a-c. *Globigerina eamesi* Blow (p. 86). IGPS coll. cat. no. 75036, from sample A-16. $\times 92$. a, spiral; b, umbilical; c, side view.
- Figs. 8a-c. *Globigerinoides elongatus* (d'Orbigny) (p. 95). IGPS coll. cat. no. 75051, from sample A-8. $\times 72$. a, spiral; b, umbilical; c, side view.
- Figs. 9a-c. *Globigerinoides ruber ruber* (d'Orbigny) (p. 96). IGPS coll. cat. no. 75055, from sample A-17. $\times 65$. a, spiral; b, umbilical; c, side view.
- Figs. 10a, b. *Globigerinoides ruber ruber* (d'Orbigny) (p. 96). IGPS coll. cat. no. 75054, from sample A-18. $\times 65$. a, spiral; b, umbilical view.
- Figs. 11a-c. *Globigerinoides sacculifer* (Brady) (p. 97). IGPS coll. cat. no. 75057, from sample A-11. $\times 68$. a, spiral; b, umbilical; c, side view.
- Figs. 12a-c. *Sphaeroidinellopsis seminulina* (Schwager) (p. 99). IGPS coll. cat. no. 75059, from sample A-16. $\times 100$. a, spiral; b, umbilical; c, side view.



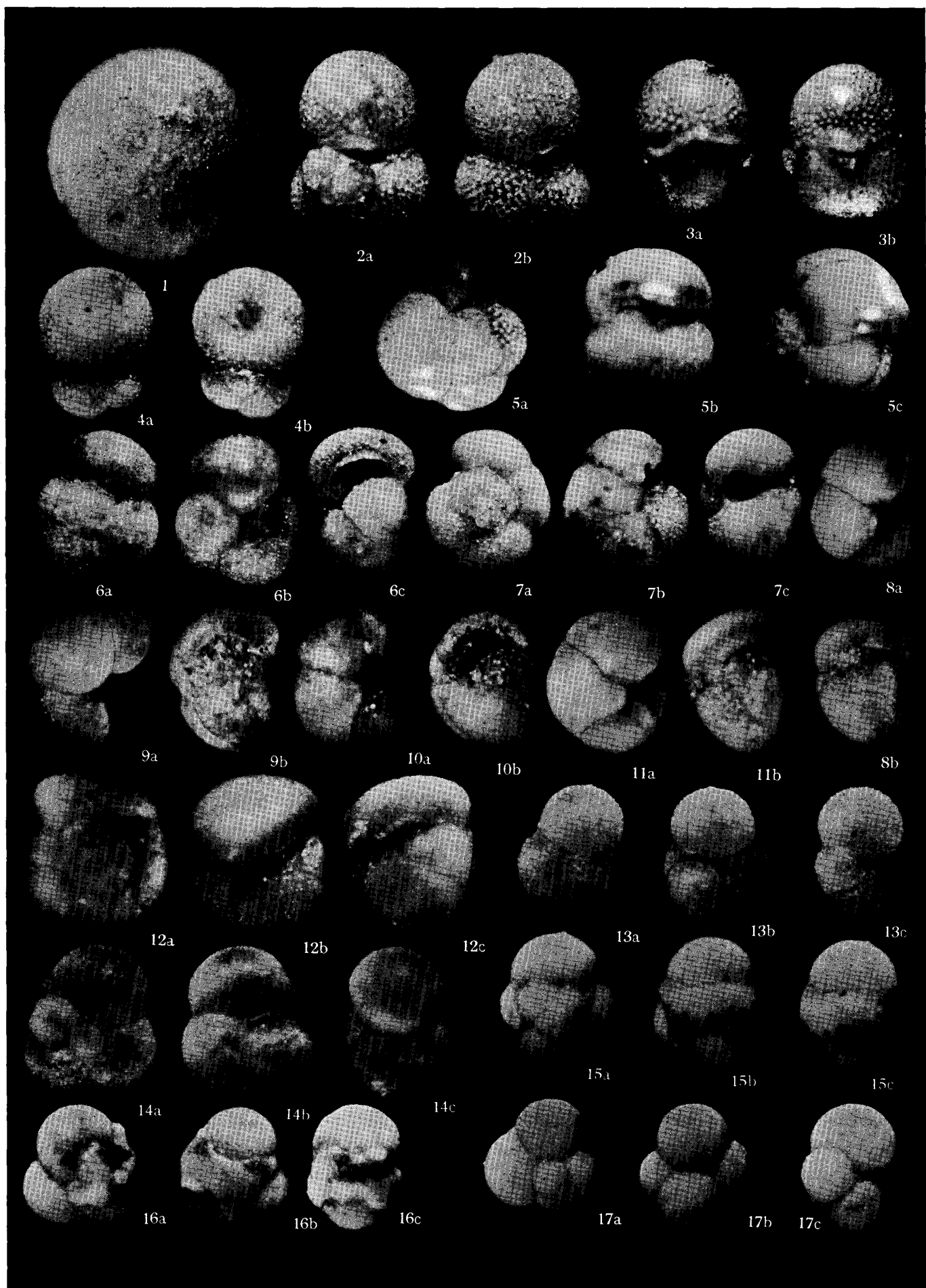


PLATE 27

- Fig. 1. *Orbulina universa* d'Orbigny (p. 100). IGPS coll. cat. no. 75025, from sample A-5. ×60.
- Figs. 2a, b. *Globigerinoides immaturus* LeRoy (p. 95). IGPS coll. cat. no. 75052, from sample A-11. ×61. a, spiral; b, umbilical view.
- Figs. 3a, b. *Sphaeroidinella dehiscens* (Parker and Jones) (p. 99). IGPS coll. cat. no. 75060, from sample A-7. ×56. a, umbilical; b, spiral view.
- Figs. 4a, b. *Globigerinoides trilobus* (Reuss) (p. 98). IGPS coll. cat. no. 75058, from sample A-16. ×56. a, umbilical; b, spiral view.
- Figs. 5a-c. *Pulleniatina obliquiloculata* (Parker and Jones) (p. 98). IGPS coll. cat. no. 75075, from sample A-6. ×75. a, spiral; b, umbilical; c, side view.
- Figs. 6a-c. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069a, from sample A-11. ×64. a, spiral; b, umbilical; c, side view.
- Figs. 7a-c. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069b, from sample A-11. ×64. a, spiral; b, umbilical, c, side view.
- Figs. 8a, b. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069c, from sample A-11. ×64. a, umbilical; b, side view.
- Figs. 9a, b. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069d, from sample A-11. ×44. a, umbilical; b, side view.
- Figs. 10a, b. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069e, from sample A-11. ×44. a, umbilical; b, side view.
- Figs. 11a, b. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069f, from sample A-11. ×44. a, umbilical; b, side view.
- Figs. 12a-c. *Globorotalia* cf. *oceanica* Cushman and Bermudez (p. 79). IGPS coll. cat. no. 75069g, from sample A-11. ×76. a, spiral; b, umbilical; c, side view.
- Figs. 13a-c. *Globigerina glutinata* Egger (p. 86). IGPS coll. cat. no. 75039a, from sample A-11. ×80. a, spiral; b, umbilical; c, side view.
- Figs. 14a-c. *Globigerina glutinata* Egger, var. (p. 88). IGPS coll. cat. no. 75061, from sample A-11. ×80. a, spiral; b, umbilical; c, side view. Dissected hypotype showing the form removed a bullae. This closely resembles to *G. glutinata* (s. s.).
- Figs. 15a-c. *Globigerina glutinata* Egger, var. (p. 88). IGPS coll. cat. no. 75062a, from sample A-17. ×72. a, spiral; b, umbilical; c, side view. A form with a distinct bullae.
- Figs. 16a-c. *Globigerina glutinata* Egger, var. (p. 88). IGPS coll. cat. no. 75062b, from sample A-17. ×72. a, spiral; b, umbilical; c, side view. Hypotype with a distinct bullae.
- Figs. 17a-c. *Globigerina glutinata* Egger (p. 86). IGPS coll. cat. no. 75039b, from sample A-11. ×72. a, spiral; b, umbilical; c, side view. Hypotype with a supplementary sutural aperture just above the junction of the last intercameral suture and spiral suture.

PLATE 28

- Figs. 1a-c. *Globorotalia humerosa* Takayanagi and Saito, n. sp. (p. 78). Holotype, IGPS coll. cat. no. 75079, from sample A-17. $\times 67$. a, spiral; b, umbilical; c, side view.
- Figs. 2a, b. *Globorotalia humerosa* Takayanagi and Saito, n. sp. (p. 78). Paratype, IGPS coll. cat. no. 75078, from sample A-18. $\times 67$. a, spiral; b, umbilical; c, side view.
- Figs. 3a-c. *Globigerina angustiumbilitata* Bolli (p. 82). IGPS coll. cat. no. 75027, from sample A-11. $\times 100$. a, spiral; b, umbilical; c, side view.
- Figs. 4a-c. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75028, from sample A-11. $\times 100$. a, spiral; b, umbilical; c, side view.
- Figs. 5a, b. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75029a, from sample A-11. $\times 82$. a, spiral; b, umbilical view.
- Figs. 6a-c. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75029b, from sample A-11. $\times 82$. a, spiral; b, umbilical; c, side view.
- Figs. 7a, b. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75029c, from sample A-11. $\times 82$. a, umbilical; b, side view. A dissected hypotype showing the form removed an aberrant last chamber.
- Figs. 8a, b. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75029d, from sample A-11. $\times 82$. a, spiral; b, umbilical view.
- Figs. 9a, b. *Globigerina angustiumbilitata* Bolli, var. (p. 83). IGPS coll. cat. no. 75030, from sample A-9. $\times 112$. a, umbilical; b, side view.
- Figs. 10a-c. *Globigerina druryi* Akers *decoraperta* Takayanagi and Saito, n. subsp. (p. 85). Holotype, IGPS coll. cat. no. 75070, from sample A-16. $\times 100$. a, spiral; b, umbilical; c, side view.
- Figs. 11a-c. *Globorotalia tosaensis* Takayanagi and Saito, n. sp. (p. 81). Holotype, IGPS coll. cat. no. 75073, from sample A-17. $\times 65$. a, spiral; b, umbilical; c, side view.
- Figs. 12a-c. *Globorotalia tosaensis* Takayanagi and Saito, n. sp. (p. 81). Paratype, IGPS coll. cat. no. 75077, from sample A-18. $\times 65$. a, spiral; b, umbilical; c, side view.
- Figs. 13a-c. *Candeina amacula* Takayanagi and Saito, n. sp. (p. 101). Holotype, IGPS coll. cat. no. 75026, from sample A-6. $\times 90$. a, spiral; b, umbilical; c, side view.

