

# Younger Cenozoic Foraminiferal Assemblages from the Choshi District, Chiba Prefecture

Yasumochi Matoba

## ABSTRACT

The vertical distribution of the planktonic and benthonic Foraminifera from the younger Cenozoic deposits distributed in the Choshi district and superposed upon the Permian and Cretaceous Systems was studied.

The lowest of the Cenozoic units or the Metogahana Formation was previously considered to be Miocene in age from stratigraphic position. The Na-arai Formation rests upon it with clino-unconformity, and is succeeded upwards with conformity by the Iioka and Toyosato Formations. They are covered by the "Katori" Formation with slight clino-unconformity and the latter is overlain with three units of volcanic ash deposits, each of which is unconformable with one another.

The Iioka, Toyosato and "Katori" Formations yield abundant Foraminifera and by the benthonic forms are divided into seven units of *Bulimina striata-Stilostomella*, *Bulimina aculeata-Uvigerina akitaensis*, *Cassidulina carinata*, *C. subglobosa*, *Bolivina pacifica*, *Nonionella-Elphidium*, and *Pseudononion-Rosalina* zones in ascending order.

Distinct changes in the coiling direction are seen in *Globigerina pachyderma*, *Globorotalia menardii s. l.* and *Pulleniatina obliquiloculata* in the Choshi section. There is a distinct short interval of sinistrally coiled *P. obliquiloculata* at the base of the Iioka Formation. This may correspond to the same coiling pattern of the species in the basal part of the Lower Pliocene in the Philippines (Bandy, 1963).

Based upon the planktonic foraminiferal fauna, the basal part of the Na-arai Formation can be correlated to Saito's Upper Miocene *Globorotalia menardii menardii/Globigerina nepenthes* Zone. Although the other part of the Na-arai Formation yielded no Miocene index species of planktonic Foraminifera, the formation is inferred to be below Bandy's Miocene-Pliocene boundary. The basal part of the Iioka Formation is correlated to the basal part of the Kurotaki Formation along the Obitsu River; the upper part of the *Bulimina aculeata-Uvigerina akitaensis* zone in the Iioka Formation is correlated to the upper part of the Umegase Formation, and is the basal Pleistocene of Asano *et al.* (1958); the middle part of the *Bolivina pacifica* zone corresponds to the uppermost part of the Kakinokidai to Chonan Formation.

The relations of the benthonic foraminiferal zones between the Choshi district and the Yoro River area in the Boso Peninsula, the sedimentary environment and the tectonic movement in the region are discussed.

Two species of benthonic Foraminifera are described as new to science.

## CONTENTS

	Page
Introduction .....	222
Acknowledgements .....	222
Previous Works .....	223
Geologic Setting .....	224
Samples and Methods .....	228
Benthonic Foraminifera .....	231
Planktonic Foraminifera .....	238
Geologic Age and Correlation .....	244
Discussion .....	247
Summary .....	250

	Page
Faunal Reference List .....	251
References .....	260

### LIST OF ILLUSTRATIONS

	Page
Figure	
1. Geologic sketch map of the Choshi district .....	226
2. Localities of samples for Foraminifera in the Choshi district .....	229
3. Columnar section of the younger Cenozoic formations of the Choshi district, showing the stratigraphic position of the samples and the benthonic foraminiferal zones. ....	230
4. Vertical frequency distribution of the important benthonic Foraminifera from the Na-arai, Iioka, Toyosato and "Katori" Formations of the Choshi district .....	233
5. Vertical variation of the planktonic foraminiferal assemblages of the Choshi district and Recent deposits, showing variation of warm and cold water species. ....	241
6. Vertical changes in the coiling direction of <i>Pulleniatina obliquiloculata</i> (Parker and Jones) and <i>Globigerina pachyderma</i> (Ehrenberg) in the Choshi district and Recent deposits. ....	243
7. Correlation of the benthonic foraminiferal zones between the Choshi district and the Yoro River area via wells drilled along Kujukuri .....	246
Table	
1. Planktonic Foraminifera from the Na-arai, Iioka, Toyosato and "Katori" Formations of the Choshi district and Recent deposits .....	239
Plates 25-30. Younger Cenozoic Foraminifera.	

### INTRODUCTION

Precise geological and paleontological studies of the Choshi district, situated at the eastern end of the Kanto Tectonic Basin and composed of Tertiary and Quaternary sediments superposed on Paleozoic and Mesozoic rocks, are inferred to contribute to the knowledge on the structural development of the Cenozoic sedimentary basins and the geologic history of the Kanto Region.

The Kanto Tectonic Line or the Tonegawa Tectonic Line has been believed to pass nearby the present district which is separated from the Boso Peninsula in the south and from the Joban district in the north by alluvial deposits of the Kujukuri-hama and the Kashima-nada respectively. Although the stratigraphic relationship of the strata developed within those areas can not be confirmed directly, the recent drillings in the southern Kanto Region have for the exploration of the natural gas resources, resulted in clarifying the relation between the Choshi district and the Boso Peninsula based chiefly on the Foraminifera. Some of the benthonic foraminiferal zones which were previously established in wells drilled in the Boso Peninsula have been found to extend to the Choshi district and farther north.

The benthonic Foraminifera are very useful for fine-cut zoning within a single sedimentary basin, and important for interpretation of the paleoecology. Although the planktonic Foraminifera are generally believed to be more valuable than the benthonic forms for correlation, their application for subdivision of the younger Cenozoic deposits has been quite impossible. The planktonic and benthonic Foraminifera from the younger Cenozoic strata in the Choshi district are analyzed both quantitatively and qualitatively, and compared with those of the Boso Peninsula, an area which is considered to be the standard of the Cenozoic strata in this region.

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#### PREVIOUS WORKS

Several papers have been published on the Cenozoic geology and paleontology of the Choshi district since the early works of Hayasaka (1922), Yamane (1924a, b), Mitsuchi (1933), and others.

Yamane (1924b) divided the Cenozoic deposits in the central and eastern parts of the present district into the Miocene, Pliocene, Upper Pliocene, Pleistocene, and Holocene, in his Explanatory Text to the Geological Map of Japan (scale 1:75,000), Choshi sheet.

Aoki and Tayama (1930), in their study on the Kanto Tectonic Basin, referred to the unconformity within the Tertiary System of the district. Mitsuchi (1933) named the lower part of Yamane's Pleistocene as the Katori Formation, in his Explanatory Text to the Geological Map of Japan (scale 1:75,000), Kashima sheet. This sheet covers the northwestern part of the present area.

Hayasaka (1922) studied the brachiopods from the basal part of the Tertiary deposits at Inuwaka, Choshi City (=the base of Yamane's Pliocene), and correlated it to the Koshiba bed in the Miura Peninsula. Later Hatai (1940) studied the brachiopods from the same bed of the same locality and discussed the sedimentary environment.

Maruhashi (1947, 1948) reported on the Foraminifera from the Iioka Mudstone ( $H_2-I_1$ ) and the Toyosato Mudstone ( $I_{1-2}$ ) of the Choshi district, based on the unpublished reports of the field works of K. Suzuki and N. Ikebe, and described the sedimentary environments. Imazeki (*in* Fujimoto 1951) divided the Tertiary System of the district into the Metogahana Formation, Na-arai Tuffaceous Sandstone and Iioka Tuffaceous Mudstone, in ascending order. She considered the first one to be Miocene in age and the latter two to be Pliocene.

Ozaki (1954a, b) made stratigraphical and paleontological studies on the basal conglomerate of the Na-arai Formation exposed along the coast of Inuwaka and other places. He found a fauna of mixed deep and shallow water forms in the matrix of the conglomerate. From the results of stratigraphical and paleontological studies of the Neogene and Pleistocene formations of the Choshi district, Ozaki (1958) assigned the Metogahana, Na-arai, Iioka and Katori Formations to Miocene, Lower Pliocene, Upper Pliocene and Pleistocene, respectively.

Suzuki (1958) emphasized the significance of the unconformity below the Na-arai Formation, and stated that it represents the orogeny at the end of the Miocene. Naruse (1959) described the geologic history of the Late Cenozoic deposits of the Boso Peninsula, and pointed out that the Toyosato Formation is the northern extension of the Kasamori Formation.

Kuno (1947), Kondo and Sano (1962), and Takai (1964) made petrological studies on the bronzite andesite intercalated in the Metogahana Formation.

For the exploration of natural gas resources many wells were drilled in the Boso Peninsula, and Ishiwada (1957, 1959), Ishiwada and Shinada (1959), Kawai (1961), Ishiwada, Higuchi and Kikuchi (1962), Kikuchi (1963, 1964), Higuchi (1964), Higuchi

and Kikuchi (1964) by means of the benthonic foraminiferal zones recognized in the wells, pointed out the characteristic features of the Kazusa Group which ranges from Pliocene to Pleistocene in age. They showed that most of zones of the lower part of the Kazusa Group gradually diminish in their thickness or become indistinguishable northeastwards towards the Choshi district, whereas the *Uvigerina akitaensis* zone of the upper part of the Umegase Formation can be traced to the middle part of the Iioka Formation in the Choshi district. In those works the Na-arai Formation has been regarded as the basal part of the Kazusa Group in contrast to the present study.

Asano *et al.* (1958) studied the planktonic Foraminifera from the surface sections along the Yoro River and the eastern coast of the Boso Peninsula, and concluded that the Pliocene-Pleistocene boundary should be drawn within the middle part of the Umegase Formation where the first lowering of the water temperature was recognized in the younger Cenozoic sequences. Subsequently Takayama (1961) studied the planktonic Foraminifera from along the Obitsu River, in the west of the Yoro River. His conclusion is similar to that of Asano *et al.*, but he stated that the sinistrally coiled form of *Globigerina pachyderma* (Ehrenberg) is dominant in the uppermost part of the Kakinokidai Formation, the uppermost horizon of his section.

Aoki (1963) in his study on the benthonic and planktonic Foraminifera from the surface section along the Yoro River, distinguished 16 zones of benthonic Foraminifera. He stated that zoning or subdivision by planktonic foraminiferal assemblages was impossible because of disagreement with the zoning by benthonic Foraminifera and of their somewhat irregular and nonsystematic variation. It is, however, noteworthy that the sinistrally coiled *G. pachyderma* is dominant in the uppermost horizon of the Kakinokidai Formation and the Chonan Formation, and this is quite similar to the result of Takayama. Aoki (1964) studied the planktonic Foraminifera obtained from four surface sections in the Boso Peninsula including those along the Yoro and Obitsu Rivers, and stated that the sinistrally coiled *G. pachyderma* is predominant in the Chonan Formation though the total frequency of the species in the planktonic population does not indicate a high value.

#### GEOLOGIC SETTING

The Choshi district is bounded by the Tone River in the northeast, by the sea of Byobugaura in the southern part and by the alluvial plain of the Kujukuri-hama in the west, and is thus topographically isolated from the Boso Peninsula. The district can be divided geomorphologically into two areas, the one in the central to western part is an elongate nearly triangular tableland, called the "Iioka upground" by Kawasaki (1960), and the other, for the sake of convenience is called the Choshi Peninsula. The latter extends into the Pacific Ocean. The Choshi Peninsula with irregular coastline is composed of Paleozoic, Mesozoic and younger rocks. The highest point of the peninsula is Atago hill, 73.6 m in height, and this is surrounded by low terraces of 20 to 30 m above sea level. The Iioka upland in the west of the peninsula, which occupies the larger part of the present Choshi district, is 50 to 60 m in height and is a part of the Shimosa upland of the Boso Peninsula. The Iioka upland has its original plain rather well preserved and slightly inclined to the north with the highest point of 68.4 m above sea level near Cape Gyobumisaki, Iioka-machi. All drainages on the upland flow towards the Tone River except for one at Tsurendo, Iioka-machi.

The stratigraphic sequence of the Tertiary and Quaternary formations in the Choshi district is as follows:

Holocene	Alluvial deposits	
Pleistocene	Tachikawa Ash	2 m
	Musashino Ash	3 m
	Shimosueyoshi Ash	1.2 m
	“Katori” Formation	20 m
	Toyosato Formation	120 m
Pliocene	Iioka Formation	520 m
Miocene	Na-arai Formation	80 m
	Metogahana Formation	100 m
Pre-Tertiary (Permian and Cretaceous)	Basement rocks	

The distribution of these formations is shown in Fig. 1 and the stratigraphic units are briefly described below in the order of older to younger.

### Metogahana Formation

Type locality: sea cliff of Metogahana, Choshi City. The Metogahana Formation is composed chiefly of bluish gray tuffaceous siltstone intercalated with thin beds of tuff, and of pumiceous sandstone and conglomerate in the lower part. At the north of Kurohae the about 4 m thick basal conglomerate with gravels of the Cretaceous sandstone rests on the Cretaceous sandstone. At the mouth of the Tone River, around Senninzuka, bronzite andesite and its agglomerate are intercalated in the formation. The two islets east of Nagasaki are composed of augite-olivine basalt underlain with pumiceous tuff. The same kind of rocks occur as gravels in the conglomerate in the sea cliff midway between Metogahana and Kurohae.

In the northern area of the distribution, around the cape of Metogahana, the formation has trends of N60°E to E-W with dips of 10°–25°SE, and in the southern area a strike of N60°W with dip of 25°NE, forming a synclinal structure with axis trending in E-W direction and somewhat plunging to the east. In the southern wing of the syncline there are many faults and the Cretaceous sandstone and conglomerate of the formation are sandwiched. The thickness of the formation is estimated to be about 100 meters. The Metogahana, resting on the Cretaceous rocks with unconformity, is overlain by the Na-arai Formation with unconformity.

The fossils from the Metogahana are very scarce, but the writer obtained one species of arenaceous Foraminifera, *Martinottiella communis* (d'Orbigny), accompanied with Radiolaria and sponge spicules. No megafossils are known to occur from the formation.

### Na-arai Formation

Type locality: sea cliff of Byobugaura at Na-arai, Choshi City. The formation comprises tuffaceous sandstone containing pumice and “glaucinite” intercalated with many thin beds of fine tuff and pumice. The formation has at the base a conglomerate derived from the Paleozoic and Mesozoic, and volcanic rocks from the Metogahana Formation. The basal conglomerate along the coast around Metogahana is about 50 cm in thickness and overlies the Metogahana Formation with rather flat plane, and contains round gravels

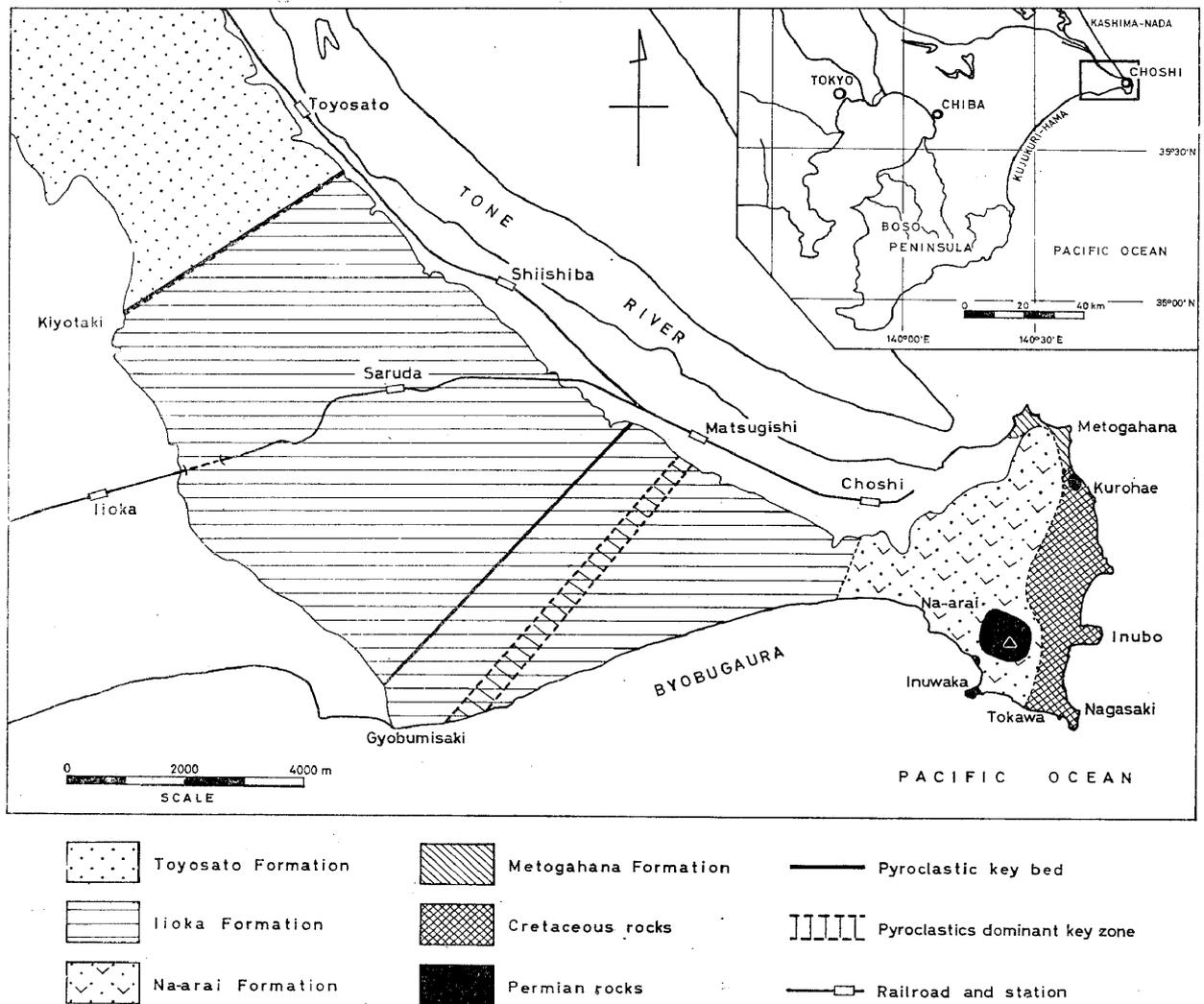


Fig. 1. Geologic sketch map of the Choshi district. In it the "Katori" Formation and younger deposits are not shown.

chiefly of andesite. At places around Atago hill, Inubo and Tokawa where the formation rests on the irregular surface of the Permian and Cretaceous Systems, the conglomerate contains a small amount of angular gravels, and there brachiopod fossils are preserved on the underlying rocks and also in the yellowish gray tuffaceous siltstone of the crevices. At the coast of Tokawa, the basal conglomerate of the Na-arai contains various size round gravels of older rocks some of which measure a few meters in diameter, and abundant fossils are preserved in its tuffaceous silty matrix.

The formation generally dips at 1-4 degrees westwards or north-westwards, but the dip direction changes according to the topography of the basements. The thickness of the formation is about 80 meters. The Na-arai overlies the Metogahana and older rocks with clino-unconformity, and is conformably overlain by an alternation of non-pumiceous sandstone and siltstone of the basal part of the Iioka Formation at the cliffs, south of the Choshi station.

Fossils are rather scarce in the formation except for the basal part where abundant brachiopods and molluscs are preserved; *Laqueus quadratus* Yabe and Hatai, *Terebratalia gouldii* (Dall), *Chlamys miurensis* (Yokoyama), *Glycymeris vestita* (Dunker), *Limopsis* (s. s.)

*tokaiensis* Yokoyama, *Perotrochus yosiwarai* (Ozaki), Foraminifera, corals, cirripeds, echinoids, Bryozoa, and fish teeth occur.

### Iioka Formation

Type locality: sea cliff of Byobugaura at Gyobumisaki, Iioka-machi, Unakami-gun, Chiba Prefecture. The formation consists chiefly of bluish gray, massive, tuffaceous siltstone intercalated with thin beds of fine grained tuff and pumice. The lowest part of the formation of 70 meters in thickness is composed of an alternation of sandstone and siltstone. The siltstone beds of the alternation, especially its lower part, contain abundant minute fragments of plants, but Foraminifera and other fossils are not noticed in them or in the sandstone beds. Intraformational deformations are often seen in the alternation deposits. In the upper part of the formation the grain size of the sediments gradually increases upwards where the lithofacies changes to sandy siltstone.

The formation of about 520 meters in thickness is distributed in a large part of the district under the Iioka upland, and dips at 2–4 degrees northwestwards. The Iioka Formation, resting conformably on the Na-arai Formation in the south of the Choshi station, is overlain by the Toyosato Formation at Tomikawa, Choshi City, and Kiyotaki, Unakami-machi.

Megafossils occur sporadically but Foraminifera are abundant everywhere throughout the formation except at the basal part. Molluscs, brachiopods and cirripeds as well as Foraminifera were collected from the formation. *Laternula* (*Laternulina*) *flexuosa* (Reeve), *Lima* (*Acesta*) *smithi* Sowerby, *Limopsis* (*s. s.*) *obliqua* A. Adams, *Aulacofusus coerulescens* Kuroda and Habe, *Fulgoraria hirasei* (Sowerby), *Spirotropis kazusensis inflatus* Otuka, *Uberella yokoyamai* (Kuroda and Habe), etc. occurred from the middle part of the formation.

### Toyosato Formation

Type locality: road cliff at Moromochi, Choshi City. The formation consists of bluish gray massive sandy siltstone to silty sandstone, increasing gradually in grain size from the lower part to the upper, and is intercalated with thin pumice beds. The upper, more sandy part is sometimes yellowish in color and non-consolidated on weathered outcrops, similar to the overlying "Katori" Formation. As it is difficult to separate the Toyosato from the underlying Iioka because of the gradual change in the lithology, the base of the Toyosato Formation is here defined by the pink colored fine tuff bed of 20 cm in thickness.

The formation exceeds 120 meters in thickness and is distributed in the northwest of the line connecting Tomikawa and Kiyotaki under the Iioka upland and dips at 2–3 degrees northwestwards. The Toyosato is conformably underlain by the Iioka, and overlain by the "Katori" with slight unconformity.

Fossils of molluscs, cirripeds and Foraminifera were collected from the formation; the molluscs are such as *Macoma nipponica* Tokunaga, *M. tokyoensis* Makiyama, *Protothaca adamsi* (Reeve), *Venericardia* (*Cyclocardia*) *ferruginea* Clessin, *Buccinum yoroianum* Ozaki, *Cancellaria nodulifera* Sowerby, *Leucosyrinx* (*Aforia*) *otohime* Ozaki, *Turritella nipponica* Yokoyama, *T. nipponica nojimaensis* Ida, etc.

### "Katori" Formation

Type locality: cliff southwest of the Shiishiba station, Funaki, Choshi City. The formation is composed of brownish yellow, medium to coarse grained sand intercalated with several silt beds. The basal part of the formation usually consists of pebbly sand, and there are a large number of sand pipes bored into the underlying rocks of the Iioka and the

Toyosato at the plane of the unconformity. The upper part of the formation is composed of sediments rather coarser than the lower part, containing pebbles and granules and is cross-bedded.

The formation has a maximum thickness of 20 meters and is distributed in the area of the Iioka upland covering almost horizontally the underlying formations with slight clino-unconformity. The upper half of the Iioka upland comprises the formation and the unconformably overlying volcanic ash deposits.

At several places molluscan shells, as well as Foraminifera, are preserved in the basal part of the formation, the former comprise such as *Anadara (Scapharca) broughtoni* (Schrenk), *Chlamys (s. s.) nipponensis* Kuroda, *Dosinia (Phacosoma) troscheli* Lischke, *Glycymeris yessoensis* (Sowerby), *Macoma nipponica* Tokunaga, *M. tokyoensis* Makiyama, *Mactra sulcataria* Reeve, *Mercenaria simpsoni* (Gould), *Protothaca adamsi* (Reeve), *Saxidomus purpuratus* (Sowerby), *Spisula sachalinensis* Schrenk, *Neverita didyma* (Röding), *Tectonatica severa* (Gould), *Turritella nipponica miyata* Ida, etc.

The Katori Formation was named by Mitsuchi (1933) in his Explanatory Text of the Geological Map of Japan (scale of 1:75,000), Kashima sheet, without designation of a type locality. Later the same author used the formation name for the deposits in an other area where the name has not been used by modern workers. Hence the formation name is used only tentatively in this study and upon the definition of Ozaki (1958) excluding the sand bed which is distributed under the low terraces in the Choshi Peninsula.

### Volcanic ash deposits

The volcanic ash deposit, the so-called Kanto Ash, is subdivided into three units in the Choshi district, and are believed to be the Shimosueyoshi, Musashino and Tachikawa Ashes in ascending order (the Kanto Loam Research Group, 1965).

The Shimosueyoshi Ash is composed of dark brown volcanic ash containing fine grained pumice. It is distributed only in the higher areas such as the Iioka upland and around Atago hill; the maximum thickness is 1.2 meters. Below the Shimosueyoshi Ash with conformity often there is a pebbly sand bed of 4 meters in maximum thickness with gravels at the base; this overlies the "Katori" Formation with unconformity. The sand bed which is distributed in the Choshi Peninsula below the Musashino Ash seems to be a part of it.

The Musashino Ash consists of brown volcanic ash intercalated with a pumice bed in the lower part; the maximum thickness is 3 meters. It overlies the Shimosueyoshi Ash with unconformity. The Tachikawa Ash consists of yellowish brown massive volcanic ash with a maximum thickness of 2 meters, and overlies the Musashino Ash with unconformity. The Musashino and Tachikawa Ashes are distributed throughout the district.

### SAMPLES AND METHODS

The rock samples were collected by the writer during 1962 and 1965 from the Cenozoic and Cretaceous strata of the Choshi district, Chiba Prefecture. In the laboratory each sample was reduced to 20, 40 or 100 grams in dry weight. The sodium sulfate-method described by Saito (1960) was applied to all except for the loose sandy sediments of the Na-arai, Toyosato and "Katori" Formations. After washing with a 200-mesh sieve (opening  $74\mu$ ) each sample was divided into a proper volume so as to take 200-500 individuals of the benthonic Foraminifera from one split-part. From the split-part all of the benthonic and planktonic foraminiferal tests were picked out. Then the benthonic Foraminifera were analyzed and the planktonic forms were only counted for the

number of tests. For the study of the planktonic Foraminifera another split-part of the same rock samples as those described above were used. After sieving with a 115-mesh screen (opening  $125\ \mu$ ), carbon tetrachloride was used to float off the Foraminifera from the sediments except for the samples from the Na-arai. Then 200 specimens of the planktonic forms were picked out at random using a picking tray which has a grid system. For the ecological interpretation of these fossil planktonic populations in the quantitative analysis, three samples of Recent sediments were analyzed by the same procedure.

The Foraminifera found in one sample of the Cretaceous shale (Cr), were put aside from this study. From the Metogahana Formation Foraminifera were found only in one sample (M) after the examination of many rock samples. Among the samples from the Na-arai Formation Foraminifera were found in three samples (A 1-3). The Iioka and Toyosato Formations yielded abundant Foraminifera throughout except for the basal part of the former. Rock samples were collected from the two formations along two geologic sections, one along the northeastern side of the Iioka upland (A 4-33), and the other supplementarily along the western side (B 1-14). Three samples (K 1-3) were selected from the "Katori" Formation; they are all from just above the unconformity at the base. The localities of these fossil foraminiferal samples are shown in Fig. 2, and stratigraphic positions are given in Fig. 3 in the columnar section in which the sections of the Iioka and Toyosato Formations are plotted on the opposite side of the column. They were correlated stratigraphically by use of key beds of pyroclastic sediments.\*

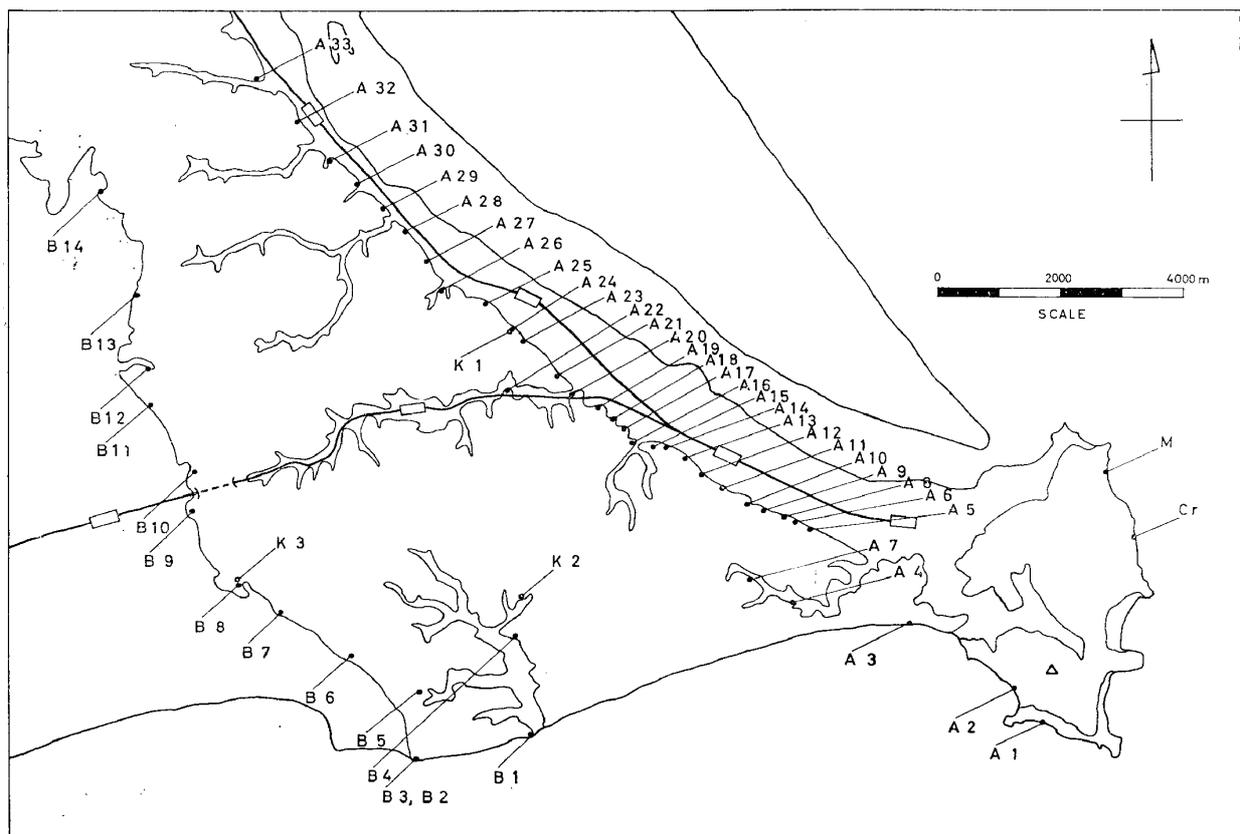


Fig. 2. Localities of samples for Foraminifera in the Choshi district. Cr: Cretaceous rock. M: Metogahana Formation. A 1-3: Na-arai Formation. A 4-30 and B 1-12: Iioka Formation. A 31-33 and B 13-14: Toyosato Formation. K 1-3: "Katori" Formation.

\* Recently Mr. Toshiaki Takayama studied the nannoplankton from the same rock samples used by the writer from the Choshi district (1967, in press). The relation of sample number of the rocks used by Takayama and the writer are as follows. (The alphabet letters N and C are those of Takayama and A is of the writer): N 6=A 3, C 2=A 4, C 3=A 7, C 4=A 10, C 5=A 15, C 6=A 18, C 7=A 19, C 8=A 22, C 9=A 24, C 10=A 25, C 11=A 26, C 12=A 28, C 13=A 29, C 14=A 31.

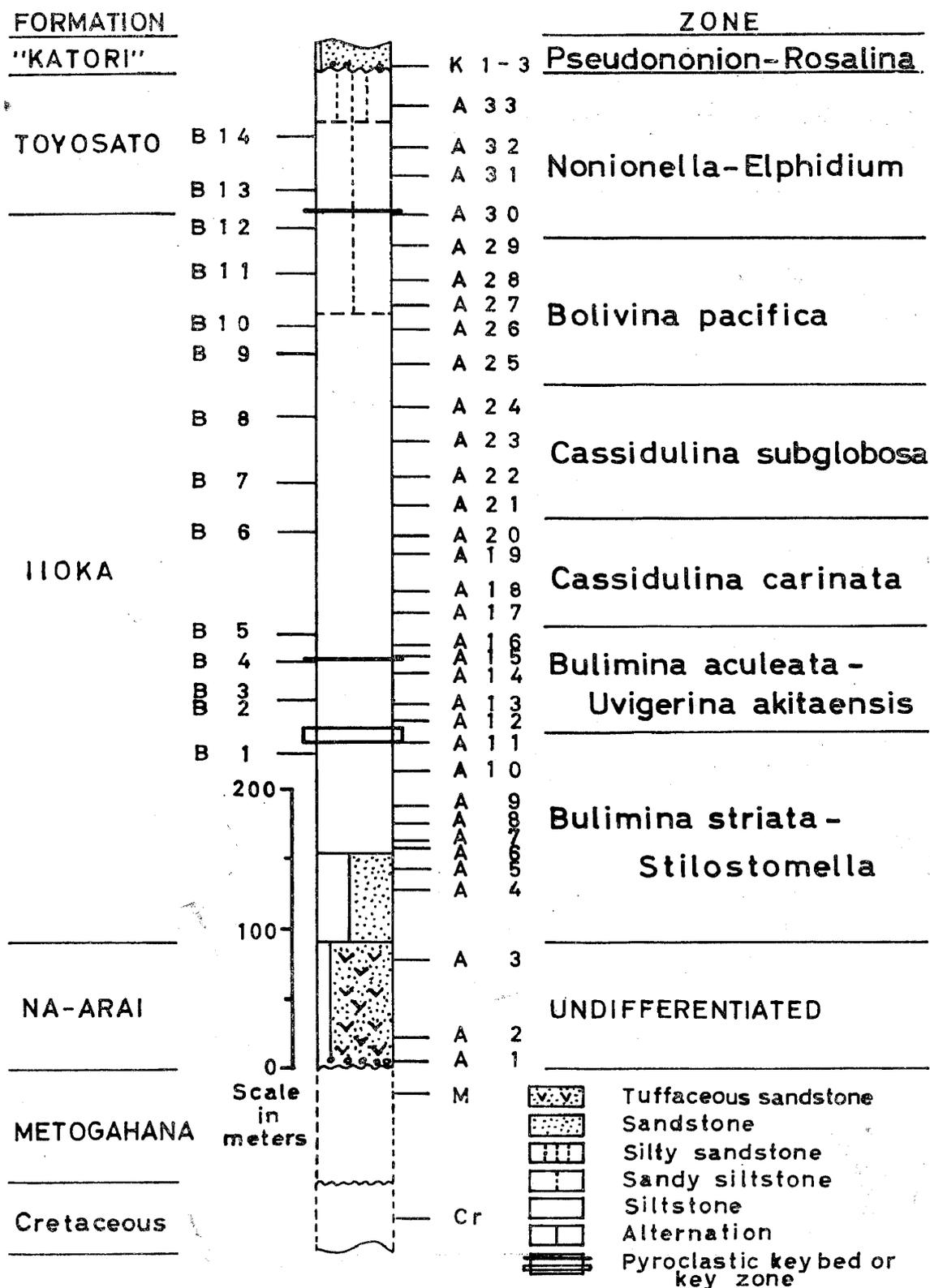


Fig. 3. Columnar section of the younger Cenozoic formations of the Choshi district, showing the stratigraphic position of the samples and the benthonic foraminiferal zones.

The Recent sediment samples on which the planktonic Foraminifera were studied are from the collection of the S.S. Soyo-maru; off Miyazaki Prefecture, st. 309 (31°41'35"N, 131°46'40"E, depth 472 m), off the Izu Peninsula, st. 258 (34°32'50"N, 138°45'30"E, depth 432 m), and off the Boso Peninsula, st. 8 (35°08'00"N, 140°47'00"E, depth 296 m).

#### BENTHONIC FORAMINIFERA

Eighteen specimens of only one species of arenaceous Foraminifera, *Martinottiella communis* (d'Orbigny), were found in one sample (100 g dry weight; sample M) from the Metogahana Formation. The species does not indicate a certain geologic age and is distributed in the outer neritic to bathyal zone of the present seas.

Among the three samples of the Na-arai Formation, sample A 1 is from the basal conglomerate which is exposed in the strand at Tokawa. In the sample, *Cassidulina subglobosa* Brady, *C. yabei* Asano and Nakamura, *C. sagamiensis* Asano and Nakamura, *Cibicides subpraecinctus* (Asano), *C. refulgens* Montfort, *C. sp.*, *Rosalina* sp. and *Trifarina kokozuraensis* (Asano) are the abundant species. The other species from the conglomerate are almost the same as those listed by Ozaki (1954b, 1958), except for *Cassidulina yabei* and several broken specimens of *Quinqueloculina* which were not reported. In the sample A 2, *Trifarina kokozuraensis* is the dominant species. It is accompanied with *Cassidulina subglobosa*, *C. yabei*, *C. carinata* Silvestri, *Planulina wuellerstorfi* (Schwager), *Epistominella naraensis* (Kuwano), *Nonionella stella* Cushman and Moyer, *Uvigerina proboscidea* Schwager, etc. in low frequencies. Species of *Fissurina* and *Parafissurina* have fairly high frequency. In the sample A 3, *Bolivina* cf. *spissa* Cushman, *Gyroidina?* *profunda* Aoki and *Bolivinita quadrilatera* (Schwager) are most abundant, and occur in association with *Bulimina striata* d'Orbigny, *Cassidulina carinata*, *C. delicata* Cushman, *C. depressa* Asano and Nakamura, *C. norcrossi* Cushman, *C. subglobosa*, *Cassidulinoides kuwanoi* Matoba, n. sp. *Melonis parkerae* (Uchio), *M. pompilioides* (Fichtel and Moll), *Eponides umbonatus* (Reuss), *Valvulineria glabra* Cushman, *Sphaeroidina bulloides* d'Orbigny, *Stilostomella* spp., etc.

The foraminiferal assemblages of each sample of the Na-arai Formation are fairly different from one another, particularly because the samples A 2 and A 3 comprise species most of which live in the upper bathyal zone whereas the fauna of the sample A 1 is of the neritic zone.

The Iioka, Toyosato and "Katori" Formations can be divided into seven units each of which is characterized by the occurrences of several abundant species of benthonic Foraminifera. The term zone employed in the present study is equivalent to the assemblage zone defined by the American Commission on Stratigraphic Nomenclature (1961). Of the about 300 benthonic forms, 55 species and subspecies or groups which are outstanding were selected for the purpose of zoning, and their stratigraphic occurrences in the Na-arai, Iioka, Toyosato and "Katori" Formations are shown in Fig. 4 with their relative frequencies. Each of the seven units or zones are described below.

#### *Bulimina striata*-*Stilostomella* zone (samples A 4-11 and B 1)

This zone is characterized by the abundant occurrence of *Bulimina striata* d'Orbigny and *Stilostomella* spp., the latter of which includes *S. lepidula* (Schwager), *S. japonica* (Ishizaki) and *Siphonodosaria oinomikadoi* (Ishizaki). Species of *Fissurina* and *Parafissurina* are also abundant in this zone. *Cassidulina norcrossi*, *Pullenia subcarinata* (d'Orbigny), *Sphaeroidina bulloides* are abundant in the upper part of this zone. *Astrononion hamadaense* Asano, *Epistominella pulchella* Husezima and Maruhasi, *Melonis parkerae*, *M. pompilioides* and *Valvulineria glabra* are almost confined to this zone.

*Cassidulina depressa* and its allied form, *C. carinata* and *Epistominella naraensis* show high frequencies in some samples of this zone though they reach their acme in the overlying zones. *Bolivina decussta* Brady and *Bulimina tenuata* (Cushman) have rather constant occurrences in this and the next younger zones in low frequencies. Sample A 5 yielded an abnormal assemblage of some shallow water species as *Pararotalia minuta* (Takayanagi), *Epistominella tamana* (Kuwano), *Buliminella elegantissima* (d'Orbigny) and *Elphidium subarcticum* Cushman in high frequencies in association with some characteristic deep water species of this zone. It is suggested that they were transported from some place to become mixed.

The ratio of planktonic forms has, in general, high value except for the lowest two samples where the benthonic foraminiferal number is also few. The fauna of this zone is of the upper bathyal zone of the temperate region.

#### ***Bulimina aculeata-Uvigerina akitaensis* zone (samples A 12-16 and B 2-4)**

This zone is defined by the characteristic occurrences of *Bulimina aculeata* d'Orbigny, *Uvigerina akitaensis* Asano, *Bolivina robusta* Brady, *Epistominella nipponica* Kuwano, n. sp and *Cassidulinoides kuwanoi*. *Stilostomella* spp., *Cassidulina carinata* and *Cassidulinoides parkerianus* (Brady) are abundant in lower part of this zone, while *Cassidulina depressa* and its allied form, *C. delicata*, *Epistominella naraensis*, *Gyroidinoides nipponicus* (Ishizaki), *Bolivina pacifica* Cushman and McCulloch, *Nonionella stella*, and *Valvulineria sadonica* Asano have high frequencies in the upper part.

In this zone, in general, the benthonic foraminiferal number is largest, attaining the maximum of 584 specimens per one gram, and the ratio of the planktonic Foraminifera to the total is highest but almost constant from the subjacent zone to the next younger two zones with the average ratio of 70-80 per cent. *Uvigerina akitaensis* is a well known subarctic bathyal species. The abundance of *Cassidulina carinata* and *Cassidulinoides parkerianus* in the lower part of this zone, and *Cassidulina depressa*, *Bolivina pacifica* and *Nonionella stella* in the upper part indicate that this zone was deposited under a condition somewhat shallower than the subjacent zone, and that the lower part of the zone was deposited under a condition relatively warmer than the upper part.

#### ***Cassidulina carinata* zone (sample A 17-20 and B 6)**

This zone is outstanding in that *Cassidulina carinata* occurs in abundance throughout. In the lower part of the zone *Elphidium subarcticum* occurs in abundance, while in the upper part *Pullenia bulloides* (d'Orbigny) and *Cassidulina subglobosa* are characteristic and the two species in abundance range up to the next younger zone. *Valvulineria sadonica* and *Epistominella naraensis* seem to reach their acme in this and the subjacent zones though their values are not so high.

The number of benthonic Foraminifera is relatively few compared with the underlying and overlying zones, but the ratio of the planktonic forms is rather constant with high value. The fauna of the zone is inferred to have flourished in the outer neritic zone under a warm water condition.

#### ***Cassidulina subglobosa* zone (samples A 21-24 and B 7-8)**

None of the species of this zone occurs continuously throughout in abundance. *Cassidulina subglobosa* is characteristic in the lower part of the zone and extends from the upper part of the subjacent zone. In association with this species occur *Cassidulina carinata*, *Bulimina aculeata*, *Bolivina pacifica*, *Elphidium clavatum* Cushman, and *Pullenia bulloides*. In the upper part of the zone, *Pseudoeponides japonicus* Uchio, *Hyalinea balthica* (Schröter), *Cassidulina depressa* and allied form, and *Pullenia bulloides* are abundant,

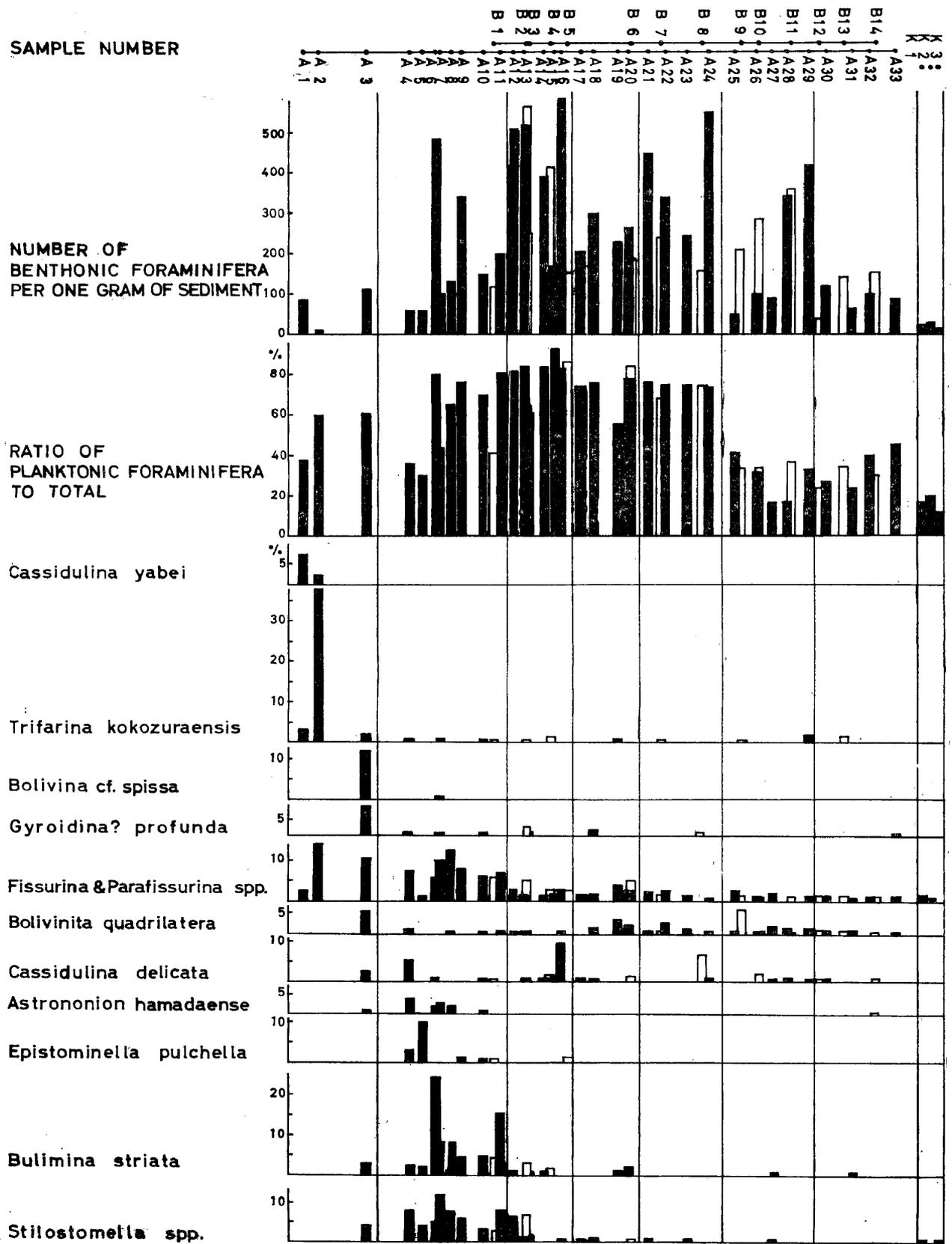


Fig. 4a.

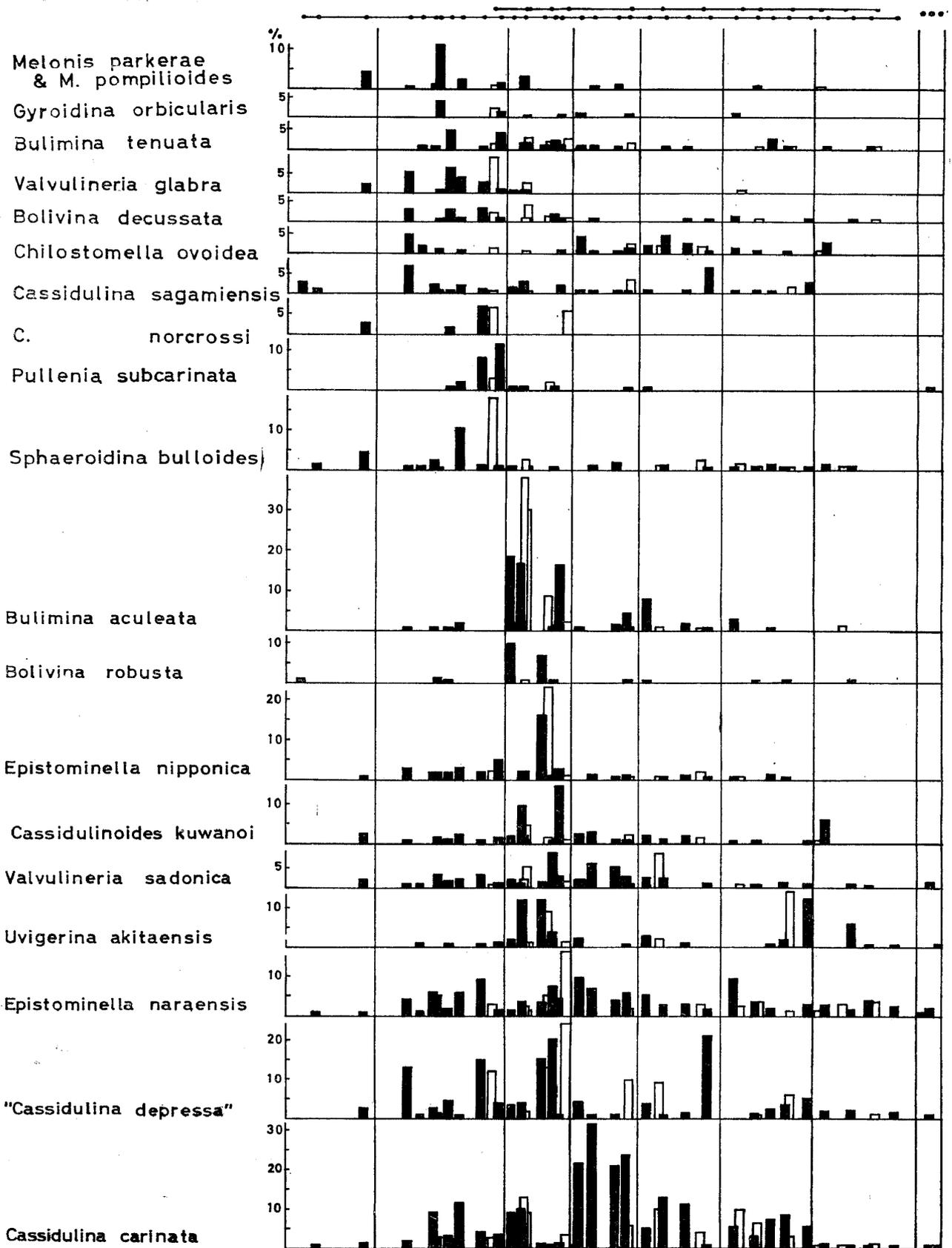


Fig. 4b.

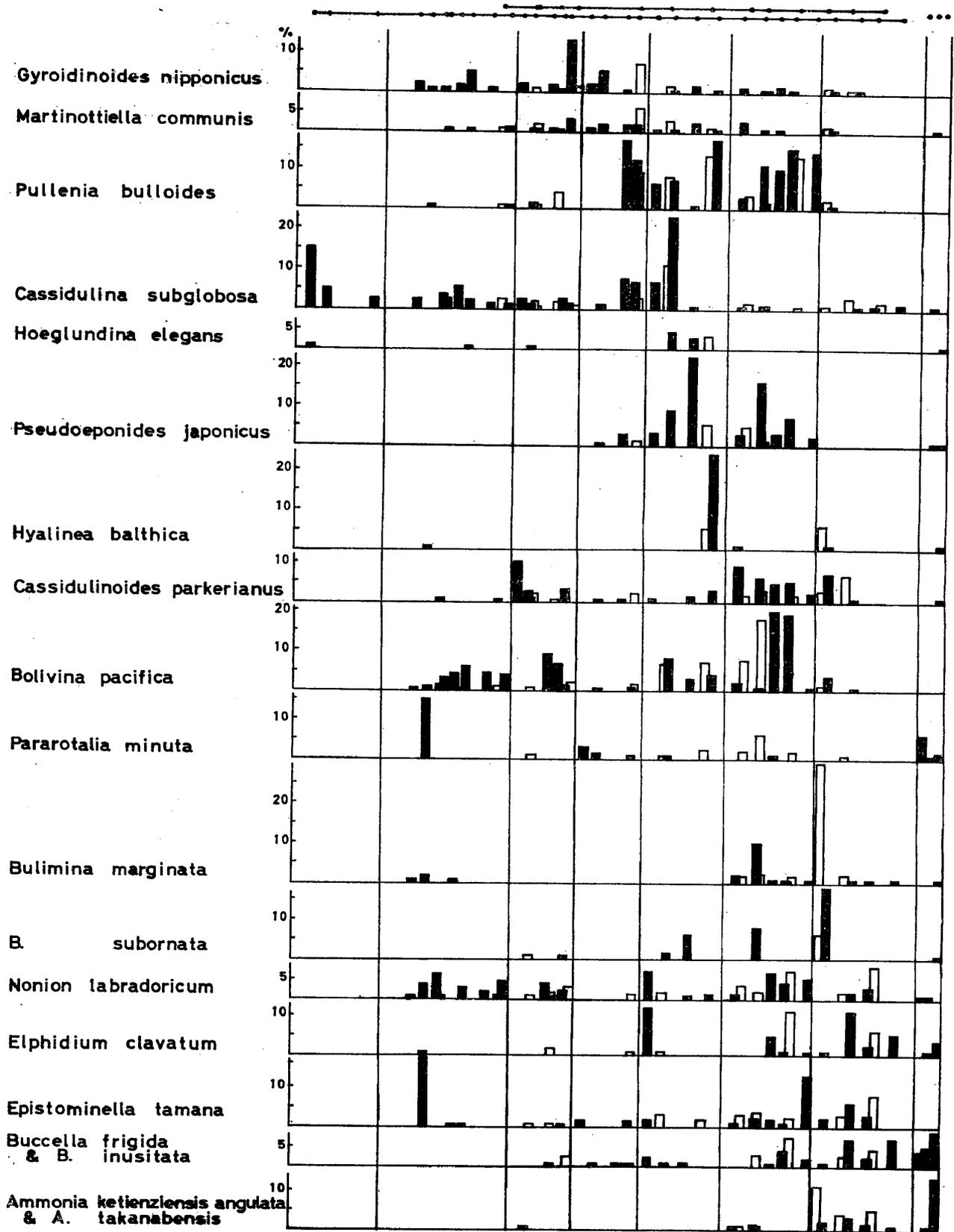


Fig. 4c.

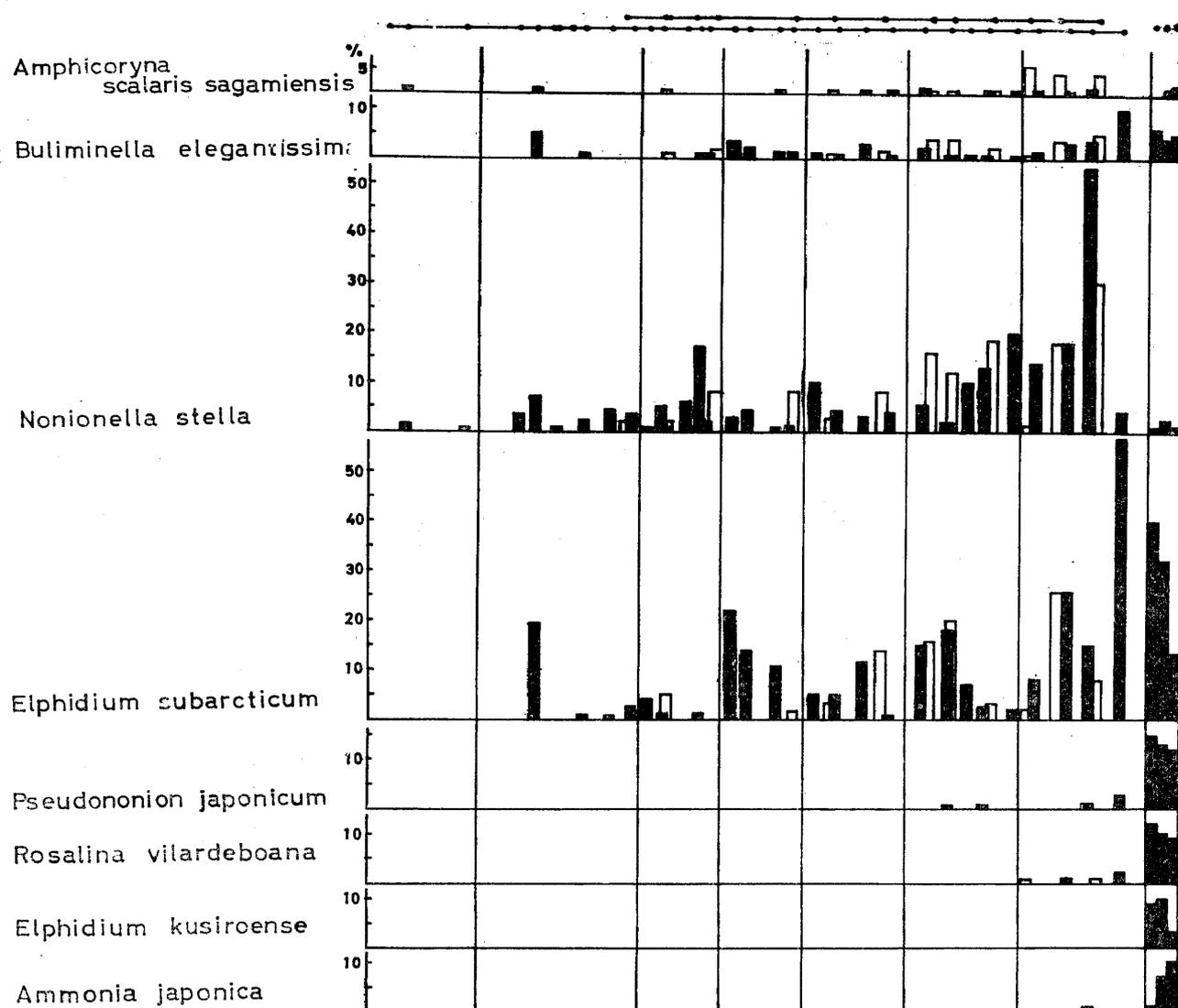


Fig. 4d.

Fig. 4. Vertical frequency distribution of the important benthonic Foraminifera from the Na-arai, Iioka, Toyosato and "Katori" Formations of the Choshi district. The black column shows the samples A 1-A 33 and K 1-K 3, and the white shows the samples B 1-B 14. The line between samples indicates the boundary of the benthonic foraminiferal zone.

accompanied with *Cassidulina delicata* *C. sagamiensis*, *Bolivina pacifica* and *Elphidium subarcticum*. *Hoeglundina elegans* (d'Orbigny) seems to be almost confined to this zone though its occurrence is rare.

In this zone the ratio of planktonic forms is very uniform in every sample with high value of 70-76 percent which is almost the same as in the subjacent three zones. On the contrary the number of benthonic Foraminifera in the zone is very variable. The remarkable changes in the sequence of the fauna are characteristic of this zone, and this seems to reflect the unstable ecologic condition. The fauna of the zone is thought to have lived in the middle to outer neritic zone. Temperature variations are indicated by such cold water species as *Elphidium clavatum* in the lowest part of the zone and *Hyalinea balthica* in the uppermost part.

***Bolivina pacifica* zone** (samples A 25–29 and B 9–11)

This zone is characterized by the abundant occurrence of *Bolivina pacifica*. *Pullenia bulloides*, *Pseudoepionides japonicus*, *Cassidulina carinata*, *Cassidulinoides parkerianus*, *Nonionella stella* and *Nonion labradoricum* (Dawson) are also abundant in the zone. In the lower part of the zone *Elphidium subarcticum* and *Epistominella naraensis*, and in the upper part *Uvigerina akitaensis*, *Elphidium clavatum* and *Epistominella tamana* have high frequencies. *Pararotalia minuta*, *Bulimina marginata* and *B. subornata* occur in some samples of the zone.

In this zone the ratio of planktonic Foraminifera (16–42%) becomes extremely low compared with the subjacent zones, and the number of benthonic Foraminifera seems also to decrease although it is very variable. The fauna is inferred to have lived in the middle to outer neritic zone. The influence of the cold water is indicated in the middle to upper part of the zone by such species as *Uvigerina akitaensis* and *Elphidium clavatum*.

***Nonionella-Elphidium* zone** (samples A 30–33 and B 12–14)

This zone is outstanding in the abundant occurrence of *Nonionella stella* and *Elphidium subarcticum*, which occupy nearly or more than half of most of the samples of the zone. In the lower part *Bulimina marginata* d'Orbigny and *B. subornata* Brady are abundant and *Cassidulinoides kuwanoii*, *C. parkerianus*, *Hyalinea balthica* and *Uvigerina akitaensis* are accompanied with them. *Ammonia ketienziensis angulata* (Kuwano), *A. takanabensis* (Ishizaki), *Amphicoryna scalaris sagamiensis* (Asano), *Buccella frigida* (Cushman), *B. inusitata* Andersen, *Buliminella elegantissima*, *Elphidium clavatum* and *Epistominella tamana* are characteristic.

In this zone the number of benthonic Foraminifera is fairly few, ranging from 40 to 160 specimens per one gram. The ratio of planktonic Foraminifera continues to be low from the subjacent zone, but there is a slight tendency to increase upwards. The fauna of the lowest part of the zone indicates an environment of the middle to outer neritic whereas that of the middle to upper part is inferred to represent the middle to inner neritic zone, which was under the influence of colder water.

***Pseudononion-Rosalina* zone** (samples K 1–3)

In this zone *Elphidium subarcticum* is most abundant, but the following ones which are also abundant characterize this zone, namely, *Pseudononion japonicum* Asano, *Rosalina vilardeboana* d'Orbigny, *Elphidium kusiroense* Asano and *Ammonia japonica* (Hada). And associated with them are *Ammonia ketienziensis angulata*, *Buccella frigida*, *B. inusitata*, *Buliminella elegantissima*, *Bolivina seminuda* Cushman, *Cibicides lobatulus* (Walker and Jacob), *Pararotalia minuta*, *Pseudorotalia gaimardii* (d'Orbigny), *Elphidium crispum* (Linné), *Hanzawaia nipponica* Asano and *Porosorotalia makiyamae* (Chiji).

The number of benthonic Foraminifera is very small, amounting to 19–24 individuals per one gram of dry sediments. The ratio of planktonic forms to the total Foraminifera is as low as 12–20 per cent. This fauna is characteristic of the inner neritic zone and is inferred to have lived under conditions similar to that now around the Choshi area.

This zone is defined by only three samples from nearly the same stratigraphic level or time plane at the base of the "Katori" Formation. Their localities are separated from one another. Therefore, it may not be proper to apply the term zone here.

## PLANKTONIC FORAMINIFERA

Planktonic Foraminifera were found from the Na-arai, Iioka, Toyosato and "Katori" Formations in association with benthonic forms. No planktonic forms were found from the Metogahana Formation. Among the same samples analyzed for the benthonic Foraminifera, samples A 1-3 of the Na-arai, samples A 4-30 of the Iioka, samples A 31-33 of the Toyosato, and sample K 1 of the "Katori" were studied as to the planktonic Foraminifera. All species of the planktonic Foraminifera identified from those samples are listed in Table 1 in comparison with those from the Recent sediments collected by the S.S. Soyo-maru. In the table the species of samples A 1 and A 2 are merely indicated as to their presence because of their preservation being unfavorable for quantitative analysis. In the other samples each species is indicated by the actual number of individuals among the 200 specimens of the total planktonic forms with the exception of sample K 1.

From sample A 1, which is from the basal conglomerate of the Na-arai Formation, the following species were discriminated; *Globigerina bulloides* d'Orbigny, *G. nepenthes* Todd, *G. pachyderma* (Ehrenberg), *Globigerinita glutinata* (Egger), *Globigerinoides obliquus* Bolli, *G. ruber* (d'Orbigny), *G. trilobus* (Reuss), *Globoquadrina conglomerata* (Schwager), *G. dutertrei* (d'Orbigny), *Globorotalia acostaensis* Blow, *G. menardii* (d'Orbigny) s.s., *G. menardii miocenica* Palmer, *G. scitula* (Brady), *G. tumida* (Brady), "*Orbulina universa*" d'Orbigny and *Sphaeroidinellopsis seminulina* (Schwager). This fauna is considered to represent the *Globorotalia menardii*/*Globigerina nepenthes* Zone of Saito (1963) in the Upper Miocene.

In sample A 2, *Globigerina nepenthes*, *Globorotalia menardii miocenica* and *Sphaeroidinellopsis seminulina* disappear, and *Globorotalia crassaformis* (Galloway and Wissler) and *Sphaeroidinella dehiscens* (Parker and Jones) appear for the first time. In sample A 3 from the upper part of the Na-arai Formation, *Globorotalia inflata* (d'Orbigny) and *Pulleniatina obliquiloculata* (Parker and Jones) make their appearance. *Globorotalia truncatulinoides* (d'Orbigny) first appears in sample A 4 from the lowest part of the Iioka Formation.

From the Iioka, Toyosato and "Katori" Formations and Recent deposits, the following species were distinguished; *Globigerina bulloides*, *G. falconensis* Blow, *G. pachyderma*, *G. quinqueloba* Natland, *G. rubescens* Hofker, *Globigerinella siphonifera* (Brady), *Globigerinita glutinata*, *G. humilis* (Brady), *G. iota* Parker, *G. uvula* (Ehrenberg), *Globigerinoides conglobatus* (Brady), *G. ruber*, *G. sacculifer* (Brady), *G. tenellus* Parker, *G. trilobus*, *Globoquadrina conglomerata*, *G. dutertrei*, *G. cf. dutertrei*, *G. hexagona* (Natland), *Globorotalia crassaformis*, *G. hirsuta* (d'Orbigny), *G. inflata*, *G. menardii*, *G. scitula*, *G. tosaensis* Takayanagi and Saito, *G. truncatulinoides*, *G. tumida*, "*Orbulina universa*", *Pulleniatina obliquiloculata*, and *Sphaeroidinella dehiscens*. All of these species except *Globorotalia tosaensis* and *Globoquadrina cf. dutertrei* are well known modern forms. *G. cf. dutertrei* is confined to the basal part of the Iioka Formation. *Globigerina bulloides*, *G. falconensis*, *G. pachyderma*, *G. quinqueloba*, *Globigerinita glutinata*, *Globoquadrina dutertrei* and *Globorotalia inflata* are usually abundant and associated with fairly large numbers of *Globigerinoides ruber* and *Globoquadrina hexagona*. Among those species, *Globigerina pachyderma* is most abundant almost throughout the section. *Globigerinita glutinata* is very abundant in the lowest horizons and *Globigerina quinqueloba* is likewise in the highest horizons of the section. In the Recent samples *Globigerina pachyderma* and *G. quinqueloba* are fairly few compared with fossil assemblages, on the contrary *Globigerinoides ruber* is fairly abundant in the Recent samples.

It is practical to group up the planktonic species into warm and cold water faunas, in order to examine the water temperature variations as reflected from the shifting of the paleo-ocean currents during deposition of the young formations. According to the studies of Bradshaw (1959), Bé (1959) and Parker (1960), the distributions of the



planktonic Recent Foraminifera are chiefly related with water temperature. The coiling direction of *Globigerina pachyderma*, a well known cold water species, was discussed by Ericson (1959) and Bandy (1960) who showed that the sinistrally coiled form is predominant in the colder waters in the area of distribution of the species. *Globigerinita uvula* and *Globigerina quinqueloba* are cold water species, whereas *Globigerinoides conglobatus*, *G. sacculifer*, *G. trilobus*, *Globigerinella siphonifera*, *Globoquadrina conglomerata*, *Globorotalia menardii*, *G. tumida*, *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens* are warm water forms. Other *Globorotalia* and *Globigerinoides*, such as *Globorotalia crassaformis*, *G. hirsuta*, *C. inflata*, *G. tosaensis*, *G. truncatulinoides*, *G. scitula*, *Globigerinoides ruber* and *G. tenellus*, and "Orbulina universa" and *Globigerinita glutinata* are here included in the warm-temperate fauna. The remaining members of the faunal groups in each sample are mostly composed of *Globigerina bulloides*, *G. falconensis*, *Globoquadrina dutertrei* and *G. hexagona*. The vertical changes in the faunal compositions are shown in the cumulative frequency graph in Fig. 5 in which the Foraminifera are arranged according to the water temperature. Although there may be some problems in the grouping, the graph indicates the relative vertical changes in the paleo-water temperature.

Compared with the planktonic Foraminifera of the Recent deposits, many of the fossil assemblages of the section, in general, seem to show water conditions colder than the present day off the Boso Peninsula (st. 8), while the assemblages from some horizons in the section are similar to the conditions, off the Izu Peninsula (st. 258). However, there are some discrepancies between the fossil and Recent faunas. Where the warm water species of a fossil sample are similar in abundance to a Recent sample, most of the fossil assemblages contain more cold water species than the Recent one. It is inferred that most of the fossil assemblages actually lived under a condition similar to the present Choshi area or a little north where is the transition area of the cold and warm currents, namely the Oyashio and the Kuroshio. On the other hand, the three Recent samples were taken from areas washed by the Kuroshio Current.

In the following paragraphs the vertical changes of the planktonic foraminiferal assemblages as well as the water condition in the section will be described in terms of the benthonic foraminiferal zones.

In the upper part of the Na-arai Formation, *Globigerina pachyderma* is abundant and most of the specimens are sinistrally coiled. *Globigerinita glutinata* and *Globorotalia inflata* are also abundant. The *Bulimina striata-Stilostomella* zone, which is in the lowest part of the Iioka Formation, has relatively few cold water species in the section, but the warm water species are not abundant in the zone except for the basal part. Sinistrally coiled specimens of *G. pachyderma* are almost absent throughout this zone and the superposed next two zones. In this zone *Globigerinita glutinata* is most abundant, *Globoquadrina* cf. *dutertrei* is confined to it, and *Globorotalia truncatulinoides* makes its appearance from the base. In the lower part of the zone almost all specimens of *Pulleniatina obliquiloculata* are sinistrally coiled. The *Bulimina aculeata-Uvigerina akitaensis* zone, especially its upper part, is characterized by the abundant occurrence of cold water species in accordance with the fewer occurrence of warm water species and more than a half of each sample is composed of the one species, *G. pachyderma*; however, sinistrally coiled form of the species is few. The transformation from this to the next *Cassidulina carinata* zone is represented by the change in water temperature from cold to warm. The *Cassidulina carinata* zone, in general, was deposited under a warmer water condition though great variations are seen.

The change in temperature from warm to cold is represented from the *Cassidulina carinata* zone to the next *Cassidulina subglobosa* zone. In the lower part of the latter,

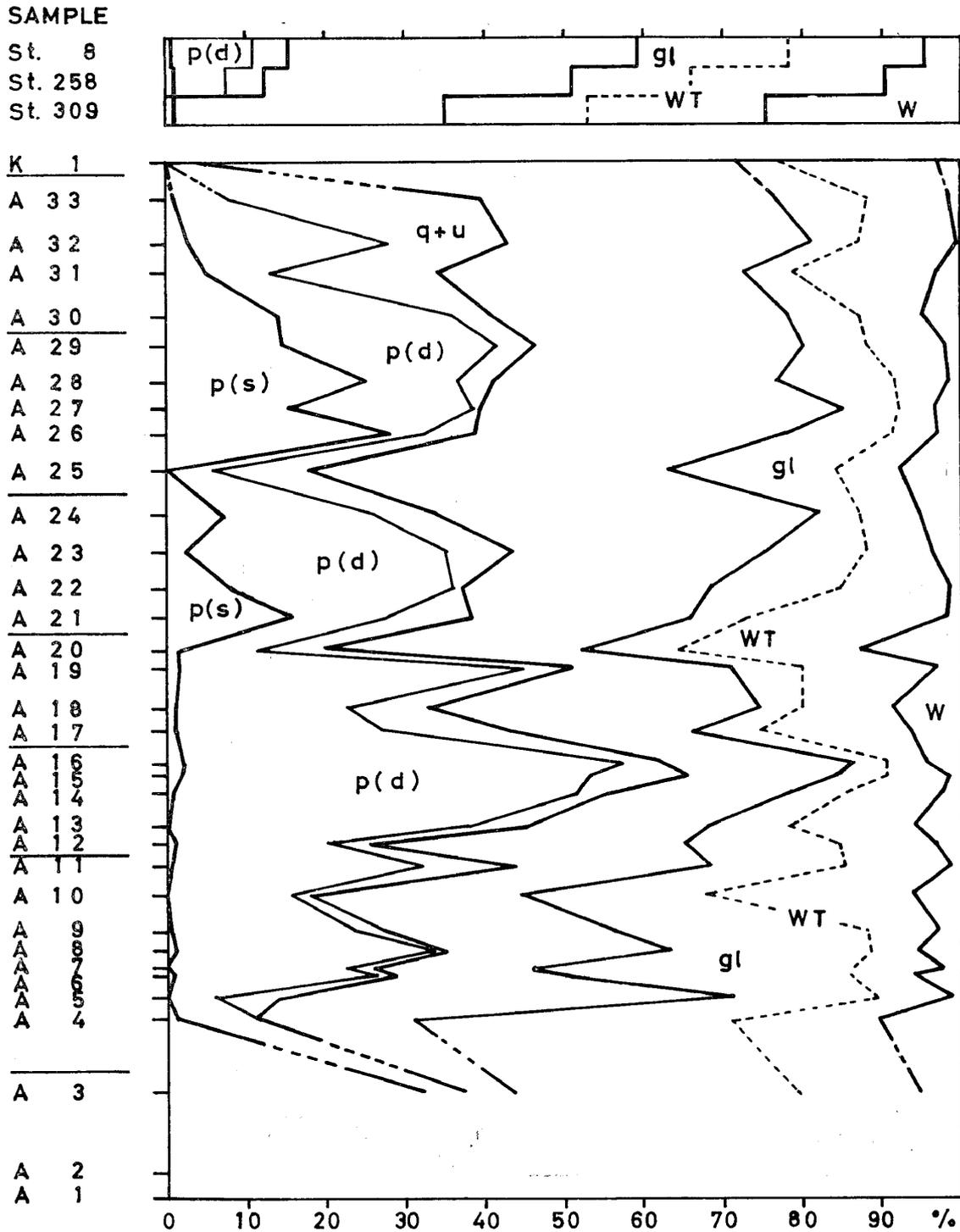


Fig. 5. Vertical variation of the planktonic foraminiferal assemblages of the Choshi district and Recent deposits, showing variation of warm and cold water species.

p(s): sinistrally coiled *Globigerina pachyderma*. p(d): dextrally coiled *G. pachyderma*. q+u: *Globigerina quinqueloba* and *Globigerinita uvula*. They are cold water species. W: warm water species. WT: warm-temperate water species. gl: *Globigerinita glutinata*. The line between sample numbers indicates the boundary of the benthonic foraminiferal zone. (see text and Table 1).

sinistrally coiled *G. pachyderma* increases in accordance with the decrease of the warm water species. The lowest part of the *Bolivina pacifica* zone has an assemblage in which the cold water species are few and the warm water species are relatively abundant whereas the middle

to upper part of the zone is characterized with the abundant occurrence of sinistrally coiled *G. pachyderma* and the fewer occurrence of the warm water species, and especially in the middle part of the zone the sinistral form of *G. pachyderma* occupies a maximum of 28 percent of the total planktonic assemblage, though the total frequencies of the cold water species are not particularly high. In the *Nonionella-Elphidium* zone, sinistrally coiled *G. pachyderma* are still abundant in the lowest part but rapidly decrease upwards. Although the total frequency of the cold water species is rather constant in the zone, both the sinistral and dextral forms of *G. pachyderma* decrease upwards whereas *G. quinqueloba* increases. In the *Pseudononion-Rosalina* zone, which is the basal part of the "Katori" Formation, planktonic Foraminifera are scarce and all of their tests are small with very thin test wall. Considering from the benthonic assemblages of the zone, it is inferred that the "Katori" Formation, at least the basal part of it, was deposited in shallow, near shore water. It seems, therefore, to be unjust to compare that fauna and also that of the upper part of the *Nonionella-Elphidium* zone with those of deeper water according to the ecology of the planktonic Foraminifera.

The coiling direction of some species of planktonic Foraminifera has been considered to be significant for interpretation of the ecology and for the evolution of foraminiferal species. After an examination of all the planktonic Foraminifera of the section, significant changes in the coiling direction were found in the three species; *Globigerina pachyderma*, *Globorotalia menardii* s.l. and *Pulleniatina obliquiloculata*.

*Globigerina pachyderma*: The frequency distribution of the sinistrally and dextrally coiled forms of *G. pachyderma* is shown in Fig. 6 (right). The curve is similar to that seen in Fig. 5 which is expressed in per cent to total planktonic forms. As already mentioned the coiling direction of the species is considered to be related with the water temperature. Ericson (1959) found a significant change in the coiling direction of *G. pachyderma* in the north Atlantic deep sea sediments. According to Ericson the sinistrally coiled form of the species is predominant in the north of the 7.2°C surface temperature isotherm in April. Bandy (1960), recognizing the similar coiling habit of the same species, applied it to the Late Cenozoic correlations of formations and sediment cores in southern California. Takayama (1961), Aoki (1963, 1964), and Takayanagi and Oba (1966) also discussed the coiling direction of the species from the younger Cenozoic deposits of Japan.

*Globorotalia menardii* s.l.: In the basal conglomerate of the Na-arai Formation (sample A 1), the ratio of the sinistrally and dextrally coiled forms of *G. menardii* s.s. and *G. menardii miocenica* are nearly equal, there being 11 sinistral and nine dextral among 20 specimens. The other samples from the Na-arai Formation (samples A 2 and A 3) yielded only dextrally coiled form of *G. menardii* though the number of specimens counted are few. In the horizons higher than the Na-arai Formation the coiling direction of the species is persistently sinistral. This coiling change of *G. menardii* from dextral to sinistral coincides with the change in *Pulleniatina obliquiloculata* from dextral to sinistral at the base of the Iioka Formation. Similar coiling change in *G. menardii* s.l. is reported from the Philippines (Bandy, 1963) and Taiwan (Huang, 1967), but in Java and Venezuela (Bolli, 1964) the coiling pattern of the species is different.

*Pulleniatina obliquiloculata*: In the upper part of the Na-arai Formation (sample A 3) four specimens of the species were obtained and all showed dextral coiling. In the basal part of the Iioka Formation (sample A 4 to A 8), however, almost all of the specimens of *P. obliquiloculata*, amounting to more than 90 percent of the total, showed sinistral coiling. After a while, the next coiling change is seen from sinistral to dextral (between sample A 8 and sample A 9), then in the later stage the coiling direction of the species is persistently dextral, amounting to more than 90 per cent, as shown in Fig. 6 (left). Thus it is evident that there are significant changes in the coiling direction of *P. obliquiloculata* and

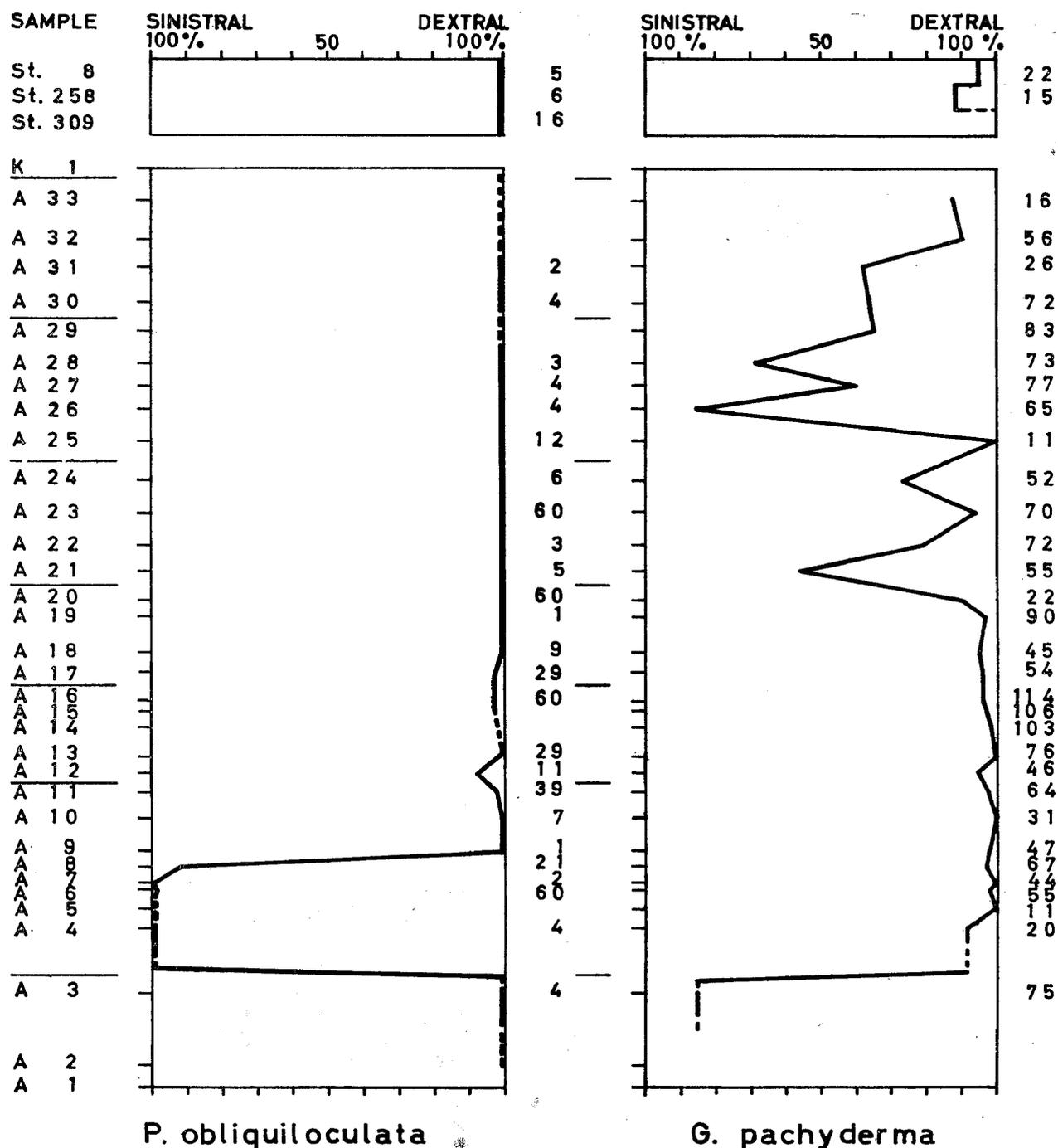


Fig. 6. Vertical changes in the coiling direction of *Pulleniatina obliquiloculata* (Parker and Jones) and *Globigerina pachyderma* (Ehrenberg) in the Choshi district and Recent deposits.

The number on the right-hand side of each figure indicates the actual number of specimens examined. The line between sample numbers indicates the boundary of the benthonic foraminiferal zone.

a short interval of sinistral coiling at the base of the Iioka Formation.

Such changes of the coiling direction of *P. obliquiloculata* were recognized by Bandy (1963) for the first time in his studies on the Cenozoic planktonic foraminiferal zonation in the Philippines. He found a *Pulleniatina* sinistral population, less than 100 m in thickness, in the lower part of the Panoran Mudstone in southern Iloilo, Panay. He

stated that in the upper part of the Lower Pliocene *Pulleniatina obliquiloculata* coils dextrally whereas in the basal part of the Lower Pliocene this species changes dramatically to sinistral and that the change is from about 98 per cent dextral to 98 per cent sinistral across this boundary. He found similar coiling change of the species in the Upper Miocene where it appears to be sinistral in the Sarmatian and dextral in the Pontian. However, the species is rare in the Upper Miocene.

Bolli (1964), in his study on some planktonic Foraminifera from the late Miocene to Recent, reported similar coiling change of *P. obliquiloculata* in Java and Venezuela which he considered to be correlative to Bandy's higher interval of sinistral coiling of the species. He stated that this characteristic coiling pattern of *Pulleniatina obliquiloculata* during its early range would probably turn out to be a useful feature for long-range stratigraphic correlation. In Japan similar sinistral coiling of the species was recognized by Takayama (personal communication) in the basal part of the Kurotaki Formation along the Obitsu River in the Boso Peninsula. Recently Huang (1967) found two intervals of sinistral coiling of *P. obliquiloculata* in his study on the late Cenozoic planktonic Foraminifera in Taiwan, just similar to those of Bandy in the Philippines.

#### GEOLOGIC AGE AND CORRELATION

Although the Metogahana Formation has yielded no significant fossils for age determination, all previous workers who had been engaged in the stratigraphical research of the district (Yamane, 1924a, b; Imazeki in Fujimoto, 1951; Ozaki, 1954b, 1958; Suzuki, 1958) considered the formation to be Miocene in age, because it is unconformably overlain by the "Lower Pliocene" Na-arai Formation. As the overlying Na-arai Formation is here considered to be Upper Miocene, the Metogahana Formation is tentatively presumed to be Middle or Lower Miocene, although the writer possesses no additional data from the formation.

The basal conglomerate of the Na-arai Formation belongs to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone of Saito (1963) in the Upper Miocene as already described. The Na-arai Formation except for the basal part yields no characteristic Miocene species. However, the change in the coiling direction of *Pulleniatina obliquiloculata* is considered to be reliable for long-range correlation. Therefore, the sinistrally coiled interval of the species at the base of the Iioka Formation can be correlated to the higher sinistrally coiled interval in Taiwan (Huang, 1967) and the Philippines (Bandy, 1963), and to the same interval in Java and Venezuela (Bolli, 1964). According to Bandy the base of his higher interval of sinistrally coiled *P. obliquiloculata* is the Miocene-Pliocene boundary, and it is inferred that the Na-arai Formation is situated below that boundary.

Asano *et al.* (1958) proposed to draw the Pliocene-Pleistocene boundary in the middle part of the Umegase Formation in the Boso Peninsula, because of the occurrence of *Globigerina pachyderma*, a typical cold water species. The upper part of abundance the *Bulimina aculeata*-*Uvigerina akitaensis* zone in the middle part of the Iioka Formation of the Choshi district is correlated to the upper part of the Umegase Formation as discussed later. The Pliocene-Pleistocene boundary of Asano *et al.*, therefore, is drawn in the middle part of the *B. aculeata*-*U. akitaensis* zone in the Choshi district.

The correlations with the formations in the Boso Peninsula are attempted primarily based on the planktonic Foraminifera. According to Saito (1962, 1963) the middle and upper part of the Kiyosumi Formation of the Boso Peninsula belongs to his *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, to which the basal part of the Na-arai Formation is correlated. Takayama (personal communication) found a short interval of sinistrally coiled *Pulleniatina obliquiloculata* at the base of the Kurotaki Formation in the

Obitsu River section, near the horizon of the key bed, Kd 38, in the Boso Peninsula. According to Mitsunashi *et al.* (1959), Kd 38 is intercalated in the basal part of the Kiwada Formation along the Yoro River. The interval of sinistrally coiled *P. obliquiloculata* at the base of the Iioka is correlated to that at the base of the Kurotaki of the Obitsu River section, and therefore to the basal part of the Kiwada and perhaps, at least the upper part of the Kurotaki Formation in the Yoro River section. Although the younger deposits are rather poor in reliable fossils for correlation, the interval in which sinistrally coiled *Globigerina pachyderma* are abundant is considered to be the most important. Therefore, such an interval in the middle part of the *Bolivina pacifica* zone in the upper part of the Iioka Formation is correlated to the uppermost part of the Kakinokidai to the Chonan of the Obitsu and Yoro River sections (Takayama, 1961; Aoki, 1963, 1964). The interval where *Globigerina pachyderma* is most abundant in the upper part of the *Bulimina aculeata-Uvigerina akitaensis* zone in the middle part of the Iioka may be correlated to the upper part of the Umegase Formation (Asano *et al.*, 1958; Takayama, 1961; Aoki, 1963, 1964).

Many studies have been published on the benthonic Foraminifera from the surface sections and wells in the Boso Peninsula, and as a result a zonal succession of them has been established. Ishiwada, Higuchi and Kikuchi (1962) summarized the subsurface zonal succession of the benthonic Foraminifera of several wells drilled in the southern Kanto Region. Aoki (1963) reported on the Foraminifera from along the Yoro River in the Boso Peninsula which is regarded as a standard area of the younger Cenozoic strata in this region. The correlations of the benthonic foraminiferal zones between the Yoro River and the Choshi districts via wells along Kujukuri-hama are shown in Fig. 7. The zonal successions of wells and the correlation of them along Kujukuri are similar to the result of Ishiwada *et al.* (*Op. cit.*) except for some modifications by the writer according to the reports of Ishiwada and Shinada (1959), Kikuchi (1964), and Higuchi (1964).

Pumiceous sandstone of the Na-arai Formation has been recognized in the basal part of the wells of Iioka, Asahi 1 and Asahi 2, resting on the basements of the Paleozoic and Mesozoic rocks. The *Bulimina striata-Stilostomella* zone of the Choshi district is correlated to the *Bulimina aculeata*, *Bulimina nipponica*, and *Bolivina* zones in the wells of Iioka, Asahi 1 and Asahi 2, and these correspond to the Kurotaki, Kiwada, and Otadai Formations and the lowest part of the Umegase Formation of the Yoro River. The *Bulimina aculeata-Uvigerina akitaensis* zone corresponds to the *Bulimina aculeata* and *Uvigerina akitaensis* zones in the wells which are correlated to the middle to upper part of the Umegase Formation. Consequently the thick interval from the Kurotaki to the Umegase Formation, from the zone 16 to the zone 7 of Aoki of the Yoro River, corresponds to the lower part of the Iioka Formation. The *Cassidulina carinata* and *Cassidulina subglobosa* zones in the Iioka Formation may be correlated nearly to Aoki's zones 6 and 5 of the Yoro River section respectively. The relations of the benthonic foraminiferal zones with one another in the upper horizons are not certain because of the areas being far apart and to the rather shallow water conditions under which they were deposited. But the *Bolivina pacifica* and *Nonionella-Elphidium* zones of the Choshi district may correspond to the Chonan, Mandano and Kasamori Formations of the Yoro River section. However, based only upon the Foraminifera the correlation of the "Katori" Formation, the *Pseudononion-Rosalina* zone, with other units is impossible, particularly because fossils are preserved only in its basal part. Because the "Katori" Formation unconformably underlies the Shimosueyoshi Ash and overlies the Toyosato Formation with slight unconformity, it may be correlated to the lower part of the Shimosu Super-group (Kawai, 1961), perhaps to the Jizodo or to the overlying Yabu Formation of the Boso Peninsula.

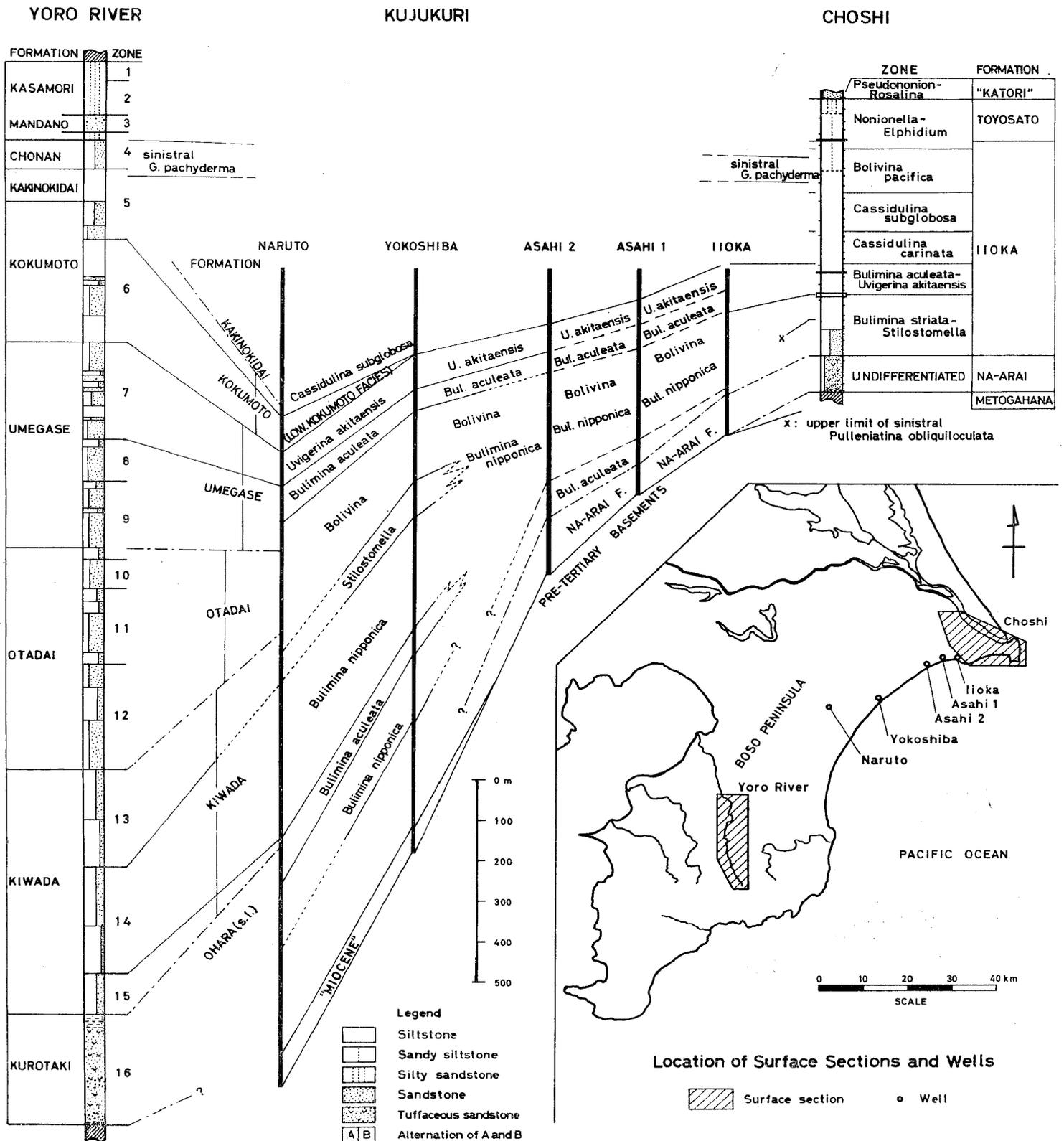


Fig. 7. Correlation of the benthonic foraminiferal zones between the Choshi district and the Yoro River area via wells drilled along Kujukuri.

The columnar section and benthonic foraminiferal zones along the Yoro River are quoted from Aoki (1963). Zonal successions of the wells and correlation of them are somewhat modified from Ishiwada, Higuchi and Kikuchi (1962).

## DISCUSSION

For the paleoecological interpretation of the fossil foraminiferal assemblages, informations are needed in their ecology and distribution in the present seas. Although there are several works on the distribution of the Recent Foraminifera in the adjacent seas of Japan, those which refer to the outer neritic to bathyal zone, to which belong most of the fossil assemblages, are rare. The following reports provide the information necessary for paleoecological interpretation, namely, the southern part of the Okhotsk Sea (Kuwano, 1953, 1954), the Pacific coast of Japan (Ishiwada, 1954, 1964), Suruga Bay on the Pacific side (Nagahama, 1954), off the Boso Peninsula and Kagoshima Bay on the Pacific side (Kuwano, 1962-63), the East China Sea (Polski, 1959), Toyama Bay in the Japan Sea (Ishiwada, 1950; Matsuda, 1957), and off Niigata in the Japan Sea (Ishiwada, 1964), besides the writer's unpublished data from Sendai Bay on the Pacific side of north Japan.

There are some discrepancies between the Recent and fossil assemblages. Ishiwada (1964) stated that *Bulimina aculeata* which is commonly distributed in the Kazusa Group does not show a high frequency in the "mixed Kuroshio" region, but occurs in the bathyal zone of Suruga Bay and Tosa Bay. On the other hand in these bays the cold-water species, *Uvigerina akitaensis* does not associate with the *Bulimina aculeata* assemblage. The association of the two species is seen in the Choshi district in the *Bulimina aculeata-Uvigerina akitaensis* zone. Ishiwada further noticed the frequent occurrence of *Bolivina robusta*, which seems to prefer a neritic environment in the present seas, in the bathyal facies of *Bulimina aculeata*, *B. nipponica* and *Bolivina spissa* in the Kazusa Group, and considered that *Bolivina robusta* was displaced from the shallow waters. Similar occurrence of the species is also seen in the Choshi district where *Bolivina robusta* associates with *Bulimina aculeata* and *Uvigerina akitaensis*. The possibility that *Bolivina robusta* in the past lived under a condition somewhat different from that of the present, will remain, as in the case of *Bulimina aculeata*.

The individual number of the benthonic Foraminifera is largest in the *Bulimina aculeata-Uvigerina akitaensis* zone, fairly small in the Na-arai Formation and *Nonionella-Elphidium* zone, and smallest in the *Pseudononion-Rosalina* zone (Fig. 4). Although the largest living population of the benthonic Foraminifera is in the neritic zone in the present seas, the number of tests in the sediments is closely related to the accumulation of the detritus. Therefore, the actual number of tests per gram of sediments increases away from the shore and, in general, has a valid trend of increasing in a seaward direction (Bandy and Arnal, 1960; Walton, 1964). In the Choshi district the smaller number of the benthonic Foraminifera in the *Nonionella-Elphidium* and *Pseudononion-Rosalina* zones corresponds to the coarseness of the sediments and to the shallowness of the water in which the faunas lived. In the case of sample A 2 of the Na-arai Formation the number may be smaller than the original one as may be inferred from the poor preservation of the test wall which suggests that many may have been dissolved after deposition.

The ratio of the planktonic forms to the total foraminiferal population is also important for the ecologic interpretation. Planktonic Foraminifera are characteristic of the off shore water masses. Smith (1955) found a significant correlation between depth and per cent of planktonic tests, and a marked effect of the islands on the distribution of the Foraminifera in the northwest Gulf of Mexico and the Mississippi sound areas based on Phleger's data. He recognized a distinct curve-linear relationship of increasing ratio of planktonic population with depth. Grimsdale and Moskhoven (1955) made a statistical analysis based on Phleger's data of the same area, on the relation between depth and the percentage of the planktonic population. Further they compared the results with those of the Atlantic coast of the United States based on Parker's study, where the ratio of planktonic

Foraminifera increased at depths shallower than the Gulf of Mexico. A similar distribution pattern of the ratio of planktonic population is seen in the East China Sea (Polski, 1959), where the ratio of more than 80 per cent of planktonic Foraminifera occurs below the depth of 400 feet. In areas of the present seas the ratio of the planktonic population does not always agree with depth because of the complicated oceanographic conditions in each area. However, the general trend is considered to be valuable in a consideration of the paleoenvironment.

The percentage distribution of planktonic Foraminifera in the Choshi section shows several distinct features; the ratio is relatively low in the basal part of the Na-arai Formation, in the basal part of the *Bulimina striata-Stilostomella* zone, and in the *Bolivina pacifica* to *Nonionella-Elphidium* zone; very low in the middle part of the *Bolivina pacifica* zone and the *Pseudononion-Rosalina* zone (Fig. 4). The change of the ratio in the basal part of the Na-arai Formation is explained by the increase in the depth from neritic to bathyal. The lower ratio in the basal part of the *Bulimina striata-Stilostomella* zone is inferred to reflect some disturbance in the sedimentary basin as is also indicated by the structure of the lithology. The lowest ratio in the *Pseudononion-Rosalina* zone obviously reflects a shallow water condition. It is remarkable that the ratio of the planktonic population decreases distinctly since the beginning of the *Bolivina pacifica* zone and that there can be seen a slight tendency to increase upwards in the *Nonionella-Elphidium* zone. This feature may be explained by the shallowing of the sea as indicated by the increasing of a shallow water species, *Nonionella stella*, but the vertical frequency distribution of the other species does not agree with the pattern of the planktonic population. *Bolivina pacifica* is living in the present sea off the Boso Peninsula at the depth of 59–276 m and is most abundant at 112 m (Kuwano, 1962–63); *Pullenia bulloides* is a component of the bathyal fauna in the East China Sea (Polski, 1959) though it occurs in the neritic zone in the other areas; and *Uvigerina akitaensis* is reported from a depth exceeding 82m off Kushiro, Hokkaido and is most abundant in the bathyal zone of northern Japan (Ishiwada, 1964). On the other hand, the curve of the general trend of the ratio of the planktonic population in the *Bolivina pacifica* to *Nonionella-Elphidium* zone seems to have an intimate correlation with the abundant occurrence of sinistrally coiled *Globigerina pachyderma* (Figs. 5, 6). The low ratio of the planktonic population here concerned, therefore, is considered to have been related with the cold surface water where some deeper water species perhaps could extend their habitat to a shallower part of the neritic zone. But some other factors may also have affected the low concentration of planktonic Foraminifera which is related to the oceanic condition during a cold climate. It is noteworthy that the same pattern is seen in the Boso Peninsula in a horizon corresponding to that of the Choshi district. From the uppermost part of the Kakinokidai Formation to the Chonan Formation the ratio of the planktonic population distinctly decrease in accordance with the increase of sinistrally coiled *Globigerina pachyderma* (Aoki, 1963).

The sea of the Choshi district deepened almost to the bathyal zone during the early stage of the deposition of the Na-arai Formation, and this condition continued almost to the *Bulimina aculeata-Uvigerina akitaensis* zone of the Iioka Formation though there may have been some fluctuation at the base of the Iioka Formation. From the *Cassidulina carinata* zone to the lower part of the *Nonionella-Elphidium* zone the sea depth changed to a condition corresponding to the outer to middle neritic with some fluctuations as inferred from the benthonic Foraminifera. Then the sea became shallower rather rapidly and the district became a land, till the beginning of deposition of the marine "Katori" Formation. Based upon the planktonic Foraminifera three zones of cold water condition can be noticed in the post-Miocene succession, though there are variations in both the warm and cold water faunas; one is at the upper part of the *Bulimina aculeata-Uvigerina akitaensis*

zone, one is at the lower part of the *Cassidulina subglobosa* zone, and the last one is at the middle part of the *Bolivina pacifica* zone. The first and last ones seem to be more remarkable. It may be possible that the cold water phases had relation with the development of glaciers. If this is so, then it may be inferred that there was some change in sea level. It is difficult to point out the changes of sea water level because of the tectonic movements in the district. However, there are some indications of shallowing during the two intervals simultaneous with the cold water temperature.

The basal conglomerate of the Na-arai Formation is notable for possessing gravels of various size being embedded in a tuffaceous silty matrix with abundant fossils. Ozaki (1954) stated that the fauna of the conglomerate comprises a few inhabitants of the tidal zone and an overwhelming number favouring depths of 100–200 m in an open sea and, from the evidence, he supposed that there once existed a steep coast, and the basement rocks had a very irregular surface configuration which submerged rapidly to the depth of some 200 m below the sea-level to become unconformably overlain by the Na-arai Formation with the mixed fauna of bathyneritic and shallow sea elements. Hatai (1940), in his study on the Cenozoic Brachiopoda of Japan, studied the fossil brachiopod from the basal part of the Na-arai Formation at the coast of Inuwaka, and stated that the fossil fauna was an interesting one and from it, he was inclined to believe that the brachiopod crevices had been deposited in fairly deep water at a temperature slightly cooler than that of the present seas at a similar latitude. And in the same paper he stated that in general, it appears that where brachiopods occur in abundance, there is generally an unconformity separating the brachiopod bearing beds from the next older, and where the unconformity is but slight, the number of species found is few. Similar brachiopod-rich parts at the base of the Na-arai Formation are seen just above the unconformity at various heights from the ebb zone along the coast of Tokawa to about 40 meters above sea level at the quarries around Atago hill. The same bathymetrical sedimentary condition of the Na-arai Formation is also inferred by the Foraminifera. The sample A 2, in which *Trifarina kokozuraensis*, a bathyal species is dominant, is from just above the unconformity but in a horizon more than ten meters higher than sample A 1.

There is a remarkable difference in the thickness of the strata between the Yoro River and Choshi sections. The thickness of about 1900 m from the Kurotaki to the Umegase Formation along the Yoro River corresponds to that of 230 m in the lower part of the Iioka Formation, but in the later stage of deposition the difference seems to become less. Kawai (1961) using the abundant data from the wells discussed in detail the sedimentary history of his Kazusa Group. In the initial stage of deposition of the Kazusa Group, both deposition and subsidence were conspicuous in the Isumi River area, in the southeastern part of the Boso Peninsula, and consequently very thick beds were laid down. Thenafter the sea area increased gradually and the maximum transgression was during the deposition of the Otadai, Umegase and Kokumoto Formations. After that the center of deposition and subsidence migrated northwestwards to the vicinity of Chiba and Yawatajuku, and the marginal areas were uplifted. Similar conclusions were obtained by Kikuchi (1964) and Higuchi (1964). Thus the Choshi district was located near the northeastern margin of the depositional area of the Kazusa Group, the Kazusa Sedimentary Basin, and in the district the deposition of the Kazusa Group was very slow though the district was under a depth condition similar to the Yoro River area. Naruse (1959) studied the Kasamori Formation in the northern part of the Boso Peninsula, and recognized three changes in almost the same period; the vast shallowing of the sea in the upper part of the Kasamori Formation, the existence of a tectonic movement at the end of deposition of the formation, and shifting of the sedimentary basin from an open sea condition to one of an inner bay (the Paleo-Tokyo Bay). This corresponds to the faunal change in the *Nonionella-Elphidium*

zone and the unconformity above the zone in the Choshi district. By this tectonic movement, which began as early as the *Cassidulina carinata* zone, the trend in dip of the Na-arai, Iioka and Toyosato Formations may have become inverted to the northwest as seen now. This represents the evolution of the Kanto Tectonic Basin from the Kazusa Sedimentary Basin.

#### SUMMARY

(1) In the Choshi district there are distributed younger Cenozoic formations on the Permian and Cretaceous basement rocks. They are as follows; the Metogahana, Na-arai, Iioka, Toyosato and "Katori" Formations, and three units of volcanic ash deposits, in ascending order. Sediment samples of one from the Metogahana, three from the Na-arai, 39 from the Iioka, five from the Toyosato, and three from the "Katori" were analyzed as to their Foraminifera.

(2) The Iioka, Toyosato and "Katori" Formations are divided into seven units based upon the benthonic foraminiferal assemblages; namely, the *Bulimina striata-Stilostomella*, *Bulimina aculeata-Uvigerina akitaensis*, *Cassidulina carinata*, *Cassidulina subglobosa*, *Bolivina pacifica*, *Nonionella-Elphidium* and *Pseudononion-Rosalina* zones in ascending order. The Metogahana and Na-arai Formations are undifferentiated because of their poor occurrence of Foraminifera.

(3) From the basal part of the Na-arai Formation *Globigerina nepenthes* was found with *Globorotalia menardii miocenica*, *Sphaeroidinellopsis seminulina* and other planktonic species. The fauna is that of the Upper Miocene *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone of Saito (1963). Such a fauna, however, is not found in the other parts of the formation.

(4) Concerning the coiling direction of planktonic Foraminifera, distinct changes were found in three species; *Globigerina pachyderma*, *Pulleniatina obliquiloculata* and *Globorotalia menardii s.l.* *G. pachyderma* is known to change its coiling direction by change in water temperature. A short interval of sinistrally coiled *P. obliquiloculata* at the base of the Iioka Formation is correlated to the same coiling pattern seen in Taiwan, the Philippines, Java, Venezuela, and at the basal part of the Kurotaki Formation along the Obitsu River; this is the basal Pliocene of Bandy. The coiling change in *Globorotalia menardii s.l.* is similar to that reported from the Philippines and Taiwan at the base of the Pliocene.

(5) By means of planktonic Foraminifera, the basal part of the Na-arai Formation is correlated to the upper part of the Kiyosumi Formation, and the basal part of the Iioka Formation to the basal part of the Kurotaki Formation of the Obitsu River area. The upper part of the *Bulimina aculeata-Uvigerina akitaensis* zone and the middle part of the *Bolivina pacifica* zone, both in the Iioka Formation, are correlated to the upper part of the Umegase Formation and the uppermost part of the Kakinokidai to the Chonan Formation of the Boso Peninsula respectively.

(6) A once existed highly jagged surface before the deposition of the Na-arai Formation submerged rapidly to fairly deep water, and above it there accumulated volcanic detritus of the Na-arai Formation. During the deposition of the lower part of the Iioka Formation under a bathyal condition, very thick sediments were deposited in the Yoro River area such as the Kurotaki, Kiwada, Otadai and Umegase Formations. Later both areas became shallower and became the outer to middle neritic zone due to tectonic uplift. Then in the later stage of the formation of the *Nonionella-Elphidium* zone of the Toyosato Formation, the Choshi district was uplifted rather rapidly and at last rose above the sea, till the beginning of deposition of the "Katori" Formation.

(7) Three periods of cold climate are seen in the post-Miocene succession in the Choshi

district; one in the upper part of the *Bulimina aculeata-Uvigerina akitaensis* zone, one in the lower part of the *Cassidulina subglobosa* zone, and one in the middle part of the *Bolivina pacifica* zone, all in the Iioka Formation. Although it is conceivable that they were related to glaciation, expected simultaneous sea-level changes are not obvious because of the tectonic movement in the district.

#### FAUNAL REFERENCE LIST

Important species of Foraminifera in the Choshi district are listed below alphabetically separately under the benthonic and planktonic forms, and most of them are illustrated in Plates 25–30 of this article. The original references and the apparent ranges in the district are given for each of the species, and brief remarks are added to some of them. In the list the two new species, *Cassidulinoides kuwano* Matoba, n. sp. and *Epistominella nipponica* Kuwano, n. sp., are described. All types are catalogued and deposited in the Institute of Geology and Paleontology, Tohoku University.

##### Benthonic Foraminifera

- Ammonia japonica* (Hada) ..... Pl. 27, figs. 1a-c.  
*Rotalia japonica* Hada, 1931, *Tohoku Univ., Sci. Rep., ser. 4*, v. 6, no. 1, p. 137, text-figs. 93a-c.  
 Apparent range: *Pseudononion-Rosalina* zone.
- Ammonia ketienziensis angulata* (Kuwano) ..... Pl. 27, figs. 2a-c.  
*Rotalia ketienziensis angulata* Kuwano, 1950, *Geol. Soc. Japan, Jour.*, v. 56, no. 657, p. 312, text-figs. 1a-c.  
 Apparent range: *Bolivina pacifica* to *Pseudononion-Rosalina* zone.
- Ammonia takanabensis* (Ishizaki) ..... Pl. 27, figs. 3a-c.  
*Streblus takanabensis* Ishizaki, 1948, *Acta Geol. Taiwan*, v. 2, no. 1, p. 57, pl. 1, figs. 5a-c.  
 Apparent range: *Bulimina aculeata-Uvigerina akitaensis* to *Pseudononion-Rosalina* zone.
- Amphicoryna scalaris sagamiensis* (Asano) ..... Pl. 25, fig. 4.  
*Lagenonodosaria scalaris sagamiensis* Asano, 1936, *Geol. Soc. Japan, Jour.*, v. 43, no. 515, p. 613, pl. 30, figs. 6, 7.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Astrononion hamadaense* Asano ..... Pl. 29, figs. 8a-b.  
 Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1, p. 6, text-figs. 29–31.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Bolivina decussata* Brady ..... Pl. 25, figs. 13  
 Brady, 1881, *Quart. Jour. Micr. Sci., n. ser.*, v. 21, p. 28.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Bolivina pacifica* Cushman and McCulloch ..... Pl. 25, figs. 11a, b, 12.  
*Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942, *Allan Hancock Pacif. Exped.*, v. 6, no. 4, p. 185, pl. 21, figs. 2, 3.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone
- Bolivina robusta* Brady ..... Pl. 25, figs. 14a, b, 15, 16.  
 Brady, 1881, *Quart. Jour. Micr. Sci., n. ser.*, v. 21, p. 27.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Bolivina spinescens* Cushman ..... Pl. 25, figs. 17.  
 Cushman, 1911, *U.S. Nat. Mus., Bull.* 71, pt. 2, p. 46.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone
- Bolivina* cf. *spissa* Cushman ..... Pl. 25, figs. 9a, b, 10a, b  
 Cf. *Bolivina subadvena* Cushman var. *spissa* Cushman, 1926, *Cushman Lab. Foram. Res., Contr.*, v. 2, pt. 2, p. 45, pl. 6, figs. 8a, b.  
 This form differs from the typical in the coarse perforations restricted in the basal part of each chamber, not limbed sutures, and slender test. It somewhat resembles to *Bolivina advena* var. *striatella* Cushman, but differs in its more compressed test, acute periphery and coarse perforations at the base of each chamber.  
 Apparent range: Na-arai Formation to *Bulimina striata-Stilostomella* zone.

- Bolivinita quadrilatera* (Schwager) ..... Pl. 25, figs. 19a, b.  
*Textularia quadrilatera* Schwager, 1866, *Novara-Exped.*, *Geol. Theil*, v. 2, p. 253, pl. 7, fig. 10.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Buccella frigida* (Cushman) ..... Pl. 26, figs. 9a-c.  
*Pulvinulina frigida* Cushman, 1922, *Canad. Biol., Contr.*, no. 9 (1921), p. 12 (144).  
 Apparent range: *Cassidulina carinata* to *Pseudononion-Rosalina* zone.
- Buccella frigida* (Cushman) var. .... Pl. 26, figs. 8a-c.  
 This form differs from the typical one in the more compressed test, slightly depressed umbilicus and more numerous chambers in the last whorl.  
 Apparent range: *Pseudononion-Rosalina* zone.
- Buccella inusitata* Andersen ..... Pl. 26, figs. 10a-c.  
 Andersen, 1952, *Washington Acad. Sci., Jour.*, v. 42, no. 5, p. 148, figs. 10a-c, 11a-c.  
 Apparent range: *Bulimina aculeata-Uvigerina akitaensis* to *Pseudononion-Rosalina* zone.
- Bulimina aculeata* d'Orbigny ..... Pl. 25, figs. 30-32.  
 d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 269, no. 7.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Bulimina marginata* d'Orbigny ..... Pl. 25, fig. 37.  
 d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 269, no. 4, pl. 12, figs. 10-12.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Bulimina striata* d'Orbigny ..... Pl. 25, figs. 33-35.  
 d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 269, no. 2.  
 This species is closely related to *Bulimina nipponica* Asano, especially in the immature stage (pl. 25, fig. 35), but differs from the latter in the more elongate test in the adult. Many specimens previously reported as *B. nipponica* from the Boso Peninsula by authors are considered to belong to this species.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Bulimina subornata* Brady ..... Pl. 25, fig. 36.  
 Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 402, pl. 51, figs. 6a, b.  
 Apparent range: *Bulimina aculeata-Uvigerina akitaensis* to *Pseudononion-Rosalina* zone.
- Bulimina tenuata* (Cushman) ..... Pl. 25, figs. 28, 29.  
*Buliminella subfusiformis* Cushman var. *tenuata* Cushman, 1927, *Scripps Inst. Oceanog. Bull., Tech. ser.*, v. 1, p. 149, pl. 2, fig. 9.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Buliminella elegantissima* (d'Orbigny) ..... Pl. 25, fig. 8.  
*Bulimina elegantissima* d'Orbigny, 1839, *Voy. Amér. Mérid., Foraminifères* v. 5, pt. 5, p. 51, pl. 7, figs. 13, 14.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Cassidulina carinata* Silvestri ..... Pl. 28, figs. 11a, b, 12.  
*Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896, *Accad. Pont. Nuovi Lincei, Mem.*, v. 12, p. 104, pl. 2, figs. 10a-c.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cassidulina delicata* Cushman ..... Pl. 28, figs. 7a, b.  
 Cushman, 1927, *Scripps Inst. Oceanog. Bull., Tech. ser.*, v. 1, p. 168, pl. 6, fig. 5.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Cassidulina depressa* Asano and Nakamura ..... Pl. 28, figs. 19a-c.  
*Cassidulina subglobosa depressa* Asano and Nakamura, 1937, *Japan. Jour. Geol. Geogr.*, v. 14, nos. 3-4, p. 148, pl. 13, figs. 8a-c.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cassidulina* cf. *depressa* Asano and Nakamura ..... Pl. 28, figs. 20, 21.  
 This form differs from the typical one only in the aperture, and is quite similar to *Cassidulina islandica* Nørvang which is the type-species of *Islandiella* Nørvang. In this article, no close examination of cassidulinids are carried out for their generic position.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cassidulina elegans bosoensis* Kuwano ..... Pl. 28, fig. 22.  
*Cassidulina elegans* Sidebottom var. *bosoensis* Kuwano, 1954, *Res. Inst. Nat. Resour., Misc. Rep.*, no. 35, p. 34, text-figs. 7-11.  
 Apparent range: *Bulimina striata-Stilostomella* to *Cassidulina carinata* zone.

- Cassidulina norcrossi* Cushman ..... Pl. 28, figs. 10a, b.  
Cushman, 1933, *Smith. Misc. Coll.*, v. 89, no. 9, p. 7, pl. 2, figs. 7a-c.  
*Cassidulina kasiwazakiensis* Husezima and Maruhasi is considered to be a junior synonym of this species.  
Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Cassidulina sagamiensis* Asano and Nakamura ..... Pl. 28, figs. 13a, b, 14a, b.  
Asano and Nakamura, 1937, *Japan. Jour. Geol. Geogr.*, v. 14, nos. 3-4, p. 147, pl. 14, figs. 5a-c.  
Apparent range: Na-arai Formation to *Bolivina pacifica* zone.
- Cassidulina subglobosa* Brady ..... Pl. 28, figs. 15a-c, 16a, b, 17, 18.  
Brady, 1881, *Quart. Jour. Micr. Sci., n. ser.*, v. 21, p. 60.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cassidulina yabei* Asano and Nakamura ..... Pl. 28, figs. 8a, b, 9a, b.  
Asano and Nakamura, 1937, *Japan. Jour. Geol. Geogr.*, v. 14, nos. 3-4, p. 145, pl. 14, figs. 1a, b.  
Apparent range: Na-arai Formation.
- Cassidulinoides kuwano* Matoba, n. sp. .... Pl. 29, figs. 1a, b, 2.  
*Description*: Test very small, oval to elongate and arcuate, in outline, not lobulate, slightly compressed, elliptical in side view; periphery broadly rounded; chambers slightly inflated, about 5 pairs in larger specimens, arranged biserially and coiled in early portion, later pairs tending to uncoil; the last-formed pair comprises about a half of the adult test, but more in the younger; sutures narrow, slightly depressed, not limbate, slightly curved but almost straight; wall thin, calcareous, finely perforate, surface smooth; aperture subterminal, an elongate loop extending from base of last chamber in a round depression, provided with a thin tooth. Length of holotype 0.18 mm, breadth 0.11 mm, thickness 0.09 mm. Length of paratype of figure 2, 0.19 mm, breadth 0.11 mm, thickness 0.09 mm. Other specimens range from 0.12 to 0.20, in length.  
*Types and occurrence*: Holotype (IGPS coll. cat. no. 87579 A) and figured paratype (IGPS coll. cat. no. 87579 B) from a road-side outcrop, Miyake-cho, Choshi City, Chiba Prefecture; sample A 16, middle part of the Iioka Formation, Early Pleistocene.  
*Remarks*: The compact, very small test and apertural feature are characteristic of this new species. This species is similar to *Cassidulinoides japonicus* Kuwano (MS, 1962, *op. cit.*, pl. 16, figs. 5a, b), but differs in its finely perforated test wall and less depressed sutures. It differs from *C. parkerianus* (Brady) in its smaller size and characters of wall, sutures and aperture.  
According to Dr. Kuwano's personal information, this species also occurs in the Recent sediments of Kagoshima Bay, Kyushu and off the Boso Peninsula.  
Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Cassidulinoides kattoi* (Takayanagi) ..... Pl. 29, figs. 3a, b.  
*Cassidulina kattoi* Takayanagi, 1953, *Tohoku Univ., Inst. Geol. Pal., Short Papers*, no. 5, p. 34, pl. 4, figs. 10a, b.  
Apparent range: *Bulimina striata-Stilostomella* to *Cassidulina carinata* zone.
- Cassidulinoides parkerianus* (Brady) ..... Pl. 28, figs. 23a, b, 24.  
*Cassidulina parkeriana* Brady, 1881, *Quart. Jour. Micr. Sci., n. ser.*, v. 21, p. 59.  
Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Chilostomella ovoidea* Reuss ..... Pl. 29, fig. 4.  
Reuss, 1850, *Denkschr. Akad. Wiss. Wien*, v. 1, p. 380, pl. 48, figs. 12a-e.  
Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Cibicides aknerianus* (d'Orbigny) ..... Pl. 28, figs. 3a-c.  
*Rotalia akneriana* d'Orbigny, 1846, *Foram. Foss. Bas. Vien.*, p. 156, pl. 8, figs. 13-15.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cibicides lobatulus* (Walker and Jacob) ..... Pl. 28, figs. 5a-c.  
*Nautilus lobatulus* Walker and Jacob, 1798, *Adams Essays*, p. 642, pl. 14, fig. 36.  
Apparent range: *Bolivina pacifica* to *Pseudononion-Rosalina* zone.
- Cibicides refulgens* Montfort ..... Pl. 28, figs. 4a-c.  
Montfort, 1808, *Conch. Syst.*, v. 1 p. 122.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Cibicides subpraecinctus* (Asano) ..... Pl. 28, figs. 6a-c.

*Eponides subpraecinctus* Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 12, text-figs. 88-90.

Apparent range: Na-arai Formation.

*Elphidium calvatum* Cushman ..... Pl. 27, figs. 8a, b.

*Elphidium incertum* (Williamson) var. *clavatum* Cushman, 1930, *U. S. Nat. Mus. Bull.* 104, pt 7, p. 20, pl. 7, fig. 10.

Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.

*Elphidium crispum* (Linné) ..... Pl. 27, figs. 7a, b.

*Nautilus crispus* Linné, 1758, *Syst. Nat.*, Ed. 10, p. 709.

Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.

*Elphidium kusiroense* Asano ..... Pl. 27, figs. 9a, b.

Asano, 1938, *Geol. Soc. Japan, Jour.*, v. 45, no. 538, p. 590, pl. 14, fig. 2.

Apparent range: *Pseudononion-Rosalina* zone.

*Elphidium subarcticum* Cushman ..... Pl. 27, figs. 10a, b, 11.

Cushman, 1944, *Cushman Lab. Foram. Res., Spec. Pub.* 12, p. 27, pl. 3, figs. 34, 35.

Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.

*Epistominella naraensis* (Kuwano) ..... Pl. 26, figs. 11a-c.

*Pseudoparrella naraensis* Kuwano, 1950, *Geol. Soc. Japan, Jour.*, v. 56, no. 657, p. 317, text-figs. 6a-c.

Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.

*Epistominella nipponica* Kuwano, n. sp. .... Figs. 8a-f; pl. 26, figs. 13a-c

*Epistominella nipponica* Kuwano (MS), 1962, *Res. Inst. Nat. Resour., Misc. Rep.*, nos. 58-59, pl. 17, figs. 7a-c. (The same specimen is re-figured below, Figs. 8a-c.)

*Description*: Test minute, trochoid throughout, moderately biconvex, rarely strongly or flattened biconvex, larger specimens frequently with a peripheral flange only dorsally; periphery very slightly to strongly lobulate, in peripheral view mostly subacute in smaller specimens, but frequently bluntly pointed or rarely rounded; umbilicus small, very slightly depressed, surrounded by the umbilical corners of ventrally weakly overlapping chambers; whorls 3 to 4 1/2 in number, tightly coiled in the early stage, becoming more or less wider in the last one or two whorls in larger specimens; chambers 4 to 5 in the last-formed whorl, not inflated dorsally but tending slightly to inflate ventrally; spiral suture very slightly limbate, not depressed in the early whorls, becoming slightly depressed later; dorsal radial sutures oblique in the early stage, later becoming very oblique to nearly tangential to the periphery of preceding whorl; ventral sutures distinct, simple, depressed, rather strongly arcuate; apertural face very poorly developed or nearly absent, occupied almost entirely by the apertural depression situated just beneath and in parallel to the periphery at the anterio-marginal corner of ventral wall, with a narrow apertural slit, about 1/4 to 1/5 as long as the chamber length; wall thin, hyaline with very fine perforations rather sparsely but evenly distributed both dorsally and ventrally.

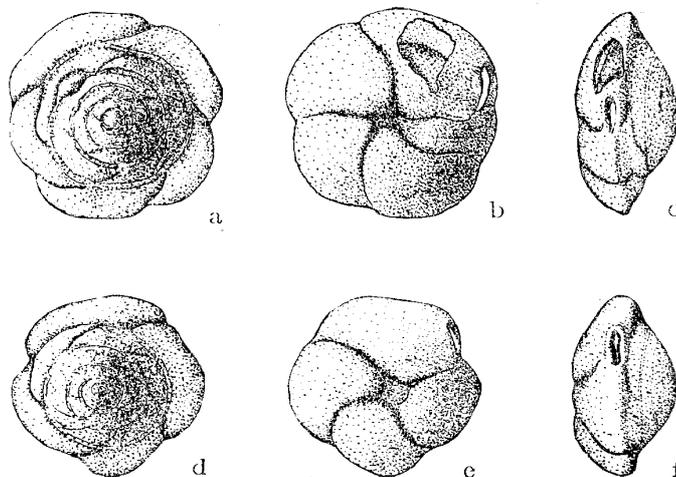


Fig. 8. *Epistominella nipponica* Kuwano, n. sp.  $\times 160$ . a-c, holotype, d-f, paratype.

*Dimensions:* (Holotype) maximum diameter ca. 130 microns, thickness ca. 75 microns; (paratype) maximum diameter ca. 130 microns, thickness ca. 70 microns.

*Type locality and horizon:* Off the Boso Peninsula, Central Honshu, Japan (station M 2; lat. 35°05'36"N., long. 140°09'54"E.; depth 118 meters), Recent.

*Registered number and depository:* (Holotype, Figs. 8a-c) YK-H-0009; (paratype, Figs. 8d-f) YK-P-0017. Deposited in Kuwano's collection in the Research Institute for Natural Resources, Shinjuku, Tokyo, Japan.

*Known distribution:* (Recent) Kagoshima Bay, South Kyushu, Japan, from the bay mouth to the innermost part of the main basin, ca. 40 to 200 meters in depth, but more frequent in depths shallower than 100 meters; off the Boso Peninsula, Central Honshu, Japan, ca. 100 to 330 meters in depth (see Y. Kuwano, 1962, 1963). (Late Miocene to Pleistocene) Choshi district, East Kwanto, Japan (see Y. Matoba, this paper).

*Remarks:* This species is well characterized by the low, long and lobulate later chambers in dorsal view. From most other species from Japan the species is also distinguished by the smaller and more or less biconvex test and by the rather less number of chambers in a whorl. The description above is based on living specimens with cytoplasm dredged from the two areas cited above, and most of them are individuals of a stage intermediate between the premature and the mature.

The writer (Kuwano) fortunately had an opportunity to examine some fossil materials from the Choshi district through the kindness of Mr. Y. Matoba of the Institute of Geology and Palaeontology, Tohoku University (sample A 14 of the middle part of the Iioka Formation from Takano-cho, Choshi City). In general the diagnosis above fits very well the Choshi specimens, but these tend to have less oblique dorsal radial sutures, in the later whorls and more or less flattened biconvex tests. Notwithstanding this the Choshi specimens can be safely referred to the new species because of coincidence in main morphologic features with the living specimens.

- Epistominella pulchella* Husezima and Maruhasi ..... Pl. 26, figs. 14a-c.  
Husezima and Maruhasi, 1944, *Sigen. Ken., Jour.*, v. 1, no. 3, p. 398, pl. 34, figs. 10a-c.  
Apparent range: *Bulimina striata*-*Stilostomella* to *Bulimina aculeata*-*Uvigerina akitaensis* zone.
- Epistominella tamana* (Kuwano) ..... Pl. 26, figs. 12a-c.  
*Pseudoparrella tamana* Kuwano, 1950, *Geol. Soc. Japan, Jour.*, v. 56, no. 657, p. 317, text-figs. 5a-c.  
Apparent range: *Bulimina striata*-*Stilostomella* to *Nonionella-Elphidium* zone.
- Eponides umbonatus* (Reuss) ..... Pl. 27, figs. 14a-c.  
*Rotalina umbonata* Reuss, 1851, *Deutsch. Geol. Gesell., Zeitschr.*, v. 3, p. 75, pl. 5, figs. 35a-c.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Globobulimina auriculata* (Bailey) ..... Pl. 26, fig. 1.  
*Bulimina auriculata* Bailey, 1851, *Smithsonian Contr.*, v. 2, p. 12, pl., figs. 25-27.  
Apparent range: *Bulimina striata*-*Stilostomella* to *Nonionella-Elphidium* zone.
- Gyroidina orbicularis* d'Orbigny ..... Pl. 29, figs. 11a-c.  
d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 278, no. 1; Modèle no. 13.  
Apparent range: *Bulimina striata*-*Stilostomella* to *Bolivina pacifica* zone.
- Gyroidina? profunda* Aoki ..... Pl. 29, figs. 12a-c.  
Aoki, 1964, *Paleont. Soc. Japan, Trans. Proc.*, N.S., no. 53, p. 167, pl. 25, figs. 17a-c.  
Aoki referred the species to *Gyroidina*, but the apertural character is not of *Gyroidina*.  
Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Gyroidinoides nipponicus* (Ishizaki) ..... Pl. 29, figs. 13a-c.  
*Gyroidina nipponica* Ishizaki, 1944, *Nat. Hist. Soc. Taiwan, Trans.*, v. 34, no. 244, p. 102, pl. 3, figs. 3a-c.  
Apparent range: *Bulimina striata*-*Stilostomella* to *Nonionella-Elphidium* zone.
- Hanzawaia nipponica* Asano ..... Pl. 29, figs. 14a-c.  
Asano, 1944, *Geol. Soc. Japan, Jour.*, v. 51, no. 606, p. 99, pl. 4, figs. 1a, b, 2a, b.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Hoeglundina elegans* (d'Orbigny) ..... Pl. 29, figs. 17a-c.  
*Rotalia (Turbinulina) elegans* d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 276, no. 54.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.

- Hyalinea balthica* (Schröter) ..... Pl. 28, figs. 2a, b.  
*Nautilus balthicus* Schröter, 1783, *Einleit. Conchyl. Linné*, v. 1, p. 20, pl. 1, fig. 2.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Laticarinina pauperata* (Parker and Jones) ..... Pl. 26, figs. 17a-c.  
*Pulvinulina repanda* var. *menardii* subvar. *pauperata* Parker and Jones, 1865, *Philos. Trans.*, v. 155, p. 395, pl. 16, figs. 50, 51.  
 Apparent range: Na-arai Formation.
- Lenticulina calcar* (Linné) ..... Pl. 25, figs. 5.  
*Nautilus calcar* Linné, 1767, *Syst. Nat., Ed. 10*, p. 1162, no. 272.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- "*Loxostomum*" *bradyi* (Asano) ..... Pl. 25, fig. 20.  
*Bolivina bradyi* Asano, 1938, *Geol. Soc. Japan, Jour.*, v. 45, no. 538, p. 603, pl. 16, fig. 2.  
 Only tentatively placed in the genus.  
 Apparent range: *Bulimina striata-Stilostomella* to *Bulimina aculeata-Uvigerina akitaensis* zone.
- "*Loxostomum*" *karrerianum* (Brady) ..... Pl. 25, fig. 21.  
*Bolivina karrerianum* Brady, 1881, *Quart. Jour. Micr. Sci., n. ser.*, v. 21, p. 28.  
 Only tentatively placed in the genus.  
 Apparent range: *Cassidulina carinata* to *Nonionella-Elphidium* zone.
- Martinottiella communis* (d'Orbigny) ..... Pl. 25, figs. 1-3.  
*Clavulina communis* d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 268, no. 4.  
 Apparent range: Metogahana Formation to *Pseudononion-Rosalina* zone.
- Melonis parkerae* (Uchio) ..... Pl. 29, figs. 15a, b.  
*Nonion parkerae* Uchio, 1960, *Cushman Found. Foram. Res., Spec. Pub. no. 5*, p. 60, pl. 4, figs. 9, 10.  
 The narrowly rounded periphery, limbate sutures and number of chambers of the Choshi specimen are the characteristic of this species. Most of specimens referred to "*Nonion nicobarense*" Cushman from the Boso Peninsula are judged to belong to this species.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Melonis pompilioides* (Fichtel and Moll) ..... Pl. 29, figs. 16a, b.  
*Nautilus pompilioides* Fichtel and Moll, 1798, *Testacea microscopica*, p. 31, pl. 2, figs. a-c.  
 Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Nonion labradoricum* (Dawson) ..... Pl. 29, figs. 7a, b.  
*Nonionia laboradorica* Dawson, 1860, *Canad. Natural.*, v. 5, p. 191, text-fig. 4.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Nonionella stella* Cushman and Moyer ..... Pl. 29, figs. 10a, b.  
*Nonionella miocenica stella* Cushman and Moyer, 1930, *Cushman Lab. Foram. Res., Contr.*, v. 6, p. 56, pl. 7, figs. 17a-c.  
 Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Pararotalia minuta* (Takayanagi) ..... Pl. 27, figs. 5a, b.  
*Rotalia? minuta* Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 52, text-figs. 29a-c.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Pararotalia minuta* (Takayanagi) var. .... Pl. 27, figs. 6a, b.  
 This differs from the typical one in the more lobulate periphery and open umbilicus.  
 Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Planulina wuellerstorfi* (Schwager) ..... Pl. 28, figs. 1a, b.  
*Anomalima wuellerstorfi* Schwager, 1866, *Novara-Exped., Geol. Theil*, v. 2, p. 258, pl. 7, figs. 105, 107.  
 Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Porosorotalia makiyamae* (Chiji) ..... Pl. 27, figs. 12a-c, 13a-c.  
*Buccella makiyamae* Chiji, 1961, *Prof. J. Makiyama Mem. Vol., Kyoto*, p. 234, text-figs. 2a-c, pl. 1, figs. 13a, b, 14a, b.  
 Apparent range: *Pseudononion-Rosalina* zone.
- Pseudoeponides japonicus* Uchio ..... Pl. 26, figs. 20a-c.  
 Uchio in Kawai et al., 1950, *Japan. Assoc. Petrol. Technol., Jour.*, v. 15, no. 4, p. 190, text-fig. 16.

- Apparent range: *Cassidulina carinata* to *Pseudononion-Rosalina* zone.
- Pseudononion japonicum* Asano ..... Pl. 29, figs. 9a-c.  
Asano, 1936, *Geol. Soc. Japan, Jour.*, v. 43, no. 512, p. 347, text-figs. a-c.  
Apparent range: *Bolivina pacifica* to *Pseudononion-Rosalina* zone.
- Pseudorotalia gaimardii* (d'Orbigny) ..... Pl. 27, figs. 4a-c.  
*Rotalia (Turbinulina) gaimardii* d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 275, no. 46.  
Apparent range: *Pseudononion-Rosalina* zone.
- Pullenia bulloides* (d'Orbigny) ..... Pl. 29, figs. 5a, b.  
*Nonionina bulloides* d'Orbigny, 1846, *Foram. Foss. Bas. Vien.*, p. 107, pl. 5, figs. 9, 10.  
Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Pullenia subcarinata* (d'Orbigny) ..... Pl. 29, figs. 6a, b.  
*Nonionina subcarinata* d'Orbigny, 1839, *Voy. Amér. Mérid., Foraminifères*, v. 5, pt. 5, p. 28, pl. 5, figs. 23, 24.  
Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Rosalina vilardeboana* d'Orbigny ..... Pl. 26, figs. 15a-c, 16a, b.  
d'Orbigny, 1839, *Voy. Amér. Mérid., Foraminifères*, v. 5, pt. 5, p. 44, pl. 6, figs. 13-15.  
Apparent range: *Nonionella-Elphidium* to *Pseudononion-Rosalina* zone.
- Sphaeroidina bulloides* d'Orbigny ..... Pl. 25, figs. 6a, b.  
d'Orbigny, 1826, *Ann. Sci. Nat. Paris, ser. 1*, v. 7, p. 267, no. 1.  
Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Siphonodosaria oinomikadoi* (Ishizaki) ..... Pl. 25, figs. 26, 27.  
*Ellipsonodosaria oinomikadoi* Ishizaki, 1943, *Nat. Hist. Soc. Taiwan, Trans.*, v. 33, nos. 242-243, p. 685, text-figs. 7-10.  
Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Siphovigerina ampullacea* (Brady) ..... Pl. 26, fig. 2.  
*Uvigerina asperula* var. *ampullacea* Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 579, pl. 75, figs. 10, 11.  
Apparent range: *Bulimina striata-Stilostomella* to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Stilostomella japonica* (Ishizaki) ..... Pl. 25, figs. 24, 25.  
*Ellipsonodosaria japonica* Ishizaki, 1943, *Nat. Hist. Soc. Taiwan, Trans.*, v. 33, nos. 242-243, p. 682, text-figs. 14, 15.  
Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* zone.
- Stilostomella lepidula* (Schwager) ..... Pl. 25, figs. 22, 23.  
*Nodosaria lepidula* Schwager, 1866, *Novara-Exped., Geol. Theil*, v. 2, p. 210, pl. 5, figs. 27, 28.  
Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Tosaia hanzawai* Takayanagi ..... Pl. 25, fig. 7.  
Takayanagi, 1953, *Tohoku Univ., Inst. Geol. Pal., Short Papers*, no. 5, p. 30, pl. 4, figs. 7a, b.  
Apparent range: *Cassidulina carinata* zone.
- Trifarina kokozuraensis* (Asano) ..... Pl. 26, fig. 3.  
*Angulogerina kokozuraensis* Asano, 1949, *Jour. Pal.*, v. 23, no. 4, p. 428, text-figs. 1 (nos. 50-53).  
Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Uvigerina akitaensis* Asano ..... Pl. 26, figs. 4-6.  
Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 2, p. 14, text-figs. 60-62.  
Apparent range: *Bulimina striata-Stilostomella* to *Pseudononion-Rosalina* zone.
- Uvigerina proboscidea* Schwager ..... Pl. 26, fig. 7.  
Schwager, 1866, *Novara-Exped., Geol. Theil*, v. 2, p. 250, pl. 7, fig. 96.  
Apparent range: Na-arai Formation to *Bolivina pacifica* zone.
- Valvulineria glabra* Cushman ..... Pl. 26, figs. 19a-c.  
*Valvulineria vilardeboana* (d'Orbigny) var. *glabra* Cushman, 1927, *Scripps Inst. Oceanog., Bull., tech. ser.*, v. 1, p. 161, pl. 4, figs. 5, 6.  
Apparent range: Na-arai Formation to *Bolivina pacifica* zone.
- Valvulineria sadonica* Asano ..... Pl. 26, figs. 18a-c.  
Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 8, text-figs. 55-57.

- Apparent range: Na-arai Formation to *Pseudononion-Rosalina* zone.
- Planktonic Foraminifera
- Globigerina bulloides* d'Orbigny ..... Pl. 29, fig. 22.  
d'Orbigny, 1826, *Ann. Sci. Nat. Paris*, ser. 1, v. 7, p. 277, no. 1; Modèles no. 76, and young, no. 17.  
Apparent range: Na-arai Formation to Recent.
- Globigerina falconensis* Blow  
Blow, 1959, *Amer. Pal., Bull.*, v. 39, no. 178, p. 177, pl. 9, figs. 40a-c, 41.  
Apparent range: Na-arai Formation to Recent.
- Globigerina nepenthes* Todd ..... Pl. 29, figs. 20a, b, 21.  
Todd, 1957, *U.S. Geol. Surv., Prof. Paper* 280-H, p. 301, pl. 78, figs. 7a, b.  
The Choshi specimens differ from the typical in their much globular tests without development of the fifth protruding chamber. Saito (1962) examined the topotype of the species and found the forms without the development of the fifth chamber in the last whorl as well as those with the thin-walled fifth chamber. He illustrated the dissected topotype removed of the protruding fifth chamber (*op. cit.*, pl. 52, figs. 2a-c). This form closely resembles the Choshi specimens, and one (pl. 29, fig. 21) has a trace of the broken fifth chamber.  
Apparent range: Na-arai Formation.
- Globigerina pachyderma* (Ehrenberg) ..... Pl. 29, figs. 18, 19.  
*Aristerospira pachyderma* Ehrenberg, 1861, *K. Preuss. Akad. Wiss. Berlin, Monatsber.*, p. 276, 277, 303.  
Apparent range: Na-arai Formation to Recent.
- Globigerina quinqueloba* Natland  
Natland, 1938, *Scripps Inst. Oceanog., Bull., Tech. ser.* v. 4, no. 5, p. 149, pl. 6, fig. 7.  
Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerina rubescens* Hofker  
Hofker, 1956, *Copenhagen, Univ., Zool. Mus., Spolia*, v. 15, p. 234, pl. 35, figs. 18-21.  
Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerinella siphonifera* (d'Orbigny)  
*Globigerina siphonifera* d'Orbigny, 1839, in de la Sagra, *Hist. Phys. Pol. Nat. Cuba, Foraminifères*, p. 83, pl. 4, figs. 15-18.  
Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerinita glutinata* (Egger) ..... Pl. 30, figs. 6, 7.  
*Globigerina glutinata* Egger, 1893, *K. Bayer, Akad. Wiss., München, Math.-Phys. Cl., Abhandl.*, v. 18, pt. 2, p. 371, pl. 13, figs. 19-21.  
Apparent range: Na-arai Formation to Recent.
- Globigerinita humilis* (Brady)  
*Truncatulina humilis* Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 665, pl. 94, figs. 7a-c.  
Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerinita iota* Parker  
Parker, 1962, *Micropaleontology*, v. 8, no. 2, p. 250, pl. 10, figs. 26-30.  
Apparent range: *Bulimina aculeata-Uvigerina akitaensis* to *Bolivina pacifica* zone.
- Globigerinita uvula* (Ehrenberg)  
*Pyloedexia uvula* Ehrenberg, 1861, *K. Preuss. Akad. Wiss. Berlin, Monatsber.*, p. 276, 277, 308.  
Apparent range: *Bulimina striata-Stilostomella* to *Cassidulina carinata* zone.
- Globigerinoides conglobatus* (Brady)  
*Globigerina conglobata* Brady, 1879, *Quart. Jour. Micr. Sci., n. ser.*, v. 19, p. 286.  
Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerinoides obliquus* Bolli ..... Pl. 30, figs. 2a, b.  
*Globigerinoides obliqua* Bolli, 1957, *U.S. Nat. Mus., Bull.*, no. 215, p. 113, pl. 25, figs. 9a-c, 10a-c.  
Apparent range: Na-arai Formation.
- Globigerinoides ruber* (d'Orbigny) ..... Pl. 30, fig. 1  
*Globigerina rubra* d'Orbigny, 1839, in de la Sagra, *Hist. Phys. Pol. Nat. Cuba, Foraminifères*, p. 82; v. 8, pl. 4, figs. 12-14.  
Apparent range: Na-arai Formation to Recent.

- Globigerinoides sacculifer* (Brady)  
*Globigerina sacculifera* Brady, 1877, *Geol. Mag., n. ser.*, v. 4, no. 12, p. 535.  
 Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globigerinoides tenellus* Parker  
 Parker, 1958, *Swedish Deep-Sea Exped., Rep.*, v. 8, p. 280, pl. 6, figs. 7-11.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.
- Globigerinoides trilobus* (Reuss)  
*Globigerina triloba* Reuss, 1850, *K. Akad. Wiss. Wien, Math.-Nat. Cl., Denkschr.*, v. 1, p. 374, pl. 47, figs. 11a-d.  
 Apparent range: Na-arai Formation to Recent.
- Globoquadrina conglomerata* (Schwager) ..... Pl. 30, figs. 3a, b.  
*Globigerina conglomerata* Schwager, 1866, *Novara-Exped., Geol. Theil*, v. 2, p. 255, pl. 7, fig. 113.  
 Apparent range: Na-arai Formation to Recent.
- Globoquadrina dutertrei* (d'Orbigny) ..... Pl. 30, figs. 4a, b.  
*Globigerina dutertrei* d'Orbigny, 1839, in de la Sagra, *Hist. Phys. Pol. Nat. Cuba, Foraminifères*, p. 84, v. 8, pl. 4, figs. 19-21.  
 Apparent range: Na-arai Formation to Recent.
- Globoquadrina cf. dutertrei* (d'Orbigny) ..... Pl. 30, figs. 5a-c.  
 This form is characteristic in the close and high trochospiral coiling. Parker (1962) indicated a similar form to be a variation among the species in the Recent Pacific sediments. In the Choshi section, however, this form is distinct and its occurrence is restricted to the basal part of the Iioka Formation.  
 Apparent range: *Bulimina striata-Stilostomella* zone.
- Globoquadrina hexagona* (Natland)  
*Globigerina hexagona* Natland, 1938, *Scripps Inst. Oceanog., Bull., Tech. ser.*, v. 4, no. 5, p. 149, pl. 7, fig. 1.  
 Apparent range: Na-arai Formation to Recent.
- Globorotalia acostaensis* Blow ..... Pl. 30, figs. 11a-c.  
 Blow, 1959, *Amer. Pal., Bull.*, v. 39, no. 178, p. 208, pl. 17, figs. 106a-c, 107.  
 Apparent range: Na-arai Formation.
- Globorotalia crassaformis* (Galloway and Wissler) ..... Pl. 30, figs. 8a-c.  
*Globigerina crassaformis* Galloway and Wissler, 1927, *Jour. Pal.*, v. 1, p. 41 pl. 7, figs. 12a-c.  
 Apparent range: Na-arai Formation to Recent.
- Globorotalia hirsuta* (d'Orbigny)  
*Rotalina hirsuta* d'Orbigny, 1839, in Barker-Webb and Berthelot, *Hist. Nat. Îles Canaries, Foraminifères*, v. 2, pt. 2, p. 131, pl. 1, figs. 37-39.  
 Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globorotalia inflata* (d'Orbigny) ..... Pl. 30, figs. 9a-c, 10a-c.  
*Globigerina inflata* d'Orbigny, 1839, in Barker-Webb and Berthelot, *Hist. Nat. Îles Canaries, Foraminifères*, v. 2, pt. 2, p. 134, pl. 2, figs. 7-9.  
 Apparent range: Na-arai Formation to Recent.
- Globorotalia menardii* (d'Orbigny) s.s. .... Pl. 30, figs. 14a-c.  
*Rotalia (Rotalie) menardii* d'Orbigny, 1826, *Ann. Sic. Nat. Paris, ser. 1*, v. 7, p. 273, no. 26; Modèle no. 10.  
 Apparent range: Na-arai Formation to Recent.
- Globorotalia menardii miocenica* Palmer ..... Pl. 30, figs. 15a-c.  
*Globorotalia menardii* (d'Orbigny) var. *miocenica* Palmer, 1945, *Amer. Pal., Bull.*, v. 29, no. 115, p. 70, pl. 1, figs. 10a-c.  
 Apparent range: Na-arai Formation.
- Globorotalia scitula* (Brady)  
*Pulvinulina scitula* Brady, 1882, *Roy. Soc. Edinburgh, Proc.*, v. 11, no. 111, p. 716.  
 Apparent range: Na-arai Formation to *Nonionella-Elphidium* zone.
- Globorotalia tosaensis* Takayanagi and Saito ..... Pl. 30, figs. 12a, b.  
 Takayanagi and Saito, 1962, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol.*, no. 5, p. 81, pl. 28, figs. 11a-c, 12a-c.  
 Apparent range: *Bulimina striata-Stilostomella* to *Nonionella-Elphidium* zone.

- Globorotalia truncatulinoides* (d'Orbigny) ..... Pl. 30, figs. 13a, b.  
*Rotalina truncatulinoides* d'Orbigny, 1839, in Barker-Webb and Berthelot, *Hist. Nat. Îles Canaries, Foraminifères*, v. 2, pt. 2, p. 132, pl. 2, figs. 25-27.  
 Apparent range: *Bulimina striata-Stilostomella* zone to Recent.
- Globorotalia tumida* (Brady)  
*Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady, 1877, *Geol. Mag., n. ser.*, v. 4, no. 12, p. 535.  
 Apparent range: Na-arai Formation to *Bolivina pacifica* zone.
- "*Orbulina universa*" d'Orbigny  
*Orbulina universa* d'Orbigny, 1839, in de la Sagra, *Hist. Phys. Pol. Nat. Cuba, Foraminifères*, p. 3; v. 8, pl. 1, fig. 1.  
 Bilobate specimens are included here. "*Orbulina*" has been considered by authors to represent a growth phenomenon in different species of globigerinids.  
 Apparent range: Na-arai Formation to Recent.
- Pulleniatina obliquiloculata* (Parker and Jones) ..... Pl. 30, fig. 16.  
*Pullenia sphaeroides* (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, *Roy. Soc. London, Philos. Trans.*, v. 155, p. 365, 368, pl. 19, figs. 4a, b.  
 Apparent range: Na-arai Formation to Recent.
- Sphaeroidinella dehiscens* (Parker and Jones) ..... Pl. 30, figs. 19a, b, 20a, b.  
*Sphaeroidina bulloides* d'Orbigny var. *dehiscens* Parker and Jones, 1865, *Roy. Soc. London, Philos. Trans.*, v. 155, p. 369, pl. 19, fig. 5.  
 Apparent range: Na-arai Formation to *Bulimina aculeata-Uvigerina akitaensis* Zone.
- Sphaeroidinellopsis seminulina* (Schwager) ..... Pl. 30, figs. 17a, b, 18.  
*Globigerina seminulina* Schwager, 1866, *Novara-Exped., Geol. Theil*, v. 2, p. 256, pl. 7, fig. 112.  
 Apparent range: Na-arai Formation.

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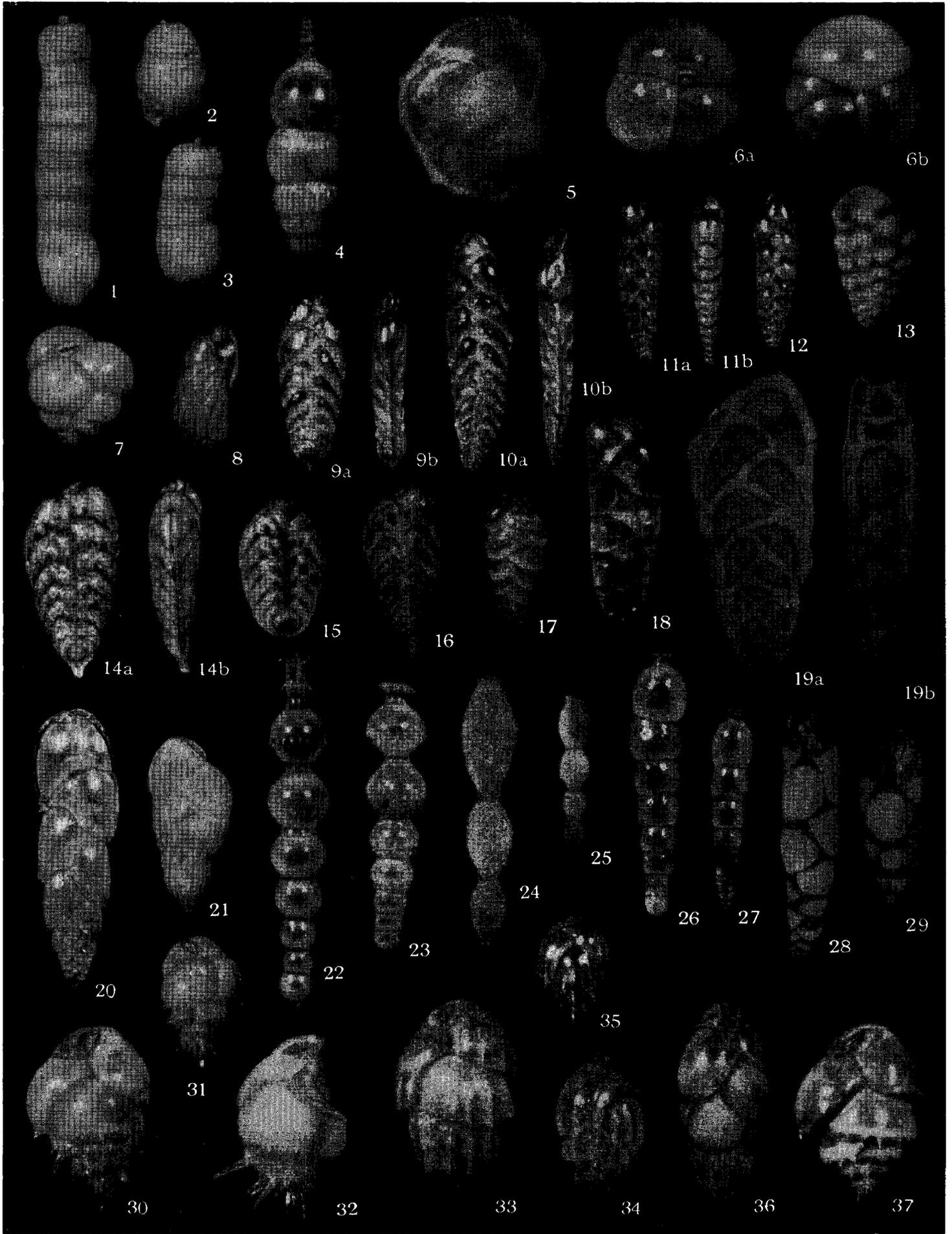
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Plate 25

- Figs. 1-3. *Martinottiella communis* (d'Orbigny)  
1-3, ×50. IGPS coll. cat. no. 87501A, B, C. Sample M, Metogahana Formation.
- Fig. 4. *Amphicoryna scalaris sagamiensis* (Asano)  
×28. IGPS coll. cat. no. 87502. Sample B 12, Toyosato Formation.
- Fig. 5. *Lenticulina calcar* (Linné)  
×50. IGPS coll. cat. no. 87503. Sample B 12, Toyosato Formation.
- Figs. 6a, b. *Sphaeroidina bulloides* d'Orbigny  
×64. IGPS coll. cat. no. 87504. Sample B 1, Iioka Formation.
- Fig. 7. *Tosaria hanzawai* Takayanagi  
×50. IGPS coll. cat. no. 87505. Sample A 20, Iioka Formation.
- Fig. 8. *Buliminella elegantissima* (d'Orbigny)  
×64. IGPS coll. cat. no. 87506. Sample K 3, "Katori" Formation.
- Figs. 9a, b, 10a, b. *Bolivina* cf. *spissa* Cushman  
9, 10, ×50. IGPS coll. cat. no. 87507A, B. Sample A 3, Na-arai Formation.
- Figs. 11a, b, 12. *Bolivina pacifica* Cushman and McCulloch 11, 12,  
×64. IGPS coll. cat. no. 87508A, B. Sample B 10, Iioka Formation.
- Fig. 13. *Bolivina decussata* Brady  
×64. IGPS coll. cat. no. 87509. Sample A 4, Iioka Formation.
- Figs. 14a, b, 15, 16. *Bolivina robusta* Brady  
14-16, ×64. IGPS coll. cat. no. 87510; 87511 A, B. 14, sample A 14; 15, 16, sample A 12, Iioka Formation.
- Fig. 17. *Bolivina spinescens* Cushman  
×64. IGPS coll. cat. no. 87512. Sample B 2, Iioka Formation.
- Fig. 18. *Bolivina seminuda* Cushman  
×64. IGPS coll. cat. no. 87513. Sample K 2, "Katori" Formation.
- Figs. 19a, b. *Bolivinita quadrilatera* (Schwager)  
×50. IGPS coll. cat. no. 87514. Sample A 3, Na-arai Formation.
- Fig. 20. "*Loxostomum*" *bradyi* (Asano)  
×50. IGPS coll. cat. no. 87515. Sample A 14, Iioka Formation.
- Fig. 21. "*Loxostomum*" *karrerianum* (Brady)  
×64. IGPS coll. cat. no. 87516. Sample B 12, Toyosato Formation.
- Figs. 22, 23. *Stilostomella lepidula* (Schwager)  
22, 23, ×50. IGPS coll. cat. no. 87517. 87518. 22, sample A 12; 23, sample A 4, Iioka Formation.
- Figs. 24, 25 *Stilostomella japonica* (Ishizaki)  
24, 25, ×50. IGPS coll. cat. no. 87519 A, B. Sample A 7, Iioka Formation.
- Figs. 26, 27. *Siphonodosaria oinomikadoi* (Ishizaki)  
26, 27, ×28. IGPS coll. cat. no. 87520; 87521. 26, sample A 4; 27, sample A 6, Iioka Formation.
- Figs. 28, 29. *Bulimina tenuata* (Cushman)  
28, 29, ×64. IGPS coll. cat. no. 87522 A, B. Sample A 8, Iioka Formation.
- Figs. 30-32. *Bulimina aculeata* d'Orbigny  
30-32, ×50. IGPS coll. cat. no. 87523; 81524A, B. 30, sample B 3; 31, 32, sample B 2, Iioka Formation.
- Figs. 33-35. *Bulimina striata* d'Orbigny  
33-35, ×64. IGPS coll. cat. no. 87525 A, B, C. Sample A 11, Iioka Formation.
- Fig. 36. *Bulimina subornata* Brady  
×50. IGPS coll. cat. no. 87526. Sample A 30, Toyosato Formation.
- Fig. 37. *Bulimina marginata* d'Orbigny  
×64. IGPS coll. cat. no. 87527. Sample B 12, Toyosato Formation.



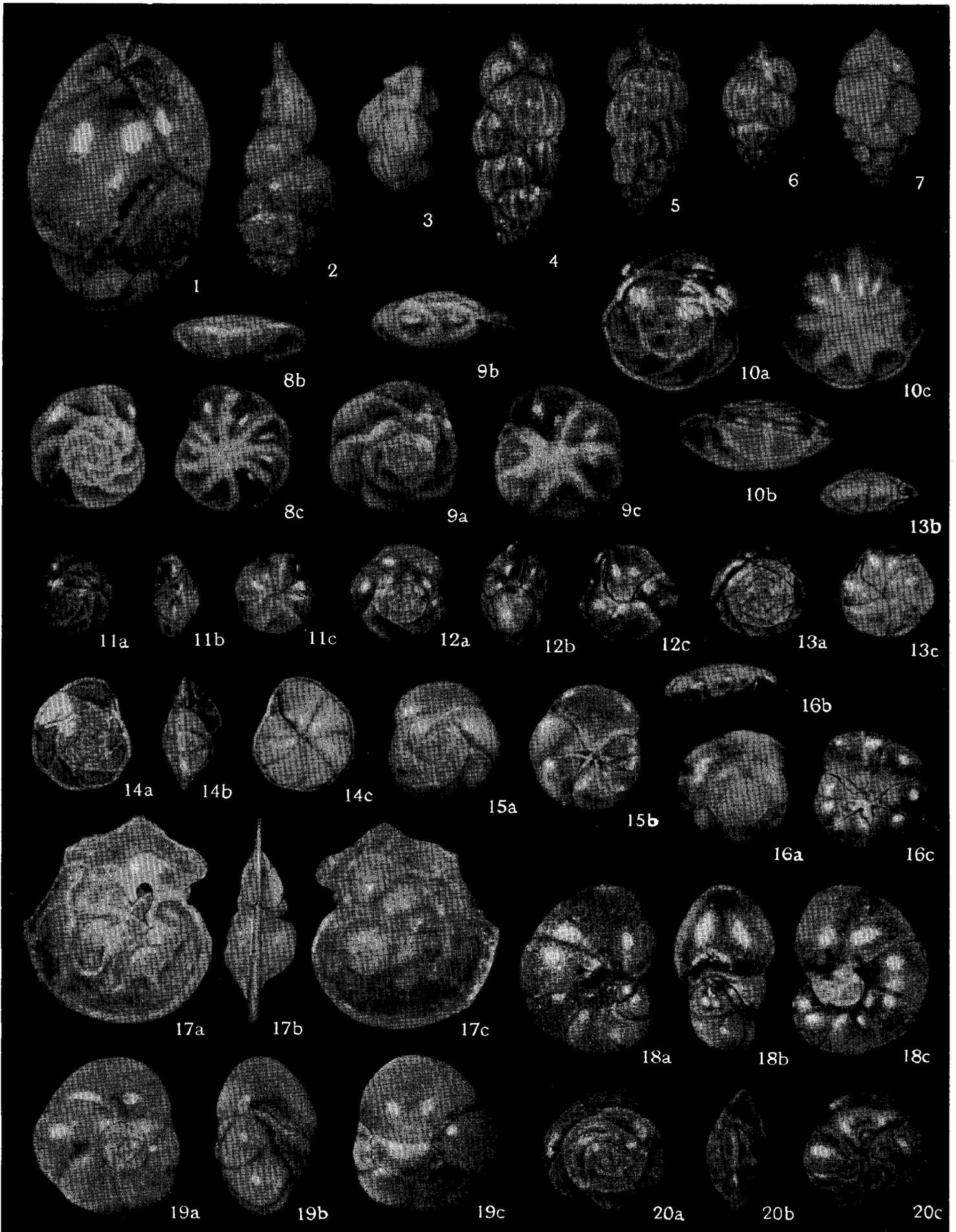
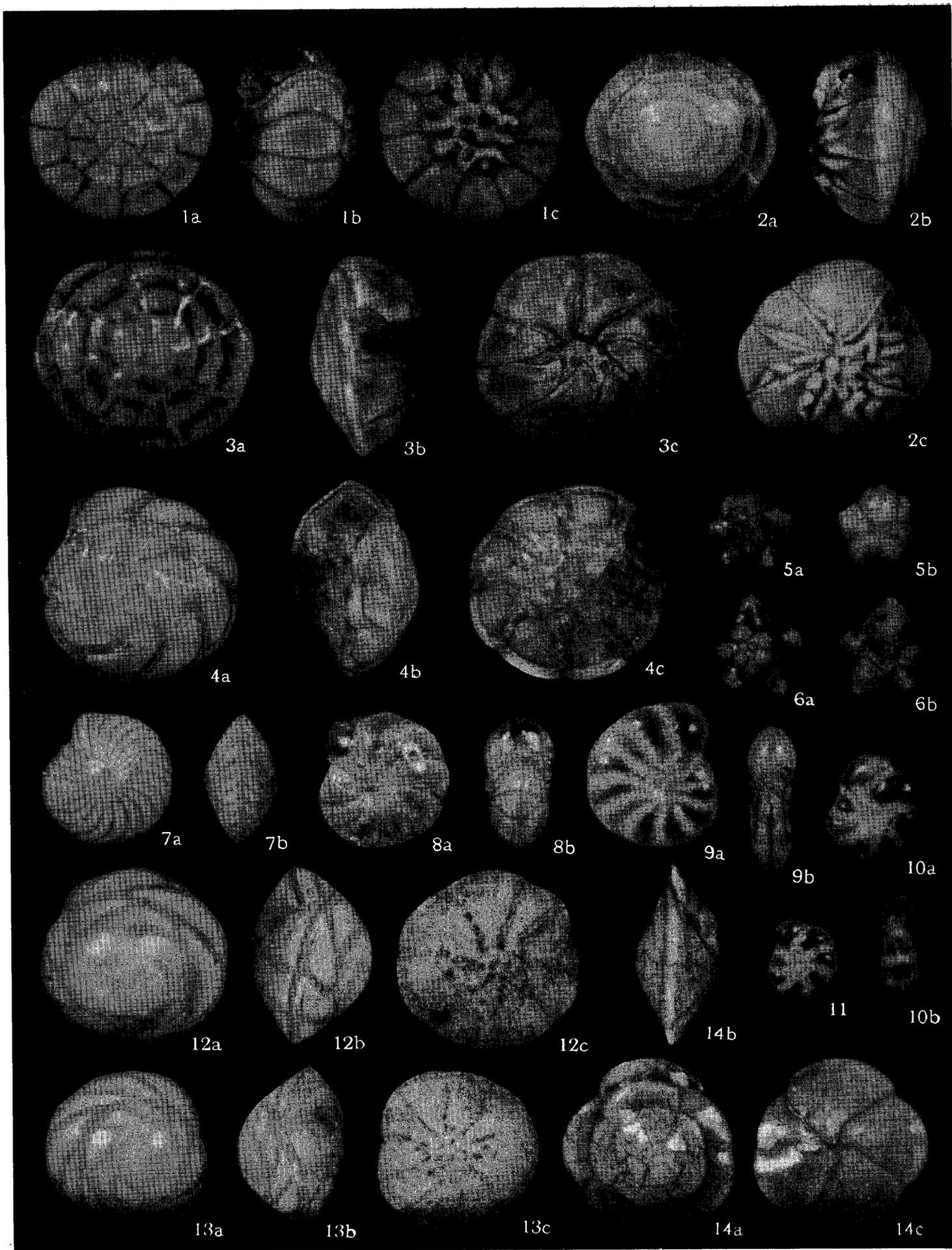


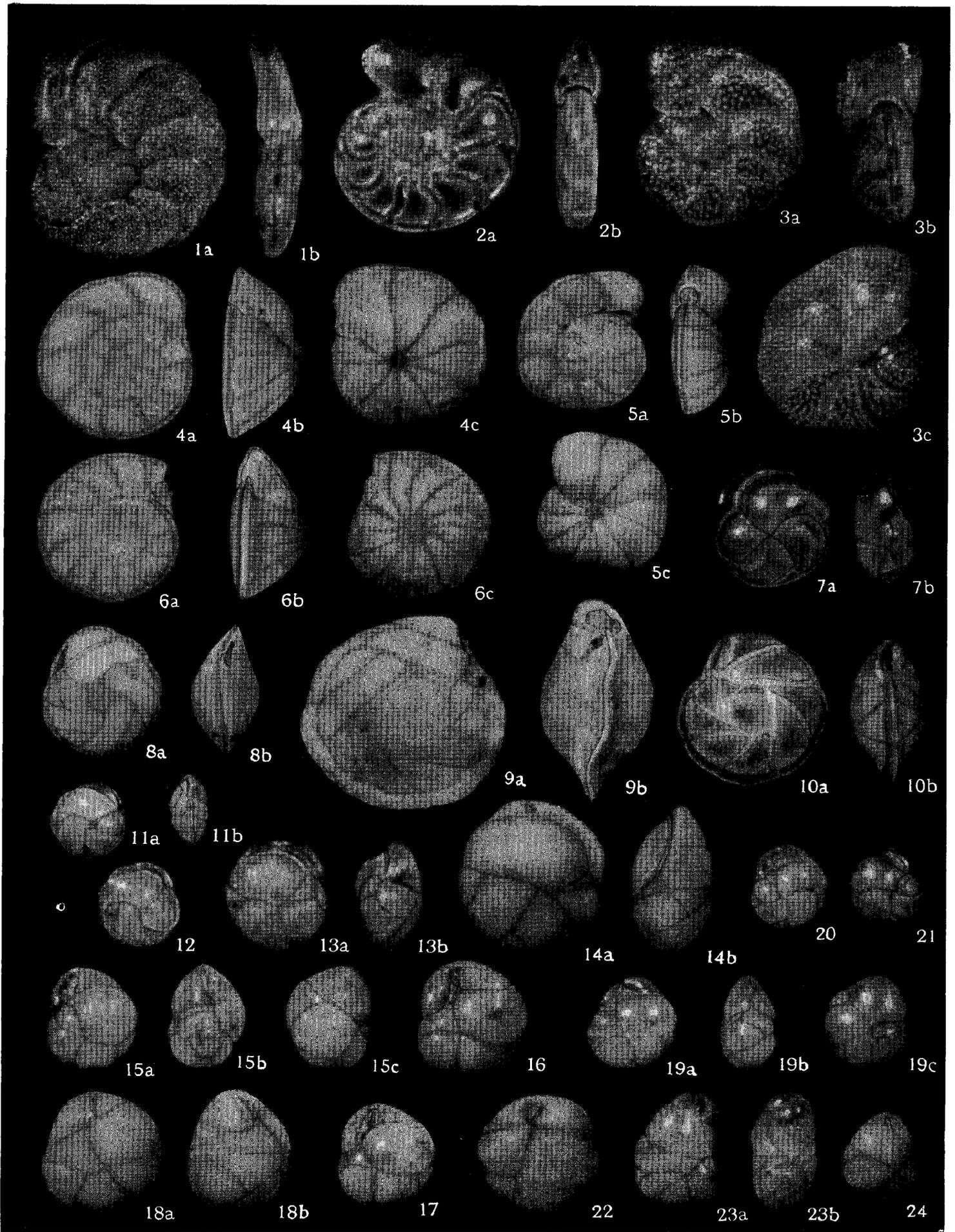
Plate 26

- Fig. 1. *Globobulimina auriculata* (Bailey)  
×50. IGPS coll. cat. no. 87528. Sample A 9, Iioka Formation.
- Fig. 2. *Siphovigerina ampullacea* (Brady)  
×64. IGPS coll. cat. no. 87529. Sample A 8, Iioka Formation.
- Fig. 3. *Trifarina kokozuraensis* (Asano)  
×50. IGPS coll. cat. no. 87530. Sample A 2, Na-arai Formation.
- Figs. 4-6. *Uvigerina akitaensis* Asano  
4-6, ×50. IGPS coll. cat. no. 87531 A, B, C. Sample A 14, Iioka Formation.
- Fig. 7. *Uvigerina proboscidea* Schwager  
×50. IGPS coll. cat. no. 87532. Sample A 11, Iioka Formation.
- Figs. 8a-c. *Buccella frigida* (Cushman) var.  
×64. IGPS coll. cat. no. 87533. Sample K 2, "Katori" Formation.
- Figs. 9a-c. *Buccella frigida* (Cushman)  
×64. IGPS coll. cat. no. 87534. Sample K 3, "Katori" Formation.
- Figs. 10a-c. *Buccella inusitata* Andersen  
×64. IGPS coll. cat. no. 87535. Sample A 28, Iioka Formation.
- Figs. 11a-c. *Epistominella naraensis* (Kuwano)  
×96. IGPS coll. cat. no. 87536. Sample A 25, Iioka Formation.
- Figs. 12a-c. *Epistominella tamana* (Kuwano)  
×96. IGPS coll. cat. no. 87537. Sample A 29, Iioka Formation.
- Figs. 13a-c. *Epistominella nipponica* Kuwano, n. sp.  
Hypotype, ×96. IGPS coll. cat. no. 87538. Sample A 14, Iioka Formation.
- Figs. 14a-c. *Epistominella pulchella* Husezima and Maruhasi  
×64. IGPS coll. cat. no. 87539. Sample B 5, Iioka Formation.
- Figs. 15a, b, 16a-c. *Rosalina vilardeboana* d'Orbigny  
15, 16, ×50. IGPS coll. cat. no. 87540; 87541. 15, sample K 1; 16, sample K 2, "Katori" Formation.
- Figs. 17a-c. *Laticarinina pauperata* (Parker and Jones)  
×50. IGPS coll. cat. no. 87542. Sample A 3, Na-arai Formation.
- Figs. 18a-c. *Valvulineria sadonica* Asano  
×50. IGPS coll. cat. no. 87543. Sample A 17, Iioka Formation.
- Figs. 19a-c. *Valvulineria glabra* Cushman  
×64. IGPS coll. cat. no. 87544. Sample A 11, Iioka Formation.
- Figs. 20a-c. *Pseudoeponides japonicus* Uchio  
×64. IGPS coll. cat. no. 87545. Sample A 26, Iioka Formation.

Plate 27

- Figs. 1a-c. *Ammonia japonica* (Hada)  
×50. IGPS coll. cat. no. 87546. Sample K 2, "Katori" Formation.
- Figs. 2a-c. *Ammonia ketienziensis angulata* (Kuwano)  
×50. IGPS coll. cat. no. 87547. Sample B 12, Toyosato Formation.
- Figs. 3a-c. *Ammonia takanabensis* (Ishizaki)  
×50. IGPS coll. cat. no. 87548. Sample B 14, Toyosato Formation.
- Figs. 4a-c. *Pseudorotalia gaimardii* (d'Orbigny)  
×28. IGPS coll. cat. no. 87549. Sample K 3, "Katori" Formation.
- Figs. 5a, b. *Pararotalia minuta* (Takayanagi)  
×96. IGPS coll. cat. no. 87550. Sample B 10, Iioka Formation.
- Figs. 6a, b. *Pararotalia minuta* (Takayanagi) var.  
×96. IGPS coll. cat. no. 87551. Sample B 10, Iioka Formation.
- Figs. 7a, b. *Elphidium crispum* (Linné)  
×28. IGPS coll. cat. no. 87552. Sample K 3, "Katori" Formation.
- Figs. 8a, b. *Elphidium clavatum* Cushman  
×64. IGPS coll. cat. no. 87553. Sample B 11, Iioka Formation.
- Figs. 9a, b. *Elphidium kusiroense* Asano  
×50. IGPS coll. cat. no. 87554. Sample K 1, "Katori" Formation.
- Figs. 10a, b, 11. *Elphidium subarcticum* Cushman  
10, 11, ×64. IGPS coll. cat. no. 87555 A, B. Sample A 33, Toyosato Formation.
- Figs. 12a-c, 13a-c. *Porosotalia makiyamae* (Chiji)  
12, 13, ×64. IGPS coll. cat. no. 87556 A, B. Sample K 3, "Katori" Formation.
- Figs. 14a-c. *Eponides umbonatus* (Reuss)  
×50. IGPS coll. cat. no. 87557. Sample A 14, Iioka Formation.



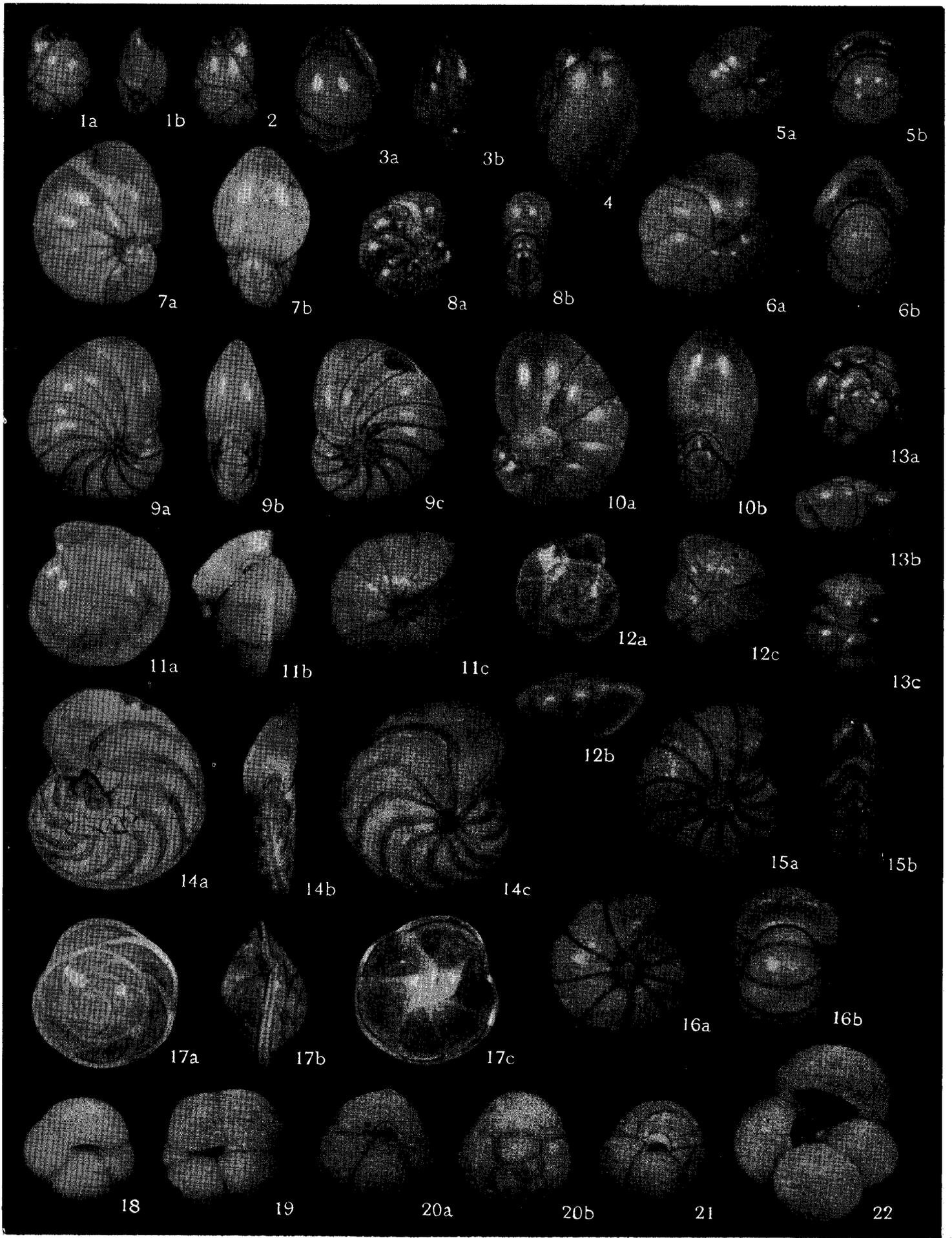


## Plate 28

- Figs. 1a, b. *Planulina wuellerstorfi* (Schwager)  
×21. IGPS coll. cat. no. 87558. Sample A 13, Iioka Formation.
- Figs. 2a, b. *Hyalinea balthica* (Schröter)  
×50. IGPS coll. cat. no. 87559. Sample A 24, Iioka Formation.
- Figs. 3a-c. *Cibicides aknerianus* (d'Orbigny)  
×50. IGPS coll. cat. no. 87560. Sample A 28, Iioka Formation.
- Figs. 4a-c. *Cibicides refulgens* Montfort  
×50. IGPS coll. cat. no. 87561. Sample A 1, Na-arai Formation.
- Figs. 5a-c. *Cibicides lobatulus* (Walker and Jacob)  
×28. IGPS coll. cat. no. 87562. Sample K 3. "Katori" Formation.
- Figs. 6a-c. *Cibicides subpraecinctus* (Asano)  
×50. IGPS coll. cat. no. 87563. Sample A 1, Na-arai Formation.
- Figs. 7a, b. *Cassidulina delicata* Cushman  
×64. IGPS coll. cat. no. 87564. Sample A 4, Iioka Formation.
- Figs. 8a, b, 9a, b. *Cassidulina yabei* Asano and Nakamura  
8, 9, ×50. IGPS coll. cat. no. 87565; 87566. 8, sample A 1; 9, sample A 2, Na-arai Formation.
- Figs. 10a, b. *Cassidulina norcrossi* Cushman  
×64. IGPS coll. cat. no. 87567. Sample A 10, Iioka Formation.
- Figs. 11a, b, 12. *Cassidulina carinata* Silvestri  
11, 12, ×64. IGPS coll. cat. no. 87568; 87569. 11, sample A 20; 12, sample B 9 Iioka Formation.
- Figs. 13a, b, 14a, b. *Cassidulina sagamiensis* Asano and Nakamura  
13, ×96; 14, ×50. IGPS coll. cat. no. 87570; 87571. 13, sample A 4, Iioka Formation; 14, sample A 1, Na-arai Formation.
- Figs. 15a-c, 16, 17, 18a, b. *Cassidulina subglobosa* Brady  
15-18, ×50. IGPS coll. cat. no. 87572A, B, C; 87573. 15, 16, 17, sample A 22, Iioka Formation; 18, sample A 1, Na-arai Formation.
- Figs. 19a-c. *Cassidulina depressa* Asano and Nakamura  
×64. IGPS coll. cat. no. 87574. Sample A 14, Iioka Formation.
- Figs. 20, 21. *Cassidulina* cf. *depressa* Asano and Nakamura  
20, 21, ×64. IGPS coll. cat. no. 87575; 87576. 20, sample B 4; 21, sample B 11, Iioka Formation.
- Fig. 22. *Cassidulina elegans bosoensis* Kuwano  
×64. IGPS coll. cat. no. 87577. Sample A 12, Iioka Formation.
- Figs. 23a, b, 24. *Cassidulinoides parkerianus* (Brady)  
23, 24, ×64. IGPS coll. cat. no. 87578 A, B. Sample A 28, Iioka Formation.

Plate 29

- Figs. 1a, b, 2. *Cassidulinoides kuwanoi* Matoba, n. sp.  
1, holotype, 2, paratype,  $\times 96$ . IGPS coll. cat. no. 87579A, B. Sample A 16, Iioka Formation.
- Figs. 3a, b. *Cassidulinoides kattoi* (Takayanagi)  
 $\times 50$ . IGPS coll. cat. no. 87580. Sample A 17, Iioka Formation.
- Fig. 4. *Chilostomella ovoidea* Reuss  
 $\times 50$ . IGPS coll. cat. no. 87581. Sample A 22, Iioka Formation.
- Figs. 5a, b. *Pullenia bulloides* (d'Orbigny)  
 $\times 50$ . IGPS coll. cat. no. 87582. Sample A 10, Iioka Formation.
- Figs. 6a, b. *Pullenia subcarinata* (d'Orbigny)  
 $\times 64$ . IGPS coll. cat. no. 87583. Sample A 10, Iioka Formation.
- Figs. 7a, b. *Nonion labradoricum* (Dawson)  
 $\times 50$ . IGPS coll. cat. no. 87584. Sample A 28, Iioka Formation.
- Figs. 8a, b. *Astrononion hamadaense* Asano  
 $\times 64$ . IGPS coll. cat. no. 87585. Sample A 4, Iioka Formation.
- Figs. 9a-c. *Pseudononion japonicum* Asano  
 $\times 50$ . IGPS coll. cat. no. 87586. Sample K 3, "Katori" Formation.
- Figs. 10a, b. *Nonionella stella* Cushman and Moyer  
 $\times 64$ . IGPS coll. cat. no. 87587. Sample A 32, Toyosato Formation.
- Figs. 11a-c. *Gyroidina orbicularis* d'Orbigny  
 $\times 50$ . IGPS coll. cat. no. 87588. Sample A 16, Iioka Formation.
- Figs. 12a-c. *Gyroidina? profunda* Aoki  
 $\times 50$ . IGPS coll. cat. no. 87589. Sample A 3, Na-arai Formation.
- Figs. 13a-c. *Gyroidinoides nipponicus* (Ishizaki)  
 $\times 50$ . IGPS coll. cat. no. 87590. Sample A 16, Iioka Formation.
- Figs. 14a-c. *Hanzawaia nipponica* Asano  
 $\times 50$ . IGPS coll. cat. no. 87591. Sample K 3, "Katori" Formation.
- Figs. 15a, b. *Melonis parkerae* (Uchio)  
 $\times 50$ . IGPS coll. cat. no. 87592. Sample A 7, Iioka Formation.
- Figs. 16a, b. *Melonis pompilioides* (Fichtel and Moll)  
 $\times 50$ . IGPS coll. cat. no. 87593. Sample A 7, Iioka Formation.
- Figs. 17a-c. *Hoeglundina elegans* (d'Orbigny)  
 $\times 28$ . IGPS coll. cat. no. 87594. Sample A 23, Iioka Formation.
- Figs. 18, 19. *Globigerina pachyderma* (Ehrenberg)  
18, 19,  $\times 64$ . IGPS coll. cat. no. 87595; 87596. 18, sample, A 27; 19, sample A 14, Iioka Formation
- Figs. 20a, b, 21. *Globigerina nepenthes* Todd  
20, 21,  $\times 64$ . IGPS coll. cat. no. 87597A, B. Sample A 1, Na-arai Formation.
- Fig. 22. *Globigerina bulloides* d'Orbigny  
 $\times 50$ . IGPS coll. cat. no. 87598. Sample A 14, Iioka Formation.



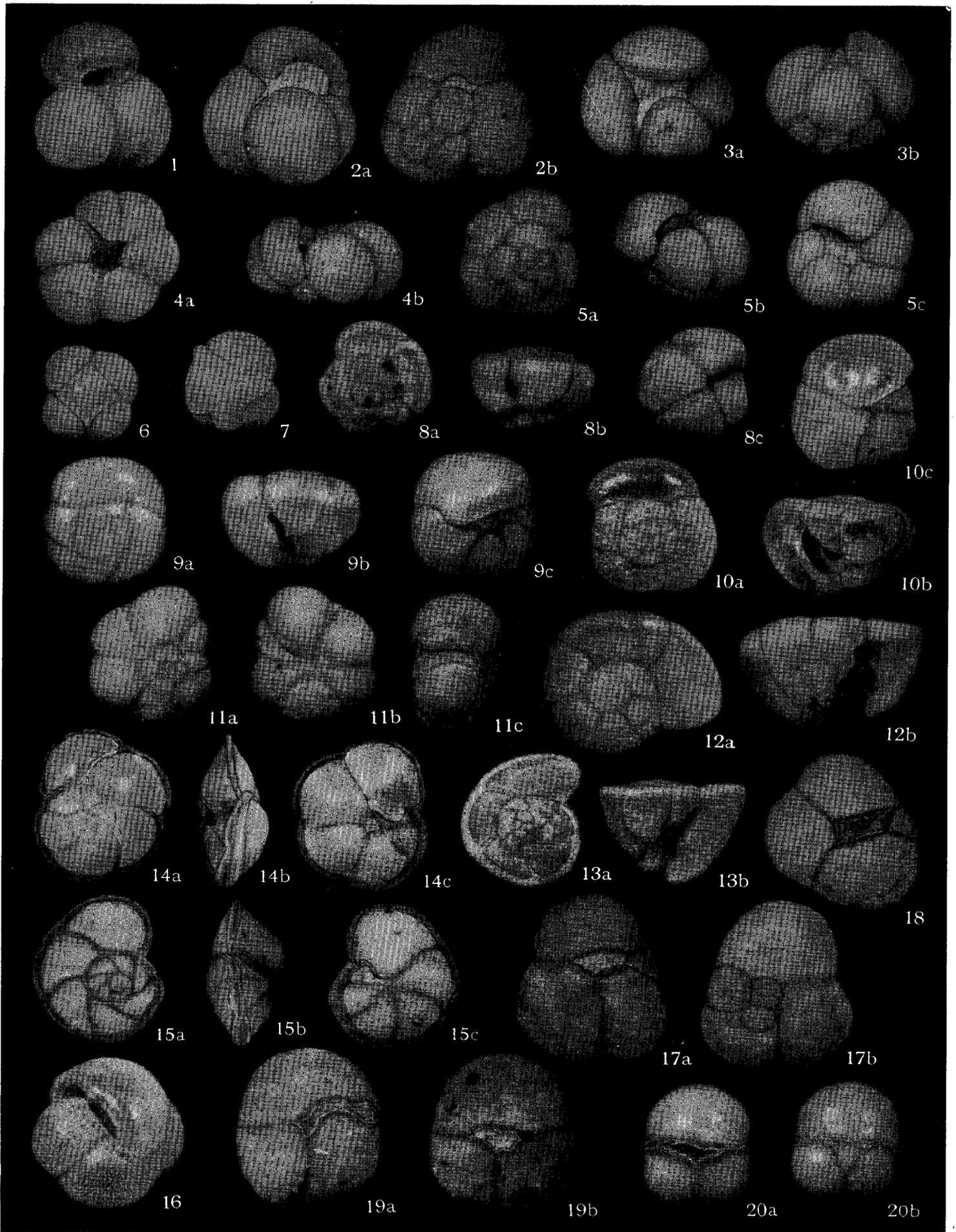


Plate 30

- Fig. 1. *Globigerinoides ruber* (d'Orbigny)  
×50. IGPS coll. cat. no. 87599. Sample A 9, Iioka Formation.
- Figs. 2a, b. *Globigerinoides obliquus* Bolli  
×64. IGPS coll. cat. no. 87600. Sample A 1, Na-arai Formation.
- Figs. 3a, b. *Globoquadrina conglomerata* (Schwager)  
×50. IGPS coll. cat. no. 87601. Sample A 1, Na-arai Formation.
- Figs. 4a, b. *Globoquadrina dutertrei* (d'Orbigny)  
×50. IGPS coll. cat. no. 87602. Sample A 9, Iioka Formation.
- Figs. 5a-c. *Globoquadrina* cf. *dutertrei* (d'Orbigny)  
×50. IGPS coll. cat. no. 87603. Sample A 9, Iioka Formation.
- Figs. 6, 7. *Globigerinita glutinata* (Egger)  
6, 7, ×64. IGPS coll. cat. no. 87604A, B. Sample A 4, Iioka Formation.
- Figs. 8a-c. *Globorotalia crassaformis* (Galloway and Wissler)  
×50. IGPS coll. cat. no. 87605. Sample A 2, Na-arai Formation.
- Figs. 9a-c, 10a-c. *Globorotalia inflata* (d'Orbigny)  
9, ×64; 10, ×50. IGPS coll. cat. no. 87606; 87607. 9, sample A 3, Na-arai Formation;  
10, sample A 17, Iioka Formation.
- Figs. 11a-c. *Globorotalia acostaensis* Blow  
×50. IGPS coll. cat. no. 87608. Sample A 1, Na-arai Formation.
- Figs. 12a, b. *Globorotalia tosaensis* Takayanagi and Saito  
×50. IGPS coll. cat. no. 87609. Sample A 7, Iioka Formation.
- Figs. 13a, b. *Globorotalia truncatulinoides* (d'Orbigny)  
×50. IGPS coll. cat. no. 87610. Sample A 6, Iioka Formation.
- Figs. 14a-c. *Globorotalia menardii* (d'Orbigny) *s. s.*  
×28. IGPS coll. cat. no. 87611. Sample A 17, Iioka Formation.
- Figs. 15a-c. *Globorotalia menardii miocenica* Palmer  
×64. IGPS coll. cat. no. 87612. Sample A 1, Na-arai Formation.
- Fig. 16. *Pulleniatina obliquiloculata* (Parker and Jones)  
×50. IGPS coll. cat. no. 87613. Sample A 20, Iioka Formation.
- Figs. 17a, b, 18. *Sphaeroidinellopsis seminulina* (Schwager)  
×64. IGPS coll. cat. no. 87614 A, B. Sample A 1, Na-arai Formation.
- Figs. 19a, b, 20a, b. *Sphaeroidinella dehiscens* (Parker and Jones)  
19, 20, ×50. IGPS coll. cat. no. 87615; 87616. 19 sample A 2; 20, sample A 3, Na-arai  
Formation.