Miocene Planktonic Foraminifera from Honshu, Japan

Tsunemasa Saito

(With 16 tables, 15 text-figs., and plates 53-56)

CONTENTS

ABSTRACT

The planktonic foraminiferal assemblages from the important Miocene sedimentary basins in Honshu, Japan are described giving full account of their systematics, stratigraphic distribution, and paleoecology.

Eight zonal subdivisions of the Japanese Miocene are proposed on the basis of local planktonic foraminiferal sequences ascertained in the individual areas studied. The correlation of the Japanese Miocene with the Caribbean as well as the mutual relationships of the Miocene formations within

Japan is attempted in terms of the established eight planktonic foraminiferal zones.

The Miocene boreal planktonic faunas are discussed, and their significance and characteristics described.

In the systematics, among the determined total of 11 genera, 58 species and 14 subspecies, two species are proposed as a new to science.

INTRODUCTION

Starting from the taxonomic re-investigations of the planktonic Foraminifera by Loeblich and his collaborators (1957), the value of this type of Foraminifera as index fossils has become recognized. The wide dispersal of the planktonic organisms by ocean currents, combined with their abundance in marine sediments and their short life-span, makes them useful for long distance correlation.

The major use of the planktonic Foraminifera for the Tertiary biostratigraphy has primarily been carried out in the Caribbean region. Owing to the outstanding and detailed works of Bolli (1950, 1951, 1957a-c), Beckmann (1953) and Blow (1959), the succession of planktonic Foraminifera established in the Caribbean region seems to be the best standard of reference.

The Cenozoic sediments are widely distributed in the Japanese Islands, and various kinds of fossils have been recorded from the different sedimentary basins. Although correlations and zonal sequences have been employed in the Cenozoic of Japan for many years, they have been of regional application due to the restricted faunal distribution and rapidly changing environments even at the same time-level.

The purpose of the present study is to describe the planktonic foraminiferal fauna and to established the planktonic foraminiferal biostratigraphy of the Miocene system in Honshu, Japan in comparison with the established planktonic foraminiferal sequences in the Caribbean region. Based upon the local planktonic foraminiferal sequences ascertained in the individual areas studied, eight biostratigraphic zones are proposed and zonal correlation of the Japanese Miocene formations are undertaken.

The writer began the study of Japanese planktonic Foraminifera in 1959, with the examination of the samples collected from different parts of Japan, and from other parts of the world. Descriptions on the stratigraphy and the foraminiferal assemblages of the sedimentary basins incorporated in this study are also given in details.

During the investigation, the Miocene boreal planktonic fauna which possibly reflects the colder-current prevailing in Miocene time was recognized in the Miocene of northern Japan after the time marked by the extinction of *Globorotalia fohsi fohsi*. Their characters and stratigraphic significance are described in comparison with the high-latitudinal planktonic assemblages in the present seas. The significance of the Miocene boreal planktonic Foraminifera may be very important for study on comparative morphology of Foraminifera, and for interpretation of the history of climatic zones.

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Dr. N. de B. Hornibrook of the New Zealand Geological Survey, provided the writer with four Miocene planktonic species described from New Zealand by him and Finlay. Professor N.N Subbotina, VNIGRI, Leningrad, USSR, kindly answered questions concerning the taxonomy of *Turborotalia bykovae* Aisenstat.

CHAPTER 1

MATERIALS AND METHOD OF STUDY

COMPOSITE SAMPLE

Three to five pieces of rocks collected at random along the length of 1 meter, measured parallel to the stratification of the exposure, compose a sample in the present paper. The pieces were collected within 5 cm. in vertical distance from the 1 meter base line; they were mixed together to form a composite sample. The composite sample thus made is taken here to represent the rock of a given time-level chosen at the outcrop, and the Foraminifera yielded from an assemblage representing that level of the outcrop.

PREPARATION OF SAMPLES

The sample was weighed in a dried condition before being subjected to the Glauber's salt hard rock maceration treatment (Kirchner, 1958). The amount subjected to the maceration treatment varies from several to a hundred gram, depending upon the concentration of Foraminifera in the rock samples. After the maceration, the sample was washed using a screen with 100 microns opening. From the residue remained on the screen, all foraminiferal specimens were separated for the study.

METHOD OF STUDY

All foraminiferal specimens separated from a sample of known weight were identified; their frequencies are listed by the species, except those badly broken and/or poorly preserved which were counted together and listed under miscellaneous; the total number of Foraminifera in the samples is obtained from the list; and the foraminiferal number (the number of Foraminifera in one gram rock) is calculated for the sample.

The present study is based on the composite samples which the writer collected from various Japanese localities. Many rock samples and separate specimens for reference that were placed at the writer's disposal materially facilitate the present work in checking the distribution and confirming the identification of species. They are;

Japanese material

Akita oil-field, Tsuchizaki: Onnagawa formation up to the Sasaoka formation (Miocene to Pleistocene), washed samples from the deep boring core of Tsuchizaki R–7 well, drilled at lat. 39°45′41″N., long. 140°03′E. (From the Akita Branch of the Japan Petroleum Exploration Company)

Boso Peninsula: Kiyosumi formation (Miocene), rock samples. (From Mr. N. Aoki, Geological and Mineralogical Institute, Tokyo University of Education).

Kanazawa district: Sunagozaka tuffaceous alternation member, Yatsuo formation (Miocene), rock sample. (From Dr. N. Fuji, Geological Institute of Kanazawa University).

Mie region: Isshi group (Miocene), rock samples. (From Dr. J. Yamada, Institute of Earth Science, Liberal Arts Department, Mie University).

Foreign material

New Zealand: Miocene, type slides. (From Dr. N. de B. Hornibrook, New Zealand Geological Survey).

Globorotalia miozea Finlay (Homoeotype)
Globorotalia zealandica Hornibrook (Ideotype)
Globigerina semivera Hornibrook (Topotype)
Globigerina zealandica Hornibrook (Topotype)

Mariana Islands, Saipan: Donni Sandstone, rock samples. (IGPS collection)

Globigerina nepenthes Todd (Topotype)
Globoquadrina eximia (Todd) (Topotype)

Mariana Islands, Saipan: Tagpochau limestone, rock samples. (IGPS collection).

Italy, Tortona: Type Tortonian washed sample. (IGPS collection).

France, Vives (Hérault), Tuilerie d'Aigues: Helvetian, rock sample. (IGPS collection).

Venezuela, eastern Falcon Region, Pozón-El Mene Road section: Upper Tocuyo (San Lorenzo) and lower Pozón formations (=type section for Miocene planktonic foraminiferal zones in Caribbean region), washed sample. (From the Humble Oil and Refining Company, New Orleans area and the Creole Petroleum Corporation, Maracaibo, Venezuela).

The *Catapsydrax stainforthi* Zone
The *Globigerinatella insueta Zone*
The *Globorotalia fohsi barisanensis* Zone

Numerous Pacific Ocean bottom sediments.

Numerous Japan Sea bottom sediments.

CHAPTER 2

PLANKTONIC FORAMINIFERAL ZONES IN THE JAPANESE MIOCENE

DESCRIPTION OF PLANKTONIC FORAMINIFERAL ASSEMBLAGES

The Cenozoic sediments of Japan were proved to have been deposited in many local and different sedimentary basins (Geol. Surv. Japan, 1960, p. 67–84). The origin, evolution and migration of these sedimentary basins have not been wholly understood, but several stratigraphers (Huzita, 1962; Kaseno, *et al.*, 1961; Kitamura, 1959) and paleontologists (Hanzawa, 1950; Ikebe, 1957; Makiyama, 1939) attempted to synthesize the Cenozoic history of Japan. From their works, it may be said that in general, the Cenozoic sedimentary basins of Japan show parallelism with each other in their development, particularly in their sedimentary cycles.

Fifteen and some additional areas were chosen for the systematic sampling to study the distribution of the planktonic Foraminifera during the Miocene in the representative sedimentary basins of Japan. Their locations are shown in text-fig. 1.

In the following section are described the general stratigraphy and the occurrences of the planktonic Foraminifera in each area. The descriptions are arranged in the order of

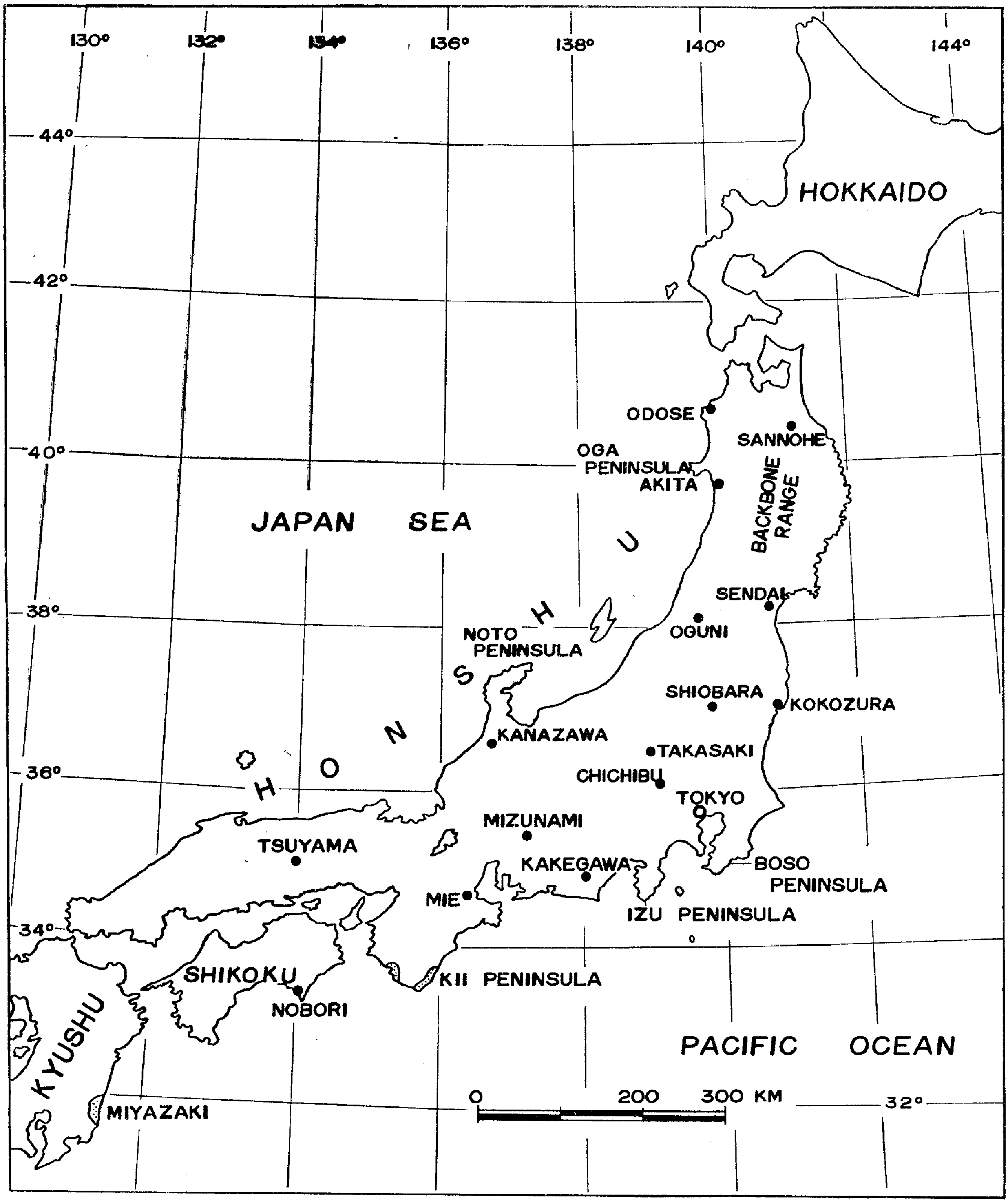

Fig. 1. Index map showing the areas treated

the geographical position of the areas; starting from the southernmost one. The summary of the planktonic foraminiferal zones of the Japanese Miocene, the establishment of which were based on the local foraminiferal sequences ascertained in these individual areas studied, will be given in the next section.

1. Kii Peninsula

Stratigraphy: – Along the east and west coasts of the southern Kii Peninsula, Cenozoic sedimentary and igneous rocks are widely distributed. The geology and paleontology of the east coast of this Peninsula had been reported by Mizuno (1956), in connection with his study on the molluscan fossils of the area. According to Mizuno, the geologic sequence of this area is as follows in descending order.

Stratigraphic unit	*Lithologic description*	*Thickness in meters*
Superjacent undifferentiated unit:	Pleistocene deposits	
....	Unconformity	
Kumano acidic igneous rocks (Post middle Miocene)	Biotite granite porphyry, persemic biotite rhyolite granophyer, etc.	
....	Unconformity	
Kumano group (middle Miocene)		
Mitsuno formation	Coarse grained quartzose sandstone, and alternation of silt-, sandstone and conglomerate. Intercalated with thin coal layers in the marginal facies.	500 –
Koguchi formation Shikiya siltstone member	Siltstone, sometimes intercalated with thin sandstone layers, showing typical graded bedding. Occasionally with slumping structures and rubble deposits.	1,200～ 1,300
Shimosato sandstone and siltstone member	Very fine grained sandstone and graded alternations of silt-, sandstone and conglomerate.	500～ 1,000+
....	Unconformity	
Subjacent unit:	Kinan group (probable Eocene)	

The stratigraphy of the Miocene formations along the west coast of the Penisula was studied by Takeyama (1934), who established the following stratigraphic succession in descending order.

Kanayama Series (=Group) 1,000 m. thick
Upper conglomerate
Lower sandstone; medium grained sandstone with *Serpula-*,*Turritella-*, and *Paphia* fossil zones in downward sequence.

.... Local disconformity ....

Tanabe Series (= Group) 2,000～1,500 m. thick
Asso formation: hard black shale with sandstone beds.
Maro formation and its equivalents: alternation of sandstone, conglomerate and shale.
Inari formation and its equivalents: sandstone and conglomerate intercalating sandy shale.
Tagawa formation: conglomerate and sandstone with some plant fossils.

.... Unconformity ....

Subjacent unit: Unknown Mesozoic Kumano formation

On the basis of the molluscan fauna and some stratigraphical evidences, the Miocene rocks on both sides of the Kii Peninsula are now regarded as equivalent; the Kumano group corresponding to the Kanayama and Tanabe groups combined. The study of benthonic smaller Foraminifera from the Kanayama and Tanabe groups of the west coast of the Peninsula was undertaken by Tai (1959). According to Tai, these two groups are divided biostratigraphically into two faunules; namely, the *Cyclammina-Martinottiella-Robulus* faunule in the lower and the *Cyclammina* faunule in the upper. The boundary

between the two faunules does not coincide with the lithology of the two groups.
Planktonnic Foraminfera:- Two sections for systematic sampling of the foraminiferal faunas of the three Miocene groups of the Kii peninsula, were selected. For the Kumano group of the southeast coast, the Nassa-Yukawa-Nachi-Izeki route was chosen; for the Kanayama and Tanabe groups of the southwest coast the Shirahama-Katada-Asso-Shirataki route was taken. A preliminary study of the planktonic Foraminifera of these two routes was undertaken.

The following four species occur occasionally in the Tanabe and the lower part of the Kanayama groups of the western section, and the Koguchi formation of the eastern section. The species are:

Globorotalia fohsi barisanensis LeRoy	*Globigerina praebulloides* Blow
Globorotalia scitula praescitula Blow	*Orbulina universa* d'Orbigny

Their occurrences enable (to be explained later) the writer to identify the three rock units with the lower *Globorotalia fohsi* Zone (s. l.).

2. Tsuyama region

Stratigraphy: – Across the central part of the Chugoku district, a number of small Miocene sedimentary basins are arranged in east-west direction. From the west to east, they are Masuda, Miyoshi, Minomi, Shobara, Niimi, Okayama and Tsuyama basins. Despite that they are separate basins at least at present, the Miocene sediments in them are so similar in stratigraphical sequence that it is reasonable to assume that the sediments had originally accummulated in a single larger sedimentary basin during the period. The Miocene sequences of these basins begin at most places with terrestrial sediments sometimes intercalated with coal layers, then gradually succeeded upwards with shallow marine deposits bearing rich molluscan faunas and occasionally *Miogypsina* and *Operculina*. The sequence ends with thick fine grained sediments which, beside some molluscan faunas, is rich in smaller Foraminifera indicating rather deeper water. The Tsuyama basin was chosen to represent the region, and its planktonic Foraminifera was studied. Suyari (1948), made a geological survey of this region, and classified the Miocene rocks into the Mimasaka coal-bearing formation (15–30 m. thick) below and the Katsuta formation (50 m. thick) above. The Katsuta formation was further subdivided by him into two units: the lower consisting of coarser grained sediments with the *Vicarya* and *Operculina* fauna, and the upper or finer-grained ones with some mollsucan fossils. Later in 1957, Kawai published the 1 : 50,000 geological map sheet "Tsuyama-tobu", and revised the Miocene stratigraphy of the region as follows.

Katsuta group
- Takakura formation (300 m.–)
  - Alternation of silt- and sandstone, with *Operculina complanata* in the lower part.
- Yoshino formation (5–70 m.)
  - Conglomerate and sandstone, occasionally intercalated with carbonaceous mudstone in the lower part. With *Vicarya callosa japonica* Yabe and Hatai.
- Uetsuki formation (2–70 m.)
  - Conglomerate, sandstone, and sandy shale intercalated with coal layers. With abundant plant fossils and vertebrate fossil, *Palaeochaerus* Takai.

.... Unconformity ....

Subjacent unit: Hirono formation (Upper Triassic)

Planktonic Foraminifera: – The foraminiferal samples treated are from a cliff of the Yoshino primary school, about 14 km. east of Tsuyama City, Okayama Prefecture (lat. 35° 04′48″ N., long. 134° 09′ 46.4″ E.). At this cliff, Suyari's Katsuta formation typically crops out. The benthonic smaller Foraminifera from the same cliff was already studied by Tai

(1954). Seven samples were collected at the cliff with one meter vertical intervals; only five samples from the upper Katsuta formation yielded the planktonic Foraminifera. The preliminary study of the planktonic Foraminifera shows that the following species are frequent in all samples from the upper Katsuta formation, and no further subdivision is possible. The species are:

Globorotalia fohsi barisanensis LeRoy
Globorotalia birnagea Blow
Globigerina woodi Jenkins
Globoquadrina dehiscens (Chapman, Parr, and Collins)
Globigerinoides ruber subquadratus Bronnimann
Globigerinoides trilobus (Reuss)
Sphaerodinellopsis seminulina (Schwager)

By the reason which will be mentioned later, the fauna represents the *Globorotalia fohsi barisanensis* Zone. According to Kawai (*loc. cit.*), the planktonic foraminiferal samples herein treated came from his Takakura formation.

3. Mie region

The Miocene sediments developed in the environs of Tsu City, Mie Prefecture, are summarized as the Isshi group. The geology and paleontology of this group has been described by Araki (1960), with the descriptions of the superjacent Agé group (Pliocene), and two Pleisotcene formations. The sequence of the Isshi group established by Araki is as follows.

Stratigraphic unit	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Pliocene Agé group	
	.... Unconformity	
Yakuôji formation	Upper part with an alternation of sandstone and siltstone (more or less tuffaceous), intercalating thin tuff and conglomerate beds with gravels of chert pebbles.	120
	Lower part with an alternation of sandstone and siltstone (more or less of flysch type) at places, and 5–10 meters thick black siltstone inserted at several horizons. Concretions and sedimentary structures common.	60
Chaya sandstone	Massive sandstone intercalating siltstone layers to form an alternation of sandstone and siltstone.	60
Kaisekizan formation		
Mitsugano member	Alternation of tuffaceous siltstone and sandstone intercalating tuff.	100
Agodani member	Dark silty sandstone with concretions and light sandy siltstone intercalating sandstone. Sedimentary structures common.	150
Furutaike sandstone	Arkosic sandstone intercalating thin conglomerate beds of gneiss and granite. Thin coal seams. Sedimentary structures at places.	120
Kongôbô formation	Alternation of conglomerate and sandstone, respective layers several meters to several decimeters thick in western part, but of cobble to boulder conglomerate of gneiss and granite in sandstone matrix in southern part.	150
	.... Unconformity	
	Subjacent unit: Ryoke complex; granitic gneiss, biotite gneiss, granite.	

Planktonic Foraminifera: – In this region, five samples were collected by J. Yamada of the Mie University, and were placed at the writer's disposal for the present study. A single sample was collected from each of the Yakuoji, Chaya, and Agodani members; the Mitsugano member is represented by two samples. Of these five samples in total, two samples, one from the Yakuoji and another from the Chaya, contained such planktonic Foraminifera as:

Yakuoji formation (upper part) (70 g. of gray siltstone)

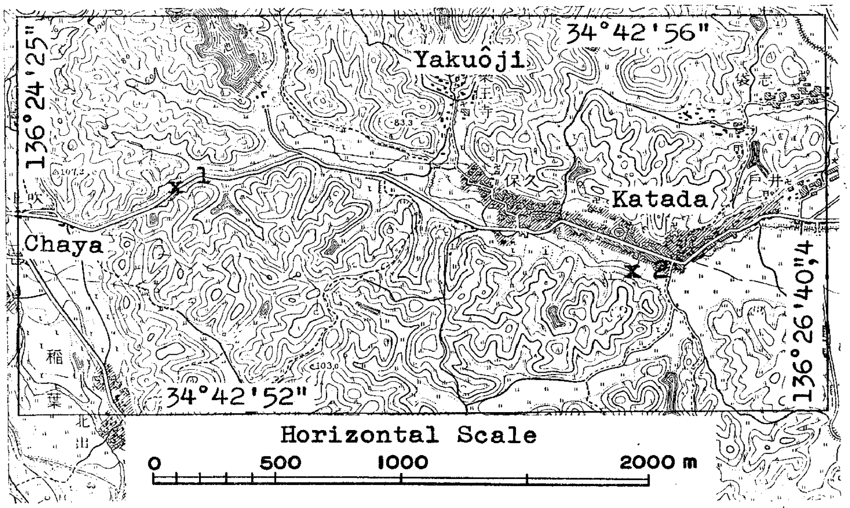

Fig. 2. Foraminiferal collection localities in the Mie region

Globorotalia opima continuosa Blow	1
Globigerina angustiumbilicata Bolli	1
Globigerina praebulloides Blow	1
Globigerina woodi Jenkins	5
Globoquadrina conglomerata (Schwager)	7
Miscellaneous	
Chaya formation (upper part) (60 g. of gray siltstone)	
Globorotalia zealandica Hornibrook	2
Globigerina angustiumbilicata Bolli	1
Globigerina falconensis Blow	5
Globigerina woodi Jenkins	3
Sphaerodinellopsis seminulina (Schwager)	2
Globigerinodies immaturus LeRoy	1

4. Mizunami region

Stratigraphy: – In this region the Miocene Mizunami group extends over four basins, the Kani, Mizunami and Iwamura basins in Gifu Prefecture, and the Seto basin in Aichi Prefecture.

The Miocene sediments of this region are very thin: generally less than 100 meters in thickness. However, the Mizunami group is one of the important Japanese Miocene sections and has been studied extensively. Many paleontological and geological works published on this region date back to the early part of this century. The two latest publications by Itoigawa (1960) and Uemura (1961) are on the geology of this region. Itoigawa (1960) gave a brief review of the previous works on the Mizunami group. The stratigraphic succession of the Mizunami group reported by Itoigawa is reproduced in fig. 3.

Nakamura formation:– Massive tuffaceous, fine to medium grained sandstone, massive tuffaceous lutite and siltstone, alternations of tuffaceous lutite and coarse-grained sandstone, and conglomerate, with interbedded layers of lignite seams. This formation yields fossil plants and mammals but no marine fossils.

Akeyo formation: – This is a transgressive facies, and yielded abundant animal fossils. Because of its abrupt and rapid change of facies, eight lithological units are recognized in this formation.

1) Tsukiyoshi facies: Massive tuffaceous siltstone and fine grained sandstone mixed with medium to coarse sand grains. Frequently including calcareous concretions.

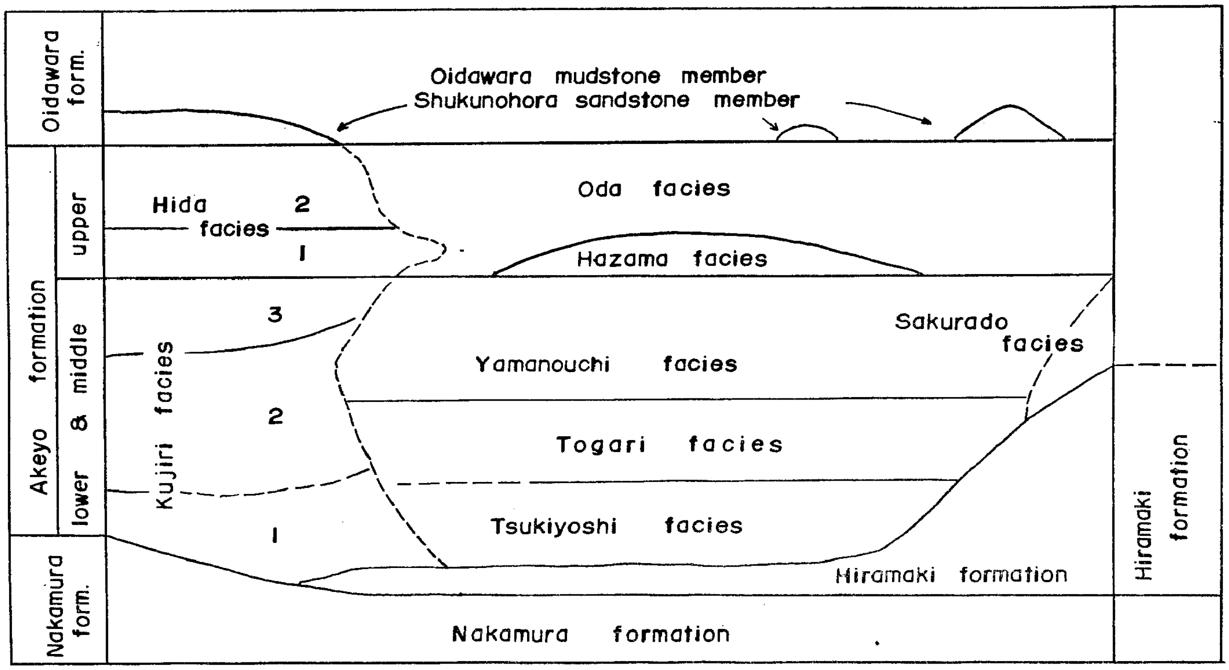

Fig. 3. Stratigraphic succession in the Mizunami region (after Itoigawa, 1961)

2) Togari facies: – Massive or cross-laminated medium to coarse grained tuffaceous sandstone with interbedded layers of tuff. Commonly with calcareous concretions and abundant molluscan fossils.

3) Yamanouchi facies: – Massive, homogenous, tuffaceous siltstone and fine grained sandstone. Frequently including concretions.

4) Kujiri facies: – Consists of three units in ascending order such as conglomerate, massive sandstone, and laminated medium grained sandstones. Marine molluscs are abundant in the middle unit. This is the marginal facies of the Tsukiyoshi, Togari and Yamanouchi facies in the western part of the Mizunami basin.

5) Sakurado facies: – Alternations of sandstone and siltstone with interbedded layers of sandstone, lutite and tuff. The sandstone is tuffaceous, medium grained and laminated. Frequently with calcareous concretions.

6) Hazama facies: – Massive or cross-laminated pumice bed, with pebbles and granules of Paleozoic rocks, and natural charcoal.

7) Oda facies: – Tuffaceous siltstone and pumice tuff, with scanty marine Mollusca.

8) Hida facies: – Consisting of two units of the upper and lower. Cross-laminated granule conglomerate and coarse grained sandstone in the lower, and tuffaceous, massive siltstone and medium to coarse grained sandstone with interbedded pumiceous tuff in the upper

Oidawara formation: – This marine deposit consists of massive siltstone, sandstone and conglomerate.

1) Shukunobora sandstone member: – The majority of this member is of medium to coarse grained sandstone and pebbly to cobbly conglomerate. In the sandstone layers calcareous concretions are found sporadically.

2) Oidawara siltstone member: – Tuffaceous, massive and homogeneous siltstone.

According to Itoigawa the following characteristic animal fossils occurred from the stratigraphic units above mentioned.

Chilotherium pugnator (Matsumoto)	Yamanouchi facies
Desmostylus japonicus Tokunaga and Iwasaki	Togari facies
Cornwallius? sp.	Kujiri facies
Cetacea and *Vicarya yokoyamai* Takeyama	Yamanouchi facies
Vicarya ishiiana (Yokoyama)	Tsukiyoshi, and the lower part of the Togari and Hida facies
Operculina complanata japonica Hanzawa *Miogypsina kotoi* Hanzawa	Shukunobora sandstone member

The stratigraphic relationship of the Shukunobora sandstone, which is isolated in distribution from the other rock units of the group, has long been debated. Its stratigraphic position is important, because it yields the *Miogypsina-Operculina* fauna. At the type locality, the Shukunobora is directly overlain by the Oidawara formation. In other places, however, the Oidawara is unconformably underlain by the Akeyo formation, and the Shukunobora formation is missing. The opinions have diverged as to whether the direct contact between the Shukunobora and Oidawara is conformable at the type locality of the Shukunobora. Because it overlies directly the Nakamura formation with unconformity, the Shukunobora formation is placed in the lowest part of the Akeyo formation by some authors (*e. g.* Huzita and Ogose, 1952) who considered the contact to be unconformable. On the other hand, several authors including Itoigawa (*e. g.* Tai, 1958), placed the Shukunobora above the Akeyo formation, by interpreting the contact to be a conformity. Tai (1958) recognized five foraminiferal faunules of benthonic Foraminifera in the Mizunami group. They are in descending order:

Bulimina-Uvigerina-Ellipsonodosaria-Epistominella-Cibicides
Miogypsina-Amphistegina-Robulus
Lagena-Rotalia-Nonion-Elphidium
Nonion-Elphidium-Eponides
Elphidium

The lower three faunules are in the Akeyo formation, namely the Tsukiyoshi, Togari, and Yamanouchi facies of Itoigawa (*loc. cit.*); and the other two in the Oidawara formation (including the Shukunobora sandstone member at the base). Tai mentioned the presence of planktonic Foraminifera in the upper part of the Togari and the lower part of the Yamanouchi facies, and in the Oidawara formation with abundance. From the foraminiferal evidences, he suggested that the lower three faunules were shallow marine dwellers of a transgressive sea, and the upper two were the fauna deposited in the littoral to outer neritic environments of the warm-water sea.

Recently, Y. Tamura (1961, MS.) established the sequences of the Miocene as shown below.

Superjacent unit: Toki formation (Pliocene to Pleistocene)

.... Unconformity ....

Oidawara formation (70 m.)

.... Local disconformity ....

Hida formation (3–90 m.)
Yamanouchi formation (35 m.)
Tsukiyoshi formation (30 m.)..........Shukunobora formation (7–8 m.)
Hiramaki formation (90 m.)
Nakamura formation (120 m.)

.... Unconformity ....

Subjacent unit: Paleozoic complex, Granite etc.

Tamura described the lithology of his stratigraphic units as follows, in descending order.

Toki formation: – The majority consists of pebbly to cobbly conglomerate with tuffaceous

claystone interbedded with peat layers and sandstone at the base.
Oidawara formation: – Massive tuffaceous siltstone, and sandstone or a few meters thick pebbly to cobbly conglomerate at the base. With wedges of laminated fine grained tuff interbedded in the marginal facies.
Hida formation: – Alternation of fine grained tuff, pumiceous tuff, tuffaceous sandstone and siltstone.
Yamanouchi formation: – Tuffaceous siltstone with calcareous concretions.
Shukunobora formation: – Tuffaceous fine to medium grained sandstone, with many calcareous concretions.
Tsukiyoshi formation: – Tuffaceous fine to medium grained sandstone with interbedded layers of fine grained tuff, and siltstone in the basal part at some places. Tamura separated the Shukunobora formation from the Oidawara formation.
Planktonic Foraminifera: – The localities at which the samples from the Mizunami basin have been collected for the present study are plotted on Tamura's geologic map (Fig. 4.). The systematic sampling was made in April, 1961, with Tamura who was then mapping the area. Three samples from the Oidawara formation collected at every 10 meters interval stratigraphically, and three samples from different exposures of the Shukunobora formation, contained abundant planktonic Foraminifera. The Kamado assemblage of the Shukunobora sandstone is from the outcrop where *Operculina complanata japonica* Hanzawa and *Miogypsina kotoi* Hanzawa occur sporadically, hence is considered as a fauna associated with these Orbitoid Foraminifera. In the other two Shukonobora samples, planktonic and Orbitoid Foraminifera were found together. Planktonic forms identified and their frequencies are shown in Table 1.

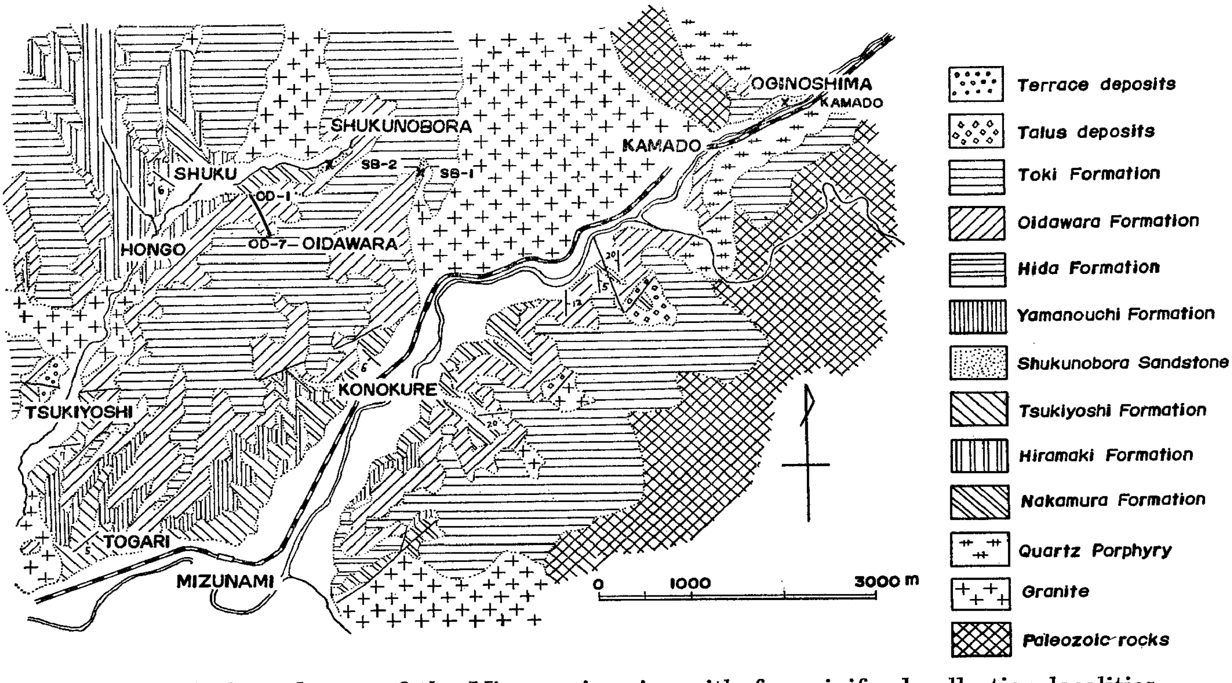

Fig. 4. Geological map of the Mizunami region with foraminiferal collection localities

The Akeyo formation is poor in planktonic Foraminifera, and the ones listed below are small in size.

Globigerina angustiumbilicata Bolli
Globigerina glutinata Egger
Globorotalia scitula praescitula Blow

Table 1. Distribution of Foraminifera in the Mizunami region

Formation	SHUKUNOBORA			OIDAWARA		
Species / Locality	Sb–1	Sb–2	Kamado	Od–1	Od–3	Od–5
Miogypsina kotoi Hanzawa	4428	378				
Globorotalia birnagea Blow				3	12	
Globorotoalia fohsi barisanensis LeRoy	8	13	2	12	57	8
Globorotalia minutissima Bolli		1		4		
Globorotalia obesa Bolli		1				
Globorotalia opima continuosa Blow	11	1			1	
Globorotalia scitula praescitula Blow				33	123	32
Globorotalia scitula scitula (Brady)						3
Globigerina angustiumbilicata Bolli	15	18		11	12	4
Globigerina falconensis Blow	36	2		8	17	16
Globigerina glutinata Egger	1			9		
Globigerina praebulloides Blow	36	11	20		13	
Globigerina triloculavis Deshayes				2		
Globigerina weissi Saito, n. sp.				24	46	13
Globigerina woodi Jenkins	24	10	9	19	93	20
Globigerinella siphonifera (d'Orbigny)	2					
Globoquadrina altispira globosa Bolli	1					
Globoquadrina conglomerata (Schwager)	1	1	1			
Globoquadrina dehiscens (Chapman, Parr and Collins)			4			
Globoquadrina obesa Akers	2					
Globigerinoides glomerosus Blow			1			
Globigerinoides immaturus LeRoy	14	1	10			
Globigerinoides ruber subquadratus Bronnimann	2	1	4			
Globigerinoides trilobus (Reuss)	6		4			
Globigerinoides sacculifer (Brady)	3					
Sphaeroidinellopsis seminulina (Schwager)	6		11			
Miscellaneous planktonic forms	56		11		86	25
Total number of planktonic forms	168	60	66	125	374	96
Weight of sample (in Gram)	50	30	50	50	50	50

Through the study of the planktonic foraminiferal assemblages in the Mizunami basin, the following features are recognized.

1. The fauna of the Shukunobora sandstone (the Shukunobora fauna) is characterized by the common occurrences of the species of *Globigerinoides*.

2. The fauna of the overlying Oidawara formation (the Oidawara fauna) differs from the Shukunobora in lacking *Globigerinoides*, and in smaller sizes of the foraminiferal specimens.

3. Generally speaking, the number of species in an assemblage decrease and the mean size of the species become smaller upwards from the Shukunobora to the Oidawara. For example, *Globorotalia fohsi barisanensis* in the former has an average size of 0.23 mm. (the maximum length of a specimen), whereas those in the latter is 0.18 mm.

Although the two faunas are different, they are not distinguishable from one another in terms of the diagnostic species of the foraminiferal zones of international application. Such species as *Globorotalia fohsi barisanensis* LeRoy and *Globorotalia scitula praescitula* Blow, occur in both fauna, and *Globigerinatella insueta* Cushman and Stainforth and/or *Globigerinoides bisphericus* whose occurrences define the "*Globigerinatella insueta/Globigerinoides bisphericus* Zone" are lacking. Therefore, the two faunas are grouped together as correlative of the *Globorotalia fohsi barisanensis* Zone. In view of the planktonic faunas of the two formations, it may be said that the time between the Shukunobora and the Oidawara was slight.

5. Kakegawa district

The area, known as the Kakegawa district, was first described by Makiyama (1931, 1941) who proposed the stratigraphic classifications of the Cenozoic sediments of this region. He also proposed a number of Stages, basing upon the rich molluscan fauna contained

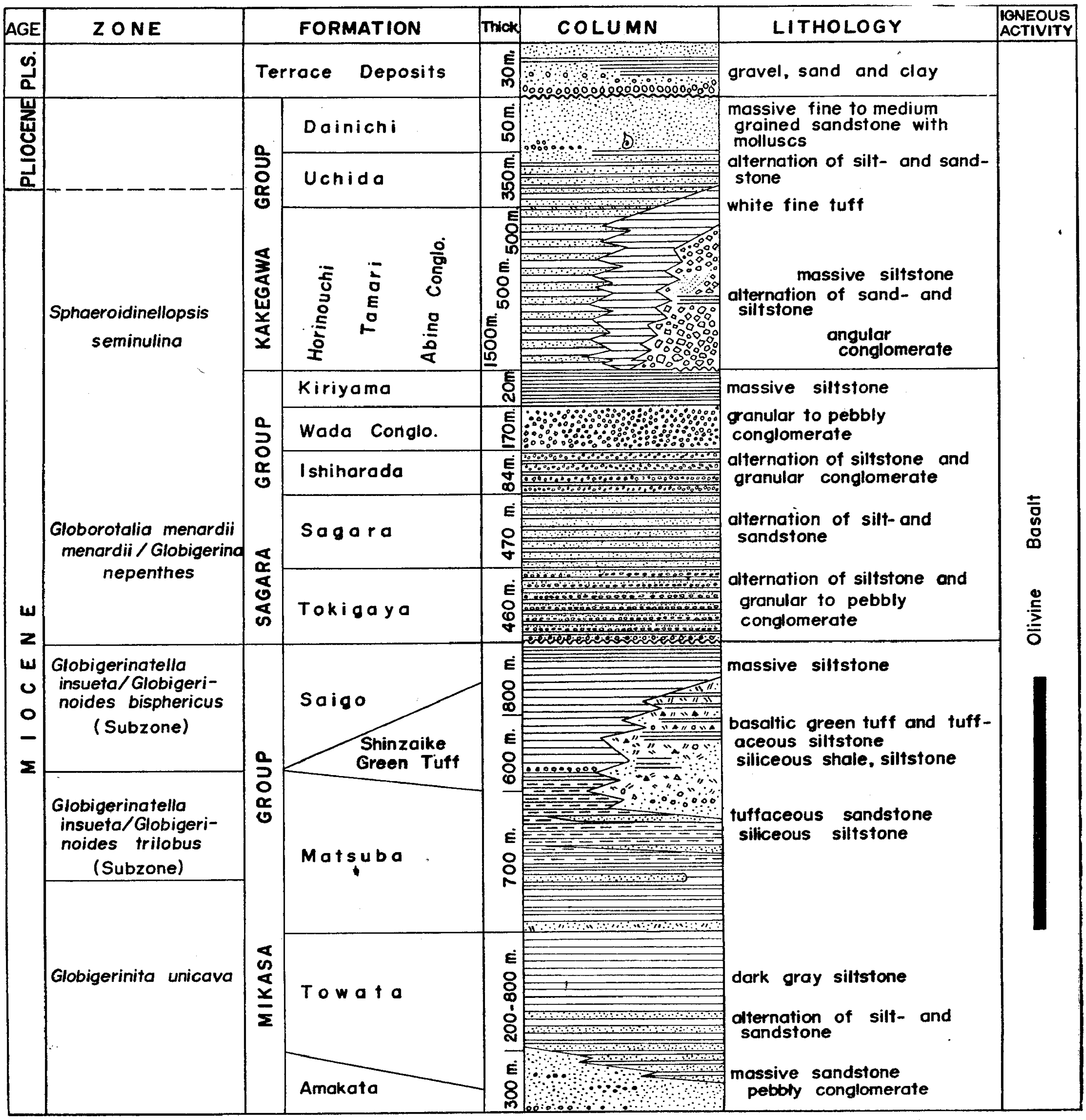

Fig. 5. Stratigrapic successions in the Kakegawa district

throughout the Cenzoic sequences of the region.

During the past decade new evidences have been added to the geology and paleontology of this area. The post-Miocene sediments of the Kakegawa district are now classified into three groups of the Mikasa, Sagara, and Kakegawa in ascending order.

The stratigraphy and preliminary analysis of the planktonic Foraminifera of the Mikasa group was once studied by the present writer (Saito, 1960).

Takashi Saito (1961, MS.) recently revised the geology of a part of the Mikasa group along the lower course of the Tenryu River. That part was hitherto known as the Futamata, Odaira and Ieda groups (M. Saito and H. Isomi, 1954). The geology, mineralogy and geography of the Sagara and Kakegawa groups have been described in detail by Ujiié (1962).

The general stratigraphic sequence of the post-Miocene series in the Kakegawa district are summarized in Fig. 5. The Kakegawa district is divided into four regions. In the following lines, the stratigraphy and planktonic assemblages of the four areas are mentioned separately.

Futamata region

Stratigraphy: – The stratigraphy of the region is summarized in Fig. 6.

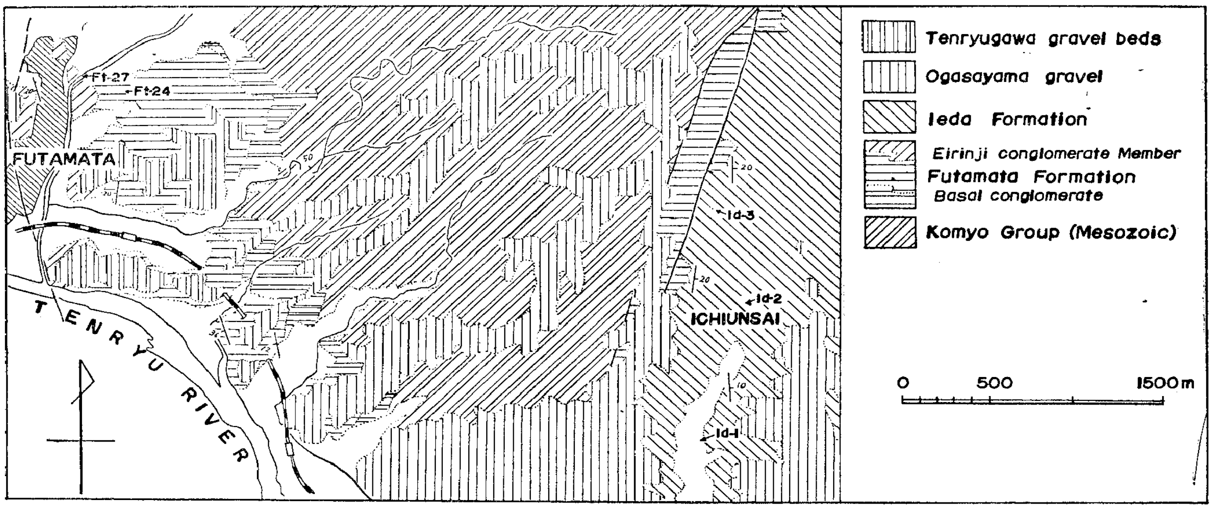

Fig. 6. Geological map of the Futamata region with foraminiferal collection localities

Planktonic Foraminifera: – In collabraotion with T. Saito, the writer sampled the Futamata and Ieda formations. Two samples from the Futamata, and three from the Ieda were found to be rich in planktonic Foraminifera. The stratigraphic positions and the localities of the samples treated are given in Fig. 6. As read from Table 2, *Globigerinatella insueta* and *Globigerinoides bisphericus* occur frequently in the samples from the Futamata and Ieda formations. From these two species and the other diagnostic species whose range has been ascertained in the Caribbean region, the foraminiferal assemblage of the Futamata and Ieda formations are judged to be the correlatives of the *Globigerinatela insueta/Globigerinoides bisphericus* Subzone. Thus the Futamata and Ieda formations are correlated with the upper part of the Mikasa group mentioned below by the planktonic Foraminifera.

Northern region of Kakegawa City

Stratigraphy (see Fig. 5): – In this region, the Mikasa group crops out extensively showing a rather simple plunging synclinal fold with NE-SW axis (Saito, 1960).

Table 2. Planktonic Foraminifera from the Futamata region, Kakegawa district

Formation	IEDA			FUTAMATA	
Species / Locality	Id–3	Id–2	Id–1	Ft–24	Ft–27
Globorotalia birnagea Blow				3	
Globorotalia fohsi barisanesis LeRoy	8			4	
Globorotalia mayeri Cushman and Ellisor				1	
Globorotalia opima continuosa Blow				2	
Globigerina angustiumbilicata Bolli				2	
Globigerina glutinata Egger			2	24	2
Globigerina praebullodies Blow	3	1	1		1
Globigerina woodi Jenkins				6	
Globoquadrina conglomerata (Schwager)	3			1	
Globoquadrina dehiscens (Chapman, Parr and Collins)	2	3		16	
Globoquadrina obesa Akers	3				
Globigerinoides bisphericus Todd	2	2		8	
Globigerinoides immaturus LeRoy				27	
Globigerinoides ruber subquadratus Bronnimann	4			5	
Globigerinoides sacculifer (Brady)				5	
Globigerinoides trilobus (Reuss)				2	
Sphaeroidinellopsis seminulina (Schwager)	8	13		31	
Total Number	33	19	3	137	3
Weight of sample (in Gram)	150	100	150	90	100

Planktonic Foraminifera: – The foraminiferal samples herein treated are the same as those of the previous report (Saito, 1960). Approximately 100 samples were collected from the Mikasa group along three routes with sampling intervals (vertical) as indicated below.

Towata formation (200–800 m. thick): approximately at every 50 meters.
Matsuba formation (700 m. thick): approximately at every 50 meters; at every 25 m. in part.
Saigo formation (800 m. thick): at every 25 m. in average; at every 10 m. in part.

The Foraminifera were found in 26 samples. The planktonic Foraminifera in the samples are summarized in Table 3. The following four subdivisions can be recognized in the foraminiferal assemblage of the Mikasa group.

The first (uppermost) assemblage is characterized by the occurrence of *Globigerinoides bisphericus* and *Sphaeroidinellopsis seminulina.* The second is an impoverished fauna between the first *Globigerinoides bisphericus* fauna and the lower fauna bearing *Globigerinita unicava* and *G. dissimilis.* The third is also rather impoverished to a certain extent, but *Globigerinita unicava* is present. It is distinguished from the fourth (lowest) by the lacking of *Globoquadrina praedehiscens* and *Globigerinita dissimilis.* The fourth assemblage is characterized by the occurrence of *Globigerinita dissimilis* and *Globoquadrina praedehiscens.* Although the diagnostic species mentioned as well as other constitutent species are very rare in most of the samples, these divisions are noteworthy, because of their bearing on the inter-continental correlation as mentioned later.

At the type locality of the Shinzaike formation, Morishima (1949) found and described a new species of *Lepidocyclina, Lepidocyclina* (*Nephrolepidina*) *makiyamai,* which he believed to indicate the middle upper Miocene (Vindobonian). The planktonic Foraminifera occurring with *L. makiyamai* are shown in Table 3, under the locality name of Shinzaike. The sample is from Morishima's type locality M–1: a small outcrop on the left bank of the Kurami River, Shinzaike (Morishima, 1949, p. 213). This planktonic assemblage accompanied by three specimens of *L. makiyamai* and 43 specimens of *Amphistegina radiata* (Fichtel and Moll) in 100 g. of the sample, are evidently those of the *Globigerinatella insueta*/

Table 3. Planktonic Foraminifera from the Mikasa group

ZONE	Globigerinita unicava						Globigerinatella insueta/ Globigerinoides trilobus				Globigerinatella insueta/ Globigerinoides bisphericus																
FORMATION	TOWATA						MATSUBA			SAIGO																SHIN-ZAIKE	KONITA
Locality Number	M						MA-SAGO	SM	FM	S																	
Species	1	2	3	4	5	7		11.5	11	0	1	2	3.5	4	4.5	7	8	15	25	26.5	27	29	32	33	34		
Cassigerinella cf. *chipolensis*														1				1						1			
Globorotalia birnageae															1	14		7	2		5		1	3	11		
G. fohsi barisanensis	1					1			1	2	1		7	6	15	7	10	7	2		4		1	3	15	4	1
G. mayeri										2	3		1			3		1	11		2		2	6	16		
G. minutissima								1						3		2	1										
G. obesa												1			1	8		2					1	6	2		
G. opima continuosa	1								2		4	2	8	3	6	11	1	5	8					3	1		
G. praemenardii																									1		
G. scitula praescitula								1			7	13	2	1		10	2	14	2		1			2	12		
G. zealandica										4	4	7		2		3		2			2		1		1		
Globigerina angustiumbilicata	3		1		7				1	8	32	22	42	21	15	30	18	48	19	5	26	7	7	42	22		2
G. druryi														1		4	4	5	2		2	2	1	14	5		
G. falconensis	7	2		2	5		5	4	35		24	16	19	9	32	47	4	28	25		13	5	4	93	19	2	4
G. foliata									1				2						1		1		2	5			
G. glutinata					2		10		12	3	61	49	40	12	45	86	7	120	39	1	31	37	9	134	118		9
G. praebulloides	6	2	1		21		2		8	1	17	3	8	6	6	37	2	10	13	1	6	2	1	33	36		12
G. weissi, n. sp.											9	5	2	4	3	10		7					1	18	4		
G. woodi	4		1					2		14	39	12	28	13	8	49	6	33	50	3	19	22	9	67	2		
Globigerinella siphonifera										5	3	3		10		6	2	3	6			3	1	5	3		
Globoquadrina altispira altispira							2			2								5									
G. altispira globosa	5	1								1	4	1	3	1	5	6									1		
G. conglomerata	13	4			14		1		4	2	15	10	3			4	1		3		5		1	4	7		2
G. dehiscens					1				1				1				1	12	18	2	9	13	1	14	28	4	
G. obesa								1			3															1	
G. praedehiscens	6	1																									
Globigerinoides bisphericus										2	3		4			2	5	2	1		3	4		17	22	3	3
G. glomerosus curvus												1				1		1				1		1	3	3	
G. glomerosus (s. s.)																									3		
G. immaturus		1			1		1		1	3	6	7	1		6	7	8	11	13		1	5		20	31		
G. obliquus											1														1		
G. ruber subquadratus					2		3		1		8	3	7	3	1	3	4	7	7		4	6		7	13	1	3
G. sacculifer									1	2	2					2		3	2	2	4	2		6	14		2
G. trilobus					1		5		1		2	2	3	2	3	6	2	5	8	1	1		2	26	9		1
Sphaeroidinellopsis seminulina										3	10	17	1	1		3	2	3	11		2	7	1	11	47	263	
Globigerinita dissimilis	12						1																				
G. unicava	6	2		1	4		1																				
G. uvula													1		2												
Globiginatella insueta							8		2	1	10	27	8	5	3	7	4	19	1		3			6	37		5
Miscellaneous (with *Globigerina* sp.)	18	4		1	16		48		12	81	225	164	83	20	57	237	19	97	164	8	90	100	40	234	261	3	
TOTAL NUMBERS	82	17	3	4	74	1	87	9	83	136	493	365	274	124	209	605	105	458	410	23	234	216	86	781	745	284	44
WEIGHT OF SAMPLE (in Gram)	100	100	100	100	100	100	100	100	100	50	30	30	50	50	50	50	50	30	50	50	50	50	50	50	50	100	120

Globigerinoides bisphericus Subzone which is uppermost Aquitanian. Accordingly, the horizon of *L. makiyamai* is early Miocene and is closely correlative with the type horizon of *L. japonica* Yabe in the Takasaki region and of *L. nipponica* Hanzawa assemblage in the Megami formation where the same foraminiferal Subzone has been identified. Hanzawa now considers *L. makiyamai* as the junior synonym of *L. japonica* Yabe (personal communication).

Sagara region

With NE-SW structural trend, the Megami formation is exposed in two rows of inliers in the present area. One extends from Tonokubo *via* Megami to Tokigaya; and the other from Shinko to near Shirahama (Fig. 7). They are approximately 6 km. apart from each other in horizontal distance. The northern inlier, where the type locality of the Megami formation is situated, consists of the complex of indurated siltstone, and cross-bedded, and medium to coarse grained sandstone. The complex contains several masses of biohermal limestone. The two larger limestone masses, of Megamiyama and Ogamiyama, are mostly algal limestone. They yield some bryozoa, reef building corals, several molluscs and poorly preserved Foraminifera. A well preserved fauna of *Lepidocyclina* and *Miogypsina* have been found only from the small limestone blocks at Konita (Hanzawa, 1943). At the Konita locality, from the quartz-sandy siltstone interbedded with the fragile limestone with *Lepidocyclina* (*Nephrolepidina*) *nipponica*, etc., the writer found the *Globigerinatella insueta-Globigerinoides bisphericus* assemblage as listed in Table 3.

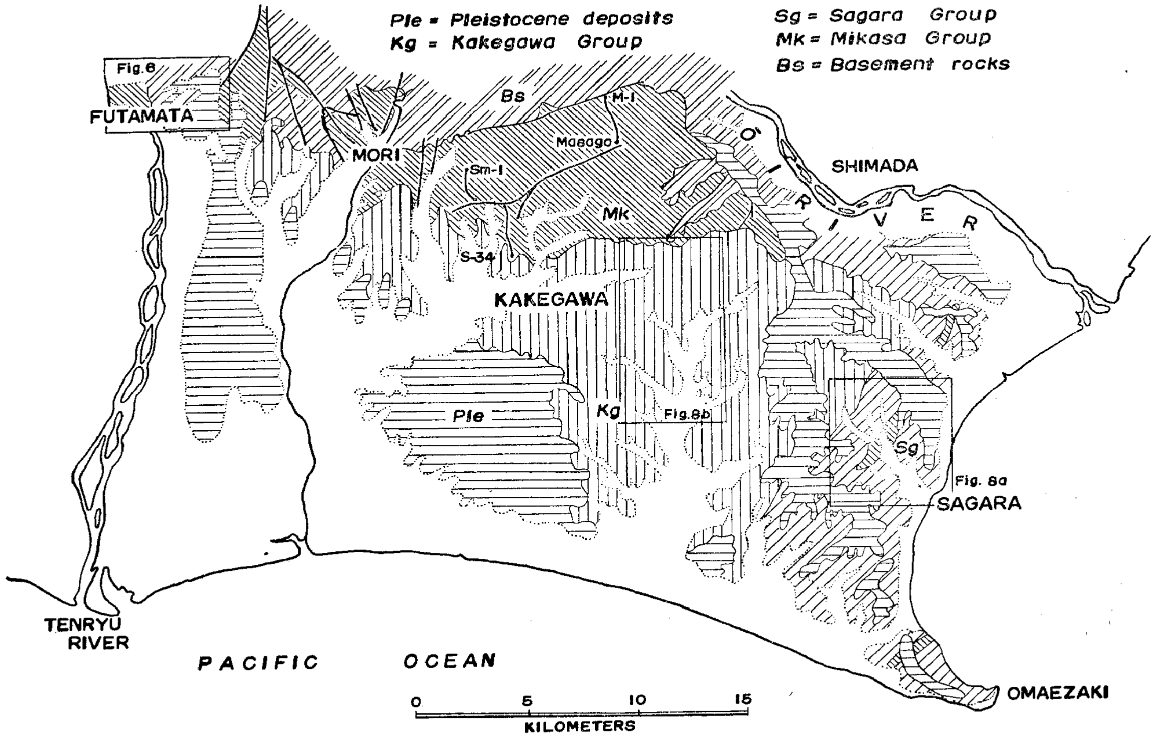

Fig. 7. Index map showing the main areas treated in the Kakegawa district and the foraminiferal collection localities of the Mikasa group

The Sagara group overlies the Megami formation with unconformity at the two inliers mentioned above, and is developed extensively throughout the region (Fig. 7). The localities of the foraminiferal samples of the Sagara group are shown in the geologic map (Fig. 8a), except the one collected at the coast immediately south of the Omaezaki lighthouse.

Planktonic Foraminifera: – The Foraminifera of the Sagara group are listed in Table 4 together with those from the superjacent Kakegawa group. As shown in the table, the assemblages from the Sagara group are uniform in faunal composition, therefore are grouped together as the Sagara assemblage. No further vertical subdivision is possible. The Sagara assemblage bears the characteristics of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone, by the joint occurrences of *Globorotalia menardii menardii*, *Globorotalia tosaensis* and *Globigerina nepenthes*.

Southern region of Kakegawa City

Stratigraphy: – The Kakegawa group, which conformably overlies the Sagara group is typically exposed in the region. The locations of the foraminiferal samples studied are shown in Fig. 8b, and the identified species in the distribution chart (Table 4).

Planktonic Foraminifera: – *Globigerina nepenthes* disappears in the upper part of the Horinouchi formation. And from the samples Kg–1 to Kg–3, a Miocene species, *Globorotalia menardii miocenica* is found from lower samples to Kg–2; the assemblage from upper samples are exclusively formed by the species which are now living.

6. Izu Peninsula

Stratigraphy : – In the Izu Peninsula, limestones rich in Foraminifera are found as small masses within thick dacitic tuff at a number of localities. Hanzawa (1931) described the

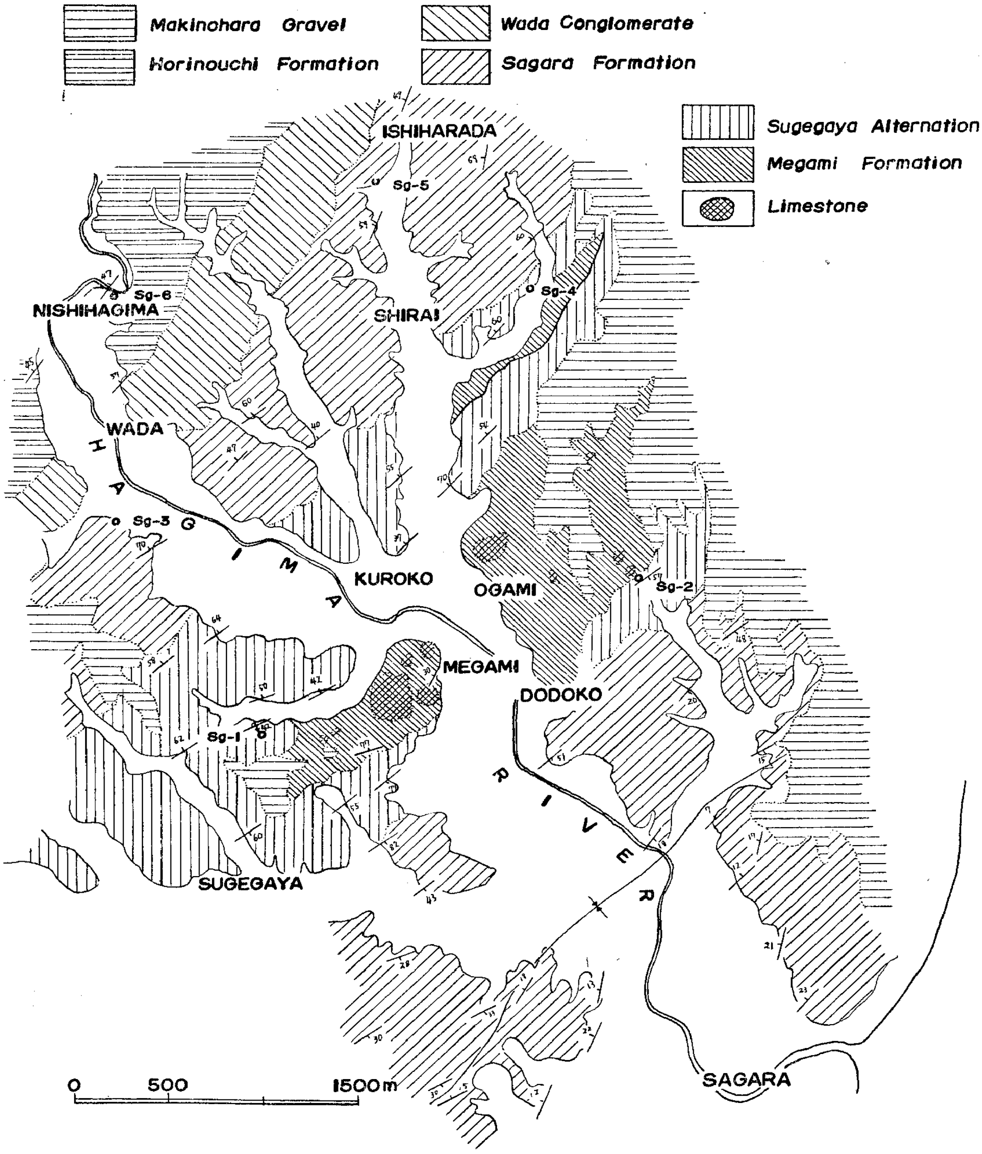

Fig. 8a. Geological map of the Sagara region with foraminiferal collection localities

Orbitoid Foraminifera found in one of these limestone masses, the Shimoshiraiwa calcareous sandstone exposed at Shimoshiraiwa (5 km. east of Shuzenji Spa; lat. 34° 58′N., long. 138° 59′E), and suggested that they indicate the Burdigalian stage of the European standard. The exact stratigraphic position of the Shimoshiraiwa calcareous sandstone, however, has remained uncertain, despite many field works since Hanzawa.

Planktonic Foraminifera: – The Foraminifera found in a sample, 10 g. of calcareous sandstone, at the Shimoshiraiwa locality, yielded the species listed below.

	Number of individuals
Orbitoid Foraminifera	
Lepidocyclina spp.	12
Amphistegina radiata (Fichtel and Moll)	107
Planktonic Foraminifera	
Globorotalia lenguaensis Bolli	130
Globorotalia mayeri Cushman and Ellisor	100
Globorotalia menardii menardii (Parker, Jones and Brady)	185

Table 4. Planktonic Foraminifera from the Sagara and Kakegawa groups

GROUP	SAGARA							KAKEGAWA								
SPECIES \ LOCALITY	Sg-1	Sg-2	Sg-3	Sg-4	Sg-5	Sg-6	Omaezaki	Sg-7	Kg-0	Adina	Tamari	Kg-1	Kg-2	Kg-3	Kg-4	Tenno
Globorotalia acostaensis Blow		2														
Globorotalia crassaformis (Galloway and Wissler)						44				4	184	16	91	48		6
Globorotalia inflata (d'Orbigny)																2
Globorotalia menardii menardii (Parker, Jones and Brady)		1	7		23			5	2	1			1			
Globorotalia menardii miocenica Palmer				1	5	1			2				1			
Globorotalia minutissima Bolli												1				
Globorotalia opima continuosa Blow			7													
Globorotalia scitula scitula (Brady)		1	3		1		3			1		2				
Globorotalia tosaensis Takayanagi and Saito						2				1		1				
Globorotalia tumida (Brady)			2	1			7	23		5	1	1	2	1		
Globigerina angustiumbilicata Bolli	1	3	29		67	4										
Globigerina bulloides d'Orbigny						13			69		1	33	24			5
Globigerina decoraperta Takayanagi and Saito		5	4	5	28						3		2			2
Globigerina falconensis Blow	2	80	33	9	79	2	2	9	63	3	28	34	36	86	134	17
Globigerina glutinata Egger		12	39	11	87	9	3	18	39	1	6	99	32	14	69	9
Globigerina nepenthes Todd		14	29	14	86	3	4	14	50		2	2				
Globigerina pachyderma (Ehrenberg)			287		100	54			86		1			77	36	2
Globigerina quinqueloba Natland											1	22	1	23	2	
Globigerina trilocularis Deshayes			11			2				2						
Globoquadrina altispira altispira (Cushman and Jarvis)			1													
Globoquadrina conglomerata (Schwager)		1	22		11	4	2		2	1	8	55	116	10	49	4
Globoquadrina dehiscens (Chapman, Parr and Collins)				1												
Globoquadrina dutertrei (d'Orbigny)			25		4	2					1	7	4	2		
Globoquadrina hexagona (Natland)													6			8
Globigerinoides bollii Blow			1			2	2	1								
Globigerinoides conglobatus (Brady)			1		2	4										
Globigerinoides elongatus (d'Orbigny)						2				1	10		12		1	2
Globigerinoides immaturus LeRoy	1		22	1	18	4	2	1	12		8		6			
Globigerinoides obliquus Bolli		7	29		115	10			9		3	2				
Globigerinoides ruber cyclostomus (Galloway and Wissler)										8	17	13		7	13	5

Table 4. (continued)

Globigerinoides ruber ruber (d'Orbigny)		1			3	7				2	1		16			5
Globigerinoides sacculifer (Brady)					7	5			2			1		1		
Globigerinoides trilobus (Reuss)		1	8		15	9		3	4							
Sphaeroidinella dehiscens (Parker and Jones)										2	9	1	14	4		
Sphaeroidinellopsis seminulina (Schwager)		3	23	3	41	20	12	12	27		1					
Sphaeroidinellopsis subdehiscens (Blow)									18							
Orbulina suturalis Bronnimann							2	1						2		
Orbulina universa d'Orbigny		3	29		39	18	4		48		1		8	1		3
Pulleniatina obliquiloculata (Parker and Jones)						9	12						2		13	
Candeina amicula Takayanagi and Saito			1		2											
Miscellaneous	1	16	422	8	286	744	13	261	221	7		80	99	215	45	3
Total Numbers	5	150	1034	54	1019	978	68	348	664	39	286	370	473	491	362	73
Weight of Sample (in Gram)	100	80	50	60	66	70	50	50	50	50	50	50	50	50	50	50

Sg-7: A cliff, 450 m. north of Nakajima, along the road between Nakajima and Shinden, Haibara-cho. Lat. 34°47′10″ N., long. 138°18′4″E.
Kg-O: A cliff along the Katsumata River, midway between Honda and Nishimura, Kiriyama, Haibara-cho. Lat. 34°46′13″N., long. 128°10′44E.
Tenno: A road side cliff, immediately northwest of a small pond at Kamiyashiki, about 1500 m. northwest of Kakegawa City. Lat. 34°48′12″N., long. 137°59′44″E.
Other localities are shown in figs. 8a, b.

	Number of individuals
Globorotalia obesa Bolli	1
Globorotalia tumida (Brady)	33
Globigerina angustiumbilicata Bolli	1
Globigerina falconensis Blow	44
Globigerina glutinata Egger	91
Globigerina nepenthes Todd	240
Globigerina praebulloides Blow	9
Globigerina woodi Jenkins	36
Globoquadrina altispira altispira (Cushman and Jarvis)	34
Globoquadrina altispira globosa Bolli	15
Globoquadrina conglomerata (Schwager)	19
Globoquadrina dehiscens (Champan, Parr and Collins)	206
Globoquadrina eximia Todd	6
Globoquadrina obesa (Akers)	5
Globigerinoides bollii Blow	46
Globigerinoides immaturus LeRoy	144
Globigerinoides obliquus Blow	227
Globigerinoides sacculifer (Brady)	18
Globigerinoides trilobus (Reuss)	67
Orbulina suturalis Bronnimann	5
Orbulina universa d'Orbigny	33
Sphaeroidinellopsis seminulina (Schwager)	110
Miscellaneous	566
	2,741

The planktonic Foraminifera from the assemblage are evidently that of the *G. mayeri/G. nepenthes* Subzone. The assemblage shows direct resemblance in composition

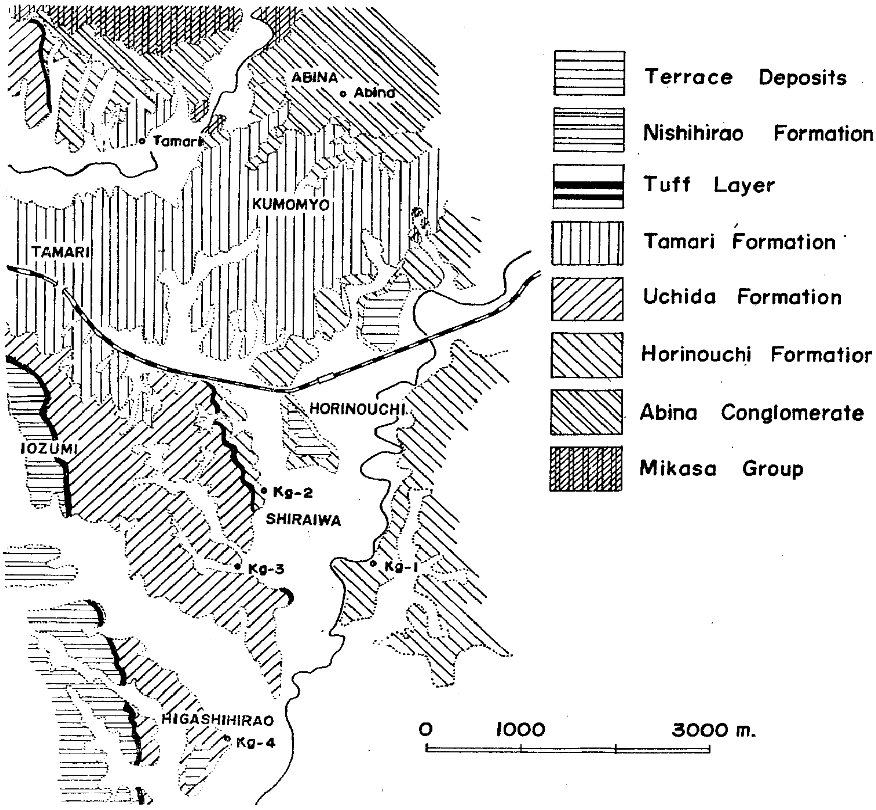

Fig. 8b. Geological map of the eastern part of Kakegawa City, with foraminiferal collection localities

to that of the Pozón formation, Venezuela, the type locality of the Subzone. It is important to point out that the sample bearing *Lepidocyclina* is correlated with the *G. mayeri/G. nepenthes* Subzone of the planktonic Foraminifera, whereas in the majority of cases in Japan the formations in which *Lepidocyclina* are found, are correlated with the *G. insueta/G. bisphericus* Subzone, which is much lower than that of *G. mayeri/G. nepenthes*. There is no evidence which may suggest the re-working of the older fauna into a younger horizon.

7. Boso Peninsula

Stratigraphy: – The Boso Peninsula mainly consists of thick marine Neogene sediments, which yield abundant fossils. The majority of them are developed northwards of the broad anticlinal axis extending from Hota to Amatsu with general trend of WNW-ESE, forming the so-called Tanzawa-Mineoka range or line. The generally accepted sequence of the Boso Tertiary north of the Tanzawa-Mineoka line are summarized as follows in descending orker (Koike, 1949; Mii, 1953, MS.).

Stratigraphic vnit	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Kurotaki formation (Pliocene)	
	.... Unconformity	
Toyooka group		
Anno formation	Alternation of tuff, tuffaceous sandstone and siltstone.	250
Kiyosumi formation	Yellowish brown medium to fine grained sandstone with interbedded layers of siltstone and tuff.	800

Sakuma group		
Amatsu formation	Upper part: Alternation of scoria, pumice and tuffaceous sandstone; alternation of tuffaceous sandstone with interbedded layers of tuff and siltstone.	600
	Lower part: Massive siltstone intercalated with 10–20 meters thick tuff layers.	
Nakahara formation		
Kinone siltstone member	Dark grey siltstone with interbedded layers of sandstone.	900–500
Nakaobara alternation member	Thin bedded alternation of siltstone and medium grained sandstone.	
Okuzure conglomerate member	Thick bedded cobbly to pebbly, subangular to rounded conglomerate, intercalating 10 m. thick basalt flow and volcanic conglomerate.	
Okuyama sandstone member	Thin bedded alternation of coarse grained sandstone and pebbly conglomerate.	
.... Unconformity		
Hota "group"	Yellowish gray siltstone with uncertain interbedded layers of fine grained tuff, tuffaceous sandstone and siltstone.	
.... Unconformity		
Subjacent unit:	Mineoka group (Paleogene or Mesozoic?)	

The four members distinguished within the Nakahara formation interfinger with one another laterally, and each of them may lie relatively above, below or within the others. Orbitoid Foraminifera, as *Lepidocyclina* and *Miogpsina* was reported from various localities of the Nakahara formation (*e. g.* Koike, 1951). The Hota group has been assigned to the Oligocene age from the occurrence of such molluscans as *Portlandia watasei* (Kanehara), *Periploma besshoense* (Yokoyama) and others (Hatai and Koike, 1957), but no planktonic Foraminifera has been found.

The Miocene sequence south of the Tanzawa-Mineoka line have been grouped up as the Nishizaki, Ageshina and Chikura formations in ascending order (Naruse *et al.*, 1951). They are developed in the southernmost area of the Boso Peninsula. According to Nakagawa (1962), the southern sedimentary basin was separated from the northern one by the uplifting of the axial zone of the Tanzawa-Mineoka line after the deposition of Sakuma group. Recently, Hattori (1962), on the basis of his sedimentological study of the southern sedimentary basin of the Peninsula, concluded that the three lithological units of Naruse *et al.* (*loc. cit.*) were the products of large slumping that resulted in the accumulation on the shelf area of the open ocean, and that the three lithofacies are in juxtaposition.

Hattori grouped these sediments of the southern sedimentary basin into a single lithogenetic unit, the Chikura formation, and recognized three lithofacies which interfinger with one another: Nishizaki, Chikura proper, and Shirahama facies. The Chikura formation of Hattori consists of an alternation of siltstone, tuff and/or sandstone, 400 meters in total thickness. The Nishizaki facies, observed typically along the west coast of southern Boso Peninsula, is mainly composed of rubble deposits of tuffaceous siltstone with erratic silt-blocks or silt-patches and sporadic pebbles. The Shirahama facies typically exposed along the coast of Shirahama, consists of large slumping masses of scrambled silt- and sandstone with rubble conglomerate.

Planktonic Foraminifera: – The writer examined the foraminiferous samples from the Nakahara, Amatsu, Kiyosumi and Anno formations collected by Asano and others during 1955–1957; the Kiyosumi material forwarded by N. Aoki of the Geological and Mineralogical Institute, Tokyo University of Eduation; and two samples of the Chikura formation of Hattori. The Nakahara assemblage which is sometimes accompanied with the *Lepidocyclina-Miogypsina* fauna, is judged to be the *Globigerinatella insueta*/*Globigerinoides bisphericus*

Subzone, although *G. insueta* is lacking. The Kiyosumi assemblage may be placed within the range of *Globigerina nepenthens* (*vide* Saito, 1962). Owing to that the fauna is impoverished, however, other assemblages could not be definitely allocated in terms of planktonic foraminiferal zones.

For the southern basin, the two samples of the Chikura formation are taken to represent the Chikura and Nishizaki facies of Hattori (*loc. cit.*); the planktonic Foraminifera from them are:

Chikura facies (Loc.: at the road side cliff, 50 m. south of the tunnel between Yamaogi and Hata. 50 g. of very fine grained sandstone)

	Number of individuals
Globorotalia opima continuosa Blow	3
Globigerina angustiumbilicata Bolli	66
Globigerina bulloides d'Orbigny	6
Globigerina falconensis Blow	74
Globigerinoides immaturus LeRoy	4
Miscellaneous	4

Nishizaki facies (Loc.: a road side cliff at 350 m. west of Okumiyagi, Tateyama City. 50 g. of tuffaceous siltstone)

	Number of individuals
Globorotalia menardii fimbriata (Brady)	3
Globorotalia menardii miocenica Palmer	21
Globorotalia tumida (Brady)	10
Globigerina angustiumbilicata Bolli	5
Globigerina bulloides d'Orbigny	1
Globigerina falconensis Blow	30
Globigerina glutinata Egger	13
Globigerina nepenthes Todd	4
Globoquadrina altispira altispira (Cushman and Jarvis)	1
Globoquadrina altipsira globosa Bolli	4
Globoquadrina conglomerata (Schwager)	2
Globigerinoides bollii Blow	4
Globigerinoides immaturus LeRoy	13
Globigerinoides obliquus Bolli	37
Globigerinoides ruber ruber (d'Orbigny)	5
Globigerinoides sacculifer (Brady)	11
Globigerinoides trilobus (Reuss)	12
Sphaeroidinellopsis seminulina (Schwager)	16
Orbulina universa d'Orbigny	3
Miscellaceous	10

The Nishizaki assemblage is correlated with that of the upper Kiyosumi in the northern basin, because, as mentioned before, both yield the members of the *Globorotalia menardii menardii/Globigerina nepenthes* Zone.

8. Chichibu basin

Stratigraphy: – The Chichibu basin is a depressed subquadrate area located in the western part of Saitama Prefecture, about 70 km. northwest of Tokyo. The basin is occupied by Tertiary sediments, being surrounded by Mesozoic and Paleozoic rocks with which they are in fault or unconformable contacts. The Tertiary sediments of this area have been estimated to be more than 4,000 m. thick; a well known assemblage of Orbitoid Foraminifera characterized by *Lepidocyclina japonica* and *Miogypsina kotoi* occur throughout a thickness of 3,000 m., from the base of the Oganomachi to the top of the Chichibu-machi group. The unusual thickness of the strata in which the same *Lepidocyclina-Miogypsina* assemblage persists called the interests of Japanese geologists, and various interpretations of the structure of the strata as of isocline, homocline, or of closely folded, have been suggested (*vide* Arai and Kanno, 1960). Tertiary sediments of the Chichibu basin consist mainly of conglomerates, sandstone and siltstone, and are of the "Flysch type": thin to thick bedded alternation and sometimes with interbedded layers of slumping or rubble deposits. A comprehensive study on the stratigraphy, sedimentology and paleontology of the Chichibu basin has recently been published by Arai and Kanno (1960). Their conclusion of the origin of these abnormal thick strata is as follows:

"These features of flow markings and positions of the slump structures in the present area show that they do not occur anywhere but have close relation with the growth of the basin, rate of deposition of the sediments, thickness of the strata, and most probably also with the stability of the sedimentary basin. These above stated evidences are directed towards rapid deposition upon an unstable foundation continued uplift of the hinterland associated with the outbuilding of the respective deposits on the one hand. In other words the position of the clinoform gradually migrated over the fondoform, thereby causing destruction of the undoform and rapid deposition along the forset strata associated with and due to the continuous uplift of the land. If the thickness of the slumping structure-contained strata are subtracted from the entire estimated thickness of each formation in which they occur, it is found that the thickness would be much reduced". (Arai and Kanno, *loc. cit.*, p. 96)

The present writer accepts their view cited above, and the general stratigraphic classification of the Tertiary strata of the basin proposed by them is shown in Fig. 9.

Fig. 9. Stratigraphic successions in the Chichibu basin

Quaternary		Younger terrace deposits Older terrace deposits (younger) Older terrace deposits (older)
Chichibumachi G.	Kamiyokoze formation	Karigome conglomerate member Siltstone Sandstone Siltstone Nakago conglomerate member
	Hiranita formation	Siltstone Alternation of conglomerate and siltstone
	Saginosu formation	Siltstone Sandstone Shibahara conglomerate member
	Nagura formation	Siltstone Toroku conglomerate member
Oganomachi G.	Sakurai formation	Alternation of sandstone and siltstone Izuzawa conglomerate member Alternation of siltstone and sandstone
	Yoshida formation	Alternation of sandstone and siltstone
	Miyato formation	Furi conglomerate member Alternation of sandstone and siltstone Chigaya tuff member
Hiko-kubo G.	Nenokami sandstone Ushikubitôge formation	Tomita siltstone member Shirasu sandstone member Basal conglomerate
Unconformity and fault		
	Basement: Mesozoic and Paleozoic rocks	

Planktonic Foraminifera: – Seventeen samples were collected from the type sections of Arai and Kanno for the present study. Three samples yielded planktonic Foraminifera sufficient for the study. Their faunal contents are listed in Table 5.

The planktonic foraminiferal assemblages of these three samples of the Miyato and Kamiyokoze formations have in common the frequent occurrences of *Globigerinoides bisphericus*, and rare *Globigerinatella insueta*, therefore they can grouped together in the *G. insueta*/*G. bisphericus* Subzone.

Table 5. Planktonic Foraminifera from the Chichibu basin

Species \ Locality	Ch–4	Ch–14	Ch–y
Globorotalia fohsi barisanensis LeRoy	2	7	2
Globorotalia mayeri Cushman and Ellisor	1	4	2
Globorotalia scitula praescitula Blow		1	
Globorotalia zealandica Hornibrook			1
Globigerina angustiumbilicata Bolli	13	4	
Globigerina druryi Akers	2	28	
Globiegerina falconensis Blow		118	20
Globigerina glutinata Egger	1	24	14
Globigerina praebulloides Blow	7	3	253
Globigerina woodi Jenkins	4		
Globoquadrina altispira altispira (Cushman and Jarvis)			6
Globoquadrina altispira globosa Bolli	1	4	1
Globoquadrina conglomerata (Schwager)	2	7	35
Globoquadrina dehiscens (Chapmam, Parr and Collins)	42	29	15
Globoquadrina obesa Akers			1
Globigerinoides bisphericus Todd	11	4	21
Globigerinoides glomerosus curvus Blow	4		15
Globigerinoides glomerosus glomerosus Blow			1
Globigerinoides immaturus LeRoy	14	38	12
Globigerinoides obliquus Bolli	1	6	
Globigerinoides ruber subquadratus Bronnimann	8	84	53
Globigerinoides sacculifer (Brady)		5	9
Globigerinoides transitorius Blow			1
Globigerinoides trilobus (Reuss)	8	10	11
Sphaeroidinellopsis seminulina (Schwager)	17	1	20
Globigerinatella insueta Cushman and Stainforth		1	
Miscellaneous	9	27	98
Total Number	134	415	583

Ch–4; Miyato formation, A cliff along the river of Ara-kawa, about 750 m. northeast of the Mitsumineguchi railroad station.

Ch–14; Hiranita formation, A cliff along a small tributary of the Yokoze River, just below the river bridge between Fukada and Tochiya.

Ch-y; Kamiyokoze formation, A river side cliff at Une.

Of three samples, two also yielded the *Lepidocyclina-Miogypsina* fauna. At the exposure where the sample Ch–4 was collected, *Lepidocyclina* was seen sporadically; three specimens of *Miogypsina kotoi* Hanzawa were found in 100 g. of the sample washed. The sample Ch–17, contained 28 *Lepidocyclina* and 5 *Miogypsina* specimens in 150 g. washed. It is from the Kamiyokoze formation which is the uppermost rock unit of the Tertiary sequence of the Chichibu basin.

From the lowest Tertiary unit, the Hikokubo group, whose age was given by Arai and Kanno (*loc. cit.*) as of the uppermost Oligocene (=Aquitanian), the writer failed to find planktonic Foraminifera in his samples, all of which came from the central part of the basin. Ujiié (1959), who studied the foraminiferal fauna of the northeastern extension of the Chichibu Tertiary reported several planktonic species from the "Akahira group" which is now considered to be an extension of the Hikokubo group. The Foraminifera are:

Globigerina cf. *foliata* Bolli
Globigerina cf. *diplostoma* Reuss
Globigerinoides triloba immatura LeRoy
Globorotalia canariensis (d'Orbigny), var.
Globigerina cf. *ciperoensis* Bolli
Catapsydrax dissimilis (Cushman and Bermudez)
Globigerina venezuelana Hedberg
Globorotalia ? sp. A.
Globigerinoides triloba triloba (Reuss)
Globigerinoides triloba altiapertura Bolli

He concluded that the age of the assemblage is Aquitanian and gave the following table for the correlation of the Tertiary rocks of the Chichibu basin.

Tortonian?		
	Chichibumachi basin	
Helvetian	....	*Lepidocyclina* bearing beds
Burdigalian	Oganomachi group	
	Akahira group	
Aquitanian		

The sample Ch–4 of the Miyato formation, which was collected from immediately above the conformable contact with the underlying Hikokubo group, yielded an assemblage which is definitely of the *G. insueta/G. bispherieus* Subzone. Elsewhere in the Kanto region, as well as in foreign localities, the assemblage of the formation which directly underlies that of the *G. insueta/G. bisphericus* Subzone, is of the *G. insueta/G. trilobus* Subzone. Therefore, the writer is in the opinion that the assemblage found by Ujiié may better be considered to be of the underlying *G. insueta/G. trilobus* and/or *Globigerinita unicava* zone. The faunal composition given by Ujiié does not contradict the present view.

9. Takasaki region

Stratigraphy: – In the southwestern hilly land of Takasaki City, thick Tertiary sediments are well exposed with rather simple geologic structures. The stratigraphic sequence of the Tertiary rocks of the Takasaki region taken from H. Mizuno's study (1961, MS.), is summarized as follows in descending order.

Stratigraphic unit	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Tate formation (Upper Miocene)	
	..........Conformity..........	
Itahana formation	Thick cross-bedded pebbly conglomerate and medium to coarse grained sandstone with several molluscan shell beds. Conglomeratic massive medium grained sandstone at the base.	600
Ono formation	Thick to very thick bedded silt- and very fine grained sandstone with interbedded layers of thin rhyolitic tuffs. Intercalating with white fine grained rhyolitic tuff layers in the middle part and rhyolitic breccia tuff at the base of the formation.	600
Isobe formation	Thin bedded very fine grained sandstone.	250
Fukushima formation	Partly thick bedded, massive siltstone with interbedded layers of pebbly conglomeratic sandstone bearing *Lepidocyclina japonica* and 10 m. thick rhyolitic tuff layers at the base.	250
Nukabe formation	Thin bedded alternation of medium to coarse grained sandstone and siltstone. Arkosic to green basic tuffaceous, boulder to	450

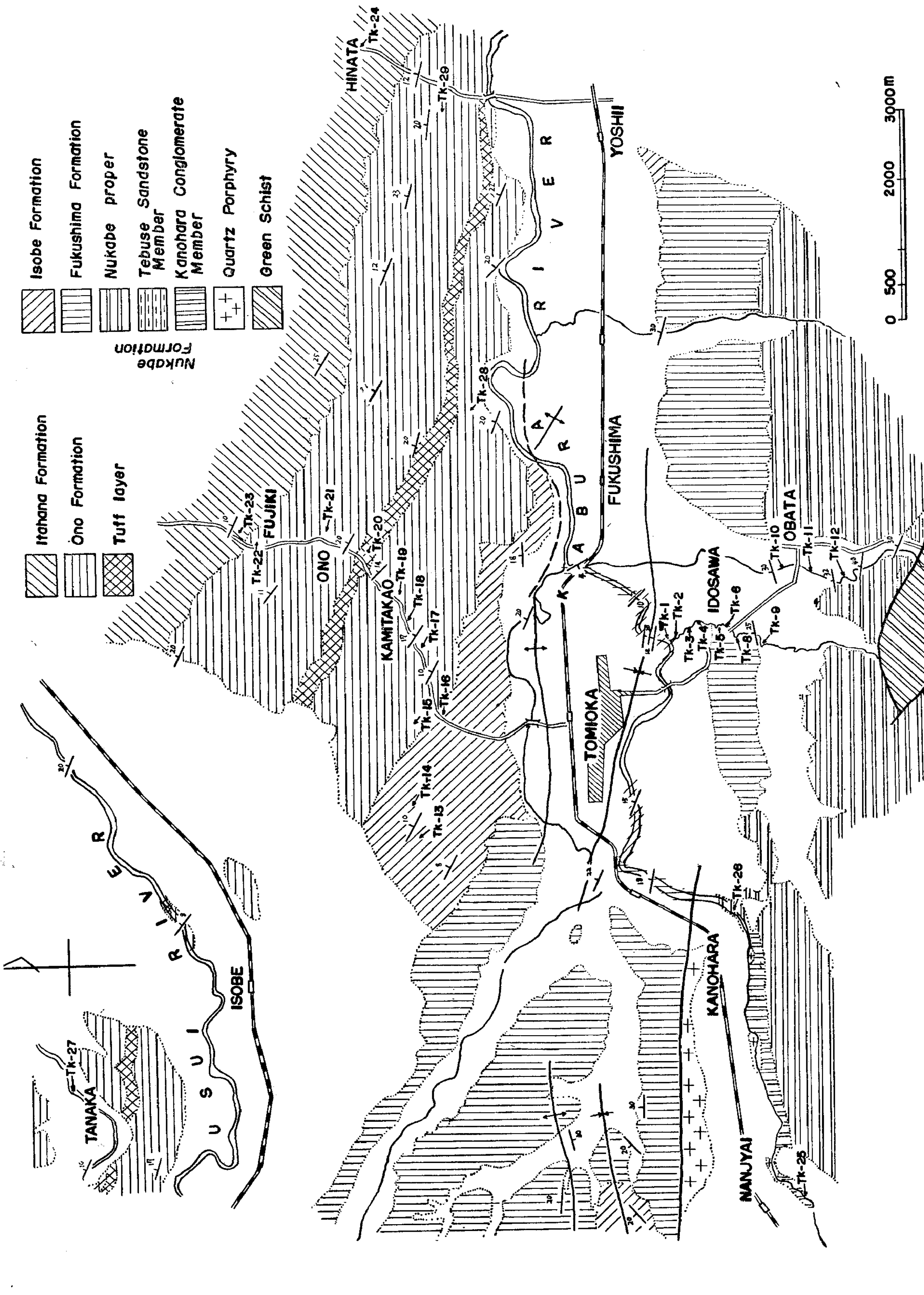

Fig. 10. Geological map of the southwestern part of the Takasaki region, with foraminiferal collection localities

Table 6. Planktonic Foraminifera from the Takasaki region

Formation	NUKABE					FUKUSHIMA			ISOBE		ONO					ITAHANA	
Species / Locality	Tk-25	Tk-26	Tk-12	Tk-11	Tk-9	Tk-8	Tk-6	Tk-3	Tk-2	Tk-13	Tk-15	Tk-17	Tk-28	Tk-19	Tk-29	Tk-27	Tk-24
Globorotalia bykovae (Aisenstat)														3			
Globorotalia fohsi fohsi Cushman and Ellisor												14	1				
Globorotalia fohsi barisaensis LeRoy	9					7		1		86		10	3				
Globorotalia mayeri Cushman and Ellisor				1		2		7									
Globorotalia menardii miocenica Palmer														18			
Globorotalia opima continuosa Blow												10					
Globorotalia praemenardii Cushman and Stainforth				1						2		3	18		1		
Globorotalia scitula praescitula Blow		1		7	1	53					9						
Globorotalia scitula scitula (Brady)												10		2			
Globorotalia tumida (Brady)														3			
Globorotalia zealandica Hornibrook						1					1						
Globigerina angustiumbilicata Bolli				1		10		4			1	12		32			
Globigerina bulloides d'Orbigny										5			18	18	7		20
Globigerina decoraperta Takayanagi and Saito														10			
Globigerina druryi Akers						3				2							
Globigerina falconensis Blow					1	30		7		5	16	136	3	263		5	
Globigerina folitata Bolli												4		6			
Globigerina glutinata Egger		1		9	1	23	2	44	1	22	24	100	5	28		3	
Globigerina praebullodies Blow	9	5	2	10		402	6	31	3	10	4						
Globigerina trilocularis Deshayes						2	1	13									
Globigerina weissi Saito, n. sp.								1									
Globigerina woodi Jenkins	2									18			3		3	6	
Globoquadrina altispira altispira (Cushman and Jarvis)				1							4		1	5			
Globoquadrina altispira globosa Bolli	1							3		3	1						
Globoquadrina conglomerata (Schwager)		1		3		1		1		4	5	5	2				

Table 6. (Continued)

Globoquadrina dehiscens (Chapman, Parr and Collins)		1		2		4	6	62	1	1	5	22	11	5			
Globoquadrina obesa Akers			1			1											
Globigerinoides bisphericus Todd					1	10	4	18									
Globigerinoides glomerosus curvus Blow			1			6	3	18									
Globigerinoides glomerosus glomerosus Blow								1									
Globigerinoides immaturus LeRoy	6	3		2		27	1	18		12		67	10	51			
Globigerinoides obliquus Bolli								1		3		8		3			
Globigerinoides ruber ruber (d'Orbigny)														29		1	
Globigerinoides ruber subquadratus Bronnimann		1		5		16	12	25		33		7	7				
Globigerinoides sacculifer (Brady)						8	1	7				4	2				
Globigerinoides transitorius Blow						3		1									
Globigerinoides trilobus (Reuss)		2				16	3	8	2	10	3	8	3				
Sphaeroidinellopsis seminulina (Schwager)	5			1		2	4	37	2	9		37	2	2	2	4	
Orbulina suturalis Bronnimann										16	2	5		12	1		
Orbulina universa d'Orbigny													26		1	1	
Globigerinita unicava (Bolli, Loeblich and Tappan)	3							2									
Globigerinatella insueta Cushman and Stainforth																	
Candeina amicula Takayanagi and Saito														14			
Miscellaneous	9	20		15	4	259	90	421	12	111	68	180		135	6	3	
Total Numbers	44	35	4	58	8	886	133	731	19	352	143	637	115	649	21	23	20
Weight of Sample (in Gram)	150	100	100	100	50	100	86	94	100	50	50	50	70	25	70	60	50

pebbly conglomerate at the base of the formation, known as the Kanohara conglomerate member.

.... Unconformity ....

Subjacent unit: Mikabu green schists, Quartz prophyry, Paleozoic formation and Mesozoic Atokura formation.

Planktonic Foraminifera: – More than 20 foraminiferal samples were collected from the exposures along or off the road from Itahana to Obata through Tomioka (Text-fig. 10). The foraminiferal assemblages from the section are shown in the distribution chart (Table 6). On the basis of the concurrent range of the diagnostic species, five foraminiferal zones are successively recognized in this section. For the uppermost impoverished interval, which lacks the marker species of the *Globorotalia fohsi robusta* Zone and higher zone, the *Globorotalia bykovae* Zone is here proposed.

10. Kanazawa region

Stratigraphy: – The Neogene sediments of the region are grouped under the Hokuriku group which comprise seven formations ranging in age from the so-called lower Miocene to the upper Pliocene. The so-called Miocene sediments of the Hokuriku group are classified into the following lithologic units in descending order (Sakamoto *et al.*, 1959; Imai, 1959).

Stratigraphic units	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Himi formation (so-called Pliocene)	
	........Conformity........	
Otokawa formation	Massive, bluish gray siltstone and fine grained sandy siltstone in the eastern part of this region, and thin fossiliferous conglomerate at the base of formation.	600
	........Local disconformity........	
Yatsuo formation		
Asagaya siltstone	Siltstone, partly siliceous and fine grained conglomeratic siltstone in the western part of Higashitonami area.	700 –
Nanamagari tuff member	Alternation of sand- and siltstone.	700 –
Sunagozaka tuffaceous alternation member	Alternation of conglomerate, sand- and siltstone. Conglomerate at the base of the member.	1,000
Iwaine formation	Andesitic volcanic complex, with interbedded layers of welded tuff.	1,000±
Nirehara formation	Conglomerate.	400 –
	........Unconformity........	
	Subjacent unit: Futomiyama group (Cretaceous ?)	

According to Kaseno *et al.* (1961), the lowest two, the Nirehara and the Iwiane, are terrestrial in origin and the brackish marine fauna, which precede the marine fauna of the formations successively above, first appears at the top of the Iwaine formation.

Planktonic Foraminifera: – One sample from the Sunagozaka tuffaceous alternation member was studied. It was collected by N. Fuji, of the Geological Institute of Kanazawa University, from the lower part of the member at a cliff along the Asano River at Nishi-ichinose, about 8 km. east of Kanazawa City. *Operculina complanata japonica* Hanzawa accompanies the smaller Foraminifera whose planktonic forms are listed below, together with their frequencies in 100 g. of rock sample treated.

	Number of individuals
Globorotalia fohsi barisanensis LeRoy	9
Globorotalia mayeri Cushman and Ellisor	1
Globorotalia scitula praescitula Blow	3
Globorotalia zealandica Hornibrook	1
Globigerina angustiumbilicata Bolli	201
Globigerina concinna Reuss	68
Globigerina falconensis Blow	43
Globigerina glutinata Egger	1
Globigerina praebulloides Blow	91
Globigerina woodi Jenkins	358
Globigerinella siphonifera (d'Orbigny)	1
Globoquadrina conglomerata (Schwager)	1
Globigerinoides obliquus Bolli	4
Miscellaneous	240

The presence of *Globorotalia fohsi barisanensis* without the association of *Globigerinoides bisphericus* places the member in the *Globorotalia fohsi barisanensis* Zone.

11. Shiobara region

Stratigraphy: – Intercalated with a thick volcanic complex, the fossiliferous marine sediments known as the Kanomatazawa formation (H. Hirasawa, 1961, MS.) crop out in the eastern slope of the Takahara volcano of the Shiobara region. The typical exposures of the Kanomatazawa formation are along the several small tributaries of the Hori River, where the formation is mainly composed of light gray, fine to medium grained sandstone with interbedded layers of sandy fine grained tuff and pale green patched tuff. Its total thickness is 350–500 meters. The lower part of the Kanomatazawa formation is light gray to green, tuffaceous medium grained sandstone and overlies the thick, massive rhyolitic green tuff of the Oya formation. The Sekiya formation overlies with conformity the Kanomatazawa formation, and represents a regressive facies; it consists of tuffaceous sandstone, pumiceous tuff, pisolitic tuff, and siltstone with interbedded layers of thin lignite.

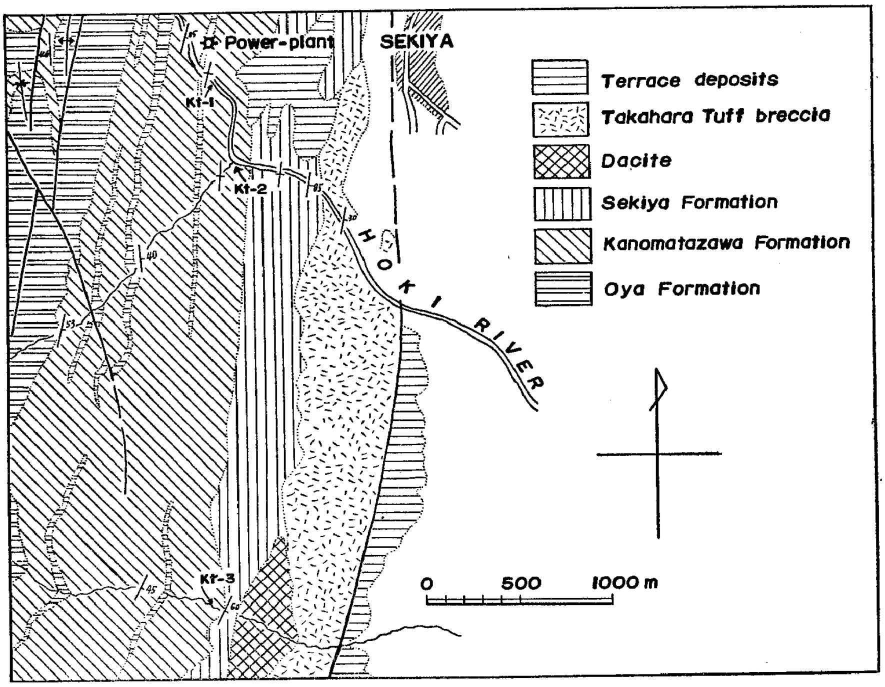

Fig. 11. Geological map of the Shiobara region showing the foraminiferal collection localities of the Kanomatazawa formation

Planktonic Foraminifera: – Three samples used in the present study were collected from the upper part of the Kanomatazawa formation by H. Hirasawa, and the localities are shown in Fig. 11. The planktonic species identified are shown in Table 7. The assemblage shows the characteristics of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone (*vide* Saito, 1962b).

12. Oguni region

Stratigraphy: – The Neogene deposits exposed in the southwestern part of Yamagata Prefecture, were studied by S. Takahashi (1961, MS.). The stratigraphic classification by Takahashi is given below.

Stratigraphic unit	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Utsutoge formation	
	..........Conformity..........	
Yugoya formation	Black banded hard siltstone intercalating tuffaceous sandstone and sandy tuff, 15–35 m. thick green to yellow rhyolitic tuff at the base.	280
Numazawa formation	Black banded hard siltstone intercalated with tuffaceous sandstone and fine tuff.	710
Myozawabashi formation	Green rhyolitic tuff breccia at the top, and black, thin bedded	620

Table 7. Planktonic Foraminifera from the Kanomatazawa formation

Species \ Locality	Kt-3	Kt-2	Kt-1
Globorotalia menardii fimbriata (Brady)	1		
Globorotalia lengauensis Bolli		2	
Globigerina bulloides d'Orbigny	10	3	
Globigerina decoraperta Takayanagi and Saito			2
Globigerina falconensis Blow			1
Globigerina foliata Bolli	1		1
Globigerina glutinata Egger	2	1	
Globigerina nepenthes Todd		2	
Globigerina woodi Jenkins			1
Globoquadrina conglomerata (Schwager)		1	1
Globoquadrina dehiscens (Chapman, Parr and Collins)	3		1
Globoquadrina dutertrei (d'Orbigny)		1	
Globigerinoides bollii Blow	9	5	1
Globigerinoides immaturus LeRoy			1
Globigerinoides ruber ruber (d'Orbigny)			1
Globigerinoides sacculifer (Brady)	3		
Globigerinoides trilobus (Reuss)	3	1	
Sphaeroidinellopsis seminulina (Schwager)	1	1	1
Orbulina suturalis Bronnimann	2	2	
Total Numbers	35	19	11
Weight of Sample (in Gram)	100	100	75

	siltstone. Green pumiceous tuff, tuff breccia and thin bedded black siltstone in the middle part. Conglomerate, conglomeratic sandstome and coarse grained sandstone in the lower part of the formation.	
Tenjindoyama formation	Conglomerate, conglomeratic sandstone, black siltstone, and dark green to purplish brown andesitic tuff.	780

....Conformity.......................................

Subjacent unit: Meganebashi formation (Lower Miocene)

Only plant fossils are found from the Tenjindoyama formation, and a typical marine fauna first appears in this section from the Myozawabashi formation upward.

Planktonic Foraminifera: – Several foraminiferous samples collected by S. Takahashi were given to writer; two of them contained planktonic species. Their assemblages are given in Table 8.

The assemblage from the lower part of the Numazawa formation is characterized by *G. fohsi fohsi* and *G. fohsi barisanesis*, and identical with that of the lower part of the *G. fohsi fohsi* Zone. Judging from the stratigraphic relation and from a comparison of the fauna the assemblage from the upper part of the Myozawabashi formation may be a correlative of the *Globorotalia fohsi barisanensis* Zone.

13. Sendai region

Stratigraphy: – Two samples herein treated were collected from the type Hatatate formation exposed along the Iwanosawa valley, a tributary of the Natori River, in the Southwestern part of Sendai City. One is from the Moniwa member of the Hatatate formation (Shibata, 1963), and it yielded many specimens of *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe. The other sample is from the lower part of the Hatatate proper, stratigraphically 9.6 m. above the former. The benthonic Foraminifera from the same section was

Table 8. Planktonic Foraminifera from the Oguni region

Species / Locality	A	B
Globorotalia adamantea Saito, n. sp.		130
Globorotalia birnagea Blow		5
Globorotalia fohsi fohsi Cushman and Ellisor		12
Globorotalia fohsi barisanesis LeRoy		5
Globorotalia mayeri Cushman and Ellisor		4
Globorotalia obesa Bolli		1
Globorotalia praemenardii Cushman and Stainforth	5	85
Globorotalia scitula praescitula Blow		4
Globigerina angustiumbilicata Bolli		14
Globigerina glutinata Egger	8	34
Globigerina falconensis Blow		52
Globigerina praebulloides Blow		63
Globigerina woodi Jenkins		45
Globoquadrina altispria altispria (Cushman and Jarvis)		14
Globoquadrina conglomerata (Schwager)		3
Globoquadrina dehiscens (Chapman, Parr and Collins)		22
Globigerinoides glomerosus curvus Blow		1
Globigerinoides immaturus LeRoy	2	53
Globigerinoides obliquus Bolli		1
Globigerinoides sacculifer (Brady)		13
Globigerinoides trilobus (Reuss)		18
Sphaeroidinellopsis seminulina (Schwager)		26
Orbulina suturalis Bronnimann	1	5
Orbulina universa d'Orbigny		16
Miscellaneous	265	6
Total Numbers	281	642
Weight of Sample (in Gram)	80	100

A: Upper part of the Myozawabashi formation. (Loc.: A cliff along the Myozawa River, about 300 m. northwest of Numazawa, Oguni-machi, Yamagata Prefecture; Lat. 38°01′N., long. 139°52′40″E.), 100 g. of siltstone.

B: Lower part of the Numazawa formation. (Loc.: A road side cliff, 100 m. east of Numazawa, Oguni-machi; Lat. 38°01′18″N., long. 139°53′04″E.), 80 g. of siltstone.

already described by Takayanagi (1952), and the upper sample of the present study roughly corresponds to sample A of Takayanagi (p. 53). Fig. 12 shows the sampling locations and the columnar section of the area concerned.

Planktonic Foraminifera: – The following species (Table 9) are noted in the 150 g. of coarse grained sandstone of the Moniwa member in association with 36 specimens of *Lepidocyclina japonica*. The specimens encountered in the 100 g. rock sample of the lower part of the Hatatate formation are listed in Table 9.

The occurrence of *Globigerinoides bisphericus* and *Globorotalia fohsi barisanensis*, definitely indicate that the Moniwa assemblage is of the *G. insueta*/*G. bisphericus* Subzone. The presence of *Globorotalia fohsi fohsi* and *Globorotalia praemenardii* suggest that the Hatatate assemblage should be referred to the lower part of the *Globorotalia fohsi fohsi* Zone.

14. Backbone range in northeast Honshu

Stratigraphy: – The geology and orogenic evolution of the Backbone range in northeast Honshu were studied by Kitamura (1959, 1960). According to him, the composite stratigraphic sequence of the Backbone range bordering Akita and Iwate Prefectures is as

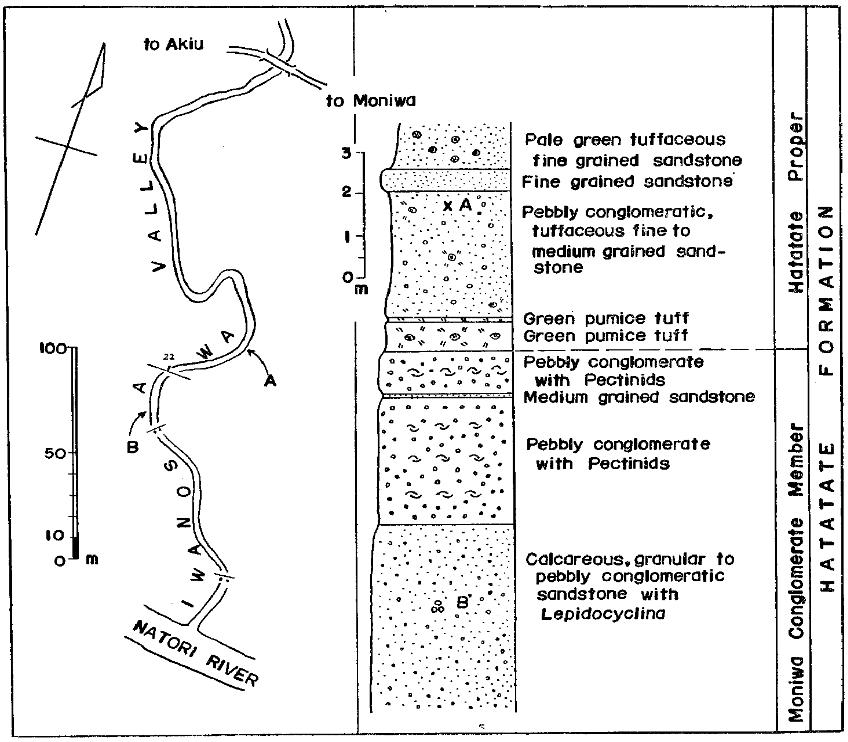

Fig. 12. Map and stratigraphic sequence of the Iwanosawa section, southwestern part of Sendai City

Table 9. Planktonic Foraminifera from the Hatatate formation in Sendai region

Species / Locality	B	A
Globorotalia fohsi fohsi Cushman and Ellisor		3
Globorotalia fohsi barisanensis LeRoy	5	10
Globorotalia mayeri Cushman and Ellisor		3
Globorotalia praemenardii Cushman and Stainforth		31
Globorotalia scitula praescitula Blow	1	42
Globorotalia zealandica Hornibrook		2
Globigerina falconensis Blow		16
Globigerina glutinata Egger	1	3
Globigerina praebulloides Blow	2	200
Globigerina woodi Jenkins	1	
Globoboquadrina altispria altispria (Cushman and Jarvis)	1	2
Globoquadrina conglomerata (Schwager)	3	4
Globoquadrina dehiscens (Chapman, Parr and (Collins)	12	10
Globigerinoides bisphericus Todd	6	
Globigerinoides obliquus Bolli	1	
Globigerinoides immaturus LeRoy	6	13
Globigerinoides ruber subquadratus Bronnimann	6	1
Globigerinoides sacculifer (Brady)	5	
Globigerinoides trilobus (Reuss)	2	
Sphaeroidinellopsis seminulina (Schwager)	1	3
Miscellaneous	17	85
Total Numbers	70	428
Weight of Sample (in Gram)	150	100

follows in descending order.

Stratigraphic unit	*Lithologic description*	*Thickness in meters*
	Superjacent unit: Mizuyama formation	
....	Unconformity	....
Orose formation	Bluish gray-green tuffaceous sandstone, gray fine grained tuff, gray to dark gray siltstone (or partly shale) and bluish gray tuff breccia. With intertongued masses of Ichinohara tuff member in the lower to middle part.	400
Maekawa formation	Mostly black to dark gray siltstone (or shale), bluish gray sandy siltstone and fine grained sandstone. With intertongued pyroclastic masses of Kosamuzawa tuff member in the middle part.	400~450
Oidegawa formation	Green breccia tuff, green sandy tuff with interbedded layers of black sandy siltstone.	500~800
Oarasawa formation	Purplish green propyrite andesite, propyritic essential tuff breccia, breccia tuff.	600~1,000
....	Unconformity	....
	Subjacent rock unit: Granitic rocks. Slate, limestone, Schalstein of Permian age.	

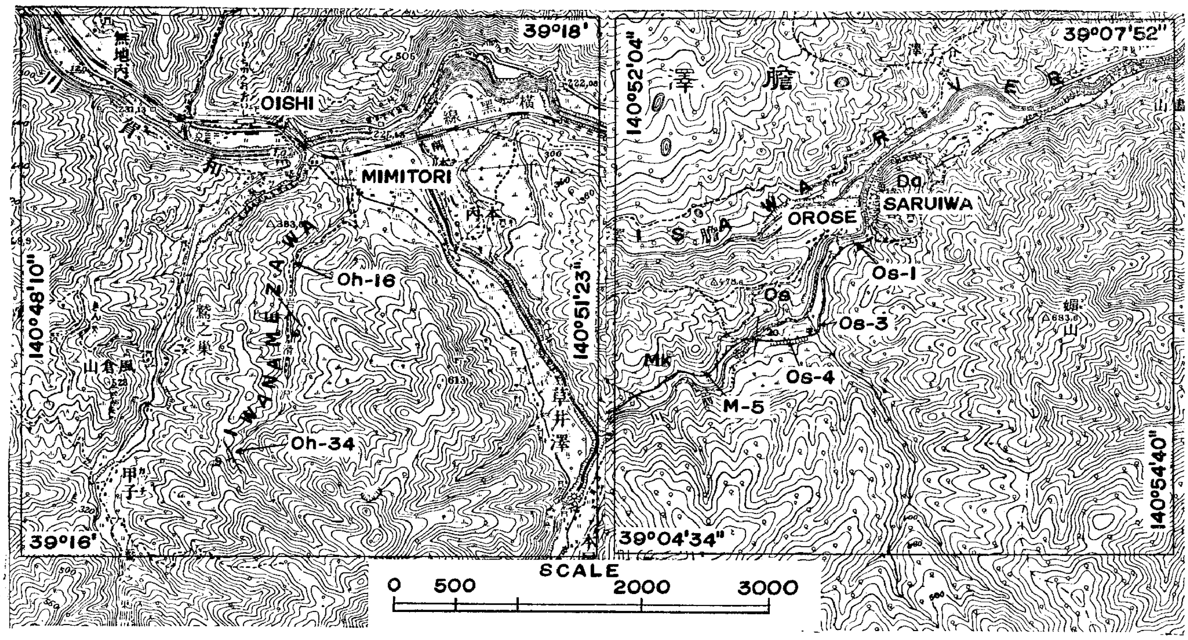

Fig. 13. Foraminiferal collection localities in the Ôu Backbone range

In the midst of the Backbone range, the Oidegawa formation is replaced by the Oishi formation which mainly consists of black siltstone, pale green tuffaceous sandstone and green to pale green massive breccia tuff. The initial growth stage of the Backbone ranges clarified by Kitamura is quoted from his work in the following lines.

"The lower part of the Neogene deposits are characterized by intense volcanism, the product of which are either formed on the floor of a narrow geosynclinal zones of subsidence, such as the Backbone ranges, or on the backland and foreland area. The first volcanism on the floor of this synclinal zones are mostly bassic lava and its pyrpoclastics (the Oarasawa formation), and these are altered to propyrite and the so-called propyritic lithoidal tuff breccia affected by hydrothermal alteration of later stages. When the rate of supply of the products of this volcanism is small compared with the rate of subsidence, fine clastic materials such as clay and silt may deposit in such narrow geosynclinal troughs (the Oishi formation). The lower half of the Oishi formation and its correlatives in the Backbone ranges which predominate in black siltstone (containing marine molluscs, Foraminifera and fish bones) rather than green tuff were formed under the same condition just stated.

The foraminiferous rocks collected by Kitamura and donnated to the writer are from the Oishi, Maekawa, and Orose formations; their localities are shown graphically in Fig. 13. The composite distribution chart of the identified Foraminifera are shown in Table 10. The planktonic fauna from the middle part of the Oishi formation is correlative with those of the Moniwa member of the Hatatate formation by the occurrence of *Globigerinoides bisphericus*. This is important to date the initial extensive marine invasion to the geosynclinal trough in northeastern Japan.

Table 10. Planktonic Foraminifera from the Ōu Backbone range

Formation	ŌISHI		MAE-KAWA	OROSE		
Specie / Locality	Oh–16	Oh–34	M–5	Os–4	Os–3	Os–1
Globorotalia birnagea Blow	4	1				
Globorotalia fohsi barisanensis LeRoy	5					
Globorotalia opima continuosa Blow	1					
Globorotalia scitula praescitula Blow	8					
Globorotalia scitula scitula (Brady)					1	
Globigerina angustiumbilicata Bolli	1				2	
Globigerina bulloides d'Orbigny				29	61	
Globigerina falconensis Blow	2	2		13	13	
Globigerina glutinata Egger		2				
Globigerina pachyderma (Ehrenberg)					2	
Globigerina praebulloides Blow	144	20				
Globigerina woodi Jenkins		4				
Globoquadrina altispira altispira (Cushman and Jarvis)			1			
Globoquadrina conglomerata (Schwager)		1				
Globoquadrina dehiscens (Chapman, Parr and Collins)		1				
Globigerinoides bisphericus Todd		1				
Globigerinoides ruber subquadratus Bronnimann		1				
Sphaeroidinellopsis seminulina (Schwager)	1	1	1		1	
Orbulina universa d'Orbigny						
Miscellaneous	50	9	2	9	19	6
Total Numbers	216	43	4	51	99	6
Weight of Sample (in Gram)	100	100	80	100	89	92

15. Akita district

Stratigraphy: – The principal oil-fields in Japan are distributed in the northern half of Japan along the Japan Sea coast. The Akita district is one of them, and the generally accepted stratigraphical classification in the Akita oil-field is shown in Fig. 14 (Kaneko, 1956; Huzioka, 1959; Y. Ikebe, 1962).

The first Miocene marine invasion into the district is represented by the Daijima formation, though the larger part of the formation was deposited under deltaic environments with interbedded layers bearing brackish water mollsucs. The Miocene Sea is believed to have attained its maximum depth and distribution during the deposition of the Funakawa formation, thereafter it retreated westwards gradually. The lower part of the Daijima formation is well known for the "Daijima flora" which has yielded such characteristic species as *Liquidambar formosana* Hance and *Comptoniphyllum Naumanii* Nathorst; these indicate a warm humid climate of the coastal region (Huzioka, *loc. cit.*).

Fig. 14. Stratigraphic succession in the Akita region

		Oga Peninsula	Akita Oil-field
Quateranary		Gatanishi formation	Terauchi formation
Tertiary	Pliocene	Shibikawa formation	Shibikawa formation
			Sasaoka formation
		Wakimoto formation	
			Tentokuji formation
		Kitaura formation	Katsurane formation
		Funakawa formation	Funakawa formation
		Onnagawa formation	Onnagawa formation
			Uyashinai formation
	Miocene	Nishikurosawa formation	
			Sunagobuchi formation
		Daishima formation	Okuramata formation
		Monzen formation	Haginari formation
		Akishima formation	Omata formation
		Granite	Granite

The 20 to 60 meters thick Nishikurosawa formation at the type area, yields *Miogypsina kotoi* Hanazawa, *Operculina complanata japonica* Hanzawa and *Amphistegina lessoni* d'Orbigny in its lower part (Hanzawa, 1935). In the south coast of the Oga Peninsula and in the eastern margins of the Akita oil-field, the thick muddy facies with deeper-water benthonic Foraminifera replaced the thin coarser sediments of the type Nishikurosawa formation. The Uyashinai formation in the eastern margin of the oil-field is exposed in the southern foot of Mt. Taihei about 17 km. east of Akita City and represents the muddy facies of the Nishikurosawa formation. The stratigraphic evidence (Y. Ikebe, 1962) validates the correlation.

The Onnagawa formation is mainly composed of siliceous or hard siltstone (or partly shale), and is rather poor in Foraminifera. They are represented by such arenaceous forms as *Haplophragmoides*, *Cyclammina*, *Martinottiella*, and *Sigmoilopsis*. The formation is partly highly diatomaceous, and the assemblages of the Onnagawa and its equivalent formations were studied by Kanaya (1959).

Planktonic Foraminifera: – The planktonic Foraminifera were not separated from the samples collected by the writer at the type section of the Nishikurosawa formation. The samples from the type Nishikurosawa formation received from the Akita Branch of the Japan Petroleum Exploration Company yielded the following species:

Globorotalia fohsi barisanensis LeRoy
Globorotalia praemenardii Cushman and Stainforth
Globigerinoides trilobus (Reuss)
Globigerina praebulloides Blow
Globigerinoides ruber subquadratus Bronnimann
Globigerina falconensis Blow

From the type Uyashinai formation, a correlative of the Nishikurosawa, along the Komata River, six samples were collected by the writer and the columnar section of the locality is shown in Fig. 15. The planktonic forms identified in the samples are shown in Table 11. The assemblages of the Uyashinai formation as a whole can be correlated with the *Globorotalia fohsi barisanensis* and the lower part of the *Globorotalia fohsi fohsi* Zones.

Generally speaking, the planktonic fauna becomes impoverished and monotonous in the formations younger than the Nishikurosawa in northwestern Japan. The possible cause of this will be discussed later.

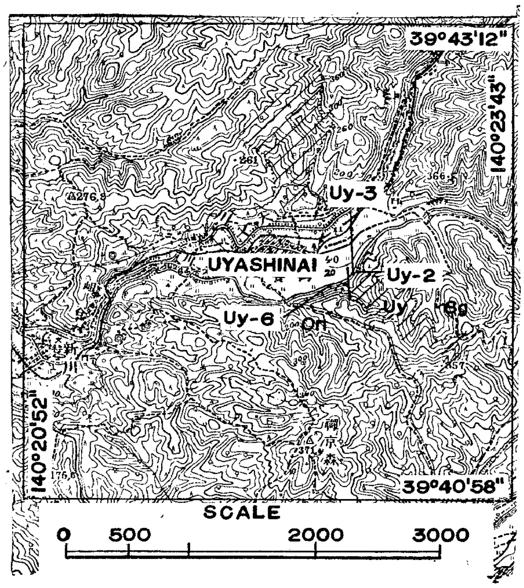

Fig. 15. Foraminiferal collection localities of the Uyashinai formation

Table 11. Planktonic Foraminifera from the Uyashinai formation

Species \ Locality	Uy–2	Uy–3	Uy–6
Globorotalia fohsi fohsi Cushman and Ellisor			36
Globorotalia fohsi barisaensis LeRoy	4		
Globorotalia scitula praescitula Blow		1	
Globigerina angustiumbilicata Bolli	1		
Globigerina falconensis Blow	9		4
Globigerina glutinata Egger	7		1*
Globigerina praebulloides Blow	10	2	8
Globigerinoides immaturus LeRoy	3		
Sphaeroidinellopsis seminulina (Schwager)	1		1
Orbulina universa d'Orbigny		1	
Miscellaneous	14		3
Total Numbers	58	4	17
Weight of Smaple (in Gram)	80	100	80

The faunal analysis of the post-Onnagawa formations in the Akita oil-field is based on the core-samples taken from the Tsuchizaki R–7 well with 5 meters interval. The R–7 well (Location: Lat. 39°45′41″N., long. 140°03′00″E., northwest of Akita City) reaches to the top of the Onnagawa formation at 2100 meters depth level. The frequencies and distribution of the species identified in the core samples are shown in Table 12. The characteristic features of the assemblages are:

(1) The assemblages at different horizons are composed mostly of several species of *Globigerina*, thus form a monotonous sequence that can be treated as of one fauna.

(2) The species of keeled *Globorotalia* are lacking throughout the sequence, and the fauna as a whole show very different appearance from those of southern Japan that are similar to the Caribbean fauna. Such cold-water species of the contemporary fauna as *Globigerina pachyderma* and *Globigerina bulloides* are consistently found from the samples of the lower part of the well. Rather temperate species in the present ocean such as *Globigerinoides ruber ruber* and *Globorotalia inflata,* first occur in the core at the 880 m. level and at

Table 12. Planktonic Foraminifera from the Tsuchizaki R–7 well

Formation	SASA-OKA	TENTOKUJI							FUNAKAWA					ONNA-GAWA
Species / Depth (m)	520	600	660	705	880	1050	1260	1381	1450	1560	1670	1749	1870	1965	2075
Globorotalia inflata (d'Orbigny)	22	19	22												
Globorotalia zealandica Hornibrook													11		12
Globigerina angustiumbilicata Bolli				13	49	26	2	28	3		3	1	1		
Globigerina bulloides d'Orbigny	10	69	10	1	104	364	165	44	13	52	28			7	1
Globigerina falconensis Blow	6	4	45	1	14	3	9	11				1	4		
Globigerina glutinata Egger					4			11	1		2			12	
Globigerina pachyderma (Ehrenberg)		16	5	3	3	42	9	32	10	19	141			11	
Globigerina quinqueloba Natland	10	72	24												
Globigerina woodi Jenkins						22	80								
Globoquadrina conglomerata (Schwager)		63	23	110	17		2	2		14					1
Globoquadrina dutertrei (d'Oribgny)			1												
Globigerinoides elongatus (d'Orbigny)	1														
Globigerinodies ruber ruber (d'Orbigny)	3	1	1		3										
Total Numbers	52	244	131	128	194	457	267	128	27	85	174	2	16	30	14

the 660 m. level, respectively. Both levels belong to the middle part of the Sasaoka formation.

16. Some additional areas

In addition to the aforementioned areas, several other samples were examined, but these are not sufficient for a systematic analysis of the foraminiferal sequence, although they may furnish evidence for checking the distribution of the foraminiferal species and zones.

The marine Shiomizaki and Odoji formations are well exposed in the vicinity of Odose, along the Japan Sea coast. *Operculina complanata japonica* which was first described from the present area (Hanzawa, 1935) occurs in abundance in the upper part of the Shiomizaki formation which consists of bluish gray fine to coarse grained sandstone and conglomerate at the base. Among the five samples, two of which are from the Shiomizaki and three from the superjacent Odoji, nine planktonic species were reported by Fujii (1962) and the writer ascertained the following:

Globigerina angustiumbilicata Bolli
Globigerina concinna Reuss
Globigerina druryi Akers
Globigerina glutinata Egger
Globigerina praebulloides Blow
Globigerina woodi Jenkins
Globigerina sp.
Globorotalia scitula praescitula Blow
Globorotalia fohsi barisanensis LeRoy

The present assemblage is correlative with those of the Nishikurosawa formation of the Oga Peninsula, the Shukunobora and Oidawara formations of the Mizunami basin, and the other assemblages which occur in association with *Operculina-Miogypsina* species.

Asano (1953) reported a rich foraminiferal fauna from the Higashi-innai formation, Noto Peninsula. In the middle part of this formation is found the *Miogypsina kotoi-Operculina complanata japonica* fauna in association with numerous fossils as *Vicarya, Cyclina, Clementia, Patinopecten* etc. Asano identified 193 species exclusive of the planktonic forms; and considered them to have close affinity with those from the Fiji and Kar Nicobar Islands. The planktonic assemblage of the Higashiinnai formation comprises:

Globorotalia fohsi barisanensis LeRoy
Globorotalia praemenardii Cushman and Stainforth
Globigerina falconensis Blow
Globigerina woodi Jenkins

Globorotalia tumida (Brady) (of subcircular form) *Globoquadrina conglomerata* (Schwager)
Globigerina glutinata Egger

The Joban district comprises one of the principal coal-fields of Japan. Although thick marine deposits are well developed over a wide area, planktonic Foraminifera are scanty, and only the Kokozura formation yielded them in abundance. The rich foraminiferal fauna from the formation was already reported by Asano (1949), except for the planktonic one, and the locality and the material of the present study are the same as those treated in Asano's paper. The following species were identified from a single rock sample collected at Kokozura, Nakoso City, Fukushima Prefecture, and the relative numbers among the total 387 specimens from washed residue are indicated.

Globorotalia bykovae (Aisenstat)	65	*Globoquadrina conglomerata* (Schwager)	20
Globorotalia minutissima Bolli	1	*Globoquadrina dehiscens* (Chapman, Parr and Collins)	20
Globorotalia obesa Bolli	4	*Globoquadrina obesa* Akers	9
Globorotalia scitula scitula (Brady)	5	*Globigerinoides immaturus* LeRoy	40
Globigerina angustiumbilicata Bolli	7	*Globigerinoides ruber ruber* d'Orbigny	6
Globigerina bulloides d'Orbigny	110	*Globigerinoides sacculifer* (Brady)	14
Globigerina concinna Reuss	45	*Globigerinoides trilobus* (Reuss)	26
Globigerina falconensis Blow	5	*Sphaeroidinellopsis subdehiscens* (Blow)	6
Globigerina foliata Bolli	1	Miscellaneous	17
Globigerina glutinata Egger	2		
Globigerina triloculars d'Orbigny	3		

In the Dewa hills between the Yokote and Honjo basins, Akita Prefecture, the fossiliferous Sugota formation crops out underlying the hard or siliceous siltstone equivalent to

Table 13. Planktonic Foraminifera from the Sannohe region

Species / Locality	A	B
Globorotalia mayeri Cushman and Ellisor		1
Globorotalia opima continuosa Blow	1	
Globorotalia scitula praescitula Blow		76
Globorotalia scitula scitula (Brady)		26
Globigerinella siphonifera (d'Orbigny)		1
Globigerina angustiumbilicata Bolli	25	15
Globigerina bulloides d'Orbigny		206
Globigerina falconensis Blow	12	43
Globigerina glutinata Egger	1	9
Globigerina woodi Jenkins		64
Globoquadrina conglomerata (Schwager)		3
Globoquadrina dehiscens (Chapman, Parr and Collins)		5
Globigerinoides immaturus LeRoy		62
Globigerinoides sacculifer (Brady)		6
Globigerinoides trilobus (Reuss)		8
Sphaeroidinellopsis seminulina (Schwager)		4
Miscellaneous		117
Total Numbers	39	646
Weight of Sample (in Gram)	100	100

A: Uppermost part of the Kadonosawa formation, the middle unit of the Shiratorigawa group. Loc.: A cliff along the Shiratori River, just below the river bridge between Fukuoka and Anaushi; Lat. 40°17′E., long. 141°16′E., 100 g. of very fine grained sandstone.

B: Miyazawa sandstone member of the Tomesaki formation, the lowest unit of the Sannohe group (Chinzei, 1958*b*). Loc.: A cliff along the Kumahara River, northern foot of Shiroyama, about 500 m. east of Sannohe City; Lat. 40°24′N., long. 141°15′20″E., 100 g. of medium grained sandstone.

the Onnagawa formation of Oga Peninsula. The lower half of the Sugota formation consists of boulder conglomerate at the base and upwards of cross-bedded, breccia tuffaceous sandstone with interbedded lenticular layers of conglomerate and siltstone. The upper half of the formation is composed of mostly bluish gray, fine to medium grained sandstone, which yields a rich molluscan fauna. The benthonic Foraminifera were described by Iwasa and Kikuchi (1954), and they amount total 149 species of inner to mid-neritic marine dwellers. The Sugota assemblage is correlated with the Nishikurosawa assemblage of the Oga Peninsula by Iwasa and Kikuchi. The associated planktonic forms are:

Globorotalia adamantea Saito, n. sp.
Globorotalia fohsi barisanensis LeRoy
Glborotalia scitula praescitula Blow
Globigerina praebulloides Blow
Globoquadrina conglomerata (Schwager)

The thick fossiliferous marine sediments in the Sannohe region, Aomori Prefecture are classified into two groups, the Shiratorigawa below and Sannohe above (Chinzei, 1958*a*, 1958*b*). The *Operculina-Miogypsina* fauna was recently found from the lower part of Kadonosawa formation at the type locality by Ujiié and Aoki (read at the 82nd meeting of the Paleont. Soc. Japan).

In the present study, two samples from the present area were examined, the identified fauna is shown in Table 13.

DEFINITION OF TERMS

It is now generally accepted that the biostratigraphic zone is the fundamental and generally the smallest biostratigraphic unit on which world-wide correlation can be established. In the biostratigraphical sense, however, the unmodified term "Zone" may imply three different categories characterized by a fossil taxon or taxa occurring in any given stratum or body of strata, namely, of assemblage zone, range zone (=biozone of some authors), and of concurrent-range zone (Code of Stratigraphic Nomenclature, 1961, p. 655–657).

In the practice of planktonic foraminiferal biostratigraphy the terms "Zone" and "Biozone" have been applied to the same biostratigraphic subdivision by the several authors (cf. Bolli, 1957a; Blow, 1959). For example, the *Globorotalia mayeri* and *Globigerinatella insueta* "Zone" represent only the later part of the total range of the species, marked by the ranges of several other specified taxa. In the same manner, two zones of Jenkins (1960), *Globoquadrina dehiscens dehiscens* and *Orbulina universa* are defined as to designate a shorter, or the earliest part of the total range of these taxa. Therefore, neither the term "range-zone" nor "biozone" can be applied to designate such divisions as now currently used in planktonic foraminiferal biostratigraphy.

The assemblage zone, the first cateogry of biostratigraphic zone, stands as the basis and it includes variations in fossil taxa in abundance of specimens, or in both. Generally speaking, the most diagnostic species for which the planktonic foraminiferal zones was named, seems to be nowhere abundant, *e. g.* in the case of *Globigerinita stainforthi, etc.* Accordingly it is also impossible to define the planktonic foraminiferal zones by means of the most dominant species among any given assemblage, because the distinct and short-ranging species are not necessarily everywhere dominant.

In this study the writer prefers to employ the term zone in the sense of "concurrent-range zone", for such biostratigraphic subdivisions as being defined by the overlapping ranges of specific taxa of planktonic Foraminifera.

According to the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1961), the concurrent range zone is defined as follows:

"A concurrent-range zone is a zone defined by the overlapping ranges of specified taxa from one or more of which it takes its name".

In addition to this definition, the following notice is added with respect to its nature:

> "The concurrent-range zone is one of the most useful kinds of zones. It is the principal basis of time correlation of strata. The specified taxa are only those that form a distinctive association because their ranges overlap; that is, some taxa range no higher than the zone, others range no lower, and some taxa may be confined to it."

DESCRIPTION OF ZONE

The Miocene formations of Japan may be classified biostratigraphically into the following eight zones by means of planktonic Foraminifera. The majority of the species diagnostic for the zones established in the Caribbean region are found in the Miocene formations of Japan, with the similar orders of appearance and/or extinction. The parallelism in evolution of several species are also recognized between the Caribbean region and Japan. The *Globorotalia fohsi*, *Orbulina universa* and *Globorotalia menardii* lineages (Blow, 1959) are such cases. In the light of biological principles, local expansion of ranges of index species or changes of sequence of zones are unlikely, inasmuch as the original zonations basing upon several well-defined evolutionary sequences. Of eight Japanese zones distinguished in the present paper, six are positively identified with the Caribbean zones by the presence of their diagnostic species. New zonal names are introduced for two Japanese zones which lacks the diagnostic species of the Caribbean zones. The biostratigraphical positions of these zones are confirmed by their relations with other zones identified with those of the Caribbean region.

The planktonic zones and their associated subzones are defined below, and the diagnostic components of each zone are briefly noted.

1. *Globigerina unicava* Zone; Amakata, Towata and Matsuba formations (major part). Samples along the Tanma-Masago route, Kakegawa district.

This zone is defined by the concurrent occurrence of *Globigerina dissimilis* Cushman and Bermudez, and *Globigerinitia unicava* (Bolli, Loeblich and Tappan). *Globoquadrina praedehiscens* Blow and Banner occurs only in the lower part of this zone. *Globorotalia fohsi barisanensis* LeRoy, *Globigerinoides trilobus* (Reuss), *Globigerinoides immaturus* LeRoy, and *Globigerinatella insueta* appear within this interval.

The lower part of the Hikokubo group in the Chichibu basin can be correlated with this zone.

2. *Globigerinatella insueta* Zone; Matsuba formation (upper part) and Saigo formation. Sample SM–11.5 to S–34, along the Kaminomiya-Saigo route. Complimentary type section for the upper part of this zone; Nukabe formation (upper half) and Isobe formation (lower half) along the Kuda-River, a small tributary of the Kabura River, Takasaki district.

This zone is characterized by *Globigerinatella insueta*, and the absence of *Globigerinita dissimilis* (Cushman and Bermudez) and *Globigerinita unicava* (Bolli, Loeblich and Tappan).

Globoquadrina obesa Akers first appears in the lower part of this zone. By the new entry of *Globigerinoides bisphericus* Todd in the upper part of this zone, the following subdivisions are also recognized as noted by Blow (*loc. cit.*. p. 76).

2a. *Globigerinatella insueta/Globigerinoides trilobus* Subzone; Matsuba formation (upper part).

The distinction of this subzone from the overlying subzone is the absence of *Globigerinoides bisphericus* within this interval, bearing upon the well established evolutional lineage of *Orbulina universa* from *Globigerinoides trilobus* via *Globigerinoides bisphericus* (Blow, 1956).

2b. *Globigerinatella insueta/Glogiberinoides bisphericus* Subzone; Matsuba formation (uppermost part) and Saigo formation; complimentary type section, Numabe and Isobe formations, Takasaki region, sample T–8 to T–3.

This subzone is distinguished by the joint occurrence of *Globigerinatella insueta* Cushman and Stainforth and *Globigerinoides bisphericus* Todd. As noted by Cole *et al.* (1961, p. 58) the more common species, *G. bisphericus* serves as a substitute zone marker for this Subzone.

The evolutional lineage of *Orbulina universa* from *Globigerinoides bisphericus* via *Globigerinoides glomerosus* (Blow, 1956) can be traced to the stage of *Globigerinoides glomerosus* within the upper half of the Saigo formation. *Sphaeroidinellopsis seminulina* (Schwager) and *Globorotalia praemenardii* Cushman and Bermudez first appear within this interval. Because of the stratigraphic break at the top of Saigo formation, the uppermost part of this subzone is missing in the Kakegawa district. In many continuous sections of foreign countries, *Orbulina universa* first occurs in the top of this sbuzone.

Most of the *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe and *Miogypsina kotoi* Hanzawa assemblages in Japan fall within the range of this subzone, on the basis of associated planktonic foraminiferal evidences.

3. *Globorotalia fohsi barisanensis* Zone; Isobe formation (upper part) and Ono formation (basal part). Sample Tk–2 to Tk–15, along the Itahana-Obara route, Takasaki region.

This zone is characterized by the occurrence of *Globorotalia fohsi barisanensis* LeRoy, *Orbulina suturalis* Bronnimann and *Orbulina universa* d'Orbigny, and the absence of *Globigerinatella insueta* Cushman and Stainforth. *Globigerinoides bisphericus* Todd is quite exclusive within this zone in Japan, though this species is found to persist in the extreme basal part of this zone in the Caribbean region (Bolli, 1957*a*; Blow, 1959).

4. *Globorotalia fohsi fohsi* Zone; Ono formation (lower part). Sample Tk–17 to just below of Tk–19, along the Itahana-Obata route.

This zone is distinguished by the first appearance of *Globorotalia fohsi fohsi* in the basal part of this interval. *G. fohsi barisanensis* still persists into the basal part of this zone. *Globorotalia scitula praescitula* disappears below this Zone, and is replaced by *Globorotalia scitula scitula.*

5. *Globorotalia bykovae* Zone; Ono formation (upper part).

Further advanced forms of *G. fohsi*-offshoot, *G. fohsi lobata* and *G. fohsi robusta* have not yet been found in the Miocene formations of Japan. This zone remains rather ambiguous in definition due to the extreme scarcity of planktonic species throughout this interval everywhere in Japan. This one represents a rather impoverished planktonic fauna between the rich assemblages; those of the *Globorotalia fohsi fohsi* Zone below and the *G. mayeri/G. nepenthes* Zones above.

However, some isolated samples contain *Globorotalia bykovae* and the incipient subcircular type of *Globorotalia tumida* (Brady).

In the larger part of southeastern Japan, the strata corresponding to the present zone are almost absent. On the other hand, in northern Japan where continuous deposition took place, the cooler water fauna dominated with the close of the flourishing of *G. fohsi fohsi* assemblage, and the tropical species diagnostic for the Caribbean zones are lacking.

6. *Globorotalia mayeri/Globigerina nepenthes* Zone; Shimoshiraiwa calcareous sandstone, Izu Peninsula. Complimentary type formation: Tano muddy sandstone member, lower part of Higashi-morogata formation; and Boroishi conglomeratic sandstone member of the Udo formation; both in the basal part of the Miyazaki group (Natori, 1962; Shuto, 1962).

This zone is characterized by the combined occurrence of *Globorotalia mayeri*

Cushman and Ellisor and *Globigerina nepenthes* Todd.

In the Caribbean region, this zone was defined as the upper subzone of *Globorotalia mayeri* Zone (s. l.). The assemblages of *G. mayeri/G. nepenthes* occurs rather common in several localities of southeastern Japan, and the characteristic fauna of the lower assemblage of the *G. mayeri* Zone (*s. l.*) has also been found in Japan.

The continuous section ranging from the present zone to the superjacent *G. menardii/ G. nepenthes* Zone are found in the lower part of the Miyazaki group, southeastern Kyushu, Japan. The planktonic fauna of the Miyazaki group was described by Natori (1962), and Shuto (1962).

7. *Globorotalia menardii menardii/Globigerina nepenthes* Zone; the Sagara group and the lower part of the Kakegawa group, Kakegawa district.

This zone is characterized by the continued occurrence of *Globigerina nepenthes* after the extinction of *Globorotalia mayeri*. *Globorotalia menardii menardii* is a significant component of keeled *Globorotalia* in this zone. *Globoquadrina altispira altispira* disappears within this zone. Further reference should be made to the paper of Saito (1962b) as to the distribution, correlation and faunal composition of this interval. *Globigerina pachyderma* migrated as far south as lat. 32°N. in the Miyazaki group within this zone.

8. *Sphaeroidinellopsis seminulina* Zone; Kakegawa group (middle part: lower part of the Uchida formation).

This zone is distinguished by the continued occurrences of both *Sphaeroidinellopsis seminulina* and *S. subdehiscens* (Blow) after the disappearance of *Globigerina nepenthes* Todd.

Following the extinction of *Sphaeroidinellopsis seminulina*, as worked out by Blow (1959) in Venezuela, there is no further change in the composition of the planktonic fauna. Blow (1959) defined the *Globigerina bulloides* Zone above the *S. seminulina* Zone, together with the following remarks:

> "The designation of this interval must be regarded as only provisional since *Globigerina bulloides* continues to the present time".

And the Miocene-Pliocene boundary is tentatively placed within the *Globigerina bulloides* Zone.

However, no sound basis for defining the Miocene-Pliocene boundary has been provided by means of planktonic Foraminifera, because no evolutional change of this floating type of Foraminifera was verified since the *S. seminulina* Zone.

CHAPTER 3

BOREAL PLANKTONIC FORAMINIFERA

In the course of the present study, it has become apparent that two different faunas occupied the Japanese Miocene Seas after the time marked by the extinction of *Globorotalia fohsi fohsi*. One of them marks northern Japan and is here tentatively called the Miocene boreal planktonic fauna as mentioned below. Another fauna is that found commonly in the southeastern part of Japan and holds close affinity with the Caribbean fauna. The correlation between these two is extremely difficult, because of lacking diagnostic species in common. Some considerations are here given to the characteristics of the northern Japanese Miocene planktonic fauna.

EVIDENCES ON BOREAL PLANKTONIC FORAMINIFERA

The term boreal has been used often in geologic literatures. Its application to the oldest fauna may be of Arkell (1957, p. *L*. 23) when he distinguished the upper Jurassic Ammonite fauna into boreal and Tethyan-Pacific realm.

In the present study, the term "boreal" fauna is applied to the Miocene fauna in a sense that it contrasts to the "tropical" fauna, whose representative is of the Caribbean region.

The accumulated knowledge on the Recent planktonic Foraminifera fauna (Bradshow, 1959 in Pacific; Bé, 1959 in Atlantic; Phleger, 1952 in Arctic; Stone, 1956 in Atlantic Ocean) permits the following generalization regarding the characteristics of the boreal planktonic Foraminifera.

(1) The number of species constituting any given assemblage of planktonic Foraminifera decrease towards high latitudes. Generally speaking, the assemblage containing the highest number of species is usually found in the tropical seas. In the high latitude, the planktonic assemblage is mainly composed of only one or two species of globigerines; such as *G. pachyderma* and *G. bulloides*. The extreme case is attained in the polar sea, where only *G. pachyderma* is present.

(2) The mean value of the maximum size of the planktonic foraminiferal tests shows the tendency to decrease from low to high latitudes. The warm water species disappears where the species latains its minimum size (Stone, *loc. cit.*; Cushman and Harris, 1927).

(3) Within a species the boreal and/or the austral specimens have much thicker test-wall than those in the low latitudes. This decreasing of wall thickness towards low latitudinal seas is ascertained in the species of *Globigerina pachyderma* and *Globigerinoides ruber* by Parker (1962, p. 224, 230).

The change in thickness of the test with different latitudes was studied by the writer on *G. bulloides*. The ratio between the maximum thickness of chamber wall and the largest length of the test has been used for the cirteria. The ratio measured on 15 specimens of *G. bulloides* is attained by the formula:

$$\frac{\text{Wall thickness of chamber}}{\text{Largest length of test}} \times 100$$

The statistics are given in Table 14 with references to the latitudes. It is evident from the statistics that the wall of *G. bulloides* are observed to be progressively thicker from low to high latitudes, attaining nearly twice in the extreme as much as those of low latitudes.

Table 14. Measurements of *Globigerina bulloides*

Station no.		Latitude	Longitude	Depth (meters)	Ratio
Manshu	140	02°50′05″ N.	133°54′50″ E.	3084	3.73
Koshu	533	34°02′06″ N.	136°37′06″ E.	856	3.41
Meiyo	12	37°10′00″ N.	141°33′09″ E.	218	7.09
Yamato	36	39°45′45″ N.	133°41′18″ E.	773	7.23
Yamato	53	39°54′04″ N.	133°55′55″ E.	820	7.38
Muk-BP	21	52°32′00″ N.	141°44′00″ W.	3792	5.80
Miocene					
Nobori	A-17	33°22′09″ N.	134°03′33″ E.	Nobori form.	3.75
Tsuchizaki	R-7	39°45′41″ N.	140°03′00″ E.	1605 (Funakawa f.)	6.00

PALEOECOLOGICAL INTEPRETATIONS OF THE NORTHERN MIOCENE ASSEMBLAGES

In Southeast and Central Japan an impoverished fauna is present between the *Globorotalia fohsi fohsi* Zone and the *Globorotalia mayeri/Globigerina nepenthes* Zone. In the northern part of Japan, on the other hand, the impoverished fauna above the *G. fohsi fohsi* Zone remained unchanged through the higher horizons until the lower Pliocene.

The faunal change of planktonic Foraminifera above the *Globorotalia fohsi* Zone is definitely traceable in the Neogene sequences developed along the Japan Sea Coast where non-interrupted sedimentation took place since the early Miocene (=the *Globigerinatella insueta/Globigerinoides bisphericus* Zone time). The Akita oil-field serves as a representative. As described before (see p. 46), sudden impoverishment or almost lacking of the planktonic fauna is noticed in the Akita oil-field at the base of the Onnagawa formation immediately above the underlying Nishikurosawa formation.

The Nishikurosawa and its correlative formations yielded sporadically such Orbitoid Foraminifera as *Miogypsina*, *Operculina* and *Amphistegina* in their coarser rock facies of the lower part. The planktonic fauna of these formations indicate that, as mentioned earlier, they belong to the assemblages of the *G. fohsi barisanensis* and *G. fohsi fohsi* Zones. The occurrence of Orbitoid Foraminifera has been believed as indicative of a warm water environment, and the planktonic Foraminifera of these zones have been reported predominantly from such regions as the Tropical Middle East and Caribbean region. Therefore, the occurrences of both types of Foraminifera definitely suggest that a warmer water environment prevailed during the deposition of the Nishikurosawa formation. The Nishikurosawa and its correlative formations distributed widely through many sedimentary basins of Japan. Although their foraminiferal assemblages bear the definite characteristics of *G. fohsi barisanensis* and *G. fohsi fohsi* Zones, in the composition of assemblages, the differences seem to suggest that a thermal gradient descreasing towards the north existed. Namely: 1) the total numbers of species constituting any given assemblage decrease towards northwest Japan. 2) Sizes of the test of any given species decrease toward the north.

The faunal change which happened in the basal part of the Onnagawa formation (that is above the *G. fohsi foshi* Zone), is by far conspicuous in degree than the lateral change observed among the Nishikurosawa and its equivalent formations discussed above. In numbers of localities the impoverished planktonic fauna, typically represented by that of Tsuchizaki R–7 well (see Akita district on p. 46), prevailed throughout the "Miocene" sequences above the Nishikurosawa formation.

The general features of these assemblages here called impoverished fauna are:

(1) The assemblages are very monotonous and uniform in composition, consisting predominantly of several species of globigerinoides; and are lacking in any species of carinate *Globorotalia*; and non-carinate *Globorotalia*, if any, they only take the minor part.

(2) The larger portion of the assemblages is occupied by the two species of *Globigerina pachyderma* and *Globigerina bulloides*.

(3) Test wall of *Globigerina pachyderma* and *Globigerina angustiumbilicata* is very thick and this results in the indented or fused suture in appearance due to crystalline thickening of their test.

(4) The sizes of foraminiferal tests constituting the assemblages are as a whole very small.

The general characters of these Miocene impoverished fauna show close resemblance to those of the Recent boreal planktonic foraminiferal fauna whose characteristics were reviewed in the foregoing lines. These similarities in the faunal characters seem to suggest that the northern Japanese planktonic fauna might have the same colder-water habitat as of the Recent boreal one.

Accordingly the marked change of planktonic foraminiferal fauna, following the *G. fohsi fohsi* Zone, may be interpreted as the consequence of prevailing cold-water current in Japan at that time.

CHAPTER 4

PLANKTONIC FORAMINIFERAL CORRELATION

PLANKTONIC FORAMINIFERAL CORRELATION OF THE MIOCENE FORMATIONS

Already in 1961, Asano reported on the faunal change of the planktonic Foraminifera through the Neogene of Japan and proposed a correlation of the Japanese Neogene formations. Below is given a summary of the planktonic foraminiferal correlation of the Japanese Miocene in terms of the eight biostratigraphical subdivisions, which were established on the basis of local planktonic foraminiferal sequences ascertained in the individual areas studied (Table 15). The stratigraphical position of the sediment barren of Foraminifera have been identified by their interrelations with the beds containing the

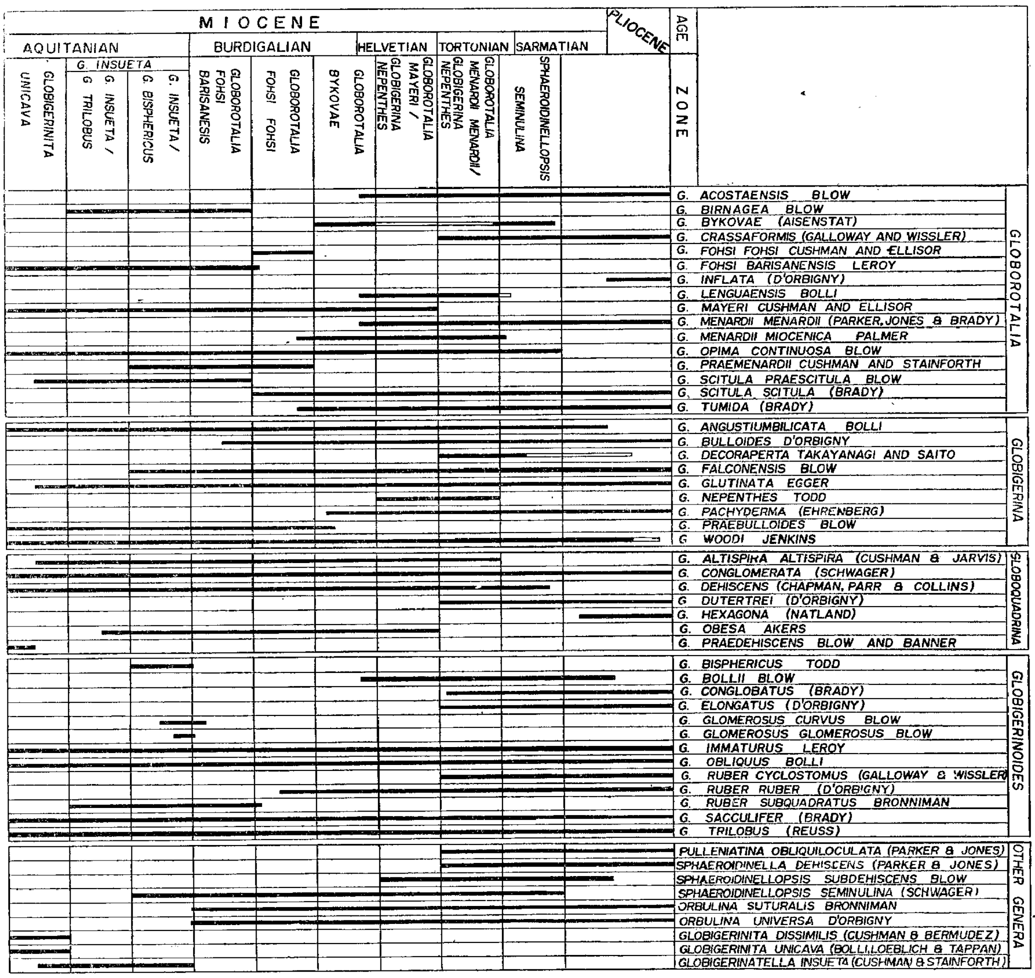

Table 15. Chronological distribution of important planktonic Foraminifera of Japan.

planktonic faunas.

The lower part of the Ashiya and Mikasa groups in the central part of Honshu and the northern part of Kyushu represent the *G. unicava* Zone.

The strata assigned to both the *G. insueta* and *Globorotalia fohsi barisanensis* Zones, have extensive distribution in contrast to the preceding and/or succeeding units.

As in many foreign countries, the largest foraminiferal assemblages of Japan have been regarded as one of the most useful marker fossil for interregional correlation. In Japan, the Orbitoid foraminiferal assemblages such as *Lepidocyclina* (*Nephrolepidina*)-*Miogypsina*, and *Operculina-Miogypsina* are usually found. The occurrences of these larger Foraminifera are shown in the correlation chart (Table 16). According to Hanzawa (1950), the *Lepidocyclina* horizon in Japan is considered to indicate the Burdigalian age in European standard and to be overalin by the *Operculina-Miogypsina* horizon of the Helvetian age. However, no continuous stratigraphic sequence bearing both fauna superposed one upon the other have been found in Japan. During the present study, many faunas of both smaller planktonic and these Orbitoid Foraminifera have been found associated in the same rock specimen. The planktonic foraminiferal evidences show that the formations bearing the *Lepidocyclina* assemblage are referred to the *Globigerinatella insueta/Globigerinoides bisphericus* Subzone, and *Operculina-Miogypsina* to the *G. fohsi barisanensis* Zone. Therefore, the former is verified to be older than the latter as suggested by Hanzawa. However, there are two exceptions of the horizon of the Orbiotid Foraminfiera derived from the following two formations: one of the large *Operculina* from the lower part of the Miyazaki group and the other of *Lepidocyclina* from the Shimoshiraiwa calcareous sandstone. The planktonic assemblages associated with the two faunas are commonly of the *Globorotalia mayeri/Globigerina nepenthes* Zone age, which is much younger than the majority of the Japanese larger foraminiferal horizons above mentioned.

In the regions now occupied by the Backbone ranges of northern Japan, accumulation began with basic pyroclastic rocks (the Oarasawa formation), succeeded in the *G. insueta/G. bisphericus* Subzone time by the finer grained marine deposits (the Oishi formation). Coarse grained sediments with the *Lepidocyclina* fauna are occasionally found; along the eastern and western borders such as the Moniwa, Yanagawa, and the lowest part of the Sugota formations. The marine facies of the *G. insueta/G. bisphericus* Subzone may be replaced there by the terrestrial facies with coal-measures, in southwest Japan (*e. g.* the Nakamura, Hiramaki, and Uetsuki formations) and along the marginal poritions of the marine facies of northern Japan (*e. g.* the Daijima, Oguni, Tsukinoki, and Kita-aiki formations).

The marine facies of the *G. fohsi barisanensis* Zone prevailed widely through almost every sedimentary basins of Japan. The terrestrial facies of the subjacent *G. insueta/G. bisphericus* Subzone are in most places succeeded by the widespread marine sediments, occasionally containing the *Operculina-Miogypsina* fauna of the *G. fohsi barisanensis* Zone.

At the close of the *G. fohsi barisanensis* Zone, or somewhere in the late *G. fohsi fohsi* Zone time, the sea commenced to retreat towards the Pacific Ocean and/or the Japan Sea borderlands. The foraminiferous strata of the *G. fohsi barisanensis* and *G. fohsi fohsi* Zone become gradually replaced upwards by the coarse grained sediments or pyroclastic rocks void of planktonic Foraminifera (*e. g.* the Itahana formation, and many acidic pyroclastics developed in the Backbone ranges of northern Japan; *vidt* Kitamura, 1959).

After the time marked by the extinction of *Globorotalia fohsi fohsi*, a remarkable faunal change happened among the planktonic Foraminifera of Japan. Two different faunas in the Japanese Miocene Seas became apparent, and the change may be caused by the sudden prevailing of the colder-current in Japan. The correlation between southern and northern Japan becomes extremely difficult above the *G. fohsi fohsi* Zone, because of lacking diagnostic species.

OVERSEAS CORRELATION AND AGE ASSIGNMENT

The biostratigraphic zone is now generally accepted as the smallest unit on which world-wide correlations can be established. Because of impoverished planktonic faunas, however, little attempt has been made on the planktonic foraminiferal biostratigraphy of the middle Tertiary type areas in Europe. Therefore, controversies still remain on the precise correlation of the planktonic foraminiferal zones established in areas outside with the classic European stages. But the evidences by several authors (Bolli, 1957*a*; Stainforth, 1960; Eames *et al.*, 1962), shed light for the sound basis of mid-Tertiary correlation in the zonal scheme of planktonic Foraminifera.

The succession of planktonic Foraminifera established in the Caribbean region is now regarded as the best standard of reference for planktonic foraminiferal biostratigraphy. In the Caribbean region, globigerines facies occur widely throughout the whole Tertiary sequence, and the sequence seems to be stratigraphically more complete and tectonically less disturbed than any other region. The establishment of the Caribbean zones are based mainly on the researches of Bolli (1957a) and Blow (1959). A suggested correlation of the Japanese Miocene zone with those established by Bolli (1957*a*) in Trinidad and by Blow (1959) in Venezuela is shown on the left side in Table 16.

The global simultaneity of the zonal correlation in such widely separated areas, as between Caribbean and Japan, may be confirmed by the parallelism in evolution of several well-esablished species, and also by a comparison of the first appearance of the specified taxa. The rapidly evolving lineage leading from *Globigerinoides trilobus* (Reuss) to *Orbulina universa* d'Orbigny has been identified throughout such widespread areas as Venezuela (Blow, 1956, 1959), the Mediterranean (Blow, 1957), Trinidad (Bolli, 1957), New Zealand (Hornibrook, 1958), Australia (Jenkins, 1958) and also in Japan. The horizon where *Orbulina universa* first occur (=the uppermost part of the *G. insueta* Zone), is proposed as the *Orbulina* surface to define a worldwide time datum of the middle Tertiary by LeRoy (1948, p. 502).

Owing to the absence of *Globigerinita stainforthi* (Bolli, Loeblich and Tappan) in Japan, the possible equivalent interval from the *G. dissimilis* to *G. stainforthi* Zones of the Caribbean region is here defined as a single unit of the *G. unicava* Zone. Also in Japan, *Globorotalia fohsi fohsi* Cushman and Ellisor represents the last stage of the evolutional lineage of the *fohsi* group, and the more advanced forms as *G. fohsi lobata* and *G. fohsi robusta* have not been found. The *G. bykovae* Zone of the present study, which is characterized by a rather impoverished fauna, is considered here to be an age equivalent of the interval between the *Globorotalia fohsi fohsi* and the *G. menardii*/*G. nepenthes* Zones.

A comprehensive study on the mid-Tertiary stratigraphical correlation was recently published by Eames *et al.* (1962). They attempted zonal correlation of the mid-Tertiary formations in many parts of the world by the Foraminifera, and suggested the age assignment of the formations in the European time scale.

Other than Eames *et al.* (*loc. cit.*), a tentative correlation of planktonic foraminiferal zones with the European type stages had been undertaken by several authors; *e. g.* Stainforth (1960), Bolli (1957*a*, 1959), Blow (1959) and others.

The present status of correlation between the planktonic foraminiferal zones and European stages, younger than Helvetian, has been discussed in detail elsewhere (Takayanagi and Saito, 1962; Saito, 1962*b*).

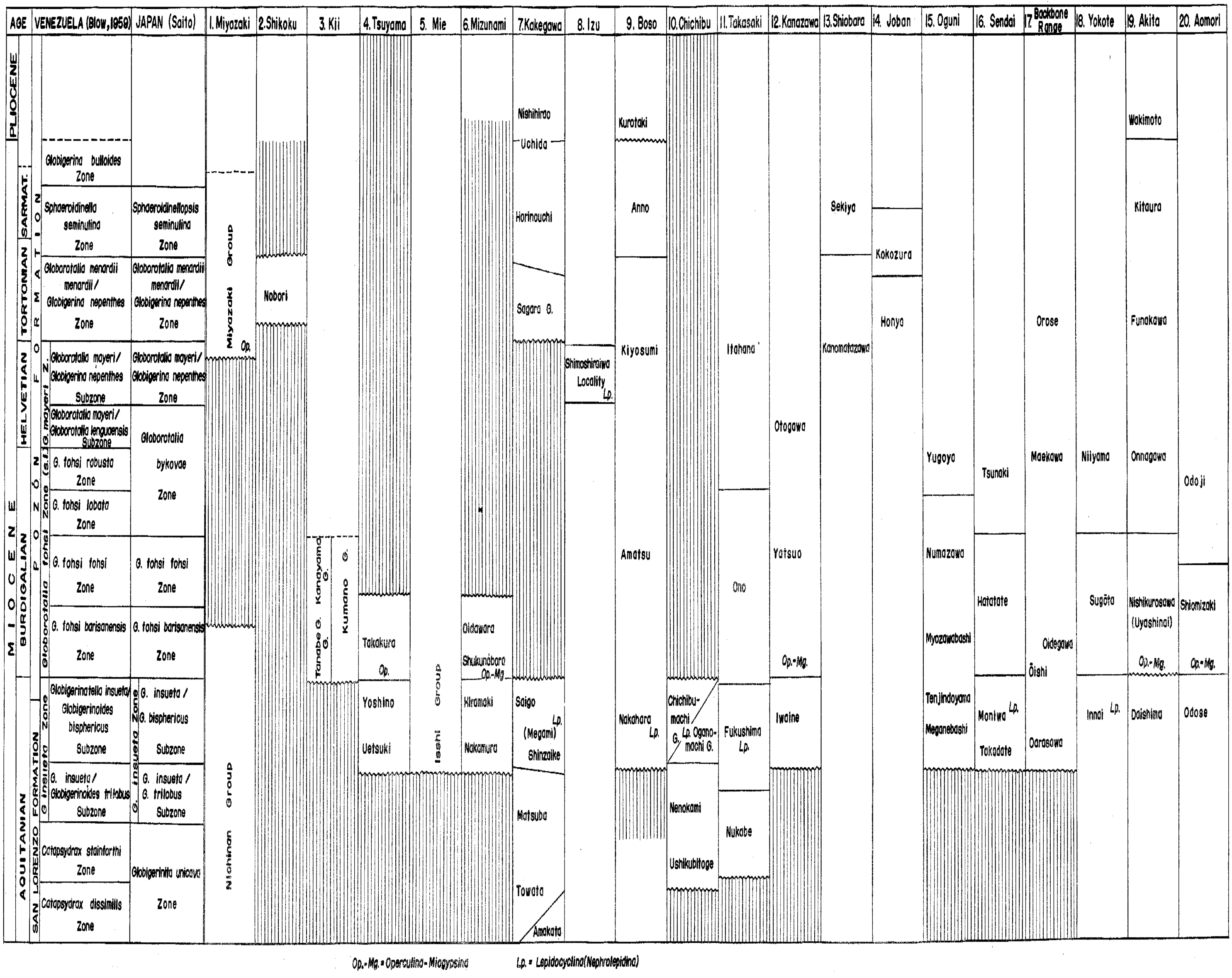

Table 16. Correlation of the planktonic Foraminifera bearing formations of Honshu, Japan.

1. T. Shuto, 1962; H. Natori, 1962: 2. J. Katto, J. Nakamura and Y. Takayanagi, 1953 (*fide* Y. Takayanagi and T. Saito, 1962): 3. A. Mizuno, 1956: 4. M. Kawai, 1957: 5. Y. Araki, 1960: 6. Y. Tamura, 1961, partly emended: 7. T. Saito, 1959 and original: 8. S. Hanzawa, 1931: 9. K. Koike, 1949; H. Mii, 1953; Hattori, 1962: 10. J. Arai and S. Kanno, 1960: 11. H. Mizuno, 1961: 12. T. Sakamoto *et al.*, 1959; I. Imai, 1959: 13. H. Hirasawa, 1961: 14. *fide* K. Asano, 1949: 15. K. Takahashi, 1961: 16. *fide* T. Shibata, 1962: 17. N. Kitamura, 1959, 1960: 18. S. Iwasa and Y. Kikuchi, 1954; the writer's original: 19. K. Huzioka, 1959; Y. Ikebe, 1962: 20. K. Fujii, 1962.

Concerning the age of the zones below the *G. fohsi* (*s.l.*), however, some marked changes have been made by Eames *et al.* (*loc. cit.*). They suggested that the Burdigalian/Aquitanian boundary may be placed at the top of the *Gl. fohsi barisanensis* Zone, whereas Blow (1959), Bolli (1957a, 1959) and Stainforth (1960) correlated this boundary consistently with the boundary between the *G. insueta* Zone and the *G. fohsi barisaensis* Zone. And the Miocene (including the Aquitanian at the base)/Oligocene boundary which had been placed at nearly the base of the *G. dissimilis* Zone by Bolli (1957*a*, 1959) and Stainforth (1960), was extended downward to include nearly all of the zones formerly regarded as Oligocene in the well-known stratigraphical sections of the Central American region as Miocene.

Following the conclusions reached by Eames *et al.*, it is suggested that, except for a few occurrences, the Oligocene sequences are almost missing in the northern hemisphere, and that the eight planktonic foraminiferal zones established in the Caribbean, ranging from the *G. ampliapertura* to *G. fohsi barisanensis* Zone, represent the interval of the Aquitanian stage (lower Miocene).

Apart from the controversy above outlined, it may be evident that the first marine deposition (=the formations of the *G. unicava* Zone) succeeding the typical Miocene in Japan commenced at the Aquitanian age.

CHAPTER 5

SYSTEMATIC PALEONTOLOGY

Order Foraminiferida
Family Globorotaliidae
Genus ***Globorotalia*** Cushman, 1927
Globorotalia acostaensis Blow, 1959

Globorotalia acostaensis Blow, 1959, p. 208–210, pl. 17, figs. 106a–107; Jenkins, 1960, p. 358, pl. 4, figs, 1a-c; Takayanagi and Saito, 1962, p. 75, 76, pl. 24, figs. 2a-c.

Remarks: – Specimens identical with this species are rarely found in the Miocene formations of Japan. Usually five chambers compose the last whorl of this and the final one is somewhat variable in shape. A fairly distinct crescent-shaped apertural lip borders the umbilical-extraumbilical aperture. The large and thicker test with more lobulated periphery distinguishes this species from *Globigerina pachyderma* (Ehrenberg).
Occurrence and distribution: — The Sagara group and the Nobori formation (Shikoku).
Known range: – The *Globorotalia mayeri* Zone to Recent (?).

Globorotala adamantea Saito, n. sp.
Pl. 54, figs. 4a–5c

Test low trochospiral, rather spiroconvex, occasionally biconvex, earlier whorl with high tightly coiled trochospire, umbilical side slightly concave, equatorial periphery lobulated with sub-rhomboidal outline, axial periphery rounded, three to four whorls visible on spiral side; chambers moderately inflated, longer than broad, elongate tangentially in spiral view, increasing gradually in size as added, five chambers in initial whorl, four or sometimes five in final one, up to 17–18; sutures depressed, slightly curved on spiral side, radial to slightly sinuous on umbilical side; wall calcareous, perforate, fairly thick with pitted surface; aperture very low arch without distinct lip umbilical-extraumbilical, extending from shallow umbilical area to test margin; sometimes developed at base of final chamber around umbilicus, pustules. Coiling of the test nearly random.

Maximum diameter of holotype 0.54 mm., thickness 0.30 mm. Other specimens range from 0.24 to 0.54 mm. in maximum diameter.

Type: – Holotype, IGPS coll. cat. no. 79033; paratype, IGPS coll. cat. no. 79034; other ten unfigured paratypes; all from the sample Nz–1, of the Numazawa formation, Yamagata Prefecture.

Remarks: – This is a species showing rather *Globigerina*-like inflated chambers. The shape of the chambers change from inflated subglobular to axially somewhat compressed, and in axial profile from narrowly to broadly rounded. In general outline, this species somewhat resembles *Globorotalia zealandica* Hornibrook, but it differs from the latter in having no vaulted test on umbilical side and very low arched aperture usually with an indistinct lip, and more inflated chambers.

Occurrence and distribution: – This species occurs abundantly only at the type locality in association with the typical assemblage of the *Globorotalia fohsi fohsi* Zone.

Globorotalia birnagea Blow, 1959
Pl. 56, figs. 3a–c

Globorotalia birnagea Blow, 1959, p. 210, 211, pl. 17, figs. 108a–c.

Remarks: – The Japanese hypotype was compared with the specimens from the sample RM 19312 of the Pozón formation in the Pozón-El Mene Road section, Venezuela (near the type horizon). *G. birnagea* has been recorded from outside the type locality, but a wider geographic distribution is to be expected. In general characters, the present species appears to be related with *G. fohsi barisanensis* and/or the immature specimens of *G. praescitula*, but is distinguishable from those species in having a less vaulted umbilical side, a more circular outline, and less tangentially elongate chambers. This species is easily distinguished from *Globorotalia mayeri* in having thinner and more finely perforate wall. The size ranges from 0.17 to 0.22 in maximum diameter.

Hypotype: – IGPS coll. cat. no. 79040 from sample Od 3; the Oidawara formation.

Occurrence and distribution: – Rare, but found from rather remote localities: the Oidawara formation, Gifu Prefecture; the Numazawa formation, Yamagata Prefecture; the Oishi formation, Iwate Prefecture.

Known-range: – The *Globigerinatella insueta*/*Globigerinoides trilobus* Subzone to the *Globorotalia fohsi barisanensis* Zone.

Globorotalia bykovae (Aisenstat), 1960
Pl. 53, figs. 9a–10

Turoborotalia bykovae Aisenstat, in Subbotina *et al.*, 1960, p. 69, 70, pl. 13, figs. 7a–8b.

Remarks: – This species was originally described from the Bogorodchanskaya formation (middle Miocene), Pred-Carpathia, USSR. The Japanese specimens were sent to Dr. Subbotina for comparison with the holotype and she kindly answered questions concerning the taxonomy of this species.

This species is characterized by having the test vaulted in umbilical side, rather sharp angular convexity of the apertural face with the finely pitted wall surface, rather deep and open umbilicus, the thin narrow indistinct apertural lip, more or less tangentially elongated chambers in spiral view with moderately curved suture and by the radial to slightly sinuous suture in umbilical side. Usually five to six, occasionally four chambers constitute the final whorl. The size ranges from 0.16 to 0.36 mm. in maximum diameter.

Hypotypes: – IGPS coll. cat. no. 79041, from sample 27, the Joyama formation; IGPS coll. cat. no. 79042, from the Kokozura formation.

Occurrence and distribution: – This species occurs rather commonly in the Joyama formation, Toyama Prefecture, and in the Kokozura formation, Fukushima Prefecture.
Known range: – At the type locality, this species is found in association with *Globorotalia mayeri*, but in Japan this species occurs from a geologic horizon higher than in the USSR.

Globorotalia crassaformis (Galloway and Wissler), 1927

Pulvinulina crassa (d'Orbigny). Brady, 1884, p. 694, pl. 103, figs. 11a–12c.
Globigerina crassaformis Galloway and Wissler, 1927, p. 41, pl. 7, figs. 12a-c.
Globorotalia (*Turborotalia*) *oceanica* Cushman and Bermudez, 1949, p. 43, 44, pl. 8, figs. 13–15.
Globorotalia punctulata (Fornasini). Phleger, Parker and Pierson, 1953, p. 20, 21, pl. 4, figs. 8–12 (not of Fornasini, 1899).
Globorotalia cf. *oceanica* Cushman and Bermudez. Takayanagi and Saito, 1962, p. 79, 80, pl. 27, figs. 6a–12c.
Globorotalia crassaformis (Galloway and Wissler). Parker, 1962, p. 235, pl. 4, figs. 17, 18, 20, 21.

Remarks: – As noted by Barker (1960, p. 212), the taxonomy of the species group "*Pulvinvulina crassa*" has caused much confusion. In a previous paper, Takayanagi and Saito (1962) considered the Japanese Miocene forms to be comparable with and therefore tentatively referable to *Globorotalia oceanica* Cushman and Bermudez because of the variations in axial profile. Considering the variation of the species, Parker (*loc. cit.*) discussed the taxonomic problem and figured many Pacific specimens. In general characters, the Japanese specimens fall within the range of variation of the species as described by Parker (*loc. cit.*).
Occurrence and distribution: – Common in the Kakegawa and Sagara group.
Known range: – *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to Recent.

Globorotalia fohsi fohsi Cushman and Ellisor, 1939
Pl. 53, figs. 1a–2

Globorotalia fohsi Cushman and Ellisor, 1939, p. 12, pl. 2, figs. 6a-c; Renz, 1948, p. 137, pl. 11, figs. 2a–c; Bermudez, 1961, p. 1288, 1289, pl. 14, figs. 10a–c.
Globorotalia fohsi fohsi Cushman and Ellisor. Bolli, 1950, p. 88, pl. 15, figs. 4a–c; Bolli, 1957, p. 119, pl. 28, figs. 9a–10c; Blow, 1959, p. 212, 213, pl. 17, figs. 112a–c; Belford, 1962, p. 28, 29, pl. 8, figs. 7–11.

Remarks: – Specimens identical with this characteristic species occur rarely from the Miocene formations of Japan. The species is characterized by having the periphery subacute to slightly rounded in the earlier portion, and more acute but not keeled with or without perpheral thickening in the later chambers. An incipient marginal thickening in the last few chambers, which becomes the true carina in the more advanced forms, is sometimes observed.

In the Japanese Miocene formations, *G. fohsi fohsi* represents the last stage of the evolutionary trend of the *fohsi*-group. The more advanced subspecies as *G. fohsi lobata* and *G. fohsi robusta* have not yet been found in Japan. In the Tertiary formation of Papua-New Guinea (Belford, 1962) and of the south Pacific Australasian region (Jenkins, 1960, and personal communciation), keeled-*fohsi* subspecies are also lacking. Considering from the geographical distribution and the associated fauna, it appears most probable that the carinate subspecies of "*G. fohsi*" may have inhabited only the rather tropical seas of the Miocene and did not migrate far into the north or south latitudes, as also assumed by Jenkins (personal communciation).
Hypotype: – IGPS coll. cat. no. 79036, from the Numazawa formation; IGPS coll. cat. no. 79037, from sample Uy–6, the Uyashinai formation.
Occurrence and distribution: – In Japan, *G. fohsi fohsi* is rare north of Lat. 39°43′N., which is the Uyashinai formation, Akita Prefecture.

Known range: – The *Globorotalia fohsi fohsi* Zone to the basal part of the *Globorotalia fohsi lobata* Zone in the Caribbean region.

Globorotalia fohsi barisanensis LeRoy, 1939
Pl. 53, figs. 3a–4

Globorotalia barisanensis LeRoy, 1939, p. 265, pl. 1, figs. 8–10 (*fide* Ellis and Messina, 1940 *et seq.*); Jenkins, 1960, p. 358, pl. 4, figs. 2a–c.
Globorotalia barisanensis sic. LeRoy, 1944, p. 41, pl. 2, figs. 43–45, p. 6, figs. 34-36; Weiss, 1955, p. 310, pl. 3, figs. 4–6.
Globorotalia fohsi barisanensis LeRoy. Bolli, 1950, p. 88, pl. 15, figs. 5–6c; Bolli, 1957, p. 119, pl. 28, figs. 8a–c; Blow, 1959, p. 212, pl. 17, figs. 110, 111a–c.
Globorotalia fohsi Cushman and Ellisor, var. *barisanensis* LeRoy. Bermudez, 1961, p. 1289, 1290, pl. 15, figs. 8a, b.
Globorotalia fohsi Cushman and Ellisor *barisanensis* LeRoy. Belford, 1962, p. 28, pl. 8, figs. 1–6.

Remarks: – The Japanese specimens were compared with the types from the *Globorotalia fohsi barisanensis* Zone of the Pozón formation, Venezuela and found to be identical. Morphological variation of this species, as discussed by Blow (*loc. cit.*), are also noted among the Japanese specimens, although the changes appear to be rather geographical than stratigraphical. The specimens associated with *G. fohsi fohsi* generally show a less vaulted umbilical side than of those from the older geological horizons. The size ranges from 0.17 to 0.34 mm. in maximum diameter.
Hypotypes: – IGPS coll. cat. no. 79038, from sample S–33, the Saigo formation; IGPS coll. cat. no. 79039, from sample S–8, from the Saigo formation, Shizuoka Prefecture.
Occurrence and distribution: – This species is one of the characteristic and fairly common species in the lower Miocene of Japan and shows rather wide geographic distribution. It is found north of Lat. 40°46′N., in the Shiomizaki and the lower part of the Odoji formation, Aomori Prefecture.
Known range: – The *Globigerinita dissimilis* Zone to the basal part of the *Globorotalia fohsi fohsi* Zone.

Globorotalia inflata (d'Orbigny), 1839

Globigerina inflata d'Orbigny, in Barker-Webb and Berthelot, 1839, p. 134, pl. 2, figs. 7–9 (*fide* Ellis and Messina, 1940 *et seq.*); Cushman, 1946, p. 16, 17, pl. 33, figs. 3a–c (Reproduction of holotype, pl. 4, figs. 1–4).
Globorotalia inflata (d'Orbigny). Parker, 1962, p. 236, pl. 5, figs. 62–9.

Remarks: – The writer agrees with Parker, who transferred this species from *Globigerina* to the genus *Globorotalia*. The general characters of the species somewhat resemble *G. crassaformis* and/or *G. centralis* Cushman and Bermudez. *G. inflata* in the lowest assemblage of the sample from the deep boring at Tsuchizaki, has an aperture which is a rather narrow elongate arch compared with the wide open one of the Recent forms; and a rounded periphery with less vaulted umbilical side. In these early forms, the aperture is much restricted and not so elongate as to occupy nearly the entire length of the final chamber. These forms are more related to the ones described as *Globorotalia* cf. *oceanica* Cushman and Bermudez from the Miocene Nobori formation (Takayanagi and Saito, 1962). Such features suggest that *G. inflata* had an ancestor common with *G. crassaformis*.
Occurrence and distribution: – In the Japanese Miocene formations distributed along the Pacific coast, no typical forms of this species have been found. In the Kakegawa district, Central Japan, the present species first occurs from the Tenno Sandstone and becomes abundant in the superjacent formations, which have been assigned to the Pliocene in age from many paleontological and stratigraphical evidences. The writer noted the present species

in the Ikego, Fukazawa and Kurotaki formations in the Kwanto district, northeast of the Kakegawa region. The Kurotaki formation which overlies with unconformity the Miocene Anno formation, is considered to represent the lowest rock unit of the Boso Pliocene by many Japanese geologists (Hatai, 1958; Mitsunashi *et al.*, 1961). In Taranaki Province, New Zealand, Geiger (1962) also reported this species as occurring from the post-Opoitian stage (=the lower part of the Wanganui series; lower Pliocene).
Known range: – Early Pliocene (?) to Recent.

Globorotalia lenguaensis Bolli, 1957
Pl. 54, figs. 1a–c

Globorotalia lenguaensis Bolli, 1957, p. 120, 121, pl. 29, figs. 5a–c; Blow, 1959, p. 113, 214, pl. 17, figs. 115a–c.

Remarks: – This species has hitherto been reported only from the Caribbean region. The present specimens which are very similar to the named species are common in the sample with numerous *Lepidocyclina* from Shimoshiraiwa locality in Izu Peninsula. This species is characteristic in the almost circular, or only very slightly lobulate equatorial periphery, a finely perforate smooth wall surface and strongly compressed chambers. Most of the specimens do not show a peripheral carina, but some exhibit a faint keel as previously noted by Blow (*loc. cit.*). The size ranges from 0.20 to 0.36 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 79044 from the Shimoshiraiwa locality, Izu Peninsula.
Occurrence and distribution: – Concerning the stratigraphy of the *Lepidocyclina* bearing limestone at Shimoshiraiwa and its relation with the strata exposed in the environs, opinions diverge because of the limited outcrop. The fauna taken from the sample is characteristic of the *G. mayeri*/*G. nepenthes* Subzone. Besides the Shimoshiraiwa locality, *G. lenguaensis* is found rather rarely from the Kanomatazawa formation, Tochigi Prefecture and the Miyazaki group of southern Kyushu.
Known range: — The *Globorotalia mayeri* Zone to *G. menardii*/*G. nepenthes* Zone or younger (?)

Globorotalia mayeri Cushman and Ellisor, 1939
Pl. 53, figs. 5a–c

Globorotalia mayeri Cushman and Ellisor, 1939, p. 11, pl. 2, figs. 4a–c; Weiss, 1955, p. 312, pl. 3, figs. 12–14; Bolli, 1957, p. 118, pl. 28, figs. 4a–c; Blow, 1959, p. 214, pl. 18, figs. 116a–c; Todd in Cole *et al.*, 1960, p. 107, pl. 13, figs. 2a-c.
Globorotalia (*Turborotalia*) *mayeri* Cushman and Ellisor. Cushman and Bermudez, 1949, p. 44, pl. 8, figs. 16–18.
Turborotalia mayeri (Cushman and Ellisor). Subbotina *et al.*, 1960, p. 70, 71, pl. 13, figs. 9a–10b; Bermudez, 1961, p. 1325, 1326, pl. 18, figs. 7a–c.

Remarks: – This species is characterized by having a test with thick wall, a broadly rounded axial periphery and fairly large and open umbilicus. In side view, the test has rather parallel-sided appearance. The size ranges from 0.14 to 0.36 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 79045 from sample Ch–14, the Kamiyokoze formation, Chichibu basin.
Occurrence and distribution: – *G. mayeri* has a wide geographic distribution in the Japanese Islands. It occurs from the south of the Miyazaki group, in Kyushu (Lat. about 32°N) to north of the Sannohe district, in the Tomezaki formation, Iwate Prefecture (Lat. 40°24′ N.). As stated by Stainforth (1960), the present taxon is a long-ranging species like *Globigerinoides trilobus* and its offshoots, and *Globorotalia fohsi barisanensis*. These species usually show wider geographic distribution than *Globigerinatella insueta*, and *Globorotalia fohsi fohsi* and its ofshoots.
Known range: – In Japan, *G. mayeri* is found commonly in association with *Globigerinoides*

bisphericus, and disappears within the stratigraphic range of *Globigerina nepenthes*. This range seems to be equivalent to those as in many foreign regions (Bolli, *loc. cit.*; Stainforth, 1960; Blow, 1959; Saito, 1962*b*).

Globorotalia menardii menardii (Parker, Jones and Brady), 1865

Rotalia (*Rotalie*) *menardii* d'Orbigny, 1826 (*nomen nudum*), (*fide* Ellis and Messina, 1940 *et seq.*).
Rotalia menardii Parker, Jones and Brady, 1865, p. 20, pl. 3, fig. 81 (*fide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960, *b*, p. 31–33, pl. 6, figs 2a–c (lectotype) [written as *Rotalia menardii* Parker, Jones and Brady 1865=*Glborotalia menardii* (Parker, Jones and Brady) ?=*Globorotalia cultrata* (d'Orbigny) in pl. 60].
Globorotalia menardii (d'Orbigny). Bolli, 1957*a*, p. 120, pl. 29, figs. 6a–10b; Bradshow, 1959, p. 44, pl. 8, figs. 3, 4; Chang, 1959, p. 69, pl. 5, figs. 10a–11c.
Globorotalia menardii menardii (d'Orbigny). Blow, 1959, p. 215, 216, pl. 18, figs. 119a–120c; Jenkins, 1960, p. 362, pl. 4, figs. 8a–c.
Rotalia cultrata d'Orbigny. Banner and Blow, 1960*b*, p. 34, 35, pl. 6, figs. 1a–c (neotype), (not of d'Orbigny, 1839).
Globorotalia cultrata cultrata (d'Orbigny). Takayanagi and Saito, 1962, p. 76, pl. 24, figs. 4a–c, see app. p. 105.
Globorotalia cultrata (d'Orbigny). Parker, 1962, p. 235, 236, pl. 5, figs. 3a–5.

Remarks: – Since the taxonomic re-investigations on some primary types of planktonic Foraminifera by Banner and Blow, much attention has been directed to the validity of "*Globorotalia menardii*" (Banner and Blow, *loc. cit.*; Todd, 1961; Parker, *loc. cit.*; Banner and Blow, 1962). It is unfortunate that the well-known and currently long-used taxon "*Globorotalia menardii* (d'Orbigny)" was not validated by the original author in accordance with the International Code of Zoological Nomenclature. As Banner and Blow (1960*b*) pointed out, *Rotalia* (*Rotalie*) *menardii* of d'Orbigny was *nomen nudum*, because d'Orbigny merely listed the name. However, abiding by the spirit of the International Code of Zoological Nomenclature, as also commented by Todd, it is not legitimate to suppress the name of *G. menardii*, even though it was predated by *Rotalia cultrata* d'Orbigny 1839 which was described and illustrated by the original author. On the other hand, *G. menardii* was first validated in 1865, when Parker, Jones and Brady published a drawing of d'Orbigny's model no. 10. Although the syntypes exist the lectotype has been designated, and therefrom one may easily understand the specific characters (Banner and Blow, *loc. cit.*).

The writer prefers to use the name "*Globorotalia menardii*" for the forms of the authors, with the authorship of Parker, Jones and Brady 1865. Since the neotype of *G. cultrata* designated by Banner and Blow (*loc. cit.*) is considered to be conspecific with *G. menardii*, the former name becomes a synonym of the latter. Banner and Blow proposed the phylogeny of the "*Globorotalia cultrata*"-group and mentioned on the subspecific differentiation between *G. culturata* (*s. s.*) and *G. cultrata menardii* from the view point of ecology and stratigraphy (1960, p. 28; 1962, p. 99). Inasmuch as the distinction between them depends upon the size of the test and the number of chambers per whorl, such procedure is artificial and not practical for their discrimination.

The size ranges from 0.32 to 0.70 mm. in maximum diameter.

Occurrence and distribution: – This species is rather rarely found in the middle to upper Miocene formations distributed along the Pacific side of Japan.

Known range: – The *Globorotalia fohsi robusta* Zone to Recent. In Japan, *G. menardii menardii* first appears in the sample from the Shimoshiraiwa locality in association with the assemblage species of the *Globorotalia mayeri*/*Globigerina nepenthes* Subzone.

Globorotalia menardii fimbriata (Brady), 1884

Pulvinulina menardii var. *fimbriata* Brady, 1884, p. 691, pl. 103, figs. 3a, b; Banner and Blow, 1960, p.

25, 26, pl. 5, figs. 2a, b (reproduction of holotype and lectotype; designated) [written as *Pulvinulina menardii* var. *fimbriata* Brady 1884 = *Globorotalia cultrata* (d'Orbigny) subsp. *fimbriata* (Brady) in pl. 5].

Remarks: – Rare specimens have the characters of the subsepcies which is the peripheral carina furnished with abundant well developed irregular spines arranged in early radial directions. Except for the spines with peripheral carina, the present forms resemble *G. menardii miocenica* in having a vaulted umbilical side and an almost flat spiral side. The Miocene forms are generally much smaller than the lectotype and the spines seem to be rather restricted only to the earlier chambers. The size ranges from 0.34 to 0.46 mm. in maximum diameter.

Occurrence and distribution: – The subspecies *fimbriata* is rarely found in the Kanomatazawa and Nishizaki formations which yielded a fauna equivalent to the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone in age.

Known range: – *G. menardii fimbriata* has been assumed to be the latest offshoot from the "*Globorotalia cultrata*" stock (Banner and Blow, 1960*b*, p. 26). Whereas the specimens referable to this subspecies are found in association with the fauna of the *G. menardii menardii*/*G. nepenthes* Zone, this form appears to have evolved from the typical species at an earlier time.

Globorotalia menardii miocenica Palmer, 1945
Pl. 53, figs. 7a–c

Globorotalia menardii (d'Orbigny) var. *miocenica* Palmer, 1945, p. 70, 71, pl. 1, figs. 10 a-c.
Globorotalia menardii miocenica Palmer. Blow, 1959, p. 216, 217, pl. 19, figs. 121a-c.
Globorotalia menardii (d'Orbigny) subsp. *miocenica* Palmer. Jenkins, 1960, p. 362, pl. 4, figs. 7a–c.
Globorotalia cultrata miocenica Palmer. Takayanagi and Saito, 1962, p. 77, pl. 24, figs. 5a–c, see app. p. 105.

Remarks: – This subspecies differs from the typical species in having a strongly vaulted umbilical side, a nearly flat spiral side, and less limbate sutures. The peripheral lobulation in equatorial profile appears rather variable in extent. The Japanese forms are more lobulated than the holotype as in the case of the specimens of Jenkins (*loc. cit.*). The specimens with the strongly vaulted umbilical side have a conical appearance in side view, first occur a little after the disappearance of *Globorotalia fohsi fohsi* in the Takasaki section, Gunma Prefecture, Central Japan. In the Lakes Entrance region of Victoria, Australia, the same relationship was pointed out by Jenkins (*loc. cit.*), where transitional forms between *G. menardii miocenica* and *G. praemenardii* are found. The above two cases suggest that *G. menardii miocenica* may have evolved directly from *G. praemenardii* nearly within the *Globorotalia fohsi* Zone (*s. l.*).

Hypotype: – IGPS coll. cat. no. 79048, from the Nishizaki formation, Boso Peninsula.

Occurrence and distribution: – Rarely found in the Miocene formations distributed along the Pacific coast of southeastern Japan.

Known range: – The *Globorotalia fohsi* Zone (*s. l.*) to the lower part of the *Sphaeroidinellopsis seminulina* Zone.

Globorotalia minutissima Bolli, 1957

Globorotalia minutissima Bolli, 1957, p. 119, pl. 29, figs. 2a–3; Blow, 1959, p. 218, pl. 19, figs. 123a–c; Takayanagi and Saito, 1962, p. 78, pl. 26, figs. 3a–c.

Remarks: – The size ranges from 0.14 to 0.16 mm. in maximum diameter.

Occurrence and distribution: – Sporadically found in the Miocene formations of Japan.

Known range : – The *Globigerinita stainforthi* Zone to the *Sphaeroidinellopsis seminulina* Zone.

Globorotalia opima continuosa Blow, 1959
Pl. 56, figs. 10 a, b

Globorotalia opima continuosa Blow, 1959, p. 218, 219, pl. 19, figs. 125 a–c; Jenkins, 1960, p. 366, pl. 5, figs. 4a–5c; Takayanagi and Saito, 1962, p. 80.

Remarks: – This species is characterized by having four ovate subspherical chambers in the last whorl, interiomarginal, umbilical-extraumbilical aperture with a distinct lip, a comma-shaped aperture in side view, and rather coarsely cancellated wall surface. The size ranges from 0.20 to 0.34 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85300 from sample A–11, the Nobori formation, Shikoku, Japan.

Known range: – Blow originally defined this species to have a range from the *Globigerinita stainforthi* Zone to *Sphaeroidinellopsis seminulina* Zone in Venezuela, but later Jenkins extended the range down to the pre-*Globoquadrina dehiscens dehiscens* Zone of Australia (=lower part of the *Globigerina ampliapertura* Zone of Bolli, 1957).

Globorotalia praemenardii Cushman and Stainforth, 1945
Pl. 53, fig. 11

Globorotalia praemenardii Cushman and Stainforth, 1945, p. 70, 71, pl. 13, figs. 14a–c; Stainforth, 1948, p. 121, pl. 26, figs. 34, 35; Cushman and Bermudez, 1949 (part), p. 31, pl. 5, figs. 17–18 (not pl. 6, figs. 1–3); Bolli, 1957, p. 120, pl. 29, figs. 4a–c.

Globorotalia archaeomenardii Bolli, 1957, p. 119, 120, pl. 28, figs. 11a–c.

Globorotalia menardii praemenardii (Cushman and Stainforth). Blow, 1959, p. 215, pl. 18, figs. 118a–c.

Globorotalia menardii archaeomenardii (Bolli). Blow, 1959, p. 214, 215, pl. 18, figs. 116a–c.

Globorotalia menardii (d'Orbigny) subsp. *praemenardii* Cushman and Stainforth. Jenkins, 1960, p. 364, pl. 5, figs. 1a–c.

Remarks: – This species differs from *Globorotalia menardii menardii* by the absence of distinctly limbate and raised sutures, and well developed carina, although a very slight peripheral carina or peripheral thickening is observed. The present species is distinct in having more convex dorsal, umbilical and/or both sides than the typical *menardii*. The writer agrees with Jenkins, who considered *G. archaeomenardii* Bolli to be a synonym of the present species. Based upon the more convex spiral side, less lobulated periphery and the smaller size range, *G. archaeomenardii* was proposed as a separate species. However, *G. praemenardii* shows considerable variations in the convexity of both spiral and umbilical sides, and in the peripheral lobulation. Some well lobulate specimens (0.6 mm. in average size; from the Numazawa formation), associated with the typical *G. fohsi*, have a very convex spiral side. Specimens with much convex spiral side of *G. praemenardii* are fairly common in the Japanese Miocene formations. The specimens of *Globorotalia miozea* Finlay from New Zealand, kindly sent to the writer by Dr. Hornibrook are very similar to the rather small specimens of *G. praemenardii* from Japan. The size ranges from 0.18 to 0.62 mm. in maximum diameter.

Hypotype:– IGPS coll. cat. no. 85301, from the Numazawa formation.

Occurrence and distribution: – This species has a rather wide distribution in the Japanese Miocene formations. It is found sometimes in the formations correlative with the *G. fohsi barisanensis* and *G. fohsi fohsi* Zones. This species is found as far north as Lat. 38°13′N., in the Hatatate formation.

Known range: – The *Globigerina bisphericus* Zone to *G. fohsi* Zone (*s. l.*).

Globorotalia obesa Bolli, 1957

Globorotalia obesa Bolli, 1957, p. 119, pl. 29, figs. 2a—c; Blow, 1959, p. 218, pl. 19, figs. 124a–c; Jenkins, 1960, p. 364, pl. 5, figs. 2a–c; Takayanagi and Saito, 1962, p. 79, pl. 24, figs. 7a–c.

Remarks: – Parker (1962, p. 228) suggested that this species should be referred to *Globigerina*. In the present study, the species is retained in the genus *Globorotalia*. The size ranges from 0.19 to 0.34 mm. in maximum diameter.
Known range: – The *Globigerina ampliapertura* Zone to the *Globigerina bulloides* Zone.

Globorotalia scitula praescitula Blow, 1959
Pl. 53, fig. 6a–c

Globorotalia scitula praescitula Blow, 1959, p. 221, pl. 19, figs. 128a–c.
Globorotalia scitula (Brady) subsp. *praescitula* Blow, Jenkins, 1960, p. 366, pl. 5, figs. 6a–c.

Remarks: – This subspecies differs from the species in having more tangentially elongate chambers with much lobulated equatorial periphery, a more convex umbilical side and is consistently smaller in size. The size ranges from 0.18 to 0.32 in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85304, from sample S–15, the Saigo formation.
Occurrence and distribution: – This subspecies is found frequently in association with *G. fohsi barisanensis*. It occurs as far north as Lat. 40°46′N., in the Odoji formation, and has a wide geographic distribution in Japan.
Known range: – The *Globigerinita stainforthi* Zone to the top of the *Globorotalia fohsi barisanensis* Zone.

Globorotalia scitula scitula (Brady), 1882

Pulvinulina scitula Brady, 1882, p. 716, 717 (*fide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960*b*, p. 27–29, pl. 5, figs. 5a–c (lectotype) written as *Pulvinulina scitula* Brady 1882= *Globorotalia* (*Turborotalia*) *scitula* (Brady) in pl. 5.
Pulvinulina patagonica (d'Orbigny). Brady, 1884, p. 683, pl. 103, figs. 7a–c (not *Rotalia patagonica* d'Orbigny).
Globorotalia scitula (Brady). Cushman and Henbest, 1940, p. 36, pl. 8, figs. 5a–c; Bolli, 1957a, p. 120, pl. 29, figs. 11a–12c; Bradshaw, 1959, p. 44, pl. 8, figs. 5, 6; Parker, 1962, p. 238, 239, pl. 6, figs. 4–6.
Globorotalia scitula scitula (Brady). Blow, 1959, p. 219, 220, pl. 19, figs. 126a–c; Takayanagi and Saito, 1962, p. 80, pl. 26, figs. 2a–c.

Remarks: – In Japan, *G. scitula scitula* first appears in association with *G. fohsi fohsi*, and forms transitional to *G. scitula praescitula* are found in the lower part of the *G. fohsi fohsi* Zone. The size ranges from 0.16 to 0.37 mm. in maximum diameter.
Occurrence and distribution: – Rather sporadically found in the Miocene formations of Japan.
Known range: – The top of the *Globorotalia fohsi barisanensis* Zone to Recent.

Globorotalia tumida (Brady), 1877
Pl. 53, figs. 8a–c

Pulvinulina menardii (d'Orbigny) var. *tumida* Brady, 1877, p. 535, (no figures given); Brady, 1884, p. 692, pl. 103, figs. 4–6; Banner and Blow, 1960b, p. 26, 27, pl. 5, figs. 1a–c (lectotype) [written as *Pulvinulina menardii* var. *tumida* Brady 1877 =*Globorotalia tumida* (Brady) in pl. 5].
Globorotalia tumida (Brady). Cushman, 1927, p. 91, pl. 19, fig. 12 (after Brady); Phleger, Parker and Peirson, 1953, p. 22, 23, pl. 3, figs. 3, 6–8, 10, 11; Bolli, Leoblich and Tappan, 1957, p. 41, 42, pl. 10, figs. 2a–c; Todd, 1957, p. 279, (table), pl. 80, figs. 4a, b; Bradshaw, 1959, p. 47, pl. 8, figs. 9, 13; Takayanagi and Saito, 1962, p. 82, pl. 24, figs. 6a–c; Parker, 1962, p. 239, pl. 6, figs. 8–10.

Remarks: – The origin of the present species is very interesting and an important subject to clarify the interrelation of *G. tumida* and *G. menardii*. Some authors believe that there are forms intermediate between the above two species in the Recent and maintain that the use of the name of *G. menardii-tumida* group will denote these types of *Globorotalia.*

The typical *G. tumida* is characterized by having a tumid, nearly biconvex test with a periphery bordered by a massive imperforate carina strongly developed on the earlier part of the last whorl, and its elongated test with a conspicuous "tongue"-like last chamber.

In Japan, nearly typical forms with the characters noted above occur in association with *Globorotalia mayeri* and *Globigerina nepenthes* in the sample from the Shimoshiraiwa locality, Izu Peninsula. These earlier forms, however, somewhat differ from the typical in having rather flat spiral side. This may suggest that the ancestor of *G. tumida* may be found in strata older than the *G. mayeri/G. nepenthes* Subzone.

The specimens showning subcircular equatorial profile with a massive imperforate carina and thicker test wall of a crystalline appearance are found in the Higashi-innai formation in association with the typical *Globorotalia praemenardii.* These forms are occasionally found in strata ranging towards higher zones in Japan. Whereas the writer once assumed these subcircular forms with the thicker test to be identical with *Globorotalia menardii miotumida* Jenkins (Saito, 1962b), the Japanese forms seem to be distinct in having usually five chambers in the last whorl, and very smooth wall. Sometimes, the fifth chamber shows a tendency to be tongue-like or subtriangular as in the Recent *tumida.* It is difficult to distinguish these forms from one another as separate species only by their outline. Thus, the subcircular forms in the lower zones of the Miocene are treated as *G. tumida.* Inasmuch as one may possibly trace the morphological characters of *G. tumida* up to the species from nearly the *G. fohsi fohsi* Zone, it may be suggested that *G. tumida* evolved from the *praemenardii* attaining chamber embracing and wall thickening. As suggested by Parker (*loc. cit.*), among the Recent forms, *G. tumida* seems to be regarded as a species separate from *G. menardii menardii* from the phylogenetical view point. The forms transitional between *G. tumida* (of sub-circular forms) and *G. praemenardii* are found in co-existence with the typical *G. praemenardii.* Some of these variations are illustrated.

Hypotype: – IGPS coll. cat. no. 85306 from the Higashi-innai formation as far north as Lat. about 37°30′N.

Known range: – The upper part of the *Globorotalia fohsi fohsi* Zone to Recent.

Globorotalia zealandica Hornibrook, 1958
Pl. 54, fig. 9a–c

Globorotalia zealandica Hornbirook, 1958, p. 667, 668, text-figs. 18, 19, 30; Jenkins 1960, p. 368, pl. 5, figs. 9a–c; Hornibrook, 1962, p. 143, 144, pl. 22, figs. 448, 451, 452, (reproduction of holotype).

Remarks: – Comparing with the ideotypes of this species, which were kindly forwarded to the writer by N. de B. Hornibrook, the Japanese specimens are very similar. The typical forms are characterized by the test with four, occasionally five chambers in the last whorl, rather strongly vaulted umbilical side and nearly flat to faintly convex spiral side, and the arched aperture with a thin lip. However, this species shows much variation in axial profile from narrowly to broadly rounded, in equatorial profile from subrounded to subquadrate, and from those with strongly vaulted umbilical side to less vaulted. The size ranges from 0.25 to 0.30 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 79032, from sample S–34, the Saigo formation.

Occurrence and distribution: – Rather rare, but occurs in several scattered localities. This species extends its distribution to as far north as Lat. 39°45′N., in the Onnagawa formation.

Known range: – Originally, Hornibrook described this species to range from the Awamoan to Altonian stage in New Zealand. In terms of planktonic foraminiferal zones as established in the Caribbean regions, this range corresponds to the *Globigerinatella insueta* Zone. But in a later paper, Hornibrook (1961) extended the range of this species up to the Lillburnian stage in New Zealand (=approximately the Helvetian age.)

Family Globigerinidae

Genus ***Globigerina*** d'Orbigny, 1826

Globigerina angustiumbilicata Bolli, 1957

Globigerina ciperoensis angustiumbilicata Bolli, 1957a, p. 109, pl. 22, figs. 12a–13c.
Globigerina angustiumbilicata (Bolli). Blow, 1959, p. 172, pl. 7, figs. 2a–c; Takayanagi and Saito, 1962, p. 82, 83, pl. 28, figs. 3a–9b; Eames *et al.*, 1962, text-fig. 9 (IV).

Remarks: – This species differs from *Globigerina concinna* Reuss by having a smaller umbilicus and a lipped aperture. In accordance with the development of the aberrant last chamber, this species shows variations in the general morphology of the test. Variations of characters of this taxon have already been discussed in detail by Takayanagi and Saito (*loc. cit.*). The variants with an aberrant final chamber closely resemble *Globigerina quinqueloba* Natland illustrated by Parker (1962). In the deep boring at Tsuchizaki, *G. angustiumbilicata* is continuously found in association with the variants like *G. quinqueloba* up to nearly a depth of 705 m., but it disappears at the depth of 660 m., where *Globorotalia inflata* first occurs and where only forms resembling the variants of *G. angustiumbilicata* persist. As the co-existence of the two forms, typical and variant in the same assemblage may be considered a mutual population of the same species, forms like the variants are regarded as an independent species, *G. quinqueloba* Natland. It is from this population where the typical *G. angustiumbilicata* disappears. As already suggested by Parker (1962, p. 225), the writer also considers *G. quinqueloba* as a descendant of *Globigerina angustiumbilicata*. Accordingly, *G. quinqueloba* appears to have its taxonomic entity at nearly the basal Pliocene. The size ranges from 0.17 to 0.34 mm. in maximum diameter.
Occurrecne and distribution: – This species is common in nearly all of the samples from the Miocene formations of Japan and has a wide geographic distribution.
Known range: – The *Globigerina turritilina turritilina* Zone (of Eames *et al.*, 1962 = uppermost Eocene) to nearly the top of the Miocene or younger (?).

Globigerina bulloides d'Orbigny, 1826

Globigerina bulloides d'Orbigny, 1826, p. 277 (no figures given) (*fide* Ellis and Messina, 1940 *et seq.*); Brady, 1884, p. 539, pl. 79, figs. 7a–c; Bolli, Loeblich and Tappan, 1957, p. 31, pl. 4, figs. 1a–c; Blow, 1959, p. 175, 176, pl. 9, figs. 38a–c; Dieci, 1959, p. 89, 90, pl. 7, fig. 21; Banner and Blow, 1960b, p. 3, 4, pl. 1, figs. 1a–c, 4a–c (lectotype designated); Takayanagi and Saito, 1962, p. 84, pl. 24, figs. 12a–c; Parker, 1962, p. 221, pl. 1, figs. 1–8.

Remarks: – This species is characteristic in its fairly large, arched aperture without a lip or rim. Usually four chambers compose the final whorl, but forms with the rudimentary fifth chamber showing all gradations of development are included as a variety. This rudimentary fifth chamber shows no trace of the apertural lip. The size ranges from 0.25 to 0.47 mm. in maximum diameter.
Occurrence and distribution: – This species is an important component of the planktonic assemblage of Japan and is found rather commonly in the Miocene and Pliocene formations of Japan.
Known range: – Blow (*loc. cit.*) described the evolutional lineage of this species from *G. praebulloides* within the middle part of the *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone. In Japan the typical *bulloides* first occurs within the range of *G. fohsi fohsi* and it may be assumed that the species evolved earlier in the high latitudinal areas than in the rather tropical regions as Venezuela and Trinidad.

Globigerina concinna Reuss, 1850
Pl. 56, figs. 6a, b

Globigerina concinna Reuss, 1850, p. 373, pl. 47, fig. 8; Galloway and Wissler, 1927, p. 41, pl. 7, figs. 7a–c; Cushman, 1946 (part), p. 20, pl. 3, figs. 10a, b (reproduction of holotype), pl. 4, figs. 11–13 (not pl. 3, figs. 11a–12, pl. 4, figs. 14, 15); Marks, 1951, p. 70, pl. 8, figs. 6a, b; Jenkins, 1960, p. 350, pl. 1, figs. 6a–c.

Remarks: – This species is characterized by having five chambers constituting the final whorl, the very wide open umbilicus and the high arched large aperture in which the aperture of the penulimate chamber opens. Usually this species has no apertural lip, but a thin fragile rim-like lip is occasionally found. The size ranges from 0.22 to 0.36 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85310, from the Sunakozaka sandstone member of the Yatsuo formation.

Occurrence and distribution: – With rather high frequencies, this species has been found from the Kurosedani formation, Ishikawa Prefecture, the Tomezaki formation, Iwate Prefecture and the Kokozura formation, Fukushima Prefecture.

Known range: – In Japan, it ranges from the *Globorotalia fohsi barisanensis* Zone to nearly the top of the Miocene.

Globigerina decoraperta Takayanagi and Saito, 1962

Globigerina druryi Akers *decoraperta* Takayanagi and Saito, 1962, p. 85, pl. 28, figs. 10a–c.

Remarks: – This species was originally described as a subspecies of *G. druryi* Akers. Compared with the specimens of *G. druryi* from Venezuela, *G. decoraperta* has thinner test wall, a subcircular, high-arched aperture and with thickened rim instead of thin lip. On account of these morphological characters, *G. decoraperta* is here treated as a separate species. This species usually has a rather high-arched aperture with thickened rim-like lip. The size ranges from 0.17 to 0.30 mm. in maximum diameter.

Occurrence and distribution:– *G. decoraperta* is occasionally found in the finer fractions of the sediments from the formations correlated with the *G. menardii menardii/G. nepenthes* Zone or younger zones.

Known range: – The *G. menardii menardii/G. nepenthes* Zone to the Pliocene (?).

Globigerina druryi Akers, 1955

Globigerina druryi Akers, 1955, p. 654, pl. 65, figs. 1a–c.

Remarks: – Specimens from the *Globorotalia fohsi barisanensis* Zone of the Pozon formation, Venezuela, are compared with the one of Japan. It is characterized by having a rather small test, coarsely perforate wall, small low arched aperture with a thin lip. This species shows rather high trochospiral chamber arrangement. The size ranges from 0.22 to 0.28 mm. in maximum diameter.

Occurrence and distribution: – Rare, occurs from the Takasaki, Chichibu, and Kakegawa districts.

Known range: – This species was originally described from the Miocene *Cibicides carstensi* var. *opimus* Zone in the oil shaft of Louisiana. This zone seems to be correlative nearly with the *G. fohsi barisanensis* Zone or lower. In Japan, *G. druryi* is found in association with *Globigerinoides bisphericus*.

Globigerina falconensis Blow, 1959
Pl. 56, fig. 5

Globigerina falconensis Blow, 1959, p. 177, pl. 9, figs. 40a–c, 41; Todd *in* Cole *et al*, 1960, p. 105, pl. 13, figs. 1a, b; Takayanagi and Saito, 1962, p. 86, pl. 24, figs. 13a–c; Parker, 1972, p. 224, pl. 1, figs. 14, 16–19.

Remarks: – This species is characterized by the low arched aperture with a prominent broad lip. The size ranges from 0.20 to 0.36 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85311, from the Shimoshiraiwa locality.
Occurrence and distribution: – This is an ubiquitous species among the Miocene planktonic assemblage of Japan.
Known range: – The *Globigerinatella insueta/G. bisphericus* Zone to Recent.

Globigerina foliata Bolli, 1957

Globigerina foliata Bolli, 1957a, p. 11, pl. 24, figs. 1a–c; Blow, 1959, p. 177, 178, pl. 10, figs. 42a–c; Takayanagi and Saito, 1962, p. 86, pl. 25, figs. 1a–c.

Remarks: – Rare, the specimens are identical with the present species. It is characterized by the lobulate spherical chambers increasing rapidly in size as added. The size ranges from 0.17 to 0.36 mm. in maximum diameter.
Occurrence and distribution: – This species is rarely found in the Kanomatazawa formation, Tochigi Prefecture and in the Ono formation, Gunma Prefecture, and the Saigo and Matsuba formations in Shizuoka Prefecture.
Known range: – The *Globigerina stainforthi* Zone to the upper part of the *Sphaeroidinellopsis seminulina* Zone.

Globigerina glutinata Egger, 1895
Pl. 56, fig. 4

Globigerina glutinata Egger, 1895, p. 371 (179), pl. 13, figs. 19, 21; Rhumbler, 1909 (part), p. 148, 149, pl. 29, figs. 15–24, 26, pl. 34, fig. 1 (not pl. 29, figs. 14, 25); Takayanagi and Saito, 1962, p. 86–88, pl. 27, figs. 13a–17c, with synonymy up to 1960.
Globigerinita glutinata (Egger). Parker, 1962, p. 246–249, pl. 9, figs. 1–16.

Remarks: – As discussed by Parker (*loc. cit.*), this taxon is interpreted on the basis of Rhumbler's figures. The generic position of this species and the comparison with the named species of authors have been discussed in a previous paper (Takayanagi and Saito, *op. cit.*). No change in the morphological characters of the species have been noted during the Miocene of Japan. The size ranges from 0.12 to 0.30 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85316, from the Shimoshiraiwa locality.
Occurrence and distribution: – Two forms with and without the apertural bulla are found in about the same numbers. This species is an ubiquitous form among nearly all of the samples from the Miocene formations of Japan.

Globigerina nepenthes Todd, 1957

Globigerina nepenthes Todd, 1957, p. 301, pl. 78, figs. 7a, b; Bolli, 1957, p. 111, pl. 24, figs. 2a–c; Blow, 1959, p. 178, 179, pl. 8, figs. 44, 45; Takayanagi and Saito, 1962, p. 89, pl. 25, figs. 2a–c; Saito, 1962, p. 332, pl. 51, figs. 1a–4c, pl. 52, figs. 1–8.
Sphaeroidinellopsis nepenthes (Todd), var. *constricta* Bermudez, 1961, p. 1278, pl. 10, figs. 2a, b.

Remarks: – The specific characters of this taxon have been discussed in detail elsewhere (Saito, *op. cit.*). The morphological change of this species as noted by Blow (*loc. cit.*) have also been observed among the specimens from the Japanese Miocene.

Known range: – Geiger (1962) listed the species as ranging from the Tongaporutan to Opoitian (upper Miocene to Pliocene) stage of New Zealand. This species has never been reported from the typical Pliocene outside of New Zealand. In this paper, the range of *G. nepenthes* is considered to be the *Globorotalia mayeri/Globigerina nepenthes* Subzone to the top of the *Globorotalia menardii menardii/Globigerina nepenthes* Zone.

Globigerina pachyderma (Ehrenberg), 1861
Pl. 54, figs. 11a, b

Aristerospira pachyderma Ehrenberg, 1861, p. 276, 277, 303 (*fide* Ellis and Messina, 1940 *et seq.*); Ehrenberg, 1873, p. 386, pl. 1, fig. 4, (*fide* Ellis and Messina, 1940 *et seq.*).
Globigerina pachyderma (Ehrenberg). Brady, 1884, p. 600, pl. 114, figs. 19, 20; Cushman and Todd, 1947, p. 70, pl. 16, figs. 27, 28; Bradshaw, 1959, p. 36, pl. 6, figs. 20–23; Bé, 1960, p. 64–68, text-fig. 1; Bandy, 1960b, p. 671–681, text-fig. 1; Takayanagi and Saito, 1962, p. 89, 90, pl. 26, figs. 4a–c; Parker, 1962, p. 224, 225, pl. 1, figs. 26–35, pl. 2, figs. 1–6.

Remarks: – In the Recent seas, *Globigerina pachyderma* is accepted as the most important Arctic-Antarctic species of the planktonic Foraminifera. Thus, its presence or absence in the sediment samples is a significant criterion for paleo-climatic interpretations. Discussions on the morphology, taxonomy, and ontogeny of the species, however, seem to be based on the Recent data and therefore reservations should be made for a phylogenetical consideration.

Although the morphological change of the planktonic Foraminifera due to the supposed temperature change has been discussed in the earlier part of this paper, it is usually noted that the boreal or also possibly the austral forms among the same species show thicker shell wall than the tropical forms (*e. g.* Parker, 1962, p. 224, 230).

Globigerina pachyderma is a species with a thick shell wall. Morphological variations during the ontogeny of this species and its shell nature have been discussed in detail on the basis of Recent material by Bé (1960). He noted that the specimens encountered in plankton-tow samples appear different from the typical *pachyderma* found in the bottom sediments. The near surface forms have thinner test with four to four and a half, spherical chambers in the last whorl, chambers regularly increasing towards the final in size, and relatively large aperture extending from umbilicus to periphery without distinct spertural ridge. He suggested that the crystalline thickening of the test of *G. pachyderma* might be attained during the process of their habitats descending towards deeper waters. Upon removal of the final somewhat reduced chamber, Parker also noted quite a different morphology of this species (1960, pl. 1, fig. 29).

In northern Japan, this species first appears in the 1965 m. deep boring sample, drilled at Tsuchizaki, Akita Prefecture. Basing upon the associated fauna as well as other stratigraphical data, this horizon of *G. pachyderma* may be considered as a equivalent to the middle Miocene, and it seems to be the oldest occurrence of this species hitherto known. The planktonic fauna of northwestern Japan in age of the post-*Globorotalia fohsi fohsi* Zone is monotonous, consisting of only a few species of mainly *Globigerina*, and show several distinct features to suggest their colder water habitat. For example, *G. bulloides* in this province, has a very thick wall and somewhat indented suture due to the crystalline thickening of the test. *Globigerina angustiumbilicata* also shows a very thick test with crystalline thickening of calcareous substance, and has the embracing chambers showing only slightly lobulate equatorial profile. Among the specimens of *G. pachyderma* of the middle Miocene age, forms transitional to the thick walled *G. angustiumbilicata* are often observed. Dissection the later chambers of the typical *pachyderma*, the writer also noted a form as described by Parker (*loc. cit*, pl. 1, fig. 29) and considered it to be closely related with *G. angustiumbilicata* in having four to five chambers in the final whorl, somewhat extraumbilical-umbilical aperture with frequently thin lip and low trochospiral chamber arrangement.

In addition, *G. angustiumbilicata* may be considered to be very variable, developing the abortive final chamber of various shapes as already discussed (*e. g.*, Takayanagi and Saito, 1962). From the foregoing lines, the writer is of the opinion that *G. pachyderma* might have evolved from *G. angustiumbilicata* within rather high latitudinal seas, in accordance with the lowering of the temperature towards the late Miocene, through the process of crystalline thickening of shell wall, although it has never been verified why the high-latitudinal forms add much calcium carbonate to their test. Almost all of these Miocene *G. pachyderma* show dextral test coiling. The size ranges from 0.17 to 0.34 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 79049, from the Tsuchizaki R–7 boring core (Depth 1670 m.), the Funakawa formation.

Occurrence and distribituion: – In Japan, this species first appears in the 1965 m. deep boring sample, the Onnagawa formation. At the age of the *Globorotalia menardii menardii/Globigerina nepenthes* Zone, this species becomes distributed south to Lat. 31°40′N., of the Miyazaki group. Later in this zone age, the present species becomes one of the ubiquitous species among the planktonic fauna of Japan.

Known range: – It ranges probably from the age equivalent to the *Globorotalia mayeri* Zone to Recent.

Globigerina praebulloides Blow, 1959

Globigerina praebulloides Blow, 1959, p. 180, 181, pl. 8, figs. 47a–c, pl. 9, fig. 48; Jenkins, 1960, p. 352, pl. 2, figs. 1a–c; Takayanagi and Saito, 1962, p. 90, pl. 25, figs. 4a–c.

Globigerina praebulloides praebulloides Blow. Blow and Banner, *in* Eames *et al.*, 1962, p. 92, pl. 9, figs. O–Q.

Remarks: – This species differs from *G. bulloides* by the elongate equatorial profile, slightly embracing chambers which increase more rapidly in size, and rather low arched aperture without lip. This species also differs from *Globigerina woodi* Jenkins by its smoother chamber wall. *Globigerina praebulloides* is considered by Blow to be ancestral to both *G. bulloides* and *G. praebulloides.* He assumed that *G. bulloides* had its taxonomic entity within the *G. menardii menardii/G. nepenthes* Zone. As stated under *G. bulloides*, however, the separation appears to have occurred rather earlier in the higher latitudinal areas because of the occurrence of the typical *bulloides* within the range of *G. fohsi fohsi* in Japan. The size ranges from 0.22 to 0.36 mm. in maximum diameter.

Occurrence and distribution: – Frequent, in nearly all of the formations of the lower Miocene age in Japan.

Known range: – The *Globigerapsis semi-involuta* Zone (upper Eocene) to the *Globorotalia menardii/Globigerina nepenthes* Zone.

Globigerina trilocularis Deshayes, 1832

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

Globigerina trilocularis d'Orbigny. Deshayes, 1832, p. 170 (*fide* Ellis and Messina, 1940 *et seq.*); Fornasini, 1897, pl. 1, figs. 6–7a, p. 12, text-fig. (*fide* Ellis and Messian, 1940, *et seq.*)

Remarks: – Rare, the specimens are identical with this species. The general characters of this taxon resemble *Globigerina glutinata* (a type without bulla). But this species is different in having three chambers in the last whorl, a thin lipped aperture which is low arched slit-like over the antepenultimate chamber in umbilical-extraumbilical position. The size ranges from 0.19 to 0.42 mm. in maximum diameter.

Occurrence and distribution: – Occasional.

Known range: – Not certain.

Globigerina weissi Saito, n. sp.
Pl. 54, figs. 13a–14

Globigerina sp. Weiss, 1955, p. 311, pl. 3, figs. 15–16.

Test very small, low to moderately trochospiral, with a subcircular, lobulated equatorial profile, axial periphery rounded, two to three whorls visible on spiral side; chambers subglobular, increasing gradually in size as added, final chamber somewhat protruded towards umbilical side, size nearly equal to chambers in last whorl, usually five chambers per whorl, 15 to 18 in all; sutures depressed, slightly curved to nearly radical on spiral side, slightly sinuous to radial on umbilical side; wall thin, calcareous, perforate, surface smooth or very finely hispid; aperture umbilical, interiomarginal, rather slit-like opening with a thin narrow lip of clear shell material. Coiling of test nearly random in direction.

Maximum diameter of holotype 0.14 mm., thickness 0.11 mm. Other specimens range from 0.12 to 0.17 mm. in maximum diameter.

Types: – Holotype; IGPS coll. cat. no. 85321, from sample S–3.5, the Saigo formation; Paratype; IGPS coll. cat. no. 85322, from sample Od–3, the Oidawara formation.

Remarks: – *G. weissi* differs from *Globigerina quinqueloba* Natland by the smaller test with thin but distinct lip, very restricted narrow slit-like aperture and smoother shell surface. *G. weissi* shows no variable last chamber or the development of various shaped overhanging lip, which may sometimes coalesce to the earlier chambers as seen in *G. quinqueloba*.

The specific name is given in honor of Mr. Lawrence Weiss of the International Petroleum Company, Ltd., who first noted and illustrated this species.

Occurrence and distribution: – This species is common in the Saigo formation (=the *Globigerinatella insueta/Globigerinoides bisphericus* Subzone) and the Oidawara formation (=the *Globorotalia fohsi barisaensis* Zone). Weiss (*loc. cit.*) reported this species to occur throughout the Oligocene to middle Miocene sediments of northern Peru.

Globigerina woodi Jenkins, 1960

Globigerina woodi Jenkins, 1960, p. 352, pl. 2, figs. 2a–c; Takayanagi and Saito, 1962, p. 91, 92, pl. 25, figs. 6a–c.

Remarks: – This species has usually thick and coarsely pitted wall, more or less depressed U-shaped sutures in the thicker walled forms. The aperture sometimes has an imperforate faint rim-like lip. The thick and coarsely pitted wall is a distinct character which seems to distinguish this species from its allied forms. The size ranges from 0.24 to 0.38 mm. in maximum diameter.

Occurrence and distribution: – This species is an important component of the Miocene planktonic foraminiferal assemblage of Japan. It is common in nearly all of the samples from the rather lower zones of the Miocene.

Genus *Globigerinella* Cushman, 1927
Globigerinella siphonifera (d'Orbigny), 1839

Globigerina siphonifera d'Orbigny, 1839, p. 83, pl. 4, figs. 15–18 (*fide* Ellis and Messina, 1940 *et seq.*).
Globigerina aequilateralis Brady, 1884, p. 605, pl. 80, figs. 18–21.
Globigerinella aequilateralis Brady var. *involuta* Cushman, 1917, p. 662; Cushman, 1921, p. 294, fig. 11.
Globigerinella aequilateralis (Brady). Cushman, 1927, p. 87, pl. 19, figs. 7a, b.
Hastigerina aequilateralis (Brady). Bolli, Loeblich and Tappan, 1957, p. 29, pl. 3, figs. 4a, b.
Hastigerina (*Hastigerina*) *siphonifera* (d'Orbigny). Banner and Blow, 1960a, p. 22, 23, text-figs. 2a–3b (lectotype designated).

Hastigerina siphonifera (d'Orbigny). Takayanagi and Saito, 1962, p. 75, pl. 24, figs. 1a, b.
Globigerinella siphonifera (d'Orbigny). Paker, 1962, p. 228, pl. 2, figs. 22–28.

Remarks: – The writer agrees with Parker (*loc. cit.*) in the relation of *Globigerinella* and *Hastigerina*. This species may be a case to be sumbitted to the "Principle of Conservation," because of the currently used name of *aequilateralis* to denote the forms with planispiral coiling test, in contrast to the name of *siphonifera*, which had almost been ignored taxonomically. The name *siphonifera* is herein used pending the acceptance or rejection of the lectotype.

The Japanese Miocene forms show often incomplete planispiral coiling of the test and sometimes are evolute as shown in the figures of Parker (*loc. cit.*, pl. 2, figs. 24a–28c). The size ranges from 0.30 to 0.47 mm. in maximum diameter.

Occurrence and distribution: – Rare, and from rather scattered localities.

Known range: – The incompletely planispirally coiled forms are occasionally found in the *Globigerinatella insueta/Globigerinoides bisphericus* Subzone in the Saigo formation.

Genus ***Globoquadrina*** Finlay, 1947

Globoquadrina altispira altispira (Cushman and Jarvis), 1947

Pl. 55, figs. 6a–c

Globigerina altispira Cushman and Jarvis, 1936, p. 5, pl. 1, figs. 13a–c, 14; Bermudez, 1949, p. 277, 278, pl. 21, figs. 43; Hamilton, 1953, p. 220, pl. 30, figs. 29, 30; Hamilton and Rex, 1959, p. 791, pl. 252, fig. 7.
Globoquadrina altispira (Cushman and Jarvis). Todd *et al.*, 1954, p. 677; Todd, 1957, p. 279 (table), pl. 79, figs. 11a, b; Bolli, Loeblich and Tappan, 1957, p. 32, pl. 5, figs. 5a–c; Chang, 1958, p. 52, pl. 4, figs. 7a, b; Chang, 1959a (part), p. 62, pl. 2, figs. 6–8c (not 9a–c); Todd *in* Cole *et al.*, 1960, p. 107, pl. 13, figs. 3–7.
Globoquadrina altispira altispira (Cushman and Jarvis). Bolli, 1957a, p. 11, pl. 24, figs. 7a–8b; Blow, 1959, p. 183, pl. 8, figs. 51a–c; Jenkins, 1960, p. 355, pl. 3, figs. 5a–c; Takayanagi and Saito, 1962, p. 92, pl. 25, figs. 7a, b; Belford, 1962, p. 21, 22, pl. 5, figs. 19–24.

Remarks: – This species is characterized by having a fairly high trochospiral test, with axially elongate and laterally compressed chambers. The size ranges from 0.12 to 0.50 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85326, from the Shimoshiraiwa locality.

Occurrence and distribution: – Rather rare in the Miocene formations of Japan. It occurs as far north as about Lat. 39°05′N., in the Maekawa formation, Iwate Prefecture.

Known range: – The *Globigerinita stainforthi* Zone to the *Globorotalia menardii menardii/Globigerina nepenthes* Zone or younger (?).

Globoquadrina altispira globosa Bolli, 1957

Pl. 55, figs. 8a–c

Globoquadrina altispira globosa Bolli, 1957, p. 111, 112, pl. 28, figs. 9a–10c; Blow, 1959, p. 183, pl. 11, figs. 52a–c; Bermudez, 1961, p. 1308, 1309, pl. 12, figs. 8–9b; Takayanagi and Saito, 1962, p. 92, pl. 25, figs. 8a, b.
Globoquadrina altispira (Cushman and Jarvis). Chang, 1959a (part) p. 62, pl. 2, figs. 9a–c.

Remarks: – This subspecies differs from the species by the low trochospiral test, more globular and less axially elongate chambers. In general, this subspecies has rather wide open umbilicus with well-marked umbilical teeth. The size ranges from 0.32 to 0.50 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85327, from the Shimoshiraiwa locality.

Occurrence and distribution: – The subspecies is rarer than the species, and occurs as far north as about Lat. 36°N., in the Takasaki District.

Known range: – The *Globigerinita dissimilis* Zone to the *Globorotalia menardii menardii/Globigerina nepenthes* Zone.

Globoquadrina conglomerata (Schwager), 1866
Pl. 55, figs. 1a–2b

Globigerina conglomerata Schwager, 1866, p. 255, pl. 7, fig. 113; Banner and Blow, 1960, p. 7, 8, pl. 2, figs. 3a–c (neotype); Beckmann, 1954, p. 391, pl. 25, figs. 6–9, text-fig. 15.
Globigerina venezuelana Hedberg, 1937, p. 681, pl. 92, figs. 7a, b; Bolli, 1957b, p. 110, pl. 23, figs. 6a–8b; Bolli, 1957c, p. 164, pl. 35, figs. 16a–17; Hamilton and Rex, 1959, p. 792, pl. 253, figs. 15, 16.
Globoquadrina venezuelana (Hedberg). Blow, 1959, p. 186, pl. 11, figs. 58a–c; Saito, 1962a, p. 217, pl. 34, figs. 9a–10.
Globoquadrina conglomerata (Schwager). Parker, 1962, p. 240, 241, pl. 6, figs. 11–18.

Remarks: – The present species was originally described from the Neogene deposits of Kar Nikobar, British India. Although Schwager published one ventral view of the holotype, this species is fully interpreted from the recent taxonomic re-investigations on the primary types by Banner and Blow (1960b). As pointed out by Banner and Blow (*loc. cit.*) and Parker (*loc. cit.*), the newly designated neotype is closely related with the forms from the upper Eocene to Miocene sediments known as *G. venezuelana*, and the distinction between them appears to be subtle.

The writer has examined many fossil specimens referred to *G. venezuelana* from various localities including Venezuela, and the Recent forms from the Pacific *Globigerina*-ooze comparable with *G. conglomerata* as figured by Parker. Parker gave detailed discussions on the morphology and ontogeny of the Recent forms, and stated that *G. conglomerata* might have evolved from *G. venezuelana* as seen in the selected samples from various deep-sea cores of the Pacific, and that *G. venezuelana* perhaps should be considered as a subspecies of *G. conglomerata*. But she did not describe the morphological change during the evolution.

The Recent forms show much variation in the chamber shape from rather globular to somewhat laterally appressed, in the apertural opening from nearly to rather wide showing typical umbilical teeth, and in the coiling form from low trochospiral to very high. The neotype chosen by Banner and Blow, is a form with rather closed apertural opening and moderately embracing, slightly, laterally appressed chamber.

Morphological variations similar to those reported in *G. venezuelana* from the lower geologic columns are observed among the specimens, even of a single population derived from the same rock. The morphological variations of the two species mentioned above are known to occur in the populations reported from various localities of the world.

G. venezuelana Hedberg which has its type locality in the middle Zone of the Carapita formation, eastern Venezuela, is a form with rather closed apertural opening and inflated chambers showing more or less lobulate equatorial profile. Since the middle Zone of the Carapita formation may be correlated with a part of the *"Catapsydrax" stainforthi* and the *Globigerinatella insueta* Zones of Blow (1959), according to the study of Renz (1948), the type horizon of this species may be lower Miocene in age.

On the other hand, *G. conglomerata* was described from the Neogene deposits of Kar Nikobar Island. From the co-existence of *Sphaeroidinellopsis seminulina*, *Globorotalia menardii menardii* and *Orbulina universa*, the Neogene of Kar Nicobar has been considered to be older than the Miocene *Sphaeroidinellopsis seminulina* Zone (*e. g.* Takayanagi and Saito, 1962, p. 73).

From the closely related range in the morphological variations and the Miocene age of the two species, the writer treats *Globigerina venezuelana* Hedberg as a junior synonym of *G. conglomerata* Schwager.

The writer agrees with Parker in placing the species in the genus *Globoquadrina* based upon the pitted surface and the umbilical teeth. To trace the morphological change during the ontogeny of this species, an attempt has been made to dissect the later chambers, as

already tried by Parker, to ascertain the juvenile form which is similar to her figure (pl. 6, fig. 18). The size ranges from 0.24 to 0.54 mm. in maximum diameter.
Hypotypes: – IGPS coll. cat. no. 85324, from the Kokozura formation; IGPS coll. cat. no. 85325, from the Recent *Globigerina* ooze (collected from the Lat. 2°50′5″N., long. 133°54′E. by the S.S. Manshu).
Occurrence and distribution: – Almost ubiquitous in the Miocene sediments of Japan.
Known range: – Middle Eocene to Recent.

Globoquadrina dehiscens (Chapman, Parr and Collins), 1934
Pl. 55, figs. 9a–c

Globorotalia dehiscens Chapman, Parr and Collins, 1934, p. 569, pl. 11, figs. 36a–c.
Globorotalia quadraria Cushman and Ellisor, 1939, p. 11, pl. 2, figs. 5a–c.
Globoquadrina dehiscens (Chapman, Parr and Collins). Finlay, 1947, p. 290; Bolli, Loeblich and Tappan, 1957, p. 31, pl. 5, figs. 5a–c; Bolli, 1957a, p. 111, pl. 24, figs. 3a–4c; Chang, 1959a, p. 62, 63, pl. 2, figs. 1a–4c; Hornibrook, 1962, p. 153, pl. 22, figs. 446, 447, 449 (reproduced holotype of *Globoquadrina subdehiscens* Finlay); Bermudez, 1961, p. 1309, 1310, pl. 13, figs. 1a, b.
Globoquadrina quadraria var. *advena* Bermudez, 1949, p. 287, pl. 22, figs. 36–38.
Globoquadrina dehiscens advena Bermudez. Blow, 1959, p. 182, pl. 8, figs. 50 a, b.
Globoquadrina dehiscens dehiscens (Chapman, Parr and Collins). Blow, 1959, p. 182, pl. 8, figs. 49 a-c; Jenkins, 1960, p. 354, 355, pl. 3, figs. 3a–c.

Remarks: – This species has a low trochospiral test with flattened or slightly convex spiral side, and a strongly protruded last chamber on the umbilical side. The umbilicus is rather large and open, with distinct asymmetrical umbilical teeth. The later chambers show lateral compression resulting in a subquadrate equatorial profile. Rarely some specimens have an abortive fifth chamber as the hypotpyes of Bolli (*loc. cit.*, pl. 24, figs. 4a–c), and in these forms the umbilicus is small and sometimes almost closed. The specimens with an abortive chamber seem to be related with the forms of Blow (1959) described as *Globoquadrina dehiscens advena*. Bermudez's *advena* is apparently closely related to *G. dehiscens* and was recently placed in the synonymy of the latter species by the original author (Bermudez, 1961). As suggested by Bolli and Bermudez, *G. quadraria* Cushman and Ellisor and *G. quadraria advena* Bermudez are considered as conspecific with *G. dehiscens*. The size ranges from 0.26 to 0.70 mm. in maximum diameter.
Hypotypes: – IGPS coll. cat. no. 85328, from sample S–33, the Saigo formation.
Occurrence and distribution: – This is the most common species of *Globoquadrina* in Japan. *G. dehiscens dehiscens* ranges from the middle part of the Towata formation, Kakegawa District, up to the Kokozura formation of Fukushima Prefecture. The Kokozura formation has not been determined in terms of planktonic foraminiferal zones, because of no diagnostic species. But it is now assumed to be correlative with the upper Miocene from the evidence of planktonic and benthonic Foraminifera (Asano, 1949).

The species is found with rather high frequencies in the lower and middle Miocene of Japan.
Known range: – Hornibrook (*loc. cit.*) reported this species from the Opoitian stage in New Zealand, which he referred to the lower Pliocene in age. This species is considered to range from the *Globoquadrina dehiscens dehiscens* Zone of Jenkins (=*Globigerina ampliapertura* Zone in the Caribbean region) to lower Pliocene with some doubts.

Globoquadrina dutertrei (d'Orbigny), 1839

Globigerina rotundata d'Orbigny, 1826, p. 277, no. 6 (*fide* Ellis and Messina, 1940 *et seq.*); Fornasini, 1898, p. 208, text-fig. 3; Banner and Blow, 1960, p. 19, pl. 2, fig. 2 (lectotype) [written as *Globigerina rotundata* d'Orbigny 1898=*Globigerina dutertrei* d'Orbigny].

Globigerina dutertrei d'Orbigny, 1839, p. 84, (plates published separately, vol. 8, pl. 4, figs. 19–21), (*fide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960, p. 11, pl. 2, figs. 1a–c (lectotype).
Globigerina eggeri Rhumbler, 1901, p. 19–20, text-fig. 20 (after Brady, 1884, pl. 79, figs. 17a–c); Banner and Blow, 1960, p. 11, pl. 2, fig. 4, (lectotype).
Globigerina subcretacea Lomnicki, 1901, p. 17 (*fide* Ellis and Messian, 1940 *et seq.*).
Globorotalia subcretacea (Lomnicki). Takayanagi and Saito, 1962, figs. 1a–2b.
Globorotalia humerosa Takayanagi and Saito, 1962, p. 78, pl. 28, figs. 1a–2b.
Globoquadrina dutertrei (d'Orbigny). Parker, 1962, p. 242, 244, pl. 7, figs. 1–13, pl. 8, figs. 1–4.

Remarks: – As shown in the synonymy, "*dutertrei*" has caused confusion and ambiguity, but the concept is herein interpreted on the basis of Banner and Blow (1960) and of Parker (1962). The writer examined many Recent Pacific specimens and noted the characters described by Parker, especially its wall characters and the presence of umbilical teeth. The Miocene Nobori specimens appear to fall within the range of variation of *G. dutertrei.* The size ranges from 0.30 to 0.56 mm. in maximum diameter.
Occurrence and distribution: – This species has not been found from depostis older than the *Globorotalia menardii menardii/Globigerina nepenthes* Zone. Rarely found from the upper Miocene samples.

Globoquadrina eximia (Todd), 1957
Pl. 55, fig. 3

Globigerina eximia Todd, 1957, p. 300, pl. 78, figs. 8a–c.

Remarks: – The writer examined the topotypes of the present species and concludes that this species should be referred to *Globoquadrina* because of its coarsely pitted wall and umbilical teeth.

Usually the umbilical tooth is invisible due to the final chamber overhanging the umbilicus and sometimes because the umbilicus is filled up with sediments. But it may be noted by dissecting the last chamber carefully. The present species is characterized by the later three chambers making up the bulk of the test, the inflated and rapidly increasing chambers in size as added, subtriangular equatorial profile, and the coarsely pitted wall surface.

The size ranges from 0.24 to 0.35 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 78046, from the Shimoshiraiwa locality, Izu Peninsula.
Occurrence and distribution: – The Shimoshiraiwa locality, Izu Peninsula.
Known range: – Uncertain.

Globoquadrina hexagona (Natland), 1938

Globigerina hexagona Natland, 1938, p. 149, pl, 7, fig. 1.
Globoquadrina hexagona (Natland), Parker, 1962, p. 244, pl. 8, figs. 5–13.

Remarks: – Specimens with low trochospiral test, usually five inflated subglobular chambers in the final whorl and rather wide open umbilicus showing sometimes distinct umbilical teeth, are referred to the present species. The interpretation of this taxon is based on the Recent Pacific specimens rather than those from the Miocene. The size ranges from 0.16 to 0.24 mm. in maximum diameter.
Occurrence and distribution: – Only six specimens from the uppermost part of the Horinouchi formation, Kakegawa district.
Known range: – Hitherto only Recent.

Globoquadrina obesa Akers, 1955
Pl. 55, fig. 10

Globoquadrina obesa Akers, 1955, p. 661, pl. 65, figs. 5a–c.

Remarks: – The specimens identified with this species have the last whorl consisting of four chambers which increase rapidly in size as added, laterally somewhat appressed chambers with subquadrate equatorial profile, a fairly wide and deep umbilicus with a distinct umbilical teeth at the base of the final chamber. Only three chambers are visible from the umbilical side, and the last one is larger or nearly equal to the preceding two chambers. In general appearance, this species resembles *Globoquadrina dehiscens praedehiscens* Blow and Banner, but differs in having much protruded last chamber in axial direction and wide umbilicus. The size ranges from 0.22 to 0.58 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. cat. no. 78047, from the Shimoshiraiwa locality, Izu Peninsula.
Occurrence and distribution: – In Japan, this species first appears in the Matsuba formation of the Kakegawa district (subjacent to the *Globigerinoides bisphericus* Subzone) and is found up to the *Globorotalia mayeri/Globigerina nepenthes* Zone of the Shimoshiraiwa locality. This species is rather restricted to the southern parts of Honshu in distribution.
Known range: – Indefinite, but it seems to be restricted to the Miocene.

Globoquadrina praedehiscens Banner and Blow, 1962
Pl. 55, figs. 7a, b

Globoquadrina rohri (Bolli). Blow, 1959, p. 185, pl. 11, figs. 57a–c (not *Globigerina rohri* Bolli, 1957).
Globoquadrina dehiscens praedehiscens Blow and Banner, *in* Eames *et al.*, 1962, p. 116, pl. 15, figs. q-s.

Remarks: – Rare, and all are from the Towata formation of the Kakegawa district. The forms show only three chambers in the umbilical side and a low trochospiral test with flattened or somewhat convex spiral side, giving a rounded subquadrate equatorial profile. The present forms are much smaller than the types, and only one incipient umbilical tooth is found at the base of the final chamber. The final chamber is not so protruded as seen in *Globoquadrina obesa* Akers.

The size ranges from 0.20 to 0.30 mm. in maximum diameter.
Hypotypes: – IGPS coll. cat. no. 79049, from sample M–1, the Towata formation, Kakegawa district.
Known range: – Blow and Banner (*loc. cit.*) recorded this species to range from the middle part of the *Globigerina ouachitaensis ciperoensis* Zone up to the lower part of the *Globigerinita stainforthi* Zone.

Genus **Globigerinoides** Cushman, 1927
Globigerinoides bisphericus Todd, 1954
Pl. 54, figs. 10a, b

Globigerinoides bispherica Todd, *in* Todd, *et al.*, 1954, p. 681, 682, pl. 1, figs. 1a–c; Blow, 1956, p. 62, 64, text-fig. 1, nos. 4–8, text-fig. 2, nos. 10, 11, text-fig. 3 (stage A, 2); Todd, 1957, p. 302, pl. 74, figs. 7a–c (reproduction of holotype), 8; Bolli, 1957, p. 114, pl. 27, figs. 1a, b; Carter, 1958 (part), p. 53, 54, pl. 7, figs. 73, 74 (not figs. 70–72); Blow, 1959, p. 189, pl. 11, fig. 64; Hamilton and Rex, 1959, p. 792, pl. 253, figs. 11–13; Todd, *in* Cole *et al.*, 1960, p. 105, 106; Jenkins, 1960, p. 353, pl. 2, figs. 4a–c.

Remarks: – This characteristic species was originally described from the "upper Oligocene" Fina-Sisu formation of Saipan, and since then it has been recorded from various regions of the world. This species is an excellent marker fossil for the lower Miocene.

The specimens identified with this species are rather commonly found in the lower Miocene of Japan and have a short stratigraphic distribution. The specimens were compared with ones from the type section of the *Globigerinatella insueta/Globigerinoides bisphericus* Zone, Agua-Salada group of Venezuela, and found to be identical.

This species has the test occupied mostly by the later three chambers, of which the

last one is nearly equal in size to the penultimate and antepenultimate chambers combined. In shell construction, this species is closely related to the *Globigerinoides trilobus-sacculifer* group, and may have evolved from *G. trilobus* as suggested by Blow (1956). In Japan, this species is found sometimes in association with *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe. The size ranges from 0.17 to 0.34 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 79044, from sample S–34, the Saigo formation.
Occurrence and distribution: – This species is rather commonly found in the lower Miocene of Japan and is distributed as far north as about Lat. 39°20′N., in the Oishi formation, Iwate Prefecture.
Known range: – The *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone to the basal part of the *Globorotalia fohsi barisanensis* Zone.

Globigerinoides bollii Blow, 1959

Globigerinoides bollii Blow, 1959, p. 189–191, pl. 10, figs. 65a–c; Takayanagi and Saito, 1962, p. 93, pl. 25, figs. 12a–c.

Remarks: – This species differs from *G. obliquus* by the embracing chambers, a small, almost circular primary aperture and the inflated globular final chamber without lateral or oblique compression. The size ranges from 0.17 to 0.34 mm. in maximum diameter.
Occurrence and distribution: – Rather common in the middle and upper Miocene of Japan.
Known range: – *Globorotalia mayeri*/*Globorotalia lenguaensis* Subzone to the *Globigerina bulloides* Zone.

Globigerinoides conglobatus (Brady), 1879

Globigerina conglobata Brady, 1879, p. 286 (no figures given), (*fide* Ellis and Messina, 1940 *et seq.*); Brady, 1884, p. 603, pl. 80, figs. 1–5, pl. 82, fig. 5; Banner and Blow, 1960b, p. 6–7, pl. 4, figs. 4a–c (lectotype) [written as *Globigerina conglobata* Brady 1879=*Globigerinoides conglobatus* (Brady) in pl. 4].
Globigerinoides conglobata (Brady). Thalmann, 1932, p. 307; Bé, 1959, pl. 2, figs. 7012; Takayanagi and Saito, 1962, p. 93, 94, pl. 25, figs. 11a–c; Parker, 1962, p. 229, pl. 3, figs. 1–5.
Globigerinoides conglobata (Brady). Phleger, Parker and Peirson, 1953, p. 15, pl. 2, figs. 1–3; Asano, 1957, p. 20, pl. 2, figs. 8, 9; Bradshaw, 1959, p. 40, pl. 7, figs. 5, 6; Chang, 1959b, p. 86, pl. 1, figs. 10a–11c.

Remarks: – This species is distinguished by the coarsely pitted test wall, and the much embracing globe-like test with four chambers in the last whorl as usual. The apertures are furnished with thickened rim-like lip. The size ranges from 0.31 to 0.49 mm. in maximum diameter.
Occurrence and distribution: – Rare, and in rather restricted localities in the southern parts of Japan.
Known range: – The *Globorotalia menardii menardii*/*Globigerina nepenthes* Zone to Recent.

Globigerinoides elongatus (d'Orbigny), 1826
Pl. 56, figs. 11a, b

Globigerina elongata d'Orbigny, 1826, p. 277, (*fide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960b, p. 12, 13, pl. 3, figs. 10a–c (lectotype) [written as *Globigerina elongata* d'Orbigny 1826=*Globigerinoides elongatus* (d'Orbigny) in pl. 3].
Globigerinoides elongata (d'Orbigny). Cushman, 1941, p. 40, pl. 10, figs. 20–23, pl. 11, fig. 3; Cushman, Todd, and Post, 1954, p. 368, 369, pl. 91, fig. 5.
Globigerinoides elongatus (d'Orbigny). Takayanagi and Saito, 1962, p. 95, pl. 26, figs. 8a–c.

Remarks: – This species is characterized by having the final chamber with much lateral compression, the sub-triangular appearance of the test in umbilical view, and thick coarsely

pitted wall. The size ranges from 0.26 to 0.37 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85330, from sample A–17, the Nobori formation.
Occurrence and distribution: – This species occurs rather rarely in the Miocene of Japan. It is found as fossil as far north as about Lat. 39°50′N.
Known range: – As suggested by Takayanagi and Saito (*loc. cit.*), this species seems to have evolved from the *G. ruber* group within nearly the *G. menardii menardii*/*Globigerina nepenthes* Zone and has never been found below this zone. This species may range from that zone to Recent.

Globigerinoides glomerosus curvus Blow, 1956
Pl. 55, fig. 4

Globigerinoides glomerosa curva Blow, 1956, p. 64, 65, text-fig. 1, nos. 9–14, text-fig. 3 (stage 3).
Porticulasphaera glomerosa curva (Blow). Bolli, 1957, p. 115, pl. 27, fig. 7; Blow, 1959, p. 201, pl. 13, figs. 84a, b.
Candorbulina glomerosa (Blow) subsp. *curva* (Blow.) Jenkins, 1960, p. 357, pl. 3, figs. 8.
Globigerinoides glomerosus var. *curva* Blow. Bermudez, 1961, p. 1230, 1231, pl. 11, fig. 10.

Remarks: – This subspecies differs from the species by the final chamber which embraces between 40–70 percent of the earlier test. This subspecies first appears in the lower part of the Saigo formation below that of the species, and after the appearance of *G. bisphericus* Todd.
Hypotype: – IGPS coll. cat. no. 85302, from sample Tk–3, the Isobe formation.
Occurrence and distribution: – This species has a short stratigraphic range as recognized in many regions outside of Japan.
Known range: – The middle part of the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone to the basal part of the *Globorotalia fohsi barisanensis* Zone.

Globigerinoides glomerosus glomerosus Blow, 1956
Pl. 55, fig. 5

Globigerinoides glomerosa glomerosa Blow, 1956, p. 65, text-fig. nos. 15–19, text-fig. 2, no. 1, text-fig. 3 (stage 4).
Porticulasphaera glomerosa glomerosa (Blow). Bolli, 1957a, p. 115, pl. 27, fig. 8; Blow, 1959, p. 202, pl. 14, figs. 85a, b.
Globorotalia (*sic*=*Candorbulina*) *glomerosa* (Blow) subsp. *glomerosa* (Blow). Jenkins, 1960, p. 357, pl. 3, figs. 9a, b.
Globigerinoides glomerosus Blow. Bermudez, 1961, p. 1229, 1230, pl. 11, figs. 7–9.

Remarks: – This species was originally described under the genus *Globigerinoides* by Blow (*loc. cit.*). At that time he described several forms which he regarded as transitional between *Globigerinoides* and *Orbulina*. As later discussed by Bolli (*loc. cit.*), however, they are somewhat different from *Orbulina* in the absence of areal supplementary apertures, and from *Globigerinoides* in having a final strongly embracing chamber without any primary umbilical aperture. Those forms were tentatively referred to the genus *Porticulasphaera* by Bolli, although he noted that there was no genetic relations between the middle Eocene and the lower Miocene forms. The writer has studied the Eocene species of the genera *Porticulasphaera*, *Globigerapsis* and *Globigerinatheka*, and arrived at the conclusion that the three Eocene genera show close genetic relationship with each other, but no phylogenetic interrelation with the spherical Miocene forms. Accordingly, it is desirable to erect a new genus to include the Miocene spherical forms. The present species is placed in the genus *Globigerinoides* laying stress on the similarity of the shell features and the absence of areal supplementary apertures.

This species is characterized in having strongly embracing inflated final chamber,

covering as much as 75 percent of the earlier chambers, and the multiple slit-like sutural supplementary apertures around the lower margin of the final chamber. The size ranges from 0.22 to 0.40 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85303, from sample S–34, the Saigo formation.
Occurrence and distribution: – Rare, but found concomitant with *Globigerinoides bisphericus* in rather restricted localities. This species has a shorter stratigraphic range than *G. glomerosus curvus*.
Known range: – The upper part of the *Globigerinatella insueta/Globigerinoides bisphericus* Zone to the basal part of the *Globorotalia fohsi barisanesis* Zone.

Globigerinoides immaturus LeRoy, 1939

Globigerinoides sacculiferus (Brady) var. *immatura* LeRoy, 1939, p. 263, pl. 3, figs. 19–21 (*fide* Ellis and Messina, 1940 *et seq.*); LeRoy, 1941a, p. 44, pl. 1, figs. 37–39; LeRoy, 1941b, p. 87, pl. 7, figs. 16–18; LeRoy, 1941c, p. 118, pl. 3, figs. 31–33.
Globigerinoides triloba immatura LeRoy. Bolli, 1957a, p. 113, pl. 25, figs. 3a–4c, text-fig. 2 (2a, b); Blow, 1959, p. 188, pl. 11, figs. 62a, b; Jenkins, 1960, p. 354, pl. 2, figs. 7a–c.
Globigerinoides quadrilobatus (d'Orbigny) *immaturus* LeRoy. Belford, 1962, p. 13, pl. 2, figs. 22–24.
Globigerinoides immaturus LeRoy. Takayanagi and Saito, 1962, p. 95, pl. 27, figs. 2 a, b.

Remarks: – Opinion concerning the taxonomic validity of *Globigerinoides quadrilobatus* (d'Orbigny) have been expressed in a previous paper (Takayanagi and Saito, *loc. cit.*). The writer also agrees with Todd (1961) on this problem.

This species is closely related to *Globigerinoides sacculifer* from which the present species was originally discriminated as a variety. The not much lobulated, elongate terminal chamber with or sometimes without sack-like appearance and the more embracing chambers of the present species serve to distinguish it from *Gl. sacculifer*. In the lower to middle Miocene, this species seems to have more embraced chamber arrangment than in the later geologic horizons. It also differs from *G. trilobus* in having the final chamber smaller than the earlier chambers. The size ranges from 0.27 to 0.49 mm. in maximum diameter.
Occurrence and distribution: – This species first appears in the lower part of the Towata formation, which may be equivalent to the *Globigerinita dissimilis* Zone of the Caribbean regions. It becomes rather common in the succeeding younger formations. It occurs frequently as fossil as far north as about Lat. 40°24′N., in association with *G. mayeri*.
Known range: – The upper part of the *Globorotalia kugleri* Zone to Recent (?).

Globigerinoides obliquus Bolli, 1957

Globigerinoides obliqua Bolli, 1957b, p. 113, pl. 25, figs. 9a–10c; Blow, 1959, p. 191, 192, pl. 11, figs. 68a, b.
Globigerinoides obliquus Bolli. Takayanagi and Saito, 1962, p. 96, pl. 25, figs. 10a–c; Belford, 1962, p. 20, pl. 5, figs. 11–14.

Remarks: – This species is characterized by having the final chamber compressed in lateral oblique manner as in *Globigerinoides elongatus*, but differs by the comparatively large, arched primary aperture, which is placed above the two sutures between three earlier chambers. The size ranges from 0.22 to 0.34 mm. in maximum diameter.
Occurrence and distribution: – Common in rather scattered localities.
Known range: – The upper part of the *Globorotalia kugleri* Zone to the *Globigerina bulloides* Zone (or younger).

Globigerinoides ruber (d'Orbigny), 1839

Remarks: – The specimens referred to *G. ruber* (s.s.) have certain morphological characters in common and the distinction among them is rather of subspecific rank depending upon ecological or stratigraphical grounds. This species is characterized by having three fairly large chambers in the last whorl with a subcircular primary aperture, which is placed and shaped symmetrically above an intercameral suture between the penultimate and antepenultimate chambers. This species, as found in Japan, may be classified into the three subspecies given below.

Globigerinoides ruber cyclostomus (Galloway and Wissler), 1927

Globigerina cyclostoma Galloway and Wissler, 1927, p. 42, pl. 7, figs. 8a–9c.
Globigerinoides ruber gomitulus (Seguenza). Emiliani *et al.*, 1961, p. 682.
Globigerinoides ruber cyclostomus (Galloway and Wissler). Takayanagi and Saito, 1962, p. 97, pl. 26, figs. 6a–c.

Remarks: – This species differs from *G. ruber ruber* in having much embracing subquadrate equatorial profile, very low sprial arrangement of chambers and larger or nearly equal width of the final chamber than the preceding two chambers in umbilical view. It is also characteristic in having subrectangular shape of the chamber of *cyclostomus* in contrast to the subcircular inflated ones of *ruber* (s. s.).

Emiliani *et al.* (*loc. cit.*) considered *G. cyclostomus* as a junior synonym of *Globigerina gomitulus* Seguenza, based on the description of Fornasini (1898, 1899), and noted marked variations in the relative abundances of *G. ruber ruber* and *G. ruber gomitulus* among the samples from the Plio-Pleistocene section at Le Castella, southern Italy. This may be interpreted to suggest the different ecology of the two subspecies. However, Fornasini (1898) stated concerning *gomitulus* as "Del resto questa pretesa specie é inseparabile de la *Globigerina conglobata* Brady" on p. 28, and placed it in the synonymy of *G. conglobata* on p. 215. The writer follows the view of Fornasini (*loc. cit.*) in this paper. The size ranges from 0.19 to 0.46 mm. in maximum diameter.

Occurrence and distribution: – This subspecies is found occasionally in rather scattered localities of the Miocene formations of Japan.

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

Globigerinoides ruber ruber (d' Orbigny, 1839)
Pl. 56, figs. 9a, b

Globigerina rubra d'Orbigny, *in* Ramon de la Sagra, 1839, p. 82, 83, pl. 4, figs. 12–14 (plates published separately), (*fide* Ellis and Messina, 1940 *et seq.*); Banner and Blow, 1960b, p. 19–21, pl. 3, figs, 8a, b (lectotype) [written as *Globigerina rubra* d'Orbigny 1839=*Globigerinoides ruber* (d'Orbigny) in pl. 3].
Globigerinoides ruber ruber (d'Orbigny). Takayanagi and Saito, 1962, p. 96, 97, pl. 26, figs. 9a–c.

Remarks: – This subspecies is distinct in having three inflated, subglobular chambers, much lobulated equatorial periphery, less width of the final chamber compared with the two preceding chambers. The size ranges from 0.22 to 0.43 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85329, from sample A–17, the Nobori formation.

Occurrence and distribution: – It is an ubiquitous form in the formations in southern Japan. In the deep boring at Tsuchizaki, this species was not found below the depth of 660 m.

Known range: – The *Globorotalia fohsi* Zone (*s. l.*) to Recent.

Globigerinoides ruber subquadratus Bronnimann, 1954
Pl. 54, figs. 12a, b

Globigerinoides subquadrata Bronnimann, *in* Todd *et al.*, 1954, p. 680, 861, pl. 1, figs. 5a, 8a–c; Todd, 1957, p. 303, pl. 74, figs. 6a–c (reproduction of holotype); Hamilton and Rex, 1959, 0. 792, pl. 253, figs. 6–8.

Globigerinoides diminuta Bolli, 1957, p. 114, pl. 25, figs. 11a–c.

Remarks: – This species was originally described from Saipa and the paratype from the Cipero formation of Trinidad. The writer agrees with Banner and Blow (1960, p. 21) who considered this species is a subspecies of *G. ruber*. In general characters, this subspecies is closely related with *G. ruber* (s. s.) and *G. ruber cyclostomus*. But it is distinguished from them by having a very tightly coiled test with somewhat trapezoidal to subquadrate equatorial profile, much embracing chambers with thick and rather coarsely pitted wall, and the much smaller subcircular primary aperture. The size ranges from 0.22 to 0.40 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85305, from sample S–33, the Saigo formation.

Occurrence and distribution: – This subspecies occurs commonly below the *Globorotalia fohsi fohsi* Zone.

Known range: – The *Globigerinatella insueta* Zone to the lower part of the *Globorotalia fohsi* Zone (*s.l.*)

Globigerinoides sacculifer (Brady), 1877

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

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

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

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

Globigerinoides sacculifer (Brady). Graham and Militante, 1959, p. 112, 113, pl. 19, figs. 1a–2b; Bé, 1959, pl. 2, figs. 13–15; Dieci, 1959, p. 93, pl. 7, fig. 30; Takayanagi and Saito, 1962, p. 97, pl. 26, figs. 11a–c.

Globigerinoides quadrilobatus sacculifer (Brady). Parker, 1962, p. 229, 230, pl. 3, figs. 6–10.

Remarks: – This species is distinct in having an elongate, well lobulate final chamber with or sometimes without development of the sack-like form. The size ranges from 0.34 to 0.51 mm. in maximum diameter.

Occurrence and distribution: – In Japan, this species first appears in the uppermost part of the Matsuba formation (just below the *Globigerinoides bisphericus* Subzone) and is found rather sporadically in the succeeding younger formations.

Known range: — The upper part of the *Globorotalia kugleri* Zone to Recent.

Globigerinoides transitorius Blow, 1956
Pl. 56, figs. 7, 8

Globigerinoides transitoria (Blow). Bolli, 1957a, p. 115, pl. 27, nos. 12–15, text-fig. 3 (stage B).

Porticulasphaera transitoria (Blow). Bolli, 1957a, p. 115, pl. 27, fig. 3; Blow, 1959, p. 202, 203, pl. 14, figs. 87a, b.

Globigerinoides transitorium Blow. Bermudez, 1961, p. 1242, pl. 12, fig. 2.

Remarks: – Rare. This species has a penultimate chamber embracing the earlier test and is nearly equal in size to the final one. The size ranges from 0.40 to 0.60 mm. in maximum diameter.

Hypotype: – IGPS coll. cat. no. 85307, from sample S–33, the Saigo formation; IGPS coll. cat. no. 85308, from sample Tk–3, the Isobe formation.

Occurrence and distribution: – This species occurs in the Kamiyokoze formation, Chichibu basin and the Fukushima formation, Takasaki district.

Known range: – The middle to upper part of the *Globigerinoides bisphericus* Subzone.

Globigerinoides trilobus (Reuss), 1850
Pl. 54, fig. 15

Globigerina triloba Reuss, 1850, p. 374, pl. 47, figs. 11a–d (*fide* Ellis and Messina, 1940 *et seq.*)
Globigerinoides triloba (Reuss). Blow, 1956, p. 62, text-fig. 1 (1–3); Hamilton and Rex, 1959, p. 792, pl. 253, figs. 17–19.
Globigerinoides triloba triloba (Reuss). Bolli, 1957a, p. 112, 113, pl. 25, figs. 2a–c, text-fig. 21 (1a, b); Blow, 1959, p. 187, pl. 11, figs. 6a, b; Chang, 1959a, p. 64, pl. 3, figs. 17a, b, pl. 4, figs. 1a, b; Jenkins, 1960, p. 353, pl. 2, figs. 5a–c.
Globigerinoides trilobus (Reuss). Takayanagi and Saito, 1962, p. 98, figs. 4a, b.

Remarks: – This species has the final chamber larger than all the earlier chambers combined. It differs from *G. glomerosus* in the absence of the multiple sutural apertures around the lower margin of the last chamber. Usually three chambers compose the bulk of the test, of which the antepenultimate one is much smaller than the penultimate. The size ranges from 0.27 to 0.51 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85309, from sample S–33, the Saigo formation.
Occurrence and distribution: – This species occurs rather ubiquitous among the Miocene formations of Japan, except for the middle to upper Miocene of northwestern Japan along the borderland of the Japan Sea.
Known range: – The *Globigerinita dissimilis* Zone to Recent.

Genus **Pulleniatina** Cushman, 1927
Pulleniatina obliquiloculata (Parker and Jones), 1865
Pl. 54, figs. 6–8

Pullenia sphaeroides (d'Orbigny) var. *obliquiloculata* Parker and Jones, 1865, p. 365, 368, pl. 19, figs. 4a, b; Banner and Blow, 1960, p. 25, pl. 7, figs. 4a–c (lectotype) [written as *Pullenia sphaeroides* var. *obliquiloculata* Parker and Jones 1865=*Pulleniatina olbiquiloculata* (Parker and Jones) in pl. 7].
Pullenia obliquiloculata Parker and Jones. Brady, 1884, p, 618, pl. 84, figs. 16–20.
Pulleniatina obliqueloculata (*sic.*) (Parker and Jones). Cushman, 1927, p. 90, pl. 19, figs. 5a, b; Bolli, Loeblich and Tappan, 1957, p. 33, pl. 4, figs. 3a–5.
Pulleniatina obliquiloculata (Parker and Jones). Takayanagi and Saito, 1962, p. 98, pl. 27, figs. 4a, b, with synonymy up to 1961; Parker, 1962, p. 234, pl. 4, figs. 13–16, 19, 22.

Remarks: – The Miocene forms are usually much smaller than the typical Recent ones and the diagnostic shiny shell structure is only found in the last one or two chambers. The smaller forms from the *G. menardii menardii*/*G. nepenthes* Zone show the finely pitted wall surface with *Globigerina*-like appearance and often have a distinct lip. Dissecting the later chambers, the following morphological changes during ontogeny are observed both in the smaller Miocene forms and the typical Recent ones. The most incipient forms with the diagnostic characters of the typical *Pulleniatina*, have the transformed last chamber with finely pitted wall surface showing smooth and shiny appearance, the low trochospiral test with four chambers per later whorl of *Globigerina*-like appearance, and the somewhat umbilical-extraumbilical aperture with rather high-arch and a rim-like lip.

Removing the later chambers further, however, quite a different form is noted. This earliest form (as nearly two and/or two and a half whorl stage), has the low trochospiral test with five chambers in the later whorl most resembling *Globigerina angustiumbilicata*, a somewhat umbilical-extraumbilical aperture with a faint lip, more or less open umbilicus, and shell surface hispid rather than pitted.

The writer has never seen forms with distinct features of *Pulleniatina* earlier than

the *G. menardii menardii/G. nepenthes* Zone. It may be probable that *Pulleniatina* evolved from *Globigerina* through the stages discussed above within the *G. menardii menardii/G. nepenthes* Zone. The size ranges from 0.22 to 0.38 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. nos. 85311–85312, from sample A–7, the Nobori formation, Shikoku; IGPS coll. cat. no. 85313, from the *Globigerina* ooze, S.S. Manshu station no. 140; Lat. 2°50′05″N., long. 133°54′E.
Occurrence and distribution: – In the Miocene of Japan this species occurs rather rarely and is distributed as far north as Lat. 34°40′N., in the Sagara formation.
Known range: – The *Globoroalia menardii menardii/Globigerina nepenthes* Zone to Recent.

Genus ***Sphaeroidinella*** Cushman, 1927
Sphaeroidinella dehiscens (Parker and Jones), 1865

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones. 1865, p. 369, pl. 1, figs. 5a–c; Banner and Blow, 1960b, p. 35, 36, pl. 7, figs. 3a, b (lectotype) [written as *Sphaeroidina bulloides* d'Orbigny var. *dehiscens* Parker and Jones 1865=*Sphaeroidinella dehiscens* (Parker and Jones) in pl. 7].
Sphaeroidina dehiscens Parker and Jones. Brady, 1884, p. 621, pl. 84, figs. 8–11.
Sphaeroidinella dehiscens (Parker and Jones). Cushman, 1927, p. 90, pl. 19, figs. 2a, b; LeRoy, 1941b, p. 87, pl. 6, fig. 19; Cushman, Todd and Post, 1954, p. 369, pl. 91, fig. 14; Bolli, Loeblich and Tappan, 1957, p, 32, 33, pl. 6, figs. 1–5, (lectotype designated); Grahm and Militante, 1959, p. 114, pl. 19, figs. 5a, b; Bradshaw, 1959, p. 49, pl. 8, figs. 21–23; Chang, 1959b, p. 88, pl. 2, fig. 11; Huang, 1960, p. 65, pl. 1, figs. 22, 26; Takayanagi and Saito, 1962, p. 99, pl. 27, figs. 3a, b; Parker, 1962, p. 234, pl. 5, figs. 1, 2.

Remarks: – This species differs from the other species of *Shaeroidinellopsis* in having supplementary sutural apertures in the adult. Both the primary and the supplementary apertures are furnished with smooth or crenulate lips and sometimes are secondarily thickened with imperforate shell material to show a flange-like appearance. *Sphaeroidinella* and *Sphaeroidinellopsis* generally show a shiny shell surface due to the development of cortex. The size ranges from 0.34 to 0.56 mm. in maximum diameter.
Occurrence and distribution: – In Japan, the typical *S. dehiscens* first appears in the Nobori formation, which is comtemporaneous with the *Globorotalia menardii menardii/Globigerina nepenthes* Zone (Takayanagi and Saito, *loc. cit.*), but is not so common in the Miocene as in the overlying formations.
Known range: – The *Globorotalia menardii menardii/Globigerina nepenthes* Zone to Recent.

Genus ***Sphaeroidinellopsis*** Banner and Blow, 1959
Sphaeroidinellopsis seminulina (Schwager), 1866
Pl. 56, fig. 13

Globigerina seminulina Schwager, 1866, p. 256, pl. 7, fig. 112; LeRoy, 1941a, p. 44, pl. 3, fig. 108; Banner and Blow, 1960, p. 24, 25, pl. 7, figs. 2a, b (neotype) [written as *Globigerina seminulina* Schwager 1866=*Sphaeroidinellopsis seminulina* (Schwager) in pl. 7].
Sphaeroidinella grimsdalei (Keijzer). Bolli, 1957a (part), p. 114, pl. 26, figs. 8–11 (not figs. 12a–c), (not *Globigerina grimsdalei* Keijzer, 1945).
Sphaeroidinella seminulina (Schwager). Todd, 1957, p. 279, pl. 79, figs, 7a, b; Chang, 1959a, p. 6, 67, pl. 4, figs. 5a, 10b.
Sphaeroidinella seminulina seminulina (Schwager). Blow, 1959, p. 197, 198, pl. 12, figs. 74–77c.
Sphaeroidinellopsis seminulina (Schwager). Takayanagi and Saito, 1962, p. 99, 100, pl. 25, figs. 12a–c.
Sphaeriodinellopsis seminulina seminulina (Schwager). Belford, 1962, p. 31, pl. 8, figs. 22–25.

Remarks: – "*Seminulina*" of Schwager has been reviewed and re-illustrated in detail by Banner and Blow (*loc. cit.*). The variation noted by Blow (1959) is also recognized in the Japanese specimens and the forms with three to four chambers in the final whorl are included

in the same species. Among the specimens from the Japanese Miocene, four chambered forms are rather rare. The size ranges from 0.28 to 0.66 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85314, from sample S–33, the Saigo formation.
Occurrence and distribution: – In Japan, this species occurs as far north as Lat. 40°24′N., in association with *G. mayeri*, and as far north as Lat. 36°57°N., in association with the assemblage of the *Globorotalia menardii menardii/Globigerina nepenthes* Zone. This species has never been found in the so-called Pliocene of Japan.
Known range: – The upper part of the *Globigerinatella insueta/Globigerinoides trilobus* Subzone to the top of the *Sphaeroidinellopsis seminulina* Zone.

Sphaeroidinellopsis subdehiscens (Blow), 1959
Pl. 56, fig. 12

Sphaeroidinella dehiscens subdehiscens Blow, 1959, p. 195, 196, pl. 12, figs. 71a–c, 72.
Sphaeroidinellopsis subdehiscens (Blow). Banner and Blow, 1959, p. 15, text-fig. 5 (a–c) (reproduction of holotype); Belford, 1962, p. 30, 31, pl. 8, figs. 26–28.

Remarks: – This species was originally separated from *S. seminulina* by the final chamber being nearly equal to the preceding two chambers combined in size. However, distinction in practice seems to be subtle. The size ranges from 0.20 to 0.50 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85315, from sample Sg–1, the Sagara group.
Occurrence and distribution: – Rare, but found from the Sagara and Kakegawa groups, Shizuoka Prefecture.
Known range: – The uppermost part of the *Globorotalia fohsi robusta* Zone to the *Globigerina bulloides* Zone, Pozon formation.

Genus ***Orbulina*** d'Orbigny, 1839
Orbulina suturalis Bronniman,, 1951

Candorbulina universa Jedlitschka, 1934 (part), p. 21, text-figs. 5, 6 (not figs. 1a–4b, 7, 19, 21–23), (*fide* Ellis and Messina, 1940 *et seq.*)
Orbulina suturalis Bronnimann, 1951b, p. 135, text-fig. 2 (1–5) text-fig. 3 (3–8, 11, 13–16, 18, 20–22), text-fig. 4 (2–4, 7–12, 15, 16. 19–22); Blow, 1956, p. 66–69, text-fig. 2 (5–7); Bolli, 1957a, p. 115, pl. 27, fig. 4; Blow, 1959, p. 200, pl. 13, figs. 82a, b; Takayanagi and Saito, 1962, p. 100, pl. 24, fig. 3.

Remarks: – This species is characterized by having the globular, inflated final chamber not entirely enveloping the earlier part of the test, and the subcircular or circular pore-like apertures distributed over the final chamber. The size ranges from 0.25 to 0.68 mm. in maximum diameter.
Occurrence and distribution: – This species is first noted in the *Globorotalia fohsi barisanensis* Zone and is occasionally found rather rarely in the superjacent formations.
Known range: – The top of the *Globigerinatella insueta/Globigerinoides bisphericus* Subzone to Recent.

Orbulina universa d'Orbigny, 1839

Orbulina universa d'Orbigny, in Ramon de la Sagra, 1839, p. 2, pl. 1, fig. 1 (*fide* Ellis and Messina, 1940 *et seq.*); Bronnimann, 1951b, p. 134, text-figs. 3 (12), 4(1, 13, 14); Blow, 1956, p. 66, text-figs. 2(8, 9); Bolli, 1957a, p. 115, 115, pl. 27, fig. 5; Blow, 1959, p. 200, pl. 13, fig. 83; Jenkins, 1960, p. 356, pl. 3, fig. 120; Takayanagi and Saito, 1962, p. 100, 101, pl. 27, fig. 1.
Candorbulina universa Jedlitschka, 1934 (part), p. 21, text-figs. 1a–4b, 7, 19, 21a–23b (not fig. 5, 6).

Remarks: – In this species, the inflated spherical last chamber completely envelops all the earlier chambers, and the apertures are irregularly distributed over the last chamber. The size ranges from 0.22 to 0.65 mm. in maximum diameter.

Occurrence and distribution: – "The point of lowest stratigraphic occurrence" of *O. universa* is defined as the *Orbulina* surface to constitute a time datum of the middle Tertiary by LeRoy (1948, p. 502). Since then, this surface had been discussed by many foraminiferologists. The supposed evolutional lineage of *G. trilobus* to *Orbulina universa* as suggested by Blow (1956) may be an excellent approach to pursue this surface.

In the Saigo formation of the Kakegawa district, the evolutional lineage of *G. trilobus* to *Orbulina universa* can be traced up to the stage of *Globigerinoides glomerosus*, but not further because of the stratigraphic break at the top of that formation. In the Tomioka section of the Takasaki district, *Orbulina universa* first appears with a fauna equivalent to the *Globorotalia fohsi barisanensis* Zone. Because of the rather rough sampling intervals, the initial appearance of this species is not definite, but may be between the *Globigerinoides bisphericus* assemblage (sample Tk–3) and the *G. fohsi barisanensis* assemblage (sample Tk–13) within some ten meters of stratigraphic interval.
Known range: – The top of the *Globigerinatella insueta* /*Globigerinoides bisphericus* Subzone to Recent.

Genus ***Globigerinita*** Bronnimann, 1951
Globigerinita dissimilis (Cushman and Bermudez), 1937
Pl. 56, figs. 1a, b

Globigerina dissimilis Cushman and Bermudez, 1937, p. 25, 26, pl. 3, figs. 4–6.
Catapsydrax dissimilis (Cushman and Bermudez), Bolli, Loeblich and Tappan, 1957, p. 37, pl. 7, figs. 6a–c (reproduction of holotype), 7a–8c; Blow, 1959, p. 203, pl. 12, figs. 88–90.
Globigerinita dissimilis (Cushman and Bermudez). Bermudez, 1961, p. 1262, 1263, pl. 7, figs. 5a–5c.
Globigerinita dissimilis dissimilis (Cushman and Bermudez). Blow and Banner, *in* Eames *et al.*, 1962, p. 106, 107, pl. 14, fig. D.
Globigerinita dissimilis ciperoensis Blow and Banner, *in* Eames *et* al., 1962, p. 107, 108, pl. 14, figs. A-C.

Remarks: – The generic position of "*dissimilis*" has been a subject of much discussion. The type species of *Catapsydrax* of Bolli *et al.* (1957) is *Globgierina dissimilis* Cushman and Bermudez, which has the umbilical aperture covered by a single umbilical bulla with one or more accessory infralaminal apertures. They stated the genus to be different from *Globigerinita* Bronnimann by having a small umbilical bulla with relatively few infralaminal accessory apertures which are sutural in position. However, in planktonic foraminiferal taxonomy many distinct species develop occasionally such features as umbilical bulla during the stages of growth. And whether such distinction is a reliable taxonomic criteria is open to question. In the case of *G. dissimilis*, it is most important to remove the umbilical bulla to determine its specific position, because the species may be a variant of some other species with bulla as is often observed. As an example of such a case, Hofker (1959, p. 6) supposed *dissimilis* to be a "reproductionary development stage of *Globigerina venezuelana* Hedberg". The writer has studied several specimens of *dissimilis* from the "*Catapsydrax*" *stainforthi* Zone of the Agua-Salada group. The bulla of these specimens as well as those from Japan, generally consist of thinner and more finely perforated wall than that of the normal chambers. In this point, the bulla of *dissimilis* resembles those of *Globigerina glutinata* and of many other globigerines. The form removed of the bulla, however, differs from *G. venezuelana* and is characterized by having the inflated subglobular chambers with coarsely perforated wall, more or less lobulated chambers with rather low trochospiral arrangement, and a low arched aperture with rim-like lip. The forms removed of the bulla do not seem to be identical with any known species. Even though the present species is only a development stage within the life-cycle of any species of globigerines, there might be some particular ecological conditions to provoke the development of such feature as a bulla during a certain geological age over the world.

Because of the inaccessibility of further materials, the writer herein follows the view of Blow and Banner (*loc. cit.*) and the name *Globigerinita* is used to include the types allied with this species. The size ranges from 0.22 to 0.42 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85318, from the Horai formation, Shizuoka Prefecture (lower Oligocene).
Occurrence and distribution: – Rather rare, found only in the Kakegawa district.
Known range: – The upper part of the *Truncorotaloides rohri* Zone (in Navet formation = middle Eocene) to the top of the *Globigerinita stainforthi* Zone.

Globigerinita unicava (Bolli, Loeblich and Tappan), 1957
Pl. 56, figs. 2a, b

Catapsydrax unicavus Bolli, Loeblich and Tappan, 1957, p. 37, pl. 7, figs. 9a–c; Blow, 1959, p. 204, 205, pl. 15, figs. 94a–c.
Globigerinita unicava unicava (Bolli, Loeblich and Tappan). Blow, and Banner, *in* Eames *et al.*, 1962, p. 113, 114, pl. 14, figs. M. N.

Remarks: – This species differs from *G. dissimilis* in having less inflated chambers and the umbilical bulla with only a single infralaminal aperture. The size ranges from 0.20 to 0.40 mm. in maximum diameter.
Hypotype: – IGPS coll. cat. no. 85319, from sample M–5, the Towata formation.
Occurrence and distribution: – Rare, found only in the Kakegawa district.
Known range: – *Globigerina ampliapertura* Zone to the *Globigerinita stainforthi* Zone.

Genus **Globigerinatella** Cushman and Stainforth, 1945
Glogigerinatella insueta Cushman and Stainforth, 1945
Pl. 54, figs. 2, 3

Globigerinatella insueta Cushman and Stainforth, 1945, p. 69, pl. 13, figs. 7–9; Bronnimann, 1950, p. 80–82, pl. 13, figs. 1–12, pl. 14, figs. 1–13; Bolli, Loeblich and Tappan, 1957, p. 38, 39, pl. 8, figs. 4–7a; Blow, 1959, p. 205, 206, pl. 15, 95–98; Bermudez, 1961, p. 1267, 1268, pl. 19, figs. 24–26 (reproduction of holotype).

Remarks: – This characteristic and distinct Miocene species occurs rather rarely in Japan. The writer has examined many specimems of this species from the San Lorenzo and Pózon formations of the Agua-Salada group and the Japanese forms are identical with them. The Venezuela specimens as well as the types of Cushman and Stainforth are much smaller in size and have thinner test wall than the present specimens. However, these forms show the areal pustules or secondary bulla and the areal secondary apertures which are characteristic. One hypotype from the Kamiyokoze formation, Chichibu basin was subjected to removal of the outer-most wall and this procedure revealed the characteristic areal secondary apertures. The size ranges from 0.18 to 0.30 mm. in maximum diameter.
Hypotypes: – IGPS coll. cat. no. 85320, from sample Ch–14, Kamiyokoze formation, Chichibu basin, Saitama Prefecture: IGPS coll. cat. no. 85323, from sample Ft–24, the Futamata formation, Shizuoka Prefecture.
Occurrence and distribution: – Rare; found in rather restricted localities in southern Japan; Kakegawa district and Chichibu basin. In New Zealand and southeast Australia, this species has not been recognized. In Japan, this species has been found as far north as Lat. 36°N., but is restricted in geographical distribution compared with usually concomitant species, *G. bisphericus*. This may suggest the rather tropical habitat of *G. insueta*.
Known range: – The base of the *Globigerinita stainforthi* Zone to the top of the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone.

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Explanation of Plate 53

Figs. 1a–2. *Globorotalia fohsi fohsi* Cushman and Ellisor.
1a, Umbilical view of hypotype (IGPS coll. cat. no. 79037); 1b, side view; 1c, spiral view. × 70. From sample Uy–6, the Uyashinai formation. 2, Spiral view of small hypotype (IGPS coll. cat. no. 79036), × 119. From the Numazawa formation.

Figs. 3a–4. *Globorotalia fohsi barisanensis* LeRoy.
3a, Umbilical view of hypotype (IGPS coll. cat. no. 79038); 3b, side view; 3c, spiral view. × 119. From sample S–33, the Saigo formation. 4, Spiral view of hypotype (IGPS coll. cat. no. 79039). × 119. From sample S–8, the Saigo formation.

Figs. 5a–c. *Globorotalia mayeri* Cushman and Ellisor.
5a, Umbilical view of hypotype (IGPS coll. cat. no. 79045); 5b, spiral view; 5c, side view. × 119. From sample Ch–14, the Kamiyokoze formation.

Figs. 6a–c. *Globorotalia scitula praescitula* Blow.
6a, Umbilical view of hypotype (IGPS coll. cat. no. 85304); 6b, side view; 6c, spiral view. × 70. From sample S–15, the Saigo formation.

Figs 7a–c. *Globorotalia menardii miocenica* Palmer.
7a, Umbilical view of hypotype (IGPS coll. cat. no. 79038); 7b, side view; 7c, spiral view. × 70. From the Nishizaki formation.

Figs. 8a–c. *Globorotalia tumida* (Brady).
8a, Umbilical view of hypotype (IGPS coll. cat. no. 85306); 8b, side view; 8c, spiral view. × 191. From the Higashi-innai formation.

Figs. 9a–10. *Globorotalia bykovae* (Aisenstat).
9a, Umbilical view of hypotype (IGPS coll. cat. no. 79042); 9b, side view; 9c, spiral view. × 119. From the Kokozura formation. 10, Spiral view of hypotype (IGPS coll. cat. no. 79041). × 119. From sample 27, the Joyama formation.

Fig. 11. *Globorotalia praemenardii* Cushman and Stainforth.
11, Spiral view of hypotype (IGPS coll. cat. no. 85301). × 119. From the Numazawa formation.


1a
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1c
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3a
3b
3c
4
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5c
6a
6b
6c
8a
8b
7a
7b
7c
8c
9a
9b
9c
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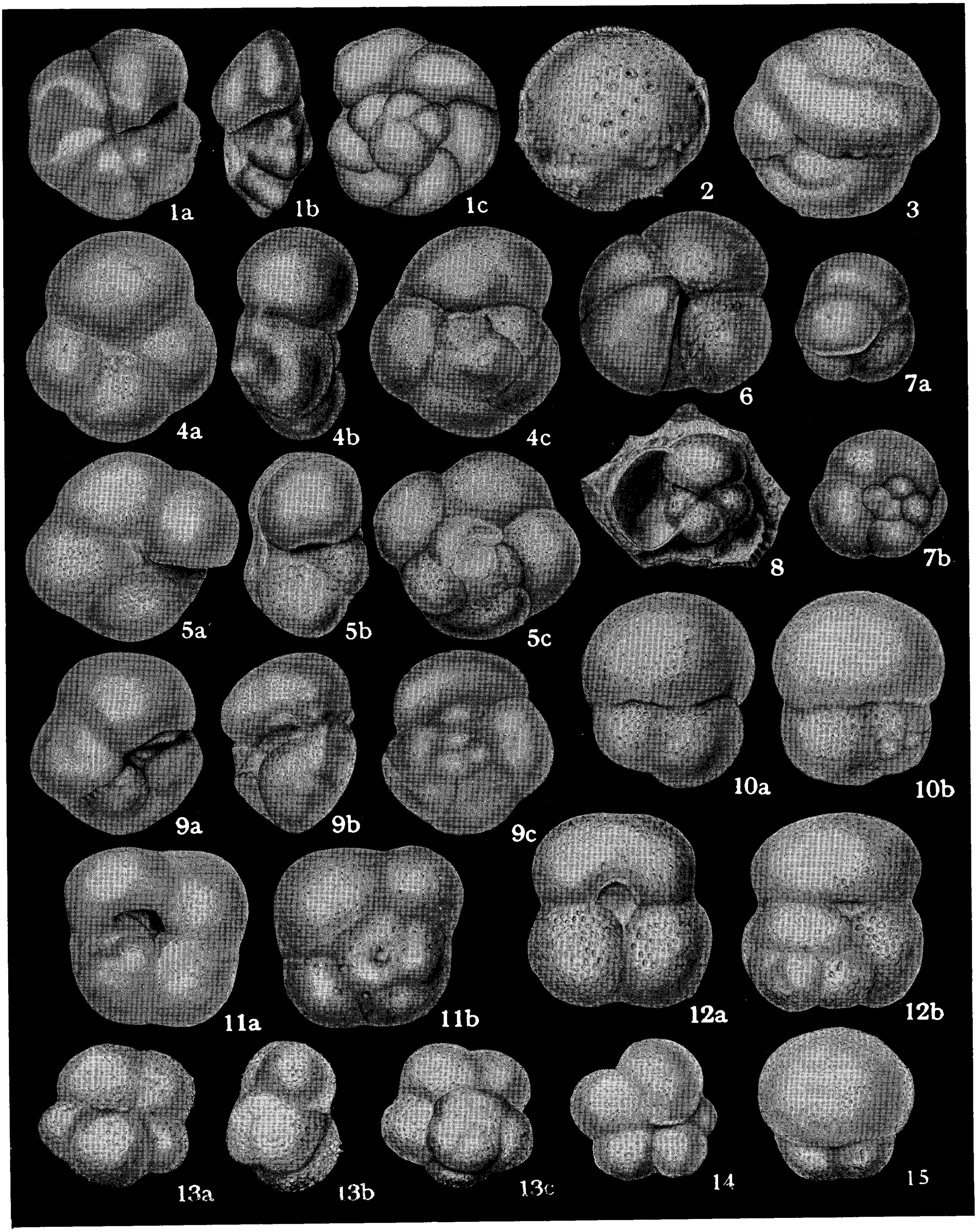
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9c
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11b
12a
12b
13a
13b
13c
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Explanation of Plate 54

Figs. 1a–c. *Globorotalia lenguaensis* Bolli.
1a, Umbilical view of hypotype (IGPS coll. cat. no. 79044); 1b, side view; 1c, spiral view. × 119. From the Shimoshiraiwa locality.

Figs. 2, 3. *Globigerinatella insueta* Cushman and Stainforth.
2, Dissected hypotype (IGPS coll. cat. no. 85320), showing areal apertures. × 70. From sample Ch–14, the Kamiyokoze formation. 3, Edge view of hypotype (IGPS coll. cat. no. 85323), showing enveloping final chamber and areal bulla. × 70. From sample Ft-24, the Futamata formation.

Figs. 4a–5c. *Globorotalia adamantea* Saito, n. sp.
4a. Umiblical view of holotype (IGPS coll. cat. no. 79033); 4b, side view; 4c, spiral view. 5a, Umbilical view of paratype (IGPS coll. cat. no. 79034), showing the form with aberrant fourth chamber. × 119. Both from the lower part of the Numazawa formation.

Figs. 6–8. *Pulleniatina obliquiloculata* (Parker and Jones).
6, Umbilical view of hypotype (IGPS coll. cat. no. 85311). 7a, Umbilical view of small hypotype (IGPS coll. cat. no. 85312), showing the earlier ontogenetic stage; 7b, spiral view. Both from sample A–7, the Nobori formation. 8, Dissected hypotype (IGPS coll. cat. no. 85313), showing neanic *Globigerina*-like stage with hispid test. From the Recent *Globigerina* ooze (collected from the Lat. 2°50′5″N., Long. 133°54′E. by the S.S. Manshu). All × 119.

Figs. 9a–c. *Globorotalia zealandica* Hornibrook.
9a, Umbilical view of hypotype (IGPS coll. cat. no. 79032); 9b, side view; 9c, spiral view. × 119. From sample S–34, the Saigo formation.

Figs. 10a, b. *Globigerinoides bisphericus* Todd.
10a, Umbilical veiw of hypotype (IGPS coll. cat. no. 79044); 10b, spiral view. × 70. From sample S–34, the Saigo formation.

Figs. 11a, b. *Globigerina pachyderma* (Ehrenberg).
11a, Umbilical view of hypotype (IGPS coll. cat. no. 79049); 11b, spiral view. × 119. From the Tsuchizaki R–7 boring core (Depth 1670 m.), the Funakawa formation.

Figs. 12a, b. *Globigerinoides ruber subquadratus* Bronnimann.
12a, Umbilical view of hypotype (IGPS coll. cat. no. 85305); 12,b spiral view. × 119. From sample S–33, the Saigo formation.

Figs. 13a–14. *Globigerina weissi* Saito, n. sp.
13a, Umbilical view of holotype (IGPS coll. cat. no. 85321); 13b, side view; 13c, spiral view. × 119. From sample S–3.5, the Saigo formation. 14, Umbilical view of paratype (IGPS coll. cat. no. 85322). × 119. From sample Od–3, the Oidawara formation.

Fig. 15. *Globigerinoides trilobus* (Reuss).
15, Umbilical view of hypotype (IGPS coll. cat. no. 85309). × 119. From sample S–33, the Saigo formation.

Explanation of Plate 55

Figs. 1a–2b. *Globoquadrina conglomerata* (Schwager).
1a, Umbilical view of hypotype (IGPS coll. cat. no. 85324), showing distinct umbilical teeth; 1b, side view; 1c, spiral veiw. From the Kokozura formation. 2a, Umbilical view of hypotype (IGPS coll. cat. no. 85325); 2b, spiral view. All × 119. From the Recent *Globigerina* ooze (collected from the Lat. 2°50′5″N., Long. 133°54′E. by the S.S. Manshu).

Fig. 3. *Globoquadrina eximia* (Todd).
3, Umbilical view of hypotype (IGPS coll. cat. no. 78046). × 70. From the Shimoshiraiwa locality.

Fig. 4. *Globigerinoides glomerosus curvus* Blow.
4, Umbilical side of hypotype (IGPS coll. cat. no. 85302). × 119. From sample Tk–3, the Isobe formation.

Fig. 5. *Globigerinoides glomerosus glomerosus* Blow.
5, Umbilical side of hypotype (IGPS coll. cat. no. 85303). × 119. From sample S–34, the Saigo formation.

Figs. 6a–c. *Globoquadrina altispira altispira* (Cushman and Jarvis).
6a, Umbilical view of hypotype (IGPS coll. cat. no. 85326); 6b, side view; 6c, spiral view. × 119. From the Shimoshiraiwa locality.

Figs. 7a, b. *Globoquadrina praedehiscens* Blow and Banner.
7a, Umbilical view of hypotype (IGPS coll. cat. no. 79049); 7b, side view. The present specimen is somewhat appressed. × 119. From sample M–1, the Towata formation.

Figs. 8a–c. *Globoquadrina altispira globosa* Bolli.
8a, Umbilical view of hypotype (IGPS coll. cat. no. 85327); 8b, side view; 8c, spiral view. × 119. From the Shimoshiraiwa locality.

Figs. 9a–c. *Globoquadrina dehiscens* (Chapman, Parr and Collins).
9a, Umbilical view of hypotype (IGPS coll. cat. no. 85328(; 9b, side view; 9c, spiral view. × 70. From sample S–33, the Saigo formation.

Fig. 10. *Globoquadrina obesa* Akers.
10, Umbilical view of hypotype (IGPS coll. cat. no. 79047). × 70. From the Shimoshiraiwa locality.


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6b
6c
7a
8a
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8c
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9b
9c
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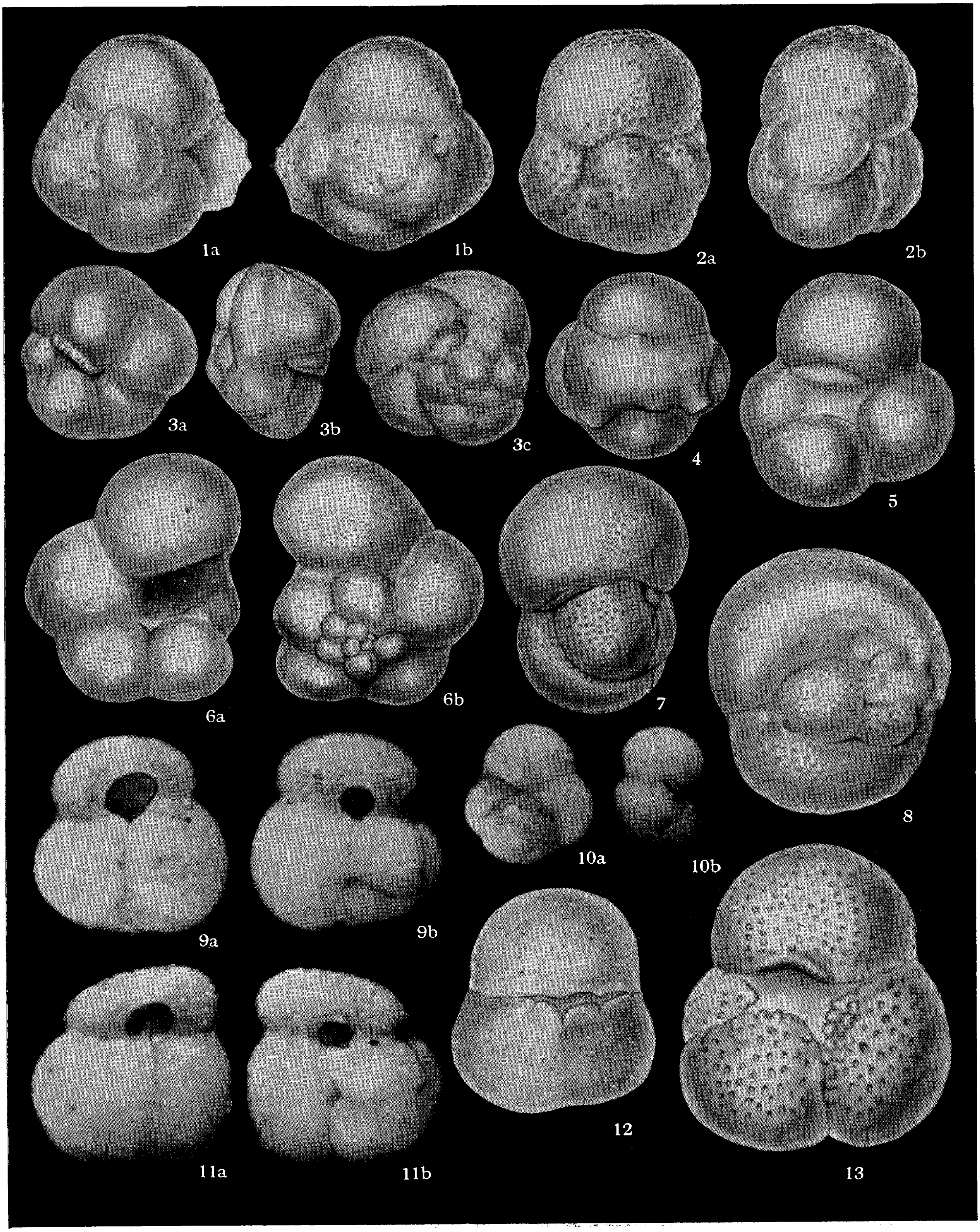
1a
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3c
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6a
6b
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9b
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11a
11b
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Explanation of Plate 56

Figs. 1a, b. *Globigerinita dissimilis* (Bolli, Loeblich and Tappan).
1a, Umbilical view of hypotype (IGPS coll. cat. no. 85318); 1b, spiral view. × 153. From the Horai formation.

Figs. 2a, b. *Globigerinita unicava* (Bolli, Loeblich and Tappan).
2a, Spiral view of hypotype (IGPS coll. cat. no. 85319); 2b, umbilical view. × 153. From sample M–5, the Towata formation.

Figs. 3a–c. *Globorotalia birnagea* Blow.
3a, Umbilical view of hypotype (IGPS coll. cat. no. 79040); 3b, side view; 3c, spiral view. × 153. From sample Od–3, the Oidawara formation.

Fig. 4. *Globigerina glutinata* Egger.
4, Umbilical side of hypotype (IGPS coll. cat. no. 85316), showing the well developed apertural bulla. × 153. From the Shimoshiraiwa locality.

Fig. 5. *Globigerina falconensis* Blow.
5, Umbilical view of hypotype (IGPS coll. cat. no. 85311). × 153. From the Shimoshiraiwa locality.

Figs. 6a, b *Globigerina concinna* Reuss.
6a, Umbilical view of hypotype (IGPS coll. cat. no. 85310); 6b, spiral view. × 153. From the Yatsuo formation.

Figs. 7, 8. *Globigerinoides transitorius* Blow.
7, Side view of hypotype (IGPS coll. cat. no. 85307). × 90. From sample S–33, the Saigo formation. 8, Side view of hypotype (IGPS coll. cat. no. 85308). × 90. From sample Tk–3, the Isobe formation.

Figs. 9a, b. *Globigerinoides ruber ruber* (d'Orbigny).
9a, Umbilical view of hypotype (IGPS coll. cat. no. 85329); 9b, spiral view. × 98. From sample A–17, the Nobori formation.

Figs. 10a, b. *Globorotalia opima continuosa* Blow.
10a, Umbilical view of hypotype (IGPS coll. cat. no. 85300); 10b, side view. × 45. From sample A–11, the Nobori formation.

Figs. 11a, b. *Globigerinoides elongatus* (d'Orbigny).
11a, Umbilical view of hypotype (IGPS coll. cat. no. 85330); 11b, spiral view. × 98. From sample A–17, the Nobori formation.

Fig. 12. *Sphaeroidinellopsis subdehsicens* (Blow).
12, Umbilical view of hypotype (IGPS coll. cat. no. 85315). × 90. From sample Sg–1, the Sagara formation.

Fig. 13. *Sphaeroidinellopsis seminulina* (Schwager).
13, Umbilical view of hypotype (IGPS coll. cat. no. 85314). × 90. From sample S–33, the Saigo formation.