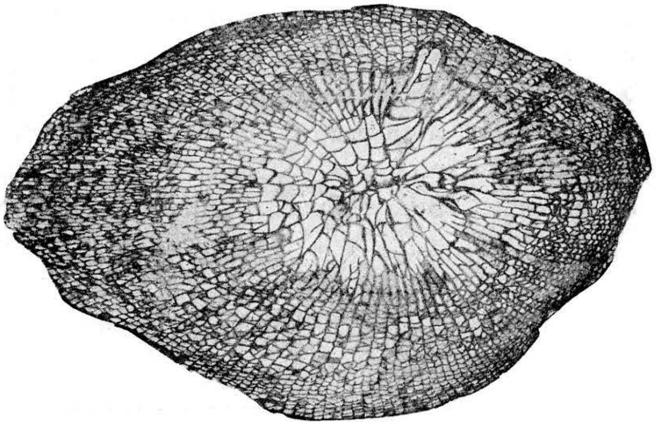
日本古生物学會
報告・紀事

Transactions and Proceedings
of the
Palaeontological Society of Japan

New Series No. 70



日本古生物学会

Palaeontological Society of Japan
June 30th, 1968

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TRANSACTIONS

All Communications relating to this Journal should be addressed to the
PALAEONTOLOGICAL SOCIETY OF JAPAN
Geological Institute, Faculty of Science, University of Tokyo, Japan

Trans. Proc. Palaeont. Soc. Japan, N. S., No. 70, pp. 233-237, June 30, 1968

537. ON SOME GASTROPODS FROM *MILLERELLA* ZONE OF THE AKIYOSHI LIMESTONE GROUP (MOLLUSCAN PALEONTOLOGY OF THE AKIYOSHI LIMESTONE GROUP-II)*

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秋吉石灰岩層群ミラエラ帯の腹足類数種について：山口県美祢市於福江原のウズラ採石場と美祢郡秋芳町秋吉の龍護峯東斜面における秋吉石灰岩層群ミラエラ帯の腕足類の殻が密集する石灰岩より産出した腹足類を検討し，このうちに従来その分布がヨーロッパの下部石炭系に限られていたアマガイモドキ亜科 *Turbonitella* 属の 2 新種および Euomphalidae 科 *Straparollus* (s. s.) 亜属の 1 新種を識別し，秋吉石灰岩層群産軟体動物化石研究の第 2 報として，こゝにそれらの記載を行う。

西 田 民 雄

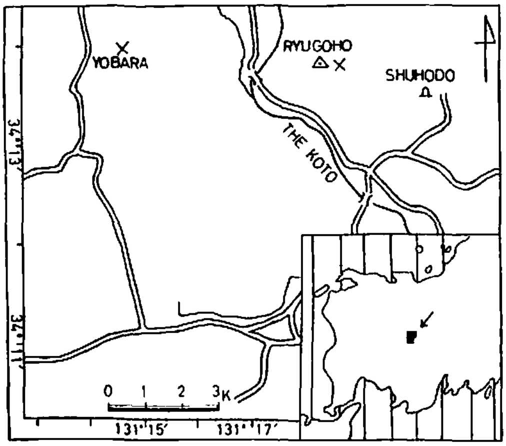
Introductory Note

Since YANAGIDA (1962) described many brachiopod species from the Uzura Limestone, which is exposed at the Uzura Limestone Quarry, 1200 m E of Yobara, Ofuku, Miné City, Yamaguchi Pref., belongs to the zone of *Millerella*, the study of the fauna of this limestone has been progressed by many investigators, YAMAGIWA and OTA (1963) for corals, YANAGIDA (1963, 1965) for brachiopods, SAKAGAMI (1964) for bryozoans and IGO (1965) for conodonts. As primarily described by YANAGIDA (1962, 1965), this limestone is massive and highly fossiliferous, its lower part being characterized by "coquinoid" or "bioclastic breccia" facies and its upper part by "true reef" facies. The limestone of a similar coquinoid facies is exposed in the limited area on the eastern slope of the Ryugoho, Akiyoshi, Shuho-cho, Miné-gun, Yamaguchi Pref., where it is slightly lower than the *Profusulinella beppensis* zone of TORIYAMA (1958) and consists mainly of brachiopod shells of almost single species, *Cleiothyridina roysii* (L'EVEILLE). I describe in this paper a new species of *Straparollus* (s. s.) and two new species of *Turbonitella* on the basis of newly collected specimens from the two localities (Text-fig. 1).

Before going further I wish to express my sincere gratitude to Professor Tatsuro MATSUMOTO of the Department of Geology, Kyushu University, for his kind encouragement during the course of this work and critical reading of the typescript.

Further I acknowledge Dr. Juichi YANAGIDA of the Department of Geology, Kyushu University and Dr. Masamichi OTA of the Akiyoshi-Dai Science Museum, who offered me valuable information on the stratigraphy and supplied me with many specimens for the study.

* Received July 22, 1967 read Sept. 23, 1967 at Tokyo.



Text-fig. 1. Map showing the collecting localities, indicated by ×.

Systematic Descriptions*

Superfamily Euomphalacea DE KONINCK, 1881

Family Euomphalidae DE KONINCK, 1881

Remarks.—EICHWALD (1871) in *Treatise* proposed Schizostomatidae to this family on the basis of *Schizostoma* BRONN, 1834, which is a subjective synonym of the subgenus *Straparollus* (*Euomphalus*) J. SOWERBY, 1814, as discussed by KNIGHT (1934) and YOCHELSON (1956).

Genus *Straparollus* DE MONFORT, 1810

Type-species.—*Straparollus dionysii* DE MONFORT, 1810, Lower Carboniferous of Belgium (original designation).

Generic Diagnosis.—Shell trochiform to discoidal, widely phaneromphalous throughout all growth stages; protoconch discoidal, followed by rounded whorls; mature whorl rounded to subquadrilateral in cross section; aperture with a shallow sinus.

Remarks.—*Straparollus* is variable in shell form, relatively high-spired trochiform to depressed discoidal. Some species referred to this genus have whorls out of contact except in younger stage and some other (of subgenus *Philoxene*) have foreign matters in addition to the contigeous whorls.

Subgenus *Straparollus* s. s.

Subgeneric Diagnosis.—Shell trochiform to discoidal, narrowly or widely phaneromphalous; whorls rounded, sometimes, with rounded spiral angulation on the upper whorl surface.

Remarks.—Some species of this subgenus have three spiral ridges or angulations on the outer whorl surfaces, which are more rounded than those of *S.* (*Euomphalus*).

Straparollus (*Straparollus*) *otai* sp. nov.

Plate 23, Figures 3-5

Material.—Holotype (ASM5025), paratype A, B (ASM5026, 7) collected by M. OTA from the eastern slope of the Ryugoho, Akiyoshi, Shuho-cho, Miné-gun, Yamaguchi Pref.

Diagnosis.—Shell low-trochiform; outer whorls with three rounded spiral angulations, of which the middle one is well defined.

Description.—Shell moderately small, trochiform, consisting of seven and a half volutions in the holotype; whorls rapidly increase and roughly rounded but with distinct three spiral angulations on its outer surface, of which the middle one on the periphery is well defined; periphery nearly at mid-whorl height; spire very low-conical; spire angle 118° in the holotype; apex, including first three and a half volutions, well flattened;

* Refer plate 23 of the preceeding volume (Trans. Proc. Palaeont. Soc. Japan, N.S., No. 69).

protoconch dextral in the holotype; umbilicus moderately deep: umbilical angle 73° in the paratype B: suture rather shallow, passing around the previous whorls at the middle angulations; growth-line, passing downward the whorls with a very slight insinuation over the upper angulation and orthocline below it.

Measurements.—

Specimen	Number of whorls	Height	Diameter	Umbilical diameter	Spire angle
Holotype (ASM5025)	7.5	8.3	16.1	9.1	118°
Paratype A (ASM5026)	7.0	8.0+	15.6	—	113°
Paratype B (ASM5027)	5.0	6.1+	10.3	—	111°

Discussion.—The three spiral angulations on the outer whorls separate this species from all other *Straparollus* (s. s.) except *Straparollus* (s. s.) *savagei* KNIGHT from the Pennsylvanian of North America. *Straparollus* (s. s.) *otai* differs from *Straparollus* (s. s.) *savagei* in having a more strongly developed middle angulation than the upper angulation. Other possible differences may be masked by the incomplete preservation of the present species.

Occurrence.—The present species occurs in the *Millerella* sp. α zone of the Akiyoshi Limestone Group.

Repository.—Type-room of the Akiyoshi-Dai Science Museum, Yamaguchi Pref.

Superfamily Neritacea RAFINESQUE, 1815

Family Neritopsidae GRAY, 1847

Subfamily Neritopsinae GRAY, 1847

Genus *Turbonitella* DE KONINCK, 1881

Type-species.—*Turbo biserialis* PHILLIPS, 1836, Lower Carboniferous Mountain Limestone, Bolland, Yorkshire, England (subsequent designation of COSSMANN, 1915).

Generic Diagnosis.—Shell trochiform, anomphalous; spire of moderate height; whorl profile strongly shouldered high up and gently arched below the shoulder; a narrow concave zone between the shoulders and a collar-like adpressed zone at the upper suture; base slightly flattened; columellar lip arcuate, thickened and extened in the plane of the aperture; outer lip nearly straight, slightly oblique backward; ribs or pustules collabrally lengthened and prominent on the shoulder and continuous downward on the spire, appearing in two rows on the last whorl.

Discussion.—Since DE KONINCK (1881) established this genus and placed it to Turbinidae, there have been much discussions as to its systematic position. ZITTEL (1885) placed this genus to Littorinidae, COSSMANN (1915) to Cyclonematidae and KNIGHT (1934) to Neritopsidae. *Turbonitella* is referred to Neritopsidae by its protruding spire and not resorbed inner whorls. As presently restricted, this genus ranges through the Lower Carboniferous in Europe.

Turbonitella yanagidai sp. nov.

Plate 23, Figures 6–9

Material.—Holotype (ASM5020), paratypes A, B, C (ASM5021-3) collected by J. YANAGIDA from the Uzura Limestone Quarry, 1200 m E of Yobara, Ofuku, Miné City, Yamaguchi Pref.

Diagnosis.—Spire rather low for the genus; spiral angle approximately 95°; pustules opistoclinely lengthened and rather strongly developed and separated by wide interspace.

Description.—Shell small, turbiniform, anomphalous; whorls rapidly expanded, consisting of four and a half volutions; whorl profile strongly shouldered high up and gently arched below the shoulder; a narrow concave zone between shoulders and a collar-like adpressed zone at the upper suture; spire small, conical; spire angle 95.6° in the holotype; protoconch simple, dextral; base slightly flattened; suture almost apressed; ornamentation consisting of growth-lines and pustules; pustules most prominent on the shoulder, being lengthened continuous below it on the spire and appearing again as an alternating row on the lower surface of the last whorl; columellar lip arcuate, thickened and with a shallow excavation within its margin; parietal lip somewhat thickened and extended in the plane of the aperture; outer lip thin, nearly straight, slightly oblique backward; shell structure not known; operculum not preserved in all specimens.

Measurements.—

Specimen	Number of whorls	Height	Spire height	Diameter	Apire angle
Holotype (ASM5020)	4.5	13.5	3.2	13.1	95.6°
Paratype A (ASM5021)	4.5	12.1	3.0	12.3	96.0°
Paratype B (ASM5022)	3.5	8.2	2.2	8.0	95.7°
Paratype C (ASM5023)	4.5	11.5	3.1	11.6	96.1°

Discussion.—The present species is closely allied to the type-species, *Turbonitella biseliaris* (PHILLIPS), from the Lower Carboniferous of Belgium, but differs by its opistocline and rather coarsely spaced pustules and a larger spire angle.

Occurrence.—The present species occurs in the *Millerella* sp. *α* zone of the Akiyoshi Limestone Group.

Repository.—Type-room of the Akiyoshi-Dai Science Museum, Yamaguchi Pref.

Turbonitella ryugohoensis sp. nov.

Plate 23, Figure 10

Material.—Holotype (ASM5030) collected by M. OTA from the eastern slope of the Ryugoho, Akiyoshi, Shuho-cho, Miné-gun, Yamaguchi Pref.

Diagnosis.—Spire rather high for the genus; spire angle about 70°; nodes prominent on the shoulder and opistoclinely elongated below it and appearing as two rows on the last whorl.

Description.—Holotype small, 13.5 mm. in height, 4.0 mm. in spire height, 11.1 mm. in diameter, trochiform, anomphalous, consisting of about four whorls; whorl profile slightly shouldered at the upper lateral part and slightly arched below the shoulder; a narrow concave zone between shoulders and a collar-like adpressed zone at the upper suture; spire small but rather large for the genus; spire angle about 70°; suture almost apressed; ornamentation consisting of growth-lines and nodes; nodes prominent on the shoulder and opistoclinely elongated below it, appearing as an alternating rows on the upper whorl face of the last whorl; aperture not observed; operculum not preserved.

Discussion.—The present species is now represented by a single specimen. It has however, so characteristic ornamentation that the establishment of a new species is warranted. Nodes on the outer whorls separate this species from all other known species of this genus. By other characters this species is safely refer to *Turbonitella*.

Occurrence.—The present species occurs in the *Millerella* sp. α zone of the Akiyoshi Limestone Group.

Repository.—Type-room of the Akiyoshi-Dai Science Museum, Yamaguchi Pref.

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ZITTEL, K. A. (1885): *Handbuch der Palaeontologie*. 2. Mollusca und Arthropoda, 900 pp., 719 pls. München und Leipzig.

Locality Guide

Uzura Limestone Quarry, 1200 m E of Yobara, Ofuku, Miné City, Yamaguchi Pref.
[Lat. N34°11′02″, long. E 131°15′21″].
ウズラ採石場，山口県美祢市於福江原東方 1200 m.

The eastern slope of the Ryugoho, Akiyoshi, Shuho-cho, Miné-gun, Yamaguchi Pref.
[Lat. E 34°13′42″, long. E 131°17′18″].
山口県美祢郡秋芳町秋吉龍護峯東斜面.

Trans. Proc. Palaeont. Soc. Japan, N. S., No. 70, pp. 238-266, pl. 27, June 30, 1968

538. BENTHONIC FORAMINIFERAL ZONATION OF THE KAZUSA GROUP, BOSO PENINSULA*

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房総半島，上総層群の底棲有孔虫分帯： 下部鮮新一下部更新統・上総層群の，房総半島北部，東京湾岸から太平洋岸にいたる東西断面内の底棲有孔虫化石群集についてまとめた。火砕岩質鍵層や岩相区分にてらして，各化石群集の層位学的分布や垂直的・水平的な変化を明らかにし，優勢種および特徴種については概略の分布を図示した。また，化石群集によって上総層群を 17 の化石帯に区分する。

これらの底棲群集やその変化は第1に，堆積盆地の海の深さによって規定されている。東部地域で最下部の勝浦一大原層にみられる *Gyroidina-Melonis* 群集は lower bathyal のものであり，中西部の基底の砂岩からの *Cassidulina* を主とする群集は一種の混合群集である。どこのセクションでも，それから上の層準にむかって順に，*Bulimina-Bolivina, Uvigerina, Cassidulina* の各群集，さらに浅海性群集へと変化する底棲群集の層序がみとめられ，中新世からの堆積盆地がこの時期に浅海化していったことを示している。水平的にはどの層準でも，東部より西部へ，次第に海がより浅くなる環境にあって，横の群集変化も垂直的な変化とよく似た傾向をもっている。また，多くの浅海性種が西より運ばれて，東のより深海性の群集のなかに混入している。

深海性の地層にあっても親潮の影響の強かった時期には，浮遊性群集ばかりでなく底棲群集の入れかえもおこなわれた。上総層群中～下部には，化石群集や構成種からそのような冷水温期が，時間に平行な化石帯として識別できる。冷水温期は数回くりかえして現われ，当時の古気候の変動を示している。

上総層群の各化石帯の群集組成・特徴や分布についてのべ，多産する小型の底棲有孔虫4新種を記載した。 青 木 直 昭

Introduction

The Boso Peninsula is situated in the central part of the Japanese Islands and bounds the Tokyo Bay on the eastern side, protecting it from the Pacific Ocean. For the study of Pliocene and Pleistocene Foraminifera, the sedimentary basin of Boso is believed to be a particularly unique and favorable field in Japan. In this region the marine sediments of these ages are considerably thick and mostly continuous. They are dominated by deeper, open sea facies and yield foraminiferal fossils in abundance throughout the sections.

This paper gives an outline of the Pliocene and lower Pleistocene benthonic foraminiferal assemblages from the Kazusa group, Boso Peninsula. The biostratigraphic subdivision of the group is made with reference to the stratigraphic distribution of these assemblages, which are expected to furnish more accurate information for the correlation of the strata, the paleo-environments and geological history of the basin.

* Received July 20, 1967; read January 25, 1966 at Sendai and September 24, 1966 at Akita.

Previous Work

The foraminifera of the Boso Peninsula were first observed by OTUKA (1932), who listed numerous species from the "Pliocene Sanuki" formation.

ASANO & NAKAMURA (1937a, b) and ASANO (1938a-e) published six monographical papers of the Tertiary and Recent smaller foraminifera of Japan. They described and figured several tens of species from the Pliocene and Pleistocene rocks of the Boso Peninsula. Numerous species were introduced as new. At the same time, ASANO (1938f-g) reported on the fossil foraminiferal assemblages.

Later, ASANO (1950-1952) engaged in the descriptive works of almost all of the known foraminiferal species from Japan and published "Illustrated catalogue of Japanese Tertiary smaller Foraminifera." Many of the benthonic species are re-figured from the Pliocene and Pleistocene formations in Boso.

UCHIO (1950-1952) studied the sequence of the foraminiferal assemblages of the "Pliocene" Kazusa group from the Otaki-Mobara natural gas field. He described some new taxa from this section and from the environs of the Minato-machi, western Boso.

TAKAYANAGI (1951) described the *Ehrenbergina* species and KUWANO (1954a, b) studied the *Cassidulina* species from the Pliocene formations in the western part of the Boso Peninsula.

HIRAYAMA (1954), KOIKE (1955), and KOMATSU & OMORI (1956) examined the foraminifera in some samples from the lower part of the Pliocene of the peninsula in relation to the sedimentological problems concerning the causes of turbidites and slumping structures.

In 1957-1958, ASANO made an important contribution to the Pleistocene geochronology in the Boso Peninsula. From the planktonic foraminiferal analysis, he concluded that the Pliocene-Pleistocene boundary can be set at the middle part of the Umegase formation.

The vertical faunal variation of the planktonic foraminifera from the Obitsu River section was studied by TAKAYAMA (1961, 1962). AOKI (1963) worked on the benthonic and planktonic assemblages from the Yoro River section. In 1964, he reported the vertical and lateral faunal variations of the planktonic assemblages in the Kazusa group.

ISHIWADA, HIGUCHI and KIKUCHI (1958-1965) studied successively the foraminifera collected from the subsurface of the various places in this region for the foraminiferal zoning and correlation of the subsurface columns, and they made clear the subsurface distributions of the Kazusa foraminiferal assemblages. ISHIWADA (1958a) first established the currently accepted zonation of the group, and recently he (ISHIWADA, 1964) attempted the paleoecological interpretations of the biofacies compared with the Recent benthonic foraminiferal assemblages off the Japanese Pacific coast.

Local Stratigraphy

The name Kazusa group was given to the Pliocene and lower Pleistocene rocks in the Boso Peninsula. Since 1950, detailed mapping of the group has been carried out by several petrolem geologists tracing a considerable number of pyroclastic layers intercalated in fine-grained sediments as very important marker-beds from the eastern side to the western one of the peninsula. Thickness and lithofacies variations in vertical and lateral directions of the strata in the important areas of the peninsula were satisfactorily clarified. The sampling of the foraminiferal material was made on the basis of these comprehensive stratigraphic works, which are listed in the bibliography at the end of this paper. Stratigraphical descriptions and reviews of this region have been given elsewhere by many workers.

The Kazusa group, in the present-day usage, is divided into the following nine formations along the Yoro River, the type section of the group (from upper to lower):

Kazusa Group
Kasamori formation (150 m): muddy fine-grained sandstone and sandy mudstone.
Mandano formation (40 m): sandstone and conglomeratic sandstone.
Chonan formation (75 m): alternation of fine-grained sandstone, muddy sandstone and mudstone.
Kakinokidai formation (75 m): massive fine-grained sandy mudstone intercalated with thin sandstone layers, and muddy fine-grained sandstone at the upper.
Kokumoto formation (340 m): thick siltstone and an alternation with sandstone.
Umegase formation (500 m): thick sandstone interbedding thin layers of siltstone, with an alternation of sandstone and siltstone.
Otadai formation (500 m): composite alternation of mud-rich and sand-rich alternations.
Kiwada formation (600 m): siltstone, and an alternation of siltstone and thin sandstone layers, intercalated with abundant layers of pyroclastic material.
Kurotaki formation (280 m): tuffaceous and scoriaceous, coarse to medium-grained sandstone, and andesitic tuffs, with conglomerate at the base and muddy sandstone at the upper.

The interval of the Kurotaki formation along the Yoro River section is diverged and thickened to the east, attaining more than 600 m in thickness at the eastern margin of the peninsula, and is further subdivided into three lithostratigraphic units as follows (from upper to lower):

Ohara formation (200 m): alternation of sandstone and siltstone.
Namihana formation (300 m): mudstone and mud-rich alternation of mudstone and sandstone.
Katsuura formation (300 m): sandstone, sandy mudstone, and an alternation of mudstone and sandstone, with conglomerate at the lower.

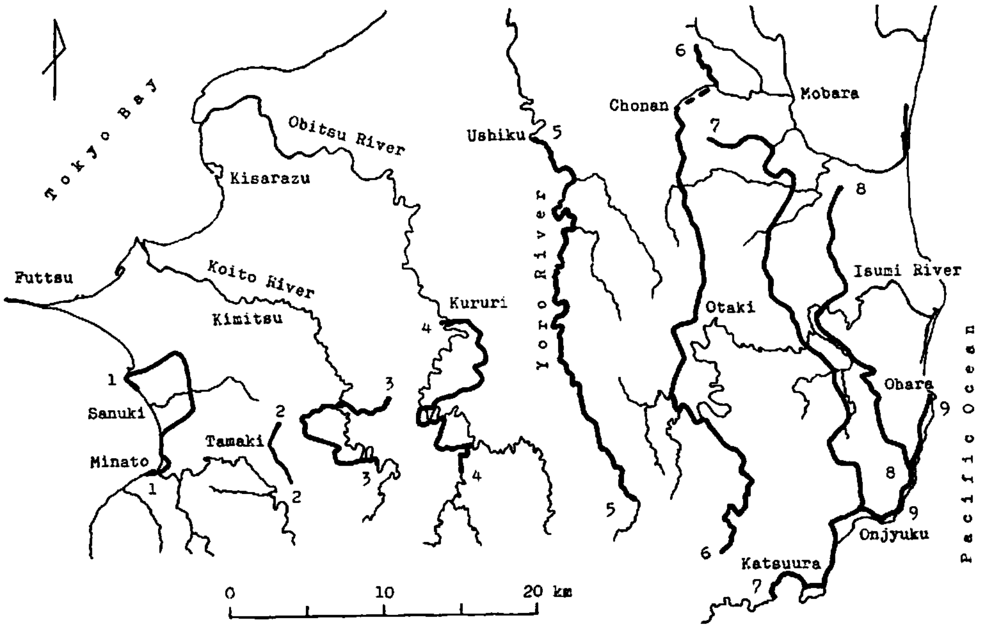
In the western part of the Boso Peninsula, the Kazusa group changes in lithofacies, becoming dominantly sandstone or sandy facies, and can be divided as follows (from upper to lower):

Kazusa Group
Sunami formation (150 m): mudstone, muddy sandstone and fine-grained sandstone.
Sanuki formation (100–200 m): mudstone and sandy mudstone.
Nagahama formation (20–100 m): conglomerate and sandstone.
—— probable unconformity ——
Ichijyuku formation (400 m): sandstone.
"Umegase formation" (100+m): alternation of sandstone and mudstone.
Higashihigasa formation (300 m): sandstone and conglomerate.
Iwasaka formation (100–200 m): silty fine-grained sandstone.
"Takamizo formation" (150 m): mudstone.
Kurotaki formation (500 m): tuffaceous sandstone and pyroclastics.

The supplementary works on the foraminifera and stratigraphy of the Nagahama and Sanuki formations are still under way, and are not treated in this paper. A stratigraphic profile of Fig. 2 illustrates the above-mentioned lithostratigraphic subdivision of the Kazusa group in the Boso Peninsula.

Rock-samples were collected from the following nine sections (routes) and some supplemental ones in the central zone of the Boso Peninsula, after measuring the strata and checking their stratigraphic positions. The locations of the sections are shown in Fig. 1.

(1) Minato-Sanuki section: Tomiya—Sanuki—Isone-saki
(2) Takamizo-Tamaki section: Takamizo—Tamaki—Tagura
(3) Koito River section: Masaki—Nishi-higasa—Naewari—Nashinoki
(4) Obitsu River section: Sasa-gawa--Kururi
(5) Yoro River section: Awamata--Ushiku
(6) Isumi-Mobara section: Katsuura—Otaki—Chonan—Mobara
(7) Katsuura-Mobara section: Katsuura—Onjyuku—Fuse—Kuniyoshi--Shin'meimae—Ikariyato—Sakamoto—Mobara
(8) Onjyuku-Ichinomiya section: Onjyuku—Namihama—Shakadani—Iwakuma—Ichinomiya
(9) East Coast section: Onjyuku—Namihana—Ohara



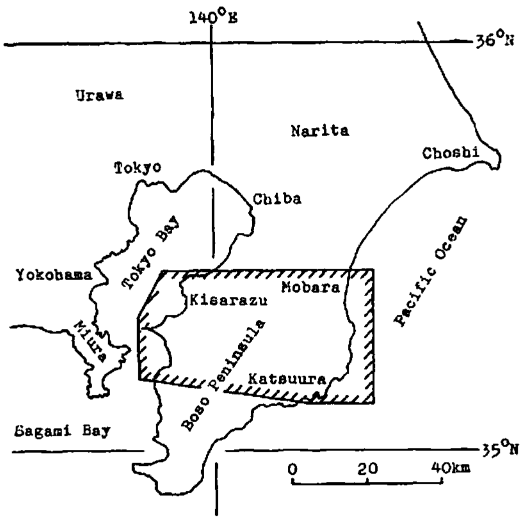


Fig. 1. Location of the examined sections (routes) of the Kazusa group, Boso Peninsula.

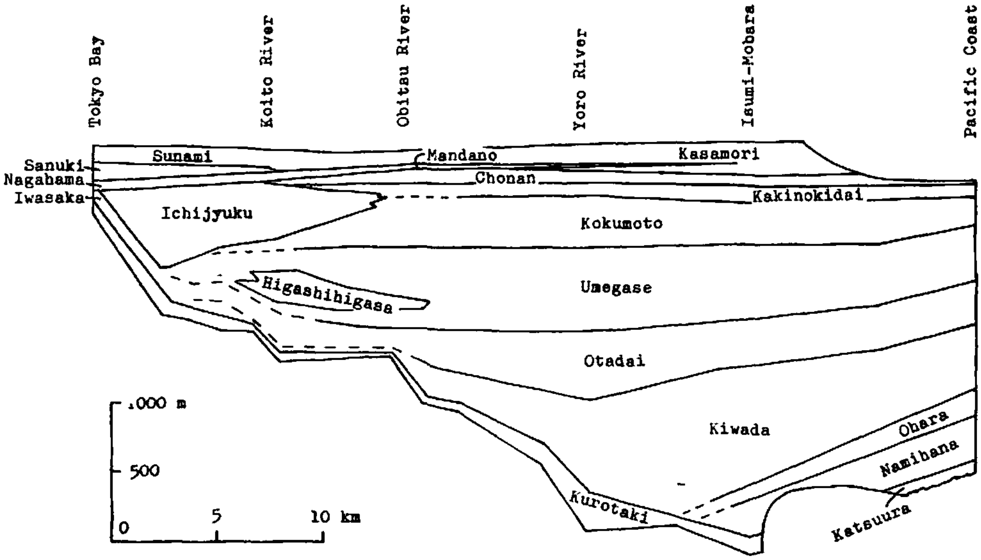


Fig. 2. Litho-stratigraphic subdivision of the Kazusa group, Boso Peninsula.

Foraminiferal Zoning

Both vertical and lateral variations of the foraminiferal assemblages are considerable in the Kazusa group, and a large number of foraminiferal species appear in and out of the section. Until present about 300 species have been distinguished. They are mostly of calcareous perforate forms. Then, cassidulinids, buliminids, bolivinids, cibidids and numerous shallow water species are important constituents of the Boso faunas. Planktonic foraminifera are also common. Porcellaneous and arenaceous forms are much less frequent, represented by a very small number of species and individuals in every horizons.

The occurrence and frequency distribution of individual species were carefully examined and checked in comparison with pyroclastic key beds as well as with lithostratigraphic divisions. Benthonic species having narrowly restricted vertical ranges are hardly detected in the Boso faunas. At least, no important ones are found. The specids previously regarded as indices of the lower Pliocene of this region are found in this study to occur in upper horizons. The stratigraphic ranges of some of these species would extend into Recent through Pleistocene. Unlike in older formations, the biostratigraphic subdivision by vertical ranges of local occurrences of the species is difficult to establish and is probably useless. Therefore, frequency distributions of the dominant and characteristic species and their assemblages are the important criteria for biostratigraphic zoning and correlation.

The benthonic foraminiferal zoning of the Kazusa group has been carried out for the purpose of the correlation of subsurface columns in natural gas exploration. Two or three sets of foraminiferal zones or zonules were proposed by the previous workers (Table 1). Some zones were named without clear difinition of the fossil contents and boundaries, although they are used by many workers and by oil companies. These subdivi-

Table 1. Comparison of the benthonic foraminiferal zonings previously established in the Kazusa group, Boso Peninsula.

Formation	UCHIO, 1951 Zone	UCHIO, 1951 Zonule	ISHIWADA, 1959 Zonule	ISHIWADA, HIGUCHI & KIKUCHI, 1962 Zonule	HIGUCHI, 1964 Zonule	KIKUCHI, 1964 Zonule	ISHIWADA, 1964 Facies	AOKI, 1962 Zone	AOKI (this paper) Zone
Kasamori				*Pseudoeponides —Elphidium*	*Pseudoeponides —Elphidium*	*Elphidium clavatum*	I	1 2	*Nonionella stella*
Mandano								3	"Mandano"
Chonan								4	*Cribroelphidium clavatum*
Kakinokidai	I	1-5	*Cassidulina subglobosa*	*Cassidulina subglobosa*	*Cassidulina subglobasa*	*Cassidulina subglobosa*	II	5	*Cassidulina snbglobosa*
Kokumoto		6-14	Lower Kokumoto	Lower Kokumoto	Lower Koku-moto Faunule	Lower Koku-moto Faunule	III	6	*Cassidulina subcarinata*
Umegase		15	*Uvigerina akitaensis*	*Uvigerina akitaensis*	*Uvigerina akitaensis*	*Uvigerina akitaensis*	VI	7	*Uvigerina akitaensis*
		16	*Bulimina aculeata —Bul. nipponica —Bolivina robusta*	*Bulimina aculeata*	*Bulimina aculeata*	*Bulimina aculeata*	V	8	*Bulimina aculeata*
	II	17-21		*Bolivina*	*Bolivina*	*Bolivina*		9	*Bulimina-Bolivina* (upper)
Otakai		22-23						10	*Bolivina spissa*
		24-28						11 12	*Bulimina-Bolivina* (lower)
Kiwada			*Ellipsonodosaria lepidula*	*Stilostomella lepidula* Subzonule	*Stilostomella lepidula* Subzonule	*Bulimina nipponica*		13	*Stilostomella ketienziensis*
			Bulimina nipponica	*Bulimina nipponica*	*Bulimina nipponica*			14	*Bulimina striata*
Ohara				*Bulimina aculeata*	*Bulimina aculeata*	*Bulimina aculeata*			*Gyroidina* cf. *orbicularis*
Namihana ~Katsuura				Basal Faunule	*Bulimina nipponica* Lower Kazusa Mixed Faunule	Basal Kazusa Faunule			*Gyroidina —Melonis* (undivided)

sions are re-examined and revised a little from the generalized standpoint in this paper based on the subaerial material obtained from the whole exposed area of the Kazusa group in the northern part of the peninsula.

The Kazusa fauna contains several different faunal groups which are easily distinguishable. It is divisible into 6 groups and further subdivided into 17 or more benthonic foraminiferal assemblages. The zones defined by these characteristic assemblages are as follows (from upper to lower):

(1) Shallow water zones
- *Nonionella stella* Zone
- "Mandano" Zone
- "Lower Kasamori" Zone
- *Cibicides-Pseudononion* Zone

(2) *Cassidulina* zones
- *Cassidulina subglobosa* Zone
- *Cassidulina subcarinata* Zone

(3) *Uvigerina* zone
- *Uvigerina akitaensis* Zone

(4) *Bulimina-Bolivina* zones
- *Bulimina aculeata* Zone
- *Bulimina-Bolivina* Zone (upper)
- *Bolivina spissa* Zone
- *Bulimina-Bolivina* Zone (lower)
- *Stilostomella ketienziensis* Zone
- *Bulimina striata* Zone

(5) Mixed assemblage zones
- *Cassidulina-Bulimina* Zone
- *Cassidulina-Cibicides* Zone

(6) *Gyroidina-Melonis* zones
- *Gyroidina* cf. *orbicularis* Zone
- *Gyroidina-Melonis* Zone (undivided)

One half of the above-listed zones are renamed and a few are newly proposed in this paper. The names of locally distributed zones are not given but conventionally substituted by the lithostratigraphic (geographic) names for simplification. The succession of the foraminiferal zones is more complete along the Yoro River section. The stratigraphic distributions of these benthonic foraminiferal zones and the lateral variations of the assemblages are shown in Fig. 3 and Table 2. The distributions of the common and characteristic benthonic foraminiferal species are shown in Fig. 4.

Depth Variations

All of the species may be distributed vertically and horizontally as wide as possible in a geologic section. The distributions of the benthonic species are naturally determined by the ecology of the species and the ecologic conditions of the environments. These species may have been assembled to form various characteristic faunal communities according to depositional environments. The complicated constitution with a considerable number of the species of the foraminiferal faunas is favorable for understanding the interrelation between the foraminifera and their environments. Minor environmental changes have an immediate effect upon the frequency of some of the constituent species. The faunal composition may be said to have resulted from the total effect of various paleo-environmental factors. Reversely, some faunal changes, vertical and lateral, should be indicative of some change of the environments.

Depth of the sea is a very important and easily distinguished factor in the fossil foraminiferal distributions, because this factor is mutually related with other paleo-ecological factors of the sea. Both distributions and faunal variations of the fossil foraminiferal assemblages in the Kazusa group may be considered to have been primarily determined by the depth of the depositional sites.

The Kazusa group had been considered to rest unconformably on the Miocene rocks. The foraminifera from the basal

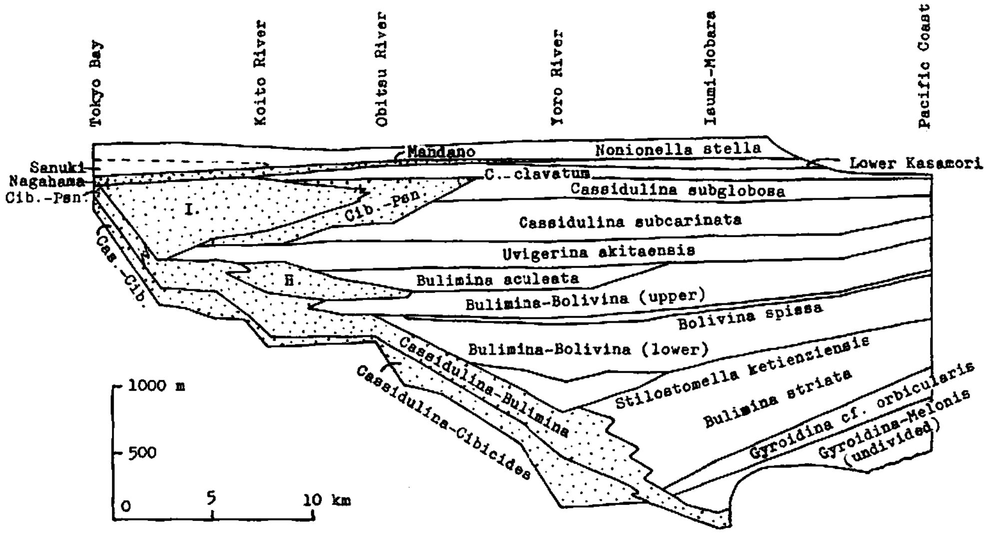
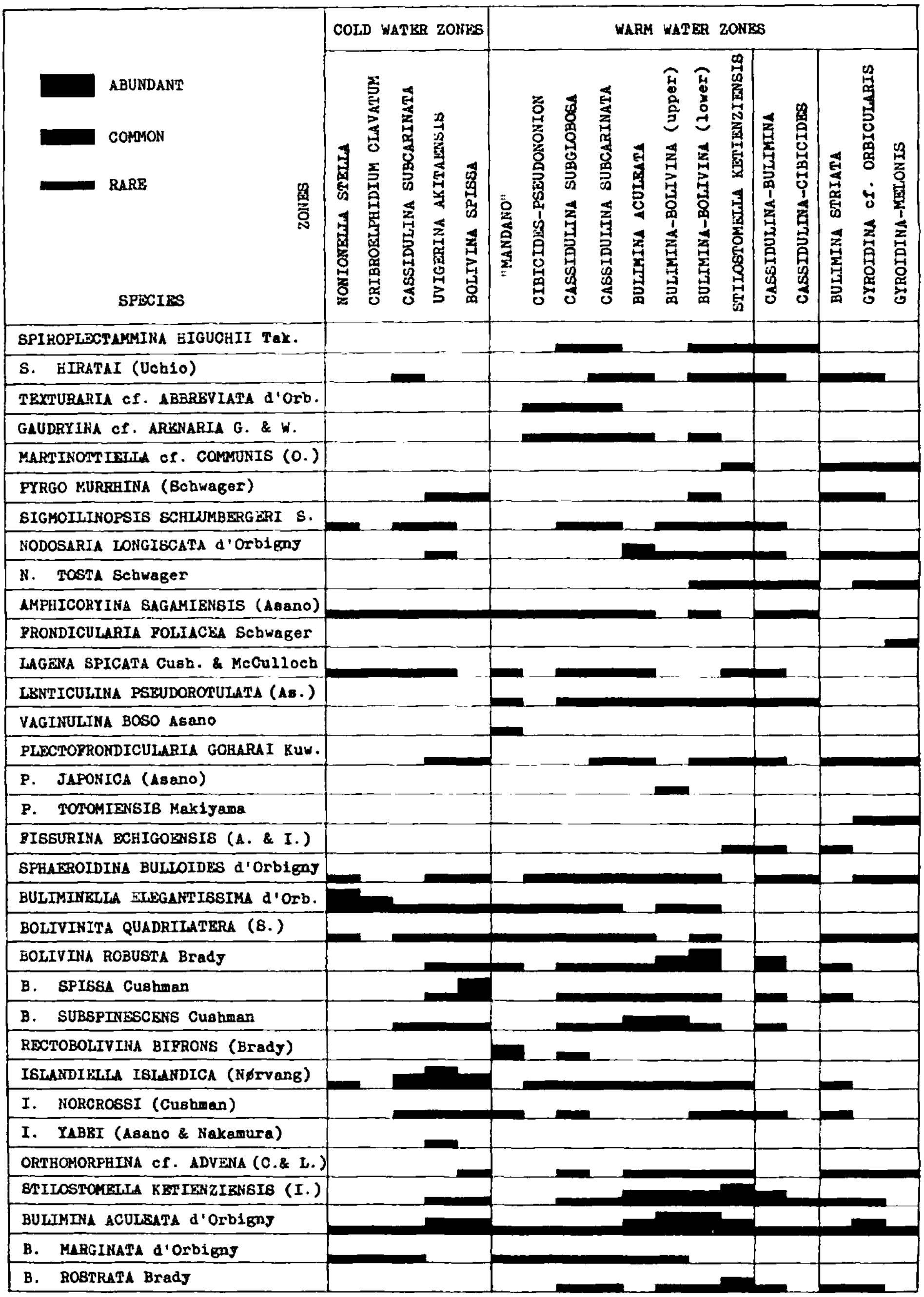


Fig. 3. Benthonic foraminiferal zones of the Kazusa group, Boso Peninsula.

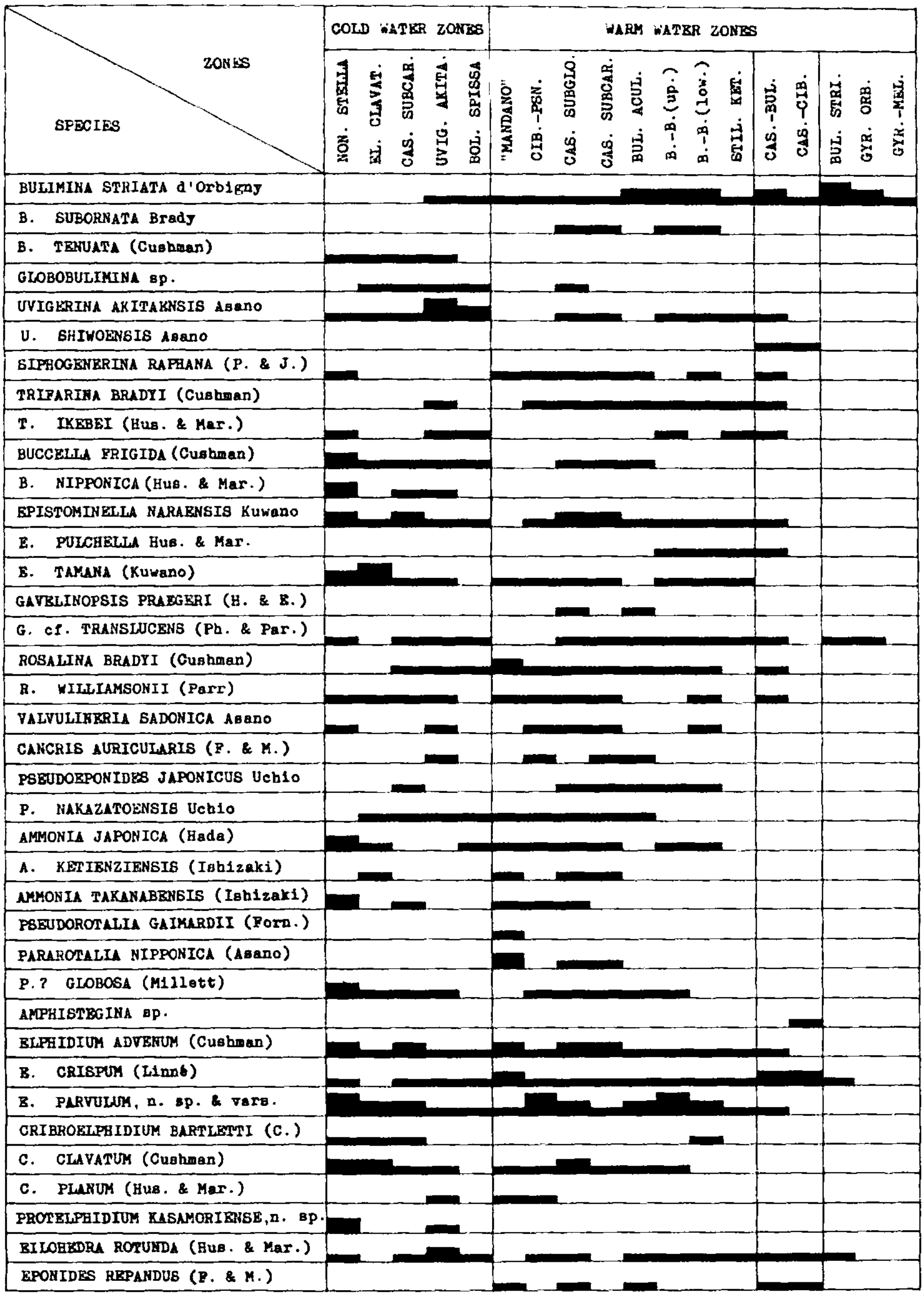
Table 2. The faunal succession of the Kazusa group, Boso Peninsula.

Formation \ Section	Minato -Sanuki	Takamizo -Tamaki	Koito River	Obitsu River	Yoro River	Isumi -Mobara	East Coast	Section \ Formation
					Nonionella stella			Kasamori
Sanuki	Sanuki			Mandano				Mandano
Nagahama	Nagahama					Lower Kasamori		
				Cribroelphidium clavatum				Chonan
		I.			Cassidulina subglobosa			Kakinokidai
			Cibicides-Pseudononion		Cassidulina subcarinata			Kokumoto
		Uvigerina akitaensis						
				Bulimina aculeata				Umegase
Iwasaka	Cibicides-Pseudononion		H.	Bulimina-Bolivina (upper)				
		Cassidulina -Bulimina		Bolivina spissa				Otadai
					Bulimina-Bolivina (lower)			
Kurotaki	Cassidulina-Cibicides				Stilostomella ketienziensis			Kiwada
					Cas.-Bul.	Bulimina striata		
					Cas.-Cib.	Gyroidina cf. orbicularis		Obara
						Cas.-Bul.	Gyroidina -Melonis (undivided)	Namihana Katsuura

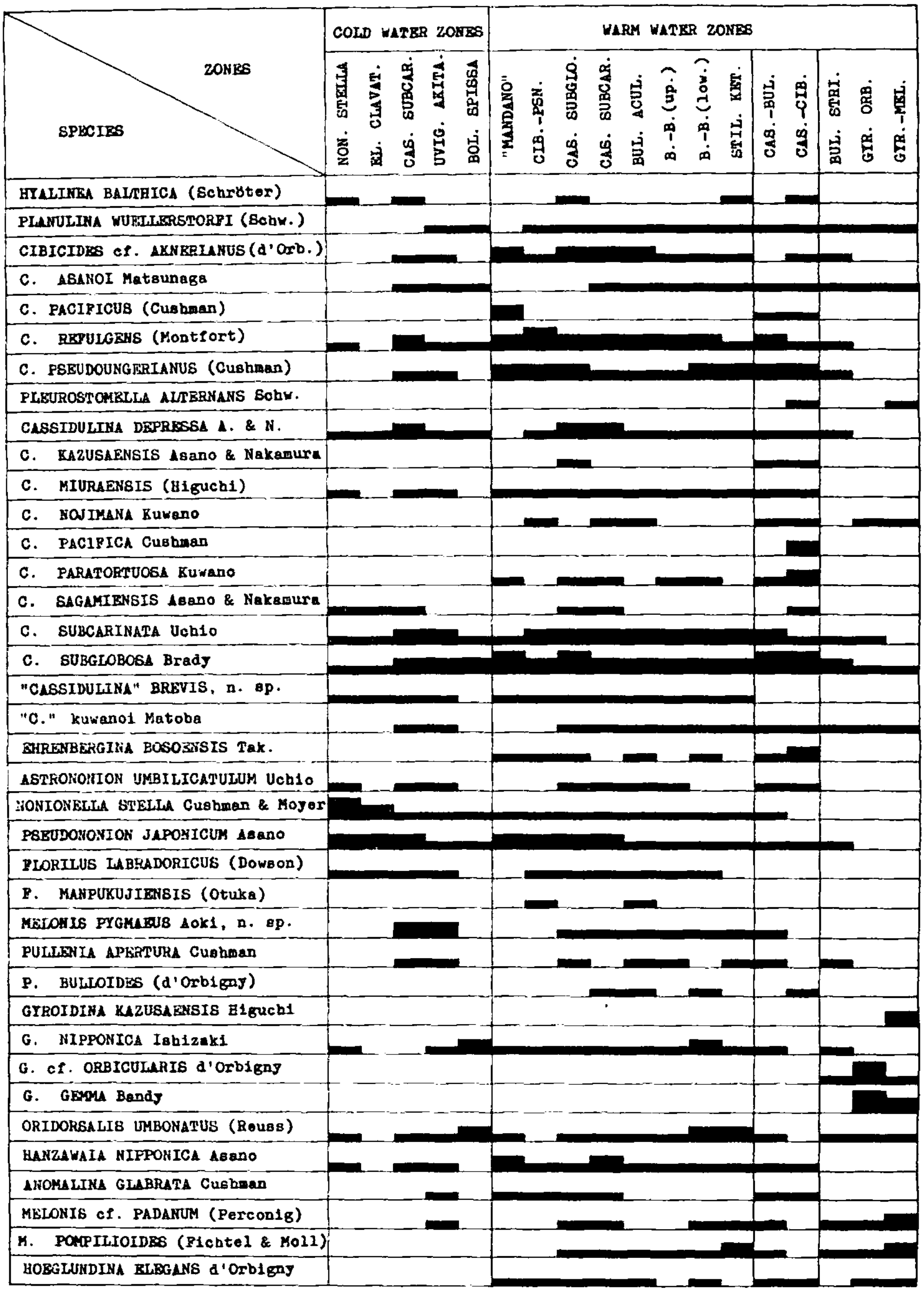


(a)

Fig. 4a-c. Generalized distributions of benthonic Foraminifera in the Kazusa group, Boso Peninsula.


COLD WATER ZONES
WARM WATER ZONES
ZONES
SPECIES
NON. STELLA
EL. CLAVAT.
CAS. SUBCAR.
UVIG. AKITA.
BOL. SPISSA
"MANDANO"
CIB.-PSN.
CAS. SUBGLO.
CAS. SUBCAR.
BUL. ACUL.
B.-B.(up.)
B.-B.(low.)
STIL. KET.
CAS.-BUL.
CAS.-CIB.
BUL. STRI.
GYR. ORB.
GYR.-MEL.
BULIMINA STRIATA d'Orbigny
B. SUBORNATA Brady
B. TENUATA (Cushman)
GLOBOBULIMINA sp.
UVIGERINA AKITAENSIS Asano
U. SHIWOENSIS Asano
SIPHOGENERINA RAPHANA (P. & J.)
TRIFARINA BRADYI (Cushman)
T. IKEBEI (Hus. & Mar.)
BUCCELLA FRIGIDA (Cushman)
B. NIPPONICA (Hus. & Mar.)
EPISTOMINELLA NARAENSIS Kuwano
E. PULCHELLA Hus. & Mar.
E. TAMANA (Kuwano)
GAVELINOPSIS PRAEGERI (H. & E.)
G. cf. TRANSLUCENS (Ph. & Par.)
ROSALINA BRADYI (Cushman)
R. WILLIAMSONII (Parr)
VALVULINERIA SADONICA Asano
CANCRIS AURICULARIS (F. & M.)
PSEUDOEPONIDES JAPONICUS Uchio
P. NAKAZATOENSIS Uchio
AMMONIA JAPONICA (Hada)
A. KETIENZIENSIS (Ishizaki)
AMMONIA TAKANABENSIS (Ishizaki)
PSEUDOROTALIA GAIMARDII (Forn.)
PARAROTALIA NIPPONICA (Asano)
P.? GLOBOSA (Millett)
AMPHISTEGINA sp.
ELPHIDIUM ADVENUM (Cushman)
E. CRISPUM (Linné)
E. PARVULUM, n. sp. & vars.
CRIBROELPHIDIUM BARTLETTI (C.)
C. CLAVATUM (Cushman)
C. PLANUM (Hus. & Mar.)
PROTELPHIDIUM KASAMORIENSE, n. sp.
BILOHEDRA ROTUNDA (Hus. & Mar.)
EPONIDES REPANDUS (F. & M.)

(b)


COLD WATER ZONES
WARM WATER ZONES
ZONES
SPECIES
NON. STELLA
EL. CLAVAT.
CAS. SUBCAR.
UVIG. AKITA.
BOL. SPISSA
"MANDANO"
CIB.-PSN.
CAS. SUBGLO.
CAS. SUBCAR.
BUL. ACUL.
B.-B.(up.)
B.-B.(low.)
STIL. KET.
CAS.-BUL.
CAS.-CIB.
BUL. STRI.
GYR. ORB.
GYR.-MEL.
HYALINEA BALTHICA (Schröter)
PLANULINA WUELLERSTORFI (Schw.)
CIBICIDES cf. AKNERIANUS (d'Orb.)
C. ASANOI Matsunaga
C. PACIFICUS (Cushman)
C. REFULGENS (Montfort)
C. PSEUDOUNGERIANUS (Cushman)
PLEUROSTOMELLA ALTERNANS Schw.
CASSIDULINA DEPRESSA A. & N.
C. KAZUSAENSIS Asano & Nakamura
C. MIURAENSIS (Higuchi)
C. NOJIMANA Kuwano
C. PACIFICA Cushman
C. PARATORTUOSA Kuwano
C. SAGAMIENSIS Asano & Nakamura
C. SUBCARINATA Uchio
C. SUBGLOBOSA Brady
"CASSIDULINA" BREVIS, n. sp.
"C." kuwanoi Matoba
EHRENBERGINA BOSOENSIS Tak.
ASTRONONION UMBILICATULUM Uchio
NONIONELLA STELLA Cushman & Moyer
PSEUDONONION JAPONICUM Asano
FLORILUS LABRADORICUS (Dowson)
F. MANPUKUJIENSIS (Otuka)
MELONIS PYGMAEUS Aoki, n. sp.
PULLENIA APERTURA Cushman
P. BULLOIDES (d'Orbigny)
GYROIDINA KAZUSAENSIS Higuchi
G. NIPPONICA Ishizaki
G. cf. ORBICULARIS d'Orbigny
G. GEMMA Bandy
ORIDORSALIS UMBONATUS (Reuss)
HANZAWAIA NIPPONICA Asano
ANOMALINA GLABRATA Cushman
MELONIS cf. PADANUM (Perconig)
M. POMPILIOIDES (Fichtel & Moll)
HOEGLUNDINA ELEGANS d'Orbigny

(c)

part of the group ranging from the Katsuura to the Ohara formations were previously reported under the name of "Lower Kazusa Mixed Faunule." The assemblages were interpreted as accumulated in a relatively shallow water environment under unstable or high energy water conditions, because of the presence of some shallow water species and the low frequencies of the benthonic foraminiferal tests as well as of the planktonic ones (HIGUCHI, 1964). In other words, this interpretation means that the lower part of the Kazusa group represents the early stage of the marine transgression over the erosional surface of the Miocene rocks. It is, therefore, necessary to determine the depth of the basal faunas of the Kazusa group for the geologic evaluation of this "unconformity" and the paleogeography of the group.

From the present foraminiferal study, it is revealed that the *Gyroidina-Melonis* fauna in the basal part of the Kazusa group comprises commonly deep water species of the bathyal depth zone. The other constituents are not diagnostic to the slope fauna because of their wide depth ranges from the central shelf to the deep, but they are characteristically or frequently found in the slope faunas. The shallow water species are very low in frequency and almost absent in the mudstone samples.

The main constituents of the *Gyroidina-Melonis* fauna are considered to be important and characteristic elements of the bathyal faunas and the majority are representatives commonly of the middle to lower bathyal biofacies rather than otherwise. It may be reasonable that the *Gyroidina-Melonis* fauna of the probable bathyal zone has low frequencies of the foraminifera. The sedimentary basin would have been of a somewhat deep stagnant environment. Besides, the mode of occurrence, characters of the assemblages and the lithofacies are consistent with this depth interpretation. Foraminiferal analysis of the *Gyroidina-Melonis* zones in Boso reveals that the assemblage has the closest affinity to the underlying Miocene Kiyosumi fauna (AOKI, 1964c). This evidence indicates a similarity of environmental conditions of the both.

In the eastern sections studied, the following vertical faunal sequence is successively found in ascending order:

Gyroidina-Melonis zones
Bulimina-Bolivina zones
Uvigerina zone
Cassidulina zones
Shallow water zones

From the faunal characters of these zones it may be concluded that this sequence indicates regressive bathymetric changes of this sedimentary basin from the lower bathyal to the middle or upper shelf in depth. Therefore, it can be said that the Kazusa group represents a series of sediments accumulated during a long-range and gradual marine "regression."

The foraminiferal assemblages from the Kurotaki formation, basal horizon of the group in the central and western areas, may be inferred as a mixed slope fauna, although they consist mostly of shelf water species. This fauna grades laterally into the slope *Bulimina* fauna of the eastern sections.

The foraminiferal assemblages of the western sections do not show such a vertical faunal trend because of the complicated distribution pattern of the strata.

As the Pliocene and Pleistocene stratigraphy of the Boso Peninsula is fairly well and rather sufficiently elucidated, the various benthonic foraminiferal as-

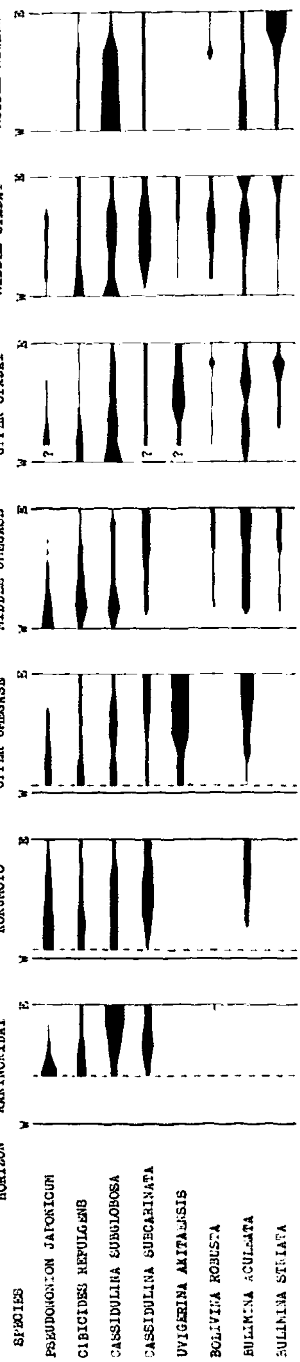


Fig. 5. Lateral frequency variation of some characteristic foraminiferal species in the Kazusa group. Boso Peninsula. Heaviness of the lines indicates relative abundance.

semblages in the geologic profile indicate the complexity of the time-space relationship in stratigraphic distribution. Fig. 3 indicates some lateral faunal variation and stratigraphic relationships among the assemblages. In general, the depth variation occurs from the west to the east and also from the lower to the upper in the section, so that some zones are time-transgressive in stratigraphic distributions.

The lateral faunal variation of a certain time-stratigraphic horizon can be observed in the east-west direction by examining samples collected from the contemporaneous strata which are traced by pyroclastic layers. In Fig. 5 the lateral frequency variations of a few dominant and diagnostic species for zonation are simply shown at seven selected horizons indicated by marker beds. This figure shows some general faunal trends.

To mention an instance, the shelf assemblages which commonly comprise *Cibicides* and *Pseudononion* are widely distributed in the western part of the peninsula. These two species are most common in the western sections, and at every horizon their frequencies decrease definitely toward the east. Some of the shallow water species are similarly distributed.

On the other hand, *Uvigerina akitaensis*, *Bolivina robusta*, *B. spissa*, *Bulimina aculeata* and *B. striata* are predominant in the mudstone of the eastern sections of Boso. *Gyroidina* cf. *orbicularis* and two species of *Melonis* are frequent in the lowermost Kazusa group in the eastern coastal area.

Cassidulina subcarinata and *C. subglobosa* have intermediate distribution patterns between those of the above-mentioned two groups of species. In the horizons where *Uvigerina akitaensis*, *Bolivina* and *Bulimina* species have higher frequencies, these cassidulinids are more common in the western sections than in the eastern ones, but in the zones dominated by *Cibicides* and *Pseudononion* the frequencies of the cassidulinids increase in the opposite direction.

In summary, the *Bolivina* and *Bulimina* faunas are widespread in the eastern sections of the Kazusa group. According to the progressive increase and decrease of relative frequencies of the constituent species, they are replaced, to the west, by the *Cassidulina* assemblages and finally by the *Cibicides-Pseudononion* assemblage at the western margin of the peninsula. This lateral faunal variation is associated with the convergence of the thickness of beds and lithofacies changes (Fig. 2). This trend is recognized in different horizons, because the faunal assemblages might have been influenced mainly by the depth of the past environment as in the vertical faunal sequence. The trend is in harmony with the sequence of the vertical faunal variation in the Kazusa sections.

Of the cold water zones in Boso, the lateral biofacies changes due to the depth appears to be less conspicuous and insignificant compared with those of the warm water zones. Perhaps it suggests vertically more uniform oceanographical conditions of cold waters. The correlation of the cold water zones by the benthonic foraminifera is, therefore, easier than that of the warm water ones.

Temperature Variations

As mentioned above, the vertical and lateral sequence of the foraminiferal assemblages is thus controlled by the depth of the Kazusa group, which reflects a tectonic history and paleo-geographic changes of the basin. This variation is modified by the temperature variation, that is, by the paleo-climatic history of the Kazusa group.

The very distinctive faunal differentiation between the Kuroshio Current and the Oyashio Current provinces is well known off the Pacific coast of the Japanese Islands, not only in the foraminiferal faunas but also in many other kinds of living organisms. As Boso is situated near the boundary of these two water provinces, the both warm and cold water currents easily invaded this basin, according to the climatic fluctuations during the late Pliocene and early Quaternary. These currents alternatively brought their respective and very different faunas into the sedimentary basin. As in the Recent faunas off Japan (ISHIWADA, 1964) the faunal differentiation due to the oscillation of water currents can be recognized even within the deep water zones of the eastern Boso, as well as in the shelf water faunas, from the characters of the faunal composition and the constituent species.

Apart from minor and short-ranged fluctuations, therefore, the gross and generalized changes by the relative water temperature are self-evident in the Pliocene and Pleistocene sections of this region, if the foraminiferal compositions are examined and compared directly with the assemblages above and below. The fluctuations of the water temperature are clearly shown by the subdivision of the Kazusa group presented in this paper, although it is unable to evaluate the absolute degree of the water temperature variations.

The planktonic foraminiferal assemblages from the Kazusa group were previously reported with regard to the vertical and lateral variations of the faunal compositions (AOKI, 1964b). Some of the cold and warm water horizons or the paleo-climatological zoning of the Boso sections were indicated. It is remarkable that these roughly defined subdivisions of the planktonic foraminiferal assemblages agree with the benthonic foraminiferal zonation of the group. In the paleo-climatological interpretation from the complicated and sharply fluctuated frequency curves made by the planktonic foraminiferal assemblages, the changes of the water temperature causing the changes in the benthonic assemblages are believed to be worthy of the independent treatment.

Compared with the living foraminiferal faunas distributed around the peninsula, the influence of the cold water is more prominent and the frequency of the cold water species is generally higher in the Boso Pliocene and Pleistocene microfaunas. The earliest of the cold water zones discriminated is situated in the lower part of the Otadai formation. Remarkable and easily distinguishable cold water zones are as follows:

(1) *Bolivina spissa* Zone (Upper part of the Otadai formation)
(2) *Uvigerina akitaensis* Zone (Upper part of the Umegase formation)
(3) Two cold water horizons within the *Cassidulina subcarinata* Zone (Kokumoto formation)
(4) *Cribroelphidium clavatum* Zone (Chonan formation)
(5) *Nonionella stella* Zone (Upper part of the Kasamori formation)

Table 3 shows the temperature-depth distribution of the benthonic foraminiferal zones of the Kazusa group. The fossil zones are listed in the order of increasing depth of water (from upper to lower). Foraminiferal zones arranged in the left column are of the warm water zones, and those in the right column indicate the corresponding zones of the cold water phase in the Kazusa group.

Table 3. Temperature-depth distribution of the benthonic foraminiferal zones of the Kazusa group, Boso Peninsula.

Depth \ Temperature		Warm water zons	Cold water zones
shelf	central		*Nonionella stella* Zone
		Cibicides-Pseudononion Zone	
			Cribroelphidium clavatum Zone
		Cassidulina subglobosa Zone	
	outer	Warm water horizons of the *Cassidulina subcarinata* Zone	Cold water horizons of the *Cassidulina subcarinata* Zone
slope	upper	*Bulimina aculeata* Zone	*Uvigerina akitaensis* Zone
		Bulimina-Bolivina Zone	*Bolivina spissa* Zone
		Bulimina striata Zone	*Uvigerina akitaensis-Bolivina spissa* zonules in the *Bulimina-Bolivina* Zone (East Coast)
	lower	*Gyroidina-Melonis* Zone	

Displaced Elements

Most of the samples treated for zoning were collected, as far as possible, from mudstones and muddy facies within the alternating rocks. The foraminifera are well preserved in these rocks but are generally absent in sandstone beds. Only foraminiferal fossils occur in much less abundance in sandstones containing molluscan shells.

The material in coarse-grained sediments has not been systematically collected for this study. Insufficient and sporadical data show that, in the alternating beds of mudstone and sandstone, the foraminiferal composition of sandstone is quite different from that of mudstone as is known well from the studies of the distribution of the Recent foraminifera. The sandstone interbeds in the *Bulimina-Bolivina* zones contain elements displaced from the shallower places. They include: *Cibicides refulgens*, *Pseudononion japonicum*, *Elphidium advenum* and vars., *E. crispum*, *Rosalina williamsonii*, *Hanzawaia nipponica*, *Cassidulina subglobosa*, many species of genera *Ammonia*, *Cassidulina*, *Elphidium*, *Quinqueloculina* and Discorbidae, etc.

The displaced shelf species may be mixed with the deep indigenous mudstone fauna in various percentages. In some horizons the faunas are composed essentially of the reworked shallow water species or the elements of the *Cibicides-Pseudononion* assemblage. They seem superficially to be the indigenous "shelf assemblages." The quantity and composition of displaced elements also play an important role in the foraminiferal assemblages of the Boso Peninsula, and in the foraminiferal zoning such elements should be taken into account as one of the indicators of the environments.

The amount of displaced specimens, in the deeper and the outer shelf facies, is generally related to the lithofacies of the sediments. There is a marked tendency that coarser-grained or more sandy sediments show a higher frequency of displaced specimens.

The two sandstone bodies distributed in western Boso, the Higashi-higasa and the Ichijyuku formations, and their lateral lithofacies changes show that a large quantity of sandy material was continuously supplied from some western region and transported to the east. The sedimentological influence of this environment is recognized in the fossil assemblages in the eastern extensions of these sandstone formations. Many shelf species, such as *Cibicides*, *Pseudononion*, *Cassidulina*, etc., were commonly transported into the *Bulimina-Bolivina* faunas.

Concerning the transportation of the foraminiferal tests the frequency distribution of *Elphidium parvulum*, new species, and its varieties is another interesting matter. The species is small-sized and occurs in mudstone facies. The high frequency horizons of this species repeatedly appear in the interval ranging from the Otadai to the Kasamori formations. Each horizon is comparatively narrowly restricted in vertical range and can be laterally traced from section to section. Though the occurrence of this species in the Recent ocean has been unknown, it is inferred that the species is probably spread out by currents with fine-grained detrital particles. The species may be useful as an indicator of such environment and also for local correlation of the strata. Some small-sized benthonic species seem to have similar distribution patterns to that of *Elphidium parvulum*.

The currents, the distance from the shore and the submarine topography of the depositional sites are the other significant factors which have influence on the distribution of foraminifera. These environmental factors have mutual relations to the depth facies variation.

Foraminiferal Zones

The foraminiferal assemblages and zones distinguished in the Kazusa group are briefly remarked in the following.

1. *Gyroidina-Melonis* zones

The mudstones of the Katsuura, Namihana and Ohara formations are poor in foraminiferal fossils. The foraminiferal data of these three formations are still insufficient for biostratigraphic and paleoecologic considerations of the basal part of the Kazusa group. The small population in these horizons is due probably to the originally meagre faunas in addition to the subaerial weathering.

Of about 200 samples examined, 55 yield foraminiferal fossils in a fair abundance represented by only a few to less than 20 benthonic species (usually 3-13 species) in each sample. Consequently, the number of common constituent species is limited, in spite of slight vertical variations of species association. In most horizons the foraminiferal assemblages contain two or three species belonging to *Gyroidina* and *Melonis* and are invariably characterized by these species.

The interval characterized by the *Gyroidina-Melonis* fauna in the lower part of the Kazusa group can be subdivided into five units, the *Gyroidina* cf. *orbicularis* Zone and the lower four unnamed zonules, on the basis of the benthonic foraminiferal assemblages. In the eastern coastal area a number of parallel faults and unsuitable field conditions make it difficult to obtain detailed stratigraphic information. The distributions of these four zonules are not so clear and the subdivision is tentative at present. These zonules seem to be laterally continuous from the Isumi-Mobara section to the eastern coast of the peninsula, and are truncated by the sea.

Zonule 1 (Lower part of the Katsuura formation)

The foraminiferous samples were collected from the mud-rich alternations of mudstone and sandstone at Katsuura, eastern coast of the peninsula. Collection of the samples was limited to a particular area and horizons. The samples yield *Gyroidina kazusaensis* and *Hoeglundina elegans*, in association with *Planulina wuellerstorfii*, *Melonis* cf. *padanum*, *Stilostomella* spp. and a few others.

HIGUCHI (1965) reported this assemblage from the subsurface samples of the Kujyukuri-hama area at depths deeper than 1000 m. The basal part of the Katsuura formation consists of coarse-grained sediments rich in pyroclastic matter. In the outcrop samples the foraminifera are entirely absent.

Zonule 2 (Middle part of the Katsuura formation)

The assemblage found in samples from the environs of Katsuura-machi is dominated by *Melonis* cf. *padanum* and *Gyroidina gemma*. The following species are frequently found: *Melonis pompilioides*, *Oridorsalis umbonatus*, *Bolivinita quadrilatera*, *Cassidulina* cf. *subglobosa* and *Hoeglundina elegans*.

Zonule 3 (Upper part of the Katsuura formation to the lower half of the Namihana formation)

The material from the upper part of the Katsuura formation contains *Orthomorphina* cf. *advena*, *Bulimina striata*, *Plectofrondicularia totomiensis*, *Stilostomella* spp. and *Gyroidina gemma* in abundance. This zone is characterized by the co-existence of two species, *Orthomorphina* cf. *advena* and *Plectofrondicularia totomiensis*.

A few samples collected from the lower half of the Namihana formation are scarce in foraminiferal fossils and they contain almost the same assemblage as that of the upper Katsuura formation.

Zonule 4 (Upper and main parts of the Namihana formation)

The constituent species are common with those of zonule 3. Although the dominant species vary with samples, *Nodosaria longiscata* is most abundant and *Melonis* cf. *padanum*, *Plectofrondicularia totomiensis*, *Hoeglundina elegans* and *Melonis pompilioides* are subdominant.

Gyroidina cf. *orbicularis* Zone (Uppermost part of the Namihana formation to the lower or basal part of the Kiwada formation)

It roughly corresponds to the Ohara formation in which the foraminifera are fairly common. It is consistently characterized by the abundance of either *Gyroidina* cf. *orbicularis* or *G. gemma*. The associated species are: *Hoeglundina elegans*, *Bulimina aculeata*, *Nodosaria longiscata*, *N. tosta*, *Melonis* cf. *padanum*, *M. pompilioides*, *Stilostomella ketienziensis*, *Bolivinita quadrilatera*, *Bulimina striata* and *Plectofrondicularia totomiensis*. The lateral faunal variation is not considerable.

Besides the basal part of the Kazusa group, the fossil foraminiferal assemblages in which *Melonis* and *Gyroidina* are frequent, are found in the central and eastern parts of the peninsula in the restricted horizons given below.

(1) Upper part of the Kokumoto formation
(2) Uppermost horizon of the Umegase formation
(3) Three or 4 horizons within the *Bulimina-Bolivina* zones of the Otadai and Kiwada formations.

In these horizons *Gyroidina* and *Melonis* are associated with the elements of the upper slope or outer shelf faunas in abundance, so the assemblages are different from the *Gyroidina-Melonis* fauna of the lowermost part of the group.

2. Mixed assemblage zones

Cassidulina-Cibicides Zone

The mixed assemblages composed largely of shelf water species with a minor amount of slope water ones are found in pebble-bearing coarse-grained sandstone to silty sandstone of the Kurotaki formation in western and central Boso. The fauna is extremely dominated by the species of *Cassidulina* and *Cibicides*, such as *Cassidulina subglobosa*, *C. pacifica*, *Cibicides pseudoungerianus*. The characteristic common species of the zone are: *Ehrenbergina bosoensis*, *Elphidium crispum*, *Cassidulina kazusaensis*, *C. paratortuosa*, etc.

Some of the diagnostic species are not discovered or are probably scarce in the Recent sediments around Japan, and any similar assemblage with the same associating species has not been reported. The Kurotaki fauna seems to be superficially analogous to the Recent *Cassidulina-Cibicides* assemblage frequently found on sandy submarine banks (ISHIWADA, 1964).

The fauna is generally associated with deep water species although small in quantity; *Bulimina aculeata*, *B. striata*, *Stilostomella ketienziensis*, *Melonis pompilioides*, *M.* cf. *padanum*, *Gyroidina* cf. *orbicularis*, etc., are not negligible elements nor unusual admixture especially in the middle and upper parts of the Kurotaki formation. Moreover, the fauna grades laterally into the *Bulimina-Bolivina* or *Gyroidina-Melonis* faunas in the eastern sections.

From these evidences, the large amounts of *Cassidulina* and *Cibicides* and other shallow water species in this fauna can be explained that they were more or less transported from the nearby shelf. This prominent faunal displacement may be indicative of steeper submarine escarpments and a continuous rapid supply of coarser material of sediments, and at the same time some tectonic movement of the basin.

Similar assemblages to the Kurotaki fauna are found in the fossiliferous sandstone beds intercalated in the Kiwada and Otadai formations.

Cassidulina-Bulimina Zone

The Kurotaki mixed assemblage changes into the typical *Bulimina-Bolivina* faunas of the superjacent middle Kazusa group, with a gradual increase in frequencies of some species of *Bulimina* and *Bolivina* and decrease of the *Cassidulina* and shelf water species. This faunal variation has an intimate relation with the lithofacies which changes from the coarse- to the fine-grained sediments. The intermediate assemblage between these two zones is separated here as the *Cassidulina-Bulimina* zone, which contains buliminid and bolivinid species in intermediate abundance. The stratigraphic distribution of this assemblage may be time-transgressive in relation with the lateral depth variation of the lower half of the Kazusa group.

3. *Bulimina-Bolivina* zones

The Pliocene slope faunas characterized by buliminid and bolivinid species range in distribution from the base of the Kiwada formation to the middle part of the Umegase formation in the central and eastern parts of the peninsula.

The diagnostic species of the fauna are limited in number. The common and useful species are four; *Bulimina aculeata*, *Bul. striata*, *Bolivina spissa* and *Bol. robusta*. The fauna is subdivided into several assemblages by the combination and abundance of these index species. Six biostratigraphic zones are defined according to these easily separable assemblages as mentioned below.

In addition, some local fauna occur within this long-ranged interval, for instance, the *Stilostomella ketienziensis* assemblage (lower part of the Kiwada formation), the *Uvigerina akitaensis-Bolivina spissa* assemblage (Otadai formation) and the *Gyroidiaa-Melonis* assemblages (in some horizons of the Kiwada formation) are found. They spread locally in short stratigraphic ranges, and are included tentatively in the *Bulimina-Bolivina* fauna.

Bulimina striata Zone

In the lower and middle parts of the Kiwada formation of the eastern sections between the Isumi River and the east coast, *Bulimina striata* is extremely abundant and its frequency amounts to one-third of the fauna. *Bulimina aculeata*, *Bolivina robusta* and *B. spissa* and other slope species which are common in the surrounding deep water zones are less frequent or almost absent.

Bulimina-Bolivina Zone

This zone corresponds mostly to the Otadai formation and the lower half of the Umegase formation in the eastern sections of the Boso Peninsula. The following three slope species are the common constituents: *Bulimina aculeata*, *B. striata* and *Bolivina robusta*. This zone is subdivided vertically into two units by the intercalation of the *Bolivina spissa* Zone. The upper zone is rich in *Elphidium parvulum*, whereas the lower one is more frequent in *Cassidulina subcarinata* and *C. subglobosa*.

Bolivina spissa Zone

This is the upper part of the Otadai formation and is particularly rich in *Bolivina spissa*, which is commonly associated with *Bulimina aculeata*, *Uvigerina akitaensis*, *Islandiella islandica* and *I. norcrossi*. The replacement of *Bolivina robusta* with *B. spissa* in this zone is caused definitely by the influence of the subarctic Oyashio Extension. This zone corresponds also to the low temperature horizon interpreted from the planktonic foraminifera assemblages. The frequencies of *Globigerinita uvula* and *Globigerina quinqueloba* are higher in this zone (AOKI, 1963, 1964). The faunal characteristics of this assemblage are recognized extensively between the Obitsu River and the eastern coast of the peninsula.

Similar assemblages are found in the *Bulimina-Bolivina* zones of the eastern sections, east of the Isumi River. They appear locally in a few horizons with cold planktonic foraminiferal assemblage and *Uvigerina akitaensis*.

Stilostomella ketienziensis Zone

This zone was originally proposed as "*Ellipsonodosaria lepidula* Zonule" (ISHIWADA, 1958a). However, *Stilostomella ketienziensis* is more abundant and characteristic. This assemblage is found only in the upper horizon of the Kiwada formation in the Yoro River section.

Bnlimina aculeata Zone

This zone is represented by the middle part of the Umegase formation and is recognized between the Koito and Yoro Rivers. In this zone *Bulimina striata* and *Bolivina robusta* disappear but only *Bulimina aculeata* remains characteristically. The fauna is composed of *Bulimina aculeata* and numerous shelf elements such as those found in the *Cassidulina* zones. *Cassidulina subcarinata* is subdominant.

4. *Uvigerina akitaensis* Zone

The upper part of the Umegase formation corresponds to the important *Uvigerina akitaensis* Zone. This zone is well defined and the faunal features continue extensively in parallel with the time-stratigraphic markers. The fauna consists of a relatively small number of species. Some species found in the *Bulimina-Bolivina* and the *Cassidulina* zones are low in frequency or absent in this zone. The most characteristic species is *Uvigerina akitaensis*. The other diagnostic species are *Islandiella islandica*, *I. norcrossi*, *I. yabei*, *Trifarina ikebei*, *Cribroelphidium planum* and *Eilohedra rotunda*. Their stratigraphic distributions are not always restricted but characteristic to this zone. They are usually more common in the upper part of this zone. Distinct warm water species are absent.

Cassidulina subglobosa, *Islandiella islandica*, *I. yabei*, *Quinqueloculina sawanensis*, *Pseudononion japonicum* and some other species tend to be common in the western sections.

In association of the diagnostic foraminifera, this zone is similar to the zonule of the same name or the *Uvigerina-Angulogerina* zonule widely distributed in the Japan Sea and the "subarctic" regions of Japan. (ISHIWADA, 1964). The Boso fauna contains relatively many species associated with *Bulimina aculeata*, species of *Cassidulina* and *Cibicides*, etc. That is, the *Uvigerina akitaensis* Zone of Boso has an intermediate faunal composition between the northern "*Uvigerina-Angulogerina* assemblages" and the southern temperate water faunas of Japan.

5. *Cassidulina* zones

The fauna characterized by the species of *Cassidulina* is found in the Kokumoto and Kakinokidai formations of the eastern half of the peninsula. Both benthonic and planktonic foraminifera are abundant elsewhere in these horizons. The fauna is composed of many species of the shelf, and is sometimes associated with rare occurrences of some deep or blackish water species. Particularily, *Cassidulina* is the largest in number of both species and individuals.

The interval in question can be divided into two major units, namely the upper zone which abounds in *Cassidulina subglobosa*, and the lower zone in which *Cassidulina subcarinata* is constantly common in the eastern sections.

Two cyclic vertical faunal variations are evidenced within the *Cassidulina subcarinata* Zone of the Kokumoto formation. *Islandiella islandica*, *Bulimina aculeata*, *Melonis* cf. *padanum*, *Stilostomella* spp., *Gyroidina nipponica*, *Bulimina striata*, and *Uvigerina* cf. *akitaensis* are relatively frequent in the lower half of each cycle, whereas *Elphidium parvulum*, *Cassidulina subglobosa*, *C. depressa* vars. and *C. subcarinata* are in the upper. The former association indicates a cooler or deeper water facies and the latter is a more typical shelf association of the temperate waters.

This faunal variation has some affinities with the vertical variation of the planktonic foraminiferal assemblages and with the alternating lithofacies changes. It is probably due to the influence of the cold water extension and not to the fluctuation of the sea depth.

If the Kakinokidai formation is included, three cyclic variations are recognized, the last of which is separated as the *Cassidulina subglobosa* Zone. This zone corresponds to the interval ranging from the upper part of the Kokumoto to the Kakinokidai formations.

6. Shallow water zones

The upper part of the Kazusa group is represented by the shallow water faunas. Owing to the clear fluctuation of the water temperature and the variation of the bottom sediments, considerable vertical and lateral variations of the foraminiferal assemblages occur in this interval. Unfortunately, the horizons barren of the foraminifera due to weathering occupy the larger part of the section. Therefore, the lateral variations of the shallow water assemblages are uncertain. The lack of the pyroclastic layer passing through different lithofacies is another reason for the insufficient reliability of the stratigraphical relation of the fossil foraminiferal assemblages.

Cibicides-Pseudononion Zone

The *Cibicides-Pseudononion* assemblage occupies the western part of the Boso Peninsula and is typically observed in the Kakinokidai formation of the Obitsu and Koito River sections, which corresponds to the interval of the *Cassidulina subglobosa* Zone of the eastern sections. ISHIWADA (1958b) subdivided this assemblage into the *Cibicides* and the *Pseudononion* assemblages.

The foraminiferal assemblages from the Iwasaka formation are similar to that of the above *Cibicides-Pseudononion* Zone but have somewhat higher frequencies of the warm water species.

Cribroelphidium clavatum Zone

The samples from the Chonan formation contain *Cribroelphidium clavatum*, *Uvigerina akitaensis*, *Florilus labradoricus* and *Islandiella islandica* in higher frequencies. It is noteworthy that the most dominant species, *Cribroelphidium clavatum*, shows the typical morphology, having a characteristic biumbonate test, and that the faunal characteristics of this zone are somewhat similar to those of the *Uvigerina akitaensis* Zone. As previously pointed out, it is the most distinct, coldest water fauna found in the Boso Peninsula. The planktonic foraminifera have also a cold water assemblage (AOKI, 1963, 1964). This zone extends from the Koito River to the eastern margin of the peninsula.

"Lower Kasamori" Zone

The foraminifera of the lower part of the Kasamori formation can be observed only in the environs of Mobara. The following species are common or frequent in this zone: *Elphidium parvulum* vars., *Cibicides aknerianus*, *Amphicoryna sagamiensis*, *Cassidulina subcarinata*, *Gaudryina* cf. *arenaria*, *Bulimina marginata*, *Epistominella naraensis*, *Bolivinita quadrilatera*, *Lagena spicata*, *Cassidulina sagamiensis*, *Nonionella stella*, *Elphidium advenum* vars., "*Cassidulina*" *brevis* and *Pararotalia* ? *globosa*.

"Mandano" Zone

The foraminifera were obtained from some localities between the Yoro and Obitsu Rivers. This assemblage is found in conglomeratic sandstone and is easily distinguished from those of the zones below and above. *Elphidium crispum*, species of *Cibicides*, *Cassidulina* and Milioidae, and *Pararotalia nipponica* appear commonly in this zone.

Nonionella stella Zone

The samples of the Kasamori formation collected from the Yoro River section and scattered localities nearby are comparatively meagre in the number of species, especially in the uppermost part of the zone. It belongs to the bay fauna influenced by brackish waters, and is characterized by *Nonionella stella*, *Elphidium parvulum* vars., *Bulsmina elegantissima*, *Pseudononion japonicum*, *Buccella frigida*, *Cribroelphidium bartletti*. No influence of the warm water current is inferred in this zone.

Description of New Species

The four new species which are cited in the text as common in some horizons of the Kazusa group are described in the following. The type specimens are now preserved in the author's private collection, at the Institute of Geology and Mineralogy, Tokyo University of Education.

Elphidium parvulum AOKI, n. sp.

Pl. 27, figs. 1a, b

Test very small, involute and planispiral, compressed, subcircular in side view, periphery slightly lobulate, and sides nearly parallel in peripheral view; chambers seven to nine in the last whorl, increasing very gradually in size as added; sutures very slightly depressed, fairly curved, sutural pores indistinct, probably several slits in a suture; central portion slightly depressed, sometimes slightly umbilicate; wall finely perforate; aperture several small rounded openings at the base of the apertural face.

Maximum diameter of holotype 0.20 mm, minimum diameter 0.16 mm, thickness 0.08 mm.

Holotype from sample #058, river-side exposure of the Yoro River, 0.5 km south of the Yoro-Keikoku station, Kamo-mura, Ichihara-gun, Boso; Umegase formation, *Bulimina-Bolivina* Zone.

Elphidium parvulum, new species, is easily distinguishable from the previously known species of *Elphidium* by its smaller-sized and much compressed test with strongly curved sutures.

This new species occurs abundantly in the *Bulimina-Bolivina* zones of the Kazusa group. All specimens from the Otadai to Umegase formations are strictly conspecific with the type of *Elphidium parvulum* from the lower part of the Umegase formation. However, forms very closely allied to this new species are also dominantly found in the mudstones of the upper part of the Kazusa group which ranges from the Kukumoto formation to the Kasamori formation. These forms show wide morphological variations in the number of chambers, inflation of chambers and the character of sutures. Though it is believed that these forms are ecologically different from the typical species and they represent two or more related species or subspecies, it is difficult to separate one another because of their almost gradational morphologies and the high frequencies of these small-sized specimens. In this paper they are treated as varieties of the present new species, *Elphidium parvulum*. *Elphidium* sp. A reported from the middle Pleistocene Izumiyatsu formation of the Shimosa group is one of these varieties (SUZUKI & AOKI, 1963, *Geol. Soc. Japan, Jour.*, v. 68, no. 804, p. 501).

Protelphidium kasamoriense AOKI, n. sp.

Pl. 27, figs. 2a, b

Test small, compressed, planispiral and involute, bilaterally symmetrical, subcircular or ovate in side view, periphery subrounded, very slightly lobulate if at all, sides almost parallel, depressed in the umbilical regions; chambers about 10-11 in number in the final whorl, not inflated, slowly increasing in size as added; sutures distinct, radiate and curved, nearly flush with the surface in the early portion, narrowly and slightly depressed later, especially in the proximal portion; sutural pores unknown; small areas of the umbilical regions and around the aperture often covered with whitish granular pustules as shown in the figure of the holotype; wall smooth, usually lustrous and opaque, very finely perforate, radiate in texture; aperture not observable.

Maximum diameter of holotype 0.27 mm, minimum diameter 0.22 mm, thickness 0.14 mm.

Holotype from sample ♯101, river-side exposure of a southern tributary of the Yoro River, at Ushiku, Nanso-machi, Ichihara-gun, Boso; Kasamori formation, *Nonionella stella* Zone.

This new species is probably similar to *Protelphidium anglicum* MURRAY (1965, *Cush. Found. Foram. Res., Contr.*, v. 16, pt. 4, p. 149, pl. 25, f. 1-5; pl. 26, f. 1-6) described from the Recent sediments of England, but the former has a smaller test with a somewhat larger number of less inflated chambers. This new species is also different from the juvenile specimens of *Protelphidium orbiculare* (BRADY) from the Arctic in having a more compressed test with depressed umbonal areas.

Protelphidium kasamoriense is common in the Kasamori formation in the Yoro River section, but hardly found in the other horizons except for occasional doubtful specimens.

Melonis pygmaeus AOKI, n. sp.

Pl. 27, figs. 3a, b

Test minute, planispiral and involute but somewhat asymmetrically coiled, subcircular in side view, weakly lobulate, thickness a little more than a half of the diameter of the test, periphery broadly rounded; chambers five or six, commonly six in the last whorl, slightly inflated, increasing slowly in size as added; sutures radial, very slightly limbate and depressed a little; narrow umbilical region distinctly depressed; aperture a narrow, arched slit at the base of the apertural face of the final chamber; wall calcareous, rather thin, fairly coarsely perforate.

Maximum diameter of holotype 0.15 mm, minimum diameter 0.13 mm, thickness 0.11 mm.

Holotype from sample #076, river-side exposure of the Yoro River, NW of the Yoro-Keikoku station, Kamo-mura, Ichihara-gun, Boso; Umegase formation, *Uvigerina akitaensis* Zone.

This species is somewhat similar to a juvenile form of *Melonis pompilioides* (FICHTEL & MOLL) which is sometimes associated with this new species in the Kazusa group, but it differs in having a much smaller test, finer perforation, thinner wall and inflated chambers. This new species is probably very similar to *Melonis guadalupae* PARKER (1964, *J. Pal.*, v. 38, no. 4, p. 633, pl. 100, f. 13-14) but the test is about one half the size of the latter and is less compressed, with fewer chambers.

Melonis pygmaeus is frequent in the *Cassidulina* and the *Uvigerina akitaensis* Zone of the Kazusa group in Boso.

"*Cassidulina*" *brevis* AOKI, n. sp.

Pl. 27, fig. 4

Cassidulinoides bradyi (NORMAN), KIKUCHI, 1964, pl. 7, f. 27-32.

Test medium, globular, ovate in side view, periphery slightly lobulate, biserial series of chambers closely coiled in the earlier stage but slightly prolonged in the last stage, about five pairs of chambers in the final whorl, inflated slightly; sutures distinct and slightly depressed; wall calcareous, rather coarsely perforate; aperture terminal, comma-shaped, at nearly a right angle to the suture of the last chambers.

Length of holotype 0.32 mm, width 0.21 mm.

Holotype from sample #219, river-side exposure of the Yoro River, ca. 600 m north of the Itabu station, Itabu, Kamo-mura, Ichihara-gun, Boso; Chonan formation, *Cribroelphidium clavatum* Zone.

This new species somewhat resembles *Cassidulina subglobosa* BRADY, but the later portion of this new species is projected from the outline of the test and the wall is distinctly perforated. It may be different from *Cassidulinoides parkeriana* (BRADY) which has a much elongate uncoiled portion and more depressed sutures, and also from *Cassidulinoides bradyi* NORMAN which has a compressed test. *Cassidulinoides japonicus* KUWANO (*nom. nud.*, 1962, *Res. Inst. Natur. Resources, Misc. Rept.*, no. 58-59, pl. 16, f. 5) from the Recent sediments off Boso is very similar to this new species.

"*Cassidulina*" *brevis* is occasionally found from the Pliocene to the Pleistocene deposits in Japan. In Boso it is common in the *Cribroelphidium clavatum* and the *Cassidulina* zones of the Kazusa group.

Acknowledgements:—The author is much indebted to the following persons: Mr. Kunio KAGEYAMA, Drs. Takashi MITSUNASHI and Kiyotsura YAZAKI of the Geological Survey of Japan, Prof. Kozo KAWAI of the University of Tokyo, Mr. Naomiki KOMATSU of the Teikoku Oil Co., Mr. Takaichiro OMORI of the Japan

Petroleum Exploration Co., Dr. Takahiro SATO of the Hydrographic Office of Japan, and Mr. Yoshijiro SHINADA of the Kwanto Natural-Gas Exploration Co., for furnishing valuable informations on the stratigraphy of the Kazusa group; Dr. Yasufumi ISHIWADA of the Geological Survey of Japan, and Dr. Takayasu UCHIO of the University of Tokyo, for many helpful suggestions on the biostratigraphy and the foraminifera of the Kazusa group; Prof. Wataru HASHIMOTO of the Tokyo University of Education for his kind advices and continued encouragement.

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Awamata	粟又	Kiwada	黄和田	Okubo	大久保
Boso	房総	Kuniyoshi	国吉	Onjyuku	御宿
Chonan	長南	Kurotaki	黒滝	Oritsu	折津
Fuse	布施	Kururi	久留里	Otadai	大田代
Higashi-higasa	東日笠	Kwanto	関東	Otaki	大多喜
Ichihara	市原	Mandano	萬田野	Sakamoto	坂本
Ichijyuku	市宿	Masaki	正木	Sanuki	佐貫
Ichinomiya	一ノ宮	Minato	湊	Sasa-gawa	笹川
Ikariyato	碇谷	Miura	三浦	Shakadani	釈迦谷
Isone-saki	磯根岬	Miyata	宮田	Shimo-Miyata	下宮田
Isumi	夷隅	Mobara	茂原	Shimosa	下総
Itabu	飯給	Naewari	苗割	Shin'meimae	神明前
Iwafune	岩船	Nagahama	長浜	Sunami	周南
Iwakuma	岩熊	Namihana	浪花	Tagura	田倉
Iwasaka	岩坂	Nanso	南総	Takamizo	高溝
Izumiyatsu	泉谷	Nashinoki	梨ノ木	Tamaki	環
Kakinokidai	柿ノ木台	Nishi-higasa	西日笠	Tokyo	東京
Kamo	加茂	Nohichiri	野七里	Tomiya	十宮
Kasamori	笠森	Nojima	野島	Tsukizaki	月崎
Katsuura	勝浦	Obitsu	小櫃	Umegase	梅ヶ瀬
Kazusa	上総	Ofuna	大船	Ushiku	牛久
Kôbundô	弘文洞	Ohara	大原	Yoro	養老
Koito	小糸	Oikawa	老川	Yoro-Keikoku	養老渓谷
Kokumoto	国本				

Explanation of Plate 27

Fig. 1. *Elphidium parvulum* AOKI, n. sp., ×110, Holotype, from sample #058, 1 km S of Yoro-Keikoku Stn., Yoro River; Umegase formation, *Bulimina-Bolivina* Zone.

Fig. 2. *Protelphidium kasamoriense* AOKI, n. sp., ×90, Holotype, from sample #101, Ushiku, Yoro River; Kasamori formation, *Nonionella stella* Zone.

Fig. 3. *Melonis pygmaeus* AOKI, n. sp., ×137, Holotype, from sample #076, south of Oritsu, NW of Yoro-Keikoku Stn., Yoro River; Umegase formation, *Uvigerina akitaensis* Zone.

Fig. 4. "*Cassidulina*" *brevis* AOKI, n. sp., ×80, Holotype, from sample #219, 0.6 km N of Itabu Stn., Yoro River; Chonan formation, *Cribroelphidium clavatum* Zone.

Fig. 5. *Gaudryina* cf. *arenaria* GALLOWAY & WISSLER, ×38, from sample #013, Tsukizaki, Yoro River; Kokumoto formation, *Cassidulina subglobosa* Zone.

Fig. 6. *Gaudryia* cf. *arenaria* GALLOWAY & WISSLER, ×30, from sample #150, Otadai, Yoro River; Chonan formation, *Bulimina-Bolivina* Zone.

Fig. 7. *Bulimina striata* D'ORBIGNY, ×60, from sample #064, near Kôbundô, Oikawa, Yoro River; Otadai formation, *Bolivina spissa* Zone.

Fig. 8. *Bulimina striata* D'ORBIGNY, ×60, from sample #143, Awamata, Yoro River; Kiwada formation, *Bulimina-Bolivina* Zone.

Fig. 9. *Bulimina aculeata* D'ORBIGNY, ×40, from sample #1536, Otaki, Isumi River; Otadai formation, *Bulimina-Bolivina* Zone.

Fig. 10. *Bulimina aculeata* D'ORBIGNY, ×90, from sample #081, south of Kazusa-Okubo Stn., Yoro River; Umegase formation, *Uvigerina akitaensis* Zone.

Fig. 11. "*Cassidulina*" *kuwanoi* MATOBA, ×125, from sample #152, south of Otadai, Yoro River; Otadai formation, *Bulimina-Bolivina* Zone.

Fig. 12. *Gavelinopsis praegeri* (HERON-ALLEN & EARLAND), ×60, from sample #2050, Shimo-Miyata, Miura Peninsula; Miyata formation, middle Pleistocene.

Fig. 13. *Gavelinopsis* cf. *translucens* (PHLEGER & PARKER), ×130, from sample #149, Otadai, Yoro River; Otadai formation, *Bulimina-Bolivina* Zone.

Fig. 14. *Cibicides* cf. *aknerianus* (D'ORBIGNY), ×33, from sample #008, Tsukizaki, Yoro River; Kokumoto formation, *Cassidulina subglobosa* Zone.

Fig. 15. *Gyroidina gemma* BANDY, ×47, from sample #2385, south of Iwafune, SE of Namihana; Namihana formation, *Gyroidina-Melonis* Zone.

Fig. 16. *Melonis* cf. *padanum* (PERCONING), ×65, from sample #027, near Kazusa-Okubo Stn., Yoro River; Kokumoto formation, *Cassidulina subcarinata* Zone.

Fig. 17. *Globobulimina* sp., ×50, from sample #002, south of Tsukizaki, Yoro River; Kokumoto formation, *Cassidulina subcarinata* Zone.

Fig. 18. *Gyroidina* cf. *orbicularis* D'ORBIGNY var., ×50, from sample #027, near Kazusa-Okubo Stn., Yoro River; Kokumoto formation, *Cassidulina subcarinata* Zone.

Fig. 19. *Gyroidina* cf. *orbicularis* D'ORBIGNY, ×30, from sample #1584, Isumi River; Namihana formation, *Gyroidina* cf. *orbicularis* Zone.

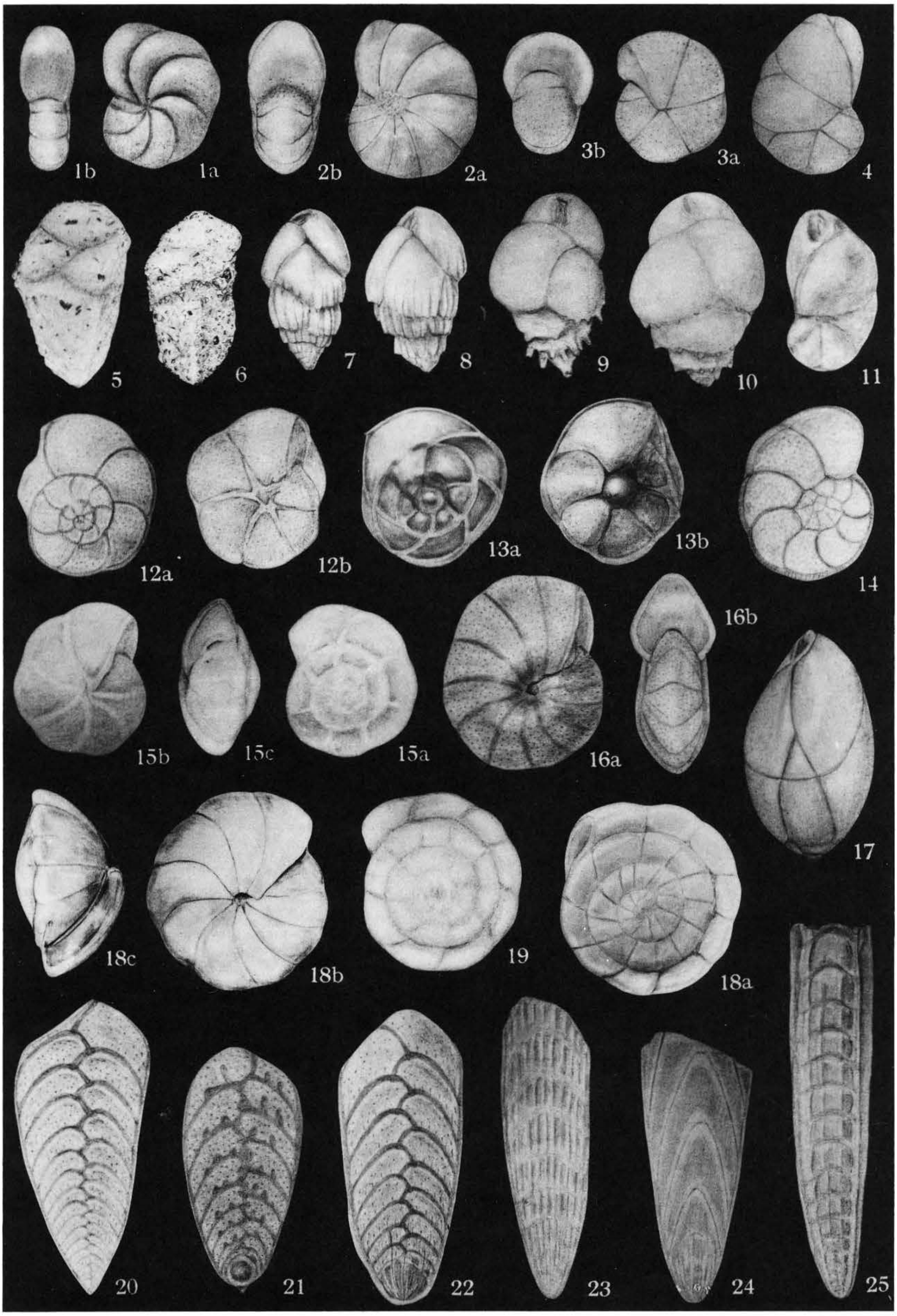
Figs. 20, 22. *Bolivina spissa* CUSHMAN, ×64, from sample #064, near Kôbundô, Oikawa, Yoro River; Otadai formation, *Bolivina spissa* Zone.

Fig. 21. *Bolivina robusta* BRADY, ×93, from sample #149, Otadai, Yoro River; Otadai formation, *Bulimina-Bolivina* Zone.

Fig. 23. *Plectofrondicularia japonica* (ASANO), ×60, from sample #1951, Nohichiri, 4 km E of Ofuna, Miura; Nojima formation, Pliocene.

Fig. 24. *Plectofrondicularia goharai* KUWANO, ×60, from sample #1951, Nohichiri, 4 km E of Ofuna, Miura; Nojima formation, Pliocene.

Fig. 25. *Plectofrondicularia totomiensis* MAKIYAMA, ×40, from sample #1951, Nohichiri, 4 km E of Ofuna, Miura; Nojima formation, Pliocene.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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 70, pp. 267-283, pl. 28, June 30, 1968

539. NOTES ON THE BENTHONIC FORAMINIFERA OF THE TONOHAMA GROUP, SHIKOKU, JAPAN*

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四国，唐ノ浜層群の底棲有孔虫について：唐ノ浜層群下部の登層は，有孔虫と貝化石から異った時代論が述べられている。地質調査および底棲有孔虫の検討から，唐ノ浜層群の層序関係を一部改めるとともに，登層下部に本層群上部の鮮新世穴内層底棲有孔虫群と類似する群集が存在することを指摘し，それらの意義について述べた。あわせて，従来未報告の3新種を含む15種を記載した。

栗 原 謙 二

Introduction

The Tonohama group has been well-known as the "Tonohama shell bed", which yields abundant molluscan fossils. This younger Neogene sediments are distributed as isolated small patches in the coastal region of Tosa Bay from Ananai, Aki City, eastwards to Hane, Muroto City, Kochi Prefecture. It was subdivided into three formations, that is, the Nobori, Ropponmatsu** and Ananai formations in ascending order (KATTO, NAKAMURA and TAKAYANAGI, 1953).

The Ananai formation has been considered to be Lower Pliocene in age based on molluscan fossils and benthonic foraminifera (ASANO, 1937; NOMURA, 1937; KATTO *et al.*, 1953, and others). However, with regard to the geologic age of the Nobori formation, the lowest part of the group, different opinions have been proposed.

KATTO *et al.* (1953) tentatively assigned the Nobori to lowermost Pliocene on the basis of benthonic foraminifera and molluscan fossils, although it was emphasized that the Nobori foraminiferal fauna was quite different from that of the Pliocene Ananai formation, and had many common species with that of the Miocene deposits of the Kar Nicobar Islands, India. Later, however, KATTO and OZAKI (1955) and KATTO (1960) concluded that the Nobori was Miocene in age for the occurrence of some molluscan fossils including *Periploma pulchellum* HATAI and NISIYAMA and shark's tooth, *Carcharodon megalodon* (CHARLESWORTH), which they regarded as characteristic Miocene species. They also mentioned that this conclusion did not contradict the results of the previous study of KATTO *et al.* (1953).

TSUCHI (1961), however, pointed out the occurrence of such characteristic species of the Kakegawa molluscan fauna of the Kakegawa group, Shizuoka Prefecture, as *Amussiopecten praesignis* (YOKOYAMA) and *Venericardia panda* (YOKOYAMA). He concluded that the Nobori as well as the Ananai was correlative with the lower or middle Kakegawa group which is usually regarded as Pliocene in Japan.

* Received Aug. 19, 1967; read June 18, 1966.

** The Nahari formation. Later, KATTO (1960) changed the name to Ropponmatsu formation.

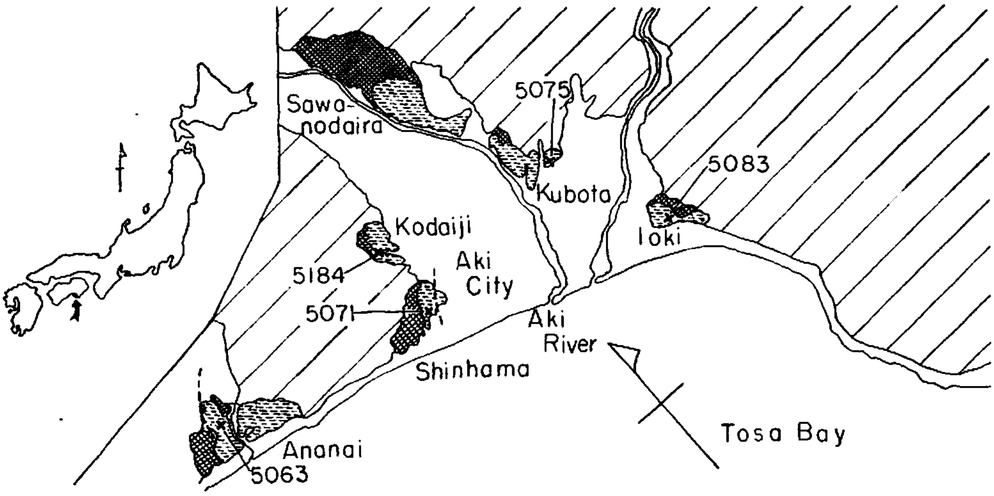


Fig. 1. Geological map of the eastern coastal

Supplementary work of the molluscan fauna of the Nobori was carried out by AOKI (1966), and he showed the close affinity of the Nobori fauna with that of the Lower Kakegawa Series of Pliocene. Accordingly the Nobori was assigned to Lower Pliocene from the molluscan fossils.

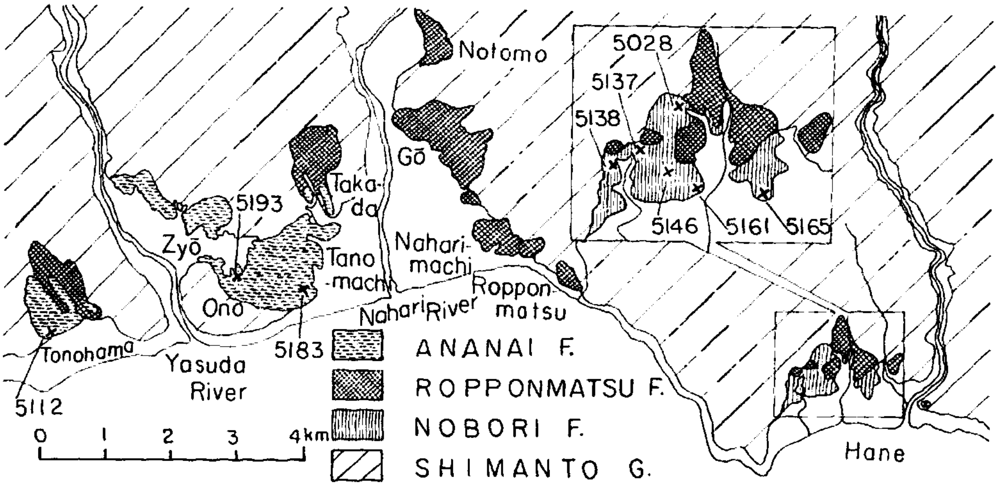
On the other hand, TAKAYANAGI and SAITO (1962) described 50 species of planktonic foraminifera including *Globigerina nepenthes* TODD from the type locality of the Nobori formation. They correlated the fauna directly with the *Globorotalia menardii menardii—Globigerina nepenthes* Zone of Venezuela and the Tortonian in Italy. Furthermore, SAITO (1963) correlated the Nobori fauna with that of the Sagara group, Shizuoka Prefecture, which is overlain by the Kakegawa group with partial unconformity. Consequently, from the planktonic foraminifera the Nobori was assigned to Upper Miocene.

Up to now there have still remained the two different opinions on the geologic age of the Nobori formation based on different kind of fossils, namely, the one is Upper Miocene by means of planktonic foraminifera and the other is Lower Pliocene on the basis of molluscan fossils.

During the stratigraphic and paleontologic investigation of the Tonohama group, the author obtained some new data concerning the stratigraphic relation and the faunal characteristics of the benthonic foraminifera of the Tonohama group. They are remarked and discussed in this paper with the description of fifteen species including three new species from the Nobori formation.

Stratigraphic notes

The Tonohama group which attains about 300 m in total thickness unconformably overlies the Mesozoic and Paleogene rocks, and is overlain by the Quaternary deposits with an unconformity. The sediments are composed of two major sedimentary cycles by intercalation of non-marine deposits, and consist of following formations as shown below in descending order (KATTO *et al.*, 1953).



region of Tosa Bay and sample locality.

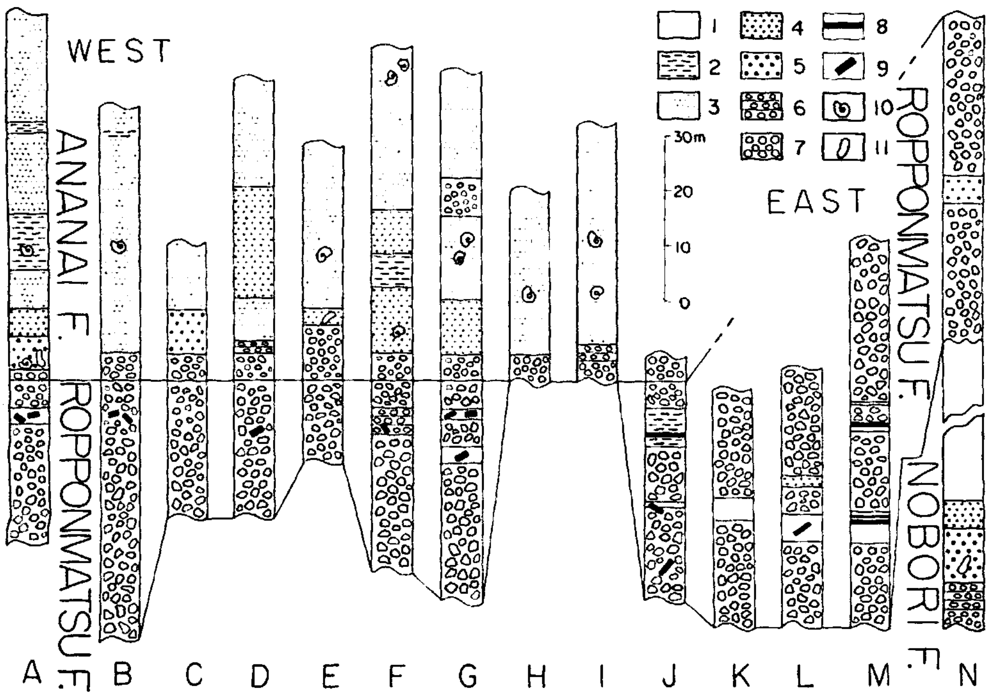


Fig. 2. Columnar sections.

1. Mudstone, 2. Muddy sandstone, 3. Fine-grained sandstone, 4. Medium-grained sandstone, 5. Coarse-grained sandstone, 6. Alternation of sandstone and conglomerate, 7. Conglomerate, 8. Lignite bed, 9. Carbonaceous matter, 10. Mollusca, 11. Lebensspuren.

A. Ananai, B. Shinhama, C. Kodaiji, D. Sawanodaira, E. Kubota, F. Ioki, G. Tonohama, H. Zyô, I. Ono, J. Takada, K. Notomo, L. Gô, M. Ropponmatsu, N. Hane.

Ananai formation: 25-65 mm. Fine-grained sandstone with abundant molluscs and foraminifers. The lower part consists of coarse- to medium-grained sandstone with basal conglomerate.

——— conformity ———

Ropponmatsu formation: 15-70 m. Non-marine conglomerate consisting of poorly sorted, subangular cobbles, often boulders at the base. Intercalated with thin lignite and lignitic siltstone beds.

——— disconformity ———

Nobori formation: About 140 m. Massive siltstone. In the basal part coarse- to fine-grained sandstone, alternating with siltstone at some places. Abundant foraminifers and molluscs. Rarely found shark's teeth, otoliths and vertebrate bones.

Some stratigraphic revisions of the previous work (KATTO *et al.*, 1953) are proposed as shown in Fig. 1 and remarked below.

(1) The conglomerate developed in the western areas between Ananai and Tonohama which was regarded as the basal conglomerate of the Ananai in the previous works is nothing but the western extension of the Ropponmatsu formation. The reason is that this conglomerate is composed of poorly sorted conglomerate intercalated with lignitic siltstone layers and being greater in thickness comparing with well-sorted subrounded basal conglomerate of the Ananai which is less than 10 m in thickness and typically developed where the Ananai directly overlies the Mesozoic or Paleogene rocks. The lithofacies of the conglomerate in question is quite similar to that of the type section of the Ropponmatsu formation at Ropponmatsu, and belongs to the Ropponmatsu formation. Accordingly the Ropponmatsu formation is distributed all over the areas where the Tonohama group is developed.

(2) The Ropponmatsu formation is conformably overlain by the Ananai formation. This relation was formerly considered to be an unconformity. In the western areas between Ananai and Tonohama the non-marine conglomerate is always covered with the marine sandstone of the Ananai which yields molluscs and foraminifers. The former, which has been correlated with the type section of the Ropponmatsu as mentioned above, gradually changes upward to the latter facies of the Ananai everywhere. Therefore the Ropponmatsu formation is conformably overlain by the Ananai. This relation is well observed at Ioki, Tonohama and some other localities.

(3) The stratigraphic relationship between the Nobori and the Ropponmatsu formations is a disconformity. According to KATTO *et al.* the Nobori was regarded to be in fault contact with the Ropponmatsu, and their stratigraphic relationship was supposed to be an angular unconformity. Judging from my own field observation, both formations are not in fault contact, and the non-marine conglomerate of the Ropponmatsu seems to lie on the deep water marine sediments of the Nobori, indicating an unconformable relation. The unconformity is, however, not an angular unconformity but may be disconformity, because the Nobori and Ropponmatsu formations slightly dip to the west less than 15° at Hane and there is no perceptible difference of the geological structure between them.

Discussion: According to KATTO *et al.* (1953), the stratigraphic relationships among the Tonohama group were regarded that the Nobori was separated from the Ropponmatsu by an angular unconformity and that the Ropponmatsu was also separated from the Ananai by an unconformity. It was, therefore, pointed out that there was a significant break between the Nobori and Ananai which indicated rather long period of non-deposition.

It is known that Plio-Miocene boundary in Japan is placed at unconformities between the Neogene formations in many cases. The break between the Nobori and Ananai was considered important (KATTO and OZAKI, 1955; TAKAYANAGI and SAITO, 1962) because it might be referrable to the unconformities of other regions in Japan at which Plio-Miocene boundary was placed. KATTO (1960) furthermore excluded the Nobori and Ropponmatsu formations from the Tonohama group. However, TSUCHI (1961) noted that three formations of the Tonohama group were appropriate to be combined into a single sedimentary group because of the obscurity of the unconformable relations and faunal evidence of molluscan fossils.

As noted before it may be concluded that the Ananai formation overlies the Ropponmatsu with conformable relation, and the stratigraphic relation between the Nobori and Ropponmatsu is not an angular unconformity but a disconformity. The widely distributed Ropponmatsu and Ananai formations may indicate the Tonohama group to be of rather horizontal structure than homoclinal one. In short, there is no significant unconformity among the three formations of the Tonohama group, and the break between the Nobori and Ananai formations is not so large as regarded in the previous studies.

Faunal remarks

Except the non-marine Ropponmatsu formation, the Nobori and Ananai formations yield rich foraminiferal faunas, and they were studied by ASANO (1937) and TAKAYANAGI (in KATTO *et al.*, 1953) in detail.

The Nobori and Ananai faunas comprise two different assemblages respectively. The assemblage found from the basal part of the Nobori is called, in the present paper, the sandstone member assemblage and that from the upper or main part of the same formation is the siltstone member assemblage. As the fauna found in the Ananai changes laterally in this region, it is divided into two biofacies which were called by TAKAYANAGI (in KATTO *et al.*, 1953) the Ioki biofacies of the west and the Senpuku biofacies of the east. These four assemblages are remarked below. The constitution of them are shown by representative samples (Table 1).

Sandstone member assemblage of the Nobori formation: This assemblage has not been reported previously from the Nobori. It is found in the basal sandstone member (20 m+) of the Nobori, and characterized by the common species listed below; *Ammonia ketienziensis* (ISHIZAKI), *Cassidulina carinata* CUSHMAN, *Bulimina marginata* D'ORBIGNY, *Hanzawaia nipponica* ASANO, *Cibicides pacificus* CUSHMAN, and *Rectobolivina raphana* (PARKER and JONES). These species occur generally 5-10% in frequencies and are almost restricted to the basal member in the Nobori. They are associated with *Stilostomella lepidula* (SCHWAGER), *Ammonia takanabensis* (ISHIZAKI), *Amphicoryna sagamiensis* (ASANO), etc. which occur in less frequencies. Some characteristic species of the Ananai fauna which were only reported from the Ananai formation previously are rarely found in this assemblage, namely, *Clavulina yabei* ASANO, *Martinottiella bradyana tarukiensis* (ASANO), *Loxostomoides amygdalaeforme iokiense* (ASANO), and *Pseudorotalia yabei* (ISHIZAKI). Although some predominant species of the overlying silt-

Table 1. Distribution of benthonic foraminifera in the Tonohama group (in percent).

Formation	NOBORI						ANANAI					
Assemblage	Siltstone mem. as.			Sandstone mem. as.			Senpuku biof.			Ioki biof.		
Sample number	5165	5161	5146	5028	5137	5138	5193	5112	5183	5063	5184	5083
Brizalina robusta	3.1	6.2	16.1			0.8						
Stilostomella sp. A	2.3	1.4	0.8			0.4						
Uvigerina proboscidea	0.8	7.6	1.7	0.5								
Eilohedra rotunda	0.4	0.4	7.6									
Cassidulina kattoi	5.0	1.1	1.2									
C. sp. A	0.4	1.4	11.2									
Gyroidina orbicularis	2.3	3.7	0.4		0.5		6.0					
Nodosaria longiscata	2.7	2.9	0.8	0.5	0.5							
Bolivinita quadrilatera	0.4	1.4	0.4		2.5	0.4						
Stilostomella lepidula	3.5	6.2	6.6	3.2	11.4	1.5	0.9					
Bulimina nipponica	14.6	3.7	0.8		3.0	1.5			0.9			
Uvigerina shiwoensis	0.4	4.2		1.1	1.5	14.5	3.5					
Cassidulina carinata	19.2	12.3	3.3	12.8	3.5	0.8	16.5	4.4		0.4		2.9
Bulimina marginata	0.4	1.4	0.8	2.1	6.9	1.5	3.5	5.9		3.8		4.1
Cibicides pseudoungerianus	1.2	0.7		3.7	1.5		2.2	2.0	4.7	1.1	2.0	4.5
Clavulina yabei				1.6		7.3	0.9					
C. yabei akiensis				1.6					0.9			
Martinottiella bradyana tarukiensis				1.6		8.4						
Rectobolivina raphana				2.6	0.5	6.9	1.9	7.4	4.7	6.8	4.7	3.3
Ammonia japonica				2.1	0.5					9.1	1.3	1.2
A. ketienziensis		1.4		6.4	15.8	5.7	2.5	2.5	9.0	1.9		1.2
A. takanabensis				1.6	3.0	4.2	0.3					
Pseudorotalia yabei				8.4							2.0	
Cibicides pacificus				4.8		7.3	1.6	2.5	8.1	13.3		5.8
Florilus manpukujiense				1.6	4.0		0.3		0.9	7.2	2.7	0.4
Hanzawaia nipponica				5.9		6.0	6.0	3.4	3.3	8.7	14.1	10.0
Melonis pompilioides				0.5		2.3			0.5			
Amphicoryna sagamiensis				1.6	3.0	0.8	0.3	2.5	0.5			
Sphaeroidina bulloides	0.4	3.6		0.5		1.1			0.9			
Brizalina cf. albatrossi		0.4					3.5	7.4	11.8	9.8	17.4	14.5
B. hanzawai				0.5				3.4	2.4	5.7		2.5
Loxostomoides amygdalaeforme iokie-		0.4						2.0		1.9		2.9
Rosalina williamsoni nse									2.9	2.6	3.4	1.6
Ammonia cf. beccarii		0.4					0.3	3.9	1.4	1.6	0.7	2.5
Elphidium advenum		0.4	0.4	0.5			3.2	10.3	3.8	2.3	4.1	9.2
E. clavatum										0.8	7.4	3.3
E. crispum	0.4	0.4	0.4				0.3	1.0	0.9	2.7	2.0	8.3
Planktonic / Benthonic + Planktonic	64.2	39.4	35.3	21.4	9.4	19.6	32.5	43.4	38.3	5.4	0	5.7

stone member assemblage occur in this assemblage, they are very low in frequencies with an exception of *Cassidulina carinata* which is frequent in both assemblages.

Siltstone member assemblages of the Nobori formation : The assemblage from the siltstone member of the Nobori occupies almost whole part of the formation, and it corresponds to the "Nobori fauna" reported by TAKAYANAGI. Diagnostic and dominant species are *Brizalina robusta* (BRADY), *Uvigerina proboscidea* SCHWAGER, *Bulimina nipponica* ASANO, *Cassidulina carinata*, *C.* sp. A, *Stilostomella lepidula*, and *S.* sp. A. Following species are almost only found in this assemblage ; *Plectofrondicularia totomiensis* MAKIYAMA, *Tosaia hanzawai* TAKAYANAGI, *Stilostomella ketienziensis* (ISHIZAKI), *Eilohedra rotunda* (HUSEZIMA and MARUHASHI), and *Cassidulina kattoi* TA-

KAYANAGI. The occurrence of the dominant and associated species are consistent through the whole section with rather uniform composition and frequencies of the species. It is, therefore, easily distinguished from the other assemblages distributed in this region. Planktonic foraminifers are abundantly found in each sample.

Ioki biofacies of the Ananai formation: The Ioki biofacies is developed in the western region between Ananai and Ioki. It is characterized by the high frequencies of the following species; *Hanzawaia nipponica*, *Elphidium advenum* (CUSHMAN), *E. crispum* (LINNÉ), *Brizalina* cf. *albatrossi* (CUSHMAN), and *Rectobolivina raphana*. The following species are also found frequently; *Rosalina williamsonii* (PARR), *Loxostomoides amygdalaeforme iokiense*, *Brizalina hanzawai* (ASANO), *Cibicides pseudoungerianus* (CUSHMAN), *Elphidium craticulatum* (FICHTEL and MOLL) and others. *Operculina ammonoides* (GRONOVIUS) is frequently found at Ioki.

Senpuku biofacies of the Ananai formation: In this assemblage developed at Tonohama and Ono the dominant species of the Ioki biofacies also occur in lower frequencies. The following species are restricted only to the Senpuku biofacies in the Ananai fauna in spite of their low frequencies; *Amphicoryna sagamiensis*, *Sphaeroidina bulloides* D'ORBIGNY, *Oridorsalis umbonatus* (REUSS), *Melonis pompilioides* (FICHTEL and MOLL), *Stilostomella lepidula* and *Bulimina nipponica*. This assemblage is also distinguished from the Ioki biofacies in having more number of specimens of planktonic foraminifera, namely, the former usually contains 30-60% for total population (benthonic+planktonic), while the latter only contains less than 6%.

Discussion

The Nobori and Ananai faunas comprise many Recent species which makes it easy to compare the two with Recent faunas. ASANO (1936) compared the Recent benthonic foraminiferal fauna of Toso Bay and the Ananai fauna, and discussed the water temperature and extinct species of the Ananai formation. ISHIWADA (1965) studied the frequency distribution of the Recent benthonic foraminifera along the one traverse of Toso Bay, and recognized neritic and bathyal faunal facies which were subdivided into two subfacies respectively.

The four assemblages of the Nobori and Ananai formations may be comparable with the Recent fauna of Toso Bay, and their inferred paleo-environments are shown (Fig. 3). The Nobori fauna comprises shelf and slope species. The environment of the sandstone member assemblage of the lower Nobori is of central or lower shelf, while that of the siltstone member assemblage is a deeper water one ranging from continental edge to upper slope. The former indicates early stage of the transgression and the latter represents maximum transgression, but regressive facies is not found in the Nobori formation. The Ananai fauna consists of shelf species. The Senpuku biofacies of the Ananai comprises more

Formation	Ananai	Nobori
Upper Shelf	Ioki biof.	
Central Shelf	(west) Senpuku biof.	Sandstone mem. as. (lower part)
Lower Shelf	(east)	
Upper Slope		Siltstone mem. as. (main part)

Fig. 3. Inferred environments of the four assemblages of the Nobori and Ananai formations.

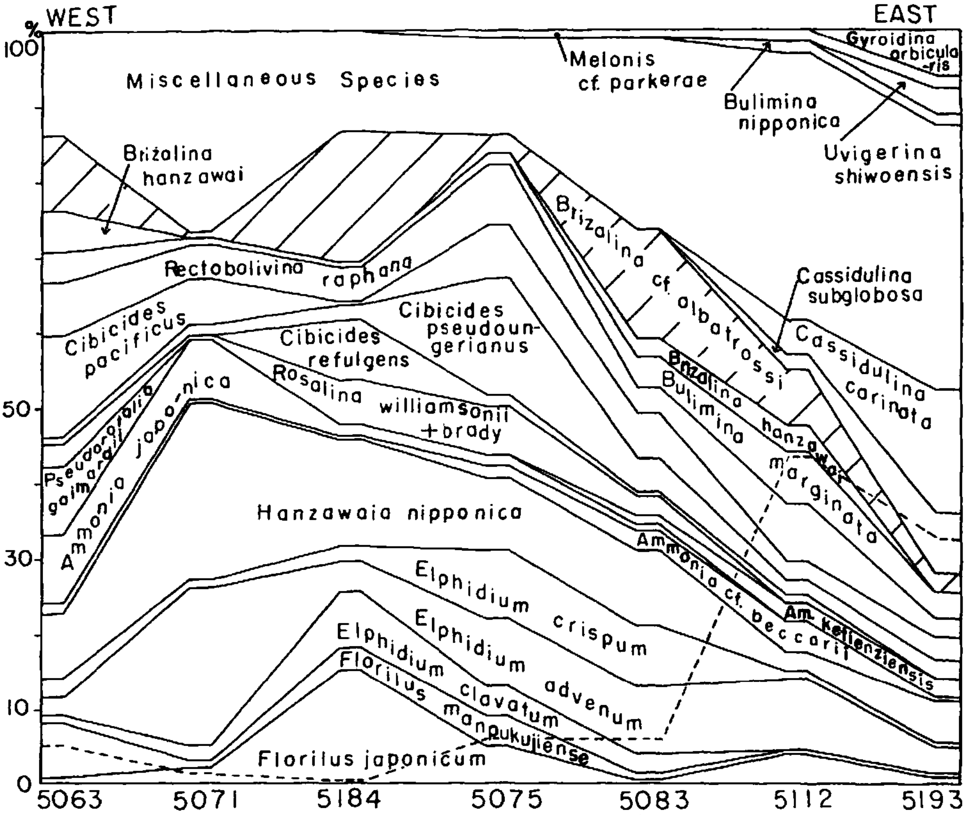


Fig. 4. Lateral faunal change of the Ananai formation. Species are arranged approximately from shallow to deep water ones in ascending order. All samples are from middle part of the Ananai formation. Sample locality is shown in Fig. 1. Dotted line is planktonic foraminiferal content for total population.

deeper water shelf species and more number of planktonic foraminifera than those of the Ioki biofacies of the same formation. The lateral faunal change of the Ananai may indicates gradual shallowing of the environment towards the west (Fig. 4).

In the comparison of the Nobori fauna with that of the Ananai, the sandstone member assemblage is more similar to the Ananai fauna rather than the siltstone member assemblage (Table 1). The dominant species of the Nobori sandstone member assemblage are also common in the two assemblages of the Ananai in rather high frequencies, but are not present or only rarely found in the Nobori siltstone member assemblage. Many other species in the Nobori sandstone member assemblage are also found in the Ananai fauna.

Comparison of the representative samples from the sandstone and siltstone member assemblages of the Nobori and the Senpuku biofacies of the Ananai are shown in Fig. 5. The dominant species in the two samples of the Nobori sandstone member assemblage and the Ananai Senpuku biofacies are almost

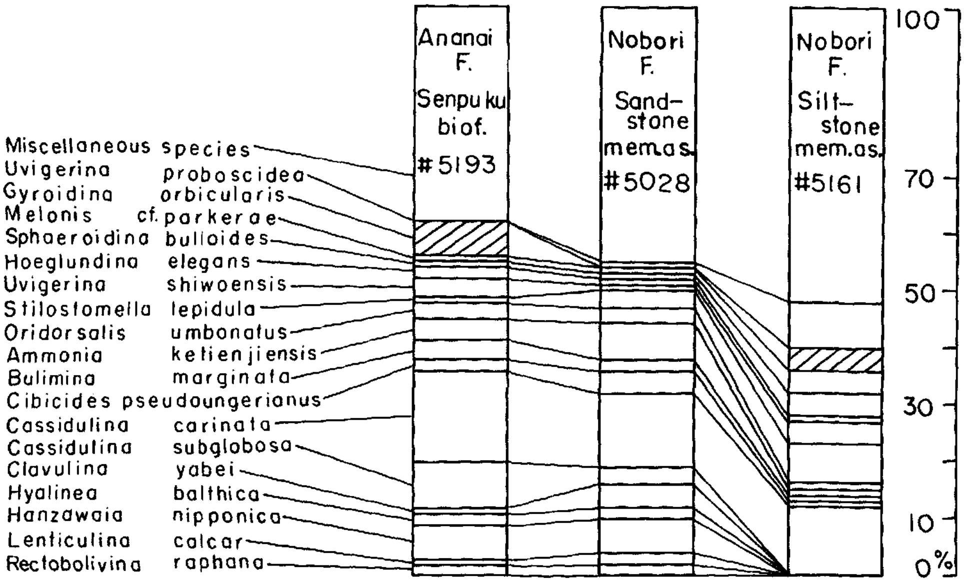


Fig. 5. Comparison of the representative samples from the three assemblages.

common with similar frequencies. While in the sample of the Nobori siltstone member assemblage a larger number of deeper water species are contained. In the sample of the Nobori sandstone member assemblage the common species with the Ananai fauna attain more than 80% in total population frequency.

Therefore, the sandstone member assemblage of the lower Nobori formation is similar to the Ananai fauna particularly to the Senpuku biofacies, and differs from the Nobori siltstone member assemblage. This seems to suggest that the difference between the Nobori siltstone member assemblage and the Ananai fauna which does not comprise the slope assemblage such as the Nobori siltstone member assemblage is simply caused by different environmental conditions. This opinion is supported by other evidences. Some species yielded in high frequencies in the Ananai formation of the upper Tonohama group, such as *Clavulina yabei*, *C. yabei akiensis* ASANO, *Martinottiella bradyana tarukiensis*, *Brizalina hanzawai*, *B.* cf. *albatrossi*, *Florilus japonicum* (ASANO), *Elphidium crispum* and *E. advenum*, occur in very low frequencies (less than 1%) in the two assemblages of the Nobori formation of the lower Tonohama group. Most of these species in the Nobori might be transported from the contemporaneous sediments of shallower places considering their preservation and occurrence. The siltstone member assemblage of the Nobori has the highest frequencies of the planktonic foraminiferal content, and has more number of the benthonic species and less number of the warm to subtropic water benthonic species than the other assemblages. These evidences all indicate that the Nobori siltstone member assemblage represents the deepest water condition in the four assemblages of the Tonohama group.

Therefore it may be concluded that the Nobori and Ananai benthonic foraminiferal faunas are not so quite different as stated in the previous papers, but rather belong to the same faunal group. The different aspect of the two faunas is mostly a reflection of the different environmental conditions.

Geologic age of the Nobori formation

The Ananai formation, the upper part of the Tonohama group, has been considered as Pliocene from the molluscan fossils and foraminifera (ASANO, 1937; NOMURA, 1937, and others). On the other hand, the Nobori molluscan fauna was generally considered to be also correlative with the Pliocene Kakegawa fauna (TSUCHI, 1961; AOKI, 1966), whereas the Nobori foraminiferal fauna was assigned to Upper Miocene in age because of the following faunal evidences by TAKAYANAGI and SAITO (1962).

(1) The Nobori planktonic foraminiferal fauna is correlated with that of the Upper Miocene *Globorotalia menardii menardii—Globigerina nepenthes* Zone of Venezuela and the Tortonian, Italy.

(2) The Nobori benthonic foraminiferal fauna is quite different from that of the Ananai, and has some resemblances to that of the Miocene deposits of the Kar Nicobar Islands.

(3) The Nobori formation contains some so called guide species which are said to occur in the Miocene strata in Japan, that is, Porifera, *Sagarites* and shark's tooth, *Carcharodon megalodon*.

Among the 50 species of planktonic foraminifera of the Nobori formation TAKAYANAGI and SAITO (1962) found three species which disappeared within the Miocene *Globorotalia menardii menardii—Globigerina nepenthes* Zone, namely, *Globigerina nepenthes*, *Globigerina praebulloides* BLOW and *Globoquadrina altispira globosa* BOLLI, and they correlated the Nobori fauna with that of the *Globorotalia menardii menardii—Globigerina nepenthes* Zone of Venezuela. However, the stratigraphic ranges of these species were extended upward by succeeding studies. For instance *Globigerina nepenthes* and *Globigerina praebulloides* were reported from the Pliocene (JENKINS, 1964; BANNER and BLOW, 1967; BOLLI, 1966), and *Globoquadrina altispira globosa* was found throughout the next younger *Sphaeroidinellopsis seminulina* Zone (BANDY, 1964) and the Pliocene (BOLLI, 1964). BOLLI (1964) and HUANG (1967) questioned the identification of the *Globigerina nepenthes* of the Nobori formation. Moreover, some species which first appear above the *Globorotalia menardii menardii —Globigerina nepenthes* Zone or in Pliocene in other regions can be found in the Nobori fauna such as *Globorotalia hirsuta* (D'ORBIGNY), *Globorotalia tosaensis* TAKAYANAGI and SAITO, *Sphaeroidinella dehiscens dehiscens* (PARKER and JONES) and *Pulleniatina obliquiloculata* (PARKER and JONES) (TAKAYANAGI and SAITO, 1962; BOLLI, 1964).

The Nobori planktonic foraminiferal fauna is, therefore, characterized by the rather peculiar association of species, and differs from those of other regions belonging to the *Globorotalia menardii menardii—Globigerina nepenthes* Zone. BOLLI (1964) and BANNER and BLOW (1967) considered the Nobori as Pliocene in age, and MCTAVISH (1966) said that the Nobori fauna was a mixed one of the *Globigerina nepenthes* and the younger Pliocene faunas, and HUANG (1967) mentioned the correlation of the Nobori is a problem to be reserved for further study. Accordingly, the correlation of the Nobori with the *Globorotalia menardii menardii—Globigerina nepenthes* Zone seems to be incorrect.

KATTO *et al.* (1953) and TAKAYANAGI and SAITO (1962) mentioned that the

Nobori fauna comprised many common species with those of the Miocene deposits of the Kar Nicobar Islands, India, such as *Pyrgo murrhina* (SCHWAGER), *Lenticulina nicobarensis* (SCHWAGER), *Bolivinita quadrilatera* (SCHWAGER), *Uvigerina nitidula* SCHWAGER, *Uvigerina proboscidea*, *Bulimina inflata* SEGUENZA, *Stilostomella lepidula*, *Pleurostomella alternans* SCHWAGER, *Osangularia bengalensis* (SCHWAGER), *Sphaeroidina austriaca* D'ORBIGNY and *Melonis nicobarensis* (CUSHMAN). However, these species are also found in the Ananai fauna except two deep water species of *Pyrgo murrhina* and *Osangularia bengalensis* which are reported from Recent sediments. Accordingly, all the species that are pointed out as common with the Miocene foraminifera of the Kar Nicobar Islands are also found in the Pliocene Ananai formation or Recent sediments, and do not indicate the Nobori to be Miocene in age. In addition the different aspect between the Nobori and Ananai benthonic foraminiferal faunas merely indicates the different environmental conditions to a large extent.

Sagarites and *Carcharodon megalodon* were reported from the Nobori formation by KATTO and OZAKI (1955) and KATTO (1960), and considered as index fossils of Miocene. The both fossils are commonly found from the Upper Miocene, but it is known that they also occur in the Lower Pliocene sediments. Their restricted occurrence in the Nobori formation is mostly due to the deeper facies of the Nobori.

In the correlation of the Nobori formation with the European standard or other foreign countries the planktonic foraminifera is believed to be the most useful. From the planktonic foraminifera, although some different opinions were stated concerning the geologic age of the Nobori formation, many authors concluded that the Nobori fauna was younger than that of the *Globorotalia menardii menardii—Globigerina nepenthes* Zone as noted already.

This conclusion seems to be also indicated from the benthonic foraminifera and the stratigraphic succession as well as molluscan fossils, because the Nobori and the Pliocene Ananai benthonic foraminifera belong to the same faunal group and there are no significant unconformities among the Tonohama group. It is most reasonable that the geologic age of the Nobori formation is regarded to be what is called Lower Pliocene in Japan.

Remarks and description of some species

The benthonic foraminifera of the Tonohama group was studied by ASANO (1937) and TAKAYANAGI (in KATTO *et al.*, 1953) who reported about 300 species. Although they were not wholly described, ASANO (1936) described 3 new species and subspecies from the Ananai formation, and TAKAYANAGI (1953) described 14 new species from the Nobori and Ananai formations. In the present paper 3 new species with other unreported species are described chiefly from the Nobori formation.

Cyclammina sp.

Pl. 28, Fig. 1

Only one specimen was obtained from the type locality of the Nobori formation. It has a large-sized test with numerous chambers and flattened sides. Diameter, 7.30 mm ; thickness, 1.55 mm.

Spiroloculina akiensis KURIHARA, n. sp.

Pl. 28, Figs. 2-4

Test large, compressed, roundly ovate in side view, longer than broad, sides flattened in some specimens, central portion depressed, often more so on one side than the other; periphery broadly rounded; chambers consisting of about eight or less in a megalospheric form, only four or five chambers visible externally due to nearly involute coiling of early chambers, inflated, rapidly increasing in size as added; sutures distinct, sometimes slightly uneven; wall chalky white, rough except the flatten portion of the chamber; aperture rather small, circular, with a tapering short neck and a small bifid tooth. Length of holotype, 1.67 mm; breadth, 1.26 mm; thickness, 0.72 mm.

Holotype, Reg. no. 68035, from a hillside cliff, at Minamihabuki, Nishinohama, Hane-machi, Muroto City, Kochi Prefecture, middle part of the Nobori formation, Upper Miocene or Pliocene, rare.

This form is characterized by having a small number of chambers externally visible, slightly asymmetry in a cross section, and projecting short neck, which are similar to *Spiroloculina subaequalis* PARR described from the Miocene of New Zealand. This new species, however, differs from it by having a shorter neck with a bifid tooth, and a involute chambers in early whorls. It is rarely found at the type locality of the Nobori formation.

Nodosaria tosta SCHWAGER

Pl. 28, Fig. 5

Nodosaria tosta SCHWAGER, 1886, Novara Exp., Geol. Theil, p. 219, pl. 5, fig. 42; ASANO, 1953, Tohoku Univ., Inst. Geol. Pal., Short Pap., no. 5, p. 8, pl. 1, figs. 23, 24.

This species is found throughout the Nobori formation (up to 8%).

Dentalina cf. *spinosa* D'ORBIGNY

Pl. 28, Fig. 6

Cf. *Dentalina spinosa* D'ORBIGNY, 1846, Foraminiferes fossiles du bassin Tertiaire de Vienne, p. 55, pl. 2, figs. 36, 37; ASANO, 1953, Tohoku Univ., Inst. Geol. Pal., Short Pap., no. 5, pl. 1, figs. 33, 34.

Few specimens are obtained from the Nobori formation. The figured specimen slightly differs from the typical form in having more number of costae.

Stilostomella sp. A

Pl. 28, Figs. 7, 8

This small species, consisting of seven to ten chambers with a slightly elongate last-formed chamber, shows somewhat resemblance to *Stilostomella antillea* (CUSHMAN). It commonly occurs in the siltstone member of the middle and upper Nobori formation (up to 8%), and also rarely found in the sandstone member of the lower Nobori and the Ananai formations. Length, up to 0.70 mm; breadth, 0.10 mm.

Parafissurina ovalis TODD

Pl. 28, Figs. 9-11

Parafissurina ovalis TODD, 1957, U.S. Geol. Surv., Prof. Pap. 280H, p. 306, pl. 76, figs. 5, 6.

Parafissurina kiyosumiensis AOKI, 1964, Trans. Proc. Palaeont. Soc. Japan, N.S., no. 53, p. 164, pl. 25, figs. 2a, b.

The Nobori specimens have slightly developed keel especially at the lower part of the test, but its development is rather variable on each specimens. *Para-*

fissurina kiyosumiensis AOKI from the Upper Miocene Kiyosumi formation of the Boso Peninsula has smaller test than the Nobori form, but both are identical. It is frequently found in the Nobori formation. Length, 0.68 mm; breadth, 0.62 mm; thickness, 0.33 mm.

"*Bulimina*" *affinis* D'ORBIGNY

Pl. 28, Fig. 12

Bulimina affinis D'ORBIGNY, 1839, *in* De la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 105, pl. 2, figs. 25, 26; CUSHMAN and PARKER, 1940, Contr. Cushman Lab. Foram. Res., v. 16, p. 7, pl. 2, figs. 1-4.

Globobulimina affinis PARKER, 1958, Swedish Deep-Sea Exped., v. 8, p. 262, pl. 2, figs. 24, 25.

The Nobori specimens characterized by distinctly perforate wall and depressed sutures are very similar to the figures by CUSHMAN and PARKER (1940). This species was referred to the Genus *Protoglobobulimina* HOFKER by BELFORD (1966). It is rarely found in the Nobori and Ananai formations (less than 1%). Length, up to 0.78 mm; breadth, 0.47 mm.

Trifarina shikokuensis KURIHARA, n. sp.

Pl. 28, Fig. 16

Angulogerina angulosa KUWANO, 1962, Misc. Rep. Res. Inst. Natur. Resources, no. 58-59, pl. 14, figs. 1, 2.

Trifarina cf. *angulosa* AOKI, 1965, Saitama Univ. Sci. Rep., ser. B, v. 5, no. 1, p. 59, pl. 7, figs. 4, 5.

Test small, fusiform, triangular in apertural view, about two times as long as broad, widest at the central portion, composed of about three whorls; chambers slightly inflated, strongly overlapping in earlier whorls, slightly angulated at the basal part; sutures depressed, nearly straight except the last whorl's ones; wall ornamented with longitudinal costae which show spine-like feature in the early whorls; aperture terminal, rounded, with a weak lip. Length of holotype, 0.26 mm; width, 0.11 mm.

Holotype, Reg. no. 68041, from a cliff near the top of a hill, about 300 m west of Nobori, Hane-machi, Muroto City, Kochi Prefecture, upper part of the Nobori formation, Upper Miocene or Pliocene, few.

This small species was referred to *Trifarina angulosa* in Japan. *Trifarina angulosa* (WILLIAMSON) was originally described from the Recent sediment without designation of the type locality. WILLIAMSON (1858, Rec. For. Gt. Br., p. 67, pl. 5, fig. 140) and LOEBLICH and TAPPAN (1964, Treatise on Invert. Paleo., pt. C, Protista 2, p. 571, figs. 450, 1-3) show that *T. angulosa* has larger size (ca. 0.60 mm), more slender form, less overlapping chambers, and more distinct lip than those of the present new species. It is also distinguished from *Trifarina angulosa pauperata* (HERON-ALLEN and EARLAND) (1932, Discovery Repts., v. 4, p. 398, pl. 12, figs. 40-43) by less inflated chambers. Other similar form is *Trifarina trigona* (SEGUENZA) (1862, Accad. Gioenia Sci. Nat. Catania, ser. 2, v. 18, p. 110, pl. 2, fig. 10) from the Pleistocene of Scicily, but it has larger test than the present new species and is regarded to be probably identical with *T. angulosa* by CUSHMAN (1941).

Trifarina shikokuensis is widely distributed from Miocene to Recent on the Pacific-side area of Japan, and frequent in the Nobori and Ananai formations (up to 3%).

Uvigerina rutila CUSHMAN and TODD

Pl. 28, Figs. 13, 14

Uvigerina rutila CUSHMAN and TODD, 1941, Contr. Cushman Lab. Foram. Res., v. 17, p. 78, pl. 20, figs. 16–22; BOOMGAART, 1949, Smaller Foraminifera from Bodjonegoro (Java), Diss. Univ. Utrecht, p. 119; DROOGER, 1953, Contr. Cushman Found. Foram. Res., v. 4, p. 136, pl. 21, figs. 29, 30.

Rare specimens only from the type locality of the Nobori formation are identical with CUSHMAN and TODD's figures from the Pliocene of the Mediterranean region. The Nobori forms have larger size than the type. This species shows a large amount of variation in the number of costae. Nobori specimens have numerous, narrow and weak costae, about 15 or more to a chamber. Weak and short spinose projections are sometimes found at the lower part of the earlier chambers of the megalospheric form.

Uvigerina substriata ASANO

Pl. 28, Fig. 15

Uvigerina substriata ASANO, 1938, Jour. Geol. Soc. Japan, v. 45, p. 614, pl. 17, figs. 21, 22; CUSHMAN, 1941, Contr. Cushman Lab. Foram. Res., v. 17, p. 77, pl. 20, figs. 14, 15; ASANO, 1950, Illust. Cat. Japan Tert. Foram., pt. 2, p. 18, figs. 83, 84; AOKI, 1965, Saitama Univ. Sci. Rep., ser. B, v. 5, no. 1, p. 57, pl. 7, figs. 28, 29.

This species is found in the Nobori formation in low frequencies (less than 1%). It has been only reported from the Pliocene and Pleistocene of the Boso Peninsula. Length, up to 1.13 mm; diameter, 0.50 mm.

Gavelinopsis translucens (PHLEGER and PARKER)

Pl. 28, Figs. 17–19

"*Rotalia*" *translucens* PHLEGER and PARKER, 1951, Geol. Soc. Amer. Memoir 46, pt. 2, p. 25, pl. 12, figs. 11, 12; PHLEGER, PARKER and PEIRSON, 1953, Swedish Deep-Sea Exped., v. 7, pt. 1, p. 42, pl. 9, figs. 22, 23; PHLEGER, 1960, Ecology and Distribution of Recent Foraminifera, pl. 13, figs. 13, 14.

The convexity of the dorsal side of the Nobori form is considerably variable. Some specimens have almost flattened dorsal side. This species occurs throughout the Nobori formation especially in the upper part (up to 14%). Diameter, up to 0.34 mm; thickness, 0.11 mm.

Eilohedra rotunda (HUSEZIMA and MARUHASI)

Pl. 28, Figs. 20–22

Eponides rotundus HUSEZIMA and MARUHASI, 1944, Misc. Rep. Inst. Natur. Resources, v. 1, no. 3, p. 399, pl. 34, figs. 12a–c.

This very small species was described from the Nishiyama formation of Niigata Prefecture. It is similar to the Recent and Pliocene Californian species of *Eilohedra levicula* (RESIG) (1958, Micropaleontology, v. 4, p. 304, text-figs. 16a–c). The Californian species, however, seems to have more broadly rounded periphery and more inflated chambers on the ventral side than the present form. It occurs commonly in the Nobori formation (up to 8%) and rarely found in the Anai formation. Maximum diameter, 0.13 mm; thickness, 0.08 mm.

Quadrimorphina akiensis KURIHARA, n. sp.

Pl. 28, Figs. 23–25

Test small, trochoid, biconvex, umbilical region depressed; periphery lobulate; edge broadly rounded; chambers inflated, five in the last whorl, gradually increasing in size as added; sutures distinct, slightly curved on both sides, more depressed ventrally; wall smooth, finely perforate; aperture a low silt extending from the umbilicus to the periphery with a elongate distinct lip. Length of holotype, 0.27 mm; width, 0.22 mm; thickness, 0.17 mm.

Holotype, Reg. no. 68046, from a hillside cliff, at Minamihabuki, Nishinohama, Hane-machi, Muroto City, Kochi Prefecture, middle part of the Nobori formation, Upper Miocene or Pliocene, few.

This species is similar to *Quadrimorphina glabra* (CUSHMAN) (1927, Scripps Inst. Oceanogr., Tech. ser., v. 1, p. 161, pl. 4, figs. 5, 6) described from the Pacific Ocean, but differs from it by having more broadly rounded periphery and more inflated last-formed chamber.

This small species is found commonly in the Nobori formation (up to 4%).

Gyroidinoides altiformis (R. E. and K. C. STEWART)

Pl. 28, Figs. 29–31

Gyroidina soldanii var. *altiformis* R. E. and K. C. STEWART, 1930, Jour. Pal., v. 4, p. 67, pl. 9, figs. 2a-c.

Gyroidina altiformis KUWANO, 1962, Misc. Rep. Res. Inst. Natur. Resources, no. 58-59, pl. 18, figs. 5a, b.

This species is reported from the Lower Miocene to Recent in Japan. It occasionally occurs in the Nobori formation (less than 1%).

Gyroidinoides torulus (BELFORD)

Pl. 28, Figs. 26–28

Gyroidina tricherasensis LEROY (not BERMUDEZ), 1964, U.S. Geol. Surv., Prof. Pap. 454-F, p. 37, pl. 7, figs. 1-3.

Gyroidina torulus BELFORD, 1966, Bur. Min. Resour. Aust. Rep., no. 79, p. 168, pl. 28, figs. 10–20, text-figs. 21, 8-9.

This species was originally described from the Upper Miocene or Pliocene deposits of New Guinea. This forms have the characteristically protruding last chamber on the umbilical side of *Gyroidinoides tricherasensis* (BERMUDEZ) (1949, Cushman Lab. Foram. Res., Special Publ. no. 25, p. 254, pl. 17, figs. 55-57), but the dorsal sutures of the present species is less curved as remarked by LEROY (1964), and peripheral edge of the last few chambers is angled. Some Nobori specimens show gently angled peripheral edge almost through the last whorl.

It is rarely found at the type locality of the Nobori formation.

Acknowledgements

The author wishes to thank Professor Wataru HASHIMOTO of Tokyo University of Education for his continuous guidance and encouragement. Thanks are also due to Dr. Naoaki AOKI of Tokyo University of Education for his kind guidance in the field and laboratory works as well as in preparing the manuscript, Dr. Toshio KOIKE of Tokyo University of Education and Mr. Sakae OHARA of Chiba University for their useful advices and reading the manuscript.

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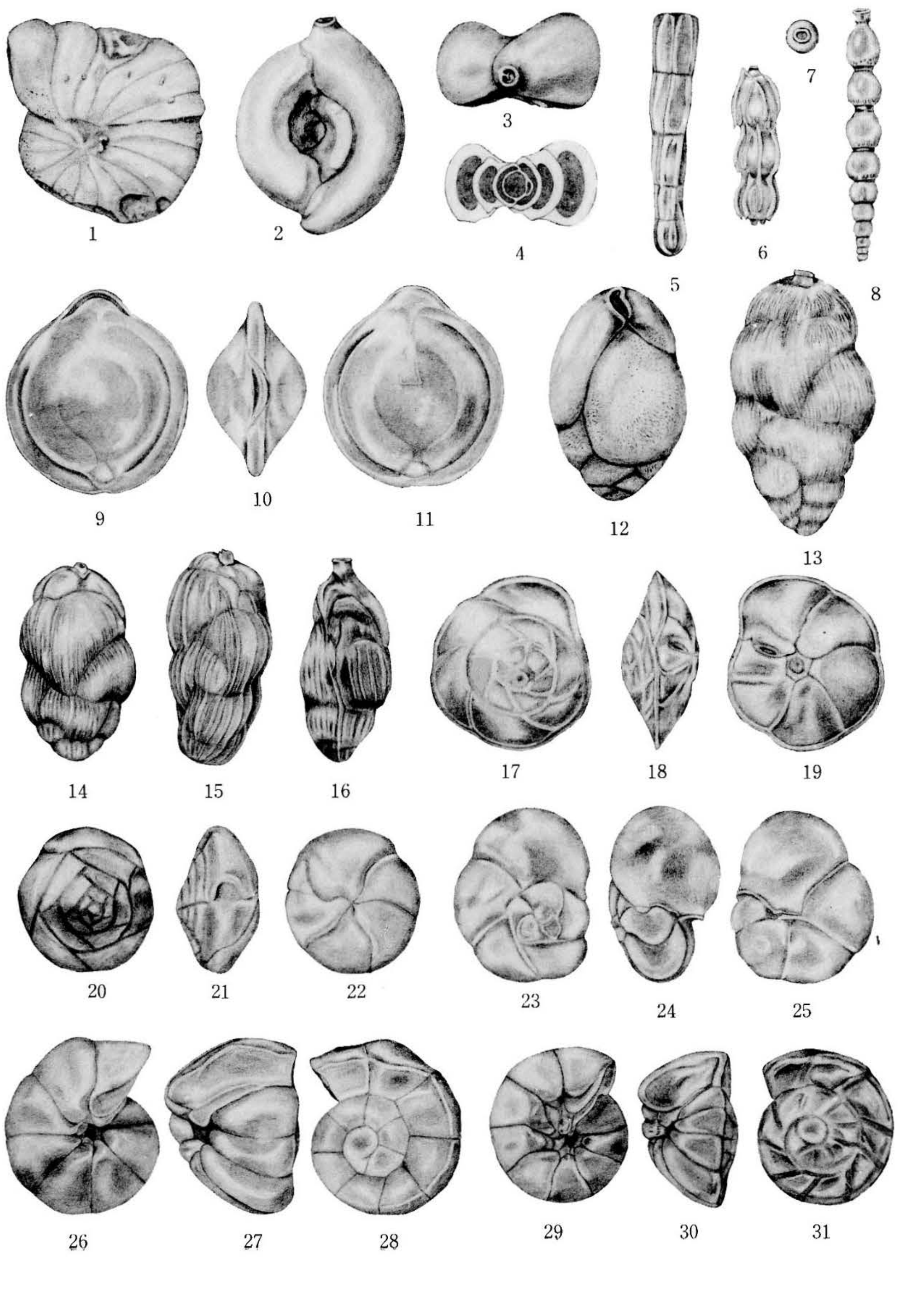
Explanation of Plate 28

Unless localities are given, all from the type locality of the Nobori formation, a hill-side cliff, at Minamihabuki, Nishinohama, Hane-machi, Muroto City, Kochi Prefecture. All figured specimens from the Nobori formation.

Fig. 1. *Cyclammina* sp. ×5, Reg. no. 68034.
Figs. 2-4. *Spiroloculina akiensis* KURIHARA, n. sp. ×20. 2, 3. Holotype, Reg. no. 68035. 2. side view; 3. apertural view. 4. Reg. no. 68036, horizontal section.
Fig. 5. *Nodosaria tosta* SCHWAGER. ×45, Reg. no. 68037.
Fig. 6. *Dentalina* cf. *spinosa* D'ORBIGNY. ×35, Reg. no. 68038.
Figs. 7, 8. *Stilostomella* sp. A. ×55, Reg. no. 68039, a hill-side cliff, at Osô, Hane-machi, Muroto City. 7. apertural view; 8. side view.
Figs. 9-11. *Parafissurina ovalis* TODD. ×45, Reg. no. 68040, a cliff near the top of a hill, about 300 m west of Nobori, Hane-machi, Muroto City. 9, 11. side view; 10. apertural view.
Fig. 12. "*Bulimina*" *affinis* D'ORBIGNY. ×45, Reg. no. 68042.
Figs. 13, 14. *Uvigerina rutila* CUSHMAN and TODD. ×30. 13. Reg. no. 68043, microspheric form. 14. Reg. no. 68044, megalospheric form.
Fig. 15. *Uvigerina substriata* ASANO. ×35, Reg. no. 68045.
Fig. 16. *Trifarina shikokuensis* KURIHARA, n. sp. ×120. Holotype, Reg. no. 68041, a cliff near the top of a hill, about 300 m west of Nobori, Hane-machi, Muroto City.
Figs. 17-19. *Gavelinopsis translucens* (PHLEGER and PARKER). ×90, Reg. no. 68047. 17. dorsal view; 18. edge view; 19. ventral view.
Figs. 20-22. *Eilohedra rotunda* (HUSEZIMA and MARUHASI). ×180, Reg. no. 68048. 20. dorsal view; 21. edge view; 22. ventral view.
Figs. 23-25. *Quadrimorphina akiensis* KURIHARA, n. sp. ×100, Reg. no. 68046, a hill-side cliff at Osô, Hane-machi, Muroto City. 23. dorsal view; 24. edge view; 25. ventral view.
Figs. 26-28. *Gyroidinoides torulus* (BELFORD). ×50, Reg. no. 68049. 26. ventral view; 27. edge view; 28. dorsal view.
Figs. 29-31. *Gyroidinoides altiformis* (R. E. STEWART and K. C. STEWART). ×50, Reg. no. 68050, a river-side cliff at Nishiya, Hane-machi, Muroto City. 29. ventral view; 30. edge view; 31. dorsal view.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例会通知

	開催地	開催日	講演申込締切日
100回例会	金沢大学	1968年9月22,23日	1968年8月20日
101回例会	北海道大学	1968年11月(予定)	1968年10月(予定)

第100回例会(金沢大,地質):コロキアム,化石硬組織内の天然同位体(世話人:小西健二・高柳洋吉)

News

Directory of Paleontologists of the World (2nd ed.) が 1968年7月刊行される。定価は1冊 $2.50 (個人) $4.00 (研究機関) の予定です。購入御希望の方は本会宛申込み下さい。なお,送本に要する費用および外国送金手数料に若干の費用がかかるので1$を400円の換算率にしてご送金下さい。

学会記事

◎ 今年秋行われる日本学術会議会員候補者に,本会より浅野 清君が推薦された。

◎ 文部省学術審議会,学術用語分科会,地学用語専門委員に鹿間時夫君が推薦された。

◎ 「化石」15号が発行された。

shall call a Special Meeting at the written request of more than one-third of the members. The request shall be granted only if the written statement fully explains the reasons for assembly and items for discussion.

Article 19. Members unable to attend the General Meeting may give an attending member a written statement signed by himself trusting the bearer with the decision of business matters. Only one attending member may represent one absentee.

Article 20. The decison of the General Meeting shall be by majority vote. When the number of votes is equal, the President shall cast the deciding vote.

Article 21. The President and Councillors shall compose the Council. The dicision of the General Meeting concerning administration shall be considered and implemented by the Council.

Article 22. The Executive Council shall carry out the decisions of the Council.

Article 23. The fiscal year of the Society shall begin on the first of January each year and end on the thirtyfirst of December of the same year.

Article 24. The amendments to the Constitution of the Society shall be decided at the General Meeting and must be approved by more than two-thirds of those members who are in attendance.

Addendum 1) Voting in the Council shall be by unsigned ballot.

◎ 本会誌の出版費の一部は文部省研究成果刊行費による。

1968年6月20日 印刷
1968年6月30日 発行

日本古生物学会報告・紀事
新篇 第70号
600円

東京大学理学部地質学教室内
日本古生物学会
編集兼発行者 花井哲郎
(振替口座東京84780番)
印刷者 東京都練馬区豊玉北2ノ13
学術図書印刷株式会社 富田 元

CONSTITUTION
of the
PALAEONTOLOGICAL SOCIETY OF JAPAN

Article 1. The Society shall be known as the Palaeontological Society of Japan.

Article 2. The object of the Society is to promote the study and popularization of palaeontology and related sciences.

Article 3. The Society, to execute Article 2, shall undertake the following business:

1. Issue the Society journal and other publications.
2. Hold or sponsor scientific le6tures and meetings.
3. Popularize the science by field trips, scientific lectures and other projects.
4. Aid and encourage research work; award outstanding contributions to the Society; carry out the objectives stated in Article 2.

Article 4. To attain the object of the Society, the Society may, by decision of the General Meeting, establish within it research committees.

Article 5. The society shall be composed of members who are active or interested in palaeontology or related sciences.

Article 6. The members shall be known as Regular Members, Fellows. Patron and Honorary Members.

Article 7. Persons desiring membership in the Society are requested to fill out the necessary application forms and receive the approval of the Council.

Article 8. Fellows are persons who have held Regular Membership in the Society for more that ten years, have contributed to the science of palaeontology, have been nominated by five Fellows and approved by the Council.

Article 9. Patrons are organizations supporting Article 2 and recommended by the Council.

Article 10. Honorary Members are persons of distinguished achievement in palaeontology. They shall be recommended by the Council and approved by the General Meeting.

Article 11. The members of the Society shall be obliged to pay the annual dues stated in Article 12. Members shall enjoy the privilege of receiving the Society journal and participating in the activities stated under Article 3.

Article 12. The rates for annual dues shall be decided by the General Meeting. Rates for annual dues are: Regular Members, Yen 1,000; Fellows, Yen 1,500; and Foreign Members, $4.00; Patrons are organizations donating more than Yen 10,000 annually; Honorary Members are free from obligations.

Article 13. The budget of the Society shall be from membership dues, donations and bestowals.

Article 14. The Society, by decision of the Council, may expel from membership persons who have failed to pay the annual dues or those who have disgraced the Society.

Article 15. The officers of the Society shall be composed of one President and fifteen Councillors, among whom several shall be Executive Councillors. The term of office is two years and they may be eligible for re-election without limitation. The President may appoint several persons who shall be Secretaries and Assistant Secretaries. An Executive Council shall be nominated and approved by the Council. Councillors shall be elected from Fellows by vote of returned mail unsigned ballot.

Article 16. The President shall be a Fellow nominated and approved by the Council. The President shall represent the Society and supervise the business affairs. The President may appoint a Vice-President when he is unable to perform his duties.

Article 17. The Society may have the honarary President. The honorary President shall be recommended by the council and approved by the General Meeting. The honorary President may participate in the Council.

Article 18. The Society shall hold regularly one General Meeting a year. The President shall be Chairman and preside over the administrative affairs. The program for the General Meeting shall be decided by the Council. The President may call a special meeting when he deems it necessary. The General Meeting requires the attendance of more than one-tenth of the members. The President