Lateral change of foraminiferal fauna at the horizon just below the tuffaceous key bed, O_7, of the Otadai Formation in Chiba Prefecture, Japan

Akio HATTA
(Received October 8, 1985)

Department of Science Education,
Faculty of Education, Kagoshima University.
Kagoshima 890, Japan

Abstract

Lateral change of foraminiferal fauna in a siltstone just below a tuff key bed O_7 of the Otadai Formation of Chiba Prefecture was investigated traversing the whole breadth of the Boso Peninsula.

Faunal composition of planktonic Foraminifera of this horizon shows insignificant lateral change (Text-figure 4). This hirizon may belong to N.22 of the BLOW (1969)'s zonation scheme, judging from the ranges of *Globorotalia tosaensis* TAKAYANAGI & SAITO, *G. hirtuta* D'ORBIGNY and *Globigerina parabulloides* BLOW. The planktonic ratios of this horizon indicate the values between 70.3 and 84.1%, and this suggests a typical off-shore environment.

Faunal composition of benthonic Foraminifera shows significant lateral change (Text-figure 5). The siltstone beneath the O_7 bed contains many specimens of deep sea species, such as *Bulimina aculeata* D'ORBIGNY, *B. nipponica* ASANO, *Bolivina robusta* BRADY and *Uvigerina akitaensis* ASANO at every locality. *Elphidium* group and *Quinqueloculina* group, which are characteristic of shallow water, are very rare in the central part, but increase westward.

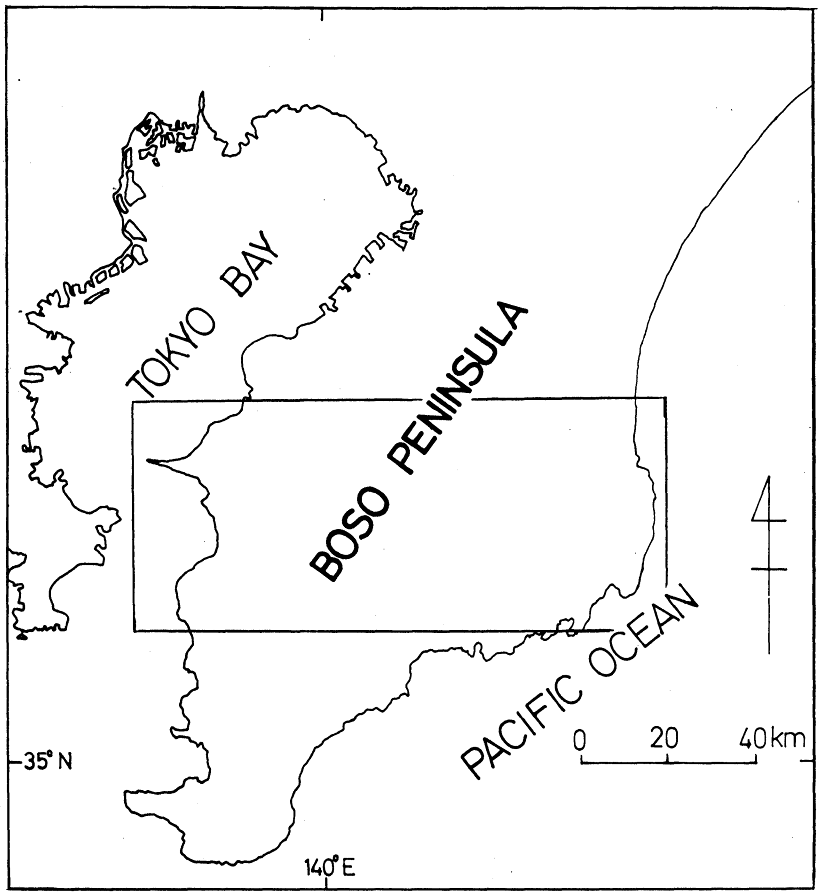
Faunal change of benthonic Foraminifera is scrutinized by using the factor analysis. The results are interpreted by referring to the distribution of Foraminifera in the adjacent seas of Japan.

From the result, it can be thought that the second factor in the *Q*-mode factor analysis is a parameter of abundance of shallow water elements (Table 2 and Text-figure 6).

The occurrence of shallow water elements in the siltstone beneath the O_7 bed may be due to displacement from further west since the second factor is high in the western part and at the same time, the planktonic ratios are rather high suggesting an open sea condition. Such a funal displacement seems to have been caused by some movement on the sea-bottom.

Introduction

The Cenozoic foraminiferal fauna from the Boso Peninsula have been investigated by many authors. Most of them are related to the vertical change of foraminiferal assemblages through some stratigraphic successions. Only a few studies have treated of lateral variation of foraminiferal faunas. Results of study on the spatial change of foraminiferal faunas within a stratum have been given by KITAZATO (1977), who studied the vertical and lateral distribution of benthonic foraminiferal fauna



Text-fig. 1 Index map of the studied area.

on the U6 horizon of the Umegase Formation of the Kazusa Group in the Boso Peninsula.

Some pyrocrastic key beds in the Umegase and the Otadai Formations were traced for a distance of about 15 km and the foraminiferal faunas therefrom were studied by KAWAI *et al.* (1950) and UCHIO (1952).

Many pyroclastic layers exposed in the Boso Peninsula were thoroughly traced by MITSUNASHI *et al.* (1959). The 0_7 tuffaceous key bed, which is intercalated in the upper part of the Otadai Formation, is regarded as an important key bed from the sedimentological point of view as already mentioned by HIRAYAMA & SUZUKI (1965, 1968) and HIRAYAMA & NAKAJIMA (1977a). (For convenience, the 0_7 tuffaceous key bed will be simply called the 0_7 bed hereafter.) HIRAYAMA & NAKAJIMA (1977a) minutely clarified the sedimantary structures of the 0_7 bed and discussed the transportation mechanisms of its components. In addision to these stratigraphical and sedimentological studies on the 0_7 bed, an analytical study on turbidites of this horizon was lately performed by HIRAYAMA & NAKAJIMA (1977b). Under these circumstances, to make the study on microfossils from the horizon close to the 0_7 bed seems worth-while for understanding the sedimentary envilonment of this horizon and the palaeoecology of microfossils.

The writer collected foraminiferal samples from the siltstone bed beneath the 0_7 bed traversing the whole breadth of the Boso Peninsula (Text-figure 1).

The lateral change of foraminiferal fauna in the siltstone will be discussed applying the factor analysis. The results of analysis will be interpreted referring to the information on the distribution of modern Foraminifera in the adjacent seas of Japan.

General stratigraphy

The main part of the Late Cenozoic strata in the Boso Peninsula is distributed in the region north of the Kurotaki Unconformity, which divides the Boso Peninsula into the northern and the southern halves. The strata distributed in the northern half of the Boso Peninsula were divided into the Kazusa Group, the Shimosa Group and the Kanto Loam in ascending order by MITSUNASHI *et al.* (1959) and others.

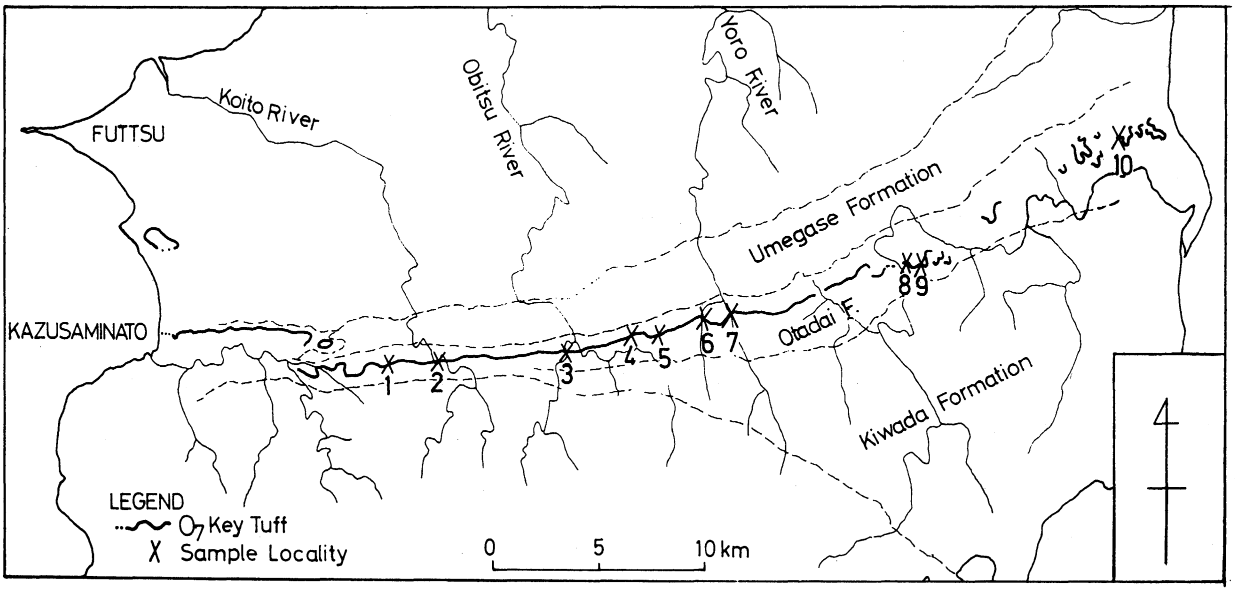
The Kanto Loam is the volcanic ash layers distributed in the southern part of the Kanto region. The Kanto Loam is classified into four volcanic ashes. The younger three volcanic ash beds are recognized to develop in the northern and northwestern parts of the Boso Peninsula overlying the Shimosa and the Kazusa Groups.

The Shimosa Group is distributed in the northern part of this Peninsula. This Group comprises seven Formations consisting mainly of loose sand with abundant molluscan fossils.

The Kazusa Group shows a general trend of strikes in east-west direction and slightly dips northward. The lithology of this Group is mostly sandstone and siltstone. In the siltstone several tuff beds are intercalated. In the area along the Yoro River running from south to north in the central part of the Boso Peninsula, the Kazusa Group was subdivided by MITSUNASHI *et al.* (1959) into the following eight formations: the Kurotaki, the Kiwada, the Otadai, the Umegase, the Kokumoto, the Kakinokidai, the Chonan and the Kasamori Formations in ascending order.

Tracing pyroclastic key beds, MITSUNASHI *et al.* (1961, 1971) recognized that the Kurotaki Formation is contemporaneous with the stratigraphic sequence ranging from the Katsuura Formation to the lower part of the Kiwada Formation through the Namihana and the Ohara Formations in the area east of the Yoro River.

The Otadai Formation containing the 0_7 bed is a flysch-type siltstone-rich alternation of siltstone and sandstone. Several pyroclastic key beds including the 0_7 bed exist in the siltstone. The sandstone beds decrease their thickness westwards resulting in thinning out of this Formation in the western part of the Boso Peninsula. This Formation is called the Takamizo Formation at the area west of the Koito River.



Text-fig. 2 Map showing the distribution of the O_7 tuffaceous key bed and the sampling localities.
1: Takagozawa, 2: Yasumidokoro, 3: Oshigome, 4: Kuratama-nishi, 5: Kuratama-higashi, 6: Kaburai-minami, 7: Kotadai, 8: Uehara-nishi, 9: Uehara-higashi, 10: Shiiki

Distribution and lithofacies of the siltstone bed beneath the O_7 bed

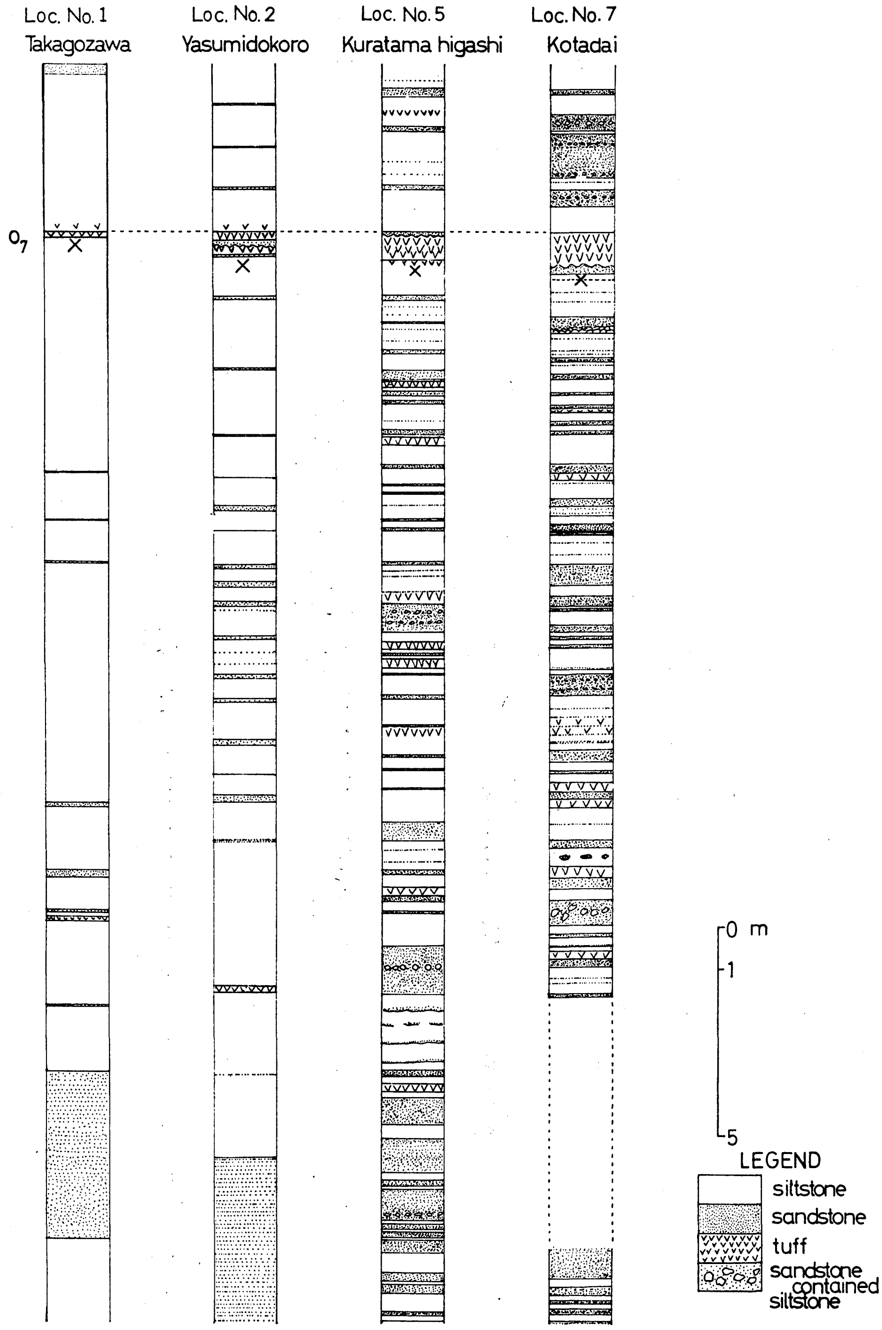
According to Mitsunashi *et al.* (1959, 1961, 1973), the 0_7 bed is a white tuff bed intercalated in the upper part of the Otadai Formation. It is distributed from Narayama of Kazusa-Ichinomiya-machi on the east coast of the Boso Peninsula to the south of Kinadayama in Futtsu City on the west coast through Kazusa-Kameyama and Mishima areas of Kimitsu City. Near Futtsu City, this bed is named the Tm_6 tuffaceous bed (Mitsunashi *et al.*, 1959) in the Takamizo Formation.

The latest information by Mitsunashi *et al.* (1976) indicated that western extremity of this tuffaceous bed is exposed at Kazusa-Minato and Sanuki in Futtsu City facing to Tokyo Bay.

Ten points selected for collecting foraminifers are shown in the geologic sketch map, in which the distribution of the O_7 bed are also indicated (Text-figure 2). Four selected geologic columns are illustrated in Text-figure 3.

The siltstone bed beneath the O_7 bed is light gray in a dry state and bluish green on fresh or wet surface, and is a pelitic stratum composed of siltstone-rich alternation of siltstone and sandstone.

The O_7 bed at Shiiki (Loc. No. 10) in the eastern part of the Boso Peninsula is approximately 2 m in thickness. At Kotadai (Loc. No. 7) of Otaki-machi in the central part of the Peninsula, it decreases in thickness down to approximately 1 m. At Kuratama-higashi (Loc. No. 5) in Kimitsu City, the thickness of O_7 bed is about 60 cm. At Yasumidokoro (Loc. No. 2) in the same City at the western part of the Boso Peninsula, the O_7 bed is only about 20 cm thick. At Takagozawa (Loc. No. 1) in Ki-



Text-fig. 3 Selected geological columnar sections.

mitsu City, the O_7 bed is found in the massive siltstone with a few thin beds of sandstone and its thickness is approximately 10 cm.

As shown in Text-figure 3, the strata below the O_7 bed clearly indicates a lateral change in lithofacies from rhythmic alternation of siltstone and sandstone in the eastern and central parts of the Boso Peninsula to massive and slightly sandy siltstone with the intercalation of thin (1 – 2 cm) sandstone beds in the western part.

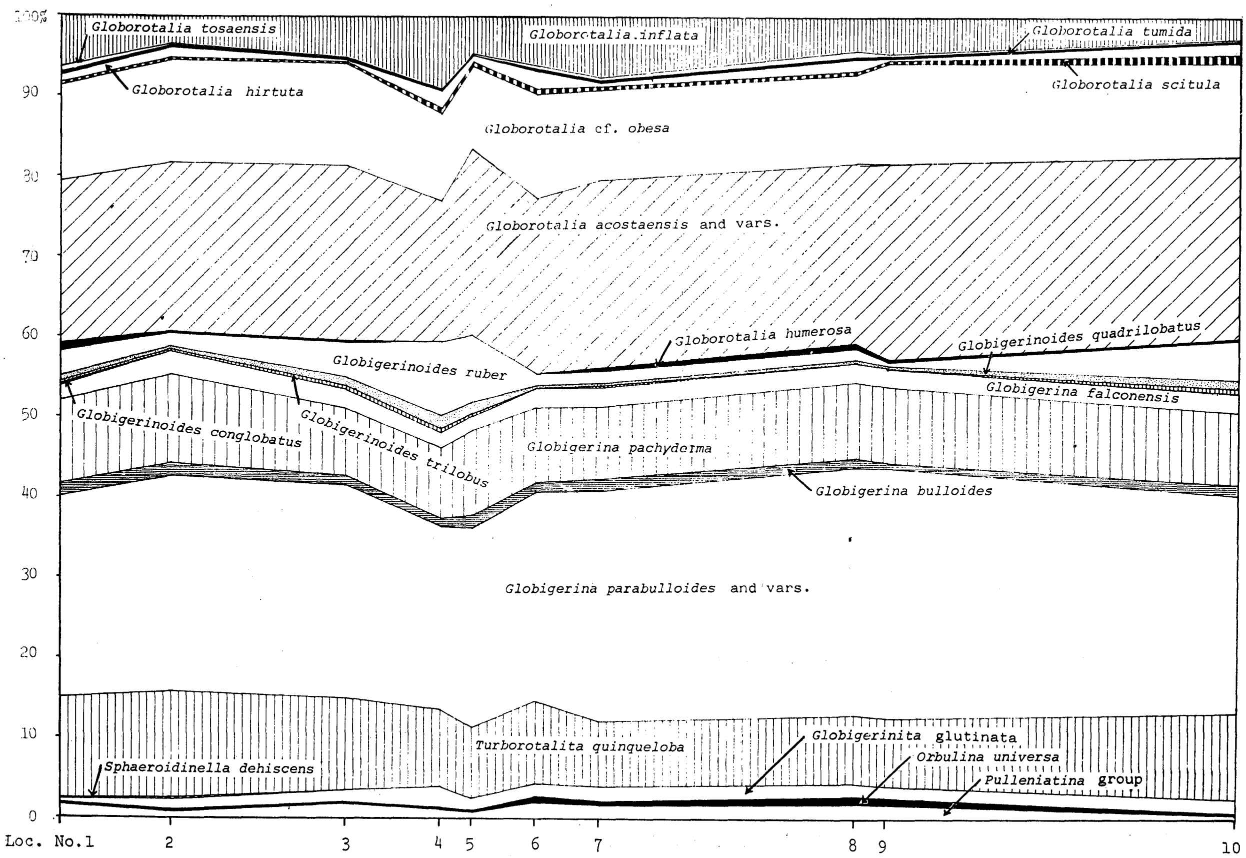
Treatment of the samples

At each locality, samples of the siltstone beneath the O_7 bed were taken from the parts about 10 cm below the O_7 bed along the bedding plane for about 1 m in length until the total weight of the pieces of fresh siltstone amounts to about 1 kg.

Each sample was dried and crushed, and about a hundred gram sample was taken out. And it was macerated by the Glauber's salt method. Aggregated grains of sand size were dried repeatedly. Foraminiferal shells were rised with CCl_4 solution and separated with a filter paper. The remaining part of sample never being rised with CCl_4 solution was checked up with a microscope, but most of them have scarcely contained foraminiferal shells.

Occurrence of planktonic Foraminifera

Faunal composition of planktonic Foraminifera obtained from the siltstone beneath the O_7 bed is summarized in Text-figure 4, which shows insignificant lateral change.



Text-fig. 4 Lateral change of relative frequencies of planktonic Foraminifera.

In the horizon; *Globigerinoides quadrilobatus* (D'ORBIGNY), *Globorotalia tumida* (BRADY), *G. inflata* (D'ORBIGNY), *G. hirsuta* (D'ORBIGNY) and *G. humerosa* TAKAYANAGI & SAITO are found to be a dominant group and they are recognized to live in the present subtropical and tropical oceans. And another group comprising *Globigerina pachyderma* (EHRENBERG), *G. bullodies* D'ORBIGNY, *Globorotalia scitula* (BRADY) and *Turborotalita quinqueloba* (NATLAND) represents about 20 per cent of planktonic foraminiferal assemblage. These species are known to live in the subarctic and subantarctic oceans (BÉ, 1977).

Globorotalia tosaensis TAKAYANAGI & SAITO, *G. hirsuta* (D'ORBIGNY) and *Globigerina parabulloides* BLOW, the good index species, were recovered from almost all samples. Judging from the ranges of these three species, this horizon may be regarded to be N. 22 of the BLOW's (1969) zonation scheme. From the sample at Uehara-nishi, the writer found only one specimen of *Globorotalia tosaensis* provided with a weak peripherial keel on the last chamber resembling the intermediate form between *Globorotalia tosaensis* and *G. truncatulinoides* (D'ORBIGNY) as reported by TAKAYAMA (1974) from Obitsu, Yoro and Choshi section. However, the writer inclines to consider that this specimen may be merely a variety of *G. tosaensis* because of its scarcity in occurrence. According to ODA (1977) who found the *Globorotalia truncatulinoides* (D'ORBIGNY) from a horizon in the Otadai Formation much lower than the O_7 bed, the age of the Otadai Formation is N.22. It is noticeable that the siltstone treated here, representing the N.22 zone, yields solely *Globorotalia tosaensis* without *G. truncatulinoides*.

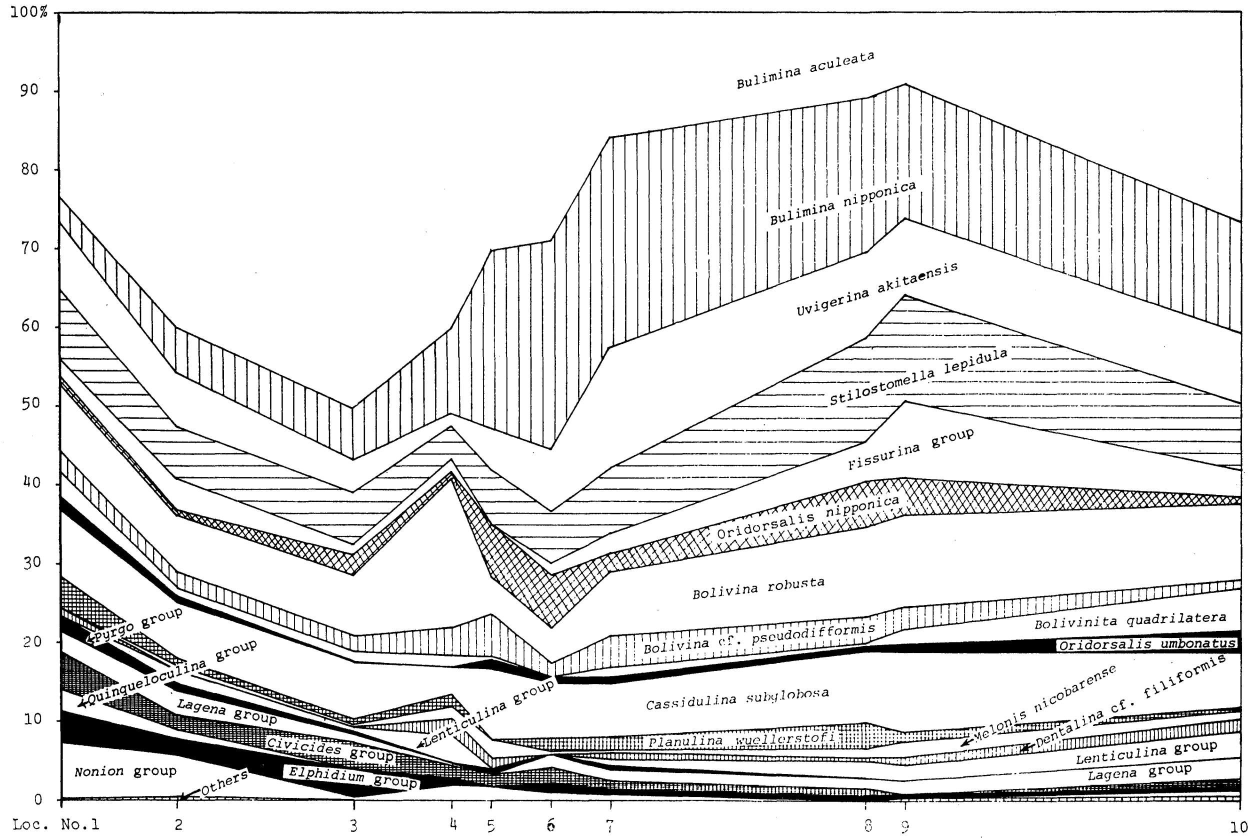
In general, the increase in "planktonic ratio", which is the ratio of the number of planktonic forams to the total number of specimsens including both planktonic and benethonic forams in a sample assemblage, indicates a gradual but definite change of sedimentary environments toward an open sea condition (UJIIÉ & KUSUKAWA, 1969). The planktonic ratio of the siltstone beneath the O_7 bed shows insignificant lateral changes within the values between ca. 70.3 and 84.1%. This suggest a typical off-shore environment.

Lateral change of benthonic foraminferal fauna

The siltstone beneath the O_7 bed contains many specimens of *Bulimina aculeata* D'ORBIGNY, *B. nipponica* ASANO and *Bolivina robusta* BRADY in every sample. This suggests that the siltstone belongs to the *Buliminia-Bolivina* Assemblage Zone of AOKI (1969).

Bulimina nipponica ASANO, *Uvigerina akitaensis* ASANO and *Stilostomella lepidula* (SCHWAGER) are abundant in the samples from the central and eastern parts, but they decrease westward. On the other hand, *Nonion manpukuziense* OTUKA, *Elphidium crispum* (LINNÉ), *E. advenum* (CUSHMAN), *Cibicides aknerianus* (D'ORBIGNY), *C. refulgens* MONTFORT, *Quinqueloculina vulgaris* D'ORBINY and some other species are very rare in the cental part, but they silightly increase westward.

Faunal change of benthonic Foraminifera is shown in Text-figure 5, in which the cumulative frequencies in occurrence of major taxa are indicated by percentage at each locality. The localities are



Text-fig. 5 Lateral change of relative frequencies of benthonic Foraminifera.

Table 1 Correlation coefficient matrix for the Q-mode analysis.

Loc. No.	1	2	3	4	5	6	7	8	9	10
1										
2	.924									
3	.886	.989								
4	.894	.990	.992							
5	.753	.839	.841	.882						
6	.716	.797	.796	.838	.936					
7	.674	.648	.623	.710	.884	.902				
8	.622	.537	.507	.660	.797	.823	.960			
9	.610	.450	.476	.595	.747	.761	.924	.983		
10	.873	.910	.887	.949	.915	.905	.864	.789	.772	

Table 2 Result of Q-mode factor analysis.
k1 – k3: factors 1 – 3, h: communality, u: uniqueness

Locality \ factor	k1	k2
1 Takagozawa	.873	.341
2 Yasumidokoro	.895	.474
3 Oshigome	.886	.456
4 Kuratama-Nishi	.938	.335
5 Kuratama-Higashi	.946	-.218
6 Kaburai-Minami	.932	-.131
7 Kotadai	.903	-.362
8 Uehara-Nishi	.849	-.465
9 Uehara-Higashi	.809	-.496
10 Shiiki	.977	.073

Table 3 Distribution chart of the planktonic and benthonic Foraminifera from the siltstone beneath the O_7 bed.

Species / Locality	1	2	3	4	5	6	7	8	9	10
(Planktonic Foraminifera)										
Globorotalia inflata (D'ORBIGNY)	62	51	76	57	34	54	87	35	34	25
G. tosaensis TAKAYANAGI & SAITO	6	2	2	0	1	4	3	10	3	2
G. tumida (BRADY)	5	4	2	1	0	2	5	2	1	1
G. hirsuta D'ORBIGNY	8	19	8	14	6	18	6	9	2	13
G. scitula (BRADY)	3	4	3	4	4	7	4	3	2	9
G. cf. obesa BOLLI	116	184	187	68	74	113	125	89	91	104
G. acostaensis BLOW and vars.	193	302	322	110	162	190	267	181	172	201
G. humerosa TAKAYANAGI & SAITO	9	2	1	0	0	0	4	6	2	1
Globigerinoides ruber (D'ORBIGNY)	30	33	65	57	58	13	15	10	9	45
G. quadrilobatus (D'ORBIGNY)	6	7	15	10	11	3	5	4	2	9
G. trilobus (REUSS)	2	3	5	4	3	0	1	0	0	4
G. conglobatus (BRADY)	1	0	0	0	0	0	0	0	0	0
Globigerina falconensis BLOW	21	33	37	12	13	22	28	19	16	22
G. pachyderma (EHRENBERG)	99	157	125	54	74	80	100	76	65	81
G. bulloides D'ORGIBNY	15	23	20	7	12	11	19	10	8	12
G. parabulloides BLOW and vars.	240	388	396	142	174	228	324	249	228	241
Turborotalita quinqueloba (NATLAND)	121	191	162	60	62	90	96	69	61	96
Sphaeroidinella dehiscens(PARKER & JONES)	1	1	0	0	0	0	0	0	0	0
Globigerinita glutinata (EGGER)	4	19	22	16	12	14	18	13	11	14
Orbulina universa D'ORBIGNY	2	5	4	2	2	6	4	8	6	2
Pulleniatina obliquiloculata (PARKER & JONES)	10	7	18	5	2	10	13	9	8	3
P. okinawaensis NATORI	3	2	7	0	1	8	5	4	5	2
(Benthonic Foraminifera)										
Bulimina aculeata D'ORBIGNY	43	110	304	95	49	72	38	20	19	65
B. nipponica ASANO	6	16	41	26	38	66	53	36	34	34
Bolivina robusta BRADY	16	20	47	45	8	11	20	21	24	23
Uvigerina akitaensis ASANO	16	19	25	3	9	20	25	20	20	23
Stilostomera lepidula (SCHWAGER)	16	19	42	10	12	16	32	24	27	21
Fissulina orbignyana SEGUENZA	1	2	3	2	0	1	2	2	4	4
F. bradii SILVESTII	2	3	1	1	0	0	3	2	5	2
F. sp. 1	1	3	2	0	0	0	0	1	5	0
F. sp. 2	0	3	2	1	0	3	1	4	6	2
Bolivina cf. pseudodifformis ASANO	5	6	13	8	9	4	10	6	6	3
Bolivinita quadrilatera (SCHWAGER)	6	3	8	4	1	0	3	1	4	13
Oridorsalis nipponica (ISHIZAKI)	2	2	16	2	11	17	6	11	10	3
O. umbonatus (REUSS)	3	2	1	0	2	2	2	1	2	8
Cassidulina subglobosa BRADY	16	19	44	8	14	18	17	17	21	17
Planulina wuellerstofi (SCHWAGER)	13	3	5	3	0	4	4	6	3	1
Cibicides aknerianus (D'ORBIGNY)	2	1	5	0	0	4	0	1	0	1
C. refulgens MONTFORT	5	5	15	4	3	6	3	1	0	1
Quinqueloculina vulgaris D'ORBIGNY	4	3	0	0	0	0	0	0	0	0
Q. sp.	0	1	0	0	0	0	0	0	0	0
Melonis nicobarense (CUSHMAN)	0	1	2	4	4	1	1	2	4	2
Dentalina cf. filiformis (D'ORBIGNY)	2	0	1	5	2	0	2	1	2	3
Pseudoglandulina laevigata (D'ORBIGNY)	0	0	7	0	3	0	0	0	0	0
Lenticulina lucidus (CUSHMAN)	0	4	1	7	0	0	2	4	4	6
L. sp.	0	1	0	1	0	0	0	0	0	2
Pyrgo murrhyna (SCHWAGER)	4	3	3	0	1	0	2	0	0	0
P. sp.	0	0	1	0	0	0	1	0	0	0
Lagena sulcata spicata CUSHMAN & MCCULLOCH	2	4	2	0	0	3	1	0	3	4
L. acticosta REUSS	3	3	4	1	0	1	2	2	1	2
L. sp. 1	0	1	0	0	0	0	0	0	0	0
L. sp. 2	0	0	0	0	0	0	0	0	0	1
Elphidium crispum (L NNE)	2	2	5	0	0	0	0	0	0	0
E. advenum (CUSHMAN)	5	4	18	2	0	0	3	1	1	1
Nonoin manpukuziense OTUKA	2	3	1	1	0	0	0	0	0	0
N. sp.	10	12	2	4	3	0	1	0	2	3
Others	2	3	1	0	0	0	0	0	2	3
Number of Planktonic Foraminifera	957	1437	1477	623	705	873	1129	806	726	887
Ratio of Planktonic Foraminifera	83.5	84.1	70.3	72.4	80.7	77.8	82.2	81.4	77.8	78.1
Number of Benthonic Foraminifera	189	280	622	237	169	249	244	184	207	246

disposed from west (left) to east (right) taking intervals approximately proportionate to actual distances.

Factor analysis was carried out for scrutinizing the lateral change of benthonic foraminiferal faunas.

Factor analysis (Q-mode analysis) was carried out to understand the lateral change in faunal composition based on the correlation coefficient (UJIIÉ & KUSUKAWA, 1969). The correlation coefficient (ρ) between a pair of samples was calculated by the following expression, based on the number of 35 taxa as designated in Text-figure 5.

$$\rho=\frac{\frac{1}{n}\sum_{i=1}^{n}X_iY_i-\bar{X}\bar{Y}}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}X_i^2-\bar{X}^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}Y^2-\bar{Y}^2}}$$

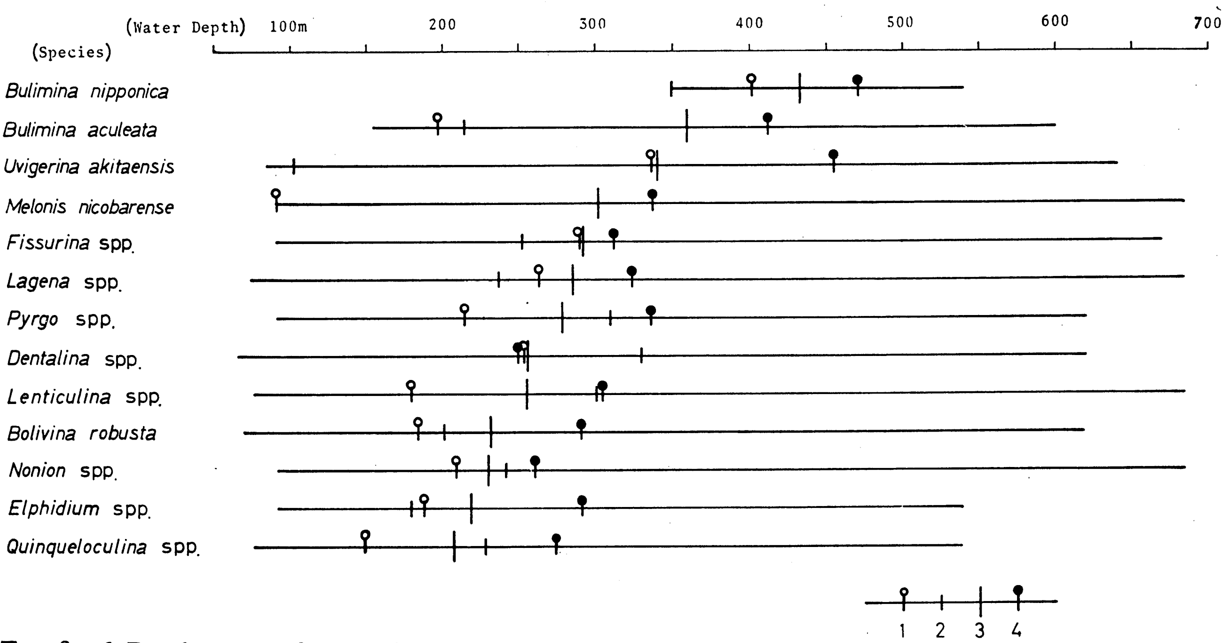
X_i is the relative abundance (e.g. number of the specimens) of a certain taxon in one sample X, and Y_i is that of the equivalent taxon in another sample Y, and they are compared with each other. $\bar{X}$ and $\bar{Y}$ are means of X_i and Y_i, respectively.

On the basis of the correlation coefficient matrix (Table 1), the factor analysis was processed and three factors were extracted (Table 2). Loadings of the first factor (K1) are consistently high ranging from 0.809 to 0.977. It is suggested that all the samples are similar to one another. In this sense the first facter can be called a common factor.

The second factor is as follows: Loadings of the second factor (K2) are negative in the samples from the central part of the Boso Peninsula, and are positive in the samples from the western and easternmost areas. This distinction appears to be resulted from the fact that *Bulimina nipponica* ASANO, *Uvigerina akitaensis* ASANO and *Stilostomella lepidula* (SCHWAGER) are more numerous in the central portion, and on the other hand, *Elphidium crispum* (LINNÉ), *Quinqueloculina vulgaris* D'ORBIGNY, *Nonion manpukuziense* OTUKA, *Pyrgo murrhyna* (SCHWAGER) and *Cibicides refulgens* MONTFORT are more abundant in the western part. As will be stated later, these species are living at present in shallow water, and *Bulimina nipponica* and *Uvigerina akitanesis* are characteristic of deep sea conditions. Therefore the second factor may be related to depth.

Palaeoenvironment

There is a slight but definite lateral change of benthonic foraminifreral fauna within the siltstone beneath the O_7 bed as indicated by the factor analysis. This result must be compared to the ecological information on the distribution of Recent benthonic Foraminifera in the adjacent seas of the Boso Peninsula.



Text-fig. 6 Depth ranges of some selected Recent benthonic Foraminifera rearanged from ASANO, 1956 – 1960. 1: mean value for Japan sea, 2: for Oyashio area, 3: for all the areas, 4: for Kuroshio area.

KUWANO (1963) reported that the Genera *Pseudononion*, *Nonion*, *Quinqueloculina* and *Cassidulina* are distributed in shallow water, and *Oridorsalis nipponica* (ISHIZAKI) and *Uvigerina akitanesis* are distributed in the deeper water off the Pacific coast of the Boso Peninsula. Also ISHIWADA (1964) indicated the depth distribution of Recent benthonic Foraminifera from off Inubo-saki. As an example, he showed that *Bulimina nipponica* and *Uvigerina akitaensis* are abundant in the depth ranging from 500 to 1200 m and *Elphidium advenum* (CUSHMAN) and *Nonion manpukuziense* OTUKA are limited to the depth shallower than 200 m. He concluded that the factors controlling the distribution of benthonic Foraminifera are water temperature and depth, and discriminated the contrast between foraminferal faunas in the Kuroshio and the Oyashio regions. According to him, *Bulimina aculeata* and *B. nipponica* occur in deep water in the Kuroshio region, while *Uvigerina akitaensis* is known to live in the subarctic bathyal facies of the mixed Kuroshio and Oyashio region.

To obtain more applicable data, the writer rearranged the distribution data of benthonic Foraminifera in the adjacent seas of whole Japan shown by ASANO (1956–1960), who gave the location datum of each species in the systematic description. Here the writer shows the depth ranges of the taxa known to occur from the siltstone beneath the O_7 bed, discriminating the three Recent habitat-the Kuroshio, the Oyashio and the Japan sea regions (Text-figure 6). Applying the mean-depths shown in the Text-figure 6, the species such as *Nonion* group, *Elphidium* group and *Quinqueloculina* group in the siltstone beneath the O_7 bed are presumed to be the shallow water elements. On the contrary, species such as *Bulimina nipponica*, *Uvigerina akitaensis* and *Melonis nicobarense* (CUSHMAN) are presumed to be the deep sea elements. Genus *Cibicides* has been regarded to be characteristic of shallow water ranging from about 100 to 200 m (e.g. in the Gulf of Mexico) as pointed out by PHLEGER (1964). No information concerning the Genus *Cibicides* in the adjacent seas of Japan were given by ASANO (1956–1960).

MATOBA (1970) reported the distribution of *Quinqueloculina vulgaris*, *Elphidium advenum*, *E. crispum* and *Cibicides aknerianus* from shallow water of Matsushima Bay.

Thus, it can be concluded that the second factor in the above-mentioned *Q*-mode analysis is a parameter of abundance of shallow water elements. However, at the same time, the second factor seems to have relation to some parameter other than water-depth as well. Rather high planktonic ratio of every sample suggests an open sea condition throughout. The deep water elements of open sea are more dominant than the shallow-water elements at every locality.

Consequently, the occurrence of the shallow water elements in the siltstone beneath the O_7 bed may be explained by the displacement from the west based on the fact that the second factor is higher in the western part.

And also the western part is judged to be shallower than the central and eastern parts as the deep-water elements decrease westward. These results are quite consistent with the sedmimentlogical data (HIRAYAMA & NAKAJIMA, 1977b) showing the westward coarsening of this siltstone. In the west of Koito River are developed sandy siltstones, while in the central part are fine-grained siltstones. Such a faunal displacement seems to have been caused by some movement on the sea bottom.

Therefore, the second factor may be regarded as the indication both of the faunal displacement and the water depth. If it is the case, a positive value of the factor at the easternmost locality (Loc. No. 10, Shiiki) may suggest a displacement probably from the east or the northeast. Toward the east or northeast the Kazusa Group is thinning out(ISHIWADA *et al.*, 1962)and finally, in the Choshi district, the Cretaceous sediments forming the basement of the Kazusa Group are exposed on the ground.

Acknowledgnents

The writer expresses his deep gratitude to Professor Hiroshi UJIIÉ of the Department of Oceanography, University of the Ryukyus, for his guidance throughout this work. The writer is also indebted to Dr. Shiro MAÉDA, Professor Emeritus of Chiba University, for his advice and encouragement for this work. Deep appreciation is expressed to Professor Sumio SAKAGAMI of the Department of the Earth science, Faculity of Science, Chiba University, for his guidance throughout the course of this work.

The writer expresses his gratitude to the following persons: Professor Toshio KOIKE of the Department of Earth Science, Faculity of Education, Yokohama National University, for discussing the palaeontological problems; Drs. Yasumoto SUZUKI, Jiro HIRAYAMA, Terumasa NAKAYAMA and

Syuichi TOKUHASHI of the Geological Survey of Japan, for their discussions on geological problems.

The writer is also indebted to Professor Shozo HAYASAKA of the Department of Earth Science, Faculty of Science, Kagoshima University, for his critically reading the manuscript.

References

AOKI, N. (1968): Benthonic foraminiferal zonation of the Kazusa Group, Boso Peninsula. Trans. Proc. Palaeont. Soc. Japan, N. S., No. 70, pp. 238 – 266, pl. 1.

ASANO, K. (1956 – 1960): The Foraminifara from the adjacent seas of Japan, collected by the S. S. Soyo-maru, 1922 – 1930. Part 1 – 4. Sci. Rep. Tohoku Univ., 2nd ser. (Geol.), Vol. 27, pp. 1 – 55, pls. 1 – 6; Vol. 28, pp. 1 – 26, pls. 1 – 2 map 1; Vol. 29, pp. 1 – 41, pls. 1 – 7; Spec. Vol. No. 4, pp. 189 – 201, pls. 21 – 22.

BÉ, A. W. H. (1977); An ecological, zoogeographic and taxonomic review of Recent planktonic Foraminifera. In Oceanic Micropalaeontology (edit. A. T. S. RAMSAY), Academic Press, 88pp., 12pls

BLOW, W. H. (1969): Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. Proc. 1st Intern. Conf. Plankt. Microfossils, Geneva 1967, Vol. 1, pp. 199 – 422, pls. 1 – 54.

HIRAYAMA, J. and NAKAJIMA, T. (1977a): Geosyncline sediments —— Fossil of turbidity current ——. Science [Kagaku], Vol. 47, No. 2, pp. 82 – 90 (In Japanese).

HIRAYAMA, J. and NAKAJIMA, T. (1977b): Analytical study of turbidites, Otadai Firmation, Boso Peninsula, Japan. Sedimentology, Vol. 24, pp. 747 – 779.

HIRAYAMA, J. and SUZUKI, Y. (1965): On the forms and textures of each layer composing the flysch-type alternation of sandstone and mudstone. Jour. Geol. Surv. Japan, Vol. 16, No. 2, pp. 1 – 15 (In Japanese with English abstract).

HIRAYAMA, J. and SUZUKI, Y. (1968): Analysis of layers —— An example in flysch-type alternations——. Earth Science [Chikyu Kagaku], Vol. 22, No. 2, pp. 43 – 62, pls. 1 – 2 (In Japanese with English abstract).

ISHIWADA, Y. (1964): Benthonic Foraminifera off the Pacific coast of Japan referred to biostratigraphy of the Kazusa Group. Rept. Geol. Surv. Japan, No. 205, pp. 1 – 45, pls. 1 – 8.

ISHIWADA, Y., HIGUCH, Y. and KIKUCHI, Y. (1962): Correlation by the smaller Foraminifera on the southern Kanto gas field. Jour. Japan. Asso. Petro. Tech. V. 27, no. 3 pp. 68 – 79, pl. 1, 10 figs.

ISHIWADA, Y., MITSUNASHI, T., SHINADA, Y. and MAKINO, T., (1971): Geological map of the oil and gas field of Japan, Nö. 10, "Mobara". Geol. Surv. Japan.

KAWAI, K., UCHIO, T., UENO, M. and HOZUKI, M. (1950): Natural gas in the vicinity of Otaki, Chiba-ken. Jour. Japan. Assoc. Petrol. Tech., Vol. 15. pp. 151 – 219 (In Japanese with English abstract).

KITAZATO, H. (1977): Vertical and lateral distribution of benthonic foraminiferal fauna and the fluctuation of warm and cold water in the Middle Pleistocene of the Boso Peninsula, Central Japan. Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.), Vol. 47, No. 1, pp. 7 – 41.

KUWANO, Y. (1963): Foraminiferal biocenoses of the seas around Japan. A survey of Pacific-side biocenoses. 3. Biocenoses off the Boso Peninsula. Misc. Rep. Res. Inst. Nat. Resources, No. 60, pp. 29 – 51.

MATOBA, Y. (1970): Distribution of Recent shallow water Formainifera of Matsushima Bay, Miyagi Prefecture, Northeast Japan. Sci. Rep. Tohoku Univ., 2nd ser. (Geol.), V. 42, no. 1, pp. 1 – 85, pls. 1 – 8.

MITSUNASHI, T. (1973): Geologic development of South Kanto and Niigata sedimentary basins from Miocene to Pleistocene. Earth Sciences [Chikyu kagaku], Vol. 27, No. 2 – 3, pp. 48 – 65, pls. 1 – 2 (In Japanese with English abstract).

MITSUNASHI, T., KIKUCHI, T., SUZUKI, Y., HIRAYAMA, J., NAKAJIMA, T., OKA, S., KODAMA, K., HORIGUCHI, M., KATSURAJIMA, S., MIYASHITA, M., YAZAKI, K., KAGEYAMA, K., NASU, N., KAGAMI, H., HONZA, E., KIMURA, M., NIREI, H., HIGUCHI, S., HARA, Y., FURUNO, K., ENDO, T., KAWASHIMA, S. and AOKI, S. (1976): Geological map of Tokyo Bay and adjacent areas. Miscellaneous maps series, No. 20. Geol. Surv. Japan.

MITSUNASHI, T., YAZAKI, K., KAGEYAMA, K., SHIMADA, T., ONO, E., YASUKUNI, N., MAKINO, T., SHINADA, Y., FUJIWARA, K., and KAMATA, S. (1961): Geological maps of the oil and gas field of Japan, No. 4, "Futtsu – Otaki". Geol. Surv. Japan.

MITSUNASHI, T., YASUKUNI, N. and SHINADA, Y. (1959): Stratigraphical section of the Kazusa Group along the shores of the Rivers Yoro and Obitsu. Jour. Geol. Surv. Japan, Vol. 10, No. 2, pp. 83 – 98 (In Japanese with English abstract).

PHLEGER, F. B. (1964): Ecology and distribution of Recent Foraminifera. Baltimore, Johns Hopkins Press, 279pp.

TAKAYAMA, T. (1973): On the distribution of calcareous nannoplankton in the Youngest Cenozoic of Japan. Mem. Geol. Soc. Japan, No. 8, pp. 45 – 63 (In Japanese with English abstract).

TAKAYANAGI, Y. and SAITO, T. (1962): Planktonic Foarminifera from Nobori Formation, Shikoku, Japan. Sci. Rep. Tohoku Univ. 2nd Ser. (Geol.), Spec. Vol. No. 5, pp. 67 – 106, pls. 24 – 28, 2text-figs., 1 table.

UCHIO, T. (1952): Geology of natural gas in the western part of Mobara-machi, Ciba Prefecture. Jour. Japan, Assoc. Petrol. Tech. Vol. 17, No. 1, pp. 22 – 37 (In Japanese with English abstract).

UJIIÉ, H. and KUSUKAWA, T. (1969): Analysis of foraminiferal assemblages from Miyako and Yamada Bays, northeastern Japan. Bull. Nat. Sci. Mus., Vol. 12, No. 3, pp. 735 – 772, pls. 1 – 5.

Explanation of Plate 1

Fig. 1 *Bulimina nipponica* ASANO, Reg. No. 1165, x 190
Fig. 2 *Bulimina aculeata* D'ORBIGNY, Reg. No. 1166, x 100
Fig. 3 *Bolivina robusta* BRADY, Reg. No. 1167, x 100
Fig. 4 *Uvigerina akitaensis* ASANO, Reg. No. 1168, x 100
Fig. 5 *Stilostomera lepidula* (SCHWAGER), Reg. No. 1169, x 50
Fig. 6 *Oridorsalis umbonatus* (REUSS), Reg. No. 1170, x 76
Fig. 7 *Cibicides aknerianus* (D'ORBIGNY), Reg. No. 1171, x 82
Fig. 8 *Lagena sulcata spicata* CUSHMAN & MCCULLOCH, Reg. No. 1172, x 128
Figs. 9 – 10 *Cibicides refulgens* MONTFORT, Fig. 9 Reg. No. 1173, x 140, Fig. 10 Reg. No. 1174, x 150
Fig. 11 *Elphidium crispum* (LINNÉ), Reg. No. 1175, x 75
Fig. 12 *Quniqueloculina vulgaris* D'ORBIGNY, Reg. No. 1176, x 100
Figs. 13 – 14 *Globorotalia tosaensis* TAKAYANAGI & SAITO, Reg. No. 1177, x 75
Fig. 15 *Globorotalia hirsuta* (D'ORBIGNY), Reg. No. 1178, x 100

All specimens illustrated in the plate are preserved in the Collection of Department of Science Education, Faculty of Education, Kagoshima University.

HATTA: Foraminifera from the Otadai Formation Plate 1