REPORT No. 205

GEOLOGICAL SURVEY OF JAPAN

BENTHONIC FORAMINIFERA OFF THE PACIFIC COAST OF JAPAN REFERRED TO BIOSTRATIGRAPHY OF THE KAZUSA GROUP

By

Yasufumi ISHIWADA

GEOLOGICAL SURVEY OF JAPAN

Hisamoto-cho, Kawasaki-shi, Japan

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Masatsugu SAITO, Director

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Abstract

Frequency distribution of recent benthonic foraminifers off the Pacific coast of Japan was studied. The Oyashio, the mixed Kuroshio and the Kuroshio water areas are represented by nine stations off Kushiro, twenty stations off Hachinohe to Inubo-saki (Northeast Honshu) and nine stations in Tosa Bay respectively.

There exist two categories of faunal gradations. A marked bathymetric change occurs at depths of about 200 m to 300 m, resulting in segregation of neritic and bathyal faunal facies. Another category of faunal variation is related to distribution of oceanographic water masses, the Oyashio waters, the Kuroshio waters, the mixed Kuroshio waters and the deep water.

Fossil assemblages of the benthonic foraminifera found in the Pliocene Kazusa group are mostly related to the recent ones off the Japanese Pacific coast. The neritic biofacies of the upper half of the group suggests the coexistence of the past Oyashio and the past Kuroshio waters within the Pliocene South Kwanto basin. *Uvigerina akitaensis* faunule in the Umegase formation may be of the bathyal zone in the past Subarctic Water, which is widespread in the eastern half of the South Kwanto region and forms a reliable "marker zone" for correlation in field practice.

I. Introduction

General Statement

In field practice the Japanese oil geologists have utilized fossil foraminifera as a tool for correlation and an indicator of the past marine environments. Since the geologic ages of prolific reservoirs in the Japanese oil and gas fields are restricted to Pleistocene down to Miocene, correlation by means of foraminifera practically depends upon *assemblage zone* on account of scarcity of reliable guide-species. It is, therefore, necessary for the field practice of biostratigraphy to understand the distribution behavior of foraminiferal assemblages in modern sediments.

A considerable amount of literature or the qualitative distribution and taxonomic description of species found in the adjacent seas of Japan is available, but the comprehensive knowledge of faunal facies distribution, particularly of outer neritic and bathyal zones, has not been sufficient.

Except for the reports referring to lake, bay and inner neritic environments, the published data available for the present purposes are:

* Received March 7, 1962

Toyama Bay in the Japan Sea (Y. Ishiwada, 1950; T. Matsuda, 1957) depth range of samples: 83–1203 m

Southern part of the Okhotsk Sea (Y. Kuwano, 1953–1954) depth range of samples: 20–1460 m

Suruga Bay in the Pacific side (M. Nagahama, 1954) depth range of samples: 24–1887 m

The purposes of the present study are: (1) to make a reconnaissance survey of the distribution of benthonic assemblages in the outer neritic and bathyal waters off the Pacific coast, (2) to relate the distribution to the oceanographic environments, and (3) to compare the fossil assemblages of the Pliocene Kazusa group with the recent ones.

The samples were collected from off Kushiro, off Hachinohe to Inubo-saki, and Tosa Bay, in order to reveal the changes of faunal facies from the subarctic to the subtropical water areas. For comparison a few additional data from other areas will be given, also.

Acknowledgments

The author is indebted to Dr. Kiyoshi Asano, Department of Geology and Paleontology, Tohoku University, for valuable advice in identification of species and to Dr. Teiichi Kobayashi and Dr. Fuyuji Takai, Department of Geology, Tokyo University, for their kind advice and encouragement. Particular thanks are also due to Dr. Takayasu Uchio, Department of Mining, Tokyo University, and Dr. Yokichi Takayanagi, Department of Geology and Paleontology, Tohoku University, who aided in identification of species and gave the author an opportunity to examine the recent materials from California.

II. Methods of Study

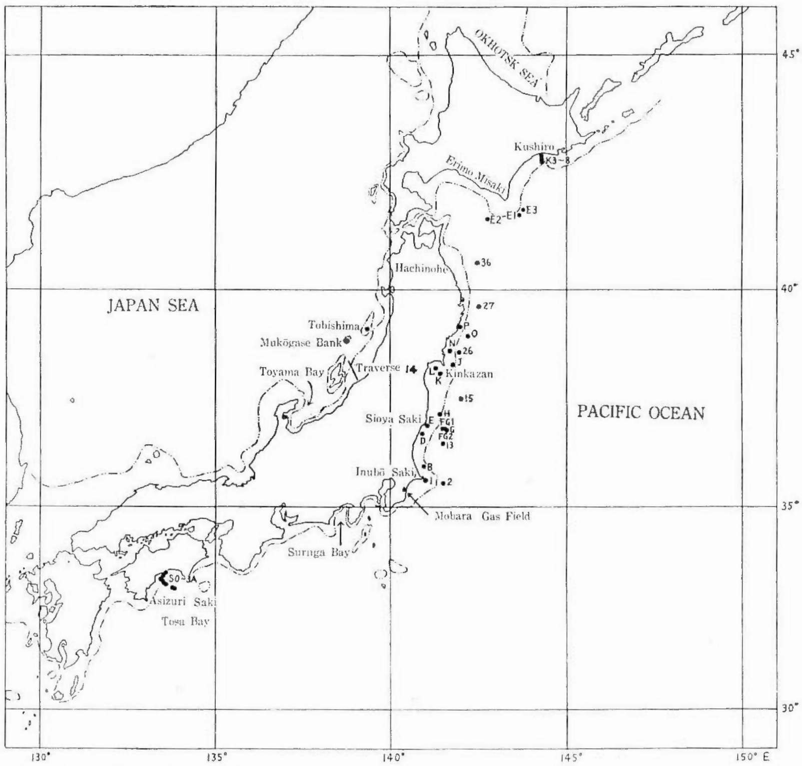
Three areas previously mentioned, representing the subarctic, the mixed, and the subtropical water areas, were selected for this study. As the normal distribution patterns were desired, coarse sand bottom and steep continental slope were avoided as far as possible, with one exception of the coarse sand bottom sample from the top of Erimo Bank.

The samples of Tosa Bay were collected in August, 1955, aboard the Shunpu-maru of the Kobe Marine Observatory. Other samples were collected in July and August, 1949, off Hachinohe to Inubo-saki and in May, 1952, off Kushiro, aboard the Kaiyo (formerly No. 4 Kaiyo-maru) of the Hydrographic Office. The sampling tool was a simple dredge made of oil-well casing pipe, six inches in diameter. The maximum depth of sampling was 1180 m at St. 2 off Inubo-saki. Two samples were separately collected from off Erimo-saki (St. E2, E3) in 1960 by a research vessel of the Fisheries Experimentary Laboratory of Hachinohe.

The bottom samples did not undergo any special treatment but were just dried in natural condition. The samples, weighing 20 to 40 g, were washed on 120 mesh screen. Foraminiferal tests were then concentrated from the sand by the floatation using carbon tetrachloride. About 200 specimens were counted and picked up by random sampling according to the method described formerly by the author (Y. Ishiwada, 1951), and the frequency composition was determined. The assemblage determined in this manner is substantially the recent "fossil assemblage" including both biocoenose and thanatocoenose. In counting, planktonic remains were omitted because they were not the aim of this study. The distribution of planktonic foraminifers in the adjacent waters of Japan was studied by K. Asano (1957), T. Uchio (1959) and J. S. Bradshaw (1959), but it may have no validity as far as a precise correlation within the Kazusa group is concerned.

Table 1 Positions of stations

AREA	STATION	N. LAT.	E. LONG.	DEPTH(m)	BOTTOM CHARACTER
Kushiro	K4	42°58.′2	144°15.′8	22	fine sand
	K5	55.9	15.0	36	very fine sand
	K6	52.8	15.0	82	muddy sand
	K7	51.3	15.2	120	muddy sand
	K3	52.4	17.4	228	mud
	E1	41 37.8	143 38.5	165	coarse sand
	E2	30 miles SE of Erimo-saki		600~655	muddy sand
	E3	80 miles NE of Hachinohe		720~800	mud
Hachinohe	I	35 38.3	141 00.0	64	muddy sand
	B	58.0	140 57.5	155	muddy sand
	L	38 13.3	141 17.2	44	clay
	K	06.3	23.9	81	sandy mud
	D	36 42.5	140 54.5	83	sandy mud
	E	53.9	141 03.0	111	mud
	P	39 09.2	58.8	135	very fine sand
	M	38 35.7	39.6	138	sandy mud
	J	18.8	44.1	146	fine sand
	H	37 11.8	23.1	154	fine sand
to	26	38 32.1	56.4	283	sandy mud
	FG1	36 51.5	29.0	403	sandy mud
	FG2	51.1	33.5	504	sandy mud
	15	37 32.0	142 00.0	527	sandy mud
	O	38 58.3	13.0	584	sandy mud
	G	36 50.0	141 34.5	650	clay
	27	39 34.9	142 27.7	819	clay
	36	40 33.1	27.2	1041	clay
	13	36 30.0	141 29.8	1111	clay
Inubo-saki	2	35 32.5	29.6	1180	clay
Tosa Bay	SO	33 25.0	133 32.5	56	sandy mud
	SOA	19.7	28.8	78	sandy mud
	S1	14.2	25.2	98	sandy mud
	S1A	10.3	28.3	135	very fine sand
	S1B	09.2	30.5	193	very fine sand
	S2	09.8	31.8	280	very fine sand
	S2A	06.0	33.0	400~410	muddy sand
	S3	04.0	36.0	680	sandy mud
	S3A	01.5	38.0	900	mud

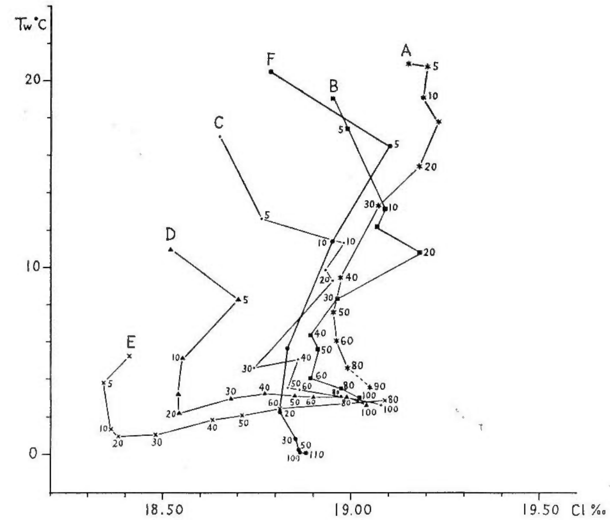


Stations from K3 to K8 and from E1 to E3 — off Kushiro, the Oyashio water area.
Stations from 36 southwards to 2 — off Hachinohe to Inubo-saki (northeast Honshu), the mixed Kuroshio water area.
Stations from SO to S3A — in Tosa Bay, the Kuroshio water area.
Traverse 14 — off Niigata (refer to Fig. 10).
Mukogase Bank — off Sado Is. (refer to Fig. 6b).
Tobishima island shelf — off Sakata (refer to Fig. 6c).

Fig. 1 Location map

III. General Oceanographic Picture of the Area

The areas of investigation extend from lat. 43°N to lat. 33°N along the Pacific coast of Japan. In these areas exist two upper water masses. The Subarctic Water is carried southward, by the cold Oyashio, while the North Pacific Central Water is carried northeastward by the warm Kuroshio. The Oyashio water is characterized by low chlorinities and temperatures caused by melting of sea-ice in the northern district, usually exsisting north of lat. 40°N along the east coast of Hokkaido. The Kuroshio water has its origin in the North Equatorial Current, hence the water is characterized by considerably high transparency, chlorinity and temperatures. The Kuroshio runs closely along the Japanese coast as far as lat. 36°N, where it turns eastward (the Kuroshio Extension), sending out finger-like branches to the northeast. Intensive mixing of these branches with the Oyashio



A: in Tosa Bay, lat. 32°51.′5N-long. 133°47.′6E, Feb. 16, 1952.
B: off Choshi, lat. 35°32.′5N-long. 141°29.′6E, July 17, 1949.
C: off Onahama, lat. 36°30.′0N-141°29.′8E, July 20, 1949.
D: off Hachinohe, lat. 40°33.′8N-142°27.′2E, Aug. 3, 1949.
E: off Kushiro, lat. 42°29.′0N-long. 144°30.′0E, July 21, 1952.
F: off Sakata in the Japan Sea (in comparison), lat. 39°13.′7N-long. 132°26.′5E, Aug. 13, 1948.

Fig. 2 Temperature-chlorinity relations off the Japanese coast.

Table 2 Stations, from which the bottom samples were collected, and the related water masses

Water mass \ Region	Oyashio Region Off Kushiro & Erimo-saki	Mixed Kuroshio Region Off Hachinohe to Inubo-saki	Kuroshio Region Tosa Bay	Notes
Subarctic Water "Oyashio"	K4, K5, K6, K7, K3, K8* E1**			*upper bathyal, others neritic **bank top
Subarctic Intermediate Water		26, FG1		bathyal
Transitional Zone Subarctic Intermediate Water to Deep Water		15, O, G, FG2		bathyal
Kuroshio Water greatly diluted by Oyashio Water		P, M, J, L, K, H, E, P		neritic
Subtropical Water "Kuroshio"		B, 1	SO, SOA, S1, S1A, S1B, S2*	*bathyal, others neritic
Southern Intermediate Water			S2A, S3	bathyal
Deep Water	E2, E3	36, 27, 13, 2	S3A	bathyal

water takes place off the Sanriku coast, resulting in the formation of the wavy Polar Front, the position of which largely varies with season.

To the south of the Polar Front the Oyashio, flowing down from the northeast, creeps below the mixed Kuroshio water as an Intermediate Water, i.e. the Oyashio undercurrent, which is characterized by a minimum chlorinity at a depth of about 300 m. On the other hand, an Intermediate Water characterized by the minimum chlorinity is also found below the Kuroshio water southwest of lat. 36°N of a depth of about 500 m in Suruga Bay and Tosa Bay, and 800–1,000 m in the area far distant from the coast. While many of Japanese oceanographic literature treat the southern Intermediate Water as an extension of the Oyashio Undercurrent to the south, H. U. Sverdrup *et al*, discussing the nature of these Intermediate Waters, commented that the Northern Intermediate Water does not flow directly south but flows towards east, sending branches off to the south, and the Southern Intermediate Water moves toward the north along off the coast of Japan.

Below the Intermediate Water exists the North Pacific Deep Water, with chlorinity gradually increasing with depth (Fig. 2).

Interrelations of the water masses and the observed stations in this study are shown in Table 2.

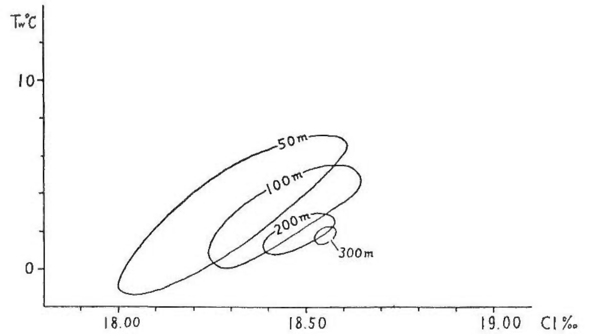


Fig. 3a Approximate variation ranges of temperature and chlorinity off Kushiro.

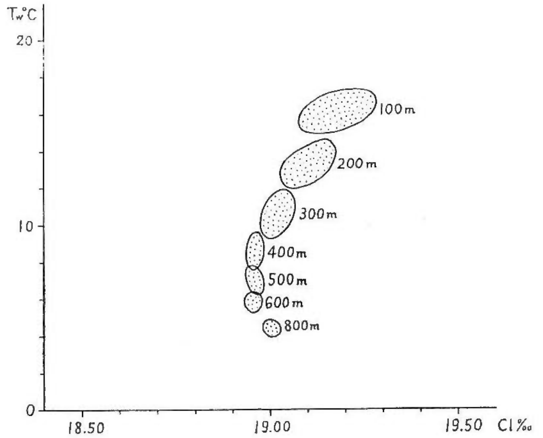


Fig. 3b Approximate variation ranges of temperature and chlorinity in Tosa Bay.

It is characteristic of the seas surrounding Japan that the water properties, such as temperature and chlorinity, considerably vary with season over a wide range. This is especially conspicuous in the mixed Kuroshio water region. The degrees of variation in temperature-chlorinity relation for subarctic and subtropical waters, off Kushiro and Tosa Bay respectively, are roughly illustrated in Figs. 3 a, b. Variations of temperature and chlorinity near the bottom in the mixed Kuroshio region are roughly estimated in Table 3.

Table 3 Temperature and chlorinity ranges of the bottom water in the mixed Kuroshio region estimated by the data of past several years after 1940

Station	Temperature	Chlorinity (‰)	Depth	Location
1, B	11–17° C	18.75–19.25	64, 155 m	off Inubo-saki
D, E	10–17	18.75–19.25	83, 111	off Shioya-saki
H	6–13	18.75–19.2	154	〃
L, P	6–16	18.6 –19.0	44, 135	near Kinkazan
K	6–14	18.65–18.95	81	〃
J, M	6–10	18.7 –18.85	146, 138	〃
26	2–4	18.6 –18.75	283	〃
FG1	3–5	18.6 –19.0	403	off Shioya-saki
FG2, 15, O	3–4	18.7 –18.9	504, 527, 584	lat. 37°N–39°N
G	4±	18.8 –18.9	650	off Shioya-saki
27	3±	18.85±	819	off Hachinohe
36, 13, 2	3±	19.05±	1041, 1111, 1180	lat. 35.5°N–40.5°N

IV. Distribution of Faunal Facies

IV. 1 Off Kushiro and Erimo-saki

Table 4 shows the distribution of species.

The assemblages in this area fall into four major faunal facies.

Facies	Species with a high frequency	Depth range
I	*Buccella frigida* (Cushman) *Buliminella elegantissima* (d'Orbigny) *Elphidium clavatum* Cushman	22–228 m (Off Kushiro Harbor)
II	*Uvigerina akitaensis* Asano *Angulogerina kokozuraensis* Asano	276 m (Off Kushiro Harbor)
III	*Nonion labradoricum* (Dawson) *Bolivina spissa* Cushman *Uvigerina akitaensis* Asano	600–800 m (Off Erimo-saki)
IV	*Cassidulina setanaensis* Asano & Nakamura *C. wakasaensis* Asano & Nakamura *Angulogerina kokozuraensis* Asano	166 m (On the top of Erimo Bank)

Excepting a bank environment (Facies IV), there is a marked faunal facies boundary at depths between 228 m and 276 m (Fig. 4).

Table 4 Distribution of foraminifers in percent of benthonic population off Kushiro and Erimo-saki

STATIONS DEPTH IN METERS	K4 22	K5 36	K6 82	K7 120	K3 228	K8 276	E2 600~655	E3 720~800	E1 165
Adercotryma glomeratum				1.5		5	12		
Angulogerina kokozuraensis			3.5	13.5	12	14	3		15
Astrononion hamadaense			1	2	4	1.5			
Bolivina spissa							12	36	
Buccella frigida	57	24	14.5	5	6.5				
B. inusitata			5	6	6.5	3	5.5	1	
Buliminella elegantissima	12.5	22		3	1				
Cassidulina islandica	1	0.5	6	9	16		4		1
C. setanaensis									35
C. wakasaensis									21.5
C. yabei			0.5	1.5			5.5	11	
Cibicides pseudoungerianus						4	1		
Eggerella advena	3	6	0.5	1					
Elphidium bartletti		0.5	5		1				
E. clavatum	17.5	20	58.5	30.5	30	5		0.5	0.5
E. sp. *4* + *E.* cf. sp. *4*	5	3.5		1.5					
Epistominella naraensis			0.5	2	4				
Karreriella baccata japonica									4
Nonion grateloupi						0.5	10		0.5
N. labradoricum			0.5	3		3	19	2	
Nonionella stella		13		1					
Pullenia salisburyi							7		0.5
Trochammina japonica			0.5	0.5		4.5		0.5	
Uvigerina akitaensis			0.5	7.5	5	50	10	36	3.5

Species of less than 4% frequencies are excluded in the list.

Facies I corresponds to neritic environment and is characterized by a dominant species, ***Elphidium clavatum***. ***Buccella frigida*** and ***Buliminella elegantissima*** occur with high frequencies in inner neritic zone, at depths shallower than 50 m. *Nonionella stella* Cushman and Moyer was found to exceed 10% in only one sample at a depth of 36 m. In outer neritic zone occurs typical *Elphidium clavatum* assemblage. Associated species with significant frequencies are *Buccella frigida, B. inusitata, Cossidulina islandica, Uvigerina akitaensis, Angulogerina kokozuraensis*, and small and thin-walled species of *Elphidium*.

Facies II may correspond to upper bathyal zone, but was found at a single station, St. K8, of 276 m depth. This is characterized by *Uvigerina akitaensis-Angulogerina kokozuraensis* assemblage.

Through Facies I and II species associated with the dominants are mostly inhabitants of the Arctic and Subarctic regions or cold water surrounding Japan.

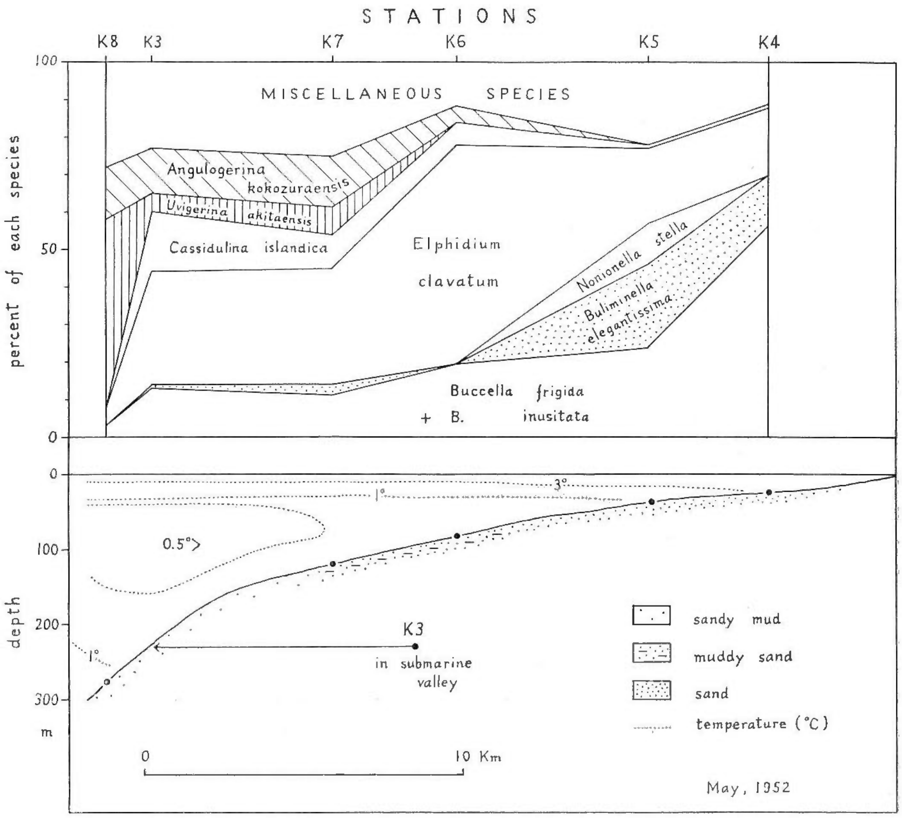


Fig. 4 Frequency distribution of benthonic foraminifers off Kushiro.

They are as follows:

Adercotryma glomeratum (Brady)
Alveolophragmium crassimargo (Norman)
A. jeffreysi (Williamson)
Astrononion hamadaense Asano
Buccella inusitata Anderson
Cassidulina japonica Asano & Nakamura
C. yabei Asano & Nakamura
Eggerella advena Cushman
Elphidium bartletti Cushman
Epistominella naraensis (Kuwano)
Haplophragmoides bradyi (Robertson)
Trochammina japonica Ishiwada

Elphidiella sibirica (Goës), which is a typical Arctic inhabitant, occurs with a very low frequency at St. K5.

Facies III includes two assemblages (Figs. 5a, b): *Nonion labradorium* assemblage and *Bolivina spissa-Uvigerina akitaensis* assemblage. Both assemblages are characterized by the presence of *Bolivina spissa* Cushman, *Bulimina nipponica* Asano, *Cassidulina delicata* Cushman, *Elphidium abyssicola* n. sp., *Nonion labra-*

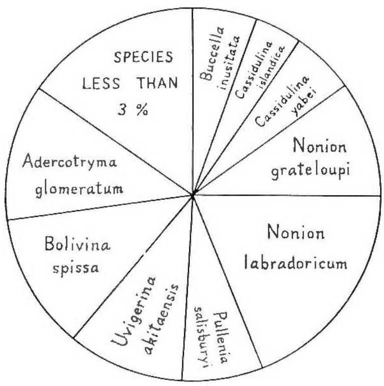


Fig. 5a Composition of the benthonic assemblage from St. E2, off Erimo-saki.

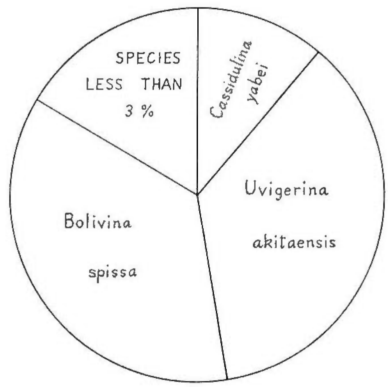


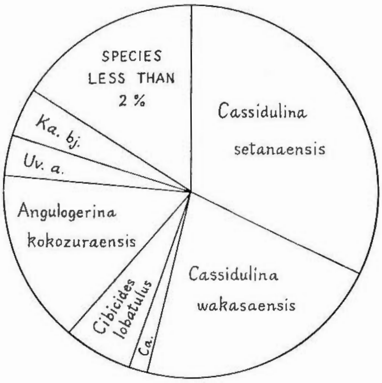
Fig. 5b Composition of the benthonic assemblage from St. E3, off Erimo-saki.

doricum (Dawson), and *Uvigerina akitaensis* Asano. Associated species are mostly common to the upper Facies. *Nonion labradoricum* assemblage occurs at a depth slightly shallower than the depth where *Bolivina spissa-Uvigerina akitaensis* assemblage was found.

Facies IV is represented by a single *Cassidulina* assemblage found at St. E1 on the top of Erimo Bank, and seems to have peculiar composition as compared with other assemblages. Since many species of the assemblage are commonly found in the Pliocene Setana group of the Southern Hokkaido, one might suspect that the assemblage originated from reworked fossils. However, it must be noticed that assemblages, the dominant elements of which are usually *Cassidulina* and *Cibicides*, are widely distributed on banks and small-island shelves irrespective of the geology of basement rocks. Pronounced cases have been known from Mogami Bank, Kamadono Bank, Mukogase Bank, the island shelf of Tobishima in the Japan Sea (Y. Ishiwada, 1951). Seno-umi Bank in the Suruga Bay is also an example on the Pacific side* in the Kuroshio water region. Similar benthonic assemblages are sometimes observed even on the broad shelf, where coastal water hardly exists and bottom sediments are generally composed of sand or sandy mud. But the bank-type assemblages differ from those on shelf in coexistence with abundant remains of planktonic foraminifers possibly concentrated by convergence caused by upwelling.

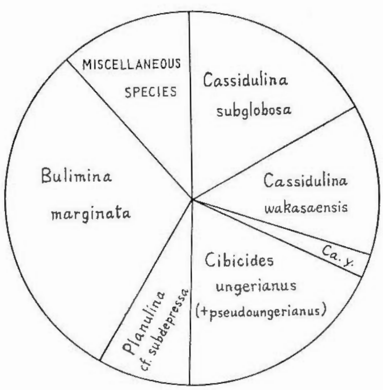
The composition of *Cassidulina* assemblage from Erimo Bank is shown in Fig. 6a with the examples of bank-type assemblages in the Japan Sea for comparison. In Fig. 6b the comparatively high frequency of *Bulimina marginata* d'Orbigny, a warm-water inhabitant in neritic zone, may reflect the seasonal development of the warm Tsushima Current, a branch of the Kuroshio, but at a slightly greater depth, as is shown in Fig. 6c, *Uvigerina akitaensis-Angulogerina kokozuraensis* combination takes the place of warm-water inhabitants. In the latter case the bank is completely immersed into the cold deep water mass in-

* *Cassidulina subglobosa–Cibicides lobatulus* assemblage occurs with a lot of planktonic remains. water depth: 300 m, bottom character: sand and clay, position: lat. 34°46′.2N–long. 138°32′.2E.



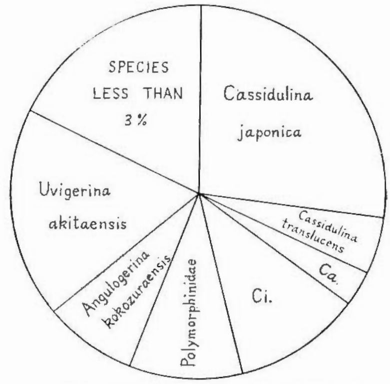
Ca.: *Cassidulina islandica* and *C. sublimbata*
Uv. a.: *Uvigerina akitaensis*
Ka. bj.: *Karreriella baccata japonica*

Fig. 6a Composition of the benthonic assemblage from St. E1 on Erimo Bank.



lat. 38°48:1N–long. 138°41:0E; at a depth of 105 m; bottom water, Cl 19.03‰ and temperature 12.9°C; Oct. 1950.
Ca.y.: *Cassidulina yabei*

Fig. 6b Composition of the benthonic assemblage from Mukogase Bank in the Japan Sea.



lat. 39°05:3N–long. 139°32:2E; at a depth of 222 m; bottom water, Cl 18.81‰ and temperature 4.75° C; Aug. 1950.
Ca.: *Cassidulina sublimbata* and *C. yabei*
Ci.: *Cibicides lobatulus*, *C. pseudoungerianus* and *C. refulgens*

Fig. 6c Composition of the benthonic assemblage from the island shelf of Tobishima in the Japan Sea.

digenous to the Japan Sea, which exists below the Tsushima Current. Because the Subarctic water covers Erimo Bank, species of the assemblage at St. E1 are mostly cold-water inhabitants. They are as follows:

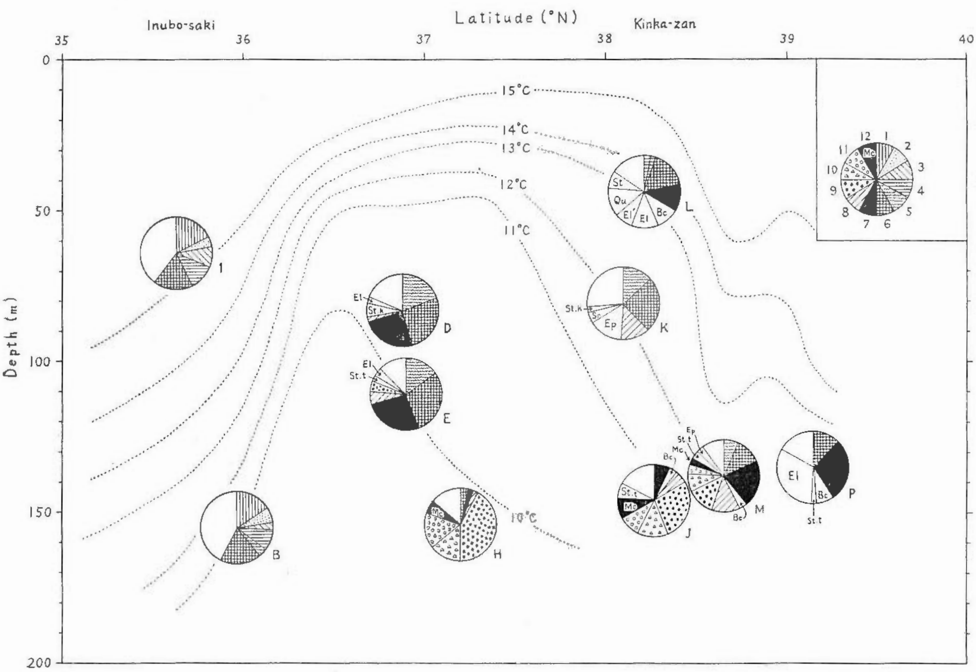
Alveolophragmium crassimargo (Norman)
Angulogerina kokozuraensis Asano
Astacolus hyalocrulus Loeblich & Tappan
Cassidulina islandica Nφrvang
C. sublimbata Asano & Nakamura
C. wakasaensis Asano & Nakamura
Elphidium clavatum Cushman
Elphidiella arctica (Parker & Jones)
Karreriella baccata japonica Asano

In this area Facies I, II and IV occur in the subarctic waters, and only Facies III in the deep water below them.

IV. 2 Off Hachinohe to Inubo-saki

In this area, the mixed Kuroshio region, the assemblages are grouped into six faunal facies as the following table. A marked boundary of faunal depth

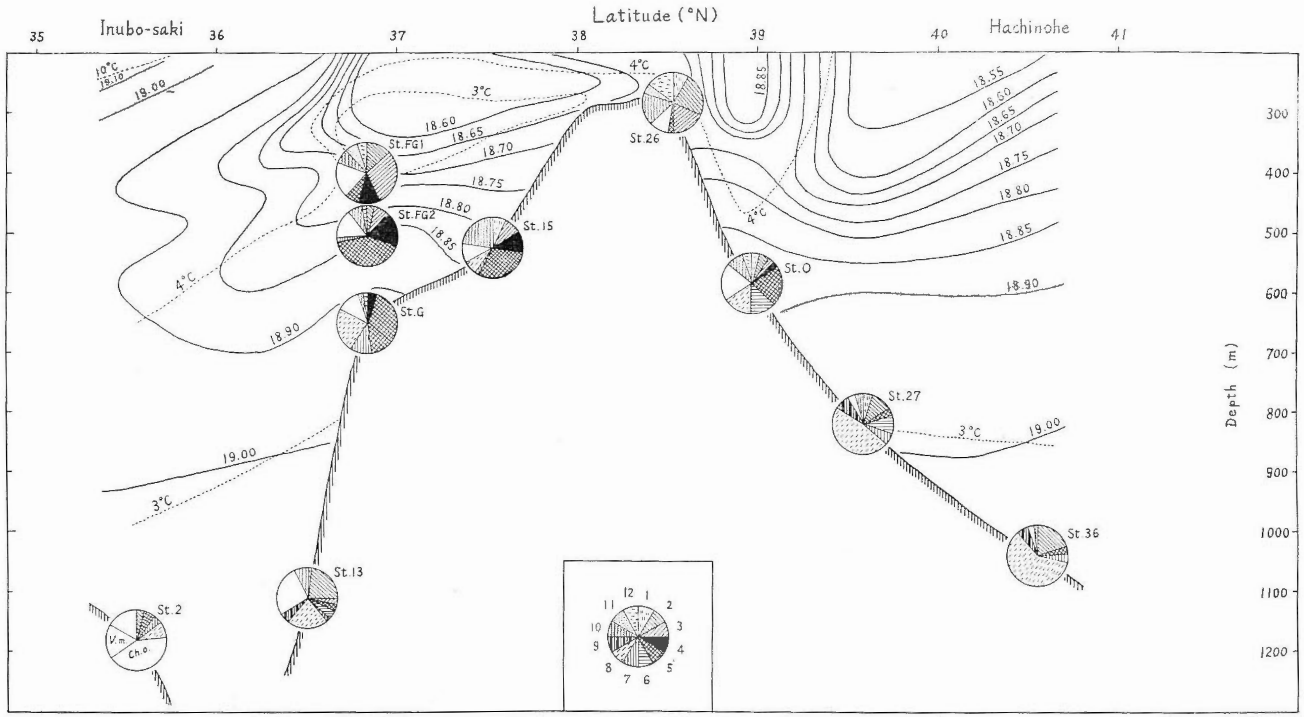
Facies	Species with a high frequency	Depth range	Latitude range
I	*Nonionella stella* Cushman & Moyer *Elphidium clavatum* Cushman *Rosalina vilardeboana* d'Orbigny *Pseudononion japonicum* Asano	44–175 m	35°40′N | 39°10′N
II	*Lagenonodosaria scalaris sagamiensis* Asano	146, 154 m	37°–38°N
III	*Uvigerina akitaensis* Asano *Angulogerina kokozuraensis* Asano	283, 403 m	37°–38.5°N
IV	*Nonion labradoricum* (Dawson)	504–650 m	37°–39°N
V	*Bolivina spissa* Cushman	819–1111 m	36.5°–40.5°N
VI	*Chilostomella oolina* Schwager	1180 m	35° N



1: *Rosalina vilardeboana* 7: *Elphidium clavatum*
2: *Cassidulina subglobosa depressa* 8: *Nonion labradoricum*
3: *Elphidium advenum depressulum* 9: *Lagenonodosaria scalaris sagamiensis*
4: *Pseudononion japonicum* 10: *Cibicides aknerianus*
5: *Bulimina marginata* 11: *Globobulimina turgida*
6: *Nonionella stella* 12: *Martinottiella communis*

Ep: *Eponides umbonata* El: *Elphidium* sp. 2 El′: *Elphidium* cf. *subgranulosum* Bc: *Buccella inusitata* Qu: *Quinqueloculina* St: *Streblus japonicus* St.k: *Streblus ketienziensis angulatus* St.t: *S. takanabensis* Sr: *Siphogenerina raphana* (Aug., 1949)

Fig. 7 Variation in the compositions of assemblages in the neritic waters of the mixed Kuroshio area.



1: *Cassidulina japonica, C. islandica* and *C. norcrossi* 2: *Uvigerina akitaensis* 3: *Angulogerina kokozuraensis* 4: *Martinottiella communis* 5: *Nonion labradoricum* 6: *Cassidulina delicata* 7: *Bulimina nipponica* 8: *Bolivina spissa* 9: *Elphidium abyssicola* 10: *Buccella frigida* and *B. inusitata* 11: *Elphidium clavatum* 12: *Elphidium bartletti, E.* sp. 2 and *E.* sp. 4
Ch.o.: *Chilostomella oolina* V.m.: *Virgulina mexicana* (Aug. 1949)

Fig. 8 Variation in the compositions of assemblages in the bathyal waters of the mixed Kuroshio area, with temperature (°C)-chlorinity (‰) distribution.

Table 5 Distribution of foraminifers in percent of

STATIONS DEPTH IN METERS	1 64	B 155	L 44	K 81	D 83	E 111	P 135
Angulogerina kokozuraensis							
Bolivina spissa							
B. robusta	1.5	4	1	4	2		0.5
Buccella inusitata		+	10				8
B. frigida		+	+				
Bulimina marginata		3.5	2	13	19	15	1
B. nipponica							
Cassidulina delicata							
C. norcrossi							
C. japonica							
C. islandica							1
C. subglobosa depressa	4.5	7					
Chilostomella oolina							
Cibicides aknerianus		1					1.5
Elphidium abyssicola n. sp.							
E. clavatum	0.5		12	2	24	26.5	29
E. bartletti							
E. sp. *2*			12				23
E. sp. *4*				1	3	4	6
E. advenum	2	14.5	5	5	+	1.5	1
E. advenum depressulum	4.5	7					
E. orbiculare			4				
E. (cf.) *subgranulosum*			8			1.5	
Eponides umbonatus				15			
Globobulimina turgida					1	1.5	
Hanzawaia nipponica	3.5	4					
Lagenonodosaria scalaris sagamiensis				3	1.5	5	1.5
L. scalaris				+			
Lagena sulcata spicata			+		3		
Martinottiella communis							
Nonion grateloupi	7				1		1.5
Nonion labradoricum		1.5	1	13	2.5	5.5	0.5
Nonionella stella	17.5	19	17	25	27	29	12
Pseudononion japonicum	11.5	9.5	3				0.5
Quinqueloculina seminula			13				
Rosalina vilardeboana	17.5	15.5					
Siphogenerina raphana	1	1		5		1	0.5
Streblus japonicus	1	+	8				
S. ketienziensis angulatus				3	6		
S. takanabensis						2.5	2
Uvigerina akitaensis							
Virgulina mexicana	0.5						

Species of less than 4% frequencies are excluded in the list.

benthonic population off Hachinohe to Inubo-saki

M 138	J 146	H 154	26 283	FG1 403	FG2 504	15 527	O 584	G 650	27 819	36 1041	13 1111	2 1180
		+	18	30	8	8.5	3				2	
				+	0.5	6.5	14	23	47	60	24	9
											1	
3	3.5		17	7.5	7.5	23	9	2.5	4		7	
			2	2.5	1	1	5	3		2		0.5
6	1	+										0.5
					1.5	2	0.5	11	6	4	2	4
							14	0.5	10	0.5	6	0.5
							4		3.5	1		
			1.5	+	1	6.5		+	1		2	
			5.5	+							0.5	
	0.5	0.5		4.5	1			4				42
	13.5	14							0.5			
								+	7	6.5	5	
21	7	2	4.5	7	1		0.5					
1			4		1		2					
			8.5	1								
				3.5			2					
												0.5
2		0.5										
3	0.5	0.5		+				2.5			1	
4	9	16										
12	15.5	40										
	12	2										
	1.5	5.5										
3	9	6	0.5	8.5	18	11	3	4.5	0.5		1	
			1.5		+							
13	5.5	2.5	2.5	8	42	30	22	43	4	3.5	4	6
12	1	3										3.5
1											1	
		+		+								
4	6.5	0.5										
	0.5		23	13	3.5		5		11	20	26	4
												18

facies is recognized at depths between 154 m and 283 m.

Facies I and II correspond to neritic zone, and others to bathyal zone. Figs. 7 and 8 will give the general aspect of faunal depth facies within this area.

Facies I characterized by the persistent presence of *Nonionella stella* includes four types of assemblage.

A: *Nonionella stella-Rosalina vilardeboana* assemblage (St. 1, B)
B: *Nonionella stella* assemblage (St. K)
C: *Nonionella stella-Elphidium clavatum* assemblage (St. L, D, E)
D: *Elphidium clavatum* assemblage (St. P, M)

Assemblage A occurs only in the vicinity of Inubo-saki where the Kuroshio water is usually developed. *Pseudononion japonicum* Asano is a subdominant species. Species substantially indicative of this assemblage are as follows:

Astrononion umbilicatulum Uchio
Cassidulina subglobosa depressa Asano & Nakamura
C. sagamiensis Asano & Nakamura
Elphidium advenum depressulum Cushman
E. sp. 5
Hanzawaia nipponica Asano
Rosalina vilardeboana d'Orbigny
Rectobolivina bifrons (Brady)

Species common to the subarctic water are scarce, excepting a high frequency of *Nonionella stella*. An assemblage having closer relation to those of Tosa Bay in the constituents was found at 125 km southwest* of St. 1, which does not contain any species typical of the subarctic waters. The species which exceed one per cent of benthonic population are as follows:

Angulogerina occidentalis (Cushman)	.... 2%
Bulimina marginata d'Orbigny	 3
Cancris auriculus (Fichtel & Moll)	 3
Cassidulina laevigata carinata Cushman	 5
C. subglobosa Brady	 9
C. sagamiensis Asano & Nakamura	 2
Elphidium advenum depressulum Cushman	 3
Miliolinella circularis (Bornemann)	 2
Nonion nicobarense Cushman	 7
Rectobolivina bifrons (Brady)	 4
Rosalina bradyi (Cushman)	 2
R. vilardeboana d'Orbigny	 4
Uvigerina proboscidea vadescens Cushman	 3

Assemblages B, C and D occur in the mixed Kuroshio water. On the whole, the D type contains the warm-water species in the lowest frequencies. This can be explained by the greater depths and the far northern positions of occurrence. Within the C type the assemblage of St. L is slightly different from those of St. D and St. E in containing *Elphidium* cf. *subgranulosum*, *Quinqueloculina* and *Streblus japonicus* in comparatively high frequencies. This is because the station is placed at inner neritic zone. Associated species in the assemblages B, C and D in outer neritic zone are as follows:

* lat. 34°52.'4 N-long. 139°59.'3 E, 206 m in depth, coarse sand on rock floor.

Bolivina robusta Brady
Buccella inusitata Anderson
Bulimina marginata d'Orbigny
Elphidium advenum (Cushman)
E. spp. (small thin-walled)
Eponides umbonatus (Reuss)
Lagenonodosaria scalaris sagamiensis Asano
Nonion labradoricum (Dawson)
Siphogenerina raphana (Parker & Jones)
Streblus ketienziensis angulatus (Kuwano)
S. takanabensis Ishizaki

Facies II is found at two stations, 130 km distant from each other. The dominant species is *Lagenonodosaria scalaris sagamiensis* Asano. *Cibicides aknerianus* (d'Orbigny) and *Globobulimina turgida* (Bailey) occur with fairly high frequencies. The stations are located near shelf-edge at depths of about 150 m, and the bottom character is fine-grained sand. It is interesting that the similar assemblage, *Lagenonodosaria scalaris sagamiensis-Cibicides aknerianus-Bolivinita quadrilatera* assemblage, occurs frequently in sandy facies of the Cainozoic formations in the South Kwanto region. This assemblage seems to be indicative of outer neritic sand facies under influence of the Kuroshio water.

Facies III is characterized by a combination of *Uvigerina akitaensis-Angulogerina kokozuraensis*. Associated species are: *Buccella inusitata*, *Elphidium clavatum*, *Martinottiella communis* and *Nonion labradoricum*, although they are not indicative of this Facies. *Uvigerina-Angulogerina* assemblage was previously mentioned (off Kushiro), and is widely found in the bathyal zone of the Japan Sea (refer to Fig. 10) and the Okhotsk Sea. Facies III occurs in the Subarctic Intermediate Water below the mixed Kuroshio water.

Facies IV is characterized by the predominance of *Nonion labradoricum*, and gradationally changes into Facies V. The lower part of this Facies is similar to *Nonion labradoricum* assemblage off Erimo-saki, excepting a low frequency of *Uvigerina akitaensis*. Associated species in Facies IV are: *Bolivina spissa*, *Buccella inusitata*, *Bulimina nipponica*, *Cassidulina delicata* (in the lower part), and *Martinottiella communis*.

Facies V is characterized by the predominance of *Bolivina spissa*. The subdominant species is *Uvigerina akitaensis*, which again increases its frequency with depth. The appearance of *Elphidium abyssicola* n. sp. is characteristic of this Facies. Other associated species with considerable frequencies are: *Bulimina nipponica*, *Cassidulina delicata* and *Nonion labradoricum*. Facies V is closely related to *Bolivina spissa-Uvigerina akitaensis* assemblage in the deep water off Erimo-saki.

Facies VI is represented by an assemblage from a single station (St. 2) off Inubo-saki. The assemblage appears somewhat strange. *Chilostomella oolina* exceeds 40 per cent of benthonic population, and *Virgulina mexicana* occupies 18 per cent. The bottom-water properties, such as temperature, chlorinity, oxygen content, do not vary between the present station and others of nearly equal depths. It is, therefore, difficult to explain the cause of such faunal differentiation.

Facies IV and V occur within the same deep water mass below the Subarctic Intermediate Water (= Oyashio undercurrent), whereas Facies VI at St. 2 occurs

Table 6 Distribution of foraminifers in percent of benthonic population in Tosa Bay

STATIONS	S0	S0A	S1	S1A	S1B	S2	S2A	S3	S3A
DEPTHS IN METERS	56	78	98	135	193	280	400~410	680	900
Alveolophragmium scitulum									4.5
Anomalina balthica		1	1.5		0.5	2	5		
Bolivina robusta	18	22	13	3	9	13	0.5	0.5	2
B. substriatula	1			3.5	5.5	2.5			
B. kiiensis	5	7.5	2						
B. subangularis ogasaensis	10	2							
Bulimina marginata	0.5	3	25	23	11.5	7.5	5	6	
B. nipponica							11	13	8
B. aculeata						0.5	5	25	12.5
Cassidulina laevigata carinata		0.5		1	6		0.5		0.5
Cassidulinoides bradyi					4	0.5			
Cibicides aknerianus					5	4.5		5.5	2
C. lobatulus					2		4		
C. pseudoungerianus				2	1.5	4.5	3		
Ehrenbergina pacifica						7			
Elphidium advenum	3	2	6.5	5.5	4	2		+	
Eponides umbonatus		0.5	2.5	1.5		1	0.5	2.5	4.5
Gyroidina orbicularis		1			2.5	0.5	4.5	6	2.5
Hanzawaia nipponica	7	0.5							
Martinottiella communis						0.5	1	1	8.5
Nonion manpukuziense	2.5	7.5	3.5		1.5				
N. nicobarense	0.5					4	3		
Planulina wuellerstorfi					1	1	2		5
Planodiscorbis rarescens	0.5			4	3	4			
Pseudoclavulina juncea									4
Rectobolivina bifrons					1.5	11.5	1.5		
Robulus lucidus		3		1		8	1		
Siphogenerina raphana	7	7.5		1.5	0.5				
Streblus ketienziensis	9	9	14.5	5	0.5	0.5			
S. papillosus	6	4.5		0.5		0.5			
Uvigerina peregrina dirupta							34	10.5	
U. sp. A								12	
U. proboscidea vadescens		2.5	10	20	19.5	6	1	0.5	
U. schencki		0.5	0.5	4	0.5				

Species of less than 4% frequencies are excluded in the list.

in the deep water underlying the Southern Intermediate Water below the Kuroshio.

IV. 3 Tosa Bay

Several faunal facies can be recognized by overlapping ranges of certain species. As is obvious in Fig. 9 and Table 6, a marked faunal facies boundary is found at depths between about 300 m and 400 m, which divides the facies into two, neritic and bathyal facies.

Facies		Diagnostic species with considerable frequency		Depth range
I	A	*Bolivina robusta* (Brady)	*Siphogenerina raphana* (P. & J.) *Streblus papillosus* (Brady)	50–80 m
	B		*Bulimina marginata* d'Orbigny *Uvigerina proboscidea vadescens* Cushman	100–280 m
II	A	*Bulimina nipponica* Asano	*Uvigerina peregrina dirupta* Todd	400–680 m
	B		*Martinottiella communis* d'Orbigny *Planulina wuellerstorfi* (Schw.)	900 m

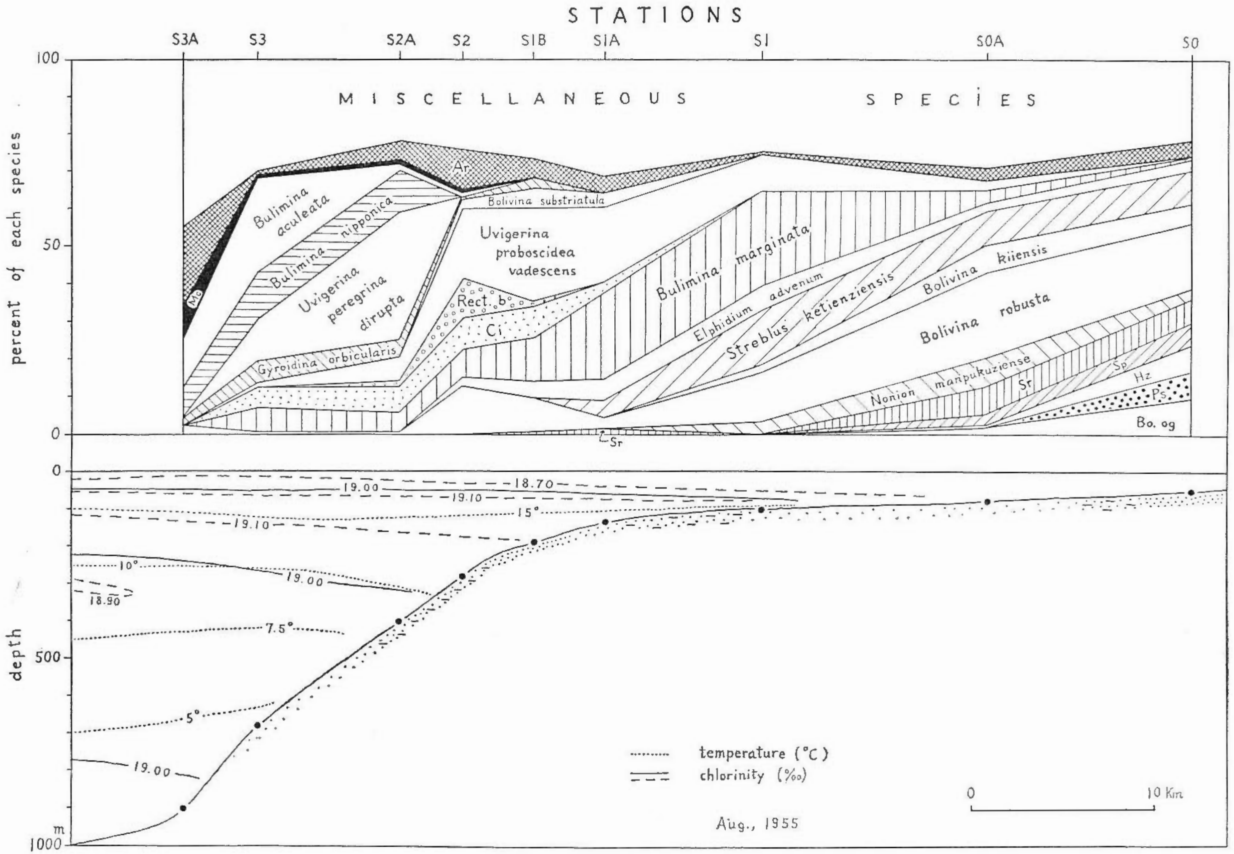
Facies I is recognized by the presence of *Bolivina robusta* in high frequencies. Subfacies IA can be recognized by the maximum depth limits of high frequencies of *Siphogenerina raphana* and *Streblus papillosus*, which coincide with the minimum depth limits of high frequencies of *Bulimina marginata* and *Uvigerina proboscidea vadescens*.

Anomalina balthica, Bolivina substriatula, Bolivina kiiensis, Elphidium advenum, Nonion manpukuziense, Planodiscorbis rarescens, Reussella aculeata, Streblus ketienziensis, Uvigerina schencki are comparatively common species throughout Facies I. *Bolivina subangularis ogasaensis, Cancris auriculus, Clavulina tosaensis* var., *Hanzawaia nipponica, Nonion japonicum, Pseudononion japonicum, Sigmoilopsis schlumbergeri* occur in Subfacies IA with significant frequencies. Subfacies IB is characterized by the high frequency occurrences of *Bolivina robusta, Bulimina marginata* and *Uvigerina proboscidea vadescens*, in which the assemblage from St. S2 is somewhat peculiar. This assemblage contains *Ehrenbergina pacifica, Lagenonodosaria scalaris sagamiensis, Rectobolivina bifrons* and *Robulus lucidus*. These species exhibit their highest frequencies at this station, and *Ehrenbergina pacifica* is not found elsewhere in the area. St. S2 is located near the end of shelf, where the bottom character is muddy sand.

Facies II is characterized by the continuous occurrence of *Bulimina nipponica*. The lower limit of Subfacies IIA can be distinctly recognized by the disappearance of *Uvigerina peregrina dirupta*.

The following species are typical of Facies II, but their low frequency occurrences are not necessarily restricted to this Facies.

Alveolophragmium scitulum (Brady)
Bulimina aculeata d'Orbigny
B. nipponica Asano
Gaudryina cf. *arenaria* Galloway & Wissler
Höglundina elegans (d'Orbigny)
Martinottiella communis (d'Orbigny)
Nonion labradoricum (Dawson)
Planulina wuellerstorfi (Schwager)
Pseudoclavulina juncea Cushman
Uvigerina peregrina dirupta Todd
U. proboscidea Schwager
U. sp. A.



Ar: arenaceous forms Mc: *Martinottiella communis* Rect.b.: *Rectobolivina bifrons* Ci: *Cibicides* Sr: *Siphogenerina raphana* Sp: *Streblus papillosus* Hz: *Hanzawaia nipponica* Ps: *Pseudononion japonicum* Bo.og.: *Bolivina subangularis ogasaensis*

Fig. 9 Frequency distribution of benthonic foraminifers in Tosa Bay.

Glancing over the whole facies, the following species seem to occur irrespective of the faunal depth facies.

Cassidulina laevigata carinata Cushman
Cibicides aknerianus (d'Orbigny)
C. pseudoungerianus (Cushman)
Eponides umbonatus (Reuss)
Gyroidina nipponica (Ishizaki)
G. orbicularis (d'Orbigny)
Virgulina mexicana Cushman

There is another collection of recent foraminifers from Tosa Bay. The sample was taken out of shell tests presented by fishermen. The location is known only as "off Ashizuri-saki at depths of about 150 m". Though the frequency composition cannot be estimated on account of incomplete sampling, the following species are contained in the sample.

Bathysiphon sp. ——common
Cibicides aknerianus (d'Orbigny)
C. praecinctus (Karrer)
C. pseudoungerianus (Cushman)
Cyclammina cancellata Brady ——abundant
Dentalina emaciata Reuss
Eponides procerus (Brady)
Martinottiella communis (d'Orbigny)
Robulus depressus Asano
R. pseudorotulatus Asano ——abundant
R. submammilligerus (Cushman) ——common
Textularia vertebralis Cushman ——common
etc.

It is interesting that more than 50 individuals of *Cyclammina* are contained in the sample of a small quantity. A similar mode of occurrence has been known from off Katsuura, Chiba Prefecture.* In the present investigation only one individual of *Cyclammina bradyi* Cushman was found at St. S2A.

In the traverse of Tosa Bay the species typical of the subarctic waters are very scarce, and even the assemblages found near the Intermediate Water do not differ essentially from those of the deep water. The assemblages in Tosa Bay contain many subtropical inhabitants. Good examples are: *Cibicides margaritiferus* (Brady), *Operculina ammonoides* (Gronovius), *Planodiscorbis rarescens* (Brady), *Pseudoclavulina juncea* Cushman, *Robulus calcarata* (Cushman), *R. costatus subdecoratus* (Cushman), *Textularia vertebralis* Cushman, *Uvigerina proboscidea vadescens* Cushman.

V. Faunal Facies and Marine Environment

V. 1 General Consideration

The environmental factors causing faunal facies are undoubtedly numerous and

* Personal communication from Prof. K. Asano.

interrelated. In such factors the influence of temperature, chlorinity, oxygen, depth and character of the bottom sediments has been discussed by many authors. Temperature is usually assigned to the most important ecologic factor affecting distribution of foraminifers. Under the open-sea condition chlorinity is frequently considered to be less important causal factor, because its variation in ordinary cases show a narrow range. Few active discussions have been made on the role of oxygen. Some authors suggest assemblages dominated by arenaceous forms or poor population of benthonic foraminifera may be caused by the oligo-oxygen status.

Depth may play a significant role directly and/or indirectly in faunal differentiation. Numerous factors controlled by water depth can be thought conceptionally. For instance, the degrees of variation in temperature and chlorinity have

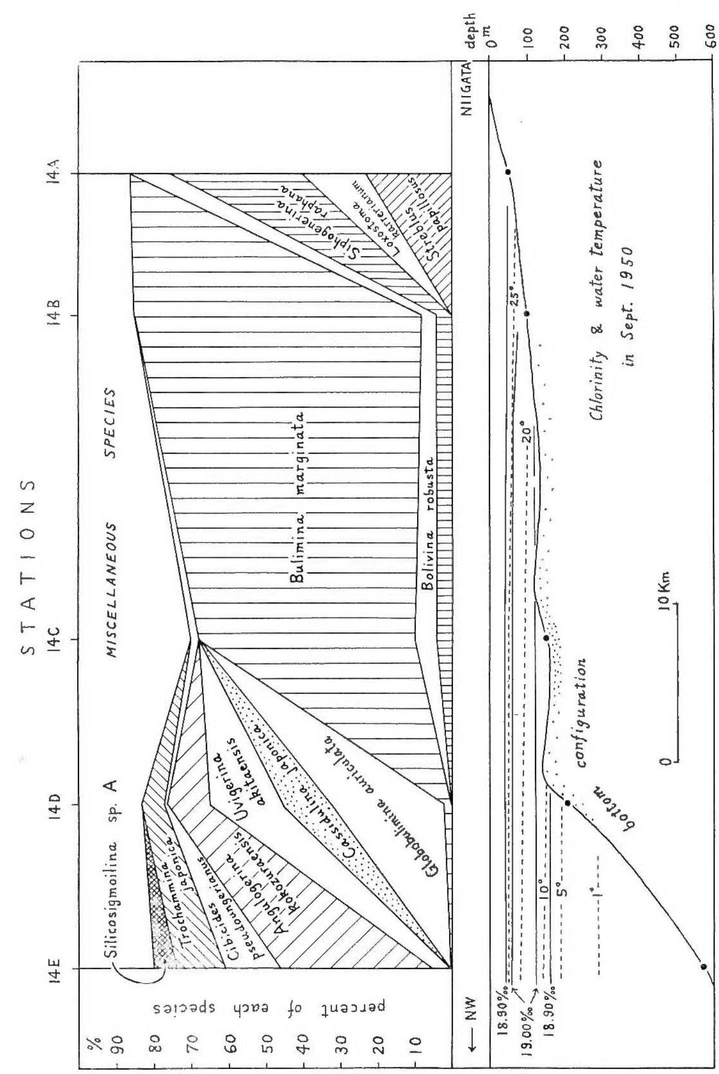


Fig. 10 Frequency distribution of benthonic foraminifers off Niigata, Japan Sea.

correlation with the water depths. Some species seem to have optimum depth ranges. In the Japanese waters *Bulimina marginata* generally occurs at depths ranging from 100 m to 150 m in the highest frequency. As previously mentioned, the most marked boundary in faunal depth facies is present at depths of about 200 m to 300 m everywhere. Particularly in the area off Kushiro marked differences in the annual averages of temperature and chlorinity do not exist between the maximum depth of *Elphidium clavatum* assemblage and the minimum depth of *Uvigerina akitaensis*-(*Angulogerina kokozuraensis*) assemblage. Fig. 10 shows the representative frequency distribution of benthonic foraminifers in the Japan Sea side. In this case there is a sharp depth facies boundary at depth of about 200 m, also. But it must be noticed that the depth of about 200 m also means the boundary depth between the warm Tsushima Current and the cold water mass indigenous to the Japan Sea in the area. Therefore, the meaning of the faunal depth facies boundary is somewhat complicated in this case.

Character of the bottom sediments may be also an important causal factor of faunal facies. Some species seem to prefer sandy bottom. Such species are expected to include *Hanzawaia nipponica, Cibicides lobatulus, C. subhaidingerii, C. praecinctus, C. aknerianus, Cassidulina subglobosa, C. sublimbata, C. wakasaensis, C. yabei, C. japonica-setanaensis* group, and possibly *Cancris auriculus*.

Cassidulina-Cibicides assemblage on submarine banks or *Lagenonodosaria scalasis sagamiensis-Cibicides* assemblages in the outer neritic zone are also inferred to be characteristic of sandy bottom.

It is expected that faunal differentiation may be caused by the overlapping ranges of species which have properly optimum variation ranges of environmental factors. Since the environmental factors work on the population not separately but in groups, discussion of the effect of completely isolated factors is hardly possible. If one would attempt an experiment on factorial analysis of the environmental factors and their effect, he would realize that no satisfactory combinations of factors are found in nature. Hence the term "ecologic water mass" of Phleger (1954) is appreciated as an excellent concept. Oceanographers have utilized temperature and chlorinity relation as an usual tool for recognition of water masses, while planktologists have long employed planktonic organisms as indicators of water masses. The term "water mass" in the latter case means oceanographic water mass, and differs essentially from the conceptional term "ecologic water mass". In this paper the term "water mass" is used in the oceanographic sense. As is previously described, the correlation between faunal facies and water masses is empirically well recognized in the areas of the present investigation. Such a correlation was found and described first in the Japan Sea (Ishiwada, 1950 & 1951) and a similar phenomenon was reported from the southern part of the Okhotsk Sea (Kuwano, 1953–1954). Consideration on the basis of water masses involves not only the composite physical-chemical properties and their confounding effects of water body but also possibly zoogeographic significance through the water movement.

V. 2 Faunal Facies and Water Masses

The preliminary results thus far obtained are summarized in the following.

There are five major groups of facies in the areas of investigation as follows:

	Kuroshio Region	Mixed Kuroshio Region	Oyashio Region
NERITIC	Subtropical neritic facies	Subtropical-Subarctic neritic facies	Subarctic neritic facies
		200–300 m	
BATHYAL		Subarctic bathyal facies	
		Deep water facies	

Subarctic neritic facies is represented by the following assemblages (off Kushiro).

1. *Buccella frigida* assemblage (22 m)
2. *Buccell frigida-Buliminella elegantissima* assemblage (36 m)
3. *Nonionella stella* assemblage* (56-70 m off Noboribetsu, ca. 30 m in Akkeshi Bay)
4. *Elphidium clavatum* assemblage (82-228 m)

These assemblages occur in the Subarctic waters (the Oyashio, including its coastal waters). Assemblages 1 and 2 seem to prefer the inner neritic environment.

Subtropical-Subarctic neritic facies is represented by the following assemblages (off Hachinohe to Inubo-saki).

1. *Nonionella stella* assemblage (44-81 m)
2. *Nonionella stella-Elphidium clavatum-(Bulimina marginata)* assemblage (83-111 m)
3. *Elphidium clavatum-(Nonionella stella)* assemblage (135-138 m)
4. *Lagenonodosaria scalaris sagamiensis-(Cibicides aknerianus-Globobulimina turgida)* assemblage (146-154 m)

Bulimina marginata, Nonion labradoricum, Lagenonodosaria scalaris sagamiensis, Siphogenerina raphana, Streblus ketienziensis angulatus, S. takanabensis are commonly the subdominants or secondary species. Assemblage 4 occurs at sand bottom near the shelf edge. These assemblages occur in the outer neritic zone under the influence of the waters of the Kuroshio greatly diluted by the Oyashio water.

Nonionella stella-Rosalina vilardeboana-Pseudononion japonicum assemblage occurs near the northern end of the main Kuroshio water, and contains more number of warm-water species than the former assemblages.

Subtropical neritic facies is represented by the following assemblages. (in Tosa Bay).

1. *Bolivina robusta* assemblage (51-78 m)
2. *Bulimina marginata* assemblage (98 m)
3. *Bulimina marginata-Uvigerina proboscidea vadescens* assemblage (135-195 m)
4. *Bolivina robusta-Rectobolivina bifrons* assemblage (280 m)

These assemblages occur in the waters of the Kuroshio, including its coastal waters.

Subarctic bathyal facies is typically represented by *Uvigerina akitaensis-Angulogerina kokozuraensis* assemblage. This occurs in the Subarctic waters off

* After T. Uchio (1959) and M. Morishima and M. Chiji (1952).

Kushiro (276 m) and in the Subarctic Intermediate Water off Kinkazan (283 m), and Onahama (403 m).

Nonion labradoricum assemblage occurring below the former assemblage (504-650 m) shows transitional character from the Subarctic water assemblages to the deep water ones. *Nonion labradoricum* is a wide-spread species in the adjacent seas of Japan, but seems to prefer colder waters. This species is found commonly in the neritic and bathyal waters of Okhotsk Sea, whereas its occurrence is comparatively rare in the Japan Sea.

Deep water facies is represented by the following assemblages.

Northern area:

Bolivina spissa-(Uvigerina akitaensis) assemblage (750-1110 m)

Off Inubo-saki:

Chilostomella oolina-(Virgulina mexicana) assemblage (1180 m)

Southern area (Tosa Bay):

Uvigerina peregrina dirupta-(Bulimina nipponica) assemblage (405 m)

Bulimina aculeata-(Bulimina nipponica)-(Uvigerina peregrina dirupta) assemblage (680 m)

Bulimina aculeata-(Martinottiella communis)-(Bulimina nipponica) assemblage (900 m)

Assemblages of Southern area are closely related to those of bathyal waters in Suruga Bay (M. Nagahama, 1954, and the author's collection). And also, the assemblage off Inubo-saki is very similar to one of the assemblages in Suruga Bay (*Chilostomella oolina* assemblage at a depth of 549 m), though it contains many species common to the Northern area as secondary species. On the other hand, the assemblages of the Northern area are comparatively different from those of Tosa Bay or Suruga Bay but have some common features to those of bathyal waters off California. The character of the deep water is fairly homogeneous throughout the areas, at least in temperature and chlorinity relation (Fig. 2). It is hardly possible, with the data available at present, to come to any

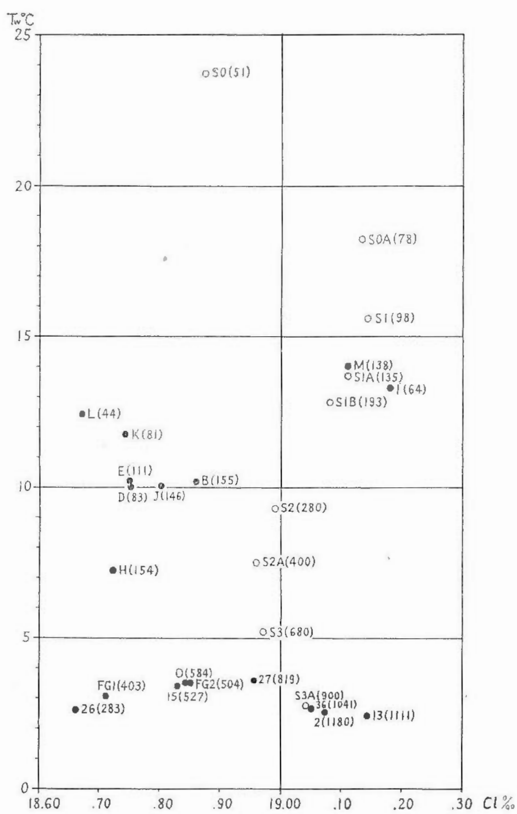


Fig. 11 Estimated temperature-chlorinity relations of the bottom water at each station.
(Tosa Bay in August 1955 and off northeast Honshu in July and August 1949)

conclusion concerning such a discordance of the faunal facies in the deep water.

Thus, the distribution of foraminiferal assemblages coincides fairly well with the distribution of water masses. Judging from the general aspect of foraminiferal distribution, temperature is undoubtedly the most important controlling factor. However, faunal differentiation cannot be interpreted separately by temperature distribution or by simple water type. It is not exceptional that mutually different assemblages overlap each other on T-Cl diagram (Fig. 11, and refer to Figs. 3a, b, Table 3). The distribution of *Uvigerina akitaensis-Angulogerina kokozuraensis* assemblage may be a good example for this problem. The assemblage, including *Angulogerina kokozuraensis* assemblage, occurs in the following areas.

Area	No. of station	Depth (m)	Temperature (°C)	Chlorinity (‰)
Off Kushiro	1	ca. 280	ca. 1	18.45-18.85
Off Onahama	1	ca. 400	3-5	18.60-19.00
Japan Sea	45	240- 950	0.2-3.7	18.82-18.86
Okhotsk Sea*	3	190-1460	0-2.9	18.4 -19.1

* Generally *Angulogerina kokozuraensis* predominates, followed by arenaceous forms.

It is obvious that this assemblage overlaps others in the deep water on T-Cl diagram. Nevertheless, the occurrence of this assemblage is limited within the bathyal waters of the Subarctic water system.

It must be noticed that, as Y. Ishiwada (1951) and Y. Kuwano (1954) point out, correspondence between water masses and faunal facies accords with the maximum developments within the seasonal variations of the distribution of the related water masses. Example are observable everywhere in the shallow waters of the Japan Sea, Okhotsk Sea and mixed Kuroshio region, as is typically exemplified by the assemblage, dominated by *Bulimina marginata, Bolivina robusta* or *Siphogenerina raphana*, in the shallow waters of the Japan Sea side.

VI. Fossil Assemblages and Correlation of the Kazusa Group

The Kazusa group is widely distributed in the southern half of the Kwanto district, consisting of marine sediments dominated by mudstone as a whole. Its geologic age may be assigned to Pliocene. The maximum thickness of the group attains more than 2500 m in the eastern part of Boso Peninsula. It is overlain by the Quaternary Shimoosa supergroup (K. Kawai, 1960) and overlies the Miocene series, which contains *Globigerina globularis, G. trilocularis, G. juvenilis, Sphaeroidinella rutschi* and species related to *Globorotalia menardii miocenica.**

Since the Kazusa group has many prolific natural gas reservoirs of dissolved-in-water type, abundant wells have been drilled in the vast Kwanto Plain. Correlation only by means of electric logging becomes rapidly less reliable for an exploratory drilling at increasing distance. This is because lithofacies and thickness of the group vary greatly with distance. Fossil foraminiferal assemblages and zonules, therefore, have been studied to a considerable extent by Geological

* Discovered in the samples taken from cores at depths of 1700 m and 1800 m of ER 10C well, Tokyo gas field, in 1960.

Survey of Japan and the major natural gas companies.

In this chapter the biofacies of the Kazusa group will be briefly delineated with paleoecological interpretation on the basis of the aforementioned knowledge of recent foraminiferal distribution.

The following is the general stratigraphic succession in descending order established by surface surveys, in which division below the Ohara formation is hardly recognizable in any gas wells. In the field practice geologists and engineers engaged in field development call the formations below the Ohara as Ohara in *sensu lato* also.

	Formation	Macroscopic lithofacies	Thickness*
Pliocene Kazusa group	Kasamori	muddy sandstone	250–300 m
	Chonan	frequent alternation (sand & mudstone)	110 m
	Kakinokidai	sandy mudstone with sand layers	10 m
	Kokumoto	alternation and sandy mudstone	210 m
	Umegase	frequent alternation (sandstone rich)	330 m
	Otadai	frequent alternation (mudstone rich)	270 m
	Kiwada	mudstone with many tuffs	610 m
	Ohara	alternation	170 m
	Namihana	mudstone and alternation	310 m
	Katsuura	alternation	less than 400 m
	Upper Miocene series		

* Measured at surface exposures.

Microbiostratigraphy in the environs of the Mobara gas field

Many foraminiferal zonules are recognized in the Kazusa group, which fall into five major biofacies as follows:

Facies	Dominant Species
I	*Anomalina balthica*, *Buccella frigida*, *Elphidium clavatum*, *E.* spp. (subarctic forms), *Pseudononion japonicum*, *Pseudoeponides japonicus*, *Streblus takanabensis*, *Cibicides aknerianus*, *Lagenonodosaria scalaris sagamiensis*, *Bolivinita quadrilatera*
II	*Cassidulina subglobosa*
III	*Elphidium* spp. (subarctic forms), *Cassidulina islandica*, *C. laevigata*, *C. delicata*, *Bulimina aculeata*, *Gyroidina nipponica*, *Epistominella japonica*
IV	*Uvigerina akitaensis*, *Bulimina aculeata*
V	*Bulimina aculeata*, *B. nipponica*, *Bolivina spissa*, *B. robusta*, *Cassidulina subglobosa*, *Gyroidina orbicularis*, *Nonion pompilioides*, *Stilostomella lepidula* (Kw 9—Kw 16), *Pseudononion japonicum* (the lower part)

Facies I corresponds roughly to the lower half of the Kasamori formation. The assemblages in the upper half of the formation have not been studied, because no gas well passed it in this field. The assemblages in the upper part of the formation which are dominated by the following species were known from the Yoro River area, 15 km west of Mobara.

Buccella frigida (Cushman)
Elphidium spp.
Nonionella stella Cushman & Moyer
Pseudononion japonicum Asano
Streblus takanabensis Ishizaki

Elphidium assemblage is common to Facies I, and *Anomalina balthica* assemblage in part. *Lagenonodosaria scalaris sagamiensis-Cibicides aknerianus-Bolivinita quadrilatera* assemblage has a limited distribution in the vicinity of the Mandano sand tongue. Secondary species of Facies I found to exceed few percent are as follows:

Bulimina aculeata d'Orbigny
B. marginata d'Orbigny
B. subornata Brady
Cassidulina laevigata d'Orbigny
Epistominella naraensis (Kuwano)
Nonion labradoricum (Dawson)
Pseudononion japonicum Asano

Assemblages in the Kasamori formation are, in general, similar to those found in the recent neritic waters of the mixed Kuroshio region.

Elphidium clavatum assemblage of Facies I occurs in the Chonan formation in the west of Mobara, occasionally containing *Uvigerina akitaensis* as a subdominant species, which slightly differs from the typical form in having less dense costae. This assemblage may have occurred in the neritic waters of the past Oyashio.

Facies II is characterized by the predominance of *Cassidulina subglobosa*, and occupies the stratigraphic interval between the Kakinokidai formation and the middle part of the Kokumoto formation. *Cassidulina subglobosa* zonule merges gradually into *Cibicides* zonule to the west of Yoro River (Y. Ishiwada *et al.*, 1958, p. 221). Although a similar assemblage was not found in the recent materials off the Pacific coast, it may be inferrable from the empirically known modes of occurrence of this species that the zonule was formed in the outer neritic zone where influence of coastal water did not exist and bottom water moved to some degree.

Facies III consists of assemblages of various types, showing transitional characters of neritic and bathyal zones. Mixing of the Subarctic and Subtropical inhabitants is also recognized.

Cassidulina delicata assemblage is present usually near the lowermost part of the Kokumoto formation in the Mobara gas field. Below the *Cassidulina delicata* subzonule *Bulimina aculeata* assemblage occurs persistently over wide area, while the upper two-third of Facies III is complicated and variable in its composition.

Facies IV is represented by *Uvigerina akitaensis* assemblage, which is always accompanied by *Bulimina aculeata*. A Subarctic planktonic species, *Globigerina pachyderma*, occurs constantly in association with this assemblage with a high frequency. In spite of difference in the associated species, the major features of this assemblage coincide with those of the recent *Uvigerina akitaensis* assemblage in the Oyashio or Subarctic Intermediate waters.

The following are comparatively common secondary species but occur with low frequencies.

Angulogerina kokozuraensis Asano
Buccella inusitata Anderson
Bulimina rostrata Brady
Buliminella exilis tenuata Cushman
Cassidulina islandica Nørvang
Cassidulinoides bradyi (Norman)
Elphidium clavatum Cushman
Eponides umbonatus (Reuss)
Gyroidina nipponica (Ishizaki)
Nonion labradoricum (Dawson)
N. nicobarense Cushman
N. pompilioides (Fichtel & Moll)
Pullenia apertula Cushman
P. bulloides (d'Orbigny)

Facies V is characterized by the assemblages dominated by *Bulimina aculeata, B. nipponica, Bolivina spissa* and *B. robusta.*

Pseudononion japonicum is abundant particularly near the base of the Kazusa group, which may have been displaced from the shallow waters. The frequency of *Bolivina robusta* in this Facies has a tendency to increase to the north of Mobara, and shows reverse correlation with those of *Bulimina aculeata, B. nipponica* and *Bolivina spissa.* This species seems to prefer neritic environment, except for the case of Suruga Bay. Accordingly, it may be suggested that *Bolivina robusta* in Facies V was probably displaced from the shallow waters. Similar occurrence of a shallow-water species is known in the Tokyo gas field, where *Pseudononion japonicum* occurs predominantly within the *Bulimina nipponica* zonule even in mudstone facies. The assemblages of this Facies have many common features to those of the recent deep-water facies.

Consequently the benthonic assemblages of the Kazusa group in this area are comparatively related to those of the recent mixed Kuroshio region. However, *Bulimina aculeata* commonly distributed in the Kazusa group does not show a high frequency in the recent deep water facies of the mixed Kuroshio region, but occurs in the bathyal zone of Suruga Bay and Tosa Bay. On the other hand in the case of these bays a cold-water species, *Uvigerina akitaensis,* does not associate with *Bulimina aculeata* assemblage.

Field practice of correlation and lateral change of biofacies

The distribution of diagnostic species in the Mobara gas field is shown in Fig. 12.

Four zonules and subzonules have been utilized as reliable "marker zones" for correlation in the environs of the Mobara gas field.

Cassidulina subglobosa zonule is indicative of the stratigraphic interval between the lower part of the Chonan formation and the middle part of the Kokumoto formation, and was found in many distant wells as far as Yawata, Chiba, Narita and Yokoshiba.

This zonule has a tendency to extend over the neighbouring horizons.

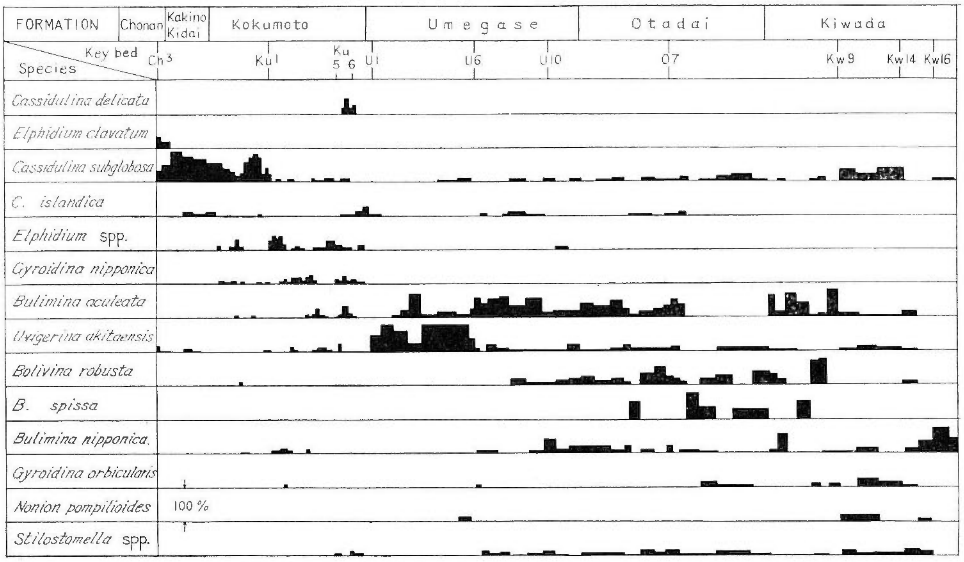


Fig. 12 Distribution of the diagnostic species of benthonic foraminifers in the Mobara gas field.

Cassidulina delicata subzonule is restricted to the horizon between Ku5 and Ku6 in the lower part of the Kokumoto formation. It is recognized everywhere in the Mobara gas field and also extends to the Naruto district, about 20 km north of Mobara.

Uvigerina akitaensis zonule is the most important "marker zone" extending over wide area, and is definitely indicative of the upper half of the Umegase formation, horizon between U1 to U6, overlying *Bulimina aculeata* zonule. Some geologists have preliminarily suggested that the Pliocene-Pleistocene boundary may be assigned to the horizon about U6, because this horizon, the lower limit of the zonule, may indicate the first appearance of remarkable boreal waters. However, it must be noticed that *Uvigerina akitaensis* assemblage completely identical with that of the Umegase formation was found in the upper part of the Otadai formation, that is, within Facies V, in the Chiba gas field (at a depth of 1600 m of FR-2 well). *Uvigerina akitaensis* subzonule just below the Koto sands in the Tokyo gas field may be correlative with this.

Fig. 13 shows the subsurface structure map drawn by the top of this zonule, practically the top of the Umegase stage, which will simultaneously demonstrate the widespread distribution of the zonule. In the South Kwanto basin this zonule disappears to the west of Chiba and is replaced by biofacies of colder shallow-waters.

Cassidulina subglobosa-Stilostomella lepidula subzonule is indicative of the middle of the Kiwada formation, horizon, between Kw9 and Kw16. In the west of Mobara the following species are main constituents of this zonule.

Cassidulina subglobosa Brady
Gyroidina orbicularis (d'Orbigny)
Nonion pompilioides (Fichtel & Moll)
Pullenia bulloides (d'Orbigny)

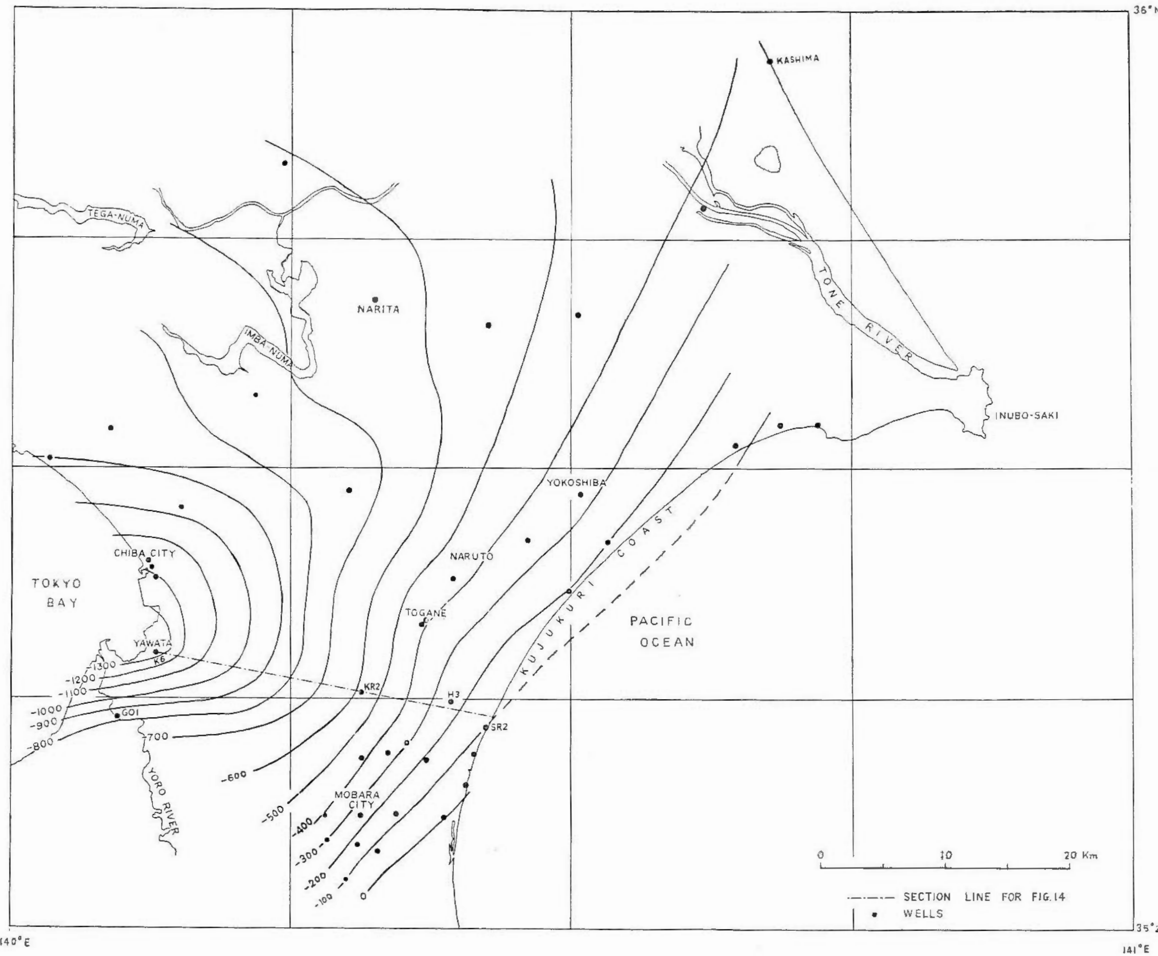


Fig. 13 Subsurface structure map in the eastern half of the South Kwanto region. Contours drawn on the top of Umegase formation in metres.

Quinqueloculina spp.
Stilostomella lepidula (Schwager)

Stilostomella and *Pullenia* increase their frequencies towards northeast, and this subzonule becomes rather *Stilostomella* subzonule. This subzonule is recognizable in the Yokoshiba area, about 30 km northeast of Mobara.

An example of correlation based on these "marker zones" was formerly exhibited by the author (Y. Ishiwada, 1959). Another example is shown in Fig. 14.

Marked changes of biofacies are recognized outside the Mobara gas field particularly in the formations above the Umegase. A good example was known in the area from Mobara to the Obitsu River district (Y. Ishiwada *et al.*, 1958, p. 221), where *Cassidulina subglobosa* zonule merges into *Cibicides* zonule and finally into *Pseudononion japonicum* zonule to the west. *Buccella inusitata-Pseudononion japonicum* assemblage appears in the *Uvigerina akitaensis* zonule in the Obitsu River district. Many warm-water species, such as *Bulimina marginata, Hanzawaia nipponica, Pseudononion japonicum, Rectobolivina bifrons, Robulus calcar, Siphogenerina raphana* and *Uvigerina schencki* were found in the upper part of the Kazusa group of Goi KR-1 well, located near the west coast of Boso Peninsula. On the contrary, at Kashima KT-1, about 70 km northeast of Mobara, occur many species typical of the Subarctic waters in the same horizons. The dominant species which represent the upper part of the Kazusa group are as follows:

Buliminella elegantissima (d'Orbigny)
Buccella frigida (Cushman)
Elphidium clavatum Cushman
E. sp.
Nonionella stella Cushman & Moyer
Uvigerina akitaensis Asano

The assemblages dominated by these species are closely related to those of the recent Oyashio water region rather than the mixed Kuroshio water region.

Consequently, it will be suggested that the Subarctic and the Subtropical waters had been contemporaneously developed in the same South Kwanto sedimentary basin during the deposition of the upper half of the Kazusa group, and that the interrelation of the past water masses may be an important consideration in the correlation on the basis of assemblage zone.

VII. Summary of Conclusions

(1) Off Kushiro, the Subarctic water region, the benthonic assemblages found at depths shallower than 300 m are closely related to those found in the cold waters of the Japan Sea and the Okhotsk Sea. The most marked boundary of the faunal facies is found at the depth of approximately 230 m to 270 m. The neritic facies is characterized by high frequencies of *Buccella frigida* and *Elphidium clavatum*, and the upper bathyal facies by *Uvigerina akitaensis-(Angulogerina kokozuraensis)* assemblage.

The assemblages found at depths of 400 m to 800 m are nearly the same as those of the deep water off Hachinohe to Inubo-saki.

(2) Tosa Bay is the region of the Subtropical Kuroshio waters. Many species are common to the Philippine waters and the tropical Pacific region. A marked boundary of faunal facies is found at the depth of 280 m to 400 m. Species of high frequency are: *Bolivina robusta, Bulimina marginata, Streblus ketienziensis* and *Uvigerina proboscidea vadescens* in neritic zone, and *Bulimina aculeata, B. nipponica, Martinottiella communis* and *Uvigerina peregrina dirupta* in bathyal zone (400 m to 900 m in water depth).

(3) Off Hachinohe to Inubo-saki the oceanographic condition is complicated. The Kuroshio water of the upper layer is greatly diluted by the Oyashio water, and the Subarctic Intermediate water is present beneath it.

The most marked depth boundary of the faunal facies is at 154 m to 283 m in water depth, and the most marked geographic boundary of the faunal facies is at approximately lat. 36°N.

Nonionella stella, Pseudononion japonicum and *Rosalina vilardeboana* present a characteristic combination in the neritic zone to the south of lat. 36°N. Species of high frequency in neritic zone to the north of that latitude are: *Bulimina marginata, Elphidium clavatum, Nonion labradoricum, Nonionella stella, Cibicides aknerianus, Globobulimina turgida* and *Lagenonodosaria scalaris sagamiensis.* The last three seem to prefer sandy bottom near the shelf-edge. Species of high frequency in bathyal zone are: *Angulogerina kokozuraensis* and *Uvigerina akitaensis* (283 m and 403 m in water depth), *Nonion labradoricum, Buccella inusitata, Bolivina spissa* and *Martinottiella communis* (504 m to 650 m in water depth), *Bolivina spissa* and *Uvigerina akitaensis* (819 m to 1111 m in water depth), and *Chilostomella oolina* and *Virgulina mexicana* (1180 m water depth).

Only the assemblage of the last two species occurs in the south of lat. 36°N.

(4) There is a marked depth facies boundary at the water depth of approximately 200 m to 300 m in all areas. The distribution of faunal facies apparently coincides with those of oceanographic water masses. This is true also in the Japan Sea and the Okhotsk Sea.

(5) Fossil assemblages of the Pliocene Kazusa group bear a considerable similarity to those from recent bottom samples off the Pacific coast. It may be important for the field practice of correlation depending upon assemblage zones as well as palaeogeographic inference to consider the past water masses.

VIII. Brief Notes on Species

In the present material species of japonic type were compared with the holotype, paratypes and topotypes as far as possible. And most of the species established by K. Asano were directly examined by himself. Some species were compared with the related Californian specimens by courtesy of T. Uchio. Other species were identified only by descriptions and figures given by the original authors and others, since the type specimens are hardly available in our country.

Some species of interest will be briefly noted in the following.

Family LITUOLIDAE

Adercotryma glomeratum (Brady)
(Plate 1, figure 5)

1878 *Lituola glomerata* Brady, Ann. Mag. Nat. Hist., ser. 5, vol. 1, p. 433, pl. 20, figs. la-c.
1910 *Haplophragmoides glomeratum* (Brady) Cushman, U.S. Nat. Mus. Bull., 71, pt. 1, p. 104, figs. 158-161.
1952 *Adercotryma glomeratum* (Brady) Loeblich and Tappan, Journ. Washington Acad. Sci., vol. 42, p. 141, figs. 1-4.

Photographed specimen has an aperture of arched slit between the periphery and the umbilicus.

Occurrence: Off Kushiro St. K7 (1.5%), St. K8 (5%), St. E2 (12%). Tosa Bay questionable specimens from St. S3A (1%).

Remarks: This species is commonly found in the cold waters of the Japan Sea and the Okhotsk Sea.

Haplophragmoides bradyi (Robertson)
(Plate 1, figure 1)

1920 *Trochammina bradyi* Robertson Cushman, U.S. Nat. Mus. Bull., 104, pt. 2, p. 76, pl. 15, fig. 5.
1947 *Haplophragmoides bradyi* (Robertson) Höglund, Zoologiska Bidrag från Uppsala, vol. 26, p. 134, pl. 10, fig. 1, text-fig. 111.

Occurrence: Off Kushiro, St. K7 (2%), St. K8 (1.5%), St. E3 (0.5%). Off NE Honshu, St. K (rare), St. O (0.5%), St. FG2 (0.5%).

Remarks: This species was formerly assigned to *Haplophragmoides trullissatum* (Brady) by the author. This is common in the Japan Sea at depths below 200 m.

Alveolophragmium scitulum (Brady)
(Plate 1, figure 4)

1881 *Haplophragmium scitulum* Brady, Quart. Journ. Micr. Sci., vol. 21, p. 50.
1884 *Haplophragmium scitulum* Brady, Rep. Voy. Challenger, Zool., vol. 9, p. 308, pl. 34, figs. 11-13.

The early portion is more or less contorted like *Recurvoides*. Character of aperture assigns it undoubtedly to this genus. It differs from *Recurvoides turbinatus* (Brady) in having a larger number of chambers and more quadrangular apertural view.

Occurrence: Off Kushiro St. E1 (1%)
Off NE Honshu St. 2 (1%)
Tosa Bay St. S3A (4.5%)

Family TEXTULARIIDAE

Textularia verteblaris Cushman
(Plate 1, figure 9)

1913 *Textularia verteblaris* Cushman, Proc. U.S. Nat. Mus., vol. 44, p. 633, pl. 78, fig. 1.

Occurrence: Tosa Bay St. S1B (0.5%), off Ashizuri-saki (at about 150 m depth, exact position unknown, abundant).

Remarks: This species is rather a deep-water inhabitant in the adjacent seas of Philippines and Borneo. This was found at depths of 150 m to 190 m in Tosa Bay and also in the shallow water off Sakata, Japan Sea.

Family VERNEUILINIDAE

Gaudryina cf. *arenaria* Galloway and Wissler

(Plate 1, figure 10)

Compared with:

1927 *Gaudryina arenaria* Galloway and Wissler, Journ. Pal., vol. 1, p. 68, pl. 11, fig. 5.

This species seems to be different from Galloway and Wissler's species in having more rapidly tapering initial portion.

Occurrence: Tosa Bay St. S2A (3.5%)

Remarks: This species is widely found in the Kazusa group, particularly in its upper part.

Pseudoclavulina juncea Cushman

(Plate 1, figure 11)

1936 *Pseudoclavulina juncea* Cushman, Spec. Publ. no. 6, Cushman Lab. Foram. Res., p. 19, pl. 3, figs. 8a, b.

The earliest portion is more rounded than the original form illustrated by Cushman. The aperture is provided with a short but definite neck. This is described from the Philippines, at the depth of 554 fathoms.

Occurrence: Tosa Bay St. S3A (4%)

Family VALVULINIDAE

Clavulina tosaensis Asano variety

(Plate 1, figure 12)

Compared with:

1936 *Clavulina tosaensis* Asano, Journ. Geol. Soc. Japan, vol. 43, p. 944, pl. 52, figs. 2, 3.

Variety differing from the typical form in nearly equal size of chambers of uniserial portion and the granulated surface of the wall. Probably a new subspecies.

Occurrrence: Tosa Bay St. SOA (1.5%), St. SO (0.5%)

Remarks: *Clavulina tosaensis* Asano is known only from the Pliocene Konomine formation.

Karreriella baccata japonica Asano

(Plate 1, figure 14)

1938 *Karreriella baccata japonica* Asano, Jap. Journ. Geol. Geogr., vol. 15, p. 90, pl. 10, fig. 1.

This is a species of very large size. The adult specimen was not found anywhere, but all specimens are completely referable to the topotypes.

Occurrence: Off Kushiro St. E1 (4%)
Off NE Honshu St. 13 (1%)

Remarks: This species is widespread in the Pliocene formations of the Japan Sea side, and is known also from the recent sediments of the Okhotsk Sea. Another species of the genus, *K. bradyi* Cushman is rarely found in Tosa Bay (St. S2, St. S2A).

Martinottiella communis (d'Orbigny)

(Plate 1, figure 16)

1826 *Clavulina communis* d'Orbigny, Ann. Sci. Nat., vol. 7, p. 268.
1846 *Clavulina communis* d'Orbigny, Foram. Foss. Vienne, p. 196, pl. 12, figs. 1, 2.

Occurrence: Off NE Honshu fairly common (see Table 5)
Tosa Bay rare (see Table 6)

Remarks: This is a common species of the Miocene formations of the Japan Sea side, occurring in association with *Haplophragmoides*, *Goësella* and *Cyclammina*, but has not been found in the recent sediments of the Japan Sea, except as reworked fossils.

Family TROCHAMMINIDAE

Trochammina japonica Ishiwada
(Plate 2, figures 19a–c)

1950 *Trochammina japonica* Ishiwada, Bull. Geol. Surv. Japan, vol. 1, no. 4, p. 9, figs. 2a-c.

This species is easily distinguished from *Trochammina pacifica* Cushman (Plate 2, figs. 20, 21) by higher whorl and greatly depressed umbilical region which is occasionally cemented by shell material.

Occurrence: Off Kushiro rare (see Table 4)
Off NE Honshu St. 26 (0.5%), St. 0 (1%)
Slightly different form occurs at St. L, M and D, which was affected by the waters of the Kuroshio.

Remarks: This species is widely distributed in the Japan Sea, particularly at depths below 200 m.

Family LAGENIDAE

Lagenonosaria scalaris sagamiensis Asano
(Plate 2, figure 30)

1936 *Lagenonodosaria scalaris sagamiensis* Asano, Journ. Geol. Soc. Japan, vol. 43, p. 613, pl. 30, figs. 6, 7.
1956 *Lagenonodosaria scalaris sagamiensis* Asano, Sci. Rep. Tohoku Univ., 2nd ser., vol. 27, p. 27, pl. 6, figs. 11-14.

The present material is slightly different from the typical form in having hispid or very roughened surface, otherwise referable to the topotypes. This subspecies is, in general, more slender than the species.

Occurrence: Off NE Honshu fairly common (see Table 5)
Tosa Bay St. S2A (1.5%), St. S2 (3%), St. S1A (0.5%)

Family NONIONIDAE

Nonion labradoricum (Dawson)
(Plate 3, figure 33)

1860 *Nonionina labradorica* Dawson, Can. Nat., vol. 5, p. 191, fig. 4.
1960 *Nonion labradoricum* (Dawson) Asano, Sci. Rep. Tohoku Univ., 2nd ser., spec. vol. no. 4, pl. 191, pl. 21, figs. 8a, b.

Occurrence: Off Kushiro St. K6 (0.5%), St. K7 (3%), St. K8 (3%), St. E2 (19%), St. E3 (2%)
Off NE Honshu abundant (see Table 5)
Tosa Bay St. S3A (3%), St. S3 (very rare)

Remarks: This is widely distributed in the adjacent waters of Japan, but has not been reported from the area south of the Tsugaru Strait in the Japan Sea.

Astrononion hamadaense Asano
(Plate 3, figure 37)

1950 *Astrononion hamadaense* Asano, Ill. Cat. Jap. Tert. Small. Foram., pt. 1, p. 6, figs. 29-31.

1953 *Astrononion gallowayi* Loeblich and Tappan, Smith. Misc. Coll., vol. 121, no. 7, p. 90, pl. 17, figs. 4-7.

Occurrence: Off Kushiro rare (see Table 4)
Off NE Honshu St. 26 (3%), St. FG1 (1%), St. FG2 (0.5%), St. 15 (0.5%), St. G (very rare), St. 2 (0.5%)

Remarks: Widely distributed in the cold waters off Japan, and the Pliocene formations of the Japan Sea side.

Astrononion umbilicatulum Uchio
(Plate 3, figure 38)

1952 *Astrononion umbilicatulum* Uchio, Journ. Jap. Ass. Petr. Tech., vol. 17, no. 1, p. 36, text-figs. la, b.

The present material was referred to Uchio's species which is characterized by narrow tubular supplementary chambers (the photograph, fig. 38, could not sufficiently indicate this character due to dirt).

Occurrence: Off NE Honshu St. 1 (1.5%), St. B (1.5%)

Pseudononion japonicum Asano
(Plate 3, figures 39a, b)

1936 *Pseudononion japonicum* Asano, Journ. Geol. Soc. Jap., vol. 43, p. 347, figs. a-c.

The original figures show an extraordinarily elongate and compressed form.

Occurrence: Off NE Honshu fairly common (see Table 5)
Tosa Bay not rare (see Table 6)

Nonionella globosa Ishiwada
(Plate 3, figure 40)

1950 *Nonionella globosa* Ishiwada, Bull. Geol. Surv. Japan, vol. 1, no. 4, p. 10, figs. 3a-c.

Specimens from the Pacific Ocean are usually slightly more slender forms than the typical form.

Occurrence: Off Kushiro St. K7 (0.5%), St. K8 (0.5%), St. E3 (0.5%)
Off NE Honshu St. FG2 (1.5%), St. G (1%), St. 36 (1%)

Nonionella stella Cushman and Moyer
(Plate 3, figures 41a, b)

1930 *Nonionella miocenica stella* Cushman and Moyer, Contr. Cushman Lab. Foram. Res. vol. 6, p. 56, pl. 7, figs. 17a-c.

1931 *Nonionella pulchella* Hada, Sci. Rep. Tohoku Imp. Univ., ser. 4, vol. 6, p. 120, text-figs. 79a-c.

Nonionella pulchella Hada may be safely referable to *N. stella* Cushman and Moyer. Abundant specimens of the former species from the recent deposits and the geologic formations in Japan show a considerable range of variation. Figures shown by Hada and later authors are usually placed toward the end of the variation.

Occurrence: Off Kushiro St. K5 (13%), St. K7 (1%)
Off NE Honshu abundant (see Table 5)

Remarks: This species is recorded from the Japan Sea and the Okhotsk Sea, and found widely in the Kazusa group and other Cainozoic formations.

Elphidium bartletti Cushman
(Plate 3, figure 44)

1933 *Elphidium bartletti* Cushman, Smith. Misc. Coll., vol. 89, no. 9, p. 4, pl. 1, fig. 9.

1938 *Elphidium yabei* Asano, Journ. Geol. Soc. Japan, vol. 45, p. 589, pl. 14, figs. 9a, b, 10a, b.

1944 *Elphidium etigoense* Husezima and Maruhasi, Journ. Sigen. Ken., vol. 1, pt. 3, p. 392, pl. 34, figs. la, b.

1951 *Cribroelphidium arcticum* Tappan, Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 6, pl. 1, figs. 27, 28.

1953 *Elphidium bartletti* Cushman Loeblich and Tappan, Smith. Misc. Coll., vol. 121, no. 7, p. 96, pl. 18, figs. 10-14.

Since the holotype of *Elphidium etigoense* was lost by fire in 1945, the topotypes from the same core sample were compared with the topotypes of *Elphidium yabei* and *Cribroelphidium arcticum*, resulting in undoubted coincidence of these three species.

Occurrence: Off Kushiro St. K5 (0.5%), St. K6 (5%), St. K3 (1%)

Remarks: This species occurs rarely in the recent sediments, but abundantly in the Pleistocene and Pliocene formations of the Japan Sea side. Most of the records using the name, *Elphidium etigoense*, do not necessarily mean of this species.

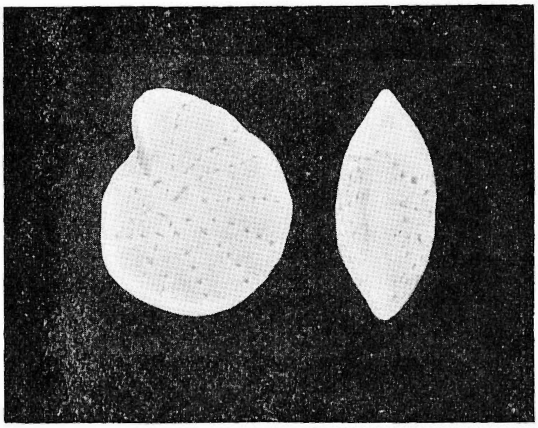
Elphidium etigoense of Asano (Ill. Cat. Jap. Tert. Small. Foram., pt. 1, p. 7, figs. 38, 39, 1950) is different species from the original.

Elphidium abyssicola n. sp.
(Plate 3, figures 48, 49; Text-figure)

Test medium size, periphery subacute, margin slightly lobulate in the last few chambers, fusiform but slightly concave near the periphery in peripheral view, umbilical regions flush with the surface, thickness approximately a half of the diameter; chambers not inflated except for the last few, about 13 in the last-formed coil; sutures not depressed, marked by the distinct openings, which are sometimes slitlike near the umbilical regions; wall thick, with porcelaneous appearance except in completely fresh sample, finely perforated; aperture composed of several small rounded openings at the base of the apertural face. Diameter 0.562 mm.

Figure 49 shows the typical appearance of the species. Figure 48 shows an unusually fresh specimen which has transparent umbonal and sutural regions.

Holotype: GSJ No. F61176 from St. 13 off Shioya-saki at a depth of 1111 m.



Text-figure *Elphidium abyssicola* n. sp. GSJ F61220 from St. 36 Diameter 0.61mm

The present species may differ from *Elphidium discoindale* (d'Orbigny) in having concaved surface near the periphery and openings rounded or slitlike parallel to the sutures.

Occurrence: Off Kushiro St. K7 (1%), St. K8 (2%), St. E2 (2%), St. E3 (2.5%)
Off NE Honshu rare (see Table 5)

Remarks: This new species may be an inhabitant in the deep water below the Subarctic Intermediate Water, and is found in the Kazusa group of deep-water facies.

Family BULIMINIDAE

Bulimina marginata d'Orbigny

(Plate 4, figures 52, 53)

1826 *Bulimina marginata* d'Orbigny, Ann. Sci. Nat., vol. 7, p. 269, pl. 12, figs. 10-12.

1931 *Bulimina aculeata* d'Orbigny, Hada, Sci. Rep. Tohoku Imp. Univ., ser. 4, vol. 6, no. 1, p. 127, text-figs. 84a, b.

The japonic type of the species from the cool waters is somewhat different from the typical. It is always stout and provided by sharp spines, especially in the earlier chambers. A good example is shown by Hada under the name *Bulimina aculeata*.

Occurrence: Off NE Honshu common (see Table 5)
Tosa Bay abundant (see Table 6)

Bulimina nipponica Asano

(Plate 4, figures 54-56)

1958 *Bulimina nipponica* Asano, Sci. Rep. Tohoku Univ., ser. 2, vol. 29, p. 6, pl. 1, figs. 13-15.

Occurrence: Off Kushiro St. E2 (1%), St. E3 (1%)
Off NE Honshu rare (see Table 5)
Tosa Bay common (see Table 6)

Virgulina mexicana Cushman

(Plate 4, figure 58)

1922 *Virgulina mexicana* Cushman, Bull. 104, U.S. Nat. Mus., pt. 3, p. 120, pl. 23, fig. 8.

Occurrence: Off NE Honshu St. 1 (0.5%), St. 2 (18%)

Tosa Bay St. S3A (1%), St. S1 (1%)

Bolivina kiiensis Asano
(Plate 4, figure 61)

1958 *Bolivina kiiensis* Asano, Sci. Rep. Tohoku Univ., ser. 2, vol. 29, p. 19, pl. 4, figs. 7, 8.

In the fresh specimens sutures mostly limbate; costae frequently extend from the initial end making short spinulose projections.

Occurrence: Tosa Bay St. S1 (2%), St. SOA (7.5%), St. SO (5%)

Bolivina spissa Cushman
(Plate 4, figures 64, 65)

1926 *Bolivina subadvena spissa* Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 2, p. 45, pl. 6, figs. 8a, b.

Occurrence: Off Kushiro abundant (see Table 4)
Off NE Honshu abundant (see Table 5)

Remarks: This species is known only from the Kazusa group and the recent deep water in the north of Inubo-saki.

Bolivina substriatula Asano
(Plate 4, figure 67)

1958 *Bolivina substriatula* Asano, Sci. Rep. Tohoku Univ., ser. 2, vol. 29, p. 23, pl. 4, figs. 11-14.

The raised costae on the lower half of test are transparent glassy shell material running somewhat irregularly.

This species is closely related to *Bolivina advena striatella* Cushman which has been recorded from off Kobe by Cushman and McCulloch (Allan Hancock Pacific Expeditions, vol. 6, no. 4, 1942).

Occurrence: Tosa Bay not rare (see Table 6)

Uvigerina akitaensis Asano
(Plate 5, figure 70)

1950 *Uvigerina akitaensis* Asano, Ill. Cat. Jap. Tert. Small. Foram., pt. 2, p. 14, figs. 60-62.

Most of the specimens in the present material have low dense costae, instead of sharp lamellate costae. But such a feature is not rare in the topotypes from the Pliocene Wakimoto formation.

It differs from *Uvigerina cushmani* Todd in less number of costae and more slender shape.

Occurrence: Off Kushiro abundant (see Table 4)
Off NE Honshu abundant (see Table 5)

Remarks: This species is a typical cold water inhabitant in the adjacent seas of Japan, and found from the Miocene to the Pleistocene formations.

Uvigerina peregrina dirupta Todd
(Plate 5, figures 70-75)

1948 *Uvigerina peregrina dirupta* Todd, Allan Hancock Pacific Expeditions, vol. 6, no. 5, p. 267, pl. 34, figs. 3a-d.

Uvigerina peregrina shiwoensis Asano (fig. 76) is easily distinguished from

this species by its heavier spines and costae, and by thick wall.
Occurrence: Off NE Honshu St. 0 (0.5%)
Tosa Bay abundant (see Table 6)

Uvigerina proboscidea vadescens Cushman
(Plate 5, figure 78)

1933 *Uvigerina proboscidea vadescens* Cushman, Contr. Cushman Lab. Foram. Res., vol. 9, p. 85, pl. 8, figs. 14, 15.
1942 *Uvigerina proboscidea vadescens* Cushman Todd, Allan Hancock Pacific Expeditions, vol. 6, no. 5, p. 268, pl. 34, fig. 5.

As noted by Todd an alignment or even very weak longitudinal costae are present at the initial end. It differs from *Uvigerina pseudoampullacea* Asano in the more projected initial end and the less roughened surface.
Occurrence: Tosa Bay abundant (see Table 6)

Siphogenerina clumellaris (Brady) *costulata* n. subsp.
(Plate 5, figure 82)

Compared with:
1881 *Sagrina columellaris* Brady, Quart. Journ. Micr. Sci., vol. 21, p. 64.
1884 *Sagrina columellaris* Brady, Rep. Voy. Challenger, Zool., vol. 9, p. 581, pl. 75, figs. 15-17.

Subspecies differing from the species in having numerous low rectilinear costae from the earliest portion to the lower half of the last chamber and broadly rounded initial end. Length: 0.76 m
Holotype: GSJ No. F61165 from St. S1B, Tosa Bay, at a depth of 193 m
Occurrence: Tosa Bay St. S1B (0.5%)

Family ROTALIIDAE

Planodiscorbis rarescens (Brady)
(Plate 5, figures 85a–86b)

1884 *Discorbina rarescens* Brady, Rep. Voy. Challenger, Zool., vol. 9, p. 651, pl. 90, figs. 2-4.
1953 *Planulina convexa* Takayanagi, Short Papers, IGPS, no. 5, p. 34, pl. 4, figs. 14a-c.

Planulina convexa is apparently of the younger stage of this species. Figs. 85a, b show the younger stage, in which the character of aperture is that of *Planulina*.
Occurrence: Tosa Bay not rare (see Table 6)

Family CASSIDULINIDAE

Epistominella naraensis (Kuwano)
(Plate 7, figures 94a–c)

1950 *Pseudoparrella naraensis* Kuwano, Journ. Geol. Soc. Japan, vol. 56, p. 317, figs. 6a-c.

The present specimens have usually seven chambers in the last-formed whorl. It differs from *E. takayanagii* Iwasa in the more inflated test and more rounded periphery.
Occurrence: Off Kushiro rare (see Table 4)

Off NE Honshu very rare at St. B, St. D and St. O.

Remarks: This species is commonly found in the deep water of the Japan Sea and rarely in the Okhotsk Sea.

Genotype species, *E. pulchella* Husezima and Maruhasi, is found at St. K3 (1%) and St. 13 (0.5%), which differs from *E. smithi* only in keeled periphery instead of thin carina.

Cassidulina delicata Cushman
(Plate 7, figure 95)

1927 *Cassidulina delicata* Cushman, Scripps Inst. Oceanography Bull., Tech. Ser., vol. 1, p. 168, pl. 6, fig. 5.

1950 *Cassidulina asanoi* Uchio, Journ. Ass. Petr. Tech., vol. 15, no. 4, p. 190, fig. 13.

Cassidulina asanoi is safely assigned to *C. delicata* by comparing the topotypes of the former with the latter from off California.

Occurrence: Off Kushiro St. E2 (3%), St. E3 (3%)
Off NE Honshu fairly common (see Table 5)

Remarks: This species has been recorded from Suruga Bay at depths deeper than 80 m (fairly common at depths below 230 m) by Nagahama.

Cassidulina norcrossi Cushman
(Plate 7, figure 101)

1933 *Cassidulina norcrossi* Cushman, Smith. Misc. Coll., vol. 89, no. 9, p. 7, pl. 2, figs. 7a-c.

1944 *Cassidulina kasiwazakiensis* Husezima and Maruhasi, Journ. Sigen. Ken., vol. 1, no. 3, p. 399, pl. 34, figs. 13a-c.

1950 *Cassidulina nakamurai* Uchio, Journ. Ass. Petr. Tech., vol. 15, no. 4, p. 40, fig. 14.

Occurrence: Off Kushiro St. E2 (2%)
Off NE Honshu rare (see Table 5)

Cassidulina wakasaensis Asano and Nakamura
(Plate 7, figure 105)

1937 *Cassidulina wakasaensis* Asano and Nakamura, Jap. Journ. Geol. Geogr., vol. 14, nos. 2-3, p. 149, pl. 14, figs. 7a-c.

The type specimen from a bank in Wakasa Bay, Japan Sea, at the depth of 190 m.

It differs from *Cassidulina tortuosa* in having slightly depressed sutures, which are usually indistinct except for later chambers, and in the shape of chambers which is not tortuous at the inner portion. It is also easily distinguishable from *Cassidulina translucens* by absence of peripheral carina.

Occurrence: Off Kushiro St. El (21.5%)

Cassidulina yabei Asano and Nakamura
(Plate 7, figures 103, 104)

1937 *Cassidulina yabei* Asano and Nakamura, Jap. Journ. Geol. Geogr., vol. 14, nos. 2-3, p. 145, pl. 14, figs. la, b.

Cassidulina teretis Tappan (1951) is possibly referred to this species.

Occurrence: Off Kushiro rare (see Table 4)
Off NE Honshu St. H (0.5%), St. 13 (1.5%)

Remarks: This species is commonly found in the Japan Sea and Okhotsk Sea, particularly in the bank deposits, and also found in the upper Miocene and the Pliocene formations of the Japan Sea side.

Judging from the descriptions and figures by Tappan (1951) and Loeblich and Tappan (1955), it is hardly possible to separate *C. yabei* and *C. teretis*.

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本邦太平洋沿岸産底棲有孔虫類

上総層群の生層位学に関連して

石和田　靖章

要　旨

北海道釧路沖より土佐湾に至る間の水域で採集した現世底質中に含まれている底棲有孔虫類の群集分布を研究した。親潮水域の釧路沖で9点，混合黒潮水域の八戸～犬吠岬沖合で20点，黒潮水域の土佐湾で9点，計38点の底質サンプルを使用した。

群集分化には2つのカテゴリーがあり，その1つは200～300mの水深を境とする深度に関連したもの，他の1つは水塊の分布に関連した群集変化である。

南関東に分布する上総層群の底棲有孔虫類化石群集は上記の現世底質産のそれらと類似している。梅ケ瀬層上半の層位を示すよい標識になっている ***Uvigerina akitaensis*** 群集は過去の亜北極中層水の存在を示すものであろう。

なお末尾に代表的な種106種の写真を付し，若干の種の同定について意見を述べるとともに1新種，1新亜種の記載をした。

PLATES AND EXPLANATIONS

(with 8 Plates)

Plate 1. LITUOLIDAE, TEXTULARIIDAE, VERNEUILINIDAE and VALVULINIDAE

Fig. 1 *Haplophragmoides bradyi* (Robertson)
GSJ F61221 from St. K7. ×60.

Fig. 2 *Alveolophragmium crassimargo* (Norman)
GSJ F61267 from St. K7. ×60.

Fig. 3 *Alveolophragmium jeffreysi* (Williamson)
GSJ F61266 from St. K7. ×60.

Fig. 4 *Alveolophragmium scitulum* (Brady)
GSJ F61256 from St. S3A. ×42.

Fig. 5 *Adercotryma glomeratum* (Brady)
GSJ F61187 from St. K8. ×42.

Fig. 6 *Cyclammina bradyi* Cushman
GSJ F61270 from St. S2A. ×30.

Fig. 7 *Cyclammina cancellata* Brady
GSJ F61280 from off Ashizuri-saki. ×10.

Fig. 8 *Spiroplectammina higuchii* Takayanagi
GSJ F61171 from St. S1B. ×60.

Fig. 9 *Textularia verteblaris* Cushman
GSJ F61238 from off Ashizuri-saki. ×10.

Fig. 10 *Gaudryina* cf. *arenaria* Galloway and Wissler
GSJ F61163 from St. S2A. ×42.

Fig. 11 *Pseudoclavulina juncea* Cushman
GSJ F61173 from St. S3A. ×30.

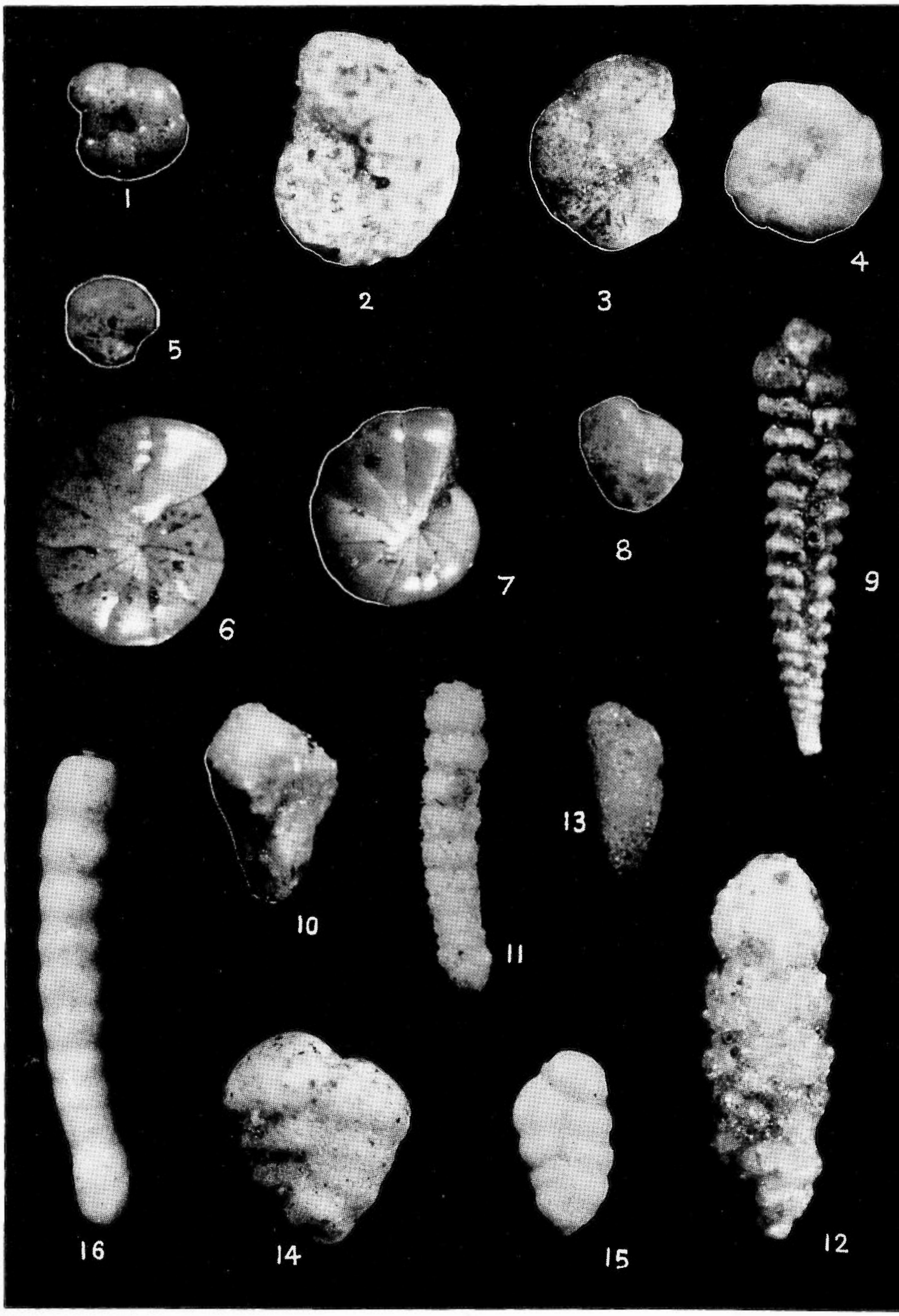
Fig. 12 *Clavulina tosaensis* Asano var.
GSJ F61261 from St. SOA. ×30.

Fig. 13 *Eggerella advena* (Cushman)
GSJ F61180 from St. K5. ×60.

Fig. 14 *Karreriella baccata japonica* Asano
GSJ F61186 from St. E1. ×30.

Fig. 15 *Karreriella bradyi* (Cushman)
GSJ F61232 from St. S2. ×30.

Fig. 16 *Martinottiella communis* (d'Orbigny)
GSJ F61208 from St. S3A. ×30.



LITUOLIDAE, TEXTULARIIDAE, VERNEUILINIDAE and VALVULINIDAE

Plate 2. MILIOLIDAE, TROCHAMMINIDAE and LAGENIDAE

Fig. 17 *Massilina* sp. A
GSJ F61276 from St. S1A. ×60.

Fig. 18 *Sigmoilopsis schulumbergeri* (Silvestri)
GSJ F61259 from St. SO. ×60.

Figs. 19a-c *Trochammina japonica* Ishiwada
GSJ F61213 from St. K8. ×60. a, dorsal view; b, edge view, c, ventral view.

Figs. 20, 21 *Trochammina pacifica* Cushman
from St. K. ×42.
20, dorsal view, GSJ F61268.
21, ventral view, GSJ F61269.

Fig. 22 *Robulus costatus multicostus* (Cushman)
GSJ F61278 from off Ashizuri-saki. ×10.

Fig. 23 *Robulus costatus subdecoratus* (Cushman)
GSJ F61277 from off Ashizuri-saki. ×10.

Fig. 24 *Robulus lucidus* (Cushman)
GSJ F61235 from St. S1B. ×60.

Fig. 25 *Robulus pseudorotulatus* Asano
GSJ F61281 from off Ashizuri-saki. ×10.

Fig. 26 *Robulus submammiligerus* (Cushman)
GSJ F61279 from off Ashizuri-saki. ×10.

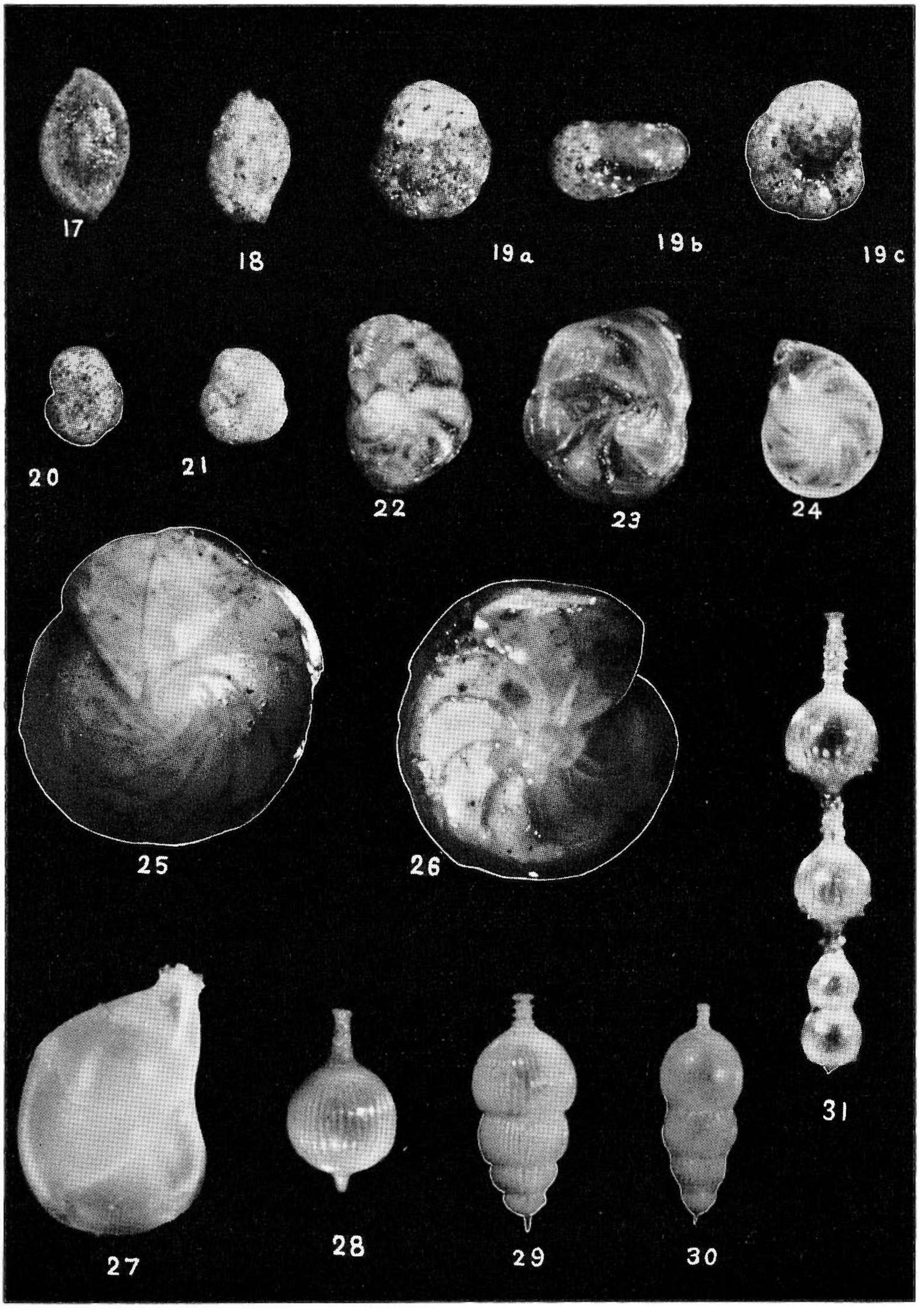
Fig. 27 *Lenticulina peregrina* (Schwager)
GSJ F61262 from St. FG1. ×60.

Fig. 28 *Lagena sulcata spicata* Cushman and McCulloch
GSJ F61206 from St. H. ×60.

Fig. 29 *Lagenonodosaria scalaris* (Batsch)
GSJ F61200 from St. H. ×30.

Fig. 30 *Lagenonodosaria scalaris sagamiensis* Asano
GSJ F61201 from St. J. ×30.

Fig. 31 *Lagenonodosaria sublineata* (Brady)
GSJ F61249 from St. S1A. ×60.



MILIOLIDAE, TROCHAMMINIDAE and LAGENIDAE

Plate 3. NONIONIDAE

Fig. 32 *Nonion grateloupi* (d'Orbigny)
GSJ F61189 from St. E2. ×60.

Fig. 33 *Nonion labradoricum* (Dawson)
GSJ F61207 from St. FG2. ×60.

Fig. 34 *Nonion manpukuziense* Otuka
GSJ F61241 from St. SOA. ×60.

Fig. 35 *Nonion nicobarense* Cushman
GSJ F61226 from St. S2A. ×60.

Fig. 36 *Nonion pacificum* (Cushman)
GSJ F61257 from St. SOA. ×60.

Fig. 37 *Astrononion hamadaense* Asano
GSJ F61220 from St. K8. ×60.

Fig. 38 *Astrononion umbilicatulum* Uchio
GSJ F61190 from St. 1. ×60.

Figs. 39a, b *Pseudononion japonicum* Asano
GSJ F61195 from St. L. ×60.

Fig. 40 *Nonionella globosa* Ishiwada
GSJ F61215 from St. FG2. ×60.

Figs. 41a, b *Nonionella stella* Cushman and Moyer
GSJ F61196 from St. L. ×60.

Fig. 42 *Elphidium advenum* (Cushman)
GSJ F61194 from St. 1. ×60.

Fig. 43 *Elphidium advenum depressulum* Cushman
GSJ F61192 from St. B. ×60.

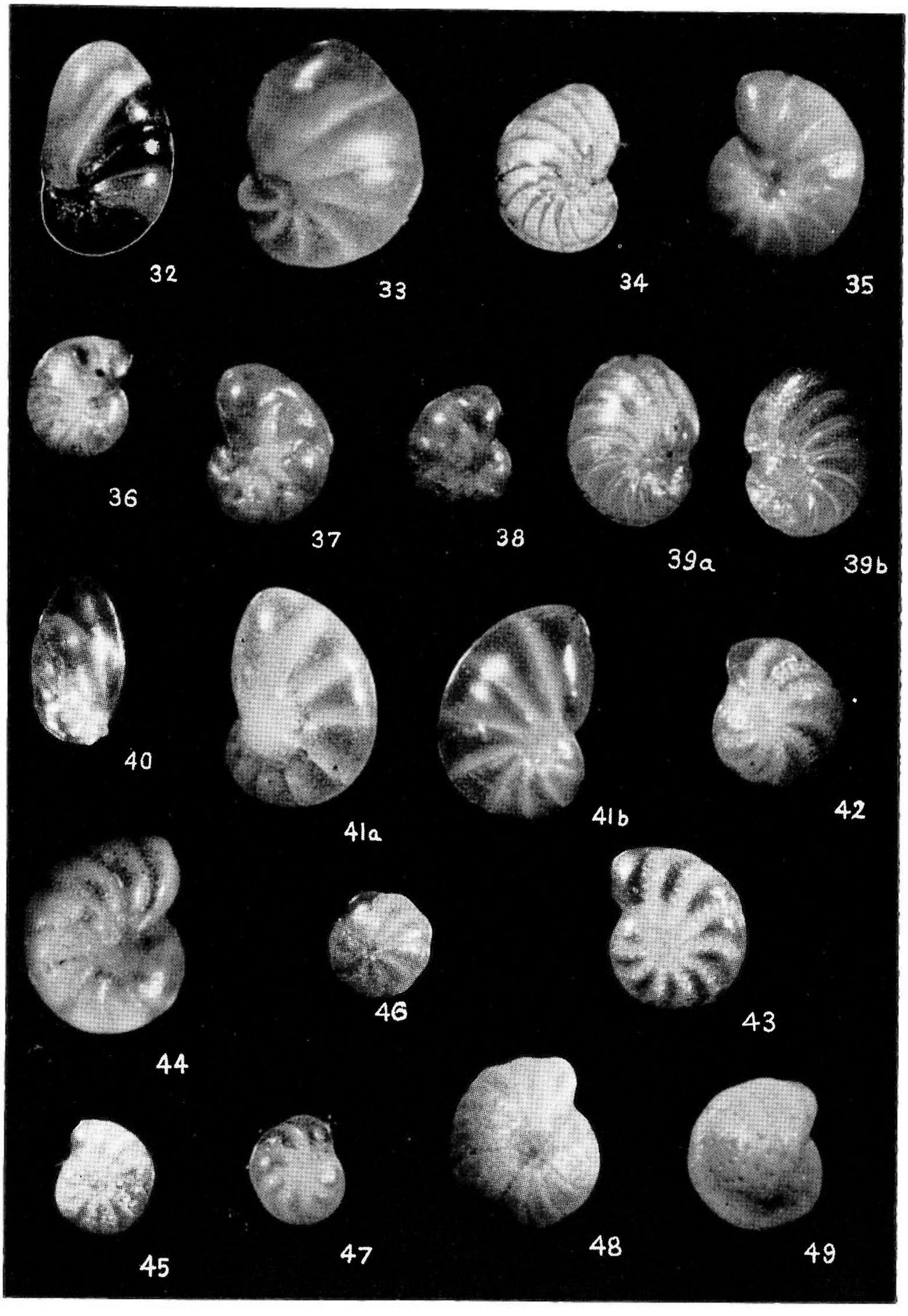
Fig. 44 *Elphidium bartletti* Cushman
GSJ F61181 from St. K6. ×30.

Fig. 45 *Elphidium clavatum* Cushman
GSJ F61182 from St. K6. ×42.

Fig. 46 *Elphidium orbiculare* (Brady)
GSJ F61205 from St. L. ×60.

Fig. 47 *Elphidium* sp. 2
GSJ F61175 from St. 26. ×60.

Figs. 48, 49 *Elphidium abyssicola* n. sp.
48, GSJ F61177 from St. 27. ×42.
49, GSJ F61176 from St. 13. Holotype. ×42.



NONIONIDAE

Plate 4. BULIMINIDAE

Fig. 50 *Buliminella elegantissima* (d'Orbigny)
GSJ F61179 from St. K5. ×60.

Fig. 51 *Bulimina aculeata* d'Orbigny
GSJ F61170 from St. St. S3. ×42.

Figs. 52, 53 *Bulimina marginata* d'Orbigny
52, GSJ F61260 from St. SO. ×60.
53, showing marginal sharp spines, GSJ F61258 from St. S3. ×85.

Figs. 54-56 *Bulimina nipponica* Asano
54, showing normal form, GSJ F61169 from St. S3. ×42.
55, GSJ F61168 from St. S3A. ×42.
56, showing the smaller form similar to *B. notoensis* Asano, GSJ F61202 from St. 15. ×60.

Fig. 57 *Globobulimina turgida* (Bailey)
GSJ F61198 from St. H. ×30.

Fig. 58 *Virgulina mexicana* Cushman
GSJ F61218 from St. 2. ×60.

Fig. 59 *Virgulina pauciloculata* Brady
GSJ F61271 from St. SOA. ×60.

Fig. 60 *Virgulina* sp. A
GSJ F61254 from St. S1. ×60.

Fig. 61 *Bolivina kiiensis* Asano
GSJ F61245 from St. SOA. ×60.

Fig. 62 *Bolivina pseudobeyrichi* Cushman
GSJ F61275 from St. 13. ×60.

Fig. 63 *Bolivina robusta* Brady
GSJ F61244 from St. SOA. ×60.

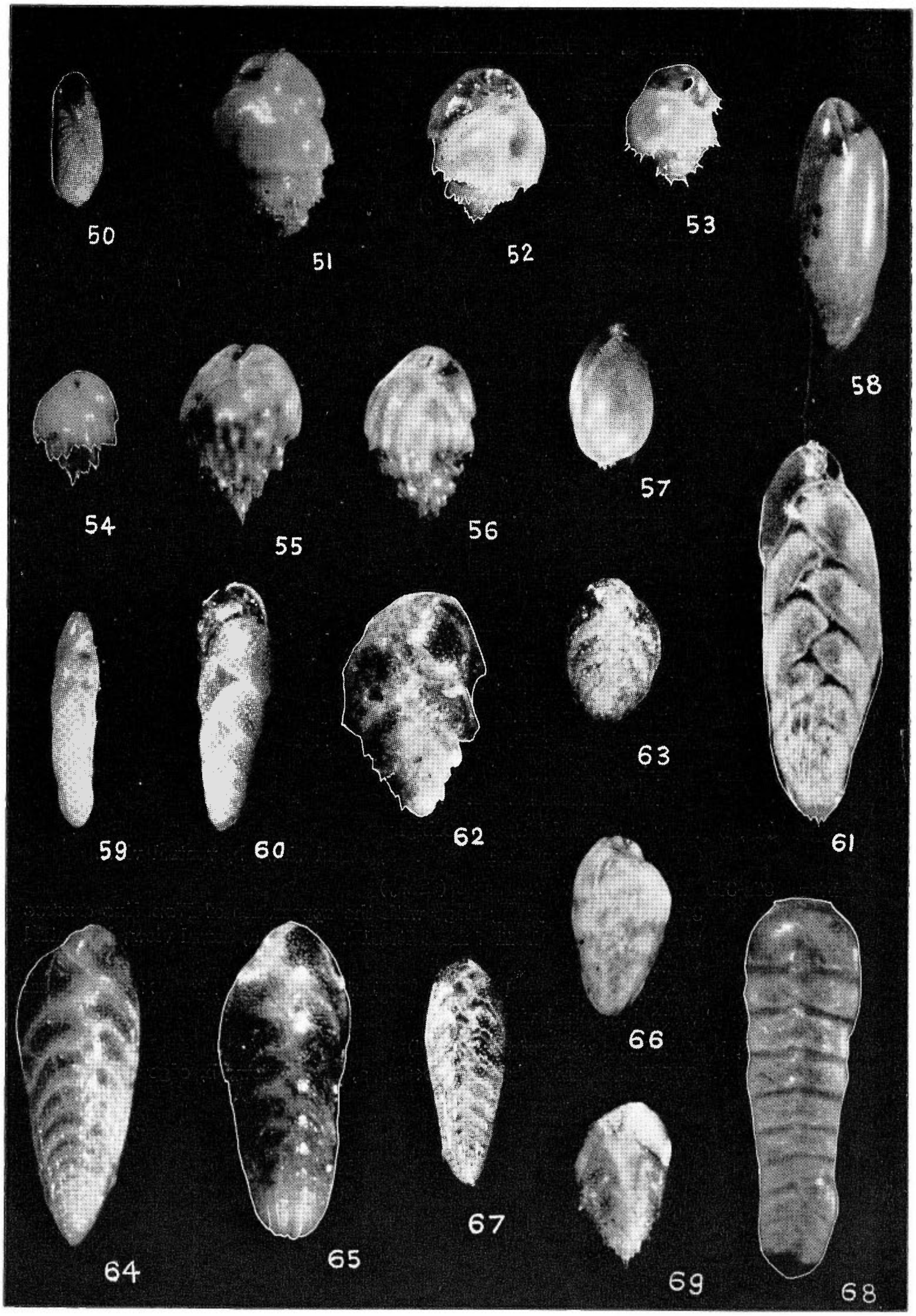
Figs. 64, 65 *Bolivina spissa* Cushman
64, microspheric form, GSJ F61211 from St. 27. ×60.
65, megalospheric form, GSJ F61210 from St. O. ×60.

Fig. 66 *Bolivina subangularis ogasaensis* Asano
GSJ F61246 from St. SO. ×30.

Fig. 67 *Bolivina substriatula* Asano
GSJ F61164 from St. S1B. ×60.

Fig. 68 *Rectobolivina bifrons* (Brady)
GSJ F61227 from St. S2. ×60.

Fig. 69 *Reussella aculeata* Cushman
GSJ F61263 from St. SOA. ×60.



BULIMINIDAE

Plate 5. BULIMINIDAE and ROTALIIDAE

Fig. 70 *Uvigerina akitaensis* Asano
GSJ F61212 from St. K8. ×60.

Fig. 71 *Uvigerina nitidula* Schwager
GSJ F61273 from St. S1B. ×30.

Figs. 72-75 *Uvigerina peregrina dirupta* Todd
from St. S2A.
72, GSJ F61174. ×60.
73, GSJ F61282. ×30.
74, GSJ F61283. ×30.
75, GSJ F61284. ×30.

Fig. 76 *Uvigerina peregrina shiwoensis* Asano
GSJ F61162 from St. S2A. ×42.

Fig. 77 *Uvigerina proboscidea* Schwager
GSJ F61251 from St. S3A. ×60.

Fig. 78 *Uvigerina proboscidea vadescens* Cushman
GSJ F61239 from St. S1B. ×60.

Fig. 79 *Uvigerina schencki* Asano
GSJ F61237 from St. S1B. ×60.

Fig. 80 *Uvigerina schwageri* Brady
GSJ F61272 from St. S1A. ×30.

Fig. 81 *Siphogenerina raphana* (Parker and Jones)
GSJ F61247 from St. SO. ×60.

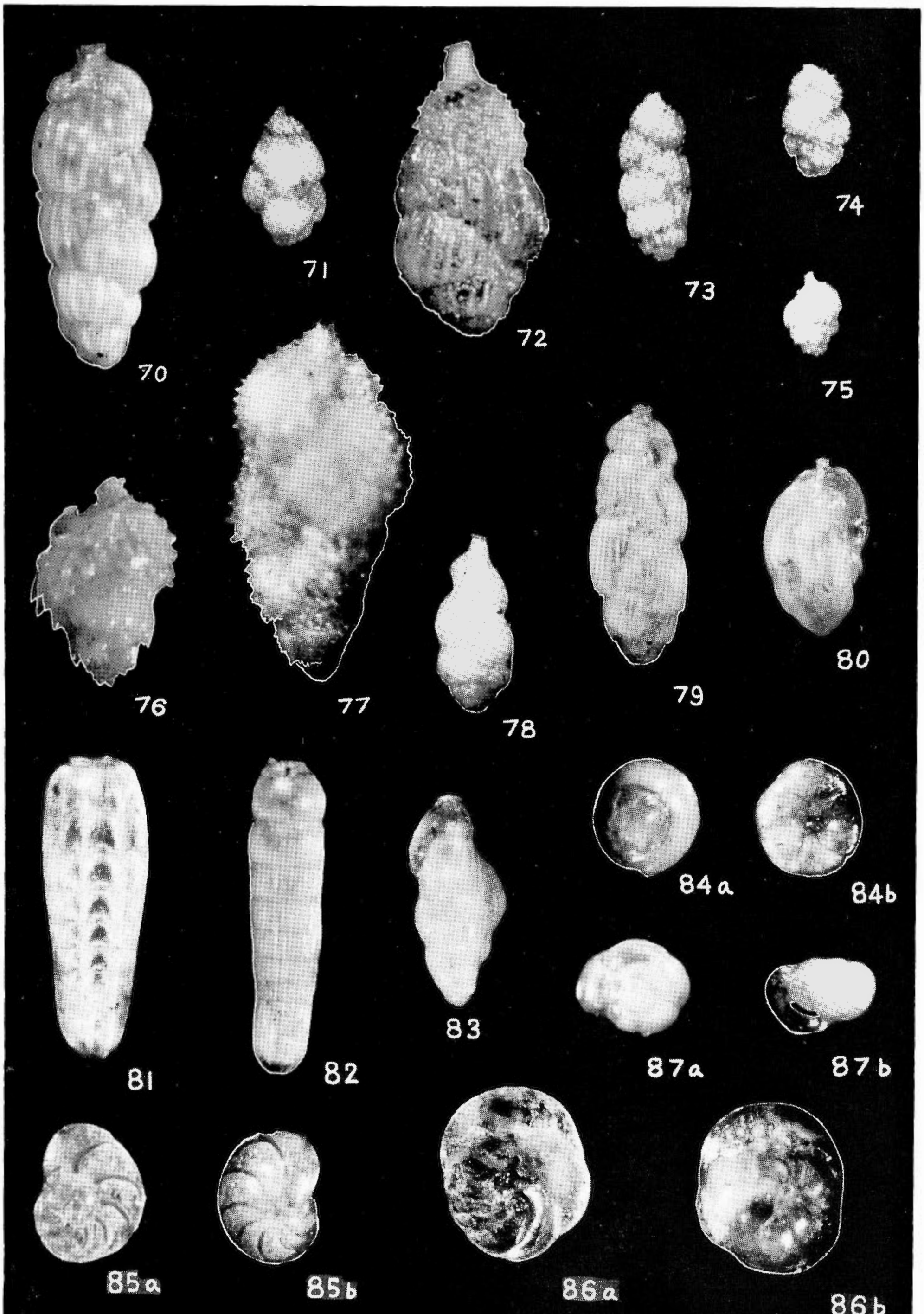
Fig. 82 *Siphogenerina columellaris costulata* n. subsp.
GSJ F61165 from St. S1B. Holotype. ×60.

Fig. 83 *Angulogerina kokozuraensis* Asano
GSJ F61204 from St. K8. ×60.

Figs. 84a, b *Rosalina vilardeboana* d' Orbigny
GSJ F61193 from St. 1. ×60. a, dorsal view; b, ventral view.

Figs. 85a-86b *Planodiscorbis rarescens* (Brady)
85a, b, showing young stage with the appearance of *Planulina convexa* Takayanagi, GSJ F61167 from St. S1B. ×60. a, dorsal view; b, ventral view.
86a, b, showing adult stage, GSJ F61166 from St. S1B. ×42. a, dorsal view; b, ventral view.

Figs. 87a, b *Gyroidina nipponica* (Ishizaki)
GSJ F61236 from St. S1B. ×60. a, dorsal view; b, edge view.



BULIMINIDAE and ROTALIIDAE

Plate 6. ROTALIIDAE

Figs. 88a, b *Gyroidina orbicularis* (d'Orbigny)
GSJ F61223 from St. S3. ×60. a, dorsal view; b, edge view.

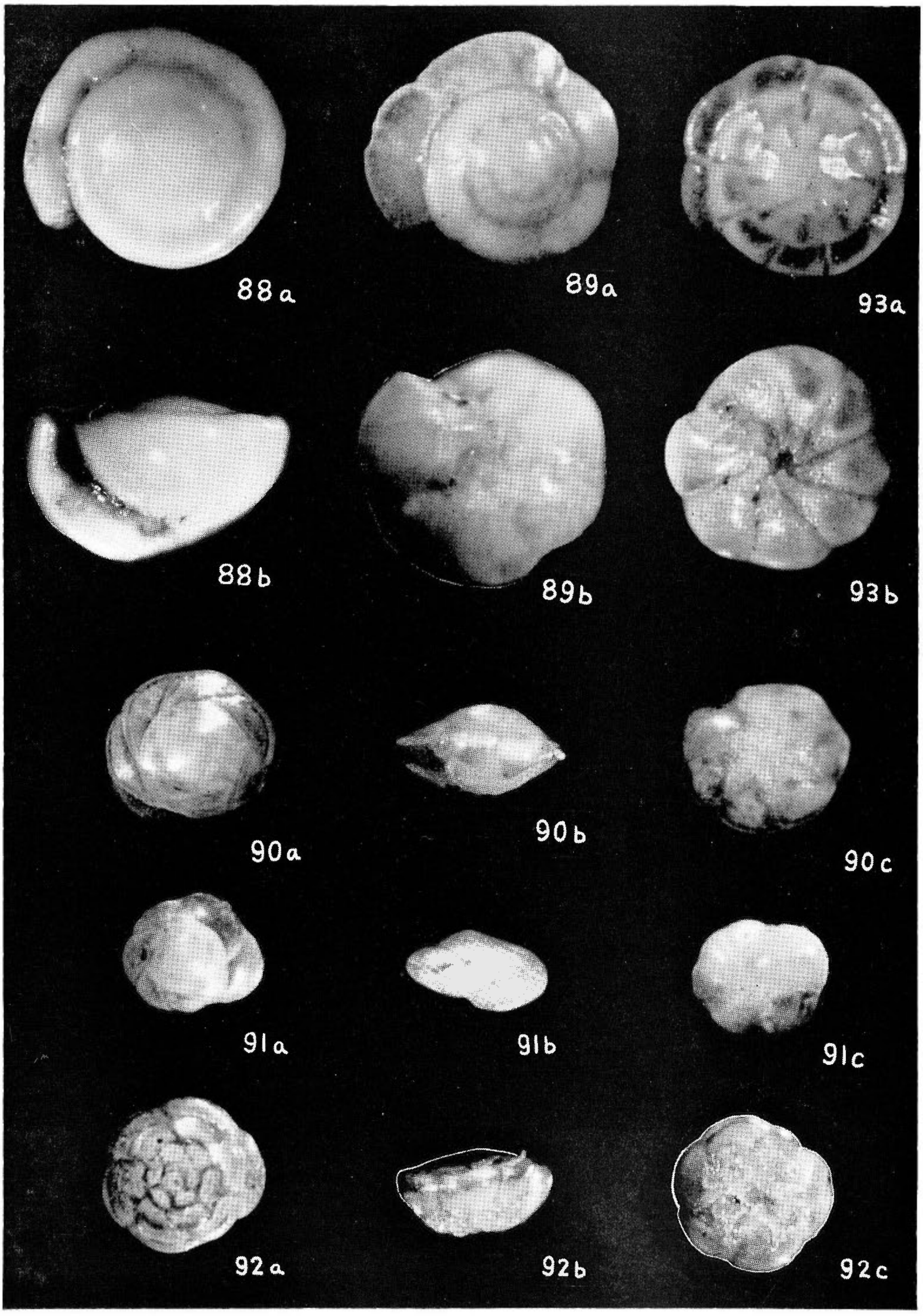
Figs. 89a, b *Eponides umbonatus* (Reuss)
GSJ F61222 from St. K. ×60. a, dorsal view; b, ventral view.

Figs. 90a-c *Buccella inusitata* Anderson
GSJ F61203 from St. K8. ×60. a, dorsal view; b, edge view; c, ventral view.

Figs. 91a-c *Buccella frigida* (Cushman)
GSJ F61178 from St. K4. ×42. a, dorsal view; b, edge view; c, ventral view.

Figs. 92a-c *Streblus ketienziensis angulatus* (Kuwano)
GSJ F61197 from St. D. ×60. a, dorsal view; b, edge view; c, ventral view.

Figs. 93a, b *Streblus takanabensis* Ishizaki
GSJ F61199 from St. J. ×60. a, dorsal view; b, ventral view.



ROTALIIDAE

Plate 7. CASSIDULINIDAE and CHILOSTOMELLIDAE

Figs. 94a-c *Epistominella naraensis* (Kuwano)
GSJ F61184 from St. K3. ×60. a, dorsal view; b, edge view; c, ventral view.

Fig. 95 *Cassidulina delicata* Cushman
GSJ F61160 from St. 13. ×60.

Fig. 96 *Cassidulina islandica* Nφrvang
GSJ F61183 from St. K7. ×60.

Fig. 97 *Cassidulina laevigata carinata* Cushman
GSJ F61233 from St. S1B. ×60.

Fig. 98 *Cassidulina subglobosa depressa* Asano and Nakamura
GSJ F61191 from St. B. ×60.

Fig. 99 *Cassidulina japonica* Asano and Nakamura
GSJ F61209 from St. 15. ×30.

Fig. 100 *Cassidulina setanaensis* Asano and Nakamura
GSJ F61185 from St. E1. ×30.

Fig. 101 *Cassidulina norcrossi* Cushman
GSJ F61217 from St. O. ×60.

Fig. 102 *Cassidulina translucens* Cushman and Hughes
GSJ F61216 from St. B. ×30.

Figs. 103, 104 *Cassidulina yabei* Asano and Nakamura
103, GSJ F61265 from St. 13. ×60.
104, GSJ F61188 from St. K7. ×60.

Fig. 105 *Cassidulina wakasaensis* Asano and Nakamura
GSJ F61161 from St. E1. ×30.
(immersed in glycerin)

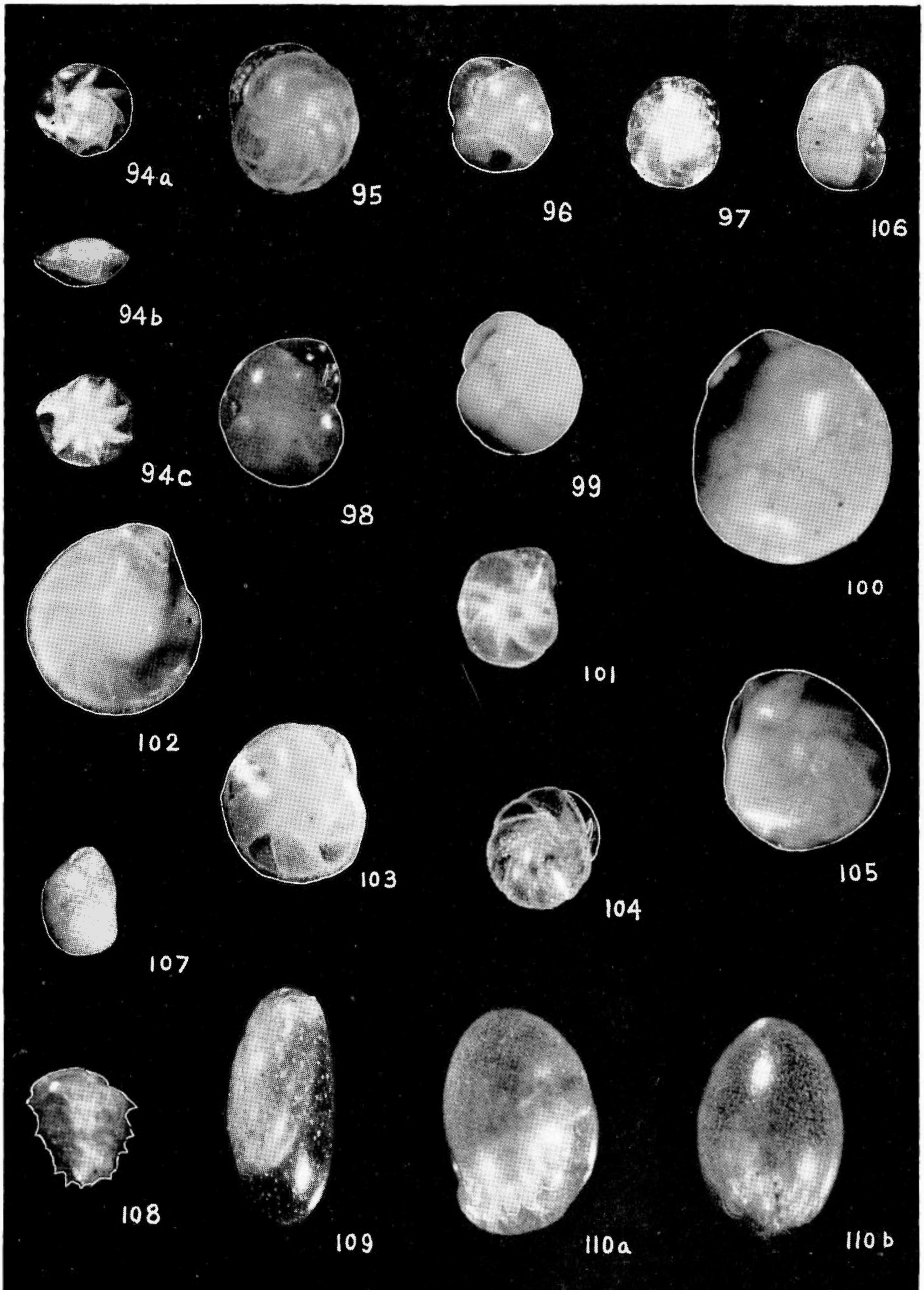
Fig. 106 *Cassidulina* sp.
GSJ F61173 from St. S1B. ×60.

Fig. 107 *Cassidulinoides bradyi* (Norman)
GSJ F61234 from St. S1B. ×60.

Fig. 108 *Ehrenbergina pacifica* Cushman
GSJ F61228 from St. S2. ×42.

Fig. 109 *Chilostomella colina* Schwager
GSJ F61219 from St. 2. ×60.

Figs. 110a, b *Chilostomellina fimbriata* Cushman
GSJ F61214 from St. O. ×60. a, side view; b, edge view.



CASSIDULINIDAE and CHILOSTOMELLIDAE

Plate 8. ANOMALINIDAE

Fig. 111 *Anomalina balthica* (Schroeter)
GSJ F61225 from St. S2A. ×60.

Figs. 112a, b *Planulina wuellerstorfi* (Schwager)
GSJ F61253 from St. S1B. ×60. a, dorsal view; b, ventral view.

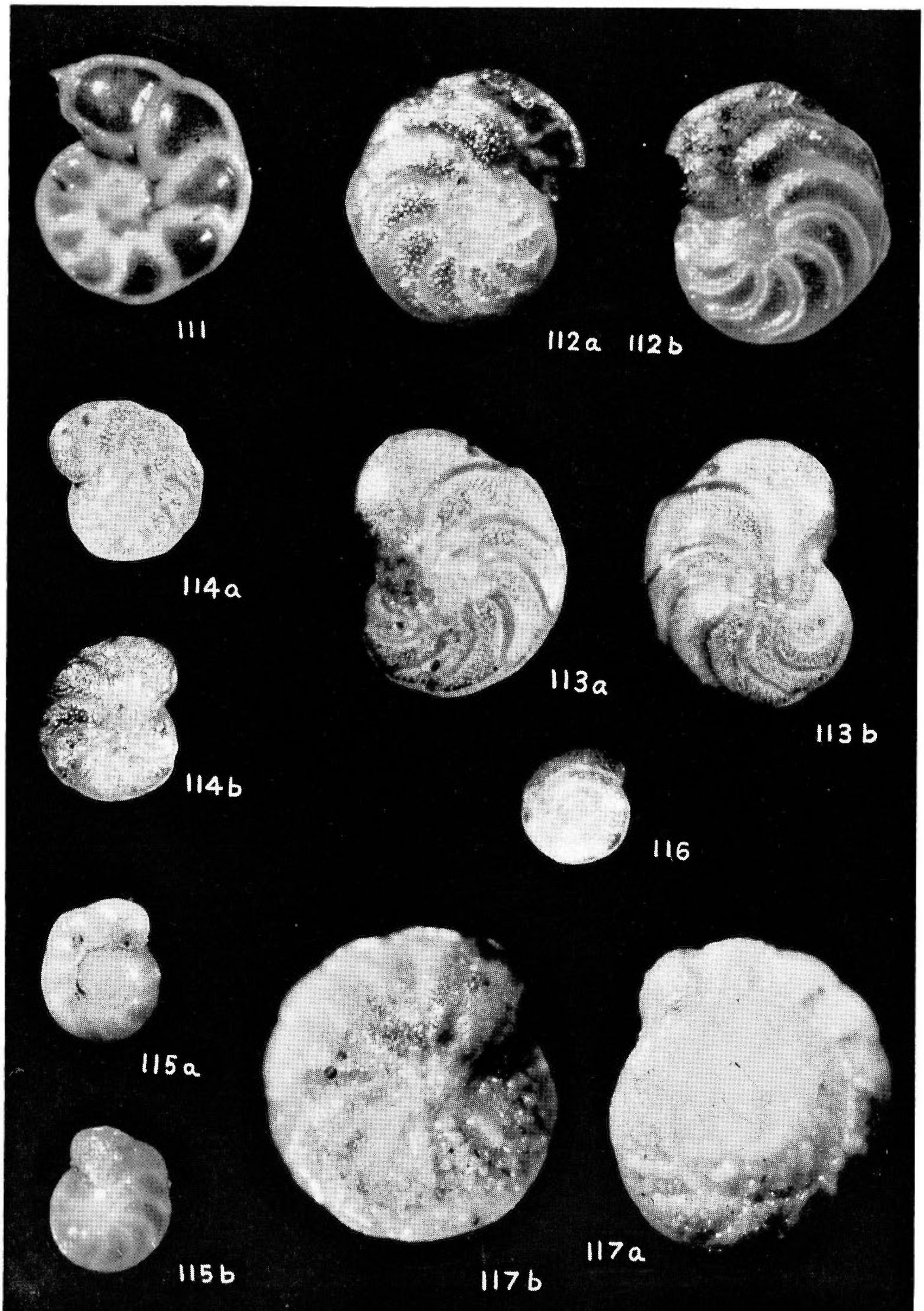
Figs. 113a, b *Hanzawaia nipponica* Asano
GSJ F61248 from St. SO. ×60. a, dorsal view; b, ventral view.

Figs. 114a, b *Cibicides aknerianus* (d'Orbigny)
GSJ F61230 from St. S1B. ×30. a, dorsal view; b, ventral view.

Figs. 115a, b *Cibicides pseudoungerianus* (Cushman)
GSJ F61229 from St. S2. ×30. a, dorsal view; b, ventral view.

Fig. 116 *Cibicides robertsonianus* (Brady)
GSJ F61264 from St. S2. ×60. Dorsal view.

Figs. 117a, b *Cibicides margaritiferus* (Cushman)
GSJ F61231 from St. S1A. ×30. a, dorsal view; b, ventral view.



ANOMALINIDAE

地質調査所報告は1報文について報告1冊を原則とし，その分類の便宜のために，次のようにアルファベットによる略号を付ける。

A. 地質およびその基礎科学に関するもの
- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B. 応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C. そ の 他

D. 事業報告

As a general rule, each issue of the Report, Geological Survey of Japan will have one number, and for convenience's sake, the following classification according to the field of interest will be indicated on each Report.

A. Geology & allied sciences
- a. Geology
- b. Petrology and Mineralogy
- c. Paleontology
- d. Volcanology and Hot spring
- e. Geophysics
- f. Geochemistry

B. Applied geology
- a. Ore deposits
- b. Coal
- c. Petroleum and Natural gas
- d. Underground water
- e. Agricultural geology, Engineering geology
- f. Physical prospecting, Chemical prospecting & Boring

C. Miscellaneous

D. Annual Report of Progress

地質調査所報告

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第 201 号

Seya, K.: On the new method of analysis in gravity prospecting, 1963

第 202 号

宮本弘道： 地質調査所化学分析成果表 III（鉱石，1946～1962），1963

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第 204 号

Mizuno, A.: Paleogene and early Neogene molluscan faunae in West Japan, 1963 (in English)

REPORT, GEOLOGICAL SURVEY OF JAPAN

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Miyamoto, H.: Table of chemical analyses by Geological Survey of Japan III (Ores, 1946～1962), 1963 (in Japanese)

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Tanemura, M.: Geological and mineralogical studies of clay and silica sand deposits in Seto district, Aichi prefecture, 1963 (in Japanese with English abstract)

No. 204

Mizuno, A.: Paleogene and early Neogene molluscan faunae in West Japan, 1963 (in English)

Ishiwada, Y.

Benthonic Foraminifera off the Pacific Coast of Japan referred to Biostratigraphy of the Kazusa Group

Yasufumi Ishiwada

Report, Geological Survey of Japan, No. 205, p. 1～45, 1964
19 illus., 8 pl., 6 tab.

Thirty-eight samples of bottom sediments from off the Pacific coast of Japan were studied for foraminiferal ecology. Three areas, representing the subarctic (off SE Hokkaido), the mixed (off NE Honshu), and the subtropical (Tosa Bay) water areas, were selected for this study. It is possible to recognize five major groups of facies, (1) subtropical neritic (Kuroshio region), (2) subtropical-subarctic neritic (mixed Kuroshio region), (3) subarctic neritic (Oyashio region), (4) subarctic bathyal (subarctic intermediate water region), and (5) deep water facies. The results can contribute to facies interpretation and correlation for the Pliocene Kazusa group of the South Kwanto region.

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