

Foraminifera of the Himi Group, Hokuriku Province, Central Japan

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ABSTRACT

The Himi Group, of which flora and fauna have been subjected to intensive studies for many years, has been analyzed for sedimentological and microfossil contents. The Himi Group was not clearly defined by previous workers and many discrepancies were present in its definition. A detailed study of fauna and lithofacies, particularly study of tephra, has made it possible to redefine this group. Thus, the Himi Group is here redescribed to include a unit (the Inazumi Formation) which has so far been excluded from this group. Many geological sections from widely separated areas were studied and a biostratigraphic succession of the Himi Group is established on the basis of stratigraphic distribution of planktonic foraminifera and calcareous nannoplankton. The Pliocene/Pleistocene boundary in Hokuriku Province is also indicated.

Beside these, Recent foraminifera from the bottom sediments of Toyama Bay are also studied. The fauna comprises four depth assemblages. These assemblages may be useful in estimating probable depth of deposition for areas having a similar faunal content.

Statistical analyses of benthonic fauna of the Himi Group were made by utilizing cluster and factor analyses, and from these analyses the fauna is classified into six assemblages. The sedimentological analysis together with the faunal analysis was used to reconstruct the character of paleo-water masses.

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INTRODUCTION

Late Cenozoic marine sediments are well exposed in Japan along the Sea of Japan coast of Honshu and Hokkaido and have been subjected to intensive paleontological studies. Foraminifera of these formations have received a good attention especially in oil-producing area but main studies made are only on benthonic species (Yabe and Hanzawa, 1923; Asano, 1936, 1937, 1938, 1939a, b, *etc.*; Oinomikado, 1939, 1940, 1941; Matsunaga, 1963; and others).

Iwasa (1955) recorded *Globorotalia inflata* (d'Orbigny) from the base of the Wakimoto Formation of the Oga Peninsula, Akita Prefecture, and suggested its significance for correlating strata of different areas. Thereafter, many contributions on planktonic foraminifera were published by various workers (Saito, 1963; Takayanagi and Oba, 1966; Shinbo and Maiya, 1971; Maiya, 1975; and Kitazato, 1975). These papers were mainly concerned with biostratigraphy and stratigraphic correlation. Takayanagi and Oba (*op. cit.*) studied the planktonic assemblage on the Sea of Japan side of Japan. They also made a comparative study of fossil and Recent benthonic foraminiferal faunas and suggested a paleocurrent pattern of the Sea of Japan. Later investigators of fossil planktonic foraminifera, however, did not carry out any paleoceanographic study except Asano *et al.* (1969). In recent years, on the basis of bottom core samples from the Sea of Japan, such paleoceanographic contributions as those by Ujiié and Ichikura (1973, 1977), Ujiié (1975, 1977) and Ingle (1975) have appeared.

With the advent of magnetostratigraphic survey, biostratigraphic study of planktonic foraminifera and other microfossils has gained its impetus and, as a result, a more precise correlation of rocks of various areas has become possible. Furthermore, detailed paleoecological analysis of benthonic foraminifera has been done at a close stratigraphic interval (Niitsuma, 1971b; Kitazato, 1977).

On the other hand, study of Recent benthonic fauna from the Sea of Japan began to receive researchers' attention since the work of Asano (1939c) on the Urashima Bank of Wakasa Bay, and, in recent years more and more workers were attracted to this study (Ishiwada, 1959; Asano, 1956-60; Matsuda, 1957; Chiji and Konda, 1970; Matoba and Nakagawa, 1972; Matoba, 1976). Hence, it is now possible to compare both fossil planktonic and benthonic faunas with their Recent counterparts and to reconstruct paleoceanographic conditions.

The Himi Group, which is the subject-matter of this work, comprises the Omma Formation and its correlatives (Zukawa Formation, Yabuta Formation and others) in Hokuriku Province, Central Honshu. This group is of Late Cenozoic age and represents

the youngest marine deposits in this province except for marine terrace deposits. These formations have yielded well-preserved and abundant molluscan fossils which are generally referred to as the "Omma-Manganzi (=Manganji) fauna" (Otuka, 1939).

The present study has attempted to describe vertical and horizontal variations in the lithofacies of the Himi Group with the help of tephra. Furthermore, a detailed analysis of foraminifera has been done and on the basis of vertical distribution of planktonic foraminifera and calcareous nannoplankton, age of the Himi Group is established. From the vertical and horizontal changes of the species of both benthonic and planktonic foraminifera combined with the grain-size analysis, paleoenvironmental changes (changes of water depth and character of water mass) have been suggested.

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HISTORICAL REVIEW

A great deal of works have been done on the stratigraphy of Late Cenozoic rocks of Hokuriku Province. The Omma and Yabuta formations, which were first defined by Motizuki (1928 and 1930, respectively), constitute the uppermost subdivision of the Late Cenozoic rocks and their molluscan fauna have been studied for many years. Motizuki studied Neogene strata in the southern part of the Noto Peninsula in 1928 and these in Ishikawa and Toyama prefectures in 1930. Later, Onoyama (1933a, b) and Otuka (1935) made a detailed study including the analysis of molluscan fauna.

After the Second World War, members of Kyoto University surveyed these areas and published many reports (Ikebe, 1949; Ichihara *et al.*, 1950; Ikebe *et al.*, 1951). Later, a survey for 1/50,000 geological map was done by Imai (1959) in Kanazawa, by Sakamoto (1963) in Toyama, by Inoue *et al.* (1964) in Johana and by Imai *et al.* (1966) in the Ochigata and Abugashima districts. Detailed geological maps of the Nadaura district (Kaseno *et al.*, 1957), around Kanazawa City (Bessho *et al.*, 1967) and the area from Kanazawa and Oyabe

(Ogasawara, 1977) have also been prepared. The study by Ogasawara (*op. cit.*) included analysis of molluscan fauna.

In comparison with molluscs, foraminifera received a little attention. A study of foraminifera was first made by Cushman and Ozawa (1929) covering the Kanazawa area and they described many species belonging to the family Polymorphinidae from the Omma Formation. Asano (1939a), who studied foraminiferal assemblages of the Omma Formation and other "Pliocene" formations, suggested that these assemblages comprise a mixed element both of the Japan Sea type and the Pacific type.

After the Second World War, microbiostratigraphical studies were advanced with a new momentum. Morishima *et al.* (1948) classified Tertiary strata of the Nadaura district into six zones, and assigned rocks of the Yabuta Formation to the *Polystomellina discorbinoides* Zone. Nagahama (1952), on the other hand, assigned rocks of the Yabuta Formation of Himi area to the *Elphidium-Cassidulina* Zone.

Chiji, who studied a foraminiferal biostratigraphy of the Nadaura and Ao districts (Chiji, 1960), established biostratigraphic zones applicable to the entire Toyama sedimentary basin in 1961. He assigned rocks of the Himi Group in the Ao River (Himi area), Asano River (Kanazawa area), Hitou-Sunagozaka (Nishitonami-southern Oyabe) and Yamada River (Higashitonami) areas to the *Elphidium bartletti* Zonule, *Rotalia papillosa* Zonule, *Elphidium clavatum* Zonule and *Elphidium crispum* Zonule, respectively. The Himi Group, as a whole, was assigned to the *Elphidium-Cassidulina* Zone. This zone, according to Chiji (1961), is characterized by the presence of *Elphidium bartletti* Cushman, *Elphidium clavatum* Cushman, *Buccella frigida* (Cushman), *Cassidulina kashiwazakiensis* Husezima and Maruhasi, *Cassidulina subglobosa* Brady and *Cassidulina subglobosa depressa* Asano.

Recently, Maiya and his collaborators (Maiya, 1975; Maiya *et al.*, 1976) established a biostratigraphical zonation for the oil-fields of the northeastern Japan.

THE HIMI GROUP

1. STRATIGRAPHY OF THE HIMI AND NADAURA AREAS

Late Cenozoic sequences developed in the Himi and Nadaura areas are regarded by the present writer one of the standard of reference section for stratigraphic correlation within Hokuriku Province (Hasegawa, 1975MS). The stratigraphic sequence below the terrace deposits in these areas is divided into ten formations (Fig. 1), viz., the Kumabuchi Formation, Taniguchi Formation, Nakanami Formation, Mio Formation, Kuzuba Formation, Sugata Formation, Inazumi Formation, Yabuta Formation, Junicho Formation and Hanyu Formation, in upward sequence (Hasegawa, *op. cit.*). The following lines provide a brief description of the stratigraphy of each unit:

a. The Kumabuchi Formation

The type locality of this formation is located at Kumabuchi, Nanao City. This formation consists of green-colored pyroxene andesite tuff breccia. It is about 25 m thick and has a limited distribution.

b. The Taniguchi Formation

This formation was defined by Ikebe (1949). The type locality is located at Taniguchi, Himi City. The Taniguchi Formation consists of conglomerates and an alternation of arkosic sandstones and micaceous mudstones and attains a maximum thickness of about 320 m. It yields larger foraminifera (*Miogypsina kotoi* Hanzawa and *Operculina complanata japonica* Hanzawa) and marine molluscs from the uppermost part (Nakaseko, 1952; Kaseno *et al.*, 1957; Kanamori, 1973MS, Hasegawa, 1975MS).

AGE	FORMATION	THICKNESS	COLUMN	LITHOLOGY	FOSSILS	VOLC. ACT.
PLIOCENE/PLEISTOCENE	Kubo Formation	20m-		gravel, sand, silt		
	Kamidako Formation	60m±		gravel, sand, silt, clay	plant	
	Hanyu Formation	35m+		alternation of fine sand & sandy silt, clay, gravel	mollusca	
Pliocene	Junicho ? Formation	185 m		calcareous coarse sandstone, silty sandstone tuff, conglomerate	mollusca, foraminifera, radiolaria, nannoplankton & diatom	
	Yabuta Formation	145 m+		calcareous sandy siltstone, massive siltstone, glauconite	mollusca, foraminifera, radiolaria, nannoplankton & diatom	
	Inazumi Formation	260 -0m		glauconite with gravel	mollusca, foraminifera, radiolaria & diatom	
	Sugata Formation	460 -160 m		diatomaceous mudstone	mollusca, radiolaria & diatom	
middle	Ogume Sandstone Member	120 -0m		massive mudstone, pumiceous tuff, massive sandstone	foraminifera	
	Kuzuba Formation	680 -0m		alternation of sandstone & siltstone tuff, tuffaceous green sandstone	mollusca, foraminifera, radiolaria & nannoplankton	
	Mio Formation	310 -0m		very fine sandstone, alternation of sandstone & siltstone	mollusca, echinoid & foraminifera	
early	Nakanami Formation	230 -0m		thin alternation of white fine tuff & tuffaceous siltstone	echinoid, foraminifera, diatom & nannoplankton	
	Taniguchi Formation	320 -30m		hard mudstone	plant, mollusca, foraminifera & nannoplankton	
	Kunimi Mudstone Member	105 -0m		fine tuff		
	Takabatake Conglomerate Member	165 -0m		alternation of sandstone & siltstone, lignite		
	Kumabuchi Formation	25m±		sandstone with breccia, fine tuff, micaceous siltstone, conglomerate		
	Basement Rocks			biotite granite, adamerite		

Fig. 1. Schematic geologic strata of the Himi and Nadaura areas.

c. The Nakanami Formation

This formation was introduced by Watanabe (1932) and Otuka (1935), and described in detail by Kaseno *et al.* (*op. cit.*). The type locality is located at Nakanami, Himi City. This formation conformably overlies the Taniguchi Formation and consists of gray or dark greenish-gray hard mudstones and tuffs. The Nakanami Formation attains a maximum thickness of about 230 m, and yields abundant foraminifera and calcareous nannoplanktons, and occasionally echinoids and molluscs.

d. The Mio Formation

This formation was first defined by Ikebe (*op. cit.*). The type locality is located at Mio, Himi City. Downward and northeastward the Mio Formation gradually merges into the Nakanami Formation. This formation consists of very fine to medium-grained sandstones. The formation attains a maximum thickness of about 370 m, and yields molluscs and foraminifera.

e. The Kuzuba Formation

The name, Kuzuba Formation was first used by Kaseno *et al.* (1961) and described in detail by Imai *et al.* (1966). The type locality is situated at Kuzuba, Himi City. This formation conformably overlies the Nakanami Formation or the Mio Formation and consists of a thick alternation of partially laminated sandstones and siltstones. It attains about 680 m in maximum thickness and contains a few molluscan fossils.

f. The Sugata Formation

This formation was erected by Ikebe (*op. cit.*), the type locality being chosen at Sugata, Himi City. The formation consists of massive, gray or greenish-gray mudstones and attains a maximum thickness of about 460 m. It conformably overlies the Nakanami Formation and has an interfingering relationship with the Kuzuba Formation. Abundant foraminifera, calcareous nannoplanktons (only in lower part), Radiolaria and diatoms are reported from this formation.

g. The Inazumi Formation

This formation was first defined by Ikebe (*op. cit.*). The type locality is located at Inazumi, Himi City. It is exposed uninterruptedly from the west of Unami through Inazumi to the west of Junicho, Himi City. This formation unconformably overlies the Sugata Formation or the Kuzuba Formation. It consists of massive, dark greenish-gray mudstones and tuffs and attains a maximum thickness of about 260 m. The basal part of this formation consists of glauconitic sandstone and/or granule conglomerate. The Inazumi Formation yields abundant siliceous microfossils such as diatoms and Radiolaria.

h. The Yabuta Formation

This formation was defined by Makiyama (1930). Yabuta, Himi City is its type locality. The formation consists mainly of massive, pale greenish-gray sandy siltstones, occasionally containing lenses of laminated, fine-grained sandstone and lenticular or irregular silty nodules which are arranged parallel to the bedding plane. This formation attains a maximum thickness of 145 m, and yields very abundant marine fossils such as foraminifera, calcareous nannoplanktons, Radiolaria, diatoms, molluscs and so on.

In the northern Nadaura, the Yabuta Formation unconformably overlies the Sugata Formation with about half a meter thick glauconite-sandstone in the basal part. In the southern part, this formation conformably overlies the Inazumi Formation.

This formation is distributed over the Nadaura Coast from the north of Ozakai to the north of Ao, Himi City. The Yabuta Formation near Ozakai contains six distinct layers of fine-grained tuffs named Y1 to Y6 in upward sequence. The description of each key tuff as observed at their type section is given in Table 1. Since the lowest tuff (Y1) occurs also in the uppermost part of the Inazumi Formation in the area north of Ao, the Yabuta Formation is considered to be a partially contemporaneous, heterotopic facies of the Inazumi Formation.

i. The Junicho Formation

This formation was first described by Hasegawa (1975MS). It corresponds to the Himi Formation of Otuka (1935) and both the Yabuta Formation (part) and "Natsukawa" beds of Ikebe (*op. cit.*). Junicho in Himi City is the type locality of this formation.

The Junicho Formation consists mainly of sandy siltstones and calcareous, medium-grained sandstones and has a thickness of 185 m. The upper part consists of siltstones with thin layers of fine-grained sandstones. The basal part is formed of a 50-centimeter-thick conglomerate and unconformably overlies the Inazumi Formation.

The Junicho Formation, like the Yabuta Formation, yields very abundant calcareous and siliceous microfossils, and a variety of molluscs. These molluscan fossils from the Junicho Formation belong to the "Omma-Manganzi Fauna" and are typified by such species as: *Acila (Truncacila) insignis* (Gould), *A. (T.) nakazimai* Otuka, *Chlamys (C.) cosibensis* (Yokoyama), *Mizuhopecten tokyoensis hokurikuensis* (Akiyama), *M. yessoensis yokoyamae* (Masuda), *Venericardia (Megacardita) ferruginosa* (Adams and Reeve), *Panope japonica* A. Adams and *Turritella (Neohaustator) saishuensis motidukii* Otuka.

Table 1. Description of key tephra beds of the Himi Group at their type sections.

Abbreviation		
Sd: sand	lam: laminated	w: white
Slt: silt	alt: alternation	bu: blue
Tf: tuff	calc: calcareous	pp: purple
sdv: sandy	c: coarse-grained	pk: pink
sty: silty	m: medium-grained	gy: gray
tf: tuffaceous	f: fine-grained	bl: black
pum: pumiceous	vf: very fine-grained	br: brown (thickness in cm)

Y1: Road-side cliff, 560 m NNW of Ozakai, Himi.
(Slt)/sdv Slt/bu gy vf Tf (65)/tf f Sd (2)/(Slt); 12 m above basal glauconite-sandstone.

Y2: Road-side cliff, 550 m NNW of Ozakai, Himi.
(Slt)/tf Slt (5)/gy w f Tf (5-2)/(Slt); 3 m above Y1 Tuff

Y3: Road-side cliff, 380 m NW of Ozakai, Himi.
(Slt)/w f Tf (10)/tf f Sd (1-0)/(Slt)/tf sdv Slt (2)/tf m Sd (5)/(Slt); 11 m above Y2 Tuff.

Y4: Road-side cliff, 280 m NW of Ozakai, Himi.
(Slt)/br sty Tf (20)/(Slt); 20 m above Y3 Tuff.

Y5: Road-side cliff, 10 m S of Nadaura Senior High School, Himi.
(Slt)/br w f sdv Tf (10)/(Slt); 29 m above Y4 Tuff.

Y6: Road-side cliff, 230 m SW of Kozakai, Himi.
(Slt)/gy sty Tf (25)/pp gy vf Tf (6)/gy f Tf (2)/w tf m Sd(1-0)/(Slt); 20 m above Y5 Tuff

J1: Road-side cliff, 20 m SW of Ariso Senior High School, Himi.
(Slt)/bu gy sty Tf (10)/bu gy vf Tf (12)/w gy f Tf (6)/c Tf (6-4)/(Slt);
4 m above base of the Junicho Formation; the same (?) to Y6 Tuff.

J2: Outcrop, 30 m N of Okizaki, Himi.
(calc f Sd)/pp gy vf Tf (10)/pp f pum Tf (2-0)/(calc f Sd); 47 m above J1 Tuff.
River-side cliff of Shizukudani, 980 m W of Zukawa, Takaoka.
(f Sd)/gy vf Tf (15)/pp m pum Tf (60-20)/(calc m Sd); 23 m above base of the Zukawa Formation.

Road-side cliff, 170 m NNW of Tagawa, Oyabe.
(f Sd)/pp f Tf (120)/gy m pum Tf (50)/tf Slt (3)/(Slt); 44 m above base of the Zukawa Formation.

J3: Road-side cliff, 70 m NW of Yazaki, Himi.
(f Sd)/pk gy vf Tf (15)/(f Sd); 19 m above J2 Tuff.

J4: Road-side cliff, beside northern entrance of Himi Nanbu Junior High School, Himi.
(sty Sd)/sty Tf (50)/gy f Tf (25)/w vf Tf (2)/gy f Tf (2)/gy vf Tf (8)/(Slt);
8 m above J3 Tuff.

O1: River-side cliff along the Fushimi River, 570 m ESE of Yamashina, Kanazawa.
(f Sd)/tf Slt (2)/pk vf Tf (45)/br gy f Tf (5)/(f Sd); 6 m above base of the Omma Formation.
Road-side cliff, 200 m NNW of Tagawa, Oyabe.
(tf Slt)/sty Tf (50)/lam w vf Tf (250)/sty Tf (200)/ c pum Tf (900)/tf f Sd-f Sd (450)/(Slt);
34 m above J2 Tuff.
Road-side cliff, 800 m SW of Hitou, Oyabe.
(Slt)/gy sty Tf (10)/gy bl tf Sd (1)/gy w vf Tf (8)/gy f Tf (13)/bl w f Tf (10)/pk c Tf (2)/
(sty Sd); 62 m above base of the Omma Formation.

O2: River-side cliff along the Fushimi River, 490 m ESE of Yamashina, Kanazawa.
(f Sd)/sty vf Tf (10)/parallel lam f Tf (8)/gy br f Tf (10)/pum f Tf-lam sdv Tf (5)/(f Sd);
20 m above O1 Tuff.

O3: River-side cliff along the Fushimi River, 460 m ESE of Yamashina, Kanazawa.
(f Sd)/sty Tf (5)/w f Tf (15)/f sdv Tf (2-0)/ (f Sd); 10 m above O2 Tuff.

O4: River bed of the Sai River, 450 m SSE of Okuwa Bridge, Okuwa, Kanazawa.
(f Sd)/pum c sdv Tf (40)/pum sty Tf-pum m sdv Tf (50)/ bu gy sty Tf (40)/alt of pum c sdv
Tf & sty Tf (30)/pum sty c Sd (15)/vc tf Sd (15)/c Sd-f Sd-lam tf Slt-massive Slt (20+);
120 m above O3 Tuff.

This formation is distributed in Asahiyama, Junicho, and north of Kawada, Himi City. At Asahiyama, it contains four tephra layers named J1 to J4 in upward sequence. The lowest tephra, J1, is very similar in lithological characters to the Y6 Tuff of the Yabuta Formation. Continuity of these two tuff beds can not be traced in the field as they are separated by an area covered by alluvial deposits, but possibly they are the same bed.

j. The Hanyu Formation

Ikebe (1949) first recognized and defined this formation, choosing its type locality at Hanyu, Oyabe City. Sakamoto (1963) applied the name Hanyu Formation to the uppermost part of the rock formations of the Himi area.

This formation consists of an alternation of sandy silts and fine-grained sands and contains carbonaceous fragments. It attains a maximum thickness of 35 m and unconformably overlies the Junicho Formation.

2. THE HIMI GROUP, ITS DISTRIBUTION AND CHARACTERS

As mentioned above, the Yabuta Formation at Nadaura and the Junicho Formation at Himi yield many molluscan fossils which belong to the "Omnia-Manganzi Fauna". These two formations have been correlated with the Omnia Formation at Kanazawa by various workers. Ikebe (*op. cit.*) called these and the other correlative formations as the "Himi Group" and designated Asahiyama, Himi City as the type locality of this group (Fig. 2). He mentioned that the Himi Group unconformably overlies the Ao Formation of the Yokawa Group in the Himi area. Furthermore, according to him, the Omnia Formation (the Himi Group) is conformable with the underlying Takakubo Formation of the Yokawa Group in the Kanazawa area.

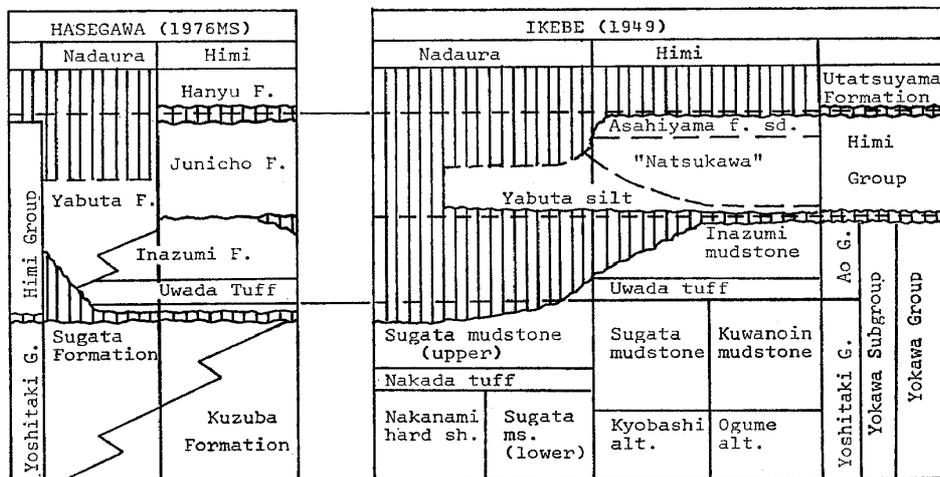


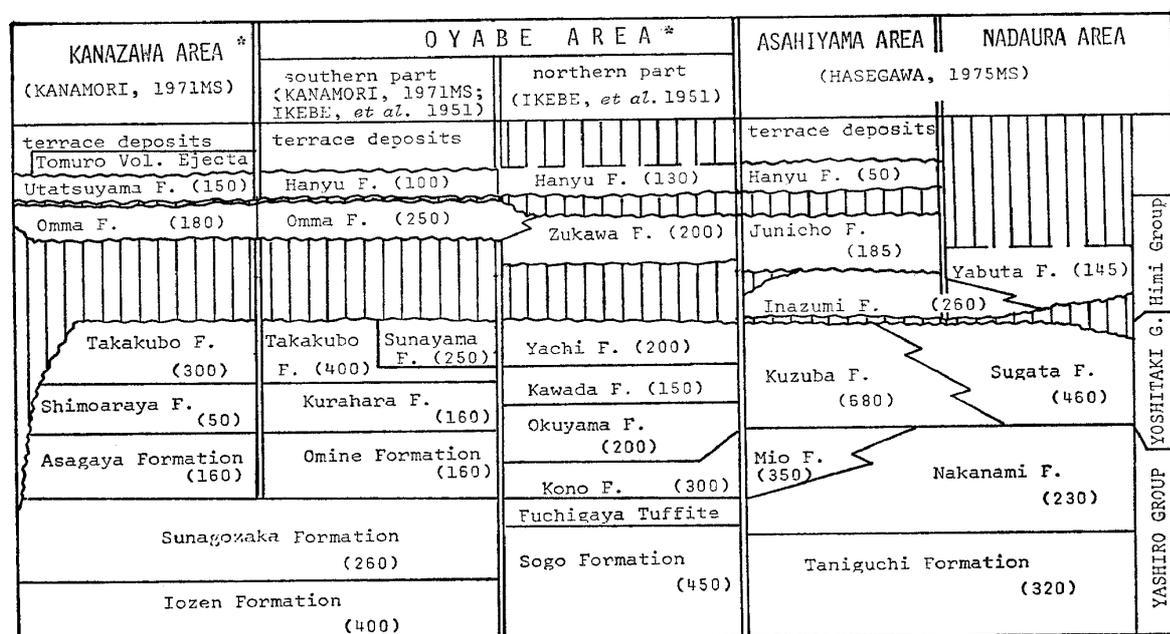
Fig. 2. Comparison of stratigraphic scheme of Ikebe (1949) with that of the present author concerning the Himi Group distributed in the Himi and Nadaura areas.

Although the Yabuta Formation is not precisely correlated with the Junicho Formation on the basis of microbiostratigraphical study, the writer is of the opinion that both of these formations belong to one group (the Himi Group) because of similarity of their lithofacies and foraminiferal assemblage (Fig. 1). The Inazumi Formation is also assigned to the Himi Group, because the former is conformably overlain by the Yabuta Formation

and both are partially contemporaneous, heterotopic facies. Furthermore, the Inazumi Formation unconformably overlies the Sugata Formation (Hasegawa, 1975MS, Fig. 2).

In the usage adopted by the present writer, the Himi Group comprises the following stratigraphic units: The Inazumi Formation, Yabuta Formation, Junicho Formation, Zukawa Formation, Omma Formation, Sakiyama Formation of Kanamori (1973MS), the Nakagawa Sandstone Member and the Suginoya Siltstone Member of the 'Himi Formation' of Imai *et al.* (1966) and the Mita Sandstone Member of the "Himi Formation" of Nakaseko (1954).

The geographic distribution of the Yabuta, Junicho, Zukawa and Omma formations and columnar sections of these formations studied are shown in Figs. 4 and 5. Furthermore, the stratigraphic relationship of these formations established by means of tephra is shown in Fig. 3. In preparing the geological map (Fig. 4), maps of the Sakiyama Peninsula (Kanamori, 1973MS) and of the northern part of the Tsubata area (Kaseno, 1977) have been consulted. The following lines deal briefly with the lithostratigraphy and distribution of the Zukawa and Omma formations of the Himi Group.



* partially rearranged by the author, especially in the upper part.
(50) maximum thickness in meter.

Fig. 3. Stratigraphic synthesis of the Himi Group in the area studied.

The Sakiyama Formation, Nakagawa Sandstone Member, Suginoya Siltstone Member and Mita Sandstone Member, although included in the Himi Group, have not been studied for their microfossils and, therefore, are not described in this paper.

a. The Zukawa Formation

This formation was defined by Motizuki (1930). The type locality of this formation is Zukawa, Takaoka City, and the strata are distributed along the Oyabe River extending from Ebisaka through Zukawa to Tagawa. This formation attains 200 m in thickness and consists of calcareous, fine to medium-grained sandstones. In the basal part, it consists of a 40-to-60-centimeter thick pebbly conglomerate containing many sand-pipes which penetrate through the subjacent formation.

Three tephra layers are observed in this formation and one of them can be correlated with the J2 Tuff of the Junicho Formation on the basis of its stratigraphical level and lithofacies. The formation yields abundant marine molluscs, echinoid spines, corals, bryozoa, foraminifera and other fossils. The Zukawa Formation unconformably overlies the Yachi Formation which mainly consists of massive mudstones and is, in turn, unconformably overlain by thick conglomerates, coarse to fine-grained sandstones and siltstones of the Hanyu Formation.

b. The Omma Formation

The formation was defined by Motizuki (1930), the type locality being chosen at Okuwa (=Omma), Kanazawa City. This formation is well exposed in the river bed of the Sai River and is also widely distributed in the southern Oyabe and Kanazawa. This formation consists of fine-grained sandstones, with its basal part frequently having medium-grained sandstones, granule conglomerates, or sometimes both.

The Omma Formation contains four tephra layers named O1 to O4 in upward sequence. The lowest tuff, O1, can be traced for a long distance in the southern part of the studied area and is situated about 34 m above the J2 Tuff at Tagawa, where the boundary between the Zukawa Formation and the Omma Formation is also observed. Broadly speaking, the Omma Formation is contemporaneous with the Zukawa Formation or it is somewhat younger.

The Omma Formation overlies the Takakubo Formation and is distributed over a large area in Kanazawa. The Takakubo Formation consists mainly of mudstone and tuffs. The uppermost part of this formation is composed of a 20 m thick (maximum) pumice-tuff and mudstone at the top. The mudstone is not observed in most localities, and the tuff beds also are partially or entirely lacking. These facts suggest an unconformable relationship between the two formations and the boundary between them can be recognized where sediments become coarser in the basal part of the Omma Formation.

At Sogi and Asagaya, south and west of Kanazawa City, respectively, the Omma Formation directly overlies the Asagaya Formation with an unconformity. The Omma Formation underlies unconformably a conglomerate of the Utatsuyama Formation in the Kanazawa area and similar conglomerate of the Hanyu Formation at Oyabe.

METHOD OF STUDY

a. Field work

In order to cover all the horizons of the Himi Group, three main traverses were chosen. They are located along the Nadaura coast (named here the Nadaura section, NDU), Asahiyama near Himi City (the Asahiyama section, ASH), and along the Sai River (the Omma section, OMM) near Okuwa, Kanazawa (Figs. 6, 7, 8). Although these sections are separated for some distance from one another, the stratigraphic relationship is determinable by tracing the key tephra.

Samples were usually taken at five to ten meters of stratigraphic interval in each of the sections. In addition to these, fifteen short traverses (abbreviated in Fig. 9 to NKD, CHS, KNG, HNG, KFT, TKM, HTU, GRM, HKD, HNY, TGW, IKB, SZK, EBS and YBT) were chosen for collecting samples, separated by a distance of about 3 km from one another.

In these traverses, samples were collected from just below or above a key tephra bed. Sometimes, rocks near these tephra are very much weathered and, in such case, samples were taken as close to the tephra as possible.

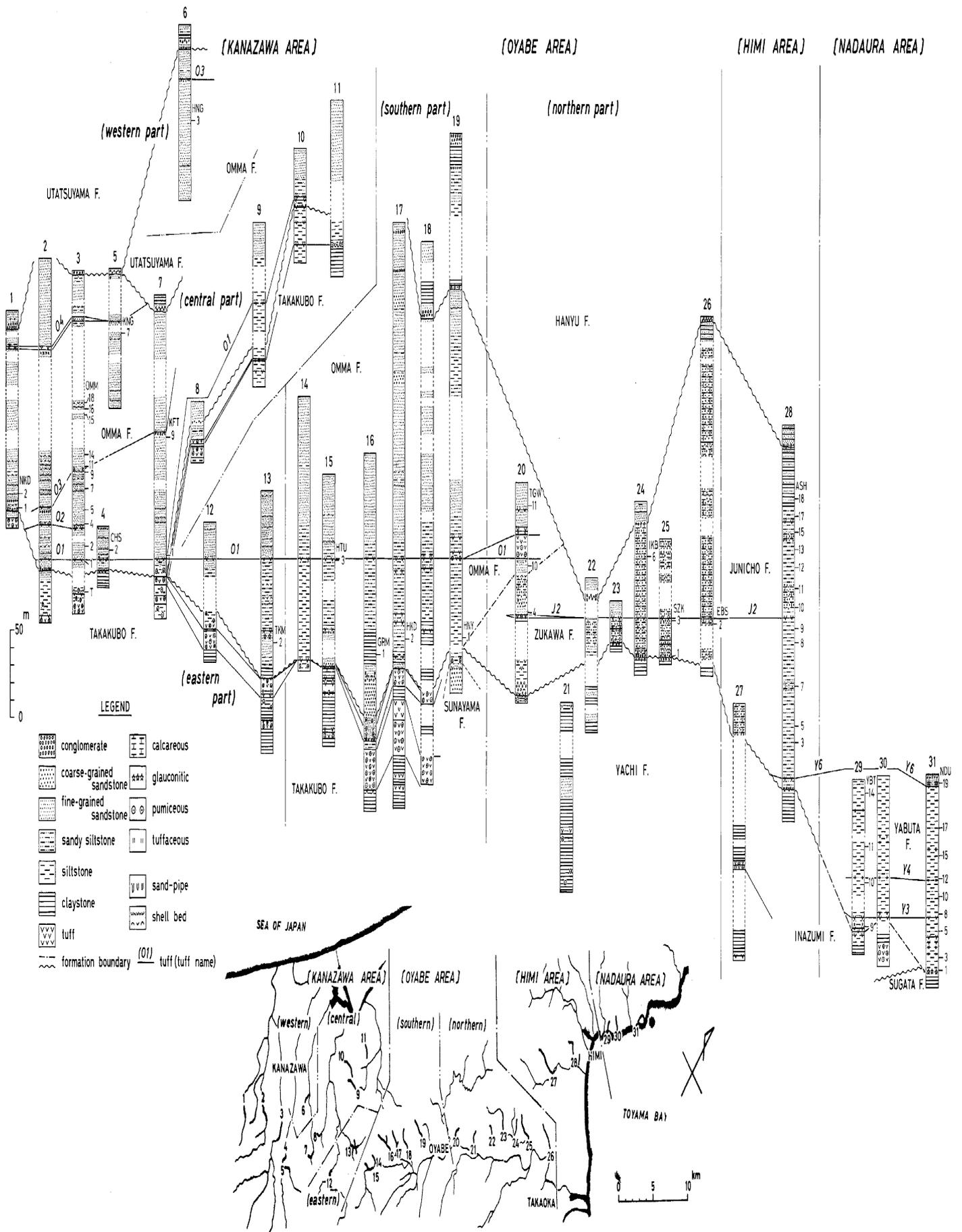


Fig. 5. Columnar sections of the Himi Group. Sampling localities on the columnar sections are also shown.

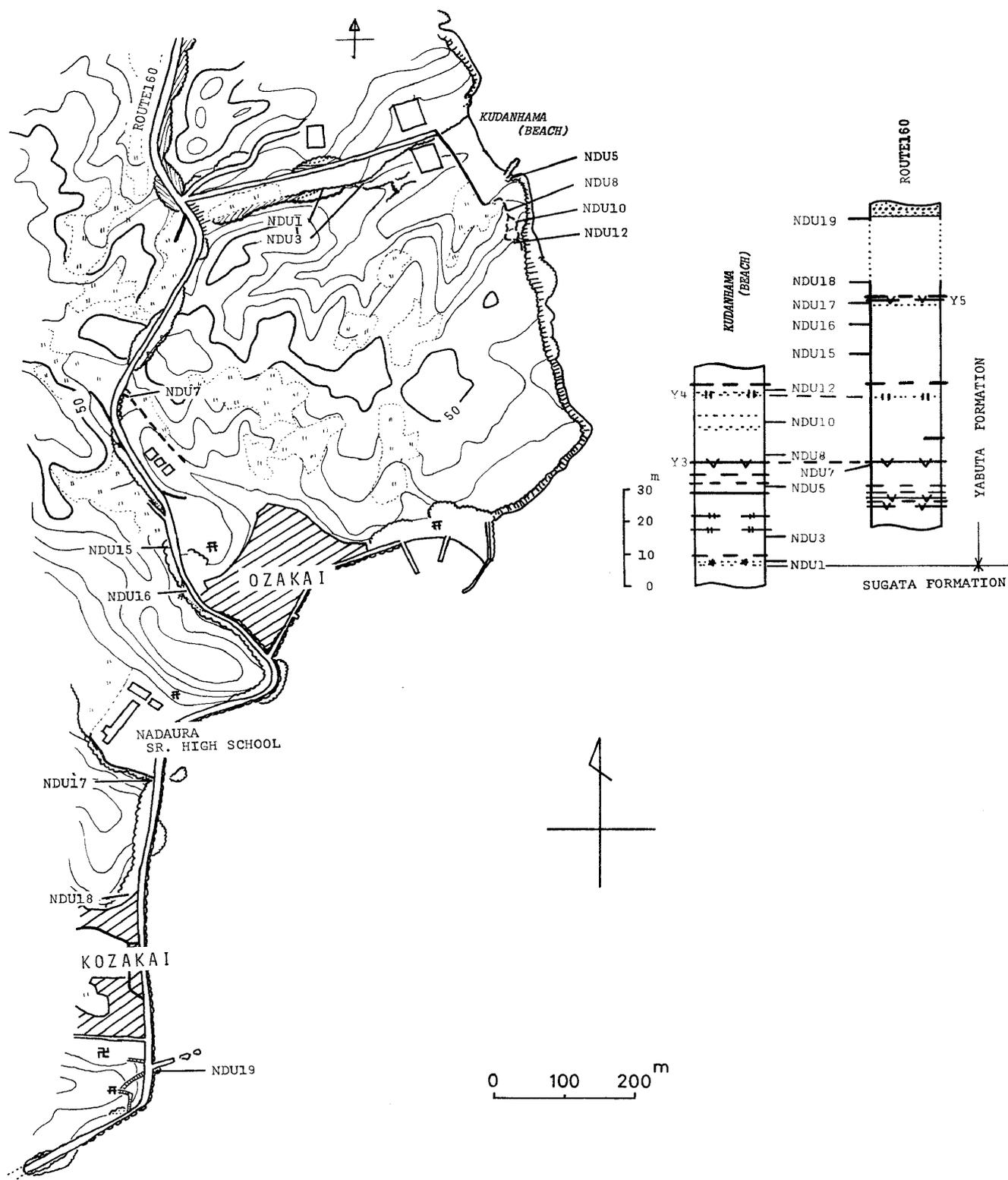


Fig. 6. Sampling localities and columnar sections of the Nadaura section (NDU) along the Nadaura Coast.

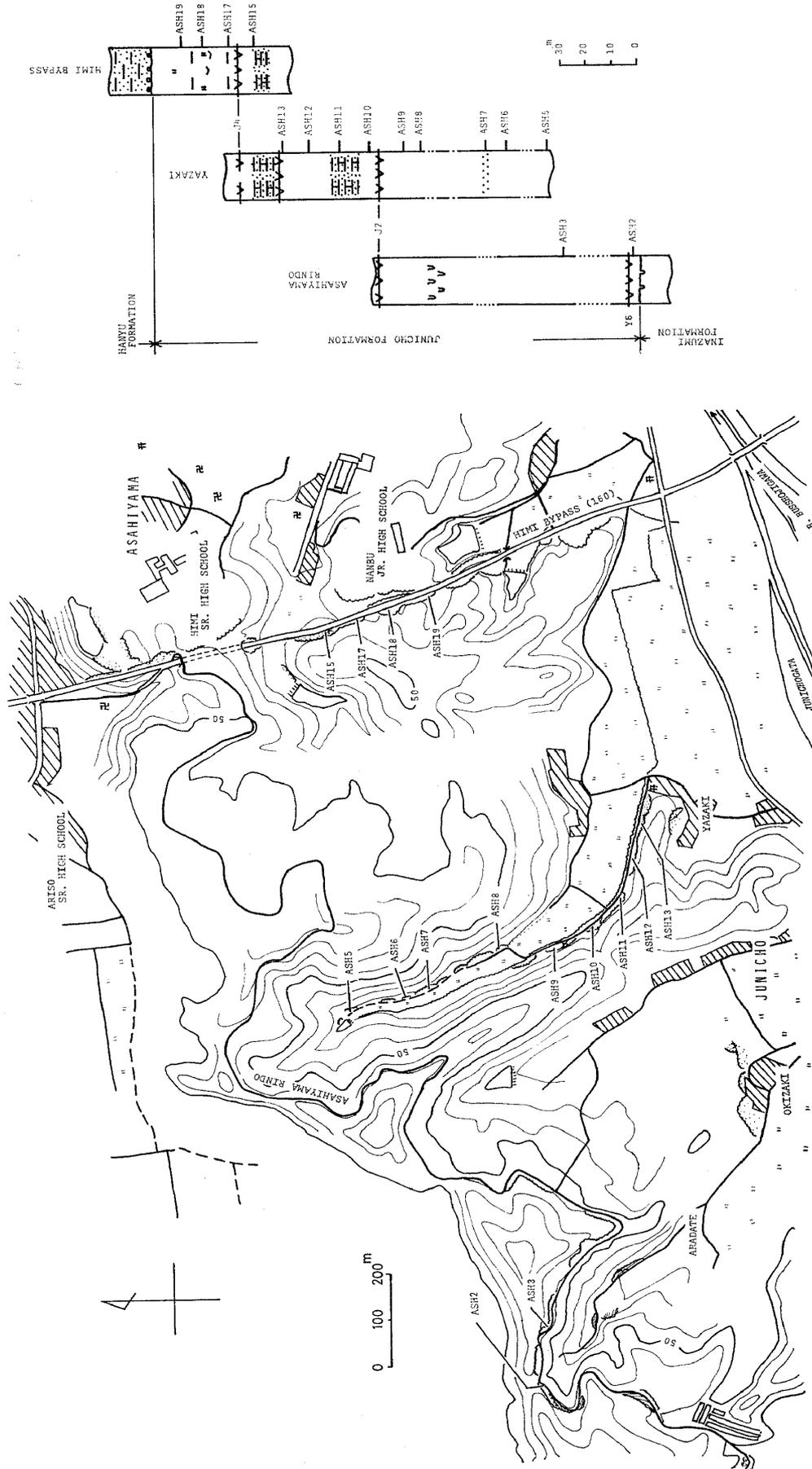


Fig. 7. Sampling localities and columnar sections of the Asahiya section (ASH) near Himi City.

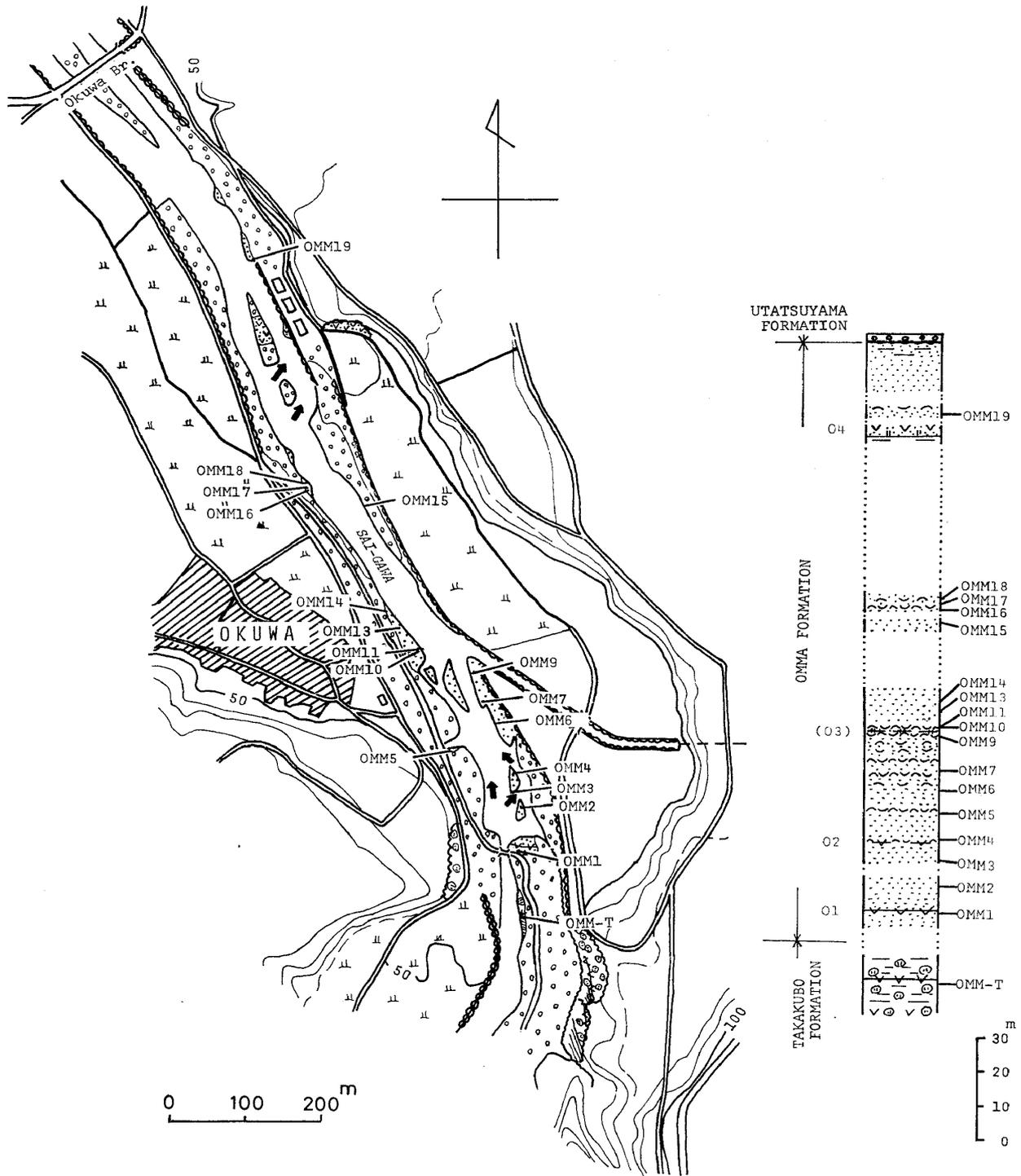


Fig. 8. Sampling localities and columnar section of the Omma section (OMM) located near Okuwa, Kanazawa.

All the tephra were used for establishing the stratigraphic framework of the studied area. Several of them are traceable for a long distance and are excellent key beds. These tephra are Y4, Y6, J2, O1, O3 and O4 in upward sequence and are named Horizons 1, 2, 3, 4, 5 and 6, respectively.

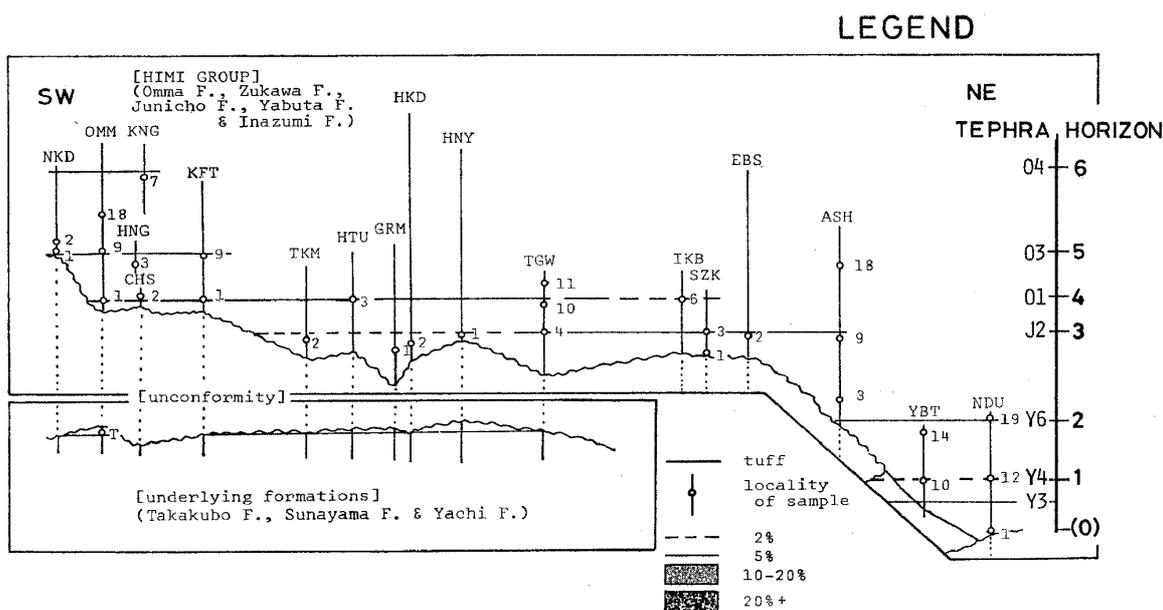


Fig. 9. Diagram showing abbreviations used for Figs. 12, 14, 16-18, 19a-n, 20, 22a, b, 27 and 32: NKD, Nukadani; OMM, Omma (=Okuwa); CHS, Choshi; KNG, Kanagawa; HNG, Higashinagae; KFT, Kofutamata; TKM, Takemata; HTU, Hitou; GRM, Goromaru; HKD, Hakkoden; HNY, Hanyu; TGW, Tagawa; IKB, Ikarabe; SZK, Shizukudani on Zukawa; EBS, Ebisaka; ASH, Asahiya; YBT, Yabuta; NDU, Nadaura.

All the sampling localities and their stratigraphic positions are shown in Figs. 4 and 5, respectively. The distance between the extreme northeastern section (the Nadaura section) and the extreme southwestern section (the Nukadani section) is about 55 km.

b. Laboratory work for foraminiferal analysis

A total of 68 samples were used for foraminiferal study. After being dried in an oven, each rock sample was treated with a saturated sodium sulfate solution and naphtha solution for disintegration (Maiya and Inoue, 1973), without using any dispersant such as sodium hexametaphosphate (Oda *et al.*, 1975). The sample was then wet-sieved through a 200 mesh screen and re-dried. The processed sample was divided by a sample splitter into aliquot part. Two hundred and odd foraminiferal specimens (both benthonic and planktonic) were picked up from aliquot part. Benthonic specimens were then identified and planktonic ones were counted. From another aliquot part of the sample, all the planktonic specimens were picked up to get 200 (or more) individuals.

c. Sedimentological analysis

In order to study the nature of substrate as an environmental factor affecting the foraminiferal distribution, grain-size analysis of sediments (the same samples used for foraminiferal study) was also conducted. After being dried in an oven, each rock sample (5 to 15 g in dry weight) was macerated using a naphtha solution and an ultrasonic cleaner. The size-frequency curve and the mud content (fraction of the grains finer than 4.0ϕ) of samples were obtained by using an automatic grain-size analyser (Niitsuma, 1971a).

PLANKTONIC BIOSTRATIGRAPHY

The occurrence and frequency of planktonic foraminifera from the Himi Group are shown in Table 3. Based on their occurrence, the Himi Group is divided into two units, the lower and the upper. The lower is characterized by the dominance of right-coiling specimens of *Globigerina pachyderma* (Ehrenberg). *Globorotalia inflata inflata* (d'Orbigny), *G. inflata praeinflata* Maiya, Siato and Sato, *G. orientalis* Maiya, Saito and Sato, *Globoquadrina asanoi* Maiya, Saito and Sato, *G. kagaensis* Maiya, Saito and Sato, *G. himiensis* Maiya, Saito and Sato, and *Orbulina universa* d'Orbigny are common in this unit. This unit encompasses samples from NDU1 to ASH12. The upper unit represents the upper half of the Himi Group including the samples OMM1 to OMM19. This unit is dominated by the left-coiling specimens of *G. pachyderma*. *Globigerinodius ruber* (d'Orbigny) also occurs constantly. In terms of Maiya's zonation (Maiya, 1975; Maiya *et al.*, 1976), these lower and upper units are assigned to the *Globigerina pachyderma* (dextral)/*Globorotalia orientalis* Zone and *Globigerina pachyderma* (sinistral)/*Globigerina quinqueloba* Zone, respectively. The following foraminiferal species occur frequently in almost all the samples; *Globigerina bulloides* d'Orbigny, *G. incompta* Cifelli, *G. pachyderma* (Ehrenberg) and *G. quinqueloba* Natland.

The vertical distribution of planktonic foraminifera and calcareous nannoplankton in the studied sequence of the Himi Group is shown in Fig. 10.

In the warm-water region, the following species are used by other workers to delineate the Pliocene/Pleistocene boundary; *Globorotalia truncatulinoides* (d'Orbigny), *Pulleniatina obliquiloculata* (Parker and Jones) and a calcareous nannoplankton, *Discoaster brouweri* Tan Sin Hok. These species are not encountered in the studied sequence by the present author. They have not been reported by Maiya (*op. cit.*) either.

Maiya (*op. cit.*) suggested that the Pliocene/Pleistocene boundary may be drawn within the *Globigerina pachyderma* (dextral)/*Globorotalia orientalis* Zone. Maiya *et al.* (1976) described a new species, *Globoquadrina asanoi*, and indicated that it becomes extinct at the base of the Olduvai Event of the Matuyama Reversed Epoch. Berggren and van Couvering (1974) placed the Pliocene/Pleistocene boundary within the Olduvai Event (Fig. 11). Subsequently, Haq *et al.* (1977) drew this boundary close to the top of the Olduvai Event.

In the studied sequence, sample ASH6 from the lower unit marks the upper limit of *G. asanoi*. Furthermore, calcareous nannoplankton *Gephyrocapsa caribbeanica* Boudreaux and Hay first appears in sample ASH8. In Italy, Japan and deep-sea sediments of the northern Philippine Sea, this species first occurs at a horizon near the top of the Olduvai Event (Takayama, 1970, 1973; Ellis, 1975; Haq *et al.* 1977). Based on these observations, the Pliocene/Pleistocene boundary in the studied sequence probably lies between samples ASH6 and ASH8.

Maiya (1975) recognized that *Globorotalia inflata inflata* first appears near the top of the Olduvai Event in North Pacific deep-sea cores, and considered its range to be restricted to the Quaternary. However, many workers reported the first occurrence of *G. inflata* (*sensu* Maiya) from horizons referable to the Pliocene (Blow, 1969; Kato, 1973; Ujiie and Oki, 1974; Stainforth *et al.*, 1975; and Oda, 1971, 1977). In the Himi sequence, *G. inflata inflata* occurs in sample NDU5 (which is located stratigraphically below ASH6) from the lower part of the Nadaura section. As already stated, the uppermost occurrence of *G. asanoi* is in sample ASH6 which is interpreted to be the base of the Olduvai Event. Hence, it is believed that that part of the Himi Group below sample ASH6 is Pliocene in age. The upper part of the lower unit and the whole upper unit of the Himi Group sequence are thus considered Pleistocene.

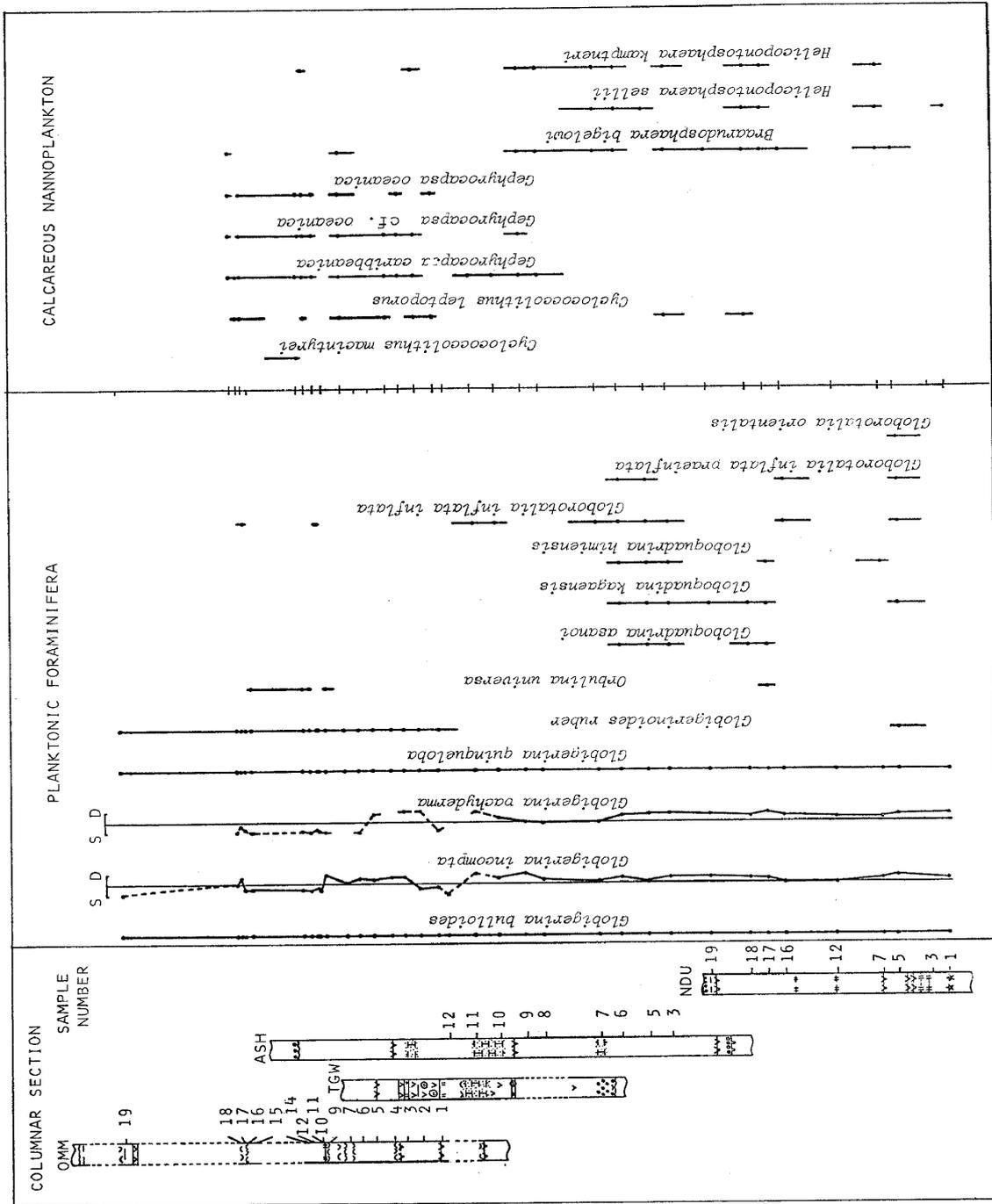


Fig. 10. Ranges of planktonic foraminifera and calcareous nannoplankton in a composite sequence made from three main sections of the Himi Group.

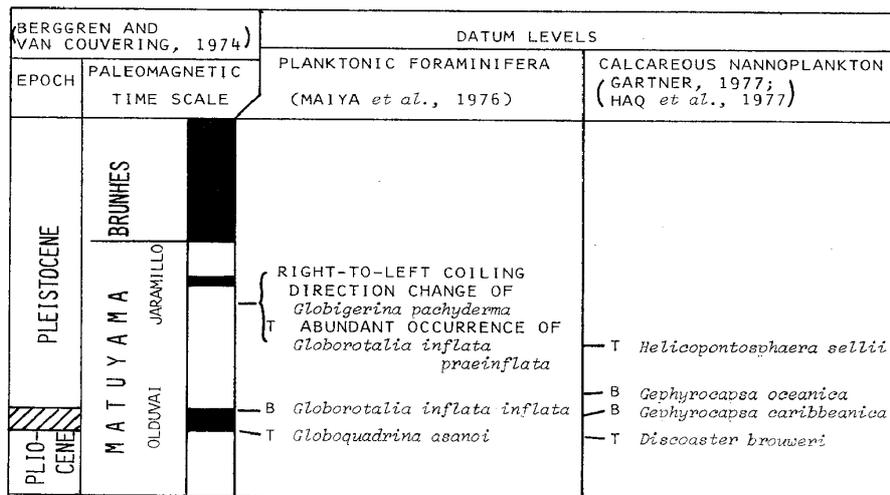


Fig. 11. Relation of Datum levels of planktonic foraminifera and calcareous nannoplankton with the paleomagnetic time scale.

SEDIMENTOLOGICAL ANALYSIS

The mud content determined in each sample is shown in Fig. 12. It ranges from 12 to 86% and generally decreases upward. In the Himi and Nadaura areas and in the southern part of the Oyabe area, the mud content is relatively high attaining more than 50%, whereas in the northern part of Oyabe and Kanazawa areas it is lower, being less than 30%.

The grain-size distribution is found to be quite variable. The samples studied are classified into three major types, namely, "sand" (sd), "sandy silt" (ss) and "silt" (st). These are further subdivided into 11 types based on the characteristics of their grain-size frequency curves (Fig. 13a). The distribution of major sediment types is shown in Fig. 14.

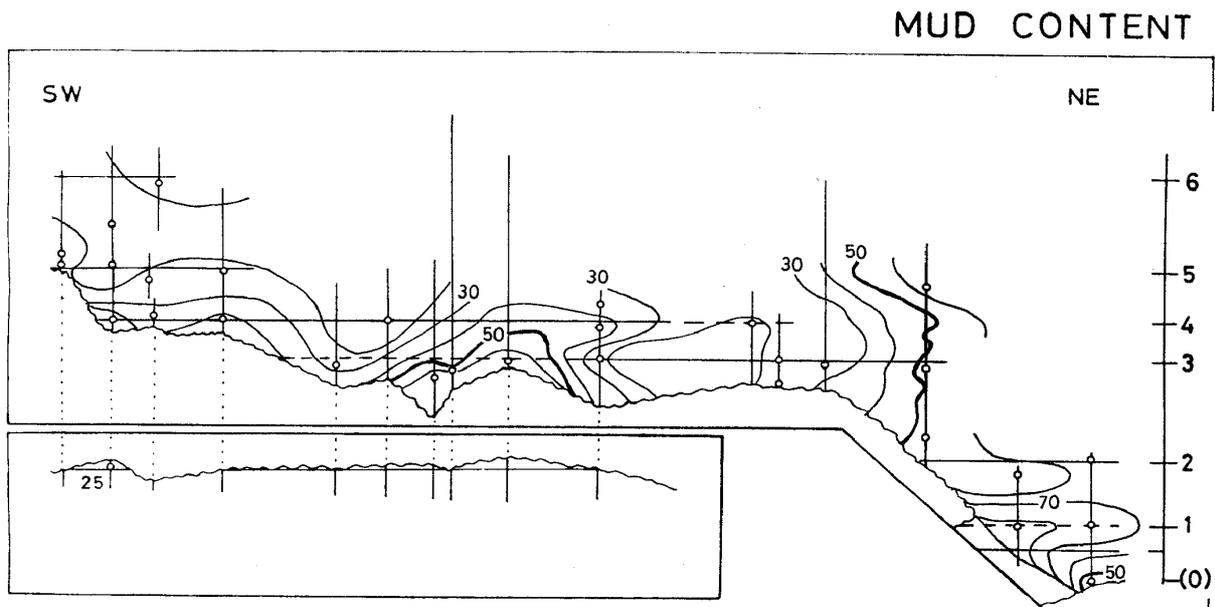


Fig. 12. Distribution of mud content in the Himi Group (in %).

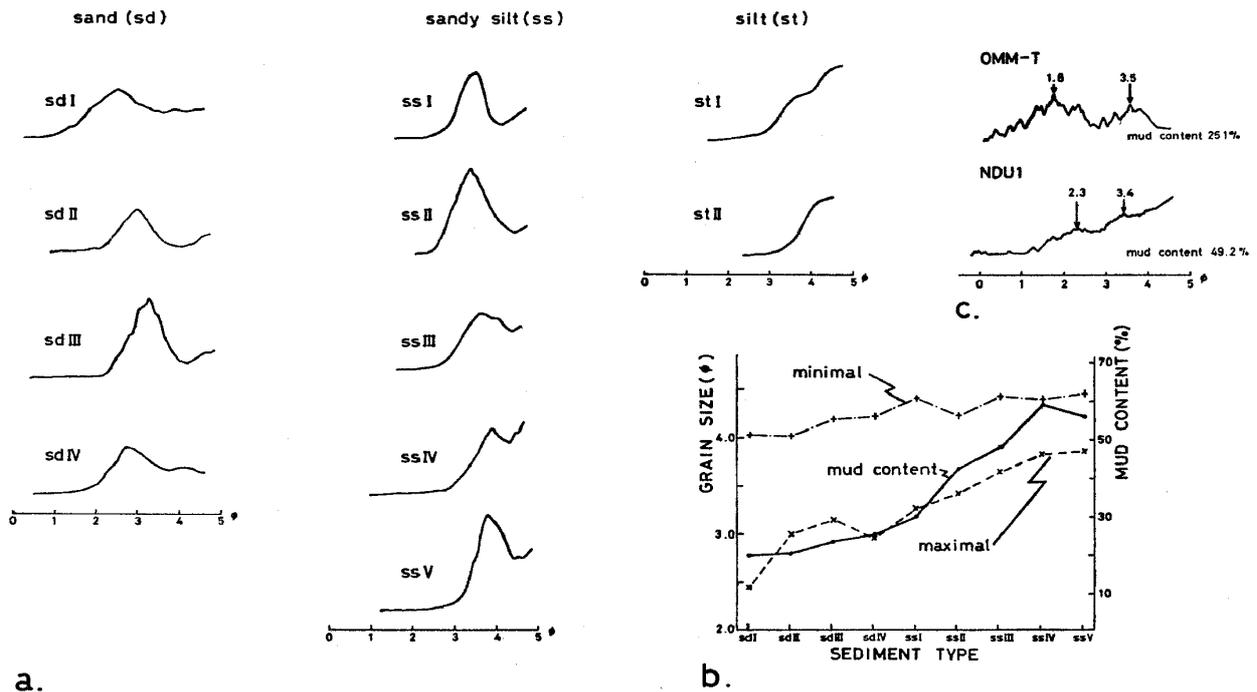


Fig. 13a-c. Result of grain-size analysis by an automatic analyser. a. Eleven types of grain-size frequency curves. b. Characteristics of sediment types "sdI-IV" and "ssI-V". c. Patterns of grain-size frequency curve in two unusual samples.

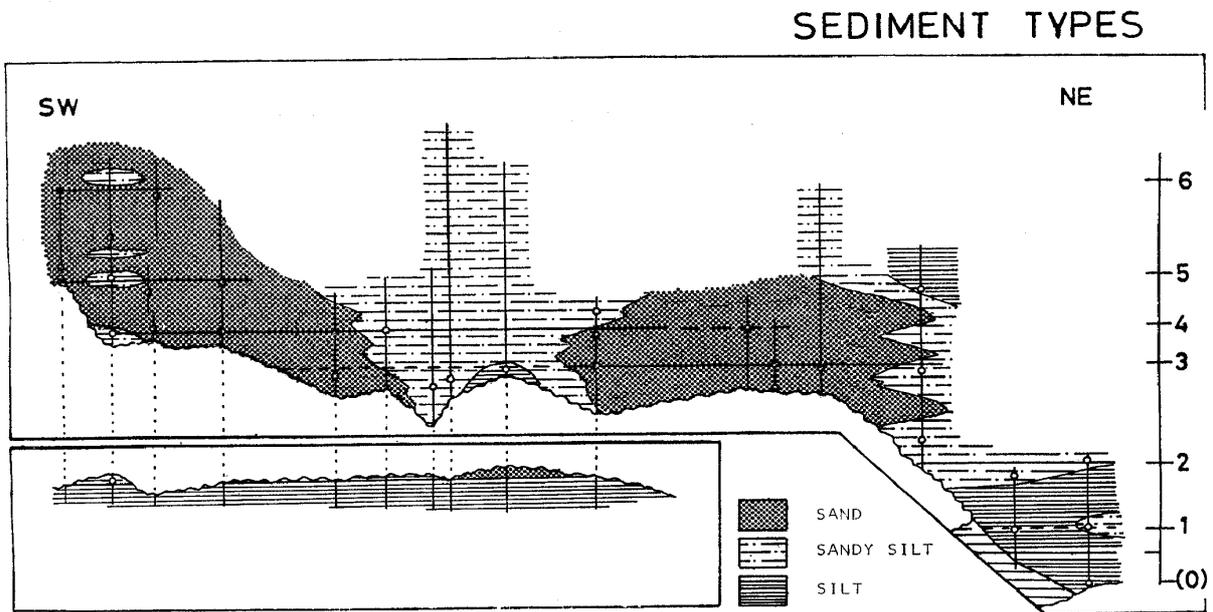


Fig. 14. Distribution of major sediment types.

The "sand" and "sandy silt" are subdivided into four and five types, respectively, on the basis of the mud content and the minimal and maximal on the frequency curve (Fig. 13b) (Niitsuma and Mekata, 1971). Although these indices change gradually, yet the distinction between "sand" and "sandy silt" is recognized on the basis of the minimal around 4.0ϕ and maximal around 3.0ϕ on the frequency curve.

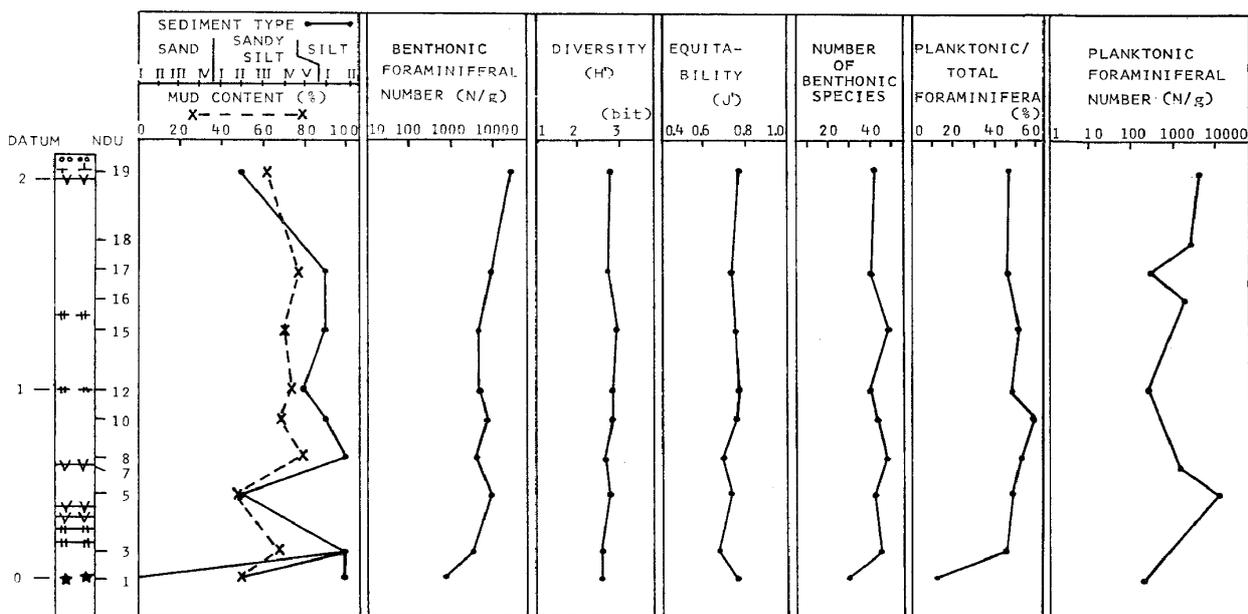


Fig. 15a. Vertical changes in sedimentological features and of foraminiferal fauna in the Nadaura section.

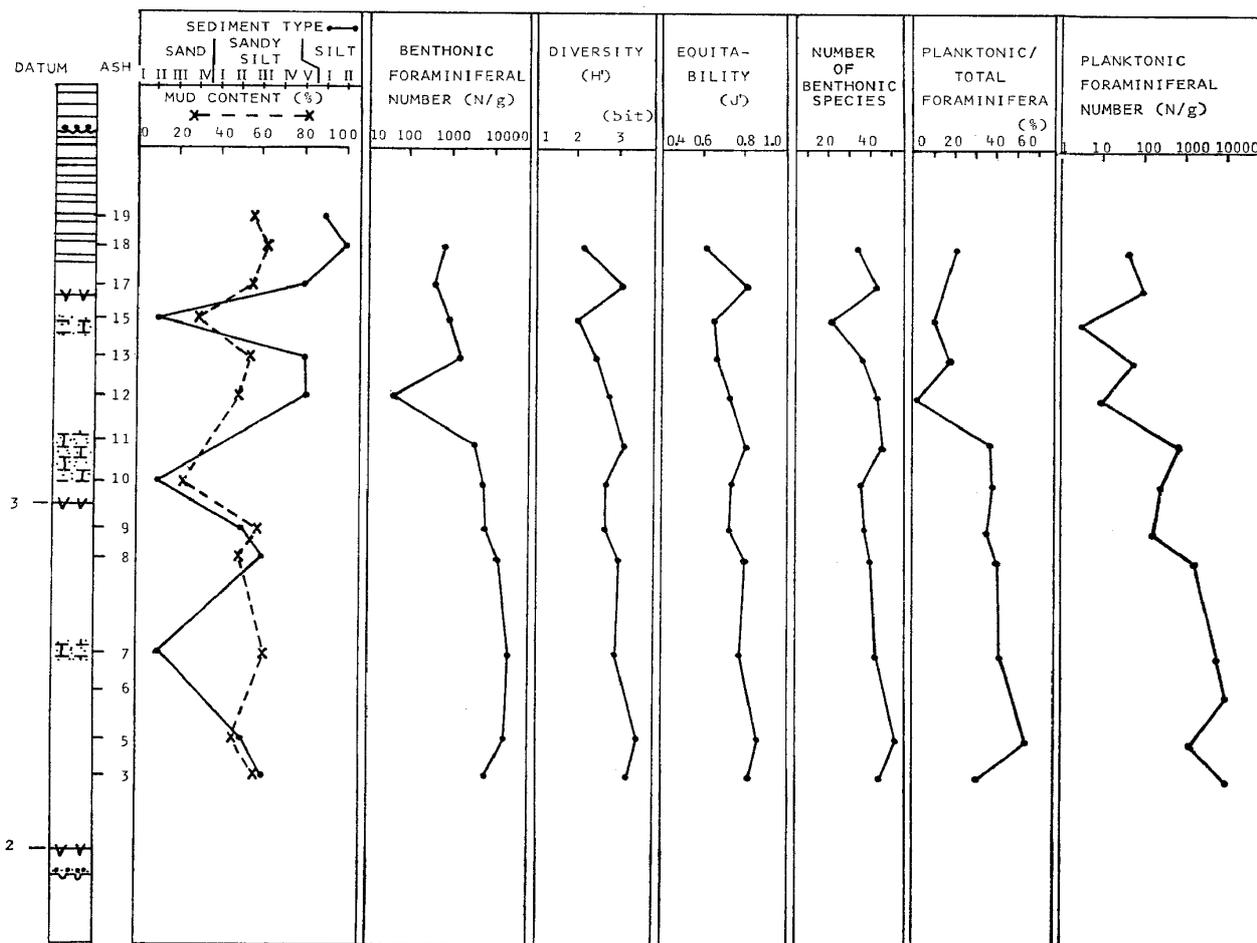


Fig. 15b. Vertical changes in sedimentological features and of foraminiferal fauna in the Asahi-yama section.

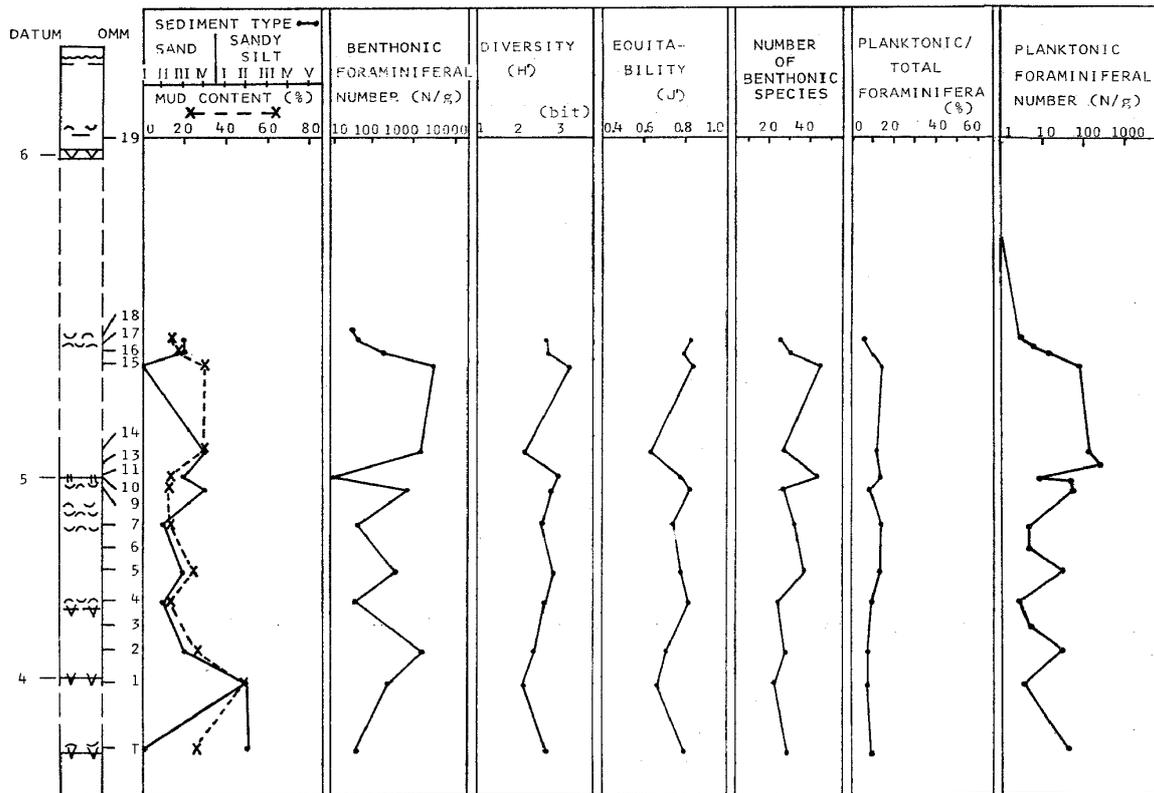


Fig. 15c. Vertical changes in sedimentological features and of foraminiferal fauna in the Omma section.

The "silt" is subdivided into two types on the basis of the shape of frequency curve around 3.5ϕ . The "silt" is distinguished from "sandy silt" by the absence of maximal at $3.0-4.0\phi$ and minimal at $4.0-4.5\phi$, and by a greater mud content. In Fig. 13b, the extreme left ("sdI") is coarser, and it becomes finer towards right. Further, the sample representing type "stII" consists of the finest sediment.

The vertical changes of sediment types in the three main sections are shown in Figs. 15a-c. In the Nadaura section, which forms the lower part of the composite sequence, sediment types vary between "silt" and "sandy silt". In the Asahiya section, which represents the middle part of the sequence, sediment types alternate between "sand" and "sandy silt"-to-"silt", and in the field these sediment types correspond to calcareous sandstones and sandy siltstones, respectively. The fine part of the alternation has a tendency to become more fine-grained upward. In the Omma section, which represents the upper part of the sequence and lies south of the studied area, sediments belong to mainly "sand" type, and have a tendency to become more coarse-grained upward.

The "sand" type samples are distributed in two regions; one in the Kanazawa and the other in the northern part of the Oyabe area (the dotted areas in the left and center, respectively, in Fig. 14). The samples in the former area range from "sdII" to "sdIV" types. They are composed of mainly rock fragments including many carbonaceous fragments. Samples in the latter area range from "sdI" and "sdII" type. They are composed mainly of quartz-grains, a few rock fragments and calcareous fragments of echinoid spines, sponges, corals, bryozoa, foraminifera and other fossils. Carbonate contents of these sediments reach as much as 30%.

Among the samples studied, there are two "unusual" samples besides the 11 types

mentioned above. These are NDU1 and OMM-T. Sample NDU1 is a glauconitic-sandstone and comes from the base of the Yabuta Formation of the Nadaura section. In the grain-size frequency curve, there are two small maximals at 2.3ϕ and 3.4ϕ and a main maximal is estimated to occur below 4.5ϕ . These maximals correspond to the peaks of "sdIV", "ssII" and "silt", respectively. Sample OMM-T is a poorly sorted silty sandstone and is the only sample taken from a shell bed in the upper part of the Takakubo Formation of the Omma section. Its grain-size frequency curve makes two major maximals at 1.8ϕ and 3.5ϕ and represent a very coarse type. The peak at 3.5ϕ corresponds to "ssII". Other samples show no peak at 1.8ϕ .

As mentioned above, these two samples show two or more maximals and one or more minimals on the frequency curves for the fraction coarser than 4.5ϕ , whereas most samples have a pair maximal and minimal. Niitsuma and Mekata (1971) assumed a pair of maximal and minimal to correspond to two independent agents of transportation in Mutsu Bay. Following this assumption, it is suggested that three or more different kinds of agent of transportation took part during the deposition of sediments represented by these two "unusual" samples. On the other hand, another mechanism of sedimentation might explain the occurrence of these "unusual" samples. Some agent of it will be discussed later.

FAUNAL DISTRIBUTION

i) Benthonic fauna

A total of 269 species belonging to 99 genera were identified. Their occurrence and frequency are shown in Table 2.

The benthonic foraminiferal number (*i.e.*, the number of benthonic foraminiferal individuals per one g of rock) varies from 11 to 25,190 and is found to increase southwestward. In upward sequence, it increases first, reaching the maximum at the Horizon 2, and then decreases to the level of much small numbers (Fig. 16). The species diversity and equitability in each sample are shown in Figs. 17 and 18, respectively.

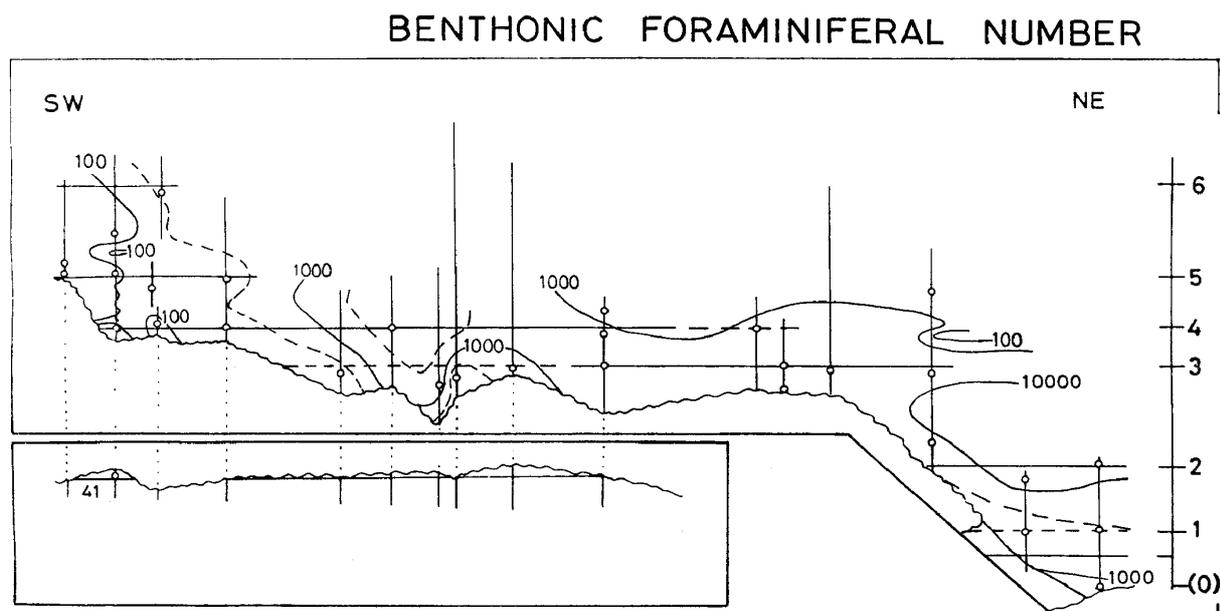


Fig. 16. Isopleth section of benthonic foraminiferal number.

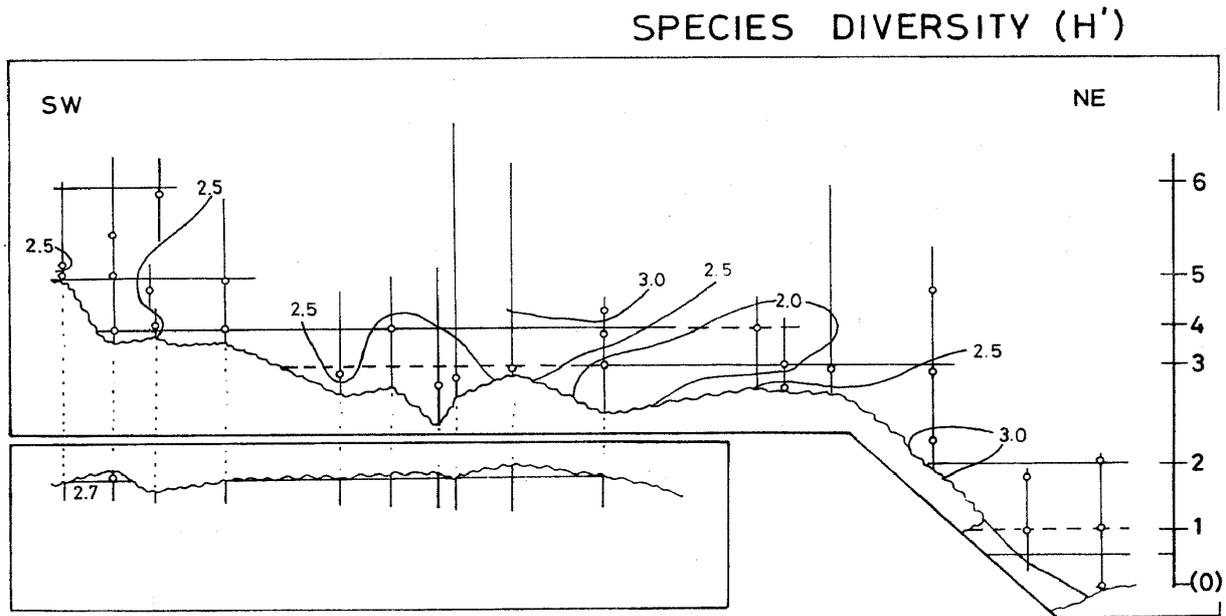


Fig. 17. Isopleth section of the species diversity, H' .

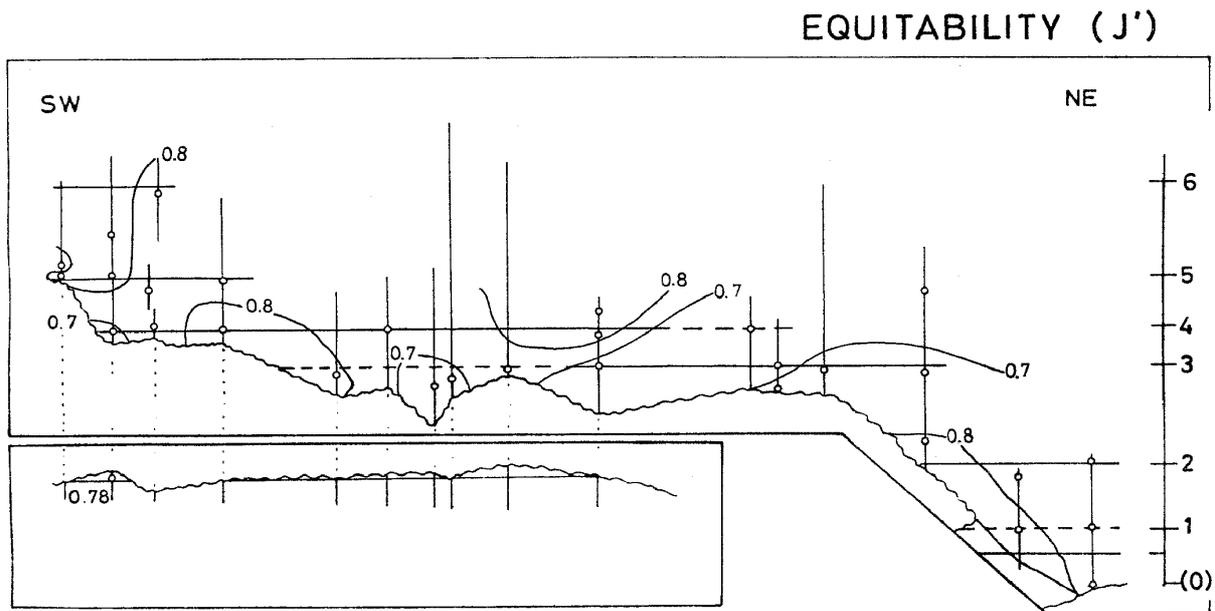


Fig. 18. Isopleth section of the equitability, J' .

To obtain an estimate of species diversity, the Shannon-Weaver function H' was used. This is given by the equation:

$$H' = - \sum_{i=1}^s p_i \log_2 p_i$$

where s is the number of species in a sample and p_i is the proportion of the i th species in that sample. In this expression, diversity H' is minimum if all individuals belong to the same species and maximum if all individuals belong to a different species. The theoretical background of the Shannon-Weaver function has been discussed by a number of authors (*e.*

g., Shannon, 1949; Margalef, 1957; Buzas and Gibson, 1969; Beerbower and Jordan, 1969; and Kimoto, 1976).

The species diversity consists of two components. One is "species richness", *i.e.*, the number of species present, and the other is "equitability", *i.e.*, the relative frequency of each species in a given sample. The number of species is the simplest measure of diversity, and is largely dependent on sample-size (Sanders, 1968).

For measuring the equitability, the techniques of Lloyd and Ghelardi (1964), Pielou (1966) and Sheldon (1969) have frequently been used for fossil and living populations. In the present study, Pielou's evenness component diversity J' is employed as an equitability

Globocassidulina depressa

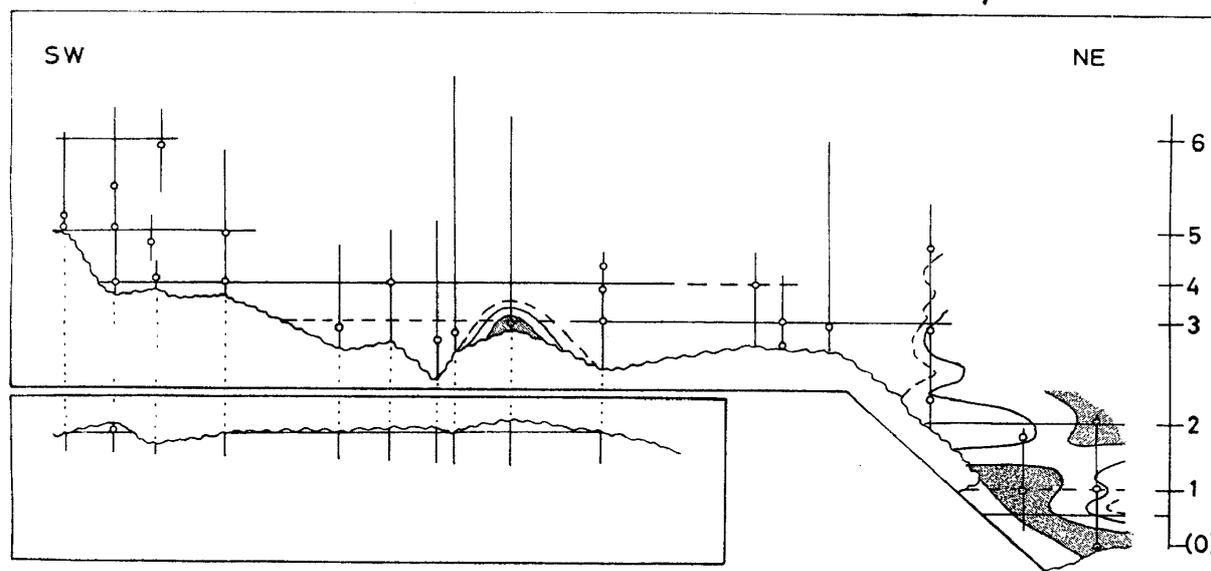


Fig. 19a. Isopleth section of *Globocassidulina depressa* (Asano and Nakamura).

Bolivina decussata

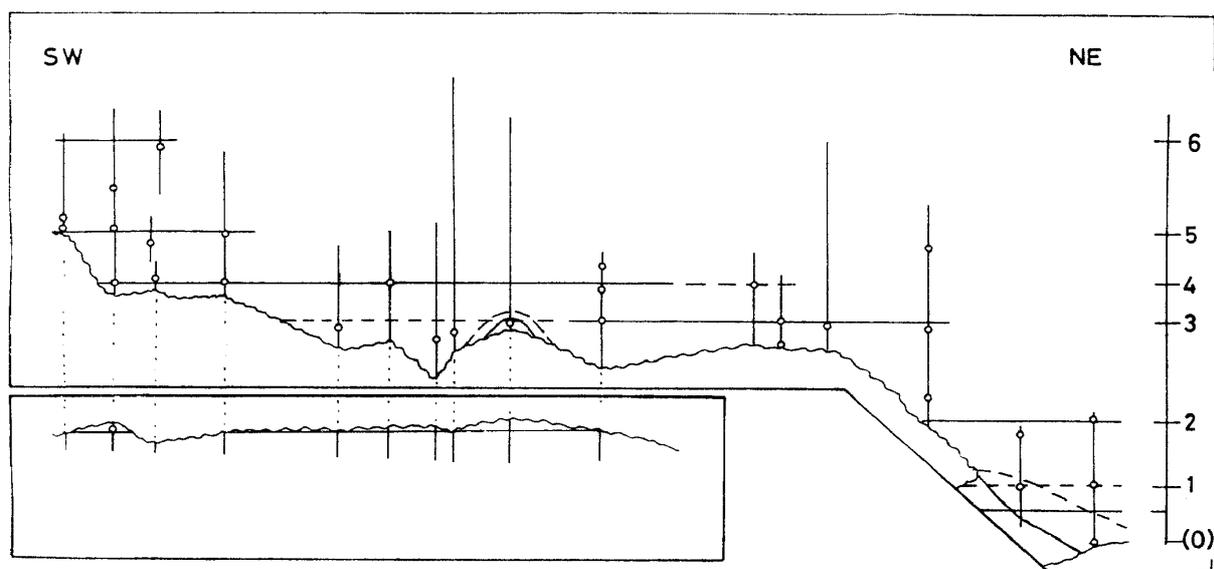


Fig. 19b. Isopleth section of *Bolivina decussata* Brady.

Bolivina sp. A

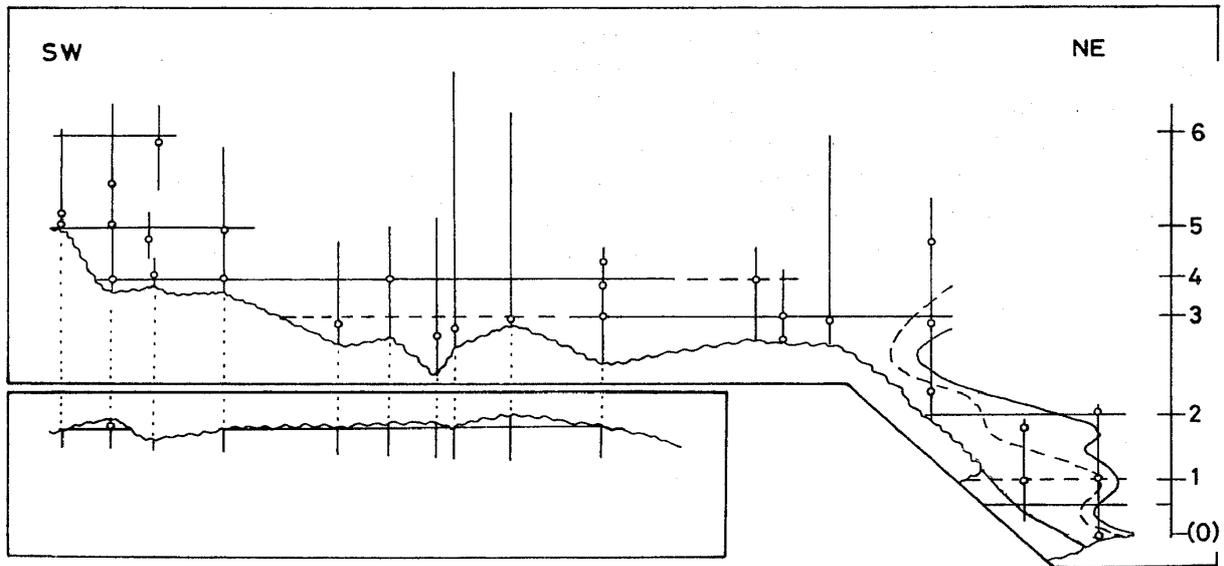


Fig. 19c. Isopleth section of *Bolivina* sp. A.

Elphidium bartletti

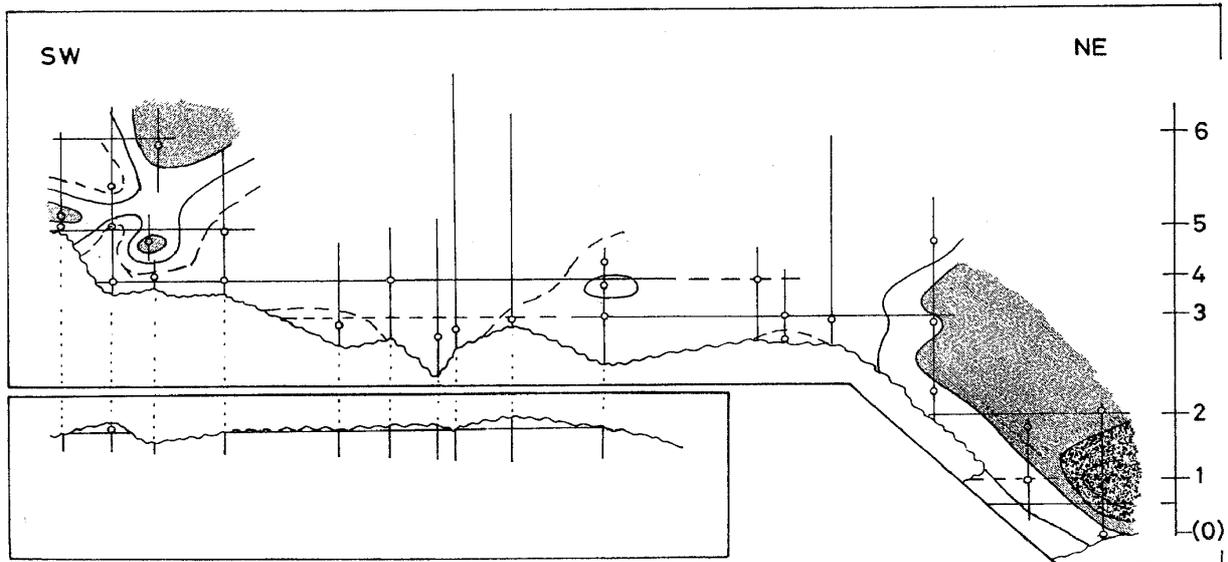


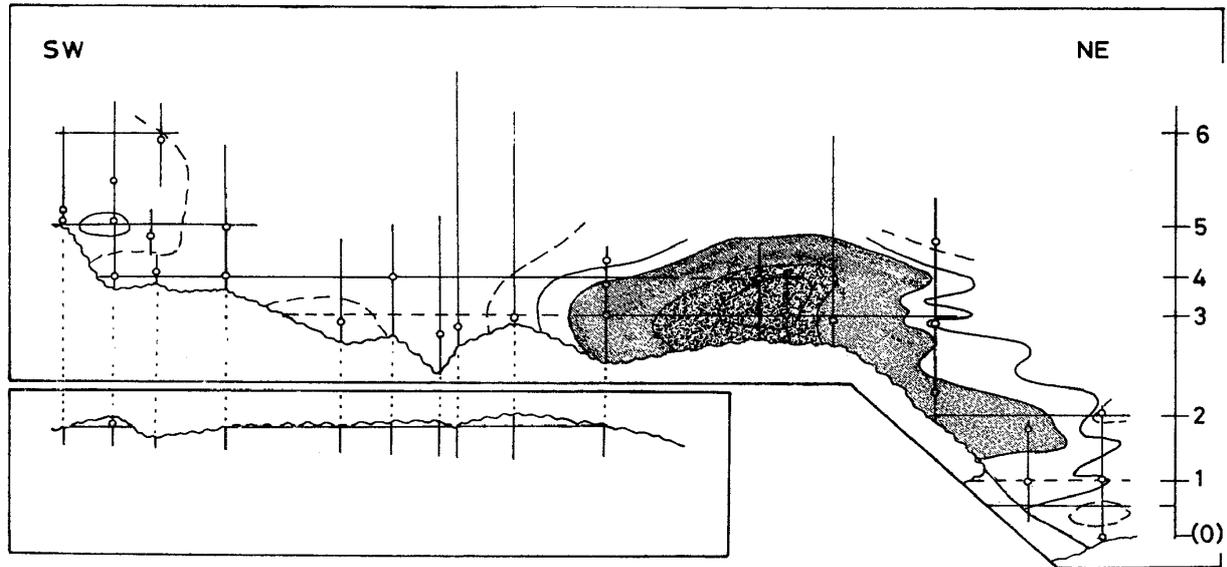
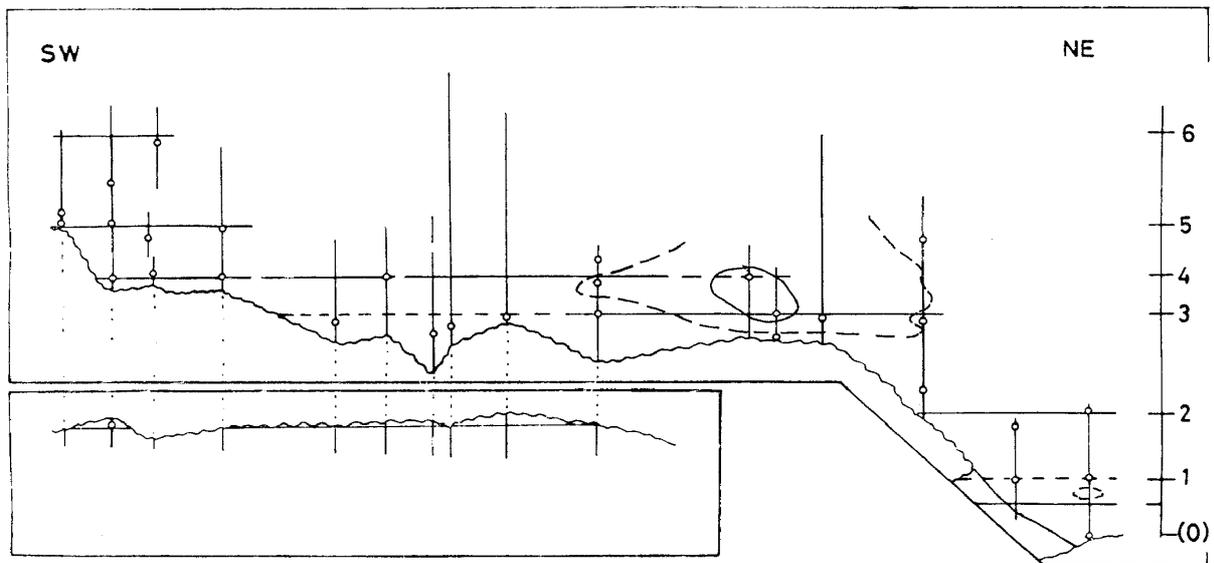
Fig. 19d. Isopleth section of *Elphidium bartletti* Cushman.

index (Pielou, 1966). This index is considered superior to other indices, being less dependent on the species count (Sheldon, 1969), and is given by the equation:

$$J' = \frac{H'}{H_{max}'} = \frac{H'}{\log_2 s}$$

where H' is the Shannon -Weaver index, " $H_{max}' = \log_2 s$ " is the maximum value of H' which occurs when all the species in a given sample are equally distributed, and s is the number of species.

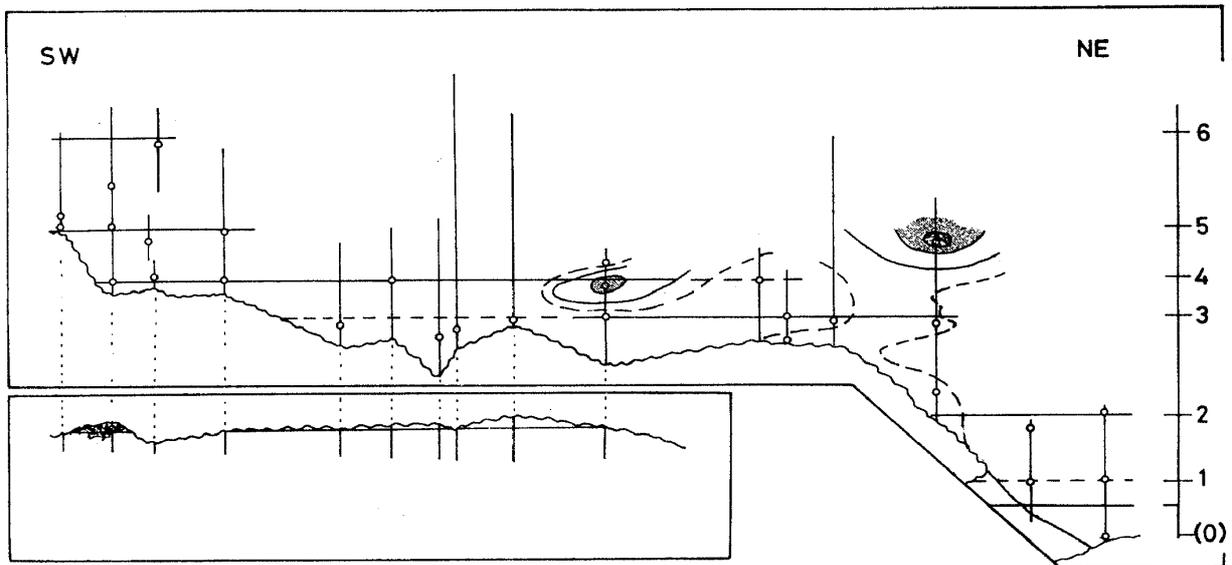
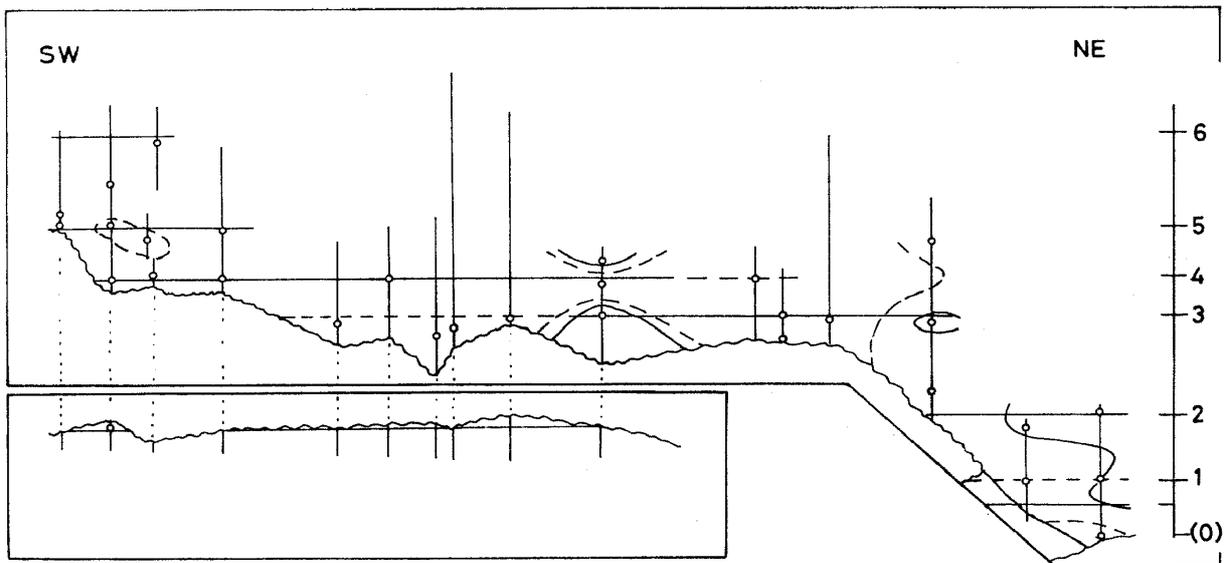
The H' values vary from 1.91 to 3.41 in bit. These values are lowest in the northern

Cibicides subpraecinctusFig. 19e. Isopleth section of *Cibicides subpraecinctus* (Asano).*Elphidium crispum*Fig. 19f. Isopleth section of *Elphidium crispum* (Linné).

part of the Oyabe area and increase northeastward. It is highest in the Himi area at the Horizon 2. The J' values are generally high in all the samples studied and vary from 0.61 to 0.86. The lowest values are found in the northern part of the Oyabe area.

The distribution of those species which have some characteristic distributional pattern is shown in Figs. 19a-n. In these figures, the occurrence of species is expressed by their relative abundance (%).

The genera *Cibicides*, *Elphidium* and *Buccella* occur in almost all the localities. *Elphidium bartletti* Cushman is abundant in the Nadaura and Himi areas, and reaches to the maximum of 38% of fauna (Fig. 19d). *Bolivina* sp. A (Fig. 19c) and *Gavelinopsis praegeri*

Cassidulina yabeiFig. 19g. Isopleth section of *Cassidulina yabei* Asano and Nakamura.*Gavelinopsis praegeri*Fig. 19h. Isopleth section of *Gavelinopsis praegeri* (Heron-Allen and Earland).

(Heron-Allen and Earland) (Fig. 19h) are similar to *E. bartletti* in their distributional patterns. *Globocassidulina depressa* (Asano and Nakamura) (Fig. 19b), *Bolivina decussata* Brady (Fig. 19a) and *Uvigerina akitaensis* Asano are also abundant in the Nadaura and Himi areas, but their distribution has an inverse relationship with those of *E. bartletti* and others.

Cibicides subpraecinctus (Asano) (Fig. 19c) is dominant in the northern part of the Oyabe area and attains 35% at Tagawa (Horizon 3, =TGW4). *Elphidium crispum* (Linné) (Fig. 19f), *Cibicides lobatulus* (Walker and Jacob), *Globocassidulina subglobosa* (Brady) and *Neoconorbina stachi* (Asano) are similar to *C. subpraecinctus* in their distribution. *Cassidulina yabei* Asano and Nakamura (Fig. 19g) also occurs in the northern Oyabe area,

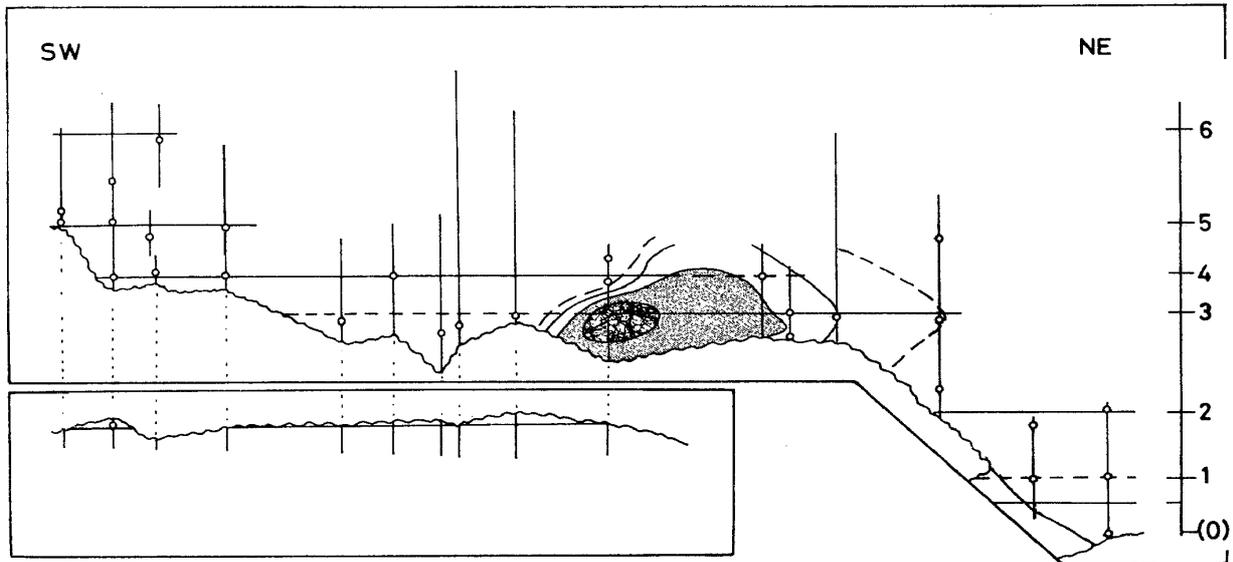
Islandiella translucens

Fig. 19i. Isopleth section of *Islandiella translucens* (Cushman and Hughes).

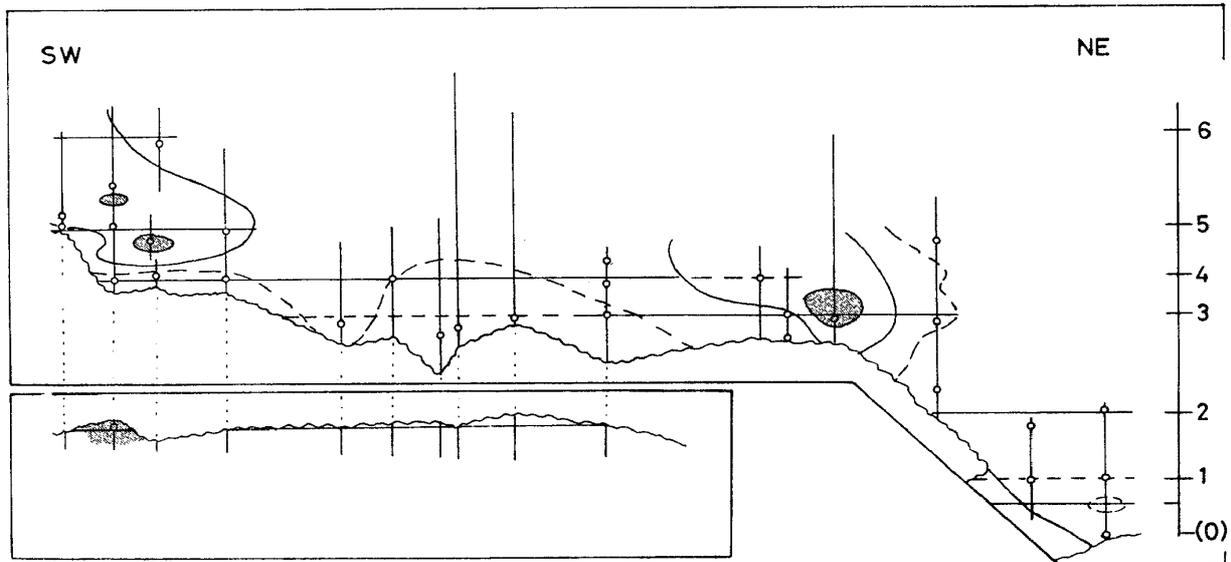
Hanzawaia nipponica

Fig. 19j. Isopleth section of *Hanzawaia nipponica* Asano.

but its distribution reveals a reversed pattern.

Buccella inusitata Andersen and *B. frigida* (Cushman) (Fig. 19m), *Elphidium clavatum* Cushman (Fig. 19n), *Elphidium subarcticum* Cushman (Fig. 19l), *Hanzawaia nipponica* Asano (Fig. 19j), *Ammonia japonica* (Hada) (Fig. 19k) and *Bolivina robusta* Brady are abundant in the Kanazawa and in the southern part of the Oyabe areas. Particularly, *A. japonica* is more frequent in Kanazawa than in Oyabe and the fauna there is associated with *Ammonia takanabensis* (Ishizaki) and *Cibicides refulgens* Montfort.

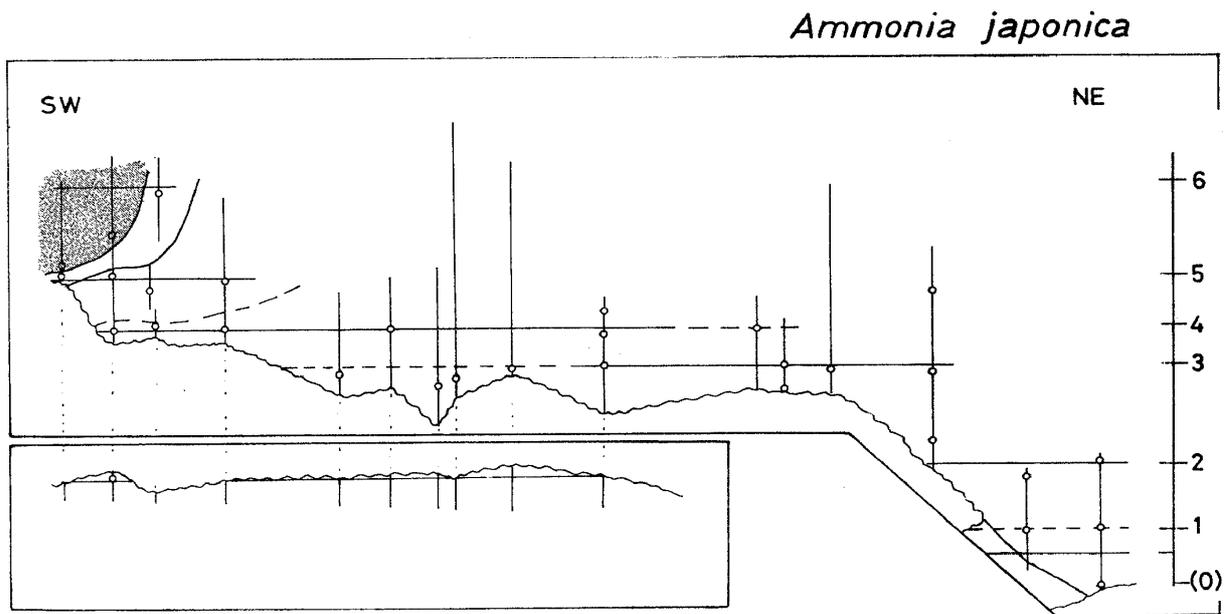


Fig. 19k. Isopleth section of *Ammonia japonica* (Hada).

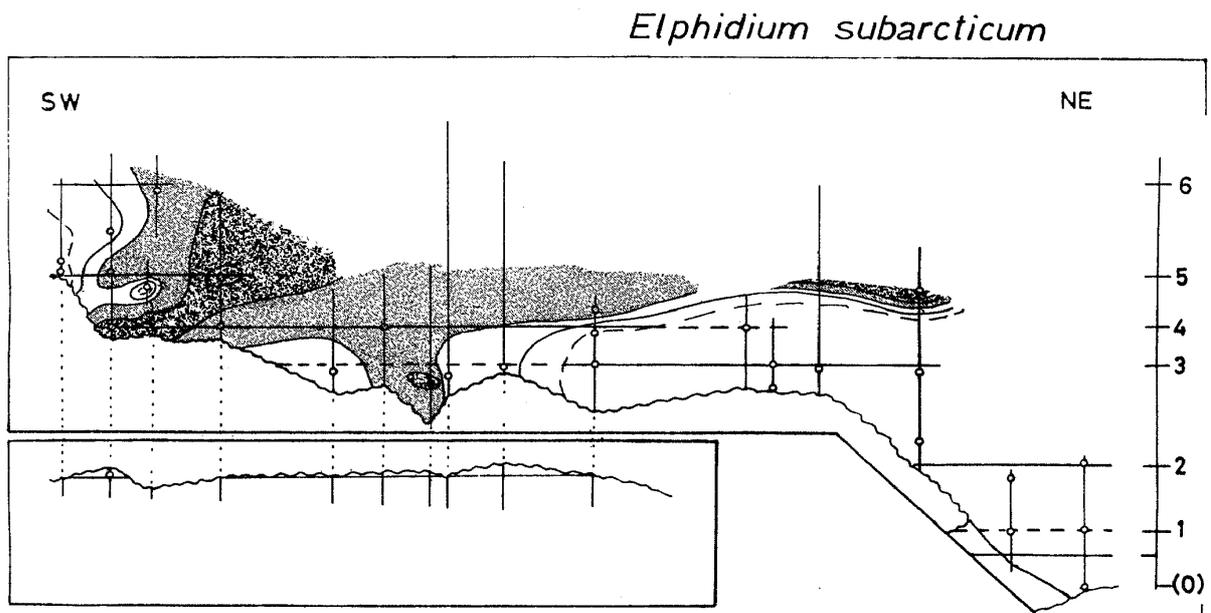


Fig. 19l. Isopleth section of *Elphidium subarcticum* Cushman.

ii) Planktonic fauna

A total of 52 species belonging to 10 genera were identified from the Himi Group (Table 3). The ratio of planktonics to the total foraminifera is shown in Fig. 20. This ratio varies from 0 to 58% and generally increases northeastward. Vertically, they reach the maximum at Horizon 2. A similar trend of distribution is shown by the planktonic foraminiferal number (Figs. 15a-c). Figs. 21a-c show the vertical distribution and relative frequency of planktonic foraminifera in three main sections. Throughout the whole sequence, *Globigerina bulloides*, *G. incompta*, *G. pachyderma* and *G. quinqueloba* are

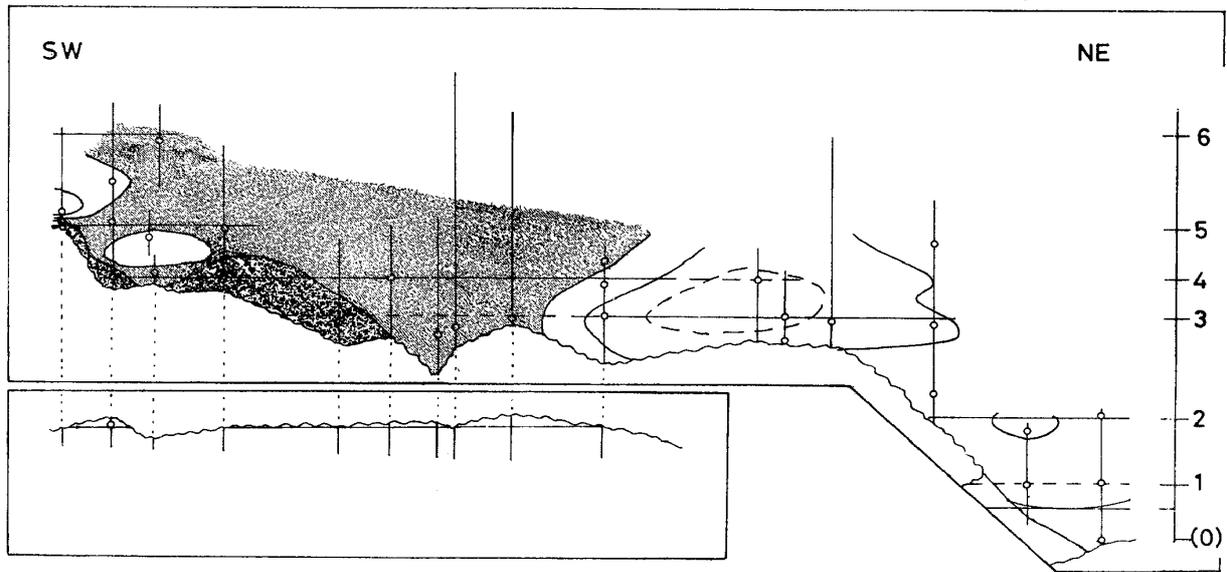
Buccella inusitata + *Buccella frigida*

Fig. 19m. Isopleth section of *Buccella inusitata* Andersen and *Buccella frigida* (Cushman).

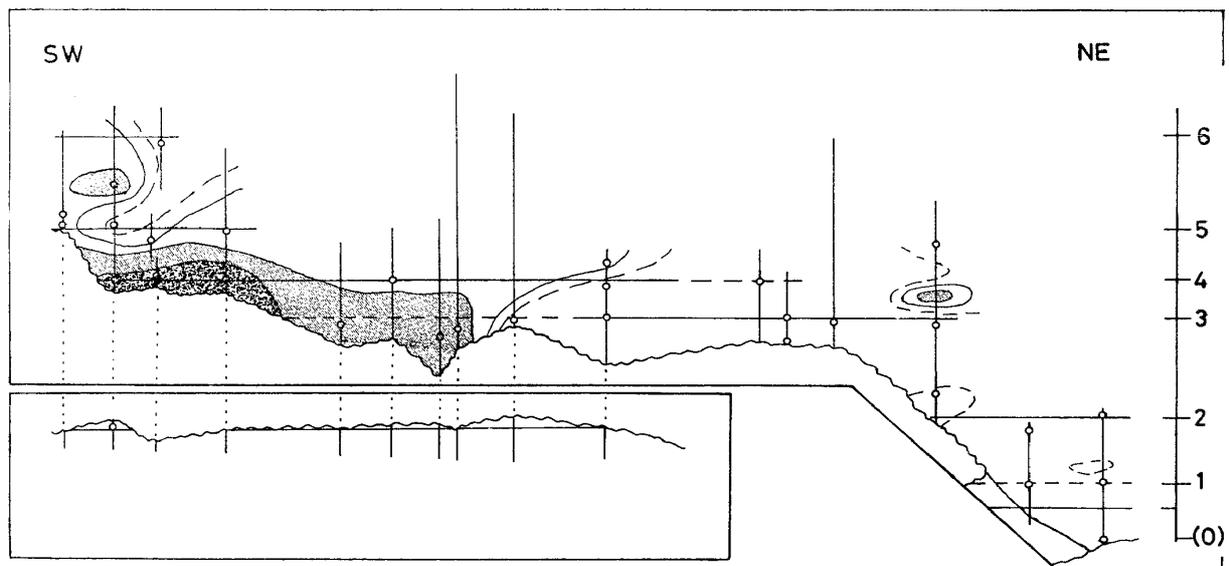
Elphidium clavatum

Fig. 19n. Isopleth section of *Elphidium clavatum* Cushman.

abundant. In the Nadaura section and in the lower part of the Asahiyama section (*i.e.*, the lower half of the sequence between the Horizons 2 and 3), *Globigerina woodi* and *Globigerinita glutinata* (Egger) occur frequently. *Globoquadrina asanoi* group and *Globorotalia inflata* group also occur in the same part of the sequences, though sporadically. However, these species are absent in the upper part of the Asahiyama section except *G. inflata inflata*.

In the upper part of the Himi Group, *G. bulloides* and *G. quinqueloba* occur more frequently. Also, the relative frequency of sinistrally coiling *G. pachyderma* is greater in the upper sequence (Horizons 3 to 5) than in the lower (Horizons 1 and 2) (Fig. 22b). At the

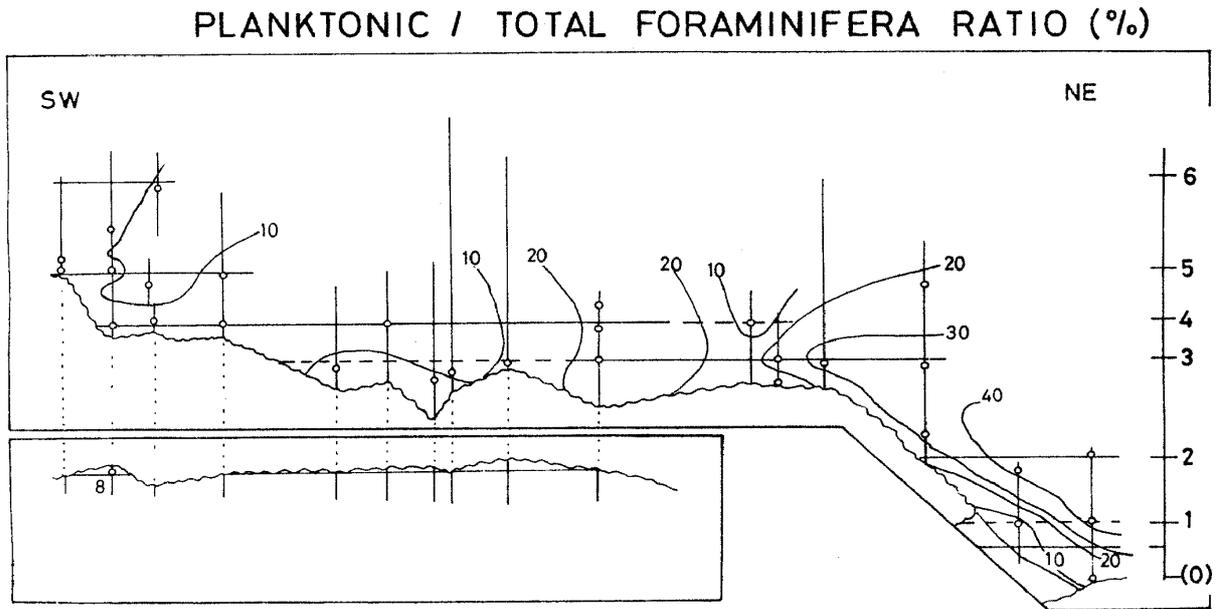


Fig. 20. Isopleth section of the ratio of planktonics to total foraminifera.

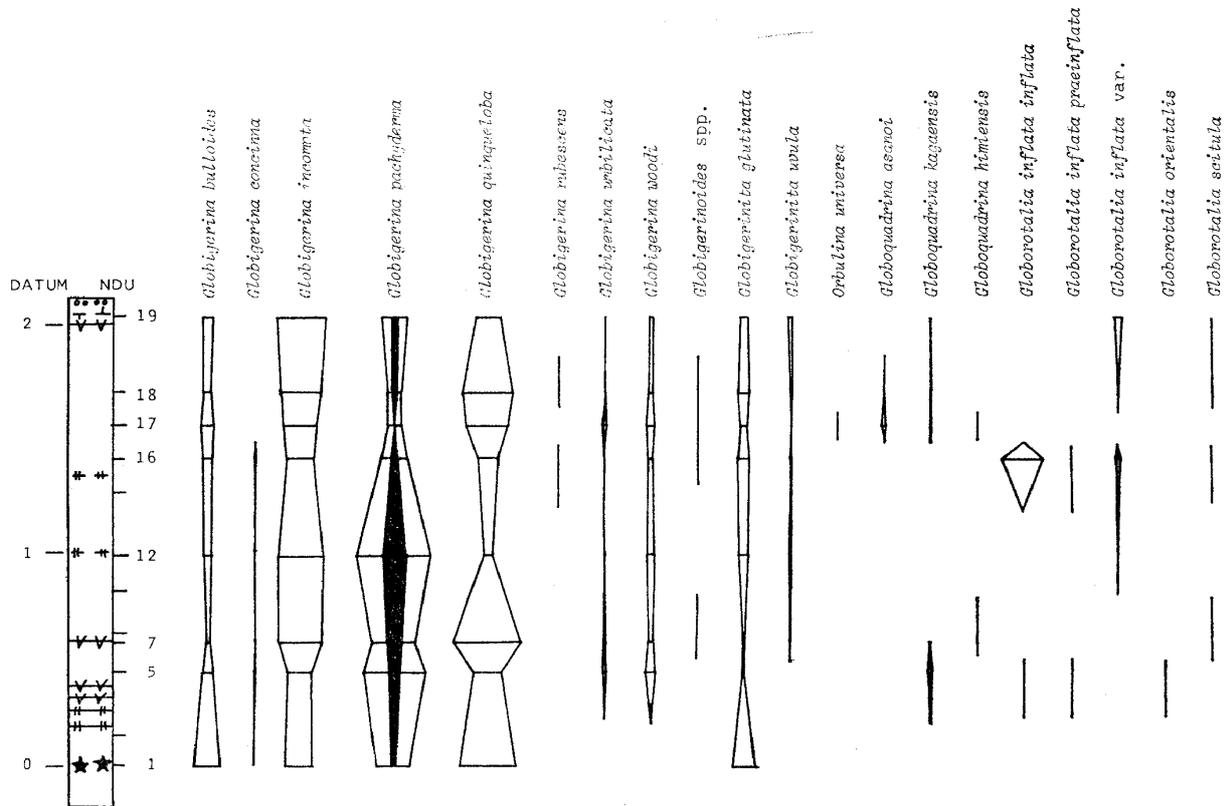


Fig. 21a. Vertical range and relative frequency of the selected planktonic foraminiferal species in the Nadaura section.

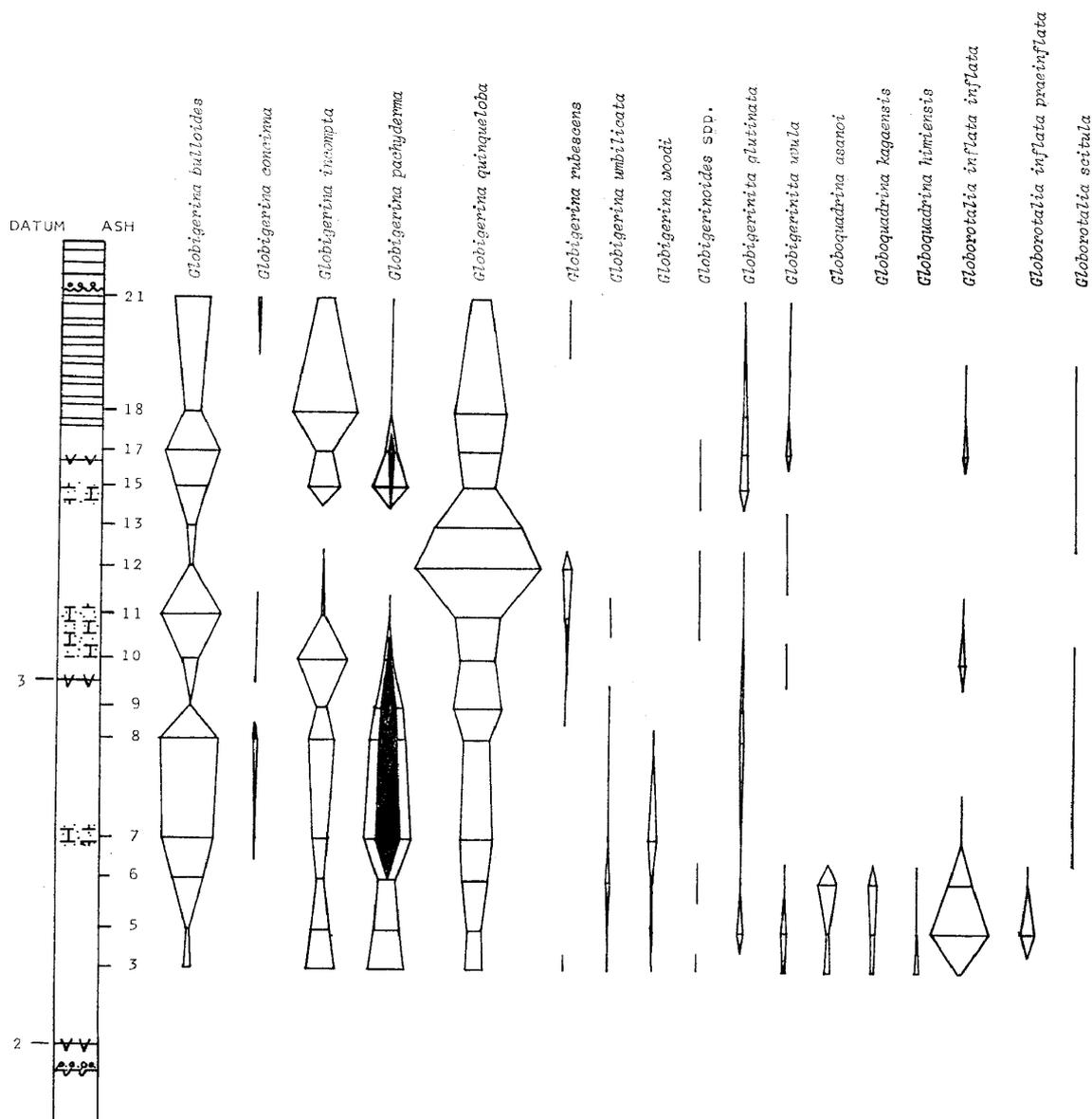


Fig. 21b. Vertical range and relative frequency of the selected planktonic foraminiferal species in the Asahiya section.

same time, it is also recognized that the abundance of *G. pachyderma* fluctuates from area to area as shown in Figs. 22a, b.

Globigerinoides ruber (d'Orbigny), which inhabits the surface water of tropical and subtropical regions, continuously occurs throughout the upper part of the sequence. A frequent occurrence of warm water species is more notable in the uppermost part of the sequence (see extreme right hand column in Fig. 33). The "warm water species" as called by the present author are those living in the present tropical and subtropical oceans (Bradshaw, 1959; Bé and Tolderlund, 1971).

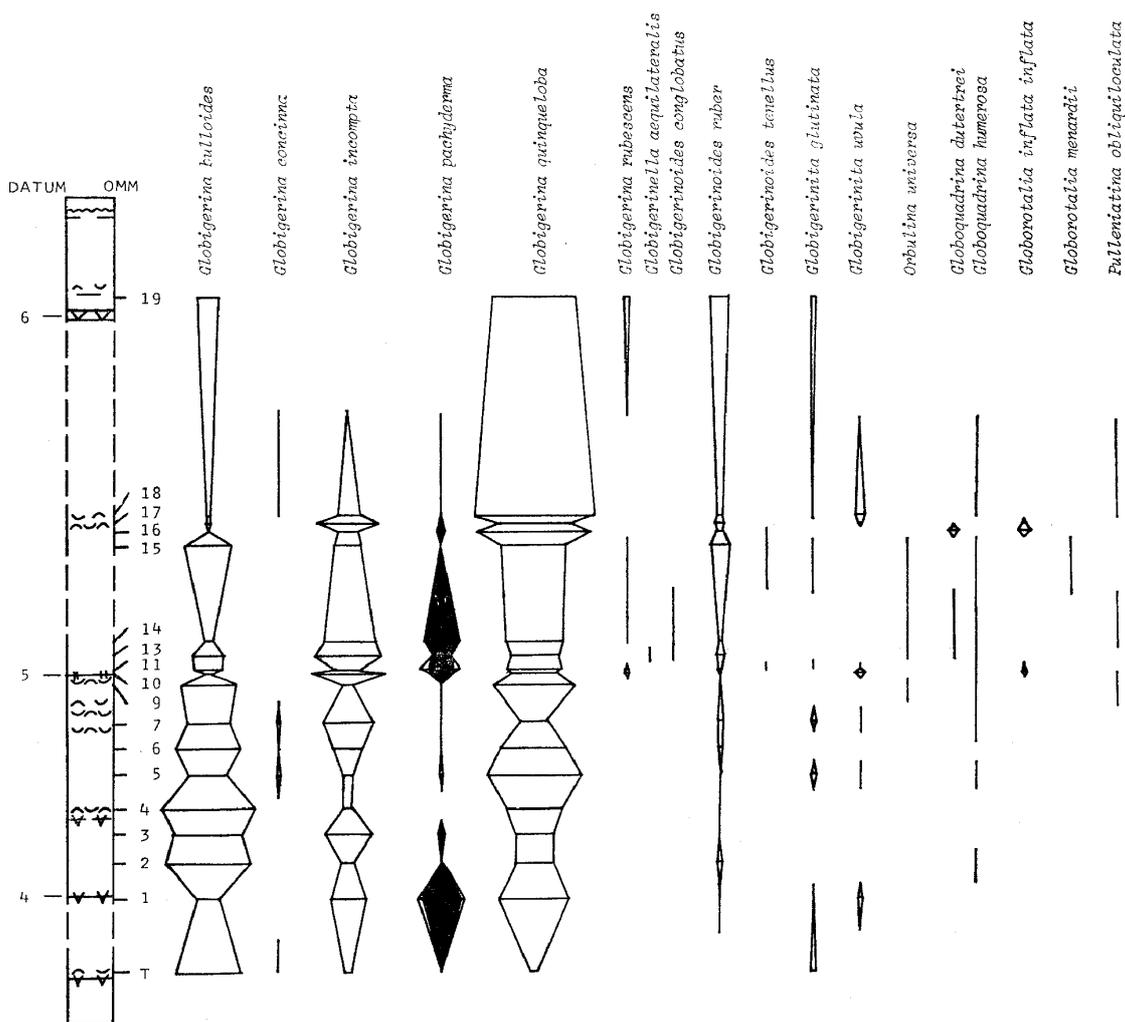


Fig. 21c. Vertical range and relative frequency of the selected planktonic foraminiferal species in the Omma section.

iii) Modern fauna

For a comparative study of the fossil fauna, Recent sea-bottom samples were also analyzed. These samples were collected by *S.S. Tansei-maru* of the Ocean Research Institute, University of Tokyo, from the inner part of Toyama Bay (Fig. 23) from depths between 45 m and 1,020 m during June 1 to 5, 1975 (KT75-6 Cruise). The characters of these samples are shown in Table 4.

Various depth assemblages have been recognized on the basis of depth distribution and abundance of the species present (Fig. 24a and Table 5). Among these species, there are some which have a well-defined depth range; *Brizalina karreriana* (Brady), for example, is restricted to the sublittoral zone, while *Adercotryma glomerata* (Brady) is restricted to bathyal depths. Also, *Ammonia takanabensis* (Ishizaki), *Bolivina robusta* Brady and *Cibicides refulgens* are more frequent in shallower bottoms. *Bolivina decussata*, *Cribrostomoides* sp., *Pseudoparella takayanagii* (Iwasa) and *Trochammina japonica* Ishiwada are abundant in deeper waters.

Fig. 24b shows a general tendency observed in the bathymetric distribution of foraminiferal fauna. It seems that, due to dissolution of calcareous test, the ratio of

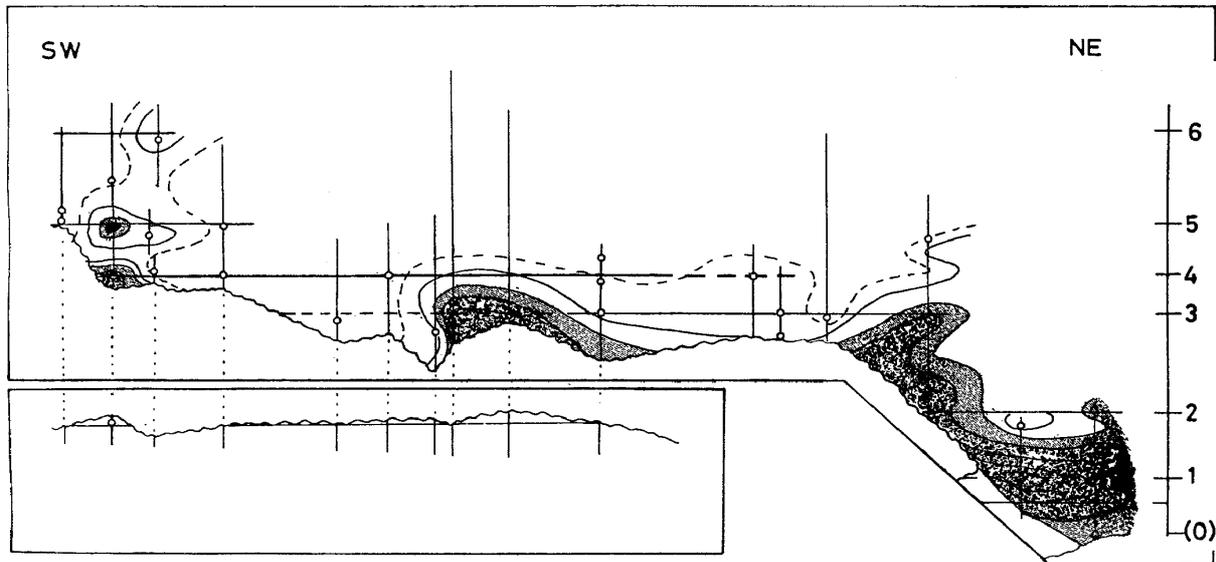
Globigerina pachyderma

Fig. 22a. Isopleth section of total *Globigerina pachyderma* (sinistral and dextral) versus total planktonics.

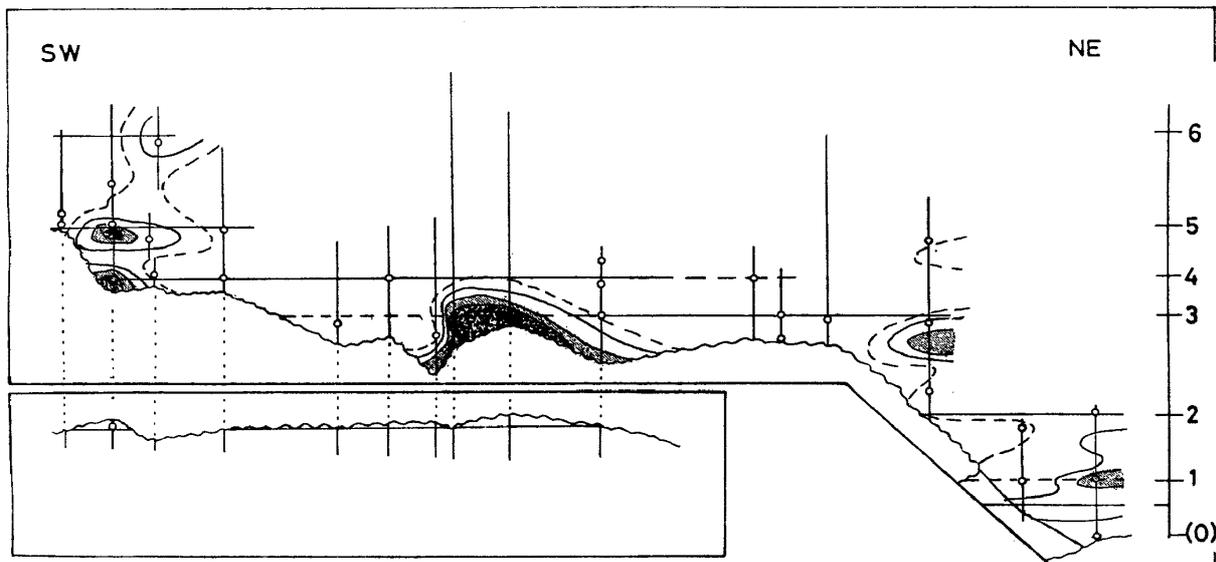
Globigerina pachyderma (sinistral)

Fig. 22b. Isopleth section of sinistral *Globigerina pachyderma* versus total planktonics.

calcareous benthonic foraminifera to the total benthonics is very small at bathyal depths. Foraminiferal number (both planktonic and benthonic) is the largest at about 100 m depth.

Globigerina bulloides and *G. incompta* occur independently of depth, while the distribution of *G. pachyderma* is more related to depth, and is more frequent in areas deeper than 200 m. The ratio of coiling-direction of *G. pachyderma* varies from station to station.

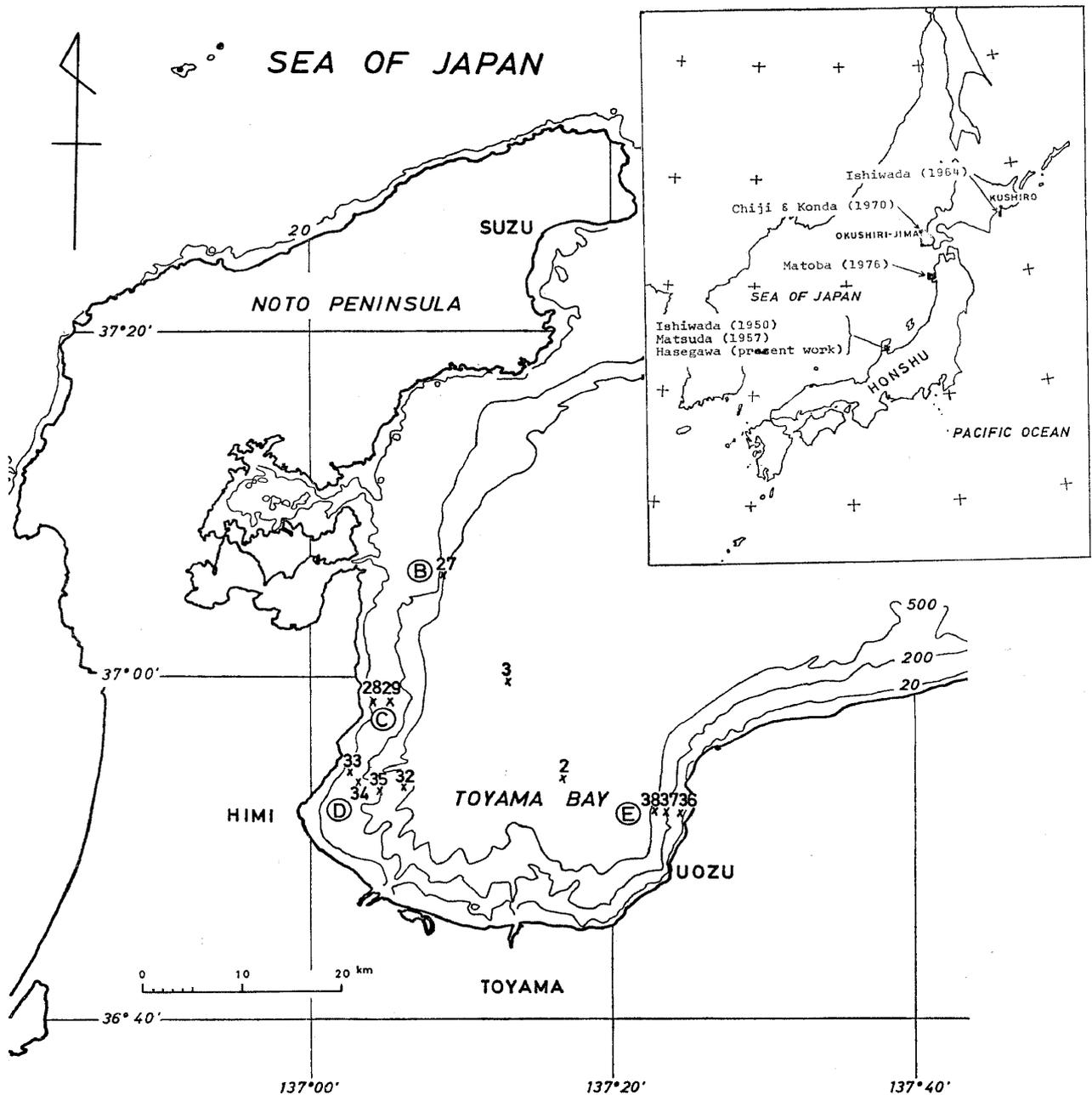


Fig. 23. Index map showing locations of areas of some previous studies referred to and the present work. Locations of bottom samples from Toyama Bay are also shown.

FAUNAL ANALYSIS AND DISCUSSION

i) Benthonic fauna

The cluster analysis (Ujiié and Kusukawa, 1969) was made for determining sample groups (Q-mode) based on the relative frequency of benthonic foraminiferal species in each sample. The correlation coefficient was applied to find out similarity between samples. The clustering was carried out by using the weighted pair group method with simple arithmetic averages (see Sokal and Sneath (1963) or Mello and Buzas (1968) for detailed explanation).

Table 4. Characteristics of the bottom samples collected by *S.S. Tansei-maru* from Toyama Bay.

STATION	POSITION		DEPTH (m)	SAMPLER	MATERIALS
	Lat. (N)	Long. (E)			
B-3-27	36°06.8' 36°06.5'	137°08.9' 137°08.7'	375-245	dredge	bluish gray mud with glauconite and rounded gravels of siltstone
C-1-28	36°58.4' 36°58.7'	137°04.3' 137°04.3'	45	dredge	brown sandy mud with mollusca and rounded gravels of siltstone
C-2-29	36°58.2' 36°58.5'	137°05.4' 137°05.3'	100	dredge	grayish brown sand with mollusca
D-1-32	36°52.7' 36°52.5'	137°05.6' 137°05.3'	390-430	dredge	grayish brown mud with gravels of siltstone
D-2-33	36°54.4'	137°02.4'	60	grab	bluish gray mud with subround to subangular gravels of siltstone
D-3-34	36°53.9'	137°03.2'	105	grab	bluish gray sandy mud with mollusca
D-4-35	36°53.3'	137°04.7'	235	grab	yellowish brown mud with gravels of siltstone
E-1-36	36°52.1'	137°24.5'	60	grab	dark gray mud
E-2-37	36°52.1'	137°23.6'	195	grab	yellowish brown sandy mud with rounded gravels
E-3-38	36°52.3'	137°22.8'	570	grab	yellowish brown mud
St-2	36°54.2' 36°54.7'	137°17.0' 137°17.0'	970-960	dredge	dark gray mud with many chips of wood
St-3	37°00.1' 37°00.2'	137°13.4' 137°13.8'	1,010- 1,020	dredge	bluish gray mud with many chips of wood

The result of the Q-mode cluster analysis obtained by this study is shown in a dendrogram of Fig. 25. The samples were classified into five groups at the level of 0.28 correlation coefficient in the dendrogram. One of the five groups was divided into two subgroups at the level of 0.45 correlation coefficient. These levels were chosen based on a break in the frequency distribution of fusing (Ujiié and Kusukawa, 1969; Ujiié, 1973). Here, four groups and two subgroups of the samples are named "Type I to Type VI". Because each group or subgroup is distinguished on the basis of similarity of species frequency in each sample, each of the grouping may involve a distinct faunal characteristic. These types are described briefly in the following lines together with characteristic species which are confined to or predominante in each type.

Type I is represented by samples NDU1, YBT10 and HNY1. These samples are all from the lowest horizon in the respective sections (Fig. 9). The samples are of "stI or stII" sediment type, and their mud contents range from 50 to 80%. In Type I, the characteristic is the concurrence of *Globocassidulina depressa*, *Bolivina decussata*, *Epistominella pulchella* Husezima and Maruhasi, *Trifarina kokozuraensis* (Asano) and *Uvigerina akitaensis* (Figs. 19a, b).

Type II is represented by samples mainly from the Nadaura area (YBT and NDU sections) and the lower part of the Asahiyama section (ASH). Their sediment type is of "ssII" to "stII" and the mud contents range from 40 to 80%. In Type II, the number of

Table 5. Recent benthonic foraminiferal assemblages of Toyama Bay.

I.	<i>Rectobolivina raphana</i> - <i>Bolivina robusta</i> Assemblage (45-105 m)
	<i>Ammonia takanabensis</i> : common
	<i>Bolivina robusta</i> : abundant
	<i>Cibicides lobatulus</i> : common
	<i>Cibicides refulgens</i> : common
	<i>Globocassidulina depressa</i> : common
	<i>Globocassidulina subglobosa</i> : common
	<i>Rectobolivina columellaris</i> : common, E traverse only
	<i>Rectobolivina raphana</i> : abundant
I-1.	<i>Brizalina karrerianum</i> Sub-assemblage (45-60 m)
I-2.	<i>Bulimina marginata</i> Sub-assemblage (100-105 m)
II.	<i>Globocassidulina subglobosa</i> - <i>Uvigerina akitaensis</i> Assemblage (195-335 m)
	<i>Astrononion gallowayi</i> : few
	<i>Bolivina decussata</i> : common
	<i>Cibicides lobatulus</i> : common
	<i>Globobulimina auriculata</i> : abundant, E traverse only
	<i>Globocassidulina depressa</i> : common
	<i>Globocassidulina subglobosa</i> : common
	<i>Pseudoparella nipponica</i> : common
	<i>Pseudoparella takayanagii</i> : abundant
	<i>Rectobolivina columellaris</i> : common, E traverse only
	<i>Trifarina kokozuraensis</i> : common
	<i>Uvigerina akitaensis</i> : common
III.	<i>Bolivina decussata</i> - <i>Trifarina kokozuraensis</i> Assemblage (390-570 m)
	<i>Adercotryma glomerata</i> : abundant
	<i>Bolivina decussata</i> : common
	<i>Pseudoparella nipponica</i> : few
	<i>Pseudoparella takayanagii</i> : abundant
	<i>Trifarina kokozuraensis</i> : common
	<i>Trochammina japonica</i> : abundant
	<i>Uvigerina akitaensis</i> : common
IV.	<i>Trochammina japonica</i> - <i>Cribrostomoides</i> Assemblage (960-1020 m)
	<i>Adercotryma glomerata</i> : common
	<i>Cribrostomoides</i> sp.: common
	<i>Trochammina japonica</i> : very abundant

species and species diversity (H') attain on the average 43 and 2.86, respectively, and usually these values are larger than those of other types. Furthermore, ratio of planktonic to total foraminifera is the highest in Type II. In this type, *Bolivina* sp. A, *Elphidium bartletti*, *Pseudoparella naraensis* Kuwano and *Trifarina kokozuraensis* are common in occurrence (Figs. 19c, d). The species characteristic in Type I also occur in Type II, though fewer in number. In addition, *Globocassidulina subglobosa*, *Pseudoparella nipponica* (Kuwano), *Bolivina pseudoplicata* Heron-Allen and Earland and *Cibicides subpraecinctus* (Asano) occur in almost all the samples of Type II.

Type III is represented by samples ASH15, SZK1, SZK3 and IKB6, all consist of calcareous sandstones and come mostly from the northern part of the Oyabe area. These samples belong to "sdI" to "sdII" and their mud contents are very low (20 to 30%). In the case of Type III, species diversity (H') and equitability (J') are lower (2.12 and 0.66, respectively), on the average, than in the other types. In Type III, the characteristic is the consistent concurrence of *Cibicides subpraecinctus*, *Elphidium crispum* and

Globocassidulina subglobosa (Figs. 19e, f). *Neoconorbina stachi*, *Cassidulina yabei*, *Cibicides lobatulus* and *Hanzawaia nipponica* are also diagnostic form frequently recognized in the said type.

Type IV is represented by samples ASH17, TGW10 and OMM-T. The sediment types of these samples vary from "sdIV" to "ssV" and their mud contents range from 25 to 55%. In Type IV, *Cassidulina yabei* (Fig. 19g) is dominant and *Gavelinopsis praegeri* (Fig. 19h) and *Ammonia beccarii* (Linné) are common in occurrence.

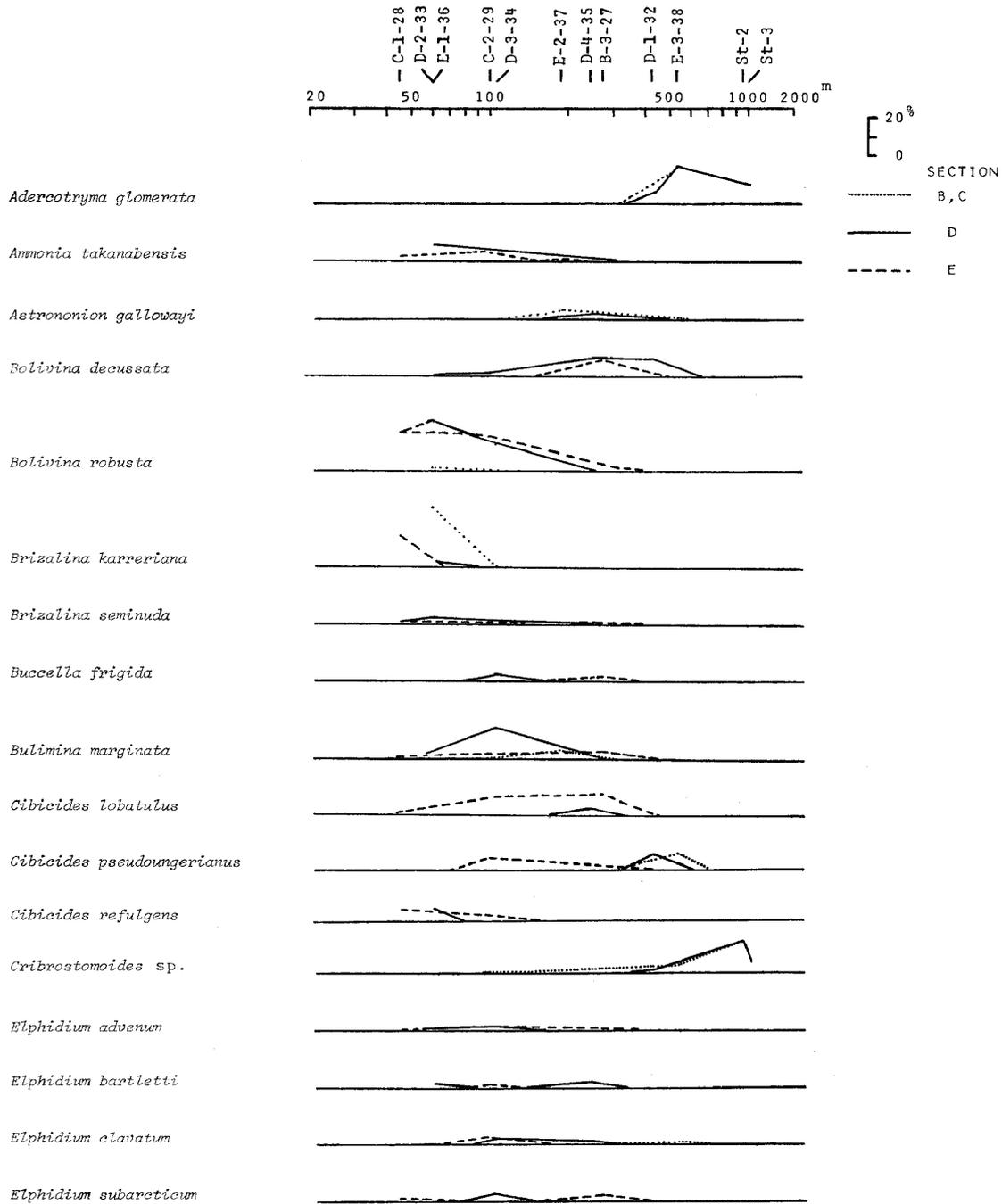


Fig. 24a. Bathymetric distribution of Recent foraminifera from Toyama Bay. Selected benthonic species.

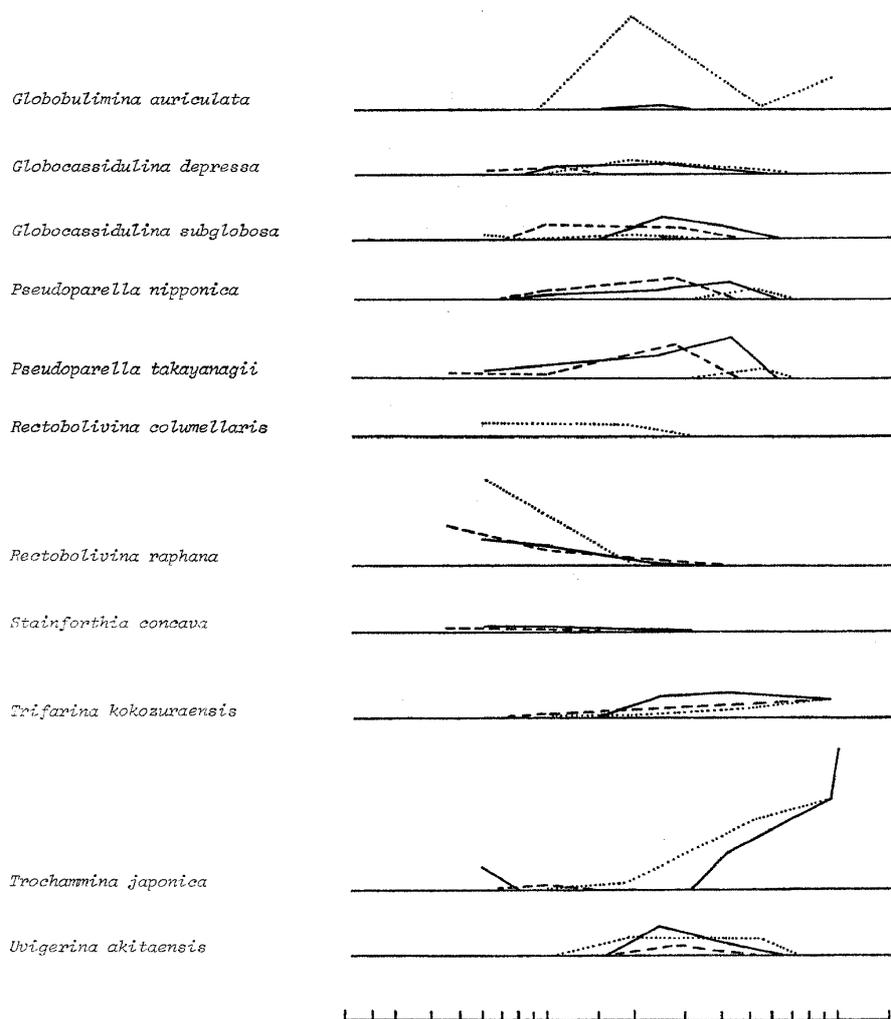


Fig. 24a. (Continued)

In Type IV, OMM-T somewhat differs from the others in common occurrence of *Amphicoryna fukushimaensis* (Asano) and *Baggina notoensis* Asano. A cause of this difference is considered that OMM-T is from the shell bed of the Takakubo Formation and its sediment type is thus peculiar as shown in Fig. 13c. The Takakubo Formation consists largely of mudstones yielding only siliceous microfossils. The other unit of this formation is a shell bed consisting of coarse-grained sediments. Thick-walled species and water-worn specimens of foraminifera are fairly abundant in the shell bed. As compared to other samples, smaller specimens of foraminifera are few. These features indicate that the foraminifera were also transported along with the sediments forming the shell bed.

Type V is represented by only sample TGW4, which consists of calcareous sandstone ("sdII"). In Type V, species diversity (H') and equitability (J') are 1.93 and 0.61, respectively, and these are the lowest value among all the samples analysed. In Type V, *Islandiella translucens* (Cushman and Hughes) (Fig. 19i) is dominant and *Gavelinopsis praegeri* is common in occurrence. In addition, the species characteristic in Type IV also occur except *Cassidulina yabei* which is very rare in the said type.

Type VI is represented by samples mainly from the Kanazawa area and the southern Oyabe area. The sediment type of these samples has a wide variation from "sdI" to "stII"

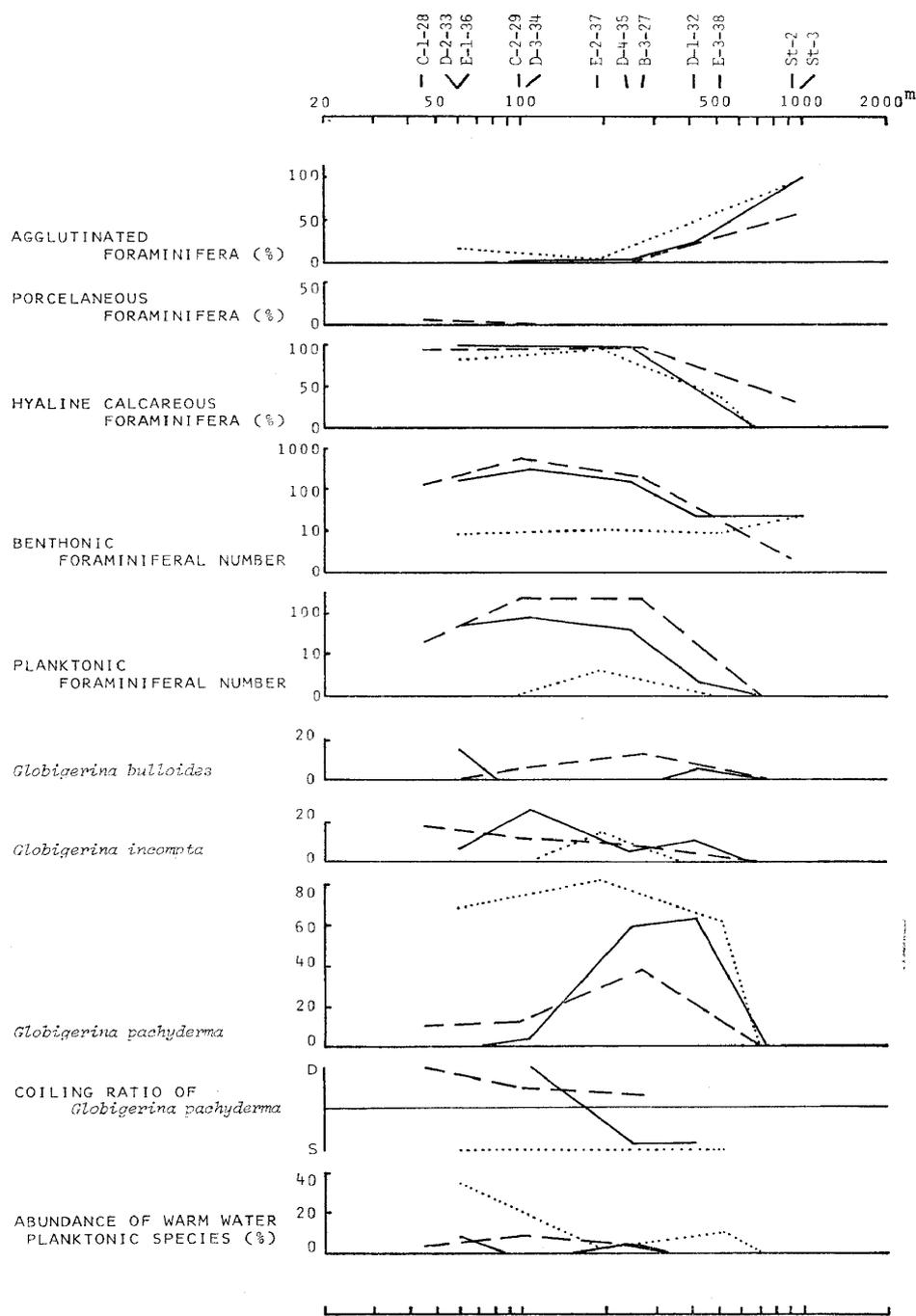


Fig. 24b. Bathymetric distribution of Recent foraminifera from Toyama Bay. General tendency.

and their mud contents range from 10 to 60%. In Type VI, the characteristic is consistent occurrence of *Elphidium bartletti*, *E. clavatum*, *E. subarcticum*, *Bolivina robusta*, *Ammonia japonica* and *Hanzawaia nipponica* (Fig. 19d, j-1, n). In addition, *Buccella frigida*, *B. inusitata* (Fig. 19m), *B. nipponica* (Husezima and Maruhasi), *Bulimina marginata* d'Orbigny, *Pseudorotalia gaimardii compressiuscula* (Brady) and *Rectobolivina raphana* (Parker and Jones) are found frequently.

In order to deduce paleoenvironmental conditions from the distributional pattern of each benthonic species, the technique of the principal factor analysis (Harman, 1960, 1967;

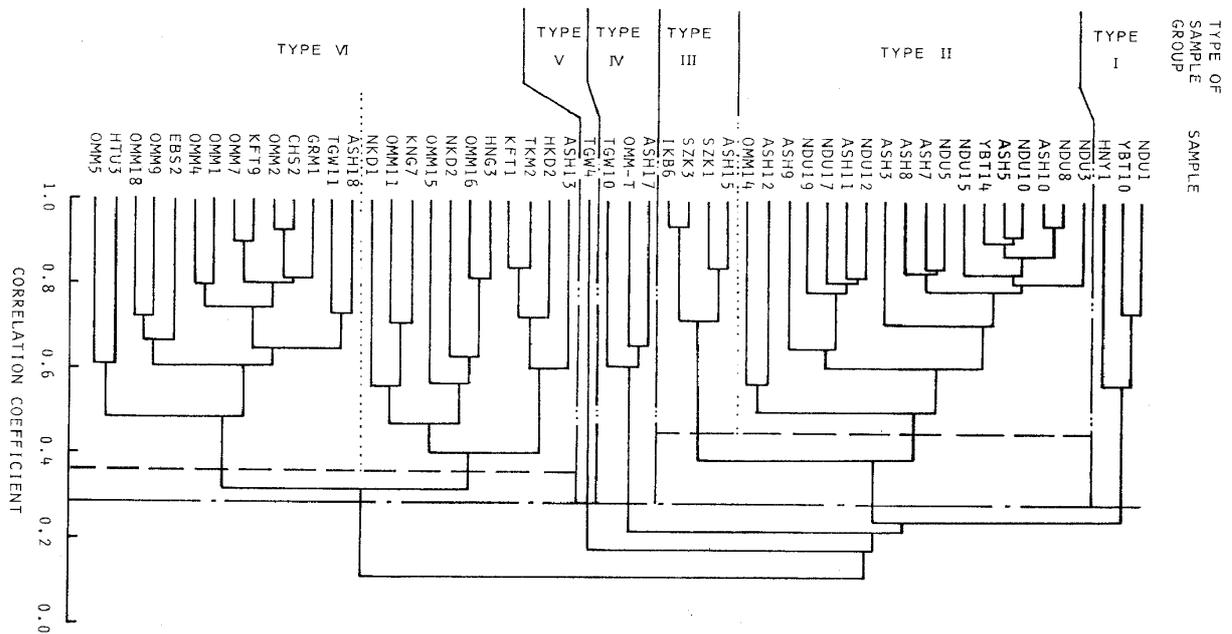


Fig. 25. Dendrogram for Q-mode cluster analysis of benthonic fauna from the Himi Group.

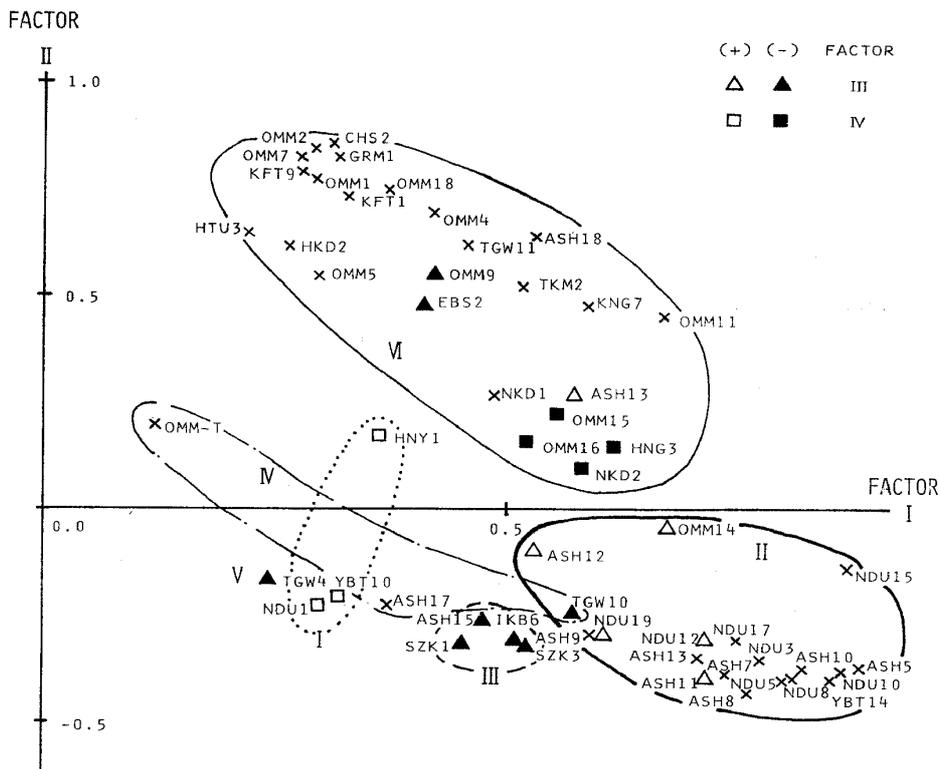


Fig. 26. Plots of samples (X) on the coordinate of Factor I-Factor II after Q-mode factor analysis. Samples of loading more than 0.3 in absolute, in respect to Factor III or IV, are plotted by other symbols (Δ , \blacktriangle , \square , \blacksquare). Each encircled group is determined after Q-mode cluster analysis.

Table 6. List of benthonic foraminiferal taxa used for factor analysis

<i>Ammonia beccarii</i> (Linné)	<i>Epistominella pulchella</i> Husezima and Maruhasi
<i>A. japonica</i> (Hada)	<i>Fissurina</i> spp.
<i>A. takanabensis</i> (Ishizaki)	<i>Florilus manpukuzeiensis</i> (Otuka)
<i>Astrononion aomoriense</i> Asano	<i>Gaudryina arenaria</i> Galloway and Wissler
<i>Bolivina decussata</i> Brady	<i>Gavelinopsis praegeri</i> (Heron-Allen and Earland)
<i>B. pseudoplicata</i> Heron-Allen and Earland	<i>Glabratella subopercularis</i> (Asano)
<i>B. robusta</i> Brady	<i>Globocassidulina depressa</i> (Asano and Nakamura)
<i>B. sp. A</i>	<i>G. nipponensis</i> Eade
<i>Brizalina seminuda</i> Cushman	<i>G. subglobosa</i> (Brady)
<i>Buccella depressa</i> Andersen	<i>Guttulina</i> spp.
<i>B. frigida</i> (Cushman)	<i>Hanzawaia nipponica</i> Asano
<i>B. inusitata</i> Andersen	<i>Hyalinea</i> sp. A
<i>B. makiyamai</i> Chiji	<i>Islandiella californica</i> (Cushman and Hughes)
<i>B. nipponica</i> (Husezima and Maruhasi)	<i>I. helenae</i> Feyling-Hanssen and Buzas
<i>Bulimina marginata</i> d'Orbigny	<i>I. norcrossi</i> (Cushman)
<i>B. sp. A</i>	<i>I. translucens</i> (Cushman and Hughes)
<i>Buliminella elegantissima</i> d'Orbigny	<i>Melonis parkerae</i> (Uchio)
<i>Cancris auriculus</i> (Fichtel and Moll)	<i>Neoconorbina stachi</i> (Asano)
<i>Cassidulina yabei</i> Asano and Nakamura	<i>Nonionella stella</i> Cushman and Moyer
<i>Cibicides aknerianus</i> (d'Orbigny)	<i>Nonionellina labradorica</i> (Dawson)
<i>C. lobatulus</i> (Walker and Jacob)	<i>Oridorsalis umbonatus</i> (Reuss)
<i>C. refulgens</i> Montfort	<i>Pseudononion japonicum</i> Asano
<i>C. subpraecinctus</i> (Asano)	<i>Pseudoparella naraesis</i> Kuwano
<i>Criboelphidium yabei</i> (Asano)	<i>P. nipponica</i> (Kuwano)
<i>Elphidium advenum</i> (Cushman)	<i>P. takayanagii</i> (Iwasa)
<i>E. advenum</i> (Cushman) var. C	<i>Pseudopolymorphina</i> spp.
<i>E. articulatum</i> (Terquem)	<i>Pseudorotalia gaimardii</i> compressiuscula (Brady)
<i>E. bartletti</i> Cushman	<i>Rectobolivina raphana</i> (Parker and Jones)
<i>E. clavatum</i> Cushman	<i>Reussella aculeata</i> Cushman
<i>E. crispum</i> (Linné)	<i>Rosalina bradyi</i> (Cushman)
<i>E. fimbriatulum</i> (Cushman)	<i>Sigmoilopsis schlumbergeri</i> (Silvestri)
<i>E. jenseni</i> (Cushman)	<i>Spiroplectammina higuchii</i> Takayanagi
<i>E. simplex</i> Cushman	<i>Trifarina hughesi</i> (Galloway and Wissler)
<i>E. subarcticum</i> Cushman	<i>T. kokozuraensis</i> (Asano)
<i>E. subgranulosum</i> Asano	<i>Uvigerina akitaensis</i> Asano

Imbrie and Purday, 1962) was applied. The computer program written by Niitsuma, Sakai and Hattori (1971) was used for the factor analysis in this work.

In compliance with the limit of species number designated on the program for the analysis, 70 species or species groups were selected from among the taxa occurring with higher frequency in plural samples (Table 6). The result of the Q-mode factor analysis (sample to sample) is shown in Table 7 and Fig. 26, and the distributions of the factor loadings of the first four factors are shown in Figs. 27a-d. In Fig. 26, the abscissa and ordinate represent the original loadings of Factor I and II, respectively. Each sample was plotted with mark "X" according to its factor loading. The sample having the loading of Factor III greater than 0.3 is shown by an open triangle and the one having the loading less than -0.3 is shown by a close triangle. Similarly, the sample with the loading of Factor IV greater than 0.3 is shown by an open square and when it is less than -0.3, by a closed square. In Fig. 26, it is recognized that there are some relations between the sample group types and the four different factors established by the factor analysis. These relations are:

Table 7. First four factor loadings for 54 samples.

SAMPLE	FACTOR I	FACTOR II	FACTOR III	FACTOR IV	SAMPLE	FACTOR I	FACTOR II	FACTOR III	FACTOR IV
NDU1	0.29770	-0.22908	-0.08870	0.66573	HNY1	0.36053	0.17244	0.02165	0.58158
NUD3	0.77287	-0.35600	-0.11473	0.11676	HKD2	0.26188	0.61433	0.11499	0.07542
NUD5	0.79600	-0.40158	0.02274	0.10746	GRM1	0.31906	0.82597	-0.08391	0.22427
NUD8	0.80866	-0.39719	-0.18408	-0.01029	HTU3	0.21977	0.65247	-0.02581	0.09250
NUD10	0.85926	-0.38641	0.07610	0.00493	TKM2	0.51683	0.51843	0.17634	-0.03833
NDU12	0.71161	-0.30608	0.47265	-0.02728	KFT1	0.32855	0.72819	0.16393	0.07455
NDU15	0.86602	-0.13699	-0.11144	-0.01377	KFT9	0.28132	0.79023	-0.20285	0.16909
NUD17	0.74935	-0.30885	0.25390	0.28738	HNG3	0.61557	0.14641	0.14766	-0.51866
NUD19	0.60655	-0.29525	0.48845	0.37504	KNG7	0.58782	0.47666	0.12928	-0.03964
YBT10	0.31875	-0.20791	0.23600	0.66110	CHS2	0.31335	0.85180	-0.04981	0.12188
YBT14	0.84963	-0.40050	-0.01489	0.03378	OMM-T	0.11959	0.20267	-0.29305	-0.24602
ASH3	0.70399	-0.34804	-0.18940	0.09123	OMM1	0.29574	0.77738	0.01231	0.21173
ASH5	0.88012	-0.36978	-0.01963	0.10802	OMM2	0.29399	0.84582	-0.08577	0.16044
ASH7	0.73753	-0.37802	0.03990	0.07963	OMM4	0.42155	0.69489	-0.27388	0.05423
ASH8	0.76223	-0.42913	0.02673	0.11197	OMM5	0.29719	0.54746	-0.14115	-0.23805
ASH9	0.59114	-0.29004	0.16203	0.04938	OMM7	0.27851	0.82285	-0.14611	0.22709
ASH10	0.81656	-0.37727	-0.25229	-0.02933	OMM9	0.42148	0.54773	-0.39327	-0.03291
ASH11	0.71464	-0.39524	0.32692	0.08245	OMM11	0.66996	0.45244	0.22780	-0.08587
ASH12	0.52964	-0.10200	0.42787	-0.23060	OMM14	0.67371	-0.04697	0.40872	-0.22373
ASH13	0.57528	0.26328	0.36794	-0.19544	OMM15	0.55155	0.21733	0.17955	-0.33322
ASH15	0.47516	-0.26300	-0.65192	-0.12648	OMM16	0.51965	0.15509	0.08601	-0.54631
ASH17	0.37186	-0.21878	0.02169	-0.05543	OMM18	0.37430	0.74593	-0.11428	-0.17779
ASH18	0.52858	0.62931	0.20863	0.12613	NKD1	0.48744	0.26740	0.20324	-0.26540
EBS2	0.41023	0.47687	-0.46102	0.03935	NKD2	0.58115	0.09288	0.26626	-0.44639
SZK1	0.45277	-0.31398	-0.70217	-0.03439					
SZK3	0.52539	-0.32218	-0.63493	-0.02259					
IKB6	0.50683	-0.30782	-0.62370	-0.00522					
TGW4	0.24494	-0.16443	-0.32988	0.01794					
TGW10	0.57285	-0.24189	-0.38292	-0.35056					
TGW11	0.45753	0.62064	-0.07189	0.16722					

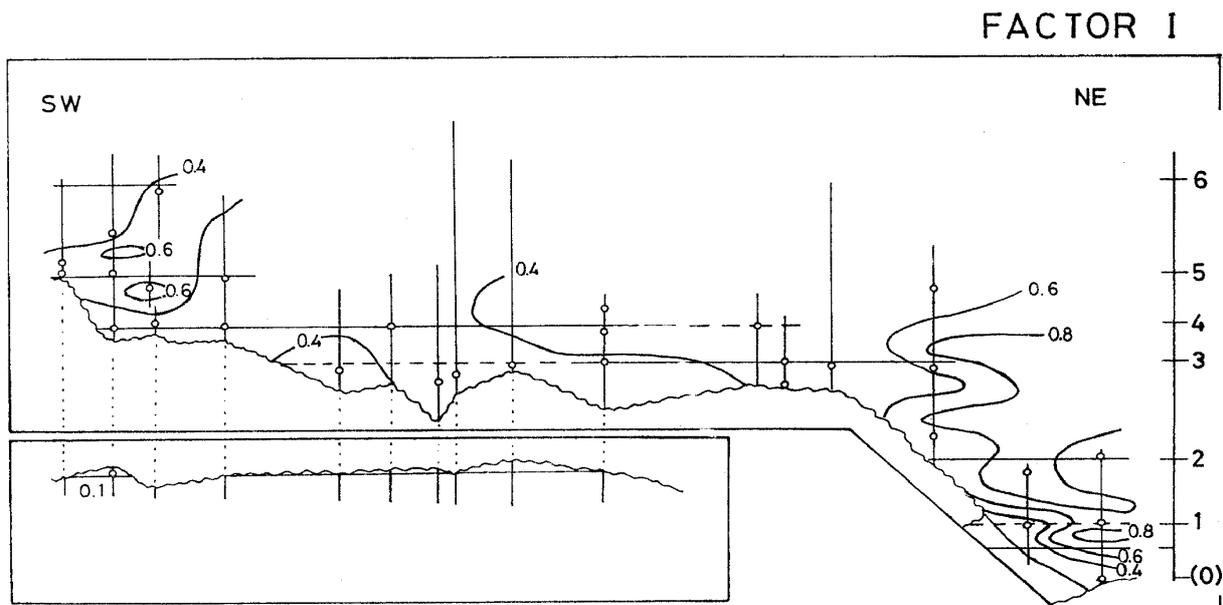


Fig. 27a. Isopleth section of loading of Factor I.

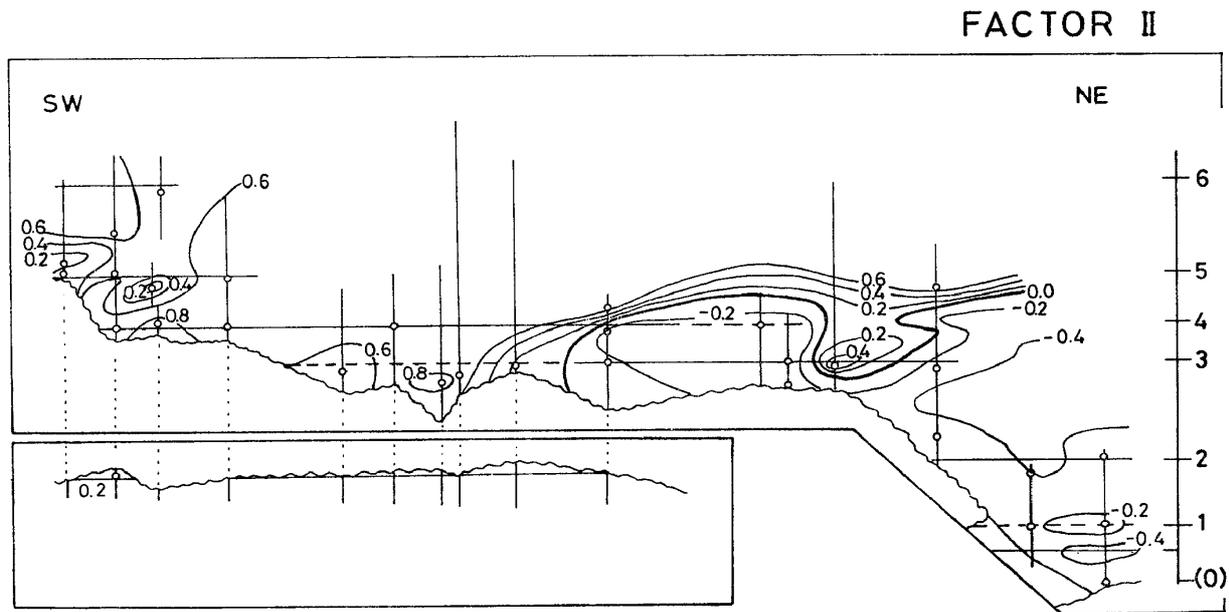


Fig. 27b. Isopleth section of loading of Factor II.

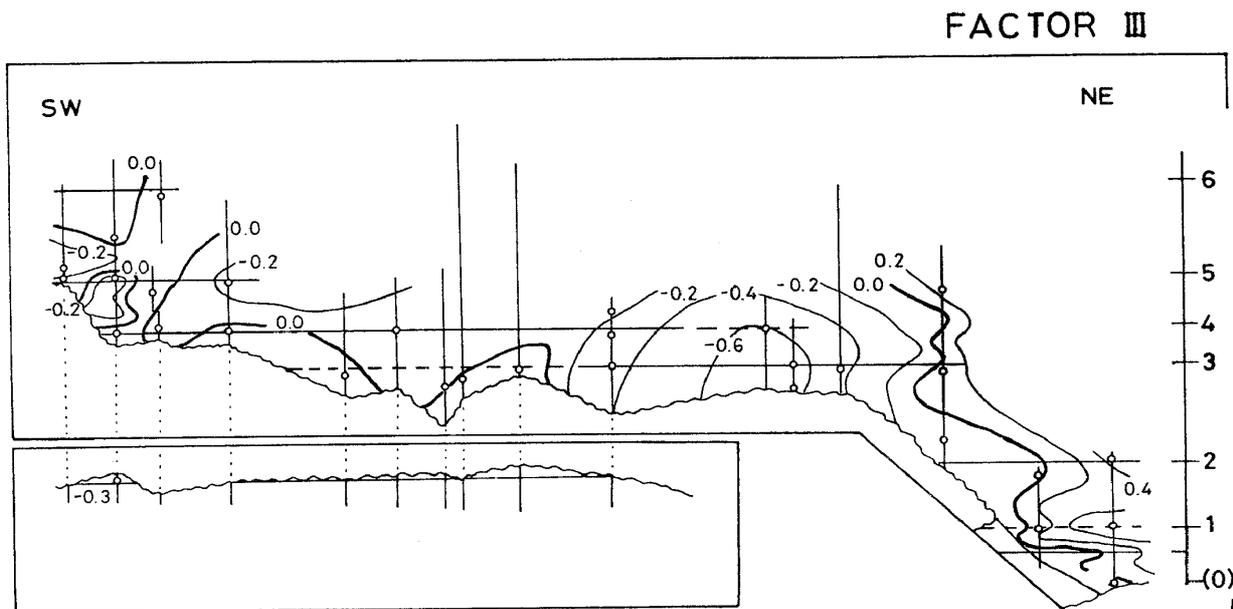


Fig. 27c. Isopleth section of loading of Factor III.

- (1) The loadings of Factor I of all the samples are positive. The loadings on Type I, Type IV and Type V are lower, whereas on Type II the value is relatively high.
- (2) The opposition of Type VI versus Type II and Type III on Factor II.
- (3) The opposition of Type II versus Type III, Type IV and Type V on Factor III.
- (4) The opposition of Type I versus Type VI on Factor IV.

It is recognized that Factors I and II are correlative to the frequency distribution of some of the species which occurs in most of the samples. Particularly, the relative frequencies of *Elphidium bartletti* and *E. subarcticum* are closely correlative to factors I and II, respectively (Figs. 28 and 29). The sum of eigen-values of the first two factors exceeds

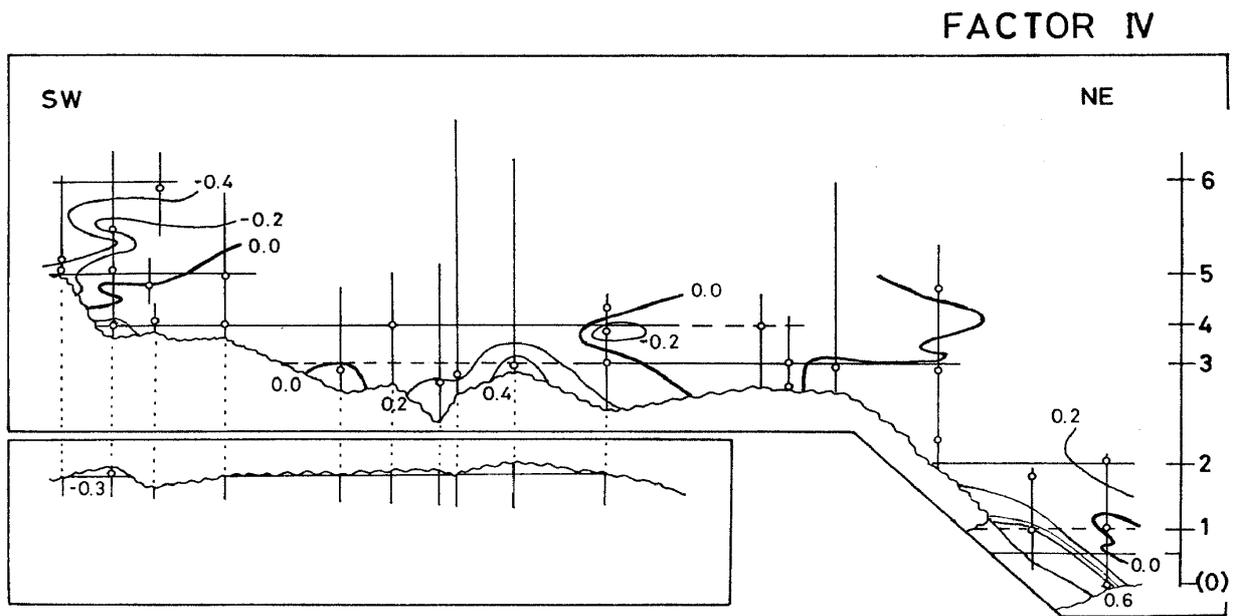


Fig. 27d. Isopleth section of loading of Factor IV.

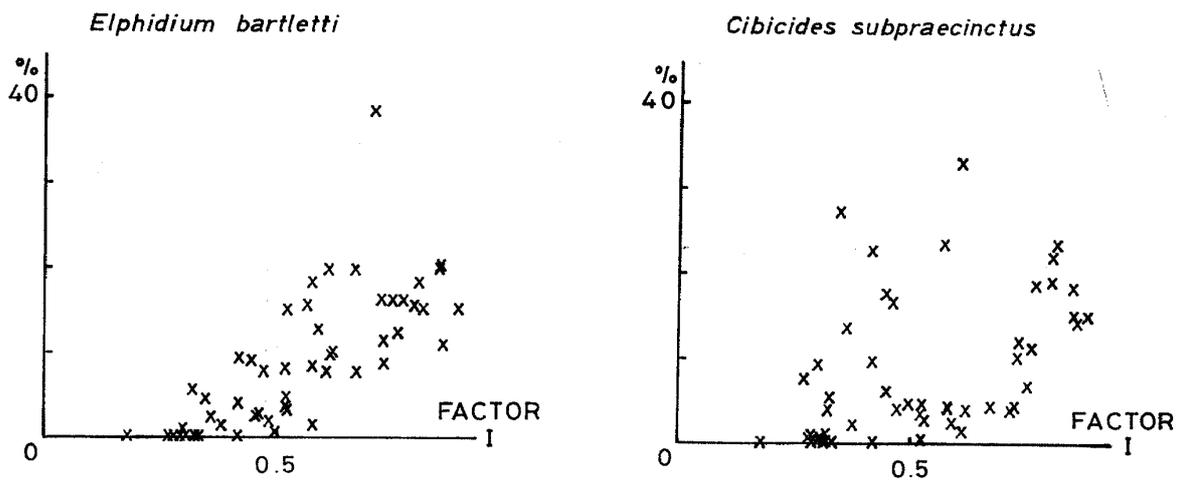


Fig. 28. The relationship between the loadings of Factor I and relative frequency of *Elphidium bartletti* and of *Cibicides subpraecinctus*.

Table 8. First six eigen-values and their percentages in Q-mode factor analysis.

FACTOR	EIGEN-VALUE	PERCENTAGE
I	16.928	31.4
II	11.650	21.6
III	4.355	8.1
IV	3.203	5.9
V	2.765	5.1
VI	1.799	3.3
⋮	⋮	⋮
SUM	54.000	100.0

50% of the total variance (Table 8). Therefore, both Factors I and II are the most important factor. The samples belonging to Type I, Type IV and Type V, particularly sample OMM-T (of Type IV), have the low loadings of Factors I and II. Hence, these samples are quite unique among the samples of various sample types.

The frequency distribution of a few species is correlated to the loading of Factor III. It is also noticed that there is a similarity in the distribution pattern of the loading of Factor III (Fig. 27) and the mud content (Fig. 12).

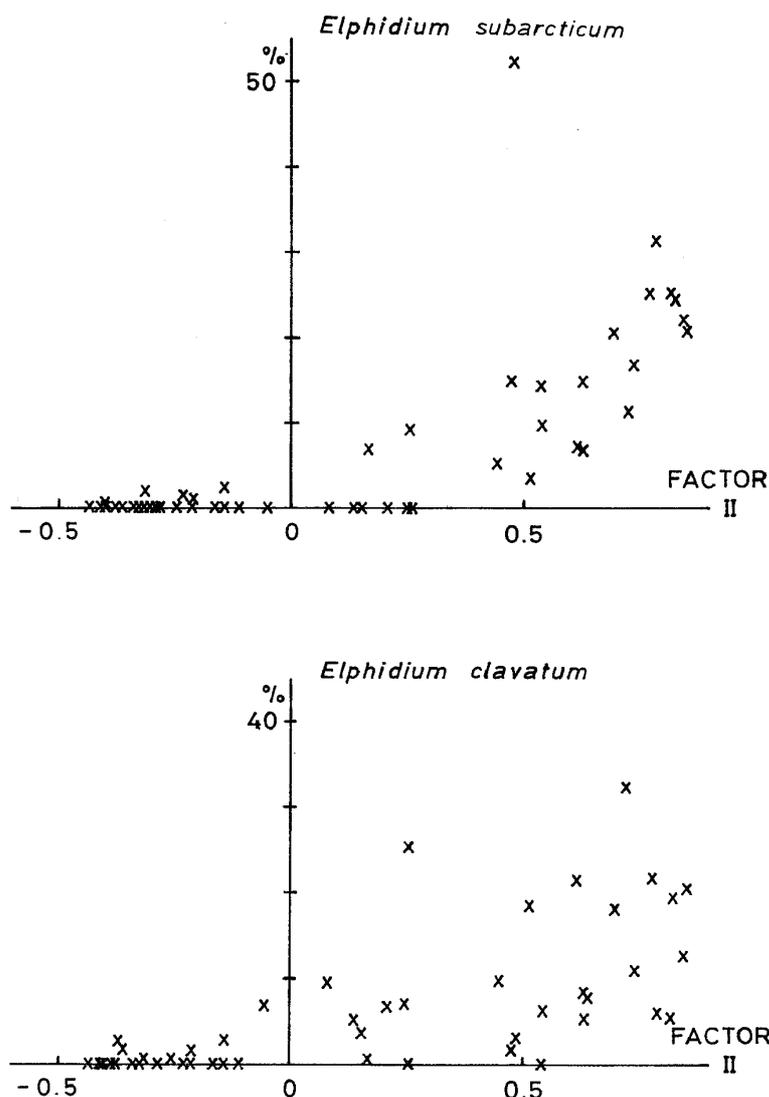


Fig. 29. The relationship between the loadings of Factor II and relative frequency of *Elphidium subarcticum* and of *Elphidium clavatum*.

On Factor IV, *Bolivina decussata*, *Epistominella pulchella*, *Globocassidulina depressa*, *Trifarina kokozuraensis* and *Uvigerina akitaensis* consistently occur in samples which have a high positive loading. *Ammonia japonica*, *Bulimina marginata*, *Elphidium clavatum* and *Hanzawaia nipponica* commonly occur in samples of high negative loading. Factor IV might represent the water depth or water mass, as mentioned in the chapter after discussing the analysis of modern fauna.

ii) Modern fauna

Modern fauna of Toyama Bay is divided into four assemblages (I to IV) and one of them (I) is subdivided into two (I-1 and I-2). The characteristic species of these assemblages are shown in Table 5.

Many previous investigators of the modern Sea of Japan fauna have mentioned the relationship between the fauna and oceanographic conditions (Ishiwada, 1950; Matsuda, 1957; Matoba and Nakagawa, 1972; Matoba, 1976). Oceanographic conditions of the Sea of Japan are summarized by Hidaka (1966). The warm Tsushima Current, originating in the East China Sea and fed mostly by a branch of the Kuroshio Current, flows northeastward along the southeastern border of the Sea of Japan. This warm current, about 200 m in thickness, consists of the "Surface Water" and the "Middle Water" and flows over the deep water, called the Japan Sea Proper Water (Hidaka, 1966). These waters are separated from one another by two distinct thermocline, namely the Upper Thermocline and Lower Thermocline (see left column of Fig. 30).

The characteristic of assemblages and their mutual relations reported by previous authors from the Sea of Japan and Toyama Bay are briefly mentioned below. The papers referred here are those by Ishiwada (*op. cit.*) and Matsuda (*op. cit.*), both dealing with Toyama

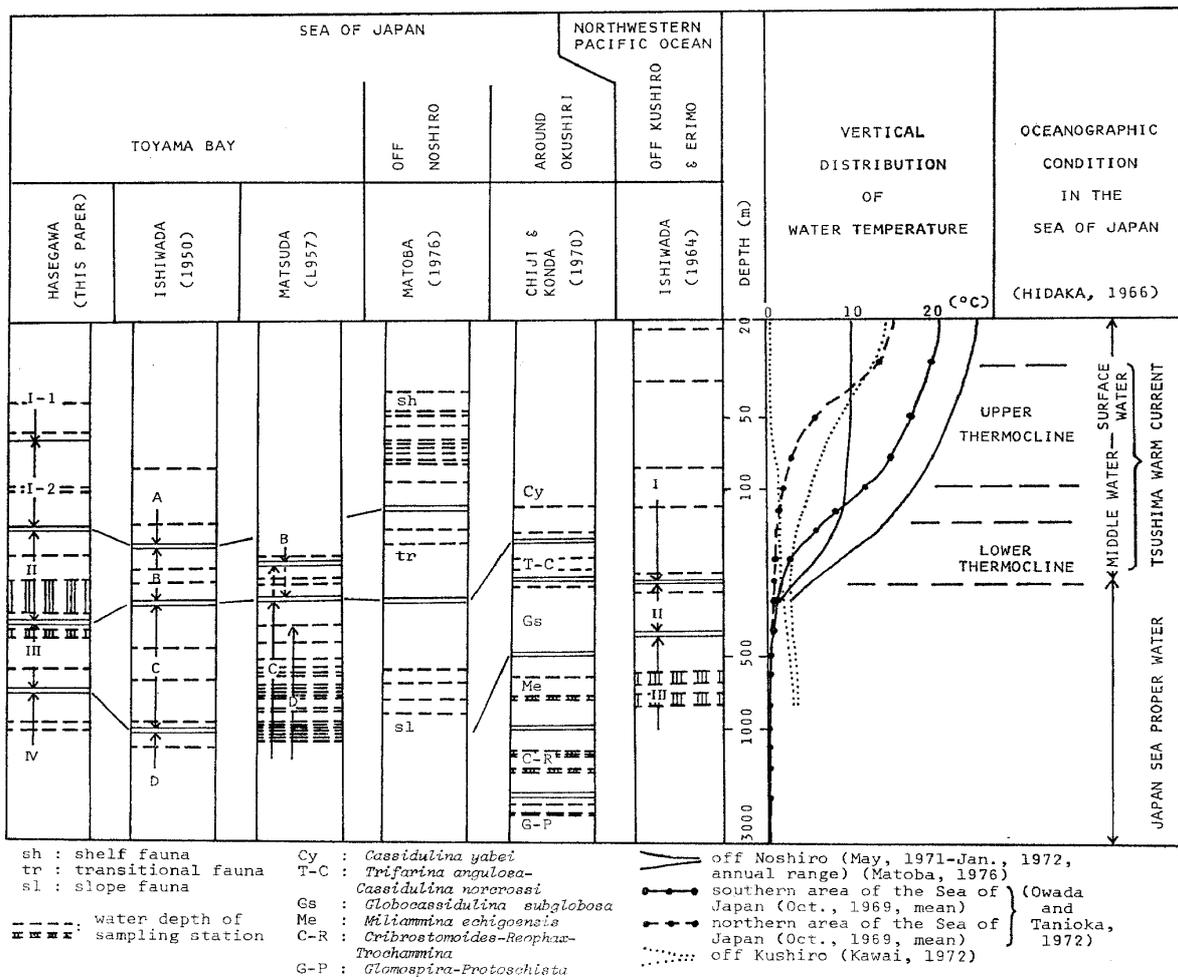


Fig. 30. Summary of depth assemblages of benthonic foraminifera reported from various seas surrounding the northern Japan.

Bay; Matoba (*op. cit.*), off Noshiro, and Chiji and Konda (1970) around Okushiri Island, all of the Sea of Japan. In addition, the report on the fauna off Kushiro in the northwest Pacific by Ishiwada (1964) is also referred (Figs. 23 and 30).

I. *Rectobolivina raphana-Bolivina robusta* Assemblage (45–105 m)

I-1 *Brizalina karreriana* Sub-assemblage (45–60 m)

This is the first report of an assemblage from depths shallower than 80 m in Toyama Bay. This assemblage differs from both Ishiwada's A Assemblage (*Siphogenerina raphana-Bulimina marginata*) and Matsuda's B Type Assemblage (*Cibicides cf. refulgens-Bulimina marginata-Bolivina robusta*) which are the shallowest assemblage in their studies.

Besides being affected by the warm Tsushima Current, this assemblage may be influenced by the influx of water from land areas and by a great seasonal variation of temperature and salinity, as noticed among the shelf fauna of the nearshore areas off Noshiro (Matoba, *op. cit.*).

I-2 *Bulimina marginata* Sub-assemblage (100–105 m)

This assemblage is the same as Ishiwada's A Assemblage and Matoba's *Rectobolivina raphana-Bulimina marginata* Assemblage of the shelf fauna and is affected by the Middle Water of the warm Tsushima Current. Around Okushiri Island, no such assemblage is found.

Ishiwada (1964) described a benthonic assemblage off Kushiro together with assemblages from other area off the Pacific Coast of Japan. The Kushiro fauna consists of *Buccella frigida*, *Buliminella elegantissima*, *Elphidium clavatum* and *Nonionella stella* in shallower waters (22 and 36 m in water depth) and *Trifarina kokozuraensis*, *Buccella inusitata*, *Elphidium bartletti*, *Pseudoparella naraensis*, *Nonionellina labradorica* and *Uvigerina akitaensis* in deeper waters (82 to 228 m in depth).

The above-mentioned assemblage is similar to that of the cold Oyashio Water in the Northwest Pacific (Ishiwada, *op. cit.*). The species recorded in the deeper part off Kushiro are also found in the deeper water of the Sea of Japan.

II. *Globocassidulina subglobosa-Uvigerina akitaensis* Assemblage (195–335 m)

This assemblage is the same as Ishiwada's B Assemblage (*Cassidulina*) and Matsuda's B Type Assemblage (*Cibicides cf. refulgens-Bulimina marginata-Bolivina robusta*) and is the fauna in the Lower Thermocline between the warm Tsushima Current and the Japan Sea Proper Water.

Transitional fauna off Noshiro also coincides with that of the Lower Thermocline, but differs from *Globocassidulina subglobosa-Uvigerina akitaensis* Assemblage in being composed of mainly arenaceous species such as *Reophax* spp. and *Trochammmina* spp. (Matoba, *op. cit.*). The *Cassidulina yabei* Assemblage around Okushiri Island has been correlated with Ishiwada's B Assemblage by Chiji and Konda (*op. cit.*). However, the former differs from the *Globocassidulina subglobosa-Uvigerina akitaensis* Assemblage of Toyama Bay in the absence of *Trifarina kokozuraensis* and *U. akitaensis*.

III. *Bolivina decussata-Trifarina kokozuraensis* Assemblage (390–570 m)

This assemblage is the same as Ishiwada's C Assemblage (*Angulogerina-Uvigerina*) and Matsuda's C Type Assemblage (*Epistominella takayanagii-Bolivina decussata-Angulogerina kokozuraensis*). Although this assemblage is slightly different from the slope fauna off Noshiro in faunal composition, and from the *Trifarina angulosa-Cassidulina norcrossi* Assemblage and the *Globocassidulina subglobosa* Assemblage both around Okushiri Island, yet every assemblage seems to be affected by the Japan Sea Proper Water.

IV. *Trochammina japonica-Cribrostomoides* sp. Assemblage (960–1020 m)

This assemblage is the same as Ishiwada's D Assemblage (Arenaceous forms) and Matsuda's D Type Assemblage (*Trochammina-Haplophragmoides*) and is similar to the *Cribrostomoides-Reophax-Trochammina* Assemblage around Okushiri Island.

According to Matsuda (*op. cit.*), C Type and D Type Assemblages are found in the same water mass, and their bathymetrical ranges overlap with each other (*i.e.*, C Type=250 to 1200 m; D Type=deeper than 400 m). Furthermore, he mentioned that the differentiation of two biofacies is due to geographical factors and not due to depth of water.

However, in the present work and also in Ishiwada's (1950), such overlapping is not found. This may be due to a very few samples from depths greater than 400 m which have been studied or due to the lack of specific bottom configuration which gives rise to upwelling as inferred by Matsuda (*op. cit.*).

iii) Analogy between modern and fossil fauna

As stated above, it is recognized that the distribution of the Sea of Japan fauna corresponds to the distribution of water masses, and many of Recent species are also present in the assemblage from the Himi Group. Because the Himi Group is of Pliocene and Pleistocene age, the species of the Himi Group which are common in both the Himi Group and Recent bottom sediments of the Sea of Japan may have been equally affected by the water having similar oceanographic features of today. In the following lines, characters of the ancient sea water which controlled the fauna of the Himi Group are reconstructed on the basis of analogy between the modern and the fossil faunas.

Among the characteristic assemblages of each Type, it is found that the assemblage of Type I resembles the fauna of the Japan Sea Proper Water and that of the Subarctic bathyal zone, because it contains abundant deep water species. Furthermore, the shallow water species of the Oyashio region also occupy fairly large part in Type I. Hence, the assemblage of Type I corresponds to the fauna between deep and shallow waters of the Subarctic region.

The assemblage in Type II somewhat resembles that in Type I. However, the former differs from the latter in showing a decrease in the individual numbers of deep water species such as *Bolivina decussata* and *Uvigerina akitaensis*. Therefore, the assemblage of Type II is shallower than that of Type I.

The assemblage in Type III is similar to the fauna of the Lower Thermocline in the Sea of Japan, because it consists of a few shallow and warm species together with many deep water species.

The assemblage in Type IV is somewhat like the fauna between the Subarctic neritic and upper bathyal waters off Kushiro (Ishiwada, 1964), as those in Type I and Type II. However, the assemblage of Type IV differs from the Subarctic fauna in having a dominant occurrence of *Cassidulina yabei*, common occurrence of *Hanzawaia nipponica* and *Cibicides lobatulus*, and by the lack of *Uvigerina akitaensis*. On the other hand, that of Type IV differs from the transition fauna off Okushiri Island except for the dominance of *Cassidulina yabei*. Thus, no fauna similar to that of Type IV is found in any sample studied. No such fauna has been reported by other workers mentioned on p. 42 either.

In the Type V, dominant species is *Islandiella translucens*, but *Cassidulina yabei* which is dominated in Type IV is very few. Except this point, the assemblage of Type V has similar species composition to that of Type IV. As the case of the assemblage of Type IV, modern fauna resembling that of Type V is not found.

With the result of cluster analysis, Type VI can be subdivided into two subgroups (Fig. 25) at the level of 0.35. The difference between these two subgroups is due to a

distinct difference in the distributional pattern between *Elphidium bartletti*+*E. clavatum* and *E. subarcticum* (Table 2). Both these species are, however, reported from the Arctic to Subarctic regions only. Here, because of their identical distribution, two subgroups are left as one group (Type VI). The assemblage in Type VI is similar to the fauna of the Middle Water in the Sea of Japan in view of the concurrence of *Ammonia japonica*, *Bulimina marginata* and *Rectobolivina raphana*. On the other hand, this assemblage also resembles the inner fauna of the Subarctic region being characterized by *E. bartletti*, *E. clavatum*, *E. subarcticum*, *Buccella frigida* and *Buliminella elegantissima*.

Hence, the assemblage of Type VI may be assumed to be a mixture of faunas of shallow, warm and shallow, cold waters. Examples of such waters are the Middle Water in the Sea of Japan and the shallow Oyashio water, respectively. In this assemblage, however, the cold water elements seem to dominate over the warm water ones.

With regard to Factor IV in the Q-mode factor analysis the samples having a high positive loading belong to Type I, whereas those with a high negative value belong to Type VI. The assemblage of the former consists mainly of deep and cold water species, while the latter's one includes shallow water species (both warm and cold) as mentioned above. Hence, Factor IV seems to represent the water depth. In Fig. 33, positive value of Factor IV is plotted showing deeper depth and negative value shallower water.

Planktonic forms *Orbulina universa* and *Globorotalia inflata* were found in samples of types II, III and VI. Both of these species are thick-walled in types II and III, but they are thin-walled in Type VI.

Among the living species, it is known that a juvenile stage *Globorotalia* lives in shallow water and later it changes the habitat to a deeper water and becomes encrusted with calcite in the adult stage (Bé, 1960; Bé and Lott, 1964). The same observation was made on *O. universa* by Bé *et al.*, 1973. On re-examining the specimens collected by *S.S. Soyo-maru* from the continental shelf bordering Japan (Asano, 1958), the present author found that *G. inflata* from shallower regions are non-crusted, whereas those from the deeper part are encrusted.

The presence of encrusted specimens found in types II and III suggests that these types may have been influenced by the intermediate water. So have Type I. Exclusive occurrence of non-crusted specimens in Type VI suggests a shallow water environment.

The relationship between the assemblages in different types and paleo-water masses is shown in Fig. 31. It is also observed that the distributional pattern of the types (Fig. 32) is very similar to that of the sediment types (Fig. 14) and mud content (Fig. 12). In the Kanazawa and southern Oyabe areas, the sediments are coarse-grained and having a low mud contents (see left part of Figs. 14 and 12), whereas in the Himi and Nadaura areas the sediments are fine-grained and show a higher mud contents. Sediments in the northern

TYPES OF SAMPLE GROUP	WATER MASS	
	WARM	COLD
	SHALLOW	DEEP
I		△ ○
II		○ △
III	△	○
IV, V	△	△
VI	△	○

△ : subordinate ○ : dominant

Fig. 31. Relation between the types of sample group of the Himi Group and paleo-water masses.

part of the Oyabe area are coarser than those in other areas. Although they seem to have been deposited in deep waters from the viewpoint of the fauna.

Scanning along the level of Horizon 3 in Fig. 32, the following facts are observed. The northeastern-most part of the Oyabe area was under the influence of a shallow water, while the north and south of this area were affected by the intermediate water. The northern area was occupied by a cold surface water, but on the contrary southern one was covered by a warm surface water. Such paleoceanographic difference is thought to be caused by a topographic high (northeastern-most Oyabe area). This topographic feature seems to correspond to the Kojiro Anticline extending westward from the northern Oyabe area to Mt. Hodatsu (Fig. 4; Ikebe *et al.*, 1951). The coarse-grained sediments and the presence of abundant organic detritus of the Zukawa Formation indicate that strong bottom currents were active during their deposition.

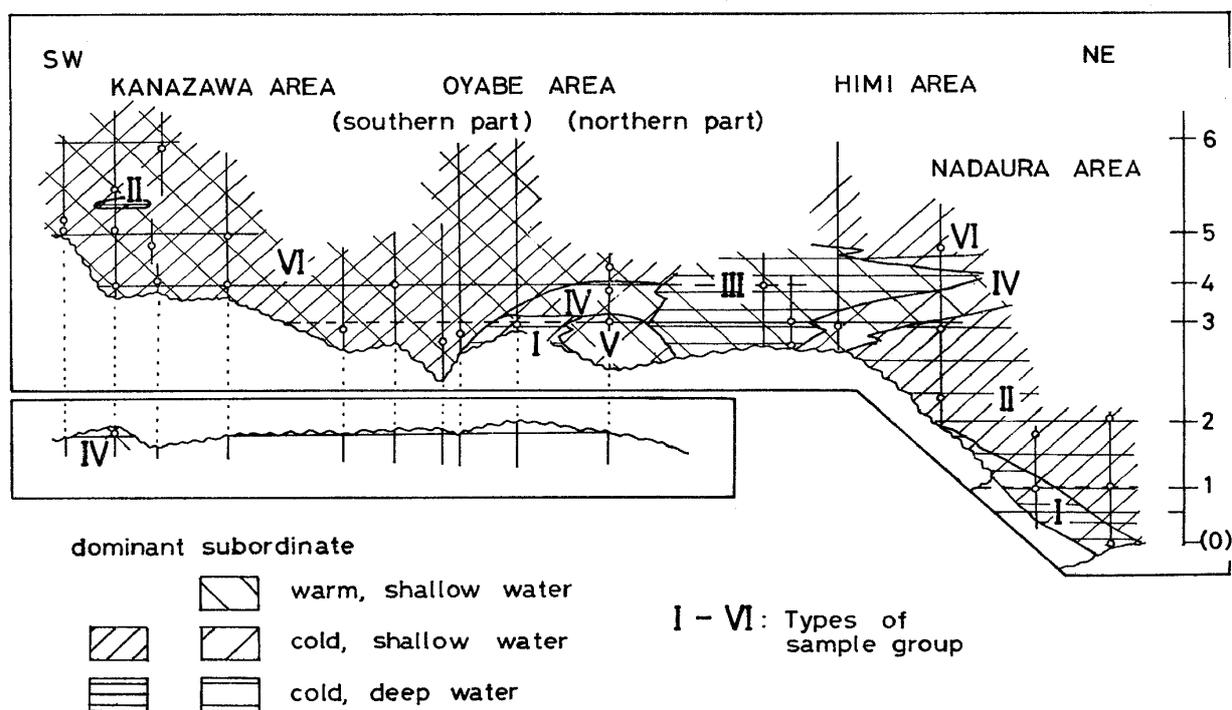


Fig. 32. Distribution of different types of sample group and paleo-water masses.

Fig. 33 is a composite chart showing sampling horizons, mud content, abundance of warm water planktonic species and other features observed in the Nadaura, Asahiyama and Omma sections. All these indices (*i.e.*, Factor IV, mud content and type of assemblage), which possibly are related to depth, suggest a decrease in water depth upward in the sections. This change in sediment type and ratios of planktonic versus total foraminifera show a similar tendency.

The occurrence of different assemblages is here interpreted to reflect changes in paleo-water masses. In the lower part of the sequence, influence of the intermediate water having characteristics between shallow cold and deep waters is suggested. In the same sequence, warm water planktonic species commonly occupy 5% of all planktonics. Furthermore, the right-coiling *G. pachyderma* are more common, suggesting that cold water flowed there was similar to the Transition water of the present time.

In the sequence above the Horizon 4, particularly in the Omma section, the

section). Hence, it is conceived that a water similar to the present Kuroshio Water or its branch (the warm Tsushima Current) flowed over the Hokuriku region. On the contrary, the left-coiling *G. pachyderma* dominates in the same part of the sequence, indicating the flow of waters having characters similar to those of the Subarctic water. Thus, during the deposition of the upper part of the Himi Group, temperature was lower than that in the lower sequence. Comparing the frequency of warm water planktonic species found in the Himi Group with that of the Sea of Japan, it is observed that the frequency is lower in the former. Hence, the inflow of warm water into the paleo-Sea of Japan is thought to have fluctuated with time during the past.

The conclusion derived from the planktonic fauna agrees with that based on the benthonics. Hitherto, the Omma-Manganzi Fauna has been interpreted to have been influenced by cold to temperate waters (Otuka, 1936, 1939; Chinzei, 1961). However, some contradictory evidence has been reported. Takayanagi (1950MS) recorded *Globorotalia menardii* (d'Orbigny) (= *G. cultrata*) from the middle part of the Omma Formation. Ogasawara (1977) found several warm water species from the uppermost part of the same formation. Besides, Minato *et al.* (1965) stated that episodic marine transgressions occurred at least twice during the Pliocene and that the warm water came into the Sea of Japan from the Pacific through a narrow channel between Korea and the Japanese Islands. The similar speculation about the paleo-Sea of Japan in Late Cenozoic has been taken by some authors such as Huzioka *et al.* (1970; glacial Pleistocene, the Kamayachi Formation of the Oga Peninsula), Huzioka (1972; lower Pliocene) and Matoba (1978; late Miocene to early Pleistocene—the Funakawa Stage to the Kitaura Stage).

Species diagnostic of warm-water environments are found in the entire sequence of the Omma Formation. The flow of warm water into the cold water regions must have been remarkable event during the Pliocene and pre-glacial Pleistocene. In the Oga Peninsula, warm water species are reported from the Wakimoto and Shibikawa formations (Takayanagi and Oba, 1966; Kitazato, 1975). Such warm-water species might be discovered from the Plio-Pleistocene strata developed along the borderland of the Sea of Japan and, if found, such species could be used for finer subdivisions of strata correlative with the Himi Group.

CONCLUSION

The results of the present study are summarized as follows:

(1) The Inazumi, Yabuta and Junicho formations in the Himi and Nadaura areas, the Zukawa Formation in the northern part of the Oyabe area, the Omma Formation in the southern part of the Oyabe and Kanazawa areas, the Nakagawa Sandstone Member and the Suginoya Siltstone Member of the "Himi Formation" near Hakui, and the Mita Sandstone Member of the "Himi Formation" near Yatsuo are all considered to belong to the Himi Group. Both the upper and lower contacts of the Himi Group are unconformable.

(2) With the help of key tephra, the stratigraphy of the Himi Group is established as follows:

i) The Yabuta Formation, which is distributed in the extreme northeast of the area studied, conformably overlies the Inazumi Formation, and the former is partially contemporaneous with the heterotopic facies of the latter.

ii) The lowermost part of the Junicho Formation is contemporaneous with the uppermost part of the Yabuta Formation.

iii) The Zukawa Formation is correlated with the upper part of the Junicho Formation.

iv) The lower part of the Omma Formation, which is distributed in the southern part of the area studied, and the middle and upper parts of the Zukawa Formation are contemporaneous.

(3) Judging from the vertical distribution of planktonic foraminifera and calcareous nannoplankton species in the composite sequence covering three main traverses of the Himi Group, the Pliocene/Pleistocene boundary is demarcated between ASH6 and ASH8 horizons in the middle part of the Asahiya section.

(4) The modern fauna of Toyama Bay is divided into four assemblages based on their bathymetric distribution. Among them, the shallowest one is further subdivided into two sub-assemblages. These assemblages coincide with the water masses of the Sea of Japan as follows:

- I. *Rectobolivina raphana-Bolivina robusta* Assemblage (45–105 m)
.....the Tsushima Warm Water
- I-1 *Brizalina karreriana* Sub-assemblage (45–60 m)the Surface Water
- I-2 *Bulimina marginata* Sub-assemblage (100–105 m)the Middle Water
- II. *Globocassidulina subglobosa-Uvigerina akitaensis* Assemblage (195–335 m)
.....the Lower Thermocline
- III. *Bolivina decussata-Trifarina kokozuraensis* Assemblage (390–570 m)
.....the Japan Sea Proper Water
- IV. *Trochammmina japonica-Cribrostomoides* Assemblage (960–1020 m)
.....the Japan Sea Proper Water

(5) A fossil benthonic foraminiferal fauna of the Himi Group is divided into six types (*i.e.*, Type I to Type VI) on the basis of cluster and factor analyses.

(6) The distribution pattern of shallower (influenced by shallow water only) and deeper regions (influenced by both shallow and deep waters), reconstructed from the foraminiferal evidence of the Himi Group, agrees closely with that based on sediment types. In the southern part of the area (the Kanazawa and southern Oyabe areas) mainly “sand” type of shallow-water facies was deposited. On the other hand, “sand” type of shallow-water facies but mixed with deep-water faunas was deposited in the central part (the northern Oyabe area). The northeastern part (the Himi and Nadaura areas) is represented by “sandy silt” and “silt” types and is considered to have deposited in deeper waters.

A study of the composite sequence made from three main sections indicates that the deep-water elements decrease upward. Judging from the distribution pattern of planktonic species, it is concluded that the lower part of the Himi Group was deposited under the influence of the Transition water and the upper part under the influence of the Subarctic water with an occasional influence of subtropical waters. Such an influence in the upper part of the Himi Group, particularly in the Omma Formation, is considered to have been greater in extent than the interpretation given by previous authors.

FAUNAL REFERENCE LIST

Foraminiferal species from the Himi Group and/or the Toyama Bay are alphabetically listed below, under the categories of benthonics and planktonics. The selected species are illustrated with the micrographs taken with scanning electron microscope or optical microscope in Plates 1 to 8. The original references are given for each of the species. Additional references are selected from those which remarks and illustrations were helpful for the present study. In addition, references concerning the changes in generic position of taxa are also listed. All types are catalogued and deposited in the Institute of Geology and Paleontology, Tohoku University.

Benthonic Foraminifera

- Adercotryma glomerata* (Brady)Pl. 3, figs. 1a, b.
Lituola glomerata Brady, 1878, Ann. Mag. Nat. Hist., London, ser. 5, v. 1, p. 433, pl. 20, figs. 1a-c.
Adercotryma glomerata (Brady), Loeblich and Tappan, 1952, Jour. Washington Acad. Sci., v. 42, no. 5, p. 141, figs. 1-4.
- Ammonia beccarii* (Linné)Pl. 6, figs. 3a-d.
Nautilus beccarii Linné, 1758, Syst. Nat., ed. 10, p. 710.
Ammonia beccarii (Linné), Frizzell and Keen, 1949, Jour. Pal., v. 23, no. 1, p. 106.
- Ammonia japonica* (Hada)Pl. 6, figs. 4a-c, 5.
Rotalia japonica Hada, 1931, Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.), v. 6, no. 3, p. 137, text-figs. 93a-c.
Ammonia japonica (Hada), Ujiie, 1963, Tokyo Kyoiku Daigaku, Sci. Rep., ser. C, no. 79, p. 236, pl. 2, figs. 3-4.
- Ammonia takanabensis* (Ishizaki)Pl. 6, figs. 6a-d.
Streblus takanabensis Ishizaki, 1948, Acta Geol. Taiwan, v. 2, no. 1, p. 57, pl. 1, figs. 5a-c.
Ammonia takanabensis (Ishizaki), Matoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 201, pl. 27, figs. 3a-c.
- Amphicoryna fukushimaensis* (Asano)Pl. 3, fig. 4.
Lagenonodo saria fukushimaensis Asano, 1949, Jour. Pal., v. 23, no. 4, p. 426, text-figs. 1 (4-11, 20, 21).
- Amphicoryna pauciloculata* (Cushman)
Nodosaria pauciloculata Cushman, 1921, U.S. Nat. Mus., Bull. 100, pt. 4, p. 205, pl. 36, figs. 10-12.
- Amphicoryna scalaris* (Batsch)
Nautilus scalaris Batsch, 1791, Conch. Seesandes, no. 4, pl. 2, figs. 4a, b.
Amphicoryna scalaris (Batsch), Barker, 1960, Soc. Econ. Pal. Min., Spec. Publ., no. 9, p. 134, pl. 63, figs. 28-31.
- Anomalinoidea* cf. *inversus* (Boomgaard)
Anomalina inversa Boomgaard, 1949, Utrecht Univ., Doctoral Dissertation, Utrecht, p. 149, pl. 13, figs. 7a-c (*vide* Ellis and Messina, 1950).
Anomalina flintii Asano (not of Cushman), 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 13, p. 14, figs. 8, 9.
This form resembles Boomgaard's figures in having a very compressed test, subacute periphery and strongly limbate sutures. However, the character of wall and umbilical area of the present specimen is not clear, because the specimen is secondarily encrusted with calcite.
- Astrononion aomoriense* Asano
Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 1, p. 5, figs. 25, 26.
- Astrononion australe* Cushman and Edwards, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 33, pl. 3, figs. 13, 14.
- Astrononion gallowayi* Loeblich and Tappan
Loeblich and Tappan, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 90, pl. 17, figs. 4-7.
- Astrononion* cf. *italicum* Cushman and Edwards
Cushman and Edwards, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 35, pl. 3, figs. 19, 20.
The present specimen differs from the typical one in having a smaller test.
- Astrononion stelligerum* (d'Orbigny)
Nonionina stelligera d'Orbigny, 1839, in Barker-Webb and Berthelot, Hist. Nat. Canaries, v. 2, pt. 2, Zool., p. 128, pl. 3, figs. 1, 2.
Astrononion stelligerum (d'Orbigny), Cushman and Edwards, 1937, Cushman Lab. Foram. Res., v. 13, pl. 31, pl. 3, figs. 7a, b.
- Astrononion umbilicatum* Uchio
Uchio, 1952, Jour. Japan. Assoc. Petrol. Technol., v. 17, p. 36, text-fig. 1.
- Baggina notoensis* AsanoPl. 4, figs. 12a-c.
Asano, 1953, Short Papers Inst. Geol. Pal. Tohoku Univ., no. 5, p. 10, pl. 3, figs. 17a-c.
- Baggina philippinensis* (Cushman)
Pulvinulina hauerii Brady (not of d'Orbigny), 1884 (part), Voy. Challenger, Rep., Zool., v. 9, p. 690, pl. 106, fig. 7 (not fig. 6).

- Pulvinulina philippinensis* Cushman, 1921, U.S. Nat. Mus., Bull. 100, p. 331, pl. 58, fig. 2.
Baggina philippinensis (Cushman), LeRoy, 1941, Colorado School Mines, Quart., v. 36, no. 1, p. 84, pl. 6, figs. 36, 37.
- Bigenerina nodosaria* d'Orbigny
Bigenerina (Bigenerina) nodosaria d'Orbigny, 1926, Ann. Sci. Nat. ser. 1, v. 7, p. 261, figs. 9-12.
Bigenerina nodosaria d'Orbigny, Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 369, pl. 4, figs. 14-18.
- Bolivina advena* Cushman
 Cushman, 1925, Cushman Lab. Foram. Res., Contr., v. 1, pt. 2, p. 29, pl. 5, figs. 1a, b.
- Bolivina albatrossi* Cushman
 Cushman, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 31, pl. 6, fig. 4.
- Bolivina decussata* Brady Pl. 3, figs. 6a, b, 7a, b.
 Brady, 1881, Quart. Jour. Micr. Sci., n. s., v. 21, p. 28; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 423, pl. 53, figs. 12, 13.
- Bolivina dilatata* Reuss
 Reuss, 1850, Denkschr. Akad. Wiss. Wien, v. 1, p. 381, pl. 48, figs. 15a-c.
- Bolivina plicatella* Cushman
Bolivina plicata Brady, Parker and Jones (not of d'Orbigny), 1888, Trans. Zool. Soc. London, v. 12, p. 122.
Bolivina plicatella Cushman, 1931, Florida State Geol. Surv., Bull., v. 4, p. 46, pl. 8, figs. 10a, b.
- Bolivina pseudoplicata* Heron-Allen and Earland Pl. 3, figs. 8a, b.
Bolivina pseudo-plicata (sic) Heron-Allen and Earland, 1930, Jour. Roy. Micr. Soc., v. 50, p. 81, pl. 3, figs. 36-40.
- Bolivina robusta* Brady Pl. 3, figs. 9a, b, 10a, b.
 Brady, 1881, Quart. Jour. Micr. Sci., London, v. 21, p. 27; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 421, pl. 53, figs. 7-9.
- Bolivina subspinescens* Cushman
 Cushman, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 48, pl. 7, fig. 5.
- Bolivina* sp. A Pl. 3, figs. 11a-c.
 This form is somewhat similar to *Bolivina decussata* Brady in its outline, but is distinguished from the latter by being smaller in size, lacking numerous well-developed, rounded lobes on the wall surface, and having limbate sutures in the early portion.
- Brizalina argentea* (Cushman)
Bolivina argentea Cushman, 1926, Cushman Lab. Foram. Res., Contr., v. 2, pt. 2, p. 42, pl. 6, fig. 5.
- Brizalina bradyi* (Asano)
Bolivina beyrichi Brady (not of Reuss, 1851), 1884, Voy. Challenger, Rep., Zool., v. 9, p. 422, pl. 53, fig. 1.
Bolivina bradyi Asano, 1938, Geol. Soc. Japan, Jour., v. 45, no. 538, p. 603, pl. 16, fig. 2.
- Brizalina compacta* (Sidebottom)
Bolivina roubsta Brady, var. *compacta* Sidebottom, 1905, Mem. Proc. Manchester Lit. Philos. Soc., v. 49, no. 5, p. 15, pl. 3, fig. 7.
- Brizalina karreriana* (Brady) Pl. 3, figs. 12a, b.
Bolivina karreriana Brady, 1881, Quart. Jour. Micr. Sci., v. 21, p. 28; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 424, pl. 53, figs. 19-21.
- Brizalina marginata* (Cushman)
Bolivina marginata Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 48, pl. 10, fig. 1.
- Brizalina pacifica* (Cushman and McCulloch)
Bolivina acerosa Cushman, var. *pacifica* Cushman and McCulloch, 1942, Allan Hancock Pacific Exped., v. 6, no. 4, p. 181, pl. 21, figs. 2, 3.
- Brizalina seminuda* (Cushman)
Bolivina seminuda Cushman, 1911, U.S. Nat. Mus., Bull. 71, pt. 2, p. 34, text-fig. 55.
- Brizalina silvestrina* (Cushman)
Bolivina silvestrina Cushman, 1936, Cushman Lab. Foram. Res., Spec. Publ., no. 6, p. 56, pl. 8, figs. 5a, b.

- Brizalina* cf. *subangularis* (Brady)
Bolivina subangularis Brady, 1881, Quart. Jour. Micr. Sci., v. 21, p. 29; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 427, pl. 53, figs. 32, 33.
 Although the present specimen is broken and lacks its adult stage, it resembles *Bolivina subangularis* Brady in numerous characters.
- Brizalina substriatula* (Asano)
Bolivina substriatula Asano, 1958, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 29, p. 23, pl. 4, figs. 11-14.
- Buccella depressa* Andersen
 Andersen, 1952, Washington Acad. Sci., Jour., v. 42, no. 5, p. 145, text-figs. 7-8.
- Buccella frigida* (Cushman)Pl. 7, figs. 1a-c.
Pulvinulina frigida Cushman, 1922, Canada. Biol., Contr., no. 9 (1921), p. 12.
Buccella frigida (Cushman), Andersen, 1952, Washington Acad. Sci., Jour., v. 42, no. 5, p. 144, figs. 4-6.
- Buccella inusitata* AndersenPl. 7, figs. 2a-c.
 Andersen, 1952, Washington Acad. Sci., Jour., v. 42, no. 5, p. 148, figs. 10-11.
- Buccella makiyamai* ChijiPl. 7, figs. 3a-d.
Eponides schreibersii Morishima and Chiji (not of Reuss), 1952, Mem. Coll. Sci., Univ. Kyoto, ser. B, v. 20, no. 2, pl. 2 (XIII), figs. 6a-c.
Buccella makiyamae (sic) Chiji, 1961, Prof. J. Makiyama, Mem. Vol., Kyoto, p. 234, text-figs. 2a-c, pl. 1, figs. 13-14.
- Buccella nipponica* (Husezima and Maruhasi)Pl. 7, figs. 4a-d.
Discorbis nipponica Husezima and Maruhasi, 1944, Jour. Shigenkagaku Kenkyusho (Res. Inst. Nat. Resour., Japan), v. 1, no. 3, p. 397, pl. 34, figs. 9a-c.
- Bulimina aculeata* d'Orbigny
 d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 269, no. 7; Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 406, pl. 51, figs. 7-9.
- Bulimina elongata subulata* Cushman and Parker
Bulimina elongata d'Orbigny var. *subulata* Cushman and Parker, 1937, Cushman Lab. Foram. Res., Contr., no. 13, p. 51, pl. 7, figs. 6, 7.
- Bulimina gibba* Fornasini
 Fornasini, 1902, Roy. Acad. Sci. Inst. Bologna, Mem. Sci. Nat., ser. 5, v. 9, p. 378, pl. 10, figs. 32, 34.
- Bulimina marginata* d'OrbignyPl. 4, figs. 5a, b, 6a, b.
 d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 405, pl. 51, figs. 3-5.
- Bulimina nojimaensis* Asano
 Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 2, p. 4, figs. 15, 16.
- Bulimina* sp. APl. 4, figs. 7a, b.
 This form is very similar to the specimen referred to as *Bulimina marginata* d'Orbigny by Higuchi [1956, Jour. Geol. Soc. Japan, v. 62, no. 725, p. 59, fig. 7(4)]. Compared with d'Orbigny's species, however, Higuchi's specimen and the specimen of the present author have a smaller test and strongly flared chambers. The present form is only tentatively identified under the name of *Bulimina* sp. A.
- Buliminella elegantissima* (d'Orbigny)Pl. 3, fig. 5.
Buliminella elegantissima d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 51, pl. 7, figs. 13, 14.
Buliminella elegantissima (d'Orbigny), Cushman, 1919, U.S. Nat. Mus., Proc., v. 56, p. 606.
- Cancris auriculus* (Fichtel and Moll)Pl. 5, figs. 1a-c.
Nautilus auriculus Fichtel and Moll, 1789, Testacea microscopica, p. 105, pl. 20, figs. a-f; 1803 var. α , p. 108, pl. 20, figs. a-c; var. β , p. 110, pl. 20, figs. d-f.
Cancris auricula (Fichtel and Moll) (sic), Cushman, 1927, Bull. Scripps Inst. Oceanogr., Tech. Ser., v. 1, no. 10, p. 164, pl. 5, fig. 10.
- Cassidulina asanoi* Uchio
 Uchio, 1950, Jour. Assoc. Petrol. Technol., v. 15, no. 4, p. 190, fig. 13 (in Japanese); 1951, Trans. Proc. Pal. Soc. Japan, N.S., no. 2, p. 39, pl. 3, figs. 2a, b.
- Cassidulina carinata* Silvestri
Cassidulina laeviaga d'Orbigny var. *carinata* Silvestri, 1896, Accad. Pont. Nouvi Lincei,

- Mem., v. 12, p. 104, pl. 2, fig. 10.
- Cassidulina yabei* Asano and NakamuraPl. 8, figs. 7a-c.
Asano and Nakamura, 1937, Japan. Jour. Geol. Geogr., v. 14, nos. 3-4, p. 145, pl. 14, figs. 1a, b.
- Cassidulinodites bradyi* (Norman)
Cassidulina bradyi Norman (MS), J. Wright, 1880, Proc. Belfast Nat. Field Club, App., p. 152; Cushman 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 128.
Cassidulinodites bradyi (Norman), Cushman, 1930, Florida State Geol. Surv., Bull., no. 4, p. 58, pl. 11, fig. 8.
- Cassidulinoides kattoi* (Takayanagi)
Cassidulina kattoi Takayanagi, 1953, Short Papers Inst. Geol. Pal. Tohoku Univ., no. 5, p. 34, pl. 4, fig. 10a, b.
Cassidulinoides kattoi (Takayanagi), Motoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 253, pl. 29, figs. 3a, b.
- Cassidulinoides parkerianus* (Brady)
Cassidulina parkeriana Brady, 1881, Quart. Jour. Micr. Sci., n.s., v. 21, p. 59; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 432, pl. 54, figs. 11-16.
Cassidulinodites parkerianus (Brady), Cushman, 1927, Cushman Lab. Forum. Res., Contr., v. 3, pt. 1, p. 84, pl. 18, figs. 4a-c.
- Chrysalidinella dimorpha* (Brady)
Chrysalidina dimorpha Brady, 1881, Quart. Jour. Micr. Sci., n. s., v. 21, p. 24; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 388, pl. 46, figs. 20-21.
Chrysalidinella dimorpha (Brady), Schubert, 1908, Neues Jb. Min. Geol. Pal., Beil.-Bd. 25, p. 242.
- Cibicides aknerianus* (d'Orbigny)
Rotalina akneriana d'Orbigny, 1846, Foram. Foss. Bas. Vienne, p. 156, pl. 8, figs. 13-15.
Cibicides aknerianus (d'Orbigny), Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 13, p. 17, figs. 30-32.
- Cibicides* cf. *floridanus compressus* Cushman and Renz
Cibicides floridanus (Cushman) var. *compressa* (sic) Cushman and Renz, 1941, Cushman Found. Forum. Res., Contr., v. 17, p. 26, figs. 9a, b.
This form resembles *C. floridanus compressus* in having a somewhat umbilicate ventral side, strongly curved and narrow chambers, limbate sutures on both sides and coarsely perforate wall. The former, however, is distinguished from the latter by having an almost flat dorsal side.
- Cibicides lobatulus* (Walker and Jacob)Pl. 6, figs. 1a-c.
Nautilus lobatulus Walker and Jacob, 1789, Adams Essays, p. 642, pl. 14, fig. 36.
Cibicides lobatula (Walker and Jacob) (sic), Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 118, pl. 21, figs. 3a-c.
- Cibicides pseudoungerianus* (Cushman)
Truncatulina ungeriana Brady (not *Rotalina ungeriana* d'Orbigny, 1826), 1884, Voy. Challenger, Rep., Zool., v. 9, p. 664, pl. 94, figs. 9a-c.
Truncatulina pseudoungeriana Cushman, 1922, U.S. Geol. Surv., Prof. Paper 129-E, p. 97, pl. 20, fig. 9.
Cibicides pseudoungeriana (Cushman) (sic), Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 124, pl. 22, figs. 3-7.
- Cibicides refulgens* MontfortPl. 6, figs. 2a-c.
Montfort, 1808, Conch. Syst., v. 1, p. 122.
Truncatulina refulgens (Montfort), Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 659, pl. 92, figs. 7-9.
- Cibicides subpraecinctus* (Asano)Pl. 5, figs. 9a-c.
Eponides subpraecinctus Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 14, p. 12, figs. 88-90.
Cibicides subpraecinctus (Asano), Matoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 253, pl. 28, figs. 3a-c.
- Clavulina yabei akiensis* Asano
Asano, 1936, Geol. Soc. Japan, Jour., v. 43, no. 519, p. 944, pl. 52, figs. 4, 5.

- Criboelphidium yabei* (Asano) Pl. 8, figs. 6a, b.
Elphidium yabei Asano, 1938, Geol. Soc. Japan, Jour., v. 45, no. 538, p. 589, pl. 14, figs. 9-10.
Criboelphidium yabei (Asano), Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 1, p. 11, figs. 64-65.
- Dentalina subsoluta* (Cushman)
Nodosaria soluta (Reuss), Brady (not *Dentalina soluta* Reuss), 1884, Voy. Challenger, Rep., Zool., v. 9, p. 503, pl. 62, figs. 13-16; pl. 64, fig. 28.
Nodosaria subsoluta Cushman, 1924, U.S. Nat. Mus., Bull. 104, pt. 4, p. 74, pl. 13, figs. 1.
Dentalina subsoluta (Cushman), Cushman and McCulloch, 1950, Allan Hancock Pacific Exped., v. 6, no. 6, p. 315, pl. 40, figs. 13-15.
- Discorbinella bertheloti* (d'Orbigny)
Rosalina bertheloti d'Orbigny, 1839, in Barker-Webb and Berthelot, Hist. Nat. Canaries, v. 2, pt. 2, Zool., p. 135, pl. 1, figs. 28-30.
Discorbinella bertheloti (d'Orbigny), Loeblich and Tappan, 1964, Treatise on Invertebrate Pal., Moore, R.C., ed., pt. C, Protista, 2, v. 2, p. C575, figs. 453 (3a-c).
- Discorbis* cf. *australis* Parr
Discorbina valvulata Brady (not *Rosalina valvulata* d'Orbigny), 1884, Voy. Challenger, Rep., Zool., v. 9, p. 644, pl. 87, figs. 5-7.
Discorbis australis Parr, Proc. Soc. Victoria, n. s., v. 44, p. 227, pl. 22, figs. 31a-c.
This form is similar to Brady's figures in having a nearly circular outline of test and a strongly recurved, thick and heavily limbate sutures on the spiral side, but differs from it in having wider chambers and recurved (not almost radial) sutures on the umbilical side.
- Discorbis* sp. A
This form is somewhat similar to *Rosalina vilardevoana* d'Orbigny, 1939, in some features of the test, but differs from it in having a umbonal plug, more limbate sutures and keeled periphery.
- Discorbitura* sp. A
This form is very similar to Cushman's figured specimen referred to as *Discorbis parisiensis* (d'Orbigny) (?) (Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 29, pl. 6, figs. 5a-c), except for the absence of radial corrugations on the ventral side.
- Dyocibicides biserialis* Cushman and Valentine
Cushman and Valentine, 1930, Contr. Stanford Geol. Dept., v. 1, no. 1, p. 31, pl. 10, figs. 1, 2.
- Dyocibicides perforata* Cushman and Valentine
Cushman and Valentine, 1930, Contr. Stanford Geol. Dept., v. 1, no. 1, p. 31, pl. 10, figs. 3a-c.
- Ehrenbergina bosoensis* Takayanagi
Takayanagi, 1951, Trans. Proc. Pal. Soc. Japan, N.S., no. 3, text-figs. 8a-c.
- Elphidium advenum* (Cushman) Pl. 7, figs. 6a, b.
Polystomella advena Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 56, pl. 9, figs. 11, 12.
Elphidium advenum (Cushman), Cushman, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 1, 2.
- Elphidium advenum* (Cushman) var. C
This form is characterized by its more strongly keeled periphery than that of the typical form and by its indistinct umbo, which is not depressed in umbilical region.
- Elphidium articulatum* (d'Orbigny)
Polystomella articulata d'Orbigny, 1839, Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 30, pl. 3, figs. 9, 10.
Elphidium excavatum (Terquem), Cushman (not *Polystomella excavata* Terquem, 1875), 1930 (part), U.S. Nat. Mus., Bull. 104, pt. 7, p. 21, pl. 8, figs. 4-7 (not 1-3).
Elphidium articulatum (d'Orbigny), Cushman, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 26, pl. 10, figs. 6-8.
- Elphidium bartletti* Cushman Pl. 7, figs. 7a, b.
Cushman, 1933, Smithsonian Misc. Coll., v. 89, no. 9, p. 4, pl. 1, figs. 9a, b; Loeblich and Tappan, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 96, pl. 18, figs. 10-14.
- Elphidium clavatum* Cushman Pl. 8, figs. 1a, b.
Elphidium incertum (Williamson) var. *clavatum* Cushman, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 20, pl. 7, figs. 10a, b.

- Elphidium crispum* (Linné)Pl. 8, figs. 2a, b.
Nautilus crispum Linné, 1758, Syst. Nat., ed. 10, p. 709.
Elphidium crispum (Linné), Cushman and Grant, 1927, San Diego Soc. Nat. Hist. Trans., v. 5, no. 6, p. 73, pl. 7, figs. 8a, b.
- Elphidium fimbriatulum* (Cushman)Pl. 8, figs. 3a, b.
Polystomella fimbriatula Cushman, 1918, U.S. Geol. Surv., Bull. 676, p. 20, pl. 8, fig. 5.
Elphidium fimbriatulum (Cushman), Cole, 1932, Florida Geol. Surv., Bull. 6, p. 33, pl. 4, fig. 7.
- Elphidium hokkaidoense* Asano
 Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 1, p. 8, figs. 44, 45.
- Elphidium jenseni* (Cushman)Pl. 8, figs. 4a, b.
Polystomella macella (Fichtel and Moll) var., Jensen, 1904, Linnean Soc. New South Wales Proc., v. 29, p. 817, pl. 23, fig. 4.
Polystomella jenseni Cushman, 1924, Carnegie Inst. Washington, Publ. 342, p. 49, pl. 16, figs. 4 (?), 6.
Elphidium jenseni (Cushman), Cushman, 1933, U.S. Nat. Mus., Bull. 161, pt. 2, p. 48, pl. 11, figs. 6, 7.
- Elphidium kusiroense* Asano
 Asano, 1938, Geol. Soc. Japan, Jour., v. 45, no. 538, p. 590, pl. 14, fig. 2.
- Elphidium macellum* (Fichtel and Moll)
Nautilus macellus Fichtel and Moll, 1798, Testacea microscopica, p. 66, var. β , pl. 10, figs. h-k.
Elphidium macellum (Fichtel and Moll), Montfort, 1808, Conch. Syst., v. 1, p. 15.
- Elphidium reticulosum* Cushman
 Cushman, 1933, U.S. Nat. Mus., Bull. 161, pt. 2, p. 51, pl. 12, figs. 5a, b.
- Elphidium simplex* Cushman
 Cushman, 1933, U.S. Nat. Mus., Bull. 161, pt. 2, p. 52, pl. 12, figs. 8, 9.
- Elphidium subarcticum* CushmanPl. 8, figs. 5a, b.
 Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ., no. 12, p. 27, pl. 3, figs. 34, 35.
- Elphidium subgranulosum* Asano
 Asano, 1938, Geol. Soc. Japan, Jour., v. 45, no. 538, p. 586, pl. 14, figs. 4a, b.
- Elphidium subincertum* Asano
 Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 1, p. 10, figs. 56, 57.
- Eoepionidella nitidula* (Chaster)
Pulvinulina nitidula Chaster, 1892, Southport Soc. Nat. Sci. Rep., 1st Rep., (1890-91), Append., p. 66, pl. 1, figs. 17a-c.
Eoepionidella nitidula (Chaster), Haman, 1973, Micropal., v. 19, no. 1, p. 102.
- Eoepionidella pulchella* (Parker)
Prinaella (?) *pulchella* Parker, 1952, Harvard Coll., Mus. Comp. Zool., Bull., v. 106, nos. 8-9, p. 420, pl. 6, figs. 18-20.
Eoepionidella pulchella (Parker), Matoba, 1970, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 42, p. 53, pl. 4, figs. 3a-c.
- Epistominella pulchella* Husezima and MaruhasiPl. 5, figs. 8a-c.
 Husezima and Maruhasi, 1944, Jour. Shigenkagaku Kenkyusho (Res. Inst. Nat. Resour., Japan), v. 1, no. 3, p. 398, pl. 34, figs. 10a-c.
- Esosyrinx curta* (Cushman and Ozawa)
Pseudopolymorphina curta Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 105, pl. 27, figs. 3a, b.
Esosyrinx curta (Cushman and Ozawa), Loeblich and Tappan, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 85, pl. 16, figs. 1-5.
- Fissurina circulo costa* Asano
Fissurina circulo-costa (sic) Asano, 1938, Tohoku Imp. Univ., Sci. Rep., 2nd ser. (Geol.), v. 19, no. 2, p. 219, pl. 30, fig. 17.
- Fissurina cucurbitasema* Loeblich and Tappan, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 76, pl. 14, figs. 10, 11.
- Fissurina* cf. *deltoidea* Seguenza
Fissurina (*Fissurina*) *deltoidea* Seguenza, 1862, Foram. monotal. Mioc. Messinina, p. 57, pl. 1, fig. 45.

- This form is very similar to *Fissurina deltoidea* Seguenza, 1862, but the aperture of the present form is decorated with a distinct neck.
- Fissurina echigoensis* (Asano and Inomata)
Entosolenia echigoensis Asano and Inomata, 1952, *Illust. Cat. Japan. Tert. Small. Foram.*, suppl. 1, p. 7, figs. 35, 36.
Fissurina echigoensis (Asano and Inomata), Matsunaga, 1963, *Tohoku Univ., Sci. Rep.*, 2nd ser. (Geol.), v. 35, no. 2, pl. 32, figs. 10a, b.
- Fissurina fukamiensis* (Asano)
Entosolenia fukamiensis Asano, 1953, *Short Papers Inst. Geol. Pal. Tohoku Univ.*, no. 5, p. 11, pl. 1, figs. 29a, b.
- Fissurina lacunata* (Burrows and Holland)
Lagenella castrensis Brady (not of Schwager), 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 485, pl. 60, figs. 1, 2.
Lagenella lacunata Burrows and Holland, 1895, *in Jones, T.R., Palaeontogr. Soc. London*, p. 205, pl. 7, fig. 12.
Fissurina orbignyana lacunata (Burrows and Holland), Asano, 1938, *Tohoku Imp. Univ., Sci. Rep.*, 2nd ser. (Geol.), v. 19, no. 2, p. 219, pl. 27, figs. 27, 28.
- Fissurina lucida* (Williamson)
Entosolenia marginata (Montagu) var. *lucida* Williamson, 1848, *Ann. Mag. Nat. Hist.*, ser. 2, v. 1, p. 17, pl. 2, fig. 17.
Fissurina lucida (Williamson), Loeblich and Tappan, 1953, *Smithsonian Misc. Coll.*, v. 121, no. 7, p. 76, pl. 14, fig. 4.
- Fissurina marginata* (Montagu)
Vermiculium marginatum Montagu, 1803, *Testacea Britannica*, p. 524.
Fissurina marginata (Montagu), Loeblich and Tappan, 1953, *Smithsonian Misc. Coll.*, v. 121, no. 7, p. 77, pl. 14, figs. 6-9.
- Fissurina obscurocostata* Galloway and Wissler
Galloway and Wissler, 1927, *Jour. Pal.*, v. 1, p. 52, pl. 9, fig. 1.
- Fissurina orbignyana* Seguenza
Seguenza, 1862, *Foram. monotal. Mioc. Messina*, p. 66, pl. 2, figs. 24, 26.
- Fissurina orbignyana* Seguenza var. A
This variety differs from the typical in having the body of the test with numerous longitudinal, weak costae. This form is distinguished from *Fissurina orbignyana* var. *variabilis* (Wright) [= *Lagenella orbignyana* (Seguenza) var. *variabilis* Wright, 1891] in having longer and weaker costae.
- Fissurina semimarginata* (Reuss)
Lagenella sp. (Nos. 64-65) von Schliet, 1870, *Die Foraminiferen Septarienthones Pielzpuhl*, p. 11, pl. 4, figs. 4-6, 10-12.
Lagenella marginata Williamson var. *semimarginata* Reuss, 1870, *Sitzb. Akad. Wiss. Wien*, v. 62, pt. 1, p. 468.
- Fissurina* sp. B
This form resembles somewhat *Fissurina orbignyana* var. *unicostata* (Sidebottom) [= *Lagenella orbignyana* (Seguenza) var. *unicostata* Sidebottom, 1912] in having three keels on the periphery and a single costa in the center of both sides of the test. The former is, however, distinguished from the latter by the following characters: Two lateral peripheral keels are thick and raised higher than the central one and a single costa on the face of the test is very short.
- Fissurina* sp. E
The present form differs from *Fissurina marginata* (Montagu) [= *Vermiculium marginatum* Montagu, 1803] in its ornamentation, which resembles *Fissurina marginato-radiata* Seguenza (*sic*), 1880, but is distinguished from the latter in the apertural feature.
- Florilus japonicus* (Asano)
Nonion japonicum Asano, 1938, *Geol. Soc. Japan, Jour.*, v. 45, no. 538, pl. 15, figs. 1, 2.
Florilus japonicus (Asano), Loeblich and Tappan, 1964, *Treatise on Invertebrate Pal.*, Moore, R.C., ed., pt. C., *Protista* 2, v. 2, p. C748, figs. 612 (5a-c); Chiji and Lopez, 1968, *Publ. Seto Mar. Biol. Lab.*, v. 16, no. 2, p. 106, pl. 15, figs. 10a, b.
- Florilus manpukuensis* (Otuka) Pl. 9, figs. 1a, b.

- Nonion manpukujiensis* Otuka, 1932, Geol. Soc. Tokyo, Jour., v. 39, no. 469, p. 654, fig. 1 (in Japanese).
- Nonion manpukujiensis* Otuka (sic) Asano, 1938, Geol. Soc. Japan, Jour., v. 45, no. 538, p. 593, pl. 15, figs. 3, 8.
- Frondicularia advena* Cushman
Cushman, 1923, U.S. Nat. Mus., Bull. 104, pt. 4, p. 141, pl. 20, figs. 1, 2.
- Gaudryina arenaria* Galloway and Wissler
Galloway and Wissler, 1927, Jour. Pal., v. 1, p. 68, pl. 11, fig. 5.
- Gaudryina matusimai* Asano
Gaudryina (*Siphogaudryina*) *matusimai* Asano, 1937, Geol. Soc. Japan, Jour., v. 44, no. 531, p. 1234, text-figs. 1-3.
- Gaudryina ogasaensis* Asano
Asano, 1936, Japan. Jour. Geol. Geogr., v. 13, nos. 3-4, p. 326, pl. 36, figs. 2a, b.
- Gaudryina yabei* Asano
Asano, 1939, Geol. Soc. Japan, Jour., v. 46, no. 551, p. 425, text-figs. 1a, b.
- Gavelinella araucana* (d'Orbigny)
Rosalina araucana d'Orbigny, 1839, Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 44, pl. 6, figs. 16-18.
Discorbina araucana (d'Orbigny), Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 645, pl. 86, figs. 10, 11.
- Gavelinopsis praegeri* (Heron-Allen and Earland) Pl. 5, figs. 2a-c.
Discorbina praegeri Heron-Allen and Earland, 1913, Royal Irish Acad., Proc., v. 31, pt. 64, p. 122, pl. 10, figs. 8-10.
Gavelinopsis praegeri (Heron-Allen and Earland), Hofker, 1951, Siboga Exped., Mon. IV, pt. 3, p. 485, figs. 332-334.
- Gavelinopsis* sp. B
This form differs from *Gavelinopsis praegeri* (Heron-Allen and Earland) in having oblique, almost straight, limbate and somewhat raised sutures on the dorsal side and slightly curved, somewhat limbate sutures on the ventral side.
- Glabratella subopercularis* (Asano)
Discorbis subopercularis Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 14, p. 3, figs. 17-19.
Glabratella subopercularis (Asano), Matoba, 1970, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 42, no. 1, p. 54, pl. 5, figs. 5a-c.
- Glandulina nipponica* Asano
Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 8, p. 14, figs. 71, 72.
- Globobulimina auriculata* (Bailey)
Bulimina auriculata Bailey, 1851, Smithsonian Contr. Know., v. 2, art. 3, p. 12, figs. 25-27.
Globobulimina auriculata (Bailey), Asano, 1958, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 29, p. 9, pl. 2, figs. 1-3.
- Globocassidulina depressa* (Asano and Nakamura) Pl. 8, figs. 8a, b.
Cassidulina subglobosa depressa Asano and Nakamura, 1937, Japan. Jour. Geol. Geogr., v. 14, nos. 3-4, p. 148, pl. 13, figs. 8a-c.
- Globocassidulina nipponensis* Eade
Cassidulina orientalis Cushman, 1925, Cushman Lab. Foram. Res., Contr., v. 1, pt. 2, p. 37, pl. 7, figs. 6a-c.
Globocassidulina nipponensis Eade, 1969, Cushman Found. Foram. Res., Contr., v. 20, pt. 2, p. 65, pl. 13, figs. 1-4.
- Globocassidulina pacifica* (Cushman)
Cassidulina pacifica Cushman, 1925, Cushman Lab. Foram. Res., Contr., no. 1, pt. 3, p. 55.
- Globocassidulina subglobosa* (Brady) Pl. 8, figs. 9a, b, 10a, b.
Cassidulina subglobosa Brady, 1881, Quart. Jour. Micr. Sci., n.s., v. 21, p. 60; 1884, Voy. Challenger, Rep., Zool., v. 9, p. 430, pl. 54, fig. 17.
- Guttulina kishinouyei* Cushman and Ozawa
Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 40, pl. 8, figs. 5, 6.
- Guttulina orientalis* Cushman and Ozawa
Cushman and Ozawa, 1928, Cushman Lab. Foram. Res., Contr., no. 4, p. 15, pl. 2, fig. 1.

- Guttulina yabei* Cushman and Ozawa
Cushman and Ozawa, 1929, Japan. Jour. Geol. Geogr., v. 6, nos. 3-4, p. 68, pl. 13, fig. 2, pl. 14, fig. 6.
- Guttulina yamazakii* Cushman and Ozawa
Cushman and Ozawa, 1930, U.S. Nat., Mus., Proc., v. 77, p. 40, pl. 8, figs. 3, 4.
- Gyroidina orbicularis* d'Orbigny
d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 278, no. 1; Models no. 13.
- Gyroidinoides nipponicus* (Ishizaki)
Gyroidina nipponica Ishizaki, 1944, Nat. Hist. Soc. Taiwan, Trans., v. 34, no. 244, p. 102, pl. 3, figs. 3a-c.
Gyroidinoides nipponicus (Ishizaki), Matoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 255, pl. 29, figs. 13a-c.
- Hanzawaia nipponica* Asano Pl. 9, figs. 8a-c.
Asano, 1943, Geol. Soc. Japan, Jour., v. 51, no. 606, p. 98, pl. 4, figs. 1-2.
- Heronallenia stellata* Takayanagi
Takayangi, 1953, Short Papers Inst. Geol. Pal. Tohoku Univ., no. 5, p. 33, pl. 4, figs. 13a-c.
- Heterolepa inagawaensis* (Matsunaga)
Cibicides inagawaensis Matsunaga, 1963, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 35, no. 2, p. 116, pl. 51, figs. 5a-c.
- Heterolepa malloryi* (Matsunaga)
Cibicides malloryi Matsunaga, 1963, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 35, no. 2, p. 116, pl. 51, figs. 7-8.
- Hoeglundina elegans* (d'Orbigny)
Rotalia (Turbinulina) elegans d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 276, no. 54.
Hoeglundina elegans (d'Orbigny), Brotzen, 1948, Sver. Geol. Undersök., v. 42, no. 2, ser. C, no. 493, p. 92, pl. 17, figs. 7, 8.
- Hopkinsina wakimotoensis* Asano
Asano, 1950, Illust. Cat. Japan. Tert. Small. Foram., pt. 2, p. 19, figs. 88-90.
- Hyalinea balthica* (Schröter)
Nautilus balthicus Schröter, 1783, Einleit. Conchyl. Linné, v. 1, p. 20, pl. 1, fig. 2.
Hyalinea balthica (Schröter), Hofker, 1951, Siboga Exped., Mon. IV, pt. 3, p. 508.
- Hyalinea nipponica* (Asano and Inomata)
Anomalina nipponica Asano and Inomata, 1952, Illust. Cat. Japan. Tert. Small. Foram., suppl. 1, p. 17, figs. 95, 96.
- Islandiella californica* (Cushman and Hughes)
Cassidulina californica Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., v. 1, pt. 1, p. 12, figs. 1a-c.
Islandiella californica (Cushman and Hughes), Nørvang, 1958, Dansk Naturh. Foren. København Vidensk. Meddel., v. 120, p. 26.
- Islandiella helenae* Feyling-Hanssen and Buzas
Cassidulina teretis Tappan, Loeblich and Tappan (not of Tappan, 1951), 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 121, pl. 24, figs. 3, 4.
Islandiella helenae Feyling-Hanssen and Buzas, 1976, Jour. Foram. Res., v. 6, no. 2, p. 155, figs. 1-4.
- Islandiella japonica* (Asano and Nakamura)
Cassidulina japonica Asano and Nakamura, 1937, Japan. Jour. Geol. Geogr., v. 14, nos. 3-4, p. 144, pl. 13, figs. 1, 2.
- Islandiella norcrossi* (Cushman) Pl. 4, figs. 3a-c.
Cassidulina norcrossi Cushman, 1933, Smithsonian Misc. Coll., v. 89, no. 9, p. 7, pl. 2, figs. 7a-c.
Islandiella norcrossi (Cushman), Nørvang, 1958, Dansk Naturh. Foren. København Vidensk. Meddel., v. 120, p. 26.
- Islandiella translucens* (Cushman and Hughes) Pl. 4, figs. 4a-c.
Cassidulina translucens Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., v. 1, pt. 1, p. 15, pl. 2, figs. 5a-c.
Islandiella translucens (Cushman and Hughes), Nørvang, 1958, Dansk Naturh. Foren.

- København Vidensk. Meddel., v. 120, p. 26.
- Karreriella baccata japonica* Asano
Asano, 1938, Japan. Jour. Geol. Geogr., v. 15, p. 90, pl. 10, fig. 1.
- Lagena apiopleura* Loeblich and Tappan
Loeblich and Tappan, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 59, pl. 10, figs. 14, 15.
- Lagena hispidula* Cushman
Cushman, 1913, U.S. Nat. Mus., Bull. 71, pt. 3, p. 14, pl. 5, figs. 2, 3.
- Lagena* cf. *perlucida* (Montagu)
Lagena cf. *perlucida* (Montagu), Asano, 1956, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 27, p. 35, pl. 5, fig. 38.
- Lagena striata* (d'Orbigny)
Oolina striata d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 21, pl. 5, fig. 12.
Lagena striata (d'Orbigny), Asano, 1938, Tohoku Imp. Univ., Sci. Rep., 2nd ser. (Geol.), v. 19, p. 217, pl. 27, fig. 26; pl. 28, fig. 28.
- Lagena sulcata spicata* Cushman and McCulloch
Lagena sulcata var. *spicata* Cushman and McCulloch, 1950, Allan Hancock Pacific Exped., v. 6, no. 6, p. 360, pl. 48, figs. 3-7.
- Lenticulina atlantica* (Barker)
Cristellaria articulata Brady (not of Reuss, 1863), 1884, Voy. Challenger, Rep., Zool. v. 9, p. 547, pl. 69, figs. 10-12.
Cristellaria lucida Cushman, 1923, U.S. Nat. Mus., Bull. 104, pt. 4, p. 111, pl. 30, fig. 2.
Robulus atlantica Barker, 1960, Soc. Econ. Pal. Min., Spec. Publ., no. 9, p. 144, pl. 69, figs. 10-12.
Thalman (1937, Ecol. geol. Helvet., v. 30, no. 2, p. 341) has pointed out that *lucida* is preoccupied by *Robulina lucida* Silvestri, 1880, and Barker proposed a new name *Robulus atlantica*.
- Lenticulina calcar* (Linné)
Nautilus calcar Linné, 1767, Syst. Nat., ed. 10, p. 1162, no. 272.
Lenticulina calcar (Linné), Barker, 1960, Soc. Econ. Pal. Min., Spec. Publ., no. 9, p. 146, pl. 70, figs. 9-12.
- Lenticulina orbicularis* (d'Orbigny)
Robulina orbicularis d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 288, pl. 15, figs. 8, 9.
- Marginulina glabra* d'Orbigny
d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 259.
- Melonis pacificus* (Cushman)
Nonionina umbilicatula (Montagu) var. *pacifica* Cushman, 1924, Carnegie Inst. Washington Publ. 342, p. 48, pl. 16, fig. 3.
- Melonis parkerae* (Uchio) Pl. 9, figs. 9a, b.
Nonion parkerae Uchio, 1960, Cushman Found. Foram. Res., Spec. Publ., no. 5, p. 60, pl. 4, figs. 9, 10.
Melonis parkerae (Uchio), Matoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 256, pl. 29, figs. 15a, b.
- Melonis pompilioides* (Fichtel and Moll)
Nautilus pompilioides Fichtel and Moll, 1798, Testacea microscopica, p. 31, pl. 2, figs. a-c.
Melonis etruscus Montfort, 1808, Conch. Syst., p. 67.
- Miliammina fusca* (Brady)
Quinqueloculina fusca Brady, 1870, Ann. Mag. Nat. Hist., ser. 4, v. 6, p. 47 (286), pl. 11, figs. 2-3.
Miliammina fusca (Brady), Hada, 1936, Zool. Mag., v. 48, nos. 8-10, p. 853, text-figs. 5a-c.
- Miliolinella circularis* (Bornemann)
Triloculina circularis Bornemann, 1855, Zeit. deutsch. Geol. Ges., v. 7, p. 349, pl. 19, fig. 4.
Miliolinella circularis (Bornemann), Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 6, p. 9, figs. 65-67.
- Neoconorbina orbicularis* (Terquem)
Rosalina orbicularis Terquem, 1876, Anim. sur la Plage de Dunkerque, p. 75, pl. 9, figs. 4a, b.

- Neoconorbina pacifica* Hofker, 1951, Siboga Exped., Mon. IV, pt. 3, p. 433.
- Neoconorbina stachi* (Asano) Pl. 4, figs. 11a-c.
Discopulvinulina stachi Asano, 1951, Illust. Cat. Japan. Tert. Small. Faram., pt. 14, p. 7, figs. 46-48.
Neoconorbina stachi (Asano), Matoba, 1970, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 42, no. 2, p. 57, pl. 4, figs. 6a-c.
- Neoeponides procerus* (Brady)
Pulvinulina procera Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 698, pl. 105, figs. 7a-c.
Neoeponides procerus (Brady), Reiss, 1960, Israel Geol. Surv., Bull. no. 29, p. 17.
- Nodosaria pyrula* d'Orbigny
d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 253, no. 13.
- Nonion tuberculatum* (d'Orbigny)
Nonionina tuberculata d'Orbigny, 1846, Foram. Fos. Bas. Vienne, p. 108, pl. 5, figs. 13, 14.
Nonion tuberculatum (d'Orbigny), Cushman, 1939, U.S. Geol. Surv., Prof. Paper 191, p. 13, pl. 3, figs. 12, 16, 17.
- Nonionella pulchella* Hada
Hada, 1931, Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.), v. 6, no. 1, p. 120, text-figs. 79a-c.
- Nonionella stella* Cushman and Moyer Pl. 9, figs. 2a-c.
Nonionella miocenica Cushman var. *stella* Cushman and Moyer, 1930, Cushman Lab. Foram Res., Contr., v. 6, pt. 1, p. 56, pl. 7, figs. 17a-c.
- Nonionellina labradorica* (Dawson)
Nonionina labradorica Dawson, 1860, Canad. Nat., v. 5, p. 191, text-fig. 4.
Nonionellina labradorica (Dawson), Voloshinova, 1958, Mikrofauna SSSR, Sbornik 9, VNIGRI, Trudy, no. 115, p. 142.
- Oolina melo* d'Orbigny
d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 20, pl. 5, fig. 9.
- Oridorsalis umbonatus* (Reuss) Pl. 9, figs. 4a-d.
Rotalia umbonata Reuss, 1851, Deutsch. geol. Gesell., Zeitschr., v. 3, p. 75, pl. 5, figs. 35a-c.
Oridorsalis umbonatus (Reuss), Parker, 1964, Jour. Pal., v. 38, no. 4, p. 626, pl. 99, figs. 4-6.
- Pararotalia* (?) *globosa* (Millett)
Discorbia imperatoria (d'Orbigny) var. *globosa* Millett, 1903, Roy. Micr. Soc. London, Jour., p. 701, pl. 7, figs. 6a-c.
Pararotalia ? *globosa* (Millett), Matoba, 1970, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 42, no. 1, p. 52, pl. 6, figs. 8a-c.
- Patellinella hanzawai* Asano
Asano, 1936, Geol. Soc. Japan, Jour., v. 43, no. 515, p. 613, pl. 31, figs. 3a-c.
- Planorbulina mediterraneanensis* d'Orbigny
d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 280, no. 2, pl. 14, figs. 4-6.
- Planulina ariminensis* d'Orbigny
d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 280, pl. 5, figs. 1-3.
- Planulinoides japonicus* (Shirai)
Discotruncana japonica Shirai, 1960, Hokkaido Univ., Fac. Sci., Jour., ser. 4, Geol. & Min., v. 10, p. 539, pl. 1, figs. 6a-c.
Planulinoides japonica (Shirai) (*sic*), Loeblich and Tappan, 1964, Treatise on Invertebrate Pal., Moore, R.C., ed., pt. C, Protista 2, v. 2, p. C 584, figs. 458 (7a-c).
- Polystomellina discorbinoides* Yabe and Hanzawa
Yabe and Hanzawa, 1923, Japan. Jour. Geol. Geogr., v. 2, p. 99, text-figs. a-c.
- Protelphidium kasamoriense* Aoki
Aoki, 1968, Trans. Proc. Pal. Soc. Japan, N.S., no. 70, p. 260, pl. 27, fig. 2.
- Pseudononion grateloupi* (d'Orbigny)
Nonionina grateloupi d'Orbigny, 1826, Ann. Sci. Nat., Paris, ser. 1, v. 7, p. 294, no. 19.
- Pseudononion japonicum* Asano Pl. 9, figs. 3a-d.
Asano, 1936, Geol. Soc. Japan, Jour., v. 43, no. 512, p. 347, text-figs. a-c.
- Pseudononion tredecum* Asano
Asano, 1936, Geol. Soc. Japan, Jour., v. 43, no. 515, p. 622, pl. 33, figs. 7a-c.
- Pseudoparella naraensis* Kuwano Pl. 5, figs. 4a-c.
Kuwano, 1950, Geol. Soc. Japan, Jour., v. 56, no. 657, p. 317, text-figs. 6a-c.

- Pseudoparella nipponica* (Kuwano)Pl. 5, figs. 5a-c, 6.
Epistominella nipponica Kuwano (MS), 1962, Res. Inst. Nat. Resour., Misc. Rep., nos. 58-59, pl. 17, figs. 7a-c.
Epistominella nipponica Kuwano, Matoba, 1967, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), v. 38, no. 2, p. 254, figs. 8a-f; pl. 26, figs. 13a-c.
- Pseudoparella takayanagii* (Iwasa)Pl. 5, figs. 7a-c.
Epistominella takayanagii Iwasa, 1955, Geol. Soc. Japan, Jour., v. 61, no. 712, p. 16, text-figs. 4a-c.
- Pseudoparella tamana* Kuwano
 Kuwano, 1950, Geol. Soc. Japan, Jour., v. 56, no. 675, p. 317, text-figs. 5a-c.
- Pseudopatellinoides primus* Krasheninnikov
 Krasheninnikov, 1958, VNIGNI, Trudy, no. 9, Pal. Sbornik, p. 241; Loeblich and Tappan, 1964, Treatise on Invertebrate Pal., Moore, R.C., ed., pt. C (2), p. C584, figs. 458 (9a-d).
- Pseudopolymorphina ishikawaensis* Cushman and Ozawa
 Cushman and Ozawa, 1929, Japan. Jour. Geol. Geogr., v. 6, p. 70, pl. 13, fig. 5; pl. 15, fig. 5.
- Pseudopolymorphina okuwaensis* Cushman and Ozawa
Pseudopolymorphina compressa d'Orbigny var. *okuwaensis* Cushman and Ozawa, 1929, Japan. Jour. Geol. Geogr., v. 6, p. 72, pl. 13, fig. 7; pl. 15, figs. 8, 9.
Pseudopolymorphina okuwaensis Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 98, pl. 25, figs. 2, 3.
- Pseudopolymorphina suboblonga* Cushman and Ozawa
 Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., v. 77, p. 91, pl. 23, figs. 3a-c.
- Pseudorotalia gaimardii compressiuscula* (Brady)Pl. 7, figs. 5a-c.
Rotalia papillosa Brady var. *compressiuscula* Brady, 1884, Voy. Challenger, Rep., Zool., v. 9, p. 708, pl. 107, figs. 1a-c; pl. 108, figs. 1a-c.
Streblus gaimardii (d'Orbigny) var. *compressiuscula* (Brady), Barker, 1960, Soc. Econ. Pal. Min., Spec. Publ., no. 9, p. 220, pl. 107, figs. 1a-c; pl. 108, figs. 1a-c.
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- Pullenia* cf. *apertura* Cushman
Pullenia apertura Asano (not of Cushman, 1927), 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 12, p. 10, figs. 3, 4.
 This form somewhat resembles the specimen referred to as *Pullenia apertura* Cushman by Asano (1951) except that the present form is smaller in size. Both specimens of Asano and present author differ from the type figure (Cushman, 1927, Bull. Scripps Oceanogr., Tech. Ser., v. 1, no. 10, p. 171, pl. 6, fig. 10) in their low arched aperture. These Japanese forms may be a juvenile of *P. apertura*.
- Pullenia salisburyi* Stewart and Stewart
 Stewart and Stewart, 1930, Jour. Pal., v. 4, p. 72, pl. 8, figs. 2a, b.
- Pyrgo murrhina* (Schwager)
Bilocolina murrhina Schwager, 1866, Novara-Exped., Geol. Theil, v. 2, p. 203, pl. 6, figs. 15a-c.
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- Quinqueloculina seminulum* (Linné)
Serpula seminulum Linné, 1758, Syst. Nat., ed. 10, p. 786.
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- Rectobolivina raphana* (Parker and Jones)Pl. 4, figs. 1, 2.
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Discopulvinulina hofkeri Asano, 1951, Illust. Cat. Japan. Tert. Small. Foram., pt. 14, p. 5, figs. 30, 31.
- Rosalina vilardevoana* d'Orbigny
d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, v. 5, pt. 5, p. 44, pl. 6, figs. 13-15.
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Cushman and Ozawa, 1928, Cushman Lab. Foram. Res., Contr., v. 4, p. 19, pl. 2, fig. 14.
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Textularia saulcyana d'Orbigny, 1839, in Sagra, R. de la, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 146, pl. 1, figs. 21, 22; Lalicker and McCulloch, 1940, Allan Hancock Pacific Exped., v. 6, no. 2, p. 139, pl. 16, figs. 22a-d.
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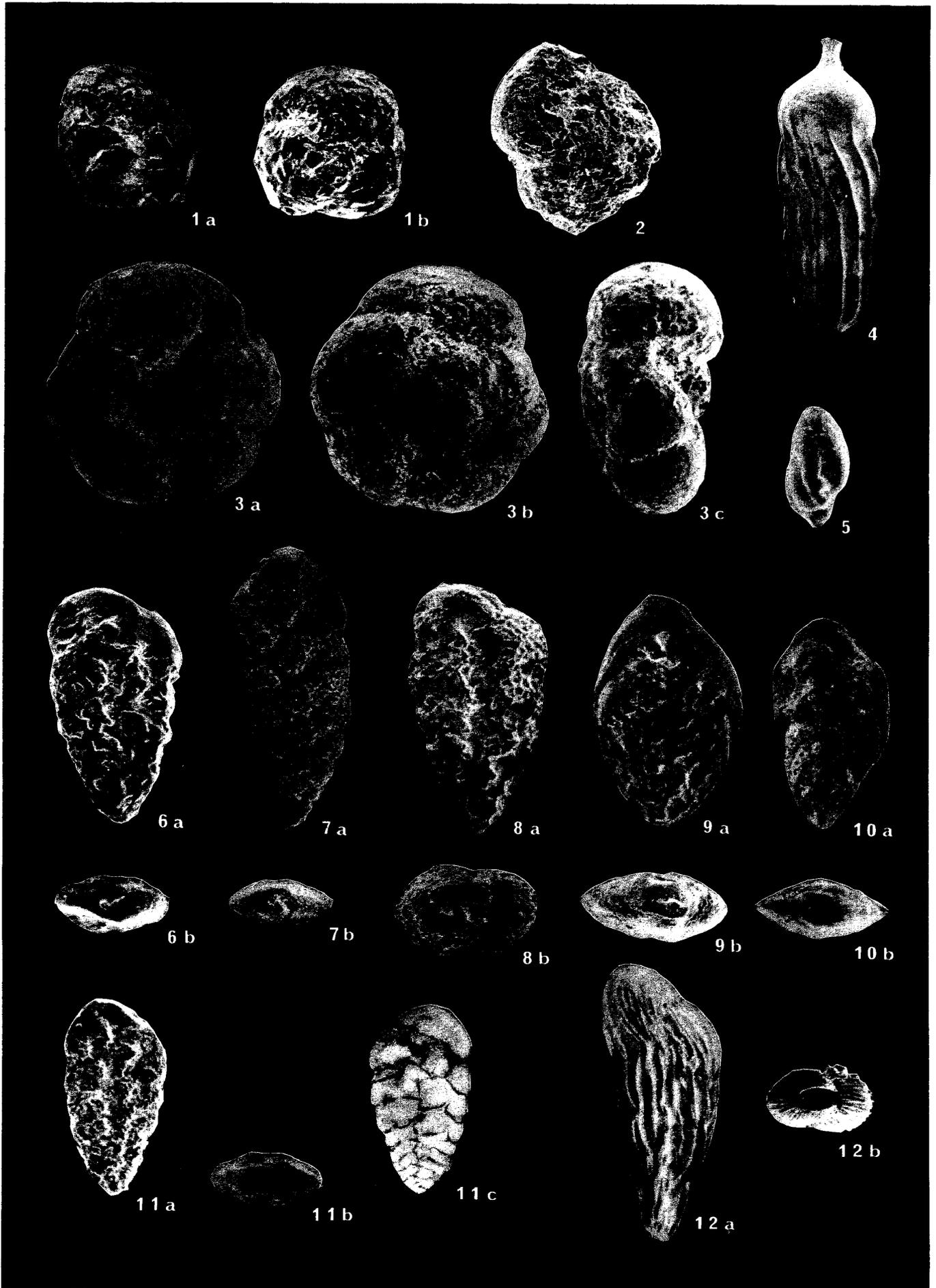
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Plate 3

(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a, b. *Adercotryma glomerata* (Brady). IGPS coll. cat. no. 96137, from station St-3; Toyama Bay, Recent. $\times 80$.
- Fig. 2. *Spiroplectamina higuchii* Takayanagi. IGPS coll. cat. no. 96138, from loc. no. OMM5; Omma Formation. $\times 160$.
- Figs. 3a-c. *Trochammima japonica* Ishiwada. IGPS coll. cat. no. 96139, from station St-3; Toyama Bay, Recent. $\times 65$.
- Fig. 4. *Amphicoryna fukushimaensis* (Asano). IGPS coll. cat. no. 96140, from loc. no. OMM-T; Takakubo Formation. $\times 45$.
- Fig. 5. *Buliminella elegantissima* (d'Orbigny). IGPS coll. cat. no. 96141, from loc. no. NDU12; Yabuta Formation. $\times 80$.
- Figs. 6a-7b. *Bolivina decussata* Brady.
- Figs. 6a, b. IGPS coll. cat. no. 96142, from loc. no. NDU8; Yabuta Formation. $\times 120$.
- Figs. 7a, b. IGPS coll. cat. no. 96143, from station D-1-32; Toyama Bay, Recent. $\times 120$.
- Figs. 8a, b. *Bolivina pseudoplicata* Heron-Allen and Earland. IGPS coll. cat. no. 96144, from loc. no. ASH5; Junicho Formation. $\times 120$.
- Figs. 9a-10b. *Bolivina robusta* Brady.
- Figs. 9a, b. IGPS coll. cat. no. 96145, from loc. no. OMM5; Omma Formation. $\times 120$.
- Figs. 10a, b. IGPS coll. cat. no. 96146, from station C-1-28; Toyama Bay, Recent. $\times 80$.
- Figs. 11a-c. *Bolivina* sp. A. IGPS coll. cat. no. 96147, from loc. no. ASH5; Junicho Formation. $\times 120$.
c-optical micrograph.
- Figs. 12a, b. *Brizalina karreriana* (Brady). IGPS coll. cat. no. 96148, from station C-1-28; Toyama Bay, Recent. $\times 55$.



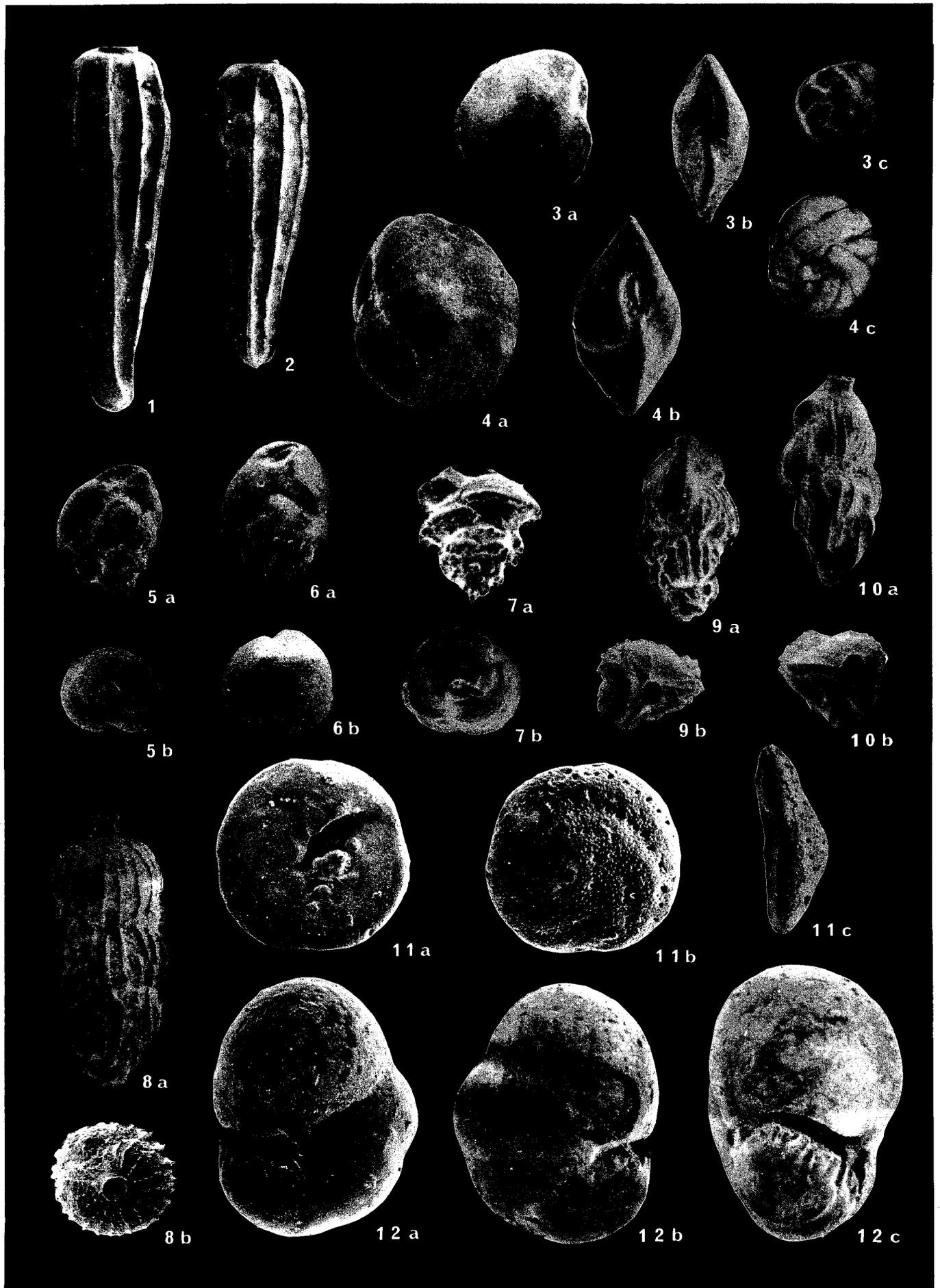


Plate 4

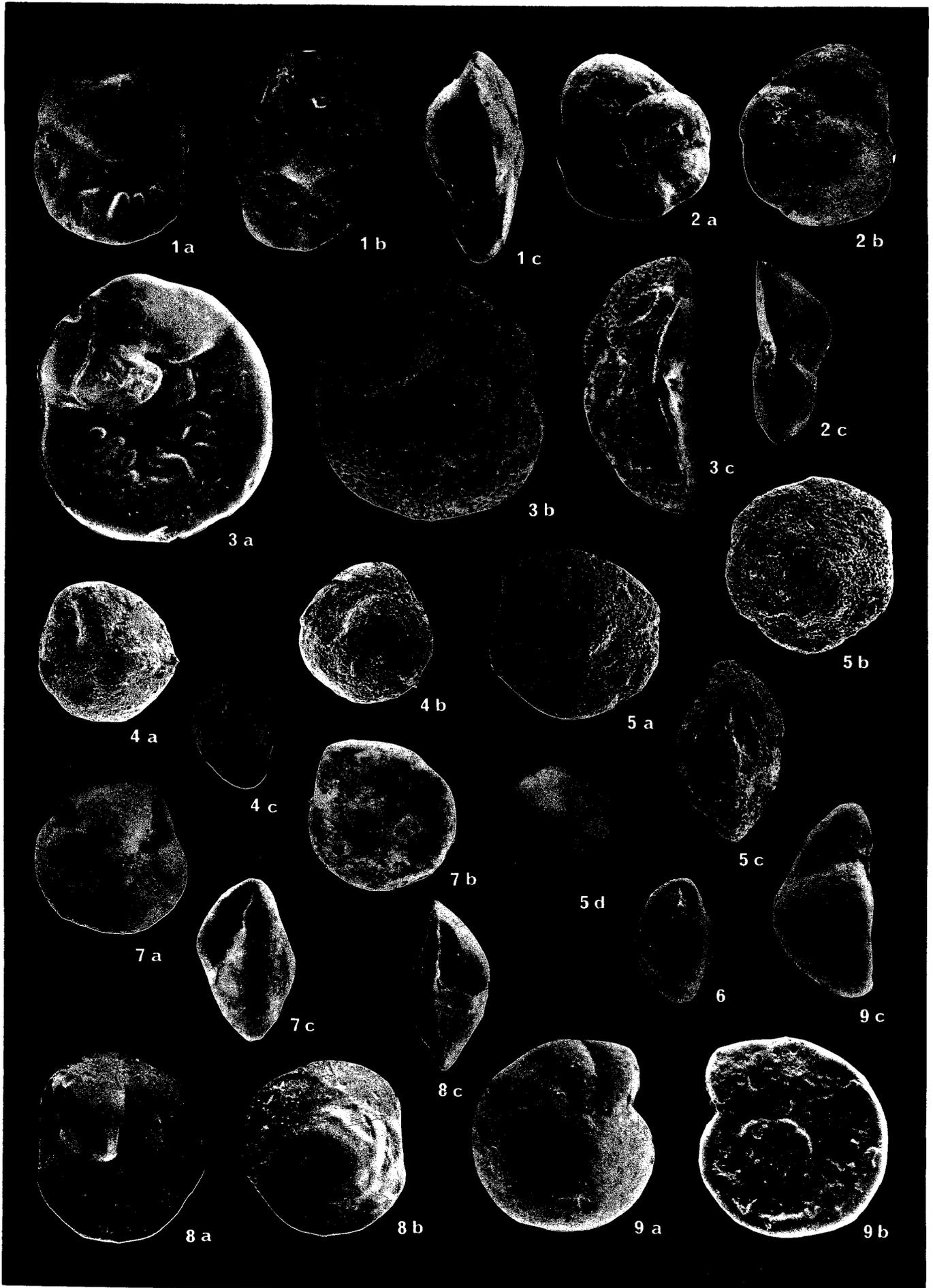
(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1, 2. *Rectobolivina raphana* (Parker and Jones).
Fig. 1. IGPS coll. cat. no. 96149, from loc. no. OMM15; Omma Formation. $\times 50$.
Fig. 2. IGPS coll. cat. no. 96150, from station C-1-28; Toyama Bay, Recent, $\times 50$.
- Figs. 3a-c. *Islandiella norcrossi* (Cushman). IGPS coll. cat. no. 96151, from loc. no. NDU17; Yabuta Formation. a, b- $\times 80$ c-optical micrograph, $\times 45$.
- Figs. 4a-c. *Islandiella translucens* (Cushman and Hughes). IGPS coll. cat. no. 96152, from loc. no. TGW4; Zukawa Formation. a, b-x 80. c-optical micrograph, $\times 45$.
- Figs. 5a-6b. *Bulimina marginata* d'Orbigny.
Figs. 5a, b. IGPS coll. cat. no. 96153, from loc. no. CHS2; Omma Formation. $\times 150$.
Figs. 6a, b. IGPS coll. cat. no. 96154, from station D-3-34; Toyama Bay, Recent. $\times 150$.
- Figs. 7a, b. *Bulimina* sp. A. IGPS coll. cat. no. 96155, from loc. no. OMM11; Omma Formation. $\times 150$.
- Figs. 8a, b. *Uvigerina akitaensis* Asano. IGPS coll. cat. no. 96156, from loc. no. ASH3; Junicho Formation. $\times 80$.
- Figs. 9a-10b. *Trifarina kokozuraensis* (Asano).
Figs. 9a, b. IGPS coll. cat. no. 96157, from loc. no. NDU8; Yabuta Formation. $\times 80$.
Figs. 10a, b. IGPS coll. cat. no. 96158, from station D-1-32; Toyama Bay, Recent. $\times 80$.
- Figs. 11a-c. *Neoconorbina stachi* (Asano). IGPS coll. cat. no. 96159, from loc. no. ASH8; Junicho Formation. $\times 120$.
- Figs. 12a-c. *Baggina notoensis* Asano. IGPS coll. cat. no. 96160, from loc. no. OMM15; Omma Formation. $\times 50$.

Plate 5

(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a-c. *Cancris auriculus* (Fichtel and Moll). IGPS coll. cat. no. 96161, from loc. no. NDU16; Yabuta Formation. $\times 80$.
- Figs. 2a-c. *Gavelinopsis praegeri* (Heron-Allen and Earland). IGPS coll. cat. no. 96162, from loc. no. ASH5; Junicho Formation. $\times 80$.
- Figs. 3a-c. *Rosalina bradyi* (Cushman). IGPS coll. cat. no. 96163, from loc. no. OMM9; Omma Formation. $\times 80$.
- Figs. 4a-c. *Pseudoparella naraensis* Kuwano. IGPS coll. cat. no. 96164, from loc. no. NDU5; Yabuta Formation. $\times 160$.
- Figs. 5a-6. *Pseudoparella nipponica* (Kuwano).
Figs. 5a-d. IGPS coll. cat. no. 96165, from loc. no. NDU19; Yabuta Formation. a-c- $\times 180$. d-optical micrograph, $\times 120$.
- Fig. 6. IGPS coll. cat. no. 96166, from station D-1-32; Toyama Bay, Recent. $\times 180$.
- Figs. 7a-c. *Pseudoparella takayanagii* (Iwasa). IGPS coll. cat. no. 96167, from loc. no. ASH8; Junicho Formation. $\times 160$.
- Figs. 8a-c. *Epistominella pulchella* Husezima and Maruhasi. IGPS coll. cat. no. 96168, from loc. no. NDU1; Yabuta Formation. $\times 80$.
- Figs. 9a-c. *Cibicides subpraecinctus* (Asano). IGPS coll. cat. no. 96169, from loc. no. SZK1; Zukawa Formation. $\times 80$.



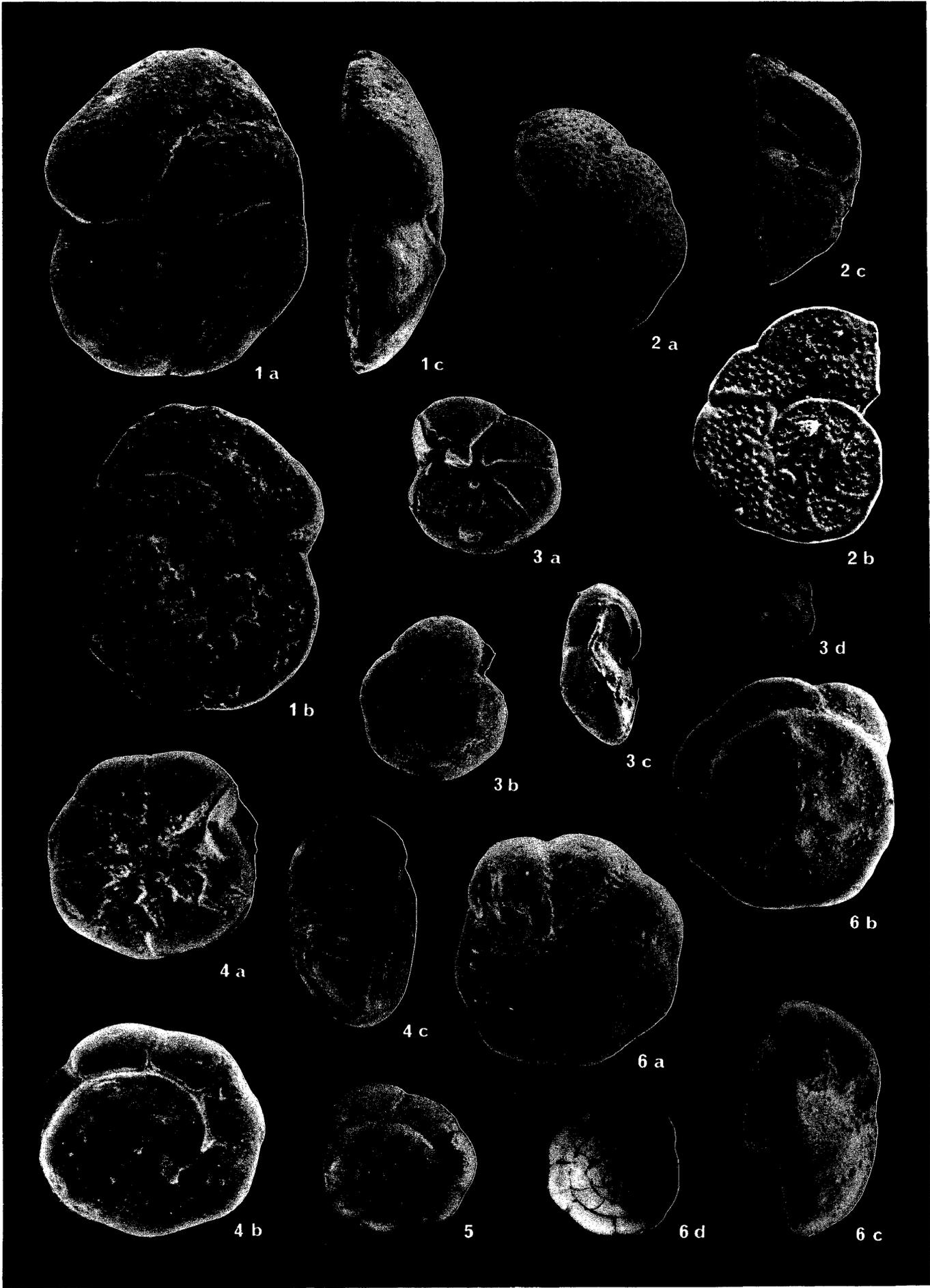


Plate 6

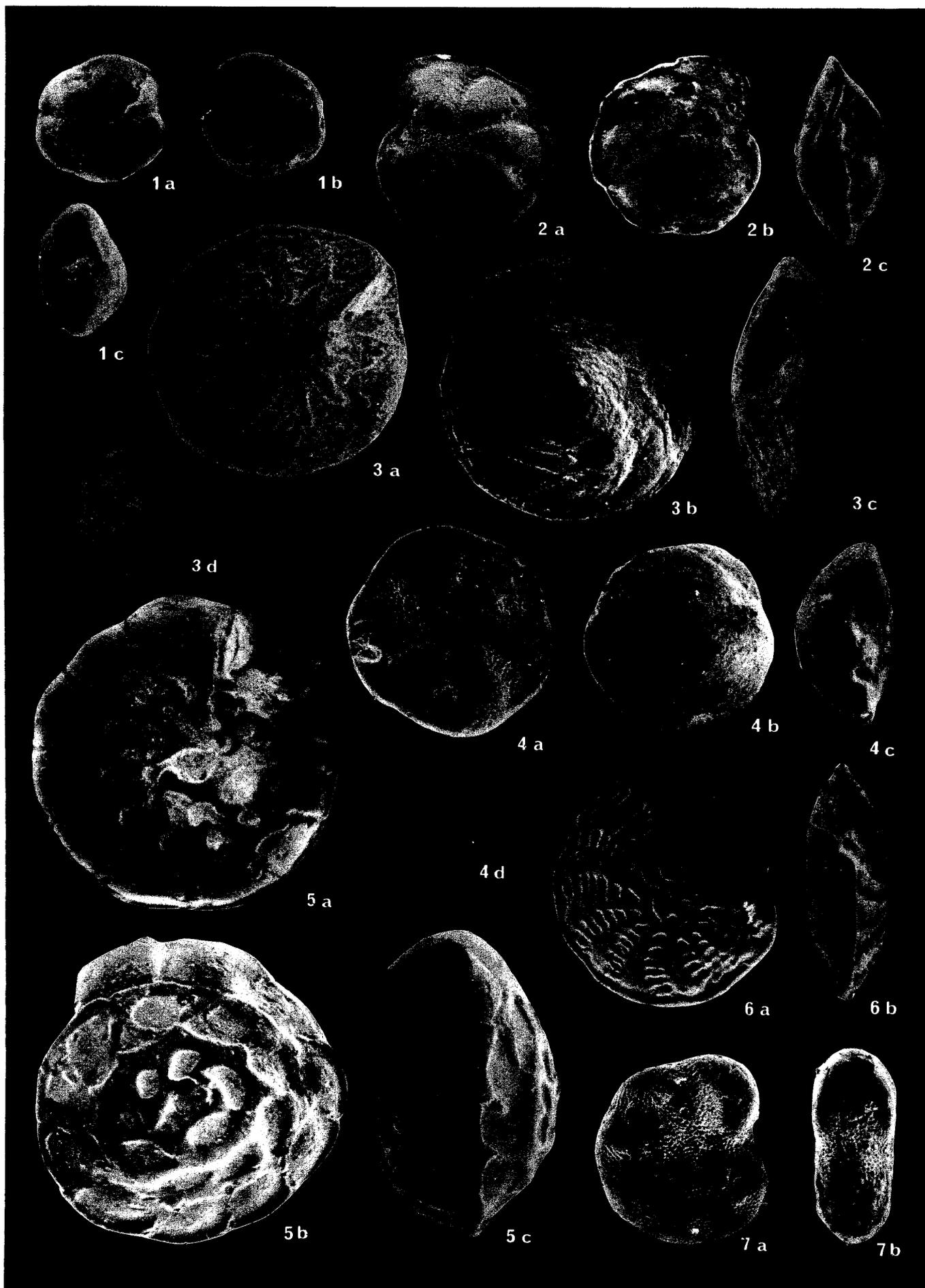
(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a-c. *Cibicides lobatulus* (Walker and Jacob). IGPS coll. cat. no. 96170, from loc. no. SZK1; Zukawa Formation. $\times 80$.
- Figs. 2a-c. *Cibicides refulgens* Montfort. IGPS coll. cat. no. 96171, from loc. no. NDU19; Yabuta Formation. $\times 80$.
- Figs. 3a-d. *Ammonia beccarii* (Linné). IGPS coll. cat. no. 96172, from loc. no. NDU8; Yabuta Formation. a-c- $\times 105$. d-optical micrograph, $\times 50$.
- Figs. 4a-5. *Ammonia japonica* (Hada). IGPS coll. cat. nos. 96173A, B, from loc. no. OMM9; Omma Formation. 4a-c- $\times 80$. 5-optical micrograph, $\times 60$.
- Figs. 6a-d. *Ammonia takanabensis* (Ishizaki). IGPS coll. cat. no. 96174, from loc. no. OMM15; Omma Formation. a-c- $\times 80$. d-optical micrograph, $\times 45$.

Plate 7

(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a-c. *Buccella frigida* (Cushman). IGPS coll. cat. no. 96175, from loc. no. OMM11; Omma Formation. $\times 80$.
- Figs. 2a-c. *Buccella inusitata* Andersen. IGPS coll. cat. no. 96176, from loc. no. KFT9; Omma Formation. $\times 80$.
- Figs. 3a-d. *Buccella makiyamai* Chiji. IGPS coll. cat. no. 96177, from loc. no. SZK1; Zukawa Formation. a-c- $\times 80$. d-optical micrograph, $\times 45$.
- Figs. 4a-d. *Buccella nipponica* (Husezima and Maruhasi). IGPS coll. cat. no. 96178, from loc. no. SZK1; Zukawa Formation. a-c- $\times 120$. d-optical micrograph, $\times 40$.
- Figs. 5a-c. *Pseudorotalia gaimardii compressiuscula* (Brady). IGPS coll. cat. no. 96179, from loc. no. OMM15; Omma Formation. $\times 50$.
- Figs. 6a, b. *Elphidium advenum* (Cushman). IGPS coll. cat. no. 96180, from loc. no. OMM9; Omma Formation. $\times 80$.
- Figs. 7a, b. *Elphidium bartletti* Cushman. IGPS coll. cat. no. 96181, from loc. no. ASH18; Junicho Formation. $\times 120$.



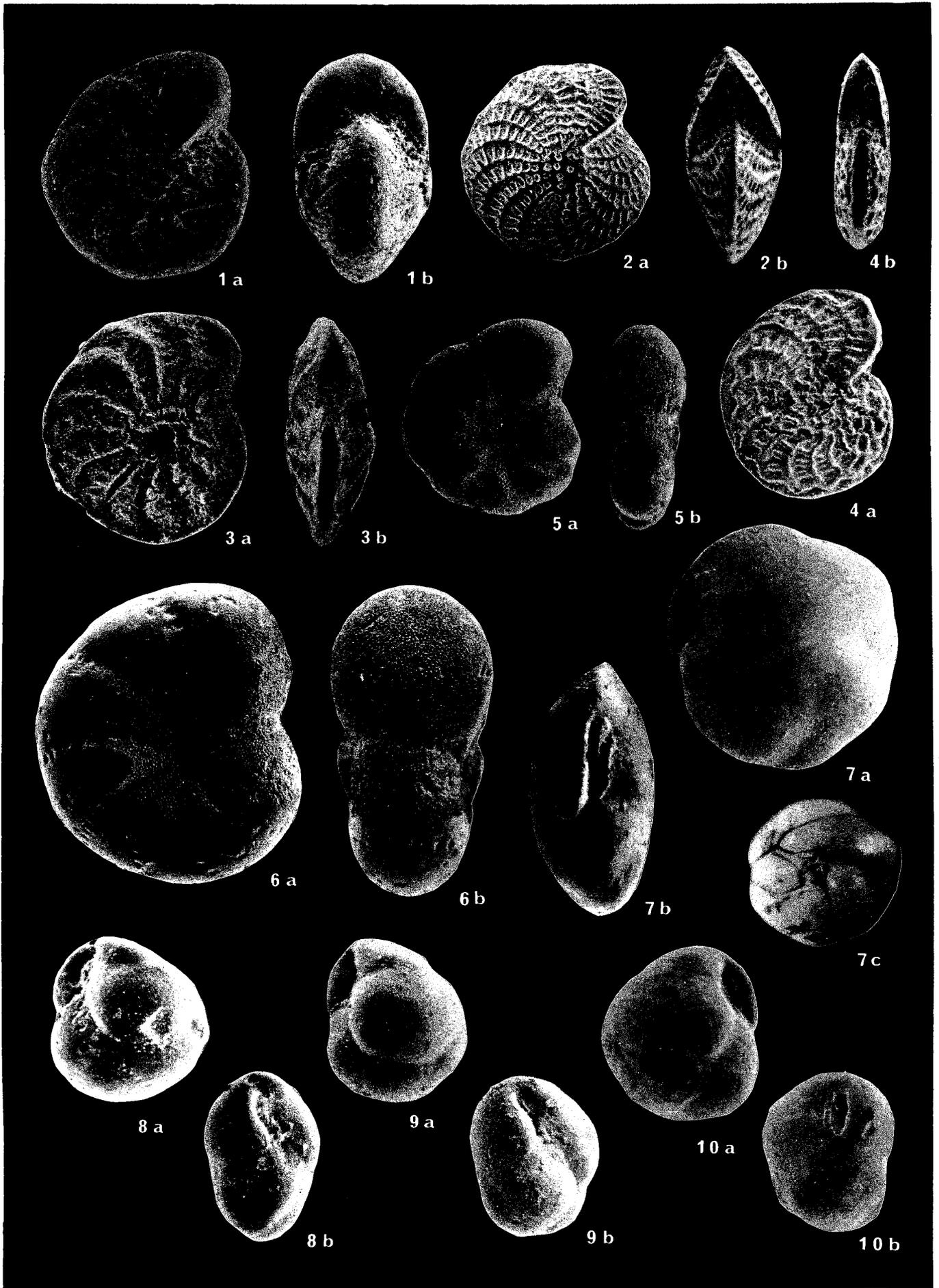


Plate 8

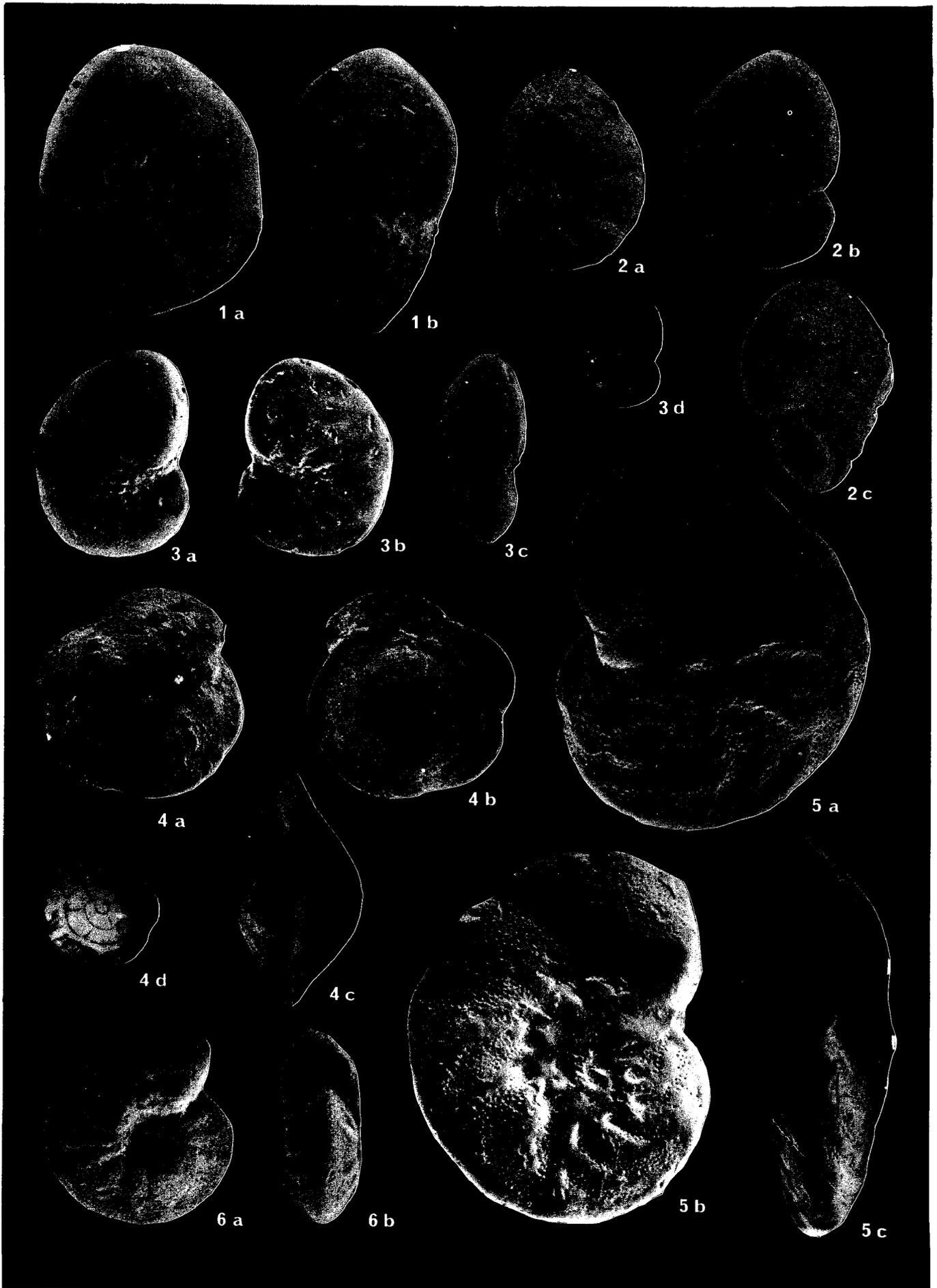
(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a, b. *Elphidium clavatum* Cushman. IGPS coll. cat. no. 96182, from loc. no. ASH17; Junicho Formation. $\times 160$.
- Figs. 2a, b. *Elphidium crispum* (Linné). IGPS coll. cat. no. 96183, from loc. no. ASH17; Junicho Formation. $\times 55$.
- Figs. 3a, b. *Elphidium fimbriatulum* (Cushman). IGPS coll. cat. no. 96184, from loc. no. SZK1; Zukawa Formation. $\times 80$.
- Figs. 4a, b. *Elphidium jenseni* (Cushman). IGPS coll. cat. no. 96185, from loc. no. ASH17; Junicho Formation. $\times 80$.
- Figs. 5a, b. *Elphidium subarcticum* Cushman. IGPS coll. cat. no. 96186, from loc. no. NDU10; Yabuta Formation. $\times 80$.
- Figs. 6a, b. *Criboelphidium yabei* (Asano). IGPS coll. cat. no. 96187, from loc. no. OMM9; Omma Formation. $\times 55$.
- Figs. 7a-c. *Cassidulina yabei* Asano and Nakamura. IGPS coll. cat. no. 96188, from loc. no. SZK1; Zukawa Formation. a, b- $\times 80$. c-optical micrograph, $\times 50$.
- Figs. 8a, b. *Globocassidulina depressa* (Asano and Nakamura). IGPS coll. cat. no. 96189, from loc. no. NDU1; Yabuta Formation. $\times 120$.
- Figs. 9a-10b. *Globocassidulina subglobosa* (Brady).
- Figs. 9a, b. IGPS coll. cat. no. 96190, from loc. no. NDU17; Yabuta Formation. $\times 80$.
- Figs. 10a, b. IGPS coll. cat. no. 96191, from station D-4-35; Toyama Bay, Recent. $\times 80$.

Plate 9

(All figures are scanning electron micrographs unless stated otherwise)

- Figs. 1a, b. *Florilus manpukuziensis* (Otuka). IGPS coll. cat. no. 96192, from loc. no. OMM15; Omma Formation. $\times 55$.
- Figs. 2a-c. *Nonionella stella* Cushman and Moyer. IGPS coll. cat. no. 96193, from loc. no. NDU17; Yabuta Formation. $\times 80$.
- Figs. 3a-d. *Pseudononion japonicum* Asano. IGPS coll. cat. no. 96194, from loc. no. OMM9; Omma Formation. a-c- $\times 80$. d-optical micrograph, $\times 40$.
- Figs. 4a-d. *Oridorsalis umbonatus* (Reuss). IGPS coll. cat. no. 96195, from loc. no. NDU5; Yabuta Formation. a-c- $\times 80$. d-optical micrograph, $\times 45$.
- Figs. 5a-c. *Hanzawaia nipponica* Asano. IGPS coll. cat. no. 96196, from loc. no. OMM9; Omma Formation. $\times 55$.
- Figs. 6a, b. *Melonis parkerae* (Uchio). IGPS coll. cat. no. 96197, from loc. no. ASH5; Junicho Formation. $\times 55$.



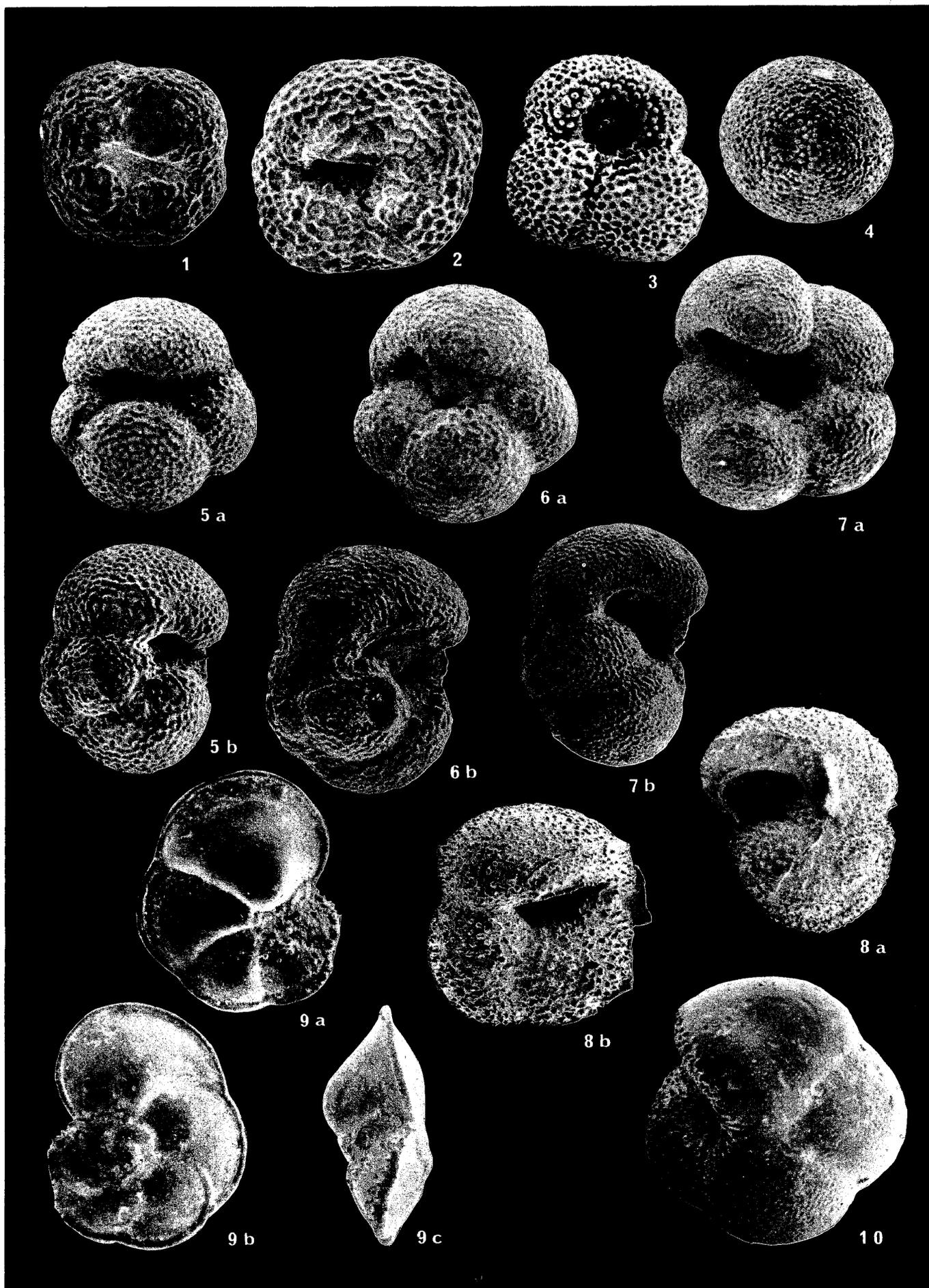


Plate 10

(All figures are scanning electron micrographs)

Figs. 1, 2. *Globigerina pachyderma* (Ehrenberg).

Fig. 1. Sinistrally coiling specimen. IGPS coll. cat. no. 96198, from loc. no. OMM1; Omma Formation. \times 160.

Fig. 2. Dextrally coiling specimen. IGPS coll. cat. no. 96199, from loc. no. NDU16; Yabuta Formation. \times 150.

Fig. 3. *Globigerinodites ruber* (d'Orbigny). IGPS coll. cat. no. 96200, from loc. no. OMM8; Omma Formation. \times 120.

Fig. 4. *Orbulina universa* d'Orbigny. IGPS coll. cat. no. 96201, from loc. no. OMM9; Omma Formation. \times 95.

Figs. 5a, b. *Globoquadrina asanoi* Maiya, Saito and Sato. IGPS coll. cat. no. 96202, from loc. no. NDU17; Yabuta Formation. \times 80.

Figs. 6a, b. *Globoquadrina kagaensis* Maiya, Saito and Sato. IGPS coll. cat. no. 96203, from loc. no. ASH6; Junicho Formation. \times 80.

Figs. 7a, b. *Globoquadrina himiensis* Maiya, Saito, and Sato. IGPS coll. cat. no. 96204, from loc. no. ASH6; Junicho Formation. \times 65.

Figs. 8a, b. *Globorotalia inflata inflata* (d'Orbigny). IGPS coll. cat. no. 96205, from loc. no. OMM8; Omma Formation. \times 80.

Figs. 9a-c. *Globorotalia cultrata* (d'Orbigny). IGPS coll. cat. no. 96206, from loc. no. OMM15; Omma Formation. \times 65.

Fig. 10. *Pulleniatina obliquiloculata* (Parker and Jones). IGPS coll. cat. no. 96207, from loc. no. OMM10; Omma Formation. \times 80.