FORAMINIFERA FROM THE SHIROYAMA FORMATION (LATE PLEISTOCENE) IN KAGOSHIMA CITY, SOUTH KYUSHU, JAPAN

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FORAMINIFERA FROM THE SHIROYAMA FORMATION (LATE PLEISTOCENE) IN KAGOSHIMA CITY, SOUTH KYUSHU, JAPAN

By

Kimihiko ŌKI*

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Introduction

The geology of the northern part of Kagoshima City (ŌKI and HAYASAKA, 1970; ŌKI, 1974) is represented by four marine formations of Pleistocene age associated with three interbeded stratal units of welded tuffs between them, as follows:

Kamô Pyroclastic Flow
Shiroyama Formation
Inuzako Pyroclastic Flow (welded tuff)
Oyamada Formation
Shimokado Pyroclastic Flow (welded tuff)
Kogashira Formation
Yoshino Pyroclastic Flow (welded tuff)
Kekura Formation

In spite of the rather abundant occurrence of fossils from these marine formations, only a few paleontological studies have hitherto been made. In 1931, OTSUKA briefly discussed the faunal character of the molluscs from Shiroyama and Ryûkyûjinmatsu (the Shiroyama Formation of ŌKI and HAYASAKA, 1970) and from Kogashira (the Kogashira Formation of ŌKI and HAYASAKA, 1970; HAYASAKA and ŌKI, 1971) in the Kagoshima City area. TAKAYANAGI (1956) reported on the fossil foraminifera from two localities viz., Yoshida and Ryûkyûjinmatsu both in Kagoshima Prefecture. The latter represents the lower part of the Shiroyama Formation of ŌKI and HAYASAKA (1970). From the occurrence of such species as *Pseudononion japonicum, Elphidium advenum, E.* cf. *clavatum, Buliminella elegantissima* and *Buccella frigida,* he pointed out that the formation at Ryûkyûjinmatsu is characterized by a shallow water fauna strongly influenced by the cold current. ŌKI and HAYASAKA (1970) described and discussed the molluscan fossils from two consecutive horizons of the Shiroyama Formation. They pointed out that the faunal characters of the two different horizons clearly indicate the change of sea water temperature with transgression. It is rather

* Institute of Earth Sciences, Faculty of Science, Kagoshima University, Kagoshima, Japan.

difficult to determine the geological ages of these Pleistocene formations based only on the fossils, and the data on their absolute age are scanty. The result of fission-track dating on the Mifune Rhyolite overlain by the lowest marine formation (the Kekura) is 800,000±80,000 yrs. B.P. (Kaneoka and Suzuki, 1970). The C–14 age of the Kamô Pyroclastic Flow overlying the youngest marine formation (the Shiroyama) is reported to be 33,000 yrs. B.P. (Ishikawa *et al.*, 1972). From the two data stated above on the absolute ages of the overlying and the underlying rock units, the age of deposition of the three marine formations can roughly be estimated to be, namely, between 800,000 yrs. B.P. and 33,000 yrs. B.P.

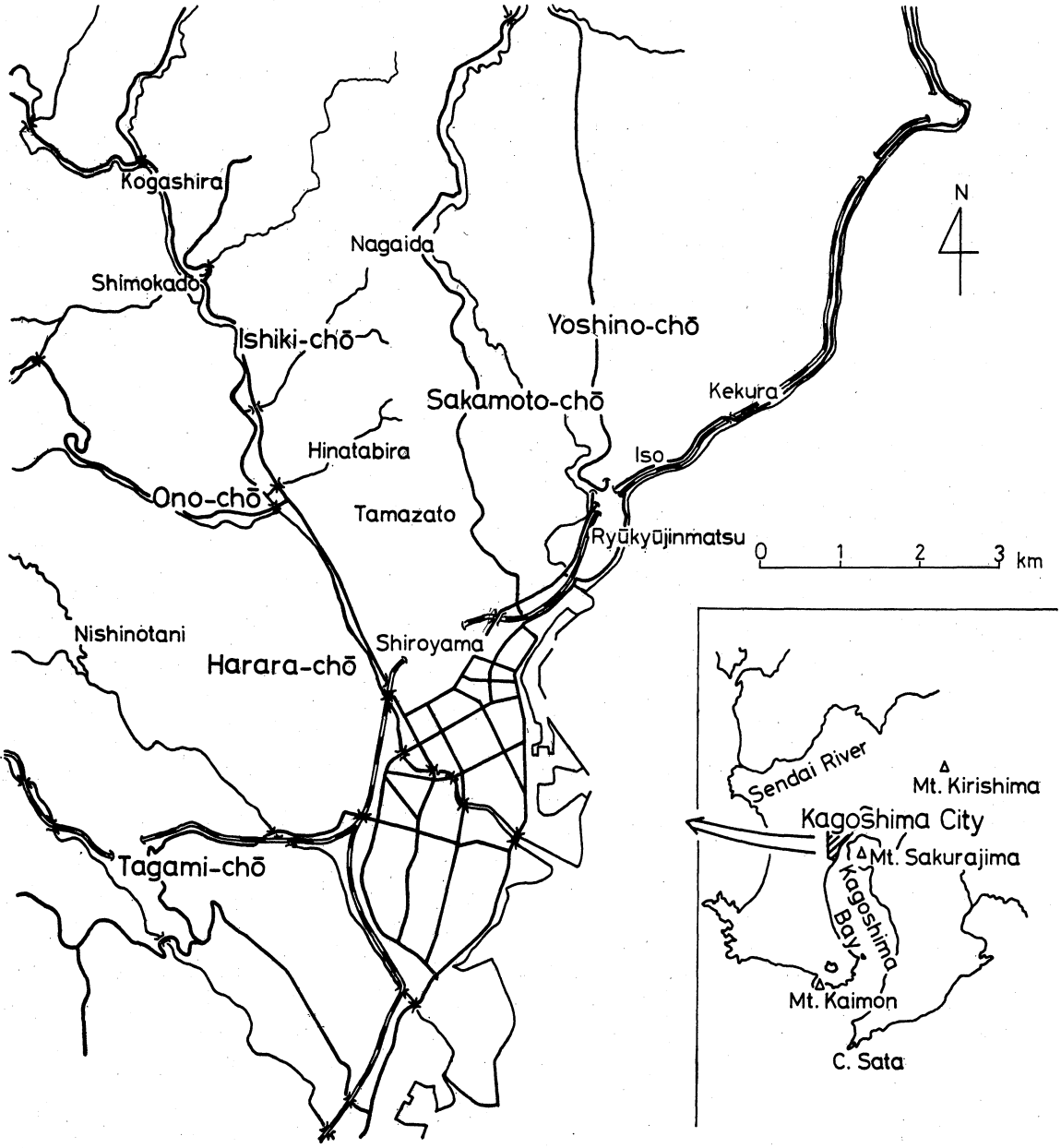

Fig. 1. Index map of the area studied.

The foraminiferal fossils totaling 27 species from the Shiroyama Formation are described and their faunal characters are discussed.

Here the writer wishes to express his deep gratitude to Dr. Kotora HATAI, Professor Emeritus of the Tohoku University and Director of the Saito Ho-on Kai Museum of Natural History, both in Sendai, for his encouragement and for reading the manuscript. He is also indebted to Professor Shozo HAYASAKA of the Kagoshima University for his kind and continued guidance, and Professor Yokichi TAKAYANAGI of the Tohoku University and Dr. Hiroshi UJIIÉ of the National Science Museum (Tokyo) for their guidance on the fossil foraminifers. Particular appreciation is due to Professor Yukitoshi URASHIMA of the Kagoshima University for his encouragement and guidance to utilize the scanning electron microscope for the present study.

Stratigraphic Relation and Fossil Localities

The Shiroyama Formation is developed widely in the Kagoshima City area, and its occurrence is ranging from about 50 meters under the ground surface (according to boring samples) to about 80 meters above sea level in the northern part of Kagoshima City. The sedimentary environments during the Shiroyama age can be classified into the following two areas (ÔKI and HAYASAKA, 1970; ÔKI, 1974).

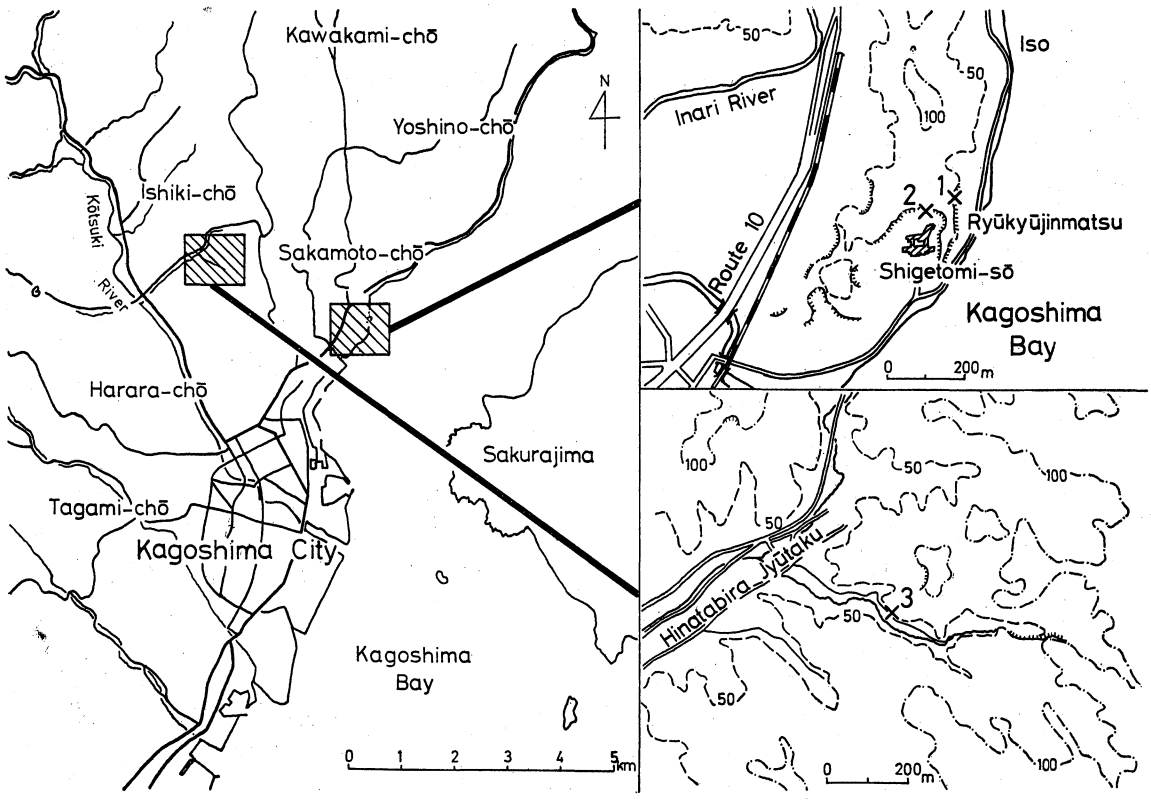

Fig. 2. Map showing the sampling localities (×) for the Shiroyama Formation (right) and their geographic relation (left).

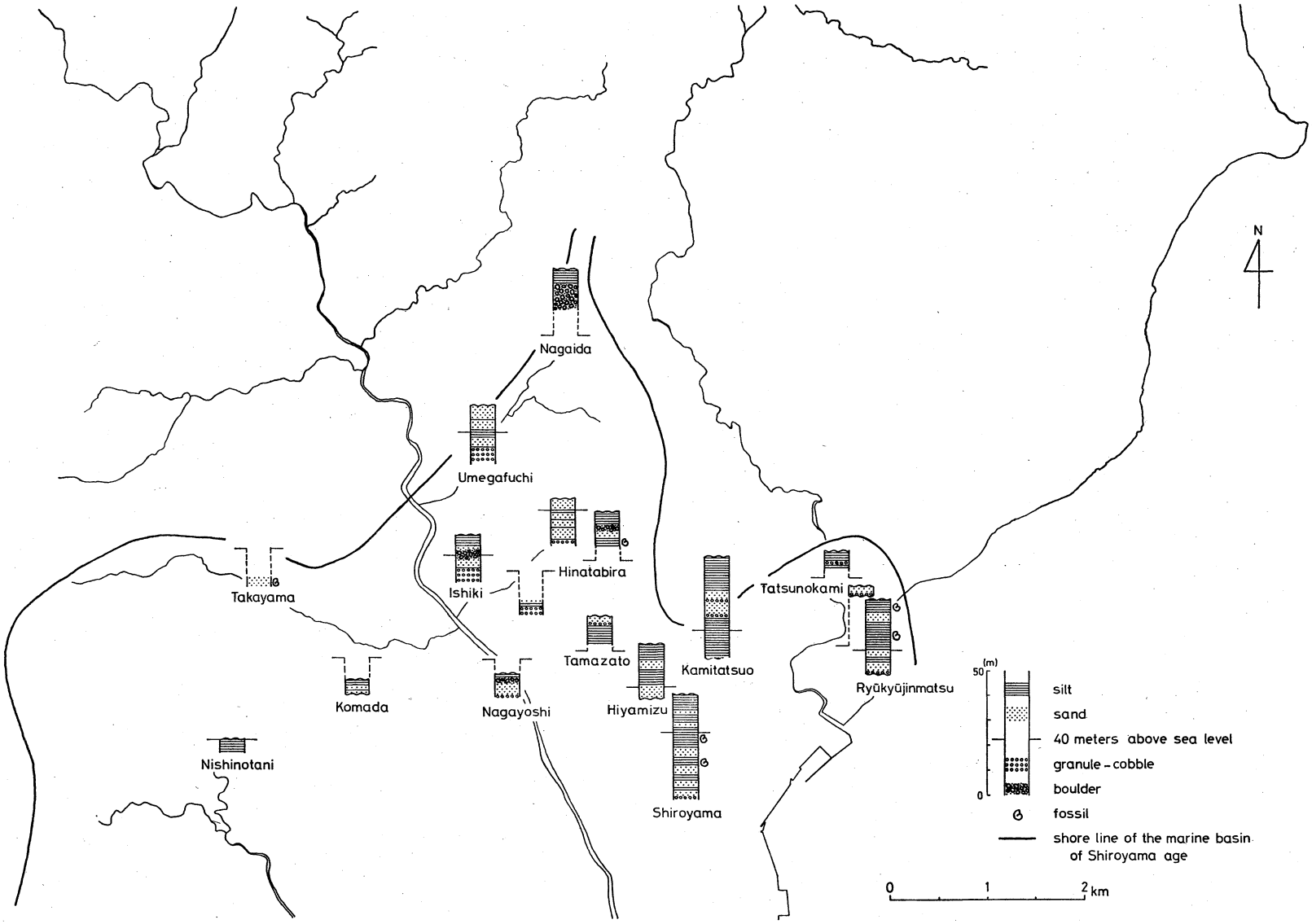

Fig. 3. Columnar sections of the Shiroyama Formation in Kagoshima City.

The eastern part: A quiet environment of embayment.
The tufaceous silt yielding many molluscan and plant fossils.
The western part: A deltaic environment.
The tufaceous sand and gravel yielding only a few molluscan and foraminiferal fossils.

The rise composed of the basement rocks in the marine basin of Shiroyama age separated the basin into two areas of different environments. The rise is recognized in the Hiyamizu-chô area (Fig. 3). The two shell beds of different horizons in the Shiroyama Formation are recognized in the Shiroyama and the Ryûkyûjinmatsu areas by ÔKI and HAYASAKA (1970). The molluscan fossils of the upper shell bed have their external shell removed by solution and the thinner test of the foraminifera are also dissolved, therefore no collections were made from this bed. The fossil foraminifera from the lower shell bed were found at the following three localities (Fig. 2).

Locality 1: A road-side cutting at Ryûkyûjinmatsu, Yoshino-chô, Kagoshima City.
Locality 2: An outcrop in the garden of the Shigetomi-so in Shimizu-chô, Kagoshima City.
Locality 3: A small stream-side outcrop at Hinatabira, Shimoishiki-chô, Kagoshima City.

The descriptions and features of the three localities are given in the following.

At the locality 1 the Shiroyama Formation attaining about 12 meters in maximum thickness overlies the Yoshino Pyroclastic Flow and is overlain by the Tatsuo Formation. The stratigraphic relationships between them are unconformities. The Shiroyama Formation is composed of gravel of about 1 meter in thickness at the basal part overlain with gray colored tufaceous silt or silty sand. A remarkable oyster bank of *Ostrea gigas* is observed in the middle gray colored tufaceous silt that corresponds to the lower shell bed mentioned above. HAYASAKA (1960) described the occurrences of oysters from the Japanese Pleistocene with features similar to the oyster bank just mentioned. He reported that *Ostrea*-reefs have been frequently observed in the Pleistocene sediments and that these indicate the early stage of transgression in the interglacial epoch. He also mentioned that the thick-shelled specimens of *Ostrea gigas* are products of a particular environment as of a partly closed brackish water embayment protected from stormy waves and currents which serve to permit oyster reef-building. He further pointed out that such kind of reefs are generally developed in areas of rather high latitude or under the influence of low temperature.

The paleogeography of the Shiroyama age shows that this area (Locality 1) seems to have been under an environment similar to such as just mentioned (Fig. 4). The foraminiferal fossils were collected from the erratic silt boulders of the outcrop about 50 meters above sea level at the Locality 1.

The same vertical sequence of rock facies as the Locality 1 is also observed at the Locality 2, where the Shiroyama Formation attains about 30 meters in thickness. The molluscan fossils, namely, *Anadara* (*Tegillarca*) *obessa*, *A.* (*Scapharca*) *subcrenata*

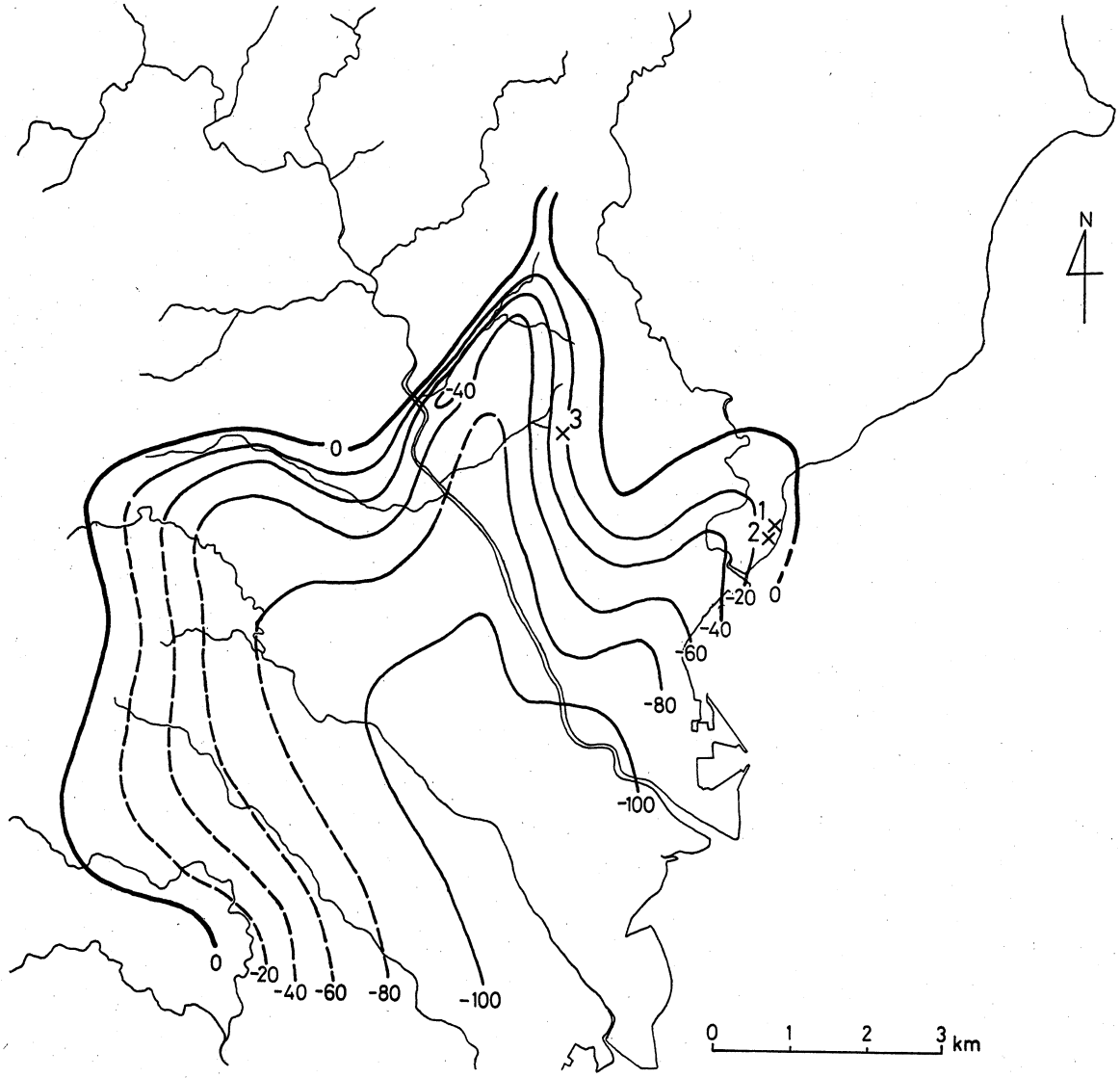

Fig. 4. Map showing the surface configuration of the basement rock of the Shiroyama Formation; interval of the contour is 20 meters.

and *Ostrea* (*Crassostrea*) *gigas* which were collected from the Locality 1 could not be found in the lower shell bed at the Locality 2. At the Locality 3, only three foraminiferal specimens were collected from the rock sample which was 5 times larger than the ones from the Localities 1 and 2. A few molluscan fossils were collected from the lower part of the outcrop at the Locality 3. The tufaceous silt which yielded the fossil foraminifera at the Locality 3 is inferred to correspond stratigraphically to the lower shell bed.

Remarks on the Fauna and Sedimentary Environments of the Shiroyama Formation

The foraminiferal fossils collected from the Shiroyama Formation are shown in

Table 1. List of foraminifera from the Shiroyama Formation

Species \ Locality	1	2	3	total
Fissurina cucurbitasema LOEBLICH and TAPPAN	3	1		4
Buliminella elegantissima (D'ORBIGNY)	1	6		7
Brizalina striatula CUSHMAN	3	1		4
Bulimina aculeata D'ORBIGNY	21	15	1	37
B. denudata CUSHMAN and PARKER	2			2
B. fijiensis CUSHMAN	1			1
B. marginata D'ORBIGNY	51	37		88
B. sp. 1		2		2
B. sp. 2	1			1
B. sp. 3	2			2
Reussella spinulosa (REUSS)		3		3
R. sp.		2		2
Hopkinsina glabra (MILLETT)	16	7		23
Buccella frigida (CUSHMAN)	33	91		124
Ammonia beccarii tepida (CUSHMAN)	148	152	1	301
Pararotalia? globosa (MILLETT)	2	4		6
Elphidium advenum (CUSHMAN)	17	59		76
E. clavatum CUSHMAN		1		1
E. cf. *reticulosum* CUSHMAN	1	16		17
E. subgranulosum aureum AOKI	14	21	1	36
E. sp.	2	6		8
Nonion grateloupi D'ORBIGNY	3	3		6
N. manpukujiense OTSUKA		1		1
Pseudononion japonicum ASANO	12	39		51
Nonionella stela CUSHMAN and MOYER		3		3
Globigerina cf. *quinqueloba* NATLAND	5	6		11
Globigerinoides ruber (D'ORBIGNY)		1		1
Total	338	477	3	818

Table 1. At the Locality 3, only three foraminiferal specimens were found indissolving 270 gr. of rock sample. This suggests that the area of the Locality 3 was under an unfavourable environment for the living foraminifera. The foraminiferal assemblages from the Localities 1 and 2 are quite similar to each other because they are situated close together. It is noted that *Reussella spinulosa* did not occur from the Locality 1 and that the Subfamily Bulimininae, in the number of species and specimens, was more abundant than at the Locality 2.

Ammonia beccarii tepida which is typical of areas of shallow and brackish waters, attains 37 percent in frequency of foraminiferal tests from the Localities 1 and 2 combined, and *Buccella frigida* which seems to be typical of areas of cold waters is the next predominant species. Those attain more than 50 percent of the total frequency.

Foraminiferal assemblage composed mainly of *Ammonia beccarii tepida* and *Buccella frigida* have not been reported from Japan. But a foraminiferal assemblage composed mainly of *Ammonia beccarii* and *Buccella frigida* with subordinate amounts of the 11 common species collected from the Shiroyama Formation, has been reported from Matsushima Bay, Miyagi Prefecture (MATOBA, 1970). The similar assemblages composed of *Ammonia beccarii*, *Buccella frigida* and the few common species of the Shiroyama Formation have been reported from Lake Saroma, Hokkaido (YOSHIDA,

1954), off Sôma City*, Fukushima Prefecture (Takayanagi, 1955) and from the Narita Group (Pleistocene) at Kasukabe, northern part of Tokyo (Kikuchi, 1964). The assemblages similar to the present fossil ones, but which lack *Ammonia beccarii*, have been reported from off Kushiro, Hokkaido (Ishiwada, 1964) and from the Imozawagawa Formation (Pliocene), Sendai (Aoki, 1961). Except for the localities of the foraminiferal fossils, all of the above-mentioned areas are distributed from the tip of northeast Japan to Hokkaido, and are presently under the influence of the cold Oyashio current. In America, the foraminiferal assemblages which are composed of dominant *Ammonia beccarii* (more than 50 percent in frequency) have been reported from the delta area of the Mississippi River and from off the barrier islands in Mississippi Sound (Phleger, 1954; 1955). *Buccella frigida* was not reported from these areas. The living specimens of *Ammonia beccarii tepida* are reported to be distributed from the Tropics to the Temperate Zone (Cushman, 1931; Phleger, 1964; Todd, 1965). Cushman mentioned that this variety is common in the warm waters of the West Indian region. Compared with them, *Ammonia beccarii* seems to be distributed in the areas of higher latitude.

In the foraminiferal assemblages which occur from the Shiroyama Formation, *Fissurina cucurbitasema*, *Buliminella elegantissima* and *Reussella spinulosa* are indicators of shallow water environments, and *Uvigerinella glabra* is an indicator of brackish water environments. The environments indicated by the foraminiferal assemblages coincide with those of the molluscan fossils from this formation.

As a conclusion, the marine basin which extends toward the south (Fig. 4) was under the influence of low temperature. The eastern area of the basin is inferred to have been a particular environment of a closed brackish water embayment where the oysters formed the bank. On the other hand, the western part of the basin which was probably a deltaic area was unfavourable as an environment for the benthonic foraminifers.

Description of Species

Superfamily NODOSARIACEA Ehrenberg, 1838

Family GLANDULINIDAE Reuss, 1860

Subfamily OOLININAE Loeblich and Tappan, 1961

Genus *Fissurina* Reuss, 1850

Fissurina cucurbitasema Loeblich and Tappan, 1953

Pl. 2, fig. 1.

Fissurina cucurbitasema Loeblich and Tappan, 1953, p. 76, pl. 14, figs. 10–11; Matsunaga, 1963, pl. 32, figs. 9a-b; Ujiié, 1963, p. 232, pl. 1, figs. 9–11; Todd and Low, 1967, p. A28, pl. 3, fig. 23; Matoba, 1970, p. 54, pl. 3, figs. 22a-b; Kameyama, 1972, p. 202, pl. 27, fig. 2.

* Takayanagi called it the Isobe Facies.

Description: Test compressed, ovate, single chamber, elongate in front view, pear shaped in side view, symmetrical; periphery subacute; wall thin, surface with sculpture; aperture slitlike at top. Length up to 0.3 mm.

Locality and repository: Localities No. 1 (ESK* Reg. no. F–5012) and No. 2 (ESK Reg. no. F–5013).

Remarks: The present species was described originally from the Arctic region, and subsequently has been reported to occur from the Miocene Higashiyama Formation (MATSUNAGA, 1963), the Miocene-Pliocene Miyazaki Group (KAMEYAMA, 1972) and from the shallow water bottom of Matsushima Bay in Miyagi Prefecture (MATOBA, 1970). TODD and LOW (1967) recorded it from the Gulf of Alaska. They also reported that this form was recorded from the Barents Sea and from off the coasts of California and Oregon.

All the records of the present species are from shallow water environments. This species is represented by only one individual from the Locality 1 and three individuals from the Locality 2.

Superfamily BULIMINACEA JONES, 1875

Family TURRILINIDAE CUSHMAN, 1927

Subfamily TURRILININAE CUSHMAN, 1927

Genus *Buliminella* CUSHMAN, 1911

Buliminella elegantissima (D'ORBIGNY), 1839

Pl. 2, fig. 2.

Bulimina elegantissima D'ORBIGNY, 1839, pt. 5, p. 51, pl. 7, figs. 13–14.

Buliminella elegantissima (D'ORBIGNY), CUSHMAN, 1921, p. 168; COLE, 1931, p. 39, pl. 2, fig. 8; ASANO, 1950–52, pt. 2, p. 2, text-figs. 1–2; CUSHMAN, 1951, p. 39, pl. 11, fig. 20; TAKAYANAGI, 1953, p. 142; YOSHIDA, 1954, p. 153, pl. 1, fig. 3; PHLEGER, 1954, p. 637, pl. 1, figs. 24–25; TAKAYANAGI, 1955, p. 43, pl. 2, fig. 1; AOKI, 1961, p. 16, pl. 3, fig. 3; KUWANO, 1962, p. 130, pl. 15, figs. 15–16; MATSUNAGA, 1963, pl. 39, figs. 4a-b; UJIIÉ, 1963, p. 230, pl. 1, fig. 16; ISHIWADA, 1964, p. 8, pl. 4, fig. 50; PHLEGER, 1964, p. 382, pl. 2, fig. 15; LOEBLICH and TAPPAN, 1964, p. C543, fig. 426, 3a-c; MATOBA, 1967, p. 252, pl. 25, fig. 8; TODD and LOW, 1967, p. A26, pl. 3, fig. 36; MATOBA, 1970, p. 50, pl. 3, fig. 32.

Description: Test small, elongate, subacute, composed of two or three whorls, with high, close spirals formed by numerous very high, narrow chambers; chambers elongate, slightly inflated; sutures distinct, bow-shaped, slightly depressed; wall calcareous, perforate, apertural face just above aperture poreless to sharp angle of apertural ridge, surface smooth, rarely spinose; aperture loop-shaped, with upper end relatively broad. Length up to 0.2 mm.

Locality and repository: Localities No. 1 (ESK Reg. no F–5014) and No. 2 (ESK Reg. no. F–5015).

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* Abbreviation for the Institute of Earth Sciences, Faculty of Science, Kagoshima University.

Remarks: The present species has been recorded from the eastern part of the Pacific Ocean, off the coast of Alaska to Peru, east coast of Mindanao (Cushman, 1951) and the West Indian region (Cole, 1931). Phleger (1965) reported that the living population of the present species occurs on the bottom shallower than 100 meters and is restricted to sandy bottoms ranging from 8 to 20 meters in depth.

The records of the fossil occurrences are the Pleistocene Kushiro Formation in Hokkaido (Takayanagi, 1953), Pliocene Imozawagawa Formation, Miyagi Prefecture (Aoki, 1961), Pliocene Hamada Formation, Aomori Prefecture (Asano, 1950–52), Neogene formations in the oil fields of northeast Honshu (Matsunaga, 1963) and the Kazusa Group, Chiba Prefecture (Ishiwada, 1964). The present species is known to live in the shallow water off the Pacific coast of northern Japan as well as in a few embayments such as Lake Saroma and Matsushima Bay both on the Pacific side of northern Japan. Kuwano (1962) reported an isolated occurrence of the present species in Kagoshima Bay situated at the southern end of Kyushu. Kuwano's opinion concerning the Recent distribution of the present species in Japan is as follows:

"This form is a possible representative of cold temperate and/or subarctic forms off Japan. The living tests are known only from the shallow open-sea waters on the Pacific coast of northern Honshu at about 36.5°N. in latitude. The living and dead tests have not been reported from off the western coast of Kyushu, the Japan Sea side of Honshu and the Pacific coast of Middle Honshu (34–35°N.)."

This species was also collected from the tropical areas by Cole (1931) and Cushman (1951). The writer reserves to support Kuwano's opinion in this paper.

This species is present in very low frequencies at the Localities 1 and 2 in the Shiroyama Formation.

Family BOLIVINITIDAE Cushman, 1927

Genus *Brizalina* Costa, 1856

Brizalina striatula (Cushman), 1922

Pl. 2, fig. 3.

Bolivina striatula Cushman, 1922, p. 27, pl. 3, fig. 10; Cole, 1931, p. 41, pl. 2, fig. 9; Cushman, 1942, pt. 3, p. 30, pl. 9, fig. 1.

Brizalina striatula (Cushman), Chiji, 1969, Q–5, fig. 4; Sliter, 1970, p. 170, pl. 7, fig. 6, pl. 8, fig. 19.

Description: Test small, biserial, about 3 times as long as broad, compressed, sometimes slightly twisted, periphery not keeled; chambers numerous, very slightly inflated, relative height increasing aperturally, where height and breadth are often about equal; sutures distinct, very slightly depressed, obliquely curved; wall distinctly perforate, smooth, fine, ornamented with numerous, longitudinal costae running up halfway of test; aperture elongate, narrow at base. Length up to 0.6 mm.; breadth 0.2 mm.; thickness 0.05 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5016) and No. 2 (ESK Reg. no. F–5017).

Remarks: CUSHMAN (1942) reported that the present species was known only from the Atlantic, being collected from the tropical Pacific region; in the Niau Lagoon and off Niau; 12 fathoms off Nairai, Fiji; and the lagoon at Pinaki Atoll. The fossil specimens are reported in America from the Pliocene and Pleistocene formations of Florida (COLE, 1931) and in Japan only from the coastal terrace deposits in Uchiura-chô, Suzu-gun, Ishikawa Prefecture (CHIJI, 1969).

This form is present in very low frequencies in the Shiroyama Formation.

Family BULIMINIDAE JONES, 1875

Subfamily BULIMININAE JONES, 1875

Genus *Bulimina* D'ORBIGNY, 1826

Bulimina aculeata D'ORBIGNY, 1826

Pl. 2, figs. 6a–b.

Bulimina aculeata D'ORBIGNY, 1826, p. 269, no. 7; CUSHMAN, 1921, p. 161, pl. 31, fig. 5; CUSHMAN, 1922, p. 96, pl. 22, figs. 1–2; HADA, 1931, p. 127, text-fig. 84; ASANO, 1950–52, pt. 2, p. 3, text-figs. 8–9; ASANO, 1958, p. 2, pl. 1, figs. 1–3; ISHIWADA, HIGUCHI and KIKUCHI, 1962, p. 71, pl. 1, fig. 16; MATSUNAGA, 1963, pl. 39, figs. 7a-b; KIKUCHI, 1964, p. 4, pl. 2, figs. 14–24; HUANG, 1964, p. 72, pl. 2, fig. 2; ISHIWADA, 1964, p. 18, pl. 4, fig. 51; BELFORD, 1966, p.58, pl. 5, figs. 1–3, text-figs. 5, 1–3, text-fig. 7, 1; MATOBA, 1967, p.252, pl. 25, figs. 30–32; AOKI, 1968, p. 246, pl. 27, figs. 9–10; KIM, 1970, p. 156, pl. IX–2, figs. 2a-b; KAMEYAMA, 1972, p. 201, pl. 28, fig. 2; LEROY and LEVINSON, 1974, p. 9, pl. 5, fig. 6; FILLON, 1974, p. 139, pl. 4, fig. 6.

Description: Test tapering, flaring, composed of 3 to 6 whorls, early portion with numerous aculeate spines; chambers tumid, triserial but in some specimens position of chambers slightly different on each whorl; sutures distinct, depressed; wall calcareous, perforate; aperture slightly curved, loop-shaped with lip in a slight depression of the ventral face of the chamber. Length up to 0.5 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5018) and No. 2 (ESK Reg. no. F–5019).

Remarks: ASANO (1958) collected the present species from depths ranging from 154 to 600 meters and from 2.9 to 16.7°C in temperature, and stated that the present species is widely distributed in the Pacific and Atlantic oceans and is found commonly in the Miocene and Pliocene formations of Japan. The living specimens are also reported to occur in the bottom sediments off the southwestern coast of the Korean Peninsula (KIM, 1970) and from the western Atlantic, ranging from the cold water south of Nova Scotia down the coast to the region of Carolina (CUSHMAN, 1922). CUSHMAN (1921) collected the Recent specimens from Gulf of Tomini, Celebes, 834 fathoms (1,525 meters); north of Celebes, 752 fathoms (1,375 meters); and Gulf of Boni, 608 fathoms (1,112 meters) bottom temperature 39.2°F. (4°C.). LEROY and LEVINSON

(1974) reported the species from the northern Gulf of Mexico.

The fossil specimens are in Japan reported from the Pliocene Iioka and the Pleistocene Toyosato formations, Chiba Prefecture (Matoba, 1967); the Ushigakubi Formation, Niigata Prefecture and the Funakawa Formation, Akita Prefecture (Matsunaga, 1963); the Kiwada, Ôtadai, Umegase and the Kasamori formations, Chiba Prefecture and the Ôfuna Formation, Kanagawa Prefecture (Kikuchi, 1964); the Pliocene Dai Formation, Akita Prefecture and the Pliocene Kanazawa Formation, Kanagawa Prefecture (Asano, 1950–52). This species is also reported from the Takangkou and the Chimei formations in Taiwan (Huang, 1964).

This species is present at three Localities in the Shiroyama Formation in low frequencies, up to 4.5 percent.

Bulimina aculeata was placed in the synonymy of *B. marginata* by Höglund (1947). But from a comparison of the two forms and an examination of the tooth-plate and pores, Belford (1966) regarded *aculeata* as a distinct species and mentioned as follows:

"*Bulimina aculeata* and *B. marginata* are closely related species, but in the present samples at least there is no difficulty in distinguishing between them on external appearance. Some Recent specimens of *marginata* from the north Atlantic have later chambers similar to those of *aculeata*, but the early chambers are invariably 'undercut', and a clear distinction may be made by examination of the finer details of the test."

The writer recognized specimens of the type intermediate between the above-mentioned two forms as shown in Pl. 2, figs. 4, 5. Research to determine the morphological relationship between *Bulimina aculeata* and *B. marginata* should be continued from the view point of both ecology and morphology in order to settle the problem on them.

Bulimina denudata Cushman and Parker, 1938

Pl. 2, fig. 7.

Bulimina pagoda Cushman, var. *denudata* Cushman and Parker, 1938, p. 57, pl. 10, figs. 1–2; Phleger, 1964, p. 382, pl. 2, fig. 4.

Description: Test tapering at initial end, triserial in younger stage, later biserial, adult stage decreases in breadth; chambers rather inflated; sutures distinct, slightly depressed; wall smooth, finely perforated; aperture loop-shaped, extending from base of final chamber toward apex. Length up to 0.3 mm.; breadth 0.15 mm.

Locality and repository: Locality No. 1 (ESK Reg. no. F–5020).

Remarks: The type specimen, originally described by Cushman and Parker (1938) from the Pliocene of California, was also reported by them from the Pleistocene of Lomita Quarry, Palos Hills, Los Angeles, California, and in the present ocean off La Jolla, California. Phleger (1964) reported the living specimens of this species from the bottom shallower than 128 meters in the Gulf of California. This species is represented by two individuals from Locality 1.

Bulimina fijiensis CUSHMAN, 1933
Pl. 2, figs. 8a–b.

Bulimina fijiensis CUSHMAN, 1933, p. 79, pl. 8, figs. 7a-c; CUSHMAN, 1942, pt. 3, p. 11, pl. 3, figs. 10–11.

Description; Test small, tapering, flaring, slightly longer than breadth, rounded; chambers inflated, increasing rapidly in size as added; sutures distinct, depressed; wall coarsely perforate except apertural face; aperture loop-shaped, placed above the junction of the second and the third chamber. Length up to 0.2 mm.

Locality and repository: Locality No. 1 (ESK Reg. no. F–5021).

Remarks: The type specimen was originally described by CUSHMAN (1933) from 12 fathoms depth off Nairai, Fiji and also from 12 fathoms depth off Levuka, Fiji (CUSHMAN, 1942). This species has not been reported in Japan previously and is represented by only one individual from the Locality 1.

Bulimina marginata D'ORBIGNY, 1826
Pl. 2, figs. 9a–b; Pl. 3, fig. 1.

Bulimina marginata D'ORBIGNY, 1826, p. 269, no. 4, pl. 12, figs. 10–12; CUSHMAN, 1922, pt. 3, p. 91, pl. 21, figs. 4–5; ASANO, 1938a, p. 10, pl. 1, fig. 17; ASANO, 1938 b, p. 71, pl. 6, fig. 5; ASANO, 1950–52, pt. 2, p. 4, text-figs. 13–14; ASANO, 1958, p. 4, pl. 1, figs. 5, 9–11; KUWANO, 1962, p. 135, pl. 15, figs. 11–14; MATSUNAGA, 1963, pl. 40, fig. 3; PHLEGER, 1964, p.382, pl. 2, fig. 3; KIKUCHI, 1964, pl. 2, figs. 11–13; HUANG, 1964, p.72, pl. 2, fig. 1; ISHIWADA, 1964, p. 39, pl. 4, figs. 52–53; BELFORD, 1966, p. 55, pl. 5, figs. 4–5, text-figs. 7 (2–3); MATOBA, 1967, p. 252, pl. 25, fig. 37; MATOBA, 1970, p. 50, pl. 3, fig. 32; MURRAY, 1970, p. 484, pl. 1, fig. 21; KAMEYAMA, 1972, p. 201, pl. 28, fig. 3; LEROY and LEVINSON, 1974, p. 9, pl. 5, fig. 7.

Description: Test tapering, flaring, composed of 3 to 5 whorls; chambers numerous, inflated, undercut at margin; wall smooth, distal margin of the chambers ornamented with tooth-like crenulations or short spines; aperture loop-shaped, near apex of test. Length up to 0.5 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5022) and No. 2 (ESK Reg. no. F–5023).

Remarks: The living specimens were reported in Japan from off NE Honshu (common), Tosa Bay (abundant), Kagoshima Bay (common) (KUWANO, 1962) and Matsushima Bay (MATOBA, 1970), and outside Japan from off the eastern coast of the United States; off the West Indies; off the British Isles; coasts of Norway, Sweden and Spitzbergen ranging in depth from 50 to 270 meters; off New Zealand; coast of south Carolina; northern part of the Gulf of Mexico; off Key West, Florida (CUSHMAN, 1922); Gulf of California (PHLEGER, 1964); western approaches to the English Channel (MURRAY, 1970). According to ASANO (1958), the present species is present at the depths between 68 and 684 meters and 1.5 and 23.3°C in temperature. The fossil occurrences are from the Kasamori Formation in Chiba Prefecture (KIKUCHI, 1964), the Early Pleistocene Toyosato Formation in Chiba Prefecture (MATOBA, 1967), the

Pliocene Dai and Kanazawa formations in the Kwanto region (Asano, 1950), the Pliocene Sasaoka Formation in Akita Prefecture (Matsunaga, 1963) and the Takangkou and Chimei formations in Sanhsienchi, Taitung, Eastern Taiwan (Huang, 1964).

This species which attains 10.8 percent in frequency, is one of the three most abundant species in the Shiroyama Formation. According to Ishiwada (1964), the japonic type of the species from the cool waters differs from the typical one which is ornamented with spines. It is noticeable that most of the specimens from the Shiroyama Formation are provided with sharp spines, especially on the earlier chambers. *Bulimina marginata* and *B. aculeata* are closely related species, but Belford (1966) regarded *aculeata* as a distinct species from a comparison of the two forms and an examination of the tooth-plate and pores. The writer recognized specimens of a type intermediate between (Pl. 2, figs. 4, 5) the above-mentioned two forms. Research on the morphological relationship between *Bulimina marginata* and *B. aculeata* should be continued from the view point of ecology and morphology in order to determine their precise classification.

Bulimina sp. 1
Pl. 3, figs. 2a–b.

Locality and repository: Locality No. 2 (ESK Reg. no. F–5024).

Remarks: Although this species is similar to *Bulimina aspero-aculeata* Brotzen, it differs from *B. aspero-aculeata* in becoming biserial in the adult stage and by lacking longitudinal costae. This species is also similar to *B. rosenkrantzi* Brotzen, but identification is reserved because there is only two individuals at hand from the Locality 2.

Bulimina sp. 2
Pl. 3, fig. 3

Locality and repository: Locality No. 1 (ESK Reg. no. F–5025) .

Remarks: This species is characterized by the test tapering at the initial end and by the chambers increasing in height and size as added. It is represented by only one individual from the Locality 1.

Bulimina sp. 3
Pl. 3, fig. 4

Locality and repository: Locality No. 1 (ESK Reg. no. F–5026).

Remarks: This species is similar to *Bulimina acanthia* Costa which was reported by Matsunaga (1963) from the Ushigakubi Formation, but naming is reserved because it is only two imperfect individuals from the Locality 1.

Subfamily PAVONININAE EIMER and FICKERT, 1899

Genus *Reussella* GALLOWAY, 1933

Reussella spinulosa (REUSS), 1850

Pl. 3, figs. 5a–b.

Verneuilina spinulosa REUSS, 1850, p. 374, pl. 47, fig. 12.
Reussia spinulosa (REUSS), HADA, 1931, p. 133, text-fig. 90.
Reussella spinulosa (REUSS), ASANO, 1938a, p. 50, pl. 1, fig. 18; CUSHMAN, 1942, pt. 3, p. 40, pl. 11, figs. 5–8; ASANO, 1953, p. 9, pl. 2, fig. 21.

Description: Test pyramidal, triangular in transverse section, tapering towards initial end, angles of test acute, initial end and angles of chambers often with spines; chambers numerous, arranged triserially; sutures distinct, limbate, raised; wall smooth, fine perforate, translucent, with definite pit near periphery of chamber; aperture a curved slit at base of inner margin of chamber. Length up to 0.7 mm.

Locality and repository: Locality No. 1 (ESK Reg. no. F–5027).

Remarks: CUSHMAN (1942) mentioned that in the shallow water material this species has occurred about Fiji near Nairai in 12 and 24 fathoms; off Levuka, Fiji, 12 fathoms; Viva Anchorage, Fiji, 3 fathoms; Mokaujar Anchorage, Fiji; and at 40–50 fathoms off Fiji. It has also occurred (Cushman, 1942) at Vavau Anchorage, Tonga Islands, 18 fathoms; Pinaki Island, Paumotu Islands; Makemo Lagoon, Paumotu Islands; off Rotonga, 7 fathoms; Rongelap Atoll, Marshall Islands; off Rangiroa, 21 fathoms; Guam Anchorage, Ladrone Islands; and at Port Lotten, Kersail, Caroline Islands. The living specimens have also been reported from the Tropical Pacific (CUSHMAN, 1942), Mutsu Bay (HADA, 1931; ASANO, 1938a), Shiogama Bay, Onnagawa Bay (ASANO, 1938a) and from Oshoro Inlet, Hokkaido (HADA, 1931). The fossil specimens were reported from the Miocene of Noto Peninsula, Ishikawa Prefecture (ASANO, 1953). This species seems to be a widely distributed one, occurring at least as far back as the Miocene and is extensively distributed especially in rather shallow waters. This species was found only at the Locality 2 in the Shiroyama Formation with frequency less than 1 percent.

Reussella sp.

Pl. 3, fig. 6.

Locality and repository: Locality No. 2 (ESK Reg. no. F–5028).

Remarks: The test of this species is triserial, the angles of the test are acute and the aperture is at the base in the last-formed chamber with an internal tooth-plate. From these characteristics this form is referred to the Genus *Reussella*. Only two specimens identified as *Reussella* sp. were examined in the materials from the garden of the Shigetomi-sô (Locality 2).

Family UVIGERINIDAE HAECKEL, 1894

Genus *Hopkinsina* Howe and Wallace, 1932

Hopkinsina glabra (Millett), 1903

Pl. 3, fig. 7.

Uvigerina auberiana var. *glabra* Millett, 1903, p. 268, pl. 5, figs. 8a-b.
Hopkinsina pacifica Cushman, Cushman, 1942, pt. 3, p. 51, pl. 15, fig. 1; Takayanagi, 1955, pl. 2, fig. 22.
Hopkinsina californica Cushman, Ujiié, 1963, pl. 1, figs. 14–15.
Hopkinsina glabra (Millett), Aoki, 1965, p. 59, pl.7, fig. 2.
Uvigerinella glabra (Millett), Matoba, 1970, p. 62, pl. 3, figs. 35a-b.

Description: Test fusiform, initial end subacute, early stage triserial, later biserial; chambers inflated, slightly elongate; sutures distinct, depressed; wall finely perforate, surface smooth; aperture extend on face of final chamber with elevated collar. Length up to 0.3 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5029) and No. 2 (ESK Reg. no. F–5030).

Remarks: Aoki (1965) reported the fossils of this species from the Sanuki, Kasamori and the Narita formations in Chiba Prefecture, the Takatsu and Iimuro formations in Kanagawa Prefecture and the mudstone of the Shimosueyoshi Formation in Kanagawa Prefecture. This species is also reported to occur from the Yûrakuchô Formation in Tokyo (Ujiié, 1963) and to live in Matsukawa-ura, Fukushima Prefecture (Takayanagi, 1955) and Matsushima Bay, Miyagi Prefecture (Matoba, 1970) and outside Japan, the Tropical Pacific (Cushman, 1942).

According to Loeblich and Tappan (1964), *Hopkinsina* differs from *Uvigerina* in its later biserial stage and from *Uvigerinella* in its terminal aperture. Cushman (1942) and Takayanagi (1955) reported *Hopkinsina pacifica* from the Tropical Pacific and Matsukawa-ura, Fukushima Prefecture respectively, and Ujiié (1963) reported *Hopkinsina californica* from the Yûrakuchô Formation (Holocene) without description, but judging from the descriptions and the illustrations of the latter two mentioned authors they seem to be identifiable as *Hopkinsina glabra*. This species is present at the Localities 1 and 2 in the Shiroyama Formation in average frequency of 2.8 percent.

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Subfamily DISCORBINAE Ehrenberg, 1838

Genus *Buccella* Andersen, 1952

Buccella frigida (Cushman), 1922

Pl. 3, figs. 8a–b.

Pulvinulina frigida Cushman, 1922, p. 12.
Eponides frigida (Cushman), Cushman, 1931, pt. 8, p. 45.

Buccella frigida (CUSHMAN), AOKI, 1961, p. 16, 19, pl. 3, figs. 5a-c; MATSUNAGA, 1963, p. 82, pl. 45, figs. 3a-b; UJIIÉ, 1963, p. 32, pl. 1, figs. 22a-c; ISHIWADA, 1964, p. 8, pl. 6, figs. 91a-c; MATOBA, 1967, p. 252, pl. 26, figs. 9a-c; TODD and LOW, 1967, p. A31, pl. 4, fig. 20; MATOBA, 1970, p. 49, pl. 4, figs. 1a-c, 2a-c; SEN GUPTA, 1971, p. 89, pl. 2, figs. 18–19.

Description: Test biconvex, rotaliform, subcircular in outline, periphery rounded, composed of 2 to 3 whorls, 5 to 7 chambers in last whorl; chamber distinct, usually six in last-formed coil; sutures distinct, not depressed on dorsal side, but slightly depressed and filled with amorphous material radiating from umbilical region, strongly oblique on dorsal side, radial on ventral side; wall perforate, translucent; aperture at base of apertural face of last chamber. Diameter up to 0.4 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5031) and No. 2 (ESK Reg. no. F–5032).

Remarks: The living specimens have been recorded from Matsushima Bay, Miyagi Prefecture (MATOBA, 1970), Hudson Bay in Canada (CUSHMAN, 1931), the Gulf of Alaska (TODD and LOW, 1967) and from the Tail of the Grand Banks of Newfoundland (SEN GUPTA, 1971). The fossil occurrences have been reported from the Early Pleistocene Imozawagawa Formation, Miyagi Prefecture (AOKI, 1961); the Miocene-Pliocene Kannonji, Maruyama and the Tateyama formations, Yamagata Prefecture and the Miocene Teradomari and the Nanatani formations (MATSUNAGA, 1963); the Holocene Yûrakuchô Formation (UJIIÉ, 1963) and the Pliocene Kazusa Group (ISHIWADA, 1964).

This species seems to be a typical cold and shallow water element (AOKI, 1961). According to MATOBA (1970), the present species shows great variation in the thickness of the test, number of chambers in the last whorl and features of the peripheral margin. Concerning the variation of the present species, UJIIÉ (1963) stated as follow:

"With regard to their geographical distribution, it is known that the rounded peripheral forms are never restricted to high latitudes, whereas the carinated forms develop in such areas, in particular, with larger test and with more frequency (for example, VOLOSHINOVA, 1960)."

This species which attains 15.2 percent in frequency, is one of the three most abundant species of the foraminiferal assemblages in the Shiroyama Formation.

Superfamily ROTALIACEA EHRENBERG, 1839

Family ROTALIIDAE EHRENBERG, 1839

Subfamily ROTALIINAE EHRENBERG, 1839

Genus *Ammonia* BRÜNNICH, 1772

Ammonia beccarii tepida (CUSHMAN), 1926

Pl. 4, figs. 1a–e.

Rotalia beccarii (LINNAEUS), var. *tepida* CUSHMAN, 1926, p. 79, pl. 1; CUSHMAN, 1931, pt. 8, p. 61, pl. 13, figs. 3a-c.

Rotalia beccarii (Linné), var. *tepida* Cushman, Cole, 1931, p. 50, pl. 3, figs. 3–4.
"Rotalia" beccarii (Linné), var., Phleger, 1954, p. 645, pl. 3, figs. 7–10.
Ammonia beccarii tepida (Cushman), Ujiié, 1963, p. 32, pl. 1, fig. 7; Chiji, 1969, Q-4, figs. 5a-b; Chiji, 1969, Q–5, figs. 8a-b.
Streblus beccarii tepida (Cushman), Todd, 1965, pt. 4, p. 29, pl. 6, fig. 1, pl. 7, fig. 2; Todd, 1966, p. 132.
Ammonia beccarii (Linné), Belford, 1966, p. 108, pl. 19, figs. 2–8.

Description: Test biconvex, low trochospiral coil of 2 or 3 volutions, periphery rounded; chambers very inflated, 6 or 7 in last whorl; sutures depressed, slightly curved; wall smooth, finely perforate; umbilicus open and umbilical surface with irregular granules along suture and over umbilical region; aperture a rounded small opening at ventral border of last chamber. Diameter up to 0.4 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5033), No. 2 (ESK Reg. no. F–5034) and No. 3 (ESK Reg. no. F–5035).

Remarks: The living specimens were reported to occur from warm and shallow water in the West Indian region (Cushman, 1931), Mississippi Sound (Phleger, 1954), the Gulf of California (Phleger, 1964) and from the tropical Pacific region (Todd, 1965). The fossil specimens were reptored from the Late Pleistocene Okuhara (Chiji, 1969) and the Holocene Yûraku-chô (Ujiié, 1963) formations and the ancient dune (Holocene) in Suzu District, Ishikawa Prefecture (Chiji, 1969) in Japan, and outside Japan, from the Pliocene and Pleistocene formations of Florida (Cole, 1931) and the Miocene and Pliocene formations in Papua and New Guinea (Belford, 1966).

This is one of the representative species indicating a shallow or brackish water environment. This species is the most abundant in the foraminiferal assemblages of the Shiroyama Formation; it has average frequencies up to 36.8 percent. This species which was collected from the Locality 1, attains 43.8 percent in frequency. *Ammonia beccarii* and *Buccella frigida* which are predominant species of the foraminiferal assemblages in the Shiroyama Formation, attain more than 50 percent in total frequency.

Genus *Pararotalia* Le Calvez, 1949

Pararotalia? *globosa* (Milleto), 1903

Pl. 4, figs. 2a–d.

Discorbina imperatoria (d'Orbigny) var. *globosa* Millett, 1903, p. 701, pl. 7, figs. 6a-c.
"Eponides"? *globosus* (Millett), Ujiié, 1963, p. 233, pl. 1, figs. 26–29.
Pararotalia? *globosa* (Millett), Matoba, 1970, p. 57, pl. 6, figs. 8a-c.

Description: Test trochospiral, periphry subrounded, peripheral outline strongly stellate, spiral side nearly flattened but inflated at central portion, umbilical side convex, umbilical region slightly depressed; chambers in two whorls, 5 in final whorl, forming a rhomboidal to triangular shape in peripheral view; sutures distinct, slightly depressed, radial on umbilical side; wall perforate, surface finely pustulous and ornamented with short, blunt spines at narrowly rounded radial end of each chamber;

aperture a rounded small opening at ventral border of last chamber. Diameter up to 0.15 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5036) and No. 3 (ESK Reg. no. F–5037).

Remarks: The living specimens of this species have been reported to occur from off the Malay Archipelago (MILLETT, 1903) and in Matsushima Bay, Miyagi Prefecture (MATOBA, 1970). The records of the fossil occurrences of the present species are from the Yûrakuchô Formation (Holocene) in Tokyo (UJIIÉ, 1963). The writer refers this species to the Genus *Pararotalia*?, following MATOBA (1970). This species is present in very low frequencies in the Shiroyama Formation.

Family ELPHIDIIDAE GALLOWAY, 1933

Subfamily ELPHIDIINAE GALLOWAY, 1933

Genus ELPHIDIUM DE MONTFORT, 1808

Elphidium advenum (CUSHMAN), 1922

Pl. 4, figs. 3a–b.

Polystomella advena CUSHMAN, 1922, p. 56, pl. 9, figs. 11–12.
Elphidium advenum (CUSHMAN), CUSHMAN, 1933, p. 50, pl. 12, figs. 1–3; ASANO, 1938b, p. 65, pl. 7, figs. 4–5; ASANO, 1938c, p. 587, pl. 14, fig. 3; ASANO, 1950–52, pt. 1, p. 6, figs. 32–33; TAKAYANAGI, 1955, p. 24, pl. 1, fig. 24; FUJITA, 1956, p. 230, pl. 8, figs. 1a-b; ASANO, 1960, p. 195–196, pl. 22, figs. 3a-b; KUWANO, 1962, p. 129 ,pl. 17, fig. 6; MATSUNAGA, 1963, p. 105, pl. 36, fig. 4; ISHIWADA, 1964, p. 14–15, pl. 3, fig. 42; KIKUCHI, 1964, p. 4, pl. 4, figs. 28–30; KAMEYAMA, 1972, p. 201, pl. 29, figs. 6a-b.

Description: Test equally biconvex, lenticular in peripheral view, periphery acute with a narrow carina, which is developed sometimes in whole or in early chambers of last formed coil; umbilical region slightly depressed; chambers distinct, 8–11, averaging 9–10 in last formed coil, slightly inflated; sutures depressed, marked by about 11 retral processes one-fourth the width of chambers; wall smooth, translucent, finely perforate; aperture a series of rounded pores at base of apertural face of chamber. Maximum diameter 0.7 mm.; thickness 0.2 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5038) and No. 2 (ESK Reg. no. F–5039).

Remarks: The present species, originally described by CUSHMAN (1922) from Tortugas, southern Florida, is a predominant one in the Shiroyama Formation. Although it has been pointed out by a few authors (CUSHMAN, 1933; ASANO, 1950; FUJITA, 1956) that the umbilical region of the species is often ornamented with a small central boss of clear shell material, such is not recognized in the present specimens. The present species is known to live in the shallow waters along the Pacific coast of Japan (ISHIWADA, 1964). It is a common species in the Japanese Miocene (Miyazaki Group, KAMEYAMA, 1972), Pliocene (Haizume Formation, MATSUNAGA, 1963; Shibikawa Formation, ASANO, 1950) and the Pleistocene (Kakinokidai Formation,

Kikuchi, 1964; Sanuki and Kiyokawa formations, Asano, 1938). The living specimens of the present species have also been recorded from the Gulf of Mexico (Phleger, 1965). According to Phleger (1965), the depth range of the living specimens (protoplasm-bearing) in the Gulf of Mexico is from 15 to 28 meters and that of the total population (including the dead shells) is from 15 to 55 meters.

Elphidium clavatum Cushman, 1930

Elphidium clavatum Cushman, 1930, pt. 7, p. 20, pl. 7, figs. 10a-b; Takayanagi, 1955, p. 42, pl. 1, fig. 25; Aoki, 1961, p. 18, pl. 3, figs. 8a-b; Ishiwada, 1964, p. 8, pl. 3, fig. 45; Kikuchi, 1964, p. 4, pl. 4, figs. 20–22; Todd and Low, 1967, p. A33, pl. 4, figs. 16–17; Matoba, 1970, p. 51, pl. 6, figs. 11a-b; Sen Gupta, 1971, p. 72, pl. 2, figs. 28–29.

Description: Test yellowish-brown in color, bilaterally symmetrical, periphery round, umbilical portions occupied by several large irregular bosses; chambers distinct, inflated, 10 in last formed coil; sutures distinct, depressed, marked by 2 or 3 retral processes; wall finely perforate; aperture of several small openings at base of apertural face. Diameter 0.6 mm.; thickness 0.2 mm.

Locality and repository: Locality No. 2 (ESK Reg. no. F–5040).

Remarks: The present species, originally described by Cushman (1922) from the Atlantic Ocean, is represented by only one individual from Locality 2. The Recent species has been recorded from Matsukawa-ura and off Sôma City, both in Fukushima Prefecture (Takayanagi, 1955), off Kushiro, Hokkaido (Ishiwada, 1964), Gulf of Alaska and off southeastern Alaska (Todd and Low, 1967) and off the Tail of the Grand Banks, Newfoundland (Sen Gupta, 1971). As fossil it has been reported from the Pliocene Imozawagawa Formation in Sendai (Aoki, 1961) and the Pleistocene Chônan Formation (Kikuchi, 1964).

Elphidium cf. *reticulosum* Cushman, 1933

Pl. 5, figs. 1a–b.

Elphidium reticulosum Cushman, 1933, p. 51, pl. 12, figs. 5a-b.
Elphidium cf. *reticulosum* Cushman, Matoba, 1970, p. 52, pl. 6, figs. 13a–b.

Description: Test equally biconvex, periphery round, umbilical regions depressed; chambers distinct, averaging 9-10 in last formed coil; sutures obscure, marked by about 6 retral processes half the width of chambers; wall finely perforate, ornamented with many short spines on early chambers of last formed coil, with bosses which run parallel with periphery of test; aperture several small openings at base of apertural face. Diameter 0.4 mm.; thickness 0.2 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5041) and No. 2 (ESK Reg. no. F–5042).

Remarks: Cushman (1933) reported this species from off Vavau Anchorage in 18 fathoms and off Rotonga in 7 fathoms, Tonga Islands. This form has been reported

from Matsushima Bay, Miyagi Prefecture (MATOBA, 1970). The specimens from the Shiroyama Formation are similar in general outline to *Elphidium bosoense* FUJITA (1956), but differ in having fewer chambers. This species also resembles *E.* cf. *reticulosum* CUSHMAN reported by MATOBA (1970) from Matsushima Bay, but according to the description of CUSHMAN (1933), this species can be discriminated from the latter by the absence of very fine net work or reticulation. It is tentatively treated as *E.* cf. *reticulosum* in this paper. This species is present in low frequencies in the Shiroyama Formation.

Elphidium subgranulosum aureum AOKI, 1960
Pl. 5, figs. 2a–b.

Elphidium subgranulosum ASANO, subsp. *aureum* AOKI, 1960, p. 99, pl. 1, nos. 7–10; AOKI, 1961, p. 18, pl. 3, figs. 7a–b.
Elphidium cf. *subgranulosum* ASANO, UJIIÉ, 1963, p. 241 (39), pl. 3, figs. 23–25.

Description: Test equally biconvex, periphery round, umbilical regions depressed; chambers distinct, very inflated, rapidly increasing in size as added, averaging 6 in last formed coil; sutures distinct slightly depressed, marked by a few retral processes, obscure in early sutures of last whorl; wall coarsely perforate; aperture several small openings at base of apertural face. Diameter 0.6 mm.; thickness 0.35 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5043), No. 2 (ESK Reg. no. F–5044) and No. 3 (ESK Reg. no. F–5045).

Remarks: The present species has been recorded to occur only from, the Recent sediments of Tokyo Bay (AOKI, 1960), from the Imozawagawa Formation (Pliocene) in Miyagi Prefecture and from the Yûrakuchô Formation (Holocene), Tokyo City (UJIIÉ, 1963).

The writer identifies the specimens from the Shiroyama Formation with *E. subgranulosum aureum* AOKI, a species that has few chambers which rapidly increase in size as added. According to the scanning electron microscopy photographs, *Feyling-Hanssen* (1972) studied a highly variable species, *E. excavatum* (TERQUEM), which he considered to include as its synonyms, *E. clavatum* CUSHMAN, *E. incertum* CUSHMAN, E. *selseyensis* (HERON-ALLEN and EARLAND) and *E. lidoensis* CUSHMAN. The species which was collected from the Shiroyama Formation is similar to *E. excavatum* (TERQUEM) forma *selseyensis* (HERON-ALLEN and EARLAND) reported by FEYLING-HANSSEN, and therefore it is possible that the present species may by future study prove to be a variety of *E. excavatum* (TERQUEM). This species occurs at the Locality 1 in frequency of 8.2 percent.

Eliphidium sp.
Pl. 5, figs. 3a–c.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5046) and No. 2 (ESK

Reg. no. F–5047).

Remarks: This species is characterized by the sutures being weakly S-shaped outer half convex toward the last chamber, inner half toward the early chamber. Although this species is similar to *Elphidium subincertum* Asano, it differs from *E. subincertum* in a few obscure retral processes. Only eight specimens identified as *Elphidium* sp. were examined in the materials from the cliff of Ryûkyûjinmatsu and the garden of the Shigetomi-sô.

Superfamily CASSIDULINACEA d'Orbigny, 1839

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus *Nonion* de Montfort, 1808

Nonion grateloupi (d'Orbigny), 1926

Pl. 5, fig. 4.

Nonionina grateloupi d'Orbigny, 1926, p. 294, pl. 6, figs. 6–7.
Nonion grateloupi (d'Orbigny), Cushman, 1930, p. 10, pl. 3, figs. 9–11, pl. 4, figs. 1–4; Cole, 1931, p. 32, pl. 7, figs. 7–8; Cushman, 1933, p. 43, pl. 10, figs. 8a–c; Asano, 1938d, p. 594, pl. 15 (4), fig. 14; Asano, 1950–52, pt. 1, p. 2, text-figs. 3–4; Asano, 1960, p. 190, pl. 21, figs. 7a–b; Kuwano, 1962, p. 132, pl. 19, figs. 10a–c, pl. 20, figs. 1a–c; Ishiwada, 1964, p. 8, pl. 3, fig. 32.
Florilus grateloupi (d'Orbigny), Brooks, 1973, p. 396, pl. 9, fig. 6.

Description: Test small, planispiral, paralel-sided, but somewhat asymmetrical, involute, periphery rounded; low chambers increasing rapidly in breadth and thickness resulting in flaring test, 9–12 chambers in last formed coil in adults; sutures distinct, slightly depressed; wall smooth, finely perforate; aperture small, at base of last formed chamber, narrow. Length up to 0.5 mm.; breadth, 0.3 mm.; thickness, 0.2 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5048) and No. 2 (ESK Reg. no. F–5049).

Remarks: The present species was originally described by d'Orbigny (1926) from the Miocene of Dax, France. Cushman (1933) regarded the present species as one of the distinct ones in the shallow water of the Pacific region. He (1931, 1933) also reported the living specimens of this species from Guam Anchorage (21 fathoms), Mokaujar Anchorage, Fiji, Montego Bay on the northern coast of Jamaica, numerous stations about the Tortugas, San Juan Harbor, Porto Rico and from the shallow water of the West Indian region. Living specimens were also reported from the southern coast of Puerto Rico (Brooks, 1973) and from Kagoshima Bay, south Kyushu (Kuwano, 1962). The fossil specimens have been reported from the Pliocene in Niigata Prefecture, the Plio-Pleistocene in Chiba and Kanagawa Prefectures (Asano, 1938d) in Japan, and from the Pliocene and Pleistocene of Florida, U.S.A.

(COLE, 1931). CUSHMAN (1930) reported this species from the Late Tertiary of the gorge of the Yumuri River, Matanzas, Cuba, and from the Bluff 3, Cercado de Mao, Santo Domingo. This species is present in low frequencies at Localities 1 and 2 in the Shiroyama Formation. LOEBLICH and TAPPAN (1964) pointed out that the genus *Pseudononion* should be taken as a synonym of the genus *Florilus*. But the writer is in the opinion that *Pseudononion* is a member of the subfamily NONIONINAE, thus he dose not use the genus *Florilus* in this paper.

Nonion manpukujiense OTUKA, 1932
Pl. 5, fig. 5.

Nonion manpukujiense OTUKA, 1932, p. 654, fig. 1; ASANO, 1950–52, pt. 1, p. 2, text-figs. 7–8.

Description: Test equally biconvex, periphery subacute with weak keel in early chambers of last whorl; chambers distinct, 12 in last formed coil; umbilical region covered with granular shell material and irregularly developed with radial ridges; sutures distinct; wall smooth, finely perforate; aperture a narrow curved slit at base of apertural face. Diameter up to 0.8 mm.; thickness 0.45 mm.

Locality and repository: Locality No. 2 (ESK Reg. no. F–5050).

Remarks: The present species was originally described from the Pliocene at Manpukuji, Kawasaki City, Kanagawa Prefecture by OTUKA (1932). ASANO (1950–52) reported the species from the Shibikawa Formation (Late Pliocene) in Akita Prefecture. This species is represented by only one individual from the Locality 2.

Genus *Pseudononion* ASANO, 1936

Pseudononion japonicum ASANO, 1936
Pl. 5, figs. 6a–b.

Pseudononion japonicum ASANO, 1936, p. 347, figs. a-c; ASANO, 1938b, pl. 7, figs. 1a-c; ASANO 1938d, p. 597, pl. 15 (4), figs. 11a–c; ASANO, 1950–52, pt. 1, p. 4, text-figs. 19–21; TAKAYANAGI, 1955, pl. 1, figs. 22a–b; ASANO, 1960, p. 193, pl. 21, figs. 2a–c; ISHIWADA, HIGUCHI and KIKUCHI, 1962, fig. 3; MATSUNAGA, 1963, pl. 38, fig. 7; KIKUCHI, 1964, pl. 4, figs. 1–3; MATOBA, 1970, p. 58, pl. 8, figs. 9a–c; KAMEYAMA, 1972, p. 203, pl. 31, figs. 10a–c.

Description: Test asymmetrical, depressed, slightly trochospiral, spiral side evolute, opposite side involute; periphery subacute; chambers distinct, 10–12 in adult; sutures distinct, slightly depressed, gently curved; wall finely perforate, surface smooth; aperture a narrow, interiomarginal slit. Length up to 0.8 mm.; breadth 0.5 mm.; thickness 0.2 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5051) and No. 2 (ESK Reg. no. F–5052).

Remarks: ASANO (1960) recorded the present species from a depth of 112 to 516 meters and a temperature of 2.4 to 18.8°C respectively. The living specimens are

reported from the Japan Sea, and the embayments on the Pacific coast, i.e. Matsukawa-ura Bay, Sôma City, Fukushima Prefecture (Takayanagi, 1955) and Matsushima Bay, Miyagi Prefecture (Matoba, 1970). Matoba (1970) stated that the species occurs rarely in the outer and middle bay facies of Matsushima Bay. The fossil occurrences of the present species are known from the Pliocene of Kaigarazawa and Nakanosawa, Kuromatsunai-mura, Suttsu-gun, Hokkaido; Pleistocene of Kushiro, Hokkaido; Pliocene of Wakimoto, Oga Peninsula, Akita Prefecture; Plio-Pleistocene of Sanuki-machi and Ônuki-machi, Kimitsu-gun, Chiba Prefecture; Plio-Pleistocene of Ôkine, Hatsuse-mura, Miura-gun, and Takaya, Muraoka-mura, Kamakura-gun, Kanagawa Prefecture; Pliocene of Ioki and Ôno, Aki-gun, Kôchi Prefecture (Asano, 1938d); Kokumoto Formation in Chiba Prefecture (Kikuchi, 1964) and the Takanabe Member of the Miyazaki Group, Miyazaki Prefecture (Kameyama, 1972).

The Genus *Pseudononion* was proposed by Asano (1936) based upon *P. japonicum*. He regarded the genus to be derived from a planispirally involute form, probably *Nonion*, based on the asymmetrical arrangement of its chambers, and stated that the type species *japonicum* is common in the Late Tertiary and Recent materials of Japan. Loeblich and Tappan (1964) pointed out that the genus *Pseudononion* should be included in the genus *Florilus*. But the writer considers *Pseudononion* to be a genus in the subfamily NONIONINAE. This species is abundant in the silt at the Localities 1 and 2 in average frequencies up to 6.4 percent.

Genus *Nonionella* Cushman, 1926

Nonionella stella Cushman and Moyer, 1930

Pl. 5, fig. 7.

Nonionella miocenica Cushman, var. *stella* Cushman and Moyer, 1930, p. 56, pl. 7, figs. 17a–c.
Nonionella miocenica stella Cushman and Moyer, Asano, 1950–52, pt. 1, p. 5, text-figs. 25–26; Matsunaga, 1963, p. 88, pl. 38, figs. 2a–c.
Nonionella stella Cushman and Moyer, Ishiwada, Higuchi and Kikuchi, 1962, p. 71, pl. 1, figs. 2a–b; Phleger, 1964, p. 383, pl. 1, figs. 33–34; Ishiwada, 1964, p. 37, pl. 3, figs. 41a–b; Matoba, 1967, p. 256, pl. 29, figs. 10a–b.
Nonionella stella Cushman, Kikuchi, 1964, p. 6, pl. 4, figs. 7–10.

Description: Test subtrochoid, peripheral margin rounded; 8–10 chambers in last whorl; chambers narrow, last chamber forms distinct stellate lobe at umbilical end with short finger-like processes extending over previous sutures; sutures distinct, depressed slightly, wall smooth, finely perforate; aperture narrow, arched slit. Length 0.2 mm.; breadth 0.15 mm.; thickness 0.13 mm.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5053) and No. 2 (ESK Reg. no. F–5054).

Remarks: The present species, originally described by Cushman and Moyer (1930) from off San Pedro, California, is present in low frequencies at the Localities 1 and 2. Ishiwada (1964) reported that this species was recorded from the Japan

Sea and the Okhotsk Sea, and that it is found widely in the Kazusa Group and other Cainozoic formations of Japan. The living species has been recorded from the Gulf of California (PHLEGER, 1964). The fossil occurrences of the present species are from the Neogene and Quaternary deposits of the southern Kwanto region (KIKUCHI, 1964).

Superfamily GLOBIGERINACEA CARPENTER, PARKER and JONES, 1862

Family GLOBIGERINIDAE CARPENTER, PARKER and JONES, 1862

Subfamily GLOBIGERININAE CARPENTER, PARKER and JONES, 1962

Genus *Globigerina* D'ORBIGNY, 1826

Globigerina cf. *quinqueloba* NATLAND, 1938

Pl. 5, fig. 8.

Globigerina quinqueloba NATLAND, 1938, p. 149, pl. 6, fig. 7; HUANG, 1966, p. 227, pl. 27, fig. 16; OBA, 1967, p. 213, pl. 21, figs. 4a–c; ASANO, INGLE and TAKAYANAGI, 1968, p. 213–241, 16 figs.; KIM, 1970, p. 153, pl. IX–3, figs. 3a–c; BÉ, VILKS and LOTT, 1971, p. 33, pl. 1, figs. 2a–c; ADEGOKE, DESSAUVAGIE and KOGBE, 1971, p. 202, pl. 2, figs. 16–20.

Globigerina cf. *quinqueloba* NATLAND, ASANO, 1957, p. 19, pl. 1, figs. 14–15.

Globigerina ? *quinqueloba* NATLAND, UJIIÉ and KAGAWA, 1963, p. 336, pl. 44, figs. 10–12.

Locality and repository: Localities No. 1 (ESK Reg. no. F–5055) and No. 2 (ESK Reg. no. F–5056).

Remarks: This species which has a range from the Upper Miocene to Recent is present in low frequencies at the Localities 1 and 2. It lacks the protruding lip and chamber over the umbilical area, so it is identified as *Globigerina* cf. *quinqueloba* NATLAND in this paper.

Genus *Globigerinoides* CUSHMAN, 1927

Globigerinoides ruber (D'ORBIGNY), 1839

Pl. 5, figs. 8a–c.

Globigerina rubra D'ORBIGNY, 1839, p. 82, pl. 4, figs. 12–14; CUSHMAN, 1914, p. 9, pl. 3, figs. 6–9; CUSHMAN, 1924, pt. 5, p. 15, pl. 3, figs. 4–7.

Globigerinoides ruber (D'ORBIGNY), CUSHMAN, 1965, p. 63, pl. 25, fig. 6; CORDEY, 1968, p. 118, pl. 5, figs. 3a–c; HUANG, 1968, p. 60, pl. 11, fig. 5; KIM, 1970, p. 153, pl. IX–3, figs. 4a–c; BÉ, VILKS and LOTT, 1971, p. 34, pl. 2, fig. 3.

Globigerinoides ruber ruber (D'ORBIGNY), UJIIÉ and KAGAWA, 1963, p. 336, pl. 45, figs. 1a–c, 2, 3a–b, 4a–b, 5a–c, 6; SAITO, 1963, p. 197, pl. 56, figs. 9a–b; HUANG, 1964, p. 72, pl. 1, fig. 6.

Locality and repository: Locality No. 2 (ESK Reg. no. F–5057).

Remarks: This species ranges from the Upper Miocene to Recent. It is represented by only one individual from the Locality 2.

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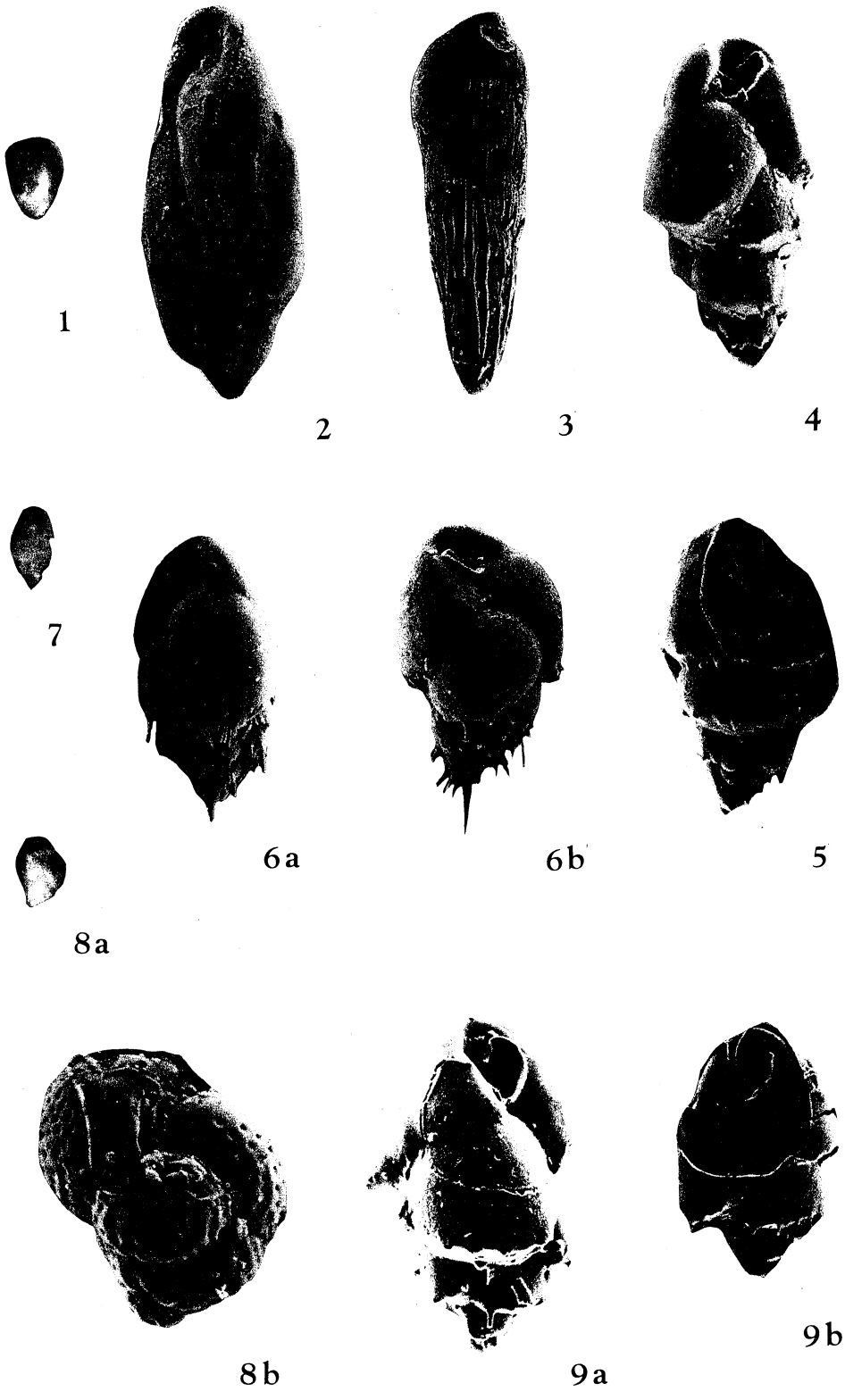
Explanation of Plate 2

Fig. 1. *Fissurina cucurbitasema* LOEBLICH and TAPPAN × 65
Fig. 2. *Buliminella elegantissima* (D'ORBIGNY) × 250
Fig. 3. *Brizalina striatula* CUSHMAN × 125
Fig. 4. *Bulimina marginata* ? D'ORBIGNY × 200
Fig. 5. *Bulimina aculeata* ? D'ORBIGNY × 200
Figs. 6a, b. *Bulimina aculeata* D'ORBIGNY × 200
Fig. 7. *Bulimina denudata* CUSHMAN and PARKER ×65
Figs. 8a, b. *Bulimina fijiensis* CUSHMAN 8a. × 65; 8b. × 300
Figs. 9a, b. *Bulimina marginata* D'ORBIGNY × 200


1
2
3
4
7
6a
6b
5
8a
8b
9a
9b

Explanation of Plate 3

Fig. 1. *Bulimina marginata* D'ORBIGNY × 250
Figs. 2a, b. *Bulimina* sp. 1 ×300
Fig. 3. *Bulimina* sp. 2 × 200
Fig. 4. *Bulimina* sp. 3 × 350
Figs. 5a, b. *Reussella spinulosa* (REUSS) × 125
Fig. 6. *Reussella* sp. × 200
Fig. 7. *Hopkinsina glabra* (MILLETT) × 250
Figs. 8a, b. *Buccella frigida* (CUSHMAN) × 120

1

2a

2b

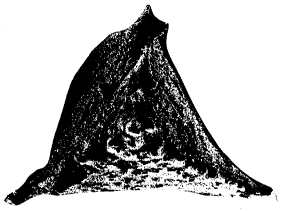
3

4

5a

7

6



5b

8a

8b

Explanation of Plate 4

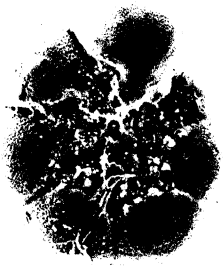
Figs. 1a–e. *Ammonia beccarii tepida* (CUSHMAN) 1a, b, e. × 200; 1b, d. × 250
Figs. 2a–d. *Pararotalia ? globosa* (MILLETT) 2a, b. × 200; 2c. × 300; 2d. × 250
Figs. 3a, b. *Elphidium advenum* (CUSHMAN) × 125

1a

1b

1c

1d



1e

2a

2b

2c

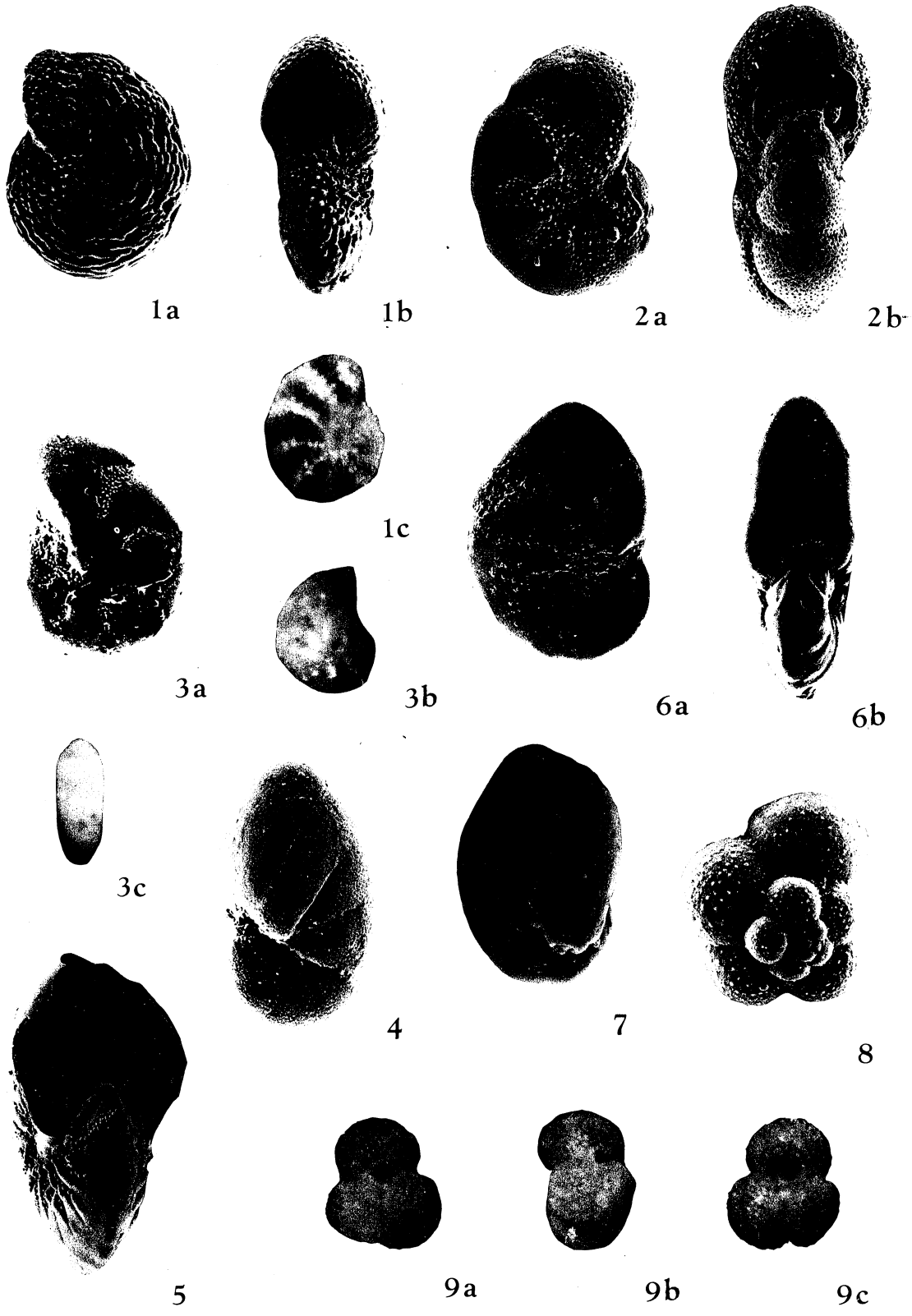
2d

3a

3b

Explanation of Plate 5

Figs. 1a–c. *Elphidium* cf. *reticulosum* CUSHMAN 1a, b. × 125; 1c. × 65
Figs. 2a, b. *Elphidium subgranulosum aureum* AOKI × 150
Figs. 3a-c. *Elphidium* sp. 3a. × 125; 3b-c. × 65
Fig. 4. *Nonion grateloupi* D'ORBIGNY × 150
Fig. 5. *Nonion manpukujiense* OTSUKA × 105
Figs. 6a, b. *Pseudononion japonicum* ASANO × 105
Fig. 7. *Nonionella stella* CUSHMAN and MOYER × 150
Fig. 8. *Globigerina* cf. *quinqueloba* NATLAND × 200
Figs. 9a–c. *Globigerinoides ruber* (D'ORBIGNY) × 65


1a
1b
2a
2b
1c
3a
3b
6a
6b
3c
4
7
8
5
9a
9b
9c