

Quaternary Benthonic Foraminiferal Changes Observed in the Sea of Japan Piston Cores

By

Hiroshi UJIIÉ

Department of Marine Sciences, University of the Ryukyus, Okinawa

Masaki ICHIKURA

Kami-shirane Junior High School, Yokohama

and

Kenji KURIHARA

Geological Laboratory, St. Paul's (Rikkyo) University, Tokyo

(Communicated by Ikuwo OBATA)

Introduction

The Lamont-Doherty Geological Observatory of Columbia University collected a number of piston cores from the whole area of the Sea of Japan by the 12th cruise of R/V Robert Conrad in 1969 (abbreviated as RC12), the 28th of R/V Vema (V28) in 1971, and the 32nd of R/V Vema (V32) in 1975. The lithology and planktonic foraminifera of majority of these cores were already reported by us (UJIIÉ and ICHIKURA, 1973; ICHIKURA and UJIIÉ, 1976; KURIHARA, 1982). Since our first work was published in 1973, many other authors have investigated and samely recognized a drastic change of coiling ratio in *Globigerina pachyderma* populations around the Holocene—Pleistocene boundary, on the basis of different cores taken by various organizations (MAIYA *et al.*, 1976; KATO, 1978; KITAZATO in OBA *et al.*, 1980; INOUE, 1980).

Concerning the benthonic foraminifera, however, only a paper has been published by INOUE (1980). Unfortunately she treated four piston cores which were collected from the continental borderland west off the Tsugaru Strait so that the results give us not general but rather local paleoenvironmental information on the sea bottom. A preliminary note by KITAZATO (in OBA *et al.*, 1980) includes some useful interpretations on the benthonic foraminiferal faunas found in two cores from off western Japan but the conclusions have been retained as tentative.

In this paper, therefore, we attempt to document the occurrence and taxonomic status of each benthonic foraminifera found in the Lamont cores as much as possible and then to discuss the significance for the paleoenvironmental change of the Sea of

Japan in relation to the suggestions by planktonic foraminifera of the same cores. At the present, however, the conclusive discussion may be restricted because the knowledge about the Recent distribution of benthonic foraminifera in the Sea of Japan is almost absent and because the investigations on the same cores by different methods, particularly micropaleontological and chemical analyses, are in progress.

Materials and Results

For the benthonic foraminiferal analysis we chose here eight cores as shown in Table 1 and Figure 1, judging from their planktonic foraminiferal fauna and lithology, details of which should be referred to the previous papers (ICHIKURA and UJIIÉ, 1976; KURIHARA, 1982).

All specimens of benthonic foraminifera were picked out from each a ca. 1 cm thick sample of vertical quarter of ca. 6 cm across core, excluding shipboard samples of the core V32-153. Total specimens in a sample variably change from only one to 643. Concerning the core V32-153, about 200 specimens per each a sample were picked out and identified as to represent the minimum number suitable for faunal analysis.

Thus identified specimens reached to 11,636 and the total number of taxa to about 90, including three new species. Their occurrences are shown in Tables 2a to 2e. Figures 2a to 2d summarize, from left to right, the stratigraphic changes of the lithology, of the "planktonic ratio" (A), of the coiling ratio in *Globigerina pachyderma* populations (B), of the relative abundances of *G. pachyderma* (*G.p.* in column C), *G. umbilicata* (*G.u.*) and the other planktonic species, of FISHER's index α in benthonic foraminiferal faunas (D), of the number of benthonic taxa (E), and of the relative abundances of nine groups of benthonic foraminifera (F). The summarization is

Table 1. Location, water depths and lengths of the Lamont cores examined on their benthonic foraminifera

	Latitude	Longitude	Water Depth	Core Length
Tsushima Trough region				
RC12-376	37°50'N	131°39'E	1,426 m	1,759 cm
RC12-377	37°35'N	132°15'E	2,226 m	1,486 cm
Yamato Trough region				
V28-265	36°17'N	134°34'E	1,218 m	920 cm
RC12-378	36°57'N	134°32.5'E	1,401 m	1,110 cm
Yamato Rise region				
RC12-390	39°42'N	136°01.5'E	1,103 m	785 cm
RC12-387	40°06'N	135°12'E	838 m	706 cm
RC12-381	38°55'N	133°48'E	1,437 m	681 cm
V32-153	39°13'N	134°34'E	631 m	655 cm

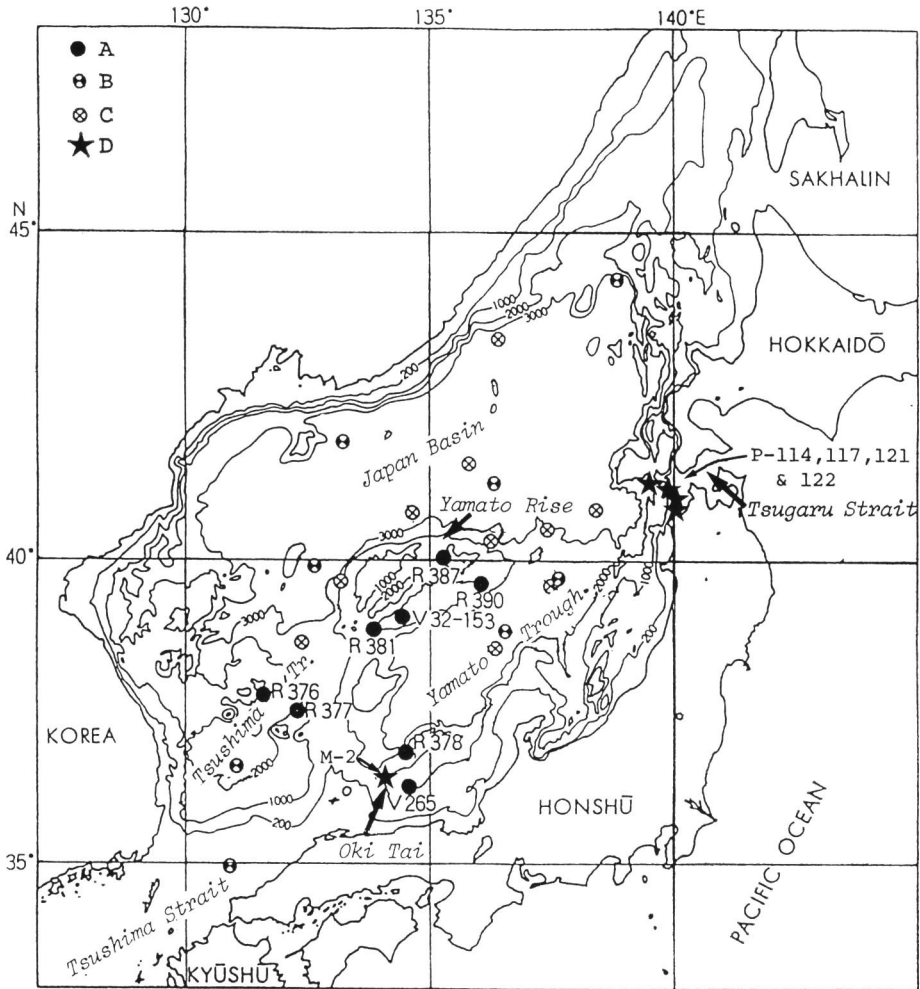


Fig. 1. Location map of the piston cores.

A: cores showing rather continuous occurrence of benthonic foraminifera; B: cores showing their sporadical occurrence; C: Lamont cores not yet studied on the benthonics, except for the previously reported lithology and planktonics (see ICHIKURA and UJIIÉ, 1976); D: cores studied by OBA *et al.*, 1980 (KH77-3, M-2) and by INOUE, 1980 (P-114, -117, -121, & -122). Bathymetric contours in meters.

restricted for four cores, RC 12-378, V28-265, V32-153 and RC12-376, since the other cores show scarce or sporadical yielding of benthonic foraminifera.

Quaternary Paleoenvironmental Changes Suggested by the Piston Cores

In both the two cores, RC12-378 and V28-265, taken from off the San'in dis-

trict, West Japan, the uppermost one meter is characterized by abundance of dextrally coiled *Globigerina pachyderma* population, while the lower portions are predominated by sinistrally coiled one. As noticed before (UJIIÉ and ICHIKURA, 1973; ICHIKURA and UJIIÉ, 1976), therefore, the upper portion was assigned as the Holocene and the lower one as the Pleistocene. The Holocene—Pleistocene boundary is also defined by the last appearance of adult *Globigerina umbilicata* ORR and ZAITZEFF which occurs alone in the Neogene to Pleistocene of the Sea of Japan region without any association of *Globigerina bulloides* D'ORBIGNY different from the other areas of the North Pacific region (ORR and ZAITZEFF, 1971; INGLE, 1975). In a closely located core, RC12-379, MAIYA *et al.* (1976) also recognized an abrupt change of coiling in *G. pachyderma* populations and assigned its ^{14}C age as 11,000 yrs. B.P.

Planktonic foraminiferal fauna and lithology of the Holocene portion indicate the invasion of the warm Tsushima Current through the Tsushima Strait on the present day scale and the extremely aerobic condition of sea bottom. On the contrary, those of the Pleistocene portion suggest that the Tsushima Current seems to have hardly flowed into the Sea of Japan and the anaerobic sea bottom condition prevailed (see ICHIKURA and UJIIÉ, 1976, for more detailed discussion).

This contrast between the two epochs may be expected in the benthonic foraminifera, too. Above the boundary, there are drastic increase of benthonic specimens (remarkable decrease of "planktonic ratio" in Figure 2) and that of the number of taxa which are expressed in terms of the taxon numbers per sample (E, histogram in Figure 2) and also of FISHER's (1943) index (D, broken line).

The index, α , is a ratio of taxon numbers (S) against the specimen numbers (N) observed in a sample population as been calculated by the equation, $S = \alpha \log(1 + N/\alpha)$, and has long been applied in many ecological works as a kind of specific diversity. Considerably concordant trends are recognized between the vertical changes of the two ratios (D and E in Figure 2) through the core length. According to a synthesis by MURRAY (1973) who used α as an important index in a series of his works on the ecology of benthonic foraminifera, the value of α less than five is always observed in hyposaline or hypersaline marsh to lagoon, while normal marine fauna shows the value higher than five. In the cases of the Sea of Japan piston cores, the Holocene portion is characterized by the value of α higher than five and, on the other hand, the values in the Pleistocene portion is almost always lower than five, although these values may have the least statistical reliability in strictly speaking due to small number of specimens per sample at many times. In the instances of the Pleistocene Sea of Japan, however, such a low value of α may not indicate any hyposaline or hypersaline environment because of the predominance of planktonic foraminifera and also because of the geographic situation. In general, low specific diversity may be produced by the oligopoly of a limited number of taxa which are tolerant of such a harsh environment as hypersaline or hyposaline waters. Similarly harsh condition for living of benthonic foraminifera may also be expected for the anaerobic sea bottom that has been presumed for the Pleistocene of the Sea of Japan since MIYAKE *et al.*

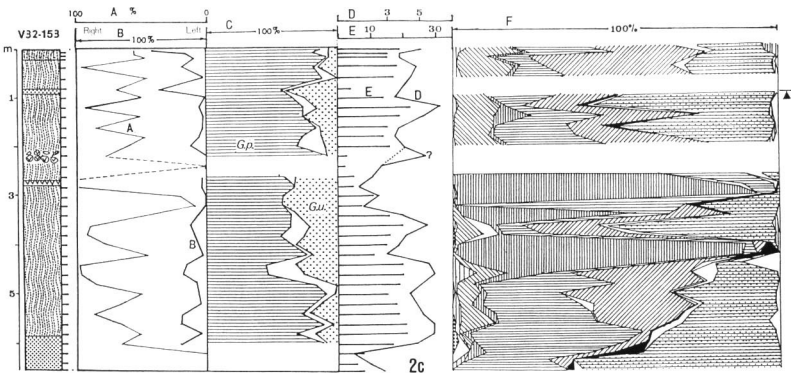
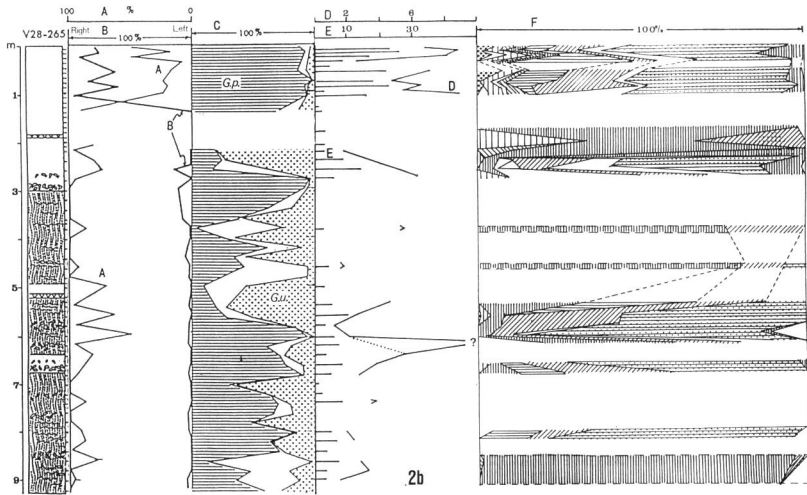
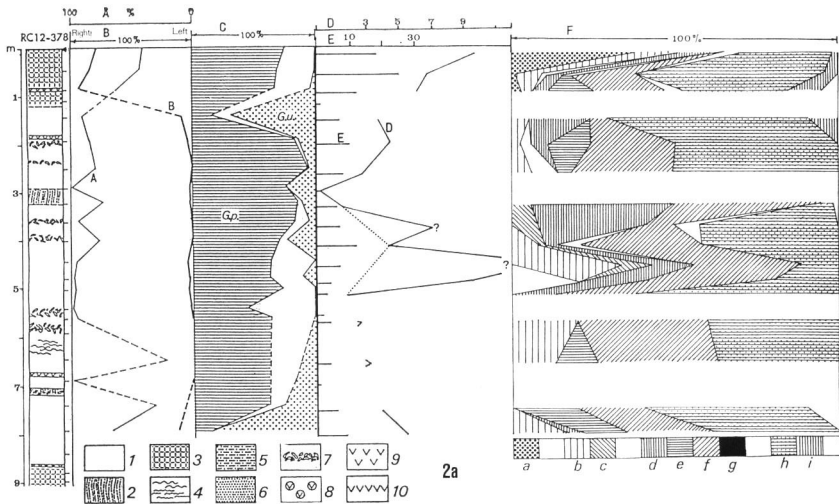
(1968), even though some rather oxidized episodes might have been intercalated as suggested by some geochemical approach upon the cores different from ours (MASUZAWA, 1983).

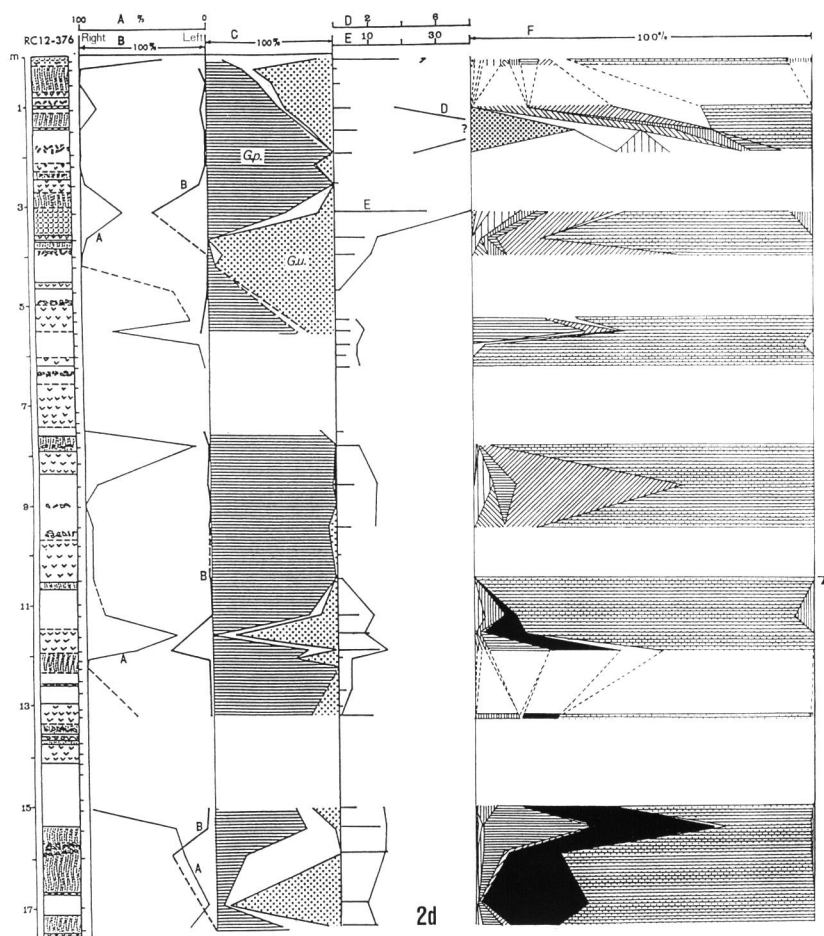
It is particularly interesting that both the benthonic and planktonic foraminifera are absolutely absent around the horizon showing a drastic change of *Globigerina pachyderma* coiling. This phenomenon was first noticed in the core KH-77-3, M2*, taken from the same region off San'in (OBA *et al.*, 1980) and it can be seen in the cores RC12-378 and V28-265 treated here, beside of a core P112 from west off the Tsugaru Strait (INOUE, 1980). OBA *et al.* (1980) interpreted this phenomenon as follows: A drastic change from anaerobic sea bottom to extremely aerobic one may have vigorously oxidized organic remains, which were accumulated under the reduced condition, and released quite an amount of carbon dioxide that dissolved the carbonate shells of all the foraminifera. Moreover, OBA *et al.* (1980) recognized that a benthonic foraminifera barren zone, ^{14}C -age of which was corrected as between ca. 19,600 and 29,000 yrs. B.P. by later measurements upon the foraminiferal shells (OBA, 1983), and presumed that this may be ascribed to a broad coverage by fresh water supplied from the ancient Yellow River, mouth of which should have been located much nearer to the Tsushima Strait. The fresh water cover prohibited much more the vertical circulation of sea water and then a seriously reduced condition was resulted in and refused living of benthonic foraminifera. This invasion of fresh water was estimated by a remarkable decrease (approximately 3‰) of $\delta^{18}\text{O}$ value in planktonic foraminiferal shells during the zone, whose age corresponds nearly to the maximum of the last glaciation (OBA *et al.*, 1980; OBA, 1983), and also by significant occurrence of a hyposaline planktonic diatom, *Melosira sulcata* (EHR.) KÜTZING (TANIMURA, 1981). In our cores, RC12-378 and V28-265, a corresponded zone barren in benthonic foraminifera are also recognizable around three meters below the core top, respectively. At the same time, however, similar barren zones repeatedly appear in the lower portion, where *Melosira sulcata* does not show any abundance change responsible to these barren zones but merely rather richer occurrence compared with the Holocene portion. To substantiate OBA's hypothesis on the fresh water coverage, therefore, further investigations are necessary concerning the $\delta^{18}\text{O}$ measurements of the other cores and also the re-examination of lithology, particularly on the basis of geochemistry.

Core V32-153 (Figure 2c) taken on the southern ridge of the Yamato Rise shows most continuous occurrence of benthonic foraminifera, even though the planktonic foraminifera** and FISHER's index indicate that the whole core belongs to the Pleistocene. This continuity may reflect its shallow water depth (631 m) and, con-

* ARAI *et al.* (1981) assigned the age of this boundary as between 6,300 and 9,300 yrs. B.P. by the correlation of two intercalated ash layers with those in land-based sections which were aged by ^{14}C method.

** This faunal analysis depends on KURIHARA (1982), although his *Globigerina bulloides* must be *G. umbilicata*. And also *G. quadrilatera* of INOUE (1980) may be the same as the latter species according to our re-examination on topotypic materials of the two species.





Figs. 2a–2d. Stratigraphic changes of foraminiferal assemblages through four cores.

A: “planktonic ratio”; B: coiling ratio of *Globigerina pachyderma* populations; C: planktonic faunal composition showing by three divisions, *G. pachyderma* (*G.p.*), *G. umbilicata* (*G.u.*), and the others; D: FISHER’S index, α , (a specific diversity index) in benthonic assemblage; E: number of benthonic taxa per each a sample; F: benthonic faunal composition showing by the following nine groups.

a: “arenaceous taxa”; b: all taxa of *Lagena*, *Oolina*, *Fissurina* and *Parafissurina*; c: *Bolivina decussata* and other *Bolivina* species; d: taxa with very thin wall such as *Brizalina pacifica*, *Globulimina auriculata*, and nearly all species of *Stainforthia*; e: *Uvigerina akitaensis* including its varieties and *Trifarina ikebei*; f: *Epistominella levicula* and *E. naraensis*; g: *Epistominella pacifica*; h: all taxa of *Cassidulina*, *Islandiella* and *Cassidulinoides*; i: *Astronion hamadaense*; no marks: other minor components.

sequently, a strictly anaerobic condition may have been limited in the deeper places even during the Pleistocene. INOUE (1980) also reported a perfectly continuous occurrence of benthonic foraminifera throughout the probably upper Pleistocene portion of a 215 cm long core, P117, which was taken from 134 m water depth west off the Tsugaru Strait.

A 17.8 m long core, RC12-376, was collected from the Tsushima Trough. It would represent the longest record about the Pleistocene among the Lamont cores treated by us, if we could regard about 10 cm at the top as to represent the whole Holocene on the basis of planktonic foraminiferal fauna. However, this Holocene thickness may be unavailable for the calculation of sedimentation rate of the Pleistocene portion, since the rate should be faster than that in the Holocene owing to vigorous erosion in glacial ages. Faint but significant increase of dextral *Globigerina pachyderma* and nearly simultaneous predominance of *G. umbilicata* can be recognized around 3 m, 12 m, and 16 m below the core top of RC12-376. Beneath the former two zones, respectively, there is a zone barren in both the planktonic and benthonic foraminifera resembling that around the Holocene-Pleistocene boundary. These three horizons may correspond to interglacial ages, although the planktonic faunas as briefly stated above and also the benthonic ones as will be indicated in the next paragraph show not so obvious change of sea bottom condition. The faint change may be due to such a geographic situation of the Tsushima Strait or the other southern entrances as not to allow the invasion of warm oceanic current in those days.

Analysis and Interpretation of Faunal Composition

To show visually the composition changes of the benthonic foraminiferal faunas, we made the relative abundance graphs in dividing 90 taxa into such nine categories from taxonomical and ecological viewpoints as indicated in legend of Figures 2a to 2d. Looking through the figures and the occurrence charts (Tables 2a-2e), it may be noticed that the *h* group composed of *Cassidulina norcrossi* and *Islandiella* species are common throughout. These taxa seem to be characteristic in the Recent faunas distributed from off the San'in district to the Yamato Rise according to the preliminary report by TROITSKAYA (1970). There is nothing of remarkable yielding of the shelf- or continental borderland-faunas as reported from off the Shikote-Alin region (TROITSKAYA, 1970) and off Northeast Japan (MATOBA and NAKAGAWA, 1972; MATOBA, 1976). The category *d*, which consists of such taxa providing with very thin wall as *Brizalina pacifica*, *Globobulimina auriculata*, and *Stainforthia* species, shows characteristic occurrence in the Pleistocene portion, particularly of the cores V28-265 and V32-153. When this group predominates, the inside of these shells was frequently filled with framboidal pyrites, which are authigenic minerals formed under the reduced condition as exemplified by OKADA and SHIMA (1973). In these cases, therefore, a little supply of Ca- and HCO₃-ions is suggested, even if the anaerobic condition is still available for living of benthonic foraminifera.

In addition to the higher specific diversity, the Holocene portion is characterized by the occurrence of arenaceous forms which are never recognized in the Pleistocene portion, except for *Karriella japonica*. Beside of the arenaceous taxa, KITAZATO (in OBA *et al.*, 1980) regarded *Cribronion clavatum* (=his *Elphidium clavatum*), *Epistominella pacifica* (= *E. pulchella*), *Cibicides lobatulus*, *Cassidulina japonica*, and *Astronion hamadaense* as to have appeared first above the zone barren in benthonic foraminifera between ca. 1.6 m and 3.2 m below the core top of KH-77-3, M-2. And then OBA *et al.* (1980) thought that the derivation of these species and the decrease of $\delta^{18}\text{O}$ value above the barren zone may be responsible to the opening of some northern entrances of the Sea of Japan such as the Tsugaru Strait. This assumption may agree with the opinion of NISHIMURA (1972) who regarded the Recent bathyal faunas (mainly molluscs, fishes, and crustaceans) in the Sea of Japan as to have been recently, in the other words secondarily, adjusted after their derivation from the north during the late (not last) Pleistocene age. So far as Figures 2a to 2d and Tables 2a to 2e of this paper are concerned, however, all the species mentioned by KITAZATO are recognizable through the Pleistocene portions except for *Astronion hamadaense*. *A. hamadaense* is relatively prominent in the Holocene portion and is characteristic on the shelf off Akita Prefecture (MATOBA and NAKAGAWA, 1972).

On the contrary, *Cribronion clavatum* seems to have disappeared around 60 cm below the core top of V28-265 and *Epistominella pacifica* did in the middle of Pleistocene of the other cores. *Valvulineria sadonica* does not occur above ca. 40 cm below the core top of V28-265 and the occurrence of *Hyalinea balthica* and *Pullenia apertura* can not reach to the uppermost Pleistocene. Abundant occurrence of *Uvigerina akitaensis* and its varieties is also limited within the lower Pleistocene. As local datum planes, we might be able to expect the last appearance of *Epistominella pacifica*, whose synonym, *E. pulchella*, was first described from an oil well in Niigata Prefecture by HUSEZIMA and MARUHASI (1944), and probably the upper limit of abundant *Uvigerina akitaensis* and its allies which was also described from the Neogene in Akita Prefecture by ASANO (1950). All the species cited here are characteristic in the oil-producing Neogene on the Sea of Japan coast. Therefore, we would like to conclude that these Neogene-type species disappeared one after another from the Sea during the Pleistocene.

Concerning the origin of the Recent benthonic foraminifera of the Sea of Japan, MATOBA (1978) suggested considerable contribution of new elements derived from the northern seas after the Pleistocene, even though he failed to show practical evidences. SAIDOVA (1960, 1961, 1962) published the detailed and synthetic works on the Recent benthonic foraminifera in the Okhotsk Sea and in the northwestern corner of the Bering Sea. Tentatively comparing our specimens with those described and illustrated by SAIDOVA (1962), we redrawn the bathymetrical and geographical distributions of probably conspecific taxa with ours in the Okhotsk Sea and its adjacent region (Figures 3 and 4, respectively). In the brackets of their captions, we indicate the name of comparable species found in the Sea of Japan cores. An inserted figure in

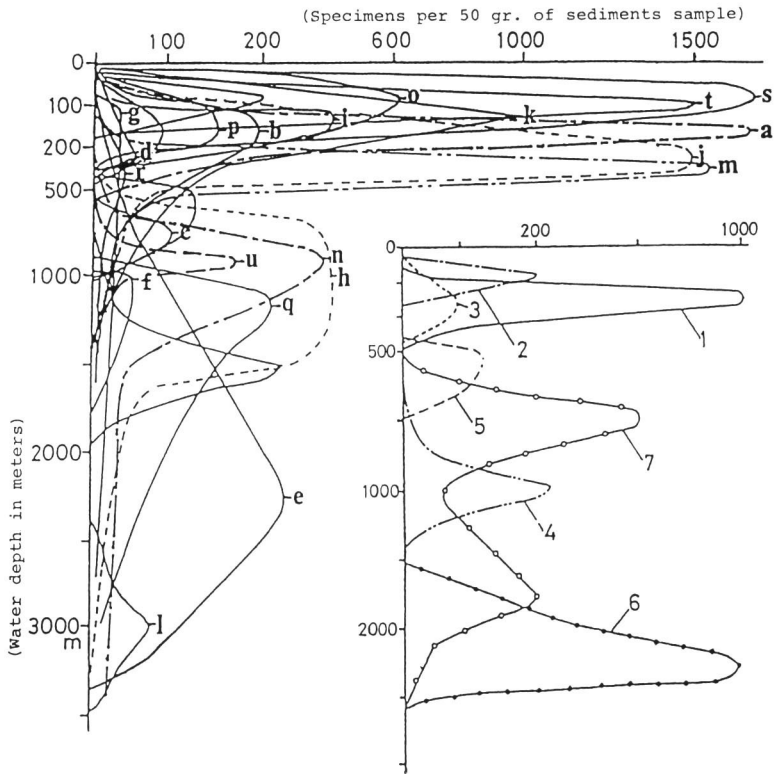


Fig. 3. Bathymetrical distribution of some benthonic foraminifera in the Okhotsk Sea (after SAIDOVA, 1961); these taxa probably conspecific with those (shown in brackets) recognized in the Sea of Japan piston cores. An inserted figure is reproduced from Figure 27 drawn by SAIDOVA.

a: *Karreriella baccata sublittoralis* [\cong *K. japonica*]; b: *Bolivina decussata* [*B. decussata*]; c: *Bulimina exilis* [\cong *B. tenuata*]; d: *Globobulimina auriculata orbiculata* [\cong *G. auriculata*]; e: *Virgulina concava* [= *Stainforthia complanata*]; f: *Virgulina mexicana* [= *Stainforthia rotundata*]; g: *Virgulina complanata* [\cong *Stainforthia cf. schreibersiana*]; h: *Uvigerina peregrina parvocostata* [\cong typical *U. akitaensis*]; i: *Uvigerina peregrina magnocostata* [\cong *U. akitaensis* with prominent costae]; j: *Angulogerina angulosa* [\cong *Trifarina ikebei*]; k: *Eponides karsteni* [\cong *Buccella inusitata*]; l: *Pseudoparrella exigua* [\cong *Epistominella naraensis*]; m: *Pseudoparrella pacifica* [= *Epistominella pacifica*]; n: *Valvulineria ochotica* [\cong *V. sadonica*]; o: *Elphidium clavatum* [= *Cribrononion clavatum*]; p: *Cassidulina carinata* [\cong *C. norcrossi*]; q: *Cassidulinoides tenuis* [*C. tenuis*]; r: *Nonionella digitata* [\cong *Chilostomellina fimbriata*]; s: *Nonion grateloupi* [\cong *Pseudononion auriculum*]; t: *Nonion labradoricum* [= *Pseudononion labradoricum*]; u: *Pullenia noncarinata* [\cong *P. apertura*].

1: "*Cassidulina californica beringiana*"; 2: "*C. californica ochotica*"; 3: "*C. californica californica*"; 4: "*C. californica lomitensis*"; 5: "*C. cushmani*"; 6: "*C. subglobosa*"; 7: "*C. delicata*".

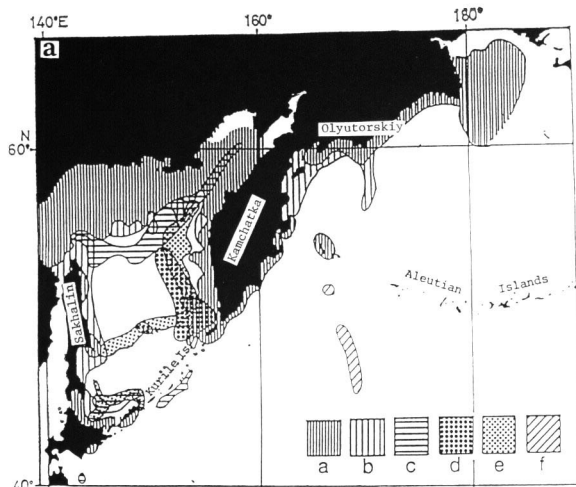


Fig. 4a. Geographic distribution of some benthonic foraminifera in the Okhotsk Sea and the northwestern corner of the Bering Sea (after SAIDOVA, 1962); these taxa probably conspecific with such taxa as recognized in the Sea of Japan piston cores and as shown in brackets of the captions of Figure 3. a: area showing the occurrence of more than one individual per 50 grams of sediments concerning *Nonion labradoricum*, *N. grateloupi*, *Elphidium clavatum*, *Globobulimina auriculata*, *Uvigerina peregrina parvocostata*, *Cassidulina californica californica* [= *Islandiella californica*], and *C. carinata*; b-f: areas of the same amount of occurrences as in but beyond the area "a" concerning *Cassidulina californica ochotica* [= *Islandiella californica*] and *Pseudoparrella pacifica* (b), concerning *Bolivina decussata* (c), concerning *Pullenia noncarinata* (d), concerning *Cassidulina cushmani* [= *Islandiella norvangi*] (e), and concerning *Pseudoparrella exigua* (f), respectively.

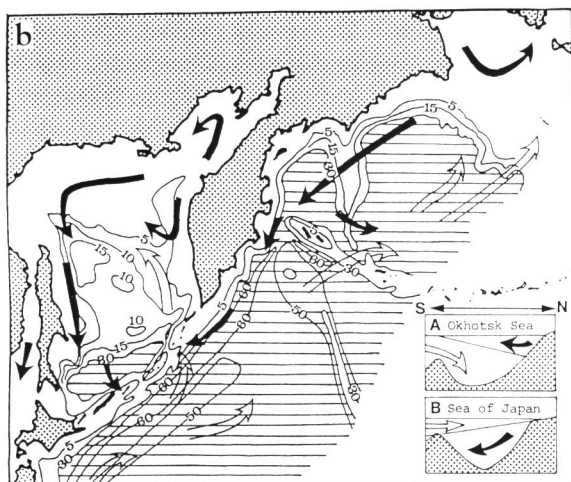


Fig. 4b. Bathymetry (SAIDOVA, 1960) and oceanic current system in the region shown in Figure 4a. Two inserted figures show the contrasting patterns between the vertical interchanges of warm-water and cold water masses in the Okhotsk Sea and the Sea of Japan. Solid arrow: cold oceanic current; white arrow: warm oceanic current; bathymetric contours in 100 meters.

Figure 3 shows somewhat remarkable bathymetric separation of *Cassidulina* (including *Islandiella*) species and subspecies. Unfortunately, however, we failed to classify our specimens in following to SAIDOVA. Excluding "Cassidulina complex", the majority of taxa common between the Sea of Japan and the Okhotsk Sea has a distinct maximum of standing crop above 500 m water depth. The other taxa showing the maxima at the deeper places are eurybathymetric and their counterparts are seldom in the Sea of Japan cores. It is also obvious that the former stenobathymetric taxa

also distribute in the nearshore or on the rises of the Okhotsk Sea region as shown in Figure 4, which is based upon SAIDOVA (1960, 1962). As a whole, therefore, the major components of the Quaternary benthonic foraminiferal fauna of the central Sea of Japan are living in the shallower waters nearer to the shore in the Okhotsk Sea region. This difference in habitat may not be ascribed to the subsidence of the Sea of Japan through the geologic time but to the adaptation of stenobathymetric, in the other words stenothermal, taxa to the deeper place in the southern region, although some problems remain to be solved. One of the problems concerns with the sea water circulation in both the seas; the invasion of relatively warm current is easier for the Okhotsk Sea than the Sea of Japan so that the majority of sea bottom in the latter is occupied by cold water as briefly illustrated in an insertion of Figure 4 and then the temperature is still low in compared with its southern latitude.

New commers into the Holocene Sea of Japan might be the arenaceous taxa cited before and the other minor elements which are not yet discriminated here, and they might have been derived from the south through the newly opened Tsushima Strait.

Concluding Remarks

In this work, we examined 11,636 specimens of benthonic foraminifera in eight piston cores taken from the southern Sea of Japan. The results indicate not so obvious difference between the Holocene and Pleistocene in comparison with that shown by means of planktonic foraminifera and of lithology previously (UJIIÉ and ICHIKURA, 1973; ICHIKURA and UJIIÉ, 1976; KURIHARA, 1982), except for the distinct increases of standing crop and of specific diversity in the Holocene portion. The faunal composition is essentially similar from each other between the two epochs.

In showing low but significant frequency of occurrence, however, the majority of arenaceous forms appeared first at the beginning of the Holocene. These new commers and someones else, which are not yet pointed out clearly at the present state of our work because of their scarce occurrence, might have been derived from the south through the Tsushima Strait.

On the contrary, some northern straits of the Sea seem to have kept as open doors for benthonic foraminifera almost throughout the Quaternary Period. A number of the benthonic taxa found in the Lamont cores, which were collected from the water depth ranging from 785 m to 1759 m, seem to be common with those alive in the Okhotsk Sea region where these taxa are preferably living at the water depth shallower than 500 m and in the nearshore. This discrepancy in habitat might be ascribed to a principle that some benthonic organisms alive in the high latitude areas may find their habitat at the deeper places in the lower latitude.

In the following annotations, 81 taxa are illustrated and/or described. Three species are proposed as new. As seen in their taxonomic remarks and references, they are closely allied to taxa characteristic in arctic to subarctic faunas as a whole.

Taxonomic Annotations

Astrorhizidae, gen. et sp. indet. [Pl. 1, fig. 1]

Rather large specimens with weakly constricted surface; probably belonged to the subfamily Hippocrepininae, particularly *Hyperammina*, although globular proloculus absent.

Lagenammina atlantica (CUSHMAN) [Pl. 1, fig. 2]

Proteonina atlantica CUSHMAN, 1944, Spec. Publ. Cushman Lab. Foram. Res., no. 12: p. 5, pl. 1, fig. 4; *Reophax difflugiformis* BRADY, 1884 (part), Rep. Voy. Challenger, Zool., vol. 9: p. 289, pl. 30, fig. 5 (not 1–4); *Proteonina difflugiformis* (BRADY), HADA, 1931, Sci. Rep. Tohoku Univ., 4th ser., vol. 6, no. 1: p. 52–53, text-fig. 4.

As pointed out by PARKER (1952), this species must be distinguished from the so-called “*Proteonina*” *difflugiformis* of authors.

Silicosigmoilina abyssalica INOUE [Pl. 1, figs. 3–5]

Silicosigmoilina abyssalica INOUE, 1980, Prof. S. KANNO Mem. Vol., Tsukuba Univ., p. 257–258, pl. 26, figs. 7, 11, 12, 14, 16, 19, 20.

Spiroplectammina biformis (PARKER & JONES) [Pl. 1, fig. 6]

Spiroplectammina biformis (PARKER & JONES), LOEBLICH & TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 34–35, pl. 4, figs. 1–6.

LOEBLICH and TAPPAN (1953) cited satisfactorily taxonomic references and stated well about the bimorphology of this species.

Trochammina hadai UCHIO [Pl. 1, figs. 11–13]

Trochammina hadai UCHIO, 1962, Seto Mar. Biol. Lab., Publ., vol. 10, no. 2: p. 387, pl. 18, fig. 9.

As pointed out by MATOBA (1970), this species has been reported as representative of bay fauna by many Japanese authors under the name of *Trochammina globigeriniformis* (PARKER & JONES) since HADA (1931).

Karreriella japonica ASANO [Pl. 1, figs. 7–10]

Karreriella baccata japonica ASANO, 1938, Jap. Jour. Geol. Geogr., vol. 15, nos. 1–2: p. 90, pl. 10, fig. 1; —, ASANO, 1950, Illust. Cat. Jap. Tert. Small. Foram., pt. 4, p. 3, figs. 14, 15.

In the later description (1950), ASANO showed a difference at specific level between this species and *Gaudryina baccata* SCHWAGER, 1866, which has somewhat undercut basal margin of the chambers. In this point, the specimens shown by CUSHMAN (1937) from the Sado Island of Japan (pl. 15, figs. 22–24) and also from the Philippines (pl. 16, fig. 1) as *Karreriella baccata* (SCHWAGER) may be conspecific with *K. japonica*.

Dentalina guttifera D'ORBIGNY [Pl. 1, fig. 17]

Dentalina guttifera D'ORBIGNY, 1846, Formainfères fossiles du Bassin tertiaire de Vienne, p. 49, pl. 2, figs. 11–13; —, CHAPMAN and PARR, 1937, Australasian Antarctic Exp., 1911–14, ser. C, 1(2), p. 60.

“*Nodosaria pyrula* D'ORBIGNY” of BRADY (1884, pl. 62, figs. 10–12) and of later many authors may belong to this species as stated by CHAPMAN and PARR (1937) and followed by BARKER (1960). This species may also include some attenuated specimens designated as *Dentalina subsoluta* (CUSHMAN), (not *Nodosaria subsoluta* CUSHMAN, 1923), by authors such as CUSHMAN and McCULLOCH (1950; pl. 40, fig. 13, not figs. 14, 15), ASANO (1956; pl. 4, fig. 35, not figs. 38, 39?, 49, 50), and so on.

Frondicularia sp. [Pl. 1, fig. 18]

The fragmental specimens resemble *Frondicularia advena* CUSHMAN, 1923.

Lagena amphora REUSS [Pl. 1, fig. 19]

Our specimens are quite similar to *Lagena amphora* REUSS of CUSHMAN and McCULLOCH (1950).

Lagena apiopleura LOEBLICH & TAPPAN [Pl. 1, fig. 20]

Lagena apiopleura LOEBLICH & TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 59, pl. 10, figs. 14, 15.

The authors well defined this species in separating from well-known “*Lagena acuticosta* REUSS”

of authors (not REUSS, 1862), even though the taxonomic discrimination of the species from *Entosolenia williamsoni* ALCOCK, 1865, and *Oolina tasmanica* PARR, 1950, has not yet been shown as pointed out by BARKER (1960).

Lagena aff. *apiopleura* LOEBLICH & TAPPAN [Pl. 1, fig. 21]

These specimens have sharp longitudinal ribs rather than costae in typical species, in resembling somewhat *Lagena acuticosta* REUSS of CUSHMAN and McCULLOCH (1950, pl. 43, fig. 10, not 9), and slender shape of test.

Lagena distoma PARKER & JONES [Pl. 1, fig. 22]

Lagena distoma PARKER & JONES, BRADY, 1864, Trans. Linn. Soc. London, vol. 24, p. 467, pl. 48, fig. 6.

Lagena elongata (EHRENBERG) [Pl. 2, fig. 1]

Miliola elongata EHRENBERG, 1844 (*vide* EHRENBERG, 1954, Mikrogeologie, pl. 25, fig. 1)

Lagena gracillima (SEGUENZA) [Pl. 2, fig. 2]

Lagena gracillima (SEGUENZA), BUCHNER, 1940, Nova Acta Leopoldina, vol. 9, no. 62, p. 415, 416, pl. 2, figs. 25–27.

Lagena nebulosa CUSHMAN [Pl. 2, fig. 3]

Lagena laevis (MONTAGU), var. *nebulosa* CUSHMAN, 1923, Bull. U.S. Nat. Mus., no. 104, p. 29, pl. 5, figs. 4, 5.

Lagena laevis (MONTAGU) of many authors must belong to this species.

Lagena striata (D'ORBIGNY) [Pl. 2, fig. 4]

Oolina striata D'ORBIGNY, 1839, Foraminifères de l'Amérique méridionale, p. 21, pl. 5, fig. 12.

Although D'ORBIGNY (1839) described and illustrated originally specimen with smooth neck, the specimens provided with ornamented neck as seen in our samples have also been assigned as this species by many authors.

Lagena substriata WILLIAMSON [Pl. 2, fig. 5]

Lagena vulgaris var. *substriata* WILLIAMSON, 1848, Recent Foraminifera of Great Britain, p. 7, pl. 1, fig. 14.

Our specimens contain a variation with two kinds of longitudinal costae; prominent and weak ones which are mutually interspaced.

Lagena aff. *substriata* WILLIAMSON [Pl. 2, fig. 6]

Differing from the above-mentioned species, this taxon has finer longitudinal costae and truncate base of test.

Lagena tricaritortuosa, n. sp. [Pl. 2, figs. 7–9]

Description: Test free, distinctly twisted, and triquetrous in cross section, having three prominent keels along the corners; wall between the keels smooth, semi-transparent, and considerably concave; test base bluntly pointed; aperture opened as a depressed triangular shape and surrounded with truncated ends of keels (figure 9), without entosolenian tube. Diameter, up to 1.1 mm; length, up to 1.7 mm.

Remarks: This species differs from *Lagena trigono-elliptica* BALKWILL & MILLETT, 1884 (*vide* ELLIS and MESSINA, 1949 *et seq.*) in having twisted test and more concave inter-keels spaces. CUSHMAN and McCULLOCH (1950) reported a taxon with clearly twisted test under the name of *Lagena striato-punctata* PARKER & JONES, var. *tricosta* CUSHMAN & GRAY, 1946, from off the west coast of the United States. This new species has much more twisted test and more sharply protruded keels, on which any ornamentation is not provided.

Planularia asanoi, n. sp. [Pl. 2, figs. 13, 14]

Cristellaria lata (CORNUEL), CUSHMAN (not *Marginulina lata* CORNUEL, 1848), 1913, U.S. Nat. Mus. Bull., 71, pt. 3, p. 71, pl. 35, fig. 4; *Vaginulina lata* (CORNUEL), ASANO (not *M. lata* CORNUEL, 1848), 1938, Sci. Rep. Tohoku Imp. Univ., 2nd ser., vol. 19, pt. 2, p. 209, pl. 28, fig. 20; pl. 25, fig. 9; *Planularia tricarinella* (REUSS), ASANO (not *Cristellaria tricarinella* REUSS, 1862), 1938, *ibid.*, p. 207, pl. 30, figs.

?2, 3; —, ASANO, 1951, *Illust. Cat. Jap. Tert. Small. Foram.*, pt. 15, p. 12, figs. ?62, 63, 64; *Planularia* sp., ASANO, 1956, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 27, p. 13, pl. 4, figs. 5–7.

Description: Test free, elongate, much compressed showing plate-shape; chambers 8 to 9, low, broad, added along slightly curved axis; sutures smooth, oblique, highest at outer margin, weakly curved; peripheral margin bluntly bicarinate; aperture radiate, terminal, at peripheral angle. Length, up to 1.5 mm according to ASANO (1951).

Remarks: As seen in the references cited above, ASANO seemingly have kept to decide what this species is new or not. He sometimes referred *Cristellaria tricarinelata* REUSS for this species, although *C. tricarinelata* possesses tricarinate margin. The specimens which was figured as to be provided with early coiling of chambers by ASANO (1938, pl. 30, fig. 2; 1951, fig. 62) might be microspheric generation of this new species, if they have not tricarinate but bluntly bicarinate margin.

Glandulina laevigata (D'ORBIGNY) [Pl. 2, figs. 11, 12]

Nodosaria (Glandulina) laevigata D'ORBIGNY, 1826 (*vide* ELLIS and MESSINA, 1949 *et seq.*)

Oolina globosa (MONTAGU) [Pl. 2, figs. 19, 20]

Vermiculum globosum MONTAGU, 1803 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Lagena globosa* BRADY, 1884, *Rep. Voy. Challenger, Zool.*, vol. 9, p. 452, pl. 56, figs. 1–3; *Oolina globosa* (MONTAGU), PARR, 1950, *B.A.N.Z. Antarctic Res. Exped. 1929–1931, ser. B, vol. 5, pt. 6, p. 302.*

Our specimens show a broad slit-shaped aperture, in differing from typical one, and sometimes very slightly compressed test with semi-transparent zones on the lateral sides.

Oolina hexagona (WILLIAMSON) [Pl. 2, fig. 16]

Entosolenia squamosa var. *hexagona* WILLIAMSON, 1848 (*vide* ELLIS and MESSINA, 1949 *et seq.*): —, WILLIAMSON, 1858, *Recent Foraminifera of Great Britain*, p. 13, pl. 1, fig. 32; *Oolina hexagona* (WILLIAMSON), LOEBLICH and TAPPAN, 1953, *Smiths. Misc. Coll.*, 121, pt. 7, p. 69, pl. 14, figs. 1, 2.

Oolina melo D'ORBIGNY [Pl. 2, fig. 15]

Oolina melo D'ORBIGNY, 1839, *Voyage dans l'Amérique méridionale*, p. 20, pl. 5, fig. 9; —, LOEBLICH and TAPPAN, 1953, *Smiths. Misc. Coll.*, 121, pt. 7, p. 71, 72, pl. 12, figs. 8–15.

Oolina striatopunctata (PARKER & JONES) [Pl. 2, figs. 17, 18]

Lagena sulcata (WALKER & JACOB) var. *striatopunctata* PARKER & JONES, 1865 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Oolina striatopunctata* (PARKER & JONES), LOEBLICH and TAPPAN, 1953, *Smiths. Misc. Coll.*, 121, pt. 7, p. 75, 76, pl. 12, figs. 2–5.

Oolina striatopunctata (PARKER & JONES), var.

This variety differs from typical species in having longitudinal costae terminated below the apertural neck.

Fissurina cucurbitasema LOEBLICH & TAPPAN [Pl. 2, figs. 21, 22]

Fissurina cucurbitasema LOEBLICH & TAPPAN, 1953, *Smiths. Misc. Coll.*, 121, pt. 7, p. 76, pl. 14, figs. 10, 11.

Fissurina echigoensis (ASANO & INOMATA) [Pl. 2, figs. 23–26]

Entosolenia echigoensis ASANO & INOMATA, 1952, in ASANO, *Illust. Cat. Jap. Tert. Small. Foram.*, suppl. 1, p. 7, figs. 35, 36.

Fissurina lagenoides (WILLIAMSON) [Pl. 2, figs. 27, 28]

Entosolenia marginata (MONTAGU), var. *lagenoides* WILLIAMSON, 1948 (*vide* ELLIS and MESSINA, 1949 *et seq.*); —, WILLIAMSON, 1858, *Recent Foraminifera of Great Britain*, p. 11, pl. 1, figs. 25, 26.

Fissurina lagenoides tenuistriata (BRADY) [Pl. 2, figs. 29, 30]

Largena lagenoides (WILLIAMSON), var. *tenuistriata* BRADY, 1884, *Rep. Voy. Challenger, Zool.*, vol. 9, p. 479, pl. 60, fig. 11, not 15, 16.

Our specimens have fewer and slightly more prominent costae compared with typical species.

Fissurina lucida (WILLIAMSON) [Pl. 3, figs. 1, 2]

Entosolenia marginata (MONTAGU), var. *lucida* WILLIAMSON, 1848 (*vide* ELLIS and MESSINA, 1949 *et*

seq.); —, WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 10, pl. 1, figs. 22, 23.

Fissurina marginata (MONTAGU) [Pl. 3, figs. 3, 4]

Vermiculum marginatum MONTAGU, 1803 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Fissurina marginata* (MONTAGU), LOEBLICH and TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 77, pl. 14, figs. 6–9.

As to be belonged to this species, we designated only specimens without marginal keel. Scanning electron micrographs reveal the presence of large pores scattered over the surface.

Fissurina marginata (MONTAGU), varieties [Pl. 3, figs. 5–8]

Among varieties provided with marginal keel, we discriminated two types; one with entirely circular side-view (α) and another with somewhat protruded neck (β).

Fissurina semimarginata (REUSS) [Pl. 3, figs. 9, 10]

Lagena marginata WILLIAMSON var. *semimarginata* REUSS, 1870 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Fissurina semimarginata* (REUSS), LOEBLICH and TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 78, pl. 14, fig. 3.

Fissurina cf. *circulo-costa* ASANO [Pl. 3, figs. 11, 12]

Cf. *Fissurina circulo-costa* ASANO, 1938, Sci. Rep. Tohoku Imp. Univ., 2nd ser., vol. 19, pt. 2, p. 219, pl. 30, fig. 17; —, ASANO, 1956, Sci. Rep. Tohoku Univ., 2nd ser., vol. 27, p. 54, pl. 5, fig. 64.

In our specimens there is no ridge connecting two circular rims at the basal side.

Fissurina aff. *trigono-ornata* (BRADY) [Pl. 3, fig. 13]

Aff. *Lagena trigono-ornata* BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 482, pl. 61, fig. 14.

Our specimens are different from typical species in having smaller test and three longitudinal keels ornamented with a row of traverse edges instead of heavily reticulated keels.

Parafissurina costata, n. sp. [Pl. 3, figs. 19, 20]

Description: Test free, unilocular, globose, very slightly compressed; surface ornamented with 16 stout longitudinal ribs except for apertural region; aperture an arched slit covered over by a thick flap from the aboral side, with an ensolenian tube on the inside, adoral lip distinct. Diameter, up to 1 mm; length, up to 1.2 mm.

Remarks: This parafissurine species is peculiar in well-developed longitudinal ribs and lip.

Parafissurina curta PARR [Pl. 3, figs. 21, 22]

Parafissurina curta PARR, 1950, B.A.N.Z. Antarctic Res. Exped. 1929–1931, ser. B, vol. 5, pt. 6, p. 318, pl. 10, figs. 6, 7.

Parafissurina felsinea (FORNASINI) [Pl. 3, figs. 23, 24]

Lagena emaciata REUSS var. *felsinea* FORNASINI, 1901 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Lagena felsinea* FORNASINI, CUSHMAN, 1913, U.S. Nat. Mus. Bull., 71, pt. 3, p. 10, pl. 4, fig. 1; *Lagena felsinea* (FORNASINI), BUCHNER, 1940, Nova Acta Leopoldina, vol. 9, no. 62, p. 528, 529, pl. 25, figs. 542, 543; pl. 26, figs. 546, 547; *Lagena apiculata* (REUSS), BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, pl. 56, fig. 4, not 15, 16, 17, 18; *Lagena fornasini* BUCHNER, 1940, *op. cit.*, p. 529, pl. 26, figs. 548, 549; *Parafissurina fusuliformis* LOEBLICH & TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 79, 80, pl. 14, figs. 18, 19.

This species is unique among *Parafissurina* species in having a round opening of aperture instead of arched slit, even though we can see the features essential as this genus such as an internal entosolenian tube and an asymmetry in test-shape, particularly around the aperture. In taxonomic remarks of *Parafissurina tectulostoma* LOEBLICH & TAPPAN, 1953, the authors stated that some North Atlantic specimens identified as *Lagena felsinea* by CUSHMAN (1923) show no parafissurine aperture depending upon their own examination on the same specimens. Unfortunately, however, they seemed to have not given attentions about many other references such as shown here nor further comparison between *P. tectulostoma* and *Parafissurina fusuliformis* LOEBLICH & TAPPAN, which may be a younger synonym of *P. felsinea*.

Parafissurina tectulostoma LOEBLICH & TAPPAN [Pl. 3, figs. 25, 26]

Parafissurina tectulostoma LOEBLICH & TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 81, pl. 14, fig. 17; *Lagena apiculata* (REUSS), BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 453, pl. 56, figs. 17, 18, not 4, 15, 16; *Ellipsolagena cucullata* CHAPMAN & PARR, 1937, Australasian Antarctic Exped. 1911–14, vol. 1, pt. 2, p. 98, pl. 8, fig. 21.

In the description of *Lagena lateralis* CUSHMAN, 1913, the author pointed out that the species may include the specimens figured by BRADY (1884, pl. 56, figs. 17 and 18) as *Lagena apiculata* (REUSS). *L. lateralis* has rather round base of test, whereas the pointed base can be recognized in Brady's figures as well as in *Parafissurina tectulostoma*. Differing from the original description, *Ellipsolagena cucullata* CHAPMAN & PARR, 1937, also shows pointed test-base so far as the figure of the specimen is concerned.

Bolivina decussata BRADY [Pl. 4, figs. 1, 2]

Bolivina decussata BRADY, 1881 (fide ELLIS and MESSINA, 1949 *et seq.*)

Brizalina pacifica (CUSHMAN & MCCULLOCH) [Pl. 4, fig. 5]

Bolivina acerosa CUSHMAN var. *pacifica* CUSHMAN & MCCULLOCH, 1942, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 185, 186, pl. 21, figs. 2, 3.

This species differs from *Bolivina acerosa* CUSHMAN in showing characteristically clear areas at the upper and inner portion of each chamber, beside of their differences in geographical and geological occurrences. The former was described from off the western coast of the United States, whereas the latter from the Dominican Miocene.

"*Bolivina*" *bradyi* ASANO [Pl. 4, figs. 3, 4]

Bolivina bradyi ASANO, 1938, Jour. Geol. Soc. Japan, vol. 45, p. 603, pl. 16, fig. 2; *Loxostomum bradyi* (ASANO), UCHIO, 1960, Cushman Found. Foram. Res., Spec. Publ., no. 5, p. 64, pl. 7, fig. 9.

UCHIO (1960) correctly united together *Bolivina bramlettei* KLEINPELL of CUSHMAN and MCCULLOCH (1942) and *Loxostomum instabile* CUSHMAN & MCCULLOCH, 1942, under this species. As a result of the emendation of *Loxostomum* by LOEBLICH and TAPPAN (1962), new generic names may become necessary for "*Brizalina*" and "*Bolivina*" which become uniserial and terminal in aperture position in later stage, respectively. Cretaceous *Bolivina plaita* CARSEY, 1926, type species of *Coryphostoma* LOEBLICH and TAPPAN, 1962, seems to have morphology somewhat peculiar as to represent the so-called *Loxostomum* species.

Bulimina aculeata D'ORBIGNY [Pl. 4, figs. 8–10]

Bulimina aculeata D'ORBIGNY, 1826 (fide ELLIS and MESSINA, 1949 *et seq.*)

As stated by CUSHMAN and PARKER (1947), this species shows a wide variation concerning spinose ornamentation from specimen with short spines restricted at the basal margin of chambers to one heavily covered with numerous spines. The extremely spinose specimens were found solely in a sample (RC32–153, 380–381 cm).

Bulimina tenuata (CUSHMAN) [Pl. 4, figs. 6, 7]

Buliminella subfusiformis CUSHMAN var. *tenuata* CUSHMAN, 1927 (fide ELLIS and MESSINA, 1949 *et seq.*); *Bulimina exilis* BRADY var. *tenuata* (CUSHMAN), CUSHMAN and PARKER, 1947, U.S. Geol. Surv. Prof. Paper, 210-D, p. 124, pl. 28, fig. 29; —, CUSHMAN and MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 5, p. 248, pl. 31, fig. 2; *Buliminella tenuata* CUSHMAN, UCHIO, 1960, Cushman Found. Foram. Res., Spec. Publ., no. 5, pl. 6, fig. 1.

One of features characteristic in this species may be clear areas at the inner and upper corner of each chamber.

Globobulimina auriculata (BAILEY) [Pl. 4, figs. 11–14]

Bulimina auriculata BAILEY, 1851 (fide ELLIS and MESSINA, 1949 *et seq.*); *Globobulimina* (*Desinobulimina*) *auriculata* (BAILEY), CUSHMAN and PARKER, 1947, U.S. Geol. Surv. Prof. Paper, 210-D, p. 129, pl. 29, figs. 22–24.

Stainforthia complanata (EGGER) [Pl. 4, figs. 15, 16]

Virgulina schreibersiana CZJZEK var. *complanata* EGGER, 1893 (fide ELLIS and MESSINA, 1949 *et seq.*);

Virgulina complanata EGGER, CUSHMAN, 1937, Cushman Lab. Foram. Res., Spec. Publ., no. 9, p. 26, 27, pl. 4, figs. 13–17; *Bulimina exilis* BRADY, LOEBLICH and TAPPAN (not BRADY, 1953), Smiths. Misc. Coll., 121, pt. 7, p. 110, pl. 20, figs. 4, 5.

UCHIO (1960) considered *Virgulina concava* HÖGLUND, 1947, *Virgulina davisii* CHAPMAN & PARR, 1937, and *Virgulina loeblichii* FEYLING-HANSSSEN, 1954, as younger synonyms of this cosmopolitan species. If it is true, we must regard this species as the type species of *Stainforthia* HOFKER, 1956, instead of *V. concava* which was designated as the type by HOFKER.

Stainforthia rotundata (PARR) [Pl. 4, figs. 17–19]

Virgulina rotundata PARR, 1950, B.A.N.Z. Antarctic Res. Exped. 1929–1931, ser. B, vol. 5, pt. 6, p. 337, pl. 12, fig. 14; —, UCHIO, 1960, Cushman Found. Foram. Res., Spec. Publ., no. 5, pl. 6, figs. 15, 16; *Virgulina subsquamosa* EGGER, BRADY, 1884 (not EGGER), Rep. Voy. Challenger, Zool., vol. 9, pl. 52, figs. 10, 11.

Stainforthia spinosa (HERON-ALLEN & EARLAND) [Pl. 4, fig. 20]

Virgulina schreibersiana CZJZEK var. *spinosa* HERON-ALLEN & EARLAND, 1932, Discovery Rep., vol. 4, p. 352, pl. 9, figs. 3, 4.

Stainforthia cf. *schreibersiana* (CZJZEK) [Pl. 4, figs. 21, 22]

Cf. *Virgulina schreibersiana* CZJZEK, 1848 (*vide* CUSHMAN, 1937, Cushman Lab. Foram. Res. Spec. Publ., no. 9); *Virgulina bramletti* GALLOWAY & MORREY, UCHIO (not GALLOWAY & MORREY), 1960, Cushman Found. Foram. Res., Spec. Publ., no. 5, pl. 6, fig. 12.

Our specimens are too small for the exact identification.

Stainforthia sp. [Pl. 4, fig. 23]

Somewhat similar to *Virgulina sandiegoensis* UCHIO, 1960.

Uvigerina akitaensis ASANO [Pl. 5, figs. 1–3, 8, 9]

Uvigerina akitaensis ASANO, 1950, Illust. Cat. Jap. Tert. Small. Foram., pt. 2, p. 14, figs. 60–62.

This species has frequently been reported from the adjacent seas of Japan and also from the late Cenozoic strata. As well as seen in those reports, our specimens show very wide variation in test shape and ornamentation so that some different specific names might be applied if we treat this population individually. As examples, there are shown a typical adult form (Pl. 5, fig. 1), young one (fig. 2), a form with sharp longitudinal ribs (fig. 3), one with faint longitudinal costae (fig. 9) and one with the later stage where the costae become faint and, instead, tubercles appear (fig. 8).

Uvigerina akitaensis ASANO, variety [Pl. 5, figs. 4–7]

This tuberculated variety is restricted and rich in two samples. The tuberculation seems to start from the interspaces of longitudinal costae which, at the same time, become to be interrupted as to form rows of prominent tubercles (see fig. 6).

Uvigerinella sp. [Pl. 5, figs. 10, 11]

Only a specimen was found in a sample (V28–265, 90–91 cm).

Trifarina ikebei (HUSEZIMA & MARUHASI) [Pl. 5, figs. 12–15]

Angulogerina ikebei HUSEZIMA & MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 396, p. 34, fig. 8; *Trifarina ikebei* (HUSEZIMA & MARUHASI), AOKI, 1950, Sci. Rep. Saitama Univ., ser. B, vol. 5, no. 1, p. 60, pl. 7, figs. 6, 7; *Angulogerina fluens* TODD, 1947, in CUSHMAN and TODD, Contr. Cushman Lab. Foram. Res., vol. 23, p. 67, pl. 16, figs. 6, 7; *Angulogerina kokozuraensis* ASANO, 1949, Jour. Paleont., vol. 23, no. 4, p. 428, text-figs. 50–53; *Angulogerina kawabensis* MATSUNAGA, 1963, Sci. Rep. Tohoku Univ., 2nd ser., vol. 35, no. 2, p. 112, pl. 42, fig. 1.

Buccella inusitata ANDERSON [Pl. 5, figs. 16–21]

Buccella inusitata ANDERSON, 1952 (*vide* ELLIS and MESSINA, 1949 *et seq.*).

As pointed out previously (UJIIÉ, 1963), this species seems to represent a cold water type among *Buccella* species.

Epistominella levicula RESIG [Pl. 6, figs. 1–3; Pl. 10, figs. 13–15]

Epistominella levicula RESIG, 1958, *Micropaleontology*, vol. 4, no. 3, p. 304, text-figs. 16; *Eilohedra levicula* (RESIG), LIPPS, 1965, *Tulane Stud. Geol.*, vol. 3, no. 2, p. 124, fig. 3, pl. 3, fig. 5; *Epistominella nipponica* KUWANO, 1970, in MATOBA, 1970, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 42, no. 1, p. 254, 255, fig. 8, pl. 26, fig. 13; ? *Eponides rotundus* HUSEZIMA & MARUHASI, 1944, *Jour. Sigenkagaku Kenkyusho*, vol. 1, no. 3, p. 399, pl. 36, fig. 12.

Epistominella has an aperture which is "an elongate vertical slit in face, near and parallel to peripheral keel" as described clearly by LOEBLICH and TAPPAN (1964), although some species may have the aperture showing a trend to bent toward the base of final chamber. On the other hand, LIPPS (1965) regarded *Epistominella levicula* RESIG as to have a basal slit-type of aperture "extending vertically up face of last chamber near periphery" and then designated this species as to represent the type species of a new genus *Eilohedra*. As shown in scanning electron micrographs of the apertural face of the species (Pl. 10, figs. 13–15), however, there is not recognized any extension of aperture toward the base of final chamber but, instead, an obscure rim near and parallel to the base. The same situation can be expected for *Epistominella nipponica* KUWANO that has recently been transferred to the genus *Eilohedra* by some Japanese authors (ex. MATOBA and NAKAGAWA, 1972; KITAZATO in OBA *et al.*, 1980) and that is here considered as to be conspecific with *E. levicula*.

According to RESIG (1958), this species appears to be characteristic in somewhat stagnant waters of the basins in the continental borderland off California.

Epistominella naraensis (KUWANO) [Pl. 6, figs. 4–6]

Pseudoparella naraensis KUWANO, 1950, *Jour. Geol. Soc. Japan*, vol. 56, no. 657, p. 317, 318, fig. 6.

This species resembles *Pulvinulina exigua* BRADY of authors; in particular, *Pseudoparella exigua* (BRADY) of PHLEGER and PARKER (1951) and *Epistominella exigua* (BRADY) of PARKER (1954).

Epistominella pacifica (CUSHMAN) [Pl. 6, figs. 7–15]

Pulvinulina pacifica CUSHMAN 1927, *Bull. Scripps Inst. Oceanogr.*, Tech. Ser., vol. 1, no. 10, p. 165, pl. 5, figs. 14, 15; *Epistominella pacifica* (CUSHMAN), LIPPS, 1965, *Tulane Stud. Geol.*, vol. 3, no. 2, p. 126–129; *Epistominella pulchella* HUSEZIMA & MARUHASI, 1944, *Jour. Sigenkagaku Kenkyusho*, vol. 1, no. 3, p. 398, pl. 34, fig. 10; *Pseudoparella japonica* ASANO, 1949, *Jour. Paleont.*, vol. 23, no. 4, p. 430, fig. 2.

This species has been reported from the Recent through Miocene deposits off and on the western coast of the United States and from the Okhotsk Sea region by so many authors as cited completely by LIPPS (1965) who doubts whether this differs from *Epistominella pulchella* or not. As well as seen in the references cited by LIPPS, a great number of specimens found in the Sea of Japan cores indicate so wide morphological variation that this species would contain *E. pulchella* and *Pseudoparella japonica* ASANO as younger synonyms. If this treatment could be accepted, then the type species of *Epistominella* would be *E. pacifica*, replaced *E. pulchella*.

Valvulineria glabra CUSHMAN [Pl. 6, figs. 16–18] shown as *V. sp. A* in Table 2a–e.

Valvulineria vilardeboana (D'ORBIGNY) var. *glabra* CUSHMAN, 1927 (*vide* ELLIS and MESSINA, 1949 *et seq.*); *Valvulineria glabra* CUSHMAN, UCHIO, 1960, pl. 8, figs. 6, 7; —, MATOBA, 1967, *Sci. Rep. Tohoku Univ.*, 2nd ser., vol. 38, no. 2, pl. 26, fig. 19; *Eponides exigua* (BRADY), CUSHMAN, 1931, *U.S. Nat. Mus. Bull.*, 104, pt. 8, p. 44, 45, pl. 8, figs. 6, 7.

Valvulineria sadonica ASANO [Pl. 7, figs. 1–6]

Valvulineria sadonica ASANO, 1951, *Illust. Cat. Jap. Tert. Small. Foram.*, pt. 14, p. 8, figs. 55–57.

A gerontic specimen with roundly inflated umbilical valve (Pl. 7, figs. 1–3) quite resembles to *Valvulineria mexicana* PARKER, 1954. When PARKER (1954) described the latter species, she designated, as the same, *Valvulineria cf. araucana* (D'ORBIGNY) of PHLEGER and PARKER (1951) who also showed the young specimens that are quite similar to adult specimens in our samples (ex. figs. 1–3) and to the holotype of *V. sadonica*.

Valvulineria sp. B [Pl. 6, figs. 19–21]

This species somewhat resembles *Anomalina hamanaoensis* ISHIWADA, 1958, and also *Valvulineria*

hamanakoensis (ISHIWADA) of MATOBA (1970) but differs from the latter in having fewer chambers per whorl and more distinct umbilical valve. Scanning electron microscope revealed a presence of fine beads arranged along the base of last whorl.

Cribrononion clavatum (CUSHMAN) [Pl. 7, figs. 7, 8]

Elphidium incertum (WILLIAMSON) var. *clavatum* CUSHMAN, 1930, U.S. Nat. Mus., Bull., 104, pt. 7, p. 20, pl. 7, fig. 10.

See *Elphidium clavatum* CUSHMAN, MATOBA, 1970, for further references. *Elphidium subgranulosum* ASANO, 1938, may be included here.

Cribrononion sp. A [Pl. 7, figs. 9, 10]

Elphidium aff. *magellanicum* HERON-ALLEN & EARLAND, UJIIÉ, 1963, Sci. Rep. Tokyo Kyoiku Daigaku, sec. C, vol. 8, no. 79, p. 241, pl. 3, fig. 28; *Elphidium subarcticum* CUSHMAN, PARKER (not CUSHMAN), 1952, p. 412, 413 pl. 5, fig. 9; —, MATOBA (not CUSHMAN), 1967, Sci. Rep. Tohoku Univ., 2nd ser., vol. 38, no. 2, p. 254, pl. 27, figs. 10, 11; —, MATOBA (not CUSHMAN), 1970, *ibid.*, vol. 42, no. 1, p. 52, pl. 7, fig. 6, 7; *Elphidium etigoense* HUSEZIMA & MARUHASI, ASANO (not HUSEZIMA and MARUHASI), 1960, *ibid.*, Spec. Vol., no. 4, p. 198, pl. 22, figs. 8, 9; —, TAKAYANAGI (not HUSEZIMA and MARUHASI), 1955, Contr. Inst. Geol. Paleont., Tohoku Univ., no. 45, p. 42, pl. 1, fig. 26.

This species is characteristically provided with opaque band filled with “amorphous material” along sutures so that sutural pores are obscure at least under optical microscope. PAKERR (1952) stated similar situation on her *Elphidium subarcticum* CUSHMAN. LOEBLICH and TAPPAN (1953) also observed opaque bands along the sutures of their *E. subarcticum*, which has, however, clear sutural pores and additional accessory pores over the apertural face likely in *Elphidium etigoense* HUSEZIMA & MARUHASI, 1944. Based upon a large suite of topotypic specimens, the sutural characters of *E. subarcticum* should be re-examined.

Hyalinea balthica (SCHROETER) [Pl. 7, figs. 11, 12]

Nautilus balthicus SCHROETER, 1783 (*vide* ELLIS and MESSINA, 1949 *et seq.*).

“*Cibicides asanoi* MATSUNAGA” [Pl. 7, figs. 13–18; pl. 8, figs. 1–3]

Cibicides asanoi MATSUNAGA, 1963, Sci. Rep. Tohoku Univ., 2nd ser., vol. 35, no. 2, p. 116, pl. 51, fig. 4.

Our specimens are identical with this species, even though the taxonomic identity of the species must be ascertained after comparison with many other *Cibicides* species. An umbilical hole is opened on the spiral side of proloculus in many our specimens, particularly young forms, similarly to *Pseudocibicoides* UJIIÉ, 1956.

Cassidulina neocarinata THALMANN [Pl. 8, figs. 4, 5]

Cassidulina laevigata D'ORBIGNY var. *carinata* CUSHMAN, 1922 (not SILVESTRI, 1896), Bull. U.S. Nat. Mus., 104, pt. 3, p. 124, pl. 25, figs. 6, 7; *Cassidulina neocarinata* THALMANN, 1950, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3 & 4, p. 536, pl. 11, fig. 3.

Cassidulina norcrossi CUSHMAN [Pl. 8, figs. 6–9]

Cassidulina norcrossi CUSHMAN, 1933 (*vide* ELLIS and MESSINA, 1949 *et seq.*); —, LOEBLICH and TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 120, pl. 24, fig. 2; *Cassidulina kasiwazakiensis* HUSEZIMA & MARUHASI, 1944, Jour. Sigenkagaku Kenkyusho, vol. 1, no. 3, p. 399, 400, pl. 34, fig. 13.

This species has frequently been reported from northern Japan and its adjacent seas as *Cassidulina kasiwazakiensis*. *Cassidulina wakasaensis* ASANO & NAKAMURA, 1937, which was described as one of the Sea of Japan type species of *Cassidulina*, might be conspecific with this species.

Cassidulina sp. A.

A young form similar to *Cassidulina laevigata* D'ORBIGNY, 1826.

Islandiella californica (CUSHMAN & HUGHES) [Pl. 8, figs. 10–17]

Cassidulina californica CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 3, p. 12, pl. 2, fig. 1; *Islandiella californica* (CUSHMAN & HUGHES), LOEBLICH and TAPPAN, 1964, Treatise

on invertebrate paleontology, (C) Protista 2, figs. 439–4; *Cassidulina japonica* ASANO & NAKAMURA, 1937, Jap. Jour. Geol. Geogr., vol. 14, pts. 2–3, p. 144, pl. 13, figs. 1, 2.

When ASANO and NAKAMURA (1937) described many new species of *Cassidulina*, *C. japonica* was regarded as characteristic in the Sea of Japan province, which has close relationship with the California province according to their opinion. In comparison with *Cassidulina californica* CUSHMAN & HUGHES, they pointed out that *C. japonica* possesses slightly more compressed test and more lobulate chambers. So far as our specimens are concerned, however, rather typical forms of *C. californica* are much more common, whereas *C. japonica* type (Pl. 8, figs. 14, 15) is seldom and considered as a variation in *Islandiella californica* population. A figure shown as typical *C. japonica* by MATSUNAGA (1963, pl. 48, fig. 4) is rather of *I. californica*.

Islandiella islandica (NØRVANG) [Pl. 8, figs. 18, 19; pl. 9, figs. 1, 2]

Cassidulina islandica NØRVANG, 1945, The zoology of Iceland, vol. 2, pt. 2, p. 41, 42, fig. 7; *Islandiella islandica* (NØRVANG), NØRVANG, 1959, Vidensk. Medd. Dansk naturhist. Foren. vol. 120, p. 26.

Some globose specimens within wide variation of this species somewhat resemble *Cassidulina subglobosa* BRADY, although the full-grown specimens are easily distinguishable from the latter species. Specimens figured as *C. subglobosa* and *C. subglobosa depressa* ASANO & NAKAMURA by MATSUNAGA (1963), which were taken from the Neogene on the Sea of Japan coast, may belong to *Islandiella islandica*.

Islandiella norvangi (THALMANN) [Pl. 9, figs. 3–6]

Cassidulina islandica forma *minuta* NØRVANG, 1945, The zoology of Iceland, vol. 2, pt. 2, p. 43, fig. 9; *Cassidulina islandica* NØRVANG var. *minuta* NØRVANG, PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 9, p. 421, pl. 6, figs. 22, 23; *Cassidulina islandica* NØRVANG var. *norvangi* THALMANN, 1952, in PHLEGER, Contr. Cushman Found. Foram. Res., vol. 3, pt. 2, p. 83.

NØRVANG (1945) pointed out only the smaller test-size of his forma compared with the typical species. LOEBLICH and TAPPAN (1953) united together both the forms, in standing upon the test-size gradation among their own specimens. As shown by a comparison between Pl. 8, figs. 18, 19 and Pl. 9, figs. 3, 4 for an example, however, many young forms of *Islandiella islandica* are provided with globose test differently from the same-sized *I. norvangi* which has consistently somewhat compressed test as well as seen in the type figure drawn by NØRVANG (1945, fig. 9)

Islandiella subglobosa (BRADY) [Pl. 9, figs. 7, 8]

Cassidulina subglobosa BRADY, 1881 (*vide* BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 430, pl. 54, fig. 17)

We found here very few specimens, aperture of which is provided with *Islandiella*-type tooth plate. Many authors have considered the species as to belong to *Globocassidulina*, which has no tooth plate. At a glance, BRADY's figure of the type specimen seems to have no tooth plate, even though many later authors observed the tooth plate on their *C. subglobosa*.

Cassidulinoides tenuis PHLEGER & PARKER [Pl. 9, fig. 9]

Cassidulinoides tenuis PHLEGER & PARKER, 1951, Mem. Geol. Soc. America, 46, pt. 2, p. 27, pl. 14, figs. 14–17.

Cassidulinoides kuwanoi MATOBA, 1967, might be a young form of this species.

Astrononion hamadaense ASANO [Pl. 9, figs. 10, 11]

Astrononion hamadaense ASANO, 1950, Illust. Cat. Jap. Tert. Small. Foram., pt. 1, p. 6, figs. 29–31; *Astrononion stellatum* CUSHMAN & EDWARDS, 1937 (not *Nonionina stellata* TERQUEM, 1882); *Astrononion gallowayi* LOEBLICH & TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 90–92, pl. 17, figs. 4–7.

Although LOEBLICH and TAPPAN (1953) gave a new name, *Astrononion gallowayi*, for well-known *Astrononion stellatum* CUSHMAN & EDWARDS, which was pre-occupied by *Nonionina stellata* TERQUEM, *A. hamadaense* may be a senior synonym of their *Astrononion*.

Chilostomellina fimbriata CUSHMAN [Pl. 9, figs. 12–15]

Chilostomellina fimbriata CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 4, p. 78, pl. 11, fig. 22; —, LOEBLICH and TAPPAN, 1953, Smiths. Misc. Coll., 121, pt. 7, p. 93, 94, pl. 17, fig. 3; *Nonionella turgida* (WILLIAMSON) var. *digitata* NØRVANG, 1945, The zoology of Iceland, vol. 2, pt. 2, p. 29, 30, fig. 4; —, PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, nos. 8–9, p. 413, pl. 5, figs. 15, 16.

Finger-like projections of chamber cover characteristically on umbilical side of test in the earlier stage likely *Nonionella* species. In the later stage, however, the projections cover on the both sides of test, which then becomes bilaterally symmetrical. This ontogenetical change has not yet been recognized.

Pseudononion auriculum (HERON-ALLEN & EARLAND) [Pl. 10, figs. 1–3]

Nonionella auricula HERON-ALLEN & EARLAND, 1930, Jour. Roy. Micr. Soc., vol. 50, p. 192, pl. 5, figs. 68–70.

This species has frequently been reported from the arctic to subarctic seas. Some specimens resemble *Pseudononion japonicum* ASANO, 1932.

Pseudononion labradoricum (DAWSON) [Pl. 10, figs. 4–8]

Nonionina labradorica DAWSON, 1860 (*vide* CUSHMAN, 1939, U.S. Geol. Surv. Prof. Paper, 191, p. 23, pl. fig. 13)

In a number of papers on the arctic to subarctic foraminiferal faunas, this species has been designated as *Nonion* species, even though some figures in those papers showed bilaterally asymmetrical tests. In our specimens, there is a general trend of such a morphological change as asymmetrical in young and then becoming symmetrical in adult, although some adults retain as asymmetrical.

Pullenia apertura CUSHMAN [Pl. 10, figs. 9, 10]

Pullenia apertura CUSHMAN, 1927, Bull. Scripps Inst. Oceanogr., Tech. Ser., vol. 1, no. 10, p. 171, pl. 6, fig. 10; —, CUSHMAN and TODD, 1943, Contr. Cushman Lab. Foram. Res., vol. 19, pt. 1, p. 22, figs. 6, 7.

Pullenia salisburyi R. E. & K. C. STEWART [Pl. 10, figs. 11, 12]

Pullenia salisburyi R. E. & K. C. STEWART, 1930, Jour. Paleont., vol. 4, p. 72, pl. 8, fig. 2; —, CUSHMAN and TODD, 1943, Contr. Cushman Lab. Foram. Res., vol. 19, pt. 1, p. 20, 21, pl. 3, figs. 10, 11.

M. ICHIKURA was supported by the grand-in-aid (491516) of the Ministry of Education, Science and Culture of Japan for this study.

References

- ARAI, F., T. OBA, H. KITAZATO, Y. HORIBE & H. MACHIDA, 1981. Late Quaternary tephrochronology and paleo-oceanography of the sediments of the Japan Sea. *The Quaternary Res.*, **20** (3): 209–228, 2 pls. [In Japanese with English abstract].
- ASANO, K., 1938. Japanese fossil Nodosariidae, with notes on the Frondiculariidae. *Sci. Rep. Tohoku Imp. Univ.*, 2nd ser., **19** (2): 179–220, pls. 24–31.
- ASANO, K., 1950 a. Illustrated catalogue of Japanese Tertiary smaller foraminifera. Part 2; Buliminidae. 19 pp., Hosokawa Printing Co., Tokyo.
- ASANO, K., 1950 b. Ditto, Part 4: Valvulinidae. 4 pp.
- ASANO, K., 1951. Ditto, Part 15: Lagenidae. 39 pp.
- ASANO, K., 1956. The foraminifera from the adjacent seas of Japan collected by the S. S. Soyo-maru, 1922–1930. Part 1. Nodosariidae. *Sci. Rep. Tohoku Univ.*, 2nd ser., **27**: 1–55, pls. 1–6.
- ASANO, K., & M. NAKAMURA, 1937. On the Japanese species of *Cassidulina*. *Jap. Jour. Geol. Geogr.*, **14** (2–3): 143–153, pls. 13, 14.
- BARKER, R. W., 1960. Taxonomic notes on the species figured by H. B. BRADY in his report on the foraminifera dredged by H.M.S. *Challenger* during the year 1873–1876. *Spec. Publ. Soc. Economic Paleont. Mineral.*, (9): xxiv+238 pp.

- BRADY, H. B., 1884. Report on the scientific results of the voyage of H.M.S. *Challenger*, vol. 9 (Zoology), 814 pp., 115 pls.
- CHAPMAN, F. & W. J. PARR, 1937. Foraminifera. Australasian Antarctic Expedition, 1911-14, Sci. Rep., ser. C, 1 (2): 1-190, pls. 7-10.
- CUSHMAN, J. A., 1923. The foraminifera of the Atlantic Ocean. Part 4. Lagenidae. *Bull. U.S. Nat. Mus.*, (104): x+228 pp., 42 pls.
- CUSHMAN, J. A., 1937. A monograph of the foraminiferal family Valvulinidae. *Spec. Publ. Cushman Lab. Foram. Res.*, (8): xiii+210 pp., 24 pls.
- CUSHMAN, J. A., & I. McCULLOCH, 1950. Some Lagenidae in the collections of the Allan Hancock Foundation. *Allan Hancock Pacific Exped.*, 6 (6): 295-365, pls. 37-48.
- CUSHMAN, J. A., & F. L. PARKER, 1947. *Bulimina* and related foraminiferal genera. *U.S. Geol. Surv. Prof. Paper*, (210-D): 55-176, pls. 15-30.
- D'ORBIGNY, A., 1839. Foraminifères. Voyage dans l'Amérique méridionale, 5 (5): 1-86, 9 pls.
- FISHER, R. A., A. S. CORBET & C. B. WILLIAMS, 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Jour. Animal Ecol.*, 12 (1): 42-57.
- HADA, Y., 1931. Report of the biological survey of Mutsu Bay. 19. Notes on the Recent foraminifera from Mutsu Bay. *Sci. Rep. Tohoku Imp. Univ.*, 4th ser., 6 (1): 45-148.
- HOFKER, J., 1956. Tertiary foraminifera of coastal Ecuador, Part II. Additional notes on the Eocene species. *Jour. Paleont.*, 30: 891-958, 101 text-figs.
- HUSEZIMA, R. & M. MARUHASI, 1944. A new genus and thirteen new species of foraminifera from the core-sample of Kasiwazaki oil-field, Niigata-ken. *Jour. Sigenkagaku Kenkyusho*, 1 (3): 391-400, pl. 34.
- ICHIKURA, M. & H. UJIIÉ, 1976. Lithology and planktonic foraminifera of the Sea of Japan piston cores. *Bull. Natn. Sci. Mus.*, ser. C, 2 (4): 151-178, 4 pls.
- INGLE, J. C., JR., 1973. Neogene foraminifera from the northeastern Pacific Ocean, Leg. 18, Deep Sea Drilling Project. *Init. Rep. D.S.D.P.*, 18: 517-567.
- INGLE, J. C. JR., 1975. Pleistocene and Pliocene foraminifera from the Sea of Japan, Leg 31, Deep Sea Drilling Project. *Ibid.*, 31: 693-701.
- INOUE, Y., 1980. Stratigraphic and paleoenvironmental considerations of Holocene to uppermost Pleistocene foraminifera in Nishi-Tsugaru basin, Sea of Japan. Prof. S. KANNO Mem. Vol., 241-261, pls. 26-28.
- KATO, M., 1978. Age assignment of the dredge and piston core samples. In: HONZA, E., ed.: Geological investigations in the northern margin of the Okinawa Trough and the western margin of the Japan Sea, *Geol. Surv. Japan, Cruise Rep.*, (10): 59-62.
- KURIHARA, K., 1982. Planktonic foraminifera in a piston core V32-153 from the Yamato Rise, the Sea of Japan. *St. Paul's Rev. Sci.*, 4 (3): 79-89, pl. 1.
- LIPPS, J. H., 1965. Revision of the foraminiferal family Pseudoparrellidae VOLOSHINOVA. *Tulane Stud. Geol.*, 3 (2): 117-148, 3 pls.
- LOEBLICH, A. R. JR. & H. TAPPAN, 1953. Studies of Arctic foraminifera. *Smiths. Misc. Coll.*, 121 (7): iv+150 pp., 24 pls.
- LOEBLICH, A. R. JR. & H. TAPPAN, 1962. Six new generic names in the Mycetozoida (Trichiidae) and Foraminiferida (Fischerinidae, Buliminidae, Caucasinidae and Pleurostomellidae), and a redescription of *Loxostomum* (Loxostomidae, new family). *Proc. Biol. Soc. Washington*, 75: 107-113.
- LOEBLICH, A. R. JR. & H. TAPPAN, 1964. Treatise on invertebrate paleontology. (C) Protista 2, 900 pp., Geol. Soc. America.
- MAIYA, S., T. SAITO & T. SATO, 1976. Late Cenozoic planktonic foraminiferal biostratigraphy. In: TAKAYANAGI, Y. & T. SAITO, eds.: Progress in micropaleontology. Spec. Publ. Amer. Mus. Nat. Hist., N.Y., 395-422, 6 pls.

- MASUZAWA, T., 1983. Cyclic appearance of reduced and oxidized conditions in the Sea of Japan bottom waters through the late Quaternary. *Kaiyo-kagaku [Marine Scis.]*, **15** (2): 68–77. [In Japanese].
- MATOBA, Y., 1970. Distribution of Recent shallow water foraminifera of Matsushima Bay, Miyagi Prefecture, northeast Japan. *Sci. Rep. Tohoku Univ., 2nd ser.*, **42** (1): 1–85, pls. 1–8.
- MATOBA, Y., 1976. Foraminifera from off Noshiro, Japan, and postmortem distribution of tests in the Japan Sea. In: TAKAYANAGI, Y. & T. SAITO, eds.: *Progress in micropaleontology*, Spec. Publ. Amer. Mus. Nat. Hist., N.Y., 169–189.
- MATOBA, Y., 1978. Benthonic foraminifera—distribution in seas around Japan. *Kaiyo-kagaku [Marine Scis.]*, **7** (4): 257–262 [In Japanese with English abstract].
- MATOBA, Y. & H. NAKAGAWA, 1972. Recent foraminiferal assemblages from the continental shelf and slope off Akita, Japan Sea coast of northeast Japan. Prof. J. IWAI Mem. Vol., 657–671. [In Japanese with English abstract].
- MATSUNAGA, T., 1963. Benthonic smaller foraminifera from the oil field of northern Japan. *Sci. Rep. Tohoku Univ., 2nd ser.*, **35** (2): 67–122, pls. 24–52.
- MIYAKE, S., Y. SUGIMURA & E. MATSUMOTO, 1968. Ionium-thorium chronology of the Japan Sea cores. *Rec. Oceanogr. Works Japan*, **9** (2): 189–195.
- MURRAY, J. W., 1973. Distribution and ecology of living benthic foraminiferids. xii+274 pp., Heinemann Educ. Books, Ltd., London.
- NISHIMURA, S., 1973. Biogeography of the Sea of Japan. iv+227 pp., Tsukiji Shokan Publ. Co., Tokyo [In Japanese].
- NØRVANG, A., 1945. Foraminifera, Zoology of Iceland, **2** (2): 1–79.
- OKA, T., 1983. Paleoenvironment of the Sea of Japan since the last glaciation. *Chikyū [Monthly the Earth]*, **5** (1): 37–46 [In Japanese].
- OKA, T., Y. HORIBE & H. KITAZATO, 1980. Analysis of the paleoenvironment since the last glacial age based on two cores from the Japan Sea. *Archeology & Nat. Scis.*, (13): 31–49. [In Japanese with English abstract].
- OKADA, A., & M. SHIMA, 1973. Authigenic minerals in the sediments of Japan Sea. On framboidal pyrite, glauconite and gypsum. *Sci. Paper Inst. Phys. Chem. Res.*, **67**: 148–154.
- ORR, W. N. & J. B. ZAITZEFF, 1971. A new planktonic foraminiferal species from the California Pliocene. *Jour. Foram. Res.*, **1** (1): 17–19, pl. 1.
- PARKER, F. L., 1952. Foraminifera species off Portsmouth, New Hampshire. *Bull. Mus. Comp. Zool.*, **106** (8–9): 391–423, 6 pls.
- PARKER, F. L., 1954. Distribution of the foraminifera in the northwestern Gulf of Mexico. *Ibid.*, **111** (10): 435–588, 13 pls.
- PHLEGER, F. B. & F. L. PARKER, 1951. Ecology of foraminifera, northwest Gulf of Mexico. Part 2. Foraminifera species. *Geol. Soc. America Mem.*, (46): 64 pp., 20 pls.
- RESIG, J. M., 1958. Ecology of foraminifera of the Santa Cruz Basin, California. *Micropaleontology*, **4** (3): 287–308.
- SAIDOVA, K. M., 1960. Distribution of foraminifera in the bottom sediments of the Okhotsk Sea. *Trudy Inst. Okeanol.*, **32**: 96–157. [In Russian].
- SAIDOVA, K. M., 1961. Foraminiferal ecology and paleogeography of the far-eastern seas of the USSR and northwestern part of the Pacific Ocean. 232 pp., 31 pls., Akad. Nauk SSSR, Inst. Okeanol., Moskva. [In Russian].
- SAIDOVA, K. M., 1962. Geographic distribution of living benthonic foraminifera in the northwestern part of the Pacific Ocean. *Voprosi Micropaleont.*, (6): 31–63. [In Russian].
- TANIMURA, Y., 1981. Late Quaternary diatoms of the Sea of Japan. *Sci. Rep. Tohoku Univ., 2nd ser.*, **51** (1–2): 1–36, pls. 1–7.
- TROITSKAYA, T. S., 1970. Environmental conditions and distribution of foraminifera in the Japan Sea. *Rep. Inst. Geol. Geophys., Siberian Div., Akad. Nauk SSSR*. **71**: 136–160. [In Russian].

- UCHIO, T., 1960. Ecology of living benthonic foraminifera from the San Diego, California, area. *Spec. Publ. Cushman Found. Foram. Res.*, (5): 72 pp., 10 pls.
- UJIIÉ, H., 1963. Foraminifera from the Yurakucho Formation (Holocene), Tokyo City. *Sci. Rep. Tokyo Kyoiku Daigaku, sec. C*, 8 (79): 229–234, pls. 1–3.
- UJIIÉ, H. & M. ICHIKURA, 1973. Holocene to uppermost Pleistocene planktonic foraminifers in a piston core from off San'in district, Sea of Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, (91): 137–150, pls. 21, 22.

Explanation of Plates

Plate 1

- Fig. 1. *Astrorhizidae*, gen. et sp. indet. RC12-378, 0 cm, $\times 60$.
- Fig. 2. *Lagenammina atlantica* (CUSHMAN), side view. RC12-378, 0 cm, $\times 100$.
- Figs. 3–5. *Silicosigmoilina abyssalica* INOUE, two side views and an apertural view, respectively. V28–265, 0 cm, $\times 150$.
- Fig. 6. *Spiroplectammina biformis* (PARKER & JONES), side view. V28–265, 0 cm, $\times 300$.
- Figs. 7–10. *Karrerriella japonica* ASANO, apertural and side views of young and adult forms, respectively. Young form from RC12-376, 11 cm $\times 80$; adult from V32-153, 500 cm, $\times 80$.
- Figs. 11–13. *Trochammina hadai* UCHIO, spiral, side, and umbilical views, respectively. RC12-378, 0 cm, $\times 100$.
- Figs. 14–16. *Pyrgo* cf. *murrhyna* (SCHWAGER). 14, 15: Top and side views, respectively, from RC12-376, 197 cm, $\times 100$; 16: Enlargement of surface showing recrystallized calcites, $\times 1,300$.
- Fig. 17. *Dentalina guttifera* D'ORBIGNY, side view. RC12-376, 11 cm, $\times 100$.
- Fig. 18. *Frondicularia* sp., side view of fragment. V32-153, $\times 100$.
- Fig. 19. *Lagena amphora* REUSS, side view. V28–265, 56 cm, $\times 300$.
- Fig. 20. *Lagena apiopleura* LOEBLICH & TAPPAN, side view. RC12-376, 315 cm, $\times 300$.
- Fig. 21. *Lagena* aff. *apiopleura* LOEBLICH & TAPPAN, side view. V32-153, 540 cm, $\times 250$.
- Fig. 22. *Lagena distoma* PARKER & JONES, side view. V28–265, 240 cm, $\times 200$.

Plate 2

- Fig. 1. *Lagena elongata* (EHRENBERG), side view. V28–265, 110 cm, $\times 40$.
- Fig. 2. *Lagena gracillima* (SEGUENZA), side view. RC12-378, 560 cm, $\times 150$.
- Fig. 3. *Lagena nebulosa* CUSHMAN, side view. V28–265, 20 cm, $\times 250$.
- Fig. 4. *Lagena striata* D'ORBIGNY, side view. RC12-378, 400 cm, $\times 200$.
- Fig. 5. *Lagena substriata* WILLIAMSON, side view. RC12-377, 484 cm, $\times 250$.
- Fig. 6. *Lagena* aff. *substriata* WILLIAMSON, side view. V28–265, 40 cm, $\times 250$.
- Figs. 7–9. *Lagena tricaritortuosa*, n. sp. 7, 8: top and side views of holotype, respectively, from RC12-378, $\times 300$. 9: close-up of apertural area, $\times 1030$.
- Figs. 11, 12. *Glandulina laevigata* (D'ORBIGNY), apertural and side view. RC12-376, 11 cm, $\times 200$.
- Figs. 13, 14. *Planularia asanoi*, n. sp., side and dorsal views, respectively. V28–265, 80 cm, $\times 100$.
- Fig. 15. *Oolina melo* D'ORBIGNY, side view. RC12-376, 1162 cm. $\times 300$.
- Fig. 16. *Oolina hexagona* (WILLIAMSON), side view. RC12-377, 75 cm, $\times 300$.
- Figs. 17, 18. *Oolina striatopunctata* (PARKER & JONES), side views of adult and young forms, $\times 200$ and $\times 300$, respectively. V32-153, 2 cm.
- Figs. 19, 20. *Oolina globosa* (MONTAGU), apertural and side views, respectively. RC12-378, 190 cm, $\times 300$.

- Figs. 21, 22. *Fissurina cucurbitasema* LOEBLICH & TAPPAN, side and apertural views, respectively. RC12-378, 444 cm, $\times 300$.
- Figs. 23–26. *Fissurina echigoensis* ASANO & INOMATA. 23, 24: side and aboral base views of adult; 25, 26: side and apertural views of a young form, respectively. RC12-378, 44 cm, $\times 350$.
- Figs. 27, 28. *Fissurina lagenoides* (WILLIAMSON), side and apertural views, respectively. V28-265, 20 cm, $\times 250$.
- Figs. 29, 30. *Fissurina lagenoides tenuistriata* (BRADY), side and apertural views, respectively. V28-265, 20 cm, $\times 250$.

Plate 3

- Figs. 1, 2. *Fissurina lucida* (WILLIAMSON), apertural and side views. V28-265, 50 cm, $\times 200$.
- Figs. 3, 4. *Fissurina marginata* (MONTAGU), apertural and side views, respectively. V32-153, 460 cm, $\times 300$.
- Figs. 5, 6. *Fissurina marginata* (MONTAGU), var. α , apertural and side views, respectively. V28-265, 90 cm, $\times 250$.
- Figs. 7, 8. *Fissurina marginata* (MONTAGU), var. β , apertural and side views, respectively. V28-265, 30 cm, $\times 200$.
- Figs. 9, 10. *Fissurina semimarginata* (REUSS), apertural and side views, respectively. V28-265, 80 cm, $\times 250$.
- Figs. 11, 12. *Fissurina* cf. *circulo-costa* ASANO, apertural and side views, respectively. V32-153, 120 cm, $\times 250$.
- Fig. 13. *Fissurina* aff. *trigono-ornata* (BRADY), side view. RC12-378, 249 cm, $\times 300$.
- Figs. 14, 15. *Fissurina* sp. A, side and apertural views, respectively. V28-265, 20 cm, $\times 300$.
- Fig. 16. *Fissurina* sp. B', side view. RC12-376, 315 cm, $\times 300$.
- Figs. 17, 18. *Fissurina* sp. B, apertural and side views, respectively. RC12-376, 315 cm, $\times 300$.
- Figs. 19, 20. *Parafissurina costata*, n. sp., top and oral side views, respectively. V32-153, 120 cm, $\times 300$.
- Figs. 21, 22. *Parafissurina curta* PARR, top and side, showing hooded aperture, views, respectively. RC12-390, 260 cm, $\times 300$.
- Figs. 23, 24. *Parafissurina felsinea* (FORNASINI), top and oral side views, respectively. V28-265, 90 cm, $\times 300$.
- Figs. 25, 26. *Parafissurina tectulostoma* LOEBLICH & TAPPAN, top and side, showing hooded aperture, views, respectively. V28-265, 30 cm, $\times 300$.

Plate 4

- Figs. 1, 2. *Bolivina decussata* BRADY, side views of broad and slender forms, $\times 250$ and $\times 240$, respectively. V32-153, 40 cm.
- Figs. 3, 4. "*Bolivina*" *bradyi* ASANO, top and side views, respectively. RC12-376, 151 cm, $\times 250$.
- Fig. 5. *Brizalina pacifica* (CUSHMAN & MCCULLOCH), side view. RC12-376, 11 cm, $\times 200$.
- Figs. 6, 7. *Bulimina tenuata* (CUSHMAN), side and top views, respectively. V32-153, 300 cm, $\times 200$.
- Figs. 8–10. *Bulimina aculeata* D'ORBIGNY, side views of normal and two highly spinose specimens, respectively. 8: from V32-153, 360 cm; 9, 10: from V32-153, 380 cm; all $\times 250$.
- Figs. 11–14. *Globobulimina auriculata* (BAILEY). 11, 12: top and side views of a young specimen, respectively, from V32-153, 340 cm; 13, 14: top and side views of an adult not yet showing a completely terminal aperture, from V32-153, 400 cm: all $\times 100$.

Figs. 15, 16. *Stainforthia complanata* (EGGER), side views of a specimen with somewhat shorter chambers than normal one $\times 200$ and of normal specimen $\times 250$, respectively. V28-265, 580 cm.

Figs. 17–19. *Stainforthia rotundata* (PARR). 17: oral side view of adult; 18, 19: oral side and opposite side views of a young form, respectively. V32-153, 400 cm, $\times 250$.

Fig. 20. *Stainforthia spinosa* (HERON-ALLEN & EARLAND), side view. V32-153, 300 cm, $\times 300$.

Figs. 21, 22. *Stainforthia* cf. *schreibersiana* (CZAJEK), side views. V32-153, 420 cm, $\times 250$.

Fig. 23. *Stainforthia* sp., side view. RC12-376, 151 cm, $\times 250$.

Plate 5

Figs. 1–3, 8, 9. *Uvigerina akitaensis* ASANO, side views. 1, 2: typical adult and young forms, from V32-153 cm, 340 cm, and RC12-376, 1547 cm, respectively; 3: a form with sharp longitudinal costae, from V32-153, 320 cm; 8: a form with costae becoming faint but with tubercles in later stage, from RC12-376, 1275 cm; 9: a form with trace of costae except for the early stage, V28-265, 90 cm; all $\times 100$.

Figs. 4–7. *Uvigerina akitaensis* ASANO, var., side views. RC12-376, 1547 cm, $\times 100$. 6: enlargement of part of Figure 5, showing development of tubercles, $\times 300$.

Figs. 10, 11. *Uvigerinella* sp., side and top views, respectively. V28-265, 900 cm, $\times 250$.

Figs. 12–15. *Trifarina ikebei* (HUSEZIMA & MARUHASI). 12, 13: top and side views of a young form, respectively; $\times 300$. 14, 15: top and side views of an adult, respectively, $\times 200$; both from V28-265, 80 cm.

Figs. 16–21. *Buccella inusitata* ANDERSON, spiral, apertural, and umbilical views of two specimens, respectively. V32-153, 520 cm, $\times 300$.

Plate 6

Figs. 1–3. *Epistominella levicula* RESIG, spiral, apertural and umbilical views, respectively. RC12-376, 315 cm, $\times 400$.

Figs. 4–6. *Epistominella naraensis* (KUWANO), spiral, apertural and umbilical views, respectively. V28-265, 20 cm, $\times 400$.

Figs. 7–15. *Epistominella pacifica* (CUSHMAN), showing wide variation in morphology, in particular, test-convexity and intercameral sutures. 7–9: spiral, apertural and umbilical views of a young form, respectively, $\times 200$, from V32-153, 420 cm; 10–12: spiral, apertural and umbilical views of an adult, respectively, $\times 150$, from RC12-376, 1743 cm; 13–15: spiral, umbilical and apertural views of a gerontic form, respectively, from V32-153, 420 cm, $\times 100$.

Figs. 16–18. *Valvulineria glabra* CUSHMAN, spiral, apertural-side and umbilical views, respectively. V32-153, 380 cm, $\times 250$.

Figs. 19–21. *Valvulineria* sp. B, umbilical, apertural-side and spiral views, respectively. V32-153, 460 cm, $\times 400$.

Plate 7

Figs. 1–6. *Valvulineria sadonica* ASANO. 1–3: umbilical, apertural-side and spiral views of a gerontic form resembling *Valvulineria mexicana* PARKER, respectively, from V32-153, 300 cm, $\times 150$; 4–6: spiral, apertural-side and umbilical views of typical *V. sadonica*, respectively, from V28-265, 80 cm, $\times 250$.

Figs. 7, 8. *Cribrononion clavatum* (CUSHMAN), apertural and side views, respectively. V28-265, 260 cm, $\times 250$.

Figs. 9, 10. *Cribrononion* sp. A, side and apertural views, respectively. V28-265, 260 cm, $\times 300$.

Figs. 11, 12. *Hyalinea balthica* (SCHROETER), apertural and side views, respectively. RC12-376,

315 cm, $\times 400$.

Figs. 13–18. "*Cibicides asanoi* MATSUNAGA". 13–15: spiral, apertural and umbilical views of a large adult form, respectively; 16–18: spiral, apertural, and umbilical views of a juvenile, respectively. V28-265, 0 cm; both $\times 150$.

Plate 8

Figs. 1–3. "*Cibicides asanoi* MATSUNAGA", umbilical, apertural and spiral views, respectively. V28-265, 0 cm, $\times 150$.

Figs. 4, 5. *Cassidulina neocarinata* THALMANN, side and apertural views, $\times 300$ and $\times 320$, respectively. V32-153, 40 cm.

Figs. 6–9. *Cassidulina norcrossi* CUSHMAN. 6, 7: apertural and side views of a distinctly keeled specimen, respectively; 8, 9: side and apertural views of a less keeled specimen, respectively. RC12-376, 1547 cm, $\times 150$.

Figs. 10–17. *Islandiella californica* CUSHMAN & HUGHES. 10, 11: side and apertural views of a large typical specimen, respectively, from V28-265, 0 cm, $\times 70$; 12, 13: apertural and side views of a moderate-sized specimen, respectively, from V28-265, 80 cm, $\times 100$; 14, 15: apertural and side views of a young form, respectively, from V28-265, 0 cm, $\times 150$; 16, 17: side and apertural views of a *japonica*-type specimen, respectively, from RC12-376, 784 cm, $\times 100$.

Figs. 18, 19. *Islandiella islandica* (NØRVANG), side and apertural views of a young specimen, respectively. RC12-376, 1323 cm, $\times 250$.

Plate 9

Figs. 1, 2. *Islandiella islandica* (NØRVANG), apertural and side views of an adult, respectively. V28-265, 0 cm, $\times 150$.

Figs. 3–6. *Islandiella norvangi* (THALMANN). 3, 4: side and apertural views of an adult, respectively, $\times 150$; 5, 6: apertural and side views of a young form, respectively $\times 250$; both from RC12-376, 1162 cm.

Figs. 7, 8. *Islandiella subglobosa* (BRADY), side and apertural views, respectively. RC12-378, 793 cm, $\times 300$.

Fig. 9. *Cassidulinoides tenuis* PHLEGER & PARKER, side view. RC12-377, 613 cm, $\times 300$.

Figs. 10, 11. *Astrononion hamadaense* ASANO, side and apertural views. V28-265, 30 cm, $\times 250$.

Figs. 12–15. *Chilostomellina fimbriata* CUSHMAN. 12: apertural view of a broken adult; 13–15: spiral, apertural and umbilical views of a young form resembling *Nonionella*, respectively. V32-153, 440 cm, $\times 250$.

Plate 10

Figs. 1–3. *Pseudononion auriculum* (HERON-ALLEN & EARLAND), spiral, apertural and umbilical views. V32-153, 440 cm, $\times 200$.

Figs. 4–8. *Pseudononion labradoricum* (DAWSON). 4, 5: apertural and spiral views of an adult showing rather bilaterally symmetrical test, $\times 150$ and $\times 200$, respectively; 6–7: spiral, apertural and umbilical views of a young form showing rather trochospiral test, $\times 400$; both from RC12-376, 11 cm.

Figs. 9, 10. *Pullenia apertura* CUSHMAN, apertural and side views, respectively. V28-265, 74 cm, $\times 250$.

Figs. 11, 12. *Pullenia salisburyi* R. E. & K. C. STEWART, spiral and side views, $\times 250$ and $\times 300$, respectively. V32-153, 60 cm.

Figs. 13–15. Close-up of apertural areas of three specimens of *Epistominella levicula* RESTG. RC12-387, 100 cm, $\times 560$.

