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ECOLOGICAL ANALYSIS OF LIVING BENTHIC FORAMINIFERA IN SURFACE SEDIMENTS FROM THE SOUTH YATSUSHIRO KAI (SEA), SOUTHWEST KYUSHU, JAPAN

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ABSTRACT

Bottom sediments were collected from 74 stations in the South Yatsushiro Kai (Sea), Japan using gravity corer in March 1996. Aimed at clarifying the relation between living benthic foraminiferal assemblage and environmental conditions, the Q-mode cluster analysis was carried out based on the predominant species of living benthic foraminifera recognized at the topmost one centimeter of 73 core samples.

The results of this study show a trend of a large number of living benthic foraminifera is found in central part of the sea, on the other hand, a small number is seen in the northern and southern part. The study area is characterized by 469 species of living benthic foraminifera belonging to 114 genera.

In relation to the five divisions of the marine environment based on oceanographic data, mechanical analysis data and sedimentation rates, the foraminiferal assemblages in the South Yatsushiro Kai were grouped into five populations. Population I occupies the areas near the straits under the influence of strong tidal and bottom currents. Population II occupies the areas surrounding the straits (Gannoshiri Seto and Kurono Seto) influenced by water masses flowing through the straits. Population III occupies the areas of rather stagnant water masses in the northern and southern parts of the sea. Population IV occupies the areas located in the northeastern and southeastern parts of the sea, and influenced by river waters. Population V occupies the nearshore area located in the northeastern, and influenced by the water masses which flow southward from the North Yatsushiro Kai.

Key words: Benthic foraminifera, sediment, marine division, population

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INTRODUCTION

The study of recent benthic foraminifera in the seas surrounding the Japanese Islands was initiated by Brady (1884). Since Brady's work, many Japanese foramini-ferologists, mostly paleontologists, have devoted their attentions to the ecology and distribution of Recent foraminifera.

In Kyushu Island waters, ecological studies of the Recent benthic foraminifera have been made since the early 1950's; Shuto (1953, 1965), Asano (1956, 1958 and 1960), Kuwano (1956), Eto (1970), Aoshima (1978), Kameyama (1984), Oki (1986a, b, and 1989), and Kobayashi (1992). However, only one of them (Kobayashi, 1992) treated the Recent benthic foraminifera from the Yatsushiro Kai.

The main purpose of this study is to clarify the relationship between the distribution of living benthic foraminifera and environmental conditions based on oceanographic data, mechanical analysis data of surface bottom sediments and sedimentation rates in the South Yatsushiro Kai.

THE STUDY AREA

The area studied is restricted within the South Yatsushiro Kai, being of about 39 km long and about 14 km wide (Rifardi *et al,* 1998a). It is situated off the west coast of central Kyushu Island, Japan (Fig. 1) and is located between the lines of 32°08' 00"N to 32°23'00"N Lat. and between 130°12'00"E to 130°29'00"E Long. This area has five outlets through straits (Karajiro Seto, Gannoshiri Seto, Mefuki Seto, Ikara Seto and Kurono Seto) leading to the East China Sea. The Sashiki, Tsunagi, Minamata and Komenotsu Rivers flow into the eastern part of the area, and the Euchi and Noda Rivers flow into the southern part of the study area. The water depth of the study area is about 50 m in the western and 10 m in the eastern parts.

According to Hydrographic Department of Maritime Safety Agency (1978) *in* Rifardi *et al* (1998a), the velocity of the flood current coming into Yatsushiro Kai, reaches 1.1 knots in the Gannoshiri Seto, 0.8 knots in the Mefuki Seto, and 4.9 knots in the Kurono Seto. On the contrary, the velocity of the ebb current reaches 1.5 knots, 2.0 knots, and 4.8 knots at each straits respectively.

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MATERIAL AND METHODS

The topmost one centimeter of 73 core samples collected from 74 station in the South Yatsushiro Kai with depths from 14 to 54 m in March 1996 (Fig. 1). All bottom samples were collected by using gravity corer made by Hisanaga Co., Ltd, Kagoshima.

Living Benthic Foraminifera Analysis

The topmost one centimeter of 73 core samples, which is approximately 10 cc of wet sediments, was preserved in alcohol and stained with Rose Bengal for discriminating the living foraminifera. Each sample was washed through a 200-mesh (0.074 mm opening) sieve, and ovendried after removal of dye stuff (Rose Bengal).

Each of the dry sample was divided into two parts by a microsplitter. One part was used for the L/Tl study (Rifardi *et al*., 1998b) and the other is utilized for this study. All specimens of living benthic foraminifera contained in the samples were picked out and identified.

Cluster Analysis

Cluster analysis was carried out based on the predominant species which occur at each sample. The criteria used are the following: 1) to determine the total number of individual at each species; 2) to determine the average of the total number of individual on the whole sample (station); 3) to select the species having more than 10 individuals at each species; 4) to select the species at each sample (station) which occur more than 3% of the average of the total number of individual on the whole sample (station). One hundred and fourteen species were retained for the cluster analysis.

Based on the occurrences of these predominant species, a dendrogram was obtained through the "Q-mode cluster analysis that were made by average linkage method", Norusis (1993). The samples were grouped according to similarity indicated by the cosine similarity coefficient*.

*** Similarity (X, Y) = ($\leq Xi, Yi$) / ($\leq X\,2i$) ($\leq Y\,2i$)**

RESULTS

Number of Individuals

The numbers of individual living benthic foraminifera range from 17 to 838 in 10 cc of the surface sediments in South Yatsushiro Kai, and their distribution is shown in Figure 2.

In general, a large number of individuals, more than 200, is found at the stations in central part of South Yatsushiro

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Kai (Stn. 27, 28, 31, 32, 33, 36, 37, 38, 39, 41, 43, 44), and Station 11 in the southern part of the area. On the other hand, a small number of individuals, less than 100, are seen at the stations in the northern and southeastern parts.

Number of Species

Through the present study, 469 species of living benthic foraminifera belonging to 114 genera were collected from the 73 stations of the South Yatsushiro Kai. The distribution of the number of the species is shown in Figure 3.

In general, this distribution shows the same trend as that of the individual numbers of living benthic foraminifera. A large number of species, more than 50, is found at the stations in the central part of South Yatsushiro Kai (Stn. 27, 31, 32, 33, 35, 36, 37, 38, 39, 41, 43, 44, 49, 50), and Station 11, 15 and 25 in the southwestern part of the area. On the other hand, a small number of individuals, less than 30, is seen at the stations near the straits (Kurono Seto, Mefuki Seto, Gannoshiri Seto and Karajiro Seto), in the northern and southeastern parts of sea, and the central section (Stn. 17, 21 and 22) of the southern part of the study area.

Cluster Analysis and the Relationship between the Distribution of Clusters and Environmental Factors

Based on the frequency of 114 predominant species (Table 1) collected from the South Yatsushiro Kai, a cluster analysis was carried out. The samples collected from 73 stations can largely be classified by cluster analysis into nine clusters (I to IX) at the level of 0.4 similarity coefficient in a dendrogram (Fig. 4). Among the nine clusters, Cluster I is subdivided into three subclusters (a to c) at 0.53 level. Geographical distribution of these clusters is shown in Figure 5. The predominant species of each cluster and subcluster are shown in Table 2.

Cluster Ia, characterized by *Nonionoides grateloupi*, *Ammonia beccarii* forma A, *Bulimina denudata* and *Ammonia beccarii* forma B, is composed of 29 stations. 27 stations are mainly distributed in the belt-like areas extending from the northwest to southeast in the southern and northern parts, and two stations are located in the eastern part. Characteristics of bottom sediments (Rifardi *et al*, 1998a) in Cluster Ia are mainly fine to very fine sand-grained substrata (*Md*Ø : 2~4Ø). Three stations (Stn. 51, 52 and 56) located in the eastern part show coarse silt-grained substrata (*Md*: 4.2~4.3Ø), and one station

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(Stn. 65) in the northern part of the sea shows medium sand-grained substrata (*Md*Ø : 1.4Ø). Almost all of the stations in Cluster Ia are distributed in areas influenced by rather weak bottom currents.

Cluster Ib, characterized by *Ammonia beccarii* forma A, *Ammonia beccarii* forma B and *Trochammina japonica*, contains 12 stations. 10 stations are mainly distributed in the nearshore area along the coastline from Izumi City to Ashikita-cho, and two stations are located in the strait between Hino-shima and Goshonoura-jima Islands. Characteristics of bottom sediments in Cluster Ib are mainly very fine sand to coarse silt-grained substrata (*Md*Ø : 3~5Ø) and high mud contents (40~70%). Four stations (Stn. 3, 5, 8 and 66) located in the southeastern part and northern parts of the sea show rather low median diameter (*Md*Ø : 2~4Ø), and rather low mud contents ranging from 10~30%. The stations in Cluster Ib are distributed in the nearshore areas influenced by river waters.

Cluster Ic, characterized by *Discorbis mira*, *Ammonia beccarii* forma B, *Bolivina striatula* and *Nonionoides grateloupi*, consists of 16 stations. 13 stations are distributed in the belt-like area extending from northwest to southeast in the central part, and three stations are in the elongate area in the southwestern part. Characteristics of bottom sediments in Cluster Ic are mainly very fine-grained substrata (*Md*Ø : 2~4Ø). Core samples at Stations 15 and 35 located in the areas off Ikara Seto and near the Mefuki Seto could not be collected, so bottom characteristics may be sandy gravel or gravelly sand. Stations in this cluster are under the influence of strong tidal currents flowing through the Gannoshiri, Ikara and Kurono straits (Rifardi *et al*., 1998a).

Cluster II, characterized by *Elphidium somaense*, *Hopkinsina glabra* and *Ammonia beccarii* forma A, consists of four stations and is distributed in the northeastern part of the South Yatsushiro Kai. Characteristics of bottom sediments in Cluster II are very fine sand to coarse silt-grained substrata (*Md*Ø : 3.7~4.2Ø). Station 74 shows trimodal distribution of grain size with a peak of granules which were derived from the coastal area of Shiba-shima during storms. The sediments at the stations of Cluster II are assumed to be supplied by the ebb current flowing southward from the North Yatsushiro Kai (Rifardi *et al*., 1998a).

Cluster III, characterized by a few specimens, is shown only at Station 62 located in the central area of the northern part of the sea. Characteristics of bottom sediments in Cluster III are very fine sand-grained substrata (*Md*: 3.5Ø) and rather high mud content (42.9%).

Cluster IV, characterized by *Cibicides lobatulus*, is shown at Station 47 near Gannoshiri Seto and at station 68 in the

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Karajiro Seto.

Cluster V, characterized by a few specimens, is shown only at Station 70 located in the southeastern part of Hino-shima.

Cluster VI, characterized by a few specimens consists of two stations located in the area near Gannoshiri Seto.

Cluster VII, characterized by *Discorbis mira*, consists of four stations. Three are distributed in the area near Kurono Seto and one is in the area near Gannoshiri Seto.

Cluster VIII, characterized by a few specimens, is only recognized at Station 73 located in the northernmost part.

Cluster IX, characterized by a few specimens, is shown at Station 29 in the area near Mefuki Seto.

Clusters IV, VI, VII and IX are distributed in the areas near the straits where strong bottom currents flowing through the straits. Clusters V and VIII are located in the northernmost part of the sea. The bottom sediments of these areas are characterized by gravel or gravelly sand except for two stations (Stn. 2 and 7) of Cluster VII that show the fine sand-grained substrata (*Md*: 2.0~2.8Ø).

DISCUSSION

Distribution of the Number of Individual and Species

Large numbers of individuals and species of living benthic foraminifera in central part of the South Yatsushiro Kai (Figs. 2 and 3) are assumed to be related to the supply of plankton into this area by the tidal current systems. This area may correspond to the boundary between the water masses which enter into the South Yatsushiro Kai through the Gannoshiri Seto and the proper water masses in the South Yatsushiro Kai, and suspended matters accumulate on the sea bottom. This may be explained by the high contents of planktic foraminifera tests in the bottom sediments (Rifardi *et al,* 1998a). It can be concluded that the environmental situation of the central part of the sea is suitable for living benthic foraminifera. The areas (Stn. 11 and 15) off the Ikara Seto and off the Mefuki Seto (Stn. 25) are also under a similar environmental situation.

A small number of individuals (less than 100) and species (less than 30) can be seen in the northern part, southeastern parts and the areas near the straits. These areas are assumed to be under the environmental conditions, namely, one is influenced by low salinity water masses which are in the North Yatsushiro Kai and nearshore areas in the former areas, and the other is influenced by strong bottom currents in the latter areas. The environmental situation of these areas is not so suitable for living benthic

foraminifera.

Recognition of the Foraminiferal Populations and their Distribution in Relation to Environmental Factors

In relation to the five divisions of the marine environment based on oceanographic data, mechanical analysis data of bottom sediments and sedimentation rates (Rifardi *et al*., 1998a), the foraminiferal assemblages in the South Yatsushiro Kai were grouped into five populations as follows: 1) *Cibicides lobatulus, Discorbis mira* (Clusters IV to IX); 2) *Discorbis mira*, *Ammonia beccarii* forma B, *Bolivina striatula*, *Nonionoides grateloupi*, *Bulimina denudata*, *Pseudorotalia gaimardii*, *Hanzawaia nipponica, Hopkinsina glabra, Cibicides lobatulus, Cibicidoides pseudoungerianus*, *Discorbis* sp A, *Fissurina cucurbitasema* (Cluster Ic); 3) *Nonionoides grateloupi*, *Ammonia beccarii* forma A, *Bulimina denudata*, *Ammonia beccarii* forma B, *Elphidium advenum*, *Bolivina striatula*, *Pseudorotalia gaimardii*, *Hopkinsina glabra* (Cluster Ia); 4) *Ammonia beccarii* forma A, *Ammonia beccarii* forma B (Clusters Ib and III); and 5) *Elphidium samoense*, *Hopkinsina glabra*, *Ammonia beccarii* forma A (Cluster II).

***Cibicides Lobatulus*, *Discorbis Mira* (Clusters IV to IX)**

This population is found in the areas near the straits (Karajiro Seto, Gannoshiri Seto, Mefuki Seto and Kurono Seto) and off the east coast of Hino-shima. These areas are influenced by strong bottom currents. Living benthic foraminifera in these areas contain small numbers of individuals and species as shown in Figures 2 and 3.

Cibicides lobatulus is well known among the attached forms of benthic foraminifera (Murray, 1973). Kitazato (1994) cultured some benthic foraminifera in the laboratory and reported that *Cibicides lobatulus* attached to a polychaete tube; therefore, this species can adapt and survive in the such high energy areas. *Discorbis mira* is very common in Kagoshima Bay with depth ranging from 28 to 213 m (Oki, 1989). The empty tests of this species are reported from shallow and/or coastal areas in Tokyo Bay (Mori-shima, 1955), Tanabe Bay (Chiji and Lopez, 1968) and Yoron Island (Eto, 1970). This information is consistent with the environmental condition of this population.

***Discorbis mira*, *Ammonia beccarii* forma B, *Bolivina striatula*, *Nonionoides gra-teloupi*, *Bulimina denudata*, *Pseudoro-talia gaimardii*, *Hanzawaia nipponica*, *Hopkinsina glabra*, *Cibicides lobatulus*, *Cibicidoides pseudoungerianus*, *Discor-bis* sp A, *Fissurina cucurbitasema* (Cluster Ic)**

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This population, characterized by the occurrence of many predominant species, is found in the areas under the influence of strong tidal currents flowing through the Gannoshiri Seto, Ikara Seto and Kurono Seto above mentioned. A large number of individuals (Fig. 2) and species (Fig. 3) of living benthic foraminifera suggests that plankton is accumulated in the areas by the tidal current systems. This may be explained by the high contents of planktic foraminifera in the bottom sediment. Therefore, these areas are characterized by the occurrence of many predominant species of living benthic foraminifera.

***Nonionoides grateloupi*, *Ammonia beccarii* forma A, *Bulimina denudata*, *Ammonia beccarii* forma B, *Elphidium advenum*, *Bolivina striatula*, *Pseudorotalia gaimardii*, *Hopkinsina glabra* (Cluster Ia)**

This population occupies the northern and southern parts of the South Yatsushiro Kai which are under the influence of relatively stagnant water masses. These predominant species except for *Ammonia beccarii* forma A and *Elphidium advenum* can also be found in Cluster Ic. This fact maybe suggests that the areas of Cluster Ia are more or less affected by the water masses flowing through the straits. But *Ammonia beccarii* forma A is known from the nearshore or inner bay areas, and *Elphidium advenum* can be found in shallow coastal areas of less than 100 in depth. Therefore, the areas in which this population is distributed, are scarcely influenced by open sea water.

***Ammonia beccarii* forma A, *Ammonia beccarii* forma B (Clusters Ib and III)**

This population is found in the nearshore area along the coast from Izumi City to Ashikita-cho. In general, the group of *Ammonia beccarii* is known as an index species of brackish and nearshore water masses and is found in lagoons and inner shelf (Murray, 1973). Matoba (1970) reported that the distribution of *Ammonia beccarii* forma A, synonymous with forma 1, seems to be related to the inflow of sewage and river water in Matsushima Bay. This species mainly occurs in the shallow coastal area in Kagoshima Bay (Oki, 1989). Kitazato (1994) reported that *Ammonia beccarii* is a deep infaunal species and can be found both near the surface and deep within the sediment, and the abundance of *Ammonia beccarii* in the nearshore area, might also be related to their life position with respect to the sediment-water interface.

Abundance of *Ammonia beccarii* forma A and *Ammonia beccarii* forma B in this area (Clusters Ib and III) might be under the influence of river water.

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***Elphidium somaense*, *Hopkinsina glabra*, *Ammonia beccarii* forma A (Cluster II)**

This population is only found in the northeastern part of the South Yatsushiro Kai. *Elphidium somaense* is found in shallow bottom sediments off Sendai (Matoba, 1976), in Matsukawa-ura (Takayanagi, 1955), in Matsushima Bay (Matoba, 1970), and in Hiroshima Bay (Kato, 1986). Living specimens are reported from Matsushima Bay with depth ranging from 1.5 to 8.7 m (Matoba, 1970). *Hopkinsina glabra* is also reported from the nearshore and bay areas mentioned above. This population seems to be nearshore fauna, and to be found in the rather low salinity water mass. The northeastern part of the sea is influenced by the water masses which flow southward as the ebb current from the North Yatsushiro Kai. As already reported in Rifardi *et al*., (1998a), the North Yatsushiro Kai has a rather flat bottom topography less than 30 m deep and is occupied by low-salinity water masses due to fresh water influence from the Kuma River with a large drainage area.

CONCLUSION

1. In the South Yatsushiro Kai, the distribution of living benthic foraminifera except for the areas near straits, don't harmonize to the distribution patterns of the bottom sediments. Some populations of benthic foraminifera based on Q-mode cluster analysis, were distributed over the different substrata.
2. In relation to the five divisions of the marine environment based on oceanographic data, mechanical analysis data of bottom sediments and sedimentation rates, the foraminiferal assemblages in the South Yatsushiro Kai were grouped into the following five populations: 1) *Cibicides lobatulus*, *Discorbis mira* (Clusters IV to IX). Areas near the straits influenced by strong tidal and bottom currents; 2) *Discorbis mira*, *Ammonia beccarii* forma B, *Bolivina striatula*, *Nonionoides grateloupi*, *Bulimina denudata*, *Pseudorotalia gaimardii*, *Hanzawaia nipponica*, *Hopkinsina glabra*, *Cibicides lobatulus*, *Cibicidoides pseudoungerianus*, *Discorbis* sp A, *Fissurina cucurbitasema* (Cluster Ic).Areas surrounding the straits (Gannoshiri Seto and Kurono Seto) influenced by the water masses flowing through the straits; 3) *Nonionoides grateloupi*, *Ammonia beccarii* forma A, *Bulimina denudata*, *Ammonia beccarii* forma B, *Elphidium advenum*, *Bolivina striatula*, *Pseudorotalia gaimardii*, *Hopkinsina glabra* (Cluster Ia). Areas occupied by rather stagnant water masses in the northern and southern parts of the

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sea; 4) *Ammonia beccarii* forma A, *Ammonia beccarii* forma B (Clusters Ib and III). Nearshore areas located in the northeastern and southeastern parts of the sea, and influenced by river waters; 5) *Elphidium somaense*, *Hopkinsina glabra*, *Ammonia beccarii* forma A (Cluster II). Nearshore area located in the northeastern part of the sea, and influenced by the water masses which flow southward from the North Yatsushiro Kai.

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REFERENCES

Aoshima, M., 1978: Depositional environment of the Plio-Pleitocene Kakegawa Group, Japan: A comparative study of the fossil and the Recent foraminifera. *Jour. Fac. Sci., Univ. Tokyo*, **12** (5):401-441.

Asano, K., 1956: The foraminifera from the adjacent seas of Japan, collected by the S. S. Soyomaru, 1922-1930, Pt. 5, Nonionodae. *Tohoku. Univ., Sci. Rep., 2th ser. (Geol.)*, 27: 1-55.

Asano, K., 1958: The foraminifera from the adjacent seas of Japan, collected by the S. S. Soyomaru, 1922-1930, Pt. 5, Nonionodae. *Ibid*., **29**: 1-41

Asano, K., 1960: The foraminifera from the adjacent seas of Japan, collected by the S. S. Soyomaru, 1922-1930, Pt. 5, Nonionodae. *Ibid*., Spec. Vol., **4**: 189-201.

Brady, H.B., 1884: Report on the foraminifera dredged by H.M.S. *Challenger*, during the Year 1873-1876. The Voyage of H.M.S. Challenger, Zoology, **9**, 1-814.

Chiji, M. and Lopez, S.M., 1968: Regional foraminiferal assemblages in

ISSN: 1410-5217
Accredited: 69/Dikti/Kep/2000

Tanabe Vay. Kii Peninsula, central Japan. *Seto Mar. Biol. Lab., Publ*., **16** (2), 85-125.

Eto, T., 1970: Statistical study of the dimorphism of Recent Calcarina spengleri (Gmelin) and foraminiferal assemblages in the "Foraminiferal Sand" of Yoron and Okino-Erabu Islands. *Yokohama Nat. Univ., Sci. Rep*., *sec*. **2**(6): 81-92.

Hydrographic Department, Maritime safety Agency, 1978: *Charts of tidal currents in Simabara Wan and Yatsushiro Kai* (in Japanese). No. 6217, Maritime Safety Agency, Tokyo, Japan.

Kameyama, T., 1984: Relationship between benthic foraminifera assemblages and the sediment character. *Earth Sci*., **38** (2), 102-112.

Kato, M., 1986: Recent shallow water foraminifera in Hiroshima Bay, Seto Inland Sea, Japan (in Japanese). *In* Matoba, Y. and Kato, M. eds., "Studies on Cenozoic Benthic Foraminifera in Japan", Mining Coll., Akita Univ., p. 27-41, 36 text-figs.

Kitazato, H., 1994: Foraminiferal microhabitats in four marine environments around Japan. *Mar. Micropaleontol*., **24**, 29-41

Kobayashi, M., 1992: Preliminary result on the distribution pattern of benthic foraminifera, in the Yatsushiro-kai, Western Kyushu, Japan. *Kumamoto Jour. Sci. Geol*., **13** (2), 13-24.

Matoba, Y., 1970: Distribution of shallow water foraminifera of Matsushima Bay, Miyagi Prefecture, northeast Japan. *Ibid*., **42** (1), 1-85.

Morishima, M., 1955: Deposits of foraminiferal tests in the Tokyo Bay, Japan. *Univ. Kyoto Coll. Sci., Mem*., *ser. B*, **22** (2): 213-222.

Murray, J. W., 1973: *Distribution and ecology of living benthic foraminiferids*. *Ibid*., Heinemann Educational Books 274p.

Norusis, M.J., 1993: *SPSS for UNIX, professional statistics release 5.0.* SPSS Inc. 345 pp.

Oki, K., 1986a: Preliminary report on living population of benthic foraminifera in Kagoshima Bay, South Kyushu Japan (in Japanese). *In* Matoba, Y. and Kato, M. *ed*., 1986: Studies on Cenozoic benthic foraminifera in Japan, Mining

ISSN: 1410-5217
Accredited: 69/Dikti/Kep/2000

College, Akita Univ., 13-26.

Oki, K., 1986b: Rate of sedimentation estimated by L/Tl of benthonic foraminifera (in Japanese). *Marine Sci. Montly*, 1*8* (9): 588-592.

Oki, K., 1989: Ecological analysis of benthonic foraminifera in Kagashima Bay, South Kyushu, Japan. *South Pacific Study*, **10** (1) : 1-191.

Rifardi., Oki, K. and Tomiyasu, T., 1998a: Sedimentary environments based on textures of surface sediments and sedimentation rates in the South Yatsushiro Kai (Sea), southwest Kyushu, Japan. *J. Sed. Soc. Japan*., **48**, 67-84.

Rifardi and Oki, K., 1998b: Relative sedimentation rates and taphonomy inferred from the L/Tl values of benthic foraminifers in the southern Yatsushiro Kai (Sea), southwest Kyushu, Japan (in Japanese with English abstract). *Fossils*, **65**, 10-30.

Shuto, T., 1953: A study on the continental foraminiferal assemblage of Omura Bay, Nagasaki Prefecture, Kyushu. Japan. *Jour. Geol. Geogr*., **23**, 127-138.

Shuto, T., 1965: Benthonic foraminifera, *in* Mistushio, H., Bottom sediments off Tsuyasaki, northeast of Fukuoka City (in Japanese). Kyushu Univ., Sci. Rept., Geol., 8 (2): 124-129.