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GEOLOGICAL STUDY ON KAGOSHIMA BAY, SOUTH KYUSHU, JAPAN. PART IV – A NOTE ON THE PECULIAR MODE OF OCCURRENCE OF FORAMINIFERS IN THE BOTTOM SEDIMENTS OF THE BAY-HEAD AREA

By

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Introduction and Acknowledgements

In the bay-head area of Kagoshima Bay, where the writers have studied bottom sediments and topography (HAYASAKA *et al.*, 1976), a joint project, which sought to explain a possible relationship between submarine fumarolic activity and mercury concentrations in fish living in the area, has been completed (OSSAKA *et al.*, 1976; KAMADA *et al.*, 1977). During the course of the project, the writers as participating members, further expanded their studies of bottom conditions in the bay-head area including the areas of fumarolic activity.

In earlier work in the bay-head area, the senior writer has been engaged in bottom sampling for Foraminifera (1972, 1975)** and noted a peculair mode of occurrence of foraminifers involving both living specimens and vacated tests. The data from the joint project, coupled with that from the foraminiferal study, suggest that the peculair mode of occurrence recognzied is closely related to submarine fumarolic activity. The purpose of this paper is to describe the mode of occurrence of foraminifers in the bay-head area and to discuss how fumarolic activity is presumed to control it.

The writers express their hearty thanks to Professor Yokichi TAKAYANAGI of the Tohoku University for his suggestions and aid in identifying the species of this fauna. Appreciation is due to Professor Masaakira KAMADA of the Kagoshima University and to Professor Joyo OSSAKA of the Tokyo Institute of Technology, for their continuous encouragement. Thanks are also due to Professor Tomio HENMI, captain of Keiten-maru, Faculty of Fishery, Kagoshima University, for his constructive advice and help

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** Samples from the St. 2, 6, 7, 8, 9 and 12 were collected by Keiten-maru of the Kagoshima University on Jan. 18–26, 1972, and those from the St. 1, 3, 4, 5, 10 and 11 by Satsunan-maru of the Kagoshima Prefectural Government on Oct. 25–27, 1975.

in the field work, and to Professor Frank H. Kilmer of the Humboldt State University, for critical reading the manuscript.

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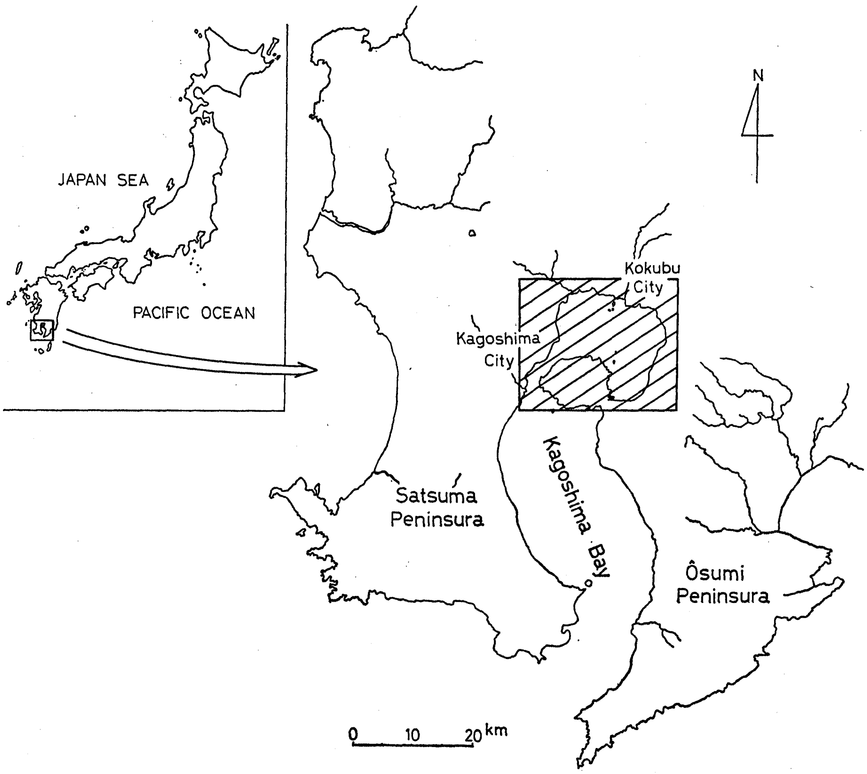


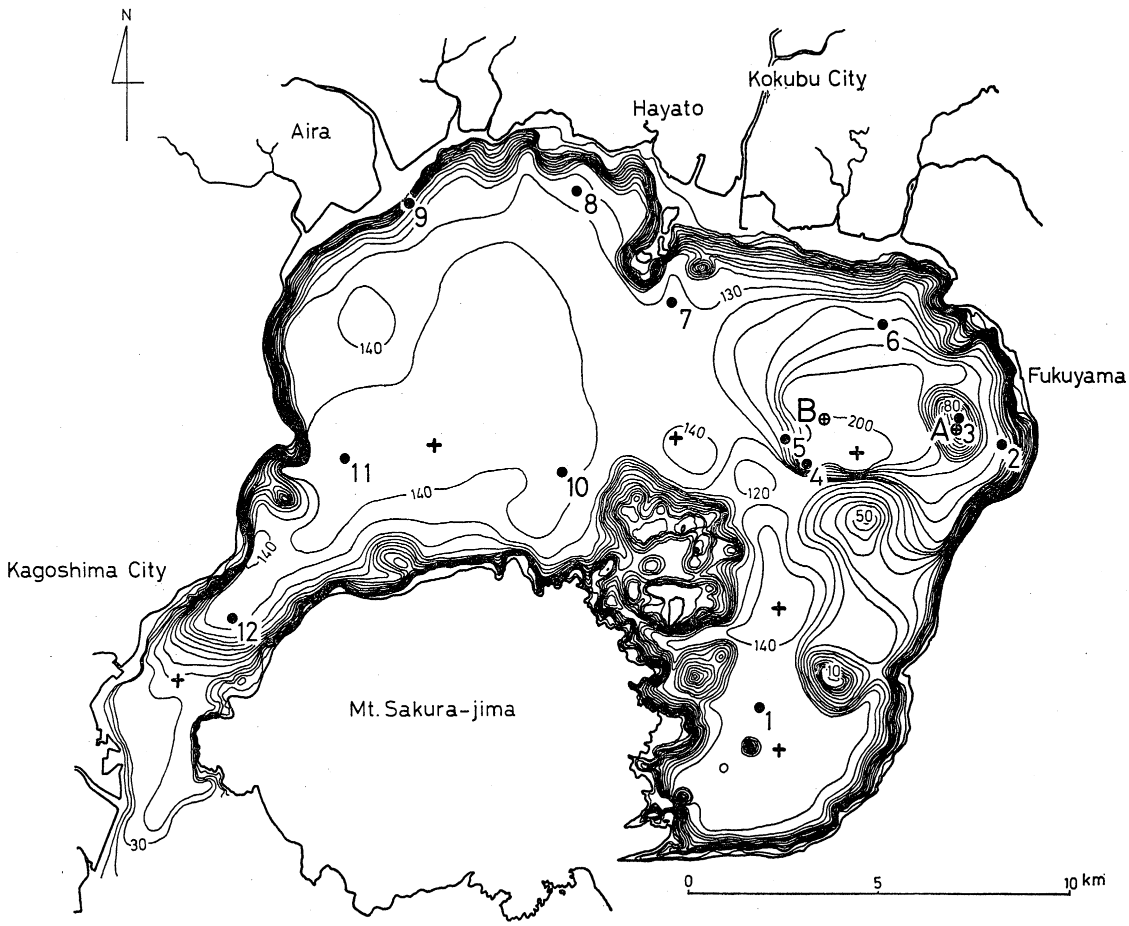
Text-fig. 1. Index map of the area studied.

General Features of the Studied Area

The bay-head area, about 20 km wide and about 18 km long, has an enclosed outline and is connected to the central part of the Kagoshima Bay by only a narrow (3 km) and shallow (30 m deep) strait west of Mt. Sakurajima.

As already reported by the writers (Hayasaka *et al.*, 1976), the bottom topography of the area may be roughly divided into two parts - a western half showing a rather flat to gently undulating topography (140 m in average depth) and an eastern half having a rather rugged topography composed of the deepest basin in the bay-head area (207 m) and a few volcanic cones with summits less than 100 m in depth. It is in the eastern half of the bay-head area that the fumaroles are known to occur. The bottom sediments of this area are characterized by the predominance of mud (50–70%) and most samples analized mechanically plotted between silty clay and silty sand.

According to Takahashi *et al.*, (1977), tidal currents in the water mass of this area are observed to be extremely slow or below 1.2 cm per second in velocity. He stated (Takahashi, 1978) that, "in summer, the water existing at the depth greater than that of the shallow strait west of Mt. Sakurajima is almost stagnant and forms several layers".



Text-fig. 2. Bathymetric contour map (in meter) of the bay-head area of Kagoshima Bay, showing the sampling stations of the writers (●) and of KUWANO (1962) (+) and the areas of submarine fumaroles (⊕).

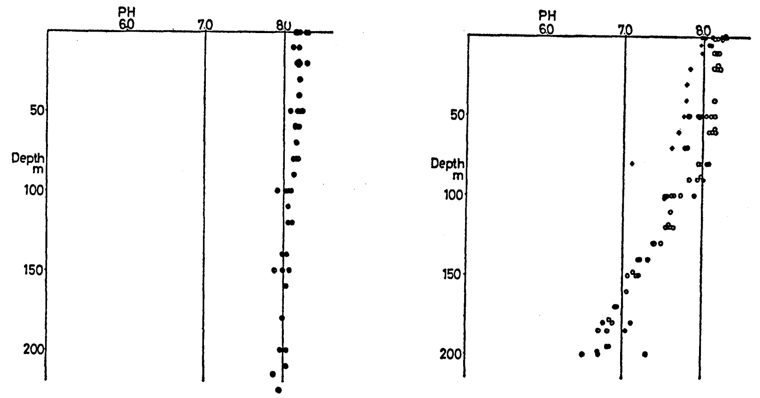
The vertical distribution of water temperature in this area is summarized as follows (KUWANO, 1962; OZAWA *et al.*, 1976; KAMADA *et al.*, 1976, 1977). From the view-point of the vertical distribution of water temperature, three layers are discriminated. In the layer from the surface to 50 m in depth, the temperature distribution is almost homogeneous in each season, about 19°C in winter and about 30°C in summer. In the deepest part ranging from 100 m to the bottom, the water temperature seems to be very stable through the year and the difference between winter and summer water temperatures is less than 3°C. The water layer ranging from 50 m to 100 m in depth is regarded to be the transitional zone between the foregoing two stable layers.

Salinity of sea water in this area is also stable – 34‰ through the year - in the water mass occupying the deepest part below 100 m in depth. The water between 25 and 100 m in depth represents a slight seasonal change of salinity within 33–34‰. Salinity of the water shallower than 25 m is about 34‰ in winter, about 32‰ in spring and autumn, and sometimes falls down to 25‰ in summer (KUWANO, 1962; HIGO *et al.*, 1974).

According to Kamada *et al.* (1977), the dissolved oxygen content shows a striking seasonal change in this area. In winter, the circulating stage, D.O. content becomes quite uniform with the value of $4^{cc}/l$, while in the season from spring to autumn, the layering stage, it rapidly falls down to below $1^{cc}/l$ as the depth increases.

Through the continuous observations of pH of sea water in this area, Kamada *et al.* (1976, 1977) and Kagoshima Prefectural Government (1978) have recognized an important fact that the pH value of water deeper than 100 m is abnormally low except for those in the coldest period in winter. According to them the pH value of the water in the deepest part (about 200 m), where the fumarolic activities have been known to occur, falls down to around 7, and sometimes in summer and autumn it goes down to 6.5. At another area of fumarolic activities, where is only about 100 m in depth, the pH value is recorded to be 6.4. The lowest value was recognzied at the area close to the fumaroles to be 5.15–6.90.

As judged from the above-mentioned distribution of pH value, the abnormal lowering of pH seems to have a close relationship to the occurrence of gases derived from submarine fumaroles in this area.



Text-fig. 3. Graph showing the relations between pH-value and depth of water at the central (left) and the bay-head (right) areas in the stage of sea-water layering, from spring through autumn (after Kamada *et al.*, 1977).

Bubbles coming up from the sea bottom off Fukuyama in the bay-head area of Kagoshima Bay were noticed and reported, for the first time, by Kamada (1961) but did not receive much attention until recently. Through the aforementioned project, details of this phenomenon have now been made clear (Ossaka *et al.*, 1976). The occurrences of submarine fumaroles have been known at the two isolated areas within the eastern half of the bay-head area. One of them (St. A) is situated at about 100 m deep portion of the southeastern slope of the bank* which is assumed to be a volcanic cone rising up to the depth of about 70 m from about 200 m deep sea bottom. The other one is at the northwestern part (St. B) of the deepest basin,** of which bottom surface

* Topographic province IIIC in the fig. 2 of Hayasaka *et al.* (1976).
** IIIA in the fig. 2 of Hayasaka *et al.* (1976).

is rather flat and about 200 m in depth (Text-fig. 2).

According to a study by the Kagoshima Prefectural Government (1978), the principal ingredient of gases collected directly from fumaroles by means of a submarine is carbon dioxide, which has been measured to be 75–80% at station A and 87–93% at station B. However, carbon dioxide has never been detected from gases collected from bubbles at the sea surface above the fumaroles. This may imply the perfect dissolving of carbon dioxide in sea water on the way from the fumaroles at the bottom to the sea surface. This explanation is supported by the fact that the total carbonate content of water samples collected from the vicinity of fumaroles ranges from 378 to 438 mg/l, and, as mentioned above, the values of pH of the same water samples range from 5.15 to 6.90, which are abnormally low compared with the pH value of surface waters. Further support comes through the experiment to blow carbonic acid gas into surface water samples collected from the bay by KAMADA (1977) who ascertained an inverse relation between the pH value and the total carbonate content.

Such being the case, the appearance of abnormally acidic sea water mass in the bay-head area could reasonably be attributed to gases rising from the fumaroles.

Mode of Occurrence of Foraminifers

The bottom sediment samples on which the foraminiferal assemblages were studied are generally with high mud content. Ten samples among the 12 were recognized to have the mud content of 60% or more. Two samples (St. 3 and 12) indicate rather low mud content: the samples from the St. 3, which is quite close to one of the fumarole areas (St. A) on the slope of a volcanic cone, have the mud content less than 10%, and those from the St. 12 situated at the strait west of Mt. Sakurajima less than 1%.

The total number of individuals of benthonic foraminifers obtained from the 5 cc sample in each station are as follows.

Station	Total Number of Individuals (in round number)
5 10 12	1000
2 3 4 8 9 11	Less than 600
1 6 7	Less than 100

These numbers of individuals are regarded to be rather small in comparison with the total numbers of individuals attaining to 9000–90000 for the unit sample taken from nearly the same depth in the central part of Kagoshima Bay.

The ratios of the number of living individuals to the total number of individuals in each station are as follows.

Station	Ratio	Remarks
1 2 5 6 7 8 11	4-8%	Regardless of water depth or of bottom sediment character
3 4	1.4%	Close to the fumaroles
10	1%	Situated at the north of Mt. Sakurajima
9	0%	Close to river-mouth

It may be mentioned incidentally that this kind of ratios recognized in the samples from about 200 m deep bottom of the central part of the bay are 2.1 to 3.8%, and those from about 100 m deep bottom 4.5 to 10% respectively.

As seen in table 2, the predominant species of the living foraminifers treated here are as follows.

Cribrostomoides kosterensis (HÖGLUND)
Textularia bigenerinoides LACROIX
T. wiesneri EARLAND
Trochammina charlottensis CUSHMAN
T. pacifica CUSHMAN
Eggerella scabra (WILLIAMSON)

These species, which also predominate in assemblages of dead specimens, can be regarded as the representative species characterizing the bay-head area of Kagoshima Bay.

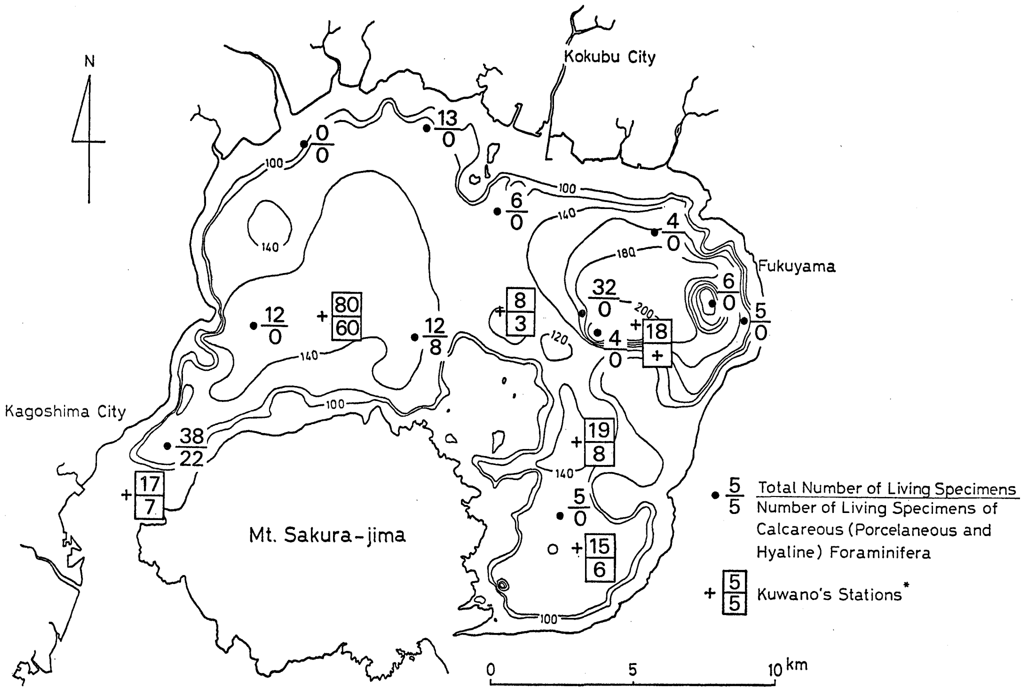
In table 2 and text-fig. 4, which show the numbers of living foraminifers in each station, it is noticeable that all the specimens of the living benthonic foraminifers are represented by the species having the agglutinated test, or in other words, the species provided with the calcareous (porcelaneous and hyaline) test are entirely absent. With regard to this problem, the previous record by KUWANO (1962) on the foraminiferal assemblage sampled in 1958 from the bay-head area is most instructive (Text-fig. 4). According to him, the assemblage in the deepest part (200 m in depth) is represented by the arenaceous species with only one calcareous (hyaline) species, *Bulimina marginata*. It is noticeable, however, that considerable numbers of living species with the hyaline test were recorded to occur from the other five stations. In this connection, it may be

Table 1. Occurrence of the total and living benthonic foraminfers

Station Number	1		2		3		4		5		6		7		8		9		10		11		12	
Depth (m)	136		170		105		174		160		185		136		130		102		142		150		138	
Total (T: living and dead) and Living (L)	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L
Benthonic Population: in 5cc of surface sediment	86	5	123	5	437	6	265	4	884	36	84	4	87	6	157	13	132	0	1244	12	572	12	810	38
Benthonic Population: actually counted	86	5	123	5	437	6	265	4	221	9	84	4	87	6	157	13	132	0	286	3	143	3	405	19
AGGLUTINATED FORAMINIFERA																								
Hyperammina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–		–		–
Psammosphaera fusca Schulze var.	–	–	–	–	–	–	–	–	12	–	–	–	–	–	–	–	–	–	–	–		–		–
Saccammina difflugiformis arenulata (Skinner)	–	–	1	1	–	–	6	–	24	–	–	–	–	–	–	–	–	–	–	–		–		–
S. atlantica (Cushman)	–	–	–	–	77	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
S. pleurostomelloides (Millett)	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	2	–	–	–		–		–
S. sp. 1	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–						
S. sp. 2	–	–	–	–	2	–	–	–	–	–	2	–	1	–	–	–	–	–	–	–		–		–
S. sp. 3	–	–	–	–	27	–	–	–	4	–	4	–	12	–	5	–	1	–	–	–		–		2
S.? sp. 4	–	–	–	–	–	–	–	–	8	4	–	–	8	–	1	–	–	–	4	–		–		–
S.? sp. 5	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
S. sp. 6	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–		–		–
S. sp. 7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–		–		–
Ammodiscus arenaceus (Williamson)	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
A. minimus Hoglund	–	–	2	–	8	–	2	–	40	–	1	–	–	–	–	–	–	–	16	–		–		–
Glomospira gordialis (Jones and Parker)	–	–	6	–	4	–	6	–	8	–	2	–	–	–	–	–	–	–	16	–		–		–
G. sp. 1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
G. sp. 2	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
G. sp. 3	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
G.? sp. 4	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
Turritellella sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Reophax cf. *catella* Hoglund	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
R. catenata Hoglund	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–		–		–
R. delicatus Hada	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	4		–		–
R. gracilis (Kiaer)	–	–	1	–	–	–	3	–	–	–	1	–	–	–	–	–	–	–	4	–		–		–
R. obliquus Hada	–	–	–	–	1	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
R. cf. *scorpiurus* Montfort	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–		–		–
R. scottii Chaster	2	1	1	1	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–		–		–
R. nana Rhumbler	6	3	3	–	1	–	5	–	36	–	–	–	–	–	–	–	–	–	48	–		–		–
R. sp. 1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
R.? sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12	–		–		–
Nouria sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–		–		–
Cribrostomoides kosterensis (Hoglund)	–	–	7	–	25	–	14	–	44	4	6	–	–	–	4	1	–	–	20	–		–		–
C. sp. 1	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
C. sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–		–		–
C. sp. 3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
C. sp. 4	–	–	4	–	6	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–		–		–
Recurvoides bosoensis Kuwano	–	–	–	–	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
Reticulophragmium aff. *gouldi* (Warthin)	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
Ammobaculites catenulatus Cushman and McCulloch	–	–	–	–	3	–	–	–	4	–	–	–	1	–	1	–	–	–	4	–		–		–
Textularia bigenerinoides Lacroix	7	–	11	1	29	5	10	–	68	4	20	–	6	–	5	–	31	–	32	–		–		4
T. bigenerinoides Lacroix var.	–	–	–	–	–	–	–	–	4	–	1	–	–	–	–	–	–	–	–	–		–		–
T. gracillima Hoglund	2	–	28	–	–	–	–	–	–	–	–	–	–	–	–	–	18	–	292	–		–		–
T. wiesneri Earland	18	–	9	–	70	–	169	3	84	12	16	–	–	–	7	–	3	–	–	–		–		2
T. sp. 1	–	–	–	–	1	–	–	–	–	–	–	–	4	–	18	–	11	–	12	–		–		–
T. sp. 2	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 3	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 4	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 5	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 6	–	–	–	–	–	–	–	–	12	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 7	–	–	–	–	–	–	–	–	24	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 8	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Trochammina charlottensis Cushman	–	–	1	–	1	–	2	–	16	–	–	–	–	–	1	–	1	–	4	–		8		–
T. conica Earland	–	–	1	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. discorbis Earland	1	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. cf. *hadai* Uchio	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. cf. *inflata* (Montagu)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. pacifica Cushman	7	–	11	–	7	–	2	1	12	4	–	–	–	–	2	–	3	–	4	–		–		4
T. pusilla Hoglund	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
T. cf. *wiesneri* Parr	–	–	–	–	–	–	3	–	–	–	2	–	–	–	–	–	–	–	–	–		4		–
T. sp. 1	1	–	–	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 3	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 4	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 5	–	–	–	–	2	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 6	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 7	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
T. sp. 8	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	3	–	–	–		–		–
T. sp. 9	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–		–		–
T. sp. 10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–		–		–
Gaudryina exilis Cushman and Bronnimann var.	–	–	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
G. sp. 1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
G. sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–		–		–
Eggerella advena (Cushman)	–	–	–	–	1	–	–	–	8	–	–	–	–	–	–	–	–	–	–	–		–		–
E. aff. *advena* (Cushman)	5	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–		–		–
E. scabra (Williamson)	35	1	22	–	132	–	24	–	384	8	25	2	44	5	110	12	51	–	192	–		–		4
CALCAREOUS PORCELANEOUS FORAMINIFERA																								
Quinqueloculina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–		–		–
CALCAREOUS HYALINE FORAMINIFERA																								
Lagena cf. *hispidula* Cushman	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Polymorphina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Guttulina sp. 1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	4		–		–
G. sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Oolina melo d'Orbigny	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Fissurina cucurbitasema Loeblich and Tappan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	4		–		–
Buliminella elegantissima (d'Orbigny)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–		–		4
Sphaeroidina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Bolivina robusta Brady	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–		–		–
B. striatula Cushman	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
B. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Bulimina marginata d'Orbigny	–	–	2	–	–	–	1	–	40	–	–	–	7	–	–	–	–	–	152	–		–		–
B. ujiiei Aoki	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	172	–		–		2
Hopkinsina cf. *glabra* (Millett)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12	–		–		–
Rectuvigerina aff. *transversa* (Cushman)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Patellinella inconspicua (Brady)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Ammonia beccarii tepida (Cushman)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Elphidium advenum (Cushman)	–	–	–	–	–	–	3	–	28	–	–	–	–	–	–	–	–	–	16	–		–		–
E. sp.	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
Cassidulina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12	–		–		–
Astrononion sp. 1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		–
A. sp. 2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Florilus japonicus (Asano)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		2
Nonionella turgida (Williamson)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–
Anomalina sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–		–		–

Table 2. Number of specimens of Foraminifera and Radiolaria in the bottom sediments of the bay-head area (T: total, L: living)

Station Number	Depth (m.)	Benthonic Foraminifera						Planktonic Foraminifera		Radiolaria
		Agglutinated		Calcareous Porcelaneous		Calcareous Hyaline				
		T	L	T	L	T	L	T	L	
1	136	86	(5)	0	(0)	0	(0)	0	(0)	33
2	170	118	(5)	0	(0)	5	(0)	0	(0)	19
3	105	437	(6)	0	(0)	0	(0)	2	(0)	277
4	174	261	(4)	0	(0)	4	(0)	0	(0)	15
5	160	816	(32)	0	(0)	68	(0)	0	(0)	280
6	185	84	(4)	0	(0)	0	(0)	0	(0)	46
7	136	80	(6)	0	(0)	7	(0)	1	(0)	37
8	130	157	(13)	0	(0)	0	(0)	0	(0)	43
9	102	132	(0)	0	(0)	0	(0)	0	(0)	3
10	142	704	(4)	8	(0)	432	(8)	48	(0)	40
11	150	272	(12)	0	(0)	300	(0)	8	(0)	120
12	138	312	(20)	2	(0)	496	(18)	16	(0)	44



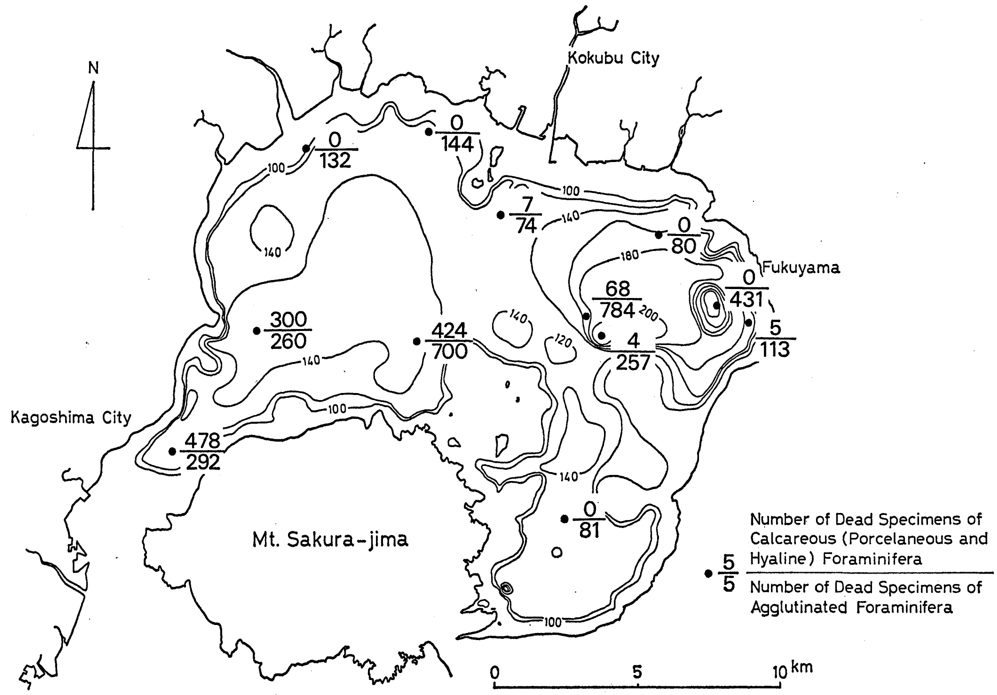
Text-fig. 4. Distribution of the benthonic populations in number of living specimens per sample.

said that there is a great difference in mode of occurrence of foraminifers between the two periods at intervals of 14 years.

The text-fig. 5 shows the number of individuals of the dead specimens in each station. As seen in the table 2, at the nine stations (St. 1–9) other than the stations 10,

* Numbers of individuals of living specimens were estimated by the writers from the Table 1 and the Fig. 8 in the KUWANO's paper.

11 and 12 situated at the strait west of Mt. Sakurajima or the area immediately north of it, foraminiferal assemblages are represented by the species with the agglutinated test with merely a low rate of occurrence (several percent) of the species with the hyaline test in four stations (St. 2, 4, 5 and 7). The stations, where the rare occurrences of the species with hyaline test were recognized, are located at the foot of steep slope in bottom topography. This is suggestive of a probability of the reworked occurrence of them.



Text-fig. 5. Distribution of the benthonic populations in number of dead specimens per sample.

On the other hand, at the three stations (St. 10, 11 and 12) close to Mt. Sakurajima, the individual numbers of the dead specimens attain to remarkably high percentages among each assemblage: 38%, 52% and 76.1% at the stations 10, 11 and 12, respectively. This means a striking contrast between the areas occupied by the stations 1 to 9 and by the stations 10, 11 and 12.

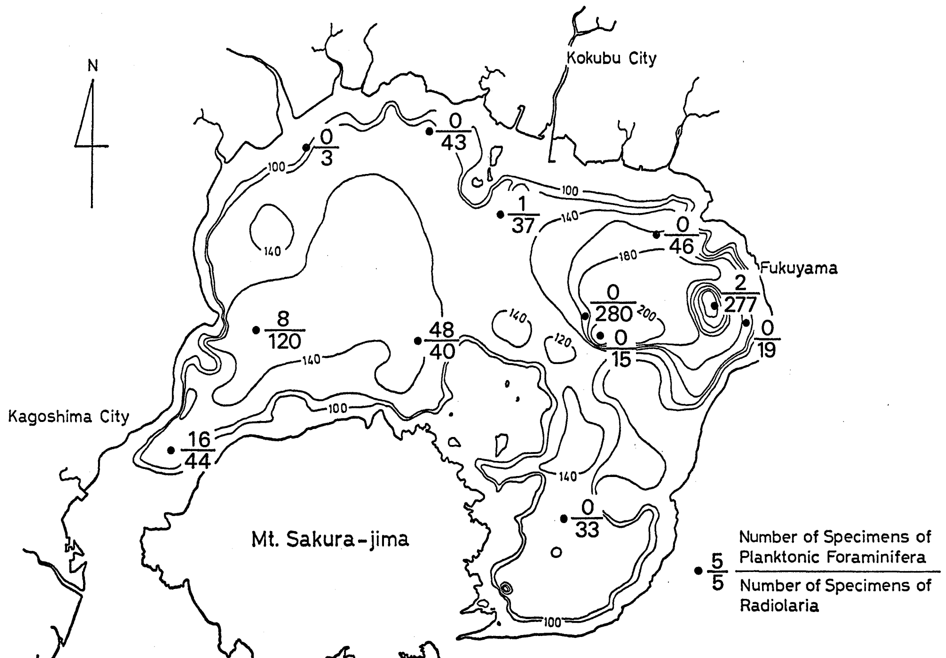
Among the predominant species of dead specimens, *Eggerella scabra* shows the highest rate of occurrence and is known to occur from the stations 1 to 10. It is noticeable, however, that the rate of occurrence of this species is exceptionally low at the station 4 close to the fumaroles (St. B), even though it is extremely high (up to 70%) at the other stations. On the contrary, *Textularia wiesneri*, which occurs at the stations other than the stations 7 and 10, exclusively shows a remarkably high rate of occurrence (63.8%) at the station 4, where that of *Eggerella scabra* is exceptionally low as mentioned above. This kind of reverse mutual relation is also recognized between *Textularia gracillima* and *T. wiesneri* (see Table 3).

It is interesting that *Saccammina atlantica* occurs with rather high rate of occurrence (17.5%) solely at the station 3 close to the fumaroles (St. A). *Recurvoides bosoensis* also occurs only at the station 3.

In spite of the almost enclosed outline of the bay-head area, considerable number of radiolarian specimens is known to occur in the bottom sediment of this area Even though the planktonic foraminifers had also been expected to occur in the bottom sediments, their occurrence is very rare in this area (Table 2; Text-fig. 6).

Table 3. Ratio (%) of the number of specimens of the predominant species to the total number in the bay-head area (numerals in black letter: most abundant, +: rare)

Species \ Station Number	1	2	3	4	5	6	7	8	9	10
Eggerella scabra (WILLIAMSON)	**40.7**	17.9	**30.1**	9.1	**43.4**	**29.8**	**50.0**	**70.1**	**38.1**	16.7
Textularia wiesneri EARLAND	20.9	7.3	15.9	**63.8**	9.5	+	0	4.5	2.2	0
T. gracillima HÖGLUND	2.3	**22.8**	0	0	0	17.9	0	0	13.4	**25.3**
Saccammina atlantica (CUSHMAN)	0	0	17.5	0	0	0	0	0	0	0
Textularia bigenerinoides LACROIX	7.0	8.9	6.6	3.8	7.7	23.8	6.8	3.2	23.1	2.8
T. sp. 1	1.2	0	+	0	0	0	4.5	10.8	8.2	1.0



Text-fig. 6. Distribution of planktonic Foraminifera and Radiolaria in number of specimens per sample.

Discussion

As already mentioned, the bay-head area of Kagoshima Bay is considerably different from the central part and the outside of the bay in the two elements of sea water property, that is, the dissolved oxygen content and the pH. Among them, abnormal lowering of pH caused by the fumarolic activities is remarkable, and the so-called acidic water mass is supposed to develop during the most part of the year except for the coldest period in winter. It is well-known and experimentally ascertained (Ôba and Ku, 1977) that the foraminiferal test composed of calcium carbonates is easily dissolved in acidic solution with pH less than 7. The absence of calcareous foraminifers in some part of the area is assumed to be closely related to the development of acidic water mass caused by the fumarolic activities in the eastern half of this area.

The decrease of living calcareous foraminifers during the past 14 years recognized through the comparison of data given by Kuwano (1962) and by the writers may imply the gradual change of environment becoming difficult to live for the calcareous foraminifers. Even in 1958, however, benthonic calcareous foraminifers were almost absent at the station close to fumaroles at the station B except for a small number of specimens of *Bulimina marginata*. This suggests that the acidic water mass was already developed to some extent in 1958. Although the writers have no evidence for the time of commencement of the acidic water mass development, it seems to be reasonable to suppose that it is started by the great eruption of Mt. Sakurajima in 1914, which resulted in the land connection between the former Sakurajima Island and the Osumi Peninsula, and at the same time, greatly changed the circulation of water in the bay-head area.

Concluding Remarks

To clarify the historical change of environment of the bay-head area of Kagoshima Bay, it is necessary to study the relics of organisms preserved in the core samples obtained from the present area. From the lower part of a few core samples, of which surface sediments bear only the arenaceous foraminifers, the writers have recognized the occurrence of hyaline calcareous foraminifers. As the result of the writers' study (Hayasaka *et al.*, 1976) on the core samples, the existence of a pumice bed in the cores were traced all over the area. Through the petrographic study, Aramaki (1976) attributed the origin of this pumice bed to the eruption of Mt. Sakurajima in 1914. The writers believe that the historical change of environment of this area in the recent years must be clarified through the comparison between the foraminiferal assemblages in the sediments above and below the pumice bed.

References

Aramaki, S., 1976, Geologic Structure of the Northern Part of Kagoshima Bay and History of Volcanic Activities viewed from Bottom Sediments (in Japanese). *Reports on the Submarine Volcanic Activities and the Natural Environment of the Northern Part of Kagoshima Bay*, p. 15–20.

Hayasaka, S., K. Ôki, H. Otsuka and S. Higashikawa, 1976, Geological Study on Kagoshima Bay, South Kyushu, Japan. Part III - Submarine Topography and Bottom Sediments of the Bay-Head Area. (in Japanese with English Abstract). *Rep. Fac. Sci., Kagoshima Univ.,* (*Earth Sci. & Biol.*), no. 9, p. 53–73.

Higo, N., S. Enami, T. Imai and G. Kawamura, 1974, Present Status of Fishery in Kagoshima Bay (in Japanese). *Reports on the Hydro-environment of Kagoshima Bay*. p. 157–207.

Kagoshima Prefectural Government, 1978, *Reports on the Environment Study in Relation to Mercury in Kagoshima Bay* (in Japanese), p. 1–38.

KAMADA, M., 1961, Distribution of Radon in Fumarolic Gases in Japan (in Japanese with English Abstract). *Nippon Kagaku Zasshi*, vol. 82, no. 10, p. 1346–1350.

————, H. ONISHI and H. SAKAMOTO, 1976, Unusual Property of Water in the Bay-Head Area of Kagoshima Bay (in Japanese). *Reports on the Submarine Volcanic Activities and the Natural Environment of the Northern Part of Kagoshima Bay*, p. 55–74.

———— and J. OSSAKA, 1977, Epitome of the Results of Joint Research (in Japanese). *Submarine Volcanic Activities and Unusual Environmental Conditions in the Bay-Head Area North of Mt. Sakurajima*, p. 81–84.

————, H. SAKAMOTO, N. YONEHARA and T. ONISHI, 1977, Unusual Property of Water in the Bay-Head Area of Kagoshima Bay (in Japanese). *Submarine Volcanic Activities and Unusual Environmental Conditions in the Bay-Head Area North of Mt. Sakurajima*, p. 64–80.

KUWANO, Y., 1962, Foraminiferal Biocoenoses of the Seas around Japan - A Survey of Pacific-side Biocoenoses. *Misc. Rep. Res. Inst. Natural Resources*, nos. 58–59, p. 116–138.

OBA, T. and T. L. KU, 1977, Measurement of $CaCO_3$ Dissolution in Deep-Sea Sediments (in Japanese with English Abstract). *Fossils*, no. 27, p. 1–14.

OZAWA, T., J. OSSAKA and J. HIRABAYASHI, 1976, Submarine Fumarolic Gases and Sea-Water Temperatures (in Japanese). *Reports on the Submarine Volcanic Activities and the Natural Environment of the Northern Part of Kagoshima Bay*, p. 15–20.

TAKAHASHI, T., 1978, Fluctuation of Current System in Embayment (in Japanese). *Research Reports on the Processes of Sea Water Circulation in Embayment*, p. 1–7.

———— and M. CHAEN, 1977, Sea-Water Movement at the Bottom of the Bay-Head Area of Kagoshima Bay (in Japanese). *Submarine Volcanic Activities and Unusual Environmental Conditions in the Bay-Head Area North of Mt. Sakurajima*, p. 43–47.