

## Recent Ostracode Fauna in the Pacific off Southwest Japan

By

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(Manuscript received March 23, 1995)

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### Abstract

Recent ostracode assemblages from the Pacific around Southwest Japan are analyzed and the species described. Six areas are investigated, namely, Kumano-nada, off Tanabe, Tosa Bay, Bungo-suido, Hyuga-nada and off Tanega-shima. From 80 surface sediment samples, a total of 191 species among 80 genera are identified, of which 61 selected species are systematically described and 10 species are described as new.

Ostracodes in this region show strong affinities with those of the Sea of Japan and of the East China Sea. The fauna is dominated by subtropical/tropical species associated with widely distributed "Japonic elements". Three cryophilic species are found very rarely, showing a deepening of the distribution of assemblages in the area studied. On the basis of the geographical distributions of shallow water ostracode species, two distinct biogeographical discontinuities are recognized along the Pacific coast of Japan. One is located between Suruga Bay and Sendai Bay, and another between Kyushu and Tanega-shima Islands. The two locations correspond with the boundary of the warm temperate/subtropical zones and that of the subtropical/tropical zones, respectively. As a result many species are characterized as subtropical or tropical.

A remarkable degree of downslope transportation of ostracode shells is evident in each area investigated. The frequent condensation of ostracode shells in the sediments, and the varying depth ranges of the same species in different areas, are considered to be the result of postmortem transportation.

The preservation states of the ostracode shells are variable. The proportion of fresh, translucent shells is, in general, inversely correlated with water depth and mud content; this fact suggests that the

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opaqueness of ostracode shells may be the result of dissolution of the calcite crystals by sea water.

## 1. Introduction

Despite a number of contributions on Recent ostracode faunas in Japan, the number of studied locations around the Pacific coast of Southwest Japan are still sparse, and most of the works are restricted to shallow environments such as inner bays and upper continental shelves. Many forms, especially those inhabiting deep water environments, have fossil records only from the Neogene and Quaternary deposits of this region. The paucity of information often makes it impossible to perform an accurate paleoenvironmental analysis or to make a lucid discussion of ostracode paleozoogeography.

A large number of surface sediment samples dredged by the Geological Survey of Japan were provided to me to study the ostracode faunas from shelf to deep sea areas of the Pacific surrounding Southwest Japan. This region is under the influence of the warm Kuroshio, and is characterized by faunas of high diversity. In this region, although there have been nine works on ostracode faunas (KAJIYAMA, 1913; ISHIZAKI, 1968; FRYDL, 1982; IKEYA and HANAI, 1982; IKEYA et al., 1985; BODERGAT and IKEYA, 1988; TABUKI and NOHARA, 1988, 1990; ZHOU, 1989MS), only my own work (ZHOU, 1989MS) has concerned the deep-water fauna; I treated the deep water fauna in Suruga Bay, and discovered many deep-sea taxa including *Krithe*, *Robertsonites*, *Pacambocythere*, *Argilloecia*, *Bradleya* etc. I also showed that the vertical zonation of ostracode assemblages in Suruga Bay is controlled by the vertical structure of sea water there.

The purpose of this study is twofold. Firstly, I describe ostracode species from the sites along SW Japan. Emphasis is concentrated on the description of those from deeper water. Such description is fundamental for any further researches on Ostracoda, in particular for the application to paleoenvironmental analyses. Secondly, I draw possible conclusions on ostracode zoogeography and habitat preferences of ostracode species in this area by synthesizing the distribution data from previous and the present studies.

## Acknowledgements

This work was carried out under the supervision of Prof. K. CHINZEI, Department of Geology and Mineralogy, Kyoto University. I would like to express my sincere gratitude to him for encouraging me to continue doing research and giving me much invaluable advise during this work. I am also indebted to Drs. T. OHNO and H. MAEDA in the same department for their discussions and advise. I am very grateful to Dr. R. M. ROSS, Shizuoka University, for his invaluable comments and thorough and careful review of the draft of this manuscript.

The Geological Survey of Japan provided me a large number of samples from 5

areas, namely Kumano-nada, Tosa Bay, Bungo-suido, Hyuga-nada and off Tanegashima. I would like to thank particularly Drs. M. ARITA and K. IKEHARA, Division of Marine Geology, the Geological Survey of Japan, for their kindness in providing me bottom samples. Dr. Y. KAMADA, Professor Emeritus of Nagasaki University, kindly offered me some frozen surface samples from the Hyuga-nada area, of which 8 were added to this study. I collected all the samples off Tanabe and some of the ones off Tanegashima during two cruises of the R/V *Tansei-maru* of the Ocean Research Institute, the University of Tokyo. I would like to express my thanks to the crew of the ship and the scientists who helped me with sampling.

I am grateful to Prof. N. IKEYA, Shizuoka University, for his critical discussions. I was privileged to be able to investigate a large amount of literature and numerous collections in his laboratory. He also provided me three samples from the area off Okinawa.

## 2. Materials and Methods

### 2-1. Sample collection

Fig. 1 shows the six areas in SW Japan investigated in this study. Characteristics of the samples used in this study are listed in Table 1. Their geographical distributions in each area are shown in Fig. 2. A total of 80 samples have three sources: 60 samples are from the collections of the Geological Survey of Japan (GSJ), 8 are from the Department of Geology, Nagasaki University, and 12 were collected by me. Samples from the GSJ were all collected by means of Smith-McIntyre grab during three cruises of the research vessel *Hakurei-maru*, aimed at getting information about marine geology and natural resources in surface sediments in the seas around SW Japan. At the GSJ the sediment samples were kept undisturbed in square plastic tubes with a bottom size of 5×6 cm and a length of about 40 cm. The samples were not fixed with formalin or alcohol solution after sampling, and mostly dried under room temperature. Accordingly, the obtained specimens are all shells without soft parts. Only the uppermost 2 cm of the sediments were used for this study. Samples from Nagasaki University were also collected by Smith-McIntyre grab and the surface sediments were put in plastic bottles and kept in a refrigerator. A part of each sample was provided for this study. I collected samples off Tanabe, and a part of the samples off Tanegashima, on board the R/V *Tansei-maru*, during two cruises aiming to investigate the organisms of the Kuroshio areas and the associated environmental factors. The very surface sediments (about the uppermost 1 cm) were shaven and used for this research. All the samples used can be considered to be surface sediments and the ostracode assemblages recovered to be Recent.

1) *Kumano-nada*. A total of 10 samples used in this study were collected during May 27 and June 25, 1982, on the *GH82-2 Cruise* of the R/V *Hakurei-maru*. The water

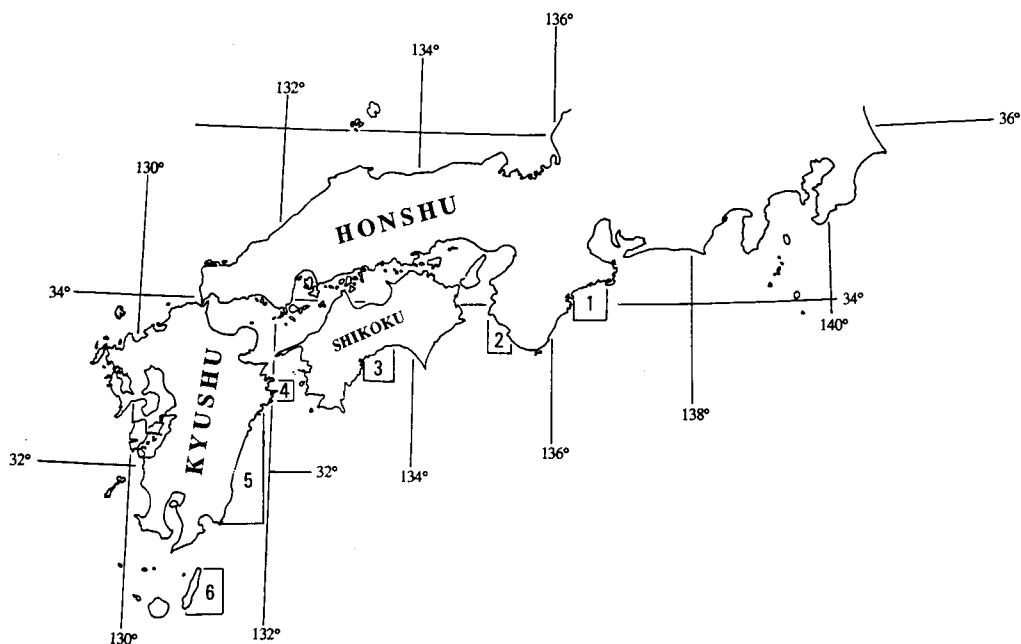


Fig. 1. Map showing the six areas treated in this study. 1: Kumano-nada, 2: off Tanabe, 3: Tosa Bay, 4: Bungo-suido, 5: Hyuga-nada, 6: off Tanega-shima.

depths of these samples range from 100 to 982 m.

2) *Off Tanabe*. I collected nine samples from this area during the *Cruise KT90-17* of the R/V *Tansei-maru*, during Nov. 27 and Dec. 4, 1990. The depth range is 44–800 m.

3) *Tosa Bay*. Fourteen samples collected during June 3 to Aug. 1, 1983, on the *Cruise GH83-2* of the *Hakurei-maru* were used. The depth range is 26–727 m.

4) *Bungo-suido*. Ten samples were collected on the *Cruise GH83-2* of the *Hakurei-maru*. The depth range is 79–1215 m.

5) *Hyuga-nada*. A total of 24 samples from this area were used, which include 16 samples collected during *Cruise GH83-2* of the *Hakurei-maru*. Eight were collected by a research group of Nagasaki University for the purpose of investigating the distribution of surface sediments and the composition of CHN (KAMADA & KONDO, 1981); these were collected during Oct. 17 to 20, 1978 using the R/V *Tachibana*, belonging to the Fishery Exploration Station of Miyazaki Prefecture. The depth range is 21–902 m.

6) *Off Tanega-shima*. A total of 13 samples include 10 collected during July 5 and Aug. 23, 1984, on *Cruise GH84-3* of the *Hakurei-maru* and 3 collected by me on Feb. 17, 1992, on *Cruise KT92-2* of the *Tansei-maru*. The depth range is 50–1,631 m.

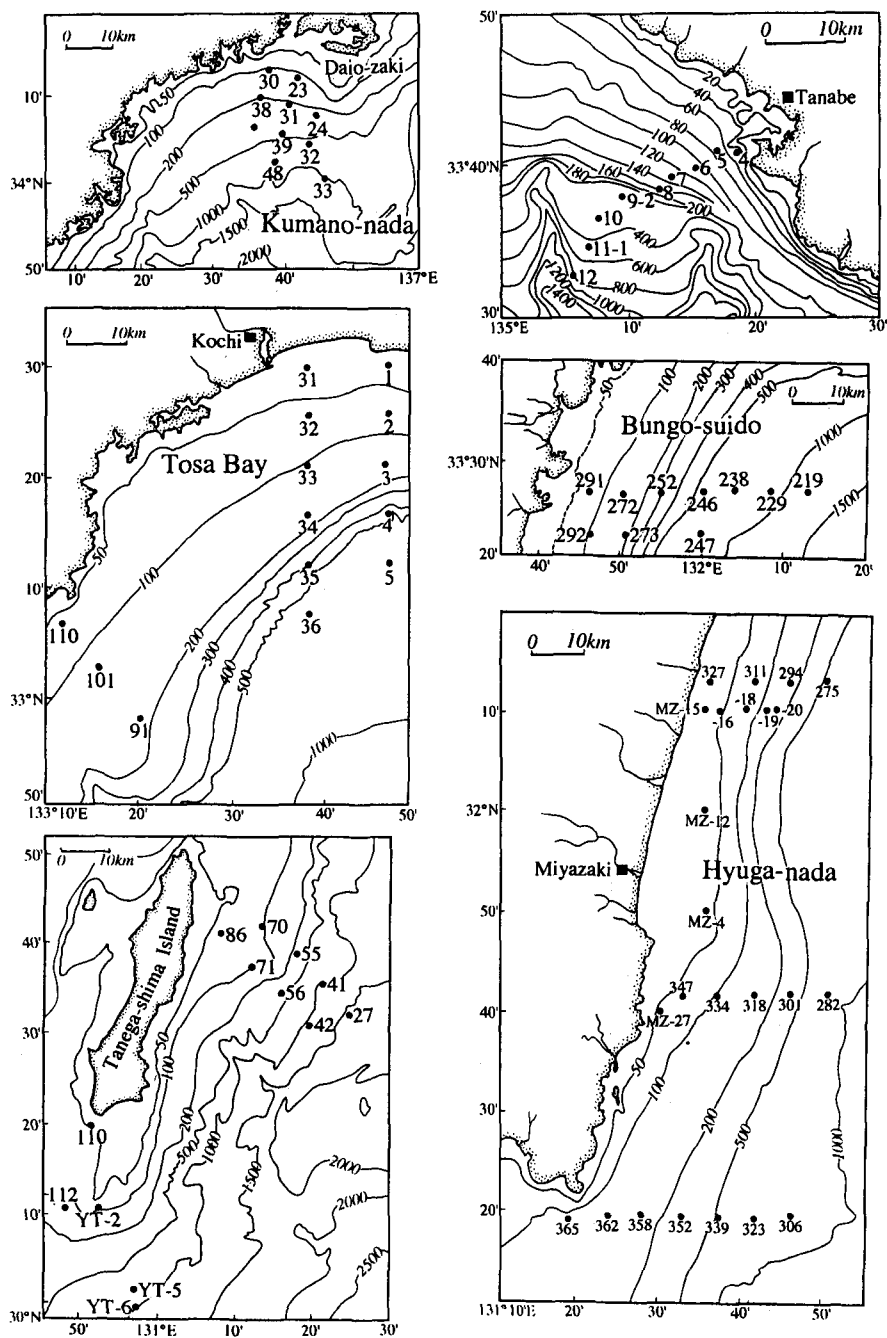


Fig. 2. Submarine topographies of the six areas studied, showing sites of samples used in this study.

## 2-2. Processing

Nine samples collected by me from off Tanabe were immediately fixed with 10% neutralized formalin solution on board and then treated in the laboratory within ten days after the sampling. In the laboratory the samples were washed through a sieve with mesh size 63  $\mu\text{m}$ , then stained with 0.1% Rose Bengal solution for 24 hours. After staining, the samples were washed over the same sieve and then oven-dried at around 70°C.

The other 71 samples were not fixed with formalin solution. In the laboratory they were simply washed through a sieve of mesh size 63  $\mu\text{m}$  and then oven-dried.

## 2-3. Picking and identification

Ostracode specimens of adult and juvenile were hand-picked under a stereo microscope using a fine brush and a gridded picking tray. From each sample more than 200 individuals were picked when possible. Specimens from one sample were pasted with water-soluble glue on a gridded microfossil slide. Specimens were examined, sorted and identified using an *Olympus* stereo microscope with a  $\times 160$  maximum magnification. A *JSM-6100* scanning electron microscope (SEM) was used to examine and photograph the details of carapace morphology.

## 2-4. Repository

All types and illustrated specimens of ostracodes described in this paper are deposited in the collections of the Department of Geology and Mineralogy, Faculty of Science, Kyoto University, Registration Nos. JC-1351 to JC-1428. The rest of all the specimens, mounted on the microfossil slides, have been deposited in the Institute of Geosciences, Faculty of Science, Shizuoka University.

# 3. Description of study areas and environmental factors

## 3-1. Submarine topography and description of surface sediments

The study areas are on the continental shelf and slope facing the Nankai Trough along the Pacific coast of Southwest Japan. The continental slope is steep in this region and is accompanied by a narrow shelf. The depth of the shelf edge in this region is about 140 to 150 m. There are several deep sea basins between the upper slope and the Nankai Trough. The bottom of the basin lies at the depths of about 2000 m in Kumano-nada, 800–1000 m off the coast of Shikoku, and 1600–1800 m in Hyuga-nada. Submarine canyons on the continental slope usually end at these basins.

The submarine topography of each of the six areas is shown in Fig. 2. The sediment type of each station is given in Table 1.

- (1) *Kumano-nada*. A characteristic topographic feature of this area is the existence

of the Kumano-nada Basin, which is one of the forearc basins along Southwest Japan. It extends about 100 km in length and about 30 km in width, the bottom of which reaches to a depth of about 2000 m. The shelf is narrow, about 10 km wide from the coast. Four large submarine canyons are seen on the continental slope: from east to west, the Gokasho, Kamisaki, Nagashima, and Owase Canyons. Sample sites are located on the lower shelf and on the upper slope, the deepest site reaching 902 m. East of the sample sites, the Shima Spur extends southward from the Shima Peninsula.

Distribution of the surface sediments was compiled by ARITA & KINOSHITA (1988) on the basis of surface sediment samples from 145 sites from Cruise GH82-2. The shelf area is dominated by sandy sediments. Sandy sediments usually extend to a depth of about 500 m, and reach over 1000 m on the Shima Spur. The sediments on the shelf and its adjoining uppermost slope are coarse grained, composed of inorganic mineral grains and shell fragments of planktonic foraminiferal tests. It is said that mineral grains are supplied by erosion of siltstone distributed on the Shima Spur (ARITA & KINOSHITA, 1988). Muddy sediments on the continental slope in the central and western parts are very thin, and cover the underlying viscous mud. The Kumano-nada Basin is covered by muddy sediments, which are transported through submarine canyons.

(2) *Off Tanabe*. The shelf is not very well-defined in this area. There are two large submarine canyons on the slope. The width of the shelf is variable; in the northern part it is broad, about 15 km, whereas in the southern part it is reduced to about 8 km. The heads of the submarine canyons are at the shelf edge, and reach to the basin. Sample sites are located on the shelf and the upper slope, with the deepest one, 800 m, at the slope of a submarine canyon.

The shelf area is covered by sand, and the slope by mud, with rocks sporadically exposed on the cliffs of the submarine canyons. Along the sampling traverse investigated in this study, mud content is under 16% at the depths above 228 m; it increases from 22 to 82% from 309 to 800 m.

(3) *Tosa Bay*. Sample sites for this study are located in the western part of the bay, from the shelf to the middle slope. The submarine topography in this part is characterized by a broad shelf and broad forearc basin. The continental shelf has a width of approximately 20 km. The depth of the shelf edge is about 140 m. There are two submarine canyon swarms on the upper shelf off the Tei Cape and off Suzaki City. The bottom of the Tosa Basin is a broad and flat plane spreading at the depths of 800–1100 m.

The distribution map of surface sediments in Tosa Bay was compiled by IKEHARA (1988), based mainly on the analysis of 141 samples taken during the Cruise GH83-2. In the area treated in this study, the bottom sediments of the coastal part (20–30 m) are composed of well-sorted fine sandy sediments of low mud content, which suggest the influence of wave action. The sediments are considered to be accumulated in the lower

shoreface. There is a tongue-shaped sandy area which starts at the coastal area south of Nangoku City, and spreads southwestward parallel to the western coast of the bay, reaching the upper slope at about 400 m. Sediments inside the tongue become finer in grain size and higher in mud content in the direction from north to south. It is considered that this distribution is brought about by the current which flows from northeast to southwest. The area sandwiched by the coastal sand and tongue-shaped sand is covered by coarse silt. Silt is distributed in the lower slope area west of the tongue.

(4) *Bungo-suido*. The sample sites are distributed from the shelf to the Hyuga-nada basin; the bottom of the basin extends at the depths of 1000–1600 m. The sample sites are located in the northern end of Hyuga-nada. From the coastal area down to 1000 m, the depth contours sub-parallel the coastlines. The shelf has a width of about 15 km, with shelf edge at about 130 m deep.

Along the traverse for the samples used for the present study, sediments above 535 m are mostly fine sand with a mud content less than 20%. Below 730 m the sediments change to muddy fine sand, with mud content over 25%.

(5) *Hyuga-nada*. Submarine topography is simple with contour lines sub-parallel to the coastline. The shelf has an average width of about 15 km, and shows southward deepening of the shelf edge from 130 m off Tsuno to 160 m off the Toi-misaki. From the shelf edge the topography becomes very steep downslope. A few depressions are recognizable at the shelf edge in the central part of this area. Sample sites for this study are located from the upper shelf to lower slope.

The distribution of surface sediments in the shelf area above 200 m in Hyuga-nada was investigated by KAMADA & KONDO (1981) based on the analysis of 38 samples. Eight of the 38 samples have been used for this study, and are demarcated with MZ before the locality number in Table 1. In addition, samples used include several ones provided from GSJ collected from deeper depths. Combining the information of these samples, the distribution of sediments can be described as following. The sediments show different distribution patterns in the areas north and south of Aoshima. In the north, upper shelf is covered with sand down to about 50 m deep; at the depths of 50–200 m silty sand dominates; below 200 m sediments become sand or sandy silt. South of Aoshima, the area shallower than 150 m is covered with sandy silt. Below 200 m is sand. Sandwiched between the sandy silt and sand is a wedge-shaped area of silty sand.

(6) *Off Tanega-shima*. The shelf is wide eastward in the northern part of Tanega-shima Island, extending 30–50 km, but narrow in the southern part. The continental slope is developed in the eastern area of the Island, and continues to the Okinawa Trough. There are two channel systems, the Nakatane and the Minamitane Canyons on the continental slope off the east of the Island, starting from the shelf edge and reaching to the Okinawa Trough. Terrigenous and shallow water sediments have been transported down to deep areas through those channels. Sample sites to the east of the Is-



land are located from middle shelf to lower slope; those to the south of the Island from upper shelf to middle slope.

The distribution of the surface sediments in the Tanega-shima area was investigated by IKEHARA & KAWAHATA (1985). In the southern area off the Island, medium sand covers the sea bottom from the coastal area to the slope. To the east of the Island, very fine sand is distributed on the slope; fine sand occupies the southern half of the shelf, and medium sand predominates on the northern half of the shelf, with sporadic very coarse sand.

### 3-2. Oceanography

The main current of the Kuroshio flows northward, along the coast of Kyushu, Shikoku and eastern coast of Honshu as far as  $36^{\circ}\text{N}$ , where it meets the intermediate water of the cold Oyashio current. The Kuroshio is characterized by high transparency, salinities of 34.5–35.0‰ in the depths between 50–100 m at about  $32\text{--}33^{\circ}\text{N}$ , and temperatures of  $16\text{--}19^{\circ}\text{C}$  in the same depths. Its velocity varies from 1 to 5 knots. Its width is about 50 km off the eastern coast of Honshu, and the thickness is about 400 m in the region of the main current. It is the most important agent controlling the geographical distribution of marine organisms in this region.

The sea water in the Pacific off Southwest Japan can be divided into the coastal water and the offshore water, the latter composed of four layers, namely the surface water, the upper water, the intermediate water, and the North Pacific Deep Water (AOSHIMA, 1978).

The coastal water is distinguished from the offshore waters by its low salinity. Though the area under the influence of the coastal water varies according to seasons and other circumstances, it is limited to the shelf area at the surface and inner shelf area at the bottom.

The upper 100 to 200 m of the offshore water are occupied by the surface water, characterized by remarkable seasonal changes of the temperature and salinity. At the surface, temperature is about  $15^{\circ}\text{C}$  in winter and as high as  $30^{\circ}\text{C}$  in summer, and salinity is about 34.8‰ in winter and less than 34.0‰ in summer.

The upper water lies directly under the surface water. It is characterized by little variation of temperature and salinity through the seasons ( $T=8\text{--}14^{\circ}\text{C}$ ,  $S=34.4\text{--}34.6\text{‰}$ ).

Under the upper water is the intermediate water, which is characterized by the minimum salinity within the water column ( $S=34.0\text{--}34.3\text{‰}$ ,  $T=6\text{--}8^{\circ}\text{C}$ ). It is uncertain whether or not this is the direct extension of the Oyashio Undercurrent. The bottom of the salinity minimum layer, which exists at about 800 m near the axis of the Kuroshio, is shallower near the coast. The layer of minimum dissolved  $\text{O}_2$  lies nearly at the same depths of 800 m.

Below the Intermediate Water exists the North Pacific Deep Water. It is characterized by high salinity and low temperature ( $S=34.5\text{‰}$ ,  $T=3-5^{\circ}\text{C}$ ), with salinity gradually increasing with depth.

Vertical profiles of temperature, salinity and dissolved  $\text{O}_2$  in the Tanega-shima area and Enshu-nada area (north of Kumano-nada) were presented by AKIMOTO (1990) based on the data of the marine meteorological and oceanographic observations from 1906 to 1981. In both areas each of the three parameters shows the same pattern of change with depth. So it can be considered that waters in southwest Japan have the same vertical structure despite geographical gradients in the parameters. The salinity maximum of about  $34.7\text{‰}$  is at about 120 m deep, which is also the lower limit of the vertical circulation of surface water in winter; the salinity minimum is about  $34.3\text{‰}$  at about 500–600 m. The oxygen minimum is about 1.5 ml/l at approximately 800 m deep.

#### 4. Ostracode assemblages

From the 80 samples used for this study, a total of 14067 valves and 579 carapaces were picked representing over 200 species. Among them, 192 species representing 80 genera were identified. The identifications include all the abundant species and most of the rare ones. Although the nine samples from the area off Tanabe were treated with formalin solution after sampling, only a few specimens with soft parts have been found in them; hence the result of this study is based on dead ostracode shells.

Occurrences of ostracode species, and the depth range of each species in each of the six areas studied, are given in ZHOU (1995, Appendices I–VI; Figs. 1–6). Based on the occurrence data, a scatter diagram of *water depth/specimen density* is shown in Fig. 3. Most samples have an ostracode specimen density less than  $100 \text{ valves/cm}^3$ , although two from Kumano-nada have values of 458 and 980. Those with a specimen density of over 100 are mostly restricted to depths shallower than 300 m, and furthermore to the sediments with a mud content around 20–30%; when the depth exceeds 400 m the specimen density for most samples is reduced to less than 10, irrespective of mud content. Usually samples with a high specimen density also have a greater number of species and conversely. This result reveals that ostracode specimen density and species diversity are closely related to water depth and mud content of the sediments.

The frequency distribution of the ten most abundant species in each area is shown in Fig. 4. Each of the six areas has 1 to 3 predominant species that far exceed any other in number of individuals. In Figs. 5–10 for each area the relative percents of the ten most abundant species across depth profile are shown.

Ostracode assemblages in each area are briefly described as below.

1) *Kumano-nada Area*. A total of 2704 valves and 61 carapaces were collected from 10 samples, in which 2117 valves and 46 carapaces were identified as 144 species belong-

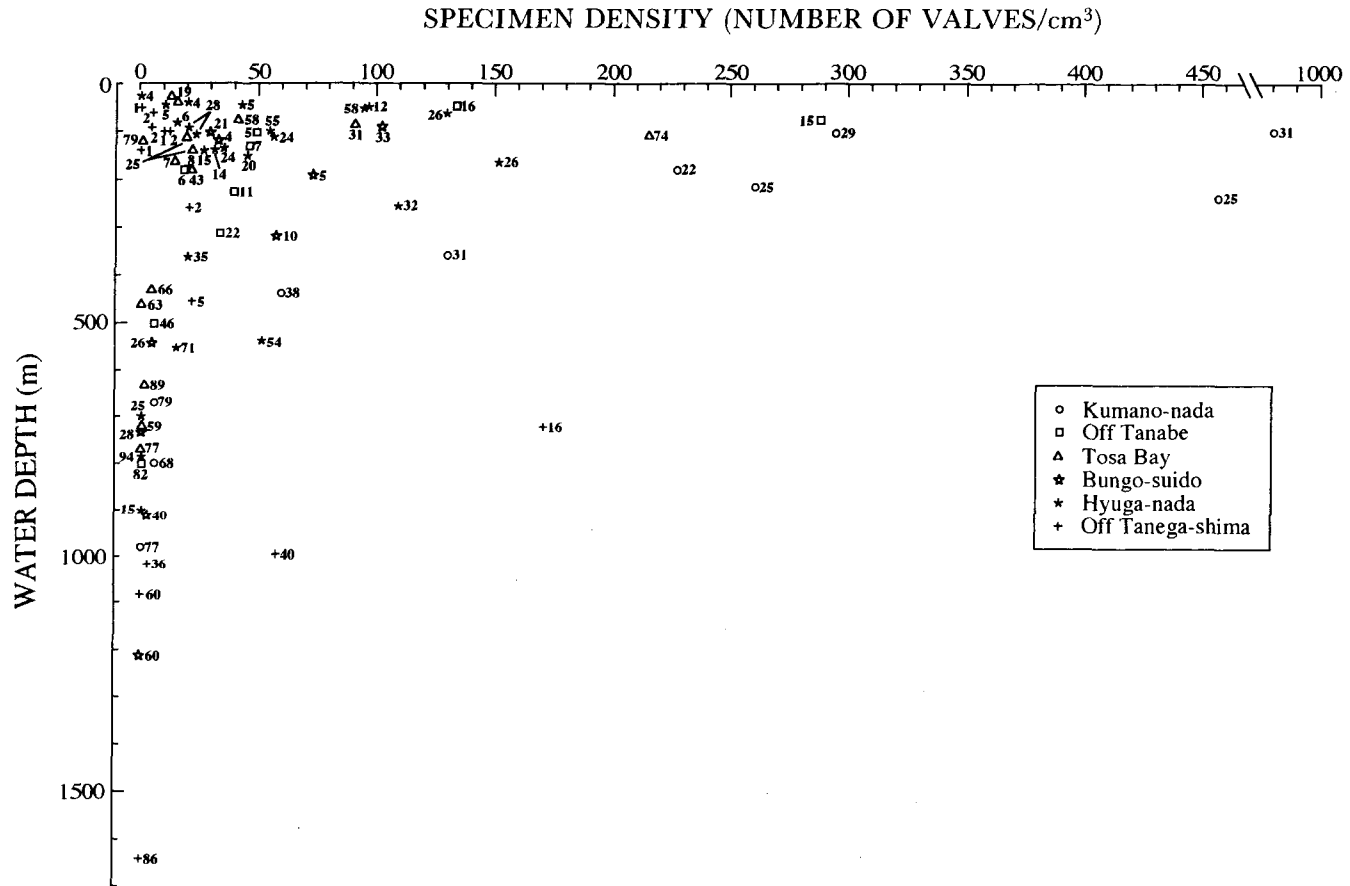


Fig. 3. Plots of ostracode specimen density against water depth. Numerals beside points show the mud contents in percentage.

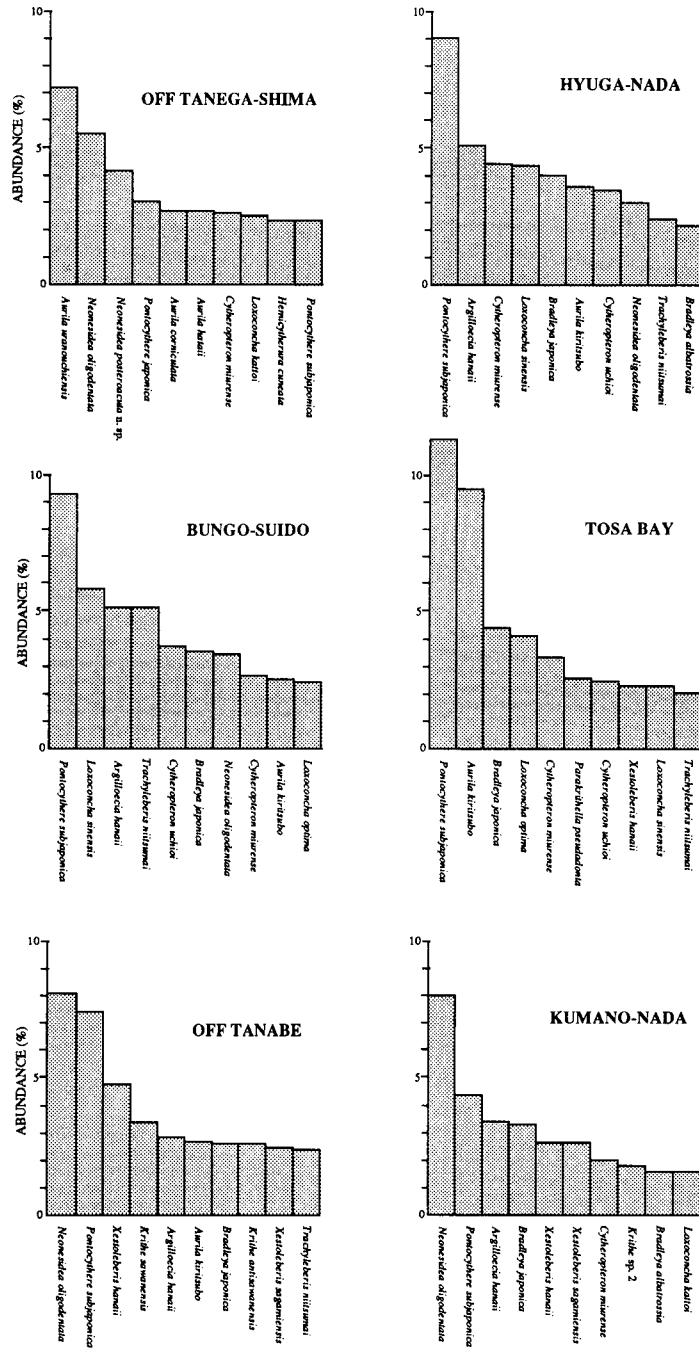


Fig. 4. Percentage abundance of the 10 most common species from each of the area studied.

Table 1. Data of surface sediment samples used for this study. Abbreviations: Lat.= latitude, Long.=longitude, Cl=clay, M=mud, Sl=silt, Sd=sand, f=fine, vf=very fine, m=medium, c=coarse, vc=very coarse, cly=clayey, mdy=muddy, sty=silty, sdy=sandy, sh=shelly, gr=gravelly, WS=well-sorted, SM=Smith-McIntyre spring loading grab, SN=sled-shaped bottom net, Ok=Okean grab, Corer=ORI spade corer.

Station Number	Locality		Depth (m)	Sampler	Sediment Type	Content of Mud (%)
	Lat. (N)	Long. (E)				
<b>Kumano-nada (Cruise GH82-2)</b>						
23	34°12.3'	136°42.0'	100	SM	organic f Sd.	30.6
24	34°08.0'	136°44.6'	238	SM	m - f Sd	24.9
30	34°13.3'	136°37.8'	100	SM	mdy m - f Sd	28.5
31	34°09.1'	136°40.8'	215	SM	mdy m Sd	25.0
32	34°04.7'	136°43.5'	670	SM	sty Cl	78.7
33	34°00.7'	136°46.0'	982	SM	soft sty Cl	77.0
38	34°10.0'	136°36.5'	186	SM	mdy m Sd	22.0
39	34°05.8'	136°39.4'	440	SM	vf Sd.	38.4
47	34°06.6'	136°35.5'	351	SM	vf Sd	30.9
48	34°02.6'	136°38.5'	797	SM	soft sty Cl	68.2
<b>Off Tanabe (Cruise KT90-17)</b>						
4	33°40.6'	135°18.9'	44	Ok	mdy f Sd	16.0
5	33°40.7'	135°17.4'	75	Ok	m Sd	14.5
6	33°39.8'	135°15.8'	102	Ok	f Sd	4.9
7	33°39.0'	135°13.8'	133	Ok	f Sd	6.5
8	33°38.2'	135°13.0'	176	Ok	f Sd	5.5
9-2	33°37.8'	135°09.8'	228	Corer	mdy f Sd	11.3
10	33°36.4'	135°07.9'	309	Corer	sdly M	21.6
11-1	33°34.5'	135°06.8'	503	Corer	M	45.6
12	33°32.8'	135°05.5'	800	Corer	M	82.4
<b>Tosa Bay (Cruise GH83-2)</b>						
1	33°29.4'	133°47.6'	26	SM	WS f Sd	5.6
2	33°25.0'	133°47.5'	76	SM	vf Sd	31.1
3	33°20.5'	133°47.1'	140	SM	f Sd	7.6
4	33°16.0'	133°47.3'	460	SM	mdy vf Sd	62.6
5	33°11.5'	133°47.4'	727	SM	Sl	58.7
31	33°29.4'	133°38.4'	27	SM	f Sd	18.6
32	33°24.9'	133°38.6'	73	SM	mdy vf Sd	58.3
33	33°20.5'	133°38.4'	106	SM	f Sd	25.8
34	33°16.0'	133°38.3'	162	SM	f Sd	7.1
35	33°11.5'	133°38.4'	430	SM	mdy f Sd	65.7
36	33°07.1'	133°38.4'	628	SM	sty Cl	89.2
91	32°57.9'	133°20.4'	174	SM	sdly Sl	42.7
101	33°02.5'	133°16.0'	117	SM	Sl	78.5
110	33°06.5'	133°12.1'	67	SM	Sl	74.4
<b>Bungo-suido (Cruise GH83-2)</b>						
219	32°26.5'	132°13.1'	1215	SM	mdy vf Sd	59.7
229	32°26.5'	132°08.5'	908	SM	mdy f Sd	40.4
238	32°26.6'	132°04.0'	730	SM	mdy f Sd	28.3
246	32°26.4'	132°00.1'	535	SM	f Sd	25.5
247	32°22.0'	131°59.6'	767	SM	sty Cl	77.3
252	32°26.4'	131°55.0'	317	SM	vf Sd	9.8
272	32°26.4'	131°50.4'	123	SM	f Sd	4.4
273	32°22.1'	131°50.5'	189	SM	f Sd	5.4
291	32°26.6'	131°46.0'	79	SM	mdy f Sd	32.9
292	32°22.0'	131°46.1'	102	SM	vf Sd	20.8

Station Number	Locality		Depth (m)	Sampler	Sediment Type	Content of Mud (%)
	Lat. (N)	Long. (E)				
Hyuga-nada						
Cruise CH83-2						
275	32°12.9'	131°50.6'	554	SM	mdy f Sd	71.1
282	31°41.4'	131°50.6'	785	SM	Cl	94.4
294	32°12.8'	131°46.0'	149	SM	f Sd	19.7
301	31°41.5'	131°46.1'	360	SM	mdy f Sd	34.9
306	31°19.0'	131°46.0'	902	SM	m Sd	15.3
311	32°13.0'	131°41.5'	82	SM	vf Sd	28.1
318	31°41.6'	131°41.6'	140	SM	m Sd	15.4
323	31°18.8'	131°41.6'	798	SM	mdy c Sd	25.3
327	32°13.0'	131°36.9'	30	SM	vf Sd	3.9
334	31°41.5'	131°37.0'	100	SM	vf Sd	55.4
339	31°19.0'	131°37.0'	535	SM	cly Sl	53.8
347	31°41.5'	131°32.6'	61	SM	vf Sd	26.1
352	31°19.1'	131°32.6'	256	SM	mdy f Sd	32.2
358	31°19.1'	131°27.9'	158	SM	mdy c Sd	25.5
362	31°19.0'	131°23.7'	135	SM	vc Sd	14.2
365	31°18.8'	131°18.9'	110	SM	mdy vc Sd	24.2
Samples from Nagasaki Univ.						
MZ-04	31°50.0'	131°35.6'	47	SM	Sd	12.0
MZ-12	32°00.0'	131°35.5'	42	SM	Sd	4.5
MZ-15	32°10.0'	131°30.4'	21	SM	Sd	3.6
MZ-16	32°10.0'	131°30.6'	36	SM	Sd	5.3
MZ-18	32°10.0'	131°40.0'	81	SM	sty Sd	28.7
MZ-19	32°10.0'	131°40.2'	110	SM	sty Sd	25.1
MZ-20	32°10.0'	131°40.4'	128	SM	Sd	23.7
MZ-27	31°40.0'	131°30.0'	54	SM	sdY Sl	58.1
Off Tanega-shima						
Cruise GH84-3						
27	30°31.0'	131°25.4'	1631	SM	Sl	85.7
41	30°34.6'	131°21.7'	1016	SM	mdy vf Sd	35.5
42	30°30.0'	131°19.9'	1072	SM	sdY Sl	59.8
55	30°38.0'	131°17.7'	254	SM	mdy f Sd	2.4
56	30°33.4'	131°16.2'	444	SM	mdy f - m Sd	4.8
70	30°41.3'	131°13.8'	98	SM	m - c Sd	1.9
71	30°36.7'	131°12.3'	90	SM	gr - vc Sd	1.5
86	30°40.4'	131°08.5'	64	SM	c sh Sd with f Sd	1.5
110	30°19.6'	130°51.5'	50	SM	vc Sd	0.7
112	30°10.4'	130°48.5'	135	SM	WS f - m Sd	1.2
Cruise KT92-2						
YT-2	30°10.3'	130°52.7'	96	SM	c sh Sd	0.5
YT-5	30°01.9'	130°57.0'	723	SM	WS f Sd	16.4
YT-6	29°59.1'	130°57.5'	986	SM	mdy f Sd	40.0

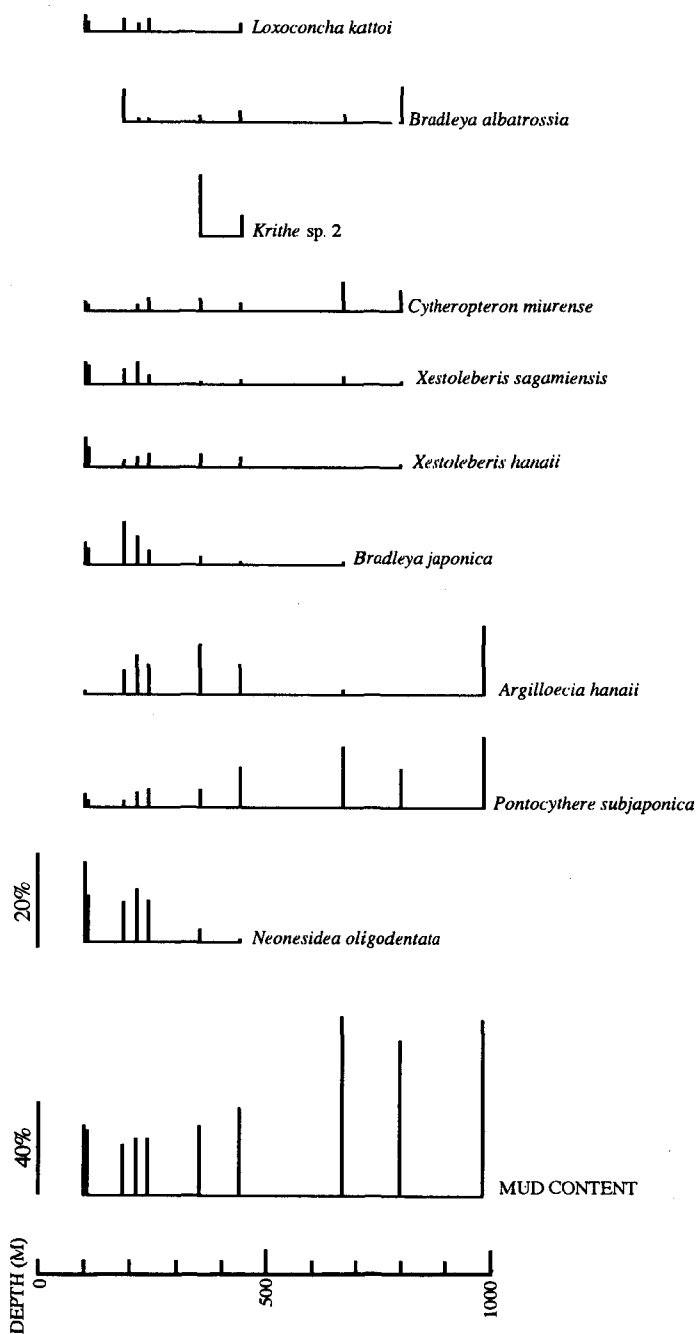


Fig. 5. Percent of mud content and the 10 most common species across depth profile in Kumano-nada area.

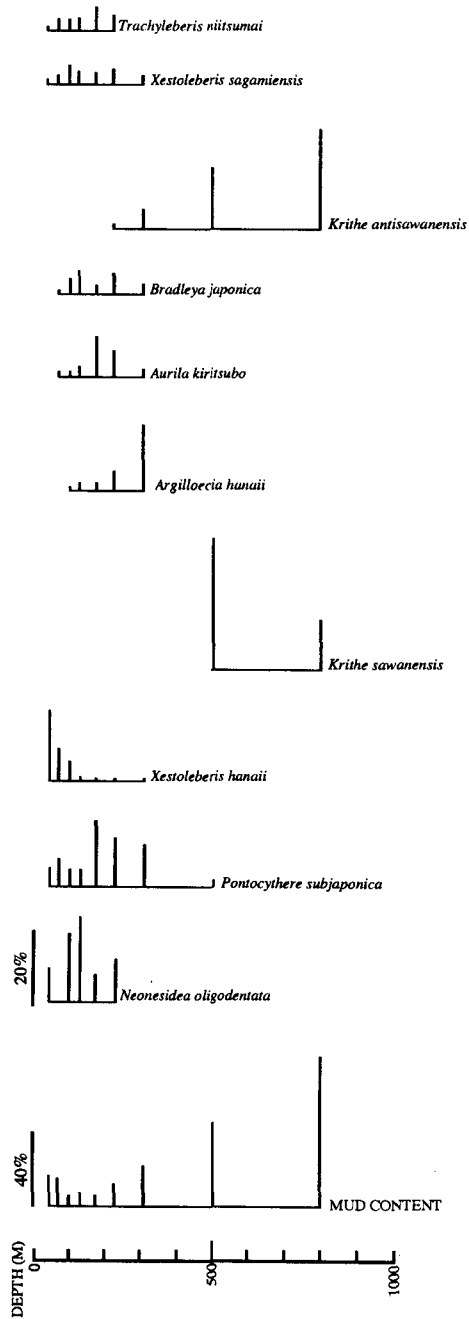


Fig. 6. Percent of mud content and the 10 most common species across depth profile in Tanabe area.



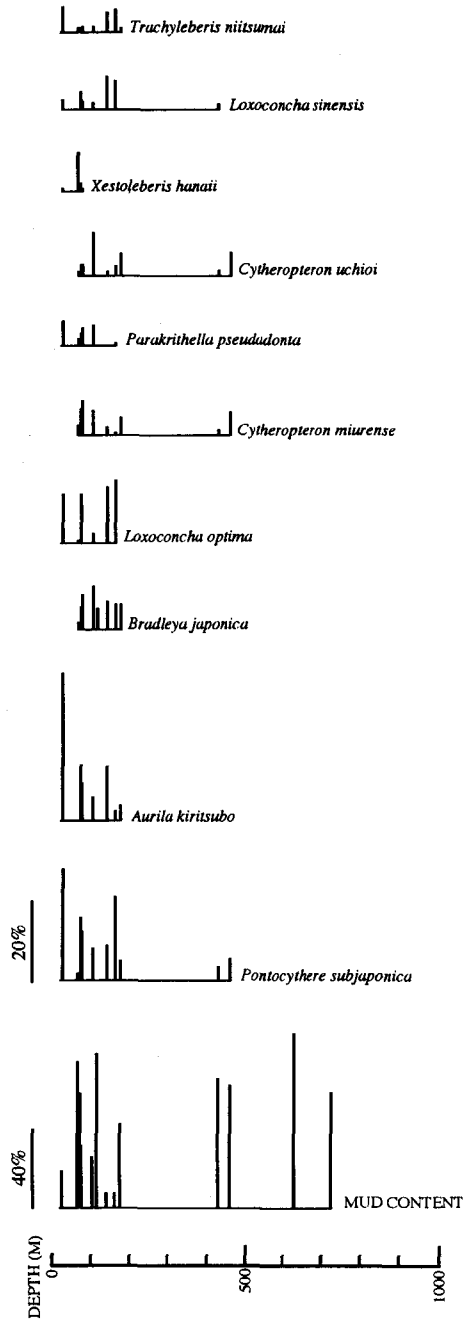


Fig. 7. Percent of mud content and the 10 most common species across depth profile in Tosa Bay.

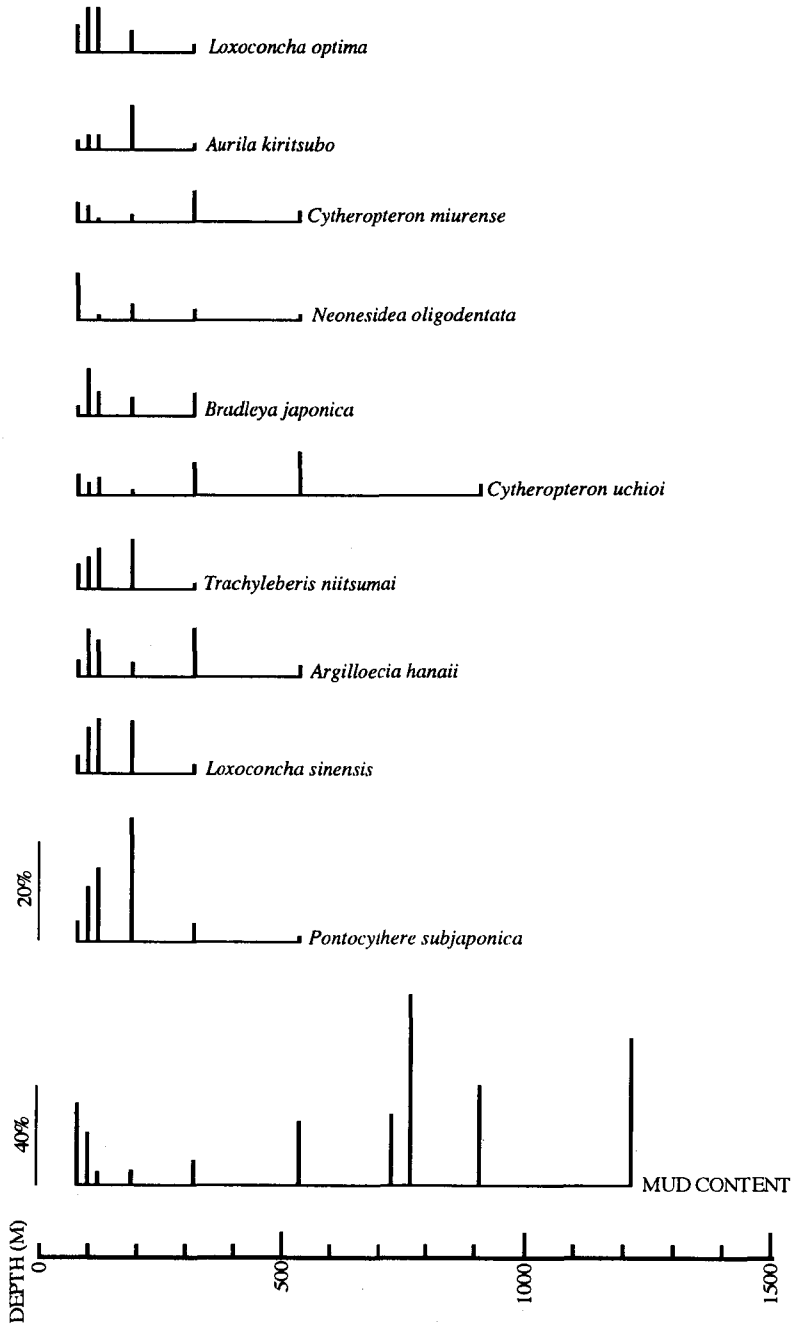


Fig. 8. Percent of mud content and the 10 most common species across depth profile in Bungo-suido area.

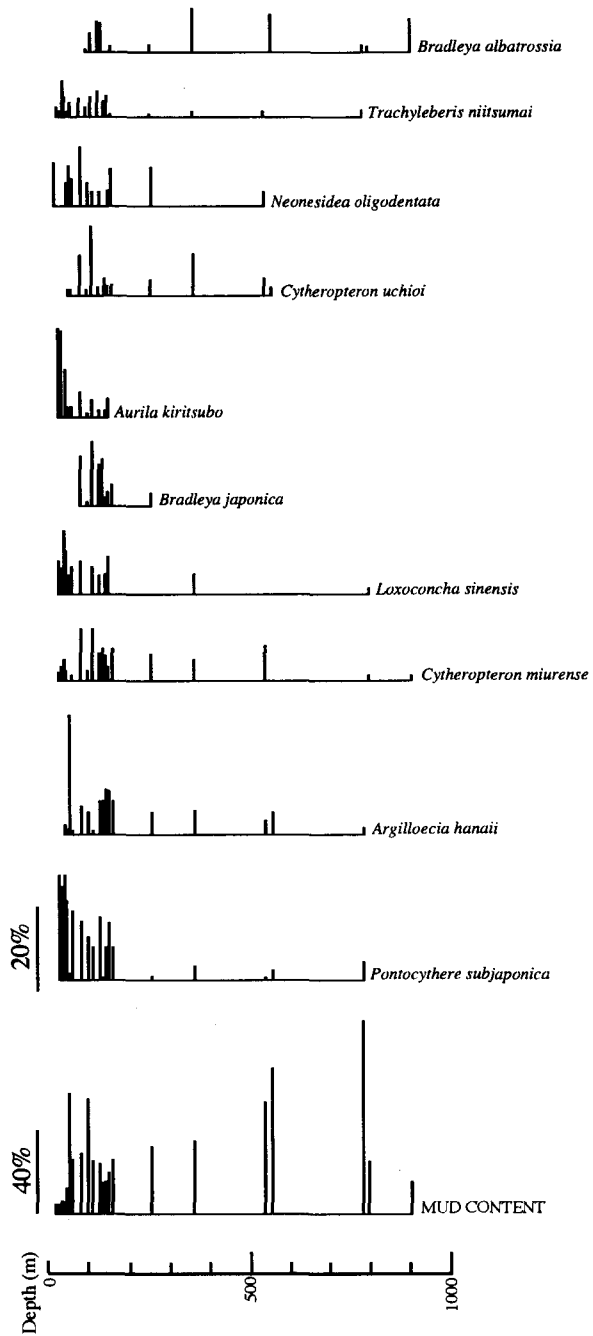


Fig. 9. Percent of mud content and the 10 most common species across depth profile in Hyuga-nada area.

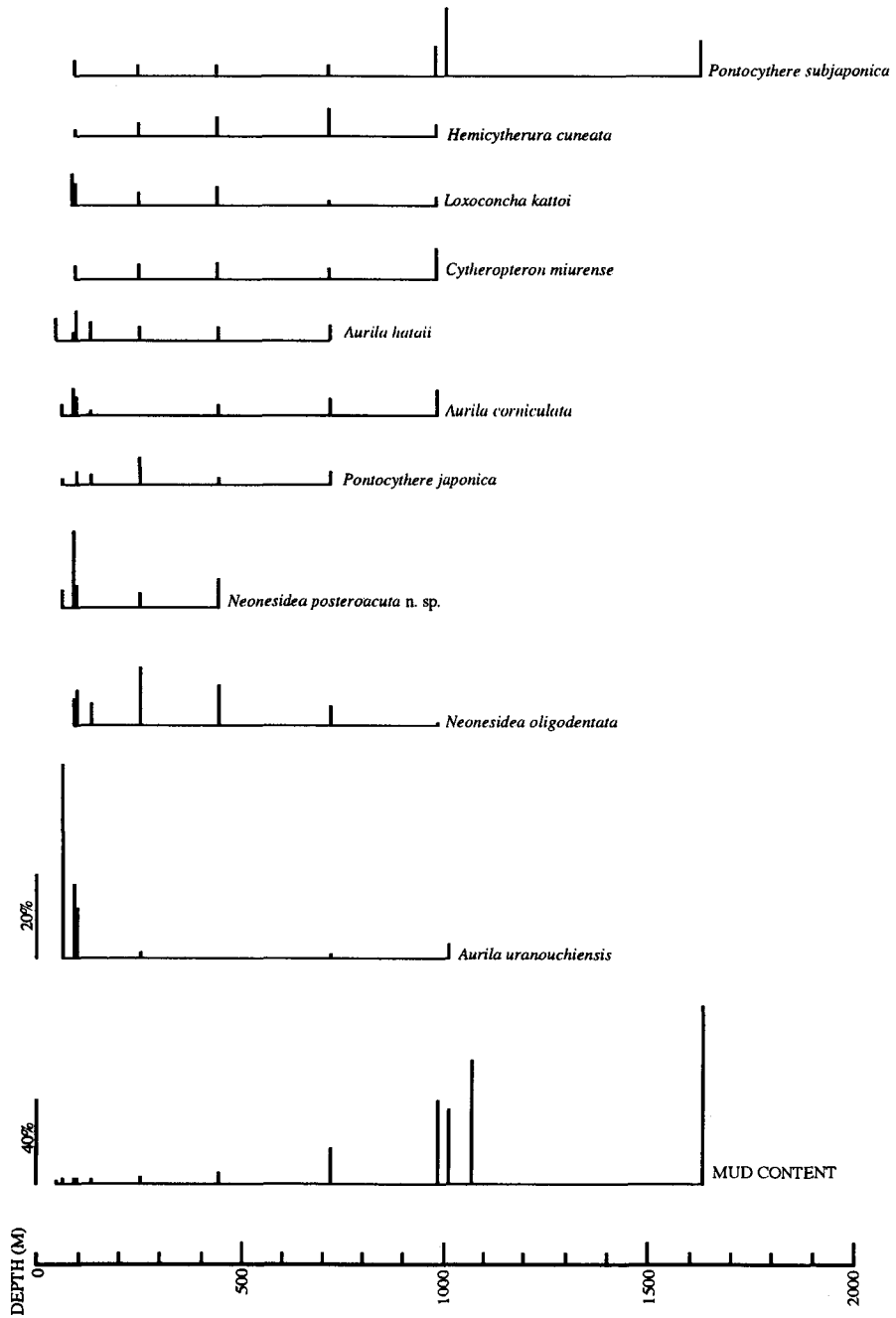


Fig. 10. Percent of mud content and the 10 most common species across depth profile in Tanega-shima area.

ing to 63 genera. In Kumano-nada the most abundant species is *Neonesidea oligodentata*, which accounts for about 8% of the fauna. This species is so far known as a phytal form living in the intertidal and upper sublittoral zones around Japan. In Kumano-nada its frequency decreases with increasing water depth, and disappears at 440 m.

The species composition of ostracode fauna in this area, as a whole, is very similar to that recognized in Suruga Bay (ZHOU, 1989MS), although some inner bay species that are common in Suruga Bay, such as *Spinileberis quadriaculeata*, *Nipponocythere bicarinata*, are absent here. Three recovered specimens of inner bay muddy bottom dwellers, namely *Pistocythereis bradyi* and *P. bradyformis*, are very poorly preserved. The occurrence of *Cytherella japonica* and *Triebelina schyroconcha*, which are found everywhere in the areas south of Kumano-nada but are absent in Suruga Bay, may be indicative of a biogeographic gradient between the two areas. Two typical cold-water species, *Finmarchinella japonica* and *Munseyella hatatensis*, were found very rarely in this area, with an upper depth limit (UDL) of 100 m and 670 m, respectively. These two species are fairly common in the intertidal and sublittoral zones along the Pacific coast of Northeast Japan, under the influence of the cold Oyashio current.

Many taxa which have been recorded living in the intertidal and/or upper sublittoral zone elsewhere in Japan were detected, although the shallowest samples from this area have a depth of 100 m. Some of these species have quite a large depth range, such as *Xestoleberis sagamiensis*, *X. hanaii*, *Cythere omotenipponica*, *Hemicytherura cuneata*, and *Aurila hataii*. It is difficult to establish vertical zonation due to the sparcity of samples, but it seems meaningful that many species have their lower depth limits (LDL) at 440 m and 797 m.

2) *Off the Tanabe Area.* A total of 1900 valves and 87 carapaces were picked from 9 samples in this area. Among them 1661 valves and 71 carapaces were assigned to 115 species belonging to 56 genera.

The fauna is characterized by the abundant occurrence of *Neonesidea oligodentata* and *Pontocythere subjaponica*, together accounting for about 15% of the total fauna. Here *Neonesidea oligodentata* is distributed at the depths of 44–228 m, with the peak of frequency at 102–133 m. *Pontocythere subjaponica* is a species commonly found from the sandy bottom of intertidal and upper sublittoral zones in Japan and its adjacent areas. Its cylindrical carapace shape suggests that it might be an interstitial inhabitant crawling between particles of sand. In this area it has a depth range of 44–503 m, with the peak of frequency at 176–309 m. The species composition in this area, as a whole, is closely similar to that in Kumano-nada, although there are two southern species, *Bythoceratina* aff. *robusta* and *Cytheropteron* sp. 2 which do not extend their distribution northward to Kumano-nada. One specimen of *Neocytheretta snellii* was found from a site at 133 m deep (Site 7) in this area. This is the first report of the genus from Japan, although in the seas around China it is common.

Most species in this area have a shorter depth range than in Kumano-nada. There appears to be a distributional boundary at about 300 m: many species have their LDL's here, and 6 species (*Amphileberis nipponica*, *Cluthia ishizakii*, *Heinzmalzina rhombiformis*, *Krithe surugensis*, *Pacambocythere reticulata*, *Paijenborchella iocosa*) have their UDL's at this depth.

3) *Tosa Bay Area*. A total of 2499 valves and 59 carapaces were extracted from 14 samples, and 2220 valves and 55 carapaces were classified into 120 species of 55 genera.

The fauna is predominated by *Pontocythere subjaponica* and *Aurila kiritsubo*, which in all account for 20% of the fauna. The abundance of *Pontocythere subjaponica* is reduced in deeper water, with the deepest occurrence at 460 m. *Aurila kiritsubo* has so far been reported living in the intertidal and upper sublittoral zones in Tateyama Bay (FRYDL, 1982) and off Cape Omaezaki (IKEYA et al., 1985). Its carapace has a flat "ventral plane", which is considered to be a morphology for adapting to epibenthic life (see KAMIYA, 1988, p. 308). Its frequency in this area decreases with the increase of water depth, with the LDL at 174 m. In this area, as compared with those in the other five areas studied, such inner-bay forms as *Pistocythereis bradyi*, *P. bradyformis*, *Nipponocythere bicarinata*, *Trachyleberis scabrocuneata* and *T. niitsumai* are rather common, reflecting the influence of coastal water.

Most ostracode species in Tosa Bay have a much smaller depth range than those in the other five areas. One hundred and nine species have depth ranges smaller than 200 m. Of the 32 species with a UDL at 26–27 m, 30 have their LDL at the depth above 100 or 200 m except for *Loxiconcha sinensis* and *Pontocythere subjaponica*, which are distributed as deeply as 400 m. Of the 58 species with UDL's at about 70 m, 36 have depth ranges smaller than 50 m. Only four species, *Amphileberis nipponica*, *Falsobuntonia taiwanica*, *Cytheropteron miurense* and *C. uchioi* have a range extending about 400 m depth. In the deep sea there are more species with larger depth ranges. Twenty-nine species have their LDL's at about 200 m, while there is a group of 7 species having their UDL's at about 450 m. This suggests the existence of a distributional boundary between the two depths.

4) *Bungo-suido Area*. A total of 1466 valves and 21 carapaces were picked from 10 samples, and 1330 valves and 21 carapaces were identified into 98 species representing 51 genera. The fauna in this area is characterized by the absence of bythocytherids except for the rare occurrence of *Bythoceratina cassidoidea*. *Pontocythere subjaponica*, the most dominant species in this area, accounts for 9% of the fauna in number of individuals. This species shows an increase in number of individuals with the deepening of water depth to 189 m, then it decreases drastically, disappearing at 535 m.

Species in this area have a depth range of about 200 m on the average, which is similar with that seen off Tanabe. Of the 57 species with UDL's at 79 m, which is the depth of the shallowest sample, 27 ones have their LDL's at 317 m. On the other hand, there is a group of 14 species with UDL's at 317 m. This indicates a boundary for the

vertical distribution of Ostracoda between 317 and 535 m.

5) *Hyuga-nada Area*. A total of 4159 valves and 118 carapaces were detected from 24 samples, and 3729 valves and 103 carapaces were assigned to 146 species belonging to 68 genera. The larger number of species from this area should be due to the larger number of samples used. The most abundant species is *Pontocythere subjaponica*, which accounts for 9% of the fauna in number of individuals. This species gradually decreases its abundance from a depth of 30 m to 286 m, then rapidly decreases and disappears at 785 m. Species composition in this area is similar to that in the northern neighboring Bungo-suido; however, some tropical forms appear, such as *Loxoconchella pulchra*, *Morkhovenia* sp., *Neobuntonia* sp., *Saida herrigi* and *Triebelina sertata*.

Most species in this area have a large depth range of over 200 m, a feature that is comparable with that of Kumano-nada. A boundary in distribution is recognizable at about 530 m, where 32 shallow water species have their LDL's, and 12 species, represented by *Krithe sawanensis*, *Cytheropteron tabukii*, *Loxoconcha parapontica* n. sp, show their UDL's.

6) *Off Tanega-shima*. From 13 samples a total of 1339 valves and 233 carapaces were obtained, of which 1048 valves and 207 carapaces were assigned to 125 species belonging to 54 genera.

Dominant species in this area are *Aurila uranouchiensis*, *Neonesidea oligodentata* and *N. posteroacuta* n. sp, which altogether account for about 17% of the fauna. The lower depth limit for the three species are 1016 m, 986 m and 444 m respectively. *Aurila uranouchiensis* is a phytal-inhabiting species, and has been so far reported from the *Zostera* beds at depths of 1–50 m from Aomori Bay, Tateyama Bay and Uranouchi Inlet (ISHIZAKI, 1968, 1971; FRYDL, 1982). *Neonesidea posteroacuta* n. sp. has a carapace design similar to *N. oligodentata*, and is undoubtedly a phytal species. On the whole, each of the three dominant species shows reduction of abundance with increasing water depth, although in a few deeper sites they are abundant.

When tracing the geographical change of Ostracoda southward within the study areas, I found that the fauna off Tanega-shima changes dramatically not only in species composition but also in abundance of many widely distributed species. The proportion of the following species markedly increases in this area: *Neonesidea posteroacuta* n. sp., *Aurila uranouchiensis*, *Pontocythere japonica*, *Schizocythere kishinouyei* subspecies. In contrast, such species as *Pontocythere subjaponica* and *Cytheropteron uchioi* are reduced there. Changes in carapace morphology have also been recognized in some species. For instance, *Cytheropteron miurense* from this area has distinctly shallower puncta on the carapace surface than from the northern areas. Contrary to expectation, some warm water forms such as *Abrocythereis*, *Cytherella*, *Cytherelloidea*, *Pacambocythere*, do not have increased populations in this area.

With respect to the vertical distribution of ostracode species off Tanega-shima, as a

whole, there are three groups of species that have lower depth limits (LDL) at 444 m, 723 m and 1000 m, respectively. Two distinct characteristic features in depth distribution are recognized in this area. The first is that most shallow water species have very large depth ranges of over 200 m. *Neonesidea oligodentata*, *Aurila corniculata*, *A. hataii* and many other species are known as intertidal to upper sublittoral inhabitants in other areas of Japan, whereas off Tanega-shima they are found from depths from shallower than 100 m to over 700 m. *Metacytheropteron ignobilis* and *Pontocythere subjaпонica* have an extremely large depth range of over 1000 m. The second characteristic is that a large number of species show a shift in distribution toward larger depths in this area. Typical examples of these species are listed in Table 2, comparing their depth ranges with those in other areas. They include both shallow sea taxa (*Xestoleberis*, *Callistocythere*, *Loxoconcha*, etc.) and deep sea taxa (e.g., *Kriithe*, *Parakriithe*).

Detailed division of the vertical zonation of ostracode assemblages is difficult in this study because of the sparsity of samples in each area. A few boundaries in vertical distribution, however, have been recognized for each area, as mentioned above, *i.e.*, 440 m (LDL) and 797 m (LDL) in Kumano-nada, 300 m (UDL and LDL) off Tanabe, 200–500 m (UDL and LDL) in Tosa Bay, 317–535 m (UDL and LDL) in Bungo-suido, and 535 m (UDL and LDL) in Hyuga-nada. Based on these results two vertical boundaries can be hypothesized, at 300–400 m, and another at about 800 m.

## 5. Ostracode taphonomy

Owing to their smallness, dead ostracode carapaces are easily transported together with sedimentary particles, and are abraded and dissolved. When investigating ostracodes from a surface sediment sample taken offshore, it is usually found that living individuals are very rare; most specimens are dead shells, which are the sum of accumulation for a long time, and may include both autochthonous and allochthonous individuals. Because ostracode specimens treated in this study are almost all dead shells, the problem of postmortem transportation cannot be ignored when considering the vertical distribution of the species.

Dead ostracodes can be transported down- or upslope by waves or currents. Based on distribution of both dead and living ostracodes, some workers have revealed the occurrence of upslope transportation, as well as downslope (e.g., ISHIZAKI and IRIZUKI, 1990). In this study upslope transportation is hardly detectable because the specimens are mostly dead shells; whereas downslope transportation is evident from the following three facts. First, as mentioned in the last chapter, many species that have been so far reported living in the intertidal and sublittoral zones, are found in this study at depths of several hundred meters. These species include the common elements in each area such as the phytal inhabitants *Neonesidea*, *Xestoleberis*, *Hemicytherura* and *Paradoxostoma*, and bot-



Table 2. Depth ranges of the representative species showing the shift of distribution toward the depth in the area off Tanega-shima. Abbreviations: TNS=Tanega-shima, HGN=Hyuga-nada, BGS=Bungo-suido, TSB=Tosa Bay, TNB=Tanabe, KMN=Kumano-nada. Data show depth ranges of species in meter. Depth range of samples in each area is given in parenthesis under the locality name.

	TNS (50-1631m)	HGN (21-902m)	BGS (79-1215m)	TSB (26-727m)	TNB (44-800m)	KMN (100-982m)
<i>Argilloecia hanaii</i> Ishizaki, 1981	254-723	47-785	79-535	106-430	102-309	100-982
<i>Aurila lunata</i> Frydl, 1982	254-986	54-535	79-317	67-162	44-228	100-440
<i>Bradleya albatrossia</i> Benson, 1972	444	128	189-908	430-628	228-497	186-797
<i>Bradleya japonica</i> Benson, 1972	444	81-256	79-317	67-174	75-309	100-670
<i>Bythoceratina angulata</i> Yajima, 1987	254-444			67-140	75-102	100
<i>Callistocythere asiatica</i> Zhao, 1984	254-444	21-535	79	67-76	75-133	100-440
<i>Callistocythere tateyamaensis</i> Frydl, 1982	723	42-140	123-189	26-174	133	100-670
<i>Cornucoquimba</i> sp.	723-986	47-158		67-76		
<i>Cythere omotenipponica</i> Hanai, 1959	444	42-54			44-228	100-797
<i>Cytherella leizhouensis</i> Gou, 1983	444	81-128			133-309	100-238
<i>Cytherelloidea munechikai</i> Ishizaki, 1968	723	30-360	79-189	26-162	102-228	100-238
<i>Cytherelloidea senkakuensis</i> Nohara, 1976	444	110-158	79-317	106-162	102-176	100-215
<i>Cytheropteron</i> ? <i>higashikawai</i> Ishizaki, 1981	723	110-535		106		100-238
<i>Cytheropteron rectocostum</i> n. sp.	1072	47-535	79-317	76-174	176-309	100-440
<i>Cytheropteron postornatum</i> Zhao, 1988	723-986	360-785	317-535		228	351
<i>Cytheropteron subuchioi</i> Zhao, 1988	254-444	47-535	79-317	67-174	102-228	100-670
<i>Cytheropteron uchioi</i> Hanai, 1957	254-444	54-535	79-908	67-460	133-503	100-797
<i>Eucytherura utsusemi</i> Yajima, 1982	723-986	100-256		76-174	75	440-670
<i>Falsobuntonia taiwanica</i> Malz, 1982	444	54-554		67-460	75-800	100-797
<i>Krithe hanaii</i> Ishizaki, 1983	1016	360-554	317	628		351-670
<i>Krithe surugensis</i> Zhou & Ikeya, 1992	1631	149-554		430-460	309	351-670
<i>Loxocoacha ikeyai</i> n. sp.	254	36-140	102-189	106-162	102-309	100
<i>Loxocoacha laeta</i> Ishizaki, 1968	444-723	47-100	79-317	67-76	75-102	100-238
<i>Loxocoacha modesta</i> Ishizaki, 1968	444	110		67	102	100
<i>Loxocoacha uranouchiensis</i> Ishizaki, 1968	444	42-256	79	140	176-228	
<i>Monoceratina sinensis</i> Zhao, 1988	444	110-158	189	117	75-228	100
<i>Neopellucistoma inflatum</i> Ikeya & Hanai, 1982	254-723	30-149	102	26-76	44-133	215
<i>Parakrithe subjaponica</i> n. sp.	723-986	360-785	317-535	174-628	503-800	351-797
<i>Parakritheella pseudadonta</i> (Hanai, 1959)	1016	42-535	189	26-162	44-228	100-440
<i>Phlyctocythere hamanensis</i> Ikeya & Hanai, 1982	723	54-785		67-174	133-238	100-238
<i>Proteoconcha tomokoae</i> (Ishizaki, 1968)	444	54-149	79	26-162		
<i>Semicytherura ensuensis</i> Ikeya & Hanai, 1982	986			67	44	100
<i>Semicytherura henryhowei</i> Hanai & Ikeya, 1977	723-986	61-535	79	26-67	44-309	100-440
<i>Sinoleberis tosaensis</i> (Ishizaki, 1968)	444	30-360	79-317	26-162		186
<i>Xestoleberis dentata</i> Schornikov, 1975	444	82-360	102	174	133-228	100-238
<i>Xestoleberis pararotunda</i> Hao, 1988	444-723	54-535	79	67	44-102	100

tom dwellers such as *Pontocythere*. The extraordinarily large depth ranges are unlikely to reflect the living distribution of ostracodes. Phytal species, in particular, can only live in the photic zone, where sea algae and seaweeds are growing. It is known that around Japan the photic zone reaches a depth of no more than 100 m. So shells found below 100 m cannot be *in situ*. Secondly, most abundant species have relatively large depth

ranges, whereas rare species usually have shorter ranges, a phenomenon that must be the result of the probability of random downslope transportation. Thirdly, the same species often shows quite different depth ranges among the areas studied. This may be the result of different magnitudes of transportation and different levels of hydraulic energy. In the Tanega-shima and Hyuga-nada areas, depth ranges are very long for most species, whereas in Tosa Bay, Bungo-suido and off Tanabe they are much shorter, with those in Kumano-nada intermediate (see ZHOU, 1995).

An abnormal distribution of some shallow-water species, such that the frequency peak is located in deeper water than the ordinary depth range, can be considered to be the result of downslope transportation. Such species include *Pontocythere subjaponica* and *Argilloecia hanaii* in Kumano-nada, *Neonesidea oligodentata* and *Pontocythere subjaponica* off Tanabe, *Pontocythere subjaponica* and *Loxococoncha sinensis* in Bungo-suido, and *Neonesidea oligodentata* and *Pontocythere subjaponica* off Tanega-shima (see Figs. 5–10).

Postmortem transportation also contributes to the condensation of ostracode individuals in sediments. In most samples with a high specimen density in Fig. 3, the majority of constituting species are those having been reported from intertidal or upper sublittoral zones, hence they should be considered not *in situ* but transported from shallow areas. For example, at least 39 of the 67 species from the site GH82-2, No. 24 in Kumano-nada (238 m deep, specimen density=458.3), are such intertidal or sublittoral forms, represented by *Neonesidea oligodentata*, *Argilloecia hanaii*, *Pontocythere subjaponica*, *Hemicytherura cuneata*, etc., that in all account for 27% of the individuals from that site.

The preservation states of ostracode specimens used in this study are variable, from fresh and translucent to opaque and encrusted. From my experience, living marine ostracode shells are all translucent and lustrous regardless of their colors (most taxa are colorless; some are brownish such as *Callistocythere*). This means that disarticulation, opaqueness and encrustation of shells are all the result of taphonomic process such as solution, oxidization, transportation and so on.

Among the 80 examined sites, there are 24 in which the ostracodes are overall poorly preserved, in which most individuals are opaque. Moreover, the extremely fragile, thin-shelled taxa, *Paradoxostoma*, *Sclerochilus*, *Propontocypris* and *Xiphichilus*, are all absent from them. The 24 sites are: No. 32, 33 and 48 in Kumano-nada; No. 10 and 11-1 off Tanabe; No. 2, 4, 33, 35 and 91 in Tosa Bay; No. 229, 238 and 246 in Bungo-suido; No. 275, 306, 311, 323, MZ-18, -19 and -20 in Hyuga-nada; No. 27, 41, 42, and YT-6 off Tanega-shima. These 24 sites have depths mostly deeper than 100 m, and a mud content mostly higher than 20%. In contrast to this, most sites with a low mud content have a better preservation state. For example, at depths of 50–444 m off Tanega-shima, where the mud content is lower than 5%, ostracode shells are overall well-preserved, and translucent shells account for the greater part. These facts suggest the correlation of preservation state to water depth and mud content, which is quantitatively

shown in Fig. 11.

In this study it is found that *translucency* and *lustrousness* are mutually related factors: translucent ostracode shells are always lustrous, while opaque ones have lost their luster. So using these two factors I was able to divide the ostracode shells into two categories, *i.e.*, “translucent” and “opaque”, in order to characterize the preservation states of Ostracoda. In the six areas studied the proportion of translucent shells among total population (PTS) changes from site to site, and it was correlated to water depth and mud content (MC) (Fig. 11). From Fig. 11 at least the following two trends can be observed. First, with an increase in water depth, PTS decreases on the whole, although it may show a wide variation at one particular depth. Second, PTS generally has an inverse correlation with MC; those sites with MC less than 10% mostly have PTS higher than 40%, while the sites showing PTS lower than 20% all have MC higher than 20%.

## 6. Ostracode zoogeography

### 6-1. Determination of the geographical distribution of the species

The distribution data of species obtained from the present study, together with those of previous studies on the Pacific side of Japan, permit me to propose a possible ostracode zoogeographical division along the Pacific coast of Japan. A list of previous studies is given in Table 3.

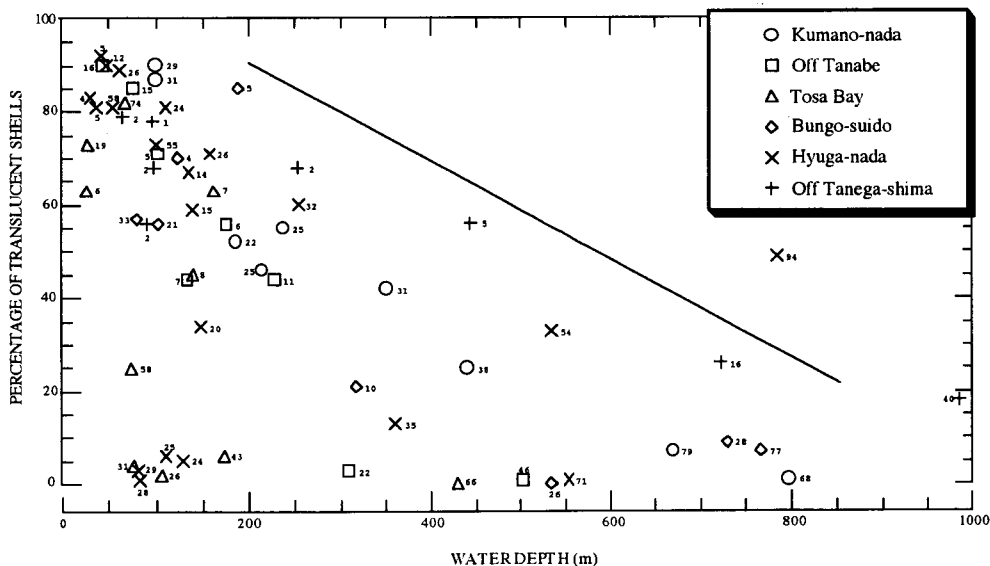


Fig. 11. Plot of percentage of translucent shells against water depth. Numerals beside plots show mud contents in percentage.

The areas of the present study are restricted to the region north of Tanega-shima. Information on ostracode faunas in the south-neighboring Okinawa Islands area is very important in clarifying the geographical range of some species. To date, however, there are only three published works on Recent ostracode assemblages in that area, which include TABUKI and NOHARA (1988, 1990) concerning the ecology of ostracodes in coral reefs, and RUAN and HAO (1988) on ostracode fauna in the Okinawa Trough, a deep-sea basin. The two works by NOHARA and TABUKI were aimed to clarify the ecology of Ostracoda in the moat of coral reef, and only about half of the species were identified and shown on species lists. As a result, many of the shallow water species there remain unknown. On the other hand, RUAN and HAO (1988) reported 367 species of 95 genera from a total 113 surface sediment and core samples from the Okinawa Trough. Their samples, although taken from the deep sea, contain a large number of intertidal and sublittoral species. Species described in their paper, together with those shown by TABUKI and NOHARA (1988, 1990), constitute the main part of our knowledge of ostracodes in the Okinawa area. In addition, I have identified a portion of the species from three samples collected from the deep-sea area off the main island Okinawa.

The six areas treated here, together with Suruga Bay (ZHOU, 1989MS), are all similar in topographic conditions, *i.e.*, located under open seas, or for the most part open seas, at water depths down to 1000 m. Therefore, the geographical distribution of most species between Suruga Bay and Tanega-shima can be traced reasonably well. In contrast, most of the above-mentioned previous studies in this region are restricted to waters shallower than 100 m, in embayments. Also, distribution of deep water species in

Table 3. Previous studies on Ostracoda in the Pacific side of Japan used for the discussion on geographical distribution of ostracode species.

Research area & environment	Author (s)	Scope of study
Uranouchi Bay, NE Japan; small inlet.	Ishizaki, 1968	Fauna
Aomori Bay, North Honshu; inner bay.	Ishizaki, 1971	Fauna
Tateyama Bay, SW Japan; inner bay.	Frydl, 1982	Fauna
Hamana-ko Lake, SW Japan; brackish-water area.	Ikeya & Hanai, 1982	Fauna
Cape Omaezaki, SW Japan; intertidal zone.	Ikeya et al., 1985	Fauna
Ise and Mikawa Bays, SW Japan; inner bay.	Bodergat & Ikeya, 1988	Fauna
Okinawa Trough; deep sea.	Ruan & Hao, 1988	Fauna
Off Sesoko Island, Okinawa; coral reef.	Tabuki & Nohara, 1988	Part of species
Sekisei-sho area, Okinawa; oral reef.	Tabuki & Nohara, 1990	Part of species
Coasts all around Japan.	Shirota, 1990 (MS)	Species of <i>Loxiconcha</i>
Sendai Bay, NE Japan; open bay.	Ikeya & Itoh, 1991	Fauna
Otsuchi Bay, NE Japan; inlet.	Ikeya et al., 1992	Fauna
Suruga Bay, SW Japan; open, deep bay.	Zhou, 1989 (MS)	Fauna
Seto Inland Sea.	Okubo, 1976-84	Part of species
Seto Inland Sea.	Schornikov, 1975	Part of species

Northeast Japan is unknown. For this reason, all the deep-water species, *i.e.*, those found below 100 m, which extend their distribution northward and reach Suruga Bay, were excluded from the analysis of geographical distribution.

Out of the 192 species identified, geographical distribution of 125 ones were tentatively determined. In addition, 10 species living in the north of Sendai Bay are also incorporated into the discussion of zoogeography. The geographical distributions of the 135 species are given in Table 4. In this table, data from Cape Omaezaki (IKEYA *et al.*, 1985) were combined with those of Suruga Bay; data of Ise and Mikawa Bays (BODERGAT and IKEYA, 1988) with those of Kumano-nada; and data of Uranouchi Bay (ISHIZAKI, 1968) with those of Tosa Bay because of their geographical adjacency. When determining the geographical distribution I assume that a given species occurs in all areas between its limits of range, because the distribution data are in most cases considered incomplete due to the sparsity of samples in each area. Vertical range is not considered. The termination of distribution in many species between Sendai Bay, Otsuchi Bay and Hokkaido may be due to the lack of data in those areas.

The depth ranges of each species south of Tateyama Bay, in Sendai Bay and in Otsuchi Bay, respectively, are given on the right side of Table 4, in order to compare the geographical change in bathymetrical distribution.

Table 4 can be summarized in Fig. 12, in which several discontinuities of geographic distribution in species are visually apparent. It should be kept in mind that, (i) the gap between Kumano-nada (KMN) and Hamana-ko Lake (HMN) is only an appearance, because the latter area is a brackish-water area, and its species composition is different from those in open sea areas; (ii) the marked discontinuity between Suruga Bay and Tateyama Bay cannot be true, because Tateyama Bay is a small inlet about 40 m deep, and only 83 shallow water and inner bay species have been found there. The nine principal distributional types are described below and shown in Fig. 12.

Type I. Species limited to south of Tanega-shima. This type includes 7 rare species, which are shown in Table 4 numbered from 1 to 7. The depth ranges of the species are not well known because of the paucity of their occurrence.

Among the 7 species, 5 have records of occurrence from areas south of Okinawa. They are: *Aponesidea tanegashimensis* n. sp., *Bradleya pitalia*, *Loxoconcha tumulosa*, *Paranesidea* sp. and *Phlyctocythere deviata*. (For details see taxonomic descriptions in part 8.)

Type II. Species distributed south of Hyuga-nada. Five species numbered from 8 to 12 in Table 4 are included in this group. They are rare in occurrence. The genera to which they belong are all typical warm water taxa, and their distribution can be traced to south of Okinawa. *Morkhovenia inconspicua* and *Neobuntonia* sp. have been reported from the coral reefs of the Ryukyu Islands (TABUKI and NOHARA, 1988; 1990). *Saida herrigi* has its Recent form in the South China Sea (HANAI *et al.*, 1980, p. 197). *Triebelina sertata* is known to have a wide circum-tropical distribution (MALZ and LORD,

Table 4. Geographic distributions of 135 ostracode species and their depth ranges in the Pacific side of Japan. Abbreviations: RUK=Ryukyu Islands, TNS=Tanega-shima, HGN=Hyuga-nada, BGS=Bungo-suido, TSB=Tosa Bay, TNB=Tanabe, KMN=

Species	Locality	RUK	TNS	HGN	BGS	TSB	TNB	KMN	HMN	SGB	TYB	SDB	OTB	HKD	Depth range (m)		
															South of TYB	SDB	OTB
1 <i>Bradleya pitaita</i>		o	o												1 - 723		
2 <i>Eucythere</i> sp.		o	o												254 - 723		
3 <i>Keijcyoidea</i> sp.		o	o												64		
4 <i>Loxococoncha tumulosa</i>		o	o												96 - 704		
5 <i>Aponesidea tanegashimensis</i> n. sp.		o	o												90 - 254		
6 <i>Paranesidea</i> sp.		o	o												50 - 723		
7 <i>Phlyocythere devitata</i>		o	o												723		
8 <i>Loxococonchella pulchra</i>		o	o	o											256		
9 <i>Markhovenia inconspicua</i>		o	o	o											1 - 1016		
10 <i>Neobuntonia</i> sp.		o	o	o											3 - 723		
11 <i>Saida herrigi</i>		o	o	o											135 - 986		
12 <i>Triebelina sertata</i>		o	o	o											2 - 723		
13 <i>Bythoceratina cassidoidea</i>		o	o	o	o	o									42 - 444		
14 <i>Celtia japonica</i>		o	o	o	o	o									61 - 444		
15 <i>Saida</i> sp.		o	o	o	o	o									158 - 986		
16 <i>Coquimba</i> sp.		o	o	o	o	o	o								79 - 986		
17 <i>Bythoceratina</i> aff. <i>robusta</i>		o	o	o	o	o	o	o							61 - 444		
18 <i>Cytheropteron</i> sp. 2		o	o	o	o	o	o	o							96 - 986		
19 <i>Cytherella leizhouensis</i>		o	o	o	o	o	o	o	o						79 - 444		
20 <i>Kriihe hanaii</i>		o	o	o	o	o	o	o	o						317 - 1016		
21 <i>Xestoleberis dentata</i>		o	o	o	o	o	o	o	o						T - 444		
22 <i>Abrocythereis guangdongensis</i>		o	o	o	o	o	o	o	o	o					20 - 535		
23 <i>Bradleya japonica</i>		o	o	o	o	o	o	o	o	o					22 - 1330		
24 <i>Bythoceratina angulata</i>		o	o	o	o	o	o	o	o	o					67 - 444		
25 <i>Chejudocythere higashikawai</i>		o	o	o	o	o	o	o	o	o					67 - 785		
26 <i>Cletocythereis rastromarginata</i>		o	o	o	o	o	o	o	o	o					25 - 320		
27 <i>Cytherelloidea munekikai</i>		o	o	o	o	o	o	o	o	o					3 - 723		
28 <i>Cytherelloidea senkakuensis</i>		o	o	o	o	o	o	o	o	o					70 - 444		
29 <i>Falsobuntonia taiwanica</i>		o	o	o	o	o	o	o	o	o					40 - 797		
30 <i>Loxococoncha zamia</i>		o	o	o	o	o	o	o	o	o					16 - 1016		
31 <i>Neonesidea posteroacuta</i> n. sp.		o	o	o	o	o	o	o	o	o					44 - 444		
32 <i>Paijenborchella iocosa</i>		o	o	o	o	o	o	o	o	o					76 - 595		
33 <i>Sclerochilus sinensis</i>		o	o	o	o	o	o	o	o	o					62 - 480		
34 <i>Semicytherura minaminipponica</i>		o	o	o	o	o	o	o	o	o					98 - 986		
35 <i>Sinoleberis tosnensis</i>		o	o	o	o	o	o	o	o	o					2 - 444		
36 <i>Xestoleberis pararotunda</i>		o	o	o	o	o	o	o	o	o					T - 723		
37 <i>Callistocythere tateyamaensis</i>		o	o	o	o	o	o	o	o	o	o				20 - 723		
38 <i>Cytheropteron uchioi</i>		o	o	o	o	o	o	o	o	o					30 - 986		
39 <i>Hanaiborchella triangularis</i>		o	o	o	o	o	o	o	o	o					6 - 798		
40 <i>Paracytheridea neolongicaudata</i>		o	o	o	o	o	o	o	o	o					T - 986		
41 <i>Pontocythere japonica</i>		o	o	o	o	o	o	o	o	o					T - 986		
42 <i>Pontocythere minuta</i>		o	o	o	o	o	o	o	o	o					T - 797		
43 <i>Loxococoncha prolaeta</i> n. sp.		o	o	o	o	o	o	o	o	o					42 - 723		
44 <i>Loxococoncha ikeyai</i> n. sp.		o	o	o	o	o	o	o	o	o					36 - 254		
45 <i>Aurila</i> sp. 1		o	o	o	o	o	o	o	o	o					54 - 723		
46 <i>Cytheropteron subuchioi</i>		o	o	o	o	o	o	o	o	o					47 - 723		
47 <i>Monoceratina sinensis</i>		o	o	o	o	o	o	o	o	o					70 - 444		
48 <i>Loxococoncha modesta</i>		o	o	o	o	o	o	o	o	o					7 - 444		
49 <i>Neopellucistoma inflatum</i>		o	o	o	o	o	o	o	o	o					1 - 723		
50 <i>Proteoconcha tomokoae</i>		o	o	o	o	o	o	o	o	o					1 - 444		
51 <i>Xestoleberis suetsumuhana</i>		o	o	o	o	o	o	o	o	o					44 - 785		
52 <i>Callistocythere hayamensis</i>		o	o	o	o	o	o	o	o	o	o				15 - 723		
53 <i>Pseudaurila japonica</i>		o	o	o	o	o	o	o	o	o					T - 723		
54 <i>Bythoceratina sutjaponica</i> n. sp.		o	o	o	o	o	o	o	o	o					27 - 228		
55 <i>Eucytherura utusemi</i>		o	o	o	o	o	o	o	o	o					75 - 986		
56 <i>Pacamocythere</i> sp.		o	o	o	o	o	o	o	o	o					81 - 360		
57 <i>Acanthocythereis munekikai</i>		o	o	o	o	o	o	o	o	o					81 - 730		
58 <i>Acinocythereis kisarazuensis</i>		o	o	o	o	o	o	o	o	o					22 - 317		
59 <i>Heinzmalzina rhombiformis</i>		o	o	o	o	o	o	o	o	o					252 - 797		
60 <i>Hirsutocythere hanaii</i>		o	o	o	o	o	o	o	o	o					22 - 908		
61 <i>Loxococoncha sinensis</i>		o	o	o	o	o	o	o	o	o					27 - 7948		
62 <i>Munseyella oborozukiyo</i>		o	o	o	o	o	o	o	o	o					30 - 797		
63 <i>Neocythereideis punctata</i>		o	o	o	o	o	o	o	o	o					3 - 535		
64 <i>Pseudopsammocythere tokyoensis</i>		o	o	o	o	o	o	o	o	o					47 - 320		
65 <i>Kobayashiina hyalinosa</i>		o	o	o	o	o	o	o	o	o	o				8 - 625		
66 <i>Ambtonia obai</i>		o	o	o	o	o	o	o	o	o	o	o			67 - 317	60 - 95	

Kumano-nada, HMN=Hamana-ko Lake, SGB=Suruga Bay, TYB=Tateyama Bay, SDB=Sendai Bay, OTB=Otsuchi Bay, HKD=Hokkaido, T=intertidal zone. "O" represents recorded occurrence, and "o" potential occurrence.

Species	Locality													Depth range (m)		
	RUK	TNS	HGN	BGS	TSB	TNB	KMN	HMN	SGB	TYB	SDB	OTB	HKD	South of TYB	SDB	OTB
67) <i>Loxococoncha hanachirusato</i>			O	o	O	o	O	o	O	o	O			47 - 186	10 - 20	
68) <i>Nipponocythere obesa</i>			O	O	O	O	O	o	O	o	O			54 - 351	15 - 95	
69) <i>Loxocorniculum miusense</i>			O	o	o	o	O	o	O	O	o			T - 370		
70) <i>Munseyella haiatensis</i>			O	O	O	o	O	o	o	o	O			174 - 797	T - 95	10 - 90
71) <i>Paradoxostoma sohni</i>			O	O	o	O	o	O	o	o	O			T - 215	T - 30	
72) <i>Aurila haiati</i>			O	O	O	O	O	O	O	O	O			T - 797	T - 35	25 - 80
73) <i>Semicytherura enshuensis</i>			O	o	o	O	O	O	O	O	O			2 - 986	T - 27	25 - 30
74) <i>Aurila kiritsubo</i>			O	O	O	O	O	O	o	O	O			T - 797	T - 70	20 - 90
75) <i>Phlyctocythere</i> sp.				O	o	O								67 - 256		
76) <i>Finmarchinella japonica</i>					O	O	O	o	O	o	O			67 - 797	10 - 30	10 - 90
77) <i>Munseyella chinzeii</i> n. sp.					O	O		o	o	o	O			75 - 797	70 - 110	
78) <i>Baffinicythere</i> sp.											O	O	O	65-105	30-90	
79) <i>Cythere uranipponica</i>											O	O	O	T		
80) <i>Cytheropteron ? kiuzatoi</i>											O	O	o	10-45	20-75	
81) <i>Cytheropteron sawanense</i>											O	O	o	T-105	10-90	
82) <i>Finmarchinella uranipponica</i>											O	O	o	T-43	10-80	
83) <i>Hemicythere ? mii</i>											O	O	o	T		
84) <i>Hemicythere cf. orientalis</i>											O	O	O	10-70		
85) <i>Loxococoncha subkotorajorma</i>											O	O	O	T-95		
86) <i>Munseyella japonica</i>											O	O	o	T-30	90	
87) <i>Semicytherura sabula</i>											O	O	o	10 - 30		
88) <i>Aurila uranouchiensis</i>			O	O	O	O	O	O	O	O	O			T - 2000	42	
89) <i>Clithrocytheridea japonica</i>			O	O	o	o	O	o	o	o	O			3 - 723	T - 13	
90) <i>Coquimba ishizaki</i>			O	O	O	O	O	O	o	O	O			T - 444	T - 35	
91) <i>Callistocythere japonica</i>			O	O	O	O	O	O	o	O	O			T - 785	10 - 33	
92) <i>Cythere omotenipponica</i>			O	O	o	O	O	O	O	O	O			T - 986	T - 78	
93) <i>Paracytheridea bosoenis</i>			O	o	o	o	O	O	O	O	O			T - 986	T - 95	
94) <i>Amphileberis nipponica</i>			O	o	O	O	O	O	o	O	O			20 - 918	80 - 95	20 - 90
95) <i>Argilloecia hanaii</i>			O	O	O	O	O	O	o	O	o			37 - 982		40 - 90
96) <i>Argilloecia lunata</i>			O	O	O	O	O	O	o	O	o			T - 986		T - 90
97) <i>Bythoceratina orientalis</i>			O	O	o	o	O	o	O	o	o			44 - 133		
98) <i>Callistocythere alata</i>			O	o	O	O	O	O	O	O	O			T - 535		10 - 50
99) <i>Callistocythere asiatica</i>			O	O	O	O	O	O	o	O	o			21 - 535		20 - 80
100) <i>Cytheropteron hanaii</i>			O	o	o	o	O	O	o	O	o			95 - 625		82 - 90
101) <i>Cytheropteron higashikawai</i>			O	O	O	o	O	o	O	o	O			22 - 723		40 - 73
102) <i>Cytheropteron miurense</i>			O	O	O	O	O	O	o	O	O			T - 986	T - 15	30 - 90
103) <i>Cornucoquimba tosaensis</i>			O	o	O	O	O	O	o	O	o			T - 986		10 - 90
104) <i>Loxococoncha japonica</i>			O	O	O	O	O	O	O	O	O			T - 723	T - 30	10 - 90
105) <i>Loxococoncha uranouchiensis</i>			O	O	O	O	O	o	O	O	O			T - 470	T - 42	10 - 90
106) <i>Nipponocythere bicarinata</i>			O	o	O	O	O	O	o	O	O			4 - 650	3.5 - 35	10 - 90
107) <i>Paracytheridea diadema</i>			O	O	O	o	O	o	O	o	o			75 - 1016		10 - 90
108) <i>Parakithella pseudanomia</i>			O	O	O	O	O	O	o	O	o			T - 1016		10 - 42
109) <i>Phlyctocythere hamanensis</i>			O	O	o	O	O	O	O	o	o			T - 723		30 - 80
110) <i>Pistocythereis bradyformis</i>			O	o	O	O	O	O	O	O	O			2 - 450	2 - 65	10 - 75
111) <i>Pistocythereis bradyi</i>			O	o	O	O	O	O	O	O	O			2 - 723	2 - 30	10 - 33
112) <i>Pontocythere miurenis</i>			O	O	O	O	O	O	O	O	O			T - 1016	10	
113) <i>Pontocythere subjaponica</i>			O	O	O	O	O	O	O	O	O			T - 1631	T - 42	10 - 73
114) <i>Semicytherura hanaii</i>			O	o	O	o	o	O	o	O	o			100 - 590		75 - 90
115) <i>Semicytherura henryhowei</i>			O	O	O	O	O	O	O	O	O			T - 986	T - 38	10 - 78
116) <i>Semicytherura miurenis</i>			O	o	O	o	O	o	O	o	O			1 - 440	T - 55	10 - 90
117) <i>Semicytherura wakamurasaki</i>			O	O	O	O	O	O	o	O	O			T - 505	T - 30	10 - 90
118) <i>Semicytherura yojimae</i>			O	o	O	o	o	O	o	O	o			30 - 186	10 - 78	20 - 60
119) <i>Aurila corniculata</i>			O	O	O	O	O	O	O	O	O			T - 986	T - 40	T - 90
120) <i>Bythocythere maisakensis</i>			O	o	O	o	O	o	O	o	O			T - 158		42 - 50
121) <i>Bythoceratina hanaii</i>			O	O	o	O	O	O	O	O	O			T - 444		25 - 50
122) <i>Hemicytherura cuneata</i>			O	O	O	O	O	O	O	O	O			T - 986	T - 70	25 - 90
123) <i>Hemicytherura kajiyamai</i>			O	O	O	O	O	O	o	O	O			T - 986	T - 20	25 - 90
124) <i>Krihe sawinensis</i>			O	O	O	O	O	O	o	O	o			120 - 1631		
125) <i>Loxococoncha bispinosa</i>			O	o	o	O	o	o	o	O	o			T - 76		
126) <i>Loxococoncha kaihoi</i>			O	O	O	O	O	O	o	O	O			T - 986	T - 13	
127) <i>Loxococoncha laeta</i>			O	O	O	O	O	O	O	O	O			T - 723	5 - 13	
128) <i>Loxococoncha optima</i>			O	O	O	O	O	O	O	O	O			T - 723		10 - 90
129) <i>Neonesidea oligodentata</i>			O	O	O	O	O	O	O	O	O			T - 986	T - 70	T - 90
130) <i>Schizocythere kishinouyei</i>			O	O	O	O	O	O	O	O	O			T - 723	T - 95	10 - 90
131) <i>Spinileberis quadriculeata</i>			O	o	O	O	O	O	O	O	O			T - 315	1 - 30	10 - 60
132) <i>Trachyleberis niitsumai</i>			O	O	O	O	O	O	O	O	O			1-986	10 - 70	
133) <i>Trachyleberis scabrocuneata</i>			O	O	O	O	O	O	O	O	O			2-723	10 - 70	10 - 50
134) <i>Xestoleberis hanaii</i>			O	O	O	O	O	O	O	O	O			T - 970	T - 95	T - 90
135) <i>Xestoleberis sagamiensis</i>			O	O	O	O	O	O	O	O	O			3 - 797	T - 43	T - 90

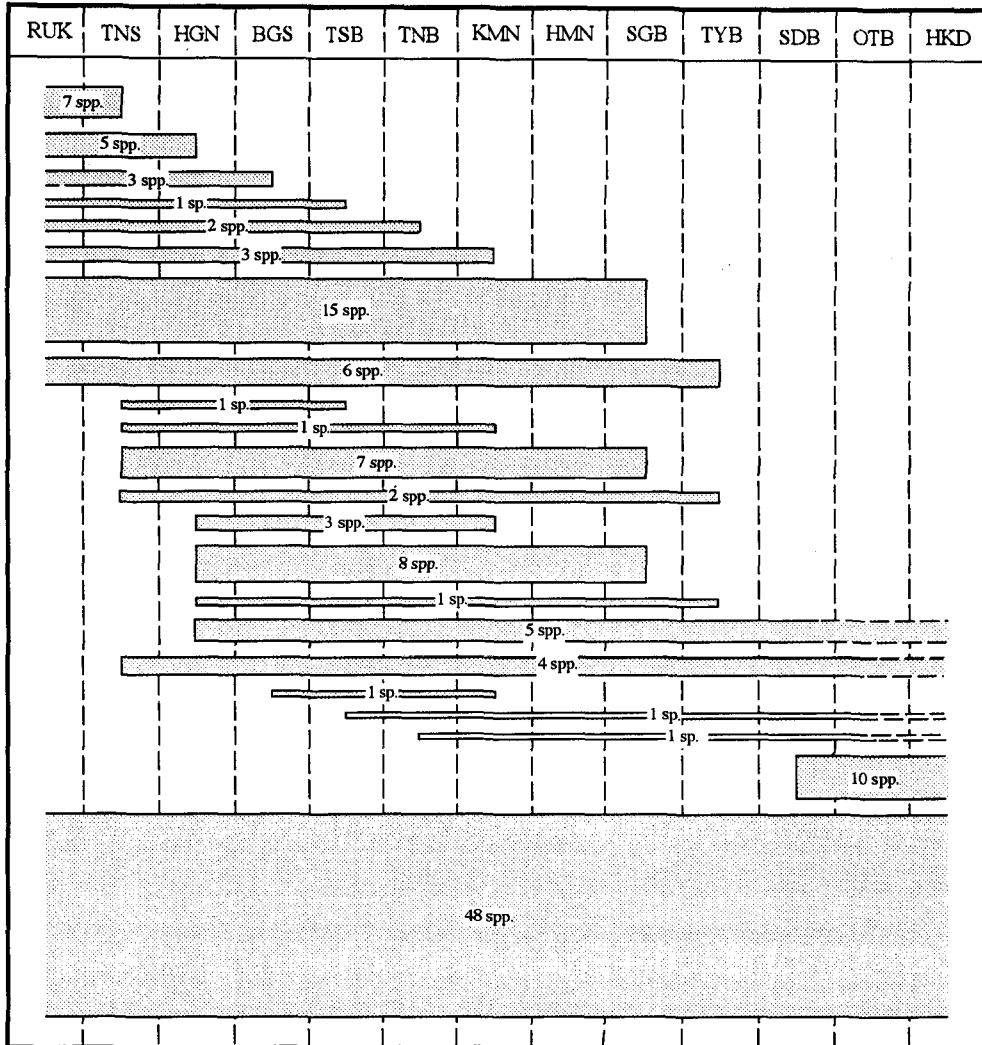


Fig. 12. Summary of geographical distribution of the 135 species shown in Table 4. Abbreviations used are the same with those in Table 4.

1988). All five species have also been recovered from off the main island of Okinawa.

Type III. Species living south of Suruga Bay. This type is composed of 15 species numbered 22–36 in Table 4. One species having a UDL in the intertidal zone (*Cytherelliodea mumechikai*), and 4 species having UDL's in the upper sublittoral zone (*Abrocythereis guangdongensis*, *Cletocythereis rastromarginata*, *Loxoconcha zamia* and *Bradleya japonica*) are included. Their absence in Tateyama Bay may reflect the environmental gra-



dient between Suruga Bay and Tateyama Bay.

Type IV. Species living south of Tateyama Bay. There are 6 species included in this type, numbered 37–42 in Table 4. Their upper depth limits are restricted to the intertidal and upper sublittoral zones.

Type V. Species distributed between Tanega-shima and Suruga Bay. It includes 7 species, numbered 45–51 in Table 4.

Type VI. Distribution between Hyuga-nada and Suruga Bay. It is composed of 8 species, numbered 57–64 in Table 4.

Type VII. Distribution north of Tanega-shima into northeast Japan. This type is composed of 4 species, numbered 71–74 in Table 4.

Type VIII. Species distributed north of Sendai Bay. Ten species are included in this type, numbered 78–87 in Table 4.

Type IX. They are distributed from Hokkaido or north Honshu to the Okinawa Islands. Forty-eight species with a broad distributional range are included in this type, numbered from 88 to 135 in Table 4, of which 30 species have a known UDL in the intertidal zone. This type, together with Type VII, are so-called “Japonic elements” (*e.g.*, HORIKOSHI, 1985). In spite of their wide geographical distribution, none of them shifts to deeper water in warm Southwest Japan.

## 6-2. Zoogeographical change of ostracode fauna

Based on the geographical distribution of species shown in Fig. 12, two distinct discontinuities in ostracode distribution are recognizable along the Pacific coast of Japan. The most distinct one is located in the area between Suruga Bay and Sendai Bay, where 49 out of the 135 species have their limit of distribution. The other discontinuity is located between Tanega-shima and Hyuga-nada, where the distribution of 33 species ends.

This result is consistent with the division of marine climatic zones around Japan based on the distribution of other benthos and some plankton (*see* CHINZEI, 1988). The discontinuity between Sendai Bay and Suruga Bay coincides with the boundary of the warm temperate and subtropical zones, which represents the front of the warm Kuroshio, located at about 36°N. The discontinuity between Hyuga-nada and Tanega-shima corresponds to the boundary of the subtropical and tropical zones. Therefore the species of Type I and II may represent tropical elements, species of Type V and VI are regarded to be subtropical elements, and those of Type VIII are typical warm temperate elements.

To express the shift of species composition with geographical change as shown in Fig. 12, the term *biogeographical gradient* is defined in the following way.

Suppose there are two faunas in neighboring areas A and B, with a total number of  $N$  species whose geographical distributions are already known. There are  $n_1$  species distributed in the direction of AB, having their limit at A, and  $n_2$  species distributed in the direction of BA, having their limit at B. The sum of  $n_1$  and  $n_2$  would represent the dif-

ference in species composition between the two faunas, and is defined here as the gap,  $G$ , between A and B,

$$G = n_1 + n_2$$

The proportion of  $G$  to  $N$  is defined here as the slope of the gap,  $S_g$ ,

$$S_g = G/N \quad (0 \leq S_g \leq 1)$$

The larger the value the more the species not common between the two areas.

If distance between the two areas is  $D$ , then  $S_g/D$  would represent the slope of change of  $S_g$ , or the *biogeographical gradient*.

The values of  $G$ ,  $S_g$  and  $D$  for each two neighboring ostracode faunas between Sendai Bay and Tanega-shima were calculated based on the results in Fig. 12, and are listed in Table 5. The biogeographic gradient between Tanega-shima and Sendai Bay is illustrated graphically in Fig. 13. It is apparent that the gradient is greatest between Sendai Bay and Suruga Bay, and between Hyuga-nada and Tanega-shima. From Suruga Bay to Hyuga-nada it changes gently.

The mean annual surface water temperature of each area is also given in Fig. 13. The change of the biogeographical gradients is coincident with the change of surface water temperature. The temperature that separates temperate and subtropical species (*i.e.*, the value between Suruga Bay and Sendai Bay) is between 15 and 20°C, and the temperature at the subtropical/tropical boundary is around 23–24°C.

How do the species compositions shift around the above two zoogeographical boundaries? Unfortunately the boundary between Sendai Bay and Suruga Bay is not known in detail because of the lack of data. I investigated the shift between the tropical and subtropical regions located south of Tanega-shima to north of Hyuga-nada by dividing the two areas into five subareas as discussed below in detail. The conclusion is that the shift is probably gradual, although it is quite sharp. Fig. 14 shows the details of the shift. Stepwise change of faunal composition is seen in this figure; however, as I have no information between these subareas, the steps may simply be an artifact. It is interesting that the range of distribution in each species is quite distinct, and ends in a certain area abruptly without reducing its abundance in the area peripheral to the center of its distribution.

The sampling localities in the Hyuga-nada area were subdivided into northern, cen-

Table 5. Values of  $G$ ,  $N$ ,  $S_g$  and  $D$  (see the text) between each two neighbouring areas. Abbreviations used are the same with those in Table 4.

	TNS & HGN	HGN & BGS	BGS & TSB	TSB & TNB	TNB & KMN	KMN & SGB	SGB & SDB
$G$	24	6	4	3	2	8	49
$N$	122	116	112	110	108	106	97
$S_g (=G/N)$	0.2	0.05	0.04	0.03	0.02	0.08	0.51
$D$ (km)	170	100	120	180	120	190	420

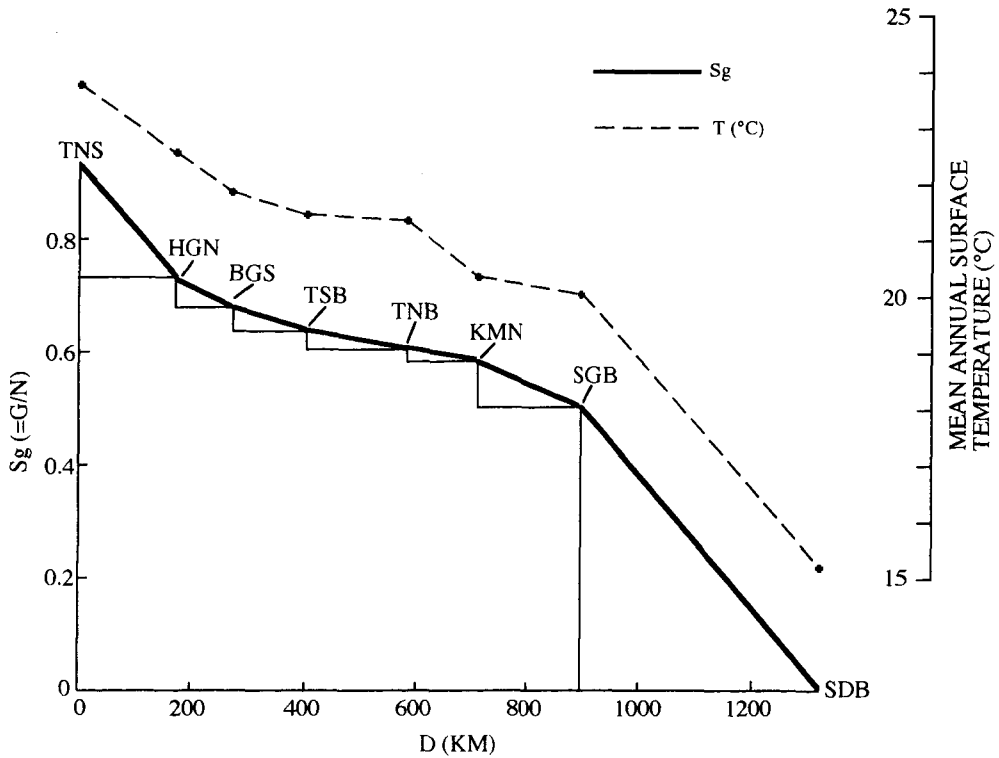


Fig. 13. Biogeographical gradients of Ostracode fauna and the average water temperatures along the Pacific coast of Japan. Data of surface water temperature are from Japan Oceanographic Data Center (1978). Abbreviations used are the same with those in Table 4.

tral and southern parts. Distributions of 22 species that have either southern or northern limits of distribution in this area are illustrated in Fig. 14. All five species that are distributed south of Hyuga-nada have their limit at its southern part. The 17 species that are distributed north of Hyuga-nada break into two groups, with *Munseyella hata-tatensis* as the lone exception: 10 species with their southern limit at the southern part, and 6 at the central part. It is obvious that there is a higher gradient between the central and the southern parts. This should be true because, (i) the depth ranges of the three sample series are overlapping with each other (Fig. 15), therefore the absence of a species in a certain part may not be due to the difference in the depth range of samples between the three parts; (ii) in most cases, the absence may not be accidental, because most species occur continuously within its distribution range, except for *Loxocorniculum mutsuense*, *Ambtonia obai*, *Pseudopsammocythere tokyoensis* and *Loxoconcha hanachirusato*.

The sampling localities in the Tanega-shima area were subdivided into eastern and

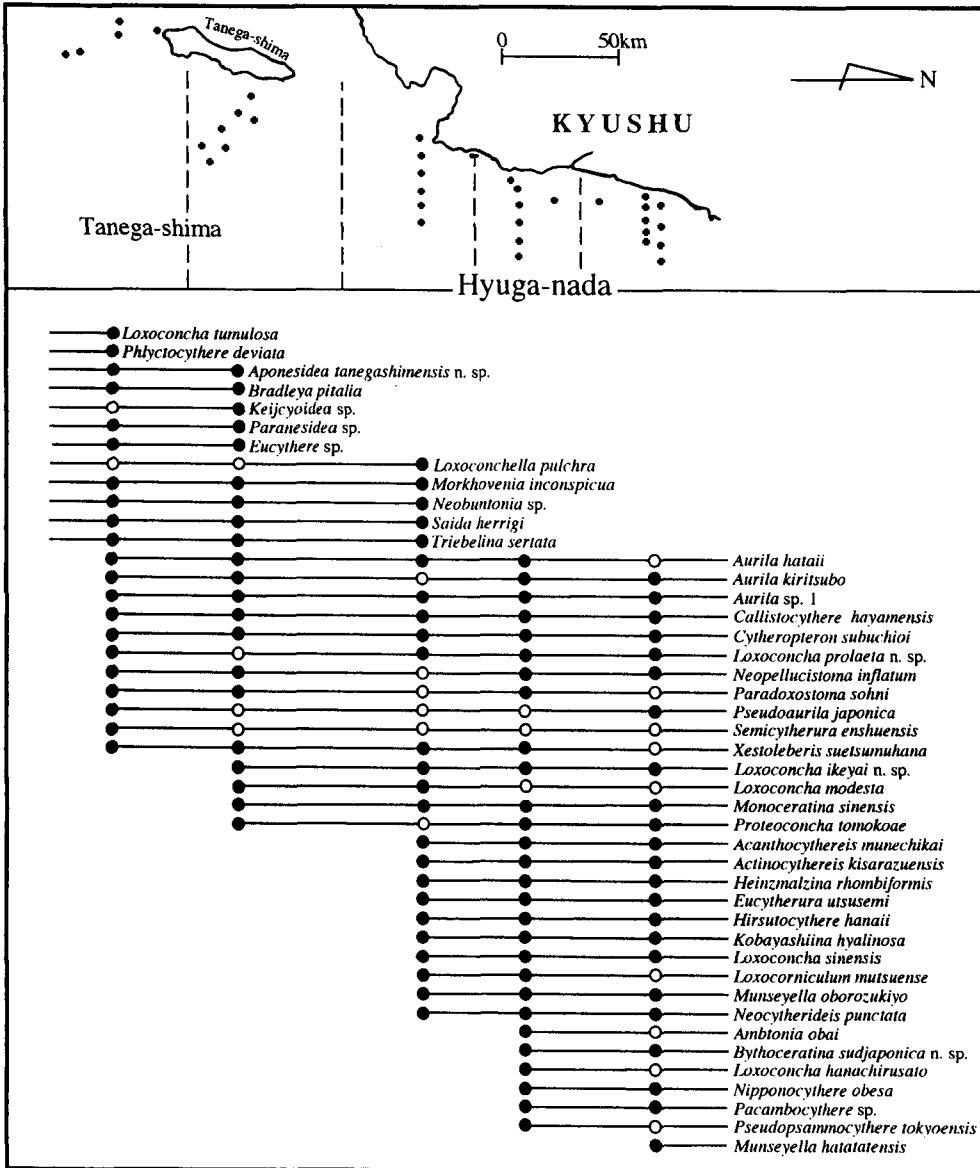


Fig. 14. Distribution of ostracode species around the south of Tanega-shima to the north of Hyuga-nada, which have either northern or southern limit in this area. Solid circle represents recorded occurrence, and white circle potential occurrence.

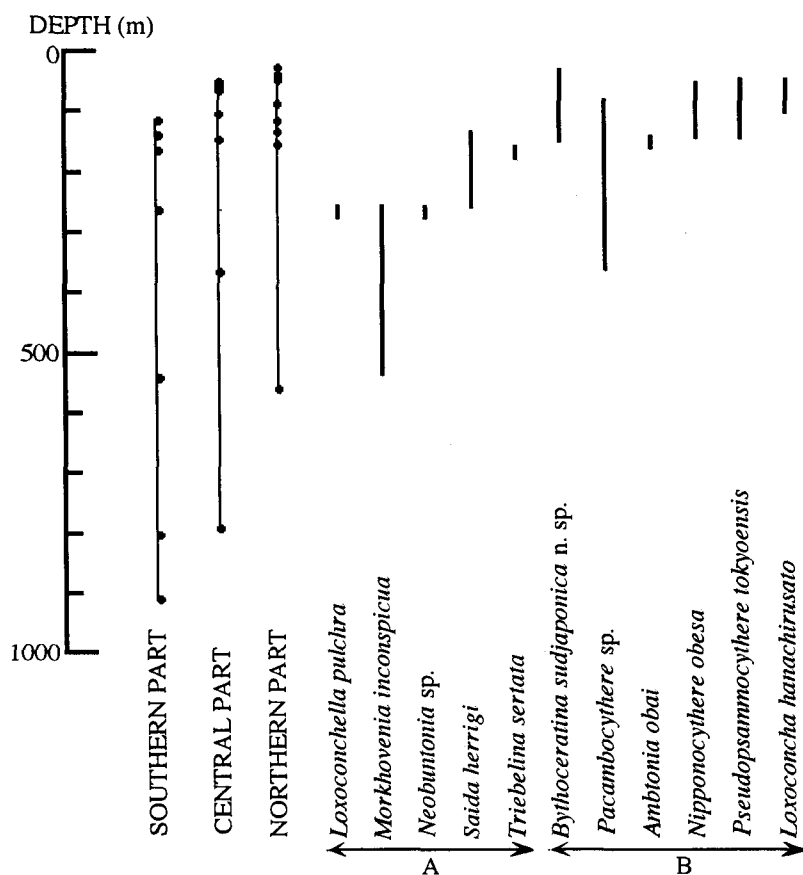


Fig. 15. Sampling depths (dark circles) in three parts of Hyuga-nada, and depth ranges of the species which have a northern distributional limit in the southern part (A), or have a southern limit in the central part (B) of this area.

southern parts. Distributions of 7 species having a northern limit in this area, and 15 species having a southern limit here, are shown in Fig. 14. Among the former species, *Loxoconcha tumulosa* has been found commonly in the three supplementary samples from Okinawa, and is obviously a tropical form. Off Tanega-shima, three individuals of this species were found in the southern part, while it is absent in the 8 samples from the eastern part. *Phlyctocythere deviata* is a species described from the Okinawa Trough (RUAN and HAO, 1988); off Tanega-shima one valve was found from the southern part. For some species, the absence in one part might be accidental because of their low frequency in the Tanega-shima area. Nevertheless, it seems true that there exists a gradient of faunal distribution between the eastern and southern part.

It was expected that a species will be reduced in its frequency of occurrence when

approaching its geographical boundary of distribution. The result of this study, however, does not support this assumption. Among the above 29 species which have a northern or southern limit around Hyuga-nada and Tanega-shima, neither rare ones like *Bradleya pitalia* and *Neobuntonia* sp. nor rather common ones such as *Acanthocythereis munechikai* and *Hirsutocythere hanaii* are significantly reduced in frequency.

### 6-3. Comparison with other areas

Faunal composition in the region studied was compared with those in the East China Sea and off Shimane Peninsula, where deep-water ostracode faunas have been investigated.

The Recent ostracode fauna off the Shimane Peninsula, Japan Sea was investigated by IKEYA and SUZUKI (1992). From 80 samples distributed from 50 m to over 1000 m depth, they recovered 225 species belonging to 82 genera, including 9 indeterminable species. Of the 216 identified species, 79 (in 41 genera) are common with those in the areas studied here, the Pacific coast of SW Japan.

A description of Recent ostracodes in the East China Sea was made by ZHAO (1988). He described a total of 178 species representing 82 genera, which were obtained from 180 surface sediment samples from estuaries to several hundred meters depth in the Okimawa Trough. The samples were from within the latitudes 26–34°N and west of longitude 129°E. There are 66 species among 43 genera in common with those of SW Japan. On the other hand, the number of common species between the East China Sea and off the Shimane Peninsula is only 48 in 39 genera.

The Jaccard similarity coefficient has been used here to compare the faunas in the three areas. This coefficient is the most widely used in ecological, biogeographical and biostratigraphical works. It is given by the following equation;

$$S_j = C / (N_1 + N_2 - C)$$

Where C is the number of objects present in both sets being compared, and  $N_1$  and  $N_2$  are the total number of objects present in each of the two sets individually. The values of Jaccard coefficient in regard to both species and genera between each two of the three areas were calculated, and the result is shown in Fig. 16. Based on  $S_j$  values, the ostracode fauna in SW Japan has nearly equal similarity with those of the other two areas; faunas off the Shimane Peninsula and the East China Sea, however, are less similar to each other. This difference is consistent with the relatively long distance between the East China Sea and the area off the Shimane Peninsula. At a generic level, the fauna in SW Japan shows a similarity with the other two areas of 0.62; *i.e.*, the combined fauna has 62% of the genera present in both areas. At a species level, the similarity is as low as about 0.2. The low similarity at a species level is in part caused by the simple comparison of occurrence lists of the three areas given by different authors, who have somewhat different concepts of the definition of the species.

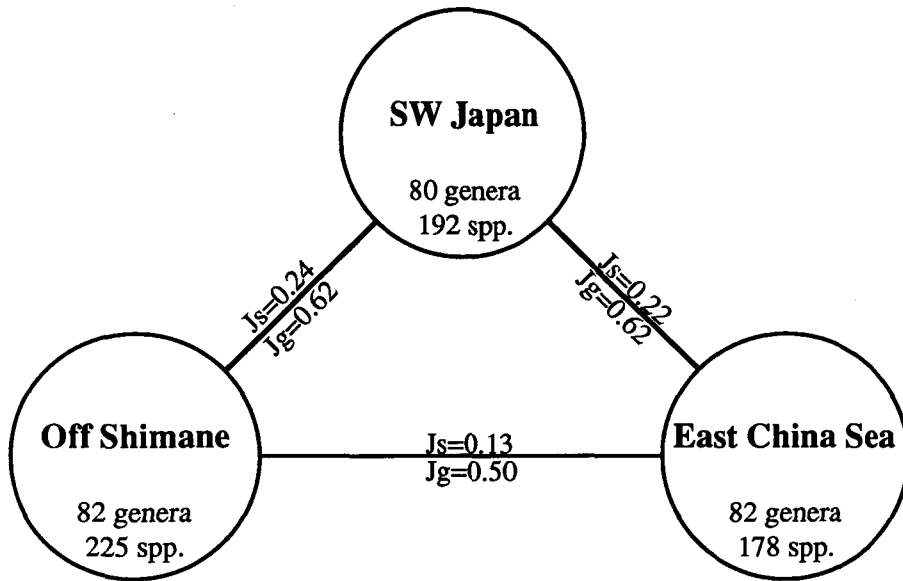


Fig. 16. Similarity of the ostracode faunas between the Pacific coast of SW Japan, the East China Sea, and the area off the Shimane Peninsula, Japan Sea, as compared with Jaccard similarity coefficient. Js: Jaccard coefficient based on species; Jg: Jaccard coefficient based on genera.

The difference between the three areas can also be seen through a comparison of the genera that do not occur commonly among them (Table 6). The area of SW Japan has 8 genera that do not occur in the other two areas; except for *Pseudopsammocythere* and *Loxocorniculum*, 6 genera are tropical forms. There are only two genera, *Palmenella* and *Rabilimis*, in the area off the Shimane Peninsula, that do not occur in the other two areas; both are distributed below 150 m, and might be the elements of the Japan Sea Proper Water. The seven genera in the East China Sea that are not found in the other two areas, are composed of two euryhaline intertidal to upper sublittoral zone forms (*Albileberis* and *Sinocytheridea*), and five continental shelf forms. SW Japan holds 4 genera in common with Shimane area, and 5 genera with the East China Sea; conversely the East China Sea and Shimane area share only two genera, *Neomonoceratina* and *Typhlocythere*, that are not found from SW Japan. The genus *Neomonoceratina* shows an interesting geographical distributional pattern. It has the highest species diversity and the largest population in Southeast Asia (see HANAI et al., 1980), with the northern limit at Okinawa (RUAN and HAO, 1988), the tropical region. It is also common in the coastal areas of China, from the South China Sea to Bohai Sea (ZHAO, 1988), an area that stretches

Table 6. Comparison of the occurrences of all the genera that are not commonly found in SW Japan, East China Sea and off Shimane. "+" represents the occurrence.

	SW Japan	Off Shimane	East China Sea	
<i>Aponesidea</i>	+			Genera limited to one area
<i>Loxococonchella</i>	+			
<i>Loxocorniculum</i>	+			
<i>Morkhovenia</i>	+			
<i>Neobuntonia</i>	+			
<i>Paranesidea</i>	+			
<i>Pseudopsammocythere</i>	+			
<i>Triebelina</i>	+			
<i>Palmenella</i>		+		Genera common between two areas
<i>Rabilimis</i>		+		
<i>Albileberis</i>			+	
<i>Alococythere</i>			+	
<i>Donghaicythere</i>			+	
<i>Sinocythereidea</i>			+	
<i>Stigmatocythere</i>			+	
<i>Sulcococytherura</i>			+	
<i>Swainocytherura</i>			+	
<i>Cletocythereis</i>	+	+		
<i>Hanaiborchella</i>	+	+		
<i>Howeina</i>	+	+		
<i>Robertsonites</i>	+	+		
<i>Cytherella</i>	+		+	
<i>Echinocythereis</i>	+		+	
<i>Neopellucistoma</i>	+		+	
<i>Saida</i>	+		+	
<i>Spinocythere</i>	+		+	
<i>Neomonoceratina</i>		+	+	
<i>Typhlocythere</i>		+	+	

across the tropical, subtropical and warm temperate zones. In Japan, fossils of *Neomonoceratina* have been commonly found in the Miocene Hatatate Formation (ISHIZAKI, 1966), and in the Pleistocene deposits of the Furuya Mud Beds (ISHIZAKI and KATO, 1976), the Boso Peninsula (YAJIMA, 1982) and Osaka Bay (ISHIZAKI, 1990); however, Recent species, except for their extremely rare occurrence at Sendai Bay (IKEYA and ITOH, 1991) and the area off Shimane, Japan Sea (IKEYA and SUZUKI, 1992), do not appear in the other areas investigated.

Some species occurring both in SW Japan and East China Sea show apparent differences in depth distribution in the two areas. The species are found at much shallower depths in the East China Sea. The tendency is apparent if the distribution of UDL's are



compared. Typical examples are: *Krihe antisawanensis* (SWJ: 120–1631 m; ECS: 15–320 m), *Cytheropteron postornatum* (SWJ: 228–986 m; ECS: 95–206 m), *Cytheropteron hanaii* (SWJ: 106–440 m; ECS: below 50 m), *Pacambocythere reticulata* (SWJ: 174–670 m; ECS: 40–585 m) This phenomenon may reflect colder temperature in the East China Sea.

## 7. Discussion

### 7-1. Geographical distribution of the ostracode faunas

Ostracodes on the Pacific coast of SW Japan, as a whole, are composed of tropical/subtropical forms and widely distributed “Japonic elements”. Only three cold-water species (*Finmarchinella japonica*, *Munseyella hatatensis* and *Howeina daishakaensis*) were found in this area, all of which have a much greater depth distribution than in Northeast Japan. In contrast to this, none of the geographically broadly distributed “Japonic elements” show the phenomenon of deepening their habitat in SW Japan. The ostracode fauna in SW Japan resembles those in the East China Sea and Japan Sea in generic composition but only 20% of the species are common to both. The SW Japan fauna differs from the fauna in the Japan Sea in having more warm water taxa, *Triebelina*, *Loxoconchella*, *Neobuntonia*, etc., and in lacking some cold water elements (e.g., *Finmarchinella uranipponica*, *Cythere uranipponica*) and representatives of the Japan Sea Proper Water (e.g., *Palmenella* and *Rabilimis*). The adjacent East China Sea, together with the other seas around China that cover climatic zones from tropical to warm temperate, is distinct from the Pacific coast of SW Japan in having a number of endemic ostracode taxa such as species of *Neomonoceratina*, *Swainocytherura*, *Sinocytheridea* and *Donghaicythere*. Like species of *Neomonoceratina*, many of the species living in the East China Sea (e.g., *Albileris sinensis* Hou, *Bythoceratina sheyanensis* Chen, *Callistocythere sinensis* Zhao, *Loxoconcha ocellata* Ho, *Neocytheretta snellii* (Kingma), *Pontocythere littoralis* Zhao, *Pontocythere triangulata* (Hou), *Sinocythere reticulata* Chen, *Sinocythere sinensis* Hou, *Sinocythere* sp.) have also been reported from the Okinawa Trough by RUAN and HAO (1988), but are completely absent or very rare around the Japanese Islands. The curious geographical distribution of these taxa suggests that, apart from the gradient in water temperature, there exists another unknown factor giving rise to the isolation of these areas.

I concluded that the two distinct discontinuities recognized in the distribution of ostracode species along the Pacific coasts of Japan are the marine climatic boundaries between the temperate/subtropical and subtropical/tropical zones. This recognition of differences in tropical, subtropical and temperate zone enhances the value of ostracodes as paleoenvironmental indicators in this area. Two principal problems remain concerning the biogeographical boundaries of ostracodes in this area. Firstly, the recognition of the warm temperate/subtropical boundary is based only on shallow water species. The northern limit of SW Japanese species living below 100 m is still obscure, especially for

many species of *Krithe*, *Pacambocythere*, *Cytheropteron* because of the lack of data from Northeast Japan. Secondly, we have little knowledge about the ostracode fauna on the Pacific side of the Ryukyu Islands, the critical area that is adjacent to the northern limit of the tropical zone.

Change of species composition around the temperate/subtropical boundary is unknown in detail due to the lack of data between Suruga Bay and Sendai Bay. Only the lack of the warm water genus *Cytherelloidea*, and the occurrence of the cold water element *Semicytherura sabura* in Tateyama Bay, are likely to reflect the gradient around this boundary. Around the subtropical/tropical boundary, I recognized a sharp replacement of species within a narrow zone between the Tanega-shima and Hyuga-nada areas.

Because the environmental gradient is gentle around the subtropical/tropical boundary, it was expected that species at the end of their respective distributions would gradually be reduced in abundance toward the boundary. The result, however, does not support this assumption. Each species seems to change in frequency randomly throughout its geographical range. The reason may be twofold. Firstly, most of these species are not common, therefore changes in their frequency may be obscured; secondly, each species may have its frequency adjusted in response to sporadic environmental change.

The *biogeographical gradient*, Sg/D, as proposed in this study, is convenient for expressing the geographical change of species composition. The result of this study has shown that Sg/D coincides well with the gradient of mean annual surface temperature (Fig. 13). This suggests that temperature is the principal factor governing the geographical distribution of ostracodes in the areas studied. Moreover, Sg/D coincides better with the mean annual temperature of surface water than with either the maximum temperature in summer or the minimum temperature in winter. This result, however, does not suggest that it is the mean temperature that determines the geographical limits of ostracodes. With respect to molluscs, for example, many authors (*e.g.*, HEDGPETH, 1957; HALL, 1964; CHINZEI, 1979) have shown that the critical factor determining the limits of marine biogeographic boundaries is the number of days or months that sea water is at temperatures required for reproduction and early growth; this might also be true for Ostracoda. Nevertheless, my result suggests that the mean annual temperature may serve as a good approximation correlating with the critical temperatures for the distribution of ostracodes.

## 7-2. Depth distribution of Ostracoda

Ostracode assemblages in Southwest Japan are changed in species composition with increase of water depth (ZHOU, 1995, Figs. 1–6). Depth zonation for ostracodes is known to be controlled principally by the vertical structure of the water column, or the distribution of water masses. In this study, it was impossible to make a detailed correlation between ostracode assemblages and water masses due to the sparsity of the sampling

stations and postmortem transportation. There are, however, two boundaries in vertical distribution that correspond with water masses in SW Japan. One is at a depth of 300–400 m, another is at about 800 m.

The result of this study shows that the sampling sites with a high specimen density, and generally also with a high species diversity, are for the most part restricted to depths above 300 m and have a mud content of 20–30%. The majority of the species are those having been reported from intertidal or sublittoral zones; their shells from the lower shelf and the slope areas are obviously allochthonous. Consequently, in most cases, the high individual density and high species diversity should be considered the result of condensation of transported material, and those places with a mud content of 20–30% on the continental shelf and upper slope seem to be suitable for this condensation.

Downslope transportation has shifted not only the lower depth limits of many ostracode species into deeper water, but also their upper depth limits. The occurrence of a large number of species in deeper waters in the area off Tanega-shima, is considered to be a case of the latter. Their deeper depth matches the deepening of the upper depth limit of muddy sediments there. In the Tanega-shima area, mud contents of the bottom sediments are very low above 500 m (<4.8%), reflecting the high hydraulic energy and accordingly high transport energy around the island. Such an environment would make the accumulation of dead ostracode shells in the sediments difficult, because the shells are easily transported downslope with finer sedimentary particles, their hydraulic equivalents. As a result, it would be difficult to find specimens from the depths at which they lived.

The observed preservation states of ostracode shells are variable, and hence are potentially useful for taphonomic study. I found distinguishing translucent from opaque shells is important for evaluating the degree of preservation of ostracode assemblages. The proportion of opaque shells appears to be correlated with the mud content (Fig. 11). Because a marine bottom with low mud content generally has a high sedimentation rate and *vice versa*, this fact could associate the opaqueness of those ostracode shells to a low sedimentation rate and accordingly to a long direct exposure of the shells to sea water. The opaqueness may be the result of dissolution of the calcium carbonate in ostracode carapaces by sea water; such corrosiveness may also explain the absence of thin-shelled *Paradoxostoma*, *Sclerochilus* and *Xiphichilus* at some of the same sites. This is supported by an experiment by MURRAY (1967), who showed that, when originally translucent tests of calcareous foraminifera have been etched and weakened by acidified water or even buffer solution of pH 7.0, they will turn opaque.

## 8. Taxonomic descriptions of selected species

The purpose of this part is to describe and/or illustrate the species that are new to science, and to discuss the taxonomic problems in the previously reported species which

have been, or are easily, misidentified, and give them synonymies. As a result only 61 of the 191 identified species are dealt with in this part. The paragraph "Occurrence" is the occurrence sites of a species from the six areas treated in this study. The boundary of warm temperate and subtropical zones for Ostracoda, at around 36°N as shown in part 6, is used here as the boundary of southwest and northeast Japan.

The following abbreviations are used in the descriptions. L=length, H=height of valve, LV=left valve, RV=right valve. All measurements are shown in mm.

Family CYTHERELLIDAE Sars, 1866

Genus *CYTHERELLA* Jones, 1849

*Cytherella leizhouensis* Gou, 1983

(Pl. 1, fig. 3)

*Cytherella leizhouensis* Gou in Gou et al., 1983, p. 110, 111, Pl. 23, figs. 8-14; Mostafawi, 1992, p. 133, Pl. 1, fig. 5.

*Cytherella japonica* Ishizaki, 1983, p. 140, 141, Pl. 32, figs. 3, 4, 6, 7.

*Illustrated specimen.* LV, JC-1351 (Pl. 1, fig. 3; L=0.83, H=0.49), from sample GH84-3, No. 56, east off Tanega-shima.

*Remarks.* GOU et al. (1983) reported this species from the Pliocene deposits of Leizhou Peninsula, Guangdong Province, China. Immediately afterward a species of *Cytherella* was reported by ISHIZAKI (1983) from the Pliocene Ananai Formation, Shikoku, Japan, and was described as a new species, *Cytherella japonica*. Through comparison of their illustrations, I concluded that *Cytherella japonica* Ishizaki, 1983 is a junior synonym of *Cytherella leizhouensis* Gou, 1983. Like *Cytherelloidea*, *Cytherella* is a warm-water representative, and is absent in the cold Oyashio-influenced northeast Japan.

This species has also been reported from Sunda shelf, between the Malay Peninsula and Borneo (MOSTAFAWI, 1992).

*Occurrence.* Sites 24, 30, 38, 47, Kumano-nada; sites 7, 9-2, 10, off Tanabe; sites 272, 291, 292, Bungo-suido; sites 311, MZ-18, MZ-19, MZ-20, Hyuga-nada; site 56, off Tanega-shima.

*Cytherelloidea* sp.

(Pl. 1, fig. 2)

*Illustrated specimen.* A juvenile RV, JC-1352 (Pl. 1, fig. 2; L=0.58, H=0.37), from sample KT90-17, No. 6, off Tanabe.

*Remarks.* Only juvenile individuals of this species were obtained in this study. The surface of its carapace is covered by thick ribs and coarse puncta. It resembles the juveniles of *Cytherelloidea senkakuensis* Nohara in lateral outline but differs from the latter in the arrangement of surface ribs. It is probably a new species.

*Occurrence.* Site 23, Kumano-nada; site 6, off Tanabe; sites 55, 70, off Tanega-shima.

Genus *KEIJCYOIDEA* Malz, 1981*Keijcyoidea* sp.

(Pl. 1, figs. 1a, b)

*Illustrated specimen.* A complete carapace, JC-1353 (LV: Pl. 1, fig. 1a; L=0.69, H=0.38. RV: Pl. 1, fig. 1b; L=0.71, H=0.42), from sample GH84-3, No. 86, east off Tanega-shima.

*Remarks.* Only a carapace of this species was obtained. It closely resembles *Keijcyoidea subaustralis* McKenzie et al., 1990 from the Pleistocene of Victoria, south Australia; the only differences are its deeper anteromarginal depression and right-angled posterodorsal angle, which in *K. subaustralis* is rounded. Like other cytherellids, it shows strong LV/RV asymmetry; the RV is larger and smoother. It is most probably a form that is not yet reported and named, but is left in open nomenclature because of the paucity of material.

*Occurrence.* Site 86, off Tanega-shima.

## Family BAIRDIIDAE Sars, 1888

Genus *NEONESIDEA* Sohn, 1954*Neonesidea posteroacuta* n. sp.

(Pl. 1, figs. 4a-c, 5a, b, 6)

*Neonesidea* cf. *antonbruuna* Maddocks, 1969: Ruan and Hao, 1988, p. 233, 234, Pl. 33, figs. 30, 31.

*Type.* Holotype, LV, JC-1354 (Pl. 1, figs. 4a-c; L=1.29, H=0.80); paratype, LV, JC-1355 (Pl. 1, figs. 5a, b; L=1.10, H=0.67); paratype, a complete carapace, JC-1356 (Pl. 1, fig. 6; L=1.08, H=0.68).

*Type locality.* Holotype from sample GH84-3, No. 56 (30°33.4'N, 131°16.2'E; 444 m deep), paratype LV from GH84-3, No. 70 (30°41.3'N, 131°13.8'E; 98 m deep), paratype carapace from GH84-3, No. 71 (30°36.7'N, 131°12.3'E; 90 m deep); off Tanega-shima.

*Etymology.* Acuta (L.)=pointed or sharp, with reference to the sharp posterior end of the species.

*Diagnosis.* A species of *Neonesidea* with a large, inflated and highly rounded carapace. Closely resembles *Neonesidea oligodentata* (Kajiyama) but has a sharper posterior end.

*Description.* Carapace large and inflated, highly rounded. LV overreaching and overlapping RV. Dorsal margin strongly arched, falling away rapidly to the front and rear. Dorsal outline weakly concave immediately before it merges with anterior and posterior margin. Anterior margin broadly rounded, posterior end acutely tapered. Ventral margin nearly straight in LV, and slightly sinuate at middle in RV. Surface smooth, no eye tubercle. Normal pores numerous and simple.

Interior undistinguishable from that of *Neonesidea oligodentata* (Kajiyama). Duplica-

ture and vestibule broad along anteroventral and posteroventral margins. Hinge lophodont. Adductor muscle scars consisting of three horizontal rows of eight wedge-shaped scars. There are two very small scars being anterior to central muscle scars.

*Remarks.* This species is different from *N. oligodentata* (Kajiyama) in having a posteriorly obliquely truncated anterior margin and more acutely projected posterior end. This difference in carapace shape is ontogenetically traceable to young instars. The geographical distribution of this species is still unclear because it is quite possible that it has been misidentified as *N. oligodentata* in previous works.

This species was previously reported by RUAN and HAO (1988) from the Okinawa Trough, as *Neonesidea* cf. *antonbruuna* Maddocks. It resembles the *Neonesidea* sp. 2 of WHATLEY and ZHAO (1987a) from the Recent of the Malacca Straits. For the latter species, only a juvenile carapace is illustrated, so a comparison is not possible to conclude if it is conspecific with *N. posteroacuta* n. sp. or not.

*Occurrence.* Site 23, Kumano-nada; sites 4, 6, 7, off Tanabe; site 352, Hyuga-nada; sites 55, 56, 70, 71, 86, YT-2, off Tanega-shima.

#### Genus *APONESIDEA* Maddocks, 1986

##### *Aponesidea tanegashimensis* n. sp.

(Pl. 1, figs. 7a-d)

*Type.* Holotype, a complete carapace, JC-1357 (LV: Pl. 1, figs. 7b, c, d; L=0.96, H=0.67. RV: Pl. 1, fig. 7a; L=0.81, H=0.47).

*Type locality.* Sample GH84-3, No. 71 (30°36.7'N, 131°12.3'E; 90 m deep), off Tanega-shima.

*Etymology.* With reference to the distribution of this species in the area off Tanega-shima.

*Diagnosis.* An *Aponesidea* with a typical bairdian shape, and characterized by a strongly beveled anterior margin and the absence of striate fringe along the RV margins.

*Description.* Carapace moderate in size, uniformly transparent, smooth; shape similar to *Neonesidea*, with an upward-pointed caudal process, but considerably inflated and ventrally flattened. Greatest thickness at about one-third of height, and greatest height at one-third length. Dorsal margin broadly arched, with slight antero- and posterodorsal concavities; anterior margin sharply beveled and slightly curved; ventral margin gently sinuate in LV, and slightly concave at one-third length of RV. In LV two to three short, conical spines located at the upper end of anterior margin, and three to four at the lower side of caudal process; in contrast, the margin of RV is completely smooth. Normal pore canals numerous, very small, simple.

Hingement and duplicature typically bairdian; adductor muscle-scar pattern very large, consisting of four close-spaced scars, the surfaces of which are finely etched in a lacy pattern.

*Remarks.* *Aponesidea* is a genus proposed by MADDOCKS (in MADDOCKS and ILIFER, 1986) for an abundant species in the marine caves of Bermuda, which shows affinities with both *Neonesidea* and *Paranesidea* but cannot be appropriately assigned to either. The morphology of *Aponesidea tanegashimensis* n. sp. agrees fairly well with the characters selected to diagnose *Aponesidea* (MADDOCKS and ILIFFE, 1986; MADDOCKS, 1991), but is different from *Neonesidea* in showing a more inflated and more ventrally flattened carapace; it is also distinct from *Paranesidea* in having a smooth carapace without a patch pattern. Its adductor muscle scars are arranged in a bythocyprid pattern, and are very similar to those of *Aponesidea ifatyensis* Maddocks in showing variable, lacy surfaces.

*Aponesidea tanegashimensis* n. sp. is distinct from *Aponesidea iliffei* Maddocks 1986 in having a sharply beveled dorsal margin; it can be easily distinguished from *A. ifatyensis* Maddocks 1991 in having a less elongate, posteriorly-tapered carapace. Furthermore, the marginal fringe of RV seen in *A. iliffei* and *A. ifatyensis* is absent in this species in my samples. Throughout the larval stages its flattened ventral bottom makes it distinct from the species of *Neonesidea*.

The distribution of *Aponesidea tanegashimensis* n. sp. is restricted to the south of the Tanega-shima area, the tropical zone, where it has been found only from carbonate sand with extremely low mud content. This fact supports the supposition by MADDOCKS and ILIFFE (1986, p. 37) and MADDOCKS (1991, p. 193) that this genus prefers cryptic habitats in reef crevices or coralline rubble.

*Occurrence.* Sites 55, 70, 71, YT-2, off Tanega-shima; also detected from the supplementary samples from Okinawa.

*Paranesidea* sp.

(Pl. 2, fig. 1)

*Illustrated specimen.* A carapace, JC-1358 (Pl. 2, fig. 1; L=0.86, H=0.57), from sample GH84-3, No. 86, off Tanega-shima.

*Remarks.* This form has a large, oval carapace; its shallow pleat near the ventral margin, in particular, makes it distinct from the other species of *Paranesidea* so far reported. It is probably a new species, but is left here in open nomenclature because I could not find an intact adult RV to fill the description of the new species.

*Occurrence.* Sites 56, 70, 86, 110, YT-2, YT-5, off Tanega-shima; common in the supplementary samples from Okinawa.

Genus *TRIEBELINA* van den Bold, 1946

*Triebelina schyroconcha* Maddocks, 1969

(Pl. 2, fig. 2)

*Triebelina schyroconcha* Maddocks, 1969, p. 65, 66, text-figs. 33G, H; Pl. 2, figs. 7, 8; Nohara, 1987, Pl. 16 (list); Ruao and Hao, 1988, p. 232, 233, Pl. 34, figs. 20–23.

*Illustrated specimen.* LV, JC-1359 (Pl. 2, fig. 2; L=0.70, H=0.35), from sample GH84-3, No. 70, off Tanega-shima.

*Remarks.* MADDOCKS (1969) described this species from the sandy sediments among coral patch reefs, north Madagascar, and also indicated its possible distribution in the Admiralty Islands and New Caledonia. In Japan previous works have reported it from the Plio-Pleistocene of Okimawa-jima (NOHARA, 1987), and from the Pleistocene to Holocene of the Okinawa Trough (RUAN and HAO, 1988). My specimens, together with those illustrated by RUAN and HAO (1988), show the same morphology as MADDOCKS'S (1969) types.

*Occurrence.* Site 24, Kumano-nada; site 282, Hyuga-nada; site 70, off Tanega-shima.

Family CANDONIDAE Kaufmann, 1900

Genus *PARACYPRIS* Sars, 1866

*Paracypris* sp.

(Pl. 2, fig. 3)

*Paracypris* sp. Yajima, 1982, p. 183, 185, Pl. 15, figs. 6, 9; text-figs. 13-1, 2.

*Illustrated specimen.* RV, JC-1360 (Pl. 2, fig. 3; L=0.86, H=0.36), from sample GH82-2, No. 23, Kumano-nada.

*Remarks.* This species was first reported by YAJIMA (1982) from the Late Pleistocene of Boso Peninsula, central Japan. It has also been found by me from Otsuchi Bay, northeast Japan. Compared with YAJIMA'S illustrated specimen, the Recent form from southwest and northeast Japan shows a more concave anterior cardinal angle.

*Occurrence.* Sites 23, 24, 30, 38, Kumano-nada; site 7, off Tanabe; sites 294, 318, 334, 352, 362, MZ-04, Hyuga-nada.

Family CYTHERIDEIDAE Sars, 1925

Genus *PONTOCYTHERE* Dubowsky, 1939

*Pontocythere* sp.

(Pl. 3, fig. 1)

*Illustrated specimen.* RV, JC-1361 (Pl. 3, fig. 1; L=0.48, H=0.23), from sample KT92-2, YT-2, off Tanega-shima.

*Remarks.* Only one valve and one complete carapace of this species are included in my material. The form most closely resembling this species is *Pontocythere* sp. 2 of YAJIMA (1982) from the Late Pleistocene of Boso Peninsula, which is different from *Pontocythere* sp. of this study in having a more elongate carapace with a less sinuate ventral margin.

*Occurrence.* Site YT-2, off Tanega-shima.



Genus *KRITHE* Brady, Crosskey and Robertson, 1874*Krithe* sp. 1

(Pl. 2, figs. 4a, b)

*Illustrated specimen.* A male LV, JC-1362 (Pl. 2, figs. 4a, b; L=0.95, H=0.44), from sample GH84-3, No. 55, off Tanega-shima.

*Remarks.* Only two valves of this species were obtained; the paucity of material makes it impossible to grasp its intraspecific morphological variation. The two specimens are similar to *Krithe surugensis* Zhou and Ikeya in lateral outline and in the posteroventral arched duplicature, but are different from *K. surugensis* in having a larger carapace.

By analogy with other species of *Krithe*, the illustrated LV, which has an elongate shape, may be male.

*Occurrence.* Site 275, Hyuga-nada; site 55, off Tanega-shima.

*Krithe* sp. 2

(Pl. 2, figs. 7a, b)

*Illustrated specimen.* A female LV, JC-1363 (Pl. 2, figs. 7a, b; L=0.83, H=0.45), from sample GH82-2, No. 47, Kumano-nada.

*Remarks.* This species closely resembles *Krithe hanaii* Ishizaki in having a short and anterior-tapered shape in lateral view, but its shell is much thinner, and as a result the internal openings of the normal pore canals are smaller.

*Occurrence.* Sites 39, 47, Kumano-nada; site 35, Tosa Bay.

Genus *PARAKRITHE* van den Bold, 1958*Parakrithe japonica* n. sp.

(Pl. 2, figs. 5a-c, 6)

*Type.* Holotype LV, JC-1364 (Pl. 2, figs. 5a-c; L=0.68, H=0.29); paratype, RV, JC-1365 (Pl. 2, fig. 6; L=0.67, H=0.28).

*Type locality.* Both holotype and paratype from sample GH83-2, No. 301 (31°41.5'N, 131°46.1'E; 360 m deep), Hyuga-nada.

*Diagnosis.* Carapace elongate and rounded at posterior end. Height about two fifths of the length.

*Description.* Carapace elongate, rather inflated, with greatest height at posterior third. Anterior margin symmetrically rounded. Dorsal margin straight. Ventral margin nearly straight, slightly sinuate at anterior third. Posterior margin narrowly rounded, merging into dorsal margin making a broad anteriorly oblique cardinal corner, and into ventral margin making a narrowly rounded posteroventral corner. Surface smooth, but dotted with numerous normal pores.

Duplicature broad along anterior and posteroventral margins, narrow along ante-

roventral and posterior margins. Vestibulum only developed anteriorly, axe-shaped. Central scar area consists of a crescent-shaped frontal margin and an anteriorly oblique row of four elongated adductor muscle scars. Hinge pseudadont, LV hinge with longitudinal furrow for reception of sharp dorsal edge of RV; posterior portion of hinge furrow shows faint crenulation.

*Remarks.* This species was also found from the surface sediments from Suruga Bay, central Japan, where it is distributed at depths of 195–595 m. It closely resembles the form reported by RUAN and HAO (1988) from the Okinawa Trough, which was assigned to *Parakrithe angusta* (Brady and Norman, 1889), but is distinguished from the latter by its rounded posteroventral corner. It also resembles a species reported by ZHAO (1988) from the East China Sea assigned to *Parakrithe dimorpha* Bonaduce, Ciampo and Masoli, in having an elongated carapace, but the species in the present study has a much larger carapace.

*Occurrence.* Sites 24, 32, 48, Kumano-nada; site 91, Tosa Bay; site 247, Bungo-suido; site 301, Hyuga-nada.

*Parakrithe subjaponica* n. sp.

(Pl. 2, figs. 8a–c, 9)

*Type.* Holotype, LV, JC-1366 (Pl. 2, figs. 8a–c; L=0.49, H=0.25); paratype, RV, JC-1367 (Pl. 2, fig. 9; L=0.46, H=0.24).

*Type locality.* Holotype from sample GH82-2, No. 47 (34°06.6'N, 136°35.5'; 351 m deep), Kumano-nada; paratype from sample GH83-2, No. 301 (31°41.5'N, 131°46.1'E; 360 m deep), Hyuga-nada.

*Diagnosis.* A *Parakrithe* with a short and slim carapace, in lateral view oval. Posterior margin meets ventral margin, making a right angle. Height about half of the length.

*Description.* Carapace short and slim, in lateral view oval. Anterior margin symmetrically rounded. Dorsal margin nearly straight. Ventral margin slightly sinuate at middle. Dorsal margin and ventral margin nearly parallel. Posterior margin nearly perpendicular to ventral margin, merging into dorsal margin making a broadly rounded cardinal angle, and into ventral margin making a narrowly rounded posteroventral angle. Surface smooth, but bearing numerous normal pores.

Duplicature broad anteriorly, narrow ventrally, and subparallel to ventral margin. Vestibulum shallow, only developed anteriorly. Central scar area consisting of a rounded frontal scar and an anteriorly oblique row of four elongated adductor muscle scars. Hingement as that of *P. japonica* n. sp.

*Remarks.* This species is different from *P. japonica* n. sp. in having a shorter carapace, a narrower posteroventral duplicature, and a coarser crenulation at the posterior portion of hinge furrow of LV. It resembles the type species of this genus, *Parakrithe ver-*

*munti* (van den Bold, 1946) in outline, but is different from *P. vermunti* in having a smaller size and nearly straight ventral margin.

*Occurrence.* Sites 32, 39, 47, 48, Kumano-nada; sites 11-1, 12, off Tanabe; sites 4, 35, 36, 91, Tosa Bay; sites 246, 252, Bungo-suido; sites 282, 301, 339, Hyuga-nada; sites YT-5, YT-6, off Tanega-shima.

Family EUCYATHERIDAE Puri, 1954

Genus *EUCY THERE* Brady, 1868

*Eucythere* sp.

(Pl. 3, figs. 3a, b)

*Illustrated specimen.* A complete carapace, JC-1368 (LV: Pl. 3, fig. 3a; L=0.35, H=0.22. RV: Pl. 3, fig. 3b; L=0.34, H=0.21), from sample GH84-3, No. 56, off Tanega-shima.

*Remarks.* The lateral shape of this species is subtriangular to oval, with fine concentric ribbing; on the posterior half of the carapace there is a posteromedian lobe. It is most similar to *Eucythere* sp. of ZHAO (1988) found from the East China Sea, except for its rounded anterior cardinal angle and beveled anterior margin.

*Occurrence.* Sites 55, 56, YT-5, off Tanega-shima.

Genus *MORKHOVENIA* Teeter, 1975

*Morkhovenia inconspicua* (Brady, 1880)

(Pl. 3, figs. 2a, b)

*Cythere inconspicua* Brady, 1880, p. 70, Pl. 13, fig. 1.

*Morkhovenia inconspicua*: Teeter, 1975, p. 435, figs. 7o–q, 8c; Krutak, 1982, p. 271, 272, Pl. 4, figs. 13–16; Gou, 1990, p. 26, Pl. 3, fig. 37.

*Munseyella inconspicua*: Holden, 1976, p. 34, Pl. 1, figs. 14–16; Pl. 11, figs. 3–5.

*Pectocythere?* sp. Tabuki and Nohara, 1988, Tables 1, 2, Pl. 1, figs. 3, 4.

*Morkhovenia* sp. 1 Tabuki and Nohara, 1990, Tables 2, 3, Pl. 1, fig. 9.

*Kotoracythere inconspicua*: Witte and van Harten, 1991, p. 434, Figs. 3–5.

*Illustrated specimen.* A complete carapace, JC-1369 (LV: Pl. 3, fig. 2b; L=0.41, H=0.23. RV: Pl. 3, fig. 2a; L=0.40, H=0.22), from sample KT92-2, YT-2, off Tanega-shima.

*Remarks.* The Recent forms of this species have been found from the shallow marine tropics around the world with the exception of the eastern Pacific, and it is an essentially littoral species which is seldom found deeper than a few meters (WITTE and van HARTEN, 1991). Its shells found from the Tanega-shima area at the depths of 96–1,016 m and from the Hyuga-nada area at 256–535 m are probably material transported downslope. It resembles *Leptocythere pulchra* Zhao and Whatley 1989 found from the southeastern Malay Peninsula, but differs from the latter in having a smaller size and a posteroventral

depression.

*Occurrence.* Sites 339, 352, Hyuga-nada; sites 41, 55, 56, YT-2, YT-6, off Tanegashima.

Genus *MUNSEYELLA* van den Bold, 1957

*Munseyella chinzeii* n. sp.

(Pl. 3, figs. 4a, b, 5, 6)

*Munseyella* sp. 2 Ikeya and Itoh, 1991, p. 119, fig. 19C.

*Type.* Holotype, RV, JC-1370 (Pl. 3, figs. 4a, b; L=0.36, H=0.21); paratype, LV, JC-1371 (Pl. 3, fig. 5; L=0.33, H=0.21); paratype, RV, JC-1372 (Pl. 3, fig. 6; L=0.35, H=0.20).

*Type locality.* Holotype and LV of paratype from GH82-2, No. 32 (34°04.7'N, 136°43.5'E; 670 m deep), RV of paratype from GH82-2, No. 39 (34°05.8'N, 136°39.4'E; 440 m deep); Kumano-nada.

*Etymology.* In honor of Prof. K. CHINZEI, Kyoto University, who has guided me and provided encouragement in my research.

*Diagnosis.* A small *Munseyella* sculptured with undulated ridges anteriorly and blunt knobs posteriorly.

*Description.* Carapace thick and small, in lateral view subtriangular, highest at anterior cardinal angle. Anterior margin nearly symmetrically rounded, with two minute denticles in its lower half. Ventral margin nearly straight. Posterior margin narrowly rounded, with one or two short spines. Within a population surface ornamentation in anterior half may vary from undulated ridges to completely smooth; posterior half sculptured with blunt knobs above posterior fourth of ventral margin and at posterior cardinal angle. Marginal rim strong along anterior margin, forming a prominent groove behind it. Eye tubercle absent.

Duplicature is widest anteriorly, moderate posteriorly. Selvage distinct along free margin. Central muscle scar area consisting of an elongate frontal scar and a vertical row of four adductor muscle scars. Hinge as for the genus. Normal pores small, few and scattered.

*Remarks.* This species was once reported by IKEYA and ITOH (1991) from Sendai Bay, northeast Japan. It is close to *M. oborozukiyo* Yajima but is different from the latter in having a rounded posterior margin, and in the absence of a concavity at posterior fourth.

*Occurrence.* Sites 24, 31, 32, 39, 47 48, Kumano-nada; sites 5, 7, 10, off Tanabe.

## Family CYTHERIDAE Baird, 1850

Genus *SCHIZOCYTHERE* Triebel, 1950*Schizocythere kishinouyei* (Kajiyama, 1913), subspecies

(Pl. 3, fig. 10)

*Illustrated specimen.* RV, JC-1373 (Pl. 3, fig. 10; L=0.61, H=0.38), from sample GH84-3, No. 70, off Tanega-shima.

*Remarks.* *Schizocythere kishinouyei* Kajiyama is represented in southwest Japan by two morphotypes A and B, which often occur sympatrically. Type A is of typical morphology of Kajiyama's type specimens, and type B is here assigned "subspecies". B resembles A in most respects, but it has a robuster shell with much stronger ornamentation of the carapace surface; this difference can be traced back to young instars. At present I consider type B to form a distinct subspecies of *S. kishinouyei*.

*Occurrence.* Sites 24, 30, 31, 38, 39, 47, 48, Kumano-nada; sites 6, 7, 8, off Tanabe; site 110, Tosa Bay; sites 246, 252, 273, Bungo-suido; sites 275, 282, 294, 301, 334, 339, 347, 352, 358, 362, 365, MZ-04, Hyuga-nada; sites 41, 55, 56, 70, 71, 86, YT-5, YT-6, off Tanega-shima.

## Family HEMICYTHERIDAE Puri, 1953

Genus *AURILA* Pokorny, 1955*Aurila* sp. 1

(Pl. 3, fig. 9)

*Aurila* sp. B Ikeya et al., 1985, Table 1, p. 17, Pl. 4, figs. 10, 11.

*Illustrated specimen.* RV, JC-1374 (Pl. 3, fig. 9; L=0.62, H=0.38), from sample GH84-3, No. 86, off Tanega-shima.

*Remarks.* This is a small *Aurila*. It was once found from a surge channel at Cape Omaezaki, central Japan (IKEYA et al., 1985). It is distinct from other species of *Aurila* so far reported from Japan and its adjacent areas, by the smallness of its carapace and its evenly reticulated carapace surface. Its occurrence in southwest Japan is very rare; the limited number of specimens preclude the description of a new species.

*Occurrence.* Sites 23, 30, 31, 39, 47, Kumano-nada; site 291, Bungo-suido; sites 311, 334, 352, 358, 365, MZ-27, Hyuga-nada; sites 56, 71, 86, YT-2, YT-5, off Tanega-shima.

Genus *BRADLEYA* Hornibrook, 1952Subgenus *BRADLEYA* Hornibrook, 1952*Bradleya* (*Bradleya*) *japonica* Benson, 1972

(Pl. 3, figs. 11, 12)

*Bradleya japonica* Benson, 1972, p. 40, Pl. 7, fig. 3; text-fig. 14B; Nohara, 1987, Pl. 16 (list); Zhao, 1988, p. 254, Pl. 47, figs. 12-15; Ikeya and Suzuki, 1992, p. 113 (list), Pl. 2, fig. 9.

*Bradleya nuda* Benson: Lee, 1990, p. 270, 271, Pl. 21, figs. 1, 2; Ikeya and Suzuki, 1992, Pl. 3, fig. 1.

*Bradleya* sp. Ikeya and Suzuki, 1992, Pl. 2, fig. 10.

*Illustrated specimens.* RV, JC-1375 (Pl. 3, fig. 11; L=1.11, H=0.64), from sample KT90-17, No. 9-2, off Tanabe; RV, JC-1376 (Pl. 3, fig. 12; L=1.07, H=0.64), from sample GH83-2, No. 292, Bungo-suido.

*Remarks.* In this study two closely related forms of *Bradleya*, the reticulate *B. japonica* Benson and the smooth *B. nuda* Benson have been recovered from north of the Tanega-shima area, but their juveniles are all smooth and cannot be discriminated from each other. The two forms often occur together, with more individuals of *B. japonica* in general. The form of *B. nuda* from SW Japan has a more prominent reticulum in the posterocentral region than its typespecimen from the Upper Pliocene of Japan; moreover faint muri are developed above the ventral carina and below the anterodorsal margin. In his original descriptions, BENSON (1972) noted the common elements of the reticulation pattern in the two forms and their common paired pores along the anterior portion of the ventral lateral carina, although he assigned the two forms to different species. Based on the material from SW Japan, I furthermore recognized that, as far as one can trace, the distributional patterns of normal pore canals in the two forms, which are genetically determined, are the same. The close relationship of the two forms has also been noticed by other workers. For example, in his work on Recent Ostracoda in the East China Sea, ZHAO (1988, Pl. 47, figs. 12–14) assigned the typical *B. japonica* and *B. nuda*, together with forms with intermediate reticulation, to *B. japonica*, although he did not mention the reason. The intermediate form between *B. japonica* and *B. nuda* has also been found from the Sea of Japan, where it was identified as *Bradleya* sp. (IKEYA and SUZUKI, 1992: Pl. 2, fig. 10). The existence of an intermediate form is very strong evidence suggesting that the smoothness of *B. nuda* is the result of mural loss; this loss can be caused within a species by environmental conditions, as in many other species of Ostracoda. In SW Japan although the degree of reticulation is bimodal, I am sure that the two “species” are more likely to be conspecific with each other, and I have placed them together herein as *B. japonica*.

*Bradleya paranuda* Benson, a species closely related to the morphotype *B. nuda*, was not found from north of Tanega-shima, but occurs in the three supplementary samples from Okinawa.

*Occurrence.* Sites 23, 24, 30, 31, 32, 38, 39, 47, Kumano-nada; sites 5–10, off Tanabe; sites 2, 3, 32, 33, 34, 91, 101, 110, Tosa Bay; sites 252, 272, 273, 291, 292, Bungo-suido; sites 294, 311, 318, 334, 352, 358, 362, 365, MZ-18, MZ-19, MZ-20, Hyuga-nada; sites 56, YT-6, off Tanega-shima.

Subgenus *QUASIBRADLEYA* Benson, 1972*Bradleya (Quasibradleya) pitalia* (Hu, 1981)

(Pl. 3, fig. 15)

*Bradleya (Quasibradleya)* species: Benson, 1972, p. 114, Pl. 2, fig. 10.*Trachyleberis pitalia* Hu, 1981, p. 86, 87, Pl. 1, figs. 12, 14, 20, 21, 22; Fig. 6.*Jugosocythereis* cf. *Radimella elongata* Hu: Tabuki and Nohara, 1990, Table 2, Pl. 1, fig. 14.*Bradleya pitalia* (Hu, 1981): Gou, 1990, p. 28, Pl. 2, fig. 24.*Quadracythere* sp. Tu et al., 1993, Pl. 13, fig. 9.*Illustrated specimen.* RV, JC-1377 (Pl. 3, fig. 15; L=0.87, H=0.49), from sample KT92-2, YT-2, off Tanega-shima.*Remarks.* HU (1981) found this species from the mudstone of Hengchun Peninsula, southern Taiwan (Late Pliocene or Early Pleistocene) and described it as *Trachyleberis pitalia*. It is the synonym of *Bradleya (Quasibradleya)* species of BENSON (1972), recovered from Recent sediments from the Philippines (at a depth of 20 fathoms). Its squared posterior margin and reticulated carapace surface with strong ridges do not agree with the diagnosis of *Trachyleberis*; all its characters are typical of *Bradleya (Quasibradleya)*.

This species has also been reported from the coral reefs of Sekisei-sho area, Ryukyu Islands (TABUKI and NOHARA, 1990), and from the South China Sea (GOU, 1990; TU et al., 1993).

*Occurrence.* Sites 86, YT-2, YT-5, off Tanega-shima.Genus *CORNUCOQUIMBA* Ohmert, 1968*Cornucoquimba* sp.

(Pl. 3, fig. 7)

*Illustrated specimen.* LV, JC-1378 (Pl. 3, fig. 7; L=0.46, H=0.25), from sample MZ-27, Hyuga-nada.*Remarks.* This species has a characteristic small and laterally sub-triangular carapace, and is clearly a new species. The total number of individuals found from Tosa Bay, Hyuga-nada and off Tanega-shima is only 3 adult valves. Its description as a new species will be delayed until enough specimens have been obtained.*Occurrence:* Sites 2, 110, Tosa Bay; sites 358, MZ-04, MZ-27, Hyuga-nada; sites YT-5, YT-6, off Tanega-shima.Genus *COQUIMBA* Ohmert, 1968*Coquimba* sp.

(Pl. 3, fig. 8)

*Coquimba* sp. Nohara and Tabuki, 1985, Tables 1, 2, Pl. 2, fig. 4.*Coquimba ishizakii* Yajima: Ruan and Hao, 1988, p. 312, Pl. 54, figs. 28-33.*Illustrated specimen.* LV, JC-1379 (Pl. 3, fig. 8; L=0.50, H=0.21), from sample

KT92-2, YT-5, off Tanega-shima.

*Remarks.* This is a very rare species in the areas studied. It was previously recovered from the Pleistocene of Okinawa-jima (NOHARA and TABUKI, 1985) and from the Upper Pleistocene to Holocene of the Okinawa Trough (RUAN and HAO, 1988). It is similar to *Coquimba ishizakii* Yajima in the total arrangement of ornamental elements, but differs from the latter in having a flattened ventral plane, a less conspicuous muscle-scar node, an obliquely truncated posterior margin, and nearly parallel dorsal and ventral margins.

*Occurrence.* Site 291, Bungo-suido; sites 56, YT-5, YT-6, off Tanega-shima.

Genus *NEOBUNTONIA* Hartmann, 1981

*Neobuntonia* sp.

(Pl. 3, fig. 16)

*Neobuntonia* sp. 1 Tabuki and Nohara, 1990, Table 2, Pl. 1, fig. 12.

*Illustrated specimen.* RV, JC-1380 (Pl. 3, fig. 16; L=0.66, H=0.37), from sample GH84-3, No. 55, Tanega-shima.

*Remarks.* TABUKI and NOHARA (1990) first reported this species from the coral reefs in Sekisei-sho area, Ryukyu Islands. As compared with the type-species of the genus, *Neobuntonia siebertorum* Hartmann 1981, this species has a more inflated, less ornamented carapace. In this study, its northern limit is Hyuga-nada, the area that is concluded herein to be the boundary of the tropical and subtropical zones for ostracodes. Material in my collection is very rare and is not sufficient for the description of a new species.

*Occurrence.* Site 352, Hyuga-nada; sites 55, YT-5, off Tanega-shima.

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948

Genus *ACANTHOCYHEREIS* R. C. Howe, 1963

*Acanthocythereis* sp. 1

(Pl. 4, fig. 4)

*Illustrated specimen.* RV, JC-1381 (Pl. 4, fig. 4; L=1.09, H=0.60), from sample GH82-2, No. 39, Kumano-nada.

*Remarks.* This is a deep-sea inhabitant of *Acanthocythereis*, found from the depths of 317–730 m in this study. It closely resembles *Acanthocythereis munechikai* Ishizaki, 1981 in most respects, but differs from the latter in having a much larger, more inflated and more spiny carapace. The depression behind the anterior cardinal angle, which also exists in *A. munechikai*, is deeper in this species. The juveniles of the two species can be distinguished more easily from each other. The juveniles of *A. munechikai* are subtriangular in lateral view, with an acute posterior end; the carapace surface is mostly smooth, except for a weak, blade like ala and some faint, latitudinal ridges in the posterior half; anterior and dorsal margins are denticulate, while the ventral margin is smooth. The juveniles of *A. sp. 1* of this study, on the other hand, are subrectangular in lateral view, with an



obtuse posterior end; the posterior half of the carapace is ornamented with tubercles and blade-like spines, and a thin ala made up of several merged blades; the margins are fringed with blade-like spines. *A. sp. 1* is probably a form that has not been reported or named.

*Occurrence.* Site 39, Kumano-nada; site 11-1, off Tanabe; site 35, Tosa Bay; sites 238, 246, 252, Bungo-suido; site 275, Hyuga-nada.

Genus *HIRSUTOCY THERE* H. V. Howe, 1951

*Hirsutocythere* sp.

(Pl. 4, fig. 1)

*Trachyleberis* sp. Nohara et al., 1988, Table 2, Pl. 2, figs. 8, 10.

*Illustrated specimen.* Immature RV, JC-1382 (Pl. 4, fig. 1; L=1.32, H=0.68), from sample GH83-2, No. 219, Bungo-suido.

*Remarks.* Only 12 juveniles of this species were obtained in this study. Except for their smaller size and a more rounded posterior end, the specimens seeming to be A-1 instars bear a remarkable resemblance to *Trachyleberis* sp. of NOHARA et al., 1988 from the Pleistocene to Recent piston core off Miyako-jima, Ryukyu Islands (and they are therefore considered here synonymous). The lack of a duplicature in the juveniles precludes knowing the characters of the duplicature or radial pore canals, which are critical for the assignment to a genus, but the more numerous spines of this species suggest that it is more likely to be *Hirsutocythere* than *Trachyleberis*.

*Occurrence.* Site 48, Kumano-nada; site 11-1, off Tanabe; site 219, Bungo-suido; site 27, off Tanega-shima.

Genus *ECHINOCY THEREIS* Puri, 1954

*Echinocythereis dasyderma* (Brady, 1880)

(Pl. 4, fig. 3)

*Cythere dasyderma* Brady, 1880, p. 105, Pl. 17, figs. 4a–f; Pl. 18, figs. 4a–f.

*Echinocythereis dasyderma*: Joy and Klark, 1977, p. 142, Pl. 2, figs. 14–17.

*Wichmannella? dasyderma* (Brady): Ruan and Hao, 1988, p. 365, Pl. 66, figs. 6–11.

*“Echinocythereis” dasyderma*: Zhao, 1988, p. 252, Pl. 46, fig. 6.

*Acanthocythereis? sp. 1* Ikeya and Suzuki, 1992, p. 112 (list), Pl. 1, fig. 4.

*Echinocythereis dasyderma*: Tu et al., 1993, Pl. 12, fig. 6.

*Illustrated specimen.* Immature RV, JC-1383 (Pl. 4, fig. 3; L=0.86, H=0.53), from sample GH83-2, No. 238, Bungo-suido.

*Remarks.* Only juveniles of this species were recovered in this study, but their sub-rectangular to oval outline and concentrically arranged spines are characteristic of *E. dasyderma*. This species is cosmopolitan in the deep sea; in the northwest Pacific it has also been reported from the East China Sea (ZHAO, 1988), from the Okinawa Trough

(RUAN and HAO, 1988), and from the Sea of Japan (IKEYA and SUZUKI, 1992).

*Occurrence.* Site 48, Kumano-nada; site 12, off Tanabe; sites 238, 247, Bungo-suido; site 41, off Tanega-shima.

Genus *PACAMBOCYTHERE* Malz, 1982

*Pacambocythere izuensis* Ikeya and Zhou (MS)

(Pl. 3, fig. 13)

*Illustrated specimen.* LV, JC-1384 (Pl. 3, fig. 13; L=0.51, H=0.47), from sample KT90-17, No. 7, off Tanabe.

*Remarks.* *Pacambocythere* was proposed by MALZ (1982) for a group of Buntoniinae from the Plio- to Pleistocene of southwest Taiwan. Its Recent records in Japan all come from areas influenced by the warm Kuroshio, and there are, as yet, no records from the Pacific side of northeast Japan. *P. izuensis* was first found from the depths of 138–335 m in Suruga Bay, and will be soon published as a new species (IKEYA and ZHOU, in prep.). This species is distinct from other *Pacambocythere* by its smooth carapace ornamented with a short sulcus and a wedge-shaped furrow above the posteroventral margin, and a vertically truncated posterior end.

*Occurrence.* Only one adult specimen was obtained from site 7, off Tanabe.

*Pacambocythere* sp.

(Pl. 3, fig. 14)

*Pacambocythere* sp. 1 Ikeya and Suzuki, 1992, p. 115 (list), Pl. 7, fig. 1.

*Illustrated specimen.* LV, JC-1385 (Pl. 3, fig. 14; L=0.55, H=0.27), from sample GH83-2, No. 110, Tosa Bay.

*Remarks.* This species was previously reported from the Sea of Japan by IKEYA and SUZUKI (1992). It is distinct from other *Pacambocythere* by its smooth carapace ornamented with an anterior marginal rim, a furrow running parallel to the anterior and ventral margin, several ridges and depressions in the posterior half, and a flange over-spreading a part of the dorsal margin. It resembles *P. izuensis* in having a smooth surface but is different from the latter in ornamentation pattern. It is also distinct from the smooth *P. japonica* (Ishizaki) in having an oblique dorsal margin and lacking small rounded depressions in the anterior area.

*Occurrence.* Site 30, Kumano-nada; sites 7, 8, 9-2, off Tanabe; sites 2, 32, 33, Tosa Bay; site 272, Bungo-suido; sites 301, 311, MZ-18, Hyuga-nada.

Family BYTHOCYTHERIDAE Sars, 1926  
 Genus *BYTHOCERATINA* Hornibrook, 1952  
*Bythoceratina angulata* Yajima, 1987

(Pl. 4, fig. 10)

*Bythoceratina angulata* Yajima, 1987, p. 66, 67, Figs. 5-5, 11-6a, b, 7a-c.

*Illustrated specimen.* LV, JC-1386 (Pl. 4, fig. 10; L=0.67, H=0.33), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* The Recent form of *B. angulata* show the same morphology as its fossil counterpart described by YAJIMA (1987) from the Pleistocene of the Atsumi Peninsula, central Japan. This species may be confused with *B. cassidoidea* Zhao, which it closely resembles. The dorsal and ventral margins of *B. angulata* are slightly convergent toward the rear, while *B. cassidoidea* shows parallel dorsal and ventral margins, a wider posterior frill, and a strong ridge below the ala, which does not exist in *B. angulata*.

*Occurrence.* Site 30, Kumano-nada; sites 5, 6, off Tanabe; sites 3, 110, Tosa Bay; sites 55, 56, off Tanega-shima.

*Bythoceratina cassidoidea* Zhao, 1988  
 (Pl. 4, fig. 7)

*Bythoceratina* sp. Ishizaki, 1981, p. 49, 50, Pl. 10, figs. 6, 7a, b.

*Bythoceratina* sp. Yajima, 1982, p. 216, Pl. 13, fig. 16.

*Bythoceratina* sp. C Nohara, 1987, p. 54, 55, Pl. 12, figs. 2a-d.

*Bythoceratina cassidoidea* Zhao, 1988, p. 272, Pl. 55, figs. 19-21; Pl. 56, fig. 1; text-fig. 5-91; Ruan and Hao, 1988, p. 257, 258, Pl. 41, figs. 15, 16; Zhao and Wang, 1988, text-figs. 5, 7, Pl. 2, fig. 17; Lee, 1990, p. 311-313, Pl. 26, figs. 7, 8.

*Illustrated specimen.* LV, JC-1387 (Pl. 4, fig. 7; L=0.77, H=0.42), from sample GH83-2, No. 273, Bungo-suido.

*Remarks.* The Recent form of this species has been previously reported from the seas around China; its fossils have been reported from the Pleistocene of Okinawa Trough, Boso Peninsula, and Cheju Island of Korea. For morphological comparisons see Remarks for *B. angulata*.

*Occurrence.* Sites 273, 291, Bungo-suido; sites 347, MZ-12, Hyuga-nada; sites 55, 56, 70, 71, off Tanega-shima.

*Bythoceratina robusta* Zhao, 1988  
 (Pl. 4, fig. 8)

*Bythoceratina* sp. A Nohara, 1987, p. 53, 54, Pl. 5, fig. 8.

*Bythoceratina robusta* Zhao, 1988, p. 273, Pl. 56, figs. 6-10.

*Bythoceratina hanaii* Ishizaki: Ruan and Hao, 1988, p. 258, Pl. 41, figs. 17-19.

*Illustrated specimen.* RV, JC-1388 (Pl. 4, fig. 8; L=0.61, H=0.35), from sample

GH84-3, No. 70, off Tanega-shima.

*Remarks.* ZHAO (1988) described this species from the depths of 90–210 m of the East China Sea. *Bythoceratina* sp. A of NOHARA (1987) illustrated from the Pleistocene of Okinawa-jima is synonymous with *B. robusta*, although it has finer puncta on its carapace surface. The specimens from the Upper Pleistocene of the Okinawa Trough that were identified by RUAN and HAO (1988) as *B. hanaii* Ishizaki are, in my opinion, *B. robusta*. Despite their close resemblance, the two species are distinct from each other in alar expansion; the ala in *B. robusta* is short and ornamented with numerous fine ridges, starting from the anteroventral area and running obliquely toward the posterior, whereas in *B. hanaii* it is long and smooth, connected with the anterior marginal rim and runs subparallel to the ventral margin.

*Occurrence.* Site 70, off Tanega-shima.

*Bythoceratina* aff. *B. robusta* Zhao, 1988

(Pl. 4, fig. 12)

*Illustrated specimen.* LV, JC-1389 (Pl. 4, fig. 12; L=0.68, H=0.35), from sample GH83-2, No. 347, Hyuga-nada.

*Remarks.* This species closely resembles *B. robusta* Zhao, but can be distinguished from the latter by its shallow sulcus and strong posteroventral spine. It is also close to *B. orientalis* (Brady) superficially, but is distinct in the development of an alar expansion, which in the latter species is replaced by two prominent ventral ribs.

*Occurrence.* Sites 5, 6, 7, off Tanabe; site 347, Hyuga-nada; sites 56, YT-2, off Tanega-shima.

*Bythoceratina sudjaponica* n. sp.

(Pl. 4, figs. 5, 6a, b)

*Type.* Holotype, RV, JC-1390 (Pl. 4, figs. 6a, b; L=0.60, H=0.32); paratype, LV, JC-1391 (Pl. 4, fig. 5; L=0.51, H=0.29).

*Type locality.* Holotype from sample MZ-16 (32°10.0'N, 131°30.6'E; 36 m deep), paratype from sample MZ-12 (32°00.0'N, 131°35.5'E; 42 m deep); Hyuga-nada.

*Etymology.* From south Japan, where it was collected.

*Diagnosis.* *Bythoceratina* with a small and stumpy carapace. Surface ornamented with fine puncta, very thin ala with a short terminal spine, and a straight, sharp ridge running obliquely on the surface of the anterior lobe.

*Description.* Carapace moderately small and stumpy, subrhomboidal in lateral outline. Anterior margin obliquely rounded, meeting dorsal margin to form a cardinal angle, but merges into ventral margin. Posterior margin compressed anterodorsally, straight in the median part, merges broadly into ventral margin, and meets dorsal margin forming an obliquely up-ward pointed caudal process. Dorsal and ventral margin

nearly straight and parallel to each other. A flange runs straightly from the middle dorsal margin, curved and ending at posterior cardinal angle. Sulcus broad and vertical. A short ridge runs obliquely on anterior lobe, starting at middle dorsal margin where it meets dorsal flange, and ending at anteromedian area. Posterior lobe obscure. Ala thin, at about one third of the height, running parallel to ventral margin from anteroventral corner to posterior fourth of length. Below the ala three to four filamentous ridges running subparallel to it. Fine puncta distributed evenly on carapace surface.

Duplicature and vestibulum narrow. Adductor muscle scars in a vertical row of five. Fulcral notch rounded and deep, just in front of adductor scars. Hinge lophodont, RV overlapping LV.

*Remarks.* The form most close to this species reported so far is *B. hanaii* Ishizaki, from which *B. sudjaponica* n. sp. can be easily distinguished in having a very thin ala.

*Occurrence.* Site 23, Kumano-nada; sites 4, 6, 9-2, off Tanabe; sites 31, 110, Tosa Bay; sites 294, 327, 334, 347, MZ-04, MZ-12, MZ-16, MZ-27, Hyuga-nada.

*Bythoceratina* sp. 1

(Pl. 4, fig. 2)

*Bythoceratina* sp. 1 Ruan and Hao, 1988, p. 260, 261, Pl. 41, fig. 29.

*Illustrated specimen.* Immature LV, JC-1392 (Pl. 4, fig. 2; L=0.33, H=0.17), from sample KT90-17, No. 4, off Tanabe.

*Remarks.* Only two juvenile valves of this species were found in my samples. The illustrated specimen shows the same external appearance as the adult of *Bythoceratina* sp. 1 of RUAN and HAO (1988) from the Holocene of the Okinawa Trough, although it is smaller than the latter.

*Occurrence.* Site 4, off Tanabe; site 110, Tosa Bay.

*Bythoceratina* sp. 2

(Pl. 4, fig. 11)

*Illustrated specimen.* RV, JC-1393 (Pl. 4, fig. 11; L=0.63, H=0.33), from sample GH83-2, No. 334, Hyuga-nada.

*Remarks.* This species is remarkably similar to *B. hanaii*, but it has a narrower, deeper sulcus and its alae are sinuated more highly anteriorly. Except for its larger size, this species is closest in overall respects to *Bythoceratina* sp. 2 of WHATLEY and ZHAO, 1987b from the Recent of the Malacca Straits, and may be conspecific with it.

*Occurrence.* Sites 334, 347, 365, Hyuga-nada; site 56, off Tanega-shima.

*Bythoceratina* sp. 3

(Pl. 4, fig. 13)

*Illustrated specimen.* LV, JC-1394 (Pl. 4, fig. 13; L=0.48, H=0.24), from sample

KT92-2, YT-2, off Tanega-shima.

*Remarks.* This species is characterized by its elongate, subparallelogrammatic carapace with shallow dorsal sulcus and evenly reticulated surface. The closest form to this species so far reported may be *B. elongata* Ikeya and Hainai 1982, which is distinct from *B. sp. 3* in having a more elongate carapace with three large globular swellings. Only two valves of this species are included in my specimens.

*Occurrence.* Site 23, Kumano-nada; site YT-2, south off Tanega-shima.

Genus *MONOCERATINA* Roth, 1928

*Monoceratina* aff. *M. sinensis* Zhao, 1988

(Pl. 4, fig. 15)

*Illustrated specimen.* LV, JC-1395 (Pl. 4, fig. 15; L=0.83, H=0.45), from sample GH84-3, No. 56, off Tanega-shima.

*Remarks.* This is a form very close to *Monoceratina sinensis* Zhao, but its dorsal sulcus is deeper, and ala more prominent with a terminal spine. It may be a subspecies of *M. sinensis*.

*Occurrence.* Site 3, Tosa Bay; site 56, off Tanega-shima.

Genus *PSEUDOCY THERE* Sars, 1866

*Pseudocythere* sp.

(Pl. 4, fig. 16)

*Illustrated specimen.* LV, JC-1396 (Pl. 4, fig. 16; L=0.56, H=0.23), from sample KT92-2, YT-2, off Tanega-shima.

*Remarks.* This species closely resembles *Pseudocythere frydli* Yajima, 1982 in many respects, especially in having an inflated carapace, but its carapace is smaller and much more elongate, and also lacks the parallel ridges on the posterior surface that can be seen in *P. frydli*. These two species are undoubtedly closely related to each other, but they do not possess the diagnostic characters of *Pseudocythere* of a compressed shell with a strongly compressed, flange-like anterior and posteroventral marginal areas. In the future a reassignment of the genus for the two species may be needed.

*Occurrence.* Site YT-2, off Tanega-shima.

Family CYTHERURIDAE G. W. Müller, 1894

Genus *SULCOCY THERURA* Zhao, 1988

*Sulcocytherura* sp.

(Pl. 5, fig. 9)

*Illustrated specimen.* RV, JC-1397 (Pl. 5, fig. 9; L=0.35, H=0.20), from sample KT90-17, No. 5, off Tanabe.

*Remarks.* The genus *Sulcocytherura* was proposed by ZHAO in 1988 to receive a new

species from the East China Sea, *Sulcoccytherura caelata*, which cannot be suitably assigned to either *Eucytherura* or *Typhlocythere* because of the development of its median sulcus and the lack of eye tubercles. The diagnosis of the genus given in Chinese by ZHAO is as follows, "Carapace small, in lateral view subrectangular. Dorsal margin long and straight; ventral margin slightly concave in the middle; anterior margin bluntly rounded; posterior margin with short caudal process. Surface ornamented with median sulcus, ridges and coarse reticula. No eye tubercle. Median sulcus prominent, dividing carapace into anterior and posterior parts. Hinge on RV shows crenulated furrow between terminal teeth. Duplicature moderate in width, vestibule narrow. Radial pore canals few and simple." My species shown here fits all the diagnostic characters of *Sulcoccytherura*. It is distinct from the type-species *S. caelata* in having a shallower sulcus, a stronger ventral alar process, the existence of a sinuate belt of reticula connecting the ala and the anterior margin, and a lack of ridges on the surface.

*Occurrence.* Sites 23, 30, Kumano-nada; site 5, off Tanabe; site 347, Hyuga-nada.

Genus *CYTHERURA* Sars, 1866

*Cytherura daishakaensis* (Tabuki, 1986)

(Pl. 5, fig. 1)

*Semicytherura?* *daishakaensis* Tabuki, 1986, p. 98, 99, Pl. 17, figs. 1–6; text-fig. 19-3; Ikeya and Itoh, 1991, p. 123, Fig. 22B.

*Illustrated specimen.* LV, JC-1398 (Pl. 5, fig. 1; L=0.49, H=0.27), from sample GH83-2, No. 31, Tosa Bay.

*Remarks.* This species was described by TABUKI (1986) from the Plio-Pleistocene of the Tsugaru Basin, north Honshu, Japan, where it was tentatively assigned to *Semicytherura*. However, its inner lamella is narrow throughout and its inner margin is subparallel to the outer margin; in *Semicytherura* the inner lamella is very broad anteriorly and posteriorly, the inner margin being strongly recurved in the posterior half. Its weak caudal process is also unusual in *Semicytherura*. It agrees in all respects to the diagnostic features of *Cytherura*. This species has also been reported by IKEYA and ITOH (1991) from Sendai Bay, northeast Japan, where it is distributed at depths of about 10–20 m.

*Occurrence.* Site 31, Kumano-nada; site 31, Tosa Bay.

Genus *SEMICYTHERURA* Wagner, 1957

*Semicytherura* aff. *S. hanaii* Ishizaki, 1981

(Pl. 5, fig. 3)

*Illustrated specimen.* RV, JC-1399 (Pl. 5, fig. 3; L=0.48, H=0.21), from sample GH83-2, No. 282, Hyuga-nada.

*Remarks.* This species has almost the same arrangement of surface ridges as that seen in *S. hanaii* Ishizaki. It is distinct from the latter in having an undulate carapace

surface with a prominent posterodorsal lobe, a blunt mid-ventral spine and embossed ridges in anterior area; its caudal process is more prominent than that of *S. hanaii*.

*Occurrence.* Site 32, Kumano-nada; site 282, Hyuga-nada; site YT-6, off Tanegashima.

*Semicytherura* sp. 1

(Pl. 4, figs. 9a, b)

*Illustrated specimen.* A complete carapace, JC-1400 (LV: Pl. 4, fig. 9a; L=0.35, H=0.16. RV: Pl. 4, fig. 9b; L=0.35, H=0.16), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* This is a small species of *Semicytherura* with an elongate subrectangular carapace, the surface of which is evenly ornamented with faint muri and punctae; an eye tubercle is distinct. The duplicature is extremely broad, a character typical of the genus. This species is distinct from *Semicytherura tetragona* (Hanai), a species which it otherwise closely resembles, in lacking a ventral alar process.

*Occurrence.* Sites 24, 30, Kumano-nada.

*Semicytherura* sp. 2

(Pl. 5, fig. 11)

*Semicytherura* sp. 1 Ikeya et al., 1992, p. 351, Figs. 12-11, 12.

*Illustrated specimen.* RV, JC-1401 (Pl. 5, fig. 11; L=0.45, H=0.20), from sample GH82-2, No. 23, Kumano-nada.

*Remarks.* This species was reported once from Otsuchi Bay, northeast Japan (IKEYA et al., 1992). It resembles *S. enshuensis* Ikeya and Hanai in having an elongate carapace and flat ventral surface, but is different from the latter in showing an oblique posterodorsal margin and non-ornamented surface.

*Occurrence.* Sites 23, 24, 31, Kumano-nada; site 110, Tosa Bay; sites 318, 347, 352, 358, Hyuga-nada.

*Semicytherura* sp. 3

(Pl. 5, fig. 7)

*Semicytherura* sp. 1 Yajima, 1987, p. 68, Figs. 12-10, 11.

*Illustrated specimen.* LV, JC-1402 (Pl. 5, fig. 7; L=0.34, H=0.16), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* This species was previously found by YAJIMA in 1987 from the Pleistocene of Atsumi Peninsula, central Japan. It is closely similar to and probably the mature form of *Semicytherura* sp. of IKEYA and HANAI (1982), which was found only as juveniles from the brackish Hamana-ko Lake in central Japan. The form described here is different in having elongate fossae in the anteromedian area.



*Occurrence.* Site 30, Kumano-nada.

Genus *CYTHEROPTERON* Sars, 1866  
*Cytheropteron tabukii* Ikeya and Zhou (MS)  
 (Pl. 5, fig. 2)

*Illustrated specimen.* A broken RV, JC-1403 (Pl. 5, fig. 2; L=0.48, H=0.33), from sample GH82-2, No. 48, Kumano-nada.

*Remarks.* This is a deep-sea form. The publication of its description as a new species, based on material from the depths of 380–595 m in Suruga Bay, will be available in IKEYA & ZHOU (in prep.). It resembles the *Cytheropteron testudo* Sars reported by WHATLEY and AYRESS (1988) from the southwest Pacific, Indian Ocean and North Atlantic, a species which has also been described by RUAN and HAO (1988) from the Okinawa Trough as *Cytheropteron perlaria* n. sp., but is distinct from the latter in having more strongly developed alae and coarser surface punctae.

*Occurrence.* Sites 39, 48, Kumano-nada; site 246, Bungo-suido; sites 275, 282, 323, Hyuga-nada.

*Cytheropteron rectocostum* n. sp.  
 (Pl. 5, figs. 5a, b, 6)

*Type.* Holotype, RV, JC-1404 (Pl. 5, figs. 5a, b; L=0.49, H=0.31); paratype, LV, JC-1405 (Pl. 5, fig. 6; L=0.44, H=0.28).

*Type locality.* Holotype from sample GH83-2, No. 362 (31°19.0'N, 131°23.7'E; 135 m deep), paratype from sample GH83-2, No. 365 (31°18.8'N, 131°18.9'E; 110 m deep); Hyuga-nada.

*Etymology.* recto (L.)=perpendicular; -costum (L.)=costal or ribbed. For the diagnostic vertical ribs.

*Diagnosis.* A *Cytheropteron* with a small, thick carapace. In lateral view sub-rhomboidal with an ala gently curved. Ornamented with vertical ribs, giving way anteriorly to fine ridges and reticulae.

*Description.* Carapace small and thick, sub-rhomboidal in lateral view, highest at middle. Anterior margin obliquely rounded. Posterior margin angular, making a horizontally pointed caudal process. Ventral margin sinuate, concave in middle; posterior third obscured by ala. An ala runs just above ventral margin, gently curved. Dorsal margin strongly arched in RV, gently arched in LV. Surface ornamented with about six sub-vertical ribs in central part, whereas in anterior and posterior areas the ornamentation becomes fine ridges and reticulae. No eye tubercle.

Duplicature moderately broad, broadest at anterior and posterior ends. Vestibule poorly developed along anterior margin, deepest at anteroventral margin. Hinge line curves in S-shape in internal view. Hingement of RV consists of anterior and posterior

teeth and median crenulate groove, to whose anterior and posterior ends the crenulation becomes a little coarser. Possesses four sub-vertically arranged, elongated adductor muscle scars with V-shaped frontal scar, and small round scar inside V.

*Remarks.* This species is similar to, but much smaller than, both *C. miurense* Hanai and *C. abnormis* Zhao.

*Occurrence.* Sites 23, 24, 39, Kumano-nada; sites 8, 10, off Tanabe; sites 2, 33, 91, 101, Tosa Bay; sites 252, 272, 273, 291, 292, Bungo-suido; sites 275, 294, 301, 311, 318, 352, 358, 362, 365, MZ-19, MZ-20, Hyuga-nada; site 42, off Tanega-shima.

*Cytheropteron* sp. 1

(Pl. 4, fig. 14)

*Illustrated specimen.* RV, JC-1406 (Pl. 4, fig. 14; L=0.45, H=0.23), from sample GH82-2, No. 23, Kumano-nada.

*Remarks.* This is a small *Cytheropteron*. Its distinctive ventral ala makes it different from any other forms of *Cytheropteron* ever reported. The ala is stick-like, with a knob at each end and a deep concavity above the middle. Carapace surface weakly ornamented with concentric filamentous ridges, almost smooth. *Cytheropteron* sp. 1 is obviously a new species, but there are very few specimens, not enough for description of a new taxon.

*Occurrence.* Sites 23, 31, Kumano-nada.

*Cytheropteron* sp. 2

(Pl. 5, fig. 8)

*Illustrated specimen.* RV, JC-1407 (Pl. 5, fig. 8; L=0.58, H=0.34), from sample KT90-17, No. 7, off Tanabe.

*Remarks.* This species is similar to *Cytheropteron eremitum* Hanai in having sub-vertically arranged ornamentation, but differs from the latter in lacking a compressed area along the anterior margin.

*Occurrence.* Site 7, off Tanabe; sites 352, 358, 362, Hyuga-nada; sites YT-2, YT-5, YT-6, off Tanega-shima.

Genus *METACYTHEROPTERON* Oertli, 1957

*Metacytheropteron ignobilis* (Guan, 1978)

(Pl. 5, fig. 4)

*Cytheropteron ignobilis* Guan, 1978, p. 251, Pl. 67, figs. 15–18; Gou et al., 1983, p. 44, Pl. 4, figs. 12–23, text-figs. 4a, b; Zhao, 1988, p. 265, Pl. 52, fig. 16; Liu, 1989, p. 144, Pl. 164, figs. 14, 15.

*Metacytheropteron concentricus* Lee, 1990, p. 353–356, Pl. 32, figs. 8–11; text-fig. 69.

*Illustrated specimen.* RV, JC-1408 (Pl. 5, fig. 4; L=0.49, H=0.27), from sample GH84-3, No. 55, off Tanega-shima.

*Remarks.* *Metacytheropteron concentricus* Lee, 1990 is obviously a junior synonym of *Cytheropteron ignobilis* Guan, 1978. Although GUAN (1978) assigned this species to *Cytheropteron*, its nearly straight dorsal margin and less prominent ventral ala suggest it should be put into *Metacytheropteron*. Recent forms of this species have been reported from the East China Sea, and from off the South Korea.

*Occurrence.* Sites 282, 301, 318, 339, 352, 358, Hyuga-nada; sites 27, 41, 55, 56, 70, 71, YT-2, YT-5, YT-6, off Tanega-shima.

Family PARACYTHERIDEIDAE Puri, 1957

Genus *PARACYTHERIDEA* G. W. Müller, 1894

*Paracytheridea* sp.

(Pl. 5, fig. 10)

*Paracytheridea* sp. Nohara and Tabuki, 1985, Table 1, Pl. 2, fig. 11.

*Illustrated specimen.* Immature LV, JC-1409 (Pl. 5, fig. 10; L=0.58, H=0.31), from sample GH84-3, No. 55, off Tanega-shima.

*Remarks.* This species was found by NOHARA and TABUKI (1985) from the Pleistocene sandy deposits of Okinawa Island. In this study only two juvenile valves were found from off Tanega-shima Island. They can be easily distinguished from the juveniles of the other three species of *Paracytheridea* from the studied areas, namely *P. bosoensis* Yajima, *P. dialata* Gou and Huang and *P. neolongicaudata* Ishizaki.

*Occurrence.* Sites 55, 86, off Tanega-shima.

Family LOXOCONCHIDAE Sars, 1925

Genus *LOXOCONCHA* Sars, 1866

Subgenus *LOXOCONCHA* Sars, 1866

*Loxoconcha (Loxoconcha) ikeyai* n. sp.

(Pl. 5, figs. 14a, b, 15)

*Loxoconcha* sp. A Lee, 1990, p. 361, Pl. 33, figs. 6-9.

*Type.* Holotype, LV, JC-1410 (Pl. 5, figs. 14a, b; L=0.54, H=0.39); paratype, RV, JC-1411 (Pl. 5, fig. 15; L=0.53, H=0.38).

*Type locality.* From sample KT90-17, No. 8 (33°38.2'N, 135°13.0'E; 176 m deep), off Tanabe.

*Etymology.* In honor of Prof. N. IKEYA, an ostracodologist at Shizuoka University, Japan, who has done extensive work on the Cenozoic and modern marine faunas of Japan.

*Diagnosis.* A large, round species of *Loxoconcha* characterized by an inflated carapace, coarse and uniform fossae, and a posteroventral flange.

*Description.* Carapace large, viewed laterally sub-circular. Anterior margin obliquely and broadly rounded; dorsal margin arched; ventral margin convex; posterior margin

protrudent at two third of the height, forming triangular caudal process.

Surface coarsely and uniformly reticulated with fossae. A weak flange runs parallel to posteroventral margin. Above it is one weak ridge, and below it are two ridges running parallel to it. Eye tubercle very weak.

Duplicature moderately wide. Inner margin parallel to outer margin, except for postroventral margin where inner margin runs rather straight and obliquely from middle of posterior margin to middle of ventral margin. Selvage distinct. Vestibulum absent. Hinge gongyodont. Muscle scars consist of ax-shaped frontal scar and an oblique row of four adductor scars.

*Remarks.* This species was first reported in open nomenclature by LEE (1990) from the Pleistocene of Cheju Island, Korea. As mentioned by Lee, this species closely resembles *L. tamakazura* Yajima, 1982 from the late Pleistocene of Boso Peninsula, central Japan, in having an inflated carapace, ovate lateral outline, uniform surface reticulation and three weakly developed ventral marginal ridges, but the latter is differentiated from this species by its more coarsely reticulated surface with larger and shallower fossae, and slightly larger carapace size. In his description, Lee also points out the occurrence of this species from the Pliocene of Shikoku, Japan and of Guangdong Province, China, and from the Recent of the East China Sea, South China Sea and Korean South Sea.

*Occurrence.* Site 23, Kumano-nada; sites 6–10, off Tanabe; sites 3, 33, 34, Tosa Bay; sites 272, 273, 292, Bungo-suido; sites 318, 362, 365, MZ-16, MZ-18, MZ-19, MZ-20, Hyuga-nada; site 55, off Tanega-shima.

*Loxococoncha (Loxococoncha) prolaeta* n. sp.

(Pl. 5, figs. 12a, b, 13)

*Loxococoncha* sp. B Ikeya et al., 1985, p. 16, Pl. 8, figs. 5, 6.

*Type.* Holotype, a complete carapace, JC-1412 (LV: Pl. 5, figs. 12a, b; L=0.50, H=0.33. RV: Pl. 5, fig. 13; L=0.51, H=0.32).

*Type locality.* From sample KT92-2, YT-2 (30°10.3'N, 130°52.7'E; 96 m deep), off Tanega-shima.

*Etymology.* For its close resemblance to *L. laeta* Ishizaki.

*Diagnosis.* A species of *Loxococoncha* with a small, subrhomboidal carapace. Surface evenly ornamented with concentric reticula.

*Description.* Carapace small, subrhomboidal. Greatest length above mid-height, greatest height near anterior terminal of dorsal margin, and thickest mid-ventrally. Dorsal margin of RV nearly straight, whereas that of LV slightly sinuous; slightly concave at posterior terminal due to caudal process. Anterior margin broadly and a little obliquely rounded. Posterior margin protrudes near the end of the dorsal margin, forming triangular caudal process. Ventral margin broadly arched. Surface ornamented with deep concentric reticula, except for caudal process, which is almost smooth. Eye tuber-

cle prominent.

Duplicature moderately wide, with narrow vestibule along anterior and posterior margin. Hinge gongyodont. Central muscle scar area consists of one mushroom-shaped frontal scar and a vertical row of four adductor scars.

*Remarks.* This species has been reported from a surge channel, on a sandy bottom at Cape Omaezaki in central Japan. It is distinct from *L. laeta* Ishizaki in lacking fine pits near the dorsal margin and several sub-horizontal crests in the median area.

*Occurrence.* Site 110, Tosa Bay; site 291, Bungo-suido; sites 347, 365, MZ-12, Hyuga-nada; sites YT-2, YT-5, off Tanega-shima.

Subgenus *PALMOCONCHA* Swain and Gilby, 1974

*Loxoconcha (Palmoconcha) propontica* Hu, 1983

(Pl. 6, figs. 1, 2a, b, 3)

*Loxoconcha propontica* Hu, 1983, p. 156, Pl. 2, figs. 8, 12; Fig. 6; Ruan and Hao, 1988, p. 327, Pl. 58, figs. 13, 14.

*Illustrated specimen.* A complete carapace, JC-1413 (LV: Pl. 6, figs. 2a, b; L=0.59, H=0.32. RV: Pl. 6, fig. 1; L=0.58, H=0.31), from sample GH83-2, No. 3, Tosa Bay; an immature RV, JC-1414 (Pl. 6, fig. 3; L=0.44, H=0.26), from sample GH82-2, No. 47, Kumano-nada.

*Remarks.* *Loxoconcha propontica* Hu was described from the possibly Late Pliocene or Early Pleistocene of Hengchun Peninsula, southern Taiwan. Recent specimens have previously been found from the Okinawa Trough and from Suruga Bay. This species, together with its close relative *Loxoconcha parapontica* n. sp., are deep water inhabitants in the studied areas. Its adult specimens from the studied areas have small but distinct eye tubercles. Its central muscle-scar pattern is peculiar: four adductor muscle-scars are arranged in an arcuate row, with a heart-shaped fulcral notch and an almond-shaped projection in front of the uppermost two scars; the frontal scar is asymmetrically U-shaped, opening upward.

*Occurrence.* Sites 24, 31, 32, 38, 39, 47, 48, Kumano-nada; sites 8, 10, off Tanabe; sites 3, 34, 91, Tosa Bay; site 252, Bungo-suido; sites 275, 294, 301, 318, 339, 358, Hyuga-nada; sites 55, YT-5, YT-6, off Tanega-shima.

*Loxoconcha (Palmoconcha) parapontica* n. sp.

(Pl. 6, figs. 4, 5, 6a, b, 7)

*Loxoconcha* sp. 1 Ruan and Hao, 1988, p. 327, Pl. 58, figs. 15, 16.

*Palmoconcha* aff. *propontica* (Hu): Ikeya and Suzuki, 1992, p. 115 (list).

*Type.* Holotype, RV, JC-1415 (Pl. 6, fig. 4; L=0.49, H=0.31); paratype, RV, JC-1416 (Pl. 6, fig. 5; L=0.50, H=0.32); paratype, LV, JC-1417 (Pl. 6, figs. 6a, b; L=0.53, H=0.33); paratype, immature RV, JC-1418 (Pl. 6, fig. 7; L=0.41, H=0.26).

*Type locality.* Holotype and paratype JC-1416 from GH82-2, No. 32 (34°04.7'N, 136°43.5'E; 670 m deep), Kumano-nada; paratypes JC-1417 and 1418 from GH83-2, No. 275 (32°12.9'N, 131°50.6'E; 554 m deep), Hyuga-nada.

*Etymology.* For its close resemblance to *Loxoconcha propontica* Hu.

*Diagnosis.* *Loxoconcha* closely resembling *L. propontica*, but having a shorter, more oval carapace. No eye tubercle.

*Description.* Carapace small, oval shaped in lateral view. Anterior margin obliquely rounded, continuing into dorsal margin, making a distinct cardinal angle; posterior marginal border flat, with caudal process directed subdorsally; dorsal margin nearly straight, with a weak posterodorsal loop; ventral margin sinuous, slightly concave near anterior one third. Surface uniformly reticulate, no eye tubercle.

Hinge gongyodont type. Four adductor muscle scars form a curved row; there is a round knob in front of the row; frontal scar U-shaped, opening upward; the mouth of the U may be very narrow or closed. Duplicature broad along anterior and posterior margins; vestibulum narrow.

*Remarks.* This species has previously been found from the Upper Pleistocene of the Okinawa Trough; from the Recent off Shimane Peninsula, Sea of Japan; and from the Recent of Suruga Bay, central Japan. It closely resembles *L. propontica* Hu, but can be easily distinguished from the latter because it has a shorter carapace with a short, arched flange at the posterodorsal margin; however, in *L. propontica* the dorsal margin is smooth and straight, and the caudal process is more prominent. These differences are traceable to young instars. *L. parapontica* n. sp. is also different from *L. propontica* in lacking eye tubercles outside and ocular sinuses inside, which suggests that it is blind. Furthermore, the fulcral notch of *L. propontica*, seen in the central muscle-scar area, is absent in *L. parapontica* n. sp. In southwest Japan *L. parapontica* n. sp. was found at the depths of 317–797 m, whereas *L. propontica* was found at 140–797 m. In the area off the Shimane Peninsula, the Sea of Japan, *L. parapontica* n. sp. occurred without accompaniment by the latter species (see IKEYA and SUZUKI, 1992).

*Occurrence.* Sites 32, 39, 48, Kumano-nada; site 35, Tosa Bay; site 252, Bungo-suido; sites 275, 282, Hyuga-nada.

#### Genus *PHLYCTOCY THERE* Keij, 1958

##### *Phlyctocythere* sp.

(Pl. 6, fig. 8)

*Phlyctocythere* sp. Ikeya et al., 1985, Table 1, Pl. 8, fig. 15.

*Illustrated specimen.* RV, JC-1419 (Pl. 6, fig. 8; L=0.36, H=0.25), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* IKEYA et al. (1985) first found this species as rare specimens from the Pleistocene Furuya Formation, central Japan. In this study only six poorly preserved,

subfossil specimens of this species were obtained. This is an unusual species of *Phlyctocythere*, with a carapace surface ornamented with numerous longitudinal sharp ridges, but in other all respects it possesses the diagnostic features of the genus. Externally it extremely resembles *Loxocauda decipiensis* Müller found from the shelf areas of Australia, and might be conspecific with it.

*Occurrence.* Site 30, Kumano-nada; site 110, Tosa Bay; site 291, Bungo-suido; sites 334, 352, Hyuga-nada.

Family XESTOLEBERIDIDAE Sars, 1928

Genus *XESTOLEBERIS* Sars, 1866

*Xestoleberis pararotunda* Hao, 1988

(Pl. 6, figs. 10, 11)

*Xestoleberis* cf. *X. sagamiensis* Kajiyama: Tabuki and Nohara, 1988, Tables 1, 2, Pl. 2, figs. 6, 7; Tabuki and Nohara, 1990, Tables 2, 3.

*Xestoleberis pararotunda* Hao (in Ruan and Hao, 1988), p. 373, Pl. 69, figs. 8–11.

*Xestoleberis* sp. 2 Ikeya and Suzuki, 1992, p. 117 (list), Pl. 9, fig. 10.

*Illustrated specimens.* LV, JC-1420 (Pl. 6, fig. 10; L=0.41, H=0.28); LV, JC-1421 (Pl. 6, fig. 11; L=0.43, H=0.29); all from sample KT90-17, No. 4, off Tanabe.

*Remarks.* *X. pararotunda* Hao was described from the Upper Pleistocene to Recent of the Okinawa Trough. Of the species of *Xestoleberis* living in Japan, *X. pararotunda* is most similar to *X. sagamiensis* (Kajiyama), but its smaller size, more broadly rounded anteroventral margin, narrower duplicature and more prominent selvage make it distinct from the latter. *Xestoleberis* cf. *X. sagamiensis* reported by TABUKI and NOHARA (1988, 1990) from the Ryukyus, and also *Xestoleberis* sp. 2 of IKEYA and SUZUKI (1992) from the Sea of Japan, are considered here synonymous with *X. pararotunda*.

*Occurrence.* Sites 23, 30, Kumano-nada; sites 4, 5, 6, off Tanabe; site 110, Tosa Bay; site 291, Bungo-suido; sites 294, 334, 339, 358, 362, 365, MZ-27, Hyuga-nada; sites 56, YT-5, off Tanega-shima.

*Xestoleberis* sp.

(Pl. 6, fig. 9)

*Xestoleberis* sp. B Ishizaki, 1968, p. 42, Pl. 6, fig. 16.

*Xestoleberis* sp. Ishizaki, 1983, p. 152, 153, Pl. 34, figs. 1–3; Pl. 35, fig. 6.

*Illustrated specimen.* LV, JC-1422 (Pl. 6, fig. 9; L=0.59, H=0.32), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* Previous discoveries of this species include two reports from the Recent and the Pliocene of Shikoku, Japan (ISHIZAKI, 1968; 1983), which in both cases were given in open nomenclatures because of the paucity of specimens. As noted by ISHIZAKI (1983), this species resembles *Xestoleberis suetsumuhana* YAJIMA, 1982 in lateral outline and

also in having a flattened ventral plane, but is distinguished from the latter in that it has an anterior vestibule much more narrowly confined to the ventral side and the longest axis is positioned more ventrally.

*Occurrence.* Sites 23, 24, 30, 31, Kumano-nada; site 5, off Tanabe; site 110, Tosa Bay; sites 301, 318, 334, 347, MZ-04, MZ-27, Hyuga-nada; sites 55, 56, 70, YT-5, off Tanega-shima.

Family MICROCYTHERIDAE Klie, 1938  
Genus *MICROCYTHERE* G. W. Müller, 1894

*Microcythere* sp. 1  
(Pl. 6, figs. 15, 16)

*Illustrated specimen.* RV, JC-1423 (Pl. 6, fig. 15; L=0.42, H=0.16); LV, JC-1424 (Pl. 6, fig. 16; L=0.42, H=0.17); all from sample GH83-2, No. 31, Tosa Bay.

*Remarks.* This species has a very narrow posteroventral duplicature, a character that does not agree with the diagnosis of *Microcythere* but is usually seen in Cobanocytherinae. The existence of its 4 adductor muscle scars, however, suggests that it is more closely related to *Microcythere* than to Cobanocytherinae, which has triple adductor scars. In this study it is tentatively assigned to *Microcythere* because there is not a genus other than *Microcythere* that is suitable to receive it. Externally it closely resembles *Microcythere* sp. B of ZHAO (1988) from the East China Sea, but differs from the latter in having a carapace about twice the size.

*Occurrence.* Sites 30, 38, 39, 47, Kumano-nada; sites 31, 32, 91, Tosa Bay.

*Microcythere* sp. 2  
(Pl. 6, fig. 14)

*Illustrated specimen.* LV, JC-1425 (Pl. 6, fig. 14; L=0.32, H=0.12), from sample GH82-2, No. 30, Kumano-nada.

*Remarks.* This species resembles *Microcythere ventricarinata* Zhao, 1988 from the East China Sea in lateral outline, but the latter has a sharp ventral margin, along which a strong ridge runs from the postero- to the anteroventral angles.

*Occurrence.* Sites 23, 30, 38, Kumano-nada; site 110, Tosa Bay.

Family PARADOXOSTOMATIDAE Brady and Norman, 1889  
Genus *XIPHICHILUS* Brady, 1870

*Xiphichilus* sp.  
(Pl. 6, fig. 12)

*Xiphichilus sinensis* Yang et Hou: Zhao, 1988, p. 278, Pl. 58, figs. 8, 9.

*Xiphichilus* sp. Yajima, 1987, p. 69, Fig. 8-2.

*Illustrated specimen.* LV, JC-1426 (Pl. 6, fig. 12; L=0.93, H=0.28), from sample



MZ-16, Hyuga-nada.

*Remarks.* Besides the areas researched for this study, I have found this species in Suruga Bay. It is conspecific with the form reported by ZHAO (1988) from the East China Sea which was described as *Xiphichilus sinensis* Yang et Hou. In my opinion, it is different from *X. sinensis* in having a more elongate carapace, and in showing a horizontally pointed posterodorsal margin. This species is also conspecific with *Xiphichilus* sp. of YAJIMA (1987) from the Pleistocene of the Atsumi Peninsula, central Japan.

*Occurrence.* Sites 23, 24, 30, Kumano-nada; site 4, off Tanabe; sites 31, 110, Tosa Bay; sites 327, 347, 352, MZ-16, Hyuga-nada.

Family uncertain

Genus *SAIDA* Hornibrook, 1952

*Saida* sp.

(Pl. 6, figs. 17a, b)

*Saida herrigi* Keij: Ruan and Hao, 1988, p. 252, Pl. 40, figs. 1-4.

*Illustrated specimen.* RV, JC-1427 (Pl. 6, figs. 17a, b; L=0.38, H=0.24), from sample GH83-2, No. 352, Hyuga-nada.

*Remarks.* This species was previously found by RUAN and HAO (1988) from the Upper Pleistocene and the Recent of the Okinawa Trough, where it was misidentified as *Saida herrigi* Keij. It is distinct from *Saida herrigi* in lacking a posteroventral knob on the ridge above the ventral margin. It closely resembles *Saida* sp. as reported by GOU and CHEN (1988) from the Pliocene of Leizhou Peninsula, south China, but is different from the latter in having a smaller carapace size and shorter ridge near the posterior cardinal angle.

*Occurrence.* Sites 246, 247, 252, Bungo-suido; sites 339, 352, 358, Hyuga-nada; site YT-6, off Tanega-shima.

Genus *SINOCY THERE* Hou, 1982

*Sinocythere* sp.

(Pl. 6, fig. 13)

*Sinocythere* sp. Zhao, 1988, p. 279, 280, Pl. 47, fig. 3.

*Illustrated specimen.* LV, JC-1428 (Pl. 6, fig. 13; L=0.56, H=0.28), from sample KT92-2, YT-6, off Tanega-shima.

*Remarks.* This species was previously reported from the East China Sea by ZHAO (1988). The genus *Sinocythere* was proposed by Hou in HOU et al. (1982) to receive four new species from the Quaternary of Jiangsu Province, east China. After its first discovery, this genus was reported from Neogene to Recent marine deposits of areas around China, and was considered endemic to China (*e.g.*, WANG and ZHAO, 1991). Recently a *Sinocythere* conspecific with the species described herein was found from the Ariake and

Yatsushiro Inland Seas, Kyushu, Japan by researchers at Kumamoto University (M. YUMOTO, pers. comm.). In this study only one adult valve of this species was detected from off Tanega-shima. The populations of this species in Japan are possibly relicts from glacial times.

*Occurrence.* Site YT-6, off Tanega-shima.

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# **P L A T E S**

### Plate 1

Figs. 1a, b. *Keijcyoidea* sp.

1a. Lateral view of LV (JC-1353),  $\times 65$ ; 1b. lateral view of RV of the same individual (JC-1353),  $\times 65$ .

Fig. 2. *Cytherelloidea* sp.

Lateral view of immature RV (JC-1352),  $\times 65$ .

Fig. 3. *Cytherella leizhouensis* Gou, 1983

Lateral view of RV (JC-1351),  $\times 65$ .

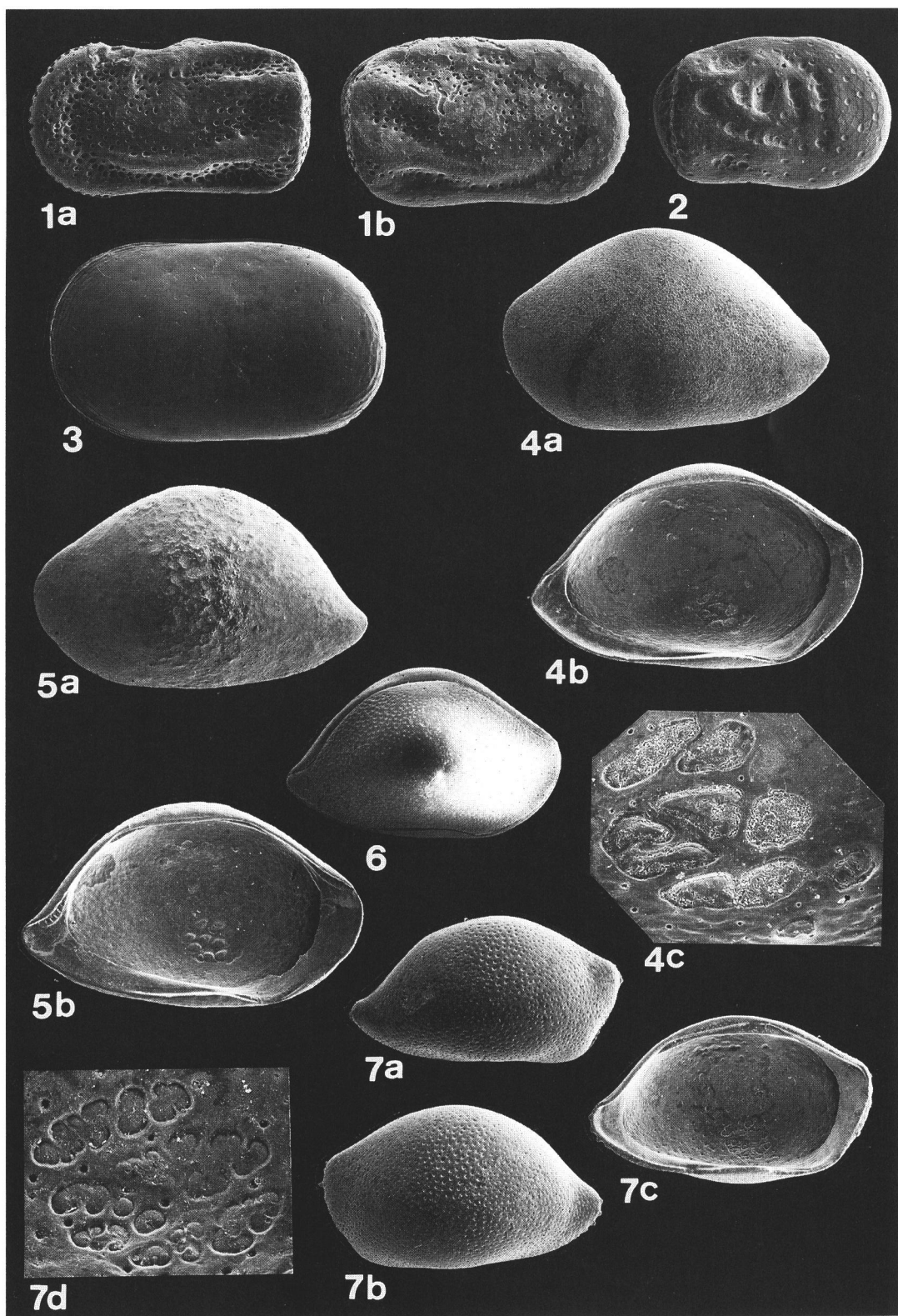
Figs. 4–6. *Neonesidea posteroacuta* n. sp.

4a. Lateral view of LV, holotype (JC-1354),  $\times 40$ ; 4b. internal view of the same LV,  $\times 40$ ; 4c. its central muscle scars,  $\times 200$ ; 5a. lateral view of LV, paratype (JC-1355),  $\times 50$ ; 5b. internal view of the same LV,  $\times 50$ ; 6. lateral view from the left side of a carapace, paratype (JC-1356),  $\times 40$ .

Figs. 7a–d. *Aponesidea tanegashimensis* n. sp.

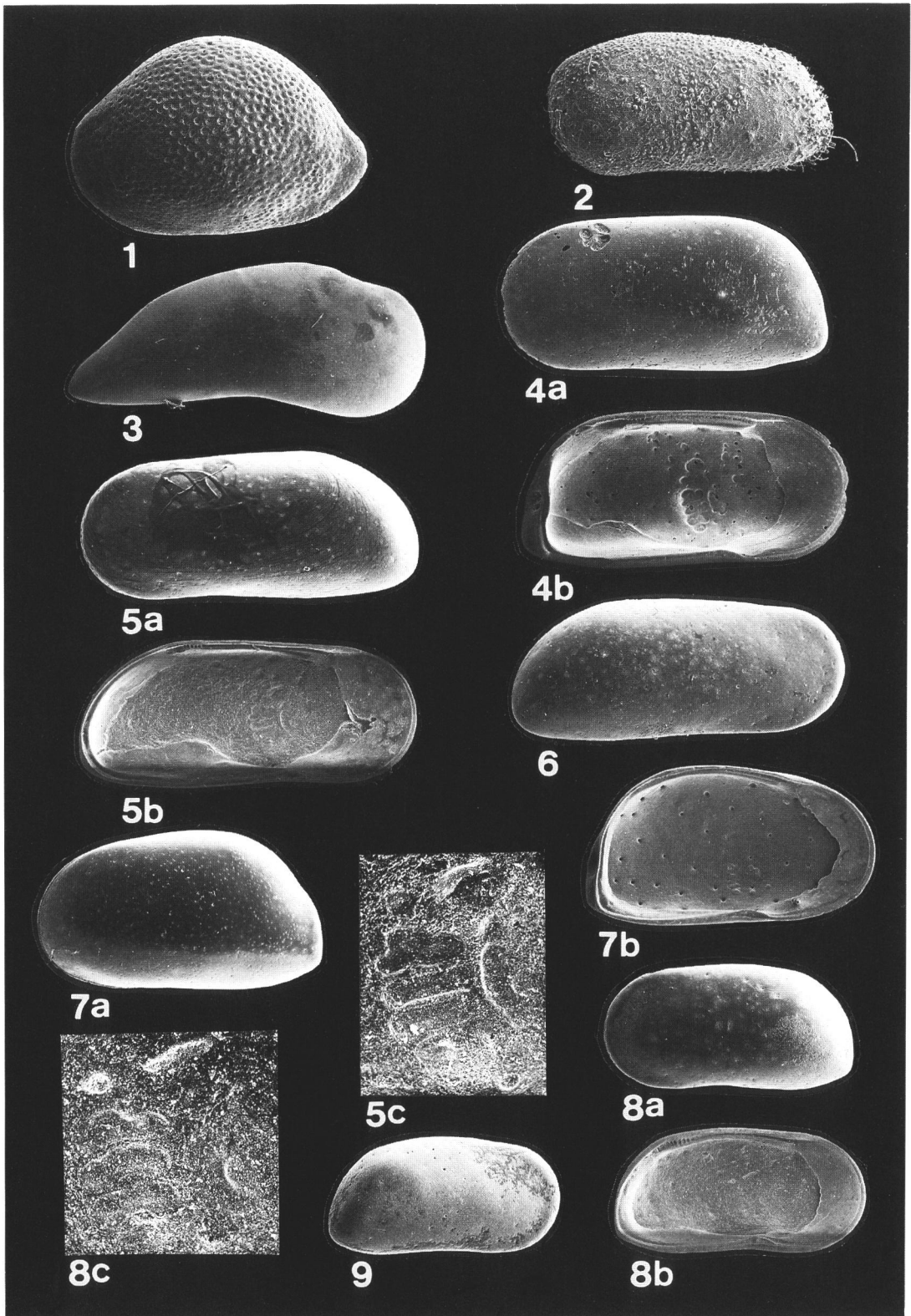
7a. Lateral view of RV (JC-1357),  $\times 55$ ; 7b. lateral view of LV from the same individual (JC-1357),  $\times 55$ ; 7c. internal view of the same LV,  $\times 55$ ; 7d. central muscle scars of the LV,  $\times 250$ .





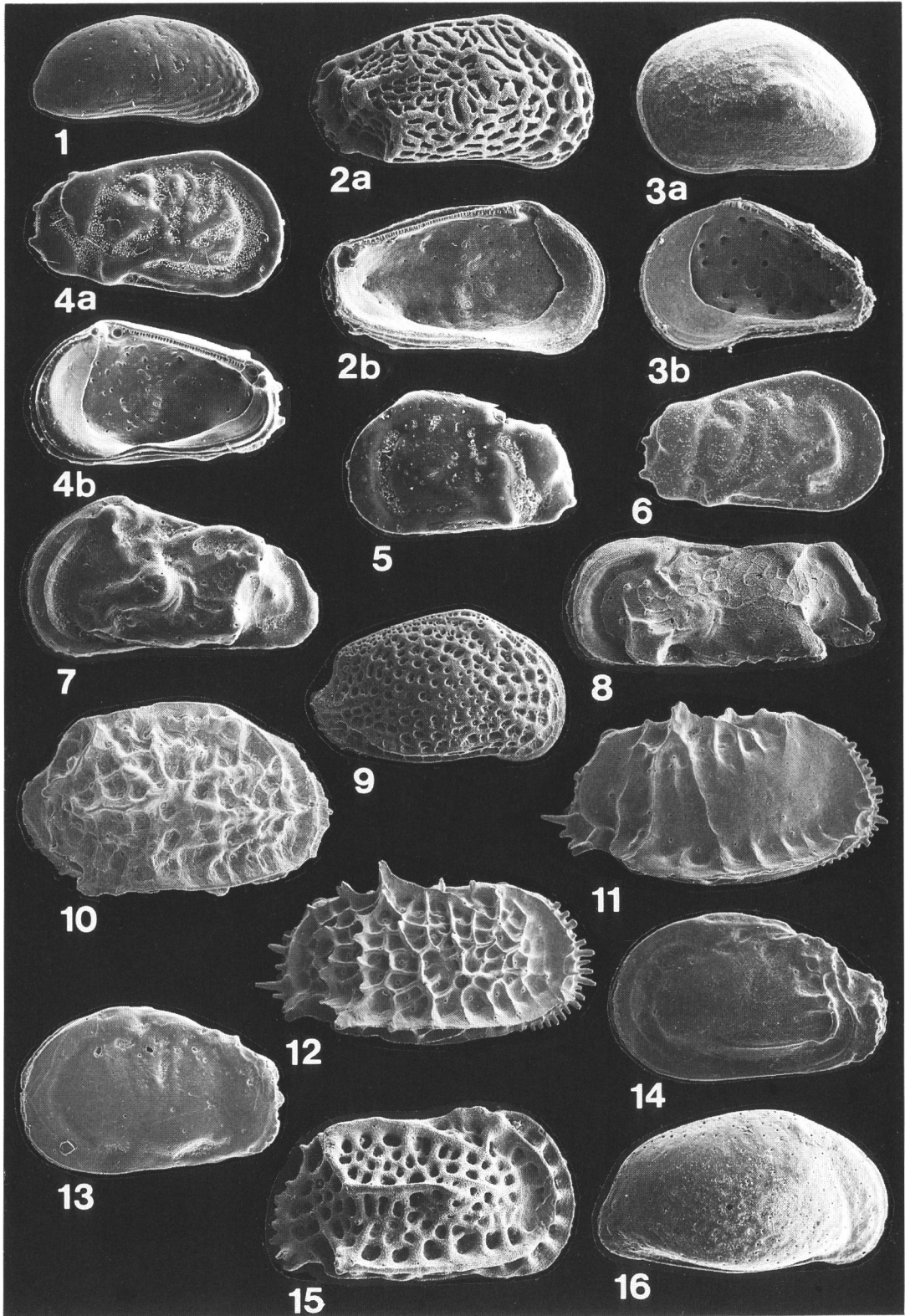
## Plate 2

- Fig. 1. *Paranesidea* sp.  
Lateral view from the left side of a carapace (JC-1358),  $\times 55$ .
- Fig. 2. *Triebelina schyroconcha* Maddocks, 1969  
Lateral view of LV (JC-1359),  $\times 65$ .
- Fig. 3. *Paracypris* sp.  
Lateral view of RV (JC-1360),  $\times 65$ .
- Figs. 4a, b. *Krithe* sp. 1  
4a. Lateral view of male LV (JC-1362),  $\times 55$ ; 4b. internal view of the same LV,  $\times 55$ .
- Figs. 5, 6. *Parakrithe japonica* n. sp.  
5a. Lateral view of LV, holotype (JC-1364),  $\times 80$ ; 5b. internal view of holotype,  $\times 80$ ; 5c. muscle scars of holotype,  $\times 250$ ; 6. lateral view of RV, paratype (JC-1365),  $\times 80$ .
- Figs. 7a, b. *Krithe* sp. 2  
7a. Lateral view of female LV (JC-1363),  $\times 55$ ; 7b. internal view of the same LV,  $\times 55$ .
- Figs. 8, 9. *Parakrithe subjaponica* n. sp.  
8a. Lateral view of LV, holotype (JC-1366),  $\times 80$ ; 8b. internal view of holotype,  $\times 80$ ; 8c. muscle scars of holotype,  $\times 350$ ; 9. lateral view of RV, paratype (JC-1367),  $\times 80$ .



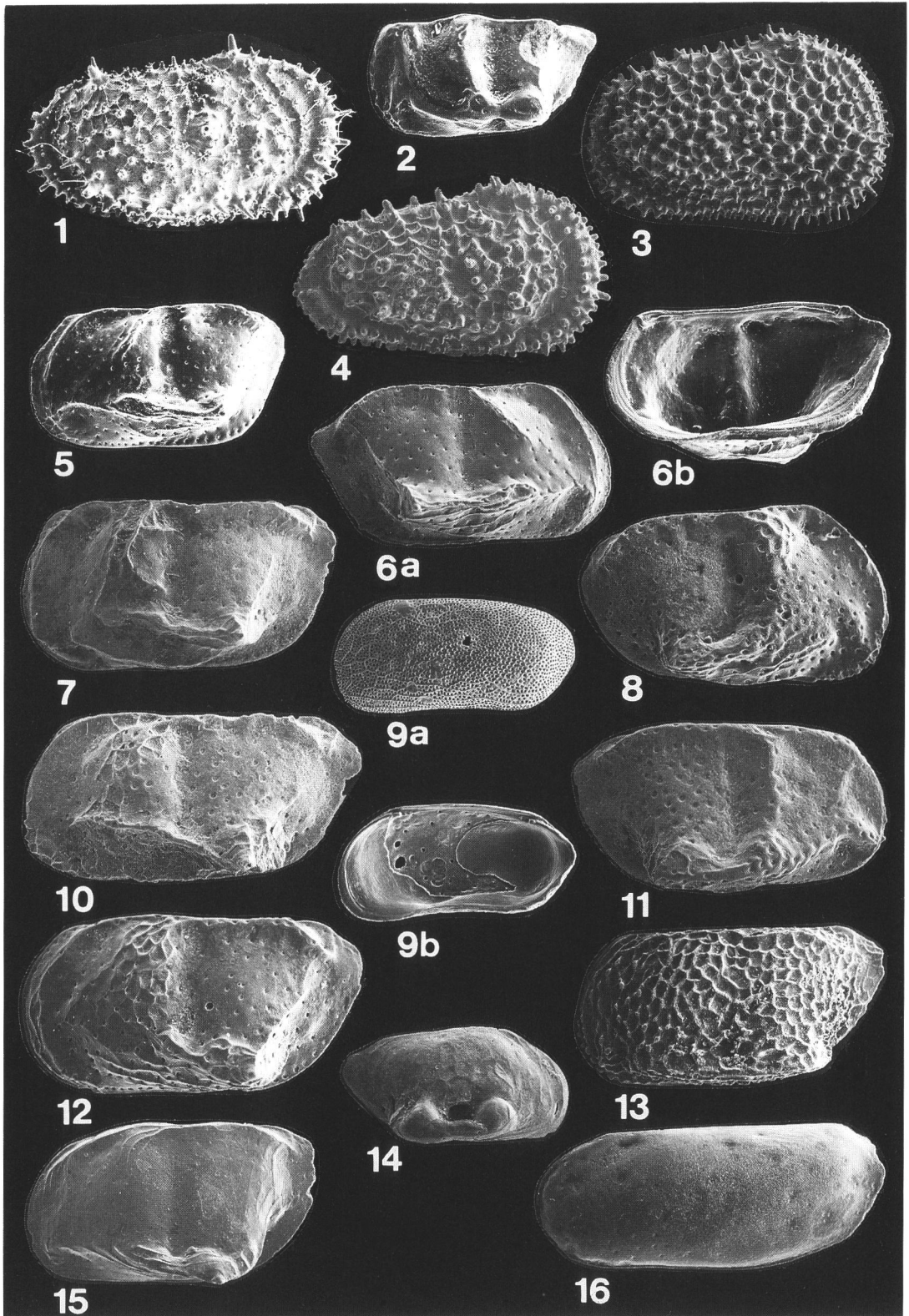
### Plate 3

- Fig. 1. *Pontocythere* sp.  
Lateral view of RV (JC-1361),  $\times 80$ .
- Figs. 2a, b. *Morkhovenia inconspicua* (Brady, 1880)  
2a. Lateral view of RV (JC-1369),  $\times 110$ ; 2b. internal view of LV from the same individual (JC-1369),  $\times 110$ .
- Figs. 3a, b. *Eucythere* sp.  
8a. Lateral view of LV (JC-1368),  $\times 110$ ; 8b. internal view of RV from the same individual (JC-1368),  $\times 110$ .
- Figs. 4–6. *Munseyella chinzeii* n. sp.  
4a. Lateral view of RV, holotype (JC-1370),  $\times 110$ ; 4b. internal view of holotype,  $\times 110$ ; 5. lateral view of LV, paratype (JC-1371),  $\times 110$ ; 6. lateral view of RV, paratype (JC-1372),  $\times 110$ .
- Fig. 7. *Cornucoquimba* sp.  
Lateral view of LV (JC-1378),  $\times 100$ .
- Fig. 8. *Conquimba* sp.  
Lateral view of LV (JC-1379),  $\times 100$ .
- Fig. 9. *Aurila* sp. 1  
Lateral view of RV (JC-1374),  $\times 65$ .
- Fig. 10. *Schizocythere kishinouyei* (Kajiyama, 1913), subspecies  
Lateral view of RV (JC-1373),  $\times 80$ .
- Figs. 11, 12. *Bradleya japonica* Benson, 1972  
11. Lateral view of RV (JC-1375),  $\times 45$ ; 12. lateral view of RV (JC-1376),  $\times 45$ .
- Fig. 13. *Pacambocythere izuensis* Ikeya & Zhou (MS)  
Lateral view of LV (JC-1384),  $\times 80$ .
- Fig. 14. *Pacambocythere* sp.  
Lateral view of LV (JC-1385),  $\times 80$ .
- Fig. 15. *Bradleya pitalia* (Hu, 1981)  
Lateral view of RV (JC-1377),  $\times 55$ .
- Fig. 16. *Neobuntonia* sp.  
Lateral view of RV (JC-1380),  $\times 70$ .



#### Plate 4

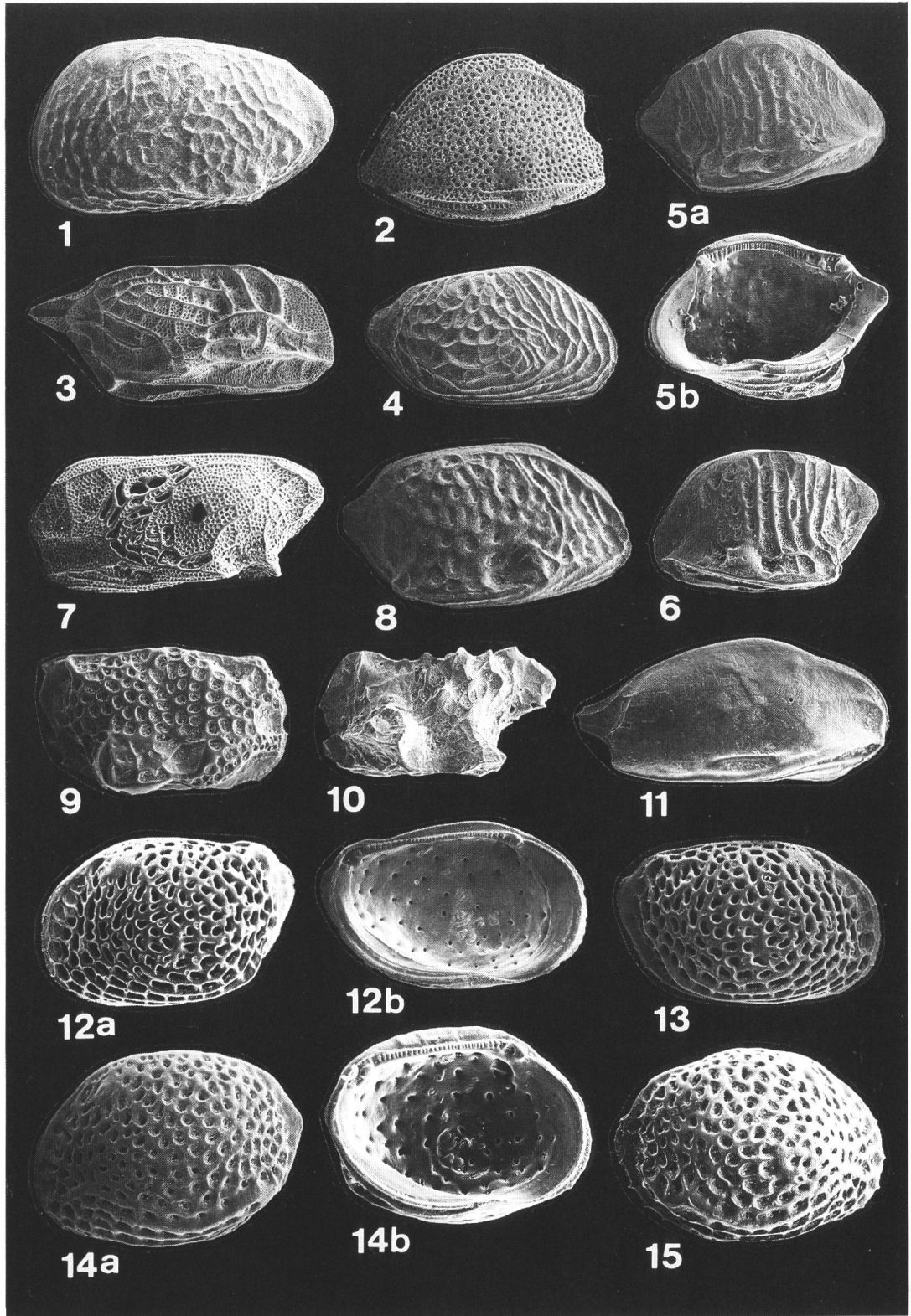
- Fig. 1. *Hirsutocythere* sp.  
Lateral view of immature RV (JC-1382),  $\times 40$ .
- Fig. 2. *Bythoceratina* sp. 1  
Lateral view of immature LV (JC-1392),  $\times 110$ .
- Fig. 3. *Echinocythereis dasyderma* (Brady, 1880)  
Lateral view of immature RV (JC-1383),  $\times 55$ .
- Fig. 4. *Acanthocythereis* sp. 1  
Lateral view of RV (JC-1381),  $\times 45$ .
- Figs. 5–6. *Bythoceratina sudjaponica* n. sp.  
5. Lateral view of LV, paratype (JC-1391),  $\times 80$ ; 6a. Lateral view of RV, holotype (JC-1390),  $\times 80$ ; 6b. internal view of the same RV,  $\times 80$ .
- Fig. 7. *Bythoceratina cassidoidea* Zhao, 1988  
Lateral view of LV (JC-1387),  $\times 65$ .
- Fig. 8. *Bythoceratina robusta* Zhao, 1988  
Lateral view of RV (JC-1388),  $\times 80$ .
- Figs. 9a, b. *Semicytherura* sp. 1  
9a. Lateral view of LV (JC-1400),  $\times 110$ ; 9b. internal view of RV from the same individual (JC-1400),  $\times 110$ .
- Fig. 10. *Bythoceratina angulata* Yajima, 1987  
Lateral view of LV (JC-1386),  $\times 80$ .
- Fig. 11. *Bythoceratina* sp. 2  
Lateral view of RV (JC-1393),  $\times 80$ .
- Fig. 12. *Bythoceratina* aff. *robusta* Zhao, 1988  
Lateral view of LV (JC-1389),  $\times 80$ .
- Fig. 13. *Bythoceratina* sp. 3  
Lateral view of LV (JC-1394),  $\times 100$ .
- Fig. 14. *Cytheropteron* sp. 1  
Lateral view of RV (JC-1406),  $\times 80$ .
- Fig. 15. *Monoceratina* aff. *sinensis* Zhao, 1988  
Lateral view of LV (JC-1395),  $\times 55$ .
- Fig. 16. *Pseudocythere* sp.  
Lateral view of LV (JC-1396),  $\times 100$ .



### Plate 5

- Fig. 1. *Cytherura daishakaensis* (Tabuki, 1986)  
Lateral view of LV (JC-1398),  $\times 100$ .
- Fig. 2. *Cytheropteron tabukii* Ikeya & Zhou (MS)  
Lateral view of a broken RV (JC-1403),  $\times 80$ .
- Fig. 3. *Semicytherura* aff. *hanaii* Ishizaki, 1981  
Lateral view of RV (JC-1399),  $\times 100$ .
- Fig. 4. *Metacytheropteron ignobilis* (Guan, 1978)  
Lateral view of RV (JC-1408),  $\times 80$ .
- Figs. 5, 6. *Cytheropteron rectocostum* n. sp.  
5a. Lateral view of RV, holotype (JC-1404),  $\times 80$ ; 5b. internal view of holotype,  $\times 80$ ; 6. lateral view of LV, paratype (JC-1405),  $\times 80$ .
- Fig. 7. *Semicytherura* sp. 3  
Lateral view of LV (JC-1402),  $\times 135$ .
- Fig. 8. *Cytheropteron* sp. 2  
Lateral view of RV (JC-1407),  $\times 80$ .
- Fig. 9. *Sulcocytherura* sp.  
Lateral view of RV (JC-1397),  $\times 110$ .
- Fig. 10. *Paracytheridea* sp.  
Lateral view of immature LV (JC-1409),  $\times 65$ .
- Fig. 11. *Semicytherura* sp. 2  
Lateral view of RV (JC-1401);  $\times 110$ .
- Figs. 12, 13. *Loxococoncha prolaeta* n. sp.  
12a. Lateral view of LV, holotype (JC-1412),  $\times 80$ ; 12b. internal view of LV (JC-1412),  $\times 80$ ; 13. lateral view of RV from the same individual, holotype (JC-1412),  $\times 80$ .
- Figs. 14, 15. *Loxococoncha ikeyai* n. sp.  
14a. Lateral view of LV, holotype (JC-1410),  $\times 80$ ; 14b. internal view of holotype,  $\times 80$ ; 15. lateral view of RV, paratype (JC-1411),  $\times 80$ .





### Plate 6

Figs. 1–3. *Loxoconcha propontica* Hu, 1983

1. Lateral view of male RV (JC-1413),  $\times 80$ ; 2a. internal view of LV from the same individual (JC-1413),  $\times 80$ ; 2b. muscle scars of the LV,  $\times 500$ ; 3. lateral view of an immature RV (JC-1414),  $\times 80$ .

Figs. 4–7. *Loxoconcha parapontica* n. sp.

4. Lateral view of RV, holotype (JC-1415),  $\times 80$ ; 5. internal view of RV, paratype (JC-1416),  $\times 80$ ; 6a. internal view of LV, paratype (JC-1417),  $\times 80$ ; 6b. muscle scars of the LV (JC-1417),  $\times 380$ ; 7. lateral view of an immature RV (JC-1418),  $\times 80$ .

Fig. 8. *Phlyctocythere* sp.

Lateral view of RV (JC-1419),  $\times 135$ .

Fig. 9. *Xestoleberis* sp.

Lateral view of LV (JC-1422),  $\times 80$ .

Figs. 10, 11. *Xestoleberis pararotunda* Hao, 1988

10. Lateral view of LV (JC-1420),  $\times 80$ ; 11. internal view of LV (JC-1421),  $\times 80$ .

Fig. 12. *Xiphichilus* sp.

Internal view of LV (JC-1426),  $\times 55$ .

Fig. 13. *Sinocythere* sp.

Lateral view of male LV (JC-1428),  $\times 80$ .

Fig. 14. *Microcythere* sp. 2

Lateral view of LV (JC-1425),  $\times 110$ .

Figs. 15, 16. *Microcythere* sp. 1

15. Lateral view of RV (JC-1423),  $\times 110$ ; 16. internal view of LV (JC-1424),  $\times 110$ .

Figs. 17a, b. *Saida* sp.

17a. Lateral view of RV (JC-1427),  $\times 110$ ; 17b. internal view of the same RV (JC-1427),  $\times 110$ .

